The results of more than 20 epidemiological studies on the association between mobile phone use and risk of intracranial tumours have yielded ambiguous results with disparate conclusions. Most studies show no increased risks overall, but commonly suggest slightly elevated risks in some subgroups including those with long-term or ipsilateral use, or large cumulative hours of use. Yet, the subset with the highest point estimate has not been very consistent across studies. Interpretation of the evidence is challenging, as the findings could reflect either a local effect of heavy long-term exposure or recall bias producing an apparent effect on features whose reporting is affected by the tumour diagnosis.
HUMAN LABORATORY STUDIES ON MOBILE PHONE EXPOSURE – A CRITICAL REVIEW

Martin Röösli, Institute of Social and Preventive Medicine, University of Basel

The conduct of human laboratory studies is the most preferred method to directly evaluate short-term effects of mobile phone radiation on humans. High quality studies use an exposure setup that results in well-defined and replicable exposure circumstances. The exposure conditions need to be applied in a randomized counter-balanced way including a sham condition. A crossover study design minimizes the impact of confounding because each volunteer is used as his or her own control in the data analysis. So far, human laboratory studies have primarily focussed on cognitive functions, electrical activity of the brain, symptoms of ill health and the auditory system.
The role of the Radical Pair Mechanism in the discussion of weak magnetic field effects on biological systems

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The Interaction Association for Cancer Research (IARC) classifies extremely low frequency (ELF) magnetic fields as ‘possibly carcinogenic to humans (category 2B). At the same time, it is an established fact that weak static magnetic fields (for instance, that of the Earth) are affecting many animals (e.g., a wide variety of birds) enabling the creatures to navigate and orient using the strength and orientation of the magnetic field to design compasses and maps. Here we discuss what role the radical pair mechanism (RPM)\textsuperscript{1} – the only known mechanism proven to act as a mediator between magnetic fields and chemical reactions - might play in the explanation of these phenomena. The theoretical basis of the RPM will be introduced before experimental evidence for the effects of weak magnetic fields on chemical and biological systems will discussed to demonstrate the importance of this mechanism.

Concomitant with numerous experiments on electromagnetic energy-exposed life systems, many hypothetical interaction mechanisms have been formulated to explain experimental outcomes. Close examination over the spectrum shows that the initial physical event requires certain combinations of field strength, frequency, etc. in order to transfer energy to a biomolecule, possibly launching a biochemical/biological cascade [1]. Per the Second Principle of Thermodynamics, any such energy transformation increases system entropy above its background level of molecular disorder. The paper suggests criteria useful in formulating new mechanisms of interaction, not an easy task, because Φύσις κρύπτεσθαι φιλεῖ (Nature likes to hide) (Heraclitus, VI century BC, Fragment 123). The hiding place is the background noise.

Effects of Time-Varying Magnetic Fields and Parametric Resonance Conditions on Circulatory and Microcirculatory Parameters using Healthy and Spontaneously Hypertensive Rats

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INTRODUCTION

There is a growing body of literature that supports the finding that pulsed and static magnetic fields (MF) can be used to manipulate microcirculatory parameters, such as blood flow and pressure \cite{1}. Most have reported an increase in blood flow post-MF exposure, or a homeostatic or regulatory effect of MF exposure on blood flow and blood pressure.

In our previous work, a 225 µT, extremely low frequency, pulsed magnetic field (PEMF) that was designed for the induction of antinociception, was tested for its effectiveness to influence blood flow within the skeletal microvasculature of a rat model (n = 103). Acetylcholine was used to perturb normal blood flow and to delineate differential effects of the PEMF based on degree of vessel dilation. The data suggested that there was no meaningful acute physiological effects of the 225 µT PEMF after 30 and 60 min of exposure on peak blood flow, heart rate, and myogenic activity, but perhaps an attenuation effect on anesthetic-induced respiratory depression.

As a follow up to this study, PEMF effects on blood pressure, measured simultaneously to blood flow, and heart rate variability (HRV) were tested. Additionally, dosimetry of the PEMF and a 60 Hz sinusoidal magnetic field were tested (100, 200, 500 µT).

It was also of interest to test whether similar effects would be observed in a spontaneously hypertensive rat model (average blood pressure of 165/100 mmHg), or rather if a homeostatic MF effect would be observed. As a separate test, we were interested in testing possible circulatory and microcirculatory effects under parametric resonance conditions, such that biological effects may be attributed to changes in conformational states of ions in biological molecules due to MF resonance effects based on the relationship between the AC MF frequency and flux density, the flux density of the static MF, and the charge-to-mass ratio of the involved biological ions \cite{2}.

Thus, here we present results related to:

i) Blood pressure, blood flow, HRV after 100, 200, 500 µT PEMF and 60 Hz sinusoidal exposure in healthy rats

ii) Blood pressure, blood flow, HRV after 200 µT PEMF and 60 Hz sinusoidal exposure in spontaneously hypertensive rats

iii) Parametric resonance conditions that we have found to reduce opioid-induced analgesia (60 Hz vertical direction with peak amplitude of 141 µT, static MF of 78 µT vertical direction, static geomagnetic field zeroed) in spontaneously hypertensive rats

MATERIALS AND METHODS

Blood flow (stimulated by acetylcholine) was measured in the surgically-exposed \textit{extensor digitorum longus} muscle of anesthetized rats using laser Doppler flowmetry, while blood...
pressure was measured via the insertion of a pressure transducer mounted in a catheter in the aorta. Physiological data was measured pre-exposure, and then after 30 and 60 min of exposure to: sham conditions, the PEMF (5 pulse segments of 853 ms separated by an increasingly long refractory period, fundamental frequency at 72 Hz), 60 Hz MF, or parametric resonance conditions. MF exposure was delivered via Helmholtz-like coils. Spectral analysis of blood flow data was generated to obtain information related to myogenic activity (0.15-0.40 Hz), respiratory rate (0.4-2.0 Hz), and heart rate (2.0-7.0 Hz).

RESULTS

There were no significant differences in peak blood flow response to acetylcholine stimulation due to exposure to sham conditions, the PEMF, or 60 Hz MF. Differences in terms of field intensity within the PEMF- and 60 Hz-exposed groups approached significance ($p = 0.078$), between 200 and 500 µT at T$_{30}$ ($p = 0.076$) and T$_{60}$ ($p = 0.073$).

Within the myogenic frequency band, MF intensity had an effect on the full width at half maximum of peak ($F(2,23) = 6.30, p < 0.05$) between the 200 and 500 µT groups ($p < 0.05$).

Within the heart rate frequency band, there was a time by exposure type by MF intensity interaction on the principal frequency ($F(4,42) = 2.66, p < 0.05$), and a main effect of exposure type on the spectral power ($F(1,23) = 8.40, p < 0.01$) between sham and PEMF ($p = 0.01$), sham and 60 Hz ($p = 0.001$), and PEMF and 60 Hz ($p = 0.05$). Further, within this frequency band, there was a main effect of exposure on the normalized area under the curve ($F(1,22) = 7.74, p < 0.05$) with differences between all exposure types (sham, PEMF, and 60 Hz), as well as a main effect of exposure type on the normalized mean within the band ($F(1,22) = 4.07, p = 0.056$).

Within the respiratory frequency band, there was a significant time by exposure interaction on the normalized area under the curve ($F(2,37) = 1.44, p < 0.05$).

In terms of blood pressure, there was time by MF intensity by exposure interaction on mean systolic pressure ($F(4,60) = 4.55, p < 0.01$), mean diastolic pressure ($F(4,54) = 4.64, p < 0.01$), and mean arterial pressure ($F(4,55) = 4.95, p < 0.001$). There was a main effect of exposure type on mean arterial pressure ($F(1,34) = 4.12, p < 0.05$), with higher values for 60 Hz-exposed animals compared to PEMF-exposed animals ($p = 0.08$). No significant effects of exposure type or MF intensity were found within the low or high frequency HRV bands.

Data related to objectives (ii) and (iii) will be presented at conference.

CONCLUSION

There does not appear to be an effect of the PEMF or 60 Hz MF at 100, 200 or 500 µT on peak blood flow in healthy rats; however, integration of the above data suggests that there may be subtle differences in other circulatory and microcirculatory effects due to MF intensity (between 200 and 500 µT) and exposure type. In hypertensive rats these differences may become more evident.

ACKNOWLEDGMENTS

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REFERENCES


Expression of MagA and Modified Ferritin Subunits for Magnetic Resonance Imaging of Cancer Cell Growth

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INTRODUCTION

We have investigated the application of gene-based contrast from overexpression of iron binding proteins, in tracking cancer cell growth using MRI. This technology is predicated upon the formation of magnetosomes: intracellular iron biominerals sequestered within a membrane compartment in magnetotactic bacteria [1]. Evidence of magnetosome-like particles has been reported subsequent to expression of MagA in mammalian cells [2,3]. We have compared the ability of MagA and modified ferritin heavy and light subunits (HF + LF) to provide intracellular contrast suitable for monitoring tumour growth in a mouse model of human breast cancer.

MATERIALS AND METHODS

MDA-MB-435 cells were transfected with plasmid bearing the pcDNA3.1 backbone and inserts for either MagA, or the modified heavy and light subunits of ferritin, which lack iron response elements. Constructs were subject to specific antibiotic selection. Imaging was performed on clonal populations, either singly-transfected with MagA or cotransfected with heavy and light ferritin (HF + LF). Cell cultures were supplemented for 7 days with media containing 250 µM ferric nitrate, and iron uptake was assessed using Prussian Blue stain.

For MRI at 11Tesla (T), cells were immobilized in porcine type A gelatin in a single well from a 96-well Nunc breakapart plate [3]. Three dimensional MRI was acquired using a dual echo sequence: spin echo at TE (time of echo) 5 ms and gradient echo at TE 15 ms. Repetition time (TR) was 1000 ms, with 8 averages, resulting in a 137 min acquisition for a 128 x 128 x 8 matrix. The field of view was 8 x 8 x 1.2 mm³ providing 65 x 65 x 75 µm³ resolution. Positive contrast images reflecting the signal from cells were obtained by subtraction of gradient echo from spin echo images.

For MRI at 3T, cells were cultured in the presence or absence of iron supplementation, harvested and injected subcutaneously into the hind limb of CD1 nu/nu mice. Animals were handled in accordance with guidelines established by the Canadian Council on Animal Care and fed either a standard or iron-enriched diet. Tumour growth was monitored over 9 weeks, with the imaging of formalin fixed mice at 3 week intervals. Endpoint analyses were obtained with a custom-built solenoid RF coil and high performance gradient insert [4]. Images were obtained using a three dimensional steady state free precession sequence.

RESULTS

Examination of cells by MRI at 11T showed that clonal populations expressing MagA or
HF + LF exhibited varying degrees of cellular contrast, similar to a heterogeneous population of selected cells and despite their ability to retain iron. Overexpression of MagA (Figure 1) and HF + LF was compatible with tumour formation in vivo. Analysis of mouse tumours by MRI at 3T confirmed the need for iron supplementation during tumour growth, to enhance cancer tissue contrast above that obtained with untransfected parental tumour cells.

![Figure 1. Tracking Cancer Cell Growth Using MagA Expression.](image)

**Figure 1. Tracking Cancer Cell Growth Using MagA Expression.** A clone of MagA expressed in human MDA-MB-435 cells was cultured for 7 days in iron-supplemented media prior to subcutaneous injection of $10^7$ cells into the hind limb of immuno-compromised, nude mice. At 3 weeks, fixed mice were imaged using a 3T MRI scanner. An axial cross section shows tumours derived from parental cells on the right flank (R) and from MagA-expressing cells on the left (L). Blue arrows point to each tumour. The image was obtained using 3D FIESTA software: bandwidth 62 kHz, TR/TE 16/8 ms, scan time 21 min, and resolution 100 x 100 x 200 $\mu$m$^3$.

**CONCLUSIONS**

Relative to ferritin constructs optimized for iron storage, our results demonstrate the potential of MagA to provide long-term contrast for cell tracking with MRI. We report that genetically identical populations of MagA or HF + LF nevertheless show varying levels of MRI contrast. This phenotypic difference likely reflects the complex regulation of iron in mammalian cells. Future study will focus on the characterization of iron homeostasis in the context of MagA and HF + LF overexpression. This research will assist in development of reporter gene expression for MRI.

**ACKNOWLEDGMENTS**

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**REFERENCES**


Effects of Radiofrequency Fields on Young Animals: WiFi Signal Exposure Effects on Immature Immune and Nervous Systems (ERYA project)

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INTRODUCTION

The impact of low-level radiofrequency (RF) exposure on health is currently being investigated, and in particular in relation to the health of children. Concern is also expressed regarding new signals such as WiFi, which is ubiquitous. The present ERYA project aims at investigating the effects of RF exposure related to WiFi on the central nervous and immune systems of young rats. In this study, pregnant females rats are exposed or sham-exposed for two weeks to 2450 MHz WiFi-like signals. Pups are exposed in utero and during the first month of their life. An original reverberation chamber for whole-body exposure of free-running animals was specifically designed for this work [1]. The average-specific absorption rate (SAR) levels are 0, 0.08, 0.4, and 4 W/kg, on the basis of ICNIRP’s public and professional guidelines.

This study will tell whether WiFi signals can alter fundamental biological processes such as apoptosis in the nervous system. We also investigated two molecular chaperones, hsp70 and hsp25 related to effects of environmental factors and more specifically to neurodegenerative disorders and cellular recovery [2]. Moreover, the triggering of de novo antibodies production by the immune system is assessed in the sera of exposed pups. Sixteen circulating neo-epitopes associated with oxidative stress, lipoperoxidation and/or autoimmunity markers are assayed in sera using antibodies directed against amino-acid conjugates [3]. This is the first experimental approach of this kind related to WiFi exposure.

MATERIALS AND METHODS

Animal exposure. Pregnant Wistar rats, obtained 3 days post coitum were acclimated for 4 days. Dams and newborn rats are exposed or sham exposed at the three SAR levels (0.08, 0.4, and 4 W/kg) in the reverberation chamber. Therefore, pups are exposed for 2 weeks in utero and 5 weeks post-natal. Daily exposure lasts 2 hours. We performed three series of exposure.

In situ Apoptosis Detection using the TUNEL method. Encoded brain cryosections (10 µm thick) were prepared on different areas (bregma –3.8, interaural 5.2) including hippocampus and retrosplenial cortex linked to memory and learning, and emotions, respectively. In situ detection of apoptosis was performed by detection of DNA strand breaks on brain slices using the TUNEL method with an in situ cell-death detection kit (NeuroTACS II, Trevigen USA). TACS-Nuclease causes DNA breaks in every cell and provides an appropriate positive labelling control. Apoptotic neurons are counted under the microscope.
**HSP staining by immunohistochemistry.** Dried cryosections are processed using an autostainer at 22°C (Dako Autostainer, France). Heat Shock Proteins primary antibodies hsp25 and hsp70 and biotinylated antibodies are successively added followed by incubation with avidin-biotin-peroxidase. The presence of Hsps is revealed as a red/brown colour (NovaRED™). Ischemic and pilocarpine treated rats are used as positive controls.

**Circulating neo-epitopes by ELISA.** Specific circulating antibodies are assayed in sera using ELISA plates coated with 16 different amino acid conjugates (GemacBio®, France).

### RESULTS

Our experimental results show no significant differences in the expression levels of hsp70 and hsp25 in rat brains among the WiFi exposed and sham-exposed groups. Moreover, no apoptotic cells were observed in the various brain areas (Fig. 1). Changes in antibody levels were seen only for one of the 16 tested antibodies: NAC-Cathecolamine, that showed, in the 4 W/kg group, levels lower than in the sham group. These changes only occur for the IgM isotype and not for IgG and IgA.

![Figure 1: In situ apoptosis detection using the TUNEL method in the granular layer of the DG dentate gyrus. Left: positive control; right: exposed sample.](image)

### CONCLUSIONS

Under our experimental conditions with early exposure of rats, our data show no evidence of apoptosis triggered by WiFi exposure, nor over-expression of hsp in the brain. Moreover, there is no significant increase in neo-epitope synthesis. WiFi exposure, even at high level, has no noticeable influence on neuronal system integrity and humoral immune response.

Further investigations within the ERYA project will be performed on a mouse model exposed to the same WiFi signal to assess effects on the immune system.

### ACKNOWLEDGMENTS

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Effects on the Immune System of Early Life Exposure to WiFi Signals

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INTRODUCTION

Wireless local area networks (WLAN) are an increasing alternative to wired data network in workplaces, homes and public places. As formerly happened for other EMF sources, the fast increase of WLAN use, especially in some critical environments such as schools and hospitals, has caused a great public concern about the possible effects of this kind of signal on human health.

The immune system is devoted to the protection of the organism from pathogens. It develops during embryogenesis and completes its maturation after birth, becoming fully competent during infancy. Perturbing factors such as toxic compounds and ionizing radiation, as well as some pathogens, can compromise the integrity of the immune system, leading to ineffective immune responses or to immune-mediated diseases.

The question of the present study is whether WiFi signals alter the development of the immune system, leading to immune dysfunctions in the adult. In this abstract we describe for the first time the effects of exposure to WiFi signals on the maturing immune system of newborn mice.

MATERIALS AND METHODS

Specific-pathogen-free pregnant female C57BL/6 mice with a predicted date of delivery were purchased from Harlan Italy Laboratories. Upon receipt, all animals were inspected by a veterinarian and left in the animal facility until delivery. It’s know that weight at birth and quality of parental cares condition the growth of newborn animals, which in turn may affect the development and maturation of several functions. Thus, to reduce possible group to group variability not due to experimental effects, newborns from biological mothers were re-assigned to adoptive mothers through a controlled randomized procedure. Each adoptive mother received the same number of newborn mice, namely 4, in order to provide uniform access to breast milk. Each experimental group was composed of the newborns fed by 4 adoptive mothers (16 newborns/group).

Groups of mice were exposed to different SAR levels (0.08, 0.4, 4 W/kg) 2 hrs/day, 5 days/week, for 5 consecutive weeks starting the day after birth. Sham-exposed mice underwent the same procedures as MW-field-exposed mice except for the presence of the MW fields in the transverse electro-magnetic (TEM) cell. MW-exposed and sham-exposed animals were kept constrained within perspex tubes during exposure. Diameter and length of these tubes were changed according to the body size of the growing animals. Exposure was performed with a blind procedure. The cage control group was maintained in the animal facility with minimal handling. Specific measures were adopted to control the temperature of newborn animals.

A commercial access point (AP) communicating with two PCs was chosen as source of
the WiFi signal. Two identical TEM cells were used as radiating structures. Several simulations were carried out considering the changes in weight and size of the growing mice. More details on exposure system, type of signals, and numerical and experimental dosimetry can be found in the abstract from Pinto et al. [1]

Twenty-four hours after last exposure animals were sacrificed and lymphatic organs collected and analyzed as previously described [2, 3]. Nucleated cells from thymi and spleens were counted and analyzed by flow cytometry. Thymocytes and spleen cells were challenged with mitogens or monoclonal antibodies to induce cell proliferation and cytokine production. Cell proliferation was evaluated by tritiated thymidine uptake. ELISA was used to measure cytokine production in culture supernatants and antibody levels in sera.

RESULTS

No differences in health conditions and weight among MW-exposed, sham-exposed and cage control mice were observed during the entire exposure period.

Thymus: Total cell numbers as well as frequencies of the four subpopulations identified by the expression of CD4 and CD8 were comparable in all the groups. Interestingly, a higher proliferative response in mitogen-stimulated thymocytes from male as compared to female mice was observed. Yet, no differences due to the MW-exposure were observed in both sexes.

Spleen: Total cell number as well as frequencies of CD4 and CD8 cells were similar in all the groups. Spleen cells challenged with anti-CD3 monoclonal antibody (T cell mitogen) or LPS (B cell mitogen) yielded comparable responses. Culture supernatants from anti-CD3-stimulated spleen cells were analyzed to assess IFNg and IL-2 concentrations. Results showed that spleen cells from male but not female mice exposed to the highest SAR level (4 W/kg) produced less IFNg; a finding not confirmed when we replicated the experiment.

Sera: Antibody levels were measured in sera. Results showed no differences among the groups for both IgM and IgG concentrations.

CONCLUSIONS

Our results show that exposure during early life from birth up to 5 weeks of age does not affect a large number of parameters in the immune system of both female and male mice. Nevertheless, a not confirmed effect of the highest SAR level (4 W/kg) on IFNγ production by spleen cells from male (but not female) mice was observed.

ACKNOWLEDGMENTS

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REFERENCES


INTRODUCTION

International exposure assessment standard IEC 62232 is under development, which requires supporting scientific work. This paper reports how specific absorption rate (SAR) in human body models depends on various parameters in the exposure setup.

MATERIALS AND METHODS

720 FDTD-SAR simulations were performed using free-space plane-wave exposure. A parallel FDTD field solver (made in TKK) with efficient CPML absorbing boundary condition was run in CSC’s HP supercluster “Murska” (CSC: Finnish IT Center for Science). Field data from FDTD was applied to produce SAR distributions and key figures such as whole-body-averaged SAR (WBASAR) and peak 10-g-averaged SAR.

The simulations were done at 300, 450, 900, 2100, 3500 and 5000 MHz, for horizontal and vertical polarizations. 15 different models whose mass varies between 18 and 105 kg were applied: VF Male and VF Boy (heterogeneous & homogeneous), VF Female (Virtual Family models from IT'IS Foundation/Switzerland), Norman (Health Protection Agency/UK, Dimbylow’s work), Japanese Male and Female (Biomedical EMC Group/NICT/Japan, Nagaoka et al.), VHP Male (based on Visible Human Project and work at Brooks Air Force Base /USA), and 6 homogeneous posture models (TKK & STUK: Radiation and Nuclear Safety Authority in Finland). The number of incoming angles depended on the model. For VF Male and Boy it was 11. The angle was varied both in the azimuth and the elevation plane around the models.

RESULTS

Chosen sample results are reported here. VF Male and VF Boy models (heterogeneous and homogeneous) were applied when studying the incoming angle dependency of SAR. In each case with fixed frequency, polarization and model, the WBASAR deviation with the incoming angle was always between $-3.5 \ldots +1.3 \text{ dB}$ ($0 \text{ dB}$ corresponds to the anterior exposure in each case). The variation of peak 10-g SAR values in limbs and in the head/trunk was somewhat higher. In the gigahertz range, anterior exposure tends to give the highest WBASAR. Figure 1 shows the results for heterogeneous VF Male (e.g. H300 refers to horizontal polarization at 300 MHz). Also the effect of model phantom variation was studied (all models in regular standing posture). For example, in the case of anterior exposure, in each fixed frequency-polarization case, WBASAR deviation due to a model change was always between $-1.6 \text{ dB}$ (VHP 105 kg) and $+3.8 \text{ dB}$ (VF Boy 18 kg), where $0 \text{ dB}$ corresponds to heterogeneous VF Male. The effect of posture variation was studied with 6 homogeneous posture phantoms (normal standing, arms out, arms up, standing and examining an object, sitting on ground, “sitting on a chair”).
WBASAR deviation was between -1.2 \ldots +1.7 \text{ dB}, where 0 \text{ dB} corresponds to the normal standing posture. Finally, with the simulated SAR results certain assumptions (e.g. effect of posture on SAR is similar with each model) and approximate methods were applied in order to produce frequency distributions of SAR (comparable to probability distributions). Figure 2 shows an example at 5000 MHz for horizontal polarization.

CONCLUSIONS

SAR variation data has been computed allowing to analyze combined effects of many parameters on SAR. The results of this research suggest that the ICNIRP SAR limits may be exceeded at the reference level of exposure. Normalized peak 10-g SAR tends to be higher in the head/trunk than in the limbs (especially at frequencies > 2 GHz with anterior exposure). Considering plane-wave WBASAR simulations of typical human bodies in standing posture in gigahertz range, it seems to be sufficient to simulate anterior and posterior cases only to find maximum WBASAR. At lower frequencies this does not hold at all, but low resolution can be used in FDTD there. An approximative approach was taken to produce frequency distributions of SAR in each polarization-frequency case.

ACKNOWLEDGMENTS

Mobile Manufacturers Forum and GSM Association are acknowledged for the funding of this research and CSC for the high-performance computing resources.
SARs in SAM and Child Head models for Mobile Phone Exposure at 835 and 1900 MHz

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INTRODUCTION

The Specific Anthropomorphic Mannequin (SAM) phantom had been designed in the shape and material in order to produce the peak spatial-average specific absorption rate (SAR) conservative for the actual value in the heads of a significant majority of persons from adults to young children during normal use of mobile phones. Therefore the ear protrusion of the SAM phantom had been selected to be very thin compared with a normal adult’s although most of other dimensions have been derived from the 90th-percentile male head data of U.S. army[1],[2]. Another factor to affect the SAR result is the dielectric properties of the phantom material. The current dielectric characteristics of the standard phantom for SAR test of a mobile phone were derived in [3].

There are not many research results to compare local SAR levels between SAM and child head models although the SAM phantom should be conservative for SAR level in children’s head. In this paper, a 7-year-old Korean (KR_7y) and a 6-year-old European (EU_6y) child head models were used to investigate if the SAM phantom offers a conservative SAR result for children’s head exposure to a mobile phone operating at 835 and 1900 MHz.

MATERIALS AND METHODS

The two child head models are very different in ear protrusion and internal tissue morphology. The ear protrusion of the Korean model is much larger than that of the European model. The fat tissue was observed to be more dominant in the cheek of the Korean model compared with the European model. The cheek and tilt test positions for a bar-typed
mobile phone with a monopole antenna were used and the compressed ear condition was considered for both of the child head models.

The finite-difference time-domain technique was used with 16 perfectly matched layers for numerical analysis and the grid size of 1x1x1 mm³ was constantly employed in all simulations.

RESULTS

Table 1 represents spatial peak 10-g SAR results at 835 and 1900 MHz and all the SARs were evaluated over a cubic tissue. The separated distance between the feed point of the phone antenna and the head tissue of EU_6y model was smaller than that for SAM phantom even when the ear was not compressed. All the SAR results were normalized to 1 W forward power calculated at the feed point of the phone model. As a result, the peak SAR averaged over 10 g in the Korean child head model did not exceed that in the SAM model in any position or frequency. However, the SAR values in the European child head model were very high compared with those in the Korean child. Except the SARs for the normal ear at 835 MHz, every other SAR results in the European child model exceeded that in the SAM phantom.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Test position</th>
<th>SAM</th>
<th>KR_7y (Ear-compressed)</th>
<th>EU_6y (Ear-compressed)</th>
</tr>
</thead>
<tbody>
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<td>835 MHz</td>
<td>Cheek</td>
<td>5.51</td>
<td>2.40</td>
<td>4.57</td>
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<td></td>
<td>Tilt</td>
<td>3.51</td>
<td>2.11</td>
<td>3.11</td>
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<tr>
<td>1900 MHz</td>
<td>Cheek</td>
<td>3.94</td>
<td>2.98</td>
<td>4.51</td>
</tr>
<tr>
<td></td>
<td>Tilt</td>
<td>5.36</td>
<td>1.93</td>
<td>6.88</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The SARs in the Korean and European child head models were evaluated and compared with those in the SAM phantom at 835 and 1900 MHz. In many cases, the European child head model overestimated SAR in the SAM phantom. The thin auricle of the head model seems to be a major cause of relatively high SAR.

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SAR Induced by Dipole Antennas to Determine Low Power Thresholds for Wireless Transmitters at Distances of 25 – 200 mm from the User

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INTRODUCTION

In two recent papers [1-2], the authors studied the SAR induced by dipole antennas of different lengths placed next to a flat phantom. Those studies were focused on developing a threshold power rationale to demonstrate inherent SAR compliance for devices that operate close to the user (within 25 mm). The current investigation extends the previous work to distances of 25 – 200 mm. Both simulated and measured data are presented for comparison. Measured data from two laboratories are shown.

MATERIALS AND METHODS

The antennas used in the current study are half-wavelength dipoles operating at 900, 1900, 2450, 3700, and 6000 MHz. The linear dipole dimensions can be found in [2]. For lower frequencies the antenna diameter was chosen to be 3.6 mm and for frequencies of 3700 and 6000 MHz the diameter was chosen to be 1 mm. Simulations were performed using XFDTD [3]. For the measurements, each antenna was fed using a balun and a 50 Ω semi-rigid coaxial line. An elliptical phantom as described in [4] was used. The phantom was filled with a tissue simulating fluid, the dielectric properties of which corresponded to the requirements of the IEC 62209-2 and the IEEE 1528 [4, 5]. The distances of the antenna feed points to the tissue simulating liquids were 40, 100, and 200 mm. The major axis of the elliptical phantom was 600 mm and the minor axis was 400 mm. The depth of the liquid was 150 mm. The phantom liquid was contained in a 2 mm thick lossless shell having a permittivity of 3.7. During measurements, RF absorbing materials were used to reduce the effect of reflections. The antennas were positioned below the phantom using an antenna holder of adjustable height.

RESULTS

Simulated and measured peak 1g and 10g averaged SAR data for the cases under consideration are plotted in Figure 1. For all cases, the SAR data are normalized to 1 Watt of rms power. Measurement data from Motorola are available at 900, 1900 and 2450 MHz. Simulated data from the University of South Carolina and measured data from the Austrian Research Center are available at all frequencies. Comparing the simulated and measured data it is clear that they are generally very close in most cases. The SAR generally increases with frequency, due to the higher conductivity of the tissue at higher frequencies. However, the relationship between SAR and frequency is complex at lower frequencies and at shorter distances, where the antenna is in the near field. This finding agrees with what was found in the previous work [1, 2]. At higher frequencies, it can be seen that the relationship is almost linear. This observation is more pronounced as the distance increases, and it demonstrates that a simpler relationship between SAR and frequency is apparent in these cases.
CONCLUSIONS

Peak 1g and 10g averaged SAR induced in an elliptical phantom representing the human body by half wave dipole antennas (900 MHz – 6 GHz) were studied at phantom-to-antenna distances 40 – 200 mm. Different effects of near-field, radiating near-field and radiating far-field were observed. These effects enable to develop a rationale to demonstrate inherent SAR compliance for devices operating at distances up to 200 mm from the body.

ACKNOWLEDGMENTS

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[4] IEC Draft Std 62209, Human exposure to radio frequency fields from handheld and body-mounted wireless communication devices - human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) in the head and body for 30 MHz to 6 GHz handheld and body-mounted devices used in close proximity to the body, Committee Draft, October 2008.

Hybrid SAR Analysis of Various Human Models in Front of Base Station Antennas in the Frequency Range from 300 MHz to 5000 MHz

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INTRODUCTION

Most studies involving simulation of detailed heterogeneous human models in front of base station antennas have used the Visible Human model. However, this model has been found to be neither representative of the average human nor leads to worst-case absorption. Plane-wave exposure of various human models, e.g. [1], show that a compliant SAR in the Visible Human does not necessarily lead to a compliant exposure of a smaller model.

Some work has been done to extract a formula to estimate the SAR due to exposure to base station antennas [2]. However, this paper only includes a few adult models and the statistical evaluation is biased by the Visible Human model. Moreover, the frequency range is limited to 800 MHz to 2200 MHz. The present study has been developed to support the International Electrotechnical Commission in the elaboration of a new international standard [3]. The aim of this project is to use various detailed human models and generic base station antennas to assess the SAR and derive an estimation formula that could be used to easily estimate the SAR.

MATERIALS AND METHODS

Two different generic base station antennas have been modeled and validated with MoM for each of six different frequencies ranging from 300 MHz to 5000 MHz. Three human models of the Virtual Family have been used: an adult male (VFM), an adult female (VFF) and a 6-year-old boy (VFB). The models have been placed at six distances from every antenna, ranging from 10 mm to 3000 mm. The whole-body average SAR and peak spatial average SAR have been evaluated in all possible configurations of a human model, orientation (face and back), antenna and distance. The numerical simulations have been carried out using the FDTD platform SEMCAD X. At larger distances for which the coupling between the antenna and the human model can be neglected, the new ‘Generalized Huygens Box’ approach has been used: the complex free-space fields computed by MoM or FDTD are used as incident fields in a simulation including the human model.

In the second part of the project, an estimation formula for the whole-body average SAR and the peak spatial average SAR has been developed. The physical and electrical characteristics of the antennas have been used to evaluate the average power density along a vertical line at the distance of the phantom [4]. An homogeneous cuboid has been
used as a simple representation of the human body in the calculations. The estimation formula based on worst-case scenario assumes a uniform power density on a section of the incident face of the cuboid representing the human model. Finally, the estimation formula has been validated against our simulation results.

RESULTS

The results of the 432 configurations simulated in this project show that the VFB model leads to higher whole-body average SAR than adults in almost all cases. Only the close near-field results, strongly dependent on the anatomical details of the models, are sometimes higher for the adults. The comparison of the estimation formula with the simulation results show that the estimation formula is generally conservative.

When the human model is placed in the reactive near-field of one antenna, the coupling between them is very important and the average power density cannot be determined. The value of the whole-body average SAR and the 10 g peak spatial average SAR are strongly influenced by the anatomical details of the human model.

CONCLUSIONS

The study shows the influence of the physical and electrical properties of the antenna and the anatomical characteristics of the human body model on the SAR. A conservative evaluation formula has been developed to quickly estimate the compliance of the SAR in a body in front of a base station antenna.

The singular nature of the 10 g SAR is particularly significant for small distances antenna-human. For such distances, our recommendation is that possible future standards should advise that compliance be determined either by the measured fields or by SAR results from a full-wave simulation; the estimation formula being too uncertain.

ACKNOWLEDGMENTS

We would like to thank the Mobile Manufacturer Forum (MMF) and the GSM Association (GSMA) for the financial support of the study.

REFERENCES


An International Inter-laboratory Comparison of Mobile Phone SAR Calculation with CAD-based Models

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INTRODUCTION
An international inter-laboratory study to compare numerically evaluated Specific Absorption Rate (SAR) using computer simulations based on Specific Anthropomorphic Mannequin (SAM) and mobile phones CAD models has been conducted in order to investigate the repeatability and reliability of such evaluation and to provide input in the development of standardized procedures. This work has been conducted within the standardization organization of the International Commission on Electromagnetic Safety (ICES) IEEE TC34 Sub-committee 2, Working Group 3 which is developing the IEEE 1528.3 standard for numerical SAR compliance testing of wireless terminals.

MATERIALS AND METHODS
For this inter-laboratory comparison, CAD files representing three different commercially available mobile phone models were provided each by Motorola, Nokia and Sony Ericsson (See Figure 1). Calculations of radiated electromagnetic fields from these phone models were conducted in free-space and when the models were positioned at the right ear of the standard SAM head phantom [1] in the cheek and +15° tilt phone positions. SAR, absorbed power in the head phantom and source impedance were calculated at one specific frequency in both the 900 MHz and 1800 MHz bands. Nine laboratories conducted the calculations, in a blind-study manner, with four different commercially available software packages; CST MICROWAVE STUDIO® and CST MICROSTRIPES™ by CST AG, SEMCAD X® by Schmid & Partner Engineering AG, and XFdtl® by Remcom Inc. The dielectric parameters of the materials of the SAM head phantom model were the international standard parameters. The parameters for the materials in the phone models were provided by the manufacturers.

RESULTS
In Figures 2 and 3 the calculated 10g averaged SAR results for all three phone models are presented as percentage of the mean result. All SAR results are normalized to the source output power. The maximum relative standard deviation for all numerical SAR results for the three simulated phone models was 30%. The largest deviation from the mean SAR results

Figure 1: The Motorola c330 phone model (left), the Nokia 8310 phone model (center) and the Sony Ericsson W810 phone model (right) positioned next to the SAM head phantom.
was about 65%. A Cumulative Distribution Function (CDF) was computed for all the deviations from the mean SAR results and is shown in Figure 3 (right). The 95-percentile is about 40% for both the 1g and 10g averaged SAR results. The variation for the Motorola and Sony Ericsson models are higher than for the Nokia model possibly indicating a higher sensitivity to differences in the simulation parameters such as meshing, simulation time, etc. Other sources of deviations include positioning errors of the phone at the phantom, source model simplifications, location of simulation boundaries and numerical method approximations. Human errors can of course also be present considering the high complexity of the CAD models.

CONCLUSIONS

The agreement in calculated SAR between the participating laboratories is very similar to the agreement obtained in inter-laboratory comparisons involving SAR measurements. This shows that reproducible results are possible to obtain and it motivates the further development of standardized procedures for numerical SAR testing of mobile phones. Sources for the observed deviations are analyzed as part of an uncertainty evaluation to be included in the IEEE 1528.3 standard.

[1] IEC 62209-1:2005, “Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 1: Procedure to determine the specific absorption rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)”, 2005.
**INTRODUCTION**

Humans, mice, and snails exposed to a weak pulsed low frequency magnetic field (PLFMF) called the complex neuroelectromagnetic pulse (Cnp) experience a reduction in pain (humans), and reduced nociception (snails and mice) [1,2,3,4]. The most reproducible phenomenon observed from mice exposed to PLFMF is antinociception. It has also been shown that this phenomenon is dependent on the opiate system [2]. Snails administered naltrexone, show an attenuation of the antinociception produced by the Cnp. A concern about this potential tool for pain reduction is that it may be habit forming. We used an animal model of reward called conditioned place preference (CPP) to test this hypothesis. This test conditions mice to prefer a novel environment when paired with a rewarding stimulus such as morphine. We conditioned mice to a novel box with the Cnp to determine whether or not mice increase their exploration time in that box on a test day following conditioning compared to preconditioning.

**MATERIALS AND METHODS**

*Conditioned place preference apparatus:* Consists of two plastic boxes (20 cm*20 cm*20 cm) separated by a clear plastic bridge. One box is white with vertical black stripes and the other is black with white horizontal stripes.

*Coils and Magnetic field generator:* One set of square Helmholtz coils consisted of two horizontal coils wound with 200 revolutions of copper wire separated by 10 cm surrounds the conditioning boxes. The generator is an in-house built amplifier and wave generator capable of producing PLFMF of 200 µT peak with a peak power output of two amps.

*Experimental design:* Twenty four male CD-1 mice weighing 25-30 g were exposed to the conditioned place preference apparatus and one of four experimental conditions; 1) Cnp, 2) or a 60 Hz sinusoidal field that was pulsed on/off with timing equivalent to the Cnp, 3) morphine sulphate (5 mg/kg) positive control, 4) or a sham condition with no current to the coils.

Mice were first habituated to the apparatus for 30 minutes per day for two days. On the third day the mice were tested for the amount of time spent in either box or the bridge for 15 minutes. All mice were then confined daily for 30 minutes to the preferred and on the next day to the non-preferred box for a total of ten days of confinement. Thus there were five conditioning trials. When the mice were confined to the non-preferred box, the experimental condition was applied and a sham condition applied when confined to the non-preferred box. On the eleventh day (post conditioning test day) the mice were exposed to the apparatus and allowed to explore both boxes. The time spent in separate compartments was recorded. All testing sessions were video recorded.

The research protocols used in this work are in accordance with the rules and
regulations of the Canadian Council on Animal Care and were approved by the University of Western Ontario’s Council on Animal Care, Animal Use Subcommittee. 

Statistics: A three way mixed analysis of variance was conducted. The within-subjects variables were, box type and pre/post conditioning, whereas experimental conditions was the between-subjects variable. The dependent variable was time.

RESULTS
A 3-way effect between condition, box preference, and pre/post treatment approached significance \([F_{5,30} = 2.014, p=.111, p\text{Eta}^2 = .241, \text{power} = .566]\). The partial eta squared which is not sensitive to sample sized did indicated that over 24% of the variance after controlling for the other sources of variance is due to the interaction. Simple one-way analysis of variance for the conditioned boxes post treatment did show that the groups were significantly different from one another \([F_{3,19} = 3.99, p<.05]\) and the posthoc Tukey test showed that is was the morphine group that was significantly different from the control (sham) group alone (Figure 1B).

![Figure 1A](https://example.com/figure1a.png)  
![Figure 1B](https://example.com/figure1b.png)

Figure 1 A, B: Shown here is the amount of exploration time spent in preferred (not conditioned), non-preferred (conditioned), and the bridge joining both boxes before conditioning (A) and after (B). Figure 1B shows that mice conditioned with morphine spent the most time in the non-preferred box following conditioning relative to preconditioning. * = significant at the .05 level.

CONCLUSIONS
This study did not support the hypothesis that the Cnp was a rewarding stimulus as shown by the CCP test. It is possible, however, that with this small sample a conclusive statement cannot be made. As is shown in Figure 1B the group that spent the greatest amount of time in the conditioned box after the morphine group was the Cnp group. In order to be more confident in stating that the Cnp is not rewarding the sample size will have to be increased.

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REFERENCES
Direct examinations of material from chronic bacterial infections have shown that the causative organisms grow in matrix-enclosed biofilms, and \textit{in vitro} and \textit{in vivo} experiments have demonstrated that the cells within these communities are protected from antibacterial agents, including antibiotics. This protected mode-of-growth allows the bacteria to escape host defenses and antibiotic treatment, and it explains the very prolonged course of diseases like prostatitis and cystic fibrosis. Modern strategies for the treatment of these chronic biofilm diseases center on the prevention of biofilm formation, and on a variety of chemical and physical technologies that undermine the inherent resistance of biofilm communities to antibacterial agents.

\textbf{References :}


\textbf{Key words :}

Biofilms, Antibiotic resistance, Chronic infections.
RECENT ADVANCES IN NEW MRI METHODS FOR ELECTRICAL IMPEDANCE AND CURRENT IMAGING OF THE BRAIN

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Magnetic resonance imaging (MRI) is nowadays a powerful tool for medicine, but conventional MRI gives no electrical information such as impedance/conductivity and currents related to the neuronal activities in the brain. We review the recent advances in impedance/conductivity MRI and current MRI based on the achievements obtained mostly in our laboratory in recent years. We have developed three different methods to obtain impedance or conductivity distributions in the human brain using MRI, allowing to visualize in vivo the electrical properties of tissues without the need to attach electrodes to the surface of the body; a large flip angle method, additional AC field method, and a method based on diffusion tensor MRI. We have also studied the sensitivity limit for the detection of neuronal currents by MRI, and obtained that the current MRI method required neuronal currents generating a change of magnetic field of order 1 nT at the imaging slice. We have demonstrated the detection of the signals related to the somatosensory evoked responses in rat brain using a 4.7 T MRI. These measurements are important not only for the diagnosis of brain diseases and cognitive dysfunctions but also for various analyses in biomedical engineering and bioelectromagnetics, such as obtaining current distributions in transcranial electrical stimulation (TES) and transcranial magnetic stimulation (TMS), calculating the specific absorption rate (SAR), and current-source estimations in electroencephalography (EEG) and magnetoencephalography (MEG).
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Title:
PHOTOACOUSTIC IMAGING FOR HIGH-RESOLUTION DIAGNOSTIC IMAGING OF CANCER

100 Word Abstract:
Optical imaging methods are sensitive indicators of tumour angiogenesis and metabolism and have the capacity to distinguish benign from malignant lesions. However, most optical techniques provide low resolution images, which degrade diagnostic specificity. To improve diagnostic specificity, several groups are developing photoacoustic imaging for cancer diagnostics. Photoacoustic imaging offers the ability to capture high resolution optical images and therefore may provide a means to distinguish benign from malignant lesions with improved specificity. This would lead ultimately to a method for positively impacting patient care, especially for women with breast lesions not readily identifiable by mammography, ultrasound, or MRI.

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Electromagnetic Fields (EMF) Health and Safety Standards Impacts: A Tutorial

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ABSTRACT
Fifty years of scientific study has led to EMF safety standards based on sound bio-effects research. Binding legislation setting EMF exposure limits for the public and the worker has been passed or proposed. Socio/economic and environmental impacts of standards have not been determined. None of the standards provides a balanced risk characterization including assessment of shifting of risk shifts or reintroduction of presently controlled risks. This tutorial will describe potential impacts of EMF safety standards on different sectors. Examples of potential decreases in overall safety due to operational effectiveness reduction or degradation of EMF based safety systems will be presented.
Radio-frequency standards have evolved over six decades to provide protection against all proven adverse effects of exposure. Current RF standards all set thresholds based on established deterministic effects. In recent years, international measures for health protection, including those supported by the WHO, sometimes promote precautionary approaches to deal with uncertainties which can include increasing safety margins. Whether this approach is valid or could produce any conceivable benefit to public health depends on factors which can be determined, even in a situation of uncertainty, and these should be taken into account in formulating both standards thresholds and advice for their application.
BEMS TUTORIAL SESSION
ON
BIOFILMS
Bruce R. McLeod

It has been known for nearly twenty years that small dc electric currents can enhance the efficacy of certain antibiotics, in vitro, against *Pseudomonas aeruginosa* biofilms and, more recently against *Staphylococcus aureus* and *Staphylococcus epidermidis*. The use of electric and possibly magnetic fields to control bacterial biofilms appears promising. Now the challenge is to move EM fields laboratory research into the clinic. One approach is to prevent a biofilm from forming on a prosthetic surface. A second is to combat a biofilm that forms, post surgery. Several questions concerning device design are presented along with possible developmental approaches.
In the RF fields of magnetic resonance (MR) scanners, implanted medical device (IMD) can receive considerable energy that may be deposited/absorbed very locally (e.g., at the lead tip). Demonstrating that the energy deposition is non-hazardous for the entire patient population is a rather complicated task since the exciting incident electric fields are strongly dependent on anatomy, position, frequency and coil design. Other potential hazards result from the gradient and static magnetic fields. The state of the art in IMD design and test procedures are discussed.
HOW SAFE IS MAGNETIC RESONANCE IMAGING (MRI)?

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MRI has evolved into a premier radiologic modality for imaging. Approximately 30 million MRI procedures are estimated to be performed annually in USA alone. Although MRI utilizes nonionizing radiofrequency waves and is considered safe for repeated procedures there are a number of hazards associated with MRI. This review will review the various safety issues associated with MRI. The most studied are the bio-effects associated with high power radiofrequency pulses, rapidly switched magnetic field gradients and slowly varying high fields on the subjects being scanned. These include risk of tissue heating, burns, peripheral nerve stimulation and temporary sensations. Furthermore, these fields can interact with active and passive devices, such as stents and infusion pumps implanted in the body. In addition, to the direct effects of the MRI device on the patient, a number of indirect hazards have also been reported. These include the risk of injury from ferromagnetic objects that are accidentally brought in the vicinity of the magnet and the potential for infection due to the challenges in cleaning the patient contact areas. Adverse events experienced during MRI scans are voluntarily reported to the FDA as a part of the Medwatch program and logged in the FDA database. All the above safety issues and reported events will be described in the context of the current MRI practice and reports from the FDA database.
Since 1988 we have studied the effects of non-thermal RF-EMF in TEM-cells upon the BBB in >2000 rats. We have shown significantly increased leakage of the rats' own blood albumin through the BBB at energy levels of 1W/kg and below, as compared to non-exposed animals.

The lowest studied energy levels, (below 10mW/kg), give rise to the most pronounced albumin leakage. SAR 1 mW/kg exists about one meter away from the mobile phone antenna and about 200 meters from base-stations. Further, we have registered neuronal damage in rat brains 28 and 50 days after a 2-hour GSM exposure.
Increased Blood-Brain Barrier Permeability As A Marker Of Brain Damage After Exposure To Mobile Telephone-Type Radiofrequency Fields

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Most BBB permeability changes after exposure to RF fields have been small and rapidly reversible, while the few positive results have been attributed to hyperthermia, procedural side-effects such as restraint, or inadequate dosimetry, and have not been successfully replicated. However, comparison between studies is often difficult due to different exposure systems, animal species, and assessment modalities.

Any vasogenic oedema produced by BBB breakdown is probably not functionally or pathologically significant as it is generally subtle and transient, after acute or protracted exposure, with re-establishment of the normal BBB and no significant rise in intracranial pressure or reduction of cerebral perfusion.
A LORENTZ MODEL FOR WEAK MAGNETIC FIELD BIOEFFECTS: MEASURES OF REACTIVITY.

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INTRODUCTION

This study considers the manner by which weak (μT-range) DC and combined AC/DC magnetic fields affect the temporal geometry of a bound charged oscillator. Previous analyses predicted that weak magnetic fields give rise to a rotation of the thermal component of the oscillator motion at the Larmor frequency, and bioeffects were based upon the assumption that the classical trajectory of the bound charge could modulate a biochemical process. A method is suggested for a measure of reactivity based upon the classical Larmor trajectory, and the results are applied to parallel and perpendicular AC/DC field combinations, with differing resonance regimes found for each. The problem of initial conditions is addressed through averaging over AC phases. AC resonance frequencies occur at the Larmor frequency, and also at other frequencies, and are dependent upon the ratio of AC/DC amplitudes and target kinetics via binding lifetime. The model is compared with experimental data reported for a test of the IPR model on data from Ca\(^{2+}\) flux in membrane vesicles and neurite outgrowth from PC-12 cells. The results do not require multiple-ion targets, superpositions of isotopes, or additional curve fitting. The sole fitting parameter is the binding lifetime of the target system and the results shown are consistent with the literature on binding kinetics.

MATERIALS AND METHODS

A geometric measure of reactivity is formed, based upon the simple assumption that greater angular excursion = greater reactivity. The angular distance \(\Omega(t)\) traversed is the integral of the absolute value of the Larmor frequency \(\omega_L\). The projection of the motion produces a geometric measure that retains invariants under phase averaging represents the net angular displacement due to rotation, relative to the axis defined by the initial oscillator position. The mean of this quantity taken over the binding lifetime \(T_b\) yields a measure of the total reactivity: the mean angular displacement, projected onto the Cartesian axis defined by the initial oscillator orientation. The reactivity \(<R>\), phase-averaged over \(n_p\) AC phases \(\phi_k\), yielding \(\text{abs}(\omega_{Lx}) = \Gamma\sqrt{B_{\text{amp}}^2 + (B_{\text{par}} + B_{\text{per}} \sin(\omega_{Lx} \tau + \phi_k))}^2\) is:

\[
<R> = \left\langle \frac{1}{n_p} \sum_{k=1}^{n_p} \cos \left( \int_0^{T_b} \text{abs}(\omega_{Lx}(\tau)) d\tau \right) \right\rangle,
\]

where \(<\cdot>_{T_b}\) denotes the mean, taken over the binding lifetime \(T_b\). \(<R>\) is independent of the initial ensemble of oscillator orientations and AC phases, and is dependent only upon the magnetic field environment via the Larmor frequency, and upon the target binding kinetics via the lifetime \(T_b\). Thus, for a target system with a well-defined charge-mass ratio, and a given magnetic field, the binding lifetime \(T_b\) is the sole parameter which must be known or deduced from experiment. The specific binding kinetics of the target system affect the specific location and height of AC and AC/DC resonances which will, in general, vary from one target system to another.
RESULTS

Resonance conditions for Ca$^{2+}$ membrane transport in vesicles have been reported for DC = 37 μT, AC = 24 Hz [1]. Application of the Lorentz model suggests a charge-mass ratio equal to that of unhydrated Mg$^{2+}$ as a potential target for the magnetic field effect. Figure below, left, shows <R> taken over 50 phase points which provides a reasonable fit of the data, compared to q/m for unhydrated Ca$^{2+}$ which is a poorer fit (right). Mg$^{2+}$ dependent Ca$^{2+}$ membrane transport is well described and could easily be checked experimentally.

Figure shows <R> for parallel vs. perpendicular fields for the above system, assuming 24 Hz = Larmor frequency. The model predicts a range of AC/DC amplitude ratios over which Ca$^{2+}$ flux increases, in contrast to its decrease over the same range, reported in the original experiment.

Figure compares <R> with IPR prediction for a neurite outgrowth system [2], again for a Mg$^{2+}$ target. The predictions of <R> provide a fit to the data obtained using only binding lifetime within the reported experimental ranges as the adjustable parameter. Results show a reasonable fit to the data for a Mg$^{2+}$ target, do not require the additional curve fitting required by the IPR model, and are consistent with the reported Mg$^{2+}$-dependence of PC-12 differentiation.

CONCLUSIONS

The Lorentz model proposes a measure of reactivity based upon the classical Larmor trajectory. The model applies to parallel and perpendicular AC/DC field combinations, with differing resonance regimes found for each. The problem of initial conditions was addressed through averaging over AC phases. AC resonance frequencies occur at the Larmor frequency, and also at other frequencies, and are dependent upon the ratio of AC/DC amplitudes and target kinetics via binding lifetime. The model is compared with experimental data reported for a test of the IPR model on data from Ca$^{2+}$ flux in membrane vesicles and neurite outgrowth from PC-12 cells. The results do not require multiple-ion targets, superpositions of isotopes, or additional curve fitting. The sole fitting parameter is the binding lifetime of the target system and the results shown are consistent with the literature on binding kinetics. Thus this Lorentz model can provide a simple testable alternative to the ICR and IPR models.

REFERENCES

The Electron Transfer Process of the SOD Enzyme in presence of a MW EM Field: a Molecular Study

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INTRODUCTION

The comprehension of interaction mechanisms between electromagnetic (EM) fields and biochemical reactions becomes particularly important when concerns on a possible action of microwave (MW) EM fields on oxidative-stress reactions and reactive oxygen species is suggested [1]. In this context the enzyme superoxide dismutase (SOD) plays a fundamental antioxidant role, by protecting cells from superoxide toxicity [2]. Previous results regarding MW field action on binding reaction in myoglobin showed that only intensities comparable to the atomic/molecular electric interactions could affect such biochemical process [3]. The objective of this work is to rigorously investigate the action of a MW EM field on the dynamics of the electron transfer reaction involving SOD, with the aim of finding a threshold for the intensity of the applied field.

MATERIALS AND METHODS

CuZnSOD is a 32-kDa homodimer, composed by a total of 310 residues, which catalyzes the dismutation of superoxide radicals (O₂⁻) into hydrogen peroxide. In this study it has been investigated the electron transfer from superoxide to the copper via three chemical states (Fig. 1), both in physiological conditions and under MW exposure. Authors fully analyzed the reaction and its molecular environment by means of a methodology combining quantum and classical methods, the Perturbed Matrix Method (PMM), already used for biochemical reactions under MW fields [3]. The binding free energy barriers for the two steps of the reaction (state 1 and 3) are evaluated. Moreover, to have an insight on the action of the field on the enzyme geometrical conformations and on its relaxation to equilibrium, the root mean square deviation (rmsd) parameter is used. Rmsd, provided by molecular dynamics simulations, is obtained by calculating for each time step of the simulation the root mean square positional deviation of each atom from the initial structure considered as a reference one [4].

RESULTS

Statistical analysis was obtained from seven simulations for the unexposed, while from six for f=1 GHz, |E|=10⁴ V/m and three for |E|=10⁵ V/m; the time-length of each run was of 20 ns. Table I reports mean values ± standard errors for the free energy barriers for the initial (state 1) and final step (state 3) of the reaction, where the process of electron transfer has already been performed. Data show no difference between exposed and unexposed for state 1, while for state 3 only for the case of 10⁵ V/m the difference in mean values is outside the standard error. Therefore two runs in exposure conditions (|E|=10⁵ V/m) and three unexposed
were prolonged up to 30 ns (Fig. 2 (a)). It can be observed that in the time interval from 20 to 30 ns (Fig. 2 (b)) the mean value for \textit{rmsd} is higher and with a broader distribution for the exposed case, clearly indicating that the applied field starts to act on the conformational structure of the protein modifying it with respect to the unexposed situation.

Figure 1: a) Molecular model of the enzyme SOD; b) Schematic view of the analyzed three chemical states.

Table I. Free energy barriers for State 1 and State 3

<table>
<thead>
<tr>
<th></th>
<th>Free energy barrier (State 1)</th>
<th>Free energy barrier (State 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean value</td>
<td>S.E.</td>
</tr>
<tr>
<td>Unexposed (n=7)</td>
<td>62.84</td>
<td>3.2</td>
</tr>
<tr>
<td>$10^5$ V/m (n=6)</td>
<td>56.77</td>
<td>1.9</td>
</tr>
<tr>
<td>$10^6$ V/m (n=3)</td>
<td>63.04</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Figure 2: a) Dynamic behavior of the \textit{rmsd} for 30 ns; b) Histogram distribution for the last 10 ns

CONCLUSIONS

Molecular simulations based on rigorous quanto-mechanical approach have been used to study the electron transfer in SOD. Results indicate that 1 GHz EM fields with intensities up to $10^5$ V/m may start to modify the conformational geometry of the enzyme with possible consequences on the final reaction.

REFERENCES

The Role of the Three-Fold Symmetry Pore in the Interaction Between Radio Frequency Magnetic Fields and Ferritin

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INTRODUCTION
Ferritin [1] plays an essential biological role in iron biochemistry. The proteic cage (apoferritin) is constituted by 24 subunits about 180 peptides each and arranged in a 4-3-2 symmetry to form a polyhedral peptidic cage of 440 kDa in mass and 12 nm in size. Inside the cage there is a ferrihydrate nanoparticle of up to 8 nm and 4500 iron ions. This nanoparticle is superparamagnetic, with an estimated magnetic moment of 0.1-1 µB per iron atom. We have in the past given experimental evidence supporting a novel, non-thermal mechanism of interaction by which the rates of iron release in proteins exposed to RF magnetic fields are reduced by up to a factor three [2]. The effect is dependent on the field-frequency product. Here we will discuss the role of the three-fold symmetry pore, the entry and exit molecular gate, in the interaction between RF magnetic fields and ferritin.

MATERIALS AND METHODS
Apoferitin and ferritin from horse equine spleen was purchased from Sigma-Aldrich (St. Louis, USA). Ferrozine (≥ 97 %) was purchased from Fluka Chem. (Milwaukee, USA). Tritisol buffers were obtained from Kanto Chem. (Osaka, Japan). Ammonium iron sulphate six-hydrate (Mohr’s salt) with spectroscopic purity ≥ 99% was purchased from Sigma.

The RF magnetic fields were generated via a TG&C AG1006 RF power source connected to a set of magnetic field standard Helmholtz coils MH-2.5 from LakeShore (Westerville, USA). The coils are calibrated to supply 2.88 mT/A, with a deviation of less than 2 % at the sample space. Typical exposure was 3 h at 180 T/s (from 15 µT at 2MHz to 120 µT at 250 kHz). The specific absorption rate (SAR) in the ferritin solution is 10^-8 to 10^-7 W/kg. The control and exposed samples’ temperature is equal (within 0.1º C) at all times.

Optical absorption was measured with a SpectraMax M5-NS from Molecular Devices (Tokyo, Japan). Iron chelation and uptake are measured at 562 nm (ε = 29700 M^-1 cm^-1) and 420 nm (ε = 550 M^-1 cm^-1), respectively. Each titration measurement was carried out in 14 to 20 samples (half control). Error bars are the added standard error of the mean.

RESULTS
Our measurements on the effects of radio frequency magnetic fields on ferritin show four characteristics: i) The effects last longer for iron release than for iron uptake (Figure 1); ii) Apoferritin, the protein without the nanoparticle, does not show an effect; iii) The effect depends on magnetic field amplitude and frequency but not on sample conductivity or electric field; iv) The power dissipated by the nanoparticle calculated from its susceptibility (~2 x 10^-6 m^3 kg^-1) and relaxation time (~ 0.1 ns) is 10 J/M for a typical exposure. This is too small to affect the interactions between protein subunits and molecules (300 and 8 kJ/M).
We define $\Delta Fe_{\text{rel/uptake}}$ as $\Delta Fe = (Fe_{\text{control}} - Fe_{\text{exposed}}) / Fe_{\text{control}}$, with $Fe_{\text{control}}$ and $Fe_{\text{exposed}}$ the iron chelation/intake in control and exposed samples, respectively. The field exposure was 180 T/s for 3 (release) and 2 hours (uptake). Left: Percentage changes in the iron released by ferritin when exposed to the iron chelator ferrozine for proteins exposed to RF fields and control samples. Right: Percentage changes in iron adsorbed.

We hypothesize that the origin for the mechanism is at the pore in the three-fold symmetry axis (Fig. 2A). This pore is the gate for the entry and exit of molecular compounds inside ferritin. The pore is negatively charged due to 6 glutamic acids. This charge will be partially screened by water molecules and ions. The screening can be altered by the energy released by the nanoparticle when exposed to an RF magnetic field, which will affect the molecular entry/exit rates for charged molecules. To test this hypothesis, we have cationized the carboxyl groups around the 3-fold symmetry pore (Fig. 2B). This will allow us to determine whether changes in protein function are associated to the charge distribution around the pore.

**CONCLUSIONS**

Radio frequency magnetic fields alter the functioning of ferritin, changing iron release and uptake after exposure for three hours to fields of up to 180 T/s (from 15 µT at 2 MHz to 120 µT at 250 kHz). The effect is not thermal or electric, as it is independent on sample conductivity and the temperature remains equal for all samples. The most likely origin for the effect is a change in the charge screening around the entry and exit point for molecules.

**ACKNOWLEDGMENTS**

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**REFERENCES**


Propagation of Uncertainties in SAR Evaluation Using a Stochastic Collocation Technique

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INTRODUCTION

Numerical techniques like FDTD (Finite Difference Time Domain) are now widely used for the analysis of the interactions of radiofrequencies with human bodies. They are reliable and accurate provided that the input parameters such as the geometry or the dielectric properties are perfectly known. However uncertainties in the position of the source, in the shapes of the system or in the permittivity and conductivity of the tissues are usual in these complex systems. These uncertainties induce an uncertainty on the result i.e. absorbed power or specific absorption rate (SAR). Assessing the uncertainties on SAR is of prime importance in numerical dosimetry either for sensitivity analysis or for risk analysis when the parameters are variable, uncontrollable or simply unknown. Stochastic finite elements techniques are able to propagate in an efficient manner random input parameters through the electromagnetic model.

MATERIALS AND METHODS

The classical method to deal with uncertainties is the Monte Carlo one; given some probabilistic laws for the input parameters, the statistical moments of the response can then be determined through drawn samples of the deterministic model. The major drawback when applied to electromagnetic model is the very slow rate of convergence, $O(1/\sqrt{N})$, with $N$ being the number of samples. The time to get one sample through a FDTD calculation may be not negligible. Stochastic finite elements have been developed to incorporate random fluctuations in the deterministic finite element methods [1]. These methods have been used in mechanics or fluid dynamics [2]. They have been introduced recently in electromagnetics in the time domain [3,4]. The principle is that a random variable can be expanded via polynomial chaos or Hermite polynomials. Collocation methods are then preferred to get non-intrusive schemes, i.e. requiring basically no modification of existing codes. Thus, the approach is more general and not restricted to the FDTD we are using here.

The SAR for example is a function of input parameters represented by a vector of random variables $X$ with its joint probability density function $P_X(x)$. It can be expanded with polynomial chaos which are orthonormal with respect to the probability measure $P_X(x)dx$.

\begin{equation}
SAR = \varphi_{FDTD}(X) = \sum_{i} \alpha_{i} \psi_{i}(X)
\end{equation}

The coefficients of the expansion can be determined with quadrature rules requiring samples given by the FDTD model. The expansion (1) can then be used to compute the statistical moments like the mean or the standard deviation.
\[
\alpha_i = \int \text{SAR}_i(X) P_X(x) dx \cong \sum \omega_q \text{SAR}_q \psi_q 
\]  

(2)

RESULTS

As an example, an incident plane wave is impinging on the SAM head phantom. The uncertain parameters are the two angles defining the direction of the incoming wave (Fig. 1). The angles follow a uniform law with a variation of 10% or 50%. In this case, the required number of samples to achieve convergence is typically 40. For 10% variation of the 2 angles, the peak SAR over 10g has a standard deviation of 5% while it is 20% for 50% variation. Furthermore, with the expansion (1) it is easy to compute global sensitivities giving a hierarchization of the factors. In Figure 2, the elevation angle is the predominant factor in the peak SAR over 10g evaluation, more important than the azimuth angle or the mixed influence of both angles.

CONCLUSIONS

Collocation stochastic techniques are efficient to compute the uncertainties in an electromagnetic model resulting from uncontrollable or unknown input parameters. These are particularly useful in complex dosimetry problems where uncertainties are to be evaluated and finally be managed.

REFERENCES

Visualization of Temperature Distribution Change Due to Millimeter-Wave Exposure with Micro-encapsulated Thermo-chromic Liquid Crystal

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INTRODUCTION

Millimeter-waves (MMWs) exposure causes highly localized energy absorption and generates steep temperature gradient within several millimeter areas. Therefore, it is necessary for the temperature measurement method to have high spatial resolution and high sensitivity to temperature changes. We proposed micro-encapsulated thermo-chromic liquid crystal (MTLC) as a micro temperature probe for dosimetry of MMW exposures. The purpose of this study is to investigate feasibility of MTLC method to apply dosimetry of MMW exposures. We show results of visualizations of 2-dimensional temperature distribution changes in both in vitro and in vivo studies.

MATERIALS AND METHODS

MTLCs of 20-30 μm in diameter are suspended into high transparency materials. When the slit light was focused on the target material, temperature distribution was visualized within the cross section illuminated by the slit light. Each MTLC changes its color from red, yellow, green, to blue according to temperature elevation. The details are shown in Ref. [1].

RESULTS AND DISCUSSION

Figure 1 shows the experimental setup for the temperature distribution measurement with MTLC method for in vitro exposure experiment. Exposure frequency was 60 GHz, and output power from the horn antenna was 2 W. We used carageenan gel instead of culture medium, because carageenan gel has higher transparency and appropriate viscosity to prevent the convection. The mixture ratio of MTLC is 0.1 wt% and the thickness of carageenan gel was 1 mm. Here, MTLC was toned depending on temperature from 25 ºC to 30 ºC. The bottom of the carageenan gel was illuminated by the slit light of 1 mm in thickness along y direction. Visualized temperature distribution was observed by a CCD camera as shown in Fig. 1 (a).

Figure 1 (b) shows the visualized temperature distribution by MTLC after 8 second from the onset of the MMW exposure. We think the spatial pattern of temperature elevation in Fig. 1 (b) is almost the same as energy absorption pattern due to MMW. The similarity of both patterns is confirmed by comparing the experimentally obtained image of temperature distribution with the numerically calculated distribution of energy absorption. We can observe temperature distributions with steep gradient within several millimeter areas by using MTLC.

Figure 2 shows the application of MTLC method to an in vivo exposure experiment.
MTLCs are suspended into the aqueous humor of rabbit’s eye. The mixture ratio of MTLC was about 0.1 wt%. It was toned depending on temperature from 35 °C to 45 °C. Exposure experiments are performed for two conditions. Figure 2 (a)-(d) indicates the results of 18 GHz exposure by the pyramidal horn antenna. The distance was set at 20 cm from the aperture of the antenna to the corneal surface of the eye. Figure 2 (e)-(h) indicates the results of 40 GHz exposure by the pyramidal horn antenna. The distance was set at 11.5 cm. Output power from horn antennas were 200 mW in both cases. It is found that we can observe temperature distribution changes simultaneously with convectional patterns in the small area such as the anterior chamber of rabbit’s eye.

These results indicate that MTLC method is effective in temperature measurement for MMW exposure experiments. In future work, we plan to quantify the temperature value from captured images and reconstruct the 3-dimensional temperature distribution from 2-dimensional distributions.

![Figure 1](image1.png)

**Figure 1:** (a) Setup of temperature distribution measurement with MTLC. (b) Temperature distribution visualized by MTLC in the x-y plane at the bottom of culture dish.

![Figure 2](image2.png)

**Figure 2:** (a)-(d) show to expose frequency of 18 GHz. (e)-(h) show to expose frequency of 40 GHz. (a) and (e) show just after from exposure. (b) and (f) show after 10 second from exposure. (c) and (g) show after 20 second from exposure. (d) and (h) show after 30 second from exposure.

**ACKNOWLEDGMENTS**

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**REFERENCES**

Comparison of RF Exposure and Thermal Response in a Mouse Dam and Mouse Fetuses using Finite-Difference Mouse Models

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INTRODUCTION

In-vivo studies involving exposure of rodents to radiofrequency (RF) exposure (for example [1, 2]) require detailed dosimetric analysis to enable correct interpretation of biological outcomes. Simple geometrical representations (such as cylinders) have been found to be inadequate. Detailed organ models of mice – a female, a pregnant female, a male, and a fetus – have been developed to support this work and to enable Specific energy Absorption Rate (SAR) and thermal modeling to be carried out using finite difference methods. The mouse models, consisting of up to 50 tissues, are available for use for research purposes by the Bioelectromagnetics community. Dielectric and thermal tissue properties have been sourced and included in the models, with allowances made for the increased water content of the fetuses. A comparison was made between the RF exposure (at 900 MHz) of the mother and the fetuses as specified by the SAR and the resultant temperature change.

DEVELOPMENT OF THE MOUSE MODELS

In the development of the finite difference mouse models, organ dimensions and positioning were based on a mouse atlas [3]. This mouse is of the ICR/ddY strain. This atlas has 93 pages of colour sectional anatomical photographs (sagittal, dorsal and transverse sections). Advice on mouse anatomy was also given by researchers at the Institute of Medical and Veterinary Science (IMVS), Adelaide, Australia.

The development of the finite difference models in Remcom’s XFDTD software [4] was performed over a two-year period. The first year consisted on a series of steps: (1) scanning the atlas images using image editing software; (2) placing a grid (with 0.75 mm spacing) over each image; (3) coding the tissue information at each grid point into spreadsheet format; (4) concatenating the data to form a three-dimensional model taking much care in the correct placement and sizing of the slices. The second year involved fastidious attention to detail of ensuring the accuracy of the models and developing the four models (male, female, fetus, and dam). The dam carries eight near full term fetuses (figures 1 and 2).

Figure 1: Three-dimensional view of the dam
COMPARISON OF RF EXPOSURE AND THERMAL RESPONSE BETWEEN DAM AND FETUSES

Computational analyses were performed to simulate the exposure in a radial exposure chamber (described in [5]) operated at a frequency of 900 MHz. A comparison was made between the exposure of the mother and the fetuses as specified by the Specific energy Absorption Rate (SAR) and the resultant temperature change. In general, the SAR levels were determined to be slightly lower (around 10-20% for the average values) and the peak temperature increase significantly lower (50%) in the fetuses, when considering the range of exposures in the exposure chamber, and averaging across the fetuses and the mother. The increased water content in the fetuses gives rise to higher thermal conductivity values. This in turn results in lower temperatures in the fetuses.

CONCLUSIONS

Detailed mouse models, based on anatomical data and consisting of up to 50 tissues and a voxel size of 0.75 mm, are available from the authors for research purposes. The pregnant mouse model, has been considered in this paper to provide an examination of exposure levels and resultant thermal effects in the dam in comparison with that of the fetuses. In general, changes are less in the fetuses than the dam.

ACKNOWLEDGMENTS

We would like to thank John Finnie and Tim Kuchel from the Institute of Medical and Veterinary Science (IMVS), Adelaide, Australia, for their input and advice.

REFERENCES

A Real Time Exposure System for Neuronal Networks in the MW Band

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INTRODUCTION

The study of possible alterations in neuronal networks functionality induced by the EM exposure is extremely relevant in understanding and defining microwave (MW) non-thermal field effects. Neurons, in fact, represent one of the favorite targets of the EM field interaction as stressed by the growing of experimental investigations \cite{1, 2, 3}. In order to deepen such studies, a new real time exposure set-up usable in the GHz region has been designed and realized. The real time recording of the neurons action potential under exposure is detected by an integrated electrically passive microelectrode array (MEA) as an alternative approach to the common used patch clamp technique \cite{1,3}.

MATERIALS AND METHODS

The adopted EM structure is a transverse electromagnetic cell (TEM) designed for working up to the MW region (structure dimensions reported in Fig. 1(a)),\cite{4}. In order to receive the recording chip (MEA) the bottom ground plate of the cell is opened by an hole. Two hole shapes, circular and squared, are possible allowing the positioning of the chip under or over the bottom ground plate of the cell respectively, Fig. 1 (b, c). The neurons are placed directly over the MEA surface thus the chip is surrounded by a cylindrical glass containing the culture medium, Fig. 1 (b, c). Therefore to optimize the biological sample positioning an in depth numerical analysis is carried out by FDTD methods evaluating E field and SAR distribution, reflection parameters as well as the impedance matching with the feed. First, an accurate numerical model of the chip tracks with minimal dimension of 200 µm have been considered for simulations. Since the electrodes dimensions in the central recording zone are extremely small (about 20 µm), it has been necessary to adopt a simplified numerical treatment, as shown in Fig. 2 (a, b). At the same time experimental characterization of the system is on going, involving temperature and E field measurements essential to validate numerical results and to evaluate possible EM field coupling with the recording electrodes.

RESULTS

Results of simulated scattering parameter $S_{11}$ confirm the good transmission behavior of the structure, with a value of $|S_{11}|$ equal or less than $-10$ dB in the whole operating band (0.5-2 GHz). The SAR (W/kg) distributions at 1.8 GHz into the biological solution have been evaluated for the configurations of Fig. 1 (b). Values of $\varepsilon = 71$ and $\sigma = 2.1$ (S/m) for the biological medium permittivity and conductivity have been adopted respectively. As observable from Fig. 2 (c, d) the SAR homogeneity in the recording zone strongly depends on numerical modeling of the electrodes, Fig. 2 (a, b), as well as the system efficiency ((W/kg)/W). For this reason comparison with experimental measures, on going at the
moment, are useful to define correct modeling features and to validate future numerical results in the different system configurations.

![Figure 1: TEM cell dimensions, b) circular hole configuration the biological sample is placed under the ground plate, c) squared hole configuration the biological sample is placed on the ground plate.](image)

![Figure 2: Two possible modeling of the chip center a) without metallizations, b) fully metallized; c) and d) SAR distribution for the two cases at the interface between the biological solution and the chip.](image)

**CONCLUSIONS**

A new exposure set-up for real time recording of neuronal networks activity through MEA is presented. A numerical analysis is ongoing as well as experimental measurements on the system. First results evidence the importance of an accurate chip modeling to correctly evaluate SAR and E field distributions homogeneity in the recording zone.

**REFERENCES**


INTRODUCTION

Transmembrane glycoproteins are negatively charged and may be connected internally to the cytoskeleton. An externally applied electric field exerts a force $F_{\text{elec}}$ on such molecules that will be transmitted to the cytoskeleton. Torque and force balance applied to this interaction along with the effects of the viscosity of the extracellular fluid, $F_{\text{drag}}$, and the restoring force exerted by the membrane, $F_{\text{memb}}$, permit the calculation of this cytoskeletal force. These forces are calculated for two pulses, each with an amplitude of 100 V/m, a repetition rate of 1 Hz and a pulse duration of 0.2 s. One pulse is unipolar; the other, bipolar. For a 27-rod unit of the glycocalyx of a hamster cremaster cell the unipolar pulse produces a maximum cytoskeletal force of 1.9 pN; the bipolar pulse, 1.6 pN. Such forces in the cytoskeleton are comparable to those observed to produce physiological effects and provide a plausible transduction mechanism for applied electric fields.

MATERIALS AND METHODS

Each pulse is decomposed into 201 Fourier components. The torque/force balance is applied separately to each component to obtain the time-varying force it produces. These individual forces are then recombined to obtain the force exerted by the pulse.

RESULTS

Figures 1 and 2 illustrate, respectively, the forces associated with the unipolar and bipolar pulses. $F_{\text{base}}$ is the force the cytoskeleton exerts on the glycoprotein; it is equal and opposite to the force exerted by the glycoprotein on the cytoskeleton. The results are shown for a 27-rod array, the basic unit in the glycocalyx, of a hamster cremaster cell. The resulting forces depend on choices made for the viscosity ($b$) of the extracellular fluid and the “spring-constant” ($k$) for the restoring force of the membrane. For reasonable choices of these parameters ($b = 0.001$ Ns/m$^2$ and $k = 10^{-5}$ N/m) the unipolar pulse produces a maximum force of 1.9 pN; the bipolar pulse, 1.6 pN. Such forces in the cytoskeleton are comparable to mechanical forces observed to produce physiological effects. At these low frequencies the cytoskeletal force is determined primarily by the membrane restoring force. At higher frequencies the drag force dominates.

The shape of the force-response curve is analogous to the charging-discharging, exponential response of an electrical RC circuit. The viscosity is the analog of the resistance ($R$) and the compliance ($1/k$) is the analog of the capacitance ($C$). The cytoskeletal force for the unipolar pulse rises slowly, but does not reach its maximum possible value during the duration of the pulse. When the pulse ends, the force decays exponentially to zero with the appropriate time constant. The bipolar-pulse force has even less time to reach the maximum possible value. It thus reaches a smaller peak value before the direction of the field is reversed and the force increases in the opposite direction. An alternative view is that the bipolar pulse contains relatively more high-frequency Fourier components than the unipolar pulse. Those high-frequency components are more heavily damped than the low-frequency components. Hence, the amplitude of the bipolar force is smaller than that of the unipolar force. The force variations for both pulses differ considerably from those produced by a 1 Hz
CONCLUSIONS

The forces produced on the cytoskeleton by externally applied electric fields differ for unipolar pulses, bipolar pulses and continuous-wave signals. For physiological strength fields the forces produced are comparable to mechanical forces known to produce biological effects. Hence, the electromechanical transduction of electric fields is a plausible mechanism to explain some of their physiological effects.
Introduction
In the last decade the everyday use of mobile phones became increasingly popular. Especially among young people a rapid increase in the number of frequent mobile phone users was seen. Recent studies even indicate that teenagers are the most frequent users of mobile phones. At the same time, concerns exist in the general population that exposure to mobile telecommunication networks could negatively affect health and well-being even at exposure levels far below the reference levels. Unspecific symptoms like headache, sleeping problems or difficulties in concentration were attributed to exposure to mobile phone frequencies. Especially children and adolescents are objects of concern because of their possibly higher vulnerability to high-frequency electromagnetic fields. This assumption is based on a longer lifetime exposure, the still developing nervous system and a greater conductivity of their brain tissue. Despite their possibly higher vulnerability to high-frequency electromagnetic fields, these age groups have so far rarely been studied.

In earlier epidemiological studies on adults, self-reported distance to the next mobile phone base station or self-reported mobile phone use were used as proxy for the actual exposure. Due to factors like orientation of the main lobe, shielding and reflections by the topographic reality, the distance to the base station is not a valid proxy for exposure. Furthermore, these measures might be prone to awareness bias. Another measure used in some recent epidemiologic studies - one-time measurements in the bedroom of the participants - only reflects parts of the overall exposure. Meanwhile, personal dosimetry is available to assess exposure to mobile telecommunication networks. The main advantage of this method is that all sources of individual exposure can be assessed. Estimation of personal exposure is now not only possible at the participant’s home, but also at school and during leisure time.

The aim of this study was to assess the potential association between exposure to mobile telecommunication networks using personal dosimetry and self-reported acute well-being in children and adolescents.

Materials and methods
A population-based sample of 1,498 children (aged between 8-12 years) and 1,524 adolescents (aged between 13-17 years) was assembled for the study (response 52%). Participants were randomly selected from the population registries of four Bavarian (South of Germany) cities and towns with different population sizes. During
a Computer Assisted Personal Interview data on socio-demographic characteristics and potential confounder was collected. Acute symptoms (headache, irritation, nervousness, dizziness, fatigue, fear and sleeping problems) were assessed three times during the study day (morning, noon, evening). Using a dosimeter (ESM-140 Maschek Electronics), we obtained an exposure profile over 24 hours for three frequency ranges (measurement interval 1 second, limit of determination 0.05 V/m) for each of the participants. Exposure levels over waking hours were summed up and expressed as mean percentage of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) reference level. Data were analysed using logistic regression models adjusting for potential confounders.

**Results**

The overall exposure to high frequency electromagnetic fields of children and adolescents was well below the ICNIRP reference level. Median exposure for adolescents was 0.19% of the ICNIRP reference level per second during waking hours and 0.18% for children. Exposure varied by size of the town of residence. Median exposure levels during waking hours were highest in Munich and lowest in the smallest town. We did not find a consistent association between measured exposure and acute symptoms, neither for children nor for adolescents. This was true for the main analysis, where measured exposure was divided into quartiles, as well as for the sensitivity analysis, where exposure was evaluated separately for the three frequency bands as well as using a binary exposure cut-off point (90% percentile).

**Conclusion**

This study is the first which used personal dosimetry to assess the individual exposure to mobile telecommunication networks in children and adolescents, enabling objective assessment of exposure from all sources. We found an overall exposure level to mobile telecommunication networks far below the current ICNIRP reference levels. No consistent association between exposure to mobile telecommunication networks and acute well-being in children and adolescents was found. More research is needed to investigate possible long-term effects.

The study was funded by the German Mobile Telecommunication Research Programme (DMF).
Exposure to Contact Currents and Magnetic Fields and the Risk of Childhood Leukemia

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INTRODUCTION

Despite the association between childhood leukemia and magnetic fields, no plausible biophysical mechanism to support this association has been identified. The objectives of this study were to examine the association between contact current exposure and the risk of childhood leukemia, and to investigate further the association with magnetic fields. Previous measurement and modeling studies have indicated that, across “typical” neighborhoods in North America, the residential magnetic field is positively associated with the putative source of children’s exposure to contact current, the voltage between the residential water pipes and the drain [1, 2]. Presumably exposure occurs while bathing, and behavioral surveys prior to data collection substantiated that the large majority of children contact the plumbing fixtures while bathing. Further, dosimetric studies report that modest, though realistic levels of contact current (up to 50-100 μA), can produce biophysically plausible doses to portions of a child’s bone marrow (~1.5 V/m per 100 μA) [3]. The study base was sampled from the Northern California Childhood Leukemia Study (NCCLS). The NCCLS is a large ongoing multi-faceted case-control study across 35 counties in northern and central California that began subject recruitment in 1995. The NCCLS was designed to study the relationship of genetic, biochemical, environmental, nutritional and behavioral factors with leukemia incidence in children under 15 years of age [e.g., 4-9].

MATERIALS AND METHODS

Cases and controls were under age eight years at diagnosis or reference date (the corresponding date for matched controls) and resided in the same home since the diagnosis/reference date. Between 2004 and 2007, indoor and outdoor contact voltage and magnetic field measurements were collected and wiring configurations assessed for the residence at diagnosis (or reference date for controls) for 245 cases and 269 controls. The magnetic field was logged every 5 seconds for 30 minutes in the room that registered the median spot-measured field. In the bathtub most frequently used by the subject child, contact voltage was recorded between the bathtub spout and the drain every 5 seconds for 30 minutes with a 1,000 ohm resistor across the voltmeter’s leads to approximate a person’s body resistance. For both exposures, the means of the 30-minute measurements were the primary estimates of magnetic field and contact current exposure. Odds ratios (OR) were calculated using logistic regression techniques, adjusting for age, sex, Hispanic status, mother’s race and household income.
RESULTS

No statistically significant associations were seen between childhood leukemia and indoor contact voltage level (exposure ≥90th percentile: OR=0.83, 95% confidence interval (CI): 0.45, 1.54), outdoor contact voltage level (exposure ≥90th percentile: OR =0.89, 95% CI: 0.48, 1.63), and indoor magnetic field levels (exposure ≥90th percentile: OR=1.27, 95% CI: 0.74, 2.20). No association between wire configuration codes and childhood leukemia was observed. There was no evidence that selection bias affected any estimates of relative risk.

CONCLUSIONS

There was no apparent evidence of an association between the risk of childhood leukemia and exposure to contact currents or to magnetic fields in this well characterized population. Exposure prevalence was lower than expected due to either lighter than expected loading on power lines in the study region, the larger than expected number of non-conductive drains (zero exposure to contact currents), or some combination of both. This was the first epidemiology study that explored the contact current hypothesis, and demonstrated that the protocol is applicable to further studies of this nature. Finally, the results indicate that the other published studies in the NCCLS concerning environmental exposures were not confounded by exposures to either contact currents or magnetic fields.

ACKNOWLEDGMENTS

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REFERENCES

Residence near power lines and mortality from neurodegenerative diseases: longitudinal study of the Swiss population
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INTRODUCTION

The World Health Organization concluded in 2007 that available data on an association between extremely low-frequency magnetic field exposure and Alzheimer’s disease were inadequate and the topic was identified as a key research priority [1]. A recent meta-analysis on occupational magnetic field exposure reported elevated risks for Alzheimer’s disease in cohort, as well as case-control studies [2], but data regarding residential exposure is lacking.

We used the Swiss National Cohort, a longitudinal study of the Swiss population [3], to investigate whether living in the vicinity of power lines was associated with mortality from neurodegenerative diseases such as Alzheimer’s disease, senile dementia, amyotrophic lateral sclerosis (ALS), multiple sclerosis and Parkinson’s disease [4].

MATERIALS AND METHODS

The Swiss National Cohort database was created by linking death records to census records. Mortality data were available for 2000-2005, with causes of death coded according to ICD-10. The database contains information on age, sex, marital status, education and occupation. Additional information includes the degree of urbanisation or building characteristics such as the number of apartments per building and the building coordinates. Our analysis was based on the census of the year 2000, but data of the census 1990 was used to identify long term residency, that is, persons who had lived at their place of residence for at least five, ten or 15 years.

We considered deaths from Alzheimer’s disease, senile dementia, ALS, Parkinson’s disease and multiple sclerosis if they were recorded anywhere on the death certificate. Exposure assessment was based on the distance of the place of residence to the nearest 220-380 kV voltage power line. We compared the risk of dying from neurodegenerative diseases across corridors (0 to <50 m, 50 to <200 m, 200 to <600 m and 600 m and beyond) and according to the duration of residence (at least five, ten and 15 years) by means of Cox proportional hazard models. All models were adjusted for age, sex, educational level, occupational attainment, civil status, urbanisation category, language region, number of apartments per building and living within 50 m of a major road.

RESULTS

The cohort consisted of 4.65 million persons, after the exclusion of persons aged less than 30 years and persons with unknown building coordinates. In total 9228 cases of Alzheimer’s disease (of which 20 were observed in the 50m corridor), 28288 of senile dementia, 744 of
ALS, of 6683 Parkinson’s disease and 773 of multiple sclerosis were analysed. Overall, the adjusted hazard ratio for Alzheimer’s disease in persons living within 50 m of a 220-380 kV power line was 1.24 (95% Confidence Interval: 0.80, 1.92) compared to persons who lived in a distance of more than 600 m, with little evidence of an increased risk beyond 50 m. There was a dose-response relationship with respect to years of residence in the immediate vicinity of power lines and Alzheimer’s disease (Figure 1), and we observed a similar pattern for senile dementia. In sensitivity analyses we stratified by sex, or excluded people aged 85 or older and obtained virtually identical results. We found no increased risk of ALS, Parkinson’s disease or multiple sclerosis. For comparison reasons, we also analysed causes of death known to be associated with socio-economic position. Neither all-cause mortality, cancer of the lung, bronchus or trachea, cancer of the oesophagus or alcoholic liver disease showed an increased risk in the 50 m corridor.

![Figure 1: Mortality from Alzheimer’s disease in relation to proximity to 220/380 kV power lines](image)

**CONCLUSIONS**

This large study of the entire Swiss population found that persons who lived within 50 m of a 220/380 kV power line were at increased risk of dying with Alzheimer’s disease or senile dementia, compared to persons who lived further away from power lines. The risk increased with increasing duration of residence in the 50 m corridor. The results of our study support the hypothesis that magnetic field exposure plays a role in the aetiology of Alzheimer’s disease and senile dementia, but not of ALS or other neurodegenerative diseases.

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**REFERENCES**

Measurement, Simulation and Uncertainty Assessment of Implant Heating During MRI

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INTRODUCTION

The heating of tissues around implants during MRI can pose severe health risks and careful evaluation is required for leads to be labeled as MR Conditionally Safe. A recent interlaboratory comparison study has shown that different groups can produce widely varying results when performing measurements according to current guidelines. To derive optimized procedures, two different generic lead structures (straight and coiled isolated wires with bare tips) have been investigated using simulations and measurements. A detailed uncertainty budget has been determined. The goal is to help in the development of an optimized testing procedure.

MATERIALS AND METHODS

Measurements: A mounting device has been employed to fix the leads at a specific position in an ASTM phantom placed in a MITS1.5 birdcage coil. Volumetric electromagnetic (EM) field measurements have been performed in a liquid filled ASTM phantom with dosimetric E- and H-field probes and a DASY5NEO robot scanner system. Temperature measurements have been made in a gel filled ASTM phantom (no convection) at positions determined based on simulations. For this, fibreoptic and thermistor probes have been precisely positioned. Reference sensors (EM and T) have been positioned in the birdcage and the phantom. The liquid and gel properties have been accurately measured.

Simulations: EM fields have been calculated using a unidirectional subgridding method (Huygens box) and graded meshes to optimally model the MRI birdcage and achieve high resolution at the leads (0.1 mm) using the SEMCAD X software [1]. Thermal simulations employing Pennes’ Bioheat equation have been performed with a novel thin structure model [2] to account for the impact of the highly thermo-conductive wires. Convergence as well as the impact of the numerical methods and discretization has been studied.

RESULTS

A detailed uncertainty analysis has been performed for the simulations and measurements (both EM and thermal), considering the impact of positioning, lead geometry, material parameters, exposure, numerical and sensor uncertainties. The state-of-the-art tools (sensors and simulation code) employed and the high control in the experiments permit the reduction of the combined uncertainty to 10-15 % (k=1). The most important factors are probe calibration uncertainty, liquid/gel electrical conductivity and probe positioning.

Excellent agreement between the simulations and measurements has been obtained with 96 % of all measurement points corresponding within the expected combined uncertainty.

Simulations help in finding the best measurement locations and getting the detailed picture in the close vicinity of the implant. SAR measurements allow the efficient measurement of a
large number of points, while temperature measurements can only be performed at a limited number of points.

For temperature measurements, gel has been found to be preferable to liquid and thermistor probes to fibreoptic probes. Extremely fine resolution (0.1 mm) has been found to be required to accurately model the coiled lead.

**CONCLUSIONS**

State-of-the-art simulations and measurements of MRI induced implant heating have been performed and a detailed uncertainty analysis developed. To obtain good repeatability and accuracy the following is required: 1) accurate simulations of the local energy deposition, 2) determination of suitable measurement locations, 3) employment of i) a suitable test system with high field precision, ii) tissue simulating materials with well defined parameters (< 5 %), iii) calibrated probes with sufficient spatial resolution, and iv) accurate positioning of the sensors (< 0.2 mm), 4) determination of assessment uncertainty, and 5) translation of assessed energy distribution to in-vivo tissue temperature increase (not discussed in this work).

The presented work should help in drafting a detailed standard on how measurements should be performed and the corresponding uncertainties assessed.

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Evaluation of the Activating Function in a 3D Deep Brain Stimulation model

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INTRODUCTION

The Deep Brain Stimulation (DBS) is a successful technique in reducing symptoms of several movement disorders and it is an effective treatment for advanced Parkinson’s disease (PD) [1]. Although the health-related quality of life of patients is actually improved by the technique, the precise mechanism of DBS functioning remains not well understood [1].

In this context, authors, in a previous work [2], have evaluated the role of ground positioning and the influence of domain dimensions on the distribution of the electric potential (V) and activating function (AF) through a 2D conducting box with different sizes. The analysis showed a significant influence of such parameters on the aforementioned electrical quantities [2]. Moreover a simplified 2D model of head, neck and trunk, filled with heterogeneous tissues, was considered as a conducting domain [3]. The obtained data suggested that even a variation in the shape of the conducting domain can strongly influence the values of both V and AF inside the target nuclei [3]. Moving to a 3D analysis, authors developed a realistic 3D geometric and electromagnetic model of the neuroanatomical nuclei involved in the stimulation [4]. The mean electric potential (V_mean) was evaluated varying box dimensions and ground positioning, on the volume and surface of Globus pallidus (Gp) and sub-thalamic nucleus (STN), because PD mainly affects neural activity and communication between these anatomical nuclei. Results showed a not negligible influence on V_mean values, confirming the results obtained with the 2D model [4]. Moreover, the influence of anisotropic properties of the white matter tissues underlined the importance of an accurate dosimetric model [4]. Moving from these results, in this work, the activating function has been evaluated for the 3D model.

MATERIALS AND METHODS

Treating the problem as a quasi-static one, the Laplace equation is solved to determine the electric potential distribution in the analysis domain using the software package Comsol Multiphysics v.3.4 (Comsol Inc) based on Finite Element Methods [4].

Moving from clinician MRI data, the 3D model has been created and imported in the software used to study the electromagnetic problem. A precise dielectric characterization taking into account both isotropic and anisotropic properties of the tissues has been considered [4]. A 3D model (Fig. 1A) whose box side was set to 30 cm and the ground position was on the base face, has been taken into account; results are obtained evaluating the AF along a line (red line in Fig. 1A) representative of a fiber, passing through the Gp and the STN. The analysis based on the AF evaluation was developed and suggested in [5], in order to describe the response of excitable tissue to an electric field. This function is defined as the
second derivative of the extracellular potential along a fiber direction and represents the driving function of the cable equation. It has been mainly used to predict the existence of regions of depolarization and hyperpolarization along the fiber and to give some estimate of the electrode efficiency to excite a nerve [5].

RESULTS

Figure 1 shows the 3D model used for the analysis (panel A) and the AF evaluated along a line representative of a neuronal fiber that lies on the zy-plane (panel B).

In our simulations, AF typically presents two main peaks: in areas where AF is negative, hyperpolarization is produced, on the contrary, to obtain an action potential AF has to become positive [5]. Such results suggest that fibers closer to the Gp should be excited by the induced stimulation, instead, neuronal target closer to the STN should be inhibited by the same stimulus (Fig. 1B).

CONCLUSIONS

In order to understand the neural response to the applied stimulation, in this work the AF has been evaluated along a line passing through the Gp and the STN.

Results seem to confirm experimental and computational studies [6] where it is suggested that DBS stimulation inhibits the neuron firing in the stimulated STN nucleus, while increases the activity of the efferent axons (fibers from STN to the Gp). This should be considered a fundamental step to correctly correlate the distribution of the electric quantities inside the neuroanatomical targets with neuronal responses.

REFERENCES

Evaluation of Artifacts by EEG Electrodes During RF Exposures

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INTRODUCTION

There is increasing evidence that pulse-modulated radio frequency electromagnetic fields (RF EMF), such as those emitted by mobile phones, can alter brain physiology [1,2,3]. For practical reasons, the exposure prior to sleep was often performed with subjects having their EEG electrodes already attached in order to minimize time between exposure and sleep onset. While the shielding effect of the leads has been sufficiently assessed in [2], possible artifacts from electrodes have been analyzed in respect to the spatial peak SAR only.

The aim of this study is to quantify (1) possible field enhancements and currents coupled via EEG leads to the tissues around the electrodes leading to high temperature increases in skin and superficial brain structures, and (2) the change of coupling of the incident field to the head by shielding of the conducting wires at 900 MHz (verification of [2]) and 2140 MHz.

MATERIALS AND METHODS

Measurements were performed using a DASY5 near field scanner (SPEAG AG, Switzerland) and a SAM Twin Phantom with HSL U10 broadband liquid inside (900 MHz: \(\varepsilon_r = 42\pm2\), \(\sigma = 0.97\pm0.08\) S/m; 2140 MHz: \(\varepsilon_r = 39.5\pm2\), \(\sigma = 1.58\pm0.12\) S/m).

The dosimetric SAR assessment matrix comprised measurements (1) without EEG electrodes, (2) electrically isolated electrodes, (3) electrodes with electrical contact to the liquid using metal connections, (4) the application of electrical contact cream, (5) ideal, typical, and worst-case placement of the leads, and (6) two carrier frequencies, 900 MHz and 2140 MHz. Subsequently, dosimetric temperature measurements were conducted at 900 MHz using specialized temperature probes (TV3Lab).

Results were compared with numerical simulations using SEMCAD X (SPEAG AG, Switzerland). The penetration depths of the field distortions caused by the electrodes were simulated using a flat human head tissue model. Findings were put in context to the dosimetric assessment of the exposure pattern.

RESULTS

Concerning the shielding effect, earlier findings [2] stated an attenuation of 9% for the 10g-psSAR at 900 MHz. The current study found values between 3% and 13% (mean 7.6%, SD 4.3%), depending on configuration. As expected, the higher frequency of 2140 MHz showed a higher attenuation between 3% and 16% (mean 9.2%, SD 5.4%).

Preliminary results for the local electrode artifact analysis showed that induced currents mainly remain within superficial skin tissues. The temperature measurements verify the dosimetric SAR measurements.
CONCLUSIONS

In order to minimize the time between exposure and sleep onset, volunteers must be exposed to EMF with the EEG electrodes already attached. This study assessed the overall attenuation of the field due to the leads, as well as the very local field enhancements caused by the EEG electrodes in a frequency dependant manner.

ACKNOWLEDGMENTS

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REFERENCES


INTRODUCTION

Nowadays wireless systems are more and more present in daily life. Even if the exposure is often very weak, the electromagnetic fields (EMF) used by these systems to communicate have induced a large public concern about possible sanitary effects. The relationship between the incident field and the whole body specific absorption rate (WBSAR) has been investigated to protect general public from overexposure. The first numerical studies have used simplified human models such as ellipsoids. Today and taking advantage of the computers improvement, the relationship between the incident field and the WBSAR has been revisited using new voxel models of humans and improved simulations tools. Several studies have been carried out and have shown a large variability of the WBSAR [1] [2]. Even if simulation tools have been improved they are limited by the small number of existing whole body models. Because of that we are looking for surrogate models [3]. In this paper, we analyze the influence of the body surface area on the power absorbed by the body.

MATERIALS AND METHODS

To analyze the relationship between the whole body exposure and the incident field we define the Absorbed Body Cross Section (ABCS) and the Radiated Body Cross Section (RBCS) as respectively the total power absorbed by the body divided by the incident power density (IPD) and the radiated power by the body divided by the IPD. In this study, we used a plane wave with a vertical polarization and a frequency of 2100 MHz.

Worldwide a limited number of whole body human phantoms models have been developed. In this study, we have used 8 of these models: the adults (Ella and Duke) of the virtual family models, the UK male model (Norman), the Korean model of ETRI, the Japanese models, the Zubal model and the Visible Human model. To assess the Specific Absorption Rate (SAR) we use the well known Finite-Difference Time-Domain (FDTD) method through an in-house code.

In order to analyse the relationship between the IPD and the absorbed plus the radiated power a box filled by different tissues has been used. The size of the box is 1.8mx0.6mx0.4m, and the incident field has a polarisation lined up with the larger dimension of the box. Four configurations have been considered. "HoB1" and "HoB2 "have been filled by an homogeneous media with conductivity of 1.49 S/m and a relative dielectric permittivity of respectively 39.8 and 49.8. "HoB3" has considered a box filled by a highly lossy dielectric (conductivity of 2.9e5 S/m and relative dielectric permittivity of 39.8). The last case "HoB4" is a box filled by a multilayer structure of skin, fat, muscle and IEC equivalent liquid.

RESULTS

We define the ratio between the whole body absorbed power and the IPD as the Absorbed
Body Cross Section (ABCS). The Projected Body Surface Area (PBSA) is defined as the projected surface of the body phantom on a plane orthogonal to the incident field. We compare the ABCS to the PBSA in Figure 2.

Dealing with the relationship between the IPD and the absorbed plus the radiated power, the table 1 shows that the sum of ABCS and RBCS, defined as the Body Cross Section (BCS), is about constant whatever the equivalent liquid is used to fill the box. The shape seems to govern the BCS while the ratio between ABCS and RBCS is depending on the media in the box.

<table>
<thead>
<tr>
<th></th>
<th>HoB1</th>
<th>HoB2</th>
<th>HoB3</th>
<th>HoB4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABCS (m²)</td>
<td>0.615</td>
<td>0.574</td>
<td>1 e-8</td>
<td>0.74</td>
</tr>
<tr>
<td>RBCS (m²)</td>
<td>2.46</td>
<td>2.46</td>
<td>3.08</td>
<td>2.308</td>
</tr>
<tr>
<td>BCS=ABCS+RBCS</td>
<td>3.015</td>
<td>3.034</td>
<td>3.08</td>
<td>3.048</td>
</tr>
</tbody>
</table>

Table 1 ABCS and RBCS vs case obtained at the frequency of 2.1 GHz

CONCLUSIONS

In this paper the relationship between the total absorbed power and the incident power has been analyzed. The shape seems to govern the BCS while the ratio between ABCS and RBCS is depending on the media in the box. Such a conclusion must be confirmed by additional studies.

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REFERENCES

Case-Control Study on Childhood Leukemia and Radio Frequency Electromagnetic Fields in the Vicinity of Television and Radio Broadcast Transmitters

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INTRODUCTION

The causes of childhood leukemia are poorly understood. The only established environmental risk factor is high doses of ionizing radiation. For many decades radio and television broadcast stations have been emitting radio frequency electromagnetic fields (RF-EMF) in the frequency range of 10 kHz to 870 MHz. Some ecological studies reported small to moderately increased incidence rates of childhood leukemia in association with proximity to broadcast towers. Other studies reported no association [1-9]. In order to further investigate a possible relation between exposure to RF-EMF and leukemia in childhood a case-control study was conducted between 2005 and 2008 in West Germany [10].

MATERIALS AND METHODS

The study region of the case-control study were municipalities near high power radio and television broadcast towers, including 16 amplitude-modulated (AM) and eight frequency-modulated (FM) transmitters. Cases were aged 0-14 years, diagnosed with leukemia between 1984-2003 and registered at the German Childhood Cancer Registry. Three age-, gender- and transmitter area-matched controls per case were drawn randomly from population registries. The analysis included 1,959 cases and 5,848 controls. The individual exposure to RF-EMF one year before diagnosis was estimated with a field strength prediction program. The quality of the RF-EMF predictions has been evaluated in a validation study, in which the prediction algorithm has been tested against 477 RF-EMF measurements conducted partly in the study region [11]. The measurements were taken during a measurement survey independently of the case-control study. Conditional logistic regression with case-control status as the dependent variable was used to estimate odds ratios and their 95 percent confidence intervals for the average exposure in the month one year before diagnosis. The distribution of the exposure from total RF-EMF was skewed to the left with a majority of study participants who were exposed to background fields. For that reason the “high exposure category” was defined by the ≥ 90 percent quantile (0.504 - 7.742 V/m for total RF-EMF). This group was further subdivided into the 90-< 95 percent and the 95-≤ 100 percent quantile.

RESULTS

The most frequent diagnosis was lymphoid leukemia with 1,586 cases (81 percent). There were 1,028 patients (52.5 percent) with leukemia diagnosed between 0 and 4 years of age. Considering total RF-EMF, the odds ratio from conditional logistic regression analysis for all
types of leukemia was 0.86 (95% confidence interval (CI): 0.67, 1.11), comparing upper (≥ 95%/0.701 V/m) and lower (< 90%/0.504 V/m) quantile of the RF-EMF distribution. An analysis for AM and FM transmitters separately did not show increased risks for leukemia. No elevated risks for leukemia have been found for the time period from 1983 to 1991, which is characterized by an exposure without major contributions from mobile phone communication technology. For children living within 2 km to the nearest broadcast transmitter the odds ratio for all types of leukemia was 1.04 (95% CI: 0.65, 1.67) compared to those living in a distance of 10-<15 km. The data did not show any elevated risks for childhood leukemia associated with RF-EMF.

CONCLUSIONS

The study did not show any significant increase in risk for leukemia in children exposed to RF-EMF emitted by broadcast towers. The results were similar for total RF-EMF from all transmitters and for AM and FM/TV separately, hence, the modulation mode and frequency range of the RF-EMF signal had no impact on the disease risk. In conclusion, our study provides little evidence for an association between exposure to RF-EMF and the risk of childhood leukemia. The population-based case-control approach with large numbers of subjects, the long study period (1984-2003) and the individual exposure estimation is superior to previous studies.

ACKNOWLEDGMENTS

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REFERENCES

**In silico BioEM: Multiscale Modeling for Assessing Effects of Non-ionizing Electromagnetic Fields in Humans**

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**INTRODUCTION**

Electricity is the most versatile and pervasive form of usable energy, and is likely to become even more widespread, with both voluntary and involuntary human exposures. Electromagnetic technology can create an almost infinite number of field waveforms (magnitude and shape) with a wide range of exposure times. Potential benefits and risks should therefore be examined more thoroughly and rapidly than possible with experiments and epidemiology alone, because individual exposures represent only islands in a huge, multi-parameter sea. In silico assessment compliments epidemiology and in vivo experiments by analyzing conditions away from these multi-parametric islands.

**METHODS**

Existing computational models can be characterized by their range of linear dimensions (length scales). Looking forward, a key idea is that models of vastly different scales can interact, with outputs of one scale providing inputs to other larger or smaller scales. Applied fields can first be processed at the top scale (Whole/Partial body) and then progress to the bottom two scales, where mechanistic interactions reside. Locally-induced biochemical changes can propagate upwards to the Cell/Multicell, Tissue or Whole Body levels, depending on the situation. At the Whole Body and Tissue level the distribution of extracellular biochemical change can be described via pharmacokinetics. Treatment of excitable cells and tissue will be more difficult, but can be initially approached by assigning known membrane models to Cell/Multicell level models.

| Table I. Order of magnitude length scale ranges in existing models |
|------------------|-------------------|
| LEVEL             | SCALE             |
| Whole/Partial body | 1 mm to 1 m       |
| Tissue (homogeneous representation) | 100 µm to 1 mm |
| Cell/Multicell    | 10 nm to 100 µm   |
| Membrane/Molecular | 0.1 nm to 10 nm   |

This table summarizes the order of magnitude length scale ranges in existing models. Whole Body/Partial body to Tissue level models have already demonstrated impressive spatial representation of human anatomy, nearby sources and medical devices [1, 2]. Cell/Multicell level models lag in morphological realism, but have partially solved the problem of rapidly changing electrical membrane properties during exposures that cause conventional or supra-electroporation [3, 4]. At Membrane/Molecular levels molecular dynamics simulations (MD) at the atomistic level for essentially dc fields have been achieved for a small patch of membrane with a protein channel [5], and also for microwave (1 GHz) fields for a myoglobin molecule [6]. We propose interaction of models with different spatial scales, to create a general capability for whole body initial assessments for almost arbitrary electromagnetic field waveforms applied locally, regionally or systemically. Throughout validation by quantitative comparison to experiments at various scales will be essential.
Plenary 3-1

RESULTS

Whole/Partial body models provide fields and current densities at the tissue level. Cell/Multicell models yield local electrical fields and the spatially distributed transmembrane voltage (membrane potential) in the outer (plasma) membrane and internal (organelle) membranes. Membrane/Molecular models are extremely complex, able to describe behavior within simulation boxes that contain several hundred thousand atoms that represent a membrane protein (e.g. a channel), phospholipid molecules, water molecules and a variety of solutes (e.g. small ions and sugars). Except for MD existing models can be used with almost arbitrary electrical waveforms. For Whole/Partial body and Cell/Multicell models the applied external fields can have characteristic times ranging from nanoseconds (microwave fields, submicrosecond, megavolt per meter supra-electroporating fields) up to milliseconds and even longer.

CONCLUSIONS

Multiscale models offer the prospect of “high throughput screening” of waveforms, which should minimize ethical concerns and economic costs associated with reliance on in vivo analysis. This is important to science and society. Generalized chemical noise [7] and ensembles of models can estimate exposure thresholds. Overall, the proposed approach should help establish exposure safety standards. If so this in silico approach will be a productivity-enhancing, pre-assessment capability. Multiscale modelling should therefore be vigorously pursued, to assist in the development of new medical interventions and initial safety assessments of electrical technology.

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Hyperthermia Using Functional Magnetite Nanoparticles

AKIRA ITO

Magnetite nanoparticles-mediated intracellular hyperthermia has been a largely experimental modality of hyperthermia, but it has the potential to achieve tumor-targeted heating without any side effects. The technique consists of targeting magnetite nanoparticles to tumor tissue and then applying an external alternating magnetic field to induce heat generation by the magnetite nanoparticles. Recent years have seen the remarkable advances in magnetite nanoparticles-mediated hyperthermia; both functional magnetite nanoparticles and alternating magnetic field generators have been developed. Currently, some researchers are attempting to begin clinical trials, suggesting that time may have come for clinical applications. This review describes recent advances in magnetite nanoparticles-mediated hyperthermia.
**Compare of Ring and Needle Electrodes on a Heterotopic Model of Hepatocellular Carcinoma with 30 Nanosecond Nanosecond Pulsed Electric Fields (nsPEFs) Treatment**

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**INTRODUCTION**

We recently reported that 300ns nsPEFs cause melanomas to self-destruct. However, to confirm the antitumor effect of nsPEFs, more tumor types need to be treated. In the clinical practice, due to the common location of neoplasm varies, different tumors request different deliver device. In this study, we examined the anti-tumor effects of 30ns nsPEFs in vivo with two different electrodes, ring and needle electrodes on liver tumor.

**MATERIALS AND METHODS**

After Hep1-6 cells implanting on mice flanks, the diameter of the tumor reached about 0.3–0.5 cm within a week. Then the mice were randomly assigned to one of the following four groups. (1) Control group: 8 mice bearing 16 tumors; (2) Sham group: 6 mice bearing 12 tumors; (3) Ring electrode group: 8 mice in bearing 16 tumors; (4) Needle electrode group: 6 mice bearing 12 tumors. Needle and ring electrodes were designed to deliver 30ns nsPEFs to Hep1-6 heterotopic hepatocellular carcinoma (HCC) on C57Bl6 mice model. The nsPEFs were given 100 pulses at 67.5KV/cm, altogether three times a week. Tumor volume was monitored by ultrasound and surviving days were compared among control, sham, needle electrode and ring electrode groups.

**RESULTS**

30 ns nsPEFs, no matter with ring or needle electrodes, can inhibit primary tumor growth on heterotopic HCC mice model. The Kaplan–Meier method and the log rank test indicate that surviving time in both ring and needle electrode groups were significantly longer than in the control group (P < 0.05). While in term of tumor volume and surviving days, there is no significant difference between ring and needle electrodes.
CONCLUSIONS

The present study provides further evidence that nsPEFs treatment has anti-tumor activity towards liver cancer in vivo (heterotopic model of Hep1-6 in C57Bl6 mouse), which is consistent with our previous preliminary study of 300ns nsPEFs on murine melanoma. To apply nsPEFs in clinical trial and make the delivery possible for any tumor shape, we designed two electrodes and model their different electric field distributions. The ultra-short and intense electric pulses can induce irreversible structural changes in the HCC through inducing apoptosis, causing the targeted tumor cell death without damaging the normal tissue. 30 ns nsPEFs inhibit liver tumor growth in the mice HCC model and could be a promising therapeutic approach. Both ring and needle electrodes are practicable although the electric field distribution is quite different.

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REFERENCES

INTRODUCTION

Myocardial ischemia with consequent loss of functioning cardiac muscle, continues to be one of the leading causes of morbidity and mortality in our society. In response to ischemic injury the myocardium attempts to retain or increase its blood supply. Treatment usually consists of an attempt to enhance the body’s natural angiogenic processes. Thus, angiogenic growth factors and pro-angiogenic cytokines have been used in attempts to induce new vessel growth. Unfortunately, this has produced very limited success. Pulsed electromagnetic fields (PEMF), of the type used for recalcitrant fracture repair, were reported to produce a seven-fold increase in endothelial cell tubularization in vitro, as well as four-fold increased angiogenesis in a diabetic mouse model, via increased FGF-2 production [1,2]. In both studies, inhibition of FGF-2 eliminated the PEMF effect. We have also demonstrated, with radio frequency PEMF, increased neovascularization in a transferred arterial loop in a rat groin model sufficient to allow elevation of a free skin flap based on the newly produced vascular bed [3,4]. This study was designed to assess the effect of radio frequency PEMF, configured a priori to modulate the Ca²⁺/CaM (calmodulin) dependent nitric oxide (NO) pathway [5,6], on angiogenesis in an experimental myocardial injury model in the rat.

MATERIALS AND METHODS

A reproducible thermal myocardial zone of injury was created in the region of the distal aspect of the Left Anterior Descending Artery at the base of the heart of 100 adult male Sprague Dawley rats [7]. Animals were randomly divided into active and sham groups. The PEMF device waveform was a 2 msec burst of 27.12 MHz sinusoidal waves repeating at 5 bursts/sec delivering 0.05 G at the tissue target (Ivivi Technologies, Inc., Montvale, NJ). Five freely roaming animals in a standard rat plastic cage, with all metal portions removed, were placed within a single turn 14 x 21 inch coil. Exposure was 30 min twice daily for 3, 7, 14 or 21 days. Sham animals were identically exposed, but received no PEMF signal. A separate group of 20 animals treated for 7 days received L-NAME, a general NOS inhibitor, in their drinking water. Upon sacrifice, myocardial tissue specimens were stained with CD-31 and the number of new blood vessels was counted on histological sections at the interface between normal and necrotic muscle at each time point. Data was analyzed using the Student’s t test or ANOVA, as required. Significance was accepted at P ≤ 0.05.

RESULTS

Of the 100 animals which entered the study, 84 were available for analysis. Overall survival rate for this rat myocardial injury model was, thus, approximately 80%. The PEMF effect in this study is best illustrated by examination of normalized (PEMF/sham) mean new
vessel counts in the peri-ischemic tissue. Mean new vessel count was not significantly increased by PEMF vs sham treatment at POD 3, but was significantly increased at POD 7 (+ 50%), POD 14 (+ 67%), and POD 21 (+ 99%). These results are summarized in the figure.

The 7 day experiment involving L-NAME, a general NOS inhibitor, was designed to assess whether the PEMF signal had its effect on angiogenesis via the NO pathway. The results show sham and treated animals were equivalent, indicating L-NAME completely blocked the PEMF effect on angiogenesis, and providing strong evidence the PEMF transduction pathway in this study involved Ca/CaM in the NO signaling cascade. These results are summarized in the figure.

CONCLUSIONS

Impaired blood flow in ischemic myocardial tissue creates a hypoxic environment, which induces expression of growth factors such as VEGF and FGF-2 [8]. Expression of these growth factors triggers angiogenesis which requires the synthesis of NO, so the manipulation of NO may constitute an effective therapy to increase angiogenesis in cardiac ischemia [9]. In fact, lack of sufficient endogenous NO may be the reason VEGF therapy has had very limited success. There is an intricate relationship between VEGF and endothelial nitric oxide synthase (eNOS) which catalyzes the formation of NO from endothelial cells. This makes the modulation of eNOS activity a potentially useful strategy for modulating angiogenesis. To this end, the PEMF signal utilized in this study was configured a priori, to increase NO production via a Ca/CaM transduction pathway. The signal was configured utilizing the well known binding kinetics of $\text{Ca}^{2+}$ to CaM in a model which predicted that millisecond range burst durations of a 27.12 MHz sinusoidal wave would increase $\text{Ca}^{2+}$ binding kinetics at amplitudes in the 0.05 G range [5,6]. Given the results of this study, it is intriguing to speculate that PEMF indeed modulated eNOS activity through an effect on $\text{Ca}^{2+}$ binding to CaM. Certainly inhibition of the PEMF effect by L-NAME provides strong support. Additionally, the ability to augment angiogenesis with PEMF at the infarct/muscle junction may allow for successful functioning myoblast engraftment, replacing the necrotic muscle.

REFERENCES

A Novel Design for Hyperthermia Treatment at the Head and Neck Region

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INTRODUCTION

Hyperthermia, or thermal therapy, is a type of cancer treatment where heating the target tissue (tumor) is applied to kill the cancer cells or enhance other treatments. The equipment which delivers the thermal energy is called an applicator. In this paper, the proposed applicator consists of a 40cm diameter ring antenna array (at 433MHz) with 20 cavity-backed slot antennas which deliver and focus the EM power at the target to raise the temperature in the tumor. A water bolus filled with de-ionized water is placed between the applicator and the patient. In the head and neck region (H&N), there are many vital tissues. The side effects of standard treatments may seriously affect the patient’s quality of life [1]. So far, only minor toxicity has been found due to hyperthermia treatment and this is unique feature in cancer treatment. In addition, it is reported that radiation therapy or chemotherapy combined with hyperthermia in the tumors at H&N region can enhance the local tumor control and/or survival rates [1,2]. Most studies on the applicator design focus only on the applicator itself, ignoring the patient position, which is also of great importance to the SAR performance of the applicator. Therefore, for the hyperthermia treatment in the H&N region, the objective of this paper is not only proposing an applicator, but also optimizing the patient position to the proposed applicator to achieve optimum SAR performance.

MATERIALS AND METHODS

The research was completed with EM simulations using SEMCAD X which uses Finite-Difference Time-Domain algorithm, FDTD. The reasons of using SEMCAD include that FDTD has excellent performance in highly inhomogeneous environment; that the algorithm provides very detailed information about EM field distribution; that the hardware acceleration technology integrated in SEMCAD X makes the simulation speed fast enough for real clinical application; and that for hyperthermia applicator design, SEMCAD X also provides an feature called Field Optimizer to optimize the source magnitude and phase of each array element to achieve maximum SAR in the target and minimum SAR in the other regions [3]. It provides important information about the best performance obtained by a given applicator and patient position. Therefore, all the SAR results provided in this paper were optimized with the Field Optimizer.

RESULTS

To show the performance of the applicator in real usage, the CAD file of a real cancer patient (Fig. 1(a)) was applied. The patient position in the applicator was optimized to obtain optimum SAR performance (Fig. 1(b)), that is, higher SAR in the tumor and lower SAR in other tissues. The simulated result was shown in Fig. 1(c) and 1(d). The 1g average SAR on the gray surface is 200W/kg, and it is higher than 200W/kg inside
Figure 1: (a) The real patient model and (b) the configuration of the applicator with the patient. (c) and (d) show the simulation results of the SAR performance. The gray surface indicated the location with 200W/kg 1g averaged SAR. The result showed that tumor was heated by sufficient EM power without creating hot spot at any other place.

the surface, so it shows that the EM power was concentrated properly on the whole tumor.

CONCLUSIONS

A novel applicator for hyperthermia treatment of the cancer in the head and neck region was proposed in this paper. It is a 40cm diameter antenna ring array with twenty cavity-backed slot antennas surround the patient’s neck. Not only the design of the applicator, but also the patient’s positions were optimized for different target regions. The simulation showed that the applicator can provide sufficient exposure to all possible locations of tumor in the patient’s neck with good resolution of EM power deposition. A real patient model was also applied to see the performance of the proposed applicator in real usage.

The applicator proposed in this paper has advantages over previous designs. The cavity-backed slot antennas provide excellent mechanical strength against pressure and erosion due to the water. In addition, more elements placed in front of the patient cause higher deposition and resolution of the EM power. Finally, optimization of patient positions for different target regions significantly increases the performance of the applicator.

REFERENCES

Effect of Pulsed Electromagnetic Fields on Post Operative Pain: A Double-Blind Randomized Pilot Study in Breast Reduction Patients

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INTRODUCTION

Post-surgical pain increases patient morbidity and slows healing, particularly if narcotics are employed for pain management. Therefore the surgeon is continually looking for other means to control post-operative pain. There is a growing body of clinical evidence that pulsed electromagnetic field (PEMF) therapy can have physiologically significant effects on tissue repair. Certainly PEMF therapy has been extensively employed for the treatment of recalcitrant bone fractures and is reported as successful as the first bone graft [1]. Recent advances in knowledge of the mechanism of PEMF effects on pain and tissue repair have allowed signals to be developed which can target the anti-inflammatory cascade involving the calmodulin (CaM) dependent nitric oxide (NO) pathway. The present study was designed to clinically assess the effect of a PEMF signal designed to modulate Ca\textsuperscript{2+} binding to calmodulin (CaM) [2], as a first step in the body’s response to injury or trauma. Tuning the drug-free PEMF signal for the NO cascade provides an immediate stimulus independent of pharmacokinetics since the time-varying magnetic field appears instantaneously in all compartments of the target tissue. This pilot study was designed to determine if PEMF treatment, given in addition to standard of care, could reduce postoperative discomfort and morbidity after breast reduction surgery.

MATERIALS AND METHODS

Twenty healthy women, aged 27 to 59 years, who were candidates for breast reduction for medical reasons, were admitted to this double-blind, placebo-controlled randomized study. Breast reduction was performed by the same surgeon using the standard Wise or vertical incision techniques with superomedial pedicles. Patients were equally divided into active and sham groups. A disposable dual coil PEMF device (Ivivi Technologies, Inc., Montvale, NJ), placed in the post surgical support bra normally used for all patients, was activated on transfer to the recovery stretcher. The PEMF signal, configured, \textit{a priori}, to modulate Ca\textsuperscript{2+} binding to CaM, consisted of a 2 msec burst of 27.12 MHz sinusoidal waves repeating at 2 bursts/sec. Peak magnetic field was 0.05G which induced an average electric field of 32 ± 6 mV/cm in each breast. An active PEMF device automatically provided a 20 minute treatment every 4 hours for the typical treatment period of seven days post-op. Sham devices were activated in exactly the same manner as the active devices, but produced no electromagnetic field in tissue. The primary outcome measure in this study was the effect of a PEMF signal on the rate of post surgical pain reduction. Pain data was obtained using a Visual Analog Scale (VAS) which patients self-recorded throughout the overnight hospital stay and for seven days thereafter. Post operative pain medication was also monitored for each patient. The Mann-Whitney Rank Sum test was used to compare mean VAS scores for each group. Significance was accepted at P ≤ 0.05.
RESULTS

A total of 19 patients were available for analysis. VAS scores were excluded for one patient who became unblinded. Mean VAS scores over the critical first 24 hour post surgical period were compared using the ratio of the score at 24 hours to the initial post-op score. The results show mean VAS decreased to 48 ± 12 % of initial value in the active group, while mean VAS increased to 129 ± 35% of initial value in the sham group. This difference was significant to P = 0.013 and represents a PEMF effect of approximately 2.7X faster pain reduction within the first 24 hours. These results are summarized in the following figure.

Use of narcotic pain medication over the first 24 hours was assessed by comparing pill count for each patient. The results show mean pill count in the active group was 2.6 ± 0.7 vs 5.2 ± 0.6 in the sham group. This difference represents a concomitant PEMF effect on narcotic use of approximately 2X which was significant to P = 0.021. No adverse effects from PEMF treatment were noted in this study.

CONCLUSIONS

This randomized study suggests PEMF therapy can have a significant impact on post operative pain management. The PEMF effects reported here are similar to those reported in a randomized study on post operative pain in breast augmentation patients [3]. The mechanism of action of PEMF signals on tissue repair is not completely elucidated. However, it is intriguing to consider that the known effects of PEMF on NO release via effects on Ca$^{2+}$ binding to CaM which, in turn, activates the constitutive nitric oxide synthases (cNOS) may be applicable here. NO is a short-lived signaling molecule which is known to be involved in anti-inflammatory cascades. Thus, the observed accelerated pain relief may occur through PEMF increases in the normal anti-inflammatory process of vasodilatation. Of potentially greater importance is that increased NO production leads to increased cGMP production which cascades to the appropriate growth factor release dependent upon the stage of healing. It is thus intriguing to speculate the use of PEMF to control post surgical pain may also lead to enhanced healing. This would impact all surgical procedures and may well lead to a reduction in the cost of health care.

REFERENCES

**Induction of Adaptive Response in Human Lymphocytes Exposed to Radiofrequency Radiation**

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**INTRODUCTION**

The phenomenon of “adaptive response” (AR) has been well documented *in vitro* and *in vivo* [1]. Mammalian cells exposed to an extremely small ‘adaptation’ dose of a genotoxic agent were found to be less susceptible to the induction of genetic damage when given a higher ‘challenge’ dose of the same or similar genotoxic agent. In this study the incidence of micronuclei (MN) was evaluated to assess the induction of AR to radiofrequency (RF) radiation in peripheral lymphocytes from five donors. Following 24 h PHA stimulation, the cells were exposed to an adaptive dose of 900 MHz RF radiation (SAR 10 W/kg peak value) for 20 hours and then challenged with a genotoxic dose of mitomycin C (MMC; 100 ng/ml) at 48 hours. Lymphocytes were collected at 72 hours. Cells from four donors exhibited the induction of AR: cells pre-exposed to 900 MHz RF radiation had significantly decreased incidence of MN induced by the challenge dose of MMC as compared to those which were not pre-exposed. These preliminary results suggested that the AR can be induced in cells that were pre-exposed to non-ionizing radiation.

**MATERIALS AND METHODS**

The exposure system was described in earlier [1]. It consisted of four wire patch cells (WPC) placed in two commercial CO₂ incubators at an average temperature of 36.9 ± 0.5°C. Two WPC were used RF exposure and two for sham exposure. A four-channel power supply PC controlled was used for the management of the power inside the WPCs. The temperature was monitored and recorded by means of a four-channel fibre-optic thermometer. Diluted blood from 5 donors were examined. The adaptation dose (900 MHz RF radiation; GSM signal; SAR 10 W/kg or sham exposure) was given from 24 h to 44 h after PHA stimulation. At 48 h after culture initiation, the challenge dose of 100 ng/ml of MMC was added to RF radiation- and sham-exposed cultures. Cytochasin-B was added at 44 hours and the cells were collected for MN assay at the end of 72 hours [1]. For each donor/treatment, 2000 cells were examined on coded slides to obtain the frequency of binucleate cells. The expected frequencies of MN in combined treatments (adaptation + challenge) were calculated as the sum of the MN in two individual treatments minus the frequency in untreated controls. The statistical significance of reductions in observed frequencies relative to the expected incidences was evaluated using two-tailed z test.
RESULTS
Among the 5 donors investigated, cells from 4 donors exhibited AR when exposed to RF radiation prior to challenge with 100 ng/ml MMC. The % decrease in the frequency of MN ranged from 35% to 56% while such decrease was not observed in cells adapted to sham exposure. However, the extent of AR was not the same in all 4 donors which suggested inter-individual variability. In contrast, lymphocytes from donor # 1 did not exhibit AR when challenged with 100 ng/ml MMC (Figure 1).

CONCLUSIONS
In earlier in vitro and in vivo studies on the induction of AR, an extremely small dose of a ‘known’ genotoxic agent was used to render the cells refractory to the induction of genetic damage induced by a higher challenge dose of the same or similar agent. Recent reviews suggested that non-ionizing RF radiation is non-genotoxic [3,4] and the results of this study confirmed this finding. Hence, the important observation made in this preliminary investigation is that a non-genotoxic agent, RF radiation, was capable of inducing AR.
Several mechanisms have been proposed for the induction of AR, including enzymes involved in DNA repair, cell cycle regulation and mitotic delay.

The results here presented indicated that, in the experimental conditions adopted, exposure to RF radiation is capable of inducing AR in human lymphocytes. This finding deserves further research whether AR can be elicited in several other in vitro and in vivo experimental conditions including various frequencies, different SARs, timing of adaptation and challenge dose treatments, different cell types, etc.

REFERENCES
Cell Growth Response to Pulse-Modulated RF Signals

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INTRODUCTION

Although in recent years the knowledge on the interactions of the electromagnetic radiation with biological materials has advanced significantly, a number of relevant questions remain unanswered and need to be investigated. On this respect, a large number of experimental studies have been conducted assessing the hypothetical carcinogenic effects of the exposure to non-thermal or subthermal doses of RF signals used in radiocommunication. Although some of these studies have reported biological responses to weak RF signals, the in vitro results are rather conflicting in terms of the mechanistic explanation of the observed effects. The present work takes part of the international project “Radiofrequency Biological Effects” (RF-Bio), of the European Defence Agency, addressed to the investigation of biological responses to complex, high-power, short RF signals. The study describes the cell growth response of two human cell lines to a 24-hour exposure to 2.2-GHz, pulse-modulated signals at subthermal doses.

MATERIALS AND METHODS

Exposure equipment

We have designed, built and experimentally validated a setup for in vitro exposure, inside CO2 incubators, to RF signals in the 2-GHz band. The RF applicator is composed of two identical waveguides (section: 90 x 45 mm; length: 500 mm) one for RF exposure of the biological samples and another for simultaneous, sham-exposure of control cells. Both waveguides are equipped with fans, independently regulated, for temperature homogeneity and proper atmosphere exchange within the guides. Each of the two guides holds in a double-shelf, teflon support for eight Petri dishes.

RF Exposure and dosimetry

The experimental samples were exposed for 24 hours to 28 W (CW), 2.2-GHz, pulse-modulated (5 µs pulse duration, 100 Hz repetition rate) signals. For numerical dosimetry, a complete discretized model of the setup was created in order to simulate its electromagnetic behavior by means of the commercial FDTD software SEMCAD X. The model includes the SMA/waveguide transitions, the coaxial probe, holders, Petri dishes and the culture medium.

Exposure protocol

Two different cell lines, the HepG2 hepatocarcinoma and the NB69 neuroblastoma were tested in independent experiments. When the cell cultures reached a 60% confluence they were transferred to the waveguides located inside a CO2 incubator. In each experimental run, two different cell growth conditions were tested simultaneously. A group of 8 dishes was grown inside the energized waveguide and exposed for 24 hours to the RF signal. An identical group of 8 dishes (control) was incubated inside the non-stimulated waveguide. A total of 8 experimental replicates were carried out using the NB69 line. For HepG2 cells, four replicates were performed. At the end of the 24-hour period of exposure and/or incubation, the cell growth and viability of the cultures was analyzed by Trypan blue exclusion. The DNA content and the proportion of cells in the different phases of the cell cycle were
determined through flow cytometry. All tests and analysis were conducted in blind conditions for treatment. The ANOVA test followed by the Student’s t test was applied for analysis of statistical differences between samples.

RESULTS

The RF exposure induced a consistent, statistically significant reduction (15.7% below controls, p<0.001) in the total number of NB69 cells. This effect was accompanied with slight but significant increases in the proportion of cells in G0/G1 (6%, p<0.05) and G2/M (9%, p<0.05) phases of the cell cycle. The HepG2 cell growth and cell cycle were not changed significantly by a 24-hour exposure to the same, pulse-modulated signal. The estimated average SAR value for continuous wave exposure conditions was 44.8 W/Kg. Provided that the samples were exposed to 5 µs pulses at a 100 pps repetition rate, and taking into consideration the temperature dispersion and dissipation in the medium, it can be assumed that the average doses of RF radiation received by the cell cultures are subthermal.

CONCLUSIONS

The obtained results indicate that a 24-hour exposure to subthermal, pulse-modulated RF signals can induce cytostatic responses in specific, sensitive human cancer cell lines. This effect seems to be mediated in part by the arrest or deceleration of the cell cycle in the G0/G1 and G2/M phases. The cellular and molecular mechanisms underlying the observed response need to be identified and characterized in order to determine its potential relevance to the human health.

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Effect of GSH depletion, hyperthermia, and a 100 mT static magnetic field on an Hsp70/Luc reporter system.

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INTRODUCTION

Heat shock proteins, particularly Hsp70, are produced in response to a number of cellular stresses. The most well known example is exposure to heat, but conditions of oxidative stress have also been shown to induce HSP70 [1; 2; 3]. GSH is one of the most important low molecular weight antioxidants in the cell. Depletion of GSH is known to increase the amount of reactive oxygen species (ROS) in a cell thus exposing the cell to oxidative stress [4]. A number of groups have found that modulating the concentration of GSH in the cell alters the Hsp70 protein levels [5; 6; 7; 8].

It has also been shown, in some circumstances, that exposure to a magnetic field alters levels of HSP70 [9]. However, this effect has not been able to be consistently reproduced. More consistency has been achieved when the application of magnetic fields was combined with a primary stress such as heat exposure.

The aim of this study was to analyze the amount of bioluminescence produced by a Hsp70/luciferase reporter system to evaluate the possibility of a synergistic effect of exposure to a 100 mT static magnetic field (SMF) following A) cellular GSH depletion, B) exposure to heat or C) a combination of GHS depletion and heat.

MATERIALS AND METHODS

The NIH3T3 cell line stably transfected with a construct consisting of the mouse HSP70 promoter driving the expression of the firefly luciferase gene was a generous gift from Dr. Christopher Contag from Stanford University, USA. The Dulbeccos Modified Essential Media (DMEM) and fetal bovine serum was purchased from Invitrogen (Burlington, ON, Canada) and D-luciferin was purchased from Promega (Madison, WI, USA).

For each experiment, cells were trypsinized and resuspended in 2 ml DMEM containing 0.75 mg D-luciferin and placed in a disposable cuvette. Bioluminescence in luciferin-loaded cell samples was measured using a modified luminescence photometry system, comprised of a photomultiplier tube detector and PC running Felix32 data collection and spectrometer control software (PTI, London, Ontario). A toroidal electromagnet (15 mm pole gap, 16 AWG copper magnet wire, Arnold Engineering; M in Fig. 1) was held within the water bath (kept at 37.0 ± 0.2°C or 42.0 ± 0.2°C) by temperature controlled circulating water. The cuvette was held between the poles of the electromagnet in a circulating water bath held at 37°C.

Exposure conditions for each sample were one of i; control (C), ii; SMF exposed (F), iii; heat exposed (H), iv; SMF and heat exposed (HF), v; treated with 1 mM DEM, vi; treated with DEM and SMF exposed and finally, vii; treated with DEM, heat and SMF exposed. Bioluminescence was measured in units of photons/s. The slope of the bioluminescence
readout was determined at four different time points, before the application of SMF, early in SMF exposure, late SMF exposure and post SMF exposure.

RESULTS

Four to six replicates of each condition were analyzed. As expected, there was a major effect of heat which increased the slope of the bioluminescence curves ($p < 1 \times 10^{-4}$) by ANOVA. There was also a major effect of 1 mM DEM ($p < 1 \times 10^{-6}$) which reduced the amount of bioluminescence produced (Fig 1). Additionally, two-way ANOVA revealed an interaction between SMF and DEM to increase bioluminescence, heat and DEM to decrease bioluminescence and the combination of SMF, heat and DEM to decrease bioluminescence ($p < 0.04$, $p < 1 \times 10^{-4}$, $p < 0.04$ respectively) (Fig 1).

CONCLUSIONS

In the current study, we examined the effect of a 100 mT SMF and 1 mM DEM on HSP70 in real-time by comparing the slope of the production of bioluminescence by a luciferase reporter system. We found that DEM alone significantly decreased the rate of bioluminescence production and thus the level of HSP70 as compared to control conditions. Although there was not a significant effect of a 100 mT SMF alone, there was an interaction between the SMF and DEM to increase the level of HSP70. There was a more dramatic reduction in bioluminescence when DEM exposure was combined with heat. Interestingly, the combination of DEM and field elicits an increase in HSP70 as compared to field or DEM alone, while the combination of DEM with heat elicits a decrease in HSP70 as compared to heat alone. When SMF is added to heat and DEM, the decrease is modulated but still dramatically less than heat alone.

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REFERENCES


**Effects Of UMTS Signal (1.95 GHz) On Cytogenetic Damage Induced By Ionising Radiation Of Varying Quality Radiation In Human Cells In Vitro**

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**INTRODUCTION**

Recently we studied the effects of an *in vitro* 24-h exposure to a 1.95 GHz UMTS signal on the yield of chromosome aberrations (CA) induced by 4 Gy of x-rays in unstimulated G0 human lymphocytes [1]. The aim was to ascertain whether the cellular repair mechanisms, which are known to be activated upon recognition of ionising radiation (IR)-induced genetic damage and to effectively remove part of the sublethal lesions, may be affected by the concomitant exposure to the radiofrequency (RF). The 24-h RF-radiation exposure time allows for the slow repair component to come to completion. This is a reasonable working hypothesis since most of the experimental data on *in vitro* effects of RF seem to exclude a direct action of such fields on DNA, whereas very little is known on the so-called co-operative effects of multiple sources of exposure, particularly of different physical characteristic such as ionising and non-ionising radiations. CA were chosen as radiobiologically relevant endpoint because they are a reliable biomarker of cytogenetic unrepaired or misrepaired damage, and because of their close correlation with the increased risk of cancer. CA were scored in Fluorescence In Situ Hybridization (FISH)-stained chromosomes 1 and 2, which account for about 16% of the human genome. Most of the existing data on the genotoxicity of RF radiation have been obtained using solid staining; FISH technique detects a wider array of chromosome alterations, including non-lethal, potentially heritable cytogenetic alterations. Results indicate an influence of SAR on the exchange frequency that was statistically significant after correction for donor variability.

In this work we aim at further investigating the possible influence of RF on the efficiency of IR-induced cytogenetic damage by using a larger number of donors screened and extending the IR treatment to particle irradiation. It is known that the complexity of DNA damage induced by IR is strongly dependent upon the quality of IR, defined by its Linear Energy Transfer (LET), which gives a measure of the ionisation density along the radiation track, with low LET radiation, such as x-rays, yielding mainly double and single-strand breaks, whereas high LET radiation such as that represented by ions, causes clusters of lesions. This is normally reflected by a higher cell lethality after high than low LET IR. However, it is of interest to consider the combined effects of high LET irradiation and RF because a common source of exposure to IR in domestic and work places is represented by high LET alpha particles emitted by radioactive decay products of the gas radon inhaled. This will be the first study to look at the combined exposure effects of RF and environmentally relevant high LET IR.

The biological systems that used are human lymphocytes and primary normal human cells, the latter being the barrier for emitted alpha particles. Alongside FISH painting of whole chromosome for acute effects, i.e. assessment of the UMTS influence after the 24-hr exposure of irradiated cells, the more sophisticated arm-specific m-FISH technique is used, which allows the simultaneous scoring of all 46 human chromosomes and detection of
complex intra-chromosome exchanges, which are a known cytogenetic signature of exposure to high LET radiation tracks. This technique was used to assess both acute damage and that in the descendents of irradiated cells exposed to RF to detect residual damage being carried over through to the progeny. This is of interest for possible induction of genomic instability and/or neoplastic transformation.

MATERIALS AND METHODS
The RF-radiation exposures are carried out using a waveguide system at two specific absorption rates (SARs), 0.5 and 2.0 W/kg, under strictly controlled dosimetric and environmental conditions. Lymphocytes and primary normal human cells are exposed to IR and then subjected to RF for the repair of IR-induced damage to be completed. Lymphocytes are exposed to x-rays followed by RF radiation or sham exposure to investigate the RF-associated modification of the damage induced by low LET IR at doses of 4 and 2 Gy as to both replicate our previous studies (i.e. in the case of 4 Gy) or to mimic therapeutic regime, 2 Gy being the typical dose per fraction in a conventional radiotherapy course; unirradiated lymphocytes exposed to RF alone or sham-exposed are used as controls. High LET irradiation of primary normal human cells is carried out using alpha particles accelerated at the tandem accelerator at the Dipartimento di Scienze Fisiche, University of Naples Federico II, Italy. Both acute and late damage will be measured to assess whether RF treatment influences the processing of IR-induced damage in the short term but also in the close progeny of surviving cells. Acute damage is assessed by conventional FISH to detect whole chromosome structural aberrations in lymphocytes that will be stimulated to proliferate immediately after the 24-hr RF treatment. Also micronuclei (MN) will be scored in lymphocytes by using the well-known cytochalasin B-induced block assay. m-FISH analysis is carried out at later times, up to 144 hr from initial exposure, to detect early signs of genomic instability which may manifest by karyotypic alterations. MN will be also scored at such later times since they too indicate ongoing cytogenetic damage. The same analysis, i.e. at both early and late times, using CA, MN and arm-specific m-FISH as endpoints, is carried out in alpha-particle irradiated primary normal human cells.

RESULTS AND CONCLUSIONS
Our data highlighted a significant inter-donor variability in the yield of x-ray-induced CA, irrespective of the UMTS treatment, which was somewhat expected because of individual radiosensitivity. When the donor factor was taken into account in our statistical analysis according to a model that considers main effects only, we concluded that the exposure of x-ray-irradiated cells to the UMTS signal did not increase the fraction of aberrant cells. In particular, no significant influence could be ascribed to the 0.5 and 2.0 W/kg SAR values used (asymptotic F test, P=0.46 after correction for donors). However, the Poisson distribution-based ANOVA analysis of the frequency of total chromosome exchanges per cell revealed a significant enhancement by SAR, albeit the magnitude of the shift due to RF exposure is small, i.e. 0.11 exchanges per cell. The influence of SAR on the exchange frequency was statistically significant after correction for donor variability. In particular, the exchanges found in the metaphases from x-irradiated lymphocytes that were treated with 2.0 W/kg SAR exhibited the highest occurrence compared to 0 W/kg SAR (P = 0.036). Further investigating are carrying out by using a larger number of donors screened and extending the IR treatment to particle irradiation.

REFERENCES
Radiofrequency Radiation Affects Cellular Oxidative Stress and Apoptosis

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INTRODUCTION

Rapidly expanding use of mobile communication devices utilizing radiofrequency (RF) radiation has raised public concern on possible health effects of weak electromagnetic fields. Although no direct effects of RF radiation on DNA are expected, indications of possible indirect (non-genotoxic or epigenetic) mechanisms of carcinogenesis has been reported, mainly in in vitro studies. For example, effects on proliferation and apoptosis (programmed cell death) after RF radiation exposure have been reported [1]. We were interested in the underlying mechanisms; if they were related to oxidative stress of the cells. Effects on oxidative stress and apoptosis were studied in cells exposed to RF radiation. Combined exposures with known oxidative stress inducing agents were used to increase the probability of observing weak and/or indirect effects of RF radiation.

MATERIALS AND METHODS

In combined exposures, menadione and tert-butylhydroperoxide (t-BOOH) were used to induce intracellular reactive oxygen species (ROS) production and subsequent depletion of reduced glutathione (GSH) levels, and lipid peroxidation, respectively. Murine L929 fibroblast and human SH-SY5Y neuroblastoma cells were exposed for 1 h to 872 MHz RF radiation alone (GSM modulated at 217 Hz or continuous wave, specific absorption rate, SAR 5 W/kg), to 50 µM menadione or 0.5 mM t-BOOH alone, or simultaneously to RF radiation and menadione or t-BOOH. Exposures were carried out in a waveguide exposure system with a precise temperature control. ROS production was assayed using dichlorofluorescein fluorescence. GSH levels were measured fluorometrically using monochlorobimane. Lipid peroxidation was examined using a fluorescent probe, diphenyl-1-pyrenylphosphine (DPPP). Apoptosis was examined by assessing caspase-3-like protease activity fluorometrically using DEVD-7-amino-4-methylcoumarin (AMC).

RESULTS

Our results show that cellular ROS production was increased by 20 % in SH-SY5Y cells co-exposed to GSM modulated RF radiation and menadione compared to cells exposed to menadione alone. Cellular reduced glutathione levels were not statistically significantly affected in either of the cell lines. A significant (p = 0.002) increase in lipid peroxidation was observed in SH-SY5Y cells co-exposed to GSM-modulated RF radiation and t-BOOH (Fig. 1). Lipid peroxidation in SH-SY5Y cells was not affected by the CW signal and no RF radiation-related differences in lipid peroxidation of L929 cells were detected. In L929 cells stimulated with menadione, cellular caspase-3 activity was significantly increased by 63 % (p = 0.008) after exposure to GSM modulated RF radiation.

CONCLUSIONS

The results of the present study suggested that GSM modulated RF radiation may increase intracellular ROS production in coexposure with menadione in SH-SY5Y cells. Zmyslony et al. [2] reported concordant results, as an increase in cellular ROS production after coexposure
to RF radiation and iron ions in rat lymphocytes was measured in their study. However, in SH-SY5Y and L929 cells GSH levels were not affected by RF radiation. The increase in lipid peroxidation in SH-SY5Y cells was associated only with GSM modulated RF radiation. As the increase was not supported by a similar finding in the other cell line used, further studies are needed to determine whether this is a chance finding or reflects a true modulation-specific biological effect in this cell line. Similarly with the lipid peroxidation findings, the RF radiation related increase in caspase-3-like protease activity was observed only in one cell line and only in the cells exposed to the GSM modulated radiation. In this case, however, there was also a small, not statistically significant increase in the cells exposed to the CW signal.

Our results indicated that RF radiation at SAR level of 5 W/kg may cause disturbances in oxidative processes in exposed cells. Thus, reported RF induced effects on proliferation and apoptosis may be mediated by disruption in cellular oxidative processes.

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REFERENCES


Using Nanosecond Pulsed Electric Fields to Treat Basal Cell Carcinomas in Mice

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INTRODUCTION

The most common treatment for skin cancer is the surgical removal of the lesion. This is time-consuming and almost always leaves a scar. An alternative approach is electrochemotherapy in which the tumor is exposed to a toxic drug following electropereabilization (1) using electric pulses in the microsecond domain. A third approach is irreversible electroporation which kills the treated tissue by necrosis resulting from permanent permeabilization using microsecond domain pulses with larger amplitudes (2). However, if the electric pulses are shortened 1000-fold into the nanosecond domain, they are able to independently initiate tumor cell apoptosis, causing the tumor to slowly self-destruct without requiring toxic drugs or permanent permeabilization (3). In addition to initiating apoptosis in the tumor cells, nanosecond pulsed electric field (nsPEF) application halts blood flow in the capillaries feeding it. This reduced blood flow to the tumor and activation of apoptosis pathways cause murine melanoma tumors to slowly shrink and disappear within an average of 47 days. Here we describe recent studies of the effects of nsPEF on an autochthonous murine model of the most common human cancer, cutaneous basal cell carcinomas (BCCs). For these studies we have used a new suction electrode design and both 100 and 300 ns pulse widths.

MATERIALS AND METHODS

Mice: Ptch1+/- mice with conditional deletion of keratinocyte p53 develop as many as 20 visible BCCs about 6 months after exposure to radiation. These tumors grow in the mouse skin in a manner similar to that observed in human BCCs. The murine and human BCCs have similar pivotal mutations and molecular defects, making this an excellent preclinical model (4).

Pulse generator: We use a Blumlein line configuration in which a coaxial cable is charged to the desired voltage and is then discharged across the tumor by a pressurized spark gap. We applied 30-40 kV/cm in each pulse with a 5 ns rise time. The electrode in contact with the tumor is a hollow hemisphere with six curved metal plates lining the sides and several small holes in the base to allow suction to be applied to pull the tumor into the hemisphere.
RESULTS

We have treated 17 BCCs on 7 different mice with either 300 pulses 300 ns in duration or 2700 pulses 100 ns in duration. In every instance we observed that the tumor began to shrink within a few days (fig. 1). When the tumors were removed and processed for histology, pyknosis was very evident (fig. 2), suggesting that they were undergoing apoptosis. Blood cells were found scattered throughout the tumor and were not confined to blood vessels, suggesting that nsPEF disrupts blood flow to BCCs. The tumors typically began to grow again after about 2 weeks unless we retreat them with nsPEF. In one case we treated the tumor three times at two-week intervals and completely eliminated the tumor as confirmed by serial section histology.

CONCLUSIONS

We conclude that nsPEF can be used to treat BCCs and probably triggers apoptosis in these tumor cells. The BCCs treated here are a model highly similar to human BCCs. There is already one report of a human BCC that has been successfully treated with nsPEF (5). This suggests that nsPEF application might someday augment or perhaps even replace the scalpel as a new therapy for treating human BCCs.

ACKNOWLEDGMENTS

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The results of a research group using microwave power will be presented: numerical modeling, experimental results, problematic in worker protection (E.U. Directive 2004/40/CE)

A lot of biological forms do not survive over the lethal temperature, that can be reached by microwave treatment.

This technology could be applied to objects of historical-artistic interest made up of wood, paper, cloth.

Experiments for disinfestations of irremovable ancient handicraft are now going on: roman walls, altar of 16th Century, chorus of 15th Century.

The treatment of the precious wooden statue of Saint Leone Magno provided a complete disinfestation of pests.
BIOPHYSICAL PROTECTION AND REPAIR OF ARTICULAR CARTILAGE

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ABSTRACT

Articular cartilage has minimal reparative capability: “when destroyed it is never recovered”. The possibility to prevent the degeneration of articular cartilage is a major challenge for modern orthopaedic surgery and regenerative medicine. Regenerative medicine foresee the replacement or repair of the damage cartilage using mesenchimal stem cells implantation, microfractures or tissue engineering procedures, such as autologous chondrocytes transplantation with or without scaffolds. The different steps of these procedures have been defined with great details: i) tissue substitute preparation or “tissue-engineering phase”; ii) preparation of the recipient tissue, iii) surgical procedure. Nevertheless, a central role is played by the “wound healing phase”; the local environment influences the metabolic activity and the phenotypic expression of the cells in the treated area. For example, it is known that surgery, even if minimally invasive, is always associated to an inflammatory reaction that may jeopardize the benefits expected from treatments. Moreover, inflammation in the joint space favours the onset of fibrotic phenotype versus a more specialised phenotype. Furthermore, the presence of pro-inflammatory cytokines, such as IL-1β and TNF-α, favours an extracellular matrix degradation and the release by sinoviocytes of PGE₂ that may induce chondrocytes apoptosis. Pharmacological therapies, like non steroidal anti-inflammatory drugs (NSAIDs), are used after surgery to limit the catabolic effects of pro-inflammatory cytokines; however, local drug concentration is limited by the poor vascularization of the cartilage tissue.

In the last years, several studies have shown that biophysical stimulation, with I-ONE therapy (IGEA, Carpi, Italy), has able to modulate articular cartilage metabolism treating the whole cartilage surface and thickness, and the underlying subchondral bone homogenously [1]. In vitro, I-ONE therapy increases the binding between adenosine and A₂A adenosine receptor on human neutrophils cell membrane, on bovine chondrocytes and fibroblast-like synoviocytes. It has been shown that drugs with A₂A adenosine receptor agonist activity prevent articular cartilage degeneration in animals. I-ONE therapy inhibits PGE₂ release from synoviocytes. We hypothesized that the adenosine agonist effect of I-ONE therapy can also prevent cartilage degeneration. Ex vitro, in bovine full thickness articular cartilage explants, I-ONE therapy induces the largest increase in proteoglycan synthesis and in IGF-1 synthesis, when cartilage is exposed to specific I-ONE parameters. These effective parameters were subsequently used in in vivo experiments. The effect of I-ONE therapy was investigated on Dunkin Hartley osteoarthritic knee by Mankin score and by histomorphometric and densitometric analysis; I-ONE therapy prevented cartilage degeneration and subchondral bone sclerosis. Osteochondral grafts were performed in the knees of sheep; I-ONE therapy favoured osteochondral grafts integration and prevented cyst-like resorption area formation, that can compromise the stability of graft and the success of the technique. To support the in vitro results histological analysis of the synovial fluid were also performed in this animal
TU 5-2

model. The amount of inflammatory catabolic cytokines (IL-1β and TNF-α) in the synovial fluid of I-ONE treated animals was significantly lower than in control animals. On the contrary, TGF-β1 was significantly higher in stimulated animals than it was in controls. These results demonstrate not only the capability of I-ONE therapy to control the inflammatory reaction, but also its capability to favours cartilage anabolic activity. Preclinical studies have shown that I-ONE therapy controls inflammation, protects extracellular matrix and favours chondrocytes metabolic activity. These results provide the rational to design clinical studies to demonstrate the possibility to transfer the treatment to humans. We hypothesized that patients undergoing arthroscopic treatment could benefit from the use of I-ONE therapy. The results of two randomized, prospective, double-blind studies demonstrated that I-ONE therapy favours patients’ recovery both in the short (90 days) and in the long term (3 years). The percentage of patients with complete functional recovery is significantly higher among of the active group compared to the control.

We think that the long term benefit results from I-ONE chondroprotection of articular cartilage and from prevention of the fibrotic stimuli exerted by pro-inflammatory cytokines on wound tissue. Biophysical stimulation can play a central role in regenerative medicine, protecting the repair tissue from the catabolic effect of the inflammatory reaction elicited by the surgical implantation procedure.

REFERENCES

A Unified Mechanism for Pulsed Electromagnetic Field Bioeffects: Cellular, Animal and Clinical Evidence

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INTRODUCTION

The author proposed starting in 1972 that weak EMF signals could be configured to modulate ion binding at electrified cell membrane/aqueous interfaces using the electrochemical information transfer model [1]. That model described all voltage dependent processes at the cell membrane in terms of electrical equivalent circuits, allowing the EMF signal to be configured according to the dielectric properties of responding pathways such as ion binding and membrane transport. This guided the configuration of the EMF signals now in routine clinical use for recalcitrant fractures. As the biological signaling pathways for tissue growth and repair have become more elucidated, the target pathway and its dielectric properties could be better defined, suggesting that, while the original bone repair signal is clearly within an effective dosimetry range, it is not configured for optimal dose. This may explain why lengthy daily treatments for up to several months are often required to reach a satisfactory clinical outcome. This work shows how more effective EMF signals may be configured a priori by using the dielectric properties of a two step ion binding pathway involving Ca$^{2+}$ binding to calmodulin (CaM), followed by Ca/CaM binding to an enzyme such as nitric oxide synthase (NOS) which leads to transient nitric oxide (NO) release. Direct evidence that PEMF affects this pathway is provided for chondrocytes and neuronal cells in culture and in a rat thermal injury model of cardiac ischemia. Strong indirect clinical evidence is also presented for post-surgical pain relief, chronic wound repair, and for cardiac myopathy patients with chronic angina.

MATERIALS AND METHODS

The proposed EMF transduction pathway relevant to tissue repair starts with Ca$^{2+}$ binding to CaM followed by Ca/CaM binding to, and activating, constitutive nitric oxide synthase (cNOS = e(nothelial)NOS or n(euronal)NOS) which catalyzes the release of the signaling molecule NO. Configuration of a PEMF signal which can modulate NO release by analysis of the kinetic equations describing this two step process in terms of its dielectric properties was performed. There results a two time constant electrical equivalent circuit analog which contains the time constants for Ca$^{2+}$ binding to CaM and Ca/CaM binding to NOS. Quantization of these dielectric properties, using literature results for CaM-dependent enzyme kinetics, allows EMF signals to be configured to increase the surface concentration of bound Ca$^{2+}$ above that due to background thermal fluctuations. Pulse modulated radio frequency signals (PRF), in clinical use for wound repair and the reduction of pain and edema, were configured using the above approach. One such signal, consisting of a 1-5 msec burst of 27.12 MHz sinusoidal waves repeating at 1-5/sec with 0.01-0.05 G peak amplitude, was used to modulate NO release in perturbed neuronal cells and angiogenesis in a cardiac injury model in the rat. Existing studies using the original PEMF bone healing signal consisting of a 5 msec burst of 200/20 μsec bipolar pulses repeating at 5/sec, were analyzed according to the model for reported effects on DNA synthesis in articular chondrocytes and growth factor dependent angiogenesis in endothelial cells and wound healing in diabetic mice. A PRF signal configured for the Ca/CaM/NO pathways...
pathway was used in double blind clinical studies for acute post-operative pain relief in breast surgery and for symptom relief in patients with cardiac myopathies exhibiting chronic angina.

RESULTS

The PRF signal configured to target the Ca/CaM pathway was applied to rat Achilles’ tendon and cutaneous wound healing models, wherein healing rates, as assessed by tensile strength, were increased at 3 weeks by 59 and 69%, respectively, [2,3]. The PEMF bone healing signal increased DNA synthesis in articular chondrocytes by 150% via a Ca/CaM/NO pathway. This study systematically used CaM, NOS and cGMP inhibitors which, individually, eliminated the PEMF effect on DNA synthesis [4]. The PRF signal increased NO release from neuronal cells, by up to 200%, when intracellular calcium was increased by glutamate or 6-OHDA in a cellular model of inflammation [5]. PRF increased angiogenesis by 200% in a thermal myocardial injury in a rat model. This effect was eliminated in rats who were fed L-NAME, a general NOS inhibitor [6]. PRF significantly accelerated post surgical pain relief by 3X with a concomitant reduction in pain medications in a randomized double-blind study on breast augmentation patients [7]. A similarly configured PRF signal provided significant relief of angina pain (4X) and decreased physical limitations (2X) within three months, in a double blind study of patients with cardiac myopathies [8].

CONCLUSIONS

Taken together, all of the available evidence provides strong support for Ca/CaM-dependent transient NO production as an important PEMF transduction pathway for tissue repair. This allows a mechanism to be suggested. PEMF signals increase the rate of Ca\(^{2+}\) binding to CaM, which then catalyzes eNOS, e.g., eNOS, producing an immediate (seconds) production of NO which can orchestrate an anti-inflammatory response via increased blood and lymph flow. NO, in turn, regulates cGMP production (minutes) which cascades to the appropriate growth factor release dependent upon the stage of healing, e.g., FGF-2 for angiogenesis. This is summarized in the figure. Disruption of tightly regulated free cytosolic Ca\(^{2+}\) in cells is a signal for endogenous tissue repair and regeneration mechanisms. PEMF signals could modulate Ca/CaM which catalyzes eNOS, allowing the PEMF signal to modulate the release of NO from eNOS and potentially affect the entire tissue repair pathway from pain and edema to angiogenesis, bone and tissue regeneration and other regenerative actions. Resting cells (in homeostasis), in which there is no transient increase in cytosolic free Ca\(^{2+}\), do not appear to respond to PEMF, providing one explanation for the reports of no known side effects from PEMF therapies.

REFERENCES

TRANSCRANIAL MAGNETIC STIMULATION AND NEURONAL CONNECTIVITY IN THE BRAIN

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Transcranial magnetic stimulation (TMS) allows one to deliver pulses to selected superficial brain sites noninvasively. A modern TMS navigation system displays in real time the location and orientation of the current that will be induced in the cortex when the pulse is given. This MRI-based targeting enables one to deliver the stimuli with an accuracy of about 3 mm, allowing functional mapping of cortical areas. Furthermore, when the TMS-evoked EEG is measured, one can obtain time-resolved measures of cortico-cortical connectivity. Such measures reflect, in addition to the anatomical connections, also vigilance and the pharmacological state of the subject. For example, functional connectivity is much reduced during deep sleep; alcohol has been found to alter the connectivity as well.
Non-Invasive Magnetic Deep Brain Stimulation: from Coil Design to Realistic Head Model Calculations

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Transcranial magnetic stimulation (TMS) has been most frequently used to study brain physiology and is also being developed as a therapeutic tool. This talk will discuss several issues relating to deep transcranial magnetic stimulation. Firstly, we will review the TMS coil design, particularly highlights the double-cone and H-coils for stimulating deeper brain regions. Secondly, we will show how to build 3D patient-specific head model from MRI images. Finally, we will present numerical results by employing 3D impedance method. The induced currents and electric fields in realistic head model by applying round, figure-of-eight, double-cone and H-coils will be presented.
Environmental parameters, first of all humidity, can damage culture heritage objects and also result in the appearance of pests and other micro-organisms. Non-invasive monitoring of these damage and also disinfection treatments and drying with the help of electromagnetic waves are preferred as they keep the object untouched after treatment. Here we discuss the application of millimeter waves for solving this problem. Millimeter waves have a high spatial resolution and absorption in water as well as in bio-objects that are usually moist and at the same time minimal interaction with dry culture heritage objects by itself.
Polarization and Separation of Live and Dead Cells in Electric Field

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INTRODUCTION

The rapid detection of live bacterial cells is essential for many applications, from environmental study and water quality monitoring to the detection of biological weapons [1]. However, it requires separation of live from dead bacterial cells. Dielectrophoresis (DEP) in microelectromechanical systems (MEMS) is considered as a tool for cell separation. DEP is the movement of cells under non-uniform electric field, causing by the polarization effects in cell under specific frequency of applied non-uniform electric field. Dielectrophoretic force ($F_{DEP}$) acting on spherical cell in an electric field gradient is given by the expression $F_{DEP} = 2\pi \varepsilon_m r^3 \text{Re}[K(\omega)] \nabla E^2$ (1), where $r$ is the radius of cells, $\varepsilon_m$ is the permittivity of the suspending medium, $\nabla$ is the gradient operator, $E$ is the root mean square of electric field, and $\text{Re} [K (\omega)]$ is the real part of the Clausius-Mossotti (CM) factor. Dielectric characterization of Escherichia coli cells (common indicator of water pollution) using DEP in microelectrode chamber was done by Sanchis et al. [2]. Selective DEP separation of live and dead cells is possible due to difference in the cell membrane conductivities [3]. The differences in the cell membrane conductivity contribute significant changes in the frequency-dependent Clausius-Mossotti factor and hence the dielectrophoretic force ($F_{DEP}$) [4]. The aim of this study was optimization of the frequency of applied AC electric field in order to generate the dielectrophoretic force ($F_{DEP}$) for separation of live and dead bacterial cells in microfluidic system.

MODEL

Various models have been proposed to study DEP of cells. The two shell spheroidal model [4] has been used in this study. Two shell smeared-out sphere model describing cell dielectrophoretic (DEP) movement takes into account conductivity and permittivity of the cytoplasm, membrane, cell wall and medium. It was validated experimentally for E. coli K12 cells by Suehiro et al. [4]. The expressions for the real, frequency-dependent Clausius-Mossotti (CM) factor is $K(\omega) = (\varepsilon^*_p - \varepsilon^*_s)/(\varepsilon^*_p + 2\varepsilon^*_s)$ (2), where $\varepsilon^*_p$ and $\varepsilon^*_s$ are the complex permittivities of the bacterial cell and surrounding medium, respectively. The complex permittivity is defined as $\varepsilon^* = \varepsilon - j\sigma/\omega$ (3), where $\varepsilon$ is the permittivity and $\sigma$ is the conductivity of the dielectric, $\omega$ is the angular frequency of the applied field, $j=(-1)^{1/2}$. The complex permittivity of the particle ($\varepsilon^*_{p eff}$) in equation (3) is replaced as effective complex permittivity of cell ($\varepsilon^*_{p eff}$) [4].

RESULTS

Optimal electrical frequency for live and dead bacterial cells DEP separation in drinking water with conductivity of 0.0525 Sm$^{-1}$ is from 0.5 to 30 MHz (Fig.1). It depends also on the
physiological status of cells, which is important for monitoring of live bacterial cells in natural ecosystems.

![Graph showing the frequency response of CM factor for viable (bold curve) and non-viable (dotted curve) bacterial cells in drinking water.](image)

**Figure 1.** Frequency response of CM factor for viable (bold curve) and non-viable (dotted curve) bacterial cells in drinking water.

The geometric and fluidic designs of cell separator have been made using the modeling of the trajectories of live and dead cells during DEP separation in the microchannels by COMSOL Multiphysics software. The cell separator for the biosensor of live bacterial cells in 1 mL of sample includes 10,000 microchannels (10 µm width), DEP electrodes at the distance 40 µm, and 1000 sequential separation microcells (20x20 µm).

**CONCLUSIONS**

Optimal electrical frequency of DEP separation of live from dead bacterial cells is expected in the range from 0.5 to 30 MHz but must be determined for real microfluidic sensor under the experimental conditions and for the defined medium.

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INTRODUCTION

In the last years, significant developments have taken place in the area of Wireless Local Area Networks (WLAN); as the popularity of portable devices grows, WLAN will become the communication infrastructure of choice. On the other side, the number of Active Implanted Medical Devices (AIMDs) being placed in patients is increasing. As a consequence, one major safety aspect is the interaction between this EMF-emitting new technology and AIMDs. Among AIMDs, Cochlear Implants (CI) are implanted auditory prosthesis used to restore hearing in deaf people. CI consists of an external portion that sits behind the ear and an internal one that is surgically implanted. All CIs share these features: i) a microphone; ii) a speech processor; iii) a transmitter and receiver/stimulator; iv) an electrode array. Since the electrode array is partly made of metal, if exposed to an external microwave, it could change the distribution of the EMF in the cochlear tissue, especially close to the implant, leading to possible biological damages.

Aim of this paper is to investigate the effects of an external microwave at 2.4 GHz on the SAR distribution in a numerical model of a human head with a CI, with particular focus on the volume close to the electrode array.

MATERIALS AND METHODS

The EM simulations were performed using a commercial software (CST Microwave, CST GmbH, Germany) based on the Finite Integration Technique [1].

An anatomical model of the human head (four tissues: skin, skull, CSF and brain) with a detailed cochlea (filled with CSF) and a model of the electrode array were implemented. The human head and the cochlea models were obtained by image segmentation. The electrical properties and the densities of the tissues were taken from Gabriel report [2]. The electrode array was modelled according to the datasheet of a true CI array (Nucleus CI24M, Cochlear Ltd., Australia) [3]. The array was modelled as if it was turned off and it was inserted following its real position inside the cochlea of an implanted patient.

The exposure source was modelled as a uniform plane wave at 2.4 GHz (E=1 V/m); the wave struck the side of the head where the array was implanted; both vertical and horizontal polarization were simulated. For each polarization two simulations were performed: once with the CI and once without the CI, the latter was taken as a reference.

For the comparisons between conditions, SAR was evaluated both as a quantity averaged over certain mass and as a discrete spatial point distribution. Usually in RF dosimetry and in regulatory issues [4-5] averaging masses of 1 g and 10 g are used. In this case, due to the small structure of the cochlea an averaging mass of 5 mg was chosen for the SAR over the cochlea (SAR$_{5mg}$).
RESULTS

Negligible changes (in the order of $10^{-7}$ W/kg) were found comparing values of maximum SAR$_{5mg}$ obtained with and without the CI. On the contrary, greater differences were found comparing point SAR distribution in the volume around the array. The comparison between data with and without the CI reveal an increase of the maximum point SAR value whether the implant is present (increase of 2 mW/kg for vertical and 0.5 mW/kg for horizontal polarization). SAR values result higher for vertical polarization independently from the presence of the CI both for maximum SAR$_{5mg}$ and for point SAR.

To give a more realistic picture of maximum interaction conditions between the EMF and the implanted subject, maximum SAR$_{5mg}$ in the implanted cochlea was calculated increasing the power density of the source to the ICNIRP reference level both for general public and occupational exposure [4]. SAR$_{5mg}$ reaches its maximum for occupational exposure with vertical polarization (approximately 0.22 W/kg): this can be considered a small value, although no other specific reference values are available in regulatory issues.

CONCLUSIONS

This paper addresses the problem of the exposure of subjects with a cochlear implant to EMF at 2.4 GHz, with a particular emphasis on the electrode-tissue interface at cochlear level. Comparisons in the different exposure conditions were conducted evaluating the maximum of SAR distribution. The results suggest that it will be unlikely to find harmful effects in the cochlear tissues due to the presence of a CI when the implanted patient is exposed to WLAN frequencies. Possible malfunctioning of the implant should be further investigated.

REFERENCES

Temperature Changes Associated with Radio Frequency Exposure near Authentic Metallic Implants in the Head Phantom - A Near Field Simulation Study with 900, 1800 and 2450 MHz Dipole.

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INTRODUCTION

One safety aspect concerning the increased use of RF devices like mobile phones is the coupling of EM fields with active or passive implants in the human body. It has been shown [e.g. 1] that a conductive implant in tissues may change the distribution of electromagnetic energy (i.e. SAR) in the body. The exposure scenario involving conductive metallic implants is not trivial as implants like screws, wires, nails, bolts, stents and plates are widely used in surgical operations to provide substitutes or support for tissues.

In this numerical study, temperature changes induced by electromagnetic field enhancements near conductive metallic implants are studied in the head region. In previous studies [1-4], it has been shown that in some cases due to high conductivity of metallic implants, the electromagnetic field flux may concentrate near the implant, leading to higher local power absorption in tissues than would occur without the presence of the implant. This effect may be seen especially for implants that locate near the body surface and thus may be close to the radiating source (e.g. mobile phone).

The EM near field associated temperature changes are studied for authentic implant models in a heterogeneous head phantom using FDTD-simulations and Pennes bioheat model. Previously, thermal simulation results for passive metallic implants in the far field have been presented [3] but here the focus is on the (dipole) near field exposure. Furthermore, recently SPEAG (Schmid & Partner Engineering AG, Switzerland) has released a new FDTD-based thermal solver which is used in these simulations. This new version enables correct simulation of high thermal conductivities of implants, in thermally steady cases.

MATERIALS AND METHODS

First the FDTD method is employed for calculating EM field distributions and SAR in tissues. For metallic implants, the perfect electric conductivity (PEC, $\sigma \rightarrow \infty$) is assigned as a boundary condition. In thermal simulations the FDTD method is used for solving the Pennes bioheat equation. The calculated SAR distribution is used as an input (i.e. a heat source) for the Pennes bioheat equation.

The heterogeneous head phantom model used is a high resolution European female (HREF) phantom to which 17 different tissue types are assigned. As an exposure source, a dipole antenna with $0.47\lambda_{air}$ length is located close to the right ear, parallel to long axis (i.e. in the craniocaudal orientation) of the head phantom. In order to minimize the implant-antenna distance, the antenna is positioned as close to the surface of the phantom as possible without touching the head and the position of the antenna is varied for different implant models.

Like the dipole, the studied implants locate close to the right ear of the phantom. All the
implants are placed to realistic locations corresponding to their authentic use and the models for the implants also imitate real designs. The implants are chosen on the basis of their location and results from our previous implant studies [2, 4]. Here implants like fixtures, a skull plate, a bone (or reconstruction) plate and an ear ring are studied. The thermal properties of the metals are modeled according to real implant materials.

The modelling and the simulations are performed using SEMCAD software (Schmid & Partner Engineering AG, Switzerland).

RESULTS

The preliminary thermal simulations indicate that for most of the studied implant models, no substantial temperature rises are caused by the redistribution of the EM energy in the surrounding tissues. However, the implants do affect the thermal distributions in tissues which are different from the similar case without an implant.

This study is a continuation for our earlier studies, where the aim was to survey how much do the passive metallic implants affect power absorption (SAR) in surrounding tissues. The geometries and the implants were chosen so that the level of the worst case enhancements for SAR could be seen. Here the induced changes in tissue temperatures for those set ups are studied. However, the implant models and exposure set ups that caused the highest SAR enhancements are not necessary the “worst cases” in terms of induced temperature changes.

In this study, the correct modelling of the thermal properties of the implants is essential. If the implant is modeled as a thermal boundary, the selection of the correct boundary condition is rarely straightforward.

CONCLUSIONS

The temperature changes induced by EM near field redistribution around metallic implants are presented for fixtures, a skull plate, a bone (or reconstruction) plate and an ear ring. The preliminary thermal simulations indicate that for most of the studied authentic implant models, no substantial temperature rises are caused by the redistribution of the EM energy in the surrounding tissues.

ACKNOWLEDGMENTS

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REFERENCES


Eliciting A Brain Model To Respond To Simple and Complex Stimuli

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INTRODUCTION
Neuromodulation has been demonstrated with deep brain stimulation, transcranial magnetic stimulation, and whole-body exposure. However, little is known about the requirements for stimulus amplitude (SA) and the size of neuron population (SPS) receiving that stimulus to elicit an effect. We previously demonstrated a computer simulation of neurotransmission in a large-scale brain model (BM) [1] possessing many features observed experimentally, such as sensitivity to frequencies near 60Hz, and entrainment to a complex Pulsed Electromagnetic Field (PEMF) [2]. Here, we characterize the response of our BM to a range of SA and SPS.

MATERIALS AND METHODS

SIMULATIONS: Our BM consisted of 800 excitatory pyramidal neurons and 200 inhibitory interneurons approximating a cortical mini-column, with electrical dynamics approximating the Hodgkin-Huxley equations [3]. The resting potential in the BM is between -70 and -60 mV, and the firing threshold depends on the history of the membrane potential prior to the spike, ranging between -55 mV and -40 mV. At rest, to mimic background thalamic influence, random populations of neurons stimulated by adding 20 mV to their transmembrane potential. At any time, the state of BM can be interrogated by summing voltages from all sub- and super-threshold (ie. firing) neurons, interpreted as an “EEG-like” signal, which can be Fourier-transformed for spectral analysis. The BM accepts external stimuli, assuming capacitive coupling to neurons. Our simple stimulus was a 60 Hz sinusoid, and our complex stimulus was our PEMF. We conducted simulations for a range of SA and SPS, with SA varying from 0.5 to 10mV transmembrane potential (0.5 mV increments), and SPS varying from 1 neuron (0.1% of population) to 200 neurons (20% of population) (10 neuron increments). We previously demonstrated that stimulation with SA=10mV and SPS=200 elicited a reproducible perturbation to EEG [1]. For each combination of SA and SPS, the BM ran for 2400s simulation time.

ANALYSIS: For both 60Hz and PEMF stimuli, and all combinations of SA and SPS, the BM’s EEG spectra were compared with baseline by calculating the mean squared difference from baseline (MSDB) for \( \alpha \) (7-13Hz), \( \beta \) (14-40Hz), and \( \gamma \) (41-80Hz) EEG bands.

RESULTS
Figure 1 shows how the EEG spectra are affected by stimuli. Figure 2 shows how varying stimulus amplitude affects MSDB for the \( \alpha \) band.
FIGURE 1: Shown are simulation results at time=2400s for: baseline condition (no stimulus, SA=0, SPS=0); and 60Hz and PEMF (SA=10, SPS=200). For the EEG corresponding to the 60Hz stimulus, the 60Hz peak can be seen (label $\omega$). The $\alpha$ band is also indicated (label $\alpha$). FIGURE 2 shows the variation of MSDB as a function of SA at time=10s (dashed lines) and time=2400s (solid lines), for both 60Hz (gray) and PEMF (black) stimuli. SPS is fixed at 200, and SA varies from 0.5 to 10mV. In all four cases, MSDB increases with SA, as intuitively expected, although the BM can be “over-stimulated” by PEMF resulting in an apparent decrease towards baseline (label $\psi$). An effect is visible as early as 10s stimulation (dashed lines), which increases with time (solid lines). Finally, PEMF – which is designed specifically to entrain neurons, has a greater effect (in a MSDB sense) than the 60Hz stimulus.

FIGURES 3A and 3B show the dependency of $\alpha$ EEG MSDB on SA and SPS for both 60Hz and PEMF stimuli. MSDB for $\beta$ and $\gamma$ bands are similar (not shown). Figure 3B suggests that for PEMF, the MSDB is relatively independent of the number of neurons stimulated, as long as minimal population (SPS>30 which is 3% of the total neuron population) receives the stimulus and the stimulus is imparted with sufficient amplitude (SA>5mV for this computer simulation). This suggests that the PEMF stimulus is more attuned than the 60Hz stimulus to being propagated from the stimulated neuron population to the entire neuron population.

CONCLUSIONS

These results demonstrate that for the same SA, the impact on the BM’s firing pattern depends on the information carried by the shape of the stimulus waveform.

ACKNOWLEDGMENTS

Funded by the Canadian Institutes of Health Research.

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Evaluating the Synergistic Effects of 872 Mhz Radiofrequency Radiation with Two Chemical Agents In Vitro

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INTRODUCTION

The aim of the present study was to investigate possible synergistic effects of radiofrequency radiation (RFR) on reactive oxygen species (ROS) production and DNA damage with two different chemical exposures (menadione & ferrous chloride (FeCl₂)). FeCl₂ was chosen as a coexposure agent because RFR has been previously reported to enhance FeCl₂-induced ROS production [1]. In addition, we compared the effects of GSM (global system for mobile communications) modulated and CW (continuous wave) RFR throughout the study. The data from menadione experiments have already been reported [2] and FeCl₂ experiments are still ongoing.

MATERIALS AND METHODS

Intracellular ROS production was measured by the fluorescent probe 2’,7’-dichlorofluorescein-diacetate (DCFH-DA). Measurements of ROS levels were made 0, 5, 10, 15, 30 and 60 min after the RF exposure. The single cell gel (SCG) electrophoresis assay, also known as comet assay, was used for quantifying DNA damage.

The exposures to 872 MHz CW and GSM modulated RF radiation were conducted at specific absorption rate (SAR) of 5 W/kg. The exposures were done in four groups: 1. sham (control), 2. RFR, 3. chemical(s), 4. chemical(s) & RFR. Human neuroblastoma (SH-SY5Y) cells were treated with 50 µM menadione or 10 µg/ml FeCl₂ in the ROS production experiments. In the comet assay experiments, 25 µM menadione or 10 µg/ml FeCl₂ + 0.015% diethyl maleate (DEM) were used. DEM was added in the FeCl₂ comet assay experiments to decrease the level of reduced glutathione and thus increase the level of DNA damage. In addition, we had to increase exposure time to 3 h for inducing observable DNA damage level. The exposure time in all other experiments was 1 h.

RESULTS

When a CW signal with menadione was used, increased DNA breakage (p<0.01) was observed in the menadione & CW RFR group compared to mere menadione exposed group (Table 1.). In addition, statistically significant increase in ROS levels was found between same groups at the 30 and 60 min timepoints (p<0.05 and p<0.01 respectively). No effect of GSM modulated RF radiation was observed on ROS production or DNA damage, with or without menadione. The data from FeCl₂ experiments are still incomplete.
Table 1. DNA damage, expressed as OTM values, in SH-SY5Y neuroblastoma cells exposed to 25 μM menadione, to continuous wave (CW) or GSM-modulated radiofrequency radiation (RFR) at 5 W/kg for 1 h, or to combined menadione and RFR.

<table>
<thead>
<tr>
<th>Signal OTM value</th>
<th>Control mean ± S.E.</th>
<th>RFR mean ± S.E.</th>
<th>menadione mean ± S.E.</th>
<th>menadione&amp;RFR mean ± S.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW</td>
<td>0.24 ± 0.05</td>
<td>0.26 ± 0.05</td>
<td>3.36 ± 0.22</td>
<td>5.30 ± 0.25</td>
</tr>
<tr>
<td>GSM</td>
<td>0.31 ± 0.03</td>
<td>0.21 ± 0.05</td>
<td>11.34 ± 0.40</td>
<td>11.53 ± 0.40</td>
</tr>
</tbody>
</table>

*Three experiments were done per exposure group.

100 cells were counted per sample.

p < 0.001, compared with control.

p < 0.01, compared with mere menadione exposed group.

CONCLUSIONS
As increased ROS production can damage macromolecules, the increased DNA damage and enhanced ROS production observed in the menadione experiments may be causally related. Similar findings of both DNA damage and ROS production have been previously reported by Yao et al, although without the presence of any coexposure agents [3]. If the increase of DNA damage observed in the CW RFR exposed cells represents a true effect, its biological relevance remains uncertain. The comet assay measures DNA damage that is repairable, and might result in no adverse consequences (such as gene mutations of chromosomal abnormalities), if repaired correctly. Although both statistically significant modifications of this study were related to CW RFR, there is no known or hypothetical mechanism for effects from a CW signal but not from a pulse-modulated signal at identical SAR level.

ACKNOWLEDGMENTS
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REFERENCES
Novel 3D Cell Culture Systems for Electromagnetic Exposure Studies

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INTRODUCTION

In vitro studies of monolayer cell cultures for the investigation of genotoxic and electrophysiological effects due to high-frequency electromagnetic fields (EMF) are well established and often replace animal experiments. Monolayer cultures are easy to handle, but obviously there is a gap between these two-dimensional in vitro models and live tissues.

We have established a scaffold-free three-dimensional (3D) cell culture system that is suitable for exploration of electrophysiological effects due to EMF. Induced by permanent rotation, dissociated neuronal cells and cardiac myocytes aggregated into spheroids. Cell-Cell and Cell-Matrix (ECM) interactions established a 3D cellular network that mimics the properties of living tissue in vivo better than conventional monolayer cultures [1]. In our preliminary studies, three-dimensional cell culture systems were exposed to EMF at a frequency of 900MHz and electrophysiological parameters like the spike rate were recorded.

MATERIALS AND METHODS

Tissue from chicken heart (E6) was mechanically dissected and enzymatically dissociated with Trypsin/EDTA PBS (0.05%/0.02%). 1.4x10^6 cells were cultivated in 35-mm dishes containing 2ml cell culture medium (DMEM with 10% FCS and 2% CS). Dissociated rat cortical neurons (E18) were purchased from Lonza, Switzerland and cultured at a density of 8x10^5 cells per petri dish. The dishes were placed on a gyratory shaker, allowing cells to reaggregate into 3D spheroids [2].

We used MEA-Chips (microelectrode array, Multi Channel Systems, Germany) with 60 microelectrodes to record the electrical activity of the 3D spheroids. Spheroids were plated on Poly-D-Lysine-treated electrodes and were allowed to settle down. Action potentials were recorded extracellular with a sampling rate of 5kHz.

Electromagnetic exposition of spheroids was performed in an open TEM-cell (Stripline), which generated a transversal and nearly homogenous field. Preliminary studies were performed with EMF at a frequency of 900MHz (95.9V/m). To exclude heating artifacts, cell culture medium was conditioned to 37.0°C with a temperature controller.

RESULTS

Dissociated cells reaggregated into three-dimensional spheroids with an average diameter of approximately 200µm within two days in rotation culture. In case of cardiac myocytes, spheroids were spontaneously contracting.
Action potentials of cardiac myocytes spheroids occurred continuously with a maximum beating rate of 1.5Hz and matched the contraction rate which was optically monitored. During EMF exposure, no significant changes in beating rate and regularity could be observed. Minor effects possibly due to micro heating effects could not be excluded, even by using a temperature controller.

Electrical activity of neuronal spheroids appeared in single spikes and bursts. This neuronal activity pattern seemed to be stochastic and no changes could be observed during EMF exposure, while in previous studies chemical treatment with the GABA-antagonist Bicuculline led to periodic burst-events.

**CONCLUSIONS**

By using 3D spheroids of neural cells and cardiac myocytes for EMF studies, we can now close the gap between monolayer cell culture and live tissue. Owing to their physiological relevance, it is assumed that 3D cellular models will become a fundamental research tool in cell biology [1].

In our preliminary studies no significant electrophysiological effects could be observed during EMF exposure. In further studies we plan to vary the field parameters (e.g. using pulsed EMF) and explore histotypic structures within individual spheroids. Rotation culture systems based on fully dissociated avian retina cells have already shown the ability to reconstitute a nearly complete arrangement of retinal layers as a result of cell sorting processes and key events in cell live cycle, like proliferation and differentiation [3].

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**REFERENCES**


Effect of Exposure to the EDGE Signal on Hydrogen Peroxide Production in Brain Cells

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INTRODUCTION

During aging, exercise, UV exposure or different form of stressing exposure, production of free radicals and hydrogen peroxide is increased. These phenomena are linked to DNA damage and oxidation of fatty and amino acids. These damages can induce alterations of cellular functions. To our knowledge, only few in vitro experiments have addressed the effects of RFR on the production of oxygen species (1-4). For the first time, effects of the EDGE signal on hydrogen peroxide production were studied in three different brain cell models: neurons, astrocytes and microglia.

MATERIALS AND METHODS

Three human cell lines were tested: SH-SY5Y, U87, and CHME5, which are used as models of neurons, astrocytes, and microglia, respectively. Cells were cultured as indicated by the manufacturer, 24 h or 48 h before 24 h or 1 h exposure to the EDGE signal. In vitro exposure to RFR was performed using SXC-1800 waveguides (IT’IS-Foundation, Zürich, Switzerland) modified to allow exposure to the EDGE signal. Six Petri dishes can be exposed simultaneously. Two waveguides (exposed, sham) are placed inside a commercial incubator to ensure constant environmental conditions (37°C, 5% CO2, 95% humidity). Four exposure conditions were tested: 2 or 10 W/kg for 1 or 24 h. Oxidative stress was measured at the end of 24 h exposure or 24 h after the one-hour exposure. All samples were coded prior to exposure and codes were revealed only when all biological parameters investigated in a given experiment had been analyzed.

Dichlorofluorescin diacetate (DCFH-DA) (5 µM, 30 min, 37°C) was used as a substrate for measuring intracellular oxidant production in all cell lines. DCFH-DA is hydrolyzed by esterases to dichlorofluorescin (DCFH), which is trapped within the cell. This nonfluorescent molecule is then oxidized to fluorescent dichlorofluorescin (DCF) by action of cellular oxidants such as hydrogen peroxide. Fluorescence analysis was measured by flow cytometry (FacsCanto II, Becton Dickinson). Positive controls were obtained using rotenone (0.12 or 2.4 µM, 16 h).

Statistical analysis was done using the StatXact software.

RESULTS

All chosen cell lines were responsive to rotenone with production of high amount of hydrogen peroxide in comparison with control cells (n=3). For the three tested cell lines and all exposure conditions (n=12), no significant oxidative stress effect of the EDGE exposure was observed using the DCFH-DA dye. Results obtained with the SH-SY5Y cell line are shown in Fig. 1.
CONCLUSIONS

Our results suggest that exposure to the EDGE signal does not induce oxidative stress in the SH-SY5Y, U87, and CHME5 human cell lines.

ACKNOWLEDGMENTS

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REFERENCES


Influence of A High-Frequency Electromagnetic Field at 2.45 GHz on Neurite Outgrowth in PC12VG Cells

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INTRODUCTION
In recent years, people have been exposed to many kinds of electromagnetic fields (EMF) generated by the use of domestic electrical appliances and mobile telecommunication devices. There is increasing public concern regarding the health risks of radio frequency (RF) radiation, particularly that produced by mobile phones. Although general concern regarding the potential hazards of exposure to an EMF has led to many epidemiological investigations, the effects of EMF exposure on human and other mammalian cells are still controversial. Some studies have reported that low frequency EMF exposure had no significant effect on neurite outgrowth in PC12 rat pheochromocytoma cells [1][2]. However, this view has not been confirmed by other studies [3]. In this study, we investigated the influence of a high-frequency electromagnetic field (HFEMF) at 2.45 GHz on PC12VG cells neurite outgrowth in vitro.

MATERIALS AND METHODS
We used a specially designed exposure apparatus that employs a cylindrical waveguide as a basic structure. This apparatus uses TM₀₁ mode, which is the basic mode of a cylindrical waveguide. The end of the waveguide is terminated by a short circuiting metallic plate, on which a culture dish is placed. The cavity in the waveguide was maintained under controlled conditions similar to those in an incubator, i.e., an atmosphere of 95% air and 5% CO₂ at a relative humidity of >95% and at a temperature of 37°C. A continuous 2.45 GHz wave signal was produced by a signal generator (Agilent E4421B, Tokyo, Japan) through a power amplifier (R&K A2450-4747-R, Shizuoka, Japan). A power meter (Power Reflection Meter NRT; Rohde & Schwarz, München, Germany) was used to monitor the input power and the reflected power. The temperature of the medium in the culture dishes was monitored at all times throughout the experiment and was maintained at 37°C using a Peltier controller (Cell TDC-1550, Kanagawa, Japan).

We studied the average length of neurites, the longest neurite length and the percentage of neurite-bearing cells in PC12VG cells cultured for 7 days after exposure to HFEMF. PC12VG cells were exposed to a HFEMF at average specific absorption rates (SARs) of 1 and 10 W/kg for 4h. Two control groups were used: the first was a sham exposure and the second was a nerve growth factor (NGF) control, used to determine the effect of NGF (50 ng/ml). The control samples were placed in a conventional incubator. The total number of cells and number of cells with neurites at least as long as one cell diameter were counted within nine 1-cm² grids in each culture dish. For quantitation of neurite outgrowth, 10 or more photographs were captured with a digital camera (Olympus DP-20, Tokyo, Japan) at each grid location and neurite-bearing cells were identified and observed out of 100 or more cells per dish. Ganglia were observed every 2-3 days under phase contrast with an inverted microscope (Olympus CKX-41, Tokyo, Japan), and neurite lengths were measured. All neurite lengths and the longest length of neurites in each cell were measured with Simple Digitizer² measuring software (Ver.3.1.1, Fujimaki Haruyuki, University of Tsukuba, Ibaraki, Japan). The average of these measurements was taken as the neurite length for the ganglion.
RESULTS

We found that HFEMF exposure slightly inhibited the percentage of neurite-bearing cells. However, at the same time, the average length of all neurites per neurite-bearing cell and the longest neurite length increased by approximately 10% and 5%, respectively. Significant increases in the average length of neurites, the longest neurite length and the percentage of neurite-bearing cells were observed in PC12VG cells cultured in the presence of NGF.

![Graphs showing neurite outgrowth](image)

Figure 1. Neurite outgrowth after exposure to SAR of 10W/kg for 4h. (a) percentage of neurite-bearing cells; (b) average length of all neurites per neurite-bearing cell; (c) average length of the longest neurite.

CONCLUSIONS

These data suggest that exposure to a HFEMF of 2.45 GHz for 4h has no significant effect on neurite outgrowth in PC12VG cells. Comparing conditioned PC12VG cells treated with 50 ng/ml NGF to untreated naive PC12VG cells, the percentage of neurite-bearing cells, the average neurite length and the greatest neurite length demonstrated a significant increase of neurite outgrowth. However, the possibility of the combined effects on activation in promoting neurite outgrowth remains, and further studies on the neurite outgrowth effects of HFEMF are required.

ACKNOWLEDGMENT

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REFERENCES

Exposure to 1950 MHz IMT-2000 Field Does Not Activate Microglial Cells in Vitro

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INTRODUCTION

Wideband Code Division Multiple Access (W-CDMA) is one of the mobile communication systems defined in the International Mobile Telecommunications 2000 (IMT-2000) specifications, and is the most commonly used form of the Universal Mobile Telecommunication System (UMTS), which is the European standard reflecting the IMT-2000 requirements for the third generation mobile communication systems. To examine biological effects on the central nervous system (CNS) elicited by 1950 MHz modulation signals controlled by the IMT-2000 cellular system, we investigated effects of RF fields on microglial cells in the brain.

MATERIALS AND METHODS

Exposure System; Briefly, two identical RF field exposure incubators, one for RF field exposure and the other for sham exposure were established in separate anechoic chambers, and a mechanical switch in a dummy box allowed the selection of RF field exposure or sham exposure [1, 2].

Cells Experimental Design; Rat newborn (postnatal days 0-1) primary-cultured microglial cells (Sumitomo Bakelite) were cultured in Culture Medium (Sumitomo Bakelite) that was constituted with DMEM/F12 contained with FBS and granulocyte-macrophage colony stimulating factor (GM-CSF), at 37 °C in a humidified atmosphere of 5% CO\(_2\). Twelve cultures were subjected to RF field or sham exposure for 2 h. The RF field exposures were processed in a blind manner. The cultures were transferred in the conventional CO\(_2\) incubator following RF or sham exposure, and were subsequently maintained for 24 or 72 h in the incubators. Microglial cells were exposed to W-CDMA radiation at SARs of 0.2, 0.8 and 2.0 W/kg for 2 h.

Immunocytochemistry; The cells exposed to RF or sham were fixed with 3.7% formaldehyde in PBS. For visualization, cells were incubated with anti-MHC class II antibody (clone OX-6, AbD Serotec), and then incubated with Alexa Fluor 488-labeled goat anti-mouse IgG antibody (Molecular Probes). Moreover, the cells were stained with 1 mg/mL propidium iodide (PI). Specimens were analyzed on a Laser Scanning Cytometer (LSC; CompuCyte) [3] equipped with a BX50 microscope (Olympus). The percentage of MHC class II-positive cells in the PI-positive cells (at least 500 cells) was calculated by use of WinCyte software (CompuCyte). MHC class II antigen positive cells (%) = MHC class II-positive cells number / PI-positive cells number.
Measurement of Inflammatory Cytokines: The culture supernatant was collected for the determination of TNF-α, IL-1β, and IL-6. Rat 9-plex Antibody Bead Kits (Bio-Rad) were used according to the manufacturer’s instruction. The specific proteins were detected using the bead-based multiplex assay [4], which is similar to a capture sandwich immunoassay.

RESULTS
We found no effects on the MHC class II expression after exposure to 1950 MHz W-CDMA RF field at 0.2, 0.8 and 2.0 W/kg. IFN-γ (50 units/mL), positive control agent, induced a significant increase in the percentage of MHC class II-positive cells in all trials. Thus, the present results suggest that W-CDMA radiation up to 2.0 W/kg might not induce MHC class II on the microglial cells. LPS (100 ng/mL), positive control agent, induced a significant increase in the production of the cytokines in all of the trials. Thus, we were able to detect any significant cytokines production induced by RF field exposures if present. In the current studies, no constant differences were observed between RF field exposure cells and sham-exposed controls in production of either TNF-α, IL-1β or IL-6. Thus, our experimental results suggested that the exposure to W-CDMA RF fields up to 2.0 W/kg might not stimulate microglial cells to produce some inflammatory cytokines. We found no effects on the MHC class II expression or cytokines production after exposure to 1950 MHz W-CDMA RF field at 2.0 W/kg in either of the experiments with or without temperature compensation.

<table>
<thead>
<tr>
<th>SAR (W/kg)</th>
<th>Cultivation time after exposure (hours)</th>
<th>Trial</th>
<th>MHC class II Positive Cells (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
<td>1</td>
<td>2.1 ± 0.7</td>
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<td></td>
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<td>2</td>
<td>4.6 ± 0.5</td>
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<td>3</td>
<td>5.2 ± 0.3</td>
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<tr>
<td>2.0</td>
<td>72</td>
<td>1</td>
<td>16.5 ± 2.5</td>
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<td>2</td>
<td>12.5 ± 2.1</td>
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<tr>
<td></td>
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<td>3</td>
<td>15.1 ± 2.1</td>
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</table>

CONCLUSIONS
Based on these results, we conclude that the exposure to RF field at SARs of 0.2, 0.8 and 2.0 W/kg does not affect or active microglial cells in the brain and may not work as direct signal of microglial activation.

ACKNOWLEDGMENTS
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REFERENCES
The Role of Voltage Gated Calcium Channels In Keratinocyte Galvanotaxis

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INTRODUCTION
Endogenous electric fields (EFs) play an important role in embryonic development and wound repair. They are the first guidance signal that wound cells will receive to indicate damage has occurred and stimulate the physiological responses required for the wound to heal. Indeed the center of the wound becomes the cathode of the endogenous EF, measured to be between 100-150mV/mm (1). In the epidermis, relatively sedentary cells at the edge of the wound must become migratory to move directionally across the newly formed fibrin clot to re-epithelialize the wound. The role of calcium in keratinocyte galvanotaxis has been extensively studied. A requirement for extracellular calcium was revealed (2), but a second study failed to show an effect of VGCC blockade (3). However, this study demonstrated that inorganic calcium channel blockers nickel and gadolinium, together with the calcium substitute strontium all decreased speed and directionality to varying degrees, suggesting an involvement of calcium in electrical sensing. A recent paper has also confirmed that gadolinium significantly reduces keratocyte (zebrafish keratinocyte equivalent) galvanotaxis by 67% (4). While earlier studies failed to identify any VGCC expression in keratinocytes (5,6), recent studies have identified L-type VGCC expression (7). Here we explore this further as gadolinium is a blocker of stretch activated calcium channels (8), L type calcium channels (9) and purinergic receptor signalling (10), all of which we hypothesise play a role in keratinocyte galvanotaxis.

MATERIALS AND METHODS
Primary human dermal keratinocytes (Invitrogen) were cultured according to Invitrogen protocols. Three cell strains were used for this study. Cells were used between passage 3 and 7. Galvanotaxis was performed, as described (11). Cells were seeded onto collagen-coated glass, in custom chambers for 2-5 hours at 37°C. Chambers were placed in a custom, heated X-Y stage on an inverted Nikon microscope and images were captured every 10 minutes for 90 minutes using Volocity software (Improvision). Cells were tracked over time (Volocity) and the average true speed and directional factor (-1, anodal, 0 random, +1, cathodal) for each treatment group was calculated.
Treatments included: verapamil, nifedepine and diltiazem (10µM).

RESULTS
In an applied EF of 100mV/mm, keratinocytes migrate at a speed of 1µM per minute towards the cathode, with a directionality factor of 0.68. While having no significant effect on cell speed, three L-type calcium channel blockers, verapamil, nifedepine and diltiazem (all 10µM) decreased directional migration by 45%, 55% and 35%, respectively. We have used time-lapse fluorescence microscopy to visualise the electric field induced membrane polarisation changes and calcium plumes, both of which we believe regulate hemichannel opening and closing to initiate purinergic receptor signalling, establish polarity and initiate electric field-mediated directional migration.

CONCLUSIONS
Here we begin to reveal the role for voltage gated calcium channels in keratinocyte galvanotaxis. Our investigations are revealing a complex picture of interacting membrane proteins and
intracellular signalling mechanisms to establish the electrical compass. Real time fluorescence imaging will now allow us to visualise spatially restricted changes within milliseconds of electric field application. Further work will hopefully reveal how the cell senses the applied electric field.

**ACKNOWLEDGEMENTS**
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**REFERENCES**


Electric Signals Guide Neutrophils To Wounds
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INTRODUCTION
Electric currents can be measured exiting stumps of regenerating limbs (1,2), transected Xenopus embryos (3) and excised cornea (4). Drugs that inhibit sodium (2,3) or chloride (5) flux through the epithelium can reduce the endogenous electric currents and inhibit regeneration and healing. A sodium channel blocker can also reduce electric fields around mammalian wounds (6). These studies highlight the importance of specific ion channels and pumps in current generation.

Neutrophil migration to a wound site occurs within minutes of wounding and contributes to the excessive fibrosis and scarring observed in adult wounds (7). The wound guidance signal is unknown. Here we describe an in vivo study using a transgenic zebrafish model (8) to investigate if electrical cues guide inflammatory cells to caudal fin wounds.

MATERIALS AND METHODS
Zebrafish larvae, seventy two hours post fertilization, were immersed in pond water containing 2% tricaine and complete transection of the tail was performed with a sterile scalpel blade. Post-wounding the larvae were incubated in the presence or absence of pharmacological agents that modify ion channel function for 6 hours, washed and stained using a fluorescein-tyramide signal amplification method (Perkin Elmer) prior to fixation in 4% paraformaldehyde. Tails were mounted and photographed on a Nikon TE-2000 inverted microscope at 20x magnification. The number of neutrophils recruited to each wounded tail was recorded (n = 15-30). Electric currents emerging from the transected caudal fin were measured with the Vibrating Probe system (9).

RESULTS
An average of 10 neutrophils were recruited to wounded tails within 6 hours of wounding. Sodium channel blockade reduced the recruitment of neutrophils to the wound by 41% (Amiloride) and inhibition of the sodium/potassium pump decreased neutrophil recruitment by 60% (Ouabain). Measurements of the wound currents from the transected zebrafish tails support the hypothesis that indeed, endogenous electric currents guide neutrophils to wounds.

CONCLUSIONS
Specific sodium channels/pumps play a role in generating the zebrafish wound electric field, that appears to be an important guidance cue in the recruitment of neutrophils to the wound site, within minutes of injury. The ability to tailor the electric guidance cues in the wound, both pharmacologically and electrically, has potential as a future therapeutic approach to reduce wound inflammation and, therefore, reduce wound fibrosis and scarring. In addition, the ability to control inflammatory cell recruitment in other pathologies where electric fields are present, e.g. cancer, could reveal novel treatment options.

ACKNOWLEDGEMENTS
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Frequency-Resonance and Demodulation in Neurones under Low Frequency Modulated Microwaves

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INTRODUCTION

We have experimentally shown in molluscan brain single neurones that as the frequency of the applied magnetic field (MF), $f_m$, was coincident with the main frequency, $f_0$ of the Fourier decomposition of the bioelectric voltage impulse, the neurone firing frequency showed a maximum, an effect so called frequency resonance [1]. The exposure of neurones to microwaves (MW) of 13.6 GHz amplitude modulated by ELF-MF around 4 and 16 Hz have shown that are the ELF-MF the responsible for the elicited responses, demodulation effect [2]. The purpose of our research by applying MW modulated by ELF-EMF was to separate out the possible effect of the MW from the one induced by modulated ELF-EMF within a wide range of frequencies, i.e. 2-100 Hz. Our results could provide data for a health risk assessment, in the sense of the arising possibility that ELF-MF modulating RF or MW in the range of human EEG could induce frequency-resonant effects on exposed human brain.

MATERIALS AND METHODS

Electrophysiology experiments were carried out on Helix aspersa neurones as described elsewhere [1]. The bioelectric impulses were Fourier spectrum analysed using computer standard methods. EMF were applied putting the ganglia within a toroidal cavity with a delivered measured power $P \approx 6$ mW from a generator, through a 50 Ω coaxial cable and with a typical peak value of $H_0 \approx 0.10$ Am$^{-1}$ (= 1.25 mOe) (the peak electric field (EF) was $E_0 \approx 50$ V/m) at the Helix brain position (cavity center). The resonant cavity is made of a dielectric ring of 1mm thickness of FR4, metalized on both surfaces, which are in turn short-circuited in their external edge. The MW field of 13.6 GHz was generated by a home made Gunn diode oscillator, which modulates the high frequency voltage by a ELF frequency signal voltage between 0-100 Hz. The MW MF is homogeneous within a rectangle of 5 mm side about the centre (nervous sample volume $\approx 6$mm$^3$) and within the cavity plane. The MW EF is polarized along Oz axis and is also homogeneous within the cavity height. The MW signal was extracted using a rectangular waveguide, working in a dominant TE$_{10}$ mode, followed by a coaxial cable, so that the mode becomes TEM, the cable being connected to the cavity by BNC gold plated connector. Modulation depth was fixed at 90%. MW frequency and generator output power were measured using a MW spectrum analyzer. Typical Poynting vector at the cavity center was $\approx 1$W/m$^2$. Homogeneity and MF polarization were checked by performing numerical simulations of the EMF in the cavity hole. The measured temperature variation was smaller than $\Delta T \approx 0.01$ C. Calculated mean SAR value is 1.25-2.35 W/Kg, considering all possible configurations interposed to the MW plus the recording borosilicate microelectrode and reference silver microelectrode.
10-3

RESULTS

Main observation is that application of a microwave EMF of carrier, $f_c=13.6$ GHz, amplitude modulated (90%) by ELF AC field of frequency, $f_m=0-100$ Hz shows: no effect under the carrier MF alone, but “resonances” at low frequencies (2, 4, 8, 12, 16, 50, 100 Hz) (Fig.1 a) similar to the case of ELF application, i.e. also with Lorentzian profiles [1, 2]. The effect is a “resonance” of Lorentzian shape, when the MF frequency matches the characteristic frequency (-ies) of the neurone impulse Fourier spectrum (Fig.1 b).

CONCLUSIONS

Neurones bioelectric activity is highly sensitive to EMF low frequency, 13.6 GHz carrier did not induced any effect: demodulation effect. ELF modulated MW radiation at non-thermal level of field power density modifies neurones bioelectric activity in a resonant way. We have also got resonances at 12, 50 and 100 Hz, values much higher than spontaneous Helix neurones frequency and similarly to the effects induced on human volunteers under 400 MHz modulated at 7, 14 and 21 Hz showing significant increases in alpha (8-13 Hz) and beta (13-30 Hz) rhythms [3]. Our conclusion is that the resonances appear when the ELF applied MF is close to a characteristic frequency of the impulse Fourier spectrum, not to the firing frequency, as formerly reported [1]. These observations suggest common characteristic to molluscan and human neurons which could explain the effects observed on human EEG.

ACKNOWLEDGMENTS

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REFERENCES

Experimental Outcomes of a Test to Detect Nonlinear Responses in Biological Preparations Exposed to RF Energy.

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INTRODUCTION

Balzano and colleagues [1, 2] have designed and constructed a doubly resonant cavity for detection of radiofrequency (RF) demodulation in living cells. We have used this cavity to search for non-linear energy conversion in a range of biological materials.

MATERIALS AND METHODS

The gold-flashed cavity [2] was housed in a temperature and humidity controlled incubator. Cell and tissue samples were placed within the cavity, exposed to 0.1 or 1 mW continuous wave RF fields at the resonant frequency (f1) of the loaded cavity (around 883MHz), and monitored for second harmonic generation by inspection of the output at 2f1. Unwanted signals were minimized using low pass filters (≤1 GHz) at the input to, and high pass filters (≥1 GHz) at the output from, the cavity. A tuned low noise amplifier allowed detection of second harmonic signals above a noise floor as low as -165 dBm.

The biological samples comprised: high density cell suspensions (human lymphocytes and mouse bone marrow cells); semi-confluent monolayers of adherent cells, (IMR-32 human neuroblastoma, G361 human melanoma, HF-19 human fibroblasts, N2a murine neuroblastoma (differentiated and non-differentiated), and CHO cells); and thin sections or slices of mouse tissues (brain, kidney, muscle, liver, spleen, testis, heart, and diaphragm). Viable and non-viable (heat killed or metabolically impaired) samples were tested.

The design of the exposure system imposed constraints on sample geometry. Adherent and suspension cells were contained beneath a 30mm diameter glass coverslip to minimize sample depth. Typically, samples were held within the cavity for less than 10 minutes, with exposures lasting 2-4 minutes. Trypan blue exclusion, resazurin, or oxygen consumption measurements showed no effect on viability of exposed cell or tissue samples compared to sham exposed or control samples.

RESULTS

Over 500 tests were carried out on the 17 different cell and tissue types. Overall, no consistent responses attributable to non-linearities in these samples were detected (e.g. figure 1). Neither viability status nor orientation relative to the field affected this result. Samples encompassed different species and levels of organization, with different potentials for cellular interactions mediated by cell membrane systems of varying complexity. Both cancer and non-cancer cell lines were included, along with cells and tissues previously reported in the literature to have shown biological effects at non-thermal levels of exposure. Occasional
Second harmonic signals were observed, but these were attributed to direct coupling between the generator and the 2f1 detector, as they were present even without biological samples in the cavity.

![Typical screenshot from Agilent model E44077B spectrum analyser.](image)

CONCLUSIONS

Within the limits of the sensitivity of the system, no consistent responses attributable to non-linearities in the exposed biological samples were detected. Therefore, these results do not support the suggestion that living cells can demodulate RF energy. Further detailed analyses of the system sensitivities and dosimetric parameters are underway.

ACKNOWLEDGMENTS

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All procedures involving animals were carried out with the approval of the local ethical review committee and in accordance with the Animal (Scientific Procedures) Act 1986.

REFERENCES


INTRODUCTION

In the scientific debate on possible non-thermal effects of low intensity radio frequency (RF) electromagnetic fields in biological organisms, many interaction mechanisms have been proposed in the past. One of these postulated mechanisms is a possible non-linear behaviour of cells [1,2]. It is known that the cell membrane has the capability to rectify signals but only up to frequencies of 10 MHz, for higher frequencies this effect is vanishing [3]. Nevertheless, if demodulation of the RF signal occurred in cells by yet undiscovered effects, the biological organism would be exposed to a low frequency field of frequencies similar to the ones of internal processes. Interference with biological processes would thus become more plausible.

Several attempts have been undertaken to identify nonlinear effects in biological materials [2]. However, the test methods used up to now were either not able to use living tissues or the measurement sensitivity was low.

MATERIALS AND METHODS

By exposing a probe to a frequency $f_0$, non-linear behaviour will generate harmonic multiples of $f_0$. However, detection of the harmonic components requires very high sensitivity. Since the first harmonic component is the double of $f_0$, the test set-up must be able to handle a large frequency bandwidth. In addition, the test set-up should have a size to allow measurements of materials of practical size. To avoid specialized measurement set-up’s standard microwave test procedures [4] utilised for quality control of RF hardware can be adapted for nonlinearity measurements. Instead of measuring the harmonic components of $f_0$ directly, two frequencies $f_1$ and $f_2$ are applied and the 3rd order intermodulation (IM) product $f_{IM}=2f_1±f_2$ or $f_{IM}=2f_2±f_1$ is detected. Fig.1 (left) shows the schematics of such extremely sensitive IM test equipment. The sample holder has been designed for the DCS frequency range (1.8 GHz). It consists of two coax to waveguide transitions. Standard waveguide WR430 were used. The coax to waveguide transitions are designed to cover the whole operating frequency range of WR430 from 1.7 to 2.6 GHz with return loss <20 dB. The insertion loss in the DCS band from 1.8-1.86 GHz is 0.2 dB. Fig. 1 (right) shows the set-up with the two waveguide to coax transitions ready for measurements. The waveguides are equipped with choke-flanges to avoid IM-products generated by electrical contacts. The dimensions of the waveguide (430 x 215 mm) allow for placing a Petri dish with a diameter of 30 mm without significant degradation of the return loss. Since this type of set-up is inherently broadband, no tuning is required whatever sample material is inserted. With a Petri dish with agar medium and a yeast cell monolayer on the top, the return loss for the DCS band was <20 dB and the additional insertion loss 0.15 db.

To avoid thermal effects in the sample, the set-up has been simulated with SemcadX [5]. Using input powers of 2 x 1W CW, a SAR of 2 W/kg/1g was generated, corresponding well with the measured insertion loss (0.07 W RF energy absorbed in sample). Since the whole IM
measurement takes only 3 s, higher input powers can be applied without inferring the average SAR limit. Therefore, also peak power conditions of pulsed signals might be studied.

RESULTS

The empty set-up was measured to generate IM levels of less than 165 dB below the carriers at input power of 2 x 20 W. At lower input power, IM-levels will even be lower.

As initial test Petri dishes with a yeast cell monolayer on an agar substrate have been measured. No alteration of the IM level compared to the empty waveguide set-up was observed. Additionally, a living snail and a grasshopper have been introduced in a Petri dish. Again, no IM alteration was measured. However, since these samples are more localized than an Agar layer, there is a possibility, that the sample is situated in a minimum of the standing wave of the second harmonics which can only propagate inside the waveguide.

CONCLUSIONS

The new method presented here allows for very sensitive testing of nonlinear behaviour of biological samples. No detectable alteration of the IM level has been observed in the tested probes. Based on these results an estimation of the threshold for the maximal induced IM levels in the cells exposed will be performed.

ACKNOWLEDGMENTS

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Comparison of the Incident RF-Fields for Implantable Medical Devices in the Human Body and in Homogeneous Phantoms

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INTRODUCTION

During magnetic resonance imaging (MRI), the patient is exposed to a magnetic field generated from the RF transmit coil. Eddy currents are subsequently induced in the lossy body tissue, causing a complex electric field in the patient’s body. If the patient wears an implantable medical device with electrically conducting parts, the the tangential electric field components can induce high currents on this device. Hazardous tissue heating can result, particularly at current discontinuities, such as the lead tips of active implants.

The methods for the assessment of the risk of excessive implant heating rely on body phantoms which are filled with a homogeneous tissue simulant [1]. Traditionally, the implant is placed into the phantom at a position which approximately corresponds to its position in the patient. Often incident field conditions the implant is exposed to are not known, and because of the complex tissue distribution in the human body, the correlation to the electrical field which can occur in the patient is not straightforward.

OBJECTIVES

The goal of this study is to quantify the E-field distribution in the human body considering a large range of anatomical variations and to compare it to the E-fields in experimental phantoms which are used for MRI safety testing of implants. In detail this encompasses:

- numerical evaluation of the E-field distribution in a number of representative anatomical body models in typical positions during MRI exams
- characterization of the incident fields in various regions of the body which are typically used for, e.g., neurostimulation applications, cardiac rhythm management or cochlear implants
- numerical and experimental evaluation of the field distribution in homogeneous body phantoms
METHODS

Anatomical models were selected regarding a statistical evaluation of the patient population. In addition to several models of the Virtual Family [2], an obese model of an adult male was developed. The models are exposed in birdcage coils of 1.5 T and 3.0 T systems operating at 64 MHz and 128 MHz, respectively. The E-fields in experimental phantoms of various shapes were evaluated numerically. Measurements were used for validation.

All numerical simulations of the induced RF fields were performed with the FDTD code SEMCAD X (SPEAG, Zurich). For the experimental evaluation, the testing birdcages MITS 1.5 and MITS 3.0 (ZMT, Zurich) were used.

RESULTS and CONCLUSIONS

The RF energy which is coupled to the implant and deposited at its lead tips depends on the characteristics (amplitude, phase) of the incident E-fields along its path at the location in the patient. The E-fields in the body can directly be correlated to the $B_1$-field induced by the birdcage coil under consideration of the parameters described above.

The E-fields along the typical lead paths of various kinds of implanted devices in the anatomical models show no direct correlation to the fields along the lead paths in homogeneous phantoms. In anatomical models, amplitude and phase changes of the incident fields or hot spots occur which can exceed the field strengths in homogeneous phantoms for the same $B_1$-field. In consequence, test setups using homogeneous phantoms can only be used to expose the implant to a controlled and well known incident E-field. SAR or temperature measurements can then be extrapolated to the actual conditions in the human body with the help of the simulated incident field conditions. The findings of this work are disseminated within standardization working groups of ISO/IEC.

REFERENCES


Time Variation of Blood Temperature in Bioheat Equation and Its Application to RF Dosimetry

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INTRODUCTION

According to the ICNIRP guidelines, the most dominant effect of RF on humans is thermal, or the temperature elevation due to RF energy absorption. When analyzing the temperature variation in humans and animals due to RF energy, a well-known bioheat equation is often applied. The bioheat equation would be a reasonable and powerful tool to analyze the temperature in the shallow region of the body (e.g., [1]). However, the thermodynamic law is not satisfied in a conventional formulation of the bioheat equation since the heat removed from tissue with blood perfusion vanishes. This violation would not be significant when the RF energy deposition in the body is smaller than the total amount of the basal metabolism like localized exposures. To analyze the temperature in the body for whole-body RF exposure, Bernardi et al treated the blood temperature in the bioheat equation as a variable over time in order to take into account the energy deposited in the blood [2]. We have presented a similar formula for blood temperature [3]. However, no detailed discussion of their effectiveness has been given in these studies. In the present study, we first revealed a fundamental limitation of the conventional bioheat equation due to an assumption that the blood temperature is constant over time. Based on that discussion, we investigated different schemes to vary blood or core temperature in the bioheat equation. The effectiveness of the schemes was discussed by comparison with measurements in earlier works [4], which investigated the temperature elevation for RF whole-body exposures in rabbits.

METHODS

The bioheat equation is often used for calculating temperature elevation in numeric phantoms. A generalized bioheat equation is given by the following:

\[
C(r) \rho(r) \frac{\partial T(r,t)}{\partial t} = \nabla \cdot (K(r) \nabla T(r,t)) + \rho(r) \text{SAR}(r) + A(r,t) - B(r,t)(T(r,t) - T_b(r,t))
\]  

where \( T(r,t) \) and \( T_b(r,t) \) denote the temperatures of tissue and blood, respectively, where \( r \) and \( t \) are the position vector and the time. \( C \) represents the specific heat of tissue, \( K \) is the thermal conductivity of tissue, \( A \) is the basal metabolism per unit volume, and \( B \) is the term associated with blood perfusion. In conventional modeling, the blood temperature in (1) was assumed to be constant: \( T_b(r,t) = T_{b0} \) where \( T_{b0} \) is the blood temperature in the state without heat load or RF absorption.

In order to take into account the core temperature elevation in the bioheat equation, it is reasonable to consider the blood temperature as a variable of time \( T_b(r,t) = T_{b0}(t) \), thus, the blood temperature is assumed to be constant over the whole body since the blood circulates throughout the human body in one minute or less. The blood circulation time in rabbits is much smaller than that of humans due to its smaller body and larger blood perfusion rate. The blood temperature variation is given by the following equation [2, 3]:

\[
\frac{\partial T_b(t)}{\partial t} = \frac{1}{\rho_b C_b} \left( \int_{V} \text{SAR}(r) dV - \int_{V} A(r,t) dV \right)
\]
\[ T_b(t) = T_{b0} + \int_0^t \frac{Q_{BT}(t)}{C_B \rho_B V_B} \, dt \]  

(2)

where \( Q_{BT} \) is the rate of heat acquisition of the blood from the body tissues. \( C_B (=4000 \ J/kg \cdot K) \), \( \rho_B (=1050 \ kg/m^3) \), and \( V_B \) denote the specific heat, mass density, and total volume of blood, respectively. The other equation is used to evaluate net rate of heat acquisition of blood from body tissues instead of (2):  

\[ T_b(t) = T_{b0} + \int_0^t \frac{Q_{BT}(t)-Q_{BT}(0)}{C_B \rho_B V_B} \, dt \]  

(3)

It should be noted that (4) was introduced to compensate for an unphysical time evolution of the blood temperature. This is because (2) is not zero even at time \( t=0 \), which is attributed to some computational simplification or assumption.

The following two auxiliary equations were used to compute the rate of heat acquisition of blood from body tissues:

\[ Q_{BT}(t) = \int_V B(t)(T_b(t)-T(r,t)) \, dV \]  

(4)

\[ Q_{BT}(t) = \int_V (\rho(r) \nabla \cdot A(r,t) - C(r) \rho(r) \frac{\partial T(r,t)}{\partial t}) \, dV - \int_S \nabla \cdot (T_b(r,t)-T_s(t)) \, dS \]  

(5)

where (4) is the formula given in [2], and (5) is another expression of (4), which is derived so that the thermodynamic law is satisfied. These two equations should be theoretically identical, while their difference is discussed from the aspect of computational physics. In addition to these factors, the effect of discretization of bioheat equation is also discussed [5].

SUMMARY

For the scenario given in [4], the effect of such modeling on body-core temperature variation in rabbits was investigated computational, in addition to the comparison with measurement [4]. The dominant factor influencing the core temperature was found to be the computational scheme for calculating the net rate of heat acquisition by blood from the body (Eq. (2) or (3)). The influence of the remaining factors on the temperature elevation will be presented at the symposium.

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INTRODUCTION

Hybrid and electric drive systems are key technologies in future car industry. Currently only a few manufacturers have such vehicles already put on the market, however, in near future a widespread array of hybrid and electric cars will be available. Current hybrid and electric vehicles, utilize one or two inverter-fed electric machines working either as motor (to provide drive power), and/or generator (to transform mechanical power from the combustion engine or from braking-recuperation to electric power). Consequently, relatively high electric currents are flowing between the main components of the system, i.e. battery, inverter, and motor(s)/generator(s), which may be seen as potential sources of significant magnetic field exposure of the passengers. In order to assess the extent of magnetic field exposure inside a sample of hybrid and electric cars already available on the European market, extensive frequency selective magnetic field measurements were carried.

MATERIALS AND METHODS

The investigated hybrid and electric cars and their main electric characteristics are listed in table 1. In all considered vehicles magnetic field measurements were carried out on the driver’s, the co-driver’s, and on one selected rear seat. On every seat 12 spatially distributed measurement points (Figure 1) were considered in which the magnetic field was frequency selectively measured in the range DC-100 kHz using the 3 channel (isotropic) analog outputs of the ELT400 system (Narda Safety Test Solution) and the magnetic field meter CA42/ field probe MF05 (Chauvin Arnoux). These, in total 6 analog signals were A/D converted and recorded at a sample rate of 200 kHz using an in-house measurement system based on the PXI system (National Instruments, Inc.) and a corresponding Labview™ user interface. Recording length in each measurement position was 1s during constant “drive conditions” which could be achieved by performing all the measurements on a car test bench allowing the application of defined and constant load torques to the wheels. Postprocessing (FFT) and final rating of the recorded measurement data according to the ICNIRP reference levels [1] was done using an in-house developed software tool based on Labview™, which allows a phase-correct combination of multiple spectral components of exposure as described in [2].
RESULTS

Figure 2 summarizes the total spectral magnetic field exposure (0-100 kHz), averaged over the 12 points investigated at each passenger position and averaged over the investigated operating (speed and torque) ranges of the vehicles, in relation to the ICNIRP reference levels for the general public. Error bars indicate the spatial variation of exposure. In case of front seats upper bounds are usually measured in the feet area (close to motors/generators and inverter), lower bounds at the front seats are usually measured in the head area. In case of rear seats maxima appear most likely in the lower back area (close to the battery). A possible influence of tire magnetization effects [3] on the measurements was taken into account and was, however, found to have only negligible impact on the results.

![Figure 2: Spatial average of total B-field exposure inside the vehicles. Error bars indicate spatial variation.](image)

CONCLUSIONS

In the considered hybrid and electric vehicles, investigated under conditions covering the entire range of real operation, the total exposure of passengers against magnetic fields up to 100 kHz was less than 5% of the ICNIRP reference levels for the general public (averaged over body area and operating range of the vehicle). Local and temporal peaks of exposure reached the order of 15% of the ICNIRP reference levels for the general public. ELF/LF magnetic field personal exposure of passengers caused by the investigated hybrid drive systems can therefore be seen as of minor relevance.

ACKNOWLEDGMENTS

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REFERENCES


Evaluation of Exposure of School Children to Electromagnetic Fields from Wireless Computer Networks (Wi-Fi): Phase 1 Laboratory Measurements

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INTRODUCTION

People using wireless computer networks (Wi-Fi), or in proximity to the equipment, are exposed to the radio signals and will absorb some of the transmitted energy in their bodies. The output power of Wi-Fi equipment is restricted to a maximum of 100 mW at 2.4 GHz in Europe, and there is no expectation that exposures will exceed international guideline levels. Nevertheless, this rapidly developing technology is increasingly used in schools and, given the existing precautionary advice in many countries to discourage non-essential use of mobile phones by children [e.g. 1], it is important to quantify the exposure from Wi-Fi equipment, as used by children in schools. Hence, in October 2007, the Board of the UK’s Health Protection Agency announced a systematic programme of research to investigate those types of Wi-Fi equipment used in schools. The first phase of the project, as reported here, is a series of laboratory measurements with selected items of Wi-Fi equipment known to be popular in schools. Later work will involve modelling of energy absorption in the body, monitoring of transmit duty factors during school lessons and ultimately a health risk assessment drawing on all of these results and other material.

MATERIALS AND METHODS

Discussions and information gathered at the start of the project showed that laptops are the most popular wireless devices used in schools, with IEEE 802.11g as the most widely utilised standard. For this work, a total of 14 laptops were chosen from among the most popular models used by the education sector in UK. The objective of the laboratory measurements was to establish the radiation pattern (i.e. angular distribution of electric field strength around each laptop) and identify the angles at which the field is maximum. The electric field strength at these angles was then measured as a function of distance. The measurements were carried out within an anechoic chamber (3.7m×2.4m×2.4m), lined internally with radiofrequency absorber material, and with a purpose built manual positioning system. Dedicated software (LanTraffic) was used to generate and monitor the Wi-Fi signal from the laptops set to transmit at roughly 22 Mbps, the maximum sustained rate that could be reliably maintained using the IEEE 802.11g standard. The screen of the laptops was opened to an angle of 115 degrees for this work. Almost all of the previous studies on the exposure assessment from Wi-Fi equipment have used spectrum analysers as their main tool to analyse the signals [2-3]. The authors of this work did not consider spectrum analysers to be ideally suited for Wi-Fi measurements due to their bandwidth (typically a maximum of 5 MHz) being less than that of Wi-Fi signals and difficulties in accounting for the stochastic nature of Wi-Fi signals. Instead, an Agilent N9020A MXA signal analyser was used which has a bandwidth of 25 MHz allowing the detection of the whole WLAN signal. This instrument captures individual
Wi-Fi bursts in the time domain and demodulates them to identify the burst power, modulation scheme and many other parameters. For this work, the power of 50 bursts was measured at each position and then analysed in terms of the statistical distribution. To establish the radiation pattern, the E-field strength at 1m distance from the laptop was measured by an ARC Seibersdorf miniature biconical antenna in horizontal and vertical polarisations for azimuth and elevation rotations in 30° steps for the laptop on the manual positioning system (168 positions in total). The measured E-field data were then analysed and the angles of maximum radiation were identified. The manual positioning system was then set up at these maximum angles and the E-field strength was measured in 10cm steps from 0.5m to 1.9m for each laptop.

RESULTS

Burst power measurements drifted by 15% in the first 30 minutes after switch-on as opposed to less than 3% after 2 hours of transmitting, emphasising the need for adequate equipment warm-up times. Furthermore the results showed that, for a given position, the power level fluctuated between 2 (and sometimes 3) distinct levels because of the use of switched diversity with several antennas within each laptop. Overall, the results showed similar radiation pattern measurements for all laptops, with a minimum in the direction of the front of the laptop (torso of the user). Generally, two angular maxima were observed that were symmetrically opposed across a vertical plane bisecting the screen and keyboard. The laptops had antennas mounted on the top left and top right corner behind their screens and each of these antennas would have been responsible for producing one of the maxima. The maximum E-field recorded at 1 m varied from \((719 \pm 14)\) mVm\(^{-1}\) to \((1306 \pm 3)\) mVm\(^{-1}\). In terms of power density, all these values are well below the level that would be expected based on the 100 mW (EIRP) limit, as shown in Figure 1. More detailed results will be presented in the full paper.

![Figure 1. The calculated power density for all 14 measured laptops. The error bar represents the repeatability of E-field measurements for 50 samples (only the highest observed variation is presented).](image)

REFERENCES


Measurement of Maximum SAR in a Spherical Phantom When Using an Actual Mobile Phone in Close Proximity to a Metallic Wall

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INTRODUCTION
A spherical phantom head irradiated with an actual mobile phone is placed in close proximity to metallic walls and its specific absorption rate (SAR) was investigated experimentally. The main goal of this study was to determine the effect of reflected electromagnetic fields from the walls on the maximum spatial average 10-g SAR. Although extensive investigations of this problem using a dipole antenna as a mobile phone have been conducted to date [1], [2], very few of these investigations were performed experimentally [3] and none have been carried out using the actual mobile phones. In this paper, we present experimental investigations of SAR for the spherical phantom-actual mobile phone configuration placed in close proximity to a metallic wall. A MapSAR2 system developed by the Indexsar Ltd [4] was used to measure 10-g SAR in the 800-MHz band.

MATERIALS AND METHODS
Figure 1 shows a photo of MapSAR2 system. It is a bench top system that uses a 2D mapping technique supplemented by 3D calculations to give a complete volume-average SAR results directly.

A schematic diagram of the MapSAR2 system, placed on top of the plastic table with a height of 1250 mm and a cross-section area of 500 × 750 mm², is shown in figure 2. The table is then placed close to a metallic wall. The wall’s dimension was 1600 × 2400 mm². The distance from the mobile phone to the wall in the x-direction is given as x. The mobile phone was in touch position with the sphere as shown in figure 1. During the measurement, the table was moved at intervals of 20 mm. A scale, fixed down on the floor, was used to measure the distances.

We used a W-CDMA Clamshell type mobile phone still in service in Japan. It was set to transmit a maximum output power, i.e., 0.25 W, using a base station simulator (Radio communication analyzer), MT8815B [5]. We used electrical properties recommended for the MapSAR2 system, i.e., 0.9 S/m and 47.5, for the conductivity and relative permittivity of the liquid, respectively.
RESULTS

Figure 3 shows measured peak 10-g SAR as a function of the position from the wall in the \( x \)-direction. The distance \( x = 264 \) mm is the minimum valid distances in the \( x \)-direction, in which the body of the MapSAR2 system is already touching the walls. We also plotted SAR values obtained in the free space in the same figure. The maximum SAR value was 0.83 W/kg, corresponding to an enhancement of about 6-% over its free-space value. This value was recorded at the distances of \( x = 264 \) mm from the wall. We have obtained a similar increase in SAR for the spherical phantom-dipole antenna system [3]. However, the actual SAR values in the spherical phantom due to dipole antenna were much larger than those obtained with the actual phone used in this work.

Furthermore, the maximum SAR recorded in this work was about 41-% of the basic restriction of ICNIRP guidelines (2 W/kg).

CONCLUSIONS

This paper has presented an experimental investigation of the SAR in a spherical phantom-mobile phone system in close proximity to a metallic wall in the 800-MHz band. Although investigations of the use of mobile phones close to metallic structures have been reported before using dipole antenna [1-3], in this work, we have provided for the first time the measurements results using an actual mobile phone. The SAR enhancement due to metallic walls obtained in simulation is slightly larger than the values obtained in this work.

In the near future, we plan to repeat this experiment using several types of actual W-CDMA mobile phones.

REFERENCES

Introduction of a Sinusoidal Magnetic Field into a Hypogeomagnetic Environment: Effect on Nociceptive Behavior in CD-1 Mice.

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INTRODUCTION
Repeated shielding of the geomagnetic field has been shown to induce analgesia in mice by the 3rd to 5th day of shielding [2]. This effect has been shown to be light-dependent [1], but moreover, the effect is specific to shielding the low-frequency components of the ambient magnetic field with mu-metal[3], as shielding the high frequencies with copper did not produce analgesia [2]. Preliminary evidence suggests that the mice are sensitive to the very weak low frequency time-varying fields that are attenuated by the mu-metal enclosure. Reintroducing these fields attenuated the analgesic effect [4].

OBJECTIVES
Here we examine the introduction of a very weak (25-500 nT) sinusoidal magnetic field into the shielded environment to determine if these fields can influence nociception, and how sensitive this response may be.

MATERIALS AND METHODS
Experiments involved five consecutive days in which each mouse (N=60) was exposed to one of the 6 conditions (for 1 hr) and pre- and post-exposure tested (hot plate latency in seconds). In each experiment, the time of day of the exposure between experiments was randomized (between 9am and 3pm). The experimenter was naïve of any anticipated outcome (DD-H, was also blinded to the exposure conditions), conducted all the latency testing, but did not analyze the data. One of us analyzed all the data (AWT) and blinding was maintained by another (LDK). Animals were used in only one experiment and exposed to only one condition and then were euthanized.

The experimental conditions used were: Sham, fiberglass enclosure (no shielding). Mu-metal enclosure with inactive coils (shielding only). Mu-metal enclosure with active coils at 120 Hz sinusoidal MF 25, 50, 100, or 500 nT (shielding plus reintroduced fields; 4 separate conditions). We used our previously established protocols [1,2] with Swiss CD1 mice 2-4 months old, placed in one of six enclosures during their mid day cycle. Internal Merritt-like electromagnetic field coils were connected to signal generators producing the 4 different active levels of 120 Hz sinusoidal magnetic fields. Mice were contained within a plastic cage that keeps them centrally located in the enclosure. Prior to being placed in the enclosure and immediately following the 1 hour exposure, nociception (pain sensitivity) was measured as the latency of a foot lift/lick to an aversive thermal stimulus produced by a hot plate at 50±0.5°C. Statistical analysis was done by three-way mixed design (2 levels repeated) analysis of variance (ANOVA) (days 1 to 5, pre- and post-exposure latency, and exposure
condition). The effects of additional sinusoidal frequencies will also be presented.

RESULTS

Figure 1: Latency to an aversive response by the mouse (foot lift/lick) displayed for each of 5 days of testing for each condition. Open circles represent pre-exposure testing, and closed circles post-exposure testing.

CONCLUSIONS

Preliminary results indicate that these very weak introduced fields can disrupt the analgesic effect of geomagnetic field shielding. Mice appear to have extraordinary sensitivity to time-varying fields under the right conditions. Results from future sinusoidal exposures conducted at different frequencies will determine if the minimum amplitude that disrupts the induced analgesia is a function of frequency. This will provide important information as to the initial transduction mechanism.

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REFERENCES

Merging Electromagnetic and Thermal Equations for Human Protection Regarding Exposure to EM Fields

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INTRODUCTION

The rationale for deriving basic restrictions to EM field exposure is not fully standardized and diverse values are employed depending upon the thermal effect being considered. In this contribution, hybrid Maxwell’s and heat- and mass-transfer equations have been solved for the human exposure to electromagnetic field problem. A human head is exposed to a fixed 125 mW of power radiated by a half-wavelength dipole at a frequency of 1800 MHz. Peak and tissue-averaged SAR values are obtained, and the effects of the human thermoregulatory mechanisms on temperature increase have been observed. A matching effect and the skull being a protection for thermal stress due to intense EM field exposure have been confirmed, validating previous studies suggesting that a combined electromagnetic-thermal basic restrictions would represent more accurate safety limits.

MATERIALS AND METHODS

The in-house software code was prepared in combination to the Partial Differential Equation (PDE) Toolbox in MATLAB®, providing the appropriate boundary conditions for a half-wavelength dipole. Its centre was settled as the coordinates’ origin, and the Ear Reference Point (ERP) was aligned with that to focus dipole radiation on it, as depicted in Fig. 1. Radiated power was forced to be 125 mW, the average power for a GSM Power Class 1 device for 1800 MHz band, thus making delivered power to the dipole variable with impedance matching. After SAR is calculated, temperature increase is evaluated for all tissues by solving a modified version of the bioheat equation [1],

\[ C \rho \partial T/\partial t = \nabla \cdot (K \nabla T) + \rho \text{SAR} + A + B(T_b - T) \]  

The electrical, physical and thermal properties of the employed materials have been extracted from the literature [2][3] and T_b is the blood temperature, set to 37 ºC.

Figure 1: Human head model extracted from the Visible Human Project and coronal plane containing the ERP.
RESULTS

Fig. 2 (a) shows the total power absorbed by the human head for 125 mW of power delivered to a half-wavelength dipole. Some impedance matching effects are observed when the dipole-head distance is varied. For the selected plane, the distance of 0.29 $\lambda$ provided the best match, with a local maximum of power absorbed by the human head. A local minimum of power absorbed by the head was found for a dipole-head distance of 0.22 $\lambda$. Fig. 2 (b) and (c) show SAR for both scenarios, with 0.29 $\lambda$ and 0.22 $\lambda$ as dipole-head distance. SAR is presented for the tissues found along a line perpendicular to the head from the ERP after 6 minutes of exposure. Analyzing SAR figures, the EM coupling effect between the dipole and the head becomes evident for the maximum coupling distance of 0.29 $\lambda$, since it provokes the maximum power absorbed by the head and so the maximum peak SAR, greater than a shorter distance of 0.22 $\lambda$, at which the minimum coupling occurs. It is worthwhile to note that being in the maximum EM coupling case (at 0.29 $\lambda$) and having a greater maximum peak SAR, the temperature increase resulted less than in the less coupling case (at 0.22 $\lambda$), being this difference of a 20%, approximately. This is due to SAR concentrates in the outer tissues of the human head up to the skull when the dipole-head distance causes the maximum EM coupling (0.29 $\lambda$), and thus SAR and temperature increase are less in the inner tissues, protecting sensitive tissues as the brain from adverse thermal effects. Thus, the skull protects the brain against the EM fields and SAR, since peak SAR decays abruptly from the skull towards the brain, due to the EM coupling of the skull and the matching effect produced in the realistic multilayer models at some source-head distances.

CONCLUSIONS

Even though temperature increases were below 0.2 ºC, that is, under the threshold which avoids adverse health effects, reinforcing the validity of the current basic restrictions, it is not risky envisaging the possibility of reducing current scientific uncertainties for human exposure to EMF by using the human thermal response. The adoption of a basic restriction directly involving the temperature increase in combination to already existing SAR-based limits would be more precise for the human-EMF exposure scenario.

REFERENCES

Modeling occupational exposure during interventional open MRI

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INTRODUCTION

European Union Directives 2004/40/EC and 2008/46/EC regulate the occupational exposure of workers to electromagnetic fields according to the safety guidelines issued by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Some MR procedures may involve the exposure of staff to electric and/or magnetic fields that exceed the action values (AVs) as defined in the guidelines. In such cases, the guidelines recommend particular measures to assert that basic restrictions for human exposure are not violated. Numerical calculations of the specific absorption rate (SAR) and of the current density ($J$) within the body can be used to demonstrate compliance with the defined exposure limit values (ELVs). Numerical dosimetry was applied to assess occupational exposure to RF and gradient fields associated with interventional procedures carried out in 1 T open MR scanner.

MATERIALS AND METHODS

The procedure considered in this work requires a radiologist to lean into an open system in order to place a clip into the breast of a patient (Figure 1). Real time imaging with a balanced TFE sequence is used, and the radiologist remains adjacent to the patient for a period of about 30 s. Since previous measurements of RF E- and H- components and of switched gradient fields had indicated that these parameters could exceed relevant AVs at and around the position of the radiologist [1], numerical modeling of this exposure was required. The manufacturers of the scanner provided generic models of RF and gradient coils. Its location within the screened room and the walls of the room with dimensions 7.1 m x 5.5 m x 2.69 m were included in the numerical model (Figure 2). An anatomically realistic voxel model of an adult male (TIM) [2,3] was used. As the model could not be articulated, only an approximation of the radiologist's upper body position within the scanner could be achieved (Figure 2 and Figure 3). Two numerical codes (SEMCAD X and Microwave Studio) were used to simulate the exposure to the RF and gradient fields. The tissue properties reported by [4] were used. SAR (whole body and averaged over 10 g of tissue), E-fields and current densities within the body were calculated using the FDTD and the FIT methods (RF) as well as frequency scaling (FS/FIT) and a finite element based quasistatic solver (gradient fields).

RESULTS

Figure 4 shows the SAR$_{10g}$ distribution inside the TIM model due to the RF coils calculated using FDTD and normalized to the maximum value that occurred in the arc of the neck. When scaled to measured values of the field [1], the maximum SAR$_{10g}$ was 0.44 W/kg and the whole body SAR was 0.053 W/kg. Figure 5 shows the E-field distribution due to the $z$-gradient coil driven at 1 kHz, calculated using FS/FIT, within the coronal plane that
contained the maximum single voxel E-field (0.74 V/m RMS) which occurred in the skin of the head. Figure 6 shows the $J$ distribution in the centre plane of the TIM model due to the z-gradient coil driven at 1 kHz, obtained using the low frequency finite element solver of SEMCAD X. The maximum single voxel value in CNS tissue was about 1.2 A/m² RMS. Maximum values due to x- and y- gradient coils were about half of this value. The maximum values of $J$ and $E$ given above assume the maximum gradient achievable (26 mT/m). Maximum $J$ in CNS tissues (averaged over 1 cm²) due to the x-, y- and z-gradient coils was estimated to be 87, 85 and 140 mA/m², respectively, when scaled to the measured dB/dt.

CONCLUSIONS

The calculated whole body SAR and SAR$_{10g}$ were compliant with relevant ELVs in the EU Directives 2004/40/EC and 2008/46/EC. The ELV relevant to the frequencies observed in switched gradient fields (10 mA/m²) was exceeded in this scenario by more than an order of magnitude. The maximum E-field (averaged over 5 mm) induced in the body by the switched gradient fields was compliant with safety guidelines recommended by IEEE [5].

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REFERENCES


Occupational exposure to RF and gradient fields in open MRI

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INTRODUCTION

EU Directives 2004/40/EC and 2008/46/EC require a risk assessment of occupational exposure to electromagnetic fields to be carried out. One application of electromagnetic fields of particular interest is MRI and especially interventional MR procedures as these may involve exposure of staff to electric and/or magnetic fields and/or magnetic flux density values that exceed action values (AVs) defined in the Directives. The application of current ICNIRP limits within 2004/40/EC might outlaw any such practice in future. In this work we investigate the use of specifically measurement procedure and analysis to systematically measure field strengths during pre-selected procedures with regard to movements of a radiologist during an interventional procedure carried out in an open 1 T scanner.

MATERIALS AND METHODS

The interventional procedure of placing a guide wire in the breast of a patient (Figure 1) requires a radiologist to lean into a 1T open system. To understand if relevant AVs at and around the position of the radiologist could be exceeded it was necessary to map gradient and RF fields on two grids, one designed for use outside the magnet, and a smaller sub-grid for inside the bore. The probe positioning was manual but supported mechanically by the grids Figure 2 and Figure 3. Position identification was done using an image projected on a screen inside the scanner room. Gradient field distribution was mapped with using a low frequency 3-axis magnetic flux meter. The required field mapping space was determined using the ICNIRP exposure limit feature of the ELT400, and then the time domain signals were obtained from the x,y,z-coils for clinical and test sequences over the volume. B$_1$ RF fields were measured with a standalone data acquisition system employing high-precision E- and H-probes. The gradient field measurements comprised two elements, firstly measurements of balanced-FFE (sBTFE), turbo spin echo and diffusion weighted single shot (D-SSh) sequences relevant to the type of MRI performed at the site in question and secondly the measurement of a test sequence exciting X, Y and Z gradients individually in order with known amplitude and rise times for all points on the measurement grid down to 0.1 of the AV. The measurements of the RF fields were done using a simple test sequence with nominal 5μT peak field strength with 33% duty cycle or 2.88μT rms. The nominal RF powers were from 450W peak envelope power (PEP) to 1100W PEP.

RESULTS

Figure 4 gives an example of gradients in the bore assuming excitation of X, Y, Z gradient coils with equal amplitude and vector addition of components. Contours are labeled in T/s. Figure 5 shows a contour plot of the RF H-field on a horizontal slice (one half of the machine to the front where the patient bed attaches) through the isocentre. The field decays below the
AV within the footprint of the machine. The RF fields outside the bore are sufficiently small not to be of concern of occupational exposure. Gradient fields exceed the AVs during interventional procedures such as clip insertion by a factor of 160 for inside the bore and by a factor of 1.5 at the bore edge. RF fields exceed the AVs in the bore by a factor of 15, or by a factor of 1.7 at the curved bore surface. The combined uncertainties for the measurement results are 1dB for gradient fields, 0.6 dB for RF H-fields and 0.5 dB for RF E-fields.

**CONCLUSIONS**

Gradient fields and RF fields exceed the AVs as laid out in EU Directives 2004/40/EC during interventional procedures such as clip insertion or guidewire placements. However, this does not necessarily imply that the basic restrictions will be exceeded.

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**REFERENCES**


Exposure to IF Electric Fields around High Voltage Plasma Ball

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INTRODUCTION

The number of devices using intermediate frequency (IF) range is relatively low, but the use of different applications has been increasing in recent years. Examples of sources utilizing IF fields are induction ovens, dielectric plastic sealers, electric article surveillance systems and other anti-theft devices. Strong IF electromagnetic fields are emitted as a secondary product in certain applications, like exhibition plasma balls. A plasma ball is indented to produce colourful plasma discharges inside a glass sphere. This high voltage device may produce also a significant electric field which can exceed the recommendations for general public and occupational exposure even at distance of a few meters from the plasma ball.

MATERIALS AND METHODS

A specially constructed plasma ball was installed at the University of Lapland’s Arctic Centre, Finland, to display Aurora Borealis in small scale at the Centre's exhibition site. This plasma ball is driven by high frequency alternating current at high voltage (29 kHz, 15 kV). As a by-product an electric field strong enough to set light to a fluorescent lamp was created.

The electric field strength was measured with Narda EFA-300 meter using the electric field probe operating at a frequency range of 5 Hz - 32 kHz. Because the nominal frequency (29 kHz) was the only significant frequency in the spectrum, the measurements were carried out as rms-measurements. The measurements were done at areas where the field strengths were close or higher that general public recommendation by ICNIRP [1]. The measurement heights were 110 cm and 150 cm.

RESULTS

The electric field was measured at two different heights and different distances from the plasma ball device. The measurement results on one side of the device are shown in figure 1. The ICNIRP reference levels for the general public (87 V/m) were exceeded even at distances over 2 m. Correspondingly, the occupational guideline (610 V/m) was exceeded at the distances less that 1 m from the plasma ball device.

As the device is intended for exhibition use and visitors should be able to approach the device, protective measures were applied. A Faraday cage was built around the plasma ball device using metal mesh with a mesh size of 20 mm (Fig. 2). The measurements were repeated and the attenuation by the Faraday cage was investigated. The use of Faraday cage attenuated the electric field strength from worst case of 6000 V/m to as low as 61 V/m. In general, the attenuation coefficient was 1:100.
CONCLUSIONS

Devices like a plasma ball can be a significant source of electromagnetic fields. Plasma balls are constructed for exhibition/display use, and the exhibition visitors are not generally aware of the possible related hazard. For example, pacemakers may malfunction in the presence of strong EMFs. For reducing electric fields, Faraday cages proved to be effective enough. Care should be used, however, in placement and grounding of the cage.

Figure 1: Electric field strengths measured at a height of 150 cm. The plasma ball is situated close to the coordinates (250,0).

Figure 2: The plasma ball device in function protected by the Faraday cage.

REFERENCES

Increased Trends in Brain Cancer under Age 40 in the U.S. SEER Program, 1975-2005

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INTRODUCTION

This paper examines the age-specific incidence of all malignant brain tumors and glioma in the United States (U.S.), to determine the long-term patterns in younger persons during the last 30 years.

MATERIALS AND METHODS

Data were obtained from the U.S. Surveillance, Epidemiology, and End Results (SEER) Program. SEER*Stat software and Joinpoint regression were used to determine age and year-specific malignant brain tumor and glioma incidence for diagnosed cases of persons less than 40 years of old between 1975 and 2005.

RESULTS

Incidence for all malignant brain tumors has increased over the past three decades in all age groups examined, except for the youngest age group (0-9 years). Trends for glioma incidence consistently increased significantly in all age groups between 1975 and 2005, more than doubling in those 0-9 years of age with an overall 1.8% estimated annual percentage change increase. Glioma incidence increased 50% or more in all other age groups over the study periods.

CONCLUSIONS

The reasons for these increased rates of malignant brain tumors and glioma in young persons should be seriously investigated, but are unlikely to result from increased diagnostic ascertainment. Among the hypotheses that should be explored are whether these increased trends in part reflect increased use of diagnostic radiation through computed tomography (CT), the growing use of cell phones in children and young adults, or other risk factors.

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Development of a Predictive Model for Personal RF-EMF Exposure

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INTRODUCTION

Assessment of long-term exposure to RF-EMF in the everyday environment is challenging. Using a simple exposure proxy, such as the lateral distance to a mobile phone base station, is inaccurate and leads to substantial exposure misclassification [1]. The use of personal exposure meters has been recommended in this context [2], but costs prohibit their use in large epidemiological studies. The objective of this study was to develop a RF-EMF exposure model which can be used to predict mean total RF-EMF exposure for a large study population.

MATERIALS AND METHODS

We collected data on RF-EMF exposure of 166 volunteers living in the city of Basel and surroundings in Switzerland by means of EME Spy 120 personal exposure meters (exposimeters), which were carried during one week. The exposimeter measures 12 different bands of RF-EMF ranging from radio FM (88-108 MHz) to Wireless LAN (2.4-2.5 GHz). As exposure predictors we used two data sources: 1) Questionnaire on characteristics and behaviours that are potentially relevant to exposure. 2) Modelled electric field strength from stationary sources (mobile phone base stations, broadcast transmitters) at the participants’ homes using a geospatial propagation model for the study region [3].

In a multivariable regression model we examined the relevance of potential predictors for personal RF-EMF exposure. In the final model we included predictors that showed an association with exposure at a significance level of p<0.1. We also performed a validation study by measuring exposure of 30 study participants during a second week using the exposimeter and applying the exposure model to the second measurements, which had not been used for the model development.

RESULTS

The following variables were included into the final model: The modeled exposure at the homes of the study participants (geospatial propagation model) (p<0.001), modified by the type of the house wall (p=0.014) and the window frame (p=0.03). Additional predictors were ownership of wireless LAN at home (p=0.059), ownership of a mobile phone (p=0.027), a cordless phone at the place where most of the time is spent during daytime (p=0.006), percent full-time equivalent spent at an external workplace (other than home) (p<0.001) and hours per week spent in a train, tram or bus (p=0.041). The model has an $R^2$ of 0.51.

Figure 1 (left panel) shows a box plot of measured RF-EMF concentrations for three
categories (0-0.1, 0.1-0.2, >0.2 mW/m²) of predicted RF-EMF values. The figure shows an increase in the 25th, 50th and 75th percentiles of the measured RF-EMF exposures across the three groups of predicted RF-EMF exposure. The same pattern can be observed for the second week of measurements in the 30 participants who took part in the repeatability study (Figure 1, right panel).

![Figure 1: Boxplots showing the distribution of measurements for three groups of predicted values for the data used for the model development (166 participants; left panel) and the data from the validation study (30 participants; right panel)](image)

**CONCLUSIONS**

We could demonstrate that it is feasible to model personal RF-EMF exposure. The validation study yielded satisfactory results. Still it has to be clarified if the model is applicable to other settings (for example other countries). The exposure model will be used in a larger study population from the region of Basel to examine the effect of RF-EMF exposure on health-related quality of life [4].

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**REFERENCES**


Effects of radio frequency electromagnetic fields on sleep quality: a cross-sectional study

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INTRODUCTION

There is public concern about the effects of exposure to radio frequency electromagnetic fields (RF-EMF) on health-related quality of life. The effect most frequently attributed to RF-EMF is impaired quality of sleep [1].

The aim of this cross-sectional study was to investigate the association between levels of exposure to RF-EMF and sleep quality.

MATERIALS AND METHODS

We sent questionnaires to 4000 individuals who were randomly selected from the inhabitants of the city of Basel and surroundings in Switzerland.

The questionnaire consisted of three parts. In the first part we asked questions about sleep quality and general health status. We assessed day-time sleepiness using the Epworth Sleepiness Scale (ESS) ranging from 0 (no day-time sleepiness) to 19 (extreme day-time sleepiness) and subjective sleep quality score (SQS) using questions from the Swiss Health Survey 2007. This score ranges from 0 (no sleeping problems) to 12 (heavy sleeping problems). In the second part of the questionnaire, we asked about RF-EMF exposure relevant behaviours and lifestyles. In the last part, socio-demographic factors were enquired.

We used the prediction model of Frei et al. [2] to assess personal RF-EMF exposure. In this model, individual determinants of exposure were combined with modelled exposure estimates from a geospatial propagation model [3]. For the final analysis three groups corresponding to exposure levels < 0.1 mW/m\textsuperscript{2}, 0.1 – 0.2 mW/m\textsuperscript{2} and > 0.2 mW/m\textsuperscript{2} were defined.

Night shift workers and users of sleeping pills were excluded from all analyses. We performed stratified analysis with individuals reporting to be electromagnetic hypersensitive (EHS) and non-EHS individuals. Multivariable models were adjusted for length of cordless phone calls, mobile phone calls, age, sex, body mass index, stress levels, physical activity, noise, environmental attitudes, general well being, smoking, alcohol consumption, education and marital status.

RESULTS

Participation rate was 37%; 58% of participants were female and 42 % were male. 89% reported a good to very good health status, similar to the Swiss Health Survey where 87% reported a good to very good health status.
Figure 1 and Figure 2 show the data distribution of the ESS and the SQS score of non-EHS (left panel) and EHS individuals (right panel) for the three different exposure categories.

In the multivariable models, adjusted for relevant confounders, neither the ESS score nor the SQS score were significantly associated with personal RF-EMF exposure in both collectives (non-EHS and EHS). In addition, we found no indication that duration of mobile phone use or cordless phone use influence day-time sleepiness (ESS) or subjective sleep quality (SQS).

CONCLUSIONS

Preliminary analyses suggest that exposure to RF-EMF is not associated with day-time sleepiness or subjective sleep quality of non-EHS and EHS individuals.

ACKNOWLEDGMENTS

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REFERENCES


A Model for the Prediction of Radiofrequency Electromagnetic Fields at Outdoor and Indoor Locations for Use in an Epidemiological Study

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INTRODUCTION

We present a geospatial model to predict the radiofrequency electromagnetic field RF-EMF) from fixed site transmitters for use in epidemiological exposure assessment. The proposed model extends an existing model for outdoor locations [1] towards the prediction of indoor exposure, i.e., at the homes of potential study participants.

MATERIALS AND METHODS

The model is based on accurate operation parameters of all stationary transmitters of mobile communication base stations, radio broadcast and television transmitters for an extended urban and suburban region in the Basel area (Switzerland). The transmitter dataset was supplemented by a digital terrain model and a 3D building model. Propagation in the 3D space was calculated using semiempirical propagation algorithms. Shielding by building roofs and walls was approximated using a constant damping coefficient per wall or roof.

The predictions of the model were compared to measurements taken at street level (n=113), in the bedrooms of study participants (n=133) and outside the windows (n=131) of these bedrooms (we refer to the three datasets as “street”, “home” and ”window”). The measurements were taken with a NARDA SRM-3000 radiation meter in the frequency range 75 MHz – 3 GHz. They were taken as short-time averages (~ minutes) during daytime and as 7-point averages in space.

RESULTS

The comparison of the calculated and measured electric fields strengths (integrated over all frequencies) is shown in Figure 1. Compared to the values outside of the windows, the field strengths in the “home” data are lower by about a factor of 2, on the average. However, the scatter of the data is comparable in all three datasets. The difference between model and measurement has a standard deviation of ~ 3.8 dB (± 55% in field strength), which is of the same order of magnitude as the estimated uncertainty of the measurements (~ 44%).

The model was evaluated by calculating Spearman rank correlations and weighted Cohen’s kappa (κ) statistics between the model predictions and measurements obtained at street level as well as in the homes of volunteers and in front of the windows of these homes. The Cohen's kappa was calculated using a classification of the data into three three tertiles with linear weights.
The correlation coefficients of the numerical predictions with street level measurements were 0.64, with indoor measurements 0.66 and with window measurements 0.67. The kappa coefficients were 0.50 for street level measurements, 0.46 for indoor measurements and 0.52 for window measurements.

A sensitivity study was performed by varying all model options and input parameters whose influence was not a priori evident. The sensitivity study showed that the output is quite insensitive of the precise choice of the parameter values. Especially, the ability of the model to distinguish between high and low exposure does not depend on these parameters.

CONCLUSIONS

We have extended a model for RF-EMF exposure that so far performed well at outdoor locations to also successfully predict exposure at indoor locations. Despite all the simplifications, the performance for indoor points is only slightly reduced compared to outdoor points. The model is robust and quite insensitive to the exact choice of parameters; and it is well suited to classify exposure levels for application in an epidemiological study.

ACKNOWLEDGMENTS

The study was funded by the Swiss National Science Foundation (Grant 405740-113595). It is part of the National Research Program 57 "Non-Ionising Radiation - Health and Environment".

REFERENCES

INTRODUCTION

This paper deals with exposure assessment for an epidemiological field study that investigates sleep quality. A transportable mobile phone base transceiver station (BTS) was built up in ten residential areas in Germany with preferable no mobile phone coverage and marginal exposure to other RF services. This paper analyses the exposures measured and states experiences with the exposure assessment method in the context of the sleep study.

MATERIALS AND METHODS

A transportable BTS for a typical mobile phone coverage of a village containing a GSM 900 and GSM 1800 system with three transmit channels per sector and system was built up in ten residential areas in Germany with preferable no mobile phone base station exposure at all. Focus of the epidemiological field study [1] was to investigate a possible influence of BTS exposure on sleep quality under residential conditions. Frequency selective exposure measurements were performed in the pillow region of subject’s beds in the range from 100 kHz to 3 GHz with the mobile spectrum analyzer SRM 3000 (Narda Safety Test Solutions) to get an exposure metric for BTS signal and ambient signals. The exposure measurements at nearly 400 beds result in a typical field strength distribution representative for mobile phone BTS with small installation height for coverage of small villages.

RESULTS

Measurements at nearly 400 points in a distance of 5 to 680 m to the BTS show electric field strengths between 0.004 and 4.52 V/m corresponding to 0.008 to 8.9 % of the ICNIRP field strength reference levels [2]. In comparison with two exposure studies within the German Mobile Telecommunication Research Program the median value of 0.09 V/m (0.2 %) shows the same dimension as found in the vicinity of base transceiver stations with focus on space and time averaged immissions and is nearly a factor 10 smaller than in a study with focus on maximal exposure. The reason for this is that the measurement points in the epidemiological study were predetermined (beds) and the majority had NLOS condition. The median exposure difference between LOS and NLOS is 13.8 dB.

Very often epidemiological studies take only the distance to the station as an exposure estimate. In figure 1 the exposure distribution in dependence of the lateral distance from the BTS is displayed and shows no dependence of lateral distance and exposure up to about 100 m. Due to the small installation height of approximately 13 m there is a trend of declining exposure observable at distances greater than 100 m but with a quite large span up to 30 dB for a single distance.
The electric field strength difference between the generic BTS signals and other RF services covers a range from –1 to 17 dB dominated by LMS (long-, medium-, short-wave). In this context it has to be kept in mind, that exposure to DECT by substituting with conventional telephones and WLAN by deactivating possible systems in the subject’s accommodations was minimized. This means, that a desirable dominance of the BTS signal under investigation of more than 13 dB (median value) with regard to ambient RF signals has proven to be unrealistic, even if places with absence of FM or TV transmitters have been chosen, mostly because of the LMS stations.

CONCLUSIONS

Besides distance, refined calculation models or dosimeters commonly used for exposure assessment in epidemiological studies, frequency selective measurements are well suited. This method has the advantage of getting the most precise exposure values in contrast to the other approaches. The typical measuring time (100 kHz to 3 GHz) has been found to be approximately 15 min per location (excluded data post processing) and is therefore well suited for epidemiological studies with up to several hundreds of subjects.

A desired dominance of the BTS signal to ambient RF signals of more than 13 dB is not realistic. On the one hand the mobile phone exposures were small, because of predetermined locations with mostly NLOS conditions. On the other hand, LMS stations generate a homogeneous and comparably high ambient exposure.

Again it was shown that the lateral distance is not a well quantity for exposure assessment.

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REFERENCES


Cardiac and Respiratory Response to nsPEFs Delivered to Rats

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INTRODUCTION

High-intensity millisecond pulses (MPs) have been used by law enforcement and the military for decades as a means of immobilizing humans posing a threat. High-voltage (HV) intensity nanosecond pulsed electric fields (nsPEFs), however, can incapacitate a subject for extended durations, affecting plasma membranes and intracellular structures and functions in unique ways. Experimental studies on single cells have shown that pulsed voltages with a duration of 300 ns and an electric field of 10 kV/cm cause sudden alterations in the intracellular free calcium concentration followed by immobilization (“stunning”) of the cell [1]. Although HV intensities are used in nsPEFs, the energy deposited per pulse is small, typically on the order of a Joule. Using pulse trains can further reduce the total energy applied while still retaining effectiveness. Preliminary experiments with ns pulses established that even a single HV pulse may evoke lasting inhibition of “voluntary” twitches [2]. Thermal increase (less than 1°C) did not play a role in the effects associated with nsPEFs in this first reporting of nsPEF incapacitation; however, no physiological parameters were recorded. The duration of immobilization, which can range from a few seconds to tens of minutes, depends not only on the amplitude of the applied voltage but also on the pulse duration. For aquatic organisms, the optimum pulse duration for stunning was found to be approximately 300 ns [3]. Based on these observations, submicrosecond pulses with low energy expenditure should cause controlled immobilization of any biological organism. The overarching aim of this research program has been to extend the studies on neuromuscular incapacitation from multimicrosecond to nanosecond electrical pulses. The present research examines stimulation with such ultrashort pulses to determine conditions producing maximal but reversible bioeffects, preventing voluntary movement without inducing twitches or seizures. Since the HV pulse is applied to the whole body, subjecting all tissues to the electric field, the immediate aim of this part of the project was to examine the myocardial and diaphragmatic changes due to the nsPEFs in order to assess any adverse effects in the animal model that would preclude use of HV nsPEFs in humans.

MATERIALS AND METHODS

We used HV nsPEFs in vertebrate immobilization trials to assess direct effects on rat myocardium and diaphragm. After ketamine anesthesia (100 mg/kg), we placed low-voltage (LV) tungsten electrodes 2 mm apart in the hind-limb area of the motor cortex with a David Kopf model 900, small animal stereotaxic instrument. The LV electrodes were fixed in place with zinc phosphate dental cement. Simulated voluntary leg movement (twitches) was induced by LV electrical stimuli delivered directly through the tungsten wires in trains of 5, 3-ms stimuli at 5 V per stimulus. The train rate was 2 Hz for 2 s (5 pulses) every 10 s, with 8-s rest between contraction series. The excitation from the cortex was conducted to the periphery via the same efferent pathway (from cortex to spinal motoneurons to muscle fibers) as would be recruited in any voluntary movement. Hence, inhibition of this efferent pathway
is equivalent to inhibition of any potential voluntary movement, or incapacitation. HV electrodes were attached to the right shoulder by a subcutaneous needle 1 cm from the spine at vertebra T5, and to the left foot by an encircling 1-inch wide copper strip with electrode paste underneath. After 2 min of baseline leg-twitch recording, an HV pulse was administered at ns duration, short rise time and variable field strengths in the kV/cm range. Physiological parameters were recorded for 10 min post-nsPEF, followed by a 5-min rest period without LV stimulation. The nsPEF treatment was applied an average of 8 times to each rat over a period of 2 to 4 hours. Data recorded were: (1) heart rate (HR) and blood pressure (BP) by an indwelling catheter in the right common carotid artery attached to a 23 Statham pressure transducer; (2) electro-cardiogram (ECG) tracings through lead I wires; and (3) hind limb contraction force with superimposed respiratory rate (RR) by a Grass force-displacement transducer attached to the ankle. All leads were coupled through an iWorx 304 data acquisition unit to a Dell computer.

RESULTS

Recordings from 5 s pre- to 5 s post-nsPEF produced no significant differences as follows: RR increased an average 3% (115 to 118 breaths/min). Average HR increased an average 4% (279 to 290 beats/min). Average BP remained constant (121/70 to 120/68). Except for ectopic tracings recorded at LV and HV pulse applications, which was expected as a direct effect of the electrical pulses, the ECG wave stayed within normal range for 10 s post-nsPEF with slight elevation of the T-wave lasting approximately 15 s. Furthermore, no significant changes in BP, HR, RR or ECG occurred over the 10 min of recovery time post nsPEF.

CONCLUSIONS

While our treatment protocol has begun to establish a set of parameters that produce skeletal muscle incapacitation not presented here, our current aim to record and analyze cardiovascular and respiratory function showed that skeletal muscle contraction can be disrupted by HV nsPEFs while respiratory and cardiac muscle continue to function immediately after the pulse application for 4 hours post-pulse treatment. These results agree with observations of police force trials of the TASER® electronic control device in which the subject shot by a TASER® device does not pass out and can scream during the TASER® pulse application.

Our research demonstrates that skeletal muscle contraction can be disrupted by nsPEFs without short-term morbidity to myocardium or diaphragm. Animal protocols were approved by Institutional Animal Care and Use Committees at both ODU and the Department of Defense in accordance with strict federal guidelines.

REFERENCES


[4] TASER® is a registered trademark of TASER International, Inc.
Micronuclei In Mice Exposed To Pulsed Magnetic Fields

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INTRODUCTION

Human behavior was reported to be affected by the numerous sources of magnetic fields including power lines, cell phones and microwaves [1]. Our laboratory has developed specifically pulsed magnetic fields (PEMFs) that have been demonstrated to significantly reduce pain in snails [2], rodents [3] and humans [4]. The goal of the current study is to determine if continuous whole body exposure of mice to PEMFs for 8 weeks induces genetic damage in polychromatic erythrocytes (PCE, immature red cells) in peripheral blood and bone marrow. A significant increase in the micronuclei in PEMFs-exposed mice compared to sham-exposed mice was the indicator used to determine the induction of genetic damage.

MATERIALS AND METHODS

Adult CD-1 male mice were placed in an exposure system where their whole body was exposed to PEMFs (at a peak flux density of 1 mT) for 8 weeks. The system is made of 2 coils, each measuring 0.8m square and spaced 0.4m apart in a Helmholtz like configuration (Figure 1). Two platforms were suspended between the coils to keep 4 mouse cages in the center. The cages were made of polycarbonate plastic and had no ferromagnetic material that might interfere with PEMFs. An identical exposure system, without PEMFs, was used for sham-exposed mice. A positive control group, exposed to ionizing radiation, was also included in the study.

Figure 1.
Apparatus used to expose mice to PEMFs at a peak flux density of 1 mT.
An identical system, without PEMFs, was used for sham-exposed mice.

From each mouse, a small sample of peripheral blood was collected initially and at 2, 4, and 6 weeks. At the end of 8 weeks, all mice were euthanized and both peripheral blood and bone marrow were collected. All samples were smeared on microscope slides and the cells were fixed using absolute methanol. Air-dried slides were stained with acridine orange. A fluorescence microscope fitted with appropriate filters was used to examine ‘coded’ slides.
In each mouse, in both peripheral blood and bone marrow smears, 2000 PCE (identified by bright orange color) were examined to record the incidence of micronuclei (identified by bright yellow color). The results were subjected to statistical analysis.

RESULTS
The incidence of micronuclei in both peripheral blood and bone marrow cells of mice exposed to PEMFs were not significantly different from those observed in sham-exposed animals. In contrast, a significantly increased numbers of micronuclei were observed in both bone marrow and peripheral blood in positive control mice exposed to .95 grey ionizing radiation.

CONCLUSIONS
The data suggested that whole body exposure of mice for 8 weeks to pulsed electromagnetic fields at a peak flux density of 1 mT did not result in an increase in genetic damage in both peripheral blood and bone marrow cells.

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Characteristics of ocular temperature rise under exposure to frequency (18-40 GHz)

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INTRODUCTION

Millimeter waves (MMW) are prevalent in wireless communication, automobile collision prevention systems and also high-resolution radar imaging. It is known that the penetration depth of electromagnetic fields into an irradiated object decreases as the frequency of the incident field increases [1]. Penetration depths of electromagnetic fields also depend on the electrical properties of the biological tissue. In the ocular surface is complicated comprising tear film (3 layers), cornea (5 layers), anterior chamber (aqueous humor circulation dependent on thermal properties), iris (2.5 magnitude blood circulation the brain), lens, and so on. The affect of frequency difference between 18 to 40 GHz on ocular temperature during MMW exposure in rabbit’s eye was examined. One-dimensional thermal analysis was also performed.

MATERIALS AND METHODS

Rabbit (Dutch) eyes were exposed unilaterally to 18, 22 and 26.5 GHz, or 26.5, 35 and 40 GHz quasi-MMW or MMW, respectively. The 18-26.5 or 26.5-40 GHz continuous MMWs were generated by an 83650B (Agilent Technologies) MW signal source driving a 40 W TWT (18-26.5 GHz: K band, 26.5-40 GHz: Ka band, Etm Electromatic Inc.) amplifier. Expose to 200 mW/cm\textsuperscript{2} was delivered using a rectangular horn antenna for 3 min per frequency at a distance of 200 mm (18-26.5 GHz) or 115 mm (26.5-40 GHz) from the corneal apex. Temperature was measured with a Fluoroptic Thermometer (Luxtron 790, Luxtron) during MMW exposure. After both general and topical anesthesia, thermometer probes (0.5 mm in diameter) were inserted into the cornea, lens and vitreous. The tip of the thermo-probe for the cornea and lens was positioned at the center of the pupillary area. After the basal ocular temperatures stabilized, the eyes were exposed to 200 mW/cm\textsuperscript{2} at 18, 22 and 26.5 GHz or 26.5, 35 and 40 GHz in sequence or reverse sequence for 3 min/frequency.

RESULTS

Ocular temperature during 200 mW/cm\textsuperscript{2} of 26.5 GHz exposure under the two different irradiation conditions (18-26.5 GHz and 26.5-40 GHz) did not show any statistical difference. Cornea and lens temperature increased with frequency, but not vitreous. Corneal temperature was always higher than that of lens temperature. The highest temperature was induced by 40 GHz, followed by 35>26.5 GHz (Fig1A), 26.5≥22>18 GHz (Fig1B).

To verify the measurement, thermal analysis was performed using a one-dimensional
analytical method and a bioheat equation as described [2].

Figure 2A depicts the one-dimensional model used in the analysis. It consisted of cornea, anterior chamber, lens, vitreous and retina. Figure 2B shows analyzed thermal elevation due to 3 min. MMW exposure. The highest temperature from thermal analysis was 40 GHz followed by 35, 26.5, 22, and 18 GHz. In vivo experimental data and thermal analysis showed good correlation.

CONCLUSIONS

Since we used 2 different exposure conditions in 18-26.5GHz and 26.5-40 GHz, the differences in ocular temperature rise for 18-26.5GHz and 26.5-40 GHz are not strictly comparable. However, because the ocular temperature of 26.5GHz exposure with two different systems showed corresponded, it is suggested that frequency difference is implicated. Further experiments are needed to elucidate the mechanism(s) underlying frequency-specific differences in increased ocular temperature.

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REFERENCES

Electromagnetic Pulse Exposure Increases Blood–Brain Barrier Permeability and Alters Tight Junctions in Rats

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INTRODUCTION

The blood-brain barrier (BBB) is formed by highly specialized endothelial cells whose tight junctions between adjacent cells restrict the paracellular diffusion of hydrophilic molecules, which protects the brain from circulating neurotoxic substances while maintaining nutrients and ions in the brain at levels necessary for neuronal function. In recent years, the effect of exposure to electromagnetic fields on BBB permeability has been investigated, but the results were controversial [1, 2]. Since the effects of exposure to electromagnetic fields on BBB and corresponding cellular mechanisms involved in disrupting the BBB remain unclear. In this study we examined the permeability of BBB and changes in TJ proteins in rats after exposure to electromagnetic pulses (EMP).

MATERIALS AND METHODS

Sprague–Dawley rats, male, weighing 200–250 g, were used in this study. The animals were sham or whole-body exposed to EMP at 200 kV/m for 400 pulses, the repetition rate was 1 Hz. The exposure conditions produced a rise in rat rectal temperature less than 0.2 °C.

The permeability of the BBB in rats was assessed by Evans blue (EB) extravasation that is known to bind to serum albumin after intravenous injection and has been used as a tracer for serum albumin [3]. At different time points after EMP exposure, the animals were injected intravenously with EB dye (2% in saline, 4 ml/kg), then anaesthetized with 60 mg/kg i.p. of sodium pentobarbital and perfused transcardially with 0.9% saline and then 4% paraformaldehyde, the brain was removed and embedded in OCT cryostat-embedding compound, 50-μm-thick coronal sections were cut. Sections were visualized on Nikon fluorescent microscope.

The expression and distribution of typical tight junction protein ZO-1 and occludin was analyzed by the Western blotting and immunofluorescence microscopy. At different time points after EMP exposure, the animals were anaesthetised and killed by decapitation. The brains were quickly dissected and cerebral cortex microvessels were isolated. The expression of ZO-1 and occludin in both cerebral cortex homogenate and cerebral cortex microvessel homogenate were determined by Western blotting. In addition, cerebral cortex microvessels were smeared onto microscope slides and immunostained for ZO-1 and occluding.

RESULTS

Effect of EMP on permeability of BBB using EB tracer No red fluorescence caused by EB leakage in cerebral cortex was observed in sham exposure animals, however, after EMP...
exposure, round or oval-shap red fluorescence in cerebral cortex was found (Fig.1), which appeared at 1h and became evident at 3h, then began to recover at 6h after EMP exposure.

Figure 1: Representative pictures of EB red fluorescence observed in cerebral cortex at 1h and 3h after EMP exposure (200kV/m, 400 pulses)

**Expression and diatribution of the tight junction-associated proteins** Western blots showed no change in the expression of the occludin after EMP exposure (Fig.2A, Fig.2B). Morphological study also showed no alteration of the immunolabeling for occludin in rat brain cerebral cortex microvessels after EMP exposure. However, the expression level of ZO-1 significantly decreased at 1h and 3h after EMP exposure in both cerebral cortex homogenate and cerebral cortex microvessel homogenate, furthermore, immunofluorescence studies also showed alterations in ZO-1 protein localization in cerebral cortex microvessel, ZO-1 immunofluorescence became weaker and lost its distribution in thin and well defined filaments after EMP exposure (Fig.2C).

Figure 2: Expression and distribution of the tight junction-associated proteins occluding and ZO-1 examined by western blot and immunofluorescence microscopy after EMP exposure. (A cerebral cortex homogenate, B cerebral cortex microvessel homogenate, C immunofluorescence in cerebral cortex microvessel)

**CONCLUSIONS**

The data suggested that EMP exposure (200kV/m, 400 pulses) could transiently increase BBB permeability in rat cerebral cortex, and this change was associated with specific alterations in tight junction protein ZO-1.

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**REFERENCES**


INTRODUCTION

For many years, we have been performing experiments on the breast tissue of juvenile female rats to find out if exposure to extremely low frequency (ELF) magnetic fields (MF) affects the mammary gland in terms of an enhanced risk for breast cancer.

In several experiments, we observed tumor-promoting effects of prolonged MF exposure over months in the dimethylbenz[a]anthracene (DMBA) breast cancer model with Sprague-Dawley (SD) rats [1], and these SD rats also showed an increased cell proliferation in the mammary gland after a 2-week MF exposure [2]. However, we also detected differing MF effects among different rat strains and substrains, indicating that the genetic background plays an important role for the effects of MF exposure [3].

In previous studies, we could discover the inbred Fischer 344 (F344) rat as a MF responsible strain by enhanced cell proliferation [4] and increased tumor development in the DMBA model [5]. In order to examine the underlying mechanisms of these MF effects in F344 rats, we investigated gene expression in the breast tissue of F344 and compared the results with Lewis (Lew) rats that are considered MF-insensitive. Surprisingly, the most striking result was a marked decrease of amylase gene expression in MF-exposed F344, but not in Lew. This outcome brought us to focus on the impact of amylase on MF effects. In the present study, mammary epithelial cells from F344 and Lewis rats were cultured after exposure to 100 or 0.15 µT to investigate response to amylase treatment in these cells.

MATERIALS AND METHODS

In the present study, we obtained F344 and Lew rats from Charles River, Sulzfeld, Germany. Rats were MF- or sham- exposed at an age of 52 days in groups of 5 animals. After 14 days of exposure (100 µT or 0.15 µT, 50 Hz), the mammary gland complexes were excised, and cell preparation was done according to the method described by the group of Bissell [6] for primary culture of mouse mammary epithelial cells with modifications for rat glands. Mammary glands were enzymatically digested, and epitheloids were seeded on Matrigel® (Becton Dickinson) coated plates. Cells were cultured with mammary epithelial cell growth medium (Promocell). After passaging, two types of experiments were performed: (1) Cell counting for determination of proliferation and (2) amylase treatment (5 and 50 U/ml) daily for 2 days with final cell counting for determination of sensitivity to amylase. Statistical analysis was performed by one-way ANOVA and post hoc Bonferroni test.

RESULTS

For cell proliferation, we could not notice any clear differences between cells from sham- and MF-exposed rats.
Amylase treatment resulted in a dose-dependent decrease in number of cells, indicating an antiproliferative effect. In first experiments with cells from non-exposed Lew and F344 rats, Lew cells responded with a higher sensitivity on amylase treatment than cells from F344. The strong decrease in cell number was vanished for cells from sham- and MF-exposed Lew after 2 weeks of 100 μT-MF exposure. In contrast, F344 cells reacted in a more sensitive way without any difference between sham (0.1 μT) and MF (100 μT). In another experiment, flux density of MF exposure was set to 0.15 μT to find out if rat mammary epithelial cells were regulated at lower flux densities. Again, we determined a higher sensitivity towards amylase in sham-exposed Lew cells. Moreover, cells from MF exposed Lew rats presented a significantly decreased sensitivity, while F344 cells were again less sensitive compared to Lew without any sham/MF differences.

CONCLUSIONS

Investigation of gene expression pointed to differences in effects of MF-exposure on amylase expression between the F344 and Lew rats, but enzyme activity was increased in both strains after MF exposure. An explanation could be that amylase might be involved in regulative mechanisms to stabilize cell cycle or proliferation and is less effective in F344 rats, which results in fading RNA levels and increase in cell proliferation.

Findings from the present study indicate that mammary epithelial cells from F344 and Lew differ in their sensitivity to amylase treatment. We observed a lower responsiveness in cells from F344 rats and a higher sensitivity towards amylase treatment in Lew cells from non-exposed rats. Regulation in mammary glands of exposed Lew rats might work well, and that resulted in a “normalized” cell proliferation. MF exposure altered sensitivity to amylase, possibly by producing stabilized cells that do not respond to amylase with high sensitivity anymore. Experiments are planned to reproduce, confirm, and extend these results.

ACKNOWLEDGMENTS

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REFERENCES


Exposure to a 900 MHz mobile phone-like signal and serum levels of S100B and transthyretin in human volunteers

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INTRODUCTION

Whether low-intensity radiofrequency radiation damages the blood-brain barrier (BBB) has long been debated [1, 2], but no experimental study has yet been performed on humans [3]. Moreover, little or no consideration has been given to the so-called blood-cerebrospinal fluid barrier (BCSFB). We tested whether acute exposure to a mobile phone-like signal in healthy volunteers gave rise to changes in the serum levels of two putative markers of BBB and BCSFB integrity.

MATERIALS AND METHODS

In total 41 volunteers, 17 men and 24 women, aged 18-30 years were recruited in the municipality of Umeå in Sweden. All persons were informed by letter and asked to give their informed consent, and to fill in a short questionnaire regarding background characteristics, wireless phone use, state of health etc, to ensure that the inclusion criteria were met.

Repeated blood sampling for analyses of potential changes in serum levels of S100B and transthyretin (TTR) was carried out before and after the provocation, enabling each participant to act as their own control.

The radiofrequency signal was generated by using a GSM 900 test phone (Ericsson GH 337). The signal was amplified and transmitted to an indoor base station (Allgon 7336). The frequency of the signal used was 890 MHz with pulse repetition time of 4.61 ms (217 Hz) and pulse duration of 0.577 ms. No DTX function was used during the provocation. For further details concerning the exposure system, see Wilén et al [4].

The subjects were seated in a reclining chair in front of a LCD computer screen with the antenna mounted on the side the subject usually held their phone. The antenna was placed at a distance of 8.5 cm from the ear with the head positioned between two wooden bars to ensure well-defined location during the provocation. The exposure set-up was adjusted so as to give a homogenous SAR distribution in the parietal area of the head with a SAR\textsubscript{10g} = 1.0 W/kg, as measured with a DASY 3 system at AMC Centurion AB, Åkersberga, Sweden.

The actual exposure lasted for 30 minutes. Blood was taken at four times: the 1\textsuperscript{st} sample at arrival to the hospital 30 minutes before the provocation, the 2\textsuperscript{nd} just before the provocation, the 3\textsuperscript{rd} right after and finally the 4\textsuperscript{th} 60 minutes following the end of the provocation.

In the analyses of S100B, Friedman’s test was used to examine differences between all
four blood samples and the Wilcoxon matched-pairs signed-rank test was used for pair-wise comparisons. For analyses of TTR, we used repeated-measures ANOVA and paired t-test. In the pair wise comparisons, adjustment for multiple comparisons was made using Bonferroni correction (n=6). All analyses were done using StataSE 10.1.

RESULTS

Statistically significant differences between all four samples were found for both markers (Table 1). After adjustment for multiple comparisons, mean and median values for all the pair wise comparisons of the different blood samples from the first and on to the second, third and fourth gave significantly decreased S100B concentrations, except between sample 3 and 4. For TTR a similar trend in decreasing concentrations were seen for sample 1 vs. 2 and 1 vs. 3, but not for the following ones. Due to these unexpected results the pre-analytic stability of both markers, which according to the literature should be stable in room temperature up to 24 hours, was double-checked. We found no significant effect of time from sampling until the sample was frozen.

No immediate effect of the exposure following sample 3 was evident for neither S100B nor TTR, although for TTR a change in the trend from decreasing to non-significantly increasing serum concentrations following the exposure was seen for sample 3 vs. 4 (p=0.10, corrected n=6). Overall, similar results were seen for men as for women.

<table>
<thead>
<tr>
<th>Sample</th>
<th>S100B (µg/l)</th>
<th>TTR (g/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean</td>
</tr>
<tr>
<td>Sample 1</td>
<td>41</td>
<td>0.063</td>
</tr>
<tr>
<td>Sample 2</td>
<td>41</td>
<td>0.050</td>
</tr>
<tr>
<td>Sample 3</td>
<td>41</td>
<td>0.049</td>
</tr>
<tr>
<td>Sample 4</td>
<td>41</td>
<td>0.047</td>
</tr>
</tbody>
</table>

Table 1. Differences between the blood samples examed by Friedman’s test and Repeated-measures ANOVA.

CONCLUSIONS

In this study on human volunteers exposed half an hour to a GSM 900 MHz signal at SAR_{10g} = 1.0 W/kg no statistically significant changes in serum levels of S100B and TTR related to the exposure was seen in the pair wise comparisons after adjustment for multiple comparisons. Further studies with use of additional markers are needed.

REFERENCES


1 Friedman’s test.
2 Repeated-measures ANOVA with Huynh-Feldt correction.
Sensibility to RF Radiation Emitted from CDMA Mobile Phones of EHS and Non-EHS Persons

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INTRODUCTION

Various provocation studies have been conducted on electromagnetic hypersensitivity (EHS) caused by Global System for Mobile Communications (GSM) phones in which sensibility was investigated [1]. However, there have been few sham-controlled provocation studies on EHS with Code Division Multiple Access (CDMA) phones where perception of RF radiation for EHS and non-EHS groups was investigated. In this study, two volunteer groups of 18 self-reported EHS and 19 non-EHS people were tested for both sham and real RF exposure from CDMA cellular phones with a 300 mW maximum exposure that lasted half an hour. In conclusion, there was no evidence that the EHS group better perceived EMF than the non-EHS group.

MATERIALS AND METHODS

Total 37 subjects participated in the experiment: 18 EHS persons (8 males and 10 females; 26.1±3.4 years) and 19 non-EHS persons (10 males and 9 females; 25.0±2.3 years). Each subject was tested for sham exposure on the first day and for real exposure on the second day, or the other way round. No matter what came first, sham or real exposure, the second one was always given at approximately the same time of the day as the first one in order to have the subject keep the same physiological rhythm. The order of sham and real exposures for a subject was randomly assigned to minimize experiment bias. A conventional headset was modified to contain a folder-type CDMA phone (SCH-V300S, Samsung Electronics, Korea) on the left side. The lower part of the cellular phone with keypad was wrapped up with a 5 mm thick insulating material so that the subject could not be aware of whether the phone was working through its generated heat.

The perception of RF exposure was investigated every five minutes during whole sessions as shown in Fig. 1. “x” and “•” indicate non-exposure and real/sham exposure timings, respectively, for inquiry about perception. Therefore, there were five inquiries during exposure (•) and four inquiries during non-exposure (x) in the case of real exposure, whereas there were nine inquiries during non-exposure in the case of sham exposure. The subjects were asked nine times to answer to the question “Do you feel EMF?”

RESULTS
The accuracy of nine times of asking for EHS and non-EHS groups was calculated in the real and sham sessions as shown in Figure 2. In the case of the sham session (A), the accuracy of the non-EHS group showed higher than that of the EHS group except the first asking. One interesting point in the EHS group in the real session (B) is that the accuracy showed the monotonically increase in #7 (61%), #8 (72%), and #9 (89%) after stopping the real exposure. This may be due to the delayed effect from the previous real exposure period. However, this effect was not shown in the real exposure session for the non-EHS group.

![Figure 2: Perception accuracy (%) of nine inquiries in EHS and non-EHS groups for the sham (A) and real exposure sessions (B).](image)

Although the accuracy during exposure was 40.1% higher in the EHS group (43.3%) than in the non-EHS group (3.2%), the EHS group’s accuracy during non-exposure (73.9%) was 21.2% lower than that of the non-EHS group (95.1%). These results could be attributable to the fact that many subjects in the EHS group answered “Yes” to the question “Do you feel EMF?” because most of them had bias that they could feel EMF. On the other hand, the non-EHS group showed higher accuracy in perception during non-exposure because they considered themselves that they could not feel EMF. Total perception accuracy for the EHS and non-EHS groups was 65.1 ± 11.5% and 69.6 ± 6.5%, respectively, and there was no significant difference (P = .165). In a recent review Röösli also concluded that the large majority of individuals who claims to be able to detect low level RF-EMF are not able to do so under double-blind conditions [2].

CONCLUSIONS
There was no evidence that the EHS group better perceived EMF than the non-EHS group. This study showed the possibility of the delayed exposure effect in the EHS group.

ACKNOWLEDGMENTS
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REFERENCES
The effect of GSM-like RF and ELF fields on the human resting EEG

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INTRODUCTION
Global System for Mobile Communications (GSM) phone handsets emit both radiofrequency (RF) and extremely low frequency (ELF) electromagnetic fields. There is some evidence that such emissions can cause changes in human brain function as measured by the electroencephalogram (EEG) [1]. The majority of reported studies have utilized small sample sizes and employed protocols that examined both the resting EEG as well as cognitive aspects of brain function. Many studies have employed exposure conditions aimed at maximizing any potential effect on the brain with the tradeoff of deviating from real exposure conditions [2]. Currently there are no studies that investigate the influence of the GSM-ELF exposure source on the brain. This study attempted to address these limitations, so employed a relatively large sample size (n=72) and a resting EEG protocol only, allowing for collection of long intervals of true resting EEG and realistic GSM-like exposures. To determine the influence of pulsing of RF fields on any observed effects, both continuous RF (CW RF) and discontinuous mode pulsed RF (PM RF) exposures were employed. In addition, the present study investigated for the first time the influence of GSM-like ELF fields on the human resting EEG.

MATERIALS AND METHODS
Seventy-two healthy volunteers participated in the study. The ethics committees of RMIT and Swinburne University approved the study protocol. A two-hour single-day protocol was employed that incorporated three active (PM RF, CW RF and ELF) exposures and a sham exposure, each lasting 20 minutes. The order of exposure was randomly assigned in a fully counterbalanced, double-blind crossover design. Resting EEG was recorded with eyes open in order to minimize vigilance fluctuations. Nineteen-channel EEG and four-channel EOG were recorded and impedances were below 5 kΩ at the start of the experiment. The EEG amplifiers were shielded appropriately to avoid RF interference. Exposures were delivered through a specially constructed handset able to produce both RF and ELF exposures. CW RF exposure was set at a 10 g spatially averaged peak SAR of 1.95 W/kg while PM RF exposures were set to emit instantaneous peak fields identical to the CW RF exposure resulting in a time averaged SAR of 0.06 W/kg. Although SAR levels are substantially different, matching peak fields ensures that any differences in induced effects are not attributed to differences in instantaneous peak field differences but rather to SAR differences or modulation content. ELF exposures were delivered through a current carrying coil and were set at ~8 µA/m² (averaged over a cross-section of 1 cm² perpendicular to the current direction), which occurred in the cerebrospinal fluid. Data could not be normalized so Wilcoxon Signed Rank tests were employed for the statistical analysis.
RESULTS

Table 1 summarizes the results of the analysis of the alpha band (8-12 Hz) of the resting EEG. Significant changes were observed during PM RF and ELF exposures. Additional trend level changes were recorded for all active exposures, predominantly during exposure.

<table>
<thead>
<tr>
<th>Summary of results</th>
<th>Exposure</th>
<th>Exposure by distal Laterality</th>
<th>Exposure by proximal Laterality</th>
<th>Exposure by Sagittality</th>
</tr>
</thead>
<tbody>
<tr>
<td>During Exp; PM RF</td>
<td>↓ (θ=−.169)</td>
<td>no effect</td>
<td>no effect</td>
<td>no effect</td>
</tr>
<tr>
<td>During Exp; CW RF</td>
<td>no effect</td>
<td>↓ (θ=−.393), trend</td>
<td>↓ (θ=−.318), trend</td>
<td>no effect</td>
</tr>
<tr>
<td>During Exp; ELF</td>
<td>no effect</td>
<td>no effect</td>
<td>↓ (θ=−.383)</td>
<td>no effect</td>
</tr>
<tr>
<td>After Exp; PM RF</td>
<td>no effect</td>
<td>no effect</td>
<td>no effect</td>
<td>↑ (θ=−.119), trend</td>
</tr>
<tr>
<td>After Exp; CW RF &amp; ELF</td>
<td>no effect</td>
<td>no effect</td>
<td>no effect</td>
<td>no effect</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The statistically significant decreases in alpha activity during PM RF and ELF RF exposure are somewhat unexpected based on previous publications in the literature (generally increased alpha activity), [2-3]. Closer inspection of the data for sham exposures reveals the results arise principally from a suppressed sham baseline (causing a larger increase during exposure minus baseline in the sham condition than in the active condition). This effect could be interpreted as a suppression of the normal tendency of alpha activity to increase throughout the experimental interval. The possibility that the sham baseline was contaminated by a carry-over effect was investigated. It was found to be remote since the carry-over effect would need to be six times larger in magnitude and in the opposite direction in comparison to the actual effect, and would need to be confined in the baseline period of the sham exposure only. Although these results are in some disagreement with the increased alpha activity that is generally reported, the distinction could be explained by a specific response to the exposure used in the unique protocol employed. For the first time the ELF exposures of GSM handsets were investigated as a potential stressor to the brain and were also found to affect alpha activity at sites close to the exposure source. The result is partly in agreement with some relevant studies, e.g. [4]. The necessity of pulsing of the electromagnetic signal to induce changes in brain activity is also supported by the current results. Replication of these findings is necessary particularly due to the apparent disagreement with the previous literature regarding effects on alpha band activity.

REFERENCES


Effects of a 60 Hz, 3000 Microtesla Magnetic Field on Human Cognitive Processing: Preliminary Results

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INTRODUCTION

To date, there is no consensus regarding the effects of Extremely Low Frequency (ELF, < 300 Hz) Magnetic Fields (MF) on human cognitive processing. Recently, our lab has examined the neurobehavioural effects of exposure to an ELF MF (60 Hz, 1800 µT) and found less postural oscillations [1]. To continue our investigations on the effects of 60 Hz MF, we are now examining potential cognitive effects. In previous studies, demonstrating cognitive effects from exposure to an ELF MF, changes generally appear in high level cognitive processes, such as attention mechanisms, learning and memory, and executive functions [2, 3]. Overall, it has been reported that MF-induced changes influence the accuracy and precision of high level cognitive mechanisms rather than the velocity of execution [2, 3]. The Stroop and mental rotation (MR) tests (selective attention) and the Fitts’ motor task (sensorimotor performance) are well known sensitive tests selected here to investigate the potential effect of a 1 hour ELF MF (60 Hz, 3000 µT) exposure on human cognitive performance [4, 5, 6]. Based on the results from previous studies, we expect exposure will result in poorer accuracy in test performance but will not affect the time participants take to carry out the task.

MATERIALS AND METHODS

This is an ongoing study. Ninety-nine participants between the ages of 18 and 55 will complete a computer driven (LabView 8.5, NI Inc., USA) double-blind protocol with real and sham exposure conditions (figure 1). After having completed a first baseline session (Se1, no MF exposure), participants will be randomly assigned to one of three groups before beginning the second session (i.e. the experimental session: Se2). During Se2 (on a later day), participants may or may not be exposed to the 60 Hz, 3000 µT MF for 1 hour (figure 1).

Figure 1: Each of the 3 groups (G1, G2, and G3) completes the same psychometric tests during experimental block 1 (B1) and block 2 (B2) with the same time frame. Only the distribution of the 1 hour exposure condition varies across the groups: G1: sham / sham, G2: real / sham, G3: sham / real).

MF exposure is produced by a whole-body Helmholtz-like coil system with the homogeneous region centered at the level of the head. During Se1, subjects are required to complete all the tests for Se2 plus the Beck Depression Index-II, the Beck Anxiety Index, and the full Wechsler Adult Intelligence Scale-III. During Se2, they complete two blocks of testing (figure 1) which each consist of performing the following tests in sequence: Digit Symbol Encoding, Block Design, Arithmetic, Digit Span, Trail Making A&B, Stroop, MR,
and Fitts’ Task. For the purpose of this abstract, only the results of the Stroop, MR, and Fitts’ tasks will be presented. Participants performed all three subtests using custom-built LabView software, quantifying performance and timing. The Stroop test presents a series of words naming colours which are printed in a colour incongruent with their meaning. The participant must select the colour and not the meaning as fast as they can. MR simultaneously presents the images of two geometric 3D shapes and the participant must decide whether they are the same objects (presented with a rotation) or not (different or mirror shapes). The Fitts’ motor task involves alternatively touching two targets (spaced 30 cm apart) with a stylus as fast and as precisely as possible.

RESULTS

Seven participants have completed both sessions thus far. Each test of a participant gives rise to the computation of accuracy/precision and timing indexes which will be used in the statistical analysis: 3 x 2 (groups x MF condition) within-subjects ANOVA. Preliminary data representing the percent accuracy in the MR task is reported in figure 2. The percent accuracy and the response time (Stroop and MR), the precision and timing on targets (Fitts’), are examples of parameters examined.

CONCLUSIONS

Three-thousand µT appears to be the greatest level of 60 Hz MF exposure used to date in published human neurocognitive studies. In addition to investigating the performances before, during, and after exposure, this protocol will represent the first step towards answering the question of the potential MF effects on learning processes. Furthermore, a second experiment using functional Magnetic Resonance Imaging is being run in parallel to this experiment studying how brain activation patterns associated with a specific task (MR for example) are modulated by the same MF exposure.

ACKNOWLEDGMENTS

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REFERENCES

Magnetic Field Exposure Can Alter Neuroprocessing in Humans

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INTRODUCTION

Previous studies have shown that magnetic fields have subtle effects on pain perception in animals as well as humans. Experiments with sinusoidal extremely low frequency magnetic fields as well as pulsed electromagnetic fields (PEMF) have indicated that PEMF may have a larger analgesic effect, and so may be more clinically relevant. Indeed, these effects have been demonstrated to be specific to the affective component of pain, not affecting the sensory thresholds in human volunteers [1]. Here, we use functional imaging to examine the underlying changes in neuroprocessing after pulsed magnetic field exposure.

MATERIALS AND METHODS

Normal human volunteers were recruited from around the university to participate in this study. After obtaining informed consent, subjects were tested for their individual tolerance to thermal pain using a Peltier thermode attached to the right hand (Medoc TSA-II; Pathway).

A functional imaging study (functional magnetic resonance imaging – fMRI) was then conducted with the heat cycling on and off 10 times during MRI data acquisition, after which the subjects verbally reported their average pain level. Subjects were then exposed to a pulsed magnetic field inside the MRI, delivered by the gradient coils of the scanner, or a sham condition, which involved lying still within the scanner without the gradient coils producing a time-varying field. The duration of the exposure condition was 15 minutes for “phase 1” and 45 minutes for “phase 2” of the study. The pulsed magnetic field exposure used Z-gradient coils (the gradient along the bore of the magnet). The peak gradient strength was 2 mT/m, and the patient table was offset 10 cm cranially from the isocentre so that the field at the brow level was set to be 200 µT, the same field strength used in whole-body exposures within our lab in the past with Helmholtz coils [1]. Following the exposure, a second fMRI scan was conducted, with the heat cycling on and off 10 times as before.

Functional images were analyzed within Brain Voyager (Brain Innovation B.V., the Netherlands), and then regions of interest (ROI) were selected based on a priori knowledge of the brain regions associated with pain processing as well as the difference maps from the fMRI analysis. Regions of interest were analyzed separately within SPSS.

RESULTS

For “phase 1”, the 15 minute exposure study, 31 subjects (17 sham, 14 PEMF) were analyzed; significant interactions were seen for neuroprocessing in the ipsilateral (right) insula, anterior cingulate, and bilaterally for the hippocampus/caudate region. No significant interaction was seen in the subjective pain scores.
Table 1: Summary of significant interactions for ROI analysis.

<table>
<thead>
<tr>
<th>Region</th>
<th>Interaction F</th>
<th>Interaction p</th>
<th>Partial eta-squared</th>
<th>Observed power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior cingulate</td>
<td>$F_{1,29} = 6.834$</td>
<td>$p &lt; 0.05$</td>
<td>0.19</td>
<td>0.72</td>
</tr>
<tr>
<td>Insula (ipsilateral)</td>
<td>$F_{1,29} = 5.204$</td>
<td>$p &lt; 0.05$</td>
<td>0.15</td>
<td>0.60</td>
</tr>
<tr>
<td>Hippocampus/Caudate (ipsilateral)</td>
<td>$F_{1,29} = 13.803$</td>
<td>$p &lt; 0.01$</td>
<td>0.32</td>
<td>0.94</td>
</tr>
<tr>
<td>Hippocampus/Caudate (contralateral)</td>
<td>$F_{1,29} = 6.055$</td>
<td>$p &lt; 0.05$</td>
<td>0.17</td>
<td>0.66</td>
</tr>
</tbody>
</table>

The “phase 2” 45 minute exposure study was then undertaken to match up the exposure duration more closely with the previous studies that had found a subjective effect of PEMF exposure on pain. No results are available at this time from “phase 2”.

CONCLUSIONS

These results indicate that PEMF exposure does alter the neuroprocessing of pain as measured by fMRI, and that the regions of the brain affected are those specifically dealing with the affective component of pain – purely sensory regions (e.g.: S1) did not appear to be affected. The use of functional imaging appears to be more sensitive to these subtle analgesic effects than subjective reporting, as significant interactions were found in the absence of a significant effect on the subjective scores with a 15-minute exposure (this was also the shortest exposure tested to date). An expanded version of this study is now underway with a 45-minute exposure to the PEMF to examine the subjective response in addition to the functional data.

ACKNOWLEDGMENTS

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Increased Susceptibility of Oxidized Phospholipid Bilayers to Electroporation

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INTRODUCTION

Molecular dynamics (MD) studies have shown that oxidative damage to phospholipid bilayers increases the frequency of water intrusion into the bilayer interior [1], suggesting that oxidized lipid systems such as those found in stressed cells may be more prone to electropermeabilization than those containing non-oxidized lipids. To further investigate this phenomenon, we used MD simulations to apply external electric fields to PLPC (1-palmitoyl-2-linoleoyl-sn-glycero-3-phosphatidylcholine) lipid bilayers containing PLPC and one of two oxidized PLPC (oxPLPC) species at various field strengths and oxidized lipid concentrations.

MATERIALS AND METHODS

All simulations were performed using the GROMACS 3.3.1 package and all initial oxPLPC systems were derived from previous work on oxidized lipids [1]. The systems were composed of PLPC plus oxPLPC lipids (with 12-oxo-cis-9-dodecenoate (12-al) or 13-hydroperoxy-trans-11,cis-9-octadecadienoate (13-tc) at the sn-2 position) in concentrations of 0%, 11%, 25%, or 50% of the total system, with the oxPLPC lipids distributed equally in the two leaflets of the bilayer. Each system contained 72 lipids and 2880 water molecules (40 waters per lipid) and was energy minimized and equilibrated for 80 ns. A simulation with a larger area was created by doubling a 72-PLPC bilayer in x and y and then individually inserting oxPLPC lipids in two opposing quadrants, creating a quilted system where two quadrants are heavily oxidized (50% oxPLPC) and the two remaining quadrants contain only PLPC. This enables us to test whether electroporation occurs preferentially in oxidized regions of a bilayer. Periodic boundary conditions were employed to mitigate system size effects and the integration time step was 2 fs. Short-range electrostatics and Lennard-Jones interactions were cut off at 1.0 nm. Long-range electrostatics were calculated by the particle mesh Ewald (PME) algorithm using fast Fourier transforms and conductive boundary conditions.

RESULTS

Our simulations show that bilayers containing oxidized lipids electroporate more quickly and at lower field strengths than those without oxidized lipids. Additionally, 12-al oxPLPC appears to form both hydrophobic and hydrophilic electropores more readily than the 13-tc variant, possibly due to a 12-al-facilitated thinning of the membrane associated with the bending of the oxidized sn-2 tail toward the aqueous interface. Electroporation appears to
occur preferentially near oxPLPC clusters, as shown in Figure 1, which implies that the presence of hydroperoxy or aldehyde oxygens facilitates the penetration of water into the interior of the bilayer. Simulation results were verified by experimental observations of enhanced permeabilization of oxidized membranes in living cells.

Figure 1: Overhead snapshot of the large quilted system (doubled for clarity) both before (left) and after (right) an electric field is applied. oxPLPC (12-al) is shaded darker than PLPC.

CONCLUSIONS

Simulated bilayers containing oxidized lipids have an increased susceptibility to electroporation. This probably results in part from facilitation of water transport into the bilayer interior by hydroperoxy or aldehyde oxygens on the oxidized residues and in part by the fact that oxPLPC bilayers containing 12-al are thinner than pure PLPC bilayers and those containing 13-tc. oxPLPC clusters attract a large number of individual waters into the bilayer, creating localized regions of electroporation susceptibility. This is consistent with experimental observations in which cells treated with peroxidizing agents electroporate more readily than untreated cells.

ACKNOWLEDGMENTS

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REFERENCES

Fluorescent Imaging Analysis of Plasma Membrane Nanopores Formed by Ultra-Short Electric Pulses

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INTRODUCTION

We have previously found the nsEP treatment of mammalian cells increases the electrical conductance of the cell plasma membrane. Contrary to conventional electroporation, this increase was not accompanied by cell uptake of membrane integrity marker dyes such as trypan blue or propidium iodide. However, it was not known if nsEP treatment resulted in activation of endogenous ion channels or de novo opening of lipidic nanopores. Furthermore, the increase of plasma membrane electrical conductance was demonstrated only by electrophysiological techniques (patch clamp), where the detection procedure itself could potentially be affected by nsEP. The goals of the present study were (1) to confirm nanopore formation by fluorescent imaging techniques, and (2) to discriminate between opening of de-novo formed lipidic nanopores and activation of endogenous ion channels.

MATERIALS AND METHODS

The experiments were performed in GH3 cells (rat pituitary) and CHO-K1 cells (Chinese hamster ovary) attached to poly-l-lysine-treated glass cover slips. NsEP of 600-ns duration, 2 to 15 kV/cm, were delivered to individual cells via a pair of tungsten rod electrodes. The E-field values between the electrodes were obtained by simulation using Amaze-3D software. The formation of nanopores and their extended lifetime were verified by fluorescent detection of cell uptake of Tl⁺. An obvious advantage of using Tl⁺-dependent fluorescence as compared to common Na⁺, K⁺, or Ca²⁺ detection techniques is that Tl⁺ is not present in living cells in any considerable amount; hence, even very small amounts of Tl⁺ entering from the outside can be detected. Real-time imaging of Tl⁺ uptake by cells was accomplished using a FluxOR™ Thallium Detection Kit (Invitrogen, Eugene, OR). Cells were loaded with a Tl⁺-sensitive fluorophore as per manufacturer’s instructions. For nsEP exposure, cells were transferred into a bath buffer containing 16 mM of Tl⁺. The same buffer but without Tl⁺ (replaced with an isoosmotic amount of Cs⁺) was used for negative control measurements and as a holding bath buffer when Tl⁺ application was delayed.

To distinguish between lipidic nanopores and activation of endogenous ion channels, we employed a test for fast externalization of phosphatidylserine (PS) residues. In healthy undisturbed cells, PS are only found on the internal leaflet of the cell membrane; they can “flip” into the external leaflet by either enzymatic action in the course of apoptosis, or by drifting out along the surface of a lipidic pore. PS externalization will not result directly from activation of any protein ion channel when no lipidic pore is formed. Externalization of PS
was visualized by Annexin V-FITC binding.

In most experiments, the bath buffer also contained 30 or 40 µg/ml of propidium iodide. The lack of propidium uptake by nsEP-treated cells was interpreted as a proof that membrane pores are too small for propidium passage. In other words, the lack of propidium uptake distinguished nsEP-opened nanopores from conventional (larger) electropores which are readily permeable to propidium.

The dyes were excited with a blue laser (488 nm). Emission was recorded at 605 nm for propidium and at 530 nm for Annexin V-FITC and Tl^+ fluorescence signals. The images were quantified with MetaMorph v. 7.5 (MDS, Foster City, CA).

RESULTS

To prevent potential Tl^+ entry through voltage-gated K^+ channels (in an unlikely case if these channels are activated by nsEP and remain open for minutes), the bath buffer contained high concentrations of several K^+ channel antagonists. Under these conditions, an immediate, dose-dependent surge in Tl^+ uptake was readily detected when cells were exposed to nsEP in a Tl^+ -containing buffer. Importantly, Tl^+ uptake was triggered at the E-field intensities far below the threshold for propidium uptake.

In a different set of experiments, cells were stimulated by nsEP in a solution that contained an isoosmotic quantity of Cs^+ instead of Tl^+, so that no immediate change in cell fluorescence occurred. The time course of resealing of nanopores was probed by the addition of the Tl^+ -containing bath buffer at various intervals after nsEP. The experiments established that nsEP-treated cells remain highly permeable to Tl^+ even 5-10 min after the nsEP stimulation.

NsEP treatment caused PS externalization within seconds, which is much faster than through activation of apoptotic cascades. Hence, PS externalized by drifting via lipidic pores and, notably, this process was not necessarily accompanied by any propidium uptake. More severe nsEP treatments (e.g., 5 pulses at 14 kV/cm) resulted just in borderline propidium staining, whereas a chemical poration of the membrane with digitonin caused immense propidium uptake and saturation of the fluorescence detector.

CONCLUSIONS

In this study, we verified the formation and extended lifetime of nanopores by non-electrophysiological methods, namely by fluorescent detection of Tl^+ uptake and of PS externalization. The results provided strong support to earlier findings using patch-clamp that nsEP stimulation is an efficient method to produce nanopores in cell plasma membrane, and that the lifetime of nsEP-opened nanopores is on the order of minutes.

ACKNOWLEDGMENTS

The work was supported in part by R01CA125482 from the National Cancer Institute, by Air Force Research Laboratory Fellows funding from Michael R. Murphy, and by HQAF SGRS Clinical Investigation Program (Neurological Impacts of Nanosecond Electric Pulse Exposure).
SINGLE NANOSECOND ELECTRIC PULSE-INDUCED INFLUX OF CALCIUM INTO ADRENAL CHROMAFFIN CELLS REQUIRES EXTRACELLULAR SODIUM

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INTRODUCTION

Recently we reported [1] that in electrically excitable adrenal chromaffin cells, exposure to a single 4 ns duration electric pulse at electric field intensities ranging from 2 to 8 MV/m increases intracellular calcium via entry of calcium into the cells, rather than releasing calcium from internal stores as has been reported for other cell types. We further observed that the pulse-induced influx of calcium could be blocked by a high concentration of nitrendipine, a selective blocker of L-type voltage-gated calcium channels. The results presented here provide additional insight into the mechanism underlying the nanoelectropulse-induced influx of calcium into chromaffin cells.

MATERIALS AND METHODS

Fluorescence imaging was used to monitor intracellular calcium levels during nanosecond electric field exposure. For these experiments, chromaffin cells were loaded with the calcium fluorophore Calcium Green-1 (1 μM) in a balanced salt solution (BSS) containing 0.1% bovine serum albumin for 1 hour in the dark at 37 °C. Following incubation, the cells were washed and resuspended in dye-free BSS and an aliquot of the cells loaded into microelectrode chambers fabricated as described in [2] using gold instead of platinum as the electrodes. Observations of the cells during pulse exposures were made in real-time with a Nikon TE2000 epifluorescence microscope where fluorescence images obtained before, during and after nanosecond field exposure were captured and analyzed with a Photometrics CoolSNAP_HQ CCD camera and SimplePCI imaging software. A fast-recovery diode-switching NanoPulser that was designed and fabricated at the University of Southern California [3] delivered 5 ns pulses directly to the microchamber electrodes on the microscope stage in ambient atmosphere at room temperature.

For assessing further the involvement of L-type calcium channels in the nanoelectropulse-induced influx of calcium, cells were incubated at varying concentrations of each of two dihydropyridine L-type channel blockers, nitrendipine and nimodipine, for 30 minutes prior to pulsing. Sodium-free BSS was prepared by replacing NaCl with osmotically equivalent amounts of either choline chloride or N-methylglucamine (NMG).

RESULTS

As previously reported, 20 μm nitrendipine blocked the pulse-induced increase in intracellular calcium. Similar results were obtained for 20 μm nimodipine. When the concentration of each dihydropyridine was reduced to 10 μm, which is still considered high for blocking cellular responses involving L-type channels in these cells, the effectiveness of
each blocker to inhibit the rise in calcium was substantially decreased. Nitrendipine and nimodipine at 5 µm similarly reduced the response substantially but did not abolish it. These results showing that only a high concentration of dihydropyridines produces total inhibition of the nanoelectropulse-induced calcium response suggest more complex effects at the plasma membrane than simply activation of L-type calcium channels. Because voltage-gated calcium channels typically are activated by cell depolarization as a consequence of sodium influx via voltage-gated sodium channels, experiments were conducted in the absence of sodium to determine whether the nanoelectropulse-induced influx of calcium would be affected. Replacement of sodium with either choline or NMG produced almost total inhibition of the rise in intracellular calcium, indicating that sodium influx precedes the entry of calcium into the cell.

CONCLUSIONS
The present study shows that the mechanism by which calcium enters chromaffin cells in response to a single nanoelectropulse is coupled to sodium influx. Whether this finding is an indication that the pulse causes cell depolarization awaits further investigation, and experiments to determine whether sodium influx occurs via voltage-gated sodium channels or instead via the formation of nanopores in the plasma membrane are underway.

ACKNOWLEDGMENTS
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REFERENCES
Microchamber Set-Up for Real Time Studies of Biological Structures In Presence of Electromagnetic Fields

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INTRODUCTION

The use of electromagnetic (EM) fields applied to specific microscopic biological targets appears to be a key point for future nano-medicine applications, in particular, it is known that electric pulses in the range of micro-nanoseconds and kilovolt-per-meter can induce reversible membrane breakdown (transient poration) letting normally excluded molecules and nanoparticles to pass through cell membrane [1, 2]. Laboratory procedures for in vitro studies on electropermeabilization require appropriate electrode chambers to achieve proper working conditions: an EM-field between electrode plates uniform as much as possible and a flexible pulse generator, able to deliver short or ultra-short electric field pulses in precisely tailored amplitudes, durations and patterns. In this work we provide a complete description of the initial steps necessary to build an exposure chamber suitable to treat nanosecond, megavolt-per-meter pulses.

MATERIALS AND METHODS

In order to construct our micro-chamber exposure system a ten-step microfabrication procedure has been followed:

1. Silicon anodization (adding of porous silicon)  
2. Metal (Cr⁺) deposition (sputtering technique)  
3. Photoresist spinning  
4. UV exposure  
5. Photoresist developing  
6. Metal wet etching  
7. Photoresist removing  
8. Dry etching (RIE)  
9. Partial porous silicon oxidation  
10. Metal deposition

In particular, Fig. 1 shows steps #4 and #10, where the structure and materials of our micro-engineering procedure are shown. Nevertheless, step #9 can be replaced by a Displacement Technique (substitution of porous silicon with desired metal) to obtain a floating metal structure, not hooked up to silicon substrate, ready to match a glass plate for optical observation. In order to obtain a detailed picture of the micro-chamber, imaging interferometry has been used, obtaining a 3D representation of the given object with very good resolution (nanometers).

RESULTS

Fig. 2 represents the result of the microfabrication process as observable by a ZoomSurf3D interferometer (Fogale Nanotech): note the trapezoidal shape of metal electrodes, adopted to minimize border effect and to optimize electric contact with any external pulse generator. In addition a cross-section profile is presented in Fig. 3, pointing out that gap length between the two electrodes is very short (∼80 µm), allowing to obtain high E-fields with relatively low-voltage generators. This structure has been simulated with Comsol Multiphysics v3.5 to evaluate the fields between the electrodes. Fig. 4 shows the field distributions in the gap from...
above and in cross-section, showing that a uniform field is applied the biological samples.

Figure 1: Micro-engineering procedure followed (UV exposure and metal deposition steps are shown)

Figure 2: Interferometric image: trapezoidal microchamber

Figure 3: Cross section profile of electrodes’ gap

Figure 4: Field profile from above and in cross-section of the gap

CONCLUSIONS
An electrode micro-chamber suitable for in-vitro experiments has been fabricated with the purpose to investigate the immediate response of biological structures in presence of external electric fields (static or pulsated ones). This represents the first step to build a complete experimental set-up suitable for laboratory studies related to new nanopulses techniques.

REFERENCES
An Integrated Job Exposure Matrix For Exposures To Magnetic Fields, Electric Fields, Nuisance Shocks, Contact Currents and Electrical Injuries

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INTRODUCTION

Electric utility workers experience exposure to electrical factors associated with the generation, transmission, distribution and use of electricity. Exposure assessments and epidemiological studies in the last two decades have developed job exposure matrices (JEM) for power-frequency magnetic fields (MF) and, to a lesser extent, electric fields (EF) for workers in electric utilities and in other industries. The studies have commonly used job category or job title as a surrogate for EF and/or MF exposure.

The objective of this investigation was to develop an integrated JEM for electric-utility workers that included all electrical factors related to the power-frequency currents and voltages found in electric-utility workplaces. These comprise 50/60-Hz MF, 50/60-Hz EF, perceivable nuisance shocks, imperceptible contact currents, and electrical injuries (electric shocks, electrocution, and flashburns resulting from the intense heat of an electric arc). Except for electrical injuries, no direct link has been established between exposure to these agents and risk of adverse chronic health outcomes. However, all these exposures have been recognized or suggested as potential health and safety risk factors.

MATERIALS AND METHODS

The job categories used in the Electric Power Research Institute (EPRI) Occupational Health Surveillance Database (OHSD) [1, 2] were selected for the integrated JEM, because of their compatibility with job categories in studies with personal exposure (PE) data for EF and MF and the availability of electric injury data in the OHSD. MF and EF exposures were based on PE measurements from a large multi-utility exposure assessment [3], and were analyzed using standard techniques to estimate exposure by job category. EF PE data represent perturbed EF at the surface of the body, and can only be used to assign exposures in a relative, not an absolute sense. Electric-injury exposures were based on reported annual rates by job category [2]. Data on nuisance shock occurrence are very limited, consisting of line worker responses to surveys implemented by the authors and anecdotal reports. Exposure data for contact currents are entirely lacking and estimates for this factor were based on knowledge of the environments and conditions conducive to their production.

The diverse sources of data and relative nature of EF PE data prompted the use of an ordinal scale for ranking exposures to all five factors. For demonstration purposes data were characterized by three ordinal categories, Low (L), Medium (M), and High (H), to describe exposures of by job category. For parametric variables, the geometric mean exposures by job category were sorted in ascending order, and the Partitioning Around Medoids (PAM) clustering procedure was applied to divide them into the three exposure groups [4].
RESULTS

The rankings for all electrical factor exposures by job category are given in Table I. With one exception (Welders), the High exposures for all factors are limited to four job categories that work near electrical equipment: cable splicer, electrician, line worker and substation operator. Eight job categories had Low exposures for all factors and are not listed. Adjustments to the default MF and EF exposures for work environment were derived but are not shown.

Table I: Exposure Rankings for All Factors by Job Category

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Magnetic Field</th>
<th>Electric Field</th>
<th>Nuisance Shocks</th>
<th>Contact Currents</th>
<th>Electric Shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable splicers</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Custodians/Cooks/Security</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Drivers/deliverers/inspectors/patrol</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Electricians</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Foremen</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Line workers</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Maintenance workers</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Material handlers/porters</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Mechanics</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Meter readers</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Other technicians</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Plant and equipment operators</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Substation operators</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Welders</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>H</td>
<td>H</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The proposed integrated JEM for electrical utility workers included exposures to MF and EF, nuisance shocks, contact currents, and electrical injuries. For MF and EF, data were sufficient to populate the matrix; for electrical injuries, the estimates provided valid entries with the prospect of improvement as the EPRI OHSD expands. Data quality was less optimal for nuisance shocks and contact currents, for which more study is required to validate the matrix entries. Linkage of the job classification scheme to that of the EPRI OHSD provides a resource for including electrical as well as chemical and other agents in a holistic approach to exposure assessments.

ACKNOWLEDGMENTS

Employees of Southern California Edison and American Electric Power Corporation conducted and participated in the nuisance-shock surveys. Michael Kelsh of Exponent assisted with analysis and interpretation of data in the EPRI Occupational Health Surveillance Database. This work was performed under EPRI Contract EP-P11573/C5739.

REFERENCES

INTRODUCTION

monIT [1] is a Portuguese project on risk communication aiming at providing public information on exposure to Electromagnetic Fields (EMFs) from mobile communication systems. During measurement campaigns near mobile communications base station antennas, it was found that fluorescent and compact fluorescent lamps are also important sources of radiation to take into consideration in indoor environments. With the purpose of saving energy, modern fluorescent and compact lamps use electronic ballasts operating at high frequencies. However, the high frequency currents generated to increase lamp efficiency can originate significant radiated noise, since the whole lamp acts like an antenna. More than increasing EMF levels in the surrounding environment, the radiated emissions from ballasts may cause interference with other devices.

MATERIALS AND METHODS

The objective of this study is twofold. On the one hand, it intends to analyse EMF spectrum radiated by compact fluorescent lamps, and on the other, it aims at evaluating their compliance with European EMF exposure thresholds [2].

The EMF levels radiated by two compact lamps are analysed. A specific measurement procedure was developed in order to conduct the study. Measurements were performed at increasing distances from the lamp, i.e., exactly under the lamp, Position 1, and at 0.5 and 1 m away from the lamp, Positions 2 and 3. As the overall dimension of the lamps under study is very small compared to the wavelengths, measurements are performed in the near-field zone. At Position 1, measurements were conducted considering three states: DISC - device disconnected from power supply; LOFF - Device connected to power supply and light off; LON - Light on. At Positions 2 and 3, only LON was considered.

For all scenarios, detailed frequency measurements were carried out using the Narda SRM-3000 spectrum analyser [3] with uniaxial electric, $E$, and magnetic, $H$, field probes, both working in the [0.1, 300] MHz band. The Anritsu MS2601B spectrum analyser [4] was also used, working in the [0.009, 2200] MHz band.

RESULTS

In Fig. 1, $E$ field measurement results are presented, for Lamp 1 in Position 1; Lamp 2 presents similar values, with the same behaviour. Measurements show that lamps exhibit significant radiation levels. Moreover, results show an increase of $E$ field levels when a lighting device is simply connected to power supply with the light off.

When the light is turned on, a significant increase of $E$ field levels is observed. These results were observed for both lamps, although with slight different frequency spectra.

For both lamps, a significant contribution in the [0.1, 1] MHz band can be observed. So, additional measurements were performed in the [100, 800] kHz band, in order to identify the
various harmonics in a more accurate way, Fig. 2, being seen that they are spaced 40 kHz from each other.

The compliance evaluation for \( E \) field measurements for both lamps was made and the total exposure ratios, considering the overall measurements, are presented in Table 1. According to [2], the total exposure ratios referred to electrical stimulation effects and to thermal effect circumstances must be calculated, and should be lower than 1. It can be seen that the total exposure ratios are larger for Lamp 2, which can be explained by its higher power, and that the levels from both lamps are in compliance with the thresholds.

Table 1. Total exposure ratios.

<table>
<thead>
<tr>
<th>Electrical stimulation effects</th>
<th>Lamp1</th>
<th>Lamp2</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1 \text{ MHz} )</td>
<td>( \sum_{i=1}^{1 \text{ MHz}} \left( \frac{E_i}{E_{lim}} \right) ) + ( \sum_{i=1 \text{ MHz}}^{10 \text{ MHz}} \left( \frac{E_i}{E_{limup}} \right) )</td>
<td>0.18424</td>
</tr>
</tbody>
</table>

CONCLUSIONS

EMF radiation measurements in the \([0.1, 5]\) MHz band show that compact fluorescent lamps used every day in homes, workplaces, subways, shopping centres and so on, exhibit significant levels at low frequencies. For the two lamps under study, the significant levels are found in the \([100, 800]\) kHz band. Additional measurements carried out in frequencies below 100 kHz enabled the identification of the frequency of operation of electronic ballasts. The two lamps under study were chosen with different powers, which allowed one to verify the relation between lamp power and radiated EMF levels. As expected, the analysis of results shows that, in the immediate vicinity of a lamp, EMF levels radiated by lighting devices depend on the lamp power. Finally, one can conclude that EMF levels from both lamps are in compliance with the EMF reference thresholds.

REFERENCES


A Scientific Approach to RF Safety Harmonization

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INTRODUCTION

In the last twenty years, with the growth of the international trade and of the rapid diffusion of wireless products, the existence of substantially different safety standards has become a major problem. We consider the harmonization of these standards an issue needing urgent attention. The first step towards the solution of the harmonization problem is the definition of a common science-based dosimetric approach. It will consist in finding a common link between the two current science-based dosimetric approaches: specific absorption rate (SAR) and a metric of EMF biological interaction with living tissue.

ICNIRP EXPOSURE ASSESSMENT AND DOSIMETRY

The exposure metrics of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) require the measurement of electric, magnetic field strength and power density (PD). In the frequency band 100 KHz-10 GHz, the ICNIRP basic restrictions \cite{1} hinge on the concept of specific absorption rate (SAR) which is defined as

\[
\text{SAR} = \frac{\sigma E^2}{\rho} = c_i \frac{dT}{dt}
\]

where $E$ is the RMS value of the electric field in tissue, $\sigma$ and $\rho$ are the tissue conductivity and mass density. In (1) also, $c_i$ and $\frac{dT}{dt}$ are the specific heat of tissue and the time derivative of the temperature at the onset of the RF exposure.

SAR measures the rate of EMF energy absorption in the unit of weight of an exposed object. SAR is used to quantify tissue exposure from EMF in the far and the near field of RF sources, where PD might not be defined or even definable. The SAR basic restrictions of ICNIRP are time independent because the rate of energy absorption is limited, not its total amount.

Russian Exposure Assessment and Dosimetry

The Russian approach to exposure assessment and dosimetry has two main differences from those of ICNIRP. First, the concept of SAR was never adopted, because near field measurements were not required until recently. The near field evaluation is performed by computations extrapolating the far field measurement values using theoretical equations. Second, the dosimetry is based on the parameter “power exposition” (PE) which is a dynamic estimate of the EMF biological effects from the exposure. This parameter differentiates the exposure dose during a given time interval. In other words, the Russian exposure limitations consider cumulative the biological effects of RF EMF. PE values depend on time, field level and frequency range using the formulas:

\[
PE_E = E^2 \cdot t \quad PE_H = H^2 \cdot t \quad \text{(for 300 kHz – 300 MHz)}
\]

and

\[
PE_{PD} = PD \cdot t \quad \text{(for 0.3 GHz – 300 GHz)}
\]
The values of $PE_E$, $PE_H$, $PE_{PD}$, and $t$ are given in [2].

The Russian exposure limitation approach and its dosimetry aim to avoid any unfavorable biological effects caused by chronic exposure. This approach defines a dose-dependent biological action of RF EMF and, so, a dependence of time and intensity of the safe RF exposure.

ADVANTAGES AND DISADVANTAGES OF THE TWO APPROACHES

Undoubtedly, both approaches have merits and drawbacks. The ICNIRP approach necessitates SAR measurements on simulated humans (phantoms). The phantoms used in the measurements do not simulate the details of the human anatomy (fine multilayered structures, blood vessels, innervations). On the positive side, it is possible to measure SAR in the near and far field of RF sources. SAR maps the distribution of the EMF absorption in tissue, with the peak value (“hot spot”) locations. The SAR distribution helps in pinpointing interaction sites, valuable information when assessing the cause of a detected biological effect in animals.

The Russian dosimetry has a major weakness in the evaluation of the near field exposure. With few exceptions, near E and H-field values cannot be reconstructed from far field measurements, because the same far field patterns can be supported by RF sources with very different near fields. The Russian approach has not adopted a dosimetric parameter like SAR; so the “hot spot” of an exposure object are undetected. However, the Russian approach has a dose-dependent science-based exposure safety criterion in PE, which is based on PD measurements and exposure time. PD is a measure of RF EMF exposure for both standards. However PE is more useful in survey situations than PD, since it does not require further exposure evaluations using phantoms. The safety determination of far field exposures is immediate.

SUGGESTED PLAN OF DOSIMETRY HARMONIZATION

Undoubtedly SAR is one of the most useful tools for the assessment of RF EMF distribution during exposure. Therefore SAR should be the fundamental dosimetric parameter in the harmonization process. The PD is one of the characteristic EMF. Some PE criteria might be a key to the correlation between biological effects and the two different approaches of dosimetry. This correlation requires the use of different methods such as numerical simulation, phantom measurement and the detection of predefined biological effects from cell culture to whole organisms. Finding this correlation is possible for far field and near field exposures using the more convenient dosimetric parameter and calculating the other. Definition of similar unequivocal interrelation between SAR and PE will allow the development of more adequate approaches to dosimetry harmonization of Russian and international standards.

SAFETY STANDARD HARMONIZATION

Safety standard harmonization is much more complicated than the harmonizing dosimetric criteria. Safety standard setting includes the mediation of various concerns and interests, such as political, economic, technological and etc. However a necessary basis is one dosimetric approach with accurate substantiation of measurement methodologies. A synthesis of the positive features of the two existing dosimetric approaches in a uniform concept will create a base for a new step to safety standard harmonization.

REFERENCE

Static Magnetic Field Blood Pressure Buffering, a Potential Clinical Implication

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INTRODUCTION

Sudden elevation in blood pressure (BP), even in the absence of elevation in average BP or “true” hypertension, has been identified as an independent cardiovascular risk factor. We measured the effect of static magnetic field (SMF) on abrupt elevation in BP (BP_{AE}) in conjunction with arterial baroreflex sensitivity (BRS) and microcirculation.

MATERIALS AND METHODS

Twenty four experiments (10 controls and 14 with SMF) were performed in conscious rabbits sedated using pentobarbital (PEN) infusion (5 mg kg^{-1} hour^{-1}). Mean femoral artery BP, heart rate (HR), BRS and ear lobe skin microcirculatory blood flow, estimated using microphotoelectric plethysmography (MPPG), were simultaneously measured before and after a 40 min exposure of the sinocarotid baroreceptors to 350 mT intensity SMF, generated by Nd₂–Fe₁₄–B alloy magnets. BRS was assessed from HR and BP responses to i.v. bolus of nitroprusside and phenylephrine, Fig. 1.

Figure 1: Upper panel: SMF, recordings following local action of a 350 mT static magnetic field (SMF) on
P-12

Results and Discussion

After SMF exposure, baroreflex-mediated HR increase, due to the same dose and hypotensive as the control pre-SMF exposure bolus injections of nitroprusside (Ni3, Ni4 before vs. Ni3, Ni4 after SMF exposure) was significantly larger, indicating an increase in BRS for nitroprusside, BRSNi (Fig. 1). In addition, a notable rise of the microvascular blood flow (MPPG) synchronized with an HR swing out, was observed. This indicates that an increase of the baroreflex stimulus-induced microcirculatory response is existing. After SMF exposure a marked increase in HR variability (HRV) is apparent. In the control runs, no change in baroreflex-mediated HR and microcirculatory response (Ni3, Ni4 after sham exposure) or in HRV was observed (Fig. 1). Analysis of percentage BP decrease revealed that SMF significantly reduced phenylephrine-induced abrupt elevation in BP compared with control experiments with sole pentobarbital infusion (ΔBPAE-SMF% vs. ΔBPÆ-PEN%, -0.83±5.4% vs. 21.1±7.65%, p < 0.017, Man-Whitney rank sum test). A significant inverse correlation was also found between SMF-induced decrease in BP abrupt elevation (ΔBPÆ%) and increase in BRS for phenylephrine (ΔBRSph%) (r=0.40, p<0.032).

Discussion and Conclusions

The principal finding in this study that SMF buffer abrupt elevation in BP effectively. SMF BP buffering is a result of direct magnetic stimulation of the sinocarotid baroreceptors and activation of the arterial baroreflex cardiovascular control mechanism, reflected in the simultaneous increase in BRS and HRV [1], and in baroreflex-mediated microcirculatory response (Fig. 1). Theoretical considerations suggest that the applied SMF may influence sinocarotid baroreceptor sensory transduction, modifying the baroreceptor Ca^{2+}-dependent gated depolarization region as well as stretch activated Ca^{2+} channels on the baroreceptor spike initiating zone [2].

Low BRS and HRV are an important independent cardiovascular risk factors [1], therefore an increase in BRS and HRV, along with enhanced BP buffering, suggests SMF to show potential cardioprotective properties. Further research is needed, because it is likely that contactless magnetic stimulation of the arterial baroreceptor cardiovascular regulatory system by easily accessible sinocarotid triangle opens new possibilities how to complexly adjust macro and microcirculation, ameliorate the arterial hypertension, cardiac disrhythmias and the vasoconstricitive state that are characteristics for various important cardiovascular conditions including ischemic heart disease, diabetes and others.

Acknowledgments

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References


Influence of Whole Body Exposure of 914 MHz RFID on the Secretion of T3, T4, and Thyroid Stimulating Hormone in Rats – Preliminary Results

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INTRODUCTION

The Radiofrequency identification (RFID) is now being used in a variety of public and private sector settings, from hospital to highway and its application scope and utility is continuously expanding. Therefore, it needs proper investigation about the potential risks of RFID to human healthy. Thyroid hormones are one of the most critically important hormones to maintain the normal biologic activities. In this study, we investigated whether the 914 MHz RFID exposure to rats can cause any changes in serum level of thyroid hormones such as T3 and T4, and Thyroid stimulating hormone (TSH).

MATERIALS AND METHODS

A reverberation chamber was designed and constructed as a whole-body exposure system for animal study at 914 MHz RFID (Eretec Inc, Ansan, Korea) (Figure 1). The SAR distribution inside the experimental animals, which is located in the non-metallic cage on the table in the chamber, was estimated (Jung et al 2008). The validity as whole body exposure system has been verified under supervision of Korea Electromagnetic Engineering Society (KEES).

Sprague-Dawley rats (250gram, male) were used for this experiment and were divided as two groups; a sham-exposed control group (placed in the chamber without RFID exposure, n=13) and a 914 MHz RFID exposed group (n=14). Whole-body average specific absorption rate was 2.0 watt/kg for RFID 914 MHz in this trial. The rats were exposed for 8 hours daily, 5 days a week for 2 weeks that is extremely high energy exposure system to detect in vivo changes of thyroid hormones and TSH. Rats were sacrificed and serum was collected after 2 week-exposure. Serum level of thyroid hormones (T3 and T4) and TSH were investigated using metabolomic analysis with GC-MS. Differences between control and exposed groups were analysed using a Student’s t-test.

RESULTS

A reverberation chamber as whole-body exposure system was verified. The estimated whole-body SAR values were 0.44~2.16w/kg (Input-power range: 10~60W).

Our preliminary results demonstrate significant increase of serum T3 (p<0.0007), T4 (p<0.04) and TSH (p<0.02) significantly in extremely high energy long-duration RFID exposed group (Figure 2).
CONCLUSIONS

Although repeated experiments and further evaluation such as analysis of subcellular level are needed, our preliminary results show that long-duration (8 hours) in high energy exposure system (whole body SAR 2 W/kg) per day for 2 weeks cause increased secretion of thyroid hormones and TSH.

REFERENCES


Abnormality of synaptic vesicular associated proteins in cerebral cortex and hippocampus after microwave radiation

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INTRODUCTION

Microwave as new techniques are increasingly used in the telecommunications, industry, medicine, and so on. There has been a growing concern among the public regarding the potential human health hazard of exposure to the microwave fields. Based on clinical and experimental data, it was claimed that microwave might produce a variety of adverse effects in vivo (e.g. headaches, sleep disturbances, even brain tumors) and alter cognitive function. But little is known about the mechanisms which underlie the cognitive perturbation of microwave exposure. Learning and memory are important aspects of cognitive function, in which the synaptic plasticity plays an essential role in this process. Among the synaptic vesicular associated proteins, it is believed that synapsin I, vesicle-associated membrane protein (VAMP), synaptosome-associated protein of 25000 (SNAP-25), syntaxin and synaptophysin play an important role in the exocytosis. But it is unclear if these synaptic vesicular associated proteins are altered under microwave exposure and the potential mechanisms which show the relation between the change and the injury of learning and memory is still unkown.

MATERIALS AND METHODS

25 Wistar rats were exposed to microwave which the average power density was 30mW/cm\textsuperscript{2} and whole body average specific absorption rate was 14.1W/kg for 5 minutes. Synaptosome preparations in the cerebral cortex and hippocampus were obtained by isotonic Percoll/sucrose discontinuous gradients at 6h, 1d, 3d and 7d. The expression of synaptic vesicular associated proteins was quantified by Western blots and image analysis. The interaction between VAMP-2 and syntaxin was examined by co-immunoprecipitation analysis. The interaction between VAMP-2 and syntaxin was examined by co-immunoprecipitation analysis.

RESULTS

Synapsin I in the cerebral cortex were decreased at 3d (p<0.01) after radiation, and in the hippocampus increased at 1d (p<0.01), decreased at 3d (p<0.01), increased again at 7d (p<0.01) after exposure, compared with the sham-treated controls. Synaptophysin were increased in 1d-7d (p<0.01) after exposure in the cerebral cortex and hippocampus. VAMP-2 were decreased at 1d and 3d (p<0.01) and syntaxin were decreased in 6h-3d (p<0.01) after radiation in the cerebral cortex and hippocampus. The interactions between VAMP-2 and syntaxin were decreased at 3d-7d (p<0.01)
after radiation in the cerebral cortex and hippocampus, compared with the sham-treated controls.

CONCLUSIONS

These results suggest 30mW/cm² (SAR 14.1W/kg) microwave radiation can result in the perturbation of the synaptic vesicles associated proteins: synapsin I, synaptophysin, VAMP-2 and syntaxin. The perturbation could induce the deposit of synaptic vesicle which might be relative to the disfunction of the synaptic transmission, even the cognition deficit.

ACKNOWLEDGMENTS

We are grateful to Dr. Ruibiao Yang, University of Denver, for kindly providing the anti-VAMP-2 and anti-syntaxin antibodies for this work.

REFERENCES


**Introduction**

The present study was undertaken to investigate whether a 900 MHz GSM cell phone long term irradiation might affect the mollusk single neuron ability to store information.

**Materials and Methods**

35 mollusks Helix Pomatia were exposed to radiation of GSM-900 MHz cell phone in the TEM-cell for two hours everyday for 2 months. The output power of the cell phone was controlled using test card. The animals were not awake during the exposure and did not move within the exposure chamber. The peak output power fed into the TEM cell was 1.7 W resulting into average whole body specific absorption rates (SAR) of 100 mW/kg or 300 mW/kg. SAR was calculated using FTDT method.

A further 15 animals served as a controls, which were sham exposed. After 2 months exposure, identified neurons from the animals were subjected to electro-physiological investigations.

Two identified giant neurons were selected for observation. Standard microelectrode technique was used. Neuron was impaled with two glass microelectrodes. One microelectrode served for registration, another one - for intracellular stimulation. Stimulant intracellular impulses represented train of depolarizing current impulses.

Neuron activities were recorded using the POWERLAB data acquisition unit "ML 866" of Adinstruments Co, accompanied with “Chart 5” software.

Action potential (AP) inter-spike intervals, AP peak parameters, latency periods and thresholds of AP firing were determined. Habituation dynamics to identical stimulus of sham
and actually irradiated neurons were compared. Habituation is regarded as a form of non-associative learning. Thereby habituation of the single neuron to the intracellular stimulation might be regarded as storage information by the single neuron.

RESULTS
The experiments show that the dynamics of habituation of sham and actually irradiated neurons to intracellular stimulation are similar. The average numbers of AP triggered as a result of stimulation are approximately equal. The time necessary for the onset of habituation are also approximately the same. Average value of the AP thresholds for sham and actually exposed identified neurons are approximately equal. AP peak parameters are approximately similar.

CONCLUSIONS
The facts that dynamics of habituation for sham and exposed neurons are similar might indicate that some adaptation of the neuron to repeated exposures can occur. Thereby a 900 MHz GSM cell phone long term irradiation in above mentioned doses dos not change neuron ability to store information.
Changes in Rat’s Duodenum Under the High Power Pulse Magnetic Field Exposure

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INTRODUCTION

Magnetic stimulation (MS) where a high power pulse magnetic field (PMF) is used; is a comparatively new method of examination and treatment in different branches of medicine: neurology, psychiatry, urology, rehabilitation medicine, sports medicine etc [1]. The magnetic field during the procedure typically has a strength about 2 T or even more. Hence, apart from stimulation of the target organs, adjacent tissues are under the magnetic field influence as well. The aim of our research is to study reaction of gastrointestinal mucosa on the magnetic stimulation of rat’s abdominal cavity organs as well as investigation of the duodenum endocrine cell reaction as an epithelial cells population responsible for the regulation of intestinal activity by changing their number and possibly their phenotype under different pathological conditions [2].

MATERIALS AND METHODS

The experiment was performed on the 35 albino rats with initial weights of 150-200 g, which were divided into 7 groups: 3 experimental, 3 control on which sham application was done and 1 untreated group (intact). The experimental animals were exposed to 1,5 T, 2.5 Hz PMF in that way that center of the coil of inductor was placed immediately under the abdomen cavity of fixed animal. Procedure lasted for 10 min per day for 2 weeks except weekends with a total of 10 procedures. Pieces of duodenum were collected on the 1st, 7th and 14th day after the last exposure, and after standard histological processing examined by light microscopy. Hematoxilin and eosin staining was used to reveal the typical pathological processes, methods of Grimelius and Masson-Hamperl were used for examination of the total endocrine cell population and EC-cell population respectively. Endocrine cells in 100 fields of vision (X90) were counted and results were recalculated as cells/mm² of epithelia. The Kruskall-Wallis test was used with p<0.05 as criterion for statistical significance.

RESULTS

On the 1st day after the experiment ended, different pathological changes in rat duodenum were observed: subtotal atrophy of mucosa with lack of villi on the major portion of the section, thinning of mucosa, lower and thicker residual villi when compared to intact or sham rats. Additional observations included, dilatation and thrombosis of blood vessels of various sizes in the mucosal and muscular layers, flattening of surface epithelia and eosinophilic contents in the crypts. Focal dystrophic changes in the deep epithelia and in crypts which reveal cell granular atrophy, pale cell cytoplasm, lack of cell nucleus and cell death in number of crypts were also visible. In some foci these changes reach more then 5-7 crypts in the focus, and there were many of such foci in the section. On the 7th and 14th day these pathological changes disappeared with the exception of some dilated and thrombosed vessels
in mucosa and muscular layer and focal cell atrophy without cell death. But these occurrences were much smaller compared to that on the 1st day.

Reaction of the endocrine cell population is showed in fig. 1 which reveal on the 1st day significant increase of EC-cells while the total population of endocrine cell had only tendency of increasing against control animals and no changes against intact. Increasing of EC-cells with no tendency in the total population reveals latent decreasing of the other type of endocrine cell. On the contrary there was clear increasing of total endocrine cell population with no alteration in EC-cells on the 7th day that is indicate to increasing of decreased on the 1st day total endocrine cells population except EC-cells. And on the 14th day both the total population and EC-cells were significantly increased.

CONCLUSIONS

We observed clear pathological changes in the duodenal epithelia of rats after high power MF exposure. All these pathological changes are thought to be not due to direct cell damage under MF exposure, but secondary changes as a result of longtime circulatory insufficiency and tissue hypoxia. Thrombosed vessels which were in abundance in the mucosa on the 1st day lead to the lack of oxygen in the particular areas of the tissue and therefore in these areas there were cell atrophy up to cell death in most severe cases. These changes occurred some days before material was taken and was compensated only on the 7th day after the experiment ended. This is because there were little residual effects of circulatory insufficiency and only a few thrombosed vessels in the whole sections of all cases by this time. The clear alteration in the endocrine cell population observed may be one of the mechanisms intended for regulation of reconstitution in the duodenal mucosa.

Thereby we conclude that high power PMF may lead to pathological changes in areas adjacent to MS tissues, particularly in the gastrointestinal epithelia. Therefore further morphological investigations should be carried out before introduction of these apparatus in clinical practice.

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REFERENCES


Alterations in Tissue’s Copper and Zinc Concentrations by Intermittently or Continuously Exposed ELF Magnetic Field

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INTRODUCTION
Physiological processes in organisms can be influenced by nonionizing electromagnetic energy. From the point of view of public health, there is now a growing demand for the studies on possible adverse health effects from the interactions between the human body and electromagnetic fields (EMFs). Epidemiological studies and many laboratory investigations have suggested a link between ELF magnetic fields and cancers specifically childhood leukemia. ELF magnetic fields have been classified as a “possible human carcinogen” by the International Agency for Research on Cancer-IARC [1]. Modifications of ion concentration could contribute to explaining the biological effects of EMF [2, 3]. Copper could have an important role in the development and maintenance of immune system function. Zinc may affect the immune status of animals and humans. The aim of this study was to investigate whether ELF magnetic field’s exposure affects the Cu and Zn concentrations in serum and renal tissues of guinea pigs.

MATERIALS AND METHODS
A total of 18 male, 250-300 gr weighted (10-12 weeks aged) guinea pigs were used. Specially designed Helmholtz coil system was used as source of homogeneous magnetic field [4]. The subjects were divided into control (n=6) and two exposure groups which were exposed continuously (4 hours/day) (n=6) or intermittently (2 hours on/ 2 hours off/ 2 hours on) (n=6) to 50 Hz magnetic field of 1.5 mT for 4 days. Cu and Zn levels were determined by flame atomic absorption spectrometric method. Mann Whitney-U test was applied for statistical analysis.

RESULTS
Increased Cu levels were found in serum and renal tissues which continuously and intermittently exposed to magnetic field. Zn concentration was not affected from magnetic field exposures in serum while Zn level of renal tissue was found decreased with the effect of continuous exposure of magnetic field.

CONCLUSION
In this study, continuous and intermittent exposure to ELF electromagnetic field influenced serum and renal tissues’ Cu distribution. Zn concentration influenced only for continuously exposed magnetic field in renal tissue. These changes could be a risk factor for physiological processes associated with these elements.
ACKNOWLEDGMENT

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REFERENCES


The Influence Of Shielding Of Electromagnetic Field On Regeneration In Planarians Dugesia Tigrina.

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INTRODUCTION

Biological effects of weak electromagnetic fields (EMF) have been insufficiently studied and consequences of exposure of various biological objects to such fields are controversial. However, the phenomenon of weakening ambient EMF is rather frequent as it takes place in industrial buildings, airplanes, trains, spacecraft and other similar applications.

The purpose of this study was to study the effects of shielding from EMF on the regeneration of flat worms and whether such effects are subject to seasonal variability.

MATERIALS AND METHODS

Asexual type of Dugestia Tigrina planaria were used and reproduced by separating the head part of the animal. Planaria were housed in 5 litre flasks filled with a mixture of distilled and tap water (1:2), at 20 degrees Centigrade under dim lights and were fed once a week 10-12 mm long worms with sharp heads were selected for experiments.

Planaria were divided into 3 groups, 30 worms in each: planaria in the first (control) group were allowed to regenerate naturally. Planaria in the second group (experimental group 1) were shielded from EMF 23 hours per day for 10 days. Measurements were taken and maintenance (temperature taking, etc.) performed from 10:00 until 11:00 every day. Planaria in the third group (experimental group 2) were exposed to shielded EMF for only one hour per day – from 10:00 until 11:00, but otherwise kept under conditions identical to those of the control group.

Planarians were dissected with a scalpel while visualized under a binocular microscope. For partial immobilization worms were placed in Petri dishes onto an ice surface covered with filter paper. The growth of the regeneration blastema of the head region was measured using Aver Media TV Capture 98 software and expressed in relative units. All images were captured with WAT-502A camera. Initial stages of regeneration have been described elsewhere (Sheinman et al, 2004). All measurements were conducted during the experimental 10 days, beginning with day one after head separation.

The shielded chamber was constructed from two-layer steel and measured 2x3x2 metres. Coefficient of magnetic attenuation was 3.85 for Z-component and 19.1 for Y component, whereas the electric field was weakened to zero. Attenuation of variable magnetic field in the diapozone of extremely low frequencies 2x for the vertical component and 7x for the horizontal component.

Experimental data was analyzed by non-parametric methods and included median (M), interquartile interval between 25 percentile and 75 percentile that included 50% of values of parameter in question. Analysis of regeneration speed was based upon cumulative data. Validity of data was confirmed by U-test of Mann-Whitney-Wilcoxon.
RESULTS

In the control group, all indeces and regeneration speed were higher in the summer than in the winter. In the summer, the rate of regeneration progressively increased from the 2\textsuperscript{nd} on to the 10\textsuperscript{th} day of observation, whereas in the winter we only noticed a tendency to an increase of the regeneration rate. A rhythmical component was clearly seen in the summer, but remained practically unnoticed in the winter. Moreover, eyes tend to appear earlier in the regenerative process in the summer and synchronously in the majority of animals; in the winter this process is considerably stretched in time.

In the experimental group 1, the following results were recorded: a) in the winter, indeces of regeneration increased 1.5-2 fold regardless of the day (from 1 to 10) of measurement, whereas in the summer only a 20\% increase in the same indeces was noted; b) winter regeneration rate increased 2-2.5 fold on any measurement day, whereas in the summer, a 3-fold increase in regeneration rate was noted on days 6 and 7; c) an increase in the periodic component of the regeneration rate and decrease in time need for eye formation are more pronounced in the winter.

In the experimental group 2, a) winter is associated with a 10\% increase in regeneration indeces, whereas in the summer a 10-12\% decrease of such indeces was recorded; b) the rate of regeneration in the winter increases 2-fold and decreases 12\% in the summer; c) an increase in the periodic component in the dynamics of regeneration indeces is more pronounced in the winter, when the time needed for eye formation is shortened, whereas no change was seen in the summer.

CONCLUSIONS

Shielding of electromagnetic fields alters regenerative processes in planariidae. These effects depend on the duration of shielding and appear to have seasonal variation. During extended shielding, stimulation of regenerative processes is more pronounced in the winter, rather than in the summer. During short-term shielding, changes in the regenerative process appear in phases, which, in turn, are more pronounced in the winter than in the summer.

It is known that the spectrum of EMF registered at the surface of the Earth spans a considerable diapazone of frequencies. Shields, depending on their properties, attenuate not only the permanent ambient geomagnetic field, but also decrease the intensity of EMF of selected frequencies. Therefore, a biological object that is placed in a shielded environment is exposed to EMF frequencies that are different from the ambient EMF spectrum. Changes of biological processes that are noted in the shielded environments may be caused by the absence of some frequencies that cannot penetrate a shield and/or by a decrease of other frequencies that can penetrate a shield.
**Immunomodulatory Effects of Charged ETS in Asthmatic Mice**

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**SUMMARY**

There is growing epidemiological evidence between the electric and magnetic fields (EMFs) and an increased risk of ill health. Corona ions emitted from high voltage power lines can attach at a given rate to atmospheric aerosols, enters the body by inhalation and may then be deposited in the respiratory system and thus may alter the inflammatory responses of the immune system. This study aims to investigate experimentally the effect of charged ETS on the immune system of the asthmatic mice. In our study, the levels of cytokines in charged ETS group and ETS alone exposed group showed no significant difference. There was no significant change in the lung weight and bodyweight in the experimental groups compared to that of control.

**INTRODUCTION**

In recent years the incidence of allergic/atopic asthma has been increasing dramatically in industrialized countries. A variety of causes have been implicated for this increase, including: increases in vehicular exhaust, increased levels of air pollutants, exposure to tobacco smoke, respiratory viral infection, and the recently coined “hygiene hypothesis” [1]. In 1992 the U.S. Environmental Protection Agency (U.S. EPA) concluded that environmental tobacco smoke (ETS) is responsible for the induction of new cases of asthma (2). The extent to which the inhaled particles deposit in the various regions of the respiratory system depends upon the physical factors such as their size, shape and density as well as charge [3]. Adding charge to these aerosols is postulated to increase the deposition on the skin and in the lungs resulting in increased health risk due to image charge effects [4]. Taking this factor into consideration we studied the effect of the charged ETS aerosols on the immune system (IL-4, IL-10, TNF-α, and IFN-γ) of the asthmatic mice.

**MATERIALS AND METHODS**

Female BALB/c mice at 8 weeks of age were immunized and challenged with OVA and aluminum hydroxide to induce asthma. The animals were divided into four groups and were subjected to exposure for one hour/day. Group I—control. Group II—mice exposed to corona discharge. Group III— mice exposed to ETS. Group IV—mice exposed to ETS and corona discharge. ETS exposure was achieved from the side-stream smoke and the ioniser experiments were carried out using a commercially available corona discharge ioniser. The asthmatic mice were subjected to the exposure for 3 days and 3 weeks for short term and long term studies. After the final exposure BAL fluid was collected and cytokine levels (IL-4, IL-10, TNF-α, and IFN-γ) were assayed using ELISA kit. Temperature, relative humidity, EMF and VOCs were also measured. Values are mean ± SD and the significance of difference between mean values was determined by one way analysis of variance (ANOVA).

**RESULTS**
CONCLUSIONS

Our study revealed that the exposure to ETS alone and charged ETS induced significant inflammatory response compared to control. Also the data reveals that the effect of charged ETS was not significant when compared to the ETS alone exposed group. Whereas, mice exposed to Corona discharge alone did not show any significant change in the cytokine levels when compared to the control group. From the above results we conclude that the effect of the corona discharge was negligible which could be attributed due to the low exposure periods.

REFERENCE:
Acute Toxicity of 20 kHz Sinusoidal Magnetic Fields in Rats

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INTRODUCTION
Very recently, interest in the biological and health effects of intermediate frequency (IF) magnetic fields (MFs), has grown because of the increase in public concern about the use of equipment utilizing MFs in the IF range for heating, detecting and switching. Equipment operating at IF are used in industry for sealing, welding by induction heating, household induction heating (IH) cookers (20-100 kHz) and other devices using IF electromagnetic fields. In this study, we investigated the acute toxicity of IF MFs in rats.

MATERIALS AND METHODS
Exposure System
We have developed a 20 kHz MF exposure system for in vivo studies[1]. This system consists of Merritt’s 4-square coil configurations and generates 0.20 mT(rms) vertical and sinusoidal MFs. The length of the sides of the coils is 1600 mm with 26 turns in the outer two coils and 11 turns in the inner two coils. The spatial uniformity of the MFs is more than 98% of the target level within an area of 1.0 m$^3$ (1.0 m × 1.0 m × 1.0 m) located in the middle of each coil. Three wooden square shelves (1.0 m × 1.0 m) were installed in this uniform field space. At the 0.20 mT(rms) exposure, background plus stray MFs in the sham-exposed facility were less than 0.001 microT(rms) at 20 kHz and 0.03 microT(rms) at 50 Hz, respectively.

Animals and MF exposure
Male and female Crl:CD(SD) rats, 7 weeks old, were randomly assigned to MF-exposed or sham-exposed group, 12 rats of each sex in each group. They were exposed to a 20 kHz, 0.20 mT(rms) MFs or sham-exposed for 22 h/day, 7 days/week for 14 days. MF exposure was turned off from 9:30 to 11:30 am to allow animal care and daily clinical observation. The experiment was conducted twice to confirm the reproducibility of the results.

Experimental evaluations
Clinical signs, including abnormal appearances and behavior, were observed once every day. Body weights were measured on day 0, 1, 3, 7, 13 and 14 of MF exposure. At the termination of MF exposure, animals were anesthetized with ether, blood samples were collected from abdominal aorta, and the animals were exsanguinated. Red blood cell count, hemoglobin concentration, hematocrit, white blood cell count, platelet count, mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration were examined. Clinical chemistry variables were measured. Endpoints
included aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), urea nitrogen, creatinine, total cholesterol, triglyceride, glucose, total bilirubin, total protein, albumin, albumin/globulin ratio, calcium, inorganic phosphorus, sodium, potassium, and chlorine. After macroscopic examination, brain, liver, spleen, kidneys, heart, lung, adrenals, thymus, testes (male), epididymides (male), ovaries (female) and uterus (female) were weighed.

RESULTS

Clinical signs and body weight
No animals showed clinical signs of ill health at any time during this study in both experiments. Both groups showed the expected slight increase in body weight over the 14 day period, with no significant differences between the groups.

Gross pathology, organ weight, hematology and clinical chemistry
Sporadic gross pathological lesions were observed in some rats that did not show significant group differences. Hematological variables did not show any significant group differences. Differences in some organ weights and clinical chemistry variables were seen between exposed and sham-exposed groups. However, since these differences were not reproducible in duplicated experiments, these were not considered to be an effect of MF exposures.

CONCLUSIONS
Base on these results, we conclude that the sinusoidal 20 kHz, 0.20 mT(rms) MFs used in this study did not show any acute toxicity in the rats.

REFERENCES
Effect of Electromagnetic Fields exposure on Thyroid Gland Histology and Function in Rats

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INTRODUCTION
An increased prevalence of hypothyroidism associated with thyroid histological alterations has been recently observed in normal population, often associated with a huge variability of symptoms. Thyroid gland plays a crucial role in the complex pathways of human endocrine system and is sensitive to exogenous physical and chemical agents. In the last decade, concerns have been expressed about the safety of exposure to radio frequency electromagnetic fields from handheld communications devices, with particular reference to cellular phone, on human growth and development for long term exposure. An hypothesis of relation between environmental or local exposure and thyroid alteration has been formulated [1,2]. Therefore the present preliminary study aimed at investigating the possible influence of exposure to radiofrequency fields (in particular, GSM-phones associated emission) on thyroid gland structure and function in an animal model.

MATERIALS AND METHODS
Thirty two Male Sprague-Dawley rats, weight of 250 gr. at the beginning of the experiment were used. They were exposed locally (in proximity of the ear), simulating the use of a cellular phone, by 3 different sets of 4 loop antennas [3,4], one for sham and two for exposed animals, 2 h per day, 5 days per week, for 2 or 4 weeks, 2 W/kg of SAR at the frequency of 900 or 1800 MHz, in blind mode. Four groups of rats were scheduled: a 900 MHz-exposed, an 1800 MHz-exposed, a sham-exposed and control (untreated) group; during the exposure rats were kept in plastic restrainers. A total of 32 rats were included, 8 in each group. Half of the rats (4 in each group) were sacrificed after 2 weeks of exposure, the others after 4 weeks.

![Figure 1: exposure system](image-url)
At the end of the exposure period, rats were sacrificed, the thyroid gland were explanted, processed to paraffin and histopathologically evaluated. In addition, blood samples were collected for measurement of serum thyroid stimulating hormone (TSH), free triiodothyronine (fT3) and free thyroxin (fT4) levels by radio-immunoassay (RIA) method.

RESULTS
In figure 1 data regarding fT3 and fT4 serum level, expressed in pG/ml, after 2 weeks (both hormones) and 4 weeks (only fT3) are showed. All values are expressed as means ± SEM. ANOVA test was performed and statistical significance was assumed at p< 0.05. The same trend is obtained for TSH (data not showed).

CONCLUSION
No statistically significant difference in hormone levels was evidenced between experimental groups. Consistently, the two groups of rats did not show appreciable differences in thyroid morphology at histological examination. In particular, the microscopic aspect of thyroid gland is considered likely to reflect the high physiological variability in the gland activation, distinctive of male rats of this age and strain. In any case, considering the possible limitation of the animal model, as stated before, due to the variability in the adopted gender and strain, the present study failed to demonstrate significant differences in terms of thyroid histology and blood hormones levels between 900 MHz, 1800 MHz, sham exposed and control animals. Further studies, considering both biochemical and physiological parameters, are warranted to fully elucidate the potential effect of electromagnetic fields exposure on thyroid histology and function.

REFERENCES
Effects Of Pulsed-Modulated Microwaves On Behavior And Blood-Brain Barrier In Adult Rat: Preliminary Results

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INTRODUCTION

Recent French Navy platforms (Charles De Gaulle Aircraft carrier; All of the Electric Frigates) are equipped with high peak power microwave radars. They are characterized by pulsed-modulated microwave (i.e. non-continuous wave) in particular in the S-band (3 GHz) or the X-band (10 GHz). Therefore, it is essential to give an evaluation of potential health risks for exposed staff. These exposures can be punctual, prolonged or repeated depending on occupational activities. A special emitting device was developed in our laboratory in order to reproduce these conditions in an experimental model. The present study focused on an acute exposure in the S-band (3 GHz) under non thermal conditions. Early kinetic effects on blood-brain barrier (BBB) were measured during the first 48 hours after exposure. Behavioral performances were tested during the first month after exposure.

MATERIALS AND METHODS

One hundred and four 4-month old male Wistar rats (Charles River, France) weighing 410-540 g on the first day of experiments were randomly housed four per cage under standard conditions of temperature (21 ± 1°C) and humidity (50-60 %), with a 12h:12h day/night cycle and free access to food and water. They were randomly divided into two groups: experiment A (n=32) to explore the effects of exposure on BBB; experiment B (n=72, 3 groups of 24 animals) to test behavioral performances. In each experiment, an equal number of animals is exposed or sham-exposed. Sham and exposed animals are placed in two identical anechoic chambers. Study design is summarized in Table 1.

The room temperature was maintained by air-conditioning (20 ± 1°C) and an electric fan ensures air renewal in the anechoic chamber. The temperature in the chamber is measured with an electronic thermometer all along the exposure. During exposure, light was set up in order to respect day/night cycle. A camera linked to a video recorder was placed at the top of the chamber in order to observe spontaneous behavior of animals.

The emitting system consisted of a microwave signal generator (Anritsu) and a 2.5-3.5 GHz pulsed amplifier (4 KW, 66 dB, IFI), connected to a coaxial antenna located in an anechoic chamber through waveguides. Especially Plexiglas designed cages were used. Numerical dosimetry was calculated using the Finite Difference Time Domain method. The carrier frequency was 3 GHz pulsed wave (600 Hz repetition time, 1.2 % duty cycle, 20 µs pulse duration time) corresponding to a mean SAR of 5.7 W/kg. The rats were exposed for 16 min, 2 periods of 8 min separated by a resting time of 4 min without emission. To study BBB permeability, each rat was killed by cardiac perfusion with cold heparinized saline followed by fixative solution. Brains were collected out at delays specified in table 1.
fixed and then processed for paraffin embedding. Sections were serially cut in the coronal level. In order to evaluate BBB breakdown, serum protein extravasation was assessed using antibodies directed against albumin (70 kDa).

### Table 1: study design

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>H0</th>
<th>H02</th>
<th>H06</th>
<th>H24</th>
<th>H48</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32</td>
<td>exposure</td>
<td>brain sampling (not per delay)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To study behavior, 3 different tests were used at different delays as presented in table 1. To test memory, rats of group B1 were trained in a single-trial passive avoidance task before exposure and tested for retention 24 hours later. Then the same rats were tested for learning and memory in a water-maze test. Rats of group B2 were tested for spontaneous locomotor activity. Different tests were applied to group B3 to determine a global neurologic score.

At day 29, rats from group B1 were decapitated, blood was sampled to measure ACTH and corticosterone levels using radio-immuno assays.

### RESULTS

The clinical observation revealed no difference between exposed and sham-exposed rats. Video recordings taken during the exposure in the anechoic chamber revealed no apparent behavioral difference between exposed and control groups. No significant behavioral effect was noted from D1 to D29, whatever the test or the delay.

Considering the weight gain between D1 and D29, exposed animals gained more weight than controls in the 3 groups of experiment B, but the difference is almost statistically significant.

Immuno-histochemistry of BBB is in course. For the moment, one exposed animal per delay (n=4) has been analyzed to explore albumin extravasation. For each rat, the five interested levels as selected in a BBB breakdown model have been studied. Whatever the delay or the level, no albumin extravasation was observed.

At D29, corticosterone and ACTH blood levels are decreased in exposed rats of group B1. This decrease (-38%) is statistically significant for ACTH levels only.

### CONCLUSIONS

Further investigations are currently in progress on the remaining rats to study more delayed effects of acute exposure in the S-band (3 GHz) under non thermal conditions. The study of chronic exposure effects will then be undertaken.

### ACKNOWLEDGMENTS

This work was supported by grants from the “Délégation Générale pour l’Armement” (DGA/DSP/STTC- contract 05co015-05- PEA 030807). We are very grateful to D. Coulon for animal care. We also thank J. Denis, V. Leroux, R. Viret and B-A. Martz for their technical help.
RESEARCH ON PREVENTIVE AND THERAPEUTIC EFFECT AND MECHANISM OF ADUOLA FUZHENGLIN ON BRAIN OF RATS AFTER MICROWAVE EXPOSURE

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Objective: Brain is one of the most sensitive targets of microwave. But the effective protective drug is deficient because it is not clear about the mechanism of the injury. Therefore, the research was to investigate the preventive and therapeutic effect and mechanism of AduoLa Fuzhenglin(ADL) on brain of rats after microwave radiation, which was important to establish safety stratageies and afford methods of prevention and treatment.

Materials and Methods: Simulating resource of microwave was used. 212 Wistar or SD rats were exposed to 30mW/cm² microwave and given 6-12g/kg/d ADL before and after radiation. Morris water maze, high performance liquid chromatogram(HPLC), gene chip, RT-PCR, western blot and quantitative pathology were used to make research in physiological and biochemical functions, characteristics of different brain injury, differential expression genes and the changes of NR2B, PSD-95 and p-CaMK II to investigate effect of ADL after radiation, to find out sensitive diagnostic indexes and molecular mechanism of ADL’s protection.

Results: (1) After microwave radiation, the abilities of rats learning and memory were descended and the contents of amino acids in the brain changed within 7d after the exposure, and recovered with ADL therapy. (2) Histology and ultrastructure of the pallium and hippocampal were damaged on 7d after the exposure of 30mW/cm² microwave, the injury grades were the 30 mW/cm² group >the drug prophylaxis group> the drug treatment group. (3) The expressions of NR2B and PSD-95 in hippocampus were increased within 7d after the exposure of 30mW/cm² microwave, which were peaked on 7d, returned to the normal level on 14d after radiation; the
expression of p-CaMKII was increased within 14d after the exposure of 30mW/cm² microwave and decreased in the 12g/kg/d drug treatment group. (4) The expressions of 12 genes were up-regulated and 7 genes down-regulated in 30mW/cm² group when compared with normal group in hippocampus on 14d after the exposure of 30mW/cm² microwave. It was found that 1 gene was up-regulated and 3 genes down-regulated in the drug prophylaxis group as compared with 30mW/cm² group. There were 6 genes up-regulated and 4 genes down-regulated in the drug treatment group as compared with 30mW/cm² group.

Conclusions: 30mW/cm² microwave exposure might damage the abilities of learning and memory and brain structure of rats, and induce the turbulence of amino acid, abnormal expressions of NR2B, PSD-95 and p-CaMKII. 12g/kg/d ADL might prevent the neuron damages induced by microwave and the effect of remedial administration was better than prophylactic administration. Alas2 and NMDA receptor signal passageway might participate the molecular mechanism of ADL on prevention of the brain injury exposure to microwave.

Key words: ADL; Microwave; Rat; Brain Injured; Pathological Change;
Prevention and Treatment; Protective Mechanism
In Utero Exposure of Young Rats to WiFi Radiofrequency Fields: Influence on the Immune System and Brain Stress Markers (ELEYAR project)

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INTRODUCTION

There is worldwide concern about the sensitivity of children to environmental agents (heavy metals, chemicals, ionizing radiation, EMF, etc.). In the case of radiofrequency (RF) fields, the current generation of children is the first to be exposed during its lifetime to RF fields emitted by mobile phones and other wireless communication devices. The present project (ELEYAR) aims at investigating the effects of in utero WiFi exposure, using a non-restraining exposure system (reverberation chamber) on immature immune and central nervous systems.

MATERIALS AND METHODS

Exposure system and dosimetry. The exposure system for rats was a reverberation chamber with 6 dipole antennas, which were activated at random and 3 stirrers for mode mixing [1]. The signal was WiFi-like, based on a "dialog" between two PCs equipped with WiFi cards. The three SAR levels were 0.08, 0.4, and 4 W/kg whole-body-averaged (WBSAR) for the dams. A 70 W amplifier was used to reach such levels. SAR determination was done by field measurements using antennas. Numerical validation was done using FDTD based on the available numerical phantoms of pregnant rats. Normalized whole-body and tissue SARs in all tested configurations varied insignificantly.

Experimental protocol. The experiments were performed on Wistar rats, purchased at day 3 post coitum. At that stage, pregnancy was not ascertained. Exposure duration was 2 hours per day, excluding weekends, starting on day 6 until birth. After delivery, newborn rats were left to growth “normally” up to 5 weeks of age. For each SAR group, there was a maximum of ten 5-week-old rats, as well as cage-controls. Rats were killed in accordance with French animal welfare guidelines, and their sera and brains were taken for analysis.

Biological tests. Sera were kept in cryotubes at –80°C until ELISA testing. With custom-made plates, immunoglobulins of the A, M and G isotypes were evaluated using circulating antibodies directed against specific antigens for (i) inflammation (NO-Cys/NO-BSA, NO-Tyr/NOW, NO2-Tyrosine, NO-Met/NO-Asp/NO-His, NO-Arg, NO-Phe), (ii) neurodegeneresence (Kyn/ Anthra, NAC-Catecholamines), (iii) neurotoxicity (Pico/Quina/3OH Kyn), (iv) autoimmunity (C14-C18, C6-C12, C6OH-C12OH, Phosphatidylinositol, Cardiolipine), and (v) lipoperoxidation (MDA/4-HNE). To validate the quality of the plates, positive controls were obtained using antibodies from hyper-immunised animals directed
against major tested antigens for the G isotype.

Brain studies were performed on anesthetised rats using isofluran. Five-week-old rats were then perfused via the heart with 4% paraformaldehyde. At that time, brains were coded and kept in the fixative solution overnight at 4°C, cryo-preserved in 20% sucrose for 48 h at 4°C, frozen in isopentane, and stored at –80°C. Ten \( \mu \)m slices brain cryosections were prepared. The following parameters were assessed in situ on brain slices (Z1: bregma –0.80, and Z2: bregma –3.80 mm): (i) apoptosis using the TUNEL method for detecting DNA fragmentation, (ii) HSP70/25, GFAP, and 3-nitrotyrosine levels using immuno-histochemistry. Positive control experiments were performed to test these different parameters.

Statistical analysis. For each SAR condition, 3 successive series of 4 rats were exposed and the statistical power was such that the detection of a 35% difference was possible at \( p<0.05 \). Statistical analysis among SAR groups was made using the Kruskal-Wallis test.

RESULTS

Body weight. The rate of growth of the young animals was not statistically different among the different groups up to 5 weeks of age.

Immune system. ELISA results were considered meaningful if the signal was above noise (i.e., Optical Density > 0.1). Under these conditions, statistical analysis showed no significant differences among exposed and sham samples, whatever tested isotypes and antigens.

Brain. In the observed brain zones (Z1: F1, CPu, and F4 regions, or Z2: M1, M3, M4, CA1, CA2, CA3, and DG regions), TUNEL apoptosis measurements were not significantly different among the various exposure conditions. Measurements and analysis of the HSP70/HSP25, GFAP, and 3-nitrotyrosine markers are in progress.

CONCLUSIONS

Completed results on 5-week-old rats (body weight, immune response), and preliminary ones (brain apoptosis) did not show any statistically significant differences among exposed (WiFi; 0.08, 0.4, and 4 W/kg WBSAR) and sham animals.

Therefore, exposure of pregnant rat did not affect the integrity of the immune and central nervous systems of these 5-week-old young rats exposed exclusively in utero. Complementary results at the brain level (HSP70/HSP25, GFAP, and 3-nitrotyrosine) will be presented at the meeting.

ACKNOWLEDGMENTS

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REFERENCES

The 60 Hz Magnetic Field Affects Sperm in Mouse Exposed Continuously for 20 Weeks

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INTRODUCTION

We recently reported that continuous exposure to ELF MF of 0.1 or 0.5 mT for 8 weeks might induce testicular germ cell apoptosis in mice [1]. Furthermore, we found that apoptosis of testicular germ cells increased after continuous exposure to 14 μT for 16 weeks [2]. In the present study, we aimed to characterize the effect of 60 Hz MF on the motility, morphology and number of sperm as well as the apoptosis of testicular germ cell in mice after continuous exposure for 20 weeks.

MATERIALS AND METHODS

The male BALB/c mice (7 weeks of age) were divided at random into four groups of 25 animals each. Three experimental groups were continuously exposed to a 60 Hz MF of 2, 20 or 200 μT for 24 h/day (except for 3 hr per week for management) for 20 weeks, and another group exposed to sham conditions served as the control. The mice were housed in specially designed non-metallic polycarbonate cages fitted with non-metallic nozzle water bottles and placed on the tray of the MF generating device. Each cage of five mice was placed in the exposure system and sequentially moved every week. Their body weights were recorded every week. After the end of the exposure the mice were sacrificed, and both testes were excised and their weights were recorded. The apoptosis of germ cell in the testis was analyzed by H&E and TUNEL staining. The motility, morphology and number of sperm were evaluated microscopically taken from epididymis.

RESULTS

There were no significant effects on the body weight and testis weight in mice exposed to 60 Hz MF. In H&E and TUNEL staining, germ cells showed a significantly higher apoptotic rate in the mice exposed to 20 μT (P<0.05) or 100 μT (P<0.01). TUNEL-positive cells were mainly spermatogonia. There were no significant effects on the morphological abnormality of sperm from the exposed mice. However, the number of sperm decreased in exposed mice (200 μT : P<0.001), and the motility also decreased (20 μT : P<0.05; 200 μT : P<0.01).
Figure 1: Effects of 60 Hz MF exposure on the apoptosis of testicular germ cells. Most of TUNEL-positive cells (arrow) were spermatogonia (A). Frequency of apoptosis increased dose-dependently in exposed mice groups (B). The data are means ± SE. *P <0.05, **P<0.01 vs sham control. ×400.

CONCLUSIONS

Our experimental results suggest that continuous exposure to 60 Hz MF of 20 μT may affect testicular functions including the motility of sperm as well as the apoptosis of testicular germ cell in mice.

ACKNOWLEDGMENTS

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REFERENCES


Whole Body Average SAR In Anatomical Child Models At Plane Wave Exposure in the 2 GHz-5.8 GHz Range

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INTRODUCTION

Several recent publications [1,2] have indicated that whole body plane wave exposure of children or small persons at field strengths corresponding to the ICNIRP reference levels [3] may, under certain circumstances, yield whole body averaged SAR (WB-SAR) values higher than the corresponding basic restriction of 0.08 W/kg. Such effects were reported with E-polarization at whole body resonance (approx. 30-100 MHz under ungrounded and 60-200 MHz under grounded conditions) and in the frequency range around 2 GHz. The data available so far are based on a very low number of child models that are essentially scaled adults. In order to investigate this issue in more detail, numerous FDTD simulations were performed using 6 different MRI-based child models.

MATERIALS AND METHODS

In total, 6 MRI-based whole body child models (Table 1), aged between 5 and 14 years [4,5] were used for FDTD computations under plane wave exposure, considering the 6 orthogonal main directions of propagation at vertical and horizontal polarization each (12 cases per child model). The specific absorption rate (SAR) was calculated at 2 GHz, 4 GHz and 5.8 GHz for each case, resulting in a total of 216 simulations. In order to compare the results with previously reported data [1,2] at the body resonance frequency, several additional computations at E-polarization were carried out for all child models, both in grounded and in ungrounded condition. The SEMCAD X simulation platform (SPEAG, Zürich, Switzerland) was used for all computations, using perfectly matched layer (PML) boundary conditions to truncate the computational domain. A series of simulations at different resolutions was run in order to determine the necessary grid resolution for convergent results in the different frequency ranges. The chosen spatial resolutions of the FDTD grids range from 0.7mm for 5.8MHz to 2.0mm for frequencies of 200MHz and below.

<table>
<thead>
<tr>
<th>Model</th>
<th>Sex</th>
<th>Age [yrs]</th>
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<tr>
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<td>5</td>
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<td>Louis</td>
<td>male</td>
<td>14</td>
<td>1.65</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1: Specifications of the child models.
RESULTS

Figure 1 summarizes the results by showing the plane wave power density required to produce a WB-SAR of 0.08 W/kg (worst case of all considered combinations of propagation direction and polarization). The results in the whole body resonance frequency range are only shown for one child model. At whole body resonance, the power density required for a WB-SAR of 0.08 W/kg is approximately 15% lower than the corresponding reference level. In the frequency range around 2 GHz it can be seen that this deviation is up to about 35% for the smallest of the considered child models. Above approximately 5 GHz, the ICNIRP reference levels can again be regarded as conservative for all of the models used in the study.

CONCLUSIONS

The computations based on 6 anatomically correct child models confirm that the ICNIRP reference levels are not conservative for younger children in the frequency range around whole body resonance and between approximately 1.5 and 5 GHz. Additional models and further investigations are necessary to find an envelope for the reference levels that is conservative for any person, including even young children.

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REFERENCES

Induced Field Evaluations of Organs and Functional Subregions of the CNS of Various Human Models for Far-Field Exposure Conditions

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INTRODUCTION

Sound and robust exposure metrics are required for use in epidemiological studies on the possible health effects of human exposure to RF fields. In the past, the applied exposure metrics were based on incident field estimates, ranging from simple distance metrics [1] over wireless propagation modeling [2] to recent in-situ incident exposure assessments, e.g., from personal dosimeters [3]. These exposure estimates resulted in an exposure metric for the incident fields which is only poorly correlated to the actually induced fields. Attempts have recently been made to transfer these incident fields to the whole-body averaged SAR [4]. Since the RF EMF levels of the considered cases are far below levels that may cause possible effects due to whole-body thermal loads, plausible exposure metrics must be based on the locally induced fields. Thus, the aim of our study was to evaluate tissue specific induced fields including functional subregions of the CNS.

MATERIALS AND METHODS

The evaluations were conducted using the Virtual Family [5]. Each model was evaluated in different postures and exposed to plane-waves incident from six sides with vertical and horizontal polarizations in the frequency range from 50 MHz to 6 GHz. The simulations were performed using SEMCAD X (SPEAG, Switzerland). As a measure of time-averaged exposure of a moving subject, the power averaged absorption at every voxel was computed as the average of the absorbed power from all 12 incident plane-waves. The SAR (power absorbed in the organ divided by the mass of the organ) was calculated for each of the organs available in the Virtual Family models. The absorbed power in various functional regions of the brain was also calculated using a novel post-processing tool based on the mapping atlas by Talairach [6]. The SAR was extracted for different levels of absorption for regions of the brain ranging from hemispherical to cellular levels.

RESULTS

Figure 1 summarizes the differences in whole-body exposure ratios for all the models in the upright position and in all configurations. The results show that for Virtual Family Boy (VFB) and Virtual Family Girl (VFG) the whole-body-averaged SAR might be closer to the limit of exposure at the incident field reference levels. The region specific absorption results will be presented at the conference.

CONCLUSIONS

For the first time, detailed information about the induced fields of specific organs and functional subregions are provided. Evaluations were conducted in the RF range
Figure 1: Percentages of the whole-body SAR relative to the limits of ICNIRP for plane-wave exposure of the human full body models from all major sides in E&H-polarizations over frequencies from 50MHz to 2450MHz.

from 50 MHz to 6 GHz. A novel exposure metric can be derived from these results and applied in epidemiological studies concerning exposure from fixed transmitters.

ACKNOWLEDGMENTS

We would like to thank the Swiss National Fund (SND) and the National Research Program 57 (NRP57) for their financial support of this study.

REFERENCES


SPECIFIC ABSORPTION EVALUATION WITHIN THE TISSUE SLICES EXPOSED TO PULSED WAVES

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BACKGROUND

The concept of SAR (Specific Absorption Rate) has been broadly used in the evaluation of energy absorption in dosimetry studies. The SAR is defined as the time derivative of the incremental energy (\(dW\)) absorbed by (dissipated in) an incremental mass (\(dm\)) contained in a volume element (\(dV\)) of given density (\(\rho\)) [1]. Hence it represents the rate of energy absorption, rather than the total quantity of the absorbed energy, which is vital in pulsed-wave exposure cases. Therefore, another concept, SA (Specific Absorption), was defined in order to express the total energy absorption in a certain time segment, such as the whole exposure range or just one pulse.

There have been several previous studies on SA in dosimetry and microdosimetry fields using the IEEE C95.1 and later standards [1]. Computationally, the FDTD technique has been used to evaluate the electric field interaction with the human body and to quantify the SA on time domain [2]. The SA calculated by this method is typically based on the point electric field values, which are not easily attainable for the commercial software based simulations. Therefore, a convenient method for calculating SA is needed.

METHODOLOGY

SA is defined as the quotient of the incremental energy (\(dW\)) absorbed by (dissipated in) an incremental mass (\(dm\)) contained in a volume (\(dV\)) of a given density (\(\rho\)) [1], as shown in equation (1):

\[
SA = \frac{dW}{dm} = \frac{dW}{\rho \cdot dV} \left(\frac{J}{kg}\right)
\]

Derive the relationship between SA and SAR in the discrete value sequence form:

\[
SA = \sum_{i=1}^{i=N} SAR(t_i) \cdot \Delta t_i
\]

Where \(\Delta t_i \equiv \Delta T\), which is the time step in calculation. Based on equation (2), this study will be based on two methods to calculate the SA: one is calculate from the E-field (similar to the method in reference [2]) as shown in equation (3), the other one is to calculate the SA from a few known SARs measured at different frequencies as presented by equation (4).
\[
SA = \frac{\text{energy}}{\text{mass density}} = \frac{\sum_{i=1}^{N} \sigma|E_i|^2 \cdot \Delta t}{\rho} (\text{J/kg})
\]  

(3)

where \( E_i \) represents the E field magnitudes at different time points measured by the E-field probe.

\[
SA = \sum_{n=1}^{N-1} \text{SAR}(i) \cdot \Delta T = \frac{1}{N} \sum_{n=1}^{N} \text{SAR}(k) \cdot Y^*(k) \cdot \Delta T
\]

(4)

where SAR\((k)\) is the total SAR value on frequency domain, and \( Y(k) \) is the DFT (discrete Fourier transform) of the all-one signal \( y(n) \). SAR\((k)\) is commonly available in the post processing part of commercial software packages, which can be conveniently used in the evaluation of SA.

In order to verify this method computationally, a virtual voltage probe has been placed in the dielectric filled transmission-line exposure system [3] to collect the signals on time and frequency domain. The probe is in the center of a sample tissue slice, which is exposed to a Gaussian wave from 0GHz to 3GHz. Based on the proposed method, the time domain calculation result is 1.065e-12 J/kg, and the frequency domain result is 1.064e-12 J/kg, which are perfectly matched with each other. Therefore, this method can be utilized in the estimation of SA from the known SAR values on frequency domain.

RESULTS AND DISCUSSION

In order to assess the SA within a sample tissue volume, a virtual probe is defined within a volume of (1mm×1mm×1mm) at the hotspot of the brain tissue slice. The unit volume SA calculated in the hotspot of tissue slice can be evaluated by both time domain and frequency domain methods.

With the knowledge of the magnitude of the signal recorded in the time domain at the hotspot of the tissue slice (Figure 1), the absorbed energy in the volume can be obtained as equation (3), with the value of 1.60e-9 J/kg. The SA also can be calculated from the peak SAR values on frequency domain (Figure 2). The computational calculated 1\( \mu \)g peak SARs have been normalised to the input Gaussian signal and evaluated. The calculated SA at the hotspot of the tissue slice is 1.49e-9 J/kg, which is quite close to the time domain method calculation.

The total energy absorption of the whole tissue slice can also be calculated from the total averaged SAR. Take the first quadrant of tissue slice 1 as an example; the calculated total SA is 0.85e-10 J/kg, which is lower than the peak SAs. The temperature rise can also be estimated based on the energy absorption and dissipation.

REFERENCES


Figure 1: The magnitude of E-field on time domain (detected by virtual probe at hotspot).

Figure 2: 1μg averaged peak SAR (plotted and fitted into a curve as a function of frequency).
Evaluation of Human Exposure to Electromagnetic Fields from RFID Device at 910 MHz

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INTRODUCTION

As radio frequency identification (RFID) technologies have been widely used in various applications, and also, they are used close by human body. General public concerns about possible health effects by electromagnetic fields from these devices. In order to solve these problems, international organizations have conducted the investigation of the human effects and standardization of the evaluation methods for the devices, and a few papers have reported their experimental results. In this paper, we describe the analyzed results for the evaluation of the human exposure from the RFID device operated at 910 MHz. The specific absorption rate (SAR), and the electric field strengths by the direct and spatially averaged measurements based on the IEC 62369-1 were measured. And also, we suggest the improved measurement method to reduce the evaluation time for the spatially averaged measurement.

EVALUATION METHODS

According to the IEC 62369-1, the SAR, and the direct measurement and the spatially averaged measurements to obtain the electric field strengths from the RFID device at 910 MHz were performed. The measurement set-up consists of the RFID device with 6 dBi antenna gain and 1 W input power, the electric field probe with isotopic field patterns, and the signal generator and emulator to generate RFID signal.

RESULTS

From the experimental results, figure 1 shows the electric fields reduced as 1/r along main beam direction of the antenna and the electric field patterns, respectively. In case of the field patterns, the measured field distributions do not exactly coincide with the radiation patterns of the antenna, because exposure measurements are not made in far-field region. And figure 2 shows the electric field strengths for the spatially averaged measurement at front, center and rear from the RFID antenna. The measured exposure levels are 17.1 V/m(front measurement), 16.3 V/m(center measurement) and 13.6 V/m(rear measurement), and the total spatially averaged exposure level is 15.7 V/m, which is below the reference level, 28 V/m of ICNIRP guideline. However, this spatially averaged measurement method takes considerable evaluation time. Therefore, we suggest the improved measurement method to reduce the evaluation time for the spatially averaged measurement in figure 3. Although the suggested measurement method has 25 measurement points, the measured result, 15.55 V/m similar to the result for the measurement method with 45 points recommended by the IEC 62369-1. As illustrated in figure 4, we assume that the SAR measurement can be applied to the RFID devices such as handheld devices used close by human body within 10 cm. The SAR values averaged over 1 g (SAR_{1g}) using flat phantom when RFID reader antenna is in contact with flat phantom shell were measured maximum 2.8 W/kg.
CONCLUSIONS

From the results of the evaluation for the RFID device with 6 dBi antenna gain and 1 W input power at 910 MHz, the following conclusions could be drawn: the electric field strengths for the direct measurement at 20 cm which is recommended measurement distance by IEC do not exceed the reference level of the ICNIRP guideline, but exceeds it at distance below 15 cm, and the spatially averaged electric field strength does not exceed the reference level. And the maximum SAR_{1g} value was measured 2.8 W/kg.
Estimation of Specific Absorption Rates in Pregnant Women and Their Fetuses at Various Stages of Pregnancy

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INTRODUCTION

In recent times, there has been an increasing concern regarding the safety of pregnant women and fetuses following exposure to radio-frequency (RF) electromagnetic fields (EMFs); considering this threat, the World Health Organization (WHO) expressed the need for numerical dosimetry studies on the effect of RF-EMF on pregnant women and fetuses [1]. Therefore, the aim of this study is to estimate the specific absorption rate (SAR) in pregnant women and fetuses using anatomically-realistic pregnant-women models at various stages of pregnancy.

MATERIALS AND METHODS

The pregnant-woman models at 10, 13, 18, 26, and 28 weeks of gestation were constructed as shown in Fig. 1. In these models, the fetuses were positioned in the left occiput anterior (LOA) position in the model’s pelvis, i.e., the fetal occiput was directed toward the model’s left anterior side. They models were composed of $2 \times 2 \times 2 \text{mm}^3$ voxels and were segmented into 56 tissue types. Further, the body shapes and masses of the maternal tissues of these models were similar to the reference values [2],[3].

![Figure 1: Pregnant woman models](image)

The finite-difference time-domain (FDTD) method was used to calculate the SARs of the pregnant woman models exposed to vertically and horizontally polarized plane wave EMFs with frequencies ranging from 30 MHz to 2 GHz. The incident power density was $10\text{W/m}^2$, which is the reference level for occupational exposure to electromagnetic waves in the VHF band [4]. The incident waves were assumed to propagate from 4 major sides (anterior, posterior, left, and right) of the model. The model was assumed to be in free space. For the electromagnetic properties corresponding to the tissues and organs of these gestational models, we referred to the previous reports[5],[6]
RESULTS

For all of these gestational models, the whole-body averaged SARs (WBA-SARs) in the case of vertically polarization were significantly higher than and comparable to those in the case of horizontally polarization in the VHF band and in the UHF band, respectively. The WBA-SARs of the pregnant models tended to decrease with later stages of gestation. The WBA-SARs of pregnant women, however, were not significantly affected by the change in body shape and weight associated with gestation age because the differences in the WBA-SARs of these gestational models were within 1.0 dB. The frequency characteristics of the fetus-averaged SARs for vertical polarization with anterior propagation are shown in Fig. 2. The fetus-averaged SARs were different for different gestational stages. However, the fetus-averaged SARs for complete exposure for all of the gestational models were smaller than or equal to the WBA-SARs although the gestation stage of the pregnant woman can affect the fetus-averaged SAR.

CONCLUSIONS

We estimated the SARs of pregnant-woman models at 5 different gestational stages following electromagnetic wave exposure ranging from 30 MHz to 2 GHz using the FDTD method. We found that the stage of pregnancy affected the fetus-averaged SAR although it hardly affected the WBA-SAR and that the fetus-averaged SAR did not greatly exceed the WBA-SAR.

REFERENCES

Design and Test of a 434MHz Multi-channel Amplifier System for Regional Hyperthermia Applicators

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INTRODUCTION

Clinical Phase III trials have demonstrated the benefit of adding Hyperthermia (HT) to Radiotherapy (RT) [1]. We focus our efforts to enhance the treatment quality by improving the specific absorption rate (SAR) deposition in the tumour, using both state of the art HT planning tools (SEMCAD-X, SPEAG, Switzerland) and accurate hardware. Recently, we have developed the HYPERcollar [2] for head and neck tumors. This phased-array applicator operates at 434MHz, however adequate hardware to control the radio-frequency (RF) driving signals was not available.

We therefore designed a multi-channel amplifier system to control the RF signals of the HYPERcollar. In this work we demonstrate the hardware system and characterize the accuracy of the power and phase control.

MATERIALS AND METHODS

We assumed a phased-array steering accuracy of 1mm to be sufficient, consequently maximum 5° phase error is allowed (λ_tissue ≈8cm @433MHz). Figure 1 a) demonstrates the twelve-channel 434MHz amplifier system. A newly developed Direct Digital Synthesizer system (DDS AD9954, Analog Devices, USA) is used to generate twelve coherent RF signals with controlled frequency, amplitudes and phases. The signals are amplified (Alba, Pavoni Group, Italy) from 10mW to maximum 200W per channel. The outputs of the amplifiers are protected by internal circulators, that directs the reflected power into an air-cooled load. Another newly developed system measures the (≈-30dB) coupled gain and phases of the forward and reflected signals. Fixed phase-shifts between...
Figure 2: Configuration (a) of the initial calibration and assessment of the long-term phase accuracy (b).

The AD8302 gain and phase detectors (Analog Devices, USA) are used to determine the sign of the phase (see Figure 1 b). A 96-channel data acquisition card (DAQ-2208, Adlinktech) measures the detector output voltages of all channels synchronously. Low-loss (<0.1dB/m) RF-cables (SSB, Germany) are used to guide the high power signals towards the applicators in the HT treatment room.

The hardware system is calibrated (Figure 2 a) at the antenna feedings by using a vector volt meter (HP8508A, Agilent, USA) and a digital power meter (EMP-442A, Agilent, USA). After the initial calibration (t=0), the accuracy of the powers and phases are assessed during four months of operation (max tree HT treatments per day).

RESULTS

Figure 2 b) demonstrates that the phase accuracy remains within 5° for the studied period of four months. Although not demonstrated here, the power accuracy remains within 5%.

CONCLUSIONS

The newly designed hardware to control power and phases remains accurate within five degrees during at least four months. Consequently, three RF signal calibrations per year are sufficient to contribute maximum 1mm to the total SAR focus position error.

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REFERENCES


Health complains among MRI personnel – a descriptive pilot study.

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INTRODUCTION

Personnel operating Magnetic Resonance Imaging (MRI) scanners are highly exposed to static fields around the MRI scanner and symptoms like headaches, nausea are sometimes reported, especially when moving fast around the magnet bore. In view of the discussion about the implementation of the EU directive on occupational EMF exposure, and discussions of specially controlled environments where higher limit values for static magnetic fields could be applied, it is of interest to get further information about possible health complaints among personnel working close to the MRI magnet bore. In this descriptive pilot study a questionnaire has been distributed to all MRI nurses in the Northern part of Sweden to obtain an overview of the degree of symptoms and when the symptoms normally occur.

MATERIALS AND METHODS

A questionnaire to all (N=60) MRI nurses in the Northern part of Sweden has been sent out for an in depth study of their working environment and health complaints. The questionnaire is concentrated on MRI related questions like how frequently and for how long time they are situated inside the MRI scanner room, which type of scanner are used and for how many years they have been working with MRI scanning. Also questions about symptoms such as dizziness, nausea, illusion of movement, sleeping disorders etc. are asked. Possible connection between symptoms and MRI work are further explored. MRI nurses working with both 1, 1.5 or 3 T will be included. At each hospital (a total of nine included in Northern Sweden) a contact person will hand out and later collect the questionnaire.

RESULTS

The questionnaire was distributed to the MRI clinics in January 2009 and the results will be presented at the conference.
The Mountain Pine Beetle ("Dendroctonus Ponderosae") is currently ravishing huge stands of lodgepole pine, and other coniferous trees, on the west slope of the Colorado Rocky Mountains—and elsewhere. In coming years the MPB is expected to cross the continental divide and destroy millions of trees along the Front Range, including many "high value" trees in parks and residential landscapes. Once a tree has been infiltrated by MPB (see below) "conventional wisdom" holds that it cannot be saved—even by chemical pesticide spraying. So, often the first sign that beetles have entered is also the "death knell" of the tree. We believe, however, that even after initial infestation is evident pine (and other coniferous trees) can be rescued if the MPB can be selectively destroyed within the tree (in situ) without unduly harming the tree itself. An approach to this may be to deploy highly selective hyperthermia. The structure of a typical conifer includes several concentric layers. The bark (outermost layer) is usually quite dry and has a low electrical, as well as thermal, conductivity. By contrast, the next layer (xylem) is quite wet (sap laden) and high in electrolyte content so it is much more conductive. The innermost layers (growth rings or cortex) are again relatively dry and low in conductance. Evidence, mainly from controlled forest fires ("burns") suggest that coniferous (pine, etc.) trees can survive fairly high temperature elevations as long as the xylem temperature does not exceed 60° C for an extended time period. This temperature resilience, along with the aforementioned electrical properties of these trees, suggests to us that selective EMF hyperthermia might be a useful approach to this burgeoning problem.

Adult Mountain Pine Beetles (MPB) can bore through the bark of conifers and settle in the xylem where they carve out "galleries" into which the females lay eggs—and these hatch into larvae which remain in the cambium. The MPB (and their larvae) produce a blue colored fungus, which spreads through large portions of the xylem, and (if it girdles the tree trunk) will block sap (nutrient) flow and this will kill the tree. Logs cut from beetle infested trees have been "decontaminated" by thermal means including microwaving, solar heating, etc). Temperatures in the range of 45 to 55° C have been reported to be effective in killing MPB and similar insects. Similar temperatures might reasonably be expected to be lethal to MPB within living trees. Thus there is a narrow, but workable, temperature range over which EMF hyperthermia could be lethal to the MPB while not killing the tree itself.—but only if the EMF field used is quite uniform and radially symmetrical. The Methods we have explored for achieving this include the use of RF coils and/or circular waveguides. The design of a specific EMF exposure system and power source is, however, dependent on the power levels needed.
RESULTS

We have estimated required levels of RF or microwave power on the basis that an elevated cambial temperature of about $55^\circ$ C, sustained for several minutes to an hour, will selectively destroy MPB and their larvae while doing only minor damage to the tree. For a one-meter length of a tree one foot (30 cm) in diameter, the sap layer has a circumference of about one meter and a typical thickness of 0.5 cm; the sap volume (xylem) is about 5000 cc. Assuming no heat dissipation from that xylem layer the energy required to raise its temperature from say $25^\circ$ C to $55^\circ$ C would be 150,000 joules or roughly 650,000 watt-seconds. This could be achieved, for example, by inputting 6500 watts for 1000 seconds (17 minutes). Taking into account thermal losses (cooling) to adjacent layers as well as source inefficiencies might reasonably double or triple this figure.

CONCLUSIONS

On the basis of the power required, it would be quite difficult and expensive to deploy EMF hyperthermia to treat large stands of coniferous trees. Power sources and applicators of the size required would likely have to be transported by truck and thus not be practical (or cost effective) in remote forest situations. However, the approach could be useful for saving especially “high value” MPB infected trees such as those near homes, in city parks, along highway medians, and even in some National Park campground/rest areas. In these situations the EMF hyperthermia approach could work even if the tree was already showing early signs of beetle infestation whereas other methods, such as chemical pesticide spraying, have to be completed before any MPB infiltration has occurred.
Reduction of Occupational Exposure from the Switched Gradient Magnetic Field from an MRI Scanner by Use of Modified Pulse Sequences

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INTRODUCTION

The Magnetic Resonance Imaging (MRI) technique makes use of a strong static and a radio frequency magnetic field, and to enable spatial encoding of the MR signal switched gradient fields in the intermediate frequency range are used. The occupational exposure to the magnetic field from the switched gradient fields is very complex, and can sometimes exceed international guidelines. So far no one has paid any attention to the difference in exposure between the uses of different pulse sequences. Depending, among other things, on what contrast the radiologist selects, a specific pulse sequence is used. The sequences can be very different in pulse repetition frequency and amplitude. But the rise and fall rate of the gradient pulsed field can also be modified; this is mainly done to suppress the noise in the machine and the sequences are therefore usually called “whisper”. In this paper we have measured the current in the gradient coils of an MRI scanner as well as the magnetic field and its time derivative near the opening of the bore for different pulse sequences in normal and “whisper” mode to get a better understanding of the occupational exposure of the staff being near the MRI machine during scanning.

MATERIALS AND METHODS

We selected three different pulse sequences: T2-TSE (T2-weighted turbo spin echo), Trufi (True FISP) and Epi2d (Epi2d_diff_3scan_trace). The T2-TSE sequence is characterized by good contrast between different kinds of tissue and is widely used to generate high-resolution images in many parts of the body. The True FISP sequence is an example of a steady state free precession sequence and is used for example in thorax imaging. It is a very common choice in cardiac MRI. The Epi2d_diff_3scan_trace sequence is based on spin echo imaging with echo planar readout and is frequently used in neuroradiological MRI. All measurements were done on a Siemens Espree which has a static field of 1.5 T.

Measurement of the broad band magnetic field and in Shape Time Domain (STD) using the weighted peak approach was done by use of the instrument ELT 400 (Narda Safety Test Solutions) connected to a 4-channel Picoscope to display the wave form for the three axes of the probe. The probe was positioned with a tripod in the center of the opening of the bore and at fixed distances from the side of the magnet.

RESULTS

For all three pulse sequences tested the values are in excess of the ICNIRP guideline for distances closer than about 50 cm. The magnetic flux density at 10 cm range from 66 to 187 µT for the three pulse sequences, whereas the difference in the STD mode is not very large; from 516 to 670% (in excess over ICNIRP reference values).

Applying the whisper mode reduced the percentage values by a factor of ~1.5 which is a direct consequence of the reduction of the rise and fall times of the pulses (Table 2 and
CONCLUSIONS

In view of the discussion about the implementation of the EU directive this could be an approach in some circumstances to reduce the occupational exposure during an MRI scan. Other pulse sequences as well as the image quality should be investigated further. Work also needs to be done to find the optimal rise and fall rate for certain medical investigation to optimize the image quality and occupation exposure during MRI scan.

Table 1. Measured B-field (µT) and STD (% of the occupational guidelines, ICNIRP 1998) for two different settings of the gradient current (Normal and Whisper). The measurements were done at 30 cm distance from the bore.

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<th>T2-TSE</th>
<th>Trufi</th>
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<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Whisper</td>
</tr>
<tr>
<td>(B_{rms})</td>
<td>39</td>
<td>33</td>
</tr>
<tr>
<td>(B_{peak})</td>
<td>185</td>
<td>143</td>
</tr>
<tr>
<td>STD (%)</td>
<td>250</td>
<td>174</td>
</tr>
</tbody>
</table>

Table 2. Rise and fall rate (A/µs) for the gradient current (x, y and z coil, respectively).

<table>
<thead>
<tr>
<th></th>
<th>T2-TSE</th>
<th>Trufi</th>
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<tr>
<td></td>
<td>Normal</td>
<td>Whisper</td>
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<tr>
<td>Rise rate</td>
<td></td>
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</tr>
<tr>
<td>X</td>
<td>1.85</td>
<td>1.31</td>
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<tr>
<td>Z</td>
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Magnetic Resonance Imaging (MRI) Safety of Implants: Estimating Specific Absorption Rate (SAR) at Design-Simplified Stents of Different Lengths Placed Inside a Virtual Phantom Model using a Generic RF Body Coil at a MR Frequency of 63.9 MHz.

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INTRODUCTION

In respect of imaging quality and patient safety, temperature rises and SAR distributions are of high interest for implants in MR tomography [1]. Radio frequency (RF) energy is always absorbed by human tissue during an MR investigation, but the presence of metallic implants can increase the local SAR in the environment caused by interaction of the applied electromagnetic fields. High local SAR values are equivalent to high local temperature increases [2]. For developing support for RF induced heating experiments, SAR values were virtually investigated at design-simplified stents with 5 different lengths inside a virtual human torso shaped phantom model. A generic RF body coil was used. The strut thickness of the stent models was chosen as thin as currently technical feasible regarding calculation time and generated data volume.

MATERIALS AND METHODS

5 design simplified stent models of an 8 mm inner diameter with five different length and same material properties as well as same strut structure and thickness (0.8 mm) were modeled with SPEAG simulation software SEMCAD X. The stents were positioned in the ‘gel’ inside a virtual body phantom with geometrical dimensions described in ASTM standard F2182-02a [3] for experimental testing of RF induced heating of implants. The virtual phantom was filled with a medium (‘gel’) having an averaged conductivity of 0.47 S/m and dielectric property (εr = 81) of human tissue. The phantom was exposed to the electromagnetic environment generated by a virtual generic birdcage coil for investigating how the stent length and the imaging frequency affect the SAR distribution in the surrounding of the stents. A simulation without implants was performed in order to determine

FIG. 1: Simulation setup, stent positioning and phantom’s SAR distribution without stent
an appropriate stent position within the phantom. The longitudinal axis of the stents was oriented parallel to the vector of the static main magnetic field B₀ and the electrical field. The middle of the stent (length) was positioned for all cases at the highest local SAR along a curve in head-feet direction for each stent length. All stent and phantom configurations were investigated at the frequency (63.9 MHz) equivalent to a 1.5 Tesla MR system. The impact of different stent lengths on SAR distribution at a Larmor frequency is well-known. Its maximum SAR values are developing design-dependent approximately at half wave length in ‘tissue/gel’. The simulation and the theoretical results have been compared.

RESULTS

The results showed that each conductive loop of the structure of a stent leads to higher local SAR values in the surrounding of the stent having a maximum effect for a stent length at approximately half the wavelength in the specific conductive medium. However, the highest local SAR spatially occurred at the ends of the stents FIG. 2. The SAR is highly localized and its magnitude depends strongly on the stent length and on the frequency of the electromagnetic field in the specific conductive environment. Design-dependent effects, which could impact the RF induced heating, were not considered in this study because of design-simplified stent models.

CONCLUSIONS

The relationship of RF induced heating is a multi-parameter dependent issue and basically related to parameters like the dimension of a conductive structure, the electromagnetic properties of the surrounding medium/tissue as well as the electromagnetic environment of the MR system including the MR transmit coil. The numerical investigation is very helpful in depicting the local SAR distribution at implants before performing experiments. Validation of numerical results and further research is necessary to establish computer modeling as a standard tool to support in RF heating testing of implants.

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REFERENCES

**Immunomodulatory Effects of Charged ETS in Asthmatic Mice**

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**SUMMARY**

There is growing epidemiological evidence between the electric and magnetic fields (EMFs) and an increased risk of ill health. Corona ions emitted from high voltage power lines can attach at a given rate to atmospheric aerosols, enters the body by inhalation and may then be deposited in the respiratory system and thus may alter the inflammatory responses of the immune system. This study aims to investigate experimentally the effect of charged ETS on the immune system of the asthmatic mice. In our study, the levels of cytokines in charged ETS group and ETS alone exposed group showed no significant difference. There was no significant change in the lung weight and bodyweight in the experimental groups compared to that of control.

**INTRODUCTION**

In recent years the incidence of allergic/atopic asthma has been increasing dramatically in industrialized countries. A variety of causes have been implicated for this increase, including: increases in vehicular exhaust, increased levels of air pollutants, exposure to tobacco smoke, respiratory viral infection, and the recently coined “hygiene hypothesis” [1]. In 1992 the U.S. Environmental Protection Agency (U.S. EPA) concluded that environmental tobacco smoke (ETS) is responsible for the induction of new cases of asthma (2). The extent to which the inhaled particles deposit in the various regions of the respiratory system depends upon the physical factors such as their size, shape and density as well as charge [3]. Adding charge to these aerosols is postulated to increase the deposition on the skin and in the lungs resulting in increased health risk due to image charge effects [4]. Taking this factor into consideration we studied the effect of the charged ETS aerosols on the immune system (IL-4, IL-10, TNF-\(\alpha\), and IFN-\(\gamma\)) of the asthmatic mice.

**MATERIALS AND METHODS**

Female BALB/c mice at 8 weeks of age were immunized and challenged with OVA and aluminum hydroxide to induce asthma. The animals were divided into four groups and were subjected to exposure for one hour/day. Group I—control. Group II—mice exposed to corona discharge. Group III—mice exposed to ETS. Group IV—mice exposed to ETS and corona discharge. ETS exposure was achieved from the side-stream smoke and the ioniser experiments were carried out using a commercially available corona discharge ioniser. The asthmatic mice were subjected to the exposure for 3 days and 3 weeks for short term and long term studies. After the final exposure BAL fluid was collected and cytokine levels (IL-4, IL-10, TNF-\(\alpha\), and IFN-\(\gamma\)) were assayed using ELISA kit. Temperature, relative humidity, EMF and VOCs were also measured. Values are mean ± SD and the significance of difference between mean values was determined by one way analysis of variance (ANOVA).

**RESULTS**
Values are mean± S.D of 6 observations
Asterisks indicate values which are significantly different from controls
p< 0.05 *, p<0.01**, p<0.001***, NS Not Significant

CONCLUSIONS
Our study revealed that the exposure to ETS alone and charged ETS induced significant inflammatory response compared to control. Also the data reveals that the effect of charged ETS was not significant when compared to the ETS alone exposed group. Whereas, mice exposed to Corona discharge alone did not show any significant change in the cytokine levels when compared to the control group. From the above results we conclude that the effect of the corona discharge was negligible which could be attributed due to the low exposure periods.

REFERENCE:
The Influence Of Shielding Of Electromagnetic Field On Regeneration In Planarians Dugesia Tigrina.

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INTRODUCTION

Biological effects of weak electromagnetic fields (EMF) have been insufficiently studied and consequences of exposure of various biological objects to such fields are controversial. However, the phenomenon of weakening ambient EMF is rather frequent as it takes place in industrial buildings, airplanes, trains, spacecraft and other similar applications.

The purpose of this study was to study the effects of shielding from EMF on the regeneration of flat worms and whether such effects are subject to seasonal variability.

MATERIALS AND METHODS

Asexual type of Dugesia Tigrina planaria were used and reproduced by separating the head part of the animal. Planaria were housed in 5 litre flasks filled with a mixture of distilled and tap water (1:2), at 20 degrees Centigrade under dim lights and were fed once a week 10-12 mm long worms with sharp heads were selected for experiments.

Planaria were divided into 3 groups, 30 worms in each: planaria in the first (control) group were allowed to regenerate naturally. Planaria in the second group (experimental group 1) were shielded from EMF 23 hours per day for 10 days. Measurements were taken and maintenance (temperature taking, etc.) performed from 10:00 until 11:00 every day. Planaria in the third group (experimental group 2) were exposed to shielded EMF for only one hour per day – from 10:00 until 11:00, but otherwise kept under conditions identical to those of the control group.

Planarians were dissected with a scalpel while visualized under a binocular microscope. For partial immobilization worms were placed in Petri dishes onto an ice surface covered with filter paper. The growth of the regeneration blastema of the head region was measured using Aver Media TV Capture 98 software and expressed in relative units. All images were captured with WAT-502A camera. Initial stages of regeneration have been described elsewhere (Sheinman et al, 2004). All measurements were conducted during the experimental 10 days, beginning with day one after head separation.

The shielded chamber was constructed from two-layer steel and measured 2x3x2 metres. Coefficient of magnetic attenuation was 3.85 for Z-component and 19.1 for Y component, whereas the electric field was weakened to zero. Attenuation of variable magnetic field in the diapole of extremely low frequencies 2x for the vertical component and 7x for the horizontal component.

Experimental data was analyzed by non-parametric methods and included median (M), interquartile interval between 25 percentile and 75 percentile that included 50% of values of parameter in question. Analysis of regeneration speed was based upon cumulative data. Validity of data was confirmed by U-test of Mann-Whitney-Wilcoxon.
RESULTS

In the control group, all indices and regeneration speed were higher in the summer than in the winter. In the summer, the rate of regeneration progressively increased from the 2\textsuperscript{nd} on to the 10\textsuperscript{th} day of observation, whereas in the winter we only noticed a tendency to an increase of the regeneration rate. A rhythmic component was clearly seen in the summer, but remained practically unnoticed in the winter. Moreover, eyes tend to appear earlier in the regenerative process in the summer and synchronously in the majority of animals; in the winter this process is considerably stretched in time.

In the experimental group 1, the following results were recorded: a) in the winter, indices of regeneration increased 1.5-2 fold regardless of the day (from 1 to 10) of measurement, whereas in the summer only a 20\% increase in the same index was noted; b) winter regeneration rate increased 2-2.5 fold on any measurement day, whereas in the summer, a 3-fold increase in regeneration rate was noted on days 6 and 7; c) an increase in the periodic component of the regeneration rate and decrease in time need for eye formation are more pronounced in the winter.

In the experimental group 2, a) winter is associated with a 10\% increase in regeneration indices, whereas in the summer a 10-12\% decrease of such indices was recorded; b) the rate of regeneration in the winter increases 2-fold and decreases 12\% in the summer; c) an increase in the periodic component in the dynamics of regeneration indices is more pronounced in the winter, when the time needed for eye formation is shortened, whereas no change was seen in the summer.

CONCLUSIONS

Shielding of electromagnetic fields alters regenerative processes in planariidae. These effects depend on the duration of shielding and appear to have seasonal variation. During extended shielding, stimulation of regenerative processes is more pronounced in the winter, rather than in the summer. During short-term shielding, changes in the regenerative process appear in phases, which, in turn, are more pronounced in the winter than in the summer.

It is known that the spectrum of EMF registered at the surface of the Earth spans a considerable diapazon of frequencies. Shields, depending on their properties, attenuate not only the permanent ambient geomagnetic field, but also decrease the intensity of EMF of selected frequencies. Therefore, a biological object that is placed in a shielded environment is exposed to EMF frequencies that are different from the ambient EMF spectrum. Changes of biological processes that are noted in the shielded environments may be caused by the absence of some frequencies that cannot penetrate a shield and/or by a decrease of other frequencies that can penetrate a shield.
INTRODUCTION
Physiological processes in organisms can be influenced by nonionizing electromagnetic energy. From the point of view of public health, there is now a growing demand for the studies on possible adverse health effects from the interactions between the human body and electromagnetic fields (EMFs). Epidemiological studies and many laboratory investigations have suggested a link between ELF magnetic fields and cancers specially childhood leukemia. ELF magnetic fields have been classified as a “possible human carcinogen” by The International Agency for Research on Cancer-IARC [1]. Modifications of ion concentration could contribute to explaining the biological effects of EMF [2,3]. Copper could have an important role in the development and maintenance of immune system function. Zinc may affect the immune status of animals and human. The aim of this study was to investigate whether ELF magnetic field’s exposure effects the Cu and Zn concentrations in serum and renal tissues of guinea pigs.

METERSIALS AND METHODS
A total of 18 male, 250-300 gr weighted (10-12 weeks aged) guinea pigs were used. Specially designed Helmholtz coil system was used as source of homogeneous magnetic field [4]. The subjects were divided into control (n=6) and two exposure groups which were exposed continuously (4 hours/day) (n=6) or intermittently (2 hours on/ 2 hours off / 2 hours on) (n=6) to 50 Hz magnetic field of 1.5 mT for 4 days. Cu and Zn levels were determined by flame atomic absorption spectrometric method. Mann Whitney-U test was applied for statistical analysis.

RESULTS
Increased Cu levels were found in serum and renal tissues which continuously and intermittently exposed to magnetic field. Zn concentration was not effected from magnetic field exposures in serum while Zn level of renal tissue was found decreased with the effect of continous exposure of magnetic field.

CONCLUSION
In this study, continuous and intermittent exposure to ELF electromagnetic field influenced serum and renal tissues’ Cu distribution. Zn concentration influenced only for continosusly exposed magnetic field in renal tissue. These changes could be a risk factor for physiological processes associated with these elements.
ACKNOWLEDGMENT

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REFERENCES


Changes in Rat’s Duodenum Under the High Power Pulse Magnetic Field Exposure

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INTRODUCTION
Magnetic stimulation (MS) where a high power pulse magnetic field (PMF) is used; is a comparatively new method of examination and treatment in different branches of medicine: neurology, psychiatry, urology, rehabilitation medicine, sports medicine etc [1]. The magnetic field during the procedure typically has a strength about 2 T or even more. Hence, apart from stimulation of the target organs, adjacent tissues are under the magnetic field influence as well. The aim of our research is to study reaction of gastrointestinal mucosa on the magnetic stimulation of rat’s abdominal cavity organs as well as investigation of the duodenum endocrine cell reaction as an epithelial cells population responsible for the regulation of intestinal activity by changing their number and possibly their phenotype under different pathological conditions [2].

MATERIALS AND METHODS
The experiment was performed on the 35 albino rats with initial weights of 150-200 g, which were divided into 7 groups: 3 experimental, 3 control on which sham application was done and 1 untreated group (intact). The experimental animals were exposed to 1.5 T, 2.5 Hz PMF in that way that center of the coil of inductor was placed immediately under the abdomen cavity of fixed animal. Procedure lasted for 10 min per day for 2 weeks except weekends with a total of 10 procedures. Pieces of duodenum were collected on the 1st, 7th and 14th day after the last exposure, and after standard histological processing examined by light microscopy. Hematoxilin and eosin staining was used to reveal the typical pathological processes, methods of Grimelius and Masson-Hamperl were used for examination of the total endocrine cell population and EC-cell population respectively. Endocrine cells in 100 fields of vision (X90) were counted and results were recalculated as cells/mm² of epithelia. The Kruskall-Wallis test was used with p<0.05 as criterion for statistical significance.

RESULTS
On the 1st day after the experiment ended, different pathological changes in rat duodenum were observed: subtotal atrophy of mucosa with lack of villi on the major portion of the section, thinning of mucosa, lower and thicker residual villi when compared to intact or sham rats. Additional observations included, dilatation and thrombosis of blood vessels of various sizes in the mucosal and muscular layers, flattening of surface epithelia and eosinophilic contents in the crypts. Focal dystrophic changes in the deep epithelia and in crypts which reveal cell granular atrophy, pale cell cytoplasm, lack of cell nucleus and cell death in number of crypts were also visible. In some foci these changes reach more then 5-7 crypts in the focus, and there were many of such foci in the section. On the 7th and 14th day these pathological changes disappeared with the exception of some dilated and thrombosed vessels.
in mucosa and muscular layer and focal cell atrophy without cell death. But these occurrences were much smaller compared to that on the 1st day.

Reaction of the endocrine cell population is showed in fig. 1 which reveal on the 1st day significant increase of EC-cells while the total population of endocrine cell had only tendency of increasing against control animals and no changes against intact. Increasing of EC-cells with no tendency in the total population reveals latent decreasing of the other type of endocrine cell. On the contrary there was clear increasing of total endocrine cell population with no alteration in EC-cells on the 7th day that is indicate to increasing of decreased on the 1st day total endocrine cells population except EC-cells. And on the 14th day both the total population and EC-cells were significantly increased.

CONCLUSIONS

We observed clear pathological changes in the duodenal epithelia of rats after high power MF exposure. All these pathological changes are thought to be not due to direct cell damage under MF exposure, but secondary changes as a result of longtime circulatory insufficiency and tissue hypoxia. Thrombosed vessels which were in abundance in the mucosa on the 1st day lead to the lack of oxygen in the particular areas of the tissue and therefore in these areas there were cell atrophy up to cell death in most severe cases. These changes occurred some days before material was taken and was compensated only on the 7th day after the experiment ended. This is because there were little residual effects of circulatory insufficiency and only a few thrombosed vessels in the whole sections of all cases by this time. The clear alteration in the endocrine cell population observed may be one of the mechanisms intended for regulation of reconstitution in the duodenal mucosa.

Thereby we conclude that high power PMF may lead to pathological changes in areas adjacent to MS tissues, particularly in the gastrointestinal epithelia. Therefore further morphological investigations should be carried out before introduction of these apparatus in clinical practice.

ACKNOWLEDGMENTS

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REFERENCES


INTRODUCTION

The present study was undertaken to investigate whether a 900 MHz GSM cell phone long term irradiation might affect on the mollusk single neuron ability to store information.

MATERIALS AND METHODS

35 mollusks Helix Pomatia were exposed to radiation of GSM-900 MHz cell phone in the TEM-cell for two hours everyday for 2 months. The output power of the cell phone was controlled using test card. The animals were not awake during the exposure and did not move within the exposure chamber. The peak output power fed into the TEM cell was 1.7 W resulting into average whole body specific absorption rates (SAR) of 100 mW/kg or 300 mW/kg. SAR was calculated using FTDT method.

A further 15 animals served as a controls, which were sham exposed. After 2 months exposure, identified neurons from the animals were subjected to electro-physiological investigations.

Two identified giant neurons were selected for observation. Standard microelectrode technique was used. Neuron was impaled with two glass microelectrodes. One microelectrode served for registration, another one - for intracellular stimulation. Stimulant intracellular impulses represented train of depolarizing current impulses.

Neuron activities were recorded using the POWERLAB data acquisition unit "ML 866" of Adinstruments Co, accompanied with “Chart 5” software.

Action potential (AP) inter-spike intervals, AP peak parameters, latency periods and thresholds of AP firing were determined. Habituation dynamics to identical stimulus of sham
P-15
and actually irradiated neurons were compared. Habituation is regarded as a form of non-
associative learning. Thereby habituation of the single neuron to the intracellular stimulation
might be regarded as storage information by the single neuron.

RESULTS
The experiments show that the dynamics of habituation of sham and actually irradiated
neurons to intracellular stimulation are similar. The average numbers of AP triggered as a
result of stimulation are approximately equal. The time necessary for the onset of habituation
are also approximately the same. Average value of the AP thresholds for sham and actually
exposed identified neurons are approximately equal. AP peak parameters are approximately
similar.

CONCLUSIONS
The facts that dynamics of habituation for sham and exposed neurons are similar might
indicate that some adaptation of the neuron to repeated exposures can occur. Thereby a 900
MHz GSM cell phone long term irradiation in above mentioned doses dos not change neuron
ability to store information.
Abnormality of synaptic vesicular associated proteins in cerebral cortex and hippocampus after microwave radiation

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INTRODUCTION

Microwave as new techniques are increasingly used in the telecommunications, industry, medicine, and so on. There has been a growing concern among the public regarding the potential human health hazard of exposure to the microwave fields. Based on clinical and experimental data, it was claimed that microwave might produce a variety of adverse effects in vivo (e.g. headaches, sleep disturbances, even brain tumors) and alter cognitive function. But little is known about the mechanisms which underlie the cognitive perturbation of microwave exposure. Learning and memory are important aspects of cognitive function, in which the synaptic plasticity plays an essential role in this process. Among the synaptic vesicular associated proteins, it is believed that synapsin I, vesicle-associated membrane protein (VAMP), synaptosome-associated protein of 25000 (SNAP-25), syntaxin and synaptophysin play an important role in the exocytosis. But it is unclear if these synaptic vesicular associated proteins are altered under microwave exposure and the potential mechanisms which show the relation between the change and the injury of learning and memory is still unknown.

MATERIALS AND METHODS

25 Wistar rats were exposed to microwave which the average power density was 30mW/cm² and whole body average specific absorption rate was 14.1W/kg for 5 minutes. Synaptosome preparations in the cerebral cortex and hippocampus were obtained by isotonic Percoll/sucrose discontinuous gradients at 6h, 1d, 3d and 7d. The expression of synaptic vesicular associated proteins was quantified by Western blots and image analysis. The interaction between VAMP-2 and syntaxin was examined by co-immunoprecipitation analysis.

RESULTS

Synapsin I in the cerebral cortex were decreased at 3d (p<0.01) after radiation, and in the hippocampus increased at 1d (p<0.01), decreased at 3d (p<0.01), increased again at 7d (p<0.01) after exposure, compared with the sham-treated controls. Synaptophysin were increased in 1d-7d (p<0.01) after exposure in the cerebral cortex and hippocampus. VAMP-2 were decreased at 1d and 3d (p<0.01) and syntaxin were decreased in 6h-3d (p<0.01) after radiation in the cerebral cortex and hippocampus. The interactions between VAMP-2 and syntaxin were decreased at 3d-7d (p<0.01)
after radiation in the cerebral cortex and hippocampus, compared with the sham-treated controls.

CONCLUSIONS

These results suggest 30mW/cm² (SAR 14.1W/kg) microwave radiation can result in the perturbation of the synaptic vesicles assciated proteins: synapsin I, synaptophysin, VAMP-2 and syntaxin. The perturbation could induce the deposit of synaptic vesicle which might be relative to the disfunction of the synaptic transmission, even the cognition deficit.

ACKNOWLEDGMENTS

We are grateful to Dr. Ruibiao Yang, University of Denver, for kindly providing the anti-VAMP-2 and anti-syntaxin antibodies for this work.

REFERENCES


Influence of Whole Body Exposure of 914 MHz RFID on the Secretion of T3, T4, and Thyroid Stimulating Hormone in Rats – Preliminary Results

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INTRODUCTION

The Radiofrequency identification (RFID) is now being used in a variety of public and private sector settings, from hospital to highway and its application scope and utility is continuously expanding. Therefore, it needs proper investigation about the potential risks of RFID to human healthy. Thyroid hormones are one of the most critically important hormones to maintain the normal biologic activities. In this study, we investigated whether the 914 MHz RFID exposure to rats can cause any changes in serum level of thyroid hormones such as T3 and T4, and Thyroid stimulating hormone (TSH).

MATERIALS AND METHODS

A reverberation chamber was designed and constructed as a whole-body exposure system for animal study at 914 MHz RFID (Eretec Inc, Ansan, Korea) (Figure 1). The SAR distribution inside the experimental animals, which is located in the non-metallic cage on the table in the chamber, was estimated (Jung et al 2008). The validity as whole body exposure system has been verified under supervision of Korea Electromagnetic Engineering Society (KEES).

Sprague-Dawley rats (250gram, male) were used for this experiment and were divided as two groups; a sham-exposed control group (placed in the chamber without RFID exposure, n=13) and a 914 MHz RFID exposed group (n=14). Whole-body average specific absorption rate was 2.0 watt/kg for RFID 914 MHz in this trial. The rats were exposed for 8 hours daily, 5 days a week for 2 weeks that is extremely high energy exposure system to detect in vivo changes of thyroid hormones and TSH. Rats were sacrificed and serum was collected after 2 week-exposure. Serum level of thyroid hormones (T3 and T4) and TSH were investigated using metabolomic analysis with GC-MS. Differences between control and exposed groups were analysed using a Student’s t-test.

RESULTS

A reverberation chamber as whole-body exposure system was verified. The estimated whole-body SAR values were 0.44~2.16w/kg (Input-power range: 10~60W).

Our preliminary results demonstrate significant increase of serum T3 (p<0.0007), T4 (p<0.04) and TSH (p<0.02) significantly in extremely high energy long-duration RFID exposed group (Figure 2).
Figure 1. A whole-body RFID exposure system (A), plane view of the reverberation chamber (B), and structure (C) and picture (D) of Z-shaped metallic mode stirrer to make RFID from the antenna distribute evenly in the reverberation chamber.

Figure 2. Metabolomic analysis of serum T3, T4, and TSH level in rat serum in 914 MHz RFID exposed rats (for 8 hours daily a week for 2 weeks) were significantly increased than the sham-control (p value : student’s t-test at 95% confidence level).

CONCLUSIONS

Although repeated experiments and further evaluation such as analysis of subcellular level are needed, our preliminary results show that long-duration (8 hours) in high energy exposure system (whole body SAR 2 W/kg) per day for 2 weeks cause increased secretion of thyroid hormones and TSH.

REFERENCES


INTRODUCTION

Sudden elevation in blood pressure (BP), even in the absence of elevation in average BP or “true” hypertension, has been identified as an independent cardiovascular risk factor. We measured the effect of static magnetic field (SMF) on abrupt elevation in BP (BP_{AE}) in conjunction with arterial baroreflex sensitivity (BRS) and microcirculation.

MATERIALS AND METHODS

Twenty four experiments (10 controls and 14 with SMF) were performed in conscious rabbits sedated using pentobarbital (PEN) infusion (5 mg kg^{-1} hour^{-1}). Mean femoral artery BP, heart rate (HR), BRS and ear lobe skin microcirculatory blood flow, estimated using microphotoelectric plethysmography (MPPG), were simultaneously measured before and after a 40 min exposure of the sinocarotid baroreceptors to 350 mT intensity SMF, generated by Nd_{2}–Fe_{14}–B alloy magnets. BRS was assessed from HR and BP responses to i.v. bolus of nitroprusside and phenylephrine, Fig. 1.

![Figure 1: Upper panel: SMF, recordings following local action of a 350 mT static magnetic field (SMF) on](image)
RESULTS

After SMF exposure, baroreflex-mediated HR increase, due to the same dose and hypotensive as the control pre-SMF exposure bolus injections of nitroprusside (Ni3, Ni4 before vs. Ni3, Ni4 after SMF exposure) was significantly larger, indicating an increase in BRS for nitroprusside, BRSNi (Fig. 1). In addition, a notable rise of the microvascular blood flow (MPPG) synchronized with an HR swing out, was observed. This indicates that an increase of the baroreflex stimulus-induced microcirculatory response is existing. After SMF exposure a marked increase in HR variability (HRV) is apparent. In the control runs, no change in baroreflex-mediated HR and microcirculatory response (Ni3, Ni4 after sham exposure) or in HRV was observed (Fig. 1). Analysis of percentage BP decrease revealed that SMF significantly reduced phenylephrine-induced abrupt elevation in BP compared with control experiments with sole pentobarbital infusion (ΔBPAE-SMF% vs. ΔBPAE-PEN%, -0.83±5.4% vs. 21.1±7.65%, p < 0.017, Man-Whitney rank sum test). A significant inverse correlation was also found between SMF-induced decrease in BP abrupt elevation (ΔBPAE%) and increase in BRS for phenylephrine (ΔBRSPh%) (r=0.40, p<0.032).

DISCUSSION AND CONCLUSIONS

The principal finding in this study that SMF buffer abrupt elevation in BP effectively. SMF BP buffering is a result of direct magnetic stimulation of the sinocarotid baroreceptors and activation of the arterial baroreflex cardiovascular control mechanism, reflected in the simultaneous increase in BRS and HRV [1], and in baroreflex-mediated microcirculatory response (Fig. 1). Theoretical considerations suggest that the applied SMF may influence sinocarotid baroreceptor sensory transduction, modifying the baroreceptor Ca2+ dependent gated depolarization region as well as stretch activated Ca2+ channels on the baroreceptor spike initiating zone [2].

Low BRS and HRV are an important independent cardiovascular risk factors [1], therefore an increase in BRS and HRV, along with enhanced BP buffering, suggests SMF to show potential cardioprotective properties. Further research is needed, because it is likely that contactless magnetic stimulation of the arterial baroreceptor cardiovascular regulatory system by easily accessible sinocarotid triangle opens new possibilities how to complexly adjust macro and microcirculation, ameliorate the arterial hypertension, cardiac disrhytmias and the vasoconstrictive state that are characteristics for various important cardiovascular conditions including ischemic heart disease, diabetes and others.

ACKNOWLEDGMENTS

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REFERENCES


A Determination Of The Electromagnetic Field Intensities Resulting From Various Wireless Devices As A Function Of Time And Location In The City Of Boulder.

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INTRODUCTION

The purpose of this paper is to provide electromagnetic field intensity measurements that can provide baseline data for the researchers carrying out epidemiological studies in the area of effects of RF radiation on humans and identify the most prominent field strength components contributing towards the emission of the RF radiation. This study will find out the EMF levels to which the general population of Boulder, Colorado is exposed to, compare the RF power levels in Boulder with the surrounding areas like Golden, Lookout Mountain in the state of Colorado and a similar survey done in for United States of America in 1980. [1]

MATERIALS AND METHODS

We have followed a methodology which included the following steps:

- **Laboratory and Equipment** – We have identified an RF meter-Electrosmog Meter [2]. The Electrosmog Meter covers the 50 MHz to 3.5 GHz frequency range and is used in 3-axis (isotropic) measurement. It is extremely sensitive (with ranges from 20mV/m to 108mV/m) and updates 2.5 times per second. It displays instantaneous value, maximum value, and average value. It measures in V/m, A/m, W/m² and has an accuracy of ±2.4dB. The meter is also affordable and easy to operate.

- **Areas and locations for measurement of data** - Initial measurements were performed on the CU campus and near Lookout Mountain for comparative reference. Areas of high public utilization and suspected areas of high wireless services like Pearl Street, Folsom field and US-36 in Boulder are going to be used for collecting data.

RESULTS / ANALYSIS

The values for the measurements of the electric field and power densities were accordingly measured and recorded.

a. A detailed analysis of the EMF measurements including average values and standard deviations will be given once all the measurements have been completed.

b. The initial readings that were taken with the Electrosmog (RF) Meter varied with the location and time of day.. The following table illustrates this difference:

<table>
<thead>
<tr>
<th>Temperature/Time</th>
<th>9 p.m. at 38°F on Jan 30th, 2009</th>
<th>2 p.m. at 50°F on Jan 31st, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-axis</td>
<td>310.5 mV/m</td>
<td>328.9 mV/m</td>
</tr>
<tr>
<td>Y-axis</td>
<td>259 mV/m</td>
<td>278.3 mV/m</td>
</tr>
<tr>
<td>Z-axis</td>
<td>460.3 mV/m</td>
<td>334.5 mV/m</td>
</tr>
</tbody>
</table>

Table 1: EMF readings taken along X, Y, Z axis at Folsom Field on the CU campus.
<table>
<thead>
<tr>
<th>Temperature/Time</th>
<th>9 p.m. at 38°F on Jan 30th, 2009</th>
<th>2 p.m. at 50°F on Jan 31st, 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-axis</td>
<td>6 mV/m</td>
<td>151.3 mV/m</td>
</tr>
<tr>
<td>Y-axis</td>
<td>33.5 mV/m</td>
<td>179.9 mV/m</td>
</tr>
<tr>
<td>Z-axis</td>
<td>6 mV/m</td>
<td>198.6 mV/m</td>
</tr>
</tbody>
</table>

Table 2: EMF readings taken along X, Y, Z axis in the lobby of the Engineering Center on the CU campus.

An initial iteration of the readings by keeping the place constant, but varying the times of the day showed that the EMF readings were higher during the day time associated with high wireless activity compared to the readings taken during the night time.

CONCLUSIONS

a. The data gathered from the measurements will be utilized in the following two ways:

1. As a resource for researchers, conducting epidemiological studies in the area of EMF radiation from wireless devices and the possibility of corresponding health hazards resulting from them.
2. Based on the data gathered and measurements made on the spectrum analyzer, we aim to identify the wireless signals which significantly contribute towards the EMF radiation in the environment.

b. The results derived from this project will help us in making a useful contribution towards the research community working specifically on the aspect of the probability of health hazards resulting from the use of wireless devices. We will also be able to understand and identify the impact of each wireless technology on the overall electromagnetic radiation in the environment, thereby, creating awareness amongst the users.

ACKNOWLEDGMENTS

Financial support from the 2004 Gordon Prize.

REFERENCES


Simultaneous Exposure of workers to EMF Radiated by a Three Band Base Station Antenna

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INTRODUCTION

Occupational exposure of maintenance workers in close proximity to transmitting base station antennas has been the focus of many studies [1][2][3]. However, most of these studies investigate exposure at a single frequency and do not consider the possibility of simultaneous exposure to several transmitting frequencies at the same time. By using numerical FDTD simulations, we have evaluated the combined EMF exposure of an anatomical human model positioned in front of a 3 band panel base station antenna, with simultaneous exposure at frequencies of 900, 1800 and 2100 MHz.

MATERIALS AND METHODS

We used the FDTD software SEMCAD X by Schmid & Partner engineering for the numerical simulations. First, we built a detailed model of the base station antenna. The antenna in question was a double cross polarized KATHREIN 742 265 (16 dBi gain, 10°vertical beamwidth at GSM and 18 dBi gain, 5°vertical beamwidth from 1700 to 2180 MHz) directional antenna. To validate the antenna model, we compared the far-field pattern, gain, horizontal and vertical beam widths with the data in the manufacturer’s datasheet and good agreement was obtained. The human model used was an adult male from the Virtual Family [4](Duke). To keep the computation time reasonably short, the maximum voxel size in the human model was limited to 5 mm. The model was positioned facing the antenna at different distances – from 15 to 50 cm away from the rear metal reflector of the antenna.

Separate simulations were performed for each of the 3 frequencies at each location. Results normalized to 1 W radiated power and spatial peak SAR were extracted for each frequency. In order to be able to straightforwardly add the SAR contribution from each frequency we had to use exactly the same computational grid in all three cases.

To evaluate simultaneous exposure, formula (1) from the ICNIRP guidelines was used:

$$\sum_{i=100\text{GHz}}^{10\text{GHz}} \frac{SAR_i}{SAR_L} \geq 1$$

Where $SAR_i$ is SAR caused by exposure at frequency $i$ and $SAR_L$ is the basic restriction for that frequency. This formula can be used for both whole-body and partial SAR. A power of 30 W for each of the carrier frequencies was chosen to represent a realistic exposure scenario.
RESULTS

Figure 1 shows a cross-section of the model and the SAR distribution. The highest SAR values were found in the head and chest regions. Locations of the spatial peak SAR can vary with frequency – the highest SAR value is located at the red square in each part of figure 1. Table 1 shows the values of SAR at the frequencies studied.

<table>
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<tr>
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<th>15 cm</th>
<th>30 cm</th>
<th>45 cm</th>
</tr>
</thead>
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<td>2.88 W/kg</td>
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<td></td>
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<td></td>
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<td>2100 MHz</td>
<td>Spatial peak</td>
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<td>0.05 W/kg</td>
<td>0.04 W/kg</td>
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<tr>
<td>Combined</td>
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<td>5.47 W/kg</td>
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<tr>
<td></td>
<td>Whole-body</td>
<td>0.55 W/kg</td>
<td>0.35 W/kg</td>
<td>0.22 W/kg</td>
</tr>
</tbody>
</table>

Figure 1: Spatial peak SAR at 30 cm distance from the antennas. From left to right: 900 MHz, 1800MHz, 2100 MHz and combined exposure.

Table 1: Spatial peak and whole body SAR values at different frequencies vs. distance from antenna

CONCLUSIONS

The results show that when considering simultaneous exposure to multiple frequencies, the whole-body SAR basic restriction presents a stricter limit than spatial peak SAR, as the latter generally does not have peaks at the same position each frequency. Therefore, the whole body SAR value will reach the basic restriction at a greater distance than spatial peak SAR. In our exposure scenario none of the separate frequencies exceeded the basic restrictions, even at the shortest distance investigated. In the case of combined exposure whole-body SAR exceeds the basic restriction at approximately 26 centimetres and spatial peak SAR at the distance of 22 centimetres.

ACKNOWLEDGMENTS

We would like to thank Mobitel d.d. for giving us access to the antenna investigated in this work.

REFERENCES

DEVELOPMENT OF A MEASUREMENT SYSTEM FOR MEASURING INTERMEDIATE-FREQUENCY MAGNETIC-FIELD FOR SIMULATION OF INDUCED CURRENT DENSITY IN A HUMAN BODY

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INTRODUCTION

In the ICNIRP [1] guidelines, the induced current density in a human body and the incident magnetic-field strength are set as the basic restriction and as one of the reference level, respectively, in the low-frequency region (up to 10 MHz). The incident magnetic-field strength that is used as the reference level is determined under the assumption of the worst exposure condition, i.e., whole-body exposure to a uniform magnetic field. Recently, induction heating (IH) hobs have become popular, which have led to increased public concern on the health effects of exposure to intermediate-frequency (IM) magnetic fields that leak from the IH hobs. Because there are few studies on human exposure to IM magnetic fields, which has been defined as the range from 300 Hz to 10 MHz by WHO, WHO has recommended that further studies relating to IM magnetic fields, especially, dosimetry for human exposure to magnetic fields from IH hobs [2], be carried out. In view of the WHO recommendation, we have performed studies involving the numerical simulation of the induced current density in humans by considering human models and on the experimental measurement of the magnetic field distribution around IH hobs [3,4]. We found that the magnetic field distributions around the IH hobs are strongly heterogeneous and that they cause large variations of the induced current density. In this paper, we describe the development of a measurement system comprising an array of sensors. The measurement system enables high-spatial-resolution and short-time measurement. We also describe numerical simulation of the induced current density on the basis of preliminary measurements.

MATERIALS AND METHODS

Figure 1 shows the measurement system comprising array sensors. The array sensors consist of two small three-axis coils [3] that can be used for performing preliminary measurements. Before the measurements, we confirmed that the interference between the two sensors can be ignored. The details of the process of confirmation are discussed in the presentation. For the preliminary measurement, an IH coil detached from an IH hob was used. The coil was powered by a 1-A sinusoidal current with a frequency of 21 kHz. The measurement was conducted at 20-420 mm from the front of the coil. The measurement interval was 20 mm, i.e., 20 measurement points. These points were used for determining the magnetic dipole moment of the IH coil, which was required for the numerical simulation. The impedance method was used for the numerical simulation of the induced current density in an adult male voxel model [5]. The voxel size was 2 mm. Details of the numerical simulation have been presented in [6].

RESULTS

The magnetic dipole was assumed to be located at a distance of 800 mm from the ground plane. The magnetic dipole moment fitting the measured magnetic field was
determined to be 2.04 mAm² as shown in Fig.2. It is shown that the fitting was better up to 100mm from the IH coil but not far from the coil. The reason was because the influence of the noise of the measurement system (0.01μT in Fig.2) could not be ignored. In the numerical simulation, a human voxel model was positioned at a distance of 104 mm from the magnetic dipole. The calculated induced current density in a vertical section of the human model is shown in Fig.3. A high induced current density is observed around the closest height of the dipole, especially in tissues with high conductivity.

CONCLUSIONS
This presentation discussed a measurement system comprising array sensors for measurement of the magnetic field in the IM band. As a preliminary measurement, the magnetic field around the IH coil was measured and the magnetic dipole moment of the coil was determined from the measured magnetic field distribution. We also calculated the induced current density in a vertical section of a human voxel model exposed to a magnetic field.

REFERENCES
Personal exposure to high frequency electromagnetic fields in Slovenia

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INTRODUCTION
Due to the introduction of different new technologies which are emitting electromagnetic fields (EMF) typical exposure of the public is increasing. Since classic measurement methods using wideband instruments or spectrum analyzer lack time and spatial information, personal exposure meter (PEM) gives good estimation of the actual personal exposure [1-3]. Such data allow time evaluation of the contributions of different sources to the overall personal exposure. To evaluate the typical exposure of Slovenian inhabitants, a study was carried out in 2007 and 2008, in which the exposure of 54 volunteers was measured using PEM.

MATERIALS AND METHODS
To capture the typical exposure of inhabitants it is important to include population from different living environment and with different daily habits. To obtain a representative sample an open invitation was published in media inviting volunteers to participate in this study. At the beginning, the volunteers were instructed to carry the PEM on the belt, in a pouch or in backpack whereas when sleeping they were allowed to place the PEM close to them. They were also instructed to fill the diary about their activities during the measurements. Since we used Antenessa EME SPY 120 (now Satimo EME SPY 121) PEM, which has very good capability to separately measure contributions of different high frequency technologies (see Table 1), combining the data from the diaries with the results of measurements allows identification of the patterns of exposure to different technologies. The PEM separately measures radio (FM, 88–108 MHz) and TV broadcasting (TV3, 174–223 MHz; TV4&5, 470–830 MHz), private mobile network (Tetra, 380–400 MHz), mobile phones (Gsm_tx, 880–915 MHz; Dcs_tx, 1710–1785 MHz; Umts_tx, 1920–1980 MHz) and base stations (Gsm_rx, 925–960 MHz; Dcs_rx, 1805–1880 MHz; Umts_rx, 2110–2170 MHz), cordless phones (Dect, 1880–1900 MHz) and Wireless Local Area Network (Wlan, 2400–2500 MHz).

When the PEM was handed to the volunteer, it was already programmed to measure EMF for 34 hours with the sampling rate of 3 samples per minute; giving a total of more than 6000 samples.

RESULTS
54 volunteers were carrying the PEM from July 2007 to November 2008. Taking together, over 280 000 measurements were acquired. Based on the data from the diaries of volunteers measurements were classified according to the area of exposure: 34% of total was considered as exposure at home, which is situated in the urban area (Home/Urban); 28% as the exposure at home, which is situated in the rural area (Home/Rural); 14% as the exposure at work (Work); 9% as the exposure outside in the urban area (Outdoor/Urban) and 3% as the exposure outdoor in the rural area (Outdoor/Rural). 12% of the remaining duration of exposure was not classified due to the inadequate information.
Table 1: Maximum and average value of the measured electric field strength and number of measurements for each area are presented.

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<tr>
<th></th>
<th>[V/m]</th>
<th>FM</th>
<th>TV</th>
<th>Tetra</th>
<th>TV_{ax}</th>
<th>Gsm_{tx}</th>
<th>Gsm_{rx}</th>
<th>Dcs_{tx}</th>
<th>Dcs_{rx}</th>
<th>Dect</th>
<th>Umts_{tx}</th>
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<th>Wlan</th>
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<td>0.05</td>
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</tbody>
</table>

Since the lower detection limit of the PEM is 0.05 V/m, all the values below the detection limit were set to 0.05 V/m. As could be seen from the Table 1 a lot of average values are equal to 0.05 V/m meaning that the average exposure due to these sources is low (FM, TV, Tetra, Gsm_{tx}, Dcs_{tx}, Umts_{tx}, Dect, Wlan). But for some of these sources (Gsm_{tx}, Dcs_{tx}, Dect) which are body worn the maximum value is reaching the upper detection limit of the PEM (5 V/m).

The ratio between the measurements with all the measured values below the lower detection limit and the total number of measurements is an informative description of the exposures. Below the lower detection limit were 45% of the measurements for Home/Urban class, 73% of the Home/Rural, 50% of the Work, 29% of the Outdoor/Urban and 48% of the Outdoor/Rural class. Overall, more than half of the time (53%) the volunteers were exposed to very low values (all the measured values below the detection limit of the PEM).

**CONCLUSIONS**

The results clearly show that the average personal exposure to high frequency EMF in Slovenia is quite low. Not only that more than half of measurements had all the measured values below the lower detection limit, also the highest average exposure levels are low: 0.16 V/m for the Outdoor/Urban exposure to the base stations (Gsm_{tx}). In the Rural area, the average values are even lower, the maximum values are 0.08 V/m for the Outdoor/Rural exposure due to the radio broadcasting (FM) and base stations (Gsm_{tx}). This means that the average exposure in the Rural environment is lower than in Urban environment.

The most important contributors to the maximum exposures are these technologies used close to the body: mobile phones (mainly in Gsm and Dcs frequency ranges), Dect cordless phones and Wlan devices.

**REFERENCES**


On The Specific Absorption Rate Measurement of Pulsed Radio Frequency Signals

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INTRODUCTION

The SAR (Specific Absorption Rate) compliance test of mobile phones is currently based on measurement standards such as IEC62209-1 [1]. The electric field induced inside a head phantom is measured using an isotropic probe. The latter consists of three mutually orthogonal diode-loaded electrically short dipole antennas connected to highly resistive lines. The equivalent electrical circuit of each branch of the probe is shown in Figure 1. The output voltage \( V_0(t) \) is proportional to the average value of the square of the electric field component measured by the dipole. Since the voltage-current characteristic of the diode is inherently nonlinear, amplitude compression is experienced when the input signal level switches from the square-law region to the linear region. The probe calibration data—which basically provide the correspondence between measured output voltages and known incident electric field levels—is used to derive the diode compression point.

The probe correction is straightforward for devices which are tested in the CW (continuous wave) mode because probes are usually calibrated using CW signals. However many commonly encountered wireless communication devices operate in a burst-type or pulsed radio frequency (RF) mode. For example, GSM (Global System for Mobile communication) mobile phones which are based on the TDMA (Time Division Multiple Access) digital modulation scheme typically transmit bursts with durations of 577 \( \mu \)s every 4.6 ms. In such cases, the CW probe calibration data may still be exploited: the probe correction is applied to the time-average of the output voltage. Two different approaches may be adopted to obtain the time-average value: (a) an ensemble average of the measured samples or (b) when possible with the probe at hand, a peak detection post-multiplied by the known duty cycle of the signal. In an aim to provide a solution for the SAR measurement of pulsed RF signals with unknown duty cycle, the time domain response of an off-the-shelf SAR probe and the two time-averaging schemes are herein investigated.

![Figure 1: Equivalent electrical circuit of the diode-loaded dipole antenna.](image_url)
MATERIALS AND METHODS

A digital storage oscilloscope is employed to measure the time domain response of the SAR probe to a GSM-type signal. To account for possible alterations of the measured response when the probe is plugged to the appropriate readout electronics, the probe’s response is further assessed in the actual SAR measurement setup using a fast sampling rate (9 kHz) which allows the reconstruction of the GSM waveform. The measured rise and fall times of the probe are employed in a simple theoretical model to mimic the data acquisition of the dosimetric system and to evaluate eventual errors induced by the adopted time-averaging scheme. The maximum 10g averaged SAR of several GSM mobile phones is evaluated using the two different averaging schemes.

RESULTS

For the SAR probe considered herein, a small imbalance is observed between the rise and fall times (see Figure 2). In this case, a small error is expected when the SAR evaluation of pulsed RF signals is based on the ensemble average approach. Due to the nonlinearity of the diode, the error increases for relatively high levels of measured electric fields. The probe response curve shows that the maximum value is reached after about 0.4 ms indicating that the SAR measurement of GSM mobile phones based on a peak detection approach is possible. Based on the one-eighth duty cycle assumption, this approach provides a slight overestimated SAR value since the GSM burst follows a predefined mask different from a true RF pulse.

CONCLUSIONS

The accuracy of the ensemble average scheme is dependent upon the time domain response of the probe. An imbalance in rise and fall times will induce an error in the SAR value. When used with the readout electronics, the probe considered herein enables peak-detection of pulsed RF signals for pulse widths exceeding 0.5 ms. If the duty cycle of such signals is unknown, a worst-case SAR value is obtained by assuming a 100% duty cycle.

REFERENCES

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Calculation Of Whole-body SAR From Exposimeter Measurements For Different Phantoms

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INTRODUCTION

Personal electromagnetic-field exposure of the general public can be characterized using personal exposure meters (PEMs). The objective of this paper is to calculate whole-body specific absorption rate (SAR) from measurement data obtained with a PEM for different human spheroid phantoms. Whole-body SAR values calculated from PEM data will be compared for an average man, an average woman, a 10-year-old child, a 5-year-old child, and a 1-year-old child. The presented method can be used in epidemiological studies and enables to obtain both field and SAR values.

MATERIALS AND METHODS

We consider the data of our measurement campaign in [1] using a PEM of type DSP120 EME SPY and focus on the scenario “outdoor walking during daytime in an urban environment” in the city of Ghent, Belgium. The PEM is worn in a backpack or shoulder bag. We consider here GSM downlink (DL) exposure. Measurement samples are acquired each 10 s for the scenario during 5 hours.

The whole-body SAR (SARwb) is calculated from the PEM-data for different homogeneous spheroid human body phantoms, defined in [2]. The sizes of the spheroid for an average man, an average woman, a 10-year-old child, a 5-year-old child and a 1-year-old child have been taken from [2]. The homogeneous tissue of the spheroid human body phantoms has been assigned the dielectric properties of head tissue (permittivity $\varepsilon_r = 41.4$ and conductivity $\sigma = 0.99$ S/m) suggested by IEC 62209 for compliance testing. The statistical tool of [3] is used for the calculation of the SAR. We have selected an urban macrocell environment. For every size of the human body phantom, 5,000 realistic exposure samples have been generated to obtain statistically relevant results.

RESULTS

Fig. 1 shows the 95 percentiles $p_{95}$ of the whole-body SAR (denoted as $p_{95}(SAR_{wb})$) as a function of the measured fields $E$ [V/m] (averaged over 6 minutes): the relation is monotone and almost quadratic. The highest SAR values (at 950 MHz) are obtained for the 1-year-old child, followed by the 5-year-old child, 10-year-old child, average woman and the average man. The reason for this is that the smaller the phantom, the smaller the amount of tissue to penetrate for an incident field (lower weight) and, consequently, the higher the overall $SAR_{wb}$. $p_{95}(SAR_{wb})$ can then be fitted to a function of the following form for the different phantoms:

$$p_{95}(SAR_{wb}) = a \cdot (E)^b \quad [W/kg]$$

With $a$ and $b$ the parameters of the fit for the GSM DL scenario and $E$ is the measured electric field averaged over 6 minutes. For a certain E-field value, the function of (1) gives the whole-body SAR for which 95 % of the possible $SAR_{wb}$ are lower than this value.
The values for the parameters a and b of the fits for the different phantoms of Fig. 1 are shown in Table 1 together with the 05, 50, 95, and 99 percentiles of the $SAR_{wb}$ for the 95-percentile of E namely, $p_{95}(E) = 0.26 \text{ V/m}$ [1]. The considered 95-percentiles of $SAR_{wb}$ increase thus almost quadratic with increasing E-fields in an environment (b = 2.0). Again the highest $SAR_{wb}$ values are obtained for the 1-year old child due to its smallest dimensions: the 99th percentile is equal to $9.22 \mu\text{W/kg}$, which is much lower than the (ICNIRP) basic restriction for the general public (0.08 W/kg).

**Table 1:** Parameters of fits and 05, 50, 95, and 99 percentiles of $SAR_{wb}$ for $p_{95}(E) = 0.26 \text{ V/m}$ (950 MHz).

<table>
<thead>
<tr>
<th>phantom</th>
<th>a</th>
<th>b</th>
<th>$p_{05}(SAR_{wb})$ [µW/kg]</th>
<th>$p_{50}(SAR_{wb})$ [µW/kg]</th>
<th>$p_{95}(SAR_{wb})$ [µW/kg]</th>
<th>$p_{99}(SAR_{wb})$ [µW/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>man</td>
<td>3.28e-5</td>
<td>2.0</td>
<td>0.31</td>
<td>0.59</td>
<td>2.22</td>
<td>4.61</td>
</tr>
<tr>
<td>woman</td>
<td>3.39e-5</td>
<td>2.0</td>
<td>0.32</td>
<td>0.60</td>
<td>2.30</td>
<td>5.13</td>
</tr>
<tr>
<td>child 10y</td>
<td>4.24e-5</td>
<td>2.0</td>
<td>0.46</td>
<td>0.82</td>
<td>2.88</td>
<td>6.71</td>
</tr>
<tr>
<td>child 5y</td>
<td>5.11e-5</td>
<td>2.0</td>
<td>0.57</td>
<td>1.00</td>
<td>3.45</td>
<td>8.22</td>
</tr>
<tr>
<td>child 1y</td>
<td>6.00e-5</td>
<td>2.0</td>
<td>0.75</td>
<td>1.24</td>
<td>4.07</td>
<td>9.22</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Whole-body SAR of different human spheroid phantoms is determined from measurement data obtained with a personal exposure meter for GSM DL signals. The highest SAR values (at 950 MHz) are obtained for the 1-year old child, followed by the 5-year old child, 10-year old child, average woman, and average man. All values are below the basic restriction of 0.08 W/kg for the general public. Functions of the SAR versus measured electric fields are provided, enabling epidemiological studies to make an analysis in combination with both E-field and actual whole-body SAR.

**REFERENCES**


Uplink Output Power Measurements in a 3G Network

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INTRODUCTION

In 2006 we presented results on the output power of 3G mobile phones based on network measurements of all calls in a limited selection of single cells in Sweden [1]. Since then the traffic in the TeliaSonera 3G network has increased substantially and the higher load could have some impact on the output power distribution which motivated a renewed assessment. In addition it is now possible to collect data on terminal output power for a whole region instead of for single cells. The objective of this project was to collect sufficient data for reliable estimation of output power distribution for both voice and data traffic and for different types of environments such as urban and rural areas.

MATERIALS AND METHODS

The output power was registered in the TeliaSonera WCDMA network in Sweden including both urban and rural areas. For Ericsson equipment the Radio Environment Statistics module (RES) which is installed in the Radio Network Controller (RNC) can be directed to record the output power of all users connected to radio base stations controlled by the RNC [2]. In total seven RNCS were selected within the WCDMA RAN P5/P6 network which control all the radio base stations in the areas shown in figure 1.

The duration of the measurements was about 23 hours per day for at least a week during November, 2008. The following services were registered in parallel: voice, video and various data application services. The sampling interval was 2 seconds and all user equipment connected to the radio base stations were selected to report their output power data. The output power was recorded in 4dB intervals apart from the lowest interval which included the whole range between -50 dBm and -21 dBm.

In the analysis the probability density function (PDF) was determined from the distribution of samples in the various output power intervals. A continuous CDF function was also modeled in the range -21 dBm to 24 dBm through piecewise fitting of a cubic polynomial function (spline-interpolation) of the experimentally determined CDF. Based on the modeled CDF various estimates such as mean, median and 90th percentile of the output power were determined. The TeliaSonera radio wave propagation classification of each base station in rural, suburban, urban or dense urban type was used.
RESULTS
In table one below the output power data for 3G terminals are shown and in figure 2 the corresponding CDFs are presented for voice, data and video connections.

<table>
<thead>
<tr>
<th>Environment</th>
<th>Median dBm</th>
<th>Mean dBm</th>
<th>90th percentile dBm</th>
<th>Calling time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>-14.0</td>
<td>-3.1</td>
<td>-1.7</td>
<td>236621</td>
</tr>
<tr>
<td>Suburban</td>
<td>-17.0</td>
<td>-4.4</td>
<td>-3.6</td>
<td>273539</td>
</tr>
<tr>
<td>Urban</td>
<td>-17.1</td>
<td>-4.6</td>
<td>-3.6</td>
<td>104097</td>
</tr>
<tr>
<td>Dense urban</td>
<td>-20.8</td>
<td>-4.9</td>
<td>-5.4</td>
<td>134382</td>
</tr>
<tr>
<td>Indoor</td>
<td>&lt;-21</td>
<td>-7.0</td>
<td>-10.4</td>
<td>10841</td>
</tr>
</tbody>
</table>

Table 1 Voice calls, output power of terminals averaged over weekdays and weeknights.

Figure 2 CDF of output power for voice, data and video connections in urban environments during weekdays and weeknights with output power expressed in dBm and mW.

CONCLUSIONS
• The average terminal output power for 3G voice calls was on average below 1 mW for any environment which is less than 1% of maximum available output power.
• The average terminal output powers were not higher than in our measurements performed 2006 which however were based on a much more limited amount of data.
• For video calls and data applications the average terminal output power was up to about 6-8 dB (4-6 times) higher than for voice calls.

REFERENCES
INTRODUCTION

In order to investigate the biological effects of exposure to microwaves from mobile phones, several localized exposure systems have been developed [1]. Recently, the development of an exposure system capable of subjecting immature rats to local exposure has been demanded. In this study, we investigated such an exposure system by using a double negative (DNG) material lens. DNG material that simultaneously has negative permittivity and negative permeability also has a negative refractive index [2]. The planar DNG material lens can realize perfect focusing [3].

METHODS

The distributions of electric field and specific absorption rate (SAR) were calculated using the recursive-convolution (RC)-FDTD method [4]. In this method, dispersive media with negative permittivity and negative permeability can be modeled. The DNG material lens is developed by using the lossless Drude model. The Drude model parameters were as follows: \( \omega_p = 2\pi \times \sqrt{2} \times 3.4 \times 10^9 \text{rad/s} \), \( \varepsilon_r = \mu_r = -1 \) and the size of the DNG lens was 600 \( \times \) 600 \( \times \) 176 mm. Therefore, the index of reflection \( n \) is \(-1\) at the target frequency of this study, i.e., \( f = 3.4 \) GHz, which is to be used for cellular phone systems beyond IMT-2000.

RESULTS AND DISCUSSION

The electric field distributions over the DNG material lens, shown in Fig. 1, are calculated and plotted in Fig. 2. The electromagnetic energy is focused onto a spot beyond the DNG material lens. The SAR distributions of the rectangular phantom and a four-week-old rat model are shown in Figs. 3(a) and (b), respectively. Each distribution is normalized against its maximum value. For the rectangular phantom, the maximum value of SAR appears at the center of the phantom surface. For the rat model, the higher values of SAR appear in the head region. We also compared the locality of the exposure, i.e., the ratio of the average SAR in the target tissue to the average SAR in the whole body with and without the DNG material lens using the rat model. In the case of cranial-window rats [5], the target tissue is the upper surface of the brain. We observed that locality almost quadruples when the DNG material lens are used. However, the locality obtained when using the DNG material lens is about one-fourth times lower than that obtained by using the previously developed 8-shaped loop antenna [1]. Further, we observed that higher values of SAR appear in areas other than the target tissue. These results suggest that the DNG material lens is not suitable for use in a localized-exposure setup for rats and mice.
CONCLUSIONS

In this study, we examined an exposure system equipped with the DNG material lens. Electromagnetic energy emanating from a dipole antenna is focused onto a spot beyond the DNG material lens. When the dipole antenna is placed 88 mm away from the rat model, the locality of exposure when the DNG material lens is used is four times that of when the DNG material lens is not used.

Figure 1: Illustration of the behavior of the DNG material lens

Figure 2: The electric field (absolute magnitude) in the x–z plane and shaft axis

Figure 3: Calculated SAR distributions (a) of the rectangular phantom and (b) of a four-week-old rat model, denoted in the x–z plane and shaft axis.

REFERENCES

Identification of factors influencing the Whole Body Absorption Rate using statistical analysis

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INTRODUCTION

To protect people from Electromagnetic Fields (EMF), ICNIRP has defined limits. The fundamental ones are the Basic Restrictions (BRs) [1]. The BRs determine the maximum values (averaged over the whole body and averaged over 10 grams of tissues) of Specific Absorption Rate (SAR). Since BRs can be complex to assess ICNIRP has also defined derived value: the reference levels (RLs). These RLs were established to guaranty the compliance to the BRs. Several studies with human model voxels (a.k.a. phantoms) show that even below the RLs, the WBSAR (Whole Body average SAR) may exceed the BRs due to the variability of human morphology [2].

In this paper we will identify the morphological factors influencing the WBSAR in the case of a frontal plane wave exposure at the frequency of 2100MHz in isolated conditions and vertical polar. The method is based on the construction of a model that makes it possible to estimate the statistical distribution of the WBSAR for a given human population.

MATERIALS AND METHODS

At the international levels, only few human voxel models exist. In our study, 12 models have been used (3 females, 7 males and 2 children). Other children phantoms were obtained using the morphing technique. Since the number of observations is very small, a purely statistical approach to estimate the distribution of the WBSAR is ruled out.

Our proposal is to build a model of the WBSAR as a function of a number of external factors (such as the Body Surface Area) and internal factors (such as the proportion of skin, muscles...). The parameters of the model are estimated by least squares. Statistical tests are used to determine the significance of the factors. Finally, we propose a technique to test the robustness of the model.

RESULTS

Recent publications [2, 3] highlighted the relationship between the WBSAR and external morphology. Several factors are found such as BSA/weight. The expression is as follow:

\[ \hat{y}_{WBSAR} = \alpha X + \varepsilon \]  

(1)

Where \( \hat{y}_{WBSAR} \) is the estimated value of the WBSAR given by (1); \( \alpha \) the unknown parameter of the models; \( X \) is the BSA/weight and \( \varepsilon \) is the error generated by (1).

The estimation of \( \alpha \) using only the set of 12 phantoms generates an important error (30% in term of relative error). However the Student test [3] shows that \( \alpha \) is very significant (different from 0). Nevertheless, the estimation of this parameter \( \alpha \) using one family among the families of phantoms (where the family of phantoms contains an initial phantom and his morphed phantoms) achieves a very good estimation of the WBSAR (Figure 1). This
parameter $\alpha$ is almost constant for each family. This leads us to conceive that $\alpha$ depends mainly on the internal morphology which is substantially the same for an adult and his morphed phantoms.

To test that $\alpha$ depends on the internal morphology. We have established this expression:

$$\hat{\alpha}(x_S, x_M, x_F, x_B) = \xi_1 + \xi_2 \left(2x_S + x_M + x_F + \frac{3}{5}x_B\right) + \nu$$

(2)

Where $\hat{\alpha}$ is the estimation of $\alpha$, $x_S$ the proportion of skin, $x_M$ the proportion of muscle, $x_F$ proportion of fat and $x_B$ proportion of bones, $\xi_1$ and $\xi_2$ the parameters of (2) and $\nu$ is the errors generated by (2). In addition, the constant of multiplication affected to each of the internal factors have been established empirically from observations made on different models. The Student's test shows that the parameters $\xi_1$ and $\xi_2$ are very significant. Moreover, the coefficient of determination is equal to 0.89.

To study the stability of $\xi_1$ and $\xi_2$, we propose to estimate them with all the combination of 9 phantoms instead of 12. The parameters are relatively robust (only 5% of variability).

CONCLUSIONS

The aim of this study is to establish a simplified relationship Whole body average SAR in term of morphology. It also shows that the internal morphological factors are important in predicting WBSAR but it is more difficult to obtain statistical data of these factors.

The objective carried on is to build a statistical law for the parameter $\alpha$ taking into account the set of phantoms and our knowledge of the physical phenomena of wave absorption by the tissue to find the maximum WBSAR for a population.

REFERENCES

System to Study CNS Responses of ELF Modulation and Cortex Versus Subcortical RF Exposures

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INTRODUCTION

There is increasing evidence that pulse-modulated radio frequency electromagnetic fields (RF EMF), such as those emitted by mobile phones, can alter brain physiology [1,2,3]. Changes in EEG, regional cerebral blood flow (rCBF) and cognitive function have been reported. Subsequent studies must be designed to obtain information about the site of interaction as well as the interaction mechanism. Novel tools and setups for human brain EMF exposure were developed to achieve focused and distinguished exposures of selected functional brain regions with a variety of exposure signals. These setups will be employed in the Swiss Research Program NFP57 to test the following hypotheses: 1) the modulation is a key parameter, 2) the thalamus is the main site of interaction, and 3) adolescents are particularly sensitive to RF EMF exposure.

MATERIALS AND METHODS

The main objectives of this study were to provide the exposure and dosimetric means to test the above hypotheses. The simulation platform SEMCAD X (SPEAG AG, Switzerland) was extended for the dosimetric analysis of functional subregions of the brain in adolescents and adults. Suitable carrier frequencies were evaluated in order to find thalamus exposure level differences of around factor 10 coming from different penetration depths, while maintaining similar exposure of the outer cortex.

A novel postprocessing module was implemented in SEMCAD X that subtracts and analyzes the dosimetric information for all 1105 functional subregions of the Talairach-Space. Transformation of any brain can be conducted automatically by defining eight distinct landmarks in the brain. The setups were developed using this numerical tool while maintaining the concept of the exposure system of [1].

RESULTS

The analysis has shown a good performance using 900 MHz and 2.14 GHz as carrier frequencies. At the high frequency, the exposure of the thalamus can be reduced by a factor of about 8, while keeping a similar exposure of the cortex as in [1,2,3]. The exposure level differences in the outer Talairach regions do not exceed 33% (SD 10.2%).

The corresponding exposure setup including hardware was built, validated using DASY5 and installed for double-blinded protocols. Furthermore, the signal generation and control hardware of [1] was enhanced to allow any pulse modulation scheme. Since spatial peak exposures of bursts of larger than 60 W/kg were applied, special safety measures including
watchdogs were incorporated to avoid any accidents. The uncertainty and variation analysis of the functional subregions revealed intriguing information about setup dependent exposure parameters.

CONCLUSIONS

Novel tools and setups for adolescent and adult human brain EMF exposure were developed to achieve focused and distinguished exposures of selected functional brain regions with a variety of exposure frequencies. The implemented Talairach transformation will substantially enhance future dosimetric analyses.

ACKNOWLEDGMENTS

This study was generously supported by the Swiss National Science Foundation NRP 57 - "Non-Ionising Radiation - Health and Environment".

REFERENCES

Dosimetric Assessment of *C. elegans* Exposure in Vivo to 900 MHz Electromagnetic Fields

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INTRODUCTION

There is evidence that pulse-modulated radio frequency electromagnetic fields (RF EMF) elicit biological effects in a variety of organisms, especially the activation of stress-dependent pathways with increased expression of heat shock proteins (hsp) [2,3]. The nematode *C. elegans* as an *in vivo* system is a well known model organism and qualified for research on EMF effects. However, dosimetric assessment has so far been restricted to thermal evaluations. The aim of this study is to provide detailed dosimetric data on *in vivo* exposure of *C. elegans* to 900 MHz EMF.

MATERIALS AND METHODS

The *C. elegans* nematodes were exposed on 9.5 ml AGAR within NUNC 60 mm Petri dishes inside the sXc900 exposure system [1]. The dielectric properties of all materials were assessed. The measurement of the *C. elegans* was performed using a 1 ml sample of concentrated nematodes. This ‘nematode paste’ was obtained by filtrating the *C. elegans* through a 0.22 \(\mu\)m filter.

The numerical FDTD analysis was conducted using the simulation platform SEMCAD X (SPEAG AG, Switzerland). As the nematodes are fairly small (\(\varnothing < 60 \mu\)m, length < 1 mm), separate simulations were used for AGAR and *C. elegans*. The voxel size was set to 300 \(\mu\)m and down to 1 \(\mu\)m for AGAR and *C. elegans* respectively, where a quasistatic solver could be used for this very high resolution. Finally, SAR values of the AGAR were linked to those of the *C. elegans*. Dosimetric temperature measurements were performed for the AGAR only, as the predominant surface area to volume ratio of the nematodes won’t allow for any significant temperature differences to the AGAR.

RESULTS

The dielectric parameter of *C. elegans* (\(\varepsilon_r = 65.5\pm2, \sigma = 1.38\pm0.1\) S/m, 900 MHz, 20\(^\circ\)C) are close to those of AGAR (\(\varepsilon_r = 77\pm2, \sigma = 1.16\pm0.1\) S/m). Simulations showed most uniform exposure of the nematodes in the E-field maximum of the waveguide. For the AGAR this results in large E-field coupling at the rear and \(H^2\)-field normalized SAR values of 0.29 W/kg/(A\(^2\)/m\(^2\)), SD 6.8 dB. By placing nourishment in the center area (\(\varnothing = 30\) mm) only, the AGAR underneath the *C. elegans* receives a quite uniform exposure of 0.064 W/kg/(A\(^2\)/m\(^2\)), SD 0.3 dB, leading to good preconditions for the uniform exposure of the nematodes. Preliminary results show a 6-15 fold higher exposure level in *C. elegans* than within the underlying AGAR, mainly coming from their geometry and size, depending on their growth state (L2, L4, Adult). \(H^2\)-field normalized temperature rise levels are comparable to those of [1], and remain below 0.02 K/(A\(^2\)/m\(^2\)).
P-40

CONCLUSIONS

The exposure of *C. elegans* to a 900 MHz EMF has been fully assessed and characterized in respect to SAR and temperature rise levels. The elaborated configuration results in an exposure non-uniformity of less than 3 dB for the adult nematodes, and allows for exposure levels up to 5 W/kg without exceeding 0.1°C thermal load.

ACKNOWLEDGMENTS

This study was generously supported by the Swiss National Science Foundation NRP 57 - "Non-Ionising Radiation - Health and Environment".

REFERENCES


Effects of Skeletal Muscle Anisotropy on Induced Currents from Low Frequency Magnetic Fields

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INTRODUCTION

Though much research has been conducted in order to assess the effects of induced electric currents in the human body due to low frequency magnetic fields, only a few studies have taken into account the anisotropy of the dielectric properties of the body tissues [1]. In this paper we compare the induced currents in two anatomical models: In the first one we assume that all tissues have isotropic conductivity, whereas in the second one we consider that the conductivity of the skeletal muscle is different in one direction.

MATERIALS AND METHODS

Many electronic devices such as RFIDs create magnetic fields which induce electric currents in the human body. Some of the RFID systems operate in the low frequency band (125kHz), such as glass tubes used to track and locate animals and people or immobilizer devices which are used in the automotive industry. In the present study we consider an immobilizer device as the generic source close to the body. The antenna was modeled as a small square loop of 3cm × 3cm, which was placed at a distance of 2mm from the body model. The latter was the left thigh extracted from the Visible Human Project (VHP) with resolution of 1mm. The model consisted of ten tissue types (fat, nerve, muscle, blood vessel, bone-cortical, cartilage, skin/dermis, blood, bone marrow and bone-cancellous).

In order to calculate the induced currents, the impedance method was used [2]. The models are split into voxels, which form an equivalent 3D resistance network. The method was programmed using Visual Fortran 6.0 and Matlab.

In the second model we assumed that the conductivity of the skeletal muscle in the parallel to the muscle fiber axis (z-axis) is 1.75 times larger than that in the axial (xy-)plane [3]. The electric current of the square loop was 1mA.

RESULTS

Figure 1a presents the current density (averaged over 1cm²) in a slice of the thigh assuming that all tissues have isotropic conductivity, while figure 1b presents the current density over the same slice of the thigh considering that the conductivity of the skeletal muscle is anisotropic. The maximum current density in the second case was calculated about 36% higher than in the first case. Differences in the maximum value of the two models depend also on the antenna orientation with respect to the anisotropy axis.
CONCLUSIONS

The current density distribution in two fine-resolution (1mm) anatomically realistic numerical models of the human thigh has been calculated using the impedance method. It is clear that the anisotropy of the tissues of the body should be taken into account when investigating the exposure to low frequency magnetic fields.

REFERENCES

Exposure to WiFi Signal of Pregnant and Newborns Mice: Dosimetry and Setup

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INTRODUCTION
The present work aims at the dosimetry evaluation of the WiFi exposure in the immature animals. Animals had to be exposed in utero and a few weeks after birth. Mice as animal models were used in this study.

MATERIALS AND METHODS
In order to supply the exposure system with a realistic WiFi signal, a commercial Access Point (AP) on the "dialog" between two PCs equipped with WiFi cards was chosen as source of the signal. The exposure system includes two identical transverse electro-magnetic (TEM) cells [1] as radiating structures. The length of the radiating part of the TEM cell is 120 cm, allowing the simultaneous exposure of 12 mice divided in three groups of four animals. The presence of higher transversal modes in the TEM cell at 2450 MHz and their contribute to the induced SAR in the target were evaluated by numerical calculations.

The position and the distance among the groups were evaluated to obtain an acceptable homogeneity of the dose and were verified by the power pulse methods [2; 3] on phantoms.

The whole-body-averaged SAR levels for the pups and dams was evaluated during the first five weeks of life and during the last two weeks before delivery, respectively.

Several simulations were carried out considering mice weight and size growth, in such a way to represent the target during the whole period of exposure. The mice were modelled with their size and weight varying according to the average ones measured on twelve mice, during the first 5 weeks of life: the considered model was homogeneous and constituted by a weighted average of the tissues ($\varepsilon \approx 41.0$ and $\sigma \approx 1.5$ S/m at 2450 MHz). Different jigs to constrain the mice during the exposure, according to the increase of mice size, were adopted and in the simulation the jigs were was taken into account.

The electromagnetic power dissipated in mice mass (SAR, W/kg) was measured by the power balance method [1]. Numerical validation was done using FIT based code (CST, Germany) on the numerical phantoms of mice.

Due to the characteristics and the spectrum of the signal, a programmable attenuator (Aeroflex-Weinschel Mod. 3408T-55.75, Maryland, US) was inserted between AP and amplifier to control the averaged power of the input during the exposure to obtain the planned level of SAR.

Pilot experiments on pups and dams of three and two weeks of exposure to WiFi at 4 W/kg were performed on C57BL/6 mice to test the system functioning.

RESULTS
The measured direct emission of AP shows that the variability of the signal amplitude is...
very high on the short period, but, during the whole considered period, the average power value can be considered stable and controlled ($\sim \pm 10\%$).

The result of the calculation suggests that the role of the higher mode can be disregarded (-25dB) respect to the dose induced by TEM mode alone.

Preliminary results of the large variations of the SAR values on mouse pups were presented [4]. The starting average weight (first day of life) was 1.39 g, after five weeks animals reached an averaged weight of 13.82 g. The SAR values per 1 W of input during the first growing period of the newborn mice varied from less than 1 W/kg to more than 6 W/kg. On the contrary, even consistent mass growth of the dams did not induced significant variation of the efficiency, i.e. 3.1 ±0.38 W/kg/W. Starting from an average weight of 26 g at the first day of exposure (five days after copulation) a weight of about 42 g were reached the last day of exposure, the day before the delivery.

CONCLUSIONS

The pilot experiments confirmed the power control and the minimal stress induced in the animals. The results pointed out how an accurate dosimetry, which schedules daily measurements, is mandatory when the biological protocols involve the newborn animals.

REFERENCES


Magnetic Fields Reduction Characteristics of Shielding Wear for a Worker Using AC Arc Welder

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INTRODUCTION

Exposure to time varying electric and magnetic fields result in induction of internal body current, and the known adverse effects are associated with nerve excitation. ICNIRP’s basic limit is set at 10 mA/m² (rms, averaged over a cross-section of 1 cm² perpendicular to the current direction) for occupational exposure [1], a value not to be exceeded at any time. This paper analyzed current densities induced inside a worker using an AC arc welder and magnetic fields reduction characteristics of materials of shielding wear for a worker.

MATERIALS AND METHODS

Power cable of an AC arc welder can surround a body of worker at the moment of welding as shown in Figure 1. Applying the boundary element method, we calculated current densities induced in organs inside a worker in case he was located at 1(cm), 3(cm), 5(cm), 10(cm), 15(cm) and 20(cm) far from power cable flowing 1000(A). A human 170 (cm) tall was modeled in the brain, heart, lungs, liver, intestines, and other parts whose shapes were spheroids or cylinders as shown in Figure 1 [2] and organ conductivity is assigned to human model as shown in Table 1 [3].

![Simulation model of a worker and power cable](image)

Table 1: Organ conductivity

<table>
<thead>
<tr>
<th>Organ</th>
<th>Conductivity (S/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>0.75</td>
</tr>
<tr>
<td>Heart</td>
<td>0.70</td>
</tr>
<tr>
<td>Lungs</td>
<td>0.10</td>
</tr>
<tr>
<td>Liver</td>
<td>0.10</td>
</tr>
<tr>
<td>Intestines</td>
<td>0.03</td>
</tr>
<tr>
<td>Other parts</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Figure 1: Simulation model of a worker and power cable

RESULTS

Figure 2 shows magnetic flux density distribution around human when a worker is 1(cm) far from power cable of an AC arc welder. The first highest field of 2.508(mT) is shown in a liver to be closest to power cable and the second highest field of 1.492(mT) is in intestines. As shown in Figure 2, the first highest current density of 11.2(mA/m²) is induced in a heart because conductivity of a heart is high even though magnetic flux density in a heart is lower than one in a liver. Maximum induction current densities of organs in each case are summarized in Table 2. We found a maximum current density induces at a heart surface and might be higher than 10(mA/m²) of ICNIRP guideline if he works within 15(cm) from power.
To solve this problem, we investigated magnetic fields reduction characteristics of materials of shielding wear when a worker was within 15 cm. Three kinds of materials of copper, silicon, and permalloy were studied. Copper, which has the highest conductivity in three materials, reduced the induced current density of 11 mA/m² at heart to 3.3 mA/m². Permalloy, which has the highest permeability in three materials, reduced the induced current density of 11 mA/m² at heart to 0.25 mA/m². Silicon, which has the lower conductivity than copper and the lower permeability than permalloy, reduced the induced current density of 11 mA/m² at heart to 2 mA/m². Table 3 shows maximum induction current densities in organs due to varying materials of shield wear and Figure 3 shows distribution of induction current densities at lungs surface of a worker wearing shield cloth.

Table 2: Maximum induction current densities in organs

<table>
<thead>
<tr>
<th>Unit: mA/m²</th>
<th>1cm</th>
<th>3cm</th>
<th>5cm</th>
<th>10cm</th>
<th>15cm</th>
<th>20cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>5.9</td>
<td>5.6</td>
<td>5.3</td>
<td>4.7</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Heart</td>
<td>11.2</td>
<td>11.6</td>
<td>11.3</td>
<td>10.5</td>
<td>9.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Lungs</td>
<td>4.6</td>
<td>4.5</td>
<td>4.2</td>
<td>3.7</td>
<td>3.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Liver</td>
<td>9.8</td>
<td>8.4</td>
<td>7.0</td>
<td>5.2</td>
<td>4.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Intestines</td>
<td>6.5</td>
<td>6.1</td>
<td>5.8</td>
<td>4.8</td>
<td>3.8</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Figure 2: Case a worker is 1 cm far from power cable

Table 3: Maximum induction current densities in organs by varying shielding materials

<table>
<thead>
<tr>
<th>Unit: mA/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
</tr>
<tr>
<td>Brain</td>
</tr>
<tr>
<td>Heart</td>
</tr>
<tr>
<td>Lungs</td>
</tr>
<tr>
<td>Liver</td>
</tr>
<tr>
<td>Intestines</td>
</tr>
</tbody>
</table>

Figure 3: Distribution of induction current densities at lungs surface of a worker wearing shield cloth

CONCLUSIONS

As results of study, we find maximum current density induced inside worker at 1 cm to 5 cm is about 11 (mA/m²) in a heart. We know worker is away from 15 cm and above to satisfy ICNIRP guideline of 10 (mA/m²) and shielding wear with high permeability materials lowers current density more than high conductivity materials.

REFERENCES


INTRODUCTION
The purpose of this work is to study the thermal response of human tissues and organs due to RF exposure with detailed consideration and modeling of blood flow. A new algorithm capable of generating realistic 3D models of blood vessels and a new method to consider capillary blood flow effect on heat distribution during exposure are presented. The proposed methodology may provide more accurate results compared to widely used Penne’s Bio-Heat equation model with constant blood perfusion term in it [1].

MATERIALS AND METHODS
The proposed algorithm can reconstruct a realistic model of vascular structure in complex geometries of human tissues and organs. First the algorithm populates a given volume of bounded region by recursive branching and growth of vascular network based on a number of predefined root points of veins and arteries entering and exiting the domain. The algorithm is relatively fast with only $O(V)$ order of complexity, where $V$ is volume of examined area. An example of generated vascular network is presented on Figure 1.

After generating the relatively large vessels, the next step is to model the effect of capillary blood perfusion. Rather than defining the individual capillaries, which is nearly impossible, the blood velocity vector field is introduced in the model. Several methods can be used to that end. The blood flow vector field is generated based on arterial and venous blood pressure difference at the endpoints of the vessels constructed as described earlier. The Method of Auxiliary Sources for simple geometries or FDTD for simplified Navier–Stokes equation in general case. As the result the model corresponds to the blood flow through capillary from arterial endpoints to the venous endpoints enforced by corresponding high and low cardio pressures. An example of generated capillary blood velocity field in some averaged cross-section is presented on Figure 2.

MODIFIED BIO-HEAT EQUATION
The widely used model to simulate heat exchange in tissue exposed to RF energy is based on Pennes bio-heat equation (1):

$$c_p \rho \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \rho \, SAR + A - B(T - T_b) \tag{1}$$

where $T_b$ is a constant for all points of examined volume. While this approach have shown to produce good results, it is possible to use more accurate model, which features both vascular and capillary blood flow. The novelty of our approach is in that $T_b$ is not constant anymore and varies spatially and in time accounting to capillary flow. Having blood velocity vector in a cell enables evaluation of $T_b$ term iteratively, thus allowing to account for and quantify the heat exchanged between blood and the tissue (2).
RESULTS
The results obtained for the described above models are shown below. Figure 1 is a vascular network for a brain model and Figure 2 shows corresponding capillary blood field. Figure 3 shows the temperature computed according to the conventional (left) and modified (right) bio-heat equation.

\[
c_{p}\rho \frac{\partial T}{\partial t} = \nabla \cdot (k \nabla T) + \rho \text{SAR} + A(\mathbf{r}, t) - h \left( T - T_b(\mathbf{r}, t) \right)
\]

CONCLUSIONS
A new method to model vascular network and capillary blood perfusion are proposed. This method is used with a new approach to calculate blood perfusion effect on heat transfer in thermal dosimetry problems. The proposed methodology can more accurately predict the temperature response of human tissue due to RF heating.

REFERENCES
Design and Analysis of Experimental Whole-Body Averaged SAR Estimation system using Cylindrical Scanning of External Fields

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*kawamura@wtemc.ist.hokudai.ac.jp

INTRODUCTION

The reference level of basic guideline is established based on the whole-body averaged specific absorption rate (SAR). Whole-body averaged SAR estimations for high accuracy human models using numerical calculations have been reported [1]. In order to confirm the validity of computer results for the whole-body averaged SAR, it is important to develop an experimental estimation system. We refer to a numerical estimation method using external cylindrical electromagnetic field scanning applied to an experimental measurement. In this paper, the validity of the experimental setup for whole-body averaged SAR of European child and adult phantom models is investigated using some numerical analyses.

PROPOSED METHODS AND MATERIAL

In order to achieve accurate measurements using high accuracy human phantom models, we propose a whole-body averaged SAR estimation method based on power consumption obtained by measuring the radiated electric power from the cylindrical surfaces including the human phantom and plane-wave exposure equipment (Figure 1). In this method, the power absorbed by the human phantom (W_{ab}) is derived by measuring the radiated power (W_{out}) and the output power of the exposure equipment (W_{in}). The absorbed power of the human phantom is obtained by the expression: W_{ab} = W_{in} - W_{out}. Moreover, the whole-body averaged SAR can be calculated from the power (W_{ab}) and the weight of the human phantom model.

The variation of the whole-body averaged SAR in human phantoms with different size is investigated using Finite-Difference Time-Domain (FDTD) calculations [2] for the purpose of determining the validity of the proposed methods on models with different ages and postures. The calculation model assumes that the standing human phantom is exposed to a 2.1 GHz plane wave. Since a 1/2 scale factor is used, the sizes of the objects in the model are reduced by a half and the antenna radiation frequency is 4.2GHz. The 1/2 scaled human phantom model made of the Virtual Family Product [3] is used in this paper. These are a 6-year-old male child and a 34-year-old male adult and those original heights are about 1.07 and 1.74 m and 17 kg and 70 kg in weight, respectively. The resolution of the models used is 1 mm. The FDTD computation parameters are summarized in Table 1. The calculated whole-body averaged SAR based on the proposed method is compared with that obtained by direct estimation methods based on the integration of electric fields inside the human body.

RESULTS

The electric power radiated from the cylindrical scanning area and both circular areas of the cylinder is evaluated from the FDTD computational result. The total output power of the exposure system is 6 W. Then, the electric power density of the plane wave becomes about 4 W/m² at the human phantom position. The whole-body averaged SARs are calculated using
the weight of the scaled human phantom models (2.28 kg and 8.55 kg) as derived from the original models. The numerical result of the whole-body averaged SAR is shown in Table 2. The whole-body averaged SAR of the male child is 0.0369 W/kg using this proposed technique and 0.0346 W/kg using the direct calculation method. With this proposed technique, an increase of about 7% on the male child and 12% on the male adult is expected when compared with direct calculations for whole-body averaged SAR.

CONCLUSIONS

The experimental whole-body averaged SAR estimation which is used in scale models and the external cylindrical electromagnetic-field scanning method is investigated by numerical calculations. We will construct the equipment and conduct experiments.

ACKNOWLEDGMENTS

This work is supported by Grant-in-Aid from the Ministry of Internal Affairs and Communications (MIC) of Japan.

REFERENCES


Table 1: Computation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>4200 MHz</td>
</tr>
<tr>
<td>Cell size</td>
<td>1 mm (minimum)</td>
</tr>
<tr>
<td></td>
<td>7 mm (maximum)</td>
</tr>
<tr>
<td>Iteration</td>
<td>150 Periods</td>
</tr>
<tr>
<td>Absorbing Boundary Condition</td>
<td>U-PML (8 Layers)</td>
</tr>
<tr>
<td>Total Program size</td>
<td>548 x 698 x 763</td>
</tr>
</tbody>
</table>
| Material                         | Human Phantom:  εₙ 39.82, σ 2.98 [S/m]
|                                  | (2/3 equivalent Muscle [4]), ρ 1000kg/m³ |
|                                  | Dielectric Lens: εₙ 4.0                |
|                                  | Rack (Air): εₙ 1.0                     |
|                                  | Metal: PEC                            |
| Sampling interval of Cylindrical | Height: 20 mm                         |
| scanning                         | Angle: 1 degree                       |

Table 2: Absorbed power and whole-body averaged SAR estimation result on different human model

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>Proposed method</th>
<th>Direct calculation method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human model</td>
<td>Male adult</td>
<td>Male child</td>
</tr>
<tr>
<td>Wₘₐₜ [W]</td>
<td>0.195</td>
<td>0.0841</td>
</tr>
<tr>
<td>WB SAR [W/kg] *</td>
<td>0.0228</td>
<td>0.0369</td>
</tr>
<tr>
<td>Variation</td>
<td>+11.2%</td>
<td>+6.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Male adult is 8.55 kg in weight, and Male child is 2.28 kg in weight.
Dosimetry of an in vitro exposure system for fluorescence measurements at 2.45 GHz

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INTRODUCTION

In this paper, the dosimetry of an in vitro system for microwave (MW) exposure of a biological medium is presented. The dosimetry is based on electromagnetic simulations which permit to estimate SAR levels in well-controlled numerical models. In the conducted experiments, a suspension of giant unilaminar vesicles (GUV) used as model of living cells is exposed to 2.45 GHz MW in a spectrofluorimetric cuvette. During the MW application, fluorescence measurements of the generalized membrane polarization (GP) are made. GP provides information regarding the amount of polar species within the membrane bilayer reflecting the integrity of the membrane sheet [1]. The aim of this work is to provide the distribution of the electromagnetic fields inside the exposure applicator in order to support the interpretation of experimental results.

MATERIALS AND METHODS

The studied exposure system is composed of a microwave generator (Sairem, France) which delivers the microwave signal, through a cable and an impedance matcher, to an antenna placed in a biological applicator. Figure 1 shows the studied applicator. It is composed of a (40*12*12 mm) spectrofluorimetric cuvette (fig. 1a) which contains the GUV suspension. The permittivity and the conductivity of the biological medium are respectively $\varepsilon = 74$ and $\sigma = 2.85$ (S/m). The cuvette is placed into a spectrofluorimeter (SPEX, Germany), inside a thermostated holder (TLC50, Quantum Northwest Inc, USA) (fig. 1(b, c)). The Peltier elements of the holder are under computer control. A Luxtron probe (USA) immersed into medium allows the temperature monitoring during the microwave exposure (the tip of the optical fiber is intimate to the antenna wire). In addition, the medium is continuously agitated with a magnetic stirrer. A three-dimensional numerical model is used to predict the distribution of the electromagnetic fields in the experiment. The Maxwell equations are solved by the Finite Difference Time Domain method.

RESULTS

The SAR distribution computed with the FDTD tool is shown figure 2 (a). The mean SAR value into the volume is 448 W/kg/Winc. During MW exposure, the emission spectra of Laurdan – a fluorescent dye, sensitive to polarization of hydrophilic environment within the lipid bilayer, are recorded and GP is calculated [1]. The evolution of the GP for several MW incident powers is presented in figure 2 (b) [2]. In MW fields, the permanent dipoles of water are supposed to align along the electric field lines. This “ordering” phenomenon of the molecules inside the membrane will hinder the energy transfer process between the excited
molecules of Laurdan and the surrounding water molecules, compared with the same process in a non-irradiated sample [2]. In order to explain the observed effects, a rigorous control of the sample exposure is mandatory. This is why we propose a model for computing the SAR profile inside the investigated suspension.

Figure 1: Studied exposure applicator. a) Antenna and the spectrofluorimetric cuvette containing the suspension. b) and c) Cuvette inside a thermostated holder.

Figure 2: a) SAR distribution at 2.45 GHz. b) General polarization of 1,2-dimyristoyl-sn-glycero-3-phosphocholine GUV suspension heated by conventional heating (black curve) and by microwave irradiation (coloured curves) at different powers [2].

CONCLUSIONS
A detailed and accurate dosimetry of a MW exposure applicator has been performed for adequate evaluations of experimental results. The FDTD dosimetric computations showed that the mean SAR in the GUV sample modeling a biological medium is 448 W/kg/Winc.

REFERENCES
Correlation of the Exposure of Mobile Phones Assessed in SAM by Applying Standard Procedures with the SAR in Anatomical Human Heads

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2 IT'IS Foundation, Zurich, Switzerland
3 SPEAG, Zurich, Switzerland
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INTRODUCTION

Epidemiologic research on possible health effects from human exposure to radio frequency (RF) electromagnetic field (EMF) from mobile phones requires scientifically sound and robust exposure metrics. Typical end-points of epidemiologic research in this field are carcinogenic effects in the tissues that are dominantly exposed [1]. Nevertheless, the difference of the power absorption in different tissues in the head can vary strongly between different types of mobile phones, which is why human provocation studies aim at a homogeneous exposure of the different regions of the brain [2]. A simple measure of the induced fields in the head would be the 10 g peak spatial average SAR determined for every phone before market approval and typically available from the mobile phones manual. However, the peak 10 g spatial average SAR is frequency dependent and generally only given for the worst-case configurations, i.e., head side. Orientation and frequency as well as the location of the 10 g peak remain generally unknown. Thus, the peak 10 g spatial average SAR can also not be correlated to a certain region of the head. Consequently, for a sound region specific exposure estimation in the head, volumetric information on the induced fields is required. Such an evaluation procedure could, for example, be implemented in SAR assessment systems and then be used to estimate the tissue region specific SAR. Such an approach has been studied in [3], but without an evaluation of the uncertainties and limitations.

The aim of our study was to test the correlation of the absorbed power in virtual regions of the homogeneous SAM phantom with the absorption in anatomical human heads as well as the estimation of the accompanied uncertainties and limitations.

MATERIALS AND METHODS

We have performed a numerical study using the FDTD method implemented in SEM-CAD X. We have used the anatomical human heads of the Virtual Family [4] for the evaluation as well as the homogeneous SAM head with virtual head regions defined. The definition of the regions in the SAM head was achieved by using a non-linear transformation of an anatomical human head such that it fits the shell of the SAM head. Thus, different virtual tissues were made available in the SAM head, allowing the evaluation of the tissue specific absorption. Tissues of interest included: cheek, inner-ear, eye, and brain. For the latter, we have also used a more region specific evaluation based on the Talairach atlas [5]. The tissue mapping using the atlas is based on a simple set of coordinates in the human brain and allows the definition of regions with different levels of abstraction ranging from hemispherical to cell level.
To test the correlation of absorption in the virtual head regions in SAM with anatomical human heads, we have conducted a set of simulations with generic dipole structures placed around the phantoms' head. The location of the dipoles relative to each other was fixed and defined for the SAM head (the largest head). Then, we defined a straight line (touch line) relative to the dipole array marking the touch position (touching the ear reference point and the cheek in one location on the ear-mouth line). The orientation of the dipole array with respect to the individual anatomical heads was set by defining the ear reference and mouth points as well as the ear-mouth line in the anatomical heads. Subsequently, the touch line was constructed on each anatomical head and the dipole arrays placed accordingly. Using this setup, we have performed simulations with driving one dipole at a time (other dipoles set to dielectric properties of air) at 900 MHz and 1800 MHz. For each scenario, we have evaluated the region specific absorption in the SAM as well as in the anatomical human heads.

RESULTS
The results of the study demonstrated that such evaluations have great potential for improving the exposure assessment for epidemiological studies and would also increase user’s information about the average exposure if it is correlated to assessments of the over-the-air evaluations. The correlation was confirmed with two realistic mobile phones placed on the head and operated and 900 and 1747 MHz.

CONCLUSIONS
We have evaluated the correlation of the head tissue and brain region specific absorption in virtual head regions in the SAM and anatomical human heads of the Virtual Family.

ACKNOWLEDGMENTS
We would like to thank the Swiss National Fund (SND) and the National Research Program 57 (NRP57) or the financial support of the study.

REFERENCES
Design and Characterize One Reverberation Chamber for Rats in Vivo Wi-Fi Exposure by Simulation-Measurement hybrid Method

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INTRODUCTION

Animal EMF exposure studies have been conducted with restrained animals by various systems. To better evaluate exposure results, non-restrained in vivo animal exposure experiments are always recommended by World Health Organization (WHO).

This paper includes the works to design one non-restrained Wi-Fi exposure system by means of Reverberation Chamber (RC) and to characterize the power absorption by the rats with simulation-measurement hybrid method. The system should be able to provide as much as 4 W/kg whole body averaged SAR (WBSAR) to four identical rats who weight 1.5 Kg in total. The rats have the ability to move in one volume of about 400 mm × 400 mm × 400 mm. Uniform exposure needs to be maintained for the rats wherever they move in this volume.

METHODS

Upon the analysis for the requests of the exposure system, RC has been chosen by comparative studies because of its abilities to provide uniform whole body non-restrained exposure, higher exposure efficiency and lower construction cost. Wi-Fi signal software is applied to ensure maximum and stable emission.

RC has six antennas on each side of the cavity. Antennas work in random pattern. Each time, only antenna emits while others keep idle. Three small size stirrers are installed in the corners of the RC. RC is fabricated by Aluminium porous material. By this way, RC with high Q could be expected [1]. Noisy from rotation of paddles of large stirrers and air-exchange system is avoided. Size of the RC is determined in term of influence between the antenna and rats on function of distance (by means of S11). Simulations have been operated with RC of different sizes. One RC with dimensions of 1.5 m × 1.5 m × 1.5 m has been constructed.

In order to compute the power distribution in the animals and verify the uniform exposure for the 4 rats, measurement and simulation method are applied distinctively. Pure measurement method and pure simulation method base on the estimation of the dissipative power in the system (or dielectric properties of the system). However, the precise estimation value can not be obtained for the constructed RC. For the simulation method, FDTD [2] has been chosen as the numerical tool because its advantage over MoM and FEM as of no need to reverse immense matrix for complicated organism. Unfortunately, it demonstrates its disadvantages as endless update steps. They inspire us one simulation-measurement hybrid method. In simulation, we can get the information of WBSAR from rats and averaged $\varepsilon^2$ in RC. In measurement, we can get the ratio of
net incident power to RC to the averaged $E^2$. Then $E^2$ can be used to link the net incident power to RC and the WBSAR in rats.

The exposure is introduced by Huygens box [2]. Measured Q for constructed RC is superior to 1000. Thus, field distribution in it follows Rayleigh distribution [3]. On each point of the Huygens box, it could be regarded as the summation of numerous plane waves as:

$$E(r) = \sum_{i=1}^{\text{nray}} A_i \cdot \exp(j \cdot \vec{k}_i \cdot r + \phi_i) \cdot \vec{v}_i$$

(1)

$A_i$, $\vec{k}_i$, $\vec{v}_i$ and $\vec{v}_i$ are amplitude, direction of propagation, phase and polarization of the $i$th plane wave. nray is number of plane waves on one point.

Then all the parameters could be determined by Rayleigh distribution. $A_i$ and nray are decided and optimized by simulation methods as random and 200. By the method, there is no need to realize the details of the RC as the complete cavity, antennas and computation volume is greatly reduced. Much computation resources are saved.

RESULTS

The power distribution on 4 rats in different positions of RC is simulated as in Figure 1.

![Rats in different positions of RC](image)

**Figure 1:** Power absorption by rats at different position of RC

CONCLUSIONS

By measurement, averaged squared E values are recorded with the incident power. The ratio of $\frac{a}{P_{inc}} < E_{mean}^2$ is obtained. About 9 W net incident power to the RC can produce 4 W/kg WBSAR in 1.5kg rats. Figure 1 demonstrates that the uniform exposure can be achieved for rats at different positions.

REFERENCES


INFLUENCE OF A REFLECTIVE ENVIRONMENT ON THE
ABSORPTION OF A HUMAN MALE EXPOSED TO
REPRESENTATIVE BASE STATION ANTENNAS FROM 300 MHz TO
5 GHz

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INTRODUCTION

The influence of a reflective ground and/or wall on the whole-body and local absorption in the human body has been numerically investigated in the proximity of representative base station antennas. The research has been carried out within the framework of the MMF-GSMA Dosimetry Program Phase 2. It has been observed that the absorption in a reflective environment can be up to 7.77 dB higher than in free space. In general, the environments which include a vertical wall can be considered as worst-case for absorption assessment.

MATERIALS AND METHODS

The numerical investigation of the influence of a reflecting ground and a vertical wall on the SAR in a human body near a base station antenna has been investigated using 3D full wave electromagnetic solvers, i.e., an FDTD based (Semcad-X) and MoM/FEM based tool (Feko). Three typical reflecting (perfectly conducting) environments have been considered: ‘ground’, ‘vertical wall’, and ‘ground + vertical wall’. Representative base station antennas have been developed for the frequencies of 300 MHz, 450 MHz, 900 MHz, 2100 MHz, 3500 MHz, and 5000 MHz. The localized and whole-body SAR has been investigated in the inhomogeneous Virtual Family Man (VFM) [1]. The dielectric properties of the VFM have been taken from the Gabriel database [2]. The distance between the human body model and the antenna varied from 0.3 m to 10 m. Only frontal exposure of the human body has been studied. The vertical wall has been placed at the left side of the human body. The minimum distance between the vertical wall and the human body and antenna was 10 cm. The ground was placed 5 cm below the feet of the human body. The absorption in the reflective environments has been compared to the absorption in free space.

RESULTS

The absorption in the reflective environments has been studied in terms of whole-body SAR (SAR_{wb}) and peak local SAR in 10 g (SAR_{10g}). The maximum SAR_{wb} and SAR_{10g} have been observed for the environments 'vertical wall' and 'ground + vertical wall', for all investigated configurations except for the base station antennas operating at 300 MHz and 450 MHz and for a distance of 10 m between antenna and VFM. For the latter two configurations the maximum SAR_{wb} and SAR_{10g} occurred for the reflective environment 'ground'. Therefore, in general the 'vertical wall' and 'vertical wall + ground' can be designated as worst-case reflection environments, although exceptions occur. The ratio R of
the SAR in a reflective environment to SAR in free space is expressed in dB. The minimum and maximum of \( R \) for the different reflective environments are listed in Table 1. The maximum SAR_{wb} for the 'vertical wall' is 5.62 dB higher than SAR_{wb,free space}, and the maximum SAR_{10g} is 7.07 dB higher than SAR_{wb,free space}. For the 'ground + vertical wall' the maximum observed SAR_{wb} is 5.67 dB higher than SAR_{wb,free space}, and the maximum SAR_{10g} is 7.77 dB higher than SAR_{wb,free space}. For the 'ground' scenario the maximum SAR_{wb} and SAR_{10g} are lower than for the worst-case scenarios. With respect to free space, \( R_{wb} \) and \( R_{10g} \) for the reflective 'ground' are 2.99 dB and 6.4 dB respectively.

Table 1: The deviation for the whole-body and localized absorption in a reflective environment with respect to the absorption in free space

<table>
<thead>
<tr>
<th>Reflective environment</th>
<th>( R_{wb} = \frac{\text{SAR}<em>{wb,reflect.env.}}{\text{SAR}</em>{wb,free space}} ) (dB)</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>-2.91 (min) 2.99 (max)</td>
<td>2100 MHz antenna at 10 m 450 MHz antenna at 10 m</td>
</tr>
<tr>
<td>Vertical wall</td>
<td>-8.71 (min) 5.62 (max)</td>
<td>300 MHz antenna at 10 m 450 MHz antenna at 0.3 m</td>
</tr>
<tr>
<td>Ground + vertical wall</td>
<td>-5.98 (min) 5.67 (max)</td>
<td>300 MHz antenna at 10 m 450 MHz antenna at 0.3 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflective environment</th>
<th>( R_{10g} = \frac{\text{SAR}<em>{10g,reflect.env.}}{\text{SAR}</em>{10g,free space}} ) (dB)</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td>-3.22 (min) 6.41 (max)</td>
<td>3500 MHz antenna at 10 m 450 MHz antenna at 10 m</td>
</tr>
<tr>
<td>Vertical wall</td>
<td>-7.39 (min) 7.07 (max)</td>
<td>300 MHz antenna at 10 m 450 MHz antenna at 0.3 m</td>
</tr>
<tr>
<td>Ground + vertical wall</td>
<td>-4.33 (min) 7.77 (max)</td>
<td>300 MHz antenna at 10 m 450 MHz antenna at 1 m</td>
</tr>
</tbody>
</table>

CONCLUSIONS
The whole-body SAR and the peak local SAR in 10 g in the Virtual Family Man placed in front of a base station antenna and in a reflective environment are up to 5.67 dB and 7.77 dB higher than in free space, respectively for the considered configurations. In general, the environments 'vertical wall', and 'ground + vertical wall' can be considered as worst-case reflecting scenarios, whereas the environment 'ground' can be referred to as a typical reflective environment.

ACKNOWLEDGMENTS
This research has been funded by the MMF-GSMA in the framework of the Dosimetry Phase 2 Program.

REFERENCES
Analysis of the influence of the direction of arrival of a plane wave on the whole body and local exposure at 2100MHz

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INTRODUCTION
Since wireless systems are used more and more, the electromagnetic fields induced by these systems have induced a public concern about possible effects on the health. Moreover since wireless technologies are continually evolving the exposure to multiple sources is increasing. To assess the exposure numerical dosimetry can be used. First studies have been carried out with simplified human models because of computation limitations, nowadays computers capacities have strongly increased and allow to handle more complex configurations. Taking advantage of such possibilities several 3D voxel human models have been developed and studies have been performed [1]-[2]. Most of them have been focused on analyzing the exposure of human models to a plane wave with a fixed incidence (mainly a frontal plane wave). In this paper, we will focus on the influence of the incidence of the plane wave on the whole body averaged SAR (WBSAR) and on the maximum local SAR averaged over 10 grams (LSAR10)

MATERIALS AND METHODS
In this study we used Visible Human model (composed of 2mm cubical voxels) exposed to a plane wave with a vertical polarization. The frequency used is 2100 MHz. Three planes of incidences have been chosen: a horizontal one, and two planes tilted of ± 20° around the horizontal axis. In all the cases the azimuth incidences are covered with a step of 10°.

To assess the Specific Absorption Rate (SAR) \( \sigma \frac{|E|^2}{2\rho} \) we use the well known Finite-Difference Time-Domain (FDTD) method through an in-house code with PML as absorbing boundaries conditions. The dielectric properties of the human tissues are those given at http://niremf.ifac.cnr.it/tissprop/htmlclie/htmlclie.htm.

RESULTS
Dealing with the whole body, the simulations (see figure 2) show that the WBSAR is varying periodically with the azimuth of the incident plane. As shown in figure 2 for the vertical polarization the highest WBSAR is obtained for frontal incident plane wave.
Dealing with the LSAR10, the simulations show (see fig 2) also an influence of the azimuth but less predictable than the influence on WBSAR. The evolution versus the azimuth is almost random and the horizontal elevation does not correspond to the highest LSAR10. Simulations show that the localization of LSAR10 depends on the incidence of the plane wave but as shown in figure 3 there is a large variability.

CONCLUSIONS

In this study the Visible Human model has been exposed to electromagnetic plane waves with different azimuths and elevations. The polarization is vertical and the frequency is 2100 MHz. The study shows that the LSAR10 is highly variable. The LSAR10 is very difficult to predict, especially because the localization of the maximal value of the LSAR10 is unsettled. The study shows also that the WBSAR is following a periodic model with the azimuth whatever the elevation.

ACKNOWLEDGMENTS

This work was supported in part by the French ANR project MULTIPASS (http://multipass.elibel.tm.fr/).

REFERENCES


Estimated variation in RF dosimeter readings at 900 MHz when worn by an adult or child

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INTRODUCTION

The FDTD method was used to calculate the electric fields near the surface of a realistic, heterogeneous adult and 10 yr child phantom model at 900 MHz. A statistical approach was then applied to determine the response of an electric field measuring dosimeter when placed at random locations in the torso region of the adult and child phantoms for a range of incident field conditions.

MATERIALS AND METHODS

The FDTD method was used to solve for the fields near the surface of a realistic, heterogeneous human body model known as NORMAN [1]. The model was re-scaled to a 4 mm cubic cell size with a height of 1.74 m and mass of 71.2 kg. A second body model, based on NORMAN with ~3 mm cubic cell resolution, was created to simulate the height (1.38 m) and mass (32 kg) of a 10y child. The electrical properties of each tissue type were based on data published by Gabriel [2]. The models were exposed to a series of free space plane waves of constant magnitude with the electric field component aligned parallel to either the \( \theta \) (Transverse Magnetic mode) or \( \phi \) (Transverse Electric mode) unit vectors (Fig. 1.). A statistical model from [2] has been simplified to calculate the weighted mean response of a body worn dosimeter in a scattering environment [3]. A rectangular probability distribution was assumed for the incident angles and the polarization was assumed equally likely between TM and TE modes. The \( \theta \) values were 60°, 90° and 120°, while \( \phi \) was varied from 0° to 270° in 90° increments. Two set of 30 random locations were identified on the front of the adult and child torsos, each at distances of 10 and 50 mm from the surface of the body. For any incident field condition, the dosimeter reading is equivalent to the logarithm of the total electric field at these locations (in terms of an equivalent power density) when normalized to the incident power density.

RESULTS

The boxplots in fig. 2 show the variation in readings for changes in incident angles at each of the random locations on the adult phantom at 10 and 50 mm from the surface of the torso. At a 10 mm distance, individual readings are spread between +6 dB and -30 dB while the weighted mean ranges from -3.7 dB to -10.6 dB. Readings above 0 dB indicate that the body enhances the electric field measurement near the surface. At 50 mm separation distance readings range from +3 dB to -30 db while the weighted mean ranges from -3 dB to -5.4 dB. Readings for the child model are generally similar with the weighted mean ranging from -2.7 dB to -9.5 dB at 10 mm and from -2 dB to -4.4 dB at 50 mm.
CONCLUSIONS

Under simplified statistical assumptions for a scattering environment, the weighted mean response of an electric field dosimeter is similar when worn on the torso of an adult or child phantom at 900 MHz. Proximity related variability in readings is observed across locations on the torso. At 10 to 50 mm from the surface, the weighted mean is -2 to -10.6 dB below the incident field over the range of 30 random locations on the front of an adult or child torso. The similarity of results between adults and children suggests that specific dosimeters for children may not be required.

ACKNOWLEDGMENTS

Dr Dimbylow (UK HPA) for kindly supplying the NORMAN data set.

REFERENCES


Figure 1: Human body model in coordinate system

Figure 2: Boxplot results for changes in incident angles at random locations on torso of adult phantom. Weighted mean result is indicated by solid line through box section.
Energy Absorption in Adult Male and Child due to Femtocell

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INTRODUCTION

In addition to widespread implementation of macro, micro and picocell base stations (GSM, UMTS) in our environment an Access Point Base Station (femtocell) is being widely introduced. It is a small cellular base station designed for use in residential or small business environments. It connects to the service provider’s network via broadband (such as DSL or cable) and typically supports 2 to 5 mobile phones in a residential setting. The thought of installing a 3G base station in the sleeping room is undoubtedly causing great consternation amongst certain sections of population and, thus, calls for detailed analysis of the exposure assessment. This study deals with the analysis of the energy absorption in the adult male and 6 y child due to electromagnetic fields (EMF) that could be found in the vicinity of typical femtocell.

MATERIALS AND METHODS

We investigated radiation pattern and EMF exposure in the vicinity of a femtocell (3G) operating at 2100 MHz with a peak transmitted power of 20 mW. The unit we investigated features an internal whip antenna printed on a circuit board, perpendicular to the main electronics circuit board in the device. We modeled the antenna to a fine precision, and the main circuit board only as a perfectly conducting plate. As all the components have a low profile, this representation is accurate enough. For modeling and simulations, we used the SEMCAD X software package from Schmid & Partner Engineering AG.

Since the Femtocell could be mounted anywhere in the home or office, it was placed close to the head of an anatomically correct non-homogenous human model. The model was placed 1 cm away from the outer casing of the Femtocell, oriented in such a way that the coupling between internal antenna and human body represents the worst case scenario.

We used the Virtual Family adult male and 6 year old child model (Duke and Thelonious), resolution 3mm³, developed by the IT’IS Foundation [1]. Tissue parameters were obtained from the well known Gabriel parametric model.

RESULTS

Detailed analysis of the space distribution of the electric field strength in the close vicinity of the Femtocell showed that E-field could reach up to 7 V/m at the distance of 1 cm (Figure 1). Taken this into account, the whole body average and spatial peak SARs were computed for adult male and 6-year old child model, respectively. Results showed that whole body SAR in male model was $4.3 \times 10^{-5}$ W/kg and $3 \times 10^{-4}$ W/kg in the child model. This is far below the reference levels (0.08 W/kg) for the general public of the ICNIRP guidelines of 1998.
In addition, spatial peak SAR values that were found in superficial tissues close to main beam of the radiated antenna were 0.031 W/kg in male model and 0.13 W/kg in the child model, respectively.

![Image](image.png)

Figure 1: Distribution of Electric field strength (V/m) in the vicinity of the femtocell.

The location of the spatial peak SAR was, as expected, in the region closest to the transmitter. In the both models, the highest local SAR was found in the frontal face area. The difference in spatial peak SAR is due to the position of the child’s head that is moved slightly forward in comparison to the adult model.

![Image](image.png)

Figure 2: SAR distribution inside of the a) adult male model b) 6-year old child model.

**CONCLUSIONS**

Taken together, it has been shown that the SAR values in the adult male and child model arising from the exposure to Femtocell base stations are far below the reference levels for the general public of the ICNIRP guidelines of 1998. In general, the values are also lower compared to energy absorption arising from any other wireless devices we have at home, for example wireless computer routers, wireless DECT phones and baby alarms. On the other hand, femtocells could improve handset’s connection to the network, the handset will use less power and RF exposure of the user may actually reduce.

**REFERENCES**

Evolution of Whole Body Averaged SAR for Small Rats in Long Term in Vivo Wi-Fi EMF Exposure

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INTRODUCTION

Study [1] has demonstrated that different human models would have different whole body averaged SAR (WBSAR) if they are exposed by the same plane wave. It means that children and adult would experience different WBSAR even in face of the same field level. Some researches have been carried with the small rats for the long term non-restrained exposure experiments.

This paper introduces the works on the evolution of the WBSAR in the young rats for in vivo non-restrained Wi-Fi exposure experiment from the embryo period to 30 days after birth. Several parameters as well as physical, physiological properties and habitudes of rat change with ages. They influence WBSAR greatly. The result of WBSAR for small rats vs. age has been presented in this paper.

METHODS

In order to analyze the effect of Wi-Fi in vivo EMF exposure for rats, one reverberation chamber has been designed to provide the uniform exposure. Power distribution in the rats can be evaluated by simulation-measurement hybrid method. This method proposes, in simulation, the net incident power and averaged squared E field strength could be obtained. On the other hand, simulation can provide the information about the WBSAR of rats as well as the averaged squared E field strength. So relationship between net incident power and WBSAR are established.

As a long term young rats in vivo non-restrained experiment, we should consider the change of the parameters which will influence the WBSAR. As the research for the humans, different ages of rats can not use the same numerical model or the scaled reduced model of the adults. Several key parameters such as the length of the head, length of the body, length of the tail, width of the body and weight are measured with the real rats in experiment of different ages. They are used to modify the scaled reduced adult model to achieve the better conformance with the real small rats.

Dielectric properties of rats change with age [2]. We have interpolated these values from 6 days to 30 days after birth. They vary about 20%. Simulations of WBSAR have been carried by increasing or lowering the dielectric properties as 20%. Results show, it will only change WBSAR for less than 5%.

The maximum variation in weight for the same age rat is shown as 20%. By simulation, it may introduce at maximum 5% difference in WBSAR.

Habits and comportments play important roles in the evolution of WBSAR for small rats. Once born, small rats are tends to be in one very close group with their mother. Gradually, they acquire the ability to move. The mother rat is taken out at 20 days after birth. Small rats
are less likely to stay in one group. In general, there are three configurations for their typical comportments as shown in Figure 1.

Figure 1: Comportment of rats after birth

Camera has been installed in the exposure system to record the probability of occurrence for each configuration. The most likely occurred configuration is defined as the standard configuration for each time point in the exposure experiment and the simulation.

Posture is another issue which influences WBSAR. Rats' bodies can either be straight or curve. We realize several symbolic models from straight to curve shapes of different extents. By simulations, WBSAR vary up to 3% among all the models.

Combination with all the above parameters is based on the self-dependence discussion. Upon evaluation, these factors are independent or less dependent. The global combination of the evolution can be achieved for the small rats from -6 days to +30 days after birth.

RESULTS

Result on WBSAR of small rats vs. age is shown in Figure 2. They based on the standard configuration as we discussed. Variation margin has also been given in this figure.

Figure 2: WBSAR of small rats vs. age (averaged E =225V/m)

CONCLUSIONS

WBSAR of small rats in the same field level may vary greatly in long term exposure experiment due to aging process. Special analysis should be made on numerous factors to determine the WBSAR.

REFERENCES

Methodology for the Reliable Assessment of the Exposure of Specific Groups of the Population with Known Uncertainty

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INTRODUCTION

There are currently about 20 human anatomical whole body models available for dosimetric simulations to the scientific community. These models are based on cryosection photographs and computer tomography and magnetic resonance images of Asian or Caucasian humans. Most of the selected volunteers for modeling best represent the average height and weight of the general population and are sufficiently accepted by the scientific community. However, in contrast to ionizing radiation, the induced fields of a given EM exposure strongly depend on the weight, height and posture of the subjects. Thus, the current approach of basing safety considerations on one model only is not adequate and can result in wrong conclusions.

OBJECTIVES

The objective of this study was to develop and verify the methodology to obtain exposure values representing a specific subgroup of the population.

MATERIALS AND METHODS

The analysis must be based on different human models that represent sufficient variations of the target subpopulation, including different genders, ages including children, size and body-mass index (BMI). Postural variations representing typical positions of the investigated application and situations are also required. Furthermore, statistical data for the subpopulation must also be available for the most relevant parameters such as age, gender, BMI distribution and estimation of the likelihood of postures.

Using the available models, a sensitivity analysis for the various parameters must be performed to extrapolate it to the entire user population. The uncertainty of the estimation will greatly depend on whether the acquired parameters sufficiently represent the variations of the population.

RESULTS and CONCLUSIONS

The sample study for MRI exposures demonstrated that the approach is feasible. The analysis was performed with SEMCAD X, the phantoms shown in Figure 1 including a recently developed obese model as well as the poser extension of SEMCAD X which permits the articulation of the limbs of the models. However, the uncertainties of the results could be substantially decreased if more models of various BMI were available, because the current set does not fully cover the actual variations.
DISCLAIMER

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

REFERENCES

Measurements of Temporal RF Exposure of the General Public

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INTRODUCTION

Up to now almost no measurement data is available about electromagnetic exposure from GSM and UMTS base stations during longer periods e.g., a day, a week. Usually, electromagnetic-field measurements are performed in an environment with a spectrum analyzer and an electromagnetic-field probe during a short period (less than 6 or 30 minutes), and compliance of exposure with guidelines of e.g., ICNIRP is tested. In this paper, temporal measurements during a week of the exposure to GSM and UMTS base stations and FM transmitters at different sites are presented. The purpose of this paper is to investigate how short-period measurements can be related to the actual maximal and average exposure following from measurement runs made over longer time e.g., a week.

MATERIALS AND METHODS

Base station sites are classified into five categories depending on type of environment, population density, and expected amount of mobile phone traffic: residential area (including schools, day-care centers, etc.), rural terrain, office environment (suburban), urban environment, and industrial environment [1]. For each of these categories, a site is selected to execute the measurements. The fields are measured in a frequency range of 80 MHz up to 2500 MHz with a tri-axial R&S TS-EMF Isotropic Antenna in combination with a spectrum analyzer (SA) of type R&S FSL6.

Temporal measurements of GSM and UMTS (and FM, if present) are executed during 7 days in sequences which last 1 to 3 minutes. One single sequence consists of consecutive electric-field measurements for each of the three orthogonal components of present GSM (900 and 1800 MHz, 3 operators), UMTS (for 3 operators, with SA and 3GPP software demodulation to extract the Common Pilot Channel (CPICH)), and FM signals. A momentary value of the electric field (denoted $E_{mom}$) associated with an RF source (e.g., GSM, UMTS) is defined as a sample of the total electric field of that RF source obtained during a measurement sequence with the spectrum analyzer.

The factor $X$ is defined as the ratio between the actual maximal value $E_{true}^{max}$ (measured during 7 days at the considered sites) and the estimated maximal value $E_{estim}^{max}$ (from short-period measurements):

$$X = E_{true}^{max} / E_{estim}^{max} \quad [-] \quad (1)$$

Moreover, to convert between maximal and median values a factor $R$ is defined as the ratio between the median and maximal value of the momentary temporal field measurements.

$$R = \frac{\text{median}(E_{mom})}{\text{max}(E_{mom})} \quad [-] \quad (2)$$

The closer $R$ to 1, the less the signal under consideration varies; low values of $R$ thus indicate a high degree of variation. The ratio $R$ is a measure for the level of variation of a certain signal over time, and enables to calculate maximal values from median values and vice versa.
RESULTS

In total about 352,800 temporal electric-field measurements are performed. Fig. 1 shows the variation of a GSM (947.5 MHz), UMTS (2162.2 MHz), and FM (103 MHz) signal for a duration of 7 days for site 1 (residential area). The variation of the electric fields due to GSM and UMTS is much higher than the variation of the FM signal due to the presence of traffic. For site 1, the GSM900 signal delivers the highest field values. The fields of GSM and UMTS are higher during daytime than at night (from 12 am to 6 am). The maximum fields in the weekend are also lower than during weekdays. Three different methods to assess X are compared and an optimal method is proposed: a method based on the extraction of the BCCH (Broadcast Control CHannel) and CPICH signal of GSM and UMTS, respectively (method 1), a max-hold measurement method (method 2), and a method to extrapolate the max-hold measurement to the worst-case moment (method 3). The median values of X according to the proposed method 3 are 1.05, 0.47, and 0.96, for FM, GSM, and UMTS, respectively [1]. Median values of R are 0.92, 0.66, and 0.71, for FM, GSM, and UMTS, respectively. For FM, R is close to 1, indicating only a little variation over time.

CONCLUSIONS

In this paper, the general public’s exposure to FM, GSM, and UMTS over 7 days time is investigated. Five different sites have been selected to perform measurements of the electric fields over time. A factor X is defined as the ratio between the actual maximal value of the temporal measurements and the estimated maximal value from short-period data. Median values of X are 1.05, 0.47, and 0.96, for FM, GSM, and UMTS, respectively. Moreover a factor R is defined as the ratio between the median and maximal value of the momentary temporal field measurements. Median values of R are 0.92, 0.66, and 0.71 for FM, GSM, and UMTS, respectively. By combining X and R one can estimate the actual maximal and median exposure during longer periods from short-period measurements.

REFERENCES

French Population Exposure to 50 Hz Magnetic Fields: Intermediate Results

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INTRODUCTION

In 1979, a study indicated that childhood cancers might be linked with extremely low frequency (ELF) magnetic field [1]. Leaning on numerous epidemiological studies, the International Agency for Research on Cancer classified in 2001 ELF MF as “possibly carcinogenic to human”. These conclusions were based on a statistical association found in some epidemiological studies, unconfirmed by experimental results, between childhood leukaemia risk and a mean exposure over 24h higher than 0.4µT.

One remaining -and critical- question about these epidemiological results is the exposure assessment. Another relevant question is to know, in the overall exposure of people, the relative contribution of all the possible field sources in the daily environment.

Starting from a previous study (50 Hz magnetic field levels in houses, half of them close to power lines [2]), the French Ministry of Health initiated in 2006 a large study of the individual exposure of a randomly selected sample of the French population.

The total exposure database will contain 1000 measurements for children and 1000 measurements for adults. The analysis of results is still ongoing, and should be published in 2010. This paper presents intermediate results, based on the data already analysed.

MATERIALS AND METHODS

The exposure data were collected during 3 measurement campaign between the beginning of 2007 and the end of 2008.

The volunteers were randomly selected from phone lists. Each of them has worn an EMDEX II (Enertech, USA) MF recorder during 24h, and has simultaneously filled in a timetable describing his activities. In addition, all volunteers answered to a questionnaire about his socioprofessional data and his house (one of the parents answered for their child).

The present paper gives the intermediate results on 990 persons: 437 children (0-14 years) and 553 adults.

RESULTS

The observed arithmetic and geometric means are respectively 0.11µT and 0.03µT for children, 0.15µT and 0.04µT for adults.

The statistical analysis has led to the following results:

- The search for the most discriminating MF descriptors from a hierarchical clustering classification followed by CART method (Classification And
Regression Tree) led to a distribution of the studied sample into three groups for each type of population (adults and children). The most discriminating descriptors are

- the arithmetic and geometric means and the Rate Change of metric standardized (RCMS) for both the two populations,
- the maximum and the median values for the adults,
- the third quartile and the standard deviation for the children.

- The factors that lead a person to be more exposed has been identified by linear and logistic regression methods or non-parametric regression models:
  - for both the two populations: the time spent in railway transport, the time spent using a computer, to sleep near a clock radio, to live in a collective building,
  - the age for the children,
  - to live in a city of more than 2,000 inhabitants and to have an individual electric water heating for the adults.

CONCLUSIONS

The most important factor influencing the personal exposure is the clock radio, which was identified in 120 series. The question whether these measurements are representative of personal exposure will be discussed.

The influence of proximity to electric transmission and distribution facilities will be analysed.

ACKNOWLEDGMENTS

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REFERENCES


The use of fluorescent dyes and other markers to measure elevated temperature in cells during RF exposure

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INTRODUCTION

International standards for radiofrequency (RF) exposure limit the Specific Absorption Rate (SAR) within regions of tissue, because this is assumed to give an indication of the local rise in temperature within that tissue. Unfortunately, the distribution of SAR differs markedly from that of temperature rise, (see [1] for example). In evaluating so-called ‘non-thermal’ effects of RF, the actual temperature change within in-vitro samples is difficult to estimate with precision. Fluorescent dyes, such as Rhodamine B (Rho B), are increasingly used to directly measure temperature changes in microfluidic applications, [2], but not, as far as the authors are aware, previously in tissue samples.

MATERIALS AND METHODS

Rho B intensity decreases with increasing temperature. Using a confocal microscope, images were obtained of a sample of cotton soaked in Rho B solution maintained at several temperatures between 24 and 42 °C (as measured via two fluoroptic probes). The average image intensity was obtained (using imaging software) and from this the average % fall in intensity per °C rise was determined. Results were also obtained using rat tail tendon and other biological tissue samples.

In order to measure the local rise in temperature in tissue samples due to RF, a purpose-made RF exposure device was used [3]. This permitted simultaneous confocal imaging of the tissue sample during exposure. The SAR pattern within this chamber had previously been determined by modeling [3]. Rat tail tendon and other tissue samples (approximately 1 x 1 x 0.3 mm) were fixed, infiltrated with Rho B, sealed between coverslips and then placed within the exposure chamber. Fluorescent images (confocal optical slices, 600 x 600 x 4 μm, typically 15 images per stack) were obtained before the RF exposure was commenced and then at various stages during exposure. RF (900 MHz, un-modulated, 8.71 W forward power) was supplied from a signal generator, power amplifier then via a coupler/attenuator to the chamber via a matched 50Ω coaxial cable. Return loss had previously been determined using a network analyzer. This permitted an estimate of SAR within the chamber.

RESULTS

Estimates of fluorescent intensity change in the cotton samples gave an average of −3.4 ± 0.2 %/°C ($r^2 = 95$). This was used to convert image intensity values to temperature. Estimation of temperature within tissue (single optical slice) at 1 min intervals following commencement of exposure showed a good correlation between values obtained from fluoroptic probe measurement and those from intensity measurement (obtained by summing pixel photon counts over the image) converted to temperature using the method just outlined. The RMS difference between the two sets of measurement was 1.5 °C.
For 3D imaging, two image stacks are shown in Fig 1, (A prior and B 2 min after commencement of RF exposure) together with the intensities obtained by subtracting B from A for each of the 15 optical slices in the stack. Again, using the procedure above, the intensity values were converted to temperature change.

CONCLUSIONS

From Fig. 1 it can be seen that the temperature rise was not uniform within the sample (maximum value 5.3 °C), with a smaller temperature rise close to the coverslip and hence to the surroundings (at room temperature).

Estimates of SAR from rise in temperature (dT/dt) in initial experiments gave estimates much less than those from absorbed power, indicating a need to capture temperature changes within a few seconds of turning on RF power. A series of experiments is underway at present to do this, and it is hoped that these results will be available for presentation at the conference.

ACKNOWLEDGMENTS

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REFERENCES

Numerical Analysis of Heart Currents in an Anatomical Human Model due to the Contact with 60Hz Energized Conductor

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INTRODUCTION

The contact currents[1,2] have received wide attention from the point of view of electric shocks and stimuli for long time. Till recently, most data associated with the contact current were collected from experimental works using the body of researchers themselves, animals, or corpses. However, several numerical human models have been developed and opened recently, and hence analyses of the contact current characteristics by using such human models become available. In this paper, numerical results of current densities in the Japanese adult model[4] under four scenarios of current paths are demonstrated[3]. Especially, currents passing through the heart are investigated.

MATERIALS AND METHODS

In this study, two modifications from the conventional SPFD method were made, which were similar to Dawson’s modifications[5]; namely, the vector potential components due to the external magnetic fields at each voxel were removed, and at least two electrodes with given electric potentials were attached to the surface voxels. Validity of our new numerical method was confirmed by reasonable agreement of the numerical results with the experimental ones that were obtained by using a rectangular vessel filled with saline solution under various electrode configurations.

An anatomically-constructed and inhomogeneous numerical model of Japanese adult male body[4] is used, and four scenarios of current paths are considered for this model; namely, left hand to both feet (LH-BF), right hand to both feet (RH-BF), hand to hand (H-H), and foot to foot (F-F). The voltage of 1V at 60Hz was applied between the two electrodes for the four scenarios, then, the current densities obtained were proportionally converted so that the total contact current became 0.5mA.

RESULTS

Fig. 1 shows vector maps and distributions of the current densities on the coronal plane of the chest region for the three current paths. It is noted that the currents inside the heart predominantly flow longitudinally for the LH-BF and RH-BF paths, and transversely for the H-H path.

A heart-current ratio, which is defined as the ratio of the current flowing into/out the heart to the total contact current, is estimated and is listed in Table 1. In addition, the heart-current factors, which are numerically obtained and are also extracted from IEC 60479-1[1], are listed in Table 1 as well. Here, the heart-current factor is a ratio of the reference total current for the LH-BF path to the total current for the current path to be interested provided that the same heart currents as each other are given. It is clear from Table 1 that the heart-
current ratios significantly depend on the current paths, and the current passing through the heart is the largest for the LH-BF path and is very little for the F-F path. The largest ratio of 40% is quite different from about 8.5% reported by Freiberger[6]. Although the heart-current factor for the RH-BF path reasonably agrees with the IEC’s one[1], the one for the H-H path is almost twice as large as the IEC’s one[1]. This result points out that, from the point of view of the magnitude of heart current, effects of the contact current for the H-H path are likely to be significantly underestimated in IEC 60479-1.

![Fig.1 Vector maps and distributions of current densities on the coronal plane of the chest.](image)

<table>
<thead>
<tr>
<th>scenario</th>
<th>Heart-current ratio</th>
<th>Heart-current factor</th>
<th>Heart-current factor by IEC</th>
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</thead>
<tbody>
<tr>
<td>LH-BF</td>
<td>39.7 %</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>RH-BF</td>
<td>33.7 %</td>
<td>0.85</td>
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<td>H-H</td>
<td>34.6 %</td>
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<td>0.4</td>
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<tr>
<td>F-F</td>
<td>0.32 %</td>
<td>0.008</td>
<td>0.04</td>
</tr>
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</table>

**CONCLUSIONS**

It is found that a part of 33 ~ 40% out of the total contact currents passes through the heart for the three current paths of one hand to either the other hand or feet, and these heart-current ratios are much larger than the ones reported by Freiberger. Furthermore, the heart-current factor is almost the same as the one in IEC 60479-1 for the right-hand-to-feet path, but is twice as large as the one in IEC 60479-1 for the hand-to-hand path.

**ACKNOWLEDGMENTS**

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**REFERENCES**

SAR Distribution and Temperature Rise in Culture Fluid in Large-Scale In Vitro Experiment System at 1.95 GHz

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INTRODUCTION

A large-scale in vitro experiment system [1] was used to investigate whether exposure to 1.95 GHz Wideband Code Division Multiple Access (W-CDMA) radiofrequency (RF) fields induces activation of microglial cells [2]. This system was originally designed for use at 2.1425 GHz and the mean specific absorption rate (SAR) of 0.08 W/kg, at which the temperature rise can be negligible. In using this system for RF field exposure at 1.95 GHz and the mean SAR of 2.0 W/kg, which correspond to the basic restriction of localized SAR for general public exposure recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [3], it is expected that the efficiency of the RF field exposure is decreased relative to 2.1425 GHz and the temperature rise in the culture fluid may not be negligible. Therefore, the SAR distribution and temperature rise in the culture fluid are newly evaluated.

MATERIALS AND METHODS

A beam-formed RF exposure incubator employs a horn antenna, a dielectric lens, and a culture case in an anechoic chamber. Two identical RF field exposure incubators, one for RF field exposure and the other for sham exposure, as shown in Fig. 1, are established in separate anechoic chambers, and a mechanical switch in a dummy box allowed the selection of RF field exposure or sham exposure. The main unit for the cell exposure provides identical air to the two culture units through sealed ducts at the appropriate temperature (37°C), CO₂ density (5%), and humidity (>90%). The Finite Difference Time Domain (FDTD) calculation method is used to assess the SAR distribution in the culture fluid using a detailed model of the aforementioned RF field exposure incubator and the bio-heat equation is used to obtain the temperature rise in the culture fluid. The dielectric and thermal properties are given in Table I. The voxel size is 0.5 mm. It is assumed that the surrounding atmosphere is stable at 37°C. To confirm the effectiveness of the bio-heat equation, the calculation results are compared to the temperature measured by a fiberoptic thermometer.

RESULTS

The SAR distribution in the culture fluid at the bottom of 35 mm diameter Petri dishes is illustrated in Fig. 2. The mean SAR and the standard deviation of the SAR distribution for the four groups (each group comprises three dishes) in Fig. 2 are 2.0 W/kg and 1.1 W/kg (57%), respectively. Figure 3 shows a comparison of the temperatures for the antenna radiated power of 25 W; it indicates that they are in very good agreement. Through calculation we determined that the mean temperature and the standard deviation of the temperature distribution in the steady state are 37.7°C and 0.1°C, respectively, in the case that the mean SAR in the culture fluid at the bottom of the Petri dishes is 2.0 W/kg for the four groups.
CONCLUSIONS

The SAR distribution and temperature rise in the culture fluid were evaluated. The experiment system contributes to the investigation of the effects of W-CDMA RF fields on microglial cells for the mean SAR of 2.0 W/kg while considering the thermal influence [2].

ACKNOWLEDGMENTS

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REFERENCES

A Comprehensive Tissue Properties Database
Provided for the Thermal Assessment of a Human at Rest

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INTRODUCTION

The calculation of induced temperature rises in humans exposed to radiofrequency (RF) electromagnetic fields requires reliable estimates of the following five tissue properties: specific heat capacity (c), thermal conductivity (k), blood perfusion rates (m), metabolic heat production (A₀), and density (ρ). A sixth property, water content (w, as a %), can also be used to derive c and k. To date, researchers have used various and inconsistent estimates of these parameters, which hinders comparison of the corresponding results. In an effort to standardize these parameters for future studies we have documented 140 key papers and books and developed a database of the six thermal properties listed above for around 50 human tissues. For each tissue and each property the following were obtained: the average value, the number of source values, the minimum and maximum of source values, and the reference for each source value.

For this database we only accepted values from reference sources that provided the original measurements. Estimates were made only if original measured values were not available. In these cases water content was used for deriving c and k, and blood perfusion for deriving A₀.

BACKGROUND

Pennes’ bioheat equation [1] is often used by researchers when calculating RF induced tissue temperature rises:

\[ \rho c \frac{dT}{dt} = \nabla \cdot (k \nabla T) + \rho \text{SAR} + A_0 - b(T - T_b) \]  

where c is the specific heat capacity (J/(kg.°C)), k is the thermal conductivity (W/(m.°C)), ρ is the mass density of the tissue, A₀ is the metabolic heat production (W/m³), b is the heat-sink strength from each tissue volume by blood perfusion (W/(m³.°C)), and Tₐ is the temperature of blood (°C), with these quantities specified for each tissue. The Specific energy Absorption Rate (SAR) is the rate of energy transferred relative to the tissue mass (W/kg). The more common blood perfusion quantity found in the literature is the blood perfusion rate, m, usually stated in ml/min/100 g. It is related to b via \( b = \rho \cdot \rho \text{blood} \cdot m \cdot c \text{blood} \cdot (10^{-5}/60) \), where the latter numerical term on the right is present to convert the quantity to SI units. An example of the use of Pennes’ equation is presented in [2].

Many authors state values for tissue properties but do so in their studies by quoting values from other authors, who in turn quote other authors, and so on. When traced back some of the original values are questionable in their derivation or measurement or were approximated. In our review we sought to obtain direct sources of original measurements. If numerous
values were available for a given property for a tissue then the spread of values was used to check data quality.

**OBTAINING DATA**

Around three hundred references (papers and books) were reviewed with 90 key references chosen to provide original data and 50 other references providing important sources of information. The references chosen were either those referred to by other references or by our own literature searches. The data was chosen as much as possible from original sources.

The integrity of the values used was checked by ensuring that there was common agreement with other values for that tissue. Consistency between tissues of a similar type was also considered. The values were selected under the constraint that they were for humans at rest and adults of less than 70 years of age. Measurement techniques were also assessed and compared, with consideration given to the changes in technologies. Data from small animals (e.g. rodents) was not used.

When measured data is not available then approximations are made as in [2] and discussed in [3]. The specific heat capacity, $c$, can be estimated using $c = 1670 + 25.1\cdot w$ and the thermal conductivity, $k$, through $k = 0.0502 + 0.00477\cdot w$ [2].

**CONCLUSIONS**

A comprehensive database has been developed that provides thermal properties of tissues. This resource is to be made available to the Bioelectromagnetics community. A key objective of the development process has been to only source original measured values to ensure high integrity of the database. Estimates for the variation of a tissue’s property has been obtained in many cases, which in turn, enables the determination of the range of possible thermal change from RF exposure.

**ACKNOWLEDGMENTS**

We would very much like to thank Joanne Cohen, our Information Officer, for sourcing many of the papers, and performing extensive literature searches for us.

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**REFERENCES**


Reliability of RF Exposimeters using real life signals for calibration

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INTRODUCTION

Several factors need to be taken into account when using RF exposimeters for the assessment of the individual exposure. Apart from the impact of the human body [1] on the exposimeter reading and the limited dynamic range the type of calibration signal has a major impact on the derived field strength. In the past it was common to use continuous wave (CW) signals for the calibration of exposimeters. CW signals are not representative for real life exposure, e.g. GSM, DECT or TETRA networks are using TDMA (Time Division Multiple Access) signals leading to variations between peak and average field levels due to the variability in occupancy of time slots. In addition, the specific implementation of the exposimeter does not allow for direct extrapolation of CW calibration data to real life signals. The dependency of the reading of an exposimeter frequently used in epidemiological studies is analyzed using realistic signals for calibration.

MATERIALS AND METHODS

SATIMO EME SPY 120 exposimeters were used for the experiments performed in fully anechoic chambers at the Austrian Research Centers in Seibersdorf. For the GSM and UMTS bands calibration signals were excited using a Rohde & Schwarz CMU 200 signal generator both for the uplink and downlink band. For the calibration in the TETRA band a TETRA test base station was used. DECT and WLAN band commercial equipment was used to generate the corresponding reference signals. An HP signal generator was used for the continuous wave signals calibrations within the TV bands and modulated FM broadcast signal. Calibrations were performed at different frequencies within the respective frequency bands, for instance in 5 MHz steps for the GSM 900 band from 920 to 960 MHz. In each frequency band the linearity, the isotropic response and the out of band response of the exposimeters were investigated.
RESULTS

The calibration factor was found to be dependent not only on the specific signal type, but also on the carrier frequency within a specific band. For instance, in the FM band calibration factors varied between 0.7 (98 MHz) and 0.96 (88 MHz). Prior to calibrations there is the need for clarification if peak or average exposure is of relevance in a specific study. Calibration factors may vary accordingly, e.g. when using a GSM 900 uplink signal at 910MHz with one active time slot as reference the calibration factor equals 0.9 when looking at the peak field level and reduces to 0.35 when investigating the average exposure. Moreover, the calibration factors of different devices of the same type of device may vary considerably. Therefore, it must be recommended to calibrate all devices individually when performing large-scale studies. In general the linearity was within +/- 1.5 dB in all frequency bands, except the DECT band when using only the synchronisation pulse of a DECT base station as reference signal. In some cases out of band signals can lead to considerable coupling into neighbouring bands, for instance DCS 1800 signals can cause false readings in the DECT band.

CONCLUSIONS

Adequate calibration of exposimeters is imperative for epidemiological studies being performed with RF exposimeters. The use of CW calibrations is not sufficient because the exposimeter readings for several signal shapes differ considerably from those of CW signals, e.g. GSM uplink signals. More research regarding the impact of the selection of specific exposure facilities, e.g. anechoic chamber versus GTEM cells and the identification of calibration signals being representative for the exposure of the population is needed.

ACKNOWLEDGMENTS

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REFERENCES

Variability of Whole-body Averaged SAR in Models of Adults and Children for Plane-Wave Exposure

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SUMMARY

There has been increasing public concern about the adverse health effects of human exposure to electromagnetic waves. According to the safety guidelines of the ICNIRP [1] and the IEEE standard [2], the whole-body averaged specific-absorption-rate (WBA-SAR) is used as a metric of basic restriction for radio-frequency whole-body exposures. The basic restriction of WBA-SAR is 0.4 W/kg for occupational exposure or 0.08 W/kg for public exposure. An incident electric /magnetic field, which does not produce EM absorption exceeding the above limit is defined as a reference level in the ICNIRP guidelines and as the maximum permissible exposure in the IEEE standard. The relationship between the reference level/maximum permissible exposure and the WBA-SAR was derived mainly from numerical calculations done dozens of years ago.

In computational dosimetry in the 1980s, human modeling was highly simplified in the figure of a prolate spheroid or a homogeneous block model (e.g., [3]). In recent years, with the development of computational resources, anatomically based human body models are used for investigating the WBA-SAR (e.g., [4, 5, 6]). As the main result, the WBA-SAR under the reference level/maximum permissible exposure is found to have a peak around several dozen megahertz due to standing waves over the body model. In addition, the WBA-SAR has another peak around 2 GHz, which is caused by a relaxation of the reference level/maximum permissible exposure with an increase in the frequency. Furthermore, the WBA-SARs in the child models were larger than those in the adult. The purpose of present study is to propose a scheme to estimate WBA-SAR in different human models for far-field exposure in these two frequency regions, in order to discuss the variability of WBA-SAR.

We proposed a formula to estimate WBA-SAR in the whole-body resonance frequencies based on the antenna theory. The uncertainty in the WBA-SAR using the formula may be up to several percents especially due to the model inhomogeneity. The variability of WBA-SAR in the child models was given using the formula. In the GHz region, we proposed a homogeneous ellipsoid having the electrical constants of muscle as a conservative WBA-SAR estimation. The effectiveness of that model was shown considering an infant model with different Kaup indexes. Our preliminary results can be found in [7, 8].

Acknowledgement

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REFERENCES


Temperature Sensitivity of Tissue Equivalent Liquids used for SAR Testing

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INTRODUCTION

Specific absorption rate (SAR) testing of wireless devices is performed by measuring the electric field in a tissue equivalent liquid, in accordance with existing and future international standards [1], [2]. The laboratory conditions must remain stable during testing. The liquid temperature should be kept within a tolerance of ±2 °C, as the liquid dielectric parameters are sensitive to temperature. It was previously assumed that the temperature sensitivity was small enough to be ignored. However, the temperature sensitivities of a large number of commonly-used tissue equivalent liquids have not been published to date.

MATERIALS AND METHODS

Fourteen tissue equivalent liquids were mixed using the recipes shown in Tables 1 and 2. The dielectric parameters were measured using a network analyzer connected to the Agilent 85070C open-ended coaxial probe. Measurements below 200 MHz were corrected for electrode polarization using the method of [3]. The liquid temperatures were adjusted to \( T_{\text{low}} = 18 \, ^\circ\text{C} \) and \( T_{\text{high}} = 25 \, ^\circ\text{C} \) using a temperature bath, and the relative permittivity \( \varepsilon_r'(T) \) and conductivity \( \sigma(T) \) were measured. The average value of three measurements was used. The temperature sensitivity of the permittivity, \( \varepsilon_r' \text{tolerance} \), over the ±2 °C temperature tolerance is then calculated from Equation (1). A similar equation is used to calculate the sensitivity of \( \sigma \).

\[
\varepsilon_r' \text{tolerance}[\%] = 100 \times \left| 2\times \frac{\varepsilon_r'(T_{\text{high}}) - \varepsilon_r'(T_{\text{low}})}{\varepsilon_r'(T_{\text{high}}) + \varepsilon_r'(T_{\text{low}})} \right| \times \frac{2 \times (T_{\text{high}} - T_{\text{low}})}{100} \tag{1}
\]

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<thead>
<tr>
<th>Freq. (MHz)</th>
<th>144</th>
<th>300</th>
<th>450</th>
<th>835</th>
<th>900</th>
<th>900</th>
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<table>
<thead>
<tr>
<th>Recipe ingredients (% by weight)</th>
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<td>Diacetin™</td>
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<td>Salt</td>
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<tr>
<td>Sucrose</td>
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<tr>
<td>Water</td>
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<table>
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<th>Measured parameters</th>
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<th>47.4</th>
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<td>σ at 18 °C (S/m)</td>
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<tr>
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</table>

Table 1: Measured dielectric parameters (ε_r' and σ) and temperature sensitivity (ε_r' tolerance and σ tolerance) for the recipes shown at 144 – 1450 MHz. The recipes were found from the published references shown.
RESULTS

Tables 1 and 2 show the measured dielectric parameters of the fourteen tissue equivalent liquids at 18 °C. The measured values are on average within 5% of the targets found in international standards [1], [2]. The temperature sensitivities of the dielectric parameters are nearly 3% in some cases. Liquid conductivity is generally more sensitive to temperature than permittivity. The temperature sensitivities should be entered into the uncertainty budget to estimate the total uncertainty of an SAR measurement.

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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>52.64</td>
<td>55.36</td>
<td>54.90</td>
<td>49.43</td>
<td>55.00</td>
<td>50.00</td>
<td>49.75</td>
</tr>
</tbody>
</table>

Table 2: Measured dielectric parameters ($\varepsilon'$ and $\sigma$) and temperature sensitivity ($\varepsilon'$ tolerance and $\sigma$ tolerance) for the recipes shown at 1800 – 2450 MHz. The recipes were found from the published references shown.

CONCLUSIONS

The temperature sensitivities of the dielectric parameters of fourteen tissue equivalent liquids are reported. The liquids are all example recipes found in international standards [1], [2]. The temperature sensitivities are not negligible. Knowing their values is important for estimating the total SAR measurement uncertainty for compliance testing of wireless devices.

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[2] IEC Draft Std 62209, Human exposure to radio frequency fields from handheld and body-mounted wireless communication devices - human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) in the head and body for 30 MHz to 6 GHz handheld and body-mounted devices used in close proximity to the body, Committee Draft, October 2008.
A Corner-Rounded Flat Phantom for the Compliance Test for Mobile Phones

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INTRODUCTION

For the compliance test of mobile phones, the Specific Anthropomorphic Mannequin (SAM) phantom is used as the standardized human head [1][2]. In the standardized test procedure, the phone must be measured at least in four phone positions, i.e., at tilt and cheek positions in the right and the left sides of the SAM head [1][2], to determine the maximum SAR for all operating frequency bands of the phone. This procedure is highly reliable; however, a simplified test procedure is expected as the number of the measurement per one mobile phone is increasing. In the draft of the IEC 62209-2 [3], a flat phantom will be utilized for compliance tests for radio devices used in close proximity to the human body except those used close to the ear. If this sort of the flat phantom can be also used for the compliance test of the mobile phones, the total number of the measurement is significantly reduced. Therefore, as a preliminary study, we investigated on the applicability of a new flat phantom which has rounded corners in the compliance test of mobile phones.

MATERIALS AND METHODS

At first, the maximum averaged SAR values of a flat phantom and the SAM phantom have been measured and compared for 38 mobile phones in the market in Japan as a preliminary measurement. Figure 1 shows measurement positions of the phones and summarizes the deviation of the maximum SAR values of the flat phantom from that of the SAM. The value is normalized to the maximum SAR of the SAM. As a result, in most cases the SAR value by the flat phantom is larger than the SAR of the SAM phantom for Straight/ Slide-shaped phones. On the other hand, for the Clamshell type phones, there is no clear tendency between the SAR by the flat phantom and that by the SAM. Therefore, an evaluation using only the "flat-part" of the phantom may be difficult for the Clamshell type phones.

![Figure 1: Measurement setting of the phone and deviation of measured maximum 10g SAR values.](image-url)
As a next step, we have fabricated a new flat phantom whose corner is rounded to be similar to the curvature of the SAM. Then the maximum 10g-average SAR of an actual Clamshell-phone at 835 MHz is measured and compared with the SAR values by the SAM. Figure 2 shows the cross section of this corner-rounded flat phantom and the phone at three positions. This flat phantom is a bathtub type whose curvature of the rounded corner is chosen to approximately fit to Ear Reference Point (ERP)-Cheek-Chin curve of the cross section of the SAM [1][2]. Positions A and C are chosen to be similar settings corresponds to Cheek and Tilt positions in the SAM, respectively. In Position B the phone is contacting to the flat bottom, and corresponds with a “flat-part” measurement.

RESULTS

Table 1 summarizes the deviation of the maximum SAR values of the flat phantom measurement. The deviation is normalized to the maximum SAR value by the SAM.

In this measurement, the flat phantom yielded the highest SAR at Position B which was at the flat part of the phantom. Therefore, if using this position to the compliance test, the SAR is overestimated and the evaluation will be conservative. Moreover, it is an interesting finding that the SAR value in Position A (Cheek-like) was higher than the value in Position C (Tilt-like), and this was a similar tendency as the SAM measurement.

<table>
<thead>
<tr>
<th>Position</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position A</td>
<td>-12.9 %</td>
</tr>
<tr>
<td>Position B</td>
<td>106 %</td>
</tr>
<tr>
<td>Position C</td>
<td>-48.3 %</td>
</tr>
</tbody>
</table>

CONCLUSIONS

We found that the maximum average SAR values of the round-cornered flat phantom and the SAM phantom are higher at flat-part. Therefore, it is suggested that this flat phantom can be used to evaluate the SAR of mobile phone. Moreover, as for the difference of SAR value by the position of the phone in both phantoms, they showed the same tendency. In the future study, more numbers and shapes of the phones should be examined.

REFERENCES

Comparison of the Results of two Hands Free Kit Dosimetry Protocols

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INTRODUCTION
Since a few years the use of hands free kits (HFK) with mobile phones is increasing. The distance between the phone antenna and the user head is larger with the use of HFK and one can think that the RF deposited power in the user head is significantly reduced. However the wire of HFK is metallic and the RF currents induced on this wire can be the sources of power deposition in the user head. This paper is the comparison between two different HFK dosimetry measurement protocols.

MATERIALS AND METHODS
We have used a first measurement protocol (HFK1) for HFK SAR measurement assessment [1]. There are 6 different measurements for each frequency band, corresponding to 2 different HFK wire configurations and 3 different frequencies: lower, center and upper frequencies. The 2 different wire configurations are 1) tensed wire (figure 1), 2) wire with two three cm diameter loops near the phone antenna (figure 2), the exact position of which corresponding to an obtained maximum SAR value at the center frequency. The tensed wire configuration corresponds to a “natural” situation and the wire with loops to a worst case. The end of the wire near the earpiece is applied to the SAM phantom surface close to the ear.

A study made it possible to define a new argued measurement protocol (HFK2) [2]. The measurement uses a parallelepipedic phantom (figures 3 and 4). The wire leaves the phantom surface with an angle of 45°. The wire comprises a folded section. The adjustment of the location and the length of this folded section allow to maximise the local SAR inside the phantom. The phone is as carried with the belt. The measurement consists, at the center of the frequency band, in the adjustment of the length (16 values with $\lambda/32$ increment) and the location (4 values with $\lambda/8$ increment) of the folded section of the wire. Then the SAR measurement is performed at the center, minimum and of the frequency band. For these two protocols the SAR of the HFK is the maximum obtained value for all configurations.

RESULTS
The comparison is carried out for 13 mobile phones. Figure 5 shows the comparison of the results corresponding to the two different protocols for GSM900 and GSM1800 frequency band. The results show a strong reduction of the SAR due to the HFK use and the SAR values corresponding to the two HFK SAR measurement protocols are significantly different, due to the different used configurations. Table 1 shows the comparison of the results in term
of mean value and standard deviation. The values are different for the two protocols, but the order of magnitude are similar.

<table>
<thead>
<tr>
<th>Band</th>
<th>Protocol</th>
<th>GSM900</th>
<th>GSM1800</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HFK1</td>
<td>HFK2</td>
<td>HFK1</td>
</tr>
<tr>
<td>Mean value</td>
<td>103</td>
<td>76</td>
<td>26</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>60</td>
<td>57</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 1: Statistical comparison of the two protocols (SAR in mW/kg).

CONCLUSIONS

In the two cases the HFK SAR values are very lower than the mobile phone SAR values. The two HFK SAR measurement protocols give different results due to the different used HFK configurations for the measurements and the high variability of the HFK SAR with the configuration. Statistically, the values are higher for the first protocol especially for the GSM1800 frequency band, but of the same order of magnitude. The repetability of the measurement of the HFK2 protocol is much better than HFK1.

ACKNOWLEDGMENTS

This research was sponsored by the french operator Bouygues Telecom and the French government within the ADONIS project (RNRT program).

REFERENCES

INTRODUCTION

The use of the Bluetooth earpiece as an accessory of mobile phones, is increasing. It must allow a significant reduction of the exposure of the head to the electromagnetic field, in a similar way to the use of the hands free kits, taking into account the difference in the emitted power between the earpiece and the phone, respectively 1mW and 1W or 2W. To quantify this reduction, it is necessary to evaluate in experiments the power deposited by the earpiece inside the user head. The level of the Specific Absorption Rate (SAR) of such an earpiece is very low, which makes impossible its measurement using a commercial dosimetric assessment system, except by using simplified methods [1]. The Electromagnetism Department of Supélec conceived and carried out a dosimetric assessment system with high performances [2] which makes it possible to carry out such measurements with the classical procedures, in particular the extrapolation of the local SAR to the surface of the phantom.

MATERIALS AND METHODS

The earpiece is emulated by a mobile phone, itself controlled by an emulator of base station. Under these conditions the envelope of the emitted signal is periodic and the proportion of the duration of the pulse of emission is 12% of the period. A specific electronic clock, able to be synchronized with the low frequency envelope of the Bluetooth earpiece emitted signal has been developed. This clock allows the synchronous detection of the signal of the dosimetric probe. Measurements are carried out on the anthropomorphic phantom SAM defined by the EN50361 standard. The axis of symmetry of the earpiece is placed on the axis ear-mouth of the phantom. The auditory canal of the earpiece is placed in front of the reference point of the phantom ear. The hole of the microphone is placed at a distance of 14mm of the cheek. The earpiece is measured successively on the two sides of the phantom head. 18 earpieces were tested.

The worst case for Bluetooth technology corresponds to one duration of the emission pulse of 50% of time, instead of 12% for the SAR measurements case. We used this value initially [3] for the evaluation of the SAR values. To obtain more precise values, we studied the emitted power in real earpiece uses then by deducing the real average emitted power and the evaluation of the real exposure to Bluetooth earpieces.

RESULTS

Several Bluetooth earpieces were tested with a mobile phone on the network. An antenna following by a radio frequency detector allows the measurement of the envelope of the earpiece emitted power. The measurements were carried out with sound (loud speaker at different sound levels) or in silence. The sound level has no effect on the result. For all the earpieces, the envelope of the radio frequency emitted power consists of one pulse the width of which is 400μs every 3750μs, leading to one relative duration of emission of 11%. Using
this value for the emitted pulse relative duration we obtain the SAR10g value presented on figure 1. The values obtained go from 0.5mW/kg to 4.2mW/kg.

CONCLUSIONS

For Bluetooth technology, the duration of the emission pulse of the envelope of the emitted power is 50% of the period of repetition, in the worst case. For real use of Bluetooth earpieces with mobile phone, this duration is only 11%. By taking of account the worst case one is led to too high values, of a factor almost equal to 5.

Then the reduction SAR of the user head of mobile phone, due to Bluetooth earpiece use, lies between 100 and 1000.

ACKNOWLEDGMENTS

This research was sponsored by the French operator Bouygues Telecom.

REFERENCES


SAR Variations by the EMI Paint Condition of the Bar and Slide Type Mobile Phone

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dgchoi@kcc.go.kr

INTRODUCTION

In recent years, the mobile phones have been used widely in our life, so public concern on the electromagnetic wave has increased rapidly. In order to solve these problems, we have studied the applicable method for the SAR reduction at the beginning stage for mobile phone development. In this paper, we investigated the SAR value variations on the bar(Cellular) and slide(PCS) type mobile phones with and without the EMI paint inside the phone(Fig. 1).

MATERIALS AND METHODS

The Bar and Slide type mobile phones were utilized in order to verify the SAR variation according to the using shape and structure of the mobile phones. In the Slide type, the up and down conditions were considered all. In order to verify the SAR variations on the mobile phone with and without the EMI paint inside the mobile phone case, the 1g and 10g averaged peak the SAR values on human head caused by the Bar and Slide type mobile phone were simulated and measured[1]. To calculate and measure the SAR of the mobile phone, SEMCAD(based on FDTD), DASY4 and ESSAY3(SAR measurement system) were used respectively. And we were also used the flat, head phantom and the simulated liquids with the human head electric parameters at 835 MHz, 1.7 GHz.

Fig. 1. The Bar and Slide type mobile phone with the EMI paint inside the mobile phone case

Fig. 2. Setup of the Bar and Slide type for SAR measurement
Table 1. The measured SAR value of the Bar and Slide type mobile phone (SAR value units: W/kg)

<table>
<thead>
<tr>
<th>Division</th>
<th>Bar type (835 MHz)</th>
<th>Slide type (1.75 GHz), Down</th>
<th>Slide type (1.75 GHz), Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>With EMI paint</td>
<td>1.63</td>
<td>0.569</td>
<td>0.251</td>
</tr>
<tr>
<td>Without EMI paint</td>
<td>0.97</td>
<td>0.948</td>
<td>0.337</td>
</tr>
</tbody>
</table>

Table 2. The simulated SAR value of the Bar and Slide type mobile phone (SAR value units: W/kg)

<table>
<thead>
<tr>
<th>Division</th>
<th>Bar type (835 MHz)</th>
<th>Slide type (1.75 GHz), Down</th>
<th>Slide type (1.75 GHz), Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>With EMI paint</td>
<td>0.865</td>
<td>1.95</td>
<td>0.691</td>
</tr>
<tr>
<td>Without EMI paint</td>
<td>0.692</td>
<td>2.11</td>
<td>1.27</td>
</tr>
</tbody>
</table>
RESULTS

For the analysis of the SAR value variation by phone type, the modeling of the Bar and Slide type were designed (Fig. 4), the SAR values were calculated and measured (Fig. 3, 5, 6). The simulated and measured the SAR values of the Bar type mobile phone with the EMI paint were 40.5%, 14.5% higher than without it, respectively (Table 1, 2). But the result of Slide type mobile phone was different from it. As a result of the Slide type, the SAR value of the down condition was bigger than it of the SAR value. In the EMI paint distribution, the results of the down and up condition of the Slide type were obtained the opposite results to the Bar type. And the SAR value of removed the EMI paint in the phone case was smaller than it of the un-removed the EMI paint (Table 1, 2).

CONCLUSIONS

In this study, the simulated and measured the SAR value variations on the Bar and Slide type mobile phone with and without the EMI paint inside the mobile phone were analyzed and discussed. As a result, the SAR values of the Bar type mobile phone with the EMI paint was higher than without it. And the SAR value of the Slide type mobile phone in the down condition was bigger than it of the SAR value. Also contrary to the Bar type result, the SAR values of the down and up condition of the Slide type mobile phone without the EMI paint was higher than with it. Consequently, the SAR values vary with the condition of the EMI paint distribution, because the SAR is proportional in the induced current value at the surface of a phantom. Therefore we suggest that we have to consider the SAR and EMI problem simultaneously when we develop a new mobile phone.

References.


The Dependence of Average SAR in Child Head on Antenna Positions of Mobile Phones

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INTRODUCTION

In recent years, the biological effects of exposure to microwaves from mobile phones have been researched numerically and experimentally. Thermal effects are dominant in the microwave region used in cellular phone systems. In international guidelines, specific absorption rate (SAR) is used as a measure for exposure to microwaves considering the thermal effects\cite{1}. Some researchers have reported an average SAR in a human head of exposure to microwaves from mobile phones numerically and experimentally. In numerical analysis, simple modeled mobile phones were used\cite{2}. On the other hand, a wide variety of mobile phones, i.e., straight shape, flip shape and so on are released. Furthermore, the antennas of recent mobile phones are embedded in the body of the mobile phones. The antenna positions of mobile phones are also a wide variety, for example, the antenna is set at upper, middle or lower position in the mobile phones. Therefore, it is considered that the SAR in a head is changed with the antenna positions of mobile phones. Especially it is important to consider this issue for dosimetry of recent epidemiological studies\cite{3}. In this paper, we calculate the average SAR in a child head for various antenna positions of the mobile phones. The antennas of the mobile phones are modeled three type, i.e., the case that antennas are located upper, middle or lower position of the mobile phones, respectively.

The Calculation Models

In this paper, the antenna of the mobile phones is modeled three types as shown in Fig.1(a), (b) and (c). The frequency is set at 1.95GHz. The 8-years old numerical head model(Isabella\cite{4}) is used as a numerical human head model. In this model 46 tissues are modeled. The SAR is used as a measure for exposure to microwave considering the thermal effects

\[ \text{SAR} = \frac{\sigma |E|^2}{\rho} \]

where $E, \sigma, \rho$ denote electric field (rms), conductivity and density of tissues, respectively. The SAR is calculated by SEMCAD X\cite{5}.

RESULTS

The calculated average SAR in the head is listed in Tabale1. In this calculation, the average SARs are calculated for the two handset angles relative to the head, i.e., the cheek position and the tilt position\cite{6} as shown in Fig.2, and a left side and a right side are also calculated. The imputed power is 1[w]. From Table1, the SAR of the upper antenna position is 60%-30% higher than the other antenna positions.
CONCLUSIONS

In this paper, we calculated the average SAR in the child head for various antenna positions of the mobile phones. In this calculation, the antennas were modeled by three types i.e., the upper, middle or lower position model. From results, the SAR of the upper position antenna was 60%-30% higher than the other antenna. Details of other SAR characteristics will be discussed at the presentation.

![Planer patch antenna on mobile substrate]

Figure 1: the studied antenna position of mobile phone

![The cheek position](a) ![The tilt position](b)

Figure 2: the studied mobile phone position

<table>
<thead>
<tr>
<th>Table1: The average SAR in head</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Upper</td>
</tr>
<tr>
<td>Middle</td>
</tr>
<tr>
<td>Lower</td>
</tr>
</tbody>
</table>

Unit:[W/kg]

REFERENCES

Specific Absorption Rate for UHF RFID Reader System

Seon Eui Hong, Jae-hoon, Yun, and Jin-kyu Byun

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2 School of Electrical Engineering, Soongsil University, Seoul, Korea
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INTRODUCTION

Radio frequency identification (RFID) is the collective term for technologies that use RF communication to remotely capture object identification data. Recently, there have been numerous explorations of fundamental characterizations of RFID system in electromagnetic fields (EMF). As RFID becomes more widespread, questions regarding the safety of human exposure to EMF will naturally be guided by those studies, guidelines and regulation, and the organizations and government agencies that developed them on behalf of the public.

In this paper, we describe the specific absorption rates (SAR) of energy for UHF RFID reader system environment. An analytical evaluation is conducted for the SAR in SAM model and a 34-year-old male adult model (Duke) of IT’IS virtually family for UHF RFID model. It is shown that the maximum SAR for UHF RFID reader antenna is approximately 2.584 W/kg when averaged over 1 g of tissue in a male adult whole body at 5 cm distance from the human.

MATERIALS AND METHODS

The diagram of using the UHF reader antenna is shown in Figure 1. The antennas consist of dual-feed radiating patch perpendicular to each other. Wilkinson Power diver and quarter wavelength is made of path difference (90 degree phase difference) to get circular polarization. The antenna gain is 6.34 dBi and -3 dB beam width is about 60 degree.

Figure 1: The RFID Reader Antenna (a) diagram (b) 3D gain for radiation point source of 1 W

The setup to evaluate the SAR in SAM model is present in Figure 2(a), where a reader antenna is positioned directly in front of the human face, and the SAR is evaluated for antenna distance of from 3 cm to 10 cm from the human face. The setup to evaluate the SAR in a male adult model (Duke) is present in Figure 2(b), where an antenna is positioned in front of the human, and in 1.0 m from the floor, and the SAR is evaluated for antenna distance of from 3 cm to 10 cm from the human. The simulation environment used here is Semcad 13.4, which is a software utilizing FDTD methods.
RESULTS

Figure 3 presents the SAR in the SAM model and Duke for the radiated source power of 1 W. It is shown that the maximum SAR for UHF RFID reader antenna is approximately 2.119 W/kg when averaged over 1 g of tissue for SAM, which is more than 1.3 times the limit for safe exposure to RF energy produced by mobile device (1.6 W/kg), as adopted by the Korea’s guidelines for limiting human exposure to EMF. It is shown that the maximum SAR is approximately 2.854 W/kg when whole-averaged over 1 g of tissue for Duke, which is more than 1.6 times the limit for safe exposure to RF energy produced by mobile device, as adopted by the Korea’s guidelines for limiting human exposure to EMF. Figure 4 is a plot of the SAR results for distance. And we notice that the maximum absorptions at 6 cm distance for SAM model and at 10 cm distance for Duke is below the accepted limits as required by the Korea’s guidelines for limiting human exposure to EMF.

CONCLUSIONS

This paper, we present an experimental study on the SAR of the human head in an environment with a typical RFID reader system. It is shown that the maximum SAR for UHF RFID reader antenna is approximately 2.854 W/kg when averaged over 1 g of tissue in a male adult whole body at 5 cm distance from the human, which is more than 1.6 times the limit for safe exposure to RF energy produced by mobile device (1.6 W/kg), as adopted by the Korea’s guidelines for limiting human exposure to EMF. We also show that the maximum value of SAR is 1.079 W/kg at 10 cm distance from the human, which is less than the maximum value allowed by the Korea’s guidelines for limiting human exposure to EMF.
Computation of Interference Voltage at a Pacemaker due to Electromagnetic Wave from a Mobile Phone with a PIFA

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INTRODUCTION

Electromagnetic interference (EMI) of an implanted pacemaker with a mobile phone have been investigated[1]. Based on the previous studies, national authorities have recommended that a mobile phone should keep safe distance from the pacemaker. As well, mechanisms of EMI of a pacemaker have also been studied. Those studies supposed a whip monopole antenna that was generally employed for second generation mobile phone handsets. However, recently, third generation mobile phones with an embedded antenna, which operates 2 GHz band, have become a majority in the world, especially in Japan. In this study, a third generation mobile phone was simplified as a PIFA (planner inverted F antenna) loaded with a metallic case. Moreover, interference voltage induced at an implanted pacemaker in a human torso model by this antenna model was calculated.

NUMERICAL SIMULATION

Figure 1 (a) shows a pacemaker model implanted in a human torso model and a mobile phone model in the vicinity of the torso. According to [1], the pacemaker housing had a dimension of 40 × 30 × 6 mm, and the lead wire had a diameter of 2 mm, and a length of 240 mm. The connector between the pacemaker housing and the lead wire had 2 mm gap. Interference voltage was induced at the connector. Figure 1 (b) shows appearance of the PIFA which resonated at 2 GHz. The PIFA was loaded with the metallic case which simulated body of a mobile phone. The pacemaker and the mobile phone were modeled with perfect conductors. The torso is a rectangular parallelepiped had electrical properties of muscle. The PIFA was kept at of 10 mm from the surface of the torso model and scanned on x-z plane. Figure 2 shows the area where we scanned the feeding point of the PIFA. We calculated interference voltage at the connector of the pacemaker in each location by FDTD (Finite Difference Time Domain) method. Moreover, we changed the direction of the PIFA with metallic case in x or z directions to study feature of influence of the metallic case direction. The antenna output power was 0.25 W.

EXPERIMENTAL SET UP

Interference voltage was also evaluated experimentally to validate the numerical calculation. Figure 3 shows the experimental set up. The height of torso phantom was reduced to 300 mm for facilitating the experiment. The validity of the reduced torso model could be confirmed by the calculation. Interference voltage at the connector was measured by a spectrum analyzer and compared to the numerical results.

RESULTS

Figure 4 shows the interference voltages obtained experimentally and numerically. Both experimental and numerical results are normalized by the maximum value of each voltage. Here, the horizontal axis is the distance between the feeding point and the origin, the point directly above the gap of the pacemaker. The longitudinal axis is the normalized interference voltage, respectively. Observation line includes maximum value of the interference voltage in the observation plane (x=30 mm). Good agreement is observed between the measured results and the calculated ones.

According to our preliminary study, a mobile phone was simplified as a dipole antenna. Interference voltage indicated the highest level when a feeding point of the dipole antenna faced to the con-
Whereas, interference voltage was not the highest level when a feeding point of the PIFA faced to the connector ($x=z=0$). The reason is that the level of interference voltage depends on not only electric field radiated from the feeding point but also induced current on the pacemaker housing and lead wire.

In addition, interference voltage was higher level when the metallic case was parallelized in $z$ direction than $x$ direction, which is not shown in this abstract.

**CONCLUSIONS**

Interference voltage was computed at the connector of pacemaker by PIFA with metallic case. In addition, we evaluated the interference voltage experimentally to validate the numerical results. As a result of the investigation. We clarified the detailed relation between interference and position of the feeding point.

**REFERENCES**

Effects of Electromagnetic Field Exposure from Mobile Phone Handset: 
– A Population-based Questionnaire Survey and Provocation Study in Japan –

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INTRODUCTION

Wide use of mobile phone has given rise to growing concerns about its health effect, above all, the effect of the electromagnetic fields (EMFs) emitted from the base station or handset. Whereas some health effects may be common to every individual, other effects are reportedly observed only in individuals who are especially susceptible to EMF. However, there has been a controversy as to whether the persons who report subjective symptoms actually have more symptoms as compared with others when exposed to EMF emitted from mobile phone terminals or mobile phone base stations (Regel et al., 2006). Recently, we reported that subjects with mobile phone related symptom (MPRS) did not show any differences in specific symptoms and subjective parameters from non-MPRS subjects when EMF from base station was present or not.

In this paper, we studied the relationship between the subjective symptoms and EMF from the mobile phone handset. Prior to the provocation study, we did the cross-sectional and population-based questionnaire survey of Japanese to find subjects for the provocation study. In the experiment, we aim to investigate whether subjects with MPRS are more susceptible to EMF than controls in several aspects, i.e. have more symptoms or show more changes in psychological, neurophysiological or physiological measures when exposed to EMF simulating that emitted by a handset.

MATERIALS AND METHODS

A questionnaire including inquiries about the frequency of mobile phone use and MPRS symptoms was sent to 7,000 men living in or close to the Kanto area, Japan. Out of the 2,821 men who gave valid responses and were eligible for the provocation study, 33 (1.2 %) seriously considered that they had some adverse MPRSs due to mobile phone use. Some other subjects reported to have MPRSs but they did not consider it an adverse effect caused by the phone. We sampled 10 subjects from these two groups with MPRS along with 25 control subjects without MPRS, who gave written informed consent to participate in the following experiments. We also selected MPRS women (N=5) and control (N=30) who
participated in our previous study (Furubayashi et al, 2009). Therefore, total numbers of subjects were 15 for MPRS and 55 for control.

In the provocation study, a double blind, cross-over design randomized within participants was used and all experiments were done in a shielded room. Prior to experiments, the participants were screened for mental disorders using the Mini-International Neuropsychiatric Interview (M.I.N.I.) and checked the personality trait using the Neo Five-Factor Inventory (NEO-FFI). In the experiments, there were four exposure conditions all lasting 30 minutes: continuous EMF exposure, intermittent exposure in which EMF was turned on or off randomly every five minutes, sham exposure without EMF, and exposure to pink noise (65dB(A)) without EMF. The subjects were exposed to a 2 GHz W-CDMA EMF from a commercial handset located at normal position (SAR=0.298W/kg). The following psychological and cognitive parameters were measured before and after exposure to EMF for 30 minutes: profiles of mood states (POMS) and the precued choice reaction time (RT) (Terao et al., 2006). Throughout the entire session, physiological measures of autonomic function were also monitored, including the skin surface temperature, arterial oxygen saturation, heart rate, and local blood flow of the finger tip. In addition, to test whether the subjects were able to judge the presence of EMF, they were asked if they felt some EMF or any discomfort during the experiment every 5 minutes.

This study is approved by the ethical committee of National Institute of Public Health.

RESULTS

The subjects with EHS like symptoms due to mobile phone use comprised 1.2% of the 2,821 men. The MPRS subjects were not different from control subjects in their personality trait. The two groups did not correctly judge the presence or absence of EMF, i.e. both were at random level. Both groups of subjects showed higher POMS subscores for fatigue, confusion after exposure than before, regardless of whether the exposure was real or sham. Exposure, whether sham or real, did not have significant effects on any of the physiological measures.

CONCLUSIONS

This cross-sectional survey on Japanese male subjects showed that approximately 1.2% of the whole population consider that the mobile phone use triggers their own health problems. This value is consistent with our previous result of the Japanese female subjects. Current results of provocation study of RF-EMF exposure from the phone handset are also consistent with our previous study of the exposure from the base station.

Our results do not support any correlation between mobile phone related symptoms and RF-EMF exposure.

ACKNOWLEDGMENTS

This study was conducted as a research for the Possible Biological Effects of Electromagnetic Fields, the Ministry of Internal Affairs and Communications (MIC), Japan.
Effects of thirty-minute mobile phone exposure on the voluntary initiation and inhibition of saccades

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INTRODUCTION

Widespread use of mobile phones has aroused a growing concern for its possible adverse effects on human brain function. We have demonstrated that that mobile phone use for thirty minutes has no short-term adverse effects on the central auditory pathways (Arai et al., 2003), sensory system (Yuasa et al., 2006) or cortical regions involved in motor preparation or even in oculomotor preparation (Terao et al., 2006), using elementary oculomotor tasks. However, it is unknown whether it has any adverse effects on cortical regions responsible for initiating or inhibiting voluntary motor responses according to the behavioral context. Here we studied oculomotor tasks suited for addressing the effect of mobile phone use on the voluntary initiation and inhibition of saccades.

MATERIALS AND METHODS

10 normal subjects were studied, with ages between 24 and 47. Pulsed EMF exposure was given in a shielded room with a handset (Sharp SH905i), which was controlled through an antenna by a radio communication analyzer (Anritsu, MT8815B). The analyzer was placed in a separate room to emit maximum output simulating the ordinary Japanese mobile phone (1.95 GHz EMF, W-CDMA). Recording saccades by an electro-oculography, we studied the performance of antisaccade (AS), cued saccade (CUED), and overlap saccade (OL) tasks before and after exposure to EMF emitted by a mobile phone for thirty minutes or sham exposure. For each trial, saccade latency, the amplitude of the first saccade, and peak velocity were determined. Also, the frequency of saccades erroneously made to the target in the antisaccade task was determined. A double blind, counterbalanced crossover design was employed. The order in which sham or real exposure was given was randomized and counterbalanced across subjects, which was blinded to the experimenter. Abstracts often contain images, graphics, equations, and various character sets (e.g., Greek letters). Please save and upload your abstract as a .pdf file. Your file name should not contain any special characters. Please use the following file naming scheme: your family name_given name_initial(s)_bioem2009.pdf (e.g., dinzeo_g_bioem2009.pdf). The PDF format helps ensure that the file appears as the author intends. To enable proper viewing of your file as you intend it to read, your PDF file must be complete. This means that it must contain embedded in it all the non-standard font characters that you used. All security permissions for your PDF files must also be set to “No Security” before you upload your PDF file. Failure to do so may result in the inability to submit your abstract.
RESULTS

All the parameters of AS, CUED and OL tasks did not change differently after real and sham exposure.

CONCLUSIONS

No significant effect of mobile phone use was demonstrated on the performance of the three oculomotor tasks, suggesting that the cortical processing for the voluntary initiation and inhibition of saccades is not affected by exposure to EMF emitted by a mobile phone.

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REFERENCES

The Effect of 2G GSM Mobile Phone Electromagnetic Fields on the Alpha Rhythm of Human Resting EEG: Retesting the Same Individuals

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INTRODUCTION

With the widespread use of mobile telephony public concern around the possible adverse effects of electromagnetic radiation has arisen. Special attention has been paid to the search of harm to the brain because the use of mobile phones typically results in higher exposures to the head. Research to date has found only subtle effects, in terms of increased alpha activity (from the electroencephalogram) (1,2,3). Previous research has been based on the assumption that any effect of mobile phones will be the same in all subjects (the nomothetic approach). We explore the possibility that the effect can be different between subjects, but consistent in the same subject in repeated exposures. To this end, we conducted a retest study using the same procedure and subjects as in a previous study.

MATERIALS AND METHODS

We obtained 15 middle-aged healthy participants (20-45 year olds) from a total of 42 subjects who participated in a previous mobile phone study with the same procedure employed in the present study (as described below). The exclusion criteria was self-reported depression, anxiety, history of epilepsy or brain damage, or illicit drug use. This study was approved by the human research ethics committee of Swinburne University. A double-blind counterbalanced (left vs right exposure) crossover (Sham vs 2G exposure) design was used, with two sessions 1 week apart. Performance and event-related potential measures for oddball and n-back tasks were collected in addition to the resting alpha. The exposure was a 2G GSM mobile phone (Nokia 6110) set to transmit with a mean power output of 250 mW, peak power of 2 W (DTX and adaptative power control disabled). The 895 MHz carrier was modulated at 217 Hz with a duty cycle of 12.5% (pulse width = 576 ms). SAR measurements were done with a specific anthropomorphic mannequin and a RF dosimetric robot (DASY4). The maximum SAR value (10g average) in the temporal lobe just below the antenna was 0.110 W/kg without the EEG cap and leads. EEG was recorded with a Neuroscan Synmap2 system and 4.2 software using a 58 scalp electrodes cap referenced to both mastoids and EOG was recorded with four electrodes. The electrode’s contact impedances were below 5 KΩ at the beginning of the recording. The data was sampled at 500 Hz and bandpass filtered (0.05-250 Hz). To explore the hypothesis that the effect can be different between subjects but consistent in the same subject in repeated exposures, we will group the subjects according to whether or not they increased alpha activity (8-12 Hz) in the first study, and then perform a directional between subjects t-test to determine whether the participants responded consistently.
RESULTS AND CONCLUSIONS.
The data is being analysed and will be presented.

ACKNOWLEDGMENTS
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REFERENCES


Do 2nd and 3rd Generation Mobile Phone Exposures Affect Sensory and Cognitive Function in Adolescents, Adults and Elderly?

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INTRODUCTION

There has been considerable interest in the possibility that mobile phones (MP) may adversely affect human sensation and cognition. In terms of sensory and cognitive function, studies have so far been inconclusive with some reports of improvements, some reports of impairments, but on the whole no consistent findings. Further to this there is uncertainty as to whether different age groups may be differentially sensitive to mobile phone-related exposures (e.g. adolescents, young adults and elderly), and whether different technologies (e.g. 2nd versus 3rd generation phones) may effect people differently. The present study addresses these uncertainties by testing cognitive function of different age-groups during exposure to 2G, 3G and sham conditions separately.

Event related potentials (ERPs), which are derivations of the electroencephalogram, offer a sensitive means of assessing brain function. The present study employed ERPs to assess brain function during an auditory oddball task, which required participants to press a response button whenever they heard a target stimulus. Non-targets and novel stimuli were also presented, which enabled the assessment of neural processing associated with sensory processing (early ERPs to non-targets), cognitive processing (later ERPs to targets), and the ‘surprise’ associated with the presentation of the ‘novel’ stimuli (ERPs to novels).

MATERIALS AND METHODS

41 children (13-15 years, 21 male, 20 female), 42 young adults (19-40 years, 21 male, 21 female) and 19 elderly (55-70 years, 10 male, 9 female) volunteers took part in the study, which was a repeated-measures, double-blind counterbalanced design. Participants were tested on 3 separate days at least 4-days apart, with one of 3 exposures on each of the testing days (2G, 3G, Sham). On each, they first performed an oddball calibration trial, followed by the oddball task itself. The calibration task was employed to select auditory stimuli that resulted 80% accuracy on the oddball task, which was deemed important as it reduces ceiling and floor effects that may otherwise obscure results.

The oddball task consisted of 320 auditory stimuli with a mean SOA of 1500 ms (range 1000-2000 ms). 80 percent were standards (80dB SPL, 200ms, including 20ms rise/fall times, 1000Hz), 10 percent were targets (differing from standards only in terms of frequency, which was determined from the above calibration task), and 10 percent were 200ms novel tones (designed specifically to be novel and very different to both standards and deviants (e.g. glass breaking). Participants were instructed to press “Yes” to the high-frequency tones (i.e. oddball tones) and ignore the standard tones and the novel tones. The total length of the task was 7 minutes.

A cradle containing a 2G handset on one side and a 3G on the other side of the head was
placed on the participant’s head, with one or neither of the phones transmitting. A Nokia 6110 (pulse modulated at 217 Hz, 894.6 MHz output) test phone was used for the 2G exposure. This was set via manufacturer software to continuously transmit at a mean power output of 250 mW (peak power of 2 W). The speaker was removed and foam was placed over the speaker inside a phone case to ensure that there was no sound audible. Further to this, in all conditions, 50 dB background white noise was continuously generated to produce a consistent ambient noise level. 3G exposure was achieved by a standard (or ‘dummy’) model of a mobile phone handset, which consists of a metallic handset approximately the shape and size of a typical mobile phone in which there is incorporated a monopole antenna which is externally fed by an RF signal source. This setup produces no audible sound or temperature rise. The 3G model handset was driven with a 1900 MHz 3G modulated signal at 125 mW (average), the maximum average transmit power of 3G mobile phone handsets. Measurements and computational modelling of specific absorption rate (SAR) were conducted to determine induced SAR. For 2G, the resulting maximum peak spatial SAR averaged over 10 g was determined to be 0.674 W/kg, while for 3G the maximum peak spatial SAR (10 g) was determined to be 1.27 W/kg.

For each of the behavioural measures, a three (Exposure; Sham, 2G, 3G) by three (Age; adolescents, young adults, elderly) repeated measures ANOVA was performed, where the dependent variable were reaction time and accuracy. For each of the ERP indices (N100 at C3, Cz, C4 to standards; P3b at P3, Pz, P4 to targets; P3a at F3, Fz, F4 to novels), similar ANOVAs were performed, differing only in that Laterality (ipsilateral versus contralateral) was added as another independent variable. For each of these (where significant), post hoc t-tests tested for differences between Sham and 2G, and Sham and 3G, for each of the age groups (Bonferroni-corrected accounting for correlations; corrected p-values shown).

RESULTS

There was no main effect of Exposure, and no interaction of Exposure with Age, for any of the behavioural or ERP indices assessed. Further, there was no effect of Laterality, or interaction of Laterality with Exposure, for any of the ERP indices assessed.

CONCLUSIONS

No evidence was found of an effect of either 2nd or 3rd generation mobile phone exposures, on either performance or ERP measures of sensory processing/cognitive function associated with an auditory oddball task. Further, no evidence was found that this lack of effect was dependent on the age of the participants being tested. Therefore, the present study does not provide support for the view that the young or elderly may be more sensitive to mobile phone exposures, and it also does not provide any evidence of an effect of mobile phones on sensory processing/cognition more generally.

ACKNOWLEDGMENTS

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REFERENCES

None.
INTRODUCTION

In March 2005, the Federal Council of Switzerland approved the launching of National Research Programme 57 (NRP 57), «Non-Ionising Radiation – Health and Environment» [1], to conduct key research projects concerning potential health related consequences of low-level radio frequency (RF) and extremely low frequency (ELF) electromagnetic fields (EMF). Funds of 5 million Swiss Francs were granted to this four-year programme to make a substantial contribution to the international research effort in order to improve assessment of the risks associated with non-ionising radiation (NIS). The programme addresses open questions related to dosimetry and exposure assessment, short term, medium and long-term exposure effects assessed by laboratory and epidemiological studies, processes at the cellular level as well as risk perception and evaluation of the topic in the public. Altogether eleven projects in these four different areas of research ("modules") are supported. Cancer studies, however, are not a part of NRP 57, as there are already many research studies underway internationally.

MATERIALS AND METHODS

Three projects on Dosimetry and Exposure Assessment deal with precise measurement of electromagnetic fields and their specific absorption in tissues or in cell cultures. Absorption is measured based on phantoms or using mathematical models and computer simulations. The aim is to determine the exposure of the foetus to EMF in everyday situations and in an uncontrolled environment, to determine cumulative RF EMF exposure in time and frequency domains of the central nervous system, and to develop an instrument for live cell imaging during ELF EMF exposure.

Two Human Laboratory Studies focus on the effects of pulse-modulated RF EMF on brain activity and cognitive function, investigating in particular critical field parameters, sites of interaction and the sensitivity in early adolescence. Also, the effects of UMTS exposure on cerebral blood circulation and oxygenation as assessed by near infrared imaging are explored. For assessment of long-term effects, one epidemiological study is performed on different sources of RF EMF exposure in conjunction with the assessment of health related quality of life in a national cohort.

Three Cell Biological Studies aim to identify and characterise the effects of electromagnetic radiation on stress-response pathways, on cell division and cell growth, on communication between cells, and on genotoxicity and gene expression. The cellular responses to RF and ELF EMF and the possible mechanisms are studied in vitro and in vivo; beside the use of various cell cultures, also the flatworm Caenorhabditis elegans is employed as a model system.
Finally, two social science studies on Risk Perception examine how the public perceives and evaluates possible risks of EMF and also how people perceive public communications and reporting on the topic. In particular, the projects focus on the determinants of risk perception and the implications of affect and perception for risk communication.

RESULTS

Single thematic topics have been presented and discussed with national and international experts in a series of three scientific workshops in 2008. A first interdisciplinary workshop entitled "Dosimetry meets Epidemiology" took place in Zurich in January 2008, a second one "Towards a mechanism-based framework in EMF research" and pertaining to the module cell biology was scheduled in May 2008. A third workshop on "Electromagnetic fields and the brain" in October 2008 focused on the effects of RF EMF on brain physiology. The respective presentations and a report on each workshop are published on the NRP 57 programme website [1].

Initial results are expected to be available in 2009. The NRP 57 will encourage all research findings to be published in peer-reviewed scientific journals to ensure openness and transparency. A final evaluation and synthesis of the results in the context of the international research effort will be published by the steering group of the NRP 57 in the course of 2010 and is expected to enhance the knowledge in the areas of risk assessment and communication.

CONCLUSIONS

The NRP 57 is designed to contribute towards an improved assessment of the possible health risks posed by NIS of current and future technologies. Among other things its research helps to assure compliance with exposure limit values and aims at developing uniform exposure conditions for experimental studies. Short and medium-term effects assessed by means of laboratory studies will enhance the understanding of the interplay between RF EMF and brain function. While epidemiologic studies can not demonstrate direct causal connections between medium or long-term EMF exposure and effects, they do allow conclusions to be drawn concerning the possible consequences of non-ionising radiation on general health. Studies on the cellular level are of highest importance for investigation of possible mechanisms of interactive effects between non-ionising radiation and biological systems. Thus they can often demonstrate a direct relation to possible effects on human health which is important for improved assessment of the risks associated with communication technologies. Moreover, the results obtained on risk perception and communication will yield insights on the mechanisms that shape public perception and opinion. These studies should provide useful information pertinent to effective communications on the effects of non-ionising radiation.

More information on the programme is available on www.nrp57.ch.

ACKNOWLEDGMENTS

REFERENCES

Attitudes Towards Possible Risks of High Frequency Electromagnetic Fields of Mobile Telecommunications in a Rural German Population Without Mobile Telephone Supply

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INTRODUCTION

In the framework of the German Mobile Telecommunication Research Programme (DMF) population surveys on identifying the general public's fears and anxieties with regard to possible risks of high frequency electromagnetic fields of mobile telecommunications were performed in four consecutive years (2003 to 2006) by telephone interviews in a representative sample of 2500 subjects each [1]. Results revealed a stable 11% prevalence of sleep disturbances attributed to electromagnetic fields (EMF). In our experimental double-blind, sham-controlled cross-over study on the impact of EMF emitted by mobile phone base stations on sleep, in residents of 10 German rural sites where no mobile phone service was available, information on attitudes towards mobile phone base stations was also collected. The aim of the present contribution was to analyse the prevalence of health concerns and possible relations between attitudes towards EMF of mobile phone base stations in this highly selected rural population as compared to the results obtained by infas [1].

MATERIALS AND METHODS

Study participants were recruited from sites, where 1) no mobile phone service was available, 2) only weak fields from other RF-sources (TV etc) were present, and 3) there was no emotional EMF-discussion in the run-up to the study. All inhabitants of a potential study site were invited to join an information meeting. Participants had to be at least 18 years old and gave their written informed consent.

Prior to the collection of consecutive sleep data and prior to the installation of the experimental mobile phone base station in the village, subjects filled in questionnaires on sociodemographic aspects, subjective sleep quality, sleep disorders, excessive daytime sleepiness, chronotype, depression and anxiety, and on personality. All participants answered a questionnaire on attitudes towards mobile telecommunications, which was based on the telephone interviews of infas [1].

Statistical analyses were performed with SAS (version 9.1. for windows). All tests were performed with a two-sided p < 0.05.

RESULTS

In total, 397 subjects from 10 villages in various parts of Germany participated in the study. 50.9% of participants were female. The mean age of participants was 45.0 ± 14.2 years with a range of 18 to 81 years. Males were slightly, but not significantly older than females (46.3 ± 14.2 years vs 43.8 ± 14.2 years). There was no indication of an increased prevalence
of sleep disorders, excessive daytime sleepiness, chronotype, depression, anxiety, and personality traits.

32% of the study population were concerned about potential health risks from EMF of mobile phone base stations, mobile phones or wireless landline telephones, without any gender differences. This result corresponds to annually repeated telephone surveys in a representative German population (27 to 31%), which included 2500 subjects. In the present study, participants within the age group 50 to 59 years worried the most, whereas subjects in the oldest (≥70 years) and youngest (18-29 years) age group were least concerned. In the infas survey, subjects younger than 24 years were the least concerned, and in contrast to our results, respondents older than 65 years and subjects from 35 to 49 years of age were most concerned.

13% of the participants stated that they experienced adverse effects from EMF of the above mentioned EMF sources, and there were no differences between age-groups as well as between women and men. In a list of 13 environmental risk factors, which may induce concerns, mobile phone base stations ranked six behind other environmental risk factors like heavy tobacco smoke, consumption of meat with unknown origins, excessive alcohol consumption, air pollution, and side effects of drugs. The potential health risk factor mobile phone base station ranked equally at 6th place in the infas surveys, whereas the number of impaired subjects was slightly lower in the infas reports (9 to 10%). 29% of the our study participants stated that they have never dealt with the topic of EMF from mobile telecommunication, 47% to some extent, 20% a little and 4% a lot, only 7% felt they were well informed, 61% to some extent, 31% not at all and 1% very well. The number of uninformed subjects was slightly lower in the infas study (27%), and the frequency of people dealing with the topic of EMF of mobile telephony was lower in the present study (29% vs 34% in the infas survey), whereas the numbers of participants feeling a little or well informed were nearly equal (68% vs 70% in the infas sample).

CONCLUSIONS

The present study indicates that even in residents living in rural sites without any mobile telephone supply and without emotional EMF discussions in those villages, possible EMF–related health effects are a reason of concern in a substantial part of the population (13%), and is similar to that of respondents of annually carried out telephone surveys in a larger representative German population samples (8-10%). Furthermore, the results are in accordance with a comprehensive population-based cross-sectional study in Germany, in which 10.3% of 30,047 participants claimed to suffer from RF-EMF [2].

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REFERENCES


Amplitude-modulated electromagnetic fields for the treatment of cancer: Discovery of tumor-specific frequencies and assessment of a novel therapeutic approach

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INTRODUCTION
Because in vitro studies suggest that low levels of electromagnetic fields may modify cancer cell growth, we hypothesized that systemic delivery of a combination of tumor-specific frequencies may have a therapeutic effect. We undertook this study to identify tumor-specific frequencies and test the feasibility of administering such frequencies to patients with advanced cancer.

MATERIALS AND METHODS
We examined patients with various types of cancer using a noninvasive biofeedback method to identify tumor-specific frequencies. We offered compassionate treatment to some patients with advanced cancer and limited therapeutic options.

RESULTS
From December 2001 until December 2007 we examined a total of 163 patients with a diagnosis of cancer and identified a total of 1524 frequencies ranging from 0.1 Hz to 114 kHz. Most frequencies (57-92%) were specific for a single tumor type. Compassionate treatment with tumor-specific frequencies was offered to 28 patients. Three patients experienced grade 1 fatigue during or immediately after treatment. There were no NCI grade 2, 3 or 4 toxicities. Thirteen patients were evaluable for response. One patient with hormone-refractory breast cancer metastatic to the adrenal gland and bones had a complete response lasting 11 months. One patient with hormone-refractory breast cancer metastatic to liver and bones had a partial response lasting 13.5 months. Four patients had stable disease lasting for +31.3 months (thyroid cancer metastatic to lung), 5.1 months (non-small cell lung cancer), 4.1 months (pancreatic cancer metastatic to liver) and 4.0 months (leiomyosarcoma metastatic to liver).

CONCLUSIONS
Cancer-related frequencies appear to be tumor-specific and treatment with tumor-specific frequencies is feasible, well tolerated and may have biological efficacy in patients with
advanced cancer. Trial registration: clinicaltrials.gov identifier NCT00805337
INTRODUCTION

Mobile phone use is ever increasing; leading to scientific and extensive public concern that exposure to radiofrequency electromagnetic fields (EMF) from mobile telephony might increase the risk of disease. This concern is mostly founded on the possibility that interactions of fields with the human body may not be fully understood. Many epidemiological studies have evaluated the relation between mobile phones and cancer, mostly focusing on tumours of the brain and acoustic neuroma. Most of these studies are however case-control studies which are inherently prone to recall bias particularly with extended recall periods [1]. The WHO in its assessment of the current knowledge on EMF and health therefore particularly stresses the need for long-term cohort studies.

In Denmark a cohort has already been established consisting of all private mobile phone subscription holders (n= 420,095) from 1982 to 1995. This cohort has been followed for cancer [2,3] and neurodegenerative diseases [4]. Ownership of a mobile subscription was not associated with overall increased risk for brain tumours (SIR = 0.97). Among long-term subscribers a decreased risk was observed (SIR = 0.66, 95% CI = 0.44 to 0.95) leading the authors to rule out a large overall risk increase for brain tumours [3]. However, the study does not allow enough detail to further investigate specific user segments. The major advantages of this cohort are the long follow-up and the population-wide coverage, as well as size. However, its exposure assessment is somewhat limited because the association between owning a subscription and being a user is not straightforward and only limited information on potential confounders is available [1,3,5].

To address these issues and to allow investigation of more subjective symptoms the international cohort study on mobile phone use and health (COSMOS) is being established.

MATERIALS AND METHODS

COSMOS is a large cohort study of mobile-phone users in five European countries (Denmark, Finland, Netherlands, Sweden, UK). A cohort of at least 200,000 adults will be established and followed for 25+ years with repeat questionnaires. Participants are followed with extensive questionnaires every four years covering widespread or new EMF technologies, health and wellbeing, as well as lifestyle factors and potential confounders information. Mobile phone exposure is assessed both by questionnaires and traffic data.
obtained from the network operators.

RESULTS

The study is in its initial phase. In the long term, the study will provide epidemiologic evaluation of possible associations of mobile phone use and risk of diseases of the brain, head and neck; such as cancer, neurological and cerebrovascular diseases, as well as symptoms including headache, sleep disorders, and tinnitus. In the short term, the comparison of self-reported usage and operator provided traffic data allow detailed investigation of recall and reporting biases. Moreover, the Danish data allows further detail on, and validation of, the subscriber cohort. Preliminary data on these issues will be presented.

CONCLUSIONS

The prospective cohort study is the gold standard for any epidemiological study on disease aetiology as it minimises the error and misclassification related to sole reliance on long-term recall. A further advantage of the COSMOS study is the repeated exposure assessment which allows the study to capture the ever-evolving exposure environment of the participants, particularly since exposure is assessed from multiple independent sources.

REFERENCES

INTRODUCTION

All living organisms are under permanent influence of environmental factors. In the course of evolution they have adapted to ambient variations but they have never stopped reacting to any sharp changes. Immutable part of biological objects’ environmental factors is the Earth’s magnetic field. There is a growing body of evidence during the last years that cell processes, blood vessel, cardiovascular, nervous and other functional systems respond [1, 2, 3, 4] to geomagnetic field (GMF) variations. Arterial blood pressure (BP) monitoring is an easily available but informative enough method for assessing cardio-vascular functional status. The possible changes in arterial BP, capillary blood flow, blood coagulation and aggregation under geomagnetic activity (GMA) changes indicate that geomagnetic disturbances might be related with the dynamic of cardio-vascular morbidity and mortality if large populations are studied. In this study results about possible effects of natural electromagnetic fields (EMF) on cardio-vascular system parameters and morbidity and mortality from cardio-vascular diseases are presented.

MATERIALS AND METHODS

A group of 86 functionally healthy volunteers was examined during periods of high GMA and BP and heart rate (HR) were measured as well as information about subjective psychophysiological complaints (SPPC) was collected. Pulse pressure (PP), i.e. the difference between systolic and diastolic BP was calculated. Some of the preliminary results were published in [5]. Here the complete main results will be summarized. Furthermore, having in mind these results about possible variations of cardio-vascular parameters under GMF intensity increase our studies continued with analyses of medical data covering the period 01.12.1995-31.12.2004 and concerning the daily distribution of patients admitted in a hospital with acute myocardial infarction (AMI) diagnose (in total 1192 cases) from the Sofia region. The number of patients dying after admittance was 175.

The statistical method ANalysis Of VAriance (ANOVA) was applied to the data to check the significance of the influence of different GMA indices on the physiological, psychophysiological parameters of the examined group and the number of the registered cardiac events. The effect of geomagnetic storms up to three days before and three days after their development on considered cases and cardio-vascular parameters was investigated. Correlation analysis was also applied and relevant coefficients were calculated.

RESULTS AND DISCUSSION

The increase in GMF intensity was related to statistically significant changes in the physiological state of the examined group. Results revealed significant increase in BP, PP and SPPC. Variations in HR were not statistically significant. Physiological variations were observed from the day before the geomagnetic storms onset till two days after they ended.
The most sensitive were the hypertensive persons and those on drug treatment, which in most instances was hypertensive therapy. A longer time was needed for the more sensitive persons to return to normal the variations obtained under different GMA changes. Females reacted more expressively to the degree of GMF variations while males needed a longer time period to return to normal the changes in BP and females needed a longer time to suppress the SPPC.

A positive statistically significant correlation between AMI morbidity and mortality and GMA indices was obtained. With increase in GMA an increase in the number of AMI incidences and lethal outcomes was observed. Peak increments of AMI morbidity and mortality were revealed on the days before, during and after geomagnetic storms with different intensities.

A possible mechanism for the effects on the days before geomagnetic storms is through the established long-period (2-240 min) GMF fluctuations prior to the beginning of geomagnetic storms. Such fluctuations according to the parametrical resonance can affect the brain and the endocrine system and initiate a “hypothalamus-hypophysis-adrenal gland” circuit, which leads to stress reaction [6]. The increase of the cardio-vascular parameters values and AMI morbidity and mortality on the days after GMF intensity increment can be due to medical and/or geophysical reasons.

CONCLUSIONS

The studies performed indicate presence of potential effects of natural EMF variations on cardio-vascular human health state. The degree of these influences depends on the individual physiological status.

GMF intensity increase was related to increase of blood pressure, pulse pressure and subjective psycho-physiological complaints of the examined volunteers as well as to increment of the number of acute myocardial infarctions and fatal outcomes.

Long-period and detailed studies must be carried out for confirmation of the results obtained and establishing the possible biophysical mechanisms of the effects. Knowledge about the relationship between GMA and human health would allow to avert unfavorable physiological reactions of vulnerable persons.

ACKNOWLEDGMENTS

This work was partially supported by National Science Fund of Bulgaria under contract NIP L-1530/05.

REFERENCES

RELATION TO CHARGED AEROSOL WITH AIR POLLUTANTS AROUND HIGH VOLTAGE AC POWER LINES

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² Green Jeonnam Environmental Complex Center Air Pollution & Indoor Quality, Suncheon first College

OBJECTIVE: To identify the interrelation factors to charged aerosol currents and calculated concentration with various air pollutants including EMF, relative humidity and temperature.

METHODS: The aerosol current and calculated concentration around 154, 345kV AC power line were measured by Aerosol Electrometer 3068B (TSI, U.S.A). For the 24 hours monitoring of air pollutants at each sites, we used Mobile Air Quality Monitoring System and EMDEX E-probe (Enertech, U.S.A) to identify electric and magnetic fields.

RESULTS AND DISCUSSIONS:

Table show that the correlation charged aerosol indices with electric and magnetic field, concentration of various air pollutants, and weather condition at each sites. The aerosol current were correlated with magnetic field (r=0.972, p<0.05) and electric field (r=0.992, p<0.01) statistically significant. This mean is high level of electromagnetic field induced increasing of aerosol current. On the other hand, the electric and magnetic field level were not well correlated with the calculated concentration. In case of positive charged aerosol and relative humidity shows well correlated. According to previous studies performed by Biskos. et al(2004), they reported that high electric field caused increasing generation rate of charged aerosol. Our results demonstrated similar finding with previous studies. Nitro dioxide, carbon monoxide, and ozone have high correlation coefficient with charged aerosol value. Although the corona discharge in air and the mechanism of nitrogen oxide and ozone are very complex and are not fully understood, the present results indicated have a relationship charged aerosol with gaseous pollutants. As defined by previous research for ion current and space charge environment, is strongly affected by weather condition. However, we can’t find the relationship charged aerosol value with relative humidity and temperature.

FUNDING AGENCY: This research work was supported by ECO2 Research Grant No. 2007-09001-0048-0 from the Korea Ministry of Environment (2008~2009).
Figure. Measurements of charged aerosol around high voltage AC power lines

Table. Correlation coefficients between charged aerosol value, concentration of particle matter and gaseous pollutants, EMF, and meteorological factors

<table>
<thead>
<tr>
<th></th>
<th>AE</th>
<th>AE(+)</th>
<th>AE(-)</th>
<th>CC</th>
<th>CC(+)</th>
<th>CC(-)</th>
<th>MF</th>
<th>EF</th>
<th>PM10</th>
<th>PM2.5</th>
<th>SO2</th>
<th>NO2</th>
<th>CO</th>
<th>O3</th>
<th>RH</th>
<th>Temp</th>
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<tr>
<td>AE</td>
<td>1</td>
<td>0.419</td>
<td>0.861</td>
<td>0.800</td>
<td>0.370</td>
<td>0.868</td>
<td>0.972</td>
<td>0.992</td>
<td>-0.071</td>
<td>0.324</td>
<td>0.072</td>
<td>0.719</td>
<td>0.927</td>
<td>0.603</td>
<td>-0.236</td>
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<tr>
<td>AE(+)</td>
<td>1</td>
<td>-0.099</td>
<td>-0.207</td>
<td>-0.996</td>
<td>-0.087</td>
<td>0.249</td>
<td>0.379</td>
<td>-0.934</td>
<td>-0.622</td>
<td>-0.328</td>
<td>-0.325</td>
<td>0.091</td>
<td>-0.470</td>
<td>-0.968</td>
<td>-0.722</td>
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</tr>
<tr>
<td>AE(-)</td>
<td>1</td>
<td>0.994**</td>
<td>0.153</td>
<td>0.999**</td>
<td>0.930</td>
<td>0.879</td>
<td>0.443</td>
<td>0.714</td>
<td>0.287</td>
<td>0.971*</td>
<td>0.960*</td>
<td>0.924</td>
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<td>CC</td>
<td>1</td>
<td>0.261</td>
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<td>0.537</td>
<td>0.776</td>
<td>0.329</td>
<td>0.991**</td>
<td>0.931</td>
<td>0.961*</td>
<td>0.377</td>
<td>-0.281</td>
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<tr>
<td>CC(+)</td>
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<td>-0.320</td>
<td>0.946</td>
<td>0.687</td>
<td>0.407</td>
<td>0.380</td>
<td>-0.052</td>
<td>0.519</td>
<td>0.961*</td>
<td>0.656</td>
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<td>CC(-)</td>
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<td>0.929</td>
<td>0.881</td>
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<td>0.252</td>
<td>0.966**</td>
<td>0.969*</td>
<td>0.918</td>
<td>0.271</td>
<td>-0.351</td>
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<td></td>
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<tr>
<td>MF</td>
<td>1</td>
<td>0.990**</td>
<td>0.098</td>
<td>0.531</td>
<td>0.283</td>
<td>0.833</td>
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<tr>
<td>EM</td>
<td>1</td>
<td>-0.035</td>
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<td>0.195</td>
<td>0.752</td>
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<td>0.637</td>
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<td>PM10</td>
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<td>0.632</td>
<td>0.269</td>
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<td>0.552</td>
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<td>PM2.5</td>
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<td>0.848</td>
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<td>0.885</td>
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<tr>
<td>SO2</td>
<td>1</td>
<td>0.406</td>
<td>0.030</td>
<td>0.410</td>
<td>0.205</td>
<td>-0.364</td>
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</tr>
<tr>
<td>NO2</td>
<td>1</td>
<td>0.876</td>
<td>0.987*</td>
<td>0.475</td>
<td>-0.209</td>
<td></td>
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<td>CO</td>
<td>1</td>
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<td></td>
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<tr>
<td>O3</td>
<td>1</td>
<td>0.610</td>
<td>-0.061</td>
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</tr>
</tbody>
</table>

* p<0.05
** p<0.01
CHARACTERISTICS OF CHARGED AEROSOL VALUE AROUND HIGH VOLTAGE AC POWER LINE

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2 Green Jeonnam Environmental Complex Center Air Pollution & Indoor Quality, Suncheon first College

OBJECTIVE: The aim of this study is to identify the mechanism of aerosol discharging around high voltage (154, 345 and 765kV) AC power line and to compare the level of charged aerosol current and calculated concentration (the number of charged aerosol per cm$^3$) with directly under and way off the power line. And also, to confirm the seasonal variation of charged aerosol value at each sites simultaneously.

METHODS: Measurements was performed at 8 sites (154 kV AC power line directly under site: 2 site, 345kV AC power line directly under site: 2 site, and way off the 154 and 345 kV power line site: 4 site) and will be measured 2 sites for 765 kV with Aerosol Electrometer 3068B (TSI, U.S.A) for aerosol current and calculated concentration during the 24 hour continuously.

RESULTS AND DISCUSSIONS:
The aerosol current was 6.35±10.89 fA at directly under (DU) site of 154 kV and -4.84±10.42 fA at DU site of 345 kV, except noise level (±1.0 fA). The positive ion was predominant part in 154 kV and the dominant ion of 345 kV was negative ion however, the difference was not statistically significant (p>0.05). The effective level of charged aerosol was 69.1 % at DU sites compare with 45.9% at way off the power line (WO) site as a mean value. The level of aerosol current due to seasonal variation were -2.69±3.33 fA for negative charged ion and 4.58±3.70 fA for positive charged aerosol at summer season. Charged aerosol values of winter season were high compare with summer season but did not statistically significant (p>0.05). The existence of high voltage AC power line exhibit a tendency to increasing rate of charged aerosol value was confirmed though limited evidence from preliminary survey.

FUNDING AGENCY: This research work was supported by ECO2 Research Grant No. 2007-09001-0048-0 from the Korea Ministry of Environment (2008~2009).
Table 1. Comparison on charged aerosol value of measuring site

<table>
<thead>
<tr>
<th>Classification</th>
<th>Aerosol Current (Except Noise Level ±1 fA, %) (fA)</th>
<th>Calculated Concentration (No. of charged particles/cm³)</th>
<th>Effective charged aerosol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(-) ion</td>
<td>(+) ion</td>
<td>Mean ± S.D</td>
</tr>
<tr>
<td>Direct 154kV (n=4)</td>
<td>-3.05±3.64(32.4)</td>
<td>6.35±10.89(38.3)</td>
<td>386.66±705.56</td>
</tr>
<tr>
<td>Under Site 345kV (n=4)</td>
<td>-4.84±10.42(62.4)</td>
<td>2.99±3.02(4.7)</td>
<td>286.70±395.39</td>
</tr>
<tr>
<td>Total</td>
<td>-4.21±8.70(47.2)</td>
<td>6.0±10.40(21.9)</td>
<td>320.82±527.87</td>
</tr>
<tr>
<td>Way Off site (n=5)</td>
<td>-3.73±7.85(31.0)</td>
<td>2.94±3.58(14.86)</td>
<td>376.17±742.98</td>
</tr>
</tbody>
</table>

Table 2. Charged aerosol value according to seasonal changes in measurement sites

<table>
<thead>
<tr>
<th>Classification</th>
<th>Aerosol Current (Except Noise Level ±1 fA, %) (fA)</th>
<th>Calculated Concentration (No. of charged particles/cm³)</th>
<th>Effective charged aerosol (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(-) ion</td>
<td>(+) ion</td>
<td>Mean ± S.D</td>
</tr>
<tr>
<td>Seasonal changes</td>
<td>Operating voltage</td>
<td>Site</td>
<td>Mean ± S.D</td>
</tr>
<tr>
<td>Summer 345kV A</td>
<td>-1.72±0.94(50.8)</td>
<td>2.57±1.42(1.1)</td>
<td>321.9±178.64</td>
</tr>
<tr>
<td>B</td>
<td>-1.78±0.88(48.1)</td>
<td>2.18±1.70(5.9)</td>
<td>334.56±165.28</td>
</tr>
<tr>
<td>C</td>
<td>-4.5±5.0(0.8)</td>
<td>4.8±3.7(96.6)</td>
<td>897.4±699</td>
</tr>
<tr>
<td>D</td>
<td>-2.44±1.54(51.6)</td>
<td>4.74±3.74(3.5)</td>
<td>467.1±311.42</td>
</tr>
<tr>
<td>Total</td>
<td>-2.69±3.33(26.8)</td>
<td>4.58±3.70(37.8)</td>
<td>504.66±625.33</td>
</tr>
<tr>
<td>Winter 345kV A</td>
<td>-3.57±3.33(61.2)</td>
<td>3.15±2.82(9.1)</td>
<td>133.77±124.79</td>
</tr>
<tr>
<td>B</td>
<td>-9.71±16.91(86.3)</td>
<td>4.80±5.49(2.3)</td>
<td>364.04±634.17</td>
</tr>
<tr>
<td>C</td>
<td>-2.0±1.97(35.8)</td>
<td>11.62±19.24(40.5)</td>
<td>75.17±73.99</td>
</tr>
<tr>
<td>D</td>
<td>-2.29±1.42(41.1)</td>
<td>2.09±1.14(13.3)</td>
<td>83.92±53.39</td>
</tr>
<tr>
<td>Total</td>
<td>-5.24±10.81(16.7)</td>
<td>8.32±15.93(56.8)</td>
<td>196.53±405.44</td>
</tr>
</tbody>
</table>
If Cellphone Use Is a Risk for Brain Tumors
When and How Many Cellphone-Induced Brain Tumors May Occur

L. Lloyd Morgan1*
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INTRODUCTION

There are 3 sets of brain tumors studies: early, Interphone, and Swedish. Use of cellphones in the early studies was too short to expect tumors. [1-5] Interphone studies found use of a cellphone protects the user from a brain tumor. [6] Swedish studies found a risk for brain tumor with ≥10 years of use and had an internal consistency if cellphones were a risk for brain tumors. That is, the larger the number of years since first use, the higher the risk; the larger the cumulative hours of use, the higher the risk; [7-8] the younger the age, the higher the risk, and; [9] the higher the radiated cellphone power, the higher the risk. [10] Assuming cellphone use is a risk for brain tumors there are two factors that affect the when and how many cellphone-induced brain tumor: latency time and the percentage of long-term cellphone users who will eventually be diagnosed with a brain tumor. Latency time for brain tumor is ~30 years [11]. The percentage of long-term cellphone users who will eventually be diagnosed with a cellphone-induced brain tumor cannot be known except in retrospect. However, we can make estimates based on the percentage of people exposed to a known carcinogen who eventually are diagnosed with the cancer associated with the carcinogen. Three carcinogens were examined: ionizing radiation, tobacco and asbestos. In a low-dose exposure (1.4Gy) of children to ionizing radiation it was found that 0.90% of the children after 40-years of follow-up have been diagnosed with a brain tumor. [11] Ten percent of long-term smokers are eventually diagnosed with lung cancer. [12] Mesothelioma is eventually diagnosed in 28% of asbestos exposed workers. [13] With estimates of the number of cellphone-induced brain tumors Precautionary Principle actions can be considered

MATERIALS AND METHODS

An Excel spreadsheet was use to calculate the number of cellphone-induced brain tumors. The calculation required data for the number of US cellphone subscribers by year (the number of subscribers beyond 2008 was estimated). [14] A Poisson distribution for a 30-year latency was used to provide the probability of a cellphone-induced brain tumor for every year of use. This result was combined with the percent of exposed subject who are diagnosed with cancer from exposure to the 3 carcinogens to provide an estimate of the number of cellphone-induced brain tumors by year.

RESULTS

Figure 1, shows the number of cellphone-induced brain tumors by year based on a 30-year latency time since first cellphone use if cellphone radiation is similar to 3 known carcinogens. In 2004 the number brain tumor was ~50K (the most recent data available). [15] Figure 1 tells us that it is not yet possible to see a change in the brain tumor incidence and it tells us there will be a relatively sudden increase in cellphone-induced brain tumors that only begins to level off in the 4th decade on the 21st century.
Figure 1. Potential Cellphone-Induced Brain Tumors by Year for a 30-Year Latency, and If Similar to a Given Carcinogen

It also shows that no matter what carcinogenic behavior is assumed a similar behavior is observed: a long time delay with no obvious increase in brain tumor followed by an explosive increase that eventually levels off.

CONCLUSIONS

If cellphones are a risk for brain tumors, no matter the assumption there will be a dramatic increase in brain tumors. Given the cost of treating a brain tumor is about $250,000 per case the cost to society will be large. [16]

REFERENCES

[16] Fisher et al. California Childhood Brain Tumor Study. 2004
Exposure to 50 Hz Magnetic Field in Apartment Buildings with Built-in Transformer Stations in Hungary

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*Corresponding author e-mail: thuroczy@hp.osski.hu

INTRODUCTION

Apartments in multi-level residential buildings located above transformer stations (TRS) might offer the possibility of conducting epidemiological studies of residential magnetic field (MF) exposure that include higher exposure levels than previous studies, avoid selection bias, and minimize confounding factors. Thus, an epidemiological study focusing on populations living in apartment buildings with transformer stations is likely to reduce the uncertainty surrounding the association between extremely low frequency (ELF) magnetic field and childhood leukaemia.

In Hungary there are many multi-level residential buildings where transformer stations are built inside the buildings. According to our estimation approximately 1500-2000 apartments are above and/or neighbouring situation to the transformer chambers. Hungary also has a reliable childhood cancer registry and population registry which allows it to participate in such an international study. To confirm that the location of transformers can reliably be used to categorize MF exposure with sufficient accuracy we conducted this measurement study.

MATERIALS AND METHODS

In cooperation with the local electric distribution companies, we identified 31 apartment-buildings with built-in 10-0.4 kV step-down (10/04 kV) transformer stations in Budapest (21) and in Miskolc (10), the two largest cities in Hungary. The transformers were selected as a random sample. In each building we selected three apartments for measurements. The apartments with room(s) directly above the transformers were selected as “exposed” or index apartments. Two “unexposed” apartments were also selected in the same buildings. One was selected on the same floor as the “exposed” apartment and another was randomly selected among all apartments of the building above the floor of the “exposed” apartment.

Typically the 10/04kV transformer stations were housed in the basement or ground floor of the buildings. The bus-bars of the TRS usually were attached to the ceiling of the transformer room about 0.2 m from the ceiling (i.e. approx. 0.5 m below the floor of the apartment above it).

Our measurement protocol was based on a study recently conducted in Finland. Measurements were accomplished in November and December, 2006, between 8-13h. Short term spot measurements were taken in every room of the residence using ELF MF meter (EMDEX II, Enertech, Campbell, California, USA). Broadband (Bb 40-800 Hz) component of MF was measured at selected measuring points. In each room, one measurement was taken at the centre of the room and four measurements at 1.4 meters away from the corners, at the height of 0.5 meter. For further analysis the average of these 5 measurement data were to be considered as the data of the room exposure. In the bedroom(s) an additional measurement was taken at the centre of the beds. In addition, one short term spot measurement was taken at the front door of each apartment. A 24-h magnetic field measurement was taken in the
RESULTS

All measured magnetic field values (mean, max, and min) in all rooms tended to be substantially higher in apartments above transformer rooms compared to other apartments. Values in apartments on the same floor as the index apartments, but not immediately above transformer rooms tended to be similar to those in apartments on higher floors. In the apartments above the transformers, the highest values were observed in the living rooms and the bedrooms, and lower values were observed in the kitchens and second bedrooms, probably reflecting the relative location of these rooms to the bus-bars or low voltage cables.

There were no substantial differences in values of the reference apartments. Measured fields in apartments immediately above transformers were slightly higher in Budapest than in Miskolc. The distribution of mean magnetic field values are clearly different in the apartments above transformers compared to other apartments except the magnetic field at the front door. Most of the index apartment (apartments located immediately above transformers) would fall in the "high" exposure categories when various cut-points (0.2, 0.4, 0.8 μT) were used; this shows relatively high sensitivity. Most importantly, however, most of the other apartment (not located immediately above transformers) would be correctly classified as "low" exposed homes, indicating high specificity. The results of 24-h magnetic field measurement indicate that the daily changes in the magnetic field exposure due to the electricity consumption are similar in all apartments at different location.

CONCLUSIONS

We conducted systematic magnetic field measurements in apartment buildings with built-in transformers in Hungary. Although, relatively few apartments were measured, these results – in conjunction with previous Finnish and Hungarian results – provide strong support for the conclusion that magnetic field exposure could be reliably categorized based on location of apartment within apartment buildings with built-in transformers. Unlike in the Finnish study, our results did not show differences in magnetic field levels in apartments on the same floor as the index apartment but farther away from the transformers and apartments on higher floors. Magnetic field measured at the front door does not appear to provide additional information to further differentiate exposed and unexposed apartments. In addition to the apartments’ location, the measured current flow in the bus-bars, however, may provide additional information for exposure assessment. Measured current flow in the bus-bars shows a positive correlation with the mean magnetic flux density in the room above the transformer station in the current study.

This exposure scenario may provide an opportunity to conduct epidemiologic studies that include highly exposed subject and that do not need to contact the study subject for exposure assessment, limiting or eliminating the potential for selection bias in the study.

ACKNOWLEDGMENTS

This project was funded by the Electric Power Research Institute (EP-P21591/C10565) and was partially supported by funds from Hungarian government’s projects (ENRISK-NKFP-1/B-047/2004 and ETT-037/2006).
Dosimetric Measured Radiofrequency Electromagnetic Field Exposure in Sleeping Rooms and Health Disturbances of Adults

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INTRODUCTION

Exposure to radiofrequency electromagnetic fields (RF-EMF) has increased continuously for many years. The rise of concern about possible effects of RF-EMF on general well-being results in public controversies. A recent scientific report by an EU expert group [1] states that there is no established health effect related to RF-EMF exposure, as long as the respective guidelines for public protection are not exceeded. We aimed to analyse the association between health disturbances and measured RF-EMF exposure in the participants’ residences as well as risk perception.

MATERIALS AND METHODS

In 2004/05, a population-based cross-sectional study on health effects from RF-EMF was carried out in Germany. On baseline the prevalence of health complaints in the general population and its association to the vicinity of base stations was investigated in about 30 000 participants [2]. For the second part, which is presented here and took place in 2006, persons mainly living in urban regions were selected.

For exposure assessment the dosimeter Type EME Spy 120 (Antennessa) was used which measures twelve frequency ranges. For each frequency sensitivity threshold was 0.05 Vm⁻¹. On the beds of the participants during day time 75 measurements during five minutes each were done on four different positions by trained interviewers. To standardize the procedure, bedroom windows were closed, and no one was allowed to enter during the measurements. Nine of the 12 frequency ranges were used for the calculation of the mean electrical field strength (total field). Mobile communication uplink frequencies were not considered. The measurements were summarized by root mean square method for each person.

At the beginning, in the middle and at the end of the exposure assessment period, dosimeters were checked by an engineer. Repeated measurements showed deviations of less than ±1 dB in all frequencies (except for one defect dosimeter).

Participants answered a postal questionnaire and gave information on risk perception of mobile phone base stations, and, using standardized questionnaires, on sleep disturbances, headaches, health complaints, and mental and physical health. Information on stress was also collected. Multiple linear regression models were used with health outcomes as dependent variables (n=1,326) [3].
RESULTS

3,526 (85%) persons responded to the postal questionnaire and 1,808 (51.0 %) had agreed to dosimetric measurements. Due to refusal or missing contact 308 persons did not participate. Furthermore, 83 persons whose measurements had been done with a defect dosimeter had to be excluded from analyses, 27 persons with incongruent personal characteristics between questionnaire and measurements, and 64 due to missing values in relevant variables. Table 1 presents the mean electrical field strength (total field values).

Table 1: Distribution of mean electrical field strength (total field; Vm⁻¹), all RF-EMF summarized (Berlin, western part of Ruhr District, Hamburg, Cologne/Bonn, Munich, Dresden, Hanover, Stuttgart), 2006

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Min*</th>
<th>Median</th>
<th>90% Percentile</th>
<th>Max*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>1326</td>
<td>0.0506</td>
<td>0.0936</td>
<td>0.2123</td>
<td>2.0944</td>
</tr>
<tr>
<td>Living situation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>665</td>
<td>0.0506</td>
<td>0.1034</td>
<td>0.2318</td>
<td>2.0944</td>
</tr>
<tr>
<td>Suburban</td>
<td>475</td>
<td>0.0508</td>
<td>0.0892</td>
<td>0.2032</td>
<td>0.9043</td>
</tr>
<tr>
<td>Rural</td>
<td>186</td>
<td>0.0509</td>
<td>0.0712</td>
<td>0.1745</td>
<td>0.5507</td>
</tr>
</tbody>
</table>

*Min: minimum; Max: maximum

Persons with mean total field values above the 90% percentile were regarded as exposed. For health scores of sleep disturbances, headaches, health complaints, and mental and physical health, no differences were seen for exposed versus non-exposed. However, we observed differences in the risk perception. Participants attributing adverse health effects to base stations had more health disturbances on all scores, compared to those who were concerned and those who were neither concerned nor attributed health complaints to base stations. Multiple linear regression models adjusted for age and gender, type of environment, school degree, mobile phone use, and stress confirmed both the lack of associations between the investigated health scores with RF-EMF exposure but nevertheless, an association with attribution particular for sleep disturbances and health complaints.

CONCLUSIONS

Overall, results of RF-EMF measurements were far below the guidelines for the public. In this study, measured exposure in sleeping rooms was not associated with health disturbances. However, sleep disturbances and health complaints were related to the attribution of adverse health effects to mobile phone base stations.

REFERENCES


Estimation of the ELF-MF Exposure Level of the Korean Population through 24-Hour Personal Exposure

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Background: The main purpose of this research is to identify the MF exposure level of the Korean population and then to estimate the size of the MF exposure population using the results of the personal-exposure measurement. Another aim of the research is to compare its results with those of the EMF RAPID program carried out by U.S. EPA to find the characteristics of ELF-MF exposure in Korea.

Method: The 250 participants of the survey on magnetic-field exposure were randomly selected, but they collectively possess the characteristics of the overall Korean population as determined through a descriptive and statistical analysis of various statistical datasets recorded in Korea National Statistical Office’s Korean Statistics Information System (KOSIS).

The research subjects were divided into six groups by residential region, according to the population residence ratio: ultra-metropolis, metropolis, large city, medium city, small city, and rural area (farming and fishing villages). They were also divided into three groups by age (under 20 years old, 20-60 years old, and above 61 years old), and according to the national sex ratio of 101.6% (the male and female participants of each residential region were chosen based on a 1:1 ratio). The male participants were also chosen considering their occupational characteristics. The EMF RAPID occupational classification was coded into six groups of occupations by considering the situation in Korea based on the standard of National Statistical Office.

The participants wore the magnetic-field meter Model EMDEX-LITE (Enertech Consultants, Inc., USA) for about 25-28 hr, and the data were stored in the meter. The levels of personal exposure to MF of the sample groups were determined through their daily activity patterns.

Results: The 24h time-weighted average of the 250 participants was 1.56±4.56 mG (range: 0.13-59.88 mG). The personal-exposure level according to residential region was highest in the rural-area group (6.85±14.58 mG), followed by the small-city group (4.36±13.19 mG), the ultra-
metropolis group (1.36±2.24 mG), the medium-city group (1.22±1.62 mG), the metropolis group 
(1.08±1.58 mG), and the large-city group (1.05±1.41 mG), but no significant difference among 
them was shown. According to gender or sex, the females had higher personal-exposure levels 
(1.88±5.80 mG) compared to the males. The 20-60 years old age group showed the highest 
personal-exposure level (1.89±5.70 mG), and the personal-exposure level according to job 
category was higher in the non-occupational group (1.78±5.82 mG) than in the male 
occupational group.

The estimated percentage of people with a 24h average magnetic field exceeding 2 mG was 
11.34% (95% CI: 10.74-11.92%), and that exceeding 4 mG was 6.07% (95% CI: 5.34-6.8%). Based on the complete data from KOSIS, it was found that the people in Korea with a 24h 
average magnetic field larger than 2 mG number between 505.2 and 569.7 million, and those 
with a 24h average magnetic field larger than 4 mG number between 251.2 and 319.8 million.

Conclusions: This study quantifies the MF exposure of the general population of Korea. 
According to the results of the EMF RAPID program that was carried out in the United States in 
1993, the percentage of the American population with MF exposure exceeding 2 mG a day is 
about 14%, but that in Korea was found to be about 11.34% in this study. It is thus thought that 
the Korean public has shown a slight decline in their MF exposure level.
### Table. Result of 24-hour average magnetic field during different type of demographic characteristic

<table>
<thead>
<tr>
<th>Classification (N=Sample of Number)</th>
<th>24-hour average magnetic field (mG)</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Range</td>
</tr>
<tr>
<td>All (250)</td>
<td>1.56±4.56</td>
<td>0.13~59.88</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<tr>
<td>Male (130)</td>
<td>0.13±2.99</td>
<td>0.13~32.93</td>
</tr>
<tr>
<td>Female (120)</td>
<td>1.88±5.80</td>
<td>0.17~59.88</td>
</tr>
<tr>
<td>age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 20</td>
<td>0.89±1.47</td>
<td>0.13~10.36</td>
</tr>
<tr>
<td>20-60</td>
<td>1.89±5.70</td>
<td>0.16~59.98</td>
</tr>
<tr>
<td>&gt; 61</td>
<td>1.33±2.06</td>
<td>0.18~12.81</td>
</tr>
<tr>
<td>The city classification follows in population size (N=250)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultra-megalopolis (60)</td>
<td>1.36±2.24</td>
<td>0.17~12.81</td>
</tr>
<tr>
<td>Megalopolis (60)</td>
<td>1.08±1.58</td>
<td>0.2~10.97</td>
</tr>
<tr>
<td>Large city (40)</td>
<td>1.05±1.41</td>
<td>0.13~10.97</td>
</tr>
<tr>
<td>Medium city (65)</td>
<td>1.22±1.62</td>
<td>0.23~10.36</td>
</tr>
<tr>
<td>Small city (20)</td>
<td>4.36±13.19</td>
<td>0.23~59.88</td>
</tr>
<tr>
<td>Rural area (5)</td>
<td>6.85±14.58</td>
<td>0.18~32.93</td>
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<td>Occupational group (N=102)</td>
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<tr>
<td>Code 1 (15)</td>
<td>0.81±0.53</td>
<td>0.23~1.83</td>
</tr>
<tr>
<td>Code 2 (26)</td>
<td>0.79±0.61</td>
<td>0.2~3.45</td>
</tr>
<tr>
<td>Code 3 (19)</td>
<td>2.18±3.09</td>
<td>0.27~12.21</td>
</tr>
<tr>
<td>Code 4 (3)</td>
<td>0.51±0.18</td>
<td>0.37~0.71</td>
</tr>
<tr>
<td>Code 5 (38)</td>
<td>1.25±1.27</td>
<td>0.16~7.43</td>
</tr>
<tr>
<td>Code 6 (1)</td>
<td>4.52</td>
<td>-</td>
</tr>
<tr>
<td>Sub total</td>
<td>1.25±1.67</td>
<td>0.16~12.21</td>
</tr>
<tr>
<td>Non-occupational group (N=148)</td>
<td></td>
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<tr>
<td>Student (72)</td>
<td>1.12±1.91</td>
<td>0.13~10.97</td>
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<td>Housewife (29)</td>
<td>3.13±10.98</td>
<td>0.17~59.88</td>
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<tr>
<td>Old person (41)</td>
<td>1.32±2.06</td>
<td>0.18~12.81</td>
</tr>
<tr>
<td>Unwaged (6)</td>
<td>5.97±13.21</td>
<td>0.3~32.93</td>
</tr>
<tr>
<td>Sub total</td>
<td>1.78±5.82</td>
<td>0.13~59.88</td>
</tr>
</tbody>
</table>
ELECTROMAGNETIC HYPERSENSITIVITY (EHS) OF BRAIN TUMOR PATIENTS AND USE OF MOBILE PHONE IN CASE-CONTROL STUDY

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**Purposes:** Among the studies in Korea on the correlation between brain tumor and electromagnetic waves produced by mobile phones, this paper aims to find out whether the subjective symptoms (Electromagnetic Hypersensitivity, EHS) of brain tumor patients are caused by the brain tumor or by the effects of their cell phone usages by means of comparing them with non-patients and analyzing the results. This paper goes further to revise and complement existing methods of research on EHS in order to find the relationship with various usage patterns of mobile phones and analyze the causes.

**Methods:** Few questions were excerpted from epidemiology survey questionnaire, developed by Department of Preventive Medicine, College of Medicine, Korea University to apply to the analysis of subjective symptoms of electromagnetic wave produced by mobile phones. The SAR (Specific Absorption Rate) values of the users' mobile phones were found on each mobile communication company's website and recorded for analysis.

**Results:** The statistical results illustrated that the group with SAR value larger than 1W/kg felt uncomfortable or showed dried skin while the group that didn't use antenna during phone calls experienced headache, heated ear, hot flush or dried skin. Group that used mobile phones longer than 84 months experienced headache and dried skin. Group that used mobile phones longer than total of 900 hours experienced dried skin. When the presence of brain tumor was adjusted, symptoms such as headache, heated ear, dried skin were affected by brain tumor, but other symptoms were more related to other
factors. Factors related to mobile phones were associated with those who make long calls, who make more than 10 calls per day, who make longer than 5 minutes per call, or who use only one ear when calling.

**Conclusion:** The OR of case-control for subjective symptoms of each usage pattern of mobile phones was found by adjusting gender, age and current residential area with multiple logistic regression analysis. Following the results of this study, more research needs to be done on subjective symptoms that are directly related to brain tumor such as headache, heated ear, dried skin and others.

**Reference :**

Cohort Study on Mobile Phone Use and Brain Tumor among Children in Japan

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INTRODUCTION

There is concern that a risk for brain tumors such as acoustic neuroma, glioma, and meningioma, or parotid gland tumor rises when mobile phone is used closely to head. Consequently, International Agency for Research on Cancer (IARC) is conducting INTERPHONE Study that is an epidemiological study on mobile phone use and brain tumor among adults [1,2,3]. By contrast, there are few epidemiological studies on mobile phone use and brain tumor among children. This study conducts a prospective survey for children to reveal presence of association between mobile phone use and formation of brain tumor by epidemiological methods. In addition, we examine presence of association between mobile phone use and outbreak of other accidents and sicknesses at the same time.

MATERIALS AND METHODS

Design of this study is cohort study. We plan more than five years of survey period starting from 2007. Survey subjects are fourth to sixth graders in elementary schools, and guardians reply the survey. We carry out this study on the Internet. Participants access a survey Web site on the Internet, agree to participation to the survey and register an address, a full name, a phone number, and an e-mail address. We regularly send e-mail requests to participants asking to answer surveys. The survey consists of a base line survey and follow-up surveys. In the base line survey, we ask about situations where children use mobile phones, personal medical histories and so on. In the follow-up survey, we ask about situations where children use mobile phones, hospitalization name of disease and so on. We carry out follow-up surveys every four months. Additionally, to conduct a nested case-control study, we are going to carry out interview surveys to some of the participants.

RESULTS

The numbers of participants were 1433 guardians and 1605 children as of January 14, 2009. The persons who withdrew from the survey were 45 guardians and 56 children. The participants were distributed over all prefectures (47 prefectures in Japan). 1493 participants responded to the base line survey. Also, 673 participants responded to the first follow-up survey. According to the base line survey, the number of children who possess mobile phones only for their own use (exclusive phone) was 344 (23.1%). The popular media of mobile phone children who have exclusive phones make uses were ‘telephone’ 301 (87.5%), ‘e-mail’ 274 (79.7%), and ‘the Internet’ 56 (16.3%). In the first follow-up survey, we asked about hospitalization in recent four months, and found three participants were hospitalized. The disease caused their hospitalization were infectious gastroenteritis and exsiccation, asthma,
and meningitis. All three of them left the hospitals already.

CONCLUSIONS

A current challenge of this study is to increase the number of the participants. For the future, we are going to publicize this study widely by PR activities such as distributing posters, handbills, or pamphlets. On top of that, we plan to increase participants by extending the rage of the survey subjects to junior high-school and high-school students from only forth to sixth graders in elementary school.

ACKNOWLEDGMENTS

This study is performing by a fund of Ministry of Internal affairs and Communications in Japan. The members of the Working Group for Epidemiological Study of Mobile Phone Use and Health in Japan are Suminori Akiba, Takuji Arima, Keiko Asakura, Noriko Kojimahara, Osami Kubo, Ippei Mouri, Yuji Nishiwaki, Yasuto Sato, Shigeru Soukejima, Chika Takahashi, Toru Takebayashi, Masao Taki, Mayumi Tsuji, Kanako Wake, Soichi Watanabe, and Naohito Yamaguchi.

REFERENCES


Evaluation of Occupational and Environmental Exposure to Extremely Low Frequency-Magnetic Fields in Workers: Results of Two Days Personal Monitoring in 543 Workers

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INTRODUCTION

Due to the ubiquity of ELF-MF, exposure occurs not only at work, but also during non-working time, both at home and outside. Accordingly, any epidemiological consideration drawn about the possible effects of ELF-MF should take into account the exposure of individuals during periods both at work and out of work. This problem was underestimated in the past, and only recently combined residential and occupational ELF-MF exposures were evaluated in epidemiological studies to reduce misclassification. Another problem of exposure evaluation in epidemiological studies is the variability of ELF-MF levels during the day and among different days: research on this topic is scant. In some studies the exposure levels are expressed as Time Weighted Average (TWA) using the arithmetic mean of measured levels while in other the geometric mean is adopted (TWA$_{am}$ and TWA$_{gm}$ respectively): in a few studies both were evaluated and compared.

Using personal meters we measured 48 hours individual exposure to ELF-MF in a group of workers engages in some common tasks in our region. Work tasks were coded according to the 1988 International Standard Classification of Occupations. MF levels have been assessed also during non-working time, both at home and outside. In a sub group monitoring was repeated some months later. Exposure is presented both as TWA$_{am}$ and TWA$_{gm}$. The results are reported.

MATERIALS AND METHODS

Five hundreds and forty three workers (383 men and 160 women) were monitored. ELF-MF exposure was measured using Emdex Lite personal magnetic field meters. All participants worn the meter during 2 complete work-shifts (8 hours a day for two days) to take into account potential within-days variability. Subjects were engaged in 31 ISCO 88 occupations. The workers were asked to wear the instrument also during the non-working period (both at home and outside). Both TWA$_{am}$ and TWA$_{gm}$ have been calculated. In 53 workers (about 10% of the whole sample) the monitoring was repeated after 6-9 months using the same procedure, and the resulting TWAs compared.

RESULTS

543 workers out of the 553 monitored were included in the analysis; exclusions were due to occasional meter malfunctioning. In the whole sample the median of TWAs$_{am}$ during work was 0.14 µT, and the 5° - 95° percentiles were 0.04 - 2.50 µT respectively, while the median of TWAs$_{gm}$ resulted 0.08 µT (5°-95° percentiles 0.02 - 0.57 µT).
The correlation between individual TWA$_{am}$ and TWA$_{gm}$, calculated with the Spearman’s correlation coefficient, resulted good: 0.85 (p < 0.001).

In 65% of the subjects the occupational exposure (TWA$_{am}$) was below 0.2 µT, and in 79% below 0.4 µT. The 95% of the workers had an exposure level lower than 2.5 µT.

The results of the replication of monitoring in 53 workers, analyzed by the Spearman’s coefficient, proved reproducible TWA levels: the correlation between the TWAs$_{am}$ measured in the first and in the second monitoring was 0.80 (p < 0.001).

Of the 31 ISCO 88 occupations evaluated in this study, tasks with TWA$_{am}$ below 0.2 µT, 0.4 µT and 2.5 µT were respectively 42% (n. 13), 65% (n. 20), and 94% (n. 29).

The variability of TWA among different workers engaged in the same ISCO occupation was evaluated using the ANOVA; results showed significant differences in several activities.

The median TWA exposure at home (Home TWA) was 0.03 µT (5° and 95° percentiles respectively 0.01 and 0.24 µT); considering the TWA$_{gm}$ the median was 0.02 µT with 5° and 95° percentiles equal to 0.01 and 0.15 µT respectively. About 94% of the subjects at home presented an exposure below 0.2 µT. The Environmental TWA not at home was also evaluated: the median TWA$_{am}$ was 0.05 µT, and the 5° and 95° percentiles respectively 0.02 and 0.28 µT; regarding TWA$_{gm}$ the median was 0.03 µT (5°-95° percentiles: 0.01-0.12 µT)

CONCLUSIONS

In the whole sample exposure proved to be low (median of TWAs$_{am}$ 0.14 µT), and relatively higher levels were observed for a small fraction of workers: as an example 5% only exceeded 2.5 µT. The results look similar also considering task-related TWAs: the ISCO 88 tasks with TWA$_{am}$ exceeding 2.5 µT were 6%.

The individual exposure at home was lower than the occupational one (median of TWAs$_{am}$ : 0.03 µT) and, in the large majority of subjects, lower than the thresholds suggested for suspected long term effects: 97% of subjects had exposure below 0.4 µT. The environmental exposure levels not at home were similar to the residential ones.

In the whole group, exposure during occupational activities gives the largest contribution to the overall 24 hours exposure, showing that, at least in working population, exposure during work must be considered and assessed in the design of epidemiological studies on the possible effects of EMF exposure.

The above-mentioned conclusions are based on TWA$_{am}$, i.e. the parameter usually reported in most epidemiological studies. Considering TWA$_{gm}$ exposure values are noticeably lower. Nevertheless, interestingly TWA$_{am}$ and TWA$_{gm}$ proved highly correlated.

ACKNOWLEDGMENTS

This research was supported by National Institute of Occupational Safety and Prevention (ISPESL), Grant B/84/DML/03, and by APAT, Grant n° 08-bis/03/GAR.
INTRODUCTION

Exposure assessment in epidemiological studies is commonly performed by analysis of distance to the exposure source, refined computation modeling taking into account technical parameter of the source as well as topography and morphography, or onsite measurements. Onsite measurements can be performed with broadband probes, spectrum analyzers, or dosimeters. This contribution describes a methodology for quality control of dosimeters, which was applied in the epidemiological QUEBEB study [1,2]. The aim of QUEBEB was to test the hypothesis, that RF EMF emitted by mobile phone base stations cause health complaints, such as headache or dizziness, in persons living in the vicinity of these stations.

MATERIALS AND METHODS

For the QUEBEB study, 20 dosimeters of the type Antennessa EME Spy 120 were used for frequency selective exposure measurements in the bed region of about 1,500 households. The EME Spy isotropically measures the exposure in 12 fixed frequency ranges, starting from 88 MHz (FM radio) up to 2500 MHz (WLAN, Bluetooth). The mobile phone services GSM 900, GSM 1800 and UMTS are enclosed with their uplink and downlink bands. The downlink frequencies were regarded to be most important for the study.

Besides an absolute measurement accuracy of the dosimeter, which has already been investigated in [3], also the repeatability and stability over the whole time span of field measurements is an important quality criterion. Possible faults, which have to be detected by the quality control include damage of the detector unit by overload, mechanical stress (e.g. fall down) with associated break or degradation of internal connectors and contacts, as well as software and hardware errors. Here it must be noted, that the dosimeters are not used by skilled RF technicians, but by interviewers outside the RF area during the field work. Moreover, simple operational tests (does the dosimeter record and output data?) will not be sufficient, because due to device’s faults these values may be wrong or at least inaccurate, e.g. by contact problems with one axis of the internal isotropic three axis sensor.

The developed quality concept was to record the initial state of each dosimeter to a known signal before the field work and to compare each device’s characteristics in the middle and at the end of the 6 months long field work with it’s initial state.

As a defined and interference-free measurement environment a GTEM cell (GTEM 250, MEB Messelektronik Berlin, Germany) was chosen. This cell represents a widened coaxial line, which is connected to a signal generator (Agilent HP 8648D, 9 kHz - 4 GHz). The signal generator applies a defined electric field between inner conductor and metallic bottom of the cell, whereas the resulting TEM wave is absorbed in a combined resistance/absorber network at the cell end, establishing field conditions in the cell undisturbed by standing waves. The
measurement concept is illustrated in Fig. 1. For the test frequencies the middle frequency for each of the 12 frequency bands was chosen, whereas for the mobile phone downlink bands the lower, middle and upper frequency of the band was used.

Figure 1: Dosimeter quality control in a GTEM cell.

A styrofoam fixture has been manufactured for reproducible positioning of the dosimeter in two tilted planes, allowing the check of all three sensor axes with two separate measurements. The reproducibility of positioning the device into the fixture was found to be better than ±0.2 dB. The repeatability of the dosimeter without position change with averaging over three consecutive exposure cycles at the same signal is in the same range for the mobile phone downlink bands.

RESULTS

From variation tests over all 20 devices the tolerance limit for the allowed deviation from the initial state was defined to be ±3 dB, which is also the typical range of RF exposure measurement uncertainty. In the quality control during the field work the deviation of the dosimeters to their separate initial states were found to be much better and achieved values about ±1 dB. In the mobile phone downlink bands they were even smaller with ±0.5 dB. One dosimeter has found to be faulty and has been sent to Antennessa for repair, whereas it’s measurements were excluded from the epidemiological analysis.

CONCLUSIONS

The developed method for dosimeter quality control has been proven to be reliably and effective. Due to the continuous quality control, the confidence in the measurements obtained in the field work was strengthened significantly. It is highly recommended to apply similar checks in other studies with exposure assessment by dosimeters.

ACKNOWLEDGMENTS

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Exposure to magnetic fields and survival after childhood leukaemia – study design of an international meta-analysis

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INTRODUCTION

The relation between exposure to extremely low-frequency magnetic fields (ELF-EMF) and the risk of childhood leukaemia has been examined in several studies. Most epidemiological studies have shown a small increase in risk with higher exposures (above 0.3 or 0.4 µT), but the overall evidence is still inconclusive as the association found in observational studies lacks both a plausible mechanism and supportive evidence from experimental studies [1]. Recently this was taken a step further; if exposure to magnetic fields is associated with increased leukaemia incidence, it could also have a relationship with survival [2], [3]. Indeed in two studies a somewhat poorer survival among childhood acute lymphoblastic leukaemia (ALL) patients exposed to ELF-EMF was observed. But due to small numbers of exposed children, the authors themselves characterized their studies as only hypothesis generating. The suggestion was to set up a pooled analysis of studies, in order to avoid further national studies with limited numbers of highly exposed cases.

MATERIALS AND METHODS

For the pooled analysis the eligible study centers were defined as those that conducted studies with either long-term ELF-EMF measurements or calculated ELF-EMF exposures for exposure assessment and with a clearly defined study population. In addition to the two studies already published ([2], [3]), this includes the studies that were previously pooled in a risk analysis in [1], namely case-control studies from Sweden, Denmark, the USA, Norway, New Zealand, Canada, the UK, and a cohort study from Finland. In addition a study in Japan that was completed after the meta-analysis in [1] is included.

The primary hypothesis is that ELF-EMF promotes growth of leukaemia cells resulting in a recurrence of disease related to poorer survival. Disease-free survival will be analyzed. The study population will exclude infants (< 12 months of age at date of diagnosis) due to their poor survival and short latency period and children not in full remission after the initial treatment. The remaining children will be followed up from the date of the full remission until relapse (event) or until the end of the observation period, a diagnosis of a secondary cancer, lost to follow up, or death. The applied exposure metric will be the geometric mean or median of the long-term ELF-EMF measurement (stationary measurement or personal dosimetry) or the average ELF-EMF from calculated magnetic fields (as used in the Nordic studies). The analysis will be adjusted for gender, age, ethnicity (in some countries), socioeconomic position (if necessary, according the country-specific definitions) and stage of the disease (represented by the white blood cell count).

The secondary hypothesis is that ELF-EMF is associated with a poorer survival among children with ALL. The study population includes all children who will be followed up from...
date of diagnosis until date of death (event) or until the end of the observation period or lost to follow up (censoring). Infants will be excluded. The overall observed survival will be analyzed, this time more inclusive with regard to the eligible studies, opposite to the primary hypothesis that is restrictive in a way, that only studies can be included that have complete data on the course of the disease.

RESULTS

Based on availability of data, the total of cases for the main hypothesis is expected to amount to about 3500. Of those, about 5% would have exposures above 0.2 µT. After 5 years of follow up, the statistical power of detecting an association would be >95%, >80% and >50% for hazard ratios of 2, 1.75 and 1.5 respectively. For the secondary hypothesis, the total of cases would be between 3650 and 4000 cases, with more than 180 cases being exposed to magnetic fields above 0.2 µT. Therefore the statistical power would be somewhat higher, but not substantially higher than for the main hypothesis. For the power calculations, the survival rate as observed in the unexposed population of the German study [3] was used as a proxy for the survival rate in the unexposed children of the pooled study.

CONCLUSIONS

We have started the data collection and will continue with the analysis as described above.

ACKNOWLEDGMENTS

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REFERENCES

Prevalence of Self-Reported Electromagnetic Hypersensitivity in Population-Based Questionnaire Surveys in 1999 and 2007

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INTRODUCTION

It is sometime claimed, e.g. by self-aid groups, that there is a substantial increase in the number of persons who experience adverse health effects due to exposure to electromagnetic fields. These self reported health complaints are often called electromagnetic hypersensitivity. One reason for the increase is said to be higher exposure to radiofrequency fields due to the increase in mobile phone use during the last decades and actions to reduce the exposure to electromagnetic fields are called for. Scientific studies have however failed to confirm a causal relationship between electromagnetic fields and subjective symptoms. A better understanding of the temporal changes in the prevalence of perceived electromagnetic hypersensitivity is desired. We here report the prevalence of self reported hypersensitivity to electromagnetic fields in populations-based questionnaire surveys in 1999 and 2007.

MATERIALS AND METHODS

Cross-sectional questionnaire surveys were conducted in 1999 and 2007. The population samples was 15 750 randomly selected Swedish adults between 19 and 80 years of age in 1999 and 43 905 randomly selected adults between 18 and 80 in 2007. The response rates were 73% and 59% respectively. In one question, the respondents were asked to report which factors they were hypersensitive or allergic to. Besides electromagnetic fields other agents were also include, e.g. furry animals, pollen, dust and amalgam. The questions were identically phrased in both 1999 and 2007. The 2007 survey also included a question on risk perception.

RESULTS

Of all respondents, 3.1% reported hypersensitivity to electromagnetic fields in the 1999 survey and 3.2% in the 2007 survey, table 1. Only about half of the subjects who reported being hypersensitive to electromagnetic fields had current complaints attributed to exposure to electromagnetic fields. There were no major changes in prevalence of reported electromagnetic hypersensitivity between the 1999 and 2007 surveys. The highest prevalence of reported electromagnetic hypersensitivity was in the age group 50 to 59 years in both surveys (4.9% 1999 and 4.7 % 2007).

In the 2007 survey, 44% reported that they believed that electromagnetic fields from appliances and power lines had a negative influence on their health. Forty-six percent reported that they believed that electromagnetic fields from mobile phones and antennas had a negative influence on their health.
Table 1. Percentage of respondents who reported hypersensitivity to electromagnetic fields in 1999 and 2007.

<table>
<thead>
<tr>
<th></th>
<th>EHS, substantial health complaints</th>
<th>EHS, minor health complaints</th>
<th>EHS, but no current complaints</th>
<th>No EHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>0.3%</td>
<td>1.4%</td>
<td>1.4%</td>
<td>96.9%</td>
</tr>
<tr>
<td>2007</td>
<td>0.4%</td>
<td>1.6%</td>
<td>1.2%</td>
<td>96.8%</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The prevalence of self-reported electromagnetic hypersensitivity was almost identical in 1999 and 2007. This applies to subjects reporting experiencing health complaints attributed to electromagnetic fields as well as symptom free subjects who report being hypersensitive to electromagnetic fields. The latter group may include subjects who avoid perceived triggering factors (e.g. electrical appliances). A high proportion of the responders reported that they believe that electromagnetic fields, from appliances and power lines as well as from mobile phones and antennas, have a negative influence on their health. In view of this and the increase in mobile phone use during the last decades it is interesting to note that there is no increase in the prevalence of reported hypersensitivity to electromagnetic fields and the highest prevalence is observed in the same age group in both surveys.
The Dutch personal EMF exposure study: measurements during everyday activities combined with GPS to build an Activity Exposure Matrix (EMF-AEM)

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INTRODUCTION

The main goal of the study is to find a proper measure of exposure, characterizing the exposure to extremely low frequency (ELF) and radiofrequency (RF) electromagnetic fields (EMF), for usage in epidemiological studies to define highly vs. lowly exposed persons. The study aims to build an Activity Exposure Matrix (AEM), describing for 30 common, everyday, indoor as well as outdoor activities in 1 ELF and 12 RF frequency bands the estimate of the exposure level. In this way the exposure to EMF in future studies can be estimated based on the AEM and a questionnaire on activity patterns without the need to actually measure.

In the national Dutch Electromagnetic Fields and Health Research Programme we collaborate with two recently started studies which will test the AEM: a cross-sectional study on non-specific physical symptoms in relation to EMF lead by RIVM, and a pooled community-based cohort study on health effects of exposure to EMF lead by IRAS of Utrecht University. We are also in contact with groups in France, Germany, Hungary and Switzerland performing similar projects, see \cite{1, 2}.

MATERIALS AND METHODS

The project consists of three stages. In the first stage we tested the 8 measurement sets consisting of a diary, a GPS, an EME Spy 121 RF-exposimeter and an Emdex Lite ELF-exposimeter. Since the EME spy 121 is a fairly new device existing for two years, the units were extensively tested in a Gigahertz Transverse ElectroMagnetic (GTEM) cell for a.o. between and within exposimeter variability, linearity of response and isotropy. In the second stage we hired temporary workers and commissioned them to perform a preliminary identified list of activities included in the AEM, while carrying the measurement set. After a linear mixed model analysis we determined the contrast ratio of the exposure between activities. Also duplicate measurements for the same sequence of activities and itineraries were performed to be able to determine within and between activity variances. In the third stage we will validate the AEM and the developed questionnaire on activities on volunteers.

New in this project is the spatial-temporal analysis by plotting the measurements in a Geographical Information System or in Google Earth, f.i. by comparing measurements at the same itinerary but at different times of day. In this way we decided on sub-classes of activities based on differences between types of area and times of day, e.g. biking – city centre – evening.
RESULTS

The EME Spy does not display an isotropic response. The input-response relation is linear, but the regression coefficients are not equal to one and differ per frequency band, leading to typical correction factors between 0.7 and 1.5. Figure 1 shows that the response of the exposimeters differs per frequency band with a minimum of 0.25 V/m for UMTStx and a maximum of 1.1 V/m for WiFi. In the bands for UMTStxt, DECT, DCSrx and DCStx the response in the GTEM is lower than the input field of 2.5 V/m.

Figure 2 shows the difference in exposure to EMF from base stations in the city vs the rural area for a bike ride and a train itinerary and a walk through the city centre of Utrecht. Clearly, the exposure in the city is almost continuous above the detection limit of 0.05 V/m whilst in the rural area it is more often below the detection limit. Also the base station density is higher in the city as can be seen from the peaks in exposure whilst biking thought the beam of a bases station.

Based on the analysis of the first 100 hours of measurements in 30 activities, the contrast ratio for the geometric mean of the B-field is 7.2 and for the electric field it is 4.1.

CONCLUSIONS

Personal EMF measurement surveys combining data from exposimeters and GPS-receivers provide a valuable tool for temporal and spatial analysis. The contrast ratio between everyday activities is clear enough to distinguish between high and low exposure activities.

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REFERENCES

Mobile Phone Use and Symptoms of Attention Deficit Hyperactivity in Third Grade Elementary School Children

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INTRODUCTION

According to the rapid increase of children’s use of mobile phone in Korea, the public concerns for the possible health effects on children due to radiofrequency radiation (RFR) exposure of the mobile phone, has been raised. It has been speculated that children might be more vulnerable to electromagnetic radiation exposure than adults because of several biological reasons including their immaturity of biological defense mechanisms [1]. On the other hand, the prevalence of attention deficit hyperactivity disorder (ADHD) in children also has been increased in Korea. Therefore, we attempted to examine a possible association between mobile phone use and symptoms of ADHD in children.

MATERIALS AND METHODS

This study was performed as a part of Children’s Health and Environmental Research (CHEER) survey, which is now conducted annually in Korea [2]. Two thousand three hundred thirty seven 3rd grade students at 22 elementary schools in 10 cities of Korea participated in this study. Parents and guardians administered a questionnaire including Korean version of DuPaul’s ADHD scale to determine the presence of ADHD symptoms [3]. The information about ownership and use of mobile phone as well as general demographic factors and other risk factors of ADHD, e.g., parental educational level, household income, maternal smoking or drinking during pregnancy and so on, was also obtained by the questionnaire administration. The presence of ADHD symptoms was defined by the total score above 19, and 10 or more categorical score of attention deficit or hyperactivity in the scale. Using logistic regression analyses, the risks of positive ADHD symptoms were estimated for ownership and different use of mobile phone (odds ratios and 95% confidence intervals). To adjust various other risk factors of ADHD, age, gender, household income, parental history of neuropsychiatric diseases and residential area were included in the multivariate models.

RESULTS

Of 2,337 children, 50.6% was boys and 10.6% has ADHD symptoms (15.1% for boys and 6.1% for girls). The prevalence of ADHD symptoms were varied by residential areas from
6.4% in Seoul to 15.6% in Jeongeup. Twenty two percent of children had their own mobile phone. Of 1,056 children using mobile phone of their own or parents, more than 89% used it for less than 30 minutes a day and 53.6% used it for less than 30 seconds a call. The risk of symptoms of ADHD increased according to increasing frequency of use of other’s mobile phone, spending time for a call, spending time of game, and internet navigation. The ownership of mobile phone and total spending time of mobile phone use a day were not associated with the symptoms of ADHD (Table 1). The frequencies of text massage sending or receiving a day were not associated with ADHD.

Table 1. Odds ratios and 95% confidence intervals of symptoms of ADHD for ownership and use of mobile phone in children

<table>
<thead>
<tr>
<th>Ownership of mobile phone</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1557</td>
<td>199</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>466</td>
<td>42</td>
<td>0.89</td>
<td>(0.62,1.29)</td>
<td>0.5502</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Use of other's mobile phone among children not having their own mobile phone</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No, rarely</td>
<td>860</td>
<td>95</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes, occasionally</td>
<td>474</td>
<td>73</td>
<td>1.51</td>
<td>(1.08, 2.12)</td>
<td></td>
</tr>
<tr>
<td>Yes, frequently</td>
<td>37</td>
<td>8</td>
<td>2.03</td>
<td>(0.88, 4.69)</td>
<td>0.0251</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spending time of mobile phone use a day‡</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30 min</td>
<td>1081</td>
<td>116</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min -&lt;1 hour</td>
<td>80</td>
<td>8</td>
<td>1.00</td>
<td>(0.46, 2.16)</td>
<td>0.8697</td>
</tr>
<tr>
<td>1 hour or more</td>
<td>37</td>
<td>5</td>
<td>1.31</td>
<td>(0.48, 3.52)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spending time for a call</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 30 sec</td>
<td>738</td>
<td>70</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 sec -&lt;1 min</td>
<td>436</td>
<td>53</td>
<td>1.41</td>
<td>(0.96, 2.07)</td>
<td></td>
</tr>
<tr>
<td>1-&lt;3 min</td>
<td>142</td>
<td>24</td>
<td>2.04</td>
<td>(1.21, 3.43)</td>
<td>0.0253</td>
</tr>
<tr>
<td>3-&lt;5 min</td>
<td>37</td>
<td>2</td>
<td>0.56</td>
<td>(0.13, 2.46)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spending time for playing game using mobile phone a day</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1075</td>
<td>101</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;3 min</td>
<td>114</td>
<td>20</td>
<td>1.71</td>
<td>(1.00, 2.91)</td>
<td></td>
</tr>
<tr>
<td>3-&lt;6 min</td>
<td>68</td>
<td>9</td>
<td>1.33</td>
<td>(0.63, 2.82)</td>
<td></td>
</tr>
<tr>
<td>6-&lt;10 min</td>
<td>66</td>
<td>13</td>
<td>1.95</td>
<td>(1.02, 3.74)</td>
<td></td>
</tr>
<tr>
<td>10-&lt;30 min</td>
<td>46</td>
<td>15</td>
<td>3.01</td>
<td>(1.58, 5.75)</td>
<td></td>
</tr>
<tr>
<td>30 min or more</td>
<td>17</td>
<td>6</td>
<td>2.98</td>
<td>(1.11, 8.02)</td>
<td>0.0022</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spending time for navigating internet using mobile phone a day</th>
<th>Normal</th>
<th>Case</th>
<th>OR*</th>
<th>(95% C.I)</th>
<th>p-trend+</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1344</td>
<td>150</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10 min</td>
<td>16</td>
<td>5</td>
<td>2.35</td>
<td>(0.81, 6.81)</td>
<td></td>
</tr>
<tr>
<td>10 min or more</td>
<td>7</td>
<td>4</td>
<td>5.36</td>
<td>(1.48, 19.41)</td>
<td>0.0120</td>
</tr>
</tbody>
</table>

* Odds ratios and 95% confidence intervals estimated using multiple logistic regression adjusted for age, gender, household income, parental history of neuropsychiatric diseases and residential area.

+ p-trend calculated using continuous scale of variables of mobile phone ownership or use in the corresponding models.

‡ Included all spending times for calls ins and outs, text message, playing game, and navigating internet using mobile phone.

CONCLUSIONS

We found associations between some variables of mobile phone use and symptoms of ADHD. However, the pattern of the mobile phone use might be resulted from the ADHD symptoms in this study. Because of the limitation of cross-sectional design, we are not able to determine the real causation. Further investigation on the relationship between RFR exposure of mobile phone and ADHD in children is warranted.

ACKNOWLEDGMENTS

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REFERENCES

INVESTIGATION OF THE EFFECTS OF NON THERMAL MICROWAVE RADIATION ON PROKARYOTIC CELLS
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INTRODUCTION

The present study examined the existence of non thermal bioeffects caused by microwave (MW) radiation on bacteria. It has long been recognised that induced MW radiation affects various processes in living organisms [1, 2]. However, since the vitality of living organisms is based on electro-kinetic activities of cells, and normal function of bacteria involves ionic currents electric fields, there is some basis for consideration of direct non-thermal electromagnetic field interactions.

Active and passive transport across cell membranes, diffusion, electrophoresis, electro-poration, electro-osmosis, electro-rotation and electro-chemical activity are all results of electro-kinetic processes in living organisms. Numerous experimental observations have suggested that non thermal exposure to MW radiation is linked to various electro-kinetic effects of living cells, such as facilitated/enhanced diffusion of ions, protein leakage and denaturation, cell membrane disruption, and osmotic transport [3]. The aim of the present study was to investigate the effect of low power MW radiation on the cellular morphology and recovery of two prokaryotes, Escherichia coli and Staphylococcus aureus. The detection and identification of cellular and cytosolic component leakage through the bacterial membrane was also to be examined. Finally, the theoretical evaluation of the non thermal effects of MW radiation on prokaryotic cells and/or cellular membranes was to be discussed.

MATERIALS AND METHODS

Bacterial samples were prepared from cultures of E. coli ATCC 15034, S. aureus CIP 103594T. Samples comprised of bacteria suspended in PBS at a concentration of 100 cfu/ml. Non thermal treatment settings were maintained by controlling the threshold temperature (45°C) reached during exposure. At this temperature, bacteria were determined to be unaffected by heat. The experiments were run using a frequency of 18 GHz and the incident power output was 16 Watt. For uniformity of exposure, each sample was placed on a Teflon pedestal within the same spot, which had been determined by an electric field modelling software [1]. This analysis allowed for the MW power distribution at that particular spot to be uniform thereby eliminating “hot spot” effects [1, 2]. Furthermore, as the wavelength of microwaves in the cavity was much greater than the dimensions of the sample (10mm x 10mm x 0.5mm), the possibility of non-even heating due to non-uniform field distribution was negligible.

In order to maximise the non thermal effect without having the internal temperature of the sample exceed 45°C, a previously developed “repeated exposure” technique was employed [1, 2]. Each sample was exposed to the MW radiation three consecutive times, allowing the sample to cool to 20°C between exposures.

Cell morphology was examined using Scanning Electron Microscopy immediately following MW radiation in order to determine whether cellular components had leaked through the cell membrane. Identification of leaked cytosolic and membrane components was carried out using the Bradford method and proteomic analysis. Cell morphology was also
examined at 10 minutes after radiation to observe for any changes. Treated cells were also recovered on Agar plates to detect whether MW radiation was cytotoxic.

RESULTS

SEM analysis revealed that *E. coli* cells examined immediately following MW radiation exhibited a different cell morphology compared to control cells (Figure 1a). As can be seen from image 2, the cells had a dehydrated appearance while the control cells appeared intact and healthy. This suggested that MW radiation caused cytosolic fluids to leak out of the *E. coli* cell membrane. This effect however, was temporary, as the fluids were reabsorbed back into the cells within 10 minutes following MW treatment (image 3).

Examination of *S. aureus* cells showed no differences in cell morphology across both times of examination and the control (Figure 1b). While the dehydration was not evident for the *S. aureus* cells under the SEM, membrane and cytosolic protein leakage was detected using the Bradford method. It was suggested that the thick peptidoglycan layer of the bacteria could have allowed the cell to remain morphologically intact during dehydration. Analysis of component leakage revealed cytosol and membrane based proteins across both bacteria. Despite leakage, both species were recovered on agar plates.

![Figure 1: SEM analysis of bacteria. Row a: E. coli, Row b: S. aureus 1: Control, 2: Image immediately after MW radiation, 3: Image ten minutes after MW radiation.](image)

CONCLUSIONS

Inferences from this study advocate that the interaction of non thermal MW radiation with bacteria is electro-kinetic in nature. Leakage of cellular components and proteins suggests that during MW treatment electroporation occurs within the bacterial cell membrane. The indicated reversibility of the observed dehydration effect has potential for a range of bio-industrial and biomedical applications.

REFERENCES


**INTRODUCTION**

For many applications of cell electroporation, it is desirable to know the size of the pores created in the cell plasma membrane. Although, the size of the pores created in the cell membrane by electric pulses has been estimated numerous times [1-4], there is a lack in the studies in which the pore sizes of would be estimated for different pulse durations. Meanwhile, modeling studies have revealed that the pulse of nanosecond-duration should create smaller pores than the pulse of micro-millisecond duration [5]. However, the number of pores created by nanosecond-duration pulses should be by 2–3 orders of magnitude more than in the case of longer pulse [5]. It can be expected, that similar differences should also exist between the pore populations created by the pulses of micro- and millisecond-durations.

Here, we compared the size of the pores created by a square-wave electric pulse with the duration of 100 μs and 2 ms. This has been done by determining the fraction of cells the membranes of which have become permeable to potassium ions (molecular weight $M_r = 39$ Da, $r \approx 0.16-0.22$ nm) and bleomycin ($M_r \approx 1500$ Da, $r \approx 0.8$ nm) as well as the fraction of the cells that were killed by the electric treatment. Experiments were done with mouse hepatoma MH-22A, Chinese hamster ovary (CHO) and rat glioma C6 cells.

**MATERIALS AND METHODS**

The cells were grown in monolayer cultures in 75-cm² flasks at 37 °C and 5 % CO₂ in a water-jacketed incubator. When cells reached confluence they were trypsinized, suspended in the culture medium at approximately 2.5×10⁷ cells/ml and kept for 60–70 min at room temperature (20–21 °C) [6]. After a 50-μl droplet of cell suspension was subjected to a single square-wave electric pulse, the extracellular potassium concentration was measured by means of a mini K⁺-selective electrode and the fraction of electroporated cells was determined [6,7]. Also, the fraction of the dead cells and the cells whose membrane has become permeable to bleomycin were determined from the reduction of the cell viability [8]. Cell viability was determined by means of a colony-forming assay [9].

**RESULTS**

The dependences of the fraction of electroporated and dead cells as well as the cells permeable to bleomycin on the pulse intensity were obtained for the cells exposed to single square-wave electric pulses with the durations of 100 μs and 2 ms (the results for MH-22A cells are shown in Fig. 1). It can be seen, that in the large portion of electroporated cells (permeable to K⁺ ions) the pores created by an electric pulse with the duration of 100 μs are smaller than the molecule of bleomycin. This means that the pores created are large enough to allow potassium ions ($r \approx 0.16-0.22$ nm) to leave the cells but small enough to prevent
bleomycin ($r \approx 0.8$ nm) from reaching the cell cytosol.

In the case of 2 ms-duration pulse, the curves showing the dependence of the fraction of the cells that have become permeable to bleomycin are close to the ones showing the release of intracellular potassium ions. This is strong evidence that the pores created by the pulse with the duration of 2 ms are larger than the pores created with a 100 μs-duration pulse.

CONCLUSIONS

For all cells studied (mouse hepatoma MH-22A, Chinese hamster ovary, and rat glioma C6 cells), the size of the pores created by a square-wave electric pulse depended on the pulse duration. Short 100 μs-duration pulse created smaller pores than longer 2 ms-duration pulse.

ACKNOWLEDGMENT

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REFERENCES

Pulsed Laser Fluorescence Microscopy as a Tool for Transmembrane-Potential Recordings of Mammalian Cells

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INTRODUCTION

The application of an external electric field to biological cells leads to an increase of membrane permeability, which is commonly known as “electropermeabilization” or “electroporation”. Current theories assign the permeability increase to the formation of micropores in the plasmamembrane of the cell. The understanding of the charging behaviour and the pore formation dynamics of biomembranes is of importance for several applications ranging from nano- to industrial-scale processes. Examples are the transfection of cells, the introduction of fluorescent nanoparticles into a cell for diagnostic purposes or the decontamination of hospital waste water [1]. Pulsed Laser Fluorescence Microscopy (PLFM) allows the examination of membrane charging processes with high temporal resolution of a few nanoseconds with the aim of the adaptation of the electric pulse parameters to the individual application and the testing of theoretical electropermeabilization models.

MATERIALS AND METHODS

The principle of measurement presented in this paper is analogue to the one reported by Frey et al. [2]. The recent experimental setup has been improved in several aspects, allowing a faster data acquisition and an easier control of experimental parameters such as the excitation wavelength provided by the laser system. To generate a homogeneous electric field, a microelectrode array has been used consisting of two titanium electrodes glued on a standard microscope slide, leaving a gap of 300 µm between both electrodes. The voltage creating the external electric field is delivered by a Blumline-line generator providing a rectangular pulse with a duration of 1 µs. Mammalian cells (HEK293, HeLa, 22Rv1) have been stained with ANNINE-6, a fast voltage-sensitive dye which exhibits fluorescence intensity changes based on electronic transitions due to the molecular Stark effect [3]. Transmembrane-potential dependent fluorescence changes under the influence of an external electric field have been measured using a fast intensified CCD camera. The fluorescence intensity at the anode- and cathode facing hemisphere of the cell has been recorded without external electric field, delivering the basic fluorescence $F_0$, and with electric field $E$ at an arbitrary point of time $t$ relative to the onset of the pulse, delivering the field-strength-dependent fluorescence $F$. The obtained relative fluorescence change $F/F_0$ has been converted to transmembrane potential values $V_M$ using a calibration curve of the voltage-sensitive dye obtained by spectroscopic measurements on leech neuron cells [4]. The excitation wavelength for all experiments was 468 nm.

RESULTS

Time-courses of the transmembrane potential $V_M$ of HEK293 cells in response to a 1 µs rectangular field pulse with an amplitude of 0.67 kV/cm exhibit a symmetric exponential
charging process at the anodic and cathodic pole of the cell. The transmembrane potential shows a saturation 300 ns after the onset of the pulse reaching a maximum membrane voltage shift of ~100 mV. The measurements show a strong deviation from the theoretically expected maximum value of $V_M$ of 700 mV considering the resting potential of the cell, the amplitude of the electric field and a typical cell diameter of 15 µm. Theoretical network model calculations describe the general shape of the data well but the maximum predicted amplitude of the transmembrane potential has to be scaled down by a factor of 5 to fit the experimental values.

To investigate a possible membrane-selectivity of the voltage-sensitive dye, the field-strength dependence of $V_M$ for three types of mammalian cells has been measured at $t = 500$ ns after the onset of the electric field pulse. At the anodic hemisphere the results for HEK293 and 22Rv1 cell lines show a good agreement up to external field strengths of 12 kV/cm, whereas HeLa cells show a similar curve progression, but a slightly lower amplitude compared to the other cell types. This might result from the possible absence of voltage-gated ion-channels in HeLa cells [5]. At the cathodic cell pole, the rise of the transmembrane potential is similar for all cell lines are up to field strengths of approx. 1 kV/cm. At higher field strengths, the field strength dependence of the transmembrane potential varies which is attributed to individual pore formation processes. The measurements show a maximum membrane potential shift of 150 mV at the hyperpolarized cell hemisphere and 250 mV at the depolarized hemisphere.

CONCLUSIONS

The deviations of the time-course measurements on HEK293 cells and theoretical predictions of the transmembrane potential are assigned to an enhanced formation of micropores in the plasma membrane of the cell 300 ns after the onset of the field pulse, limiting a further charging of the membrane.

The measurements of the field strength dependence of the membrane potential for different mammalian cell lines suggests a value of $V_M$ for the onset of enhanced pore formation of approximately 200 mV, assuming a typical resting potential of the cell of $V_{\text{rest}} = -50$ mV.

Regarding the measurements below the field strength leading to enhanced pore formation, our data indicate a non-specific membrane-integration of the voltage sensitive dye ANNINE-6.

REFERENCES


Comparison of Electroporation Threshold of Different Cell Lines

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INTRODUCTION

The expose of cells to high-voltage electric pulses leading to the formation of nanometer-sized pores in the cell membrane - electroporation - is widely used in cell biology, biotechnology and medicine [1]. Often, it is important to know how many of cells have become electroporated as a result of a particular electric treatment. Unfortunately, it is difficult to predict responses of different cells to electric treatment [2,3] and electrical parameters for cell electroporation have to be determined empirically for each cell line [3].

In addition, up to now, there are no studies in which the electroporation threshold would be compared for different cell lines. Either the increase of the cell membrane permeability to a particular substance (e.g., propidium iodide) [2] or the reduction of the cell viability [3] due to the exposure by electric pulses were compared. Here, we compared the electroporation threshold for four cell lines - human erythrocytes, mouse hepatoma MH-22A, Chinese hamster ovary (CHO) and rat glioma C6 cells at various electric pulse durations (0.02-2 ms).

MATERIALS AND METHODS

The cells (except erythrocytes) were grown in monolayer cultures in 75-cm² flasks at 37 °C and 5 % CO₂ in a water-jacketed incubator. When cells reached confluence they were trypsinized, suspended in the culture medium at approximately 2-5×10⁷ cells/ml and kept for 60–70 min at room temperature (20–21 °C) [4]. A 50-μl droplet of cell suspension was subjected to a single square-wave electric pulse and immediately transferred to a chilled Eppendorf tube. The cells were kept at 10-11 °C for 30-40 min and the extracellular potassium concentration was measured by means of a mini K⁺-selective electrode. Then, the fraction of electroporated cells was determined [4,5].

RESULTS

First, the dependences of the fraction of electroporated cells on the pulse intensity were obtained for the cells exposed to single square-wave electric pulses with the durations of 0.02-2 ms. The amplitude of an electric pulse was varied from 0.6 to 2 kV/cm for erythrocytes and from 0.2 to 1.2 kV/cm for hepatoma MH-22A, Chinese hamster ovary and rat glioma C6 cells. Increasing the intensity of the electric field pulse increased the fraction of electroporated cells. The electric field strength which led to a given percentage of electroporation decreased with increasing the pulse length.

Because the transmembrane potential generated by the external electric field E₀ depends on the cell radius a [6], we compared the transmembrane potential inducing electroporation of 50% of cells, which was calculated from $\Delta \Phi_m = 1.5 E_0 a$ [6]. The obtained dependences of the transmembrane potential required to electroporate 50% of cells on the pulse duration are presented in Fig. 1. The values of the transmembrane potential $\Delta \Phi_m$ are in the range of 0.47-
Figure 1: The dependences of the maximal transmembrane potential (at the polar regions of the cell), required to electroporate 50% of cells on the pulse duration, obtained for human erythrocytes (○), mouse hepatoma MH-22A (▲), Chinese hamster ovary (□) and rat glioma C6 cells (▼). 1.0 V and are similar to the transmembrane potentials that have been reported as leading to membrane permeabilization [2,7].

CONCLUSIONS

The electric field strength necessary to electroporate cells depends on the cell size and decreases with increasing the amplitude or the duration of the pulse. However, the transmembrane potential required to electroporate 50% of cells as well as its dependences on the pulse duration are almost the same for human erythrocytes, mouse hepatoma MH-22A, Chinese hamster ovary, and rat glioma C6 cells.

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REFERENCES


Specification and Evaluation of SAR Values of Different Mobile Phones

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INTRODUCTION
In the meantime SAR values are a general product attribute of mobile phones, which are available for customers. SAR measurements in Europe are made according to the European Basic Standard EN 62209-1 [1] and for body worn configurations according to the International Standard IEC 62209-2 [2]. SAR values are compared to the limits given in the European Council Recommendation 1999/519/EC.

In this paper the exposure from relevant mobile phones in different frequency and operating mode configurations is investigated. Technical reasons for the assessed SAR values are discussed.

MATERIALS AND METHODS
For the investigation four different mobile phones according to Figure 1 were used: two bar type phones, one slider and one flip phone.

![Figure 1: Devices under investigation](image)

The dosimetric measurements were made with a DASY system from SPEAG, Zurich. In addition the total radiated power (TRP) in free space configuration was assessed with a measurement setup according to the CTIA [3] description. Both systems are covered by the IMST accreditation scope according to ISO/IEC 17025.

RESULTS
The measurement results are shown in Figure 2. In general the highest SAR value is observed for GSM 900. One potential reason is the higher nominal mean output power at GSM 900 (250 mW) compared to 125 mW at GSM 1800 and WCDMA respectively.

The huge variation of the SAR values can be mainly attributed to the TRP of the mobiles. The correlation coefficient between the worst case SAR and the TRP is 0.98 for GSM 900, 0.68 for GSM 1800 and 0.82 for WCDMA I respectively. Because of the small sample size the significance of this correlation is limited. Nevertheless the correlation can be understood with the SAR patterns of the mobiles. At GSM 900 the maximum SAR is located near the
middle of the PCB and it is nearly independent of the specific mobile and the antenna respectively. Therefore a very high correlation between the SAR and the TRP for the different mobiles can be observed. At GSM 1800 and at WCDMA the SAR is also depending on the antenna position with respect to the human body. Therefore the correlation coefficient decreases and other parameters like e.g. the mobile phone position become significant.

Figure 2: (a) Measured maximum SAR values in comparison to the SAR value published by the manufacturer, (b) Measured maximum TRP values.

Figure 3: Measured SAR distribution for device 1 in a flat phantom. (a) GSM 900, (b) GSM 1800.

CONCLUSIONS
In this work the SAR and the TRP for four different mobile phones were measured. It was shown that for GSM 900 the maximum SAR mainly depends on the TRP of the mobile under investigation. For GSM 1800 and WCDMA the correlation between the SAR and the TRP decreases. In this case the antenna position on the mobile dominates the SAR distribution and the resulting maximum SAR value.

ACKNOWLEDGMENTS
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[3] Test plan for Mobile Station Over the Air Performance; Method of Measurement for Radiated RF Power and Receiver Performance (CTIA Revision 2.21, January 2008).
Combining Ray–Tracing and Full-Wave Numerical Methods for the Assessment of Human Exposure at RF Transmitter Sites

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KEYWORDS: Base station exposure, Compliance assessment, Full-wave antenna simulations.

OBJECTIVES AND METHOD: The assessment of radiation intensity around cellular base station antennas is necessary for the prevention of overexposure to the general public and RF-trained personnel. To perform the assessment a computational tool has been developed for calculating 3-D regions where the power density exceeds specified reference levels.

Panel and omnidirectional antennas are modeled using a ray-tracing technique for a linear array of point sources. The E-field at an observation point is calculated for each of these antennas considering the path length, radiation pattern and phase of each individual point source.

For other kinds of antennas such as Yagi-Uda or folded dipole antennas simulations are performed using full-wave method of moment computation. Models for these antennas are created by calculating and storing the E-fields on a 3-D uniform grid. Our computational tool then uses fast trilinear interpolation to calculate the E-field at any observation point within the boundaries of the 3-D uniform grid.

The individual power density for each antenna is determined using the calculated E-field in a free-space medium. The total power density at an observation point is calculated by summing the individual power density of all transmitting antenna.

RESULTS AND CONCLUSIONS: A method was presented for combining ray-tracing and full-wave numerical methods for calculating the power density at an observation point. Fast trilinear interpolation is used to calculate the power density at a given point for pre-calculated full-wave antenna models. The individual power densities of the different models are summed to determine the total power density at a given point in space. 3-D regions can be drawn where specified reference levels are exceeded as seen in the figures below. The figures show public (yellow) and occupational (red) compliance zones for a panel and Yagi-Uda antenna mounted on the side of a building.
Conservative Evaluation of Combined Exposure from Multiple RF Sources
(100 kHz - 300 GHz)

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INTRODUCTION

This study aims at establishing basic, rigorous techniques to estimate conservatively the combined exposure from multiple RF sources. Depending on the signal characteristics, said combination may involve the scalar or vector superposition of field quantities, potentially requiring vector sensors. Alternative approaches, which are shown to be conservative, are described to enable the use of scalar sensors in all cases, thus simplifying the evaluation process when measurements are involved. Results of the study form a Technical Report issued by the IEC Technical Committee 106 to provide guidance to Project Teams drafting guidelines for the evaluation of the exposure from RF emitting devices and antennas.

MATERIALS AND METHODS

Signals by different RF transmitters may be either correlated or uncorrelated in time. Signals occupying separate frequency bands are uncorrelated. This case is particularly important since in many practical instances multiple RF sources operate in separate bands (e.g., GSM and Wi-Fi). However, when different sources share the same operating band the waveforms may be correlated or uncorrelated depending on the communication protocol. For instance, CDMA waveforms sharing the same spectrum are uncorrelated if they employ orthogonal Walsh codes. On the other hand, the fields produced by individual radiating elements of beam-steered smart antennas used in WiMAX systems may be correlated. The former is the most common case, allowing the straightforward summation of SAR or power density distributions to yield the total exposure, thus permitting the use of scalar field sensors, e.g., diode-detector probes currently used in SAR evaluations of single-transmitter products. Therefore, implementing experimental assessment procedures for uncorrelated narrowband waveforms is not likely to require significant equipment upgrades or added measurement complexity. Concerning the latter case, evaluating the accurate combined field or SAR for multiple correlated sources necessarily requires estimating the magnitude of the vector-sum of the individual fields (see Fig. 1), which may require significant test equipment upgrades and increased test complexity. For instance, vector sensors capable of measuring magnitude and phase of each source field components would be required.

In order to allow the use of widely available scalar field sensors when evaluating the combined exposure from multiple correlated sources, two conservative approaches have been derived through rigorous analytical steps, each introducing a degree of overestimation. One approach involves summing the local field magnitudes; the other is based on a combination of the magnitudes of the local field components, as visually described in Fig. 1.
RESULTS

A mobile phone equipped with Wi-Fi connection may allow simultaneous GSM and Wi-Fi transmission. Since GSM and Wi-Fi operate on different frequency bands, the two signals are uncorrelated, so individual SAR distributions can be summed, as schematically illustrated in Fig. 2, thus resulting in an overall peak SAR lower than the sum of the individual peaks. Results regarding the superposition of correlated sources in smart antenna systems will be also presented, quantifying the overestimation introduced by the aforementioned approaches.

CONCLUSIONS

Based on a rigorous analysis, it was shown that a conservative evaluation of the combined exposure from multiple RF sources (whether correlated or not) may be performed using scalar sensors alone. SAR summation may be used for conservative SAR evaluation of multi-band handsets, while measurement techniques using scalar summation in the near field of base station antennas may exhibit a systematic overestimation and hence be conservative.

Figure 1: Different approaches to estimate conservatively the combined exposure from correlated RF sources, yielding correspondingly distinct upper-bounds of the true field vector-sum (red arrow)

Figure 2: Qualitative description of the individual and combined SAR distributions for a mobile phone transmitting simultaneously GSM and Wi-Fi signals
INTRODUCTION

The SAR in thin (<100 μm), small volumes (10-100 μl) of biological preparations is difficult to measure with good precision. We show that the SAR in thin, small volume samples placed in a large cylindrical cavity can be evaluated conveniently from the measurements of frequency shift and Q degradation before and after the insertion of the sample.

MATERIALS AND METHODS

The samples used are thin layers (<<1 mm) of biological preparations (e.g., medium or cells + medium), located in the center of a cavity, have axial symmetry and a radius much smaller than the cavity radius (12.1 cm). The samples are placed on a thin shelf of very low loss dielectric material anchored to the side of the metal cavity. The Q (quality factor) of a cavity is the ratio of the RF energy stored to the energy dissipated during one cycle of the fields [1]. Q₀ is the cavity quality factor with no sample on the shelf. The cavity resonates at the angular frequency ω₀. With the addition of the sample, the cavity resonates at angular frequency ωₗ lower than ω₀ and has a (lower) Q = Qₗ < Q₀.

By definition of the quality factor we have:

\[ Q₀ = \omega₀ \left| V₀ \right|^2 E / \left( \left| V₀ \right|^2 / R₀ \right) = \omega₀ E / (1 / R₀) \]  

\[ Qₗ = \omegaₗ \left| Vₗ \right|^2 E / \left( \left| Vₗ \right|^2 / Rₗ \right) = \omegaₗ E / (1 / Rₗ) \]  

where \( \left| V₀ \right|^2 / R₀ \) and \( \left| Vₗ \right|^2 / Rₗ \) represent the power lost in the cavity in the two different conditions and E is a dimensionless geometrical factor that relates the stored electric energy to the geometry of the cavity and its load; \( 1/Rₗ = 1 / R₀ + 1 / R_B \); the factor \( 1 / R_B \) gives the dissipation loss in the biological sample. The Loss Factor (LF), i.e. the ratio of power in the biological sample to the initial and input power, is given by:

\[ LF = (1 / Qₗ - 1 / Q₀) / (1 / Q₀) = (Q₀ / Qₗ - 1) = (\omega₀ / \omegaₗ)(R₀ / Rₗ + 1) - 1 \approx R₀ / Rₗ \]  

The loss factor gives the fractional value of the input RF power that is dissipated in the biological sample. If the mass \( m \) of the biological sample and the power \( P \) input into the cavity are known, then the average SAR is given by:

\[ SAR = (LF)P / m \ [mW/g] \]

It is necessary to measure \( Q₀ \) and \( Qₗ \) with precision. This is done by recording the reflection coefficient Γ \( (0 ≤ Γ ≤ 1) \) values in the pass band of the cavity. These data are fitted to a Lorenzian function to find the half power bandwidth of the cavity. The Q is obtained by dividing the frequency of resonance by the half power bandwidth.
RESULTS

This measurement methodology has been applied to evaluate the SAR in a variety of liquid samples. Table I shows the data relative to one simple case. The series of samples were different volumes of phosphate buffered saline (PBS).

Table I. SAR values from reflection measurements of PBS samples

<table>
<thead>
<tr>
<th>Buffer vol. (μl)</th>
<th>Freq. (MHz)</th>
<th>BW (MHz)</th>
<th>Q</th>
<th>Δ (1/Q)/(1/Q)</th>
<th>SAR (mW/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>887.1</td>
<td>0.3597</td>
<td>2466</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>887.0</td>
<td>0.3792</td>
<td>2339</td>
<td>5.43E-02</td>
<td>3.6</td>
</tr>
<tr>
<td>25</td>
<td>886.9</td>
<td>0.3923</td>
<td>2261</td>
<td>9.07E-02</td>
<td>3.6</td>
</tr>
<tr>
<td>35</td>
<td>886.9</td>
<td>0.3959</td>
<td>2240</td>
<td>1.01E-01</td>
<td>2.9</td>
</tr>
<tr>
<td>45</td>
<td>886.8</td>
<td>0.4118</td>
<td>2153</td>
<td>1.45E-01</td>
<td>3.2</td>
</tr>
<tr>
<td>55</td>
<td>886.7</td>
<td>0.4173</td>
<td>2125</td>
<td>1.60E-01</td>
<td>2.9</td>
</tr>
<tr>
<td>65</td>
<td>886.7</td>
<td>0.4226</td>
<td>2098</td>
<td>1.75E-01</td>
<td>2.8</td>
</tr>
</tbody>
</table>

The data were collected using 1 mW power incident into the cavity. The overall mean SAR is 3.2 mW/g and the distribution width ±0.3 mW/g.

The experimental results shown by mode tracking in the cavity [1-2] point out that the dissipation model adopted to evaluate average SAR is indeed correct, because $\omega_o / \omega_L \approx 1$. This fact supports the statement that there is not a substantial redistribution of field lines in the cavity, only some field paths become dissipative. In addition, since the biological preparation has a small radius with respect to that of the cavity and has axial symmetry, the RF energy absorption is uniform throughout the sample, except at the very edges, where fringing effects may alter the SAR distribution.

CONCLUSIONS

A simple and direct method for evaluating the SAR in thin biological preparations has been devised. The application of this method requires that the geometrical shape of the biosample be a thin circular cylinder centered on the axis of the cavity. The method requires fitting a Lorenzian function to the reflection coefficient data. Should the $Q$ change substantially after insertion of the biological preparation, the cavity is overloaded and this SAR measurement method is invalid.

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REFERENCES

A Numerical Study on Milli-Meter Band Electromagnetic Dosimetry with Complex Envelope FDTD Method

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INTRODUCTION

The FDTD method\(^1\) has contributed toward solving a lot of problems in electromagnetic dosimetry for radio frequency band. The voxel size in the FDTD method is restricted by not only scattering models, but also restricted by wavelength \(\lambda\) inside the models. A general guideline in the FDTD method recommends to set the voxel size as smaller than 1/10 of the \(\lambda\) to obtain sufficient calculation accuracy\(^2\). If \(\lambda\) will become smaller than 1 mm in biological tissue, therefore recommended voxel sizes are required to set smaller than 0.1 mm. It is quite difficult to perform the numerical simulations for the MMW dosimetry with the FDTD method by using such a small voxel size, because of its enormous computational costs. An effective numerical method is required for the dosimetry in the MMW band exposure.

In this study, we focused on the complex envelope FDTD (CE-FDTD) method\(^3\) as the numerical method for the dosimetry in the MMW exposure. The goal of this study was to demonstrate the effectivity of the CE-FDTD method for the MMW dosimetry. The method was applied to the scattering analysis for a homogeneous sphere model as a case study.

MATERIALS AND METHODS

Here we show characteristics of the CE-FDTD method. Equation (1) indicates relationship between electromagnetic field and its envelope components.

\[
\begin{align*}
\mathbf{E}, \mathbf{H}, \omega_c, \text{ and } t \text{ indicate electric field, magnetic field, carrier angular frequency, and time.} \\
\text{Re}\{\cdot\} \text{ in Eq. (1) denotes the real part of a complex number. } \mathbf{E}^\epsilon \text{ and } \mathbf{H}^\epsilon \text{ represent complex envelope components.} \\
\text{This method is based on the scheme to solve time proceeding of complex-envelope components. One of the advantages of this method is that the voxel size is not restricted by } \lambda \text{ of the carrier frequencies, i. e. only restricted by resolution of scattering models.} \\
\text{Equation (2) denotes a stability condition of the CE-FDTD method\(^4\).} \\
\Delta t \leq \left\{\frac{\sqrt{(1/\Delta x)^2 + (1/\Delta y)^2 + (1/\Delta z)^2}}{2\nu v} \right\}^{-1/2}
\end{align*}
\]

Where, \(\nu\) and \(\Delta t\) indicate the wave velocity and the interval of time step. \(\Delta x, \Delta y, \text{ and } \Delta z\) are voxel sizes. Equation (2) indicates that the maximum \(\Delta t\) of the method becomes larger than that of the FDTD method, if \(\nu\) and voxel sizes are the same values in both methods.

We applied the CE-FDTD method to the simple scattering analysis as a case study. Conditions for the simulation were as follows. Figure 1 shows schematic view of the calculation model for scattering analysis with the homogeneous dielectric sphere. The calculation region was 35 mm \(\times\) 35 mm \(\times\) 35 mm. The radius of the sphere model was 10 mm. The center of the sphere was located on (20 mm, 17.5 mm, 17.5 mm). The relative permittivity and electric conductivity in the sphere were 5.6 and 39.4 S/m, respectively.
These values are electric constants of the dry skin at 100 GHz[5]. The outer region of the sphere was vacuum. The voxel sizes (Δx, Δy, Δz), Δt, and carrier frequency were 0.5 mm, 1 ps, and 100 GHz, respectively. A small electric dipole was located at (5 mm, 17.5mm, 17.5 mm), and its dipole moment was oriented along z axis. We employ 10 GHz sinusoidal wave source as an envelope component. The amplitude of electric field was 1 V/m at the dipole source. The perfectly matched layer[6] was applied for an absorbing boundary condition.

RESULTS

We observed RMS values of electric field |E| rms in the steady state inside the sphere. Figure 2 indicated the |E| rms distribution on the x-y cross-section at z=17.5 mm with the CE-FDTD method.

The appropriate voxel size and Δt was smaller than 0.1 mm and 0.19 ps, if the ordinary FDTD method is used. Here, Δt must be decided under a stability condition of the FDTD method[2]. The required voxel number with the CE-FDTD method was decreased to 1/125 of those with the FDTD method in whole calculation region. Moreover, number of time steps required for the CE-FDTD became 1/5 of the FDTD method until achieving to the steady state in this case.

CONCLUSIONS

In this study, we focused on the CE-FDTD method for the MMW band electromagnetic dosimetry. The simple sphere was employed for the scattering model as a case study. We showed that the CE-FDTD method had significant advantage in computational costs for the MMW dosimetry by comparing with the conventional FDTD method. The CE-FDTD method was expected as the practical numerical method for the MMW dosimetry.

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Figure 1: Schematic view of the calculation model.

Figure 2: Distribution of the RMS value of electric field on the x-y plane at z=17.5 mm.
INTRODUCTION

Current SAR (Specific Absorption Rate) measurement standards cover devices which transmit deterministic pulsed or continuous signals such as 2G and 3G mobile phones. The recommended measurement procedure is not immediately applicable to the SAR evaluation of WiFi devices. Indeed, the signal transmitted by a typical WiFi device during data exchange is complex and cannot be easily predicted during time. The average power emitted by a WiFi device strongly depends on the data rate which in turn depends on the communication link at a given moment. For example, the data rate of a WiFi device based on the IEEE802.11b specification can be theoretically anywhere between 1 to 11 Mbps. Furthermore, although it is always possible to generate WiFi-type waveforms using a synthesizer to perform tests in the passive mode i.e. with a coaxial cable directly connected to the antenna under test, there is currently no equivalent of a standard base station emulator which enables SAR compliance tests in the active mode. The recommendations for SAR conformity assessment of WiFi devices are therefore based on the so-called manufacturer’s test mode [1]. Since the device has to be operated at maximum power level during the SAR measurement, the test mode is required to produce a duty cycle close to 100%. Unfortunately the manufacturer’s test mode is not always available. An alternative solution must be found to control the communication link of the WiFi device under test. In fact, even when the test mode is made available by the manufacturer, the SAR measurement of WiFi devices remains challenging. Since the output power of a WiFi device is relatively low – typically less than 100 mW EIRP (Effective Isotropic Radiated Power) – the magnitude of the electric field induced inside a phantom is usually close to the sensitivity level of the probe. The present study provides a procedure for the SAR measurement of laptops with WiFi functionality. It ensures repeatable measurements and it does not require the manufacturer’s test mode.

MATERIALS AND METHODS

The SAR measurement procedure is developed following a detailed analysis of the waveforms generated by WiFi communication systems based on the IEEE802.11 b and g standards. The setup for the SAR measurement is shown in Figure 1. A flat phantom filled with the appropriate tissue equivalent liquid is employed for the measurement. Several PCMCIA-based WiFi cards are tested using the same laptop computer. A commercially available software is herein chosen to generate specific WiFi waveforms compatible with the probe’s response. A peak detection approach is adopted and the usual continuous wave probe calibration data are applied for the correction of the raw measured data.
RESULTS
Table I shows typical maximum 10g averaged SAR values obtained with WiFi cards. The SAR measurement corresponds to the value obtained for a 100% duty cycle. The typical data rate observed during the measurement shows that the average power delivered by the device is about half the peak power. Thereupon it can be deduced that the actual maximum 10g averaged SAR is about half the value obtained for the case of a 100% duty cycle.

<table>
<thead>
<tr>
<th>WiFi Card</th>
<th>Typical data rate observed during SAR measurement [Mbps]</th>
<th>100% duty cycle SAR [W/kg]</th>
<th>Actual SAR [W/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco</td>
<td>4.5</td>
<td>0.10</td>
<td>0.05</td>
</tr>
<tr>
<td>Dlink 1</td>
<td>5.0</td>
<td>0.17</td>
<td>0.08</td>
</tr>
<tr>
<td>Dlink 2</td>
<td>5.0</td>
<td>0.14</td>
<td>0.07</td>
</tr>
</tbody>
</table>

CONCLUSIONS
The waveform produced by a WiFi device during data transfer is complex and unpredictable. A procedure is proposed to ensure repeatable SAR measurements of laptops with WiFi functionality. It provides the maximum 10g averaged SAR corresponding to a 100% duty cycle.

ACKNOWLEDGMENTS
The initial investigation of the exposure to electromagnetic fields from WiFi devices was done for ARCEP (Autorité de Régulation des Communications Electroniques et des Postes), France. Additional investigation is financed by the French National Research Agency in the framework of the MULTIPASS project (http://multipass.elibel.tm.fr/).

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Absorption in an adult and child body at 900 MHz for oblique incidence of a plane wave

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INTRODUCTION
The FDTD method has been used to examine the variation in whole body average specific absorption rate (SARW) in an adult and child sized body for oblique incidence of a 900 MHz plane wave. For a constant amplitude plane wave, the SARW remains relatively constant over a range of incident angles and polarisations of the field.

MATERIALS AND METHODS
The FDTD method was used to solve for the fields near the surface of a realistic, heterogeneous human body model known as NORMAN [1]. The model was re-scaled to a 4 mm cubic cell size with a height of 1.74 m and mass of 71.2 kg. A second body model, based on NORMAN with ~3 mm cubic cell resolution, was created to simulate the height (1.38 m) and mass (32 kg) of a 10y child. The electrical conductivity (σ), relative permittivity (ε_r) and mass density (ρ) values of each tissue type were based on data published by Gabriel [2]. The SARW for the human body was computed for a series of free space plane waves of magnitude 1 V/m (r.m.s.) and with the electric field component aligned parallel to either the θ or φ unit vectors in the coordinate system (Fig. 1.), or transverse magnetic (TM) and transverse electric (TE) polarization respectively. The direction of propagation of the wave towards the body was varied from θ=0° to 180° in 30° increments and from φ=0° to 270° in 90° increments. The long axis of the body was parallel to the z-axis with the front facing φ=0° and the rear facing φ=180°.

RESULTS
The absorption characteristics are plotted in fig. 2 for the adult model and in fig. 3 for the child model. The plots are for TM and TE polarisations for front (i.e. TMf or TEf) and one side (i.e. TMs or TEs) incidence of the field. The remaining exposure cases (not plotted) show similar values and characteristics. The peak SARW for the adult model is 16.7 μW/kg for TE wave while the minimum value is 7.3 μW/kg (for TM or TE) and the ratio of peak to minimum SARW is 2.3. The peak SARW for the child model is 22.6 μW/kg for TE wave while the minimum value is 12.1 μW/kg (for TM or TE) and the ratio of peak to minimum SARW is 1.9. The results indicate a 35% increase in the peak value of SARW in the child model when compared to the adult model under the same incident field conditions. If the angle θ is restricted to the most likely value in a realistic environment of 90° [3], then the peak to minimum SARW ratio is 1.9 for the adult phantom and 1.6 for the child.

CONCLUSIONS
For a constant amplitude field at 900 MHz, the SARW in an adult or child sized body
remains relatively constant over the statistically most probable incident angles and for TM and TE polarisations of the field. Assuming maximum absorption in the body when the incident field condition is unknown (i.e. during isotropic field strength measurements) could result in an over-estimation in the actual SAR\(_w\) of up to 2.3 over all angles. This value reduces to 1.9 if the angle \(\theta\) is restricted to the most likely value in a realistic environment of 90°. The analysis indicates that SAR\(_w\) estimates based on isotropic measurements of the field are relatively insensitive to the angle of incidence of the field.

ACKNOWLEDGMENTS

Dr Dimbylow (UK HPA) for kindly supplying the NORMAN data set.

REFERENCES


The magnetic field measurement of the sensitive areas near T/Ls and the evaluation of the predicted maximum/average magnetic field value


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INTRODUCTION

In 2006 and 2008, we carried out magnetic field (MF) measurements near transmission lines (T/L) around apartments, schools, kindergartens, and hospitals to study residential exposure assessment to magnetic fields in sensitive areas near T/Ls. Measurements were taken in 258 MF sensitive areas near T/Ls in 2006. We selected 51 areas (over 1µT) of the 258 sensitive areas measured in 2006 and measured them again.

When constructing the new T/Ls, electric power companies should prepare an "Environmental impact assessment" and confer with the Korean Ministry of Environment. The Korean Ministry of Environment generally requires electric utilities to submit the predicted maximum MF value because MF changes proportional to the T/L load. We don't have the any calculating standards for predicting the maximum MF value for each year, so we generally calculate it based on 50% MF value using transmission line thermal capacity. This is based on double transmission line operating conditions. When a fault occurs on one circuit, the other circuit should take charge of all loads (N-1 contingency), according to our transmission line design criteria.

Therefore, we analyzed the transmission load from magnetic field measurements in 2006 and 2008, and the max/average T/L load from those years, to calculate the predicted max MF value of the year exactly. We concluded that these max/average MF values are a defined percent of MF value, based on T/L thermal capacity.

Also, we analyzed the max/average load of that year through the overall transmission line load data in 2007. We concluded that these max/average MF values are a defined percent of MF value based on T/L thermal capacity.

Through the analysis results above, we are able to predict the max/average MF value of that year exactly by calculating the predicted valued of MF, based on the real flow of max/average transmission loads.

MATERIALS AND METHODS

304 sensitive areas were selected in 2006, and 258 were selected as final, geographically even collection of Korea. The MF measurement location is on each storey, around the apartments, schools, kindergartens, and hospitals. The maximum value of all the spot measurement values will be taken in one area.

51 areas had a value of more than 1µT, among 258 areas measured in 2006. These areas
were measured again in 2008. The measurement instrument was Narda EFA-300, EMDEX II and the type of probe is a three-axis coil.

The data analysis of the yearly maximum/average electric flow power used SOMAS (Substation Operation Result Management System) designed to calculate the real time transmission power flow. Electric power data of 2007 year on transmission line is extracted from SOMAS. Yearly maximum/average transmission loads was calculated and 2795 T/L of 154kV, 345kV, 765kV was analyzed.

RESULTS

The maximum and average values of the 258 sensitive spots near transmission lines measured in 2006 were 8.4µT and 0.28µT. We selected 51 areas (Over 1µT) from among the 258 sensitive areas measured in 2006. The maximum and average values of those areas were 6.2µT and 0.5µT.

The values are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of areas</th>
<th>Average MF Value</th>
<th>Max MF Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>258</td>
<td>0.28µT</td>
<td>8.4µT</td>
</tr>
<tr>
<td>2008</td>
<td>51</td>
<td>0.57µT</td>
<td>6.2µT</td>
</tr>
</tbody>
</table>

The reason why the average measured value of 51 areas (over 1µT) was 0.57µT in 2008 is due to the partial T/L shifting since 2006.

We analyzed the load value of each T/L at a time when MF measurements (in both 2006 and 2008) were taken and max/average T/L load values of that year. Then we concluded that the max/ average MF value was the defined percentage of MF values, based on transmission thermal capacity.

Analysis result are as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of measurements</th>
<th>Average Spot Value</th>
<th>MF Value based thermal capacity (A)</th>
<th>max MF value based yearly max load (B)</th>
<th>average MF value based yearly average load (C)</th>
<th>Analysis results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>106 area</td>
<td>1.21µT</td>
<td>5.96µT</td>
<td>2.22µT</td>
<td>1.45µT</td>
<td>B/A×100 = 37%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C/A×100 = 24%</td>
</tr>
<tr>
<td>2008</td>
<td>45 area</td>
<td>1.61µT</td>
<td>8.54µT</td>
<td>3.07µT</td>
<td>2.14µT</td>
<td>B/A×100 = 36%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C/A×100 = 25%</td>
</tr>
</tbody>
</table>

Continuous allowable currents for each T/L circuit (Heating Capacity) are:
- 154kV (ACSR 410㎟×2B) Continuous allowable current = 848A/1B × 2 B =1696A
- 345kV (ACSR 480㎟×4B) Continuous allowable current= 909A/1B × 4B =3636A
- 765kV (ACSR 480C㎟×6B) Continuous allowable current= 917A/1B × 6B =5502A

We analyzed all of the T/L load values in Korea in 2007, one year of load data, and calculated the max/ average T/L load to evaluate the max/ average MF level exactly.

The result of the analysis is as follows.

<table>
<thead>
<tr>
<th>year</th>
<th>analyzed number of T/Ls</th>
<th>Total sum of thermal capacity (A)</th>
<th>Total sum of yearly max T/L load (B)</th>
<th>Total sum of yearly average T/L load (C)</th>
<th>Analysis results</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>2795 T/L</td>
<td>1,234,003 MVA</td>
<td>213,608 MW</td>
<td>555,360 MW</td>
<td>B/A×100 = 45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C/A×100 = 25%</td>
</tr>
</tbody>
</table>

The number of the T/L : 154kV 2596T/Ls, 345kV 193T/Ls, 765kV 6T/Ls
CONCLUSIONS

The average value measured for 258 sensitive spots near transmission lines is less than 0.3µT. The maximum value is 8.54µT, as measured on the roof of the building 5 meters from 154kV transmission lines.

The magnetic field strength of the T/L is directly proportional to the T/L load. Therefore, we could estimate the predicted maximum and average magnetic field strength of that year with the maximum and average load value. We analyzed the magnetic field strengths of each transmission line measured in 2006 and 2007 to estimate the accurate predicted maximum and average magnetic field strength of the year for the new transmission lines.

We also analyzed the load value data from 2007 in transmission lines around Korea.

We found the following results:
- predicted value of max MF strength of that year (New T/L) = 45% of magnetic field value based on transmission thermal capacity
- predicted value of average MF strength of that year (New T/L) = 25% of magnetic field value based on transmission thermal capacity

Therefore, we can estimate the maximum predicted MF strength of the new T/L as 45% of the MF strength based on the T/L thermal capacity. We can estimate the average predicted MF strength of the new T/L as 25% of the MF strength based on the T/L thermal capacity as well.

ACKNOWLEDGMENTS

The measurement of sensitive area near transmission lines was performed by KIEE (Korea Institute of Electrical Engineers).
Exposure of the Driver and the Passenger of a Car to the Radiation of a GPS Equipment

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INTRODUCTION

Certain vehicles are equipped with a GPS making it possible to locate it remotely. This GPS equipment sends its data by the GSM network. During the exchange of the data the driver of the vehicle and the possible passenger are exposed to a radiofrequency electromagnetic field. It is interesting to characterize this exposure. This study is devoted to this characterization in the case of a Renault Laguna car.

MATERIALS AND METHODS

The GPS equipment regularly sends its data on network GSM900 when the contact of the vehicle is put. The SARmeter [1] [2] was used to characterize these emissions (figure 1). It makes it possible to obtain, the relative power and the presence of an emitted pulse, over an important duration. The SARmeter sensor is placed on the GPS antenna. Then the software execution is started, the contact of the vehicle is put, and the GPS radiated power is recorded.

The data are processed to evaluate the duration of each transaction, its number of TDMA frames with pulses, the normalized average power of these frames, its radiated relative energy and the period of repetition of the transactions.

RESULTS

The used GSM frames of each transaction comprise two pulses (TDMA time slots). Five successive measurements were carried out, leading to a total of 24 transactions. The transactions 1 to 10 and 14 to 24 took place with the motionless vehicle on a carpark. The transactions 11 to 13 took place when the vehicle ran. The characteristics of the transactions (figures 2 to 5) are relatively stable with some variations for that corresponding to the moving car, in particular the number 12. The period duration (figure 6) is also stable.

The electric field radiated by the GPS equipment on the front seats of the vehicle was measured by a field meter. Its maximum value is 7V/m. For a six minutes duration, there are two transactions in the worst case. Taking account the mean number of frames with emitted pulses for two transactions and the normalized radiated power, the mean value of the electric field is about 1V/m.

CONCLUSIONS

The measurements of the emitted power of an embarked GPS equipment in function of time, and the radiated electric field during the emission allowed the evaluation of the exposure level on the front seats of the vehicle. This level is very lower than the normative limits. The use of the SARmeter hardly simplifies this evaluation.
Figure 1: Measurement of the GPS radiation with the SARmeter

Figure 2: Transactions duration

Figure 3: Normalized mean power of each transaction

Figure 4: TDMA pulses number

Figure 5: Normalized energy of each transaction

Figure 6: Transaction period

REFERENCES


Parameters Affecting Numerical Estimation of Internal Body Resistance of Human Model at Power Frequency

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INTRODUCTION

Characteristics of power-frequency touch current inside an anatomically realistic human model of Japanese adult[1] were numerically analyzed under various scenarios of current paths by using a modified spfd method[2]. In this paper, complex distributions of the electric fields and current densities in the model is visually illustrated, and effects of both the tissue conductivity in computational work and the potential electrodes in experimental work on the internal body impedance are discussed.

NUMERICAL CONDITIONS, RESULTS AND DISCUSSIONS

A numerical model employed was composed of about 8 million cubic voxels of 2 mm × 2 mm × 2 mm in size, and had 51 tissues or organs identified. Two kinds of the numerical models were used: a homogeneous model with the conductivity of 0.164 S/m for all voxels, and an inhomogeneous model. Furthermore, two sets of conductivities were assigned to the inhomogeneous model in order to investigate the influence of conductivity. Major difference between the two sets are the conductivity of the muscle for 60 Hz: one has $\sigma_{\text{muscle}} = 0.24\text{ S/m}$[3], and another has $\sigma_{\text{muscle}} = 0.35\text{ S/m}$[4].

Whole-body profiles of electric fields and resultant current densities obtained for the inhomogeneous model of 0.5 mA contact current are shown in Fig. 1 for the three current scenarios. It is visually demonstrated that the distributions of $E$ and $J$ largely depend on the current scenarios. It is clear that the $E$ and $J$ of significantly high magnitude appear not only in the extremities, but also in the chest. Especially, $J$ of high magnitude appears at tissues of high conductivity such as muscle, CSF and blood. Meanwhile, there is only minimal current flow into the head for all the current scenarios.

Figure 1: Profiles of electric fields and resultant current densities. Contact current of 0.5 mA. $\sigma_{\text{muscle}} = 0.24\text{ S/m}$. Position of electrodes: RH: Palm of right hand, LH: Palm of left hand, BF: Sole of both feet.
Internal body impedance $R_i$ and resistance of the equivalent five-resistor model obtained for the four current scenarios are shown in Table 1. Data derived from other sources[5, 6, 7] are also listed in Table 1 for comparison. It is obviously indicated in Table 1 that $\sigma_{\text{muscle}}$ significantly affects the estimation of $R_i$. It is seen that the present numerical value is similar to another numerical resistance[5], and is larger than the experimental resistance[6, 7].

In measuring $R_i$, a contact current meter usually uses the four-terminal method [6], in which a pair of potential electrodes (PE’s) is attached near a pair of current electrodes (CE). In this situation, the potentials of PE’s with a finite area are floating, and hence the voxels attached to the PE’s are forced to be equipotential of a single floating value. Effects of the attachment of such floating electrodes (20–25 cm$^2$ in area) on $R_i$ are investigated, and the calculated results are shown in Table 2. It is clear that the existence of the large-area floating electrodes significantly underestimates $R_i$ by a factor of up to 1.27 in the present cases, depending on the current scenarios.

CONCLUSIONS

The internal body resistances $R_i$ obtained are larger than the measured values reported to date. It is demonstrated that $R_i$ measured by the four-terminal method may be underestimated when the large potential detection electrodes are used. It is also indicated that the conductivity of muscle significantly affects the estimated value of $R_i$.

REFERENCES


Table 1: Internal body resistance $R_i$, and resistances of five-resistor model.

<table>
<thead>
<tr>
<th>Homogeneous</th>
<th>Inhomogeneous, $\sigma_{\text{muscle}} = 0.24$ S/m</th>
<th>Inhomogeneous, $\sigma_{\text{muscle}} = 0.35$ S/m</th>
<th>Ref.[5] (Num.)</th>
<th>Ref.<a href="Exp.">6</a></th>
<th>IEC<a href="Exp.">7</a></th>
</tr>
</thead>
<tbody>
<tr>
<td>LH-BF</td>
<td>1.080</td>
<td>1.460</td>
<td>1.510</td>
<td>1.183</td>
<td>775</td>
</tr>
<tr>
<td>RH-BF</td>
<td>1.040</td>
<td>1.460</td>
<td>1.270</td>
<td>1.685</td>
<td>755</td>
</tr>
<tr>
<td>H-H</td>
<td>1.440</td>
<td>1.940</td>
<td>1.270</td>
<td>1.560</td>
<td>843</td>
</tr>
<tr>
<td>F-F</td>
<td>1.130</td>
<td>1.630</td>
<td>1.270</td>
<td>1.270</td>
<td>51.5%</td>
</tr>
<tr>
<td>Legs</td>
<td>563</td>
<td>815</td>
<td>635</td>
<td>560(M)</td>
<td>690(F)</td>
</tr>
<tr>
<td>Arms</td>
<td>720</td>
<td>971</td>
<td>755</td>
<td>280(M)</td>
<td>280–290(F)</td>
</tr>
<tr>
<td>Trunk</td>
<td>58.5</td>
<td>79</td>
<td></td>
<td>265–270(M)</td>
<td>334–345(F)</td>
</tr>
</tbody>
</table>

Table 2: Effect of potential electrodes in measuring the internal body resistance. $\sigma_{\text{muscle}} = 0.35$ S/m.

<table>
<thead>
<tr>
<th>Potential electrodes are:</th>
<th>RH-LF</th>
<th>RH-RF</th>
<th>LH-LF</th>
<th>H-H</th>
<th>F-F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignored; $R_c$</td>
<td>1.450</td>
<td>1.450</td>
<td>1.440</td>
<td>1.510</td>
<td>1.270</td>
</tr>
<tr>
<td>Considered; $R_m$</td>
<td>1.210</td>
<td>1.210</td>
<td>1.240</td>
<td>1.330</td>
<td>1.010</td>
</tr>
<tr>
<td>$R_c/R_m$</td>
<td>1.20</td>
<td>1.20</td>
<td>1.16</td>
<td>1.14</td>
<td>1.27</td>
</tr>
</tbody>
</table>
SAR and Temperature Elevation Evaluation Using Japanese Anatomical Human Models for Body-Worn Usage

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INTRODUCTION

We previously presented Specific Absorption Rate (SAR) calculation results for Japanese adult male and female models at 900 MHz using the Finite-Difference Time-Domain (FDTD) method when an antenna is located in close proximity to the trunk of the body [1]. It was shown that the 10g average SAR of the male model was approximately two times higher than that for the female model. The next step is to investigate the relationship between the SAR and the temperature elevation including other higher frequencies.

MATERIALS AND METHODS

We employ the Japanese anatomical male and female models [2] to calculate the SAR distribution at 900, 1950, and 3500 MHz and the temperature elevation. The 3500 MHz is the center frequency for IMT-Advanced, which is defined by the International Telecommunication Union (ITU) as systems beyond IMT-2000 [3]. A half-wave dipole antenna is located in front of the abdomen of each anatomical model such that the antenna feeding point is 15 mm away from the closest surface of the phantom. The electrical properties and thermal constants are obtained from [4] and [5], respectively. At first, the SAR distribution is calculated using the FDTD method. Then the temperature elevation is obtained through simulation using the bio-heat equation and the calculated SAR results.

RESULTS

The peak 10g average SAR normalized to that of the male model at 900 MHz is illustrated in Fig. 1. The SARs of the male model at 1950 MHz and 900 MHz are higher than those for the female model. This may be due to the effect of fat thickness [1]. On the other hand, the SARs of these models are almost the same at 3500 MHz. In addition, the SARs at 3500 MHz for both models are lower than the respective values at 1950 MHz. This is because the peak local SAR appears in the skin layer at 3500 MHz while it appears in a deeper region of the body at lower frequency. The fixed distance of 15 mm away from the body also affects the SAR because the antenna position relatively becomes farther away from the surface as frequency higher considering the wavelength in air.

Figure 2 shows the maximum temperature elevation with the same input power. The results in Fig. 2 are also normalized to the temperature elevation in the male model at 900 MHz. It is clear that the temperature elevation in the male and female models at 900 MHz and 1950 MHz are almost the same even though the peak SARs of the male model are higher than those of the female model and vice versa at 3500 MHz. Note that the maximum temperature elevations are located in the skin layer for all cases. This can be partly explained by calculating the absorbed power ($\rho \times \text{SAR}$) in the body, where $\rho$ is the density of the tissue.
The absorbed power is almost the same between the male and female models at 900 and 1950 MHz while the peak 10g SARs are different. On the other hand, the absorbed power of the female model is higher than that for the male model at 3500 MHz. This might be due to the standing wave effect at a higher frequency [6].

CONCLUSIONS

The SAR and temperature elevation using Japanese anatomical human models for body-worn usage at 900, 1950, and 3500 MHz were evaluated. The results show that there is a difference in the 10g average SAR between the male and the female models, but the temperature elevation is almost the same at 900 and 1950 MHz and vice versa at 3500 MHz. However, both the SAR and temperature elevation at 3500 MHz are smaller than those at 1950 MHz. These are preliminary results and more detailed evaluation is necessary.

ACKNOWLEDGMENTS

The authors thank Prof. Akimasa Hirata of the Nagoya Institute of Technology for his valuable suggestions regarding the temperature calculations.

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Analysis of Ray-Tracing Techniques in RF Exposure Assessment

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INTRODUCTION

Personal exposure meters (PEM) are usually employed to assess individual RF exposure in bioelectromagnetic research. Nevertheless some shortcomings have been reported in the scientific community as shadowing effect caused by the subject body or false summation of signals within the same band [1][2]. Moreover, the large proportion of measurements below the detection limit difficult the post-processing and data analysis. Therefore it could be stated that there is a need for reliable propagation models in terms of statistical parameters to assess the accuracy of PEM and help researchers in post-processing. While indoor there are models able to predict CDF with a maximum deviation of less than 1% [3], outdoor correlation between PEM readings and propagation prediction tools still has to be defined.

MATERIALS AND METHODS

Data sets of measurements were gathered in an outdoor environment with a personal exposure meter DSP-090 from SATIMO, synchronized with a GPS receiver in order to geo-position each of the PEM samples. The device was placed in a small backpack at a height of 1.4m; maintaining vertical axis pointing upwards. Several walking routes were made, all of them with more than 100 samples. Two of them were in LOS and avoiding shadowing effect, with the purpose of model calibration. We contrasted the results of these PEM data logs with the ray-tracing simulator introduced in [1]. A dual-frequency (950 MHz/2150 MHz) 30m height base station was the nearest GSM source in the testing area. Additional frequency selective measurements were made to discard other possible near sources.

Each value below the PEM detection limit was substituted for the threshold value in order to emulate the response of the device. In addition, E-field levels were quantified at intervals of 0.01V/m. With the aim of offering an approximation of the shadowing effect we defined a “shadow area” as a function of the direction of the person while walking. Rays whose Angle of Arrival fell in this area were not considered in E-field calculation, as shown in Figure 1.

Figure 1: Identification and approximation of shadowing effect. (a) Azimuth between a sample and the next one is computed and limits are defined around it as a function of a limit angle. (b) Example of simulation route with a limit angle of 60°. Rays in red would fall in “shadow area” and would be discarded.
RESULTS

We employed the mean error of all routes to adjust the EIRP of the source. It should be noticed that in GSM band, the axial isotropy of the device provided by manufacturer is ±2 dB and there is an additional error associated to GPS geo-position. In general, a sixth-order scattering, including the first order of diffraction, was enough to emulate PEM and no further improvements were found in representation by employing a higher order.

Approximation of shadowing effect showed an improvement. But it tends to slightly underestimate E-Field levels, most likely because diffraction effect around the body is not taken into account. Instead, it has been proved as a simple and useful tool to identify readings affected by shadowing effect and provide estimation to E-field level in the absence of the body. A representation of results in a route using a limiting angle of 60° is shown in Figure 2.

Figure 2: Analysis of routes with the influence of shadowing effect. (a) Simulated E-Field levels. In samples from 11 to 70 the person carrying PEM was walking towards base station as shown in Figure 2b. Ray-tracing without shadowing effect reflects higher levels in these samples. (b) Empirical CDF

CONCLUSIONS

Ray-tracing techniques can provide a general idea of PEM results in a dynamic outdoor environment. A simple technique has been presented to detect measurements affected by body shadowing and compute E-Field levels in absence of the body. It should be noticed that this method could be extended to offer a similar approximation to axial isotropy effect, as it depends also on azimuth angle while maintaining vertical axis.

ACKNOWLEDGMENTS

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REFERENCES

Computed SAR and Temperature Rise in an Anatomical Head Model by a 900 MHz Dipole Antenna

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INTRODUCTION

Earlier we reported on a threshold power rationale for low power wireless devices compliance test exemption based on the SAR results of low directivity antennas next to a flat phantom [1, 2]. In the present work we attempt to develop a similar rationale based on temperature rise in an anatomical head model due to radiation from dipole antennas. SAR and temperature rise due to wireless hand-held terminals have been studied for various different antennas and head models [3]. In this work, numerical simulations of exposure were conducted with the flat phantom and in the Duke anatomical head model. Antenna considered in this study include a half-wave dipole antenna operating at 900 MHz. Two FDTD simulation solvers XFDTD® [4] and FDTDLab™ [5] were used.

MATERIALS AND METHODS

The Duke head model was obtained from the Duke whole body model developed by the ITIS foundation [6]. It contains 47 different tissues/organs. The electrical and thermal properties of the different tissues/organs were collected from [7]. The pinna in this model was compressed by reducing its thickness from 18 mm to 5 mm, to represent the morphology during a phone call. The flat phantom (225 mm x 150 mm x 150 mm) has two tissue types: the skin (2 mm thick) and the average brain tissue with the properties taken from [7]. The dipole was placed at 10 mm distance from the head model (Figs. 1(a)-1(b)). The distance of the antenna was measured from the outermost part of the pinna to the antenna feed point (see Fig. 1(b)). For the flat phantom the distances are measured from the antenna feed point to the skin-brain interface. In each simulation setup the cell size was 1 mm throughout the whole geometry. A sinusoidal excitation was applied and eight layers of PML absorbing boundary were employed.

Figure 1: (a) Dipole antenna next to the Duke head model, (b) separation distance ‘h’.
RESULTS

The SAR and temperature rise from dipole antennas computed by XFDTD® and FDTDLab™ are shown in Table 1. Peak 1g and 10g average SAR values are in good agreement. The temperature rise data obtained from the two programs are within the range for similar simulated scenarios described in the literature, e.g., [3]. The observed differences in temperature rise can probably be attributed to the different way those two programs model this physical problem: use of thermally conductive air surrounding the skin in XFDTD® and the convective boundary condition at the skin surface in FDTDLab™. Those differences will be further investigated to determine the effect of the modeling on the results.

Table 1: SAR and Temperature Rise for Dipole Antenna for 0.6 W input power.

<table>
<thead>
<tr>
<th></th>
<th>Duke Head (10 mm) XFDTD®</th>
<th>Duke Head (10 mm) FDTDLab™</th>
<th>Flat Phantom (8 mm) XFDTD®</th>
<th>Flat Phantom (8 mm) FDTDLab™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak 1g average SAR, W/Kg</td>
<td>3.50</td>
<td>3.65</td>
<td>8.06</td>
<td>8.04</td>
</tr>
<tr>
<td>Peak 10g average SAR, W/Kg</td>
<td>1.82</td>
<td>2.09</td>
<td>4.69</td>
<td>5.07</td>
</tr>
<tr>
<td>Max temperature rise, °C</td>
<td>0.20</td>
<td>0.12</td>
<td>0.19</td>
<td>0.40</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The SAR and temperature rise in the anatomic ally correct human head model exposed to EM radiation from dipole antennas were computed using two different simulation tools. The obtained results will contribute to the development of a new threshold power rationale for low power wireless devices compliance test exemption based on the temperature response of human tissue exposed to RF energy.

ACKNOWLEDGMENTS

This work is supported by the Mobile Manufacturers Forum (MMF), Brussels, Belgium and the GSM Association (GSMA), London, UK.

REFERENCES


INTRODUCTION

Classical dosimetric assessment systems are very slow, which leads to important measurement durations, typically 15 minutes per mobile phone configuration. This duration comprises two parts: the movement of the probe and the time of measurement on each space point. The reduction of the duration of measurement requires either to increase the speed of mechanical displacements of the probe, and/or to reduce the time of measurement per space point. The use of fast mechanical displacements solves the first point. The second point requires a sufficient measurement sensitivity and to take into account the possible time variations of the radiation of the mobile phone.

MATERIALS AND METHODS

We have conceived and implemented a new dosimetric assessment system at Supélec [1]. We use new mechanical displacements allowing high speeds and accelerations. The dimensions of the explored area are 2.17m by 1.80m in a horizontal plane and 0.60m following the vertical axis. The movement duration for a 5mm spatial step is about 0.1s. We have developed a specific electronic interface, consisting of a low noise amplifier and a coherent detector. This interface presents excellent performances in term of noise and stability.

This dosimetric assessment system allows the SAR measurement of mobile phone, even at very low level. For GSM mobile phones, the period of the emitted power envelope is the multiframe, and its duration is of 120ms. This multiframe is made up of 26 TDMA frames with a duration of 4.6ms. Each TDMA frame contains one or several timeslot (one for GSM and several for GPRS and EDGE technologies) with a duration of 577μs, except one among the 26 TDMA frames of a multiframe (figure 1). In classical system, the measurement duration per space point is greater than 120ms, and the measurement corresponds to the mean emitted power of the GSM phone.

A measurement time of two frames per space point allows the reduction of the SAR test duration, while guaranteeing the presence of at least one pulse of emission during the measurement. The SAR values obtained in this way must be corrected of a factor 25/26.

RESULTS

Figure 2 shows the comparison of local SAR map of a GSM mobile phone obtained respectively by multiframe (a) and single frame (b) measurements. The difference on the
maximum SAR value is about 0.5%. Figure 3 presents the comparison of the SAR1g and SAR10g obtained respectively by multiframe (1-6) and single frame (7-12) measurements. The measurements were carried out successively in the following order: 1, 2, 3, 7, 8, 9, 4, 5, 6, 10, 11, 12. The peak to peak differences between the obtained SAR values are about 3%. The durations of multiframe and single frame measurements are respectively 72s ans 40s. The SAR data processing duration is 20ms.

Figure 2 : Comparison of local SAR maps (mW/kg) of a GSM mobile phone (a: multiframe, b: single frame).

CONCLUSIONS

The dosimetric assessment system of Supélec and the proposed method allow fast SAR measurement of GSM mobile phones, with low accuracy degradation, a few percents. Measurement durations of 40s were carried out. The 6 different measurements corresponding at a given frequency band take about 4 minutes. This speed will make it possible to reduce the cost of measurements.

ACKNOWLEDGMENTS

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REFERENCES

Assessment of the SAR from Hands-free Kits for Mobile Phones

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INTRODUCTION

There have been discussions as to what extent the use of wired hands-free kits (HFK) with mobile phones impacts on the SAR in the human body. For example, a controversial study in the British \textit{Which?} magazine found a considerable increase of the SAR in the human head when using wired HFK. The results and shortcomings of the \textit{Which?} study have been discussed in a scientific paper \cite{1}. This paper also evaluated the effect of wired HFK numerically and experimentally at 900 MHz. Another study \cite{2} focused on the effect of a wired HFK used with a DCS (1750 MHz) GSM mobile phone worn at the trunk. Besides these two publications, little peer-reviewed data on the effect of using a wired HFK on the SAR in the human head and trunk are available. Today, wireless HFK are becoming even more popular than wired HFK. Besides SAR measurement results in \cite{3} from 2 wireless HFK, no peer-reviewed data on the exposure from those devices are currently available. The most important questions discussed in this study are whether separate compliance testing is required for HFK and the extent to which the use of wired and wireless HFK can reduce human exposure.

MATERIALS AND METHODS

In the experimental part of the study, a worst-case analysis regarding the maximum human exposure when using wired HFK in the ear was performed. The experiments used with a brick type phone with integrated antenna and a clam-shell phone with an external antenna and 3 different HFK each. The tests were conducted with the phones operating in the GSM900, DCS1800, and UMTS1950 bands. The analysis especially focused on the compliance with the limits of the ICNIRP guidelines. Therefore the evaluation procedure was based on 1) a method of maximizing the current coupling on the hand-free kit cable, and 2) disregarding losses along the cable. In addition to the worst-case scenario, we also investigated various realistic scenarios concerning distance of the cable from the body. We further analyzed the SAR from 3 wireless HFK in a newly developed measurement phantom for devices that are partially surrounded by tissue.

In the numerical part of the study, a mobile phone and a compatible HFK were modeled. Both models were validated and used on two anatomical human models. The simulations were performed at the chest and pant pocket positions with both front and back sides of the phones facing the human phantom. A realistic routing of the HFK towards the ear was simulated. A generic exposure scenario with the earbud in the ear compared to the ear-bud as measured on the flat phantom was also simulated.

RESULTS

In none of the evaluated worst-case configurations was the SAR with wired HFK higher than the ICNIRP limit. Even the maximum determined SAR was lower than
the limit by a factor of 5. Investigating the relative increase or decrease of the SAR when using a HFK compared to the phone at the ear might result in an increase when using a HFK under worst-case conditions. However, this increase is only due to the low absolute SAR of modern SAR-optimized phones. The study also revealed that, despite significant differences between the phones and the individual HFK, there was no significant difference in the SAR on the earbud. We found that bringing the cable to a distance of 15 mm to the body already decreases the SAR by 4-15 dB. With direct contact of the cable to the body, the attenuation may be as high as 13-26 dB. Using a mobile phone with HFK does not increase the SAR in the trunk compared to the worst-case compliance test value without HFK. The dosimetric assessment of wireless HFK has shown that a very low SAR can be expected from those devices, i.e., a SAR in the range of that from wired HFK with strong attenuation along the body.

The evaluation of the numerical results confirmed the results of the experimental study. In the pant pocket configuration, the SAR in the head corresponded to the SAR values determined in the experimental study at 0-15 mm distance between the cable and the body. The shirt position caused higher SAR in the head due to lower attenuation on the cable running along the body. We found that the 10 g averaged SAR in the ear was reliably reproduced by a flat phantom measurement. In contrast to this, the comparison of the 1 g averaged SAR shows an underestimation by 5 dB. This suggests a very localized exposure in the ear that is not reliably reproduced in the flat phantom.

CONCLUSIONS
In conclusion, there is no need for additional compliance testing of wired HFK. In the worst-case there may be a very localized increase of the exposure in the inner ear when using wired HFK. In general, however, hand-free kits lead to a considerable reduction in the exposure of the head. This reduction depends on transmit power of the mobile phone, the coupling from the phone to the cable, the external attenuation and possibly additional cable specific attenuation. Wireless HFK cause a low but also constant level of exposure, whereas the exposure from wired HFK depends on the aforementioned factors and specifically the power control of the mobile phone.

Future research should look into the estimation of real-life coupling scenarios. Further investigations are necessary in order to evaluate the extent to which functional regions of the brain or the ear are affected by the very localized exposure in the anatomical ear.

ACKNOWLEDGMENTS
We would like to thank the German Federal Office for Radiation Protection (BfS) for the financial support of the study.

REFERENCES
Characterization of Magnetic Field Exposure on British Electrified and Non-electrified Trains.

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INTRODUCTION

Following two pooled analyses of epidemiological studies, it is now largely accepted that there is an approximate doubling of risk of childhood leukaemia associated with exposure to time-weighted average (TWA) power frequency magnetic fields (MF) greater than 0.3/0.4 μT [1, 2]. Further investigations have shown the significance of \textit{in utero} MF exposure in relation to increased risk of miscarriage [3, 4]. Whilst occupational and residential exposures have been considered in epidemiological studies, there remains the potential for high exposures from other sources such as those from public transport systems. Alternating MFs up to 30 μT have been recorded in passenger cars of electric powered trains, with static fields reaching several mT in magnitude [5]. This may have implications for pregnant women travelling by train.

The majority of epidemiological studies investigating MFs in relation to health effects have used 12- and 24-hour TWA field strengths as a measure of exposure accompanied by spot measurements. Due to the inherent complexity of power frequency MFs from multiple sources, it has been suggested that the TWA may be too simplistic in characterizing exposure. The rate of change metric, a measure of the temporal stability, has recently been employed in a number of studies and evidence suggests that the variability of MFs may be more effective in inducing biological response [6].

This study highlights the complex exposure patterns encountered on British electrified and non-electrified trains with measurements taken over the entire journey period.

MATERIALS AND METHODS

MF measurements were made using EMDEX II monitors, calculating the r.m.s. magnitude of the field vector over a broadband frequency of 40 – 800 Hz. Measurements were taken continuously at 1.5 s intervals on board 25 kV a.c. electrified and diesel powered trains. EMDEXs were placed at head, waist and floor heights in areas of the carriage where passengers are able to sit or stand. TWA, maximum and minimum field strength, and the time spent above a certain threshold were then calculated, as well as the rate of change metric.

RESULTS

Figure 1 gives an example data set of the resultant MF measured at waist and floor heights on a diesel powered train. It can be seen at the start of the journey (arrow) that the field is much more variable, indicated by the higher rate of change metric, compared to the rest of the journey. This corresponds to the train travelling along a section of track with overhead electrified supply lines. Also, the average MF is higher at floor height (0.56 ± 0.15 μT) compared to that at waist height (0.25 ± 0.16 μT). This agrees with previous measurements [5] which attribute this to traction and control circuitry mounted beneath the carriage.
CONCLUSIONS

The results highlight that the type of train and route taken are important factors to consider when estimating passenger exposure. The position within the carriage and height above floor level are significant factors. MFs up to 11 μT were recorded on electrified trains and the variability of exposure was dependent on position within the carriage. It was noted that periodic peaks in MF ~2.5 μT in magnitude occurring for approximately 25 s were recorded at the end carriages on the diesel train studied.

ACKNOWLEDGMENTS

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REFERENCES

On the relationship between handset emitted and received powers in 2G and 3G operating networks

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INTRODUCTION

The power emitted by wireless systems and especially for mobile communications like GSM and UMTS is monitored by the network to ensure a target signal to noise level. For this purpose, power control mechanisms are implemented to adjust dynamically the emitted power and to minimize interference depending on the path loss, the environment fading [1] severity, the network density [2] and the access technology. Hence, the worst case assessment approach recommended by EMF standards overestimates the real use conditions exposure and losses a comprehensive or end to end view of the link between a handset and a base station in terms of exposure.

Many studies have been published to analyze instantaneous emitted power by mobile devices. For example, [3] [4] give an analysis of the power control and handover mechanisms influence for GSM handsets while in [5], UMTS terminals emissions are characterized for different environments. It is clearly shown that the real power is relatively much lower than their allowed power capabilities. In the other hand, exposure to fixed base stations studies based on both simulation and on-site measurements are conducted to respond to the public concern about EMF. However, the state of art in dosimetry studies does not take into account the link between exposure induced by operating base stations and by the handsets in real conditions. Indeed, the channel being used in duplex mode is one of the most important characteristics of the physical channel in mobile communications compared to broadcasting.

METHOD

A measurement campaign has been conducted in France (Paris) to collect the stream exchange between mobile phones and some selected base stations in different areas. For this purpose dedicated probes were connected to base stations. The uplink emitted (Tx)/downlink received (Rx) powers were recorded during real calls with a rate of about 2 samples per second.

For 2G measurements, around 3.5 millions pair values of TxPower and RxPower were collected. All environments (urban, rural, indoor, outdoor, static, moving, in car….) were covered. Moreover, around 400 mobiles have been taken into account. In the case of 3G measurements, around 145000 pair values of TxPower and RxPower are considered from trace mobiles.

RESULTS

Figure 1 shows an example of the time variation of the transmitted and the received signal captured by a handset during a real call in different environments. It is shown that the received (Rx) signal is highly variable but still correlated to the level of the transmitted (Tx) power. Indeed, a weak received signal reveals a high downlink path loss which induces as
expected a high transmitted power for the (Tx) uplink propagation.

The (Tx/Rx) pairs of measurements are plotted in Figure 2. It is shown that power is better controlled in 3G-UMTS system than in GSM due to the faster power control and the handover management (the emitted power is set to the maximum after a hard-handover in GSM systems).

Hence, the average handset transmitted power in UMTS is around 1% of the maximum while in GSM it is between 25% and 50%. A clear relation is observed between emitted and received power especially for UMTS signals which indicates that the better is the reception the lower is the mobile phone transmitted power.

The presented results can be extrapolated to evaluate daily real exposure and to estimate the ratio between instantaneous and the normative maximum exposure. This is very important to inform the public about exposure to EMF and its variability due to the reception conditions while underlining the close link between handsets and base stations in operating networks.

Figure 1: Time variation of the transmitted (Tx) and received (Rx) for indoor/outdoor measurements

Figure 2: Correlation between TxPower and RxPower for 2G and 3G services.

REFERENCES

Evaluation Of Electromagnetic Fields From WiFi Devices: In-Situ Measurements

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INTRODUCTION

Following the advent of WiFi communication systems in our everyday life, the question regarding the electromagnetic field exposure from devices such as WiFi laptops and access points or hot spots was raised. The verification of the basic restriction quantified by the Specific Absorption Rate (SAR) measurement is discussed in a companion paper. Herein the in-situ characterization of the electric fields generated by WiFi access points is considered. Currently, WiFi devices operate according to three different flavors of the IEEE802.11 standards: a, b and g [1,2]. Among other parameters, each flavor specifies a given modulation scheme, maximum achievable data rate and EIRP (Effective Isotropic Radiated Power) limit. For example, the EIRP of IEEE802.11b devices based on the Direct Sequence Spread Spectrum (DSSS) modulation scheme is limited to 100mW while the maximum theoretical data rate is 11 Mb/s. However, depending upon the electromagnetic environment at a given moment, the actual data rate can be anywhere in-between 1-11 Mb/s. The output signal and the average power delivered by the device will not be constant when the electromagnetic field measurement is performed in an uncontrolled environment.

MATERIALS AND METHODS

The in-situ measurement procedure is developed following a detailed analysis of the communication protocols of WiFi systems based on the IEEE802.11 b and g standards which both share the 2400 MHz frequency band. The electric field is measured using a bi-conical antenna connected to a standard spectrum analyzer. For the measurements presented herein, the basic spectrum analyzer parameters are set as follows: RBW=5 MHz, ZERO SPAN and MAX HOLD. The RBW value is limited by the spectrum analyzer. An appropriate correction factor is therefore applied to account for the difference between the enforced RBW setting and the actual bandwidth of the WiFi signal. These settings provide the maximum electric field independently of the data rate. The measurements are performed at several sites where access points are already installed: conference room, library, cafeteria and office. For the case of the conference room wherein only one access point was initially installed, two additional access points were appropriately mounted to obtain an optimized three channel WiFi network at the same site (see Figure 1). The measurements are performed either while the access point is in the beacon mode or while extensive data are transferred between two laptop computers via the access point (see Figure 2). The electric fields are recorded for several distances of the antenna with respect to the nearest point of the access point under investigation.
RESULTS

The measurements show that the maximum electric field is typically of the order of 1 V/m at about 1 meter from the access point. At a distance of 20 cm, for which the SAR evaluation is actually recommended, maximum electric fields of about 6 V/m are measured at some sites.

CONCLUSIONS

The maximum electric fields measured near WiFi access points are much lower than the reference level (61 V/m). These measured values are consistent with those which would be theoretically derived using the EIRP of the device.

ACKNOWLEDGMENTS

The initial investigation of the exposure to electromagnetic fields from WiFi devices was done for ARCEP (Autorité de Régulation des Communications Electroniques et des Postes), France. Additional investigation is financed by the French National Research Agency in the framework of the MULTIPASS project (http://multipass.elibel.tm.fr/).

REFERENCES


Formulations for Numerical Dosimetry of Currents Induced in the Human Body by ELF Magnetic Fields

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INTRODUCTION

The fields induced in the human body by ELF electromagnetic fields are extremely weak, and hence very difficult to measure; therefore numerical dosimetry is an important issue. The most used formulation of magnetically induced fields is the $\phi - a$ formulation, which takes benefit of the particular features of the human body \cite{1,2}: the displacement currents and the reaction field may be neglected for low frequencies (less than 1 MHz). However, this formulation requires as source term a magnetic vector potential, which is difficult to obtain from measurements of the magnetic field. This requirement can be a problem in practical situations where an accurate model of the radiating source is not available. In this work, we propose a new $t - b$ formulation for ELF numerical dosimetry which, under the same assumptions of $\phi - a$ formulation, allows to compute the induced fields by taking as source term directly $b$. As in the $\phi - a$ formulation, the computation domain is bounded to the human body.

THE FORMULATION

Let $b$ a source magnetic flux density, and assume that it is not modified by the human body. From: \( \text{curl} \ h = j \) one obtains: \( \text{div} \ j = 0 \Rightarrow j = \text{curl} \ t \). The vector potential \( t \in H(\text{curl}, \Omega) \) is the unknown. The equation \( \text{curl} \ e = -\partial_t b \) can be written as:

\[
\text{curl} \frac{1}{\sigma} \text{curl} \ t = -\partial_t b
\]  \hspace{1cm} (1)

Green’s formula for curl-curl leads to a weak form of the formulation:

\[
\left( \frac{1}{\sigma} \text{curl} \ t, \text{curl} \ w \right) + \left( \partial_t b, w \right) = 0 \ \forall w \in H(\text{curl}, \Omega)
\]  \hspace{1cm} (2)

The boundary condition: \( n \cdot j = 0 \) implies that: \( n \times t = 0 \) on $\partial \Omega$. At the discrete level $t$ is approximated by edge functions: therefore all the degrees of freedom on $\partial \Omega$ are set to 0. So as to ensure the unicity of $t$, it is imposed $\int_e t \ dx$ on all edges $e \in T$ where $T$ is a tree spanning over all the nodes of the mesh, which is complete\textsuperscript{2} on $\partial \Omega$ \cite{4}.

COMPARISON WITH ANALYTICAL SOLUTIONS

Both $\phi - a$ and $t - b$ formulations are implemented by using MATLAB and the GETFEM++ library \cite{5}. Some preliminary validations have been done by using a homogeneous disk (not shown) and a prolate spheroid\textsuperscript{3} (figure 1a) exposed to a 50 Hz vertical flux density of 500 $\mu$T,
Figure 1: a) Induced current $|\mathbf{j}|$ in a 60 × 120 cm prolate spheroid by using the $\phi - a$ and $t - b$ formulation, and the exact analytical expression ($|\mathbf{b}| = 500 \mu \text{T vertical}, f = 50 \text{Hz}, \sigma = 0.2 \text{S/m}$). b) The obtained error is less than 1% for more than 75% of elements. c) Exemple of computation with an anatomical phantom.

for which exact analytical formula for $\mathbf{j}$ exist. The error obtained with these configurations is less than 1% for most of the elements (figure 1b).

EXEMPLARY OF COMPUTATION WITH AN ANATOMICAL PHANTOM

We performed a computation at 50 Hz by using an anatomical phantom irradiated by a uniform vertical magnetic field (figure 1c). The conductivities have been taken from [6]. The results obtained by the $\phi - a$ and $t - b$ formulations are similar. The number of unknowns is 84 293 for the $\phi - a$ formulation, and 567 299 for the $t - b$ formulation.

CONCLUSION

These preliminary results indicate that the new $t - b$ formulation could effectively be used for numerical dosimetry. As its computational cost is higher than the classical $\phi - a$ formulation, its usage should be restricted to the cases where a source magnetic vector is either unavailable, or very difficult to obtain.

REFERENCES


1A somehow similar formulation can be found in a paper by Sekino et al [3], but it is not for induced currents.
2A tree $T$ is said to be complete on a surface $\Gamma$, when $T \cap \Gamma$ is a tree spanning over the nodes of $\Gamma$.
3$|\mathbf{j}| = \frac{2\pi \sigma f |\mathbf{b}|}{a^2 + b^2 z} \sqrt{(a^2 y^2 + b^2 x^2)}$ for a spheroid of axis $2a$, $2b$ and $2c$ along the $x$, $y$ and $z$ directions.
SAR AND TEMPERATURE RISE IN DIFFERENT HEAD MODELS DUE TO THE ELECTROMAGNETIC RADIATION FROM CANONICAL ANTENNAS

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INTRODUCTION
Bernardi et al. [1] studied the temperature rise in the human eye due to electromagnetic (EM) exposure from 6-30 GHz. A number of other studies have also been conducted on temperature rise in human head models [2, 3] due to EM radiation. The objective of this work is to study the SAR and temperature increase due to the radiation from a half-wave 900 MHz dipole antenna and a 1900 MHz planar inverted-F antenna (PIFA) in two different head models, the Duke head model [4] and the standard head model [5].

MODELS AND METHOD
The duke head model is an anatomically accurate human head model with 1mmx1mmx1mm resolution which consists of 47 tissue types. By contrast, the standard head model [5] is composed of only 6 different tissue types with 3mmx3mmx3mm resolution. To make a reasonable comparison between the two models, the 17.5mm thick ear of the Duke head model was removed as because there is no ear in the standard head model. However, the removal of the ear from the former resulted in a notch in the tissue which is not so pronounced in the standard head. The electrical properties of the tissues for both models were collected from [6] and the thermal properties were obtained from [4]. In the standard head model the parameters of the average brain were used [7]. Simulations were performed using XFDTD with a uniform discretization of 1 mm in all directions. The distance from the feed point of the antenna to the nearest part of the head was 15 mm in each case and an input power of 1 W was used. The immersive medium for temperature rise calculation was air with a temperature of 23°C and a thermal conductivity of 0.03W/m/˚C whereas the perfusive medium was blood at 37°C.

RESULTS
Distributions of temperature increase in the plane where the maximum value of thermal rise

Fig. 1: Distribution of maximum temperature increase (ΔT) in (a) Duke head model for dipole and (b) for PIFA; (c) Standard head model for dipole and (d) for PIFA.

occurred are shown in Fig. 1. In the cases with the 900 MHz dipole, the hottest spot in the
Duke head model was located 4 mm inside from the head surface whereas the same for the standard head was 15 mm inside from the surface. On the other hand, the hottest spot was 9 mm inside from the surface for both models when the radiator was a PIFA. The two models resulted in nearly equal temperature rise for the dipole till 5 minutes of exposure but for longer durations the temperature rise in the two models were different (Fig. 2a). However, the models provided different temperature rise profiles for the PIFA (Fig. 2b).

![Fig. 2: Profile of temperature rise with the duration of exposure for (a) Dipole (b) PIFA.](image)

<table>
<thead>
<tr>
<th>Head Models against the antennas</th>
<th>Duke Head Dipole (900 MHz)</th>
<th>Standard Head Dipole (900 MHz)</th>
<th>Duke Head PIFA (1900 MHz)</th>
<th>Standard Head PIFA (1900 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max 1g SAR (W/Kg)</td>
<td>5.93</td>
<td>7.85</td>
<td>5.60</td>
<td>7.94</td>
</tr>
<tr>
<td>Max 10g SAR (W/Kg)</td>
<td>3.33</td>
<td>4.64</td>
<td>3.23</td>
<td>4.34</td>
</tr>
<tr>
<td>Max Temp. rise (°C)</td>
<td>0.38</td>
<td>0.65</td>
<td>0.43</td>
<td>0.51</td>
</tr>
</tbody>
</table>

CONCLUSION

The temperature rise due to the radiation from a dipole and a PIFA were studied in two head models. The temperature rise is dependent on the head model under consideration. For the same antenna a higher 10g SAR corresponded to a higher temperature rise.

ACKNOWLEDGMENTS

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REFERENCES


Dosimetric Analysis Of An In Vitro Exposure Setup At 3 GHz

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INTRODUCTION

This paper describes the dosimetric analysis of an in vitro exposure setup used at 3 GHz. The system has not been yet numerically studied and experimental investigations at that frequency are ongoing. The incubator chosen to expose suspended cells in Petri dishes has been previously characterized on a large frequency band (0.8 to 10 GHz), and results for experiments at 1.8 and 2.45 GHz have already been presented [1]. The biological solution used to expose the cells has been characterized at 3 GHz. The incubator is exposed in the far field zone of an adapted horn antenna, thus the Petri dishes can be considered as exposed to a plane wave.

MATERIALS AND METHODS

The whole system (incubator, and horn antenna) is placed in an anechoic chamber. This kind of exposure set-up is usable on an extremely wide frequencies band (from 0.8 up to 10 GHz) which seems a great advantage performing experimental activity on cells. The temperature in the cell cultures is maintained constant by water circulation controlled by a cryostat.

The numerical analyses (FDTD methods) at different frequencies have been conducted step by step to take into account the influence of each part of the set-up on the E field and SAR distributions in the biological sample volumes. Following the previous indications the horn antenna alone has been characterized at 3 GHz. Then the numerical results at that frequency have been validated by E field measurements inside the anechoic chamber. Finally, the incubator with six Petri dishes has been added and the numerical dosimetry of the whole exposure set up has been performed adopting appropriate dielectric properties (\(\varepsilon_r=73.9\) and \(\sigma=3.5\) at 3GHz) of cell suspending medium (DMEM). Also in this case numerical results have been validated by E field and temperature measurements during the experiment. Moreover numerical studies considering a simple plane wave exposure have been conducted.

With this method, the uncertainties due to the modeling and numerical computation can be considered in the mean SAR calculation inside the Petri dishes.

RESULTS

A detailed analysis of all the system parameters has allowed to perform accurate dosimetry of the exposure setup at 3 GHz, determining SAR values in the six Petri dishes exposed.

A first analysis with an in plane wave exposure was performed. Then simulations with a circularly polarized horn antenna have been realized. Consequently, both the E field (E field is parallel to the longest dimension of the incubator) and H field (H field is parallel to the longest dimension of the incubator) polarization have been considered for SAR calculation.
distribution in the exposed dishes.

Figure 1: SAR distribution in the Petri dishes inside the incubator, for a plane wave exposure at 3 GHz, for H and E field polarization

<table>
<thead>
<tr>
<th>Field polarization</th>
<th>In the dishes</th>
<th>Average SAR (W/kg / W/m²)</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>H field</td>
<td>1,2,3,4</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td>5,6</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>E field</td>
<td>1,2,3,4</td>
<td>1.25</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>5,6</td>
<td>0.51</td>
<td>0.26</td>
</tr>
</tbody>
</table>

Table 1: SAR in the Petri dishes for the H and E polarization, for a plane wave exposure at 3 GHz.

The SAR distributions in the six Petri dishes illuminated in a plane wave at 3 GHz are presented Figure 1, for the H and E field polarization. The SAR shows almost a uniform distribution only for four of the six Petri dishes exposed (as evidenced in Figure 1). Consequently, only dishes one to four are considered for biological experiments. The mean SAR in the dishes has been calculated as the average of the values obtained in the whole volume of the biological solution. The mean SAR values in different dishes are reported in Table 1, different values are obtained for the dishes from 1 to 4 with respect the dishes 5, 6 for both the analyzed polarization (E, H). A mean SAR of 0.71 W/kg for 1 W/m² incident is presented in the four dishes used for biological experiments. Moreover the mean SAR values for E field polarization are stronger than the values obtained for the H field polarization (Table 1).

CONCLUSIONS

A detailed and accurate dosimetry of the exposure setup has been performed for adequate interpretations and valuations of in vitro results. An in vitro exposure system constituted by and horn antenna and an incubator used for experiments at 1.8 and 2.45 GHz, has been numerically characterized at 3 GHz. The exposure is realized both with an in plane wave and with a circular polarized horn antenna, SAR distributions are calculated in both cases at 3 GHz.

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REFERENCES

The Influence of Cell Splitting on Public Exposure from GSM Systems

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INTRODUCTION
The proliferation of mobile phone users results in the need to install new base stations (BS) with lower power and smaller coverage area. On the other hand, the increase in the number of BS antennas amplifies public concerns about the exposure from their radiation. Until now most studies have focused on the effect of network architecture on mobile phone behavior, showing that better coverage leads to less exposure of the mobile phone user [1]-[3]. There is only scarce literature about the influence of a GSM network configuration on the general public exposure due to BS radiation [4],[5]. The current study aims at examining one of the parameters of the network, i.e., that of BS density and power.

MATERIALS AND METHODS
The area to be covered by the network is subdivided into hexagonal cells. Seven of such hexagonal cells make up a cluster. Due to the smaller frequency reuse distance of the GSM1800 system, the total area studied is smaller (2km x 2km) than that for the GSM900 system (4km x 4km). Base stations are placed in the center of the hexagons. It is assumed that all cells are identical in terms of traffic (number or density of active users are constant) and technical configuration of receiving terminal. Power density is determined at the center of a uniform rectilinear grid with a step of 9.8m and 5.6m for GSM900 and GSM1800, respectively. Initially a sparse network of BS radiating at 40W is assumed, which is later replaced with a dense network of BS with 10W emitted power. The lowest acceptable power at the receiver is assumed at -102dBm, i.e. 2dB above the sensitivity of mobile phones, in order to calculate the cell radius in each case. The latter depends also on the propagation model employed. In the current study COST 231 [6] was used for the calculation of the cell radius in an urban environment, whereas Hata [7] and COST extended Hata [6] models were additionally applied in the appropriate frequency range for the calculation of power density. The free space model was also examined for comparison purposes. It should be pointed out that antenna characteristics are not considered for the calculation of the resulting power density. The omission of antenna gain is not important, because this is a comparative study between the two systems, however, the antenna pattern in the vertical plane (together with tilting) could affect the results.

RESULTS
The difference in exposure resulting from the two system networks is obvious (Fig. 1a) in the cumulative Exposure Quotient (EQ) calculated according to the ICNIRP guidelines for an environment with sources of multiple frequencies above 10MHz:
EQ = \sum_{f_i > 10\text{MHz}} \left( \frac{E_{f_i}^2}{E_{t,i}^2} \right) \quad (1)

Figure 1: (a) Cumulative exposure difference between the sparse and the dense GSM900 network with the COST 231 propagation model. (b) Exposure Quotient calculated as a function of distance from the BS of the central cell for the two network configurations (GSM900, COST 231).

It appears that for the same number of frequencies operated by the BS in the two configurations, i.e. for the same number of users, the cumulative exposure is only slightly higher for the dense network with lower emissions. This result is true for both COST 231 and Hata models, but not for the free space model where the EQ is the same. The higher EQ for lower power base stations can be attributed to the contribution of the neighboring BS (Fig. 1b). When the user density is kept the same for the two network (an assumption closer to reality for urban areas) and the sparse network BS need to operate more frequencies to serve the traffic, the picture changes and the EQ in this case can become larger.

CONCLUSIONS

Cell splitting in areas where there are no or very few users will not lower exposure. On the contrary when the density of active users remains the same or increases, cell splitting can lead to lower exposure of public. Future work is necessary to take into account more of the network technical characteristics.

REFERENCES

Is Human Brain Functional Activation Modulated By A 60 Hz, 1800 µT Magnetic Field Exposure?

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INTRODUCTION

Human response to Extremely Low Frequency (below 300Hz, ELF) Magnetic Field (MF) exposure has been studied for the last 3 decades. It has been demonstrated that human neurophysiology [1, 2] can be modulated by exposure to ELF MF. Recent studies suggest that central exposure can modulate brain rhythms and motor functions, reporting for example changes in the electroencephalogram (EEG) and evoked potentials of healthy subjects [1, 2]. Interestingly, it has also been shown that ELF MF exposure decreases the amplitude of spontaneous motor activity of healthy subjects such as standing balance [3] and physiological postural tremor recorded at the tip of the index finger [4]. The aim of this pilot work is to use functional Magnetic Resonance Imaging (fMRI) as a new tool to investigate if brain activation patterns can be modulated by a 30 minute exposure to a 60Hz, 1800 µT MF. Indeed, it is well documented that a simple finger tapping task activates the controlateral Supplementary Motor Area (SMA) and the controlateral Primary Motor Area (M1). It has also been demonstrated that the level of activation of these areas is positively correlated with the frequency and the amplitude of the task [5]. Based on literature results, we hypothesize that for an index finger tapping task at natural frequency, a 60Hz, 1800 µT MF exposure will decrease Blood Oxygen Level Dependent (BOLD) activation in the involved brain regions.

MATERIALS AND METHODS

9 right handed subjects (mean age=25.5; range=21-33) were tested in a single blind pilot trial: functional brain images were collected while participants tapped their thumb and index finger together at a spontaneous rhythm before and after a 30 minute resting period. During this resting period, 4 participants (real group) were exposed to a 60 Hz MF at 1800 µT (maximal intensity at the cortical level, top of the head) by the Z gradient coil of the scanner itself (specially programmed by one of our physicists) and 5 of them have not (control group). BOLD images were acquired with a 1.5 Tesla Siemens Advanto MRI. High resolution anatomical images were collected and co-registered with the functional images.

RESULTS

Participant data was analyzed using Brain Voyager QX 1.9.10 (BrainVoyager, Brain Innovation, the Netherlands). Data was corrected for potential movement artifacts using 3D motion correction, temporal and spatial smoothing, and trilinear interpolation. Functional images were co-registered to an anatomical, T1 weighted image, and normalized into a Talairach brain space. A Bonferroni correction (p < .001) was employed to correct for multiple comparison confounds, ensuring that the change in activation observed was not due to chance. The pre-exposure group image clearly showed the activation of the controlateral
primary and supplementary motor cortex (M1 and SMA), primary somatosensory cortex (SI) and anterior cingulate (AC), and of the ipsilateral cerebellum, anterior lobe (the cortical activation is illustrated in Figure 2, Top). Post minus Pre exposure comparison images were produced for each experimental group and showed a deactivation in the controlateral SI and AC, and in the ipsilateral cerebellum, anterior lobe (see Figure 2, Middle, for the SI). Surprisingly, no Post minus Pre deactivation was found for the group actually exposed (see Figure 2, Bottom, for the SI). These three regions were defined as Regions Of Interest (ROI) and corresponding Beta weight values were extracted and exported into SPSS where within subjects ANOVAs with a between subjects factor (group) were conducted. Main effects showed a marginally lower activation Post than Pre exposure in the SI (F=4.77, p=0.06), in the AC (F=4.31, p=0.76) and in the cerebellum (F=3.30, p=0.11). Interestingly, in the AC, a significant interaction showed that the Post exposure deactivation was stronger in the control group than in the real group (F=10.30, p<0.05). The interaction was close to significance for the SI (F=2.44, p=0.16) and the cerebellum (F=4.56, p=0.07).

CONCLUSIONS

Results seem to suggest that after a 30 minute period of rest, less activation is required to produce a rhythmic thumb vs. index finger opposition task, and that exposure to a 60Hz MF of 1800µT cancel this effect. Although these results, which will be discussed at the conference, have to be cautiously taken due to our small sample size so far, they demonstrate the potential of using fMRI as a new tool to study the effects of ELF MF on brain functions.

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The authors would like to thank Dr. Jean Théberge for programming the 60 Hz into the scanner’s gradient coil allowing its use as an active MF exposure device. Research funded by Hydro-Québec, EDF-RTE (France), ORDCF (Ontario), CIHR (Canada) and LHRI.

REFERENCES

In vitro cytogenetic effects of GSM-900 MHz on human cells

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INTRODUCTION

The possible effects of radiofrequency (RF) exposure on the genetic material of cells are considered very important since DNA damages of somatic cells can be linked to cancer development or cell death whereas damages of germ cells can lead to genetic changes in the next and subsequent generations. The genotoxic effects of RF radiations are most often investigated with comet assay, micronucleus test, chromosomal aberration test and sister chromatid exchange method.

The objective of this study was to investigate whether exposure to radiofrequency radiation similar to those emitted by mobile phones of second generation standard Global System for Mobile communication (GSM, 900 MHz) induces genotoxic effects in cultured human amniotic cells using R-banded karyotype.

R-banded karyotype is a reliable method to detect chromatid breaks, chromosome rearrangements, aneuploidies and to identify chromosomes involved in rearrangements. To our knowledge, it is the first time that this method is used to investigate genotoxic effects of RF radiations.

MATERIALS AND METHODS

Human amniotic cells were exposed to GSM-900 radiation and sham-exposed for 24h. The exposures were carried in wire-patch cell (WPC) under strictly controlled conditions of temperature [1]. The average-specific absorption rate (SAR) was 0.25 W/kg. The genotoxic effects of GSM-900 were evaluated immediately and 24 h after exposure using R-banded karyotype method. The experiment was performed on four different samples. One hundred metaphase cells were analysed per assay. Positive controls were provided by using bleomycin.
RESULTS

R-banded karyotype results were analyzed as number of metaphase cells with structural and numerical chromosome aberrations and the aberrations frequency given as the total number of chromatid breaks involved per 100 cells: 0.5 = gap, 1 = breaks of one chromatid, 2 = breaks of one chromosome and deletions, 4 = duplications, translocations, rings and complex rearrangements. Figure 1 gives the results of investigations.

CONCLUSION

Although some cytogenetic damages were observed in vitro, no significant effect was found between RF-exposed and sham-exposed cells for mean percentages of metaphase cells with numerical and structural aberrations and for chromosome aberrations frequency at 0 h and 24 h after the end of exposure. Exposure under these conditions does not directly cause numerical or structural aberration of chromosome. There is no delayed effect 24h post-exposure. Our results are in agreement with the majority of the literature [2] [3] [4] [5].

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REFERENCES

Viability of Mammalian Neural Progenitor Cells in Electric Fields

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INTRODUCTION

Previously, we used platinum electrodes to stimulate rat neural progenitor cells (NPCs) (similar to [1]). Slight changes in the differentiation of NPCs were observed. However, NPCs vitality seemed to be negatively affected due to lower cell counts in EF treatments of 5 -10mV/mm exceeding 10hrs. Thus, a different methodology was used to test physiologically relevant EF (50-500mV/mm). Investigators used agarose gel to culture mammalian neurons in EF of 29 to 500mV/mm [2]. However, in these experiments cell viability was not measured, therefore any malignant effects from EF treatments on mammalian neurons are unknown. Thus, the effect that EFs have on the viability of NPCs (precursors to neurons) must be determined to attribute changes in differentiation of NPCs due to EF stimulation.

MATERIALS AND METHODS

Slight modifications to McCaig’s design [3] were made to accommodate mammalian cells instead of Xenopus neurons. The apparatus consisted of agarose gel bridges made with cell growth media and two electrochemical half cells (Figure 1).

NPCs were grown on laminin-coated glass slides adhered to the bottom of glass petri dishes. A custom culture chamber (Grace Bio-Labs, Inc. Bend, OR) was used to culture the cells in a confined space (0.5 x 12 x 30 mm) through which electric current flowed from one half-cell to the other. The EF was calculated using the current, the cross sectional area perpendicular to current flow, and the resistivity of the media. The two agarose filled glass tubes had one end submerged in the media and the other in the saline solution. An EF was created by establishing a voltage difference between the two Ag/AgCl electrodes.

Differences in cell vitality between EF treated and non-treated cells will be determined using propidium iodide (necrosis marker) and YO-PRO-1 (Invitrogen).

Traces of cell processes were superimposed to determine directional process growth in
relation to the EF vector.

RESULTS

![Three images of neurons with labels: Control (No EF), Oscillating EF, Constant EF.](image)

Figure 2 - Process guidance due to a low voltage oscillating and constant EFs. Superposition of traced processes from 30 cells, for each condition at 1DIV.

![Bar graph showing differentiation of EF Treated AHPCs.](image)

Figure 3 – Percent of cells that were TUJ1, MAP2ab or GFAP immunoreactive. NPCs in EFs, 6DIV. Numbers at the bottom of each bar indicate cells/mm² for each condition. TUJ1 immunoreactivity of cells grown in an oscillating EF and without EF stimulation, n=2. All other data were from one experiment only, n=1.

CONCLUSIONS

Hippocampal NPCs did not align in relation to the EF vector. Therefore, NPCs do not respond to EFs as Xenopus neurons or mammalian hippocampal neurons do [2, 3]. Preliminary observations indicate that the method used does not negatively affect NPC, but quantitative data is still needed. The differentiation of NPCs was not statistically different for the three phenotypic markers tested but further testing is needed to obtain a set of statistically valid data.

ACKNOWLEDGMENTS

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REFERENCES


MAPHYS Program: Characterization of Human Keratinocyte Responses to a High Frequency Electromagnetic Field by Micro-array Analysis

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INTRODUCTION
The increasing use of wireless communication devices during the last decade (especially mobile phones) has led to questioning the potential biological effects of High Frequency Electromagnetic Field (HF EMF). In contrast to most studies focusing on energy aspects of EMF exposure, we were interested in the induced physiological consequences. We have recently demonstrated [1;2] that tomato plants respond to HF EMF by increasing the quantity of at least 5 stress-related mRNAs. Here we describe the MAPHYS program that will furnish a thorough analysis of the human keratinocyte transcriptome (using micro-array technology) after low amplitude HF EMF exposure.

MATERIALS AND METHODS
Normal Human Epidermal Keratinocytes (NHEK) were exposed, in a custom-made incubator, to 10 min HF EMF generated within a 200 m³ Mode Stirred Reverberation Chamber (MSRC), acting as a Faraday Cage to protect the experiment from environmental EMF (Fig 1). The field (900 MHz, average electric field: 8 V/m, average SAR: 0.03 W/kg calculated by considering a culture dish illuminated by a finite sum of plane waves) has been extensively characterized for its uniformity by a test of goodness-of-fit between experimental and theoretical statistical law distributions.

Cell samples were collected immediately before and after EMF exposure (0 -180 min) and total RNA was isolated and assayed using the gene-candidate approach to determine the appropriate physiological conditions required for micro-array analysis.
We selected the “Human Genome U133 Plus 2.0” (Affymetrix) to assay the 54,000 probes (representing 47,000 human transcripts). Quality tests and raw data production were conducted at the Strasbourg Institute of Genetic and Molecular and Cellular Biology (IGBMC). Data were then normalized using the RMAexpress tool (available online), and statistical analysis (ratio, student tests and False Discovery Rate - FDR) were performed with IGBMC tools (available online).

RESULTS

Figure 2-A illustrates an example of the gene-candidate approach: it shows that the calmodulin (calm1) transcript quantity increased significantly (2.6-fold) 120 min after the end of the exposure although no variation was detected in sham condition.

We pooled the samples coming from the 90 and 120 min time points to perform micro-array analysis: four per condition - exposed or control (sham). Among the 54,000 probes, only 16 displayed significant differences in the expression ratio between EMF exposed and control cells, corresponding to 13 genes (0.3 ‰), Figure 2-B.

CONCLUSIONS

Although the gene-candidate assay (Fig 2A) indicates the accumulation on an important mRNA in response to HF EMF, the preliminary output data furnished by the micro-array (Fig 2B) imply only minor effects of HF EMF exposure on human cells. However, these results need to be verified using quantitative PCR.

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REFERENCES


Effects of Exposure to 1.8 GHz Radiofrequency Field on the Expression of HSPs and Phosphorylation of MAPKs in Human Lens Epithelial Cells.

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INTRODUCTION

The growing public concerns about the possible health effects of exposure to radio frequency (RF) fields from mobile telephones have arisen in many countries because of the increased use of mobile telecommunication devices [1]. This in turn has led to an increase in epidemiological and experimental investigations. However, the results from epidemiological or basic experimental studies are conflicting. Some have indicated an increased risk [2, 3], but most studies have shown no effects [4, 5].

The lens epithelial cell is a single layer of cuboidal cells at the anterior surface of the lens which retains a proliferative capacity throughout its lifespan and is important for maintaining metabolic homeostasis and transparency. Damage to lens epithelial cells (LECs) has been found to be associated with cataractogenesis [6, 7, 8, 9]. In our research group, exposure of human LECs to 1.8 GHz RF has been found to result in repairable DNA damage and increased heat shock protein (HSP)70 protein expression [10], and we have also pointed out the effect of 2.45 GHz RF exposure on rabbit LECs [11, 12, 13]. Inaloz et al. [14] demonstrated that low power microwave radiation can apparently bring about histological changes in rabbit LECs.

HSPs are one family of stress-activated proteins that participate in the protein folding, repair, and degeneration [15] which characterize the cellular responses to various types of stresses, such as changes in pH, heavy metal, and sudden temperature increases [16]. HSPs are classified into four major families according to molecular weight: HSP90, -70, and -60, and the small HSPs, such as HSP10, HSP27, αA-crystallin, and αB-crystallin [17]. The main function of these adenosine triphosphate (ATP)-dependent proteins is to chaperone and assist in protein folding. They also participate in the activation of glucocorticoid receptors, polymerization of actin, and transfer of proteins to lysosomes [15]. HSPs help to prevent apoptosis after a shocking stimulus, providing time for the repair mechanisms to act. Our laboratory has described the stress response in human LECs 2 h after 1.8 GHz RF exposure elicits HSP70 up-expression[10]. However, other literature has found that the Hsp70 expression level in human blood cells and MO54 cells post-exposure to RF of the cell phone type at 2 W/kg for 2 h did not exhibit any difference compared to sham control[18, 19]. The conflicting findings may be resulted from the different cell lines used in experiments and we suppose human LECs to be more sensitive to RF exposure.

Mitogen-activated protein kinases (MAPKs) mediate the response of cells to a wide variety of physiological and stress-related stimuli, including ultraviolet light, heat shock, ischemia, and oxygen free radicals, for example [20]. Studies have provided evidence that the induction of the MAPK pathway plays significant roles in the activation of specific HSPs [21]. It has been proposed that activation of c-Jun N-terminal kinases (JNKs) and p38 MAP kinases contributes to cell death, whereas activation of extracellular signal-regulated kinases (ERKs) contributes to protection against cell injury in multiple organs [22, 23].

In the present study, we investigated whether 1.8 GHz RF exposure of human LECs...
activates HSP90, HSP70, and HSP27 in vitro. Subsequently, to gain insight into the cell signaling pathway in human LECs following 1.8 GHz magnetic fields exposure, we studied the behavior of the MAPKs family.

MATERIALS AND METHODS

Cell culture
A human LECs line SRA01/04 was purchased from the Riken cell bank (Japan). The cells were seeded into 35-mm (1 × 105) diameter dishes and maintained in Dulbecco’s modified Eagle’s medium (DMEM, Gibco, New York) containing 20% fetal bovine serum (FBS, Hyclone Laboratories Inc., UT) at 37°C in a humidified atmosphere of 5% CO2 and 95% air.

RF field apparatus and exposure
RF fields were generated by an sXc-1800 system which was purchased from the Agilent Co. (Switzerland). The sXc-1800 system is designed to test RF electromagnetic field exposure from mobile communication devices operating at the frequency of 1.8 GHz and with a repetition frequency of 217 Hz. The setup consists of two rectangular anechoic single-mode resonator cavities of 1.8 GHz which are placed within an incubator (37°C, 5% CO2, saturated vapor, Heraeus, cell 240, German). Six Petri dishes (diameter: 35 mm, NUNC, Denmark) can be exposed in one waveguide. The dish holder guarantees that the dishes are placed exactly in the H-field maximum of the standing wave inside the waveguide. Each waveguide is equipped with a fan for rapid environmental atmosphere exchange (between the sham and exposure samples). The airflow temperature was monitored with a highly accurate DIN 1/10 probe fixed on top of the fans. Furthermore, the temperature response of the medium was assessed in terms of the incident field strength, liquid height and airflow and calculated by software equipped with the sXc-1800 system. This enables the prediction of the temperature difference between sham and exposure with sufficient precision.

During the entire course of exposure, the temperature was maintained at 37 ± 0.08°C via digital channels and the computer stored all data and experimental setting every 10 s as necessary for a full reproduction of the exposure. The temperature difference between sham and exposure never exceeded 0.08°C. These data were stored in an encoded file [Niels Kuster, Summary of Dosimetric Functions for sXc-1800 System, 2002. (The manual provided by Agilent co. Switzerland)].

Exponentially growing cells were cultured in 35 mm dishes (3 × 10^5 cells/dish) with a total volume of 2 ml and were moved to dish holders in two waveguides, one for sham and the other for exposure, for 30 min before the RF-field power was turned on to allow for temperature equilibration. For detecting the expression of HSP, cells were exposed to sham conditions or 1.8 GHz continuous-wave for 2 hours. Specific absorption rates (SARs) were 1, 2, 3 and 4 W/kg. Other cells were treated at 43°C for 1 h as a positive control for the induction of HSP expression. Based on the results of HSP expression following 1.8 GHz RF exposure of human LECs, we detected the phosphorylation of p38 MAPK, JNK and ERK1/2 immediately after the cells were exposed to a 1.8 GHz continuous-wave for 0, 5, 15, 30, 60 and 120 min. SARs were 2, 3 and 4 W/kg. Anisomycin (10 μg/ml for 30 min) was used as a positive control for p38 activation.

HSP expression by Western Blot analysis
Immediately after exposure and sham exposure to a 1.8 GHz RF for 2 h, or heat shock at 43°C for 1 h, cells were harvested by scraping in ice-cold PBS and centrifuged (1500 rpm for 5 min at 4°C). Cell pellets were lysed in Mammalian Protein Extraction Reagent (Pierce, America) for 15 min at 4°C, then subjected to centrifugation at 14000 rpm for 15 min at 4°C.
℃. The total cell protein concentration was determined using the BCA method. Thirty micrograms of protein per sample were separated by a 12% SDS-polyacrylamide gel and immediately transferred to a polyvinylidene difluoride (PVDF) membrane (Bio-Rad, America). Membranes were blocked with 5% (wt/vol) nonfat milk (GuangMing, China) in Tris buffer saline with Tween-20 (TBST) at 4 ℃ overnight and then incubated at room temperature for 1 h with a specific anti-HSP90 antibody (Santa Cruz, America), anti-HSP70 antibody (Santa Cruz, America) and anti-actin antibody (Santa Cruz, America), or incubated at room temperature for 2 h with a specific anti-HSP27 antibody (Santa Cruz, America). Blots were washed three times for 10 min each in TBST and then incubated with horseradish peroxidase-conjugated secondary antibody (Santa Cruz, America) for 1 h at room temperature. After three 10-min washes in TBST, blots were developed using an enhanced chemiluminescence (ECL) system (Santa Cruz, America).

MAPK pathways

Three MAPK pathways were analyzed: p38, JNK1/2 and ERK1/2. To determine activation, protein samples were harvested immediately after various time exposures. Anisomycin (10 μg/ml for 30 min) was used as a positive control for p38 activation. Phosphorylated MAPK isoforms, indicators of pathway activation, were detected using specific antibodies against active phospho-JNK (Thr183/Tyr185), active phospho-p38 (Tyr182), or active phospho-ERK1/2 (Tyr204) (Santa Cruz Biotechnology, America) by Western Blot analysis. The total amount of each MAPK (using antibodies that recognize both the phosphorylated and nonphosphorylated forms) was also examined to control for differences in protein loading. Secondary antibodies conjugated with horseradish peroxidase (Santa Cruz Biotechnology, America) were detected by the ECL system.

Data analysis

Protein bands were quantitated by scanning densitometry, and protein loading was normalized with actin. Within each experiment, the control value in the detection of HSPs expression was set to 100%, against which all samples were calculated as a percentage. The values from all appropriate experiments were then used to calculate the mean and standard errors.

Statistical analyses were performed using the ANOVA. P values <0.05 were considered statistically significant.

RESULTS

Effects of 1.8 GHz RF exposure on the induction of HSP27, HSP70 and HSP90 in human LECs

We evaluated HSP expression at the protein level by Western Blot analysis immediately after exposure to RF fields (SAR: 1, 2, 3, 4 W/kg) for 2 h. Although a small and significant change in HSP27 and HSP70 was observed in three RF exposed cells (SAR: 2, 3, 4 W/kg) compared with sham exposed cells, no significant difference in expression of HSP27 and HSP70 among the three RF exposed cells (SAR: 2, 3, 4 W/kg) was observed (Fig. 1). RF field exposure had no significant effect on HSP90 expression (Fig. 1). The expression of actin, a housekeeping protein, was used as an internal control, and its expression was similar in all samples. In addition, we established the levels of HSP27, HSP70, and HSP90 induced by heat stress (43 ℃, 1h ) as positive control proteins.

Effect of RF field exposure on the phosphorylation of p38 MAPK in LECs

To investigate whether or not RF exposure activates p38 MAPK in LECs, we examined the effect of RF exposure on the phosphorylation of p38 MAPK. However, RF exposure did not induce the phosphorylation of p38 MAPK (Fig. 2).

Effect of RF field exposure on the phosphorylation of ERK1/2 in LECs
RF exposure significantly induced the phosphorylation of ERK1/2 in a time-dependent manner (Fig. 3). In cells exposed to the three different SAR, the ERK1/2 was markedly activated as early as 5 min after RF exposure, and peaked at 30 min. A similar pattern was seen in cells exposed to the three SAR (2, 3, 4 W/kg) RF fields.

Effect of RF field exposure on the phosphorylation of JNK1/2 in LECs

In these studies, we found that the JNK family of MAPKs was activated after 2 h RF exposure at SAR 2, 3, 4 W/kg (Fig. 4).

Fig 1.

A

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Fig 2.

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Fig 3.

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CONCLUSIONS
Our results suggest that exposure to RF of wireless communications can induce expression of Hsp27 and Hsp70 and the activation of ERK1/2 and JNK1/2 in human LECs. The induction of Hsp27 and Hsp70, by a non-thermal stress, together with the activation of signal transduction pathways, provides reliable and sensitive biomarkers that could serve as the basis for improved mobile phone safety guidelines.

ACKNOWLEDGMENTS
This work was supported by the National Natural Science Foundation of China (grant number 30570439) and Zhejiang Provincial Natural Science Foundation of China (grant number Y207118).
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P-156


INTRODUCTION
Mesenchymal stem cells (MSCs) have been regarded as a promising cell type for regenerative medicine, by virtue of their great capacity for self-renewal and potential for differentiation into cells of various types of tissues, such as bone, cartilage, and adipose. Due to the pulsed electromagnetic fields (PEMFs) have been widely used as an effective treatment for ununited fractures, failed arthrodeses, and osteoporosis, in this study, we intend to compare the effect of PEMF stimulation with three magnetic field intensities on murine MSCs, and observe the multipotent differentiation capability of MSCs is whether affected by PEMF treatment.

MATERIALS AND METHODS
Murine MSCs were obtained from 6–8-week-old Wistar rats in an aseptic and modified procedure. Briefly, the adherent cells were isolated from the bone marrow and maintained as monolayer cultures for further expanded cultures. To induce the osteogenesis, cells were supplemented with 100 nM dexamethasone, 50 μg/ml L-ascorbic acid, and 10 mM β-glycerophosphate. To induce the chondrogenesis, 100 nm dexamethasone, 0.1 mM L-ascorbic acid, 1X sodium pyruvate, 1X ITS, and 10 ng/ml TGF-β1 were supplemented. To induce the adipogenesis, 1 mM dexamethasone, 5 μg/ml insulin, 60 μM indomethacin, and 50 mM IBMX were additionally supplemented. To evaluate the effect of PEMF stimulation on MSC proliferation, 50, 500, and 1,000 cells/cm² were individually used as initial cell densities. MSCs at P3 were cultured in 8-well chamber slides for 2 days at the initial cell density of 1,000 cells/cm² before exposing to PEMF stimulation. Cells at different cell densities were exposed to daily PEMF stimulation with three magnetic field intensities, 1.3, 2.4, and 3.2 G. The PEMF stimulation with induced electric waveform was consisted of single, narrow 300 μs quasi-rectangular pulses with a repetition rate of 7.5 Hz. The cell viability was determined by MTT assay at each time point. The multipotent differentiation of MSCs was examined by ALP, von Kossa, alcian blue and oil red O staining before and after PEMF treatment.

RESULTS
The cell viability of MSCs was determined by MTT assay. The results showed that the PEMF-treated groups at lower magnetic fields (1.3 G) expressed higher cell proliferation. However, the cell viability of other PEMF-treated groups was inhibited at the magnetic fields of 2.4 G and 3.2 G, respectively. The histochemical staining showed that MSCs still possessed the multipotent capability differentiating into osteoblasts, chondrocytes, and adipocytes after 14-day PEMF treatment (Fig 2.).
Figure 1: Cell viability of MSCs exposed to PEMF stimulation at different magnetic field intensities. (top: 1.3 G; middle: 2.4 G; bottom: 3.2 G)

CONCLUSIONS
The specific PEMF stimulation with different magnetic field intensities showed a modulatory effect on murine MSC proliferation in vitro. Besides, MSCs still possessed the capability of multipotential differentiation into several cell types. PEMF stimulation at the magnetic field intensity of 1.3 G has the potential on enhancing the proliferation of MSCs.

ACKNOWLEDGMENTS
The authors thank National Science Council (NSC 93-2213-E-033-037, NSC 93-2120-M-033-001) for financial support to this research.

REFERENCES
INHIBITORY EFFECTS OF CLINICAL USED LOW-FREQUENCY ELECTROMAGNETIC FIELDS ON DIFFERENT BACTERIA STRAINS WITH AND WITHOUT ANTIBIOTICS

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INTRODUCTION

A clinically established treatment of non-unions is the magnetic-field therapy [1, 2]. In case of bone infection and implant-related bone infections this technique is applied in combination with antibiotics. This work focuses on the impact of different electric and electromagnetic fields on growth of bacterial pathogens and the increase of antibiotic efficacy under the influence of the used low-frequency electromagnetic fields.

MATERIALS AND METHODS

Especially, cultures of Staphylococcus aureus were exposed to low-frequency electromagnetic field, an electro-magnetic field combined with an additional electric field, a sinusoidal electrical alternating field and a direct current electrical field [3]. Elucidating the synergistic effect of antibiotics under the influence of the four different fields, cultures of Staphylococcus aureus in presence of gentamicin were exposed.

RESULTS

Staphylococcus aureus concentrations could clearly be reduced under the influence of the four different applied fields within 24 hours. The strongest effects were observed for a direct current electrical field which could decrease CFU/ml of 37.3%. A low-frequency electromagnetic field with additional induced electric alternating field, revealed a decrease of staphylococci concentration by 36.9% (fig.2). In presence of gentamicin, each of the four applied fields showed an additional significant reduction of Staphylococcus aureus concentration compared to the effect of gentamicin without field influence. The strongest
synergistic effect showed a direct current field with a CFU/ml decrease of almost 92%.

**CONCLUSIONS**

The effects of the used fields on staphylococci growth are significantly pronounced. A clinical application of applied voltage of 1.0 V is not advisable. Data from field application of low-frequency electromagnetic fields corroborate the clinical results in case of magnetic-field therapy and the synergistic antibiotic treatment of non-union bone infections. The effect of other antibiotics/antiseptics on *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas* are under investigation.

**ACKNOWLEDGMENTS**

This work is supported by Bayerische Forschungsstiftung.

**REFERENCES**


EFFECTS OF MAGNETIC FIELDS GENERATED BY INDUCTION HEATING (IH) COOKTOPS ON MUTAGENICITY AND HSP EXPRESSION IN CULTURED CELLS

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INTRODUCTION

Replacement of gas and electric cooktops with IH cooktops has become popular in Japan and Europe. IH cooktops generate IF magnetic fields of 20 to 90 kHz from heating coils, with induction of currents in metal pans that results in heating of the pans. There has been a small number of studies examining the biological effects of IF electromagnetic fields. Because the devices that produce IF electromagnetic fields have entered widespread use, it is important to evaluate the human health effect(s). We previously reported that short-term exposure (2 hours) to an IF magnetic field at 532 μT rms (85-fold greater than the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guideline) did not cause cellular genotoxic damage [1]. In this study, we evaluated the effect of exposure to 23 kHz an IF magnetic fields at more high density, 6 mT rms (960-fold of ICNIRP guideline), on cell growth, bacterial mutation and expression of HSPs.

MATERIALS AND METHODS

(1) Exposure system

We used a built-in type IF magnetic field generation system consisting of a coil that generates IF magnetic fields of 6 mT rms at 23 kHz, with a sinusoidal wave form, and a perpendicular and uniaxial orientation. The temperature of the medium in the dishes was monitored at all times during the experiment and was maintained at 37.0 ± 0.5 °C.

(2) Cell growth

Chinese hamster ovary K-1 (CHO-K1) cells obtained from American Type Culture Correction (ATCC, Manassas, VA) were cultured in Ham’s F-12 medium supplemented with 10% fetal bovine serum (FBS, BioWest, Miami, FL). After the cells were exposed to the IF field or sham-exposed for 2 h, the cell number was counted using a particle counter every 24 h for up to 6 days.

(3) Mutagenicity

Strains of Salmonella typhimurium (TA98, TA100 and TA1537) and Escherichia coli (WP2 uvrA and WP2 uvrA pKM101) were used. In each experiment, two of three aliquots (0.6ml) of the cell suspension were exposed to IF magnetic fields at 6 mT rms for 30 min. For the positive controls, 2-(2-furyl)-3-(5-nitro-2-furyl) acrylamide (AF-2) and sodium azide (Wako Pure Chemical Industries Ltd, Osaka, Japan) were used. The plate incubation method [2] was used for detection of mutagenicity following exposure to the IF magnetic field. Each experiment was performed independently at least three times.

(4) Western blotting

A172 cells (ATCC) derived from human glioblastoma were seeded in a 100 mm dish at density of 9×10^5 cells/cm^2 in 10 ml of high glucose DMEM medium supplemented with 10 % FBS, cultured for 24 h, and then exposed to the IF field or sham-conditions for 2 h.
positive controls, the cells were heated at 42.5 or 43 °C for 2 h. After exposure, cells were collected by cell scraper and proteins were extracted with CelLytic™-M (Sigma-Aldrich) supplemented with protease inhibitor cocktail (Sigma-Aldrich) and 1 mM dithiothreitol. Rabbit anti-phospho-Hsp27 (p-HSP27; Ser 78, polyclonal, Stressgen, 1:1000) and mouse anti-β-actin (monoclonal, Sigma, 1:5000) were used as antibodies. The protein expression was visualized using an ECL kit (GE Healthcare Biosciences) according to the manufacturer's instructions, and quantified by densitometry of the band intensity using a lumino capture system and CS analyzer software version 2.0.

(5) Immunofluorescence

A172 cells were seeded on 35 mm Celldesk dishes and exposed to the IF field or sham-conditions for 2 h, as described for the Western blotting. For positive controls, the cells were heated at 43 °C for 2 h. After exposure, cells were fixed with 4% paraformaldehyde PBS for 10 min and permeated with 0.2% Triton X-100/PBS (-) for 15 min. Nonspecific binding was blocked with 10% normal goat serum, and cells were incubated with rabbit anti-Hsp105 (polyclonal, Santa Cruz Biotechnology; N-187, 1:20) for 1 h. Cells were subsequently incubated with goat rhodamine-conjugated anti-rabbit IgG (Millipore, 1:250) for 30 min in the dark.

RESULTS

Exposure to the IF magnetic field at 6 mT_{ms} for 2 h did not affect the growth of CHO-K1 cells. The results of the Ames test indicated that the number of revertant colonies of the exposure group was fewer than that of the positive control group among all strains. The number of revertant colonies of the exposure group was not statistically significant different from that of the sham-exposure group among all strains. For the expression of p-HSP27 and HSP105, no significant changes were observed following exposure to the IF magnetic field for 2 h based on Western blot analysis and immunofluorescence.

CONCLUSIONS

These results demonstrate that exposure to an IF magnetic field at a high magnetic density of 6 mT_{ms} (960-fold of ICNIRP guideline) for 2 h did not cause mutagenicity. Expression of the HSPs was also not affected by the IF magnetic field exposure. However, the possibility of effects on other cellular functions remains, and further studies on the cellular effects of IF magnetic fields are required.

REFERENCES


Intermediate Frequency Magnetic Fields Did Not Have Genotoxic Potentials In Mouse Lymphoma Assay (MLA)

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INTRODUCTION

In contrast to extremely low frequency and radio frequency electromagnetic fields (EMFs), the biological effects of the intermediate frequency (IF; from 300Hz to 10MHz) EMFs have not been studied very well. In Japan, the widespread use of household induction cookers has raised public concern regarding the health effects of IF magnetic fields (MFs). In our previous studies [1], we have reported that the IF MFs (2 kHz, 20 kHz or 60 kHz) did not have mutagenicity or co-mutagenicity for known mutagens, including radicals, DNA reactive agents or metabolically activated DNA reactive agents, in the bacterial mutation assay. The IF MF did not affect the gene conversion, point mutation, mutagenesis by UV irradiation and cell survival in model eukaryotic cells, yeast. The IF MF did not induce micronucleus formation and did not affect DNA damage by MMC or DNA damage repair system in mammalian cells [2]. In this study, we have investigated the effects of the IF MFs on genotoxicity in Mouse Lymphoma Assay (MLA).

MATERIALS AND METHODS

Exposure System

We constructed a Helmholtz type exposure system, which generates a vertical and sinusoidal IF MFs in the frequency range of 2-60 kHz (Fig. 1). The characteristics are shown in Table 1. The incubator was located in the center of the system. The incubation temperature was controlled at 37 +/- 0.4°C.

Test Strains

The MLA can detect both point mutation (as large colony) and chromosomal aberration such as deletion (as small colony). A mouse lymphoma cell line, L5178Y tk+-3.7.2c, was used to evaluate the effects of the MF exposure on direct genotoxicity and DNA damage repair caused by methylmethane sulfonate (MMS). The cells were exposed to MFs of 0.91mTrms at 2 kHz, 1.1mTrms at 20 kHz or 0.11mTrms at 60 kHz, for 24h under a humidified atmosphere of 5% CO2 /95% air at 37°C.

Mouse Lymphoma Assay (MLA)

The L5178Y tk+-3.7.2c cells (1x10^5 cells/ml, 35ml) were inoculated into twelve T-175 flasks, and the flasks were randomly divided into two groups. One group (six flasks) was used for investigating the effect of the IF MFs on genotoxicity. Three of six flasks were placed into the unenergized control incubator, and another three flasks were placed into the incubator for the MF exposure. Another six flasks were added methylmethane sulfonate (MMS) at a final concentration of 5ng/ml to investigate the effect of the IF MFs on DNA damage by MMS or DNA damage repair system in mammalian cells. Then, three of six flasks were placed into the unenergized control incubator, and another three flasks were placed into the incubator for the MF exposure. The cells were exposed to MFs of 0.91mTrms at 2 kHz, 1.1mTrms at 20 kHz or 0.11mTrms at 60 kHz, for 24h at 37°C in 5% carbon dioxide.
dioxide. After the exposure, the cells were inoculated into 96 well plates. After the plates were incubated for 10-14 days, the colonies were counted to evaluate the ratio of mutation frequency of point mutation, chromosomal aberration or total mutation between MF exposed and unexposed control groups.

RESULTS
The ratio of mutation frequency of point mutation, chromosomal aberration or total mutation between MF exposed and unexposed control groups were mostly in the range from 0.8 to 1.2. In statistical analysis, neither significant nor reproducible difference in the mutation frequencies was found between exposure and control groups under the all MF exposure conditions. To examine the effects on DNA damage, the cells were exposed to each MF with MMS that potentiates mutation. In statistical analysis, neither significant nor reproducible difference in the mutation frequencies was found between exposure and control groups under the all MF exposure conditions.

CONCLUSIONS
We conclude that the strong IF MFs used in this study did not induce point mutation and chromosomal aberration, and did not affect DNA damage by MMS or DNA damage repair system in mammalian cells.

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Na/K ATPase upregulation and membrane hyperpolarization involve in electrically guided cell migration

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It is known that Na/K ATPase highly involves in maintaining the resting membrane potential in the cells. Besides its electrogenic properties which keep ions equilibrated, data have been reported also on its potential interactions with other membrane or cytoskeletal proteins. Here, we investigated the intracellular distribution and the expression levels of Na/K ATPase during electrically guided cell migration. Cell membrane potential during the migration process was also analysed. Murine calvarial osteoblasts, directing towards the cathode in an applied electric field, were noninvasively stimulated by an external direct current of 5 V/cm for 5 hours then analysed using immunofluorescence (IF), time-lapse video microscopy or fluorescence activated cell sorting (FACS) techniques. Direct current electric fields induced accumulations of Na/K ATPase at the leading-edge (cathodal side) of the cells compared to the controls which were not exposed to electric fields. FACS analysis revealed that intracellular expression levels of the protein was also increased while it was not the case for some other electrogenic proteins e.g. Na\(^+/\)H\(^+\) exchanger isoform-3 considered in our studies. Dual labelling of Na/K ATPase with vinculin in the cells using IF indicated that Na/K ATPase might involve in this guided migration process via an interaction with the focal adhesion protein complex. Additionally, the cell membrane was overall hyperpolarized with a following recovery within the first minutes of electrical stimulation as monitored by time-lapse vital imaging of the membrane potential using DiBAC\(_4\)(3) dye. But interestingly thereafter membrane again became hyperpolarized as cells migrate, shown by FACS measurements after 5 hours of stimulation. Moreover, recording the fluorescence intensity kinetics during dye uptake we could visualize the differences between the rear-edge and the leading-edge being depolarized and hyperpolarized, respectively. Considering all together, we suggest that sustained hyperpolarization of cell membrane during electrically guided migration may lead to upregulation of Na/K ATPase at the leading-edge and this might involve in directional sensing upon interacting with focal adhesion proteins. Therefore we think that our data can give important insights into the mechanism of electrical stimulation on cell membrane biology addressing the guided cell migration process.
INTRODUCTION

Whilst effects due to radio-frequency (RF) heating are not in dispute, there is continued interest as to whether other, more subtle effects exist which may be hazardous to health in the long term. In particular, there is a lack of data upon the effects of pulsed RF exposure to underpin safety guidelines: such exposures are characteristic of many military RF sources. This study used a purified human white blood cell preparation to examine alterations in a gene expression cell system following exposure to pulsed RF sources.

MATERIALS AND METHODS

In the current study, human T lymphocytes were exposed to a range of pulsed RF signal exposures. These cells were used as they are involved in many disease states including cancer and inflammation. Use of this normal cell type as opposed to a transformed cell line lowers the risk of inappropriate gene transcript regulation in defective genes. The T lymphocytes were purified from peripheral blood mononuclear cells using a magnetic cell separation/CD3+ capture technique. A propidium iodide/annexin V flow cytometer based cell viability assay was used to characterise T lymphocytes responses to HD exposure. The microarray system selected was the Operon Human V4 OpArray, with specialist analysis conducted by Agilent. We have previously reported positive gene changes in this model following exposure to a sulphur mustard positive control, thereby validating the methodology (1). Three different pulsed RF signals are being investigated. The first RF exposure was a 1.6 GHz pulsed signal from a horn antenna generating 200 V m$^{-1}$ in the sample area, with 550 ns pulse duration at a pulse repetition frequency (PRF) of 300 Hz. The second signal had the same characteristics with a PRF of 909 kHz. Exposures are now underway with a 1.6 GHz pulsed signal from a horn antenna generating 311 V m$^{-1}$ in the sample area, with a 550 ns pulse duration at a PRF of 909 kHz.

RESULTS

T lymphocyte preparations were found to have a purity of 99.4% (+/-0.4) and could be maintained for a minimum of 48 h in culture. Cells have been exposed to a positive control with sulphur mustard and an RF test set has been completed. Despite the measured 200 V m$^{-1}$ peak field strength, the pulsing gives a low calculated time-averaged power density of 0.0175 W m$^{-2}$. Altered regulation of 912 gene transcripts was associated with the positive control sulphur mustard exposure, whereas none of the RF exposures to date have induced any significant (P<0.05) changes in transcript expression (figure 1).
CONCLUSIONS

We previously reported that the first of the RF exposures at a low average power (0.0175 W m$^{-2}$) did not produce changes in gene transcription. The latest RF exposure data (average power density 53.05 W m$^{-2}$) are currently being analysed and will be presented at this meeting. In our existing exposure apparatus the maximum average power exposure is 119 W m$^{-2}$, which is 14.9 times the ICNIRP power density limit for public exposures. The use of a variety of pulsed signals in this study will demonstrate whether or not RF-induced genetic changes are caused by exposure to such fields. These data will be useful for informing future pulsed RF safety guidelines.

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REFERENCES

Real-time measurement of Hsp70/Luc reporter system in response to a 100 mT static magnetic field.

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INTRODUCTION

The heat shock family of genes is highly conserved among a wide variety of organisms. Heat shock proteins (HSP) are involved in molecular chaperoning, and the facilitation of protein folding [1]. Under conditions of hyperthermia, the expression of heat shock genes is dramatically increased. This increase in expression is thought to be a protective mechanism in response to an external stress that leads to protein aggregation, and disrupts normal protein folding and structure [2].

The classic example of HSP70 induction is exposure to hyperthermia. However, a number of other physiological stresses, including exposure to magnetic fields, have been found to activate hsp70 transcription and translation. The effect of a magnetic field on the expression of heat shock genes was first examined by Goodman et.al. [3] who observed an increased amount of hsp70 transcript in HL-60 cells and yeast after exposure to an extremely low frequency magnetic field (ELF-MF). In the time since this report, the effect of a magnetic field on hsp70 has become an issue of debate. There is less literature on the effect of static magnetic fields (SMF), however, like the work done on low frequency magnetic fields, there are studies which have found an effect [4] and those that have found no effect [5]. Interestingly, several groups have reported an effect of magnetic fields only when the exposure was applied as a second stress in addition to a mild heat shock [6,7,8].

The purpose of this study was to examine, in real-time, the expression of HSP70 using a luciferase reporter system in response to A) a 100 mT SMF, B) 30 min of hyperthermia and C) a combination of exposure to a 100 mT SMF and hyperthermia.

MATERIALS AND METHODS

The NIH3T3 cell line stably transfected with a construct consisting of the mouse HSP70 promoter driving the expression of the firefly luciferase gene was a generous gift from Dr. Christopher Contag from Stanford University, USA. The Dulbeccos Modified Essential Media (DMEM) and fetal bovine serum was purchased from Invitrogen (Burlington, ON, Canada) and D-luciferin was purchased from Promega (Madison, WI, USA).

For each experiment cells were trypsinized and resuspended in 2 ml DMEM containing 0.75 mg D-luciferin and placed in a disposable cuvette. Bioluminescence in luciferin-loaded cell samples was measured using a modified luminescence photometry system, comprised of a photomultiplier tube detector and PC running Felix32 data collection and spectrometer control software (PTI, London, Ontario). A toroidal electromagnet (15 mm pole gap, 16 AWG copper magnet wire, Arnold Engineering; M in Fig. 1) was held within the water bath (kept at 37.0 ± 0.2°C or 42.0 ± 0.2°C) by temperature controlled circulating water. The cuvette was held between the poles of the electromagnet in a circulating water bath held at...
37°C.

Exposure conditions for each sample were one of A) control (C): cells held at 37°C for 7200 s, B) SMF exposed (F): at 3900 s a 100 mT SMF applied, at 4800 s field returned to 0 mT, C) heat exposed (H): at 300 s water bath temperature increased to 42°C, at 2100 s bath returned to 37°C or D) SMF and heat exposed (HF): at 300 s bath turned to 42°C, at 2100 s bath returned to 37°C, at 3900 s SMF applied and at 4800 s SMF returned to 0 mT.

Bioluminescence was measured in units of photons/s. The slope of the bioluminescence readout was determined at four different time points, before the application of SMF, early in SMF exposure, late SMF exposure and post SMF exposure.

RESULTS

Six replicates of C, F, H and 4 replicates of HF conditions were analyzed. As expected, there was a statistically significant difference in the slopes of the bioluminescence trace between C and H and between F and HF conditions ($p < 1 \times 10^{-4}$) by ANOVA. There was a major effect of time point on the slope the bioluminescence trace under both control and hyperthermic conditions ($p < 8 \times 10^{-15}$, $p < 5 \times 10^{-14}$ respectively). Examination of the effect of a 100 mT SMF under no heat conditions revealed no significant difference in the slope of the bioluminescence trace ($p > 0.2$) by two way ANOVA. However, there did appear to be a trend towards an increase in slope under SMF conditions as compared to control during the post-field time point (6600 – 6900 s). Under conditions of hyperthermia, similar results were obtained. There were no significant differences in slope between heat alone and heat plus SMF conditions for any of the time points ($p > 0.3$). There did however, appear to be a slight trend toward an increase in slope in the post-field time points.

CONCLUSIONS

In the current study, we examined the effect of a 100 mT SMF on HSP70 in real-time by comparing the slope of the production of bioluminescence by a luciferase reporter system. To our knowledge this is the first time that truly real-time measurements have been made of HSP70 induction. We did not find any significant effect of SMF exposure under control or hyperthermic conditions. However, a trend of increased levels of bioluminescent production was observed in the time points after the SMF was removed. It is possible with the addition of more replicates, that this difference may become statistically significant.

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REFERENCES


The Effects of Extremely Low Frequency Magnetic Fields on Adipogenesis

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INTRODUCTION

Obesity is becoming a serious health problem because of its implication in various diseases, including type 2 diabetes, hypertension, coronary heart disease, and cancer. Obesity is characterized by increased adipose tissue mass, which could be regulated by inhibition of adipogenesis from preadipocytes to mature adipocytes and induction of apoptosis in adipose tissues. The effects of extremely low frequency magnetic fields (ELFMFs) on adipogenesis have not been well elucidated. However, it thought to be important because many people who suffer from obesity have increased opportunities for exposure to ELFMFs. We have previously evaluated the effects of ELFMFs on insulin-secreting cells to elucidate the effects of ELFMFs on diabetes [1-3]. In this study, we evaluated the effects of ELFMFs on adipogenesis in a preadipocyte cell line, 3T3-L1.

MATERIALS AND METHODS

The 3T3-L1, mouse embryo-derived preadipocyte cell line was obtained from Health Science Research Resources Bank. Cells were cultured in DMEM supplemented with 10% fetal bovine serum (FBS). Two days after the cells reached confluence, the cells were stimulated to differentiate with DMEM containing 10% FBS, 167 nM insulin, 0.5 μM isobutylmethyl-xanthine, and 1 μM dexamethasone for 2 days. Cells were then maintained in DMEM supplemented with 10% FBS and 167 nM insulin for another 2 days, and in DMEM supplemented with 10% FBS for an additional 4 days. During induction of adipocyte differentiation, cells were exposed to ELFMFs or sham-conditions. Exposure to ELFMFs was performed using our previously-developed ELFMF-exposure system [4]. The effects of exposure to ELFMFs on adipogenesis were quantified by measuring lipid content, and PPARγ and leptin mRNA expression. The lipid content was measured using AdipoRed™ assay kit, and mRNA expression was evaluated using a SYBER® Premix Ex Taq™ kit (TaKaRa Bio) and a Smart Cycler® II System with SYBR Green I as an intercalating dye.

RESULTS

The effects of ELFMFs on lipid content and mRNA expression are shown in Figures 1 and 2, respectively. Both lipid content and expression of mRNA encoding PPARγ and leptin were not affected by exposure to ELFMFs.
CONCLUSIONS

Our results suggest that exposure to ELFMFs does not affect adipogenesis of 3T3-L1 cells and hence has no effect on patients suffering from obesity.

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REFERENCES


Evaluation of the Effect of 2.45 GHz Radiofrequency Electromagnetic Field on the Thermal Tolerance of Saccharomyces cerevisiae

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INTRODUCTION

The major biological effects by exposure to radiofrequency electromagnetic fields (RFs) is known as thermal one, but several reports claim possible athermal effects recently. It was reported that 2.45 GHz RF exposure increased the ability of budding yeast to tolerate thermal stress by Bisciglia et al.[1] This study suggested athermal effect of RF exposure, however, to conclude the RF exposure caused the effect, it is necessary to report the details of exposure such as characterization of exposure apparatus, estimation of dosimetry, etc. For this purpose, we have used RF exposure apparatus well-characterized by Sonoda et al.[2] and investigated thermal tolerance of budding yeast exposed to RF under the active temperature regulation. In our previous study, the thermal tolerance of budding yeast exposed to 2.45 GHz RF was examined by survival rate following heat treatment at a fatal temperature to yeast cells, resulting that survival rate of RF-exposed cells was higher than that of unexposed cells. In this study, expression of several stress response genes in yeast cells was investigated.

MATERIALS AND METHODS

The RF exposure apparatus employed a cylindrical waveguide as a basic structure. This exposure apparatus was designed for exposing 2.45 GHz RF to cells suspended in liquid medium in a petri dish with 90 mm in diameter[2]. Budding yeast Saccharomyces cerevisiae ATCC2601 (wild-type strain) was used as the tester strain. 50 W/kg SAR of RF was exposed to yeast cells in MRS broth according to our previous study[3]. Incubation temperature was 25°C to minimalize the effect of temperature fluctuation on survival rate of yeast cells following fatal heat treatment. Temperature was controlled using Peltiert device placed under the exposure stage. Stress response of yeast cells were analyzed by survival rate after heat treatment at 47 or 48°C for 5 min[3] and level of gene expression as quantity of mRNA of four stress response genes. For gene expression analyses, yeast cells exposed to RF were harvested by centrifugation and cells pellet was stored at -80°C until use. Total RNA was extracted from yeast cells using hot phenol method. Extracted total RNA was used as template for quantitative RT-PCR. Targeted mRNA was reverse-transcribed and amplified using TaqMan One-Step RT-PCR Master Mix Reagents Kit (Applied Biosystems, Foster City, CA, USA) according to manufacture’s instruction and its signal was detected by ABI PRISM 7000 (Applied Biosystems) and quantity was calculated. TaqMan probes and primer sets, which were specific to hsp12, hsp26, hsp82 and ddr2, respectively, were designed by...
Primer Express ver. 2 software (Applied Biosystems). The specificities of these probes and primers were confirmed using the BLAST\(^4\) of DNA data bank of Japan (DDBJ).

RESULTS AND DISCUSSION

Amplification condition of RT-PCR was determined using total RNA that extracted from \textit{S. cerevisiae} incubated at 37°C. Comparing the amount of \textit{hsp82} mRNA between RF-exposed cells and unexposed cells, quantity of \textit{hsp82} was little lower in RF-exposed cells, but not statistically significant. Thus, this suggests that the effects of RF exposure on \textit{hsp82} expression was not observed in this study. Most heat shock genes in \textit{S. cerevisiae} are induced by interacting HSF (heat shock transcription factor) with HSE (heat shock element) or by interacting MSN2/4 (general stress transcription factors) with STRE (stress response element). Because the expression of \textit{hsp82} is regulated by HSF, at least the pathway regulated by HSF might not respond to RF exposure in this study. On the other hand, our previous study showed statistically significant increase of survival rate treated at either 47 or 48°C, which was fatal for \textit{S. cerevisiae}, for 5 min. These results suggest that there might be a mechanism not associating with increase of \textit{hsp82} to increase of heat tolerance of yeast cells, or the effect of RF exposure is too small to detect using the analysis of expression of \textit{hsp82} gene in this study. About exposure condition, we observed there was little (less than 0.5°C) temperature distribution in MRS broth at 0, 10 and 30 mm points from center of the bottom of Petri dish using optic fiber temperature sensors. However, numerical evaluation of the dosimetry in MRS broth\(^5\) indicated that RF exposure would result in larger temperature distribution on the bottom of Petri dish than practical measurement. Thus, mechanism of the effect observed in our study should be considered carefully. To clarify the effect, expression of other stress response genes such as \textit{hsp12} and \textit{hsp26}, which are regulated by both HSF and MSN2/4 and \textit{ddr2}, which is regulated by MSN2/4 will be examined following RF exposure and also effect of SAR and temperature distribution in detail would be examined.

CONCLUSION

The effect on expression of \textit{hsp82} in \textit{S. cerevisiae} following RF exposure (2.45 GHz, 50 W/kg) did not observed in this study. This suggests that stress response pathway regulated by HSF might little respond to RF exposure under the condition in this study.

REFERENCES

The Effects of Strong Static Magnetic Fields on Astrocyte Differentiation

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INTRODUCTION

Magnetic resonance imaging (MRI) has been introduced to many hospitals as a non-invasive diagnostic tool. A strong static magnetic field (SMF) is one of the key components of MRI, and MRI systems with a much higher magnetic flux density have been under development [1]. A main application of MRI systems with a much higher magnetic flux density is to analyze brain function. Therefore, it is becoming important to evaluate the biological effects of exposure to a strong SMF on the central nervous system. In this study, we evaluated the effects of exposure to strong SMFs on astrocyte differentiation in an astrocyte progenitor cell line.

MATERIALS AND METHODS

The AP-16 mouse neonatal cerebra-derived astrocyte progenitor cell line was obtained from Health Science Research Resources Bank. Cells were cultured in DMEM supplemented with 5 µg/ml insulin, 10 ng/ml endothelial growth factor, 50 µg/ml transferrin, 10 ng/ml biotin and 30 nM sodium selenite. On the day of evaluation, the cells were seeded on poly-L-lysine, fibronectin, laminin coated-well-plates, and exposed to SMF at a magnetic flux density of 6 T (41.7 T/m of magnetic field gradient, 251 T²/m of the product of magnetic flux density and magnetic field gradient, respectively) or 10 T (0 T/m, 0 T²/m), or sham-exposure for 30 minutes. Immediately after exposure, the culture medium was changed to transforming growth factor-β1 (TGF-β1) containing medium, and cultured for 2 days in a conventional incubator to evaluate the effects of exposure to SMFs on differentiation to astrocytes from astrocyte progenitor cells. Exposure to SMFs was performed using our previously developed system [2]. The effects of exposure to SMFs were quantified by the expression of mRNA encoding glial fiber-associated protein (GFAP) and cystatin C (Cst3) using a SYBER® Premix Ex Taq™ kit and a Smart Cycler® II System with SYBR Green I as an intercalating dye.

RESULTS

The effects of exposure to strong SMFs on mRNA expression encoding GFAP and Cst3 are shown in Figure 2. GFAP is a marker for mature astrocytes. Treatment with TGF-β1 markedly increased GFAP mRNA expression both under exposure to SMFs and sham-exposure conditions. Under exposure to SMF at 10 T (0 T/m, 0 T²/m), GFAP mRNA expression was increased. Cst3 is thought to play an important role in astrocyte development. Treatment with TGF-β1 markedly increased Cst3 mRNA expression. The exposure to SMFs did not affect Cst3 mRNA expression.
CONCLUSIONS

In this study, we evaluated the effects of exposure to strong SMFs on astrocyte differentiation in an astrocyte progenitor cell line, AP-16. Exposure to SMF at a magnetic flux density of 10 T (0 T/m, 0 T^2/m) increased GFAP mRNA expression and did not affect Cst3 mRNA expression.

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REFERENCES


Effects of 900 MHz GSM In Vitro Exposure on Gene Expression in Human Fibroblasts

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INTRODUCTION
The potential stress response(s) of biological systems to radiofrequency (RF) energy is the subject of a rapidly accumulating literature. However, there are both conflicting aspects within the data and a relative lack of mechanistic explanation for the molecular events observed, particularly in the absence of gross cell/tissue heating. The central nervous system (CNS) is among the biological targets of cell phones emission; many studies in the last decade dealt with this subject, including effects on neuronal cells in vitro, blood brain barrier, cognitive studies, neuro-physiological evaluations on animals and humans, obtaining, by and large, limited or scarce evidence of effect [1]. Fibroblasts represent an useful peripheral cellular system to study the putative RF fields effects on the CNS, due to their analogy with neuronal cells in many aspects, i.e. presence of the same cell-cell adhesion molecules, growth factors action and phospholipids-derived membrane second-messengers [2,3]. Their ease in culture procedures and handling make fibroblasts a helpful system for the evaluation of possible biochemical and neurotransmitter alterations in the CNS. Furthermore, fibroblasts are, as well as lymphocytes, a fine model to check and analyze the systemic response. The aim of this study was the evaluation of possible effects of exposure to 900 MHz GSM RF fields on gene expression in human fibroblasts.

MATERIALS AND METHODS
A wire patch cell (WPC) operating at the frequency band of GSM 900 MHz has been utilized [4,5]. The small dimensions of the WPC enable it to be placed in a standard incubator, where environmental conditions are strictly monitored and controlled (figure 1). In order to avoid disturbances to the electronic set-up of the incubator, produced by radiated power, the WPC can be shielded by means of a metal grid box and four blocks of foam absorbing material.

A single WPC allows the simultaneous exposure of four dishes at the same conditions. The exposure system used in biological experiments has been designed with four WPCs placed two by two into a couple of incubators (see design in the figure) and a four-RF channel system remotely controlled by a PC. The experiments were performed in blind. An appropriate system has been
developed to allow thermal control inside the samples during the exposure. Six fibroblast cell lines, yet available in the BioBank of our Institute I.R.C.C.S., Centre S.Giovanni di Dio, Fatebenefratelli (Brescia, Italy), were used in this study. All the cell lines come from 6 healthy volunteers (3 males and 3 females) and at the same passage. Cells were grown in Eagle’s Minimum essential Medium (Invitrogen) supplemented with 10% fetal calf serum, penicillin (100U/ml), streptomycin (100μg/ml), non essential amino acid solution (1%v/v) and glutamine (1%v/v) at 37°C in 5%CO2/95% air and when at confluence were divided into 3.5 mm Petri dishes and exposed to 0.4 W/kg, 1 W/kg or sham exposed for 24 or 72 hours. After the exposure, samples have been frozen and stored up to the biological analysis. Total RNA isolation was performed. Following quality controls, 2 μg of total RNA were reverse transcribed into cDNA. The expression levels of the target genes (B cell lymphoma gene-2, BCL2; Bel-2-associated X protein, BAX; P38 mitogen-activated protein kinases, MAPK-P38; Brain-derived neurotrophic factor, BDNF; cAMP response element binding 1, CREB1 and Extracellular Regulated Kinase 1, ERK1) have been normalized on the arithmetic media of two housekeeping genes (Glyceraldehyde 3-phosphate dehydrogenase, GAPDH and B2microglobulin, B2M). The quantitative analysis have been performed by Real Time PCR (TaqMan Real Time PCR System, Applied Biosystem).

RESULTS
We found that 24h electromagnetic field exposure affected the expression levels of BCL2, MAPK-P38 and BDNF genes. In particular, BCL2 mRNA levels were reduced both at 0.4 and 1 W/kg (0.72±0.2, p= 0.039 and 0.75±0.27, p=0.022 versus sham respectively), MAPK-P38 mRNA levels were reduced in stimulated group but only with a SAR of 0.4 W/kg (0.86±0,14, p=0.025 versus sham), whereas BDNF levels were negatively affected only with a dose of 1 W/kg. After 72 hours of exposure, we found that only BDNF mRNA levels were significant modulated, in particular, the dose of 1 W/kg caused a significant reduction (0.82±0,18, p=0.019 versus sham).

CONCLUSION
A reduction in the expression levels of some genes involved in cell stress response, neuronal differentiation and apoptosis processes were evidenced, at different SAR levels and exposure times, failing to put in evidence a dose-response trend. Further investigation are planned to better define possible effects of exposure to GSM electromagnetic fields on human fibroblasts.

REFERENCES
High Power Microwave (HPM) weapon systems employ very short pulses of microwaves, which may significant destructive effects on electronic equipment. HPM weapons are assumed to be non-lethal without any chronic or degenerative effects on biological tissue. Microwaves have well known biological effects that probably are induced by heating of the tissue. Such thermal effects include burn injuries, pain and increased vascular permeability. HPM weapons employ extremely short pulses of microwaves, which are unlikely to induce the same types of thermal effects in biological tissue. Research on bio-effects of HPM therefore often has a focus on non-thermal effects. In previous papers we have reported studies on possible biological effects after exposure to short (0.55 microseconds) pulsed fields of HPM. In a study on adult rats it was we reported an absence of effects on the Blood Brain-Barrier or cell death. No structural changes in the hippocampus of the brain could be detected (Risling et al., 2001). In order to use simpler but also more sensitive biological systems it was decided to use cell cultures for further experimentation. Changes in the shape of neuroblastoma cells exposed could be observed after exposure to long series of HPM pulses (Risling et al., 2003) as well as in primary cultures of neurons from the hippocampus of rat embryos (Risling et al., 2007). In endothelial cells exposed to multiple pulses of HPM a decrease in the content of the cytoskeletal protein tubulin (Risling et al., 2005) (HPM). In other experiments the gene expression in C6 glioma cell lines has been evaluated with GeneChip® Rat Gene 1.0 ST Arrays (Affymetrix). Low to moderate changes was observed in about 500 of the more than 27000 examined genes, but significant changes in genes for cell death, cytoskeleton, inflammation or heat shock proteins were found, except for a moderate decrease in the expression for neurofilament heavy polypeptide gene. Interestingly, we also observed a decrease in the expression for aquaporin 3, 4 and 6. It was concluded that the observed effects on tubulin probably are related to changes at the protein level and not a decrease in the expression of the mRNA for tubulin. In the present study we have performed experiments with a 9.1 GHz source (0.55 microseconds at 14 kV/m) in order to examine the possible effect on tubulin of HPM at different frequency. In addition, we have exposed cell cultures to a controlled 2°C temperature increase (in an cell incubator) to reveal if heating alone could induce a decrease in the content of tubulin. The content of tubulin was evaluated with immunoblots. The results showed that also the 9.1 GHz induced a decrease of tubulin. The threshold for the effect was similar as for the 1.6 GHz fields (about 90000 pulses). No evidence for a heating effect from the HPM could be detected in experiments with a thermal imaging camera. Furthermore, heating in an incubator was found to increase both tubulin and depolymerized β-Tubulin. In future studies, it will also be important to reveal the threshold
thermal effects in cells exposed to this type of fields cf. (Pakhomov et al., 2000) and to evaluate if localized hot spots could induce a decrease in tubulin.

REFERENCES


Effect of Static and Gradient Magnetic Fields on DNA Repair

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INTRODUCTION

The aim of this study was to examine in human lymphocytes whether the static homogenous or gradient magnetic field (SMF) has any effects on DNA, or could influence the 4 Gy 60Co-γ irradiation induced damage of the DNA if SMF exposure was applied before or after the irradiation.

MATERIALS AND METHODS

The effects of homogeneous (hSMF) and inhomogeneous (iSMF) static magnetic field on human lymphocytes in whole blood were studied in two parallel experiments. The venous blood samples originated from 3 healthy, non-smoking volunteers (men aged 26, 26, 50 y) on 4 different occasions: 2 parallels for the hSMF and 2 parallels for the iSMF. Participants had not been exposed to chemicals, drugs, or X-rays in 3 months preceding blood sampling. Some sample was exposed only to hSMF or iSMF for 30 min, 1, 2, 4, 6, 18, 20 or 24 h. The DNA damage was induced by 4 Gy 60Co-γ irradiation. During the DNA repair some of the incubated samples were exposed to a homogeneous static magnetic field of 145.8 ± 0.1 mT magnetic flux density for a time period of 30 min, 1, 2, 4, 6, or 24 h, while other samples were exposed to inhomogeneous gradient static magnetic fields of peak-to-peak magnetic flux density layer 1 (L1: 476.7 ± 0.1 mT), layer 2 (L2: 12.0 ± 0.1 mT) or layer 3 (L3: 2.8 ± 0.1 mT) with a lateral magnetic flux density gradient of 47.7 T/m, 1.2 T/m and 0.3 T/m, respectively. Another set of samples was exposed to the aforementioned magnetic fields for 24 h, before irradiation. The results were compared to the negative control (not irradiated, not exposed to static magnetic field), and the positive control (irradiated by 4 Gy 60Co-γ, not exposed to static magnetic field). DNA repair analysis was made by a single-cell gel electrophoresis technique (Comet-assay). The DNA strand brakes were determined using fluorescent microscope on 100 cells by Komet 4.0 (Kinetic Imaging, Ltd, UK) image analyzing software. The Tail DNA% was determined (Tail% DNA=100%-head%DNA) as a result.

RESULTS

Inhomogeneous or homogeneous SMF had no significant effect to the Tail DNA% of the lymphocytes compared to the negative control. We found the smallest number of DNA strand breaks in L2, among those treatments, where the cells were irradiated before the iSMF and hSMF exposure.

There was no significant effect of the exposure to hSMF on the number of the DNA strand breaks in the irradiated and exposed samples, except at 4 hours of exposure. Here the Tail DNA% was significantly lower in the hSMF exposed and 4 Gy irradiated sample than in the
positive control. The Tail DNA% in the hSMF only sample was significantly lower than in the negative control (Fig1).

The Tail DNA% was significantly higher in the iSMF exposed and in the 4 Gy irradiated samples than in the negative control in the first two hours of the experiment. The repair had gone similar in the iSMF to the positive control. L1 has no significant effect on the DNA repair, while L2 delays it. (Fig2).

**CONCLUSIONS**

We found no harmful effect for either hSMF or any layer of iSMF as compared to control on healthy human lymphocytes.

Nevertheless the layer 2 of the inhomogeneous SMF treatment reduces the damage as compared to the positive control, if the treatments are applied for 24 h preceding the irradiation.
In Vitro Cytostatic Response to 0.57-MHz Electric Currents

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INTRODUCTION
The capacitive-resistive electric transfer (CRET) therapy is a non-invasive electro-thermal strategy that uses electrode pairs to transdermically deliver electric currents in the 0.4 – 0.6 MHz range, inducing temperature increases in internal, targeted tissues. Although currently applied to the treatment of osteoarticular injuries, preliminary clinical results are indicative that some oncological lesion could be responsive to CRET therapy. It has been proposed that the beneficial effects of the electro-thermal treatments could be the result of two combined actions: a tissular effect of the electrically-induced hyperthermia plus a cellular or subcellular response to the electric currents themselves. The present study investigates the in vitro response of the human hepatocarcinoma cell line HepG2 to subthermal, 0.57-Hz currents, within the CRET frequency range.

MATERIALS AND METHODS
On day 4 after plating, stainless steel electrode pairs were placed in all, experimental and control Petri dishes, and connected in series to an INDIBA (Mod. M-500) stimulator set to deliver 5-minute pulses of 0.57-MHz, sinus wave currents at a subthermal current density of 50 µA/mm². The electrode pairs in the control dishes remained unenergyzed. After 12 or 24 hours of exposure and/or incubation, the cultures were either analyzed in blind conditions for treatment, or incubated for 18 or 24 additional hours in the absence of the electric stimulus (total incubation time, 42 or 48 h) before blind analysis.

RESULTS
The study of the cultures trough Trypan blue exclusion analysis at the end of the 12 – 48 hour experimental period revealed a progressive decrease in the number of viable cells. The maximum effect, about 20% reduction with respect to controls, was obtained at the end of the 24-h period of post-exposure incubation (Fig. 1). No changes were observed in the rates of necrosis or apoptosis that could explain the described effect. The expression of the proliferating cell nuclear antigen (PCNA) after 24 h of treatment was quantified through immunofluorescence and Western Blot. The results showed that PCNA was significantly subexpressed in the exposed samples, indicating that the reduction in the cell number observed in treated samples could be attributable to electrically-induced reduced rates of cell proliferation. As revealed by flow cytometry analysis, the putative antiproliferative response could be due to a partial blocking of the cell cycle progression in a fraction of the cellular population, being the G1 and S phases particularly affected (Table 1). In order to characterize the effects on the cell cycle, immunofluorescence and Western Blot analysis were carried out of the expression of proteins controlling the cell cycle progression, cyclins A and D1, and p27Kip1. After 12 hours of treatment a significantly increased expression of cyclin A was observed that is consistent with an arrest or prolongation of S phase of the cycle. After a 24-hour exposure, increased levels of cyclin D1 were obtained, together with enhanced activation of the p27Kip1 inhibitor and significant decrease of cyclin A; which could result in a deceleration of the cell cycle in phase G1. After 18 hours of post-exposure incubation in the
absence of electric treatment, the expression of the three proteins was significantly reduced in the exposed samples with respect to controls. This could represent an adaptative, compensatory reaction of the cellular system in response to stimulus deprivation.

![Figure 1: Number of cells per dish during and after exposure to CRET currents at 50 μA/mm². The points represent means ± SEM of five experimental replicates, with five dishes per experimental condition and replicate (25 values per point). *: 0,01 < p < 0,05 **: 0,001 ≤ p ≤ 0,01. Student’s t-test.](image)

Table 1: Percent of cells in the different phases of the cycle after 12 or 24 h of CRET exposure, and after 18 hours of post-exposure incubation (42 h). Flow cytometry. The values are percents over the respective controls and represent means ± SEM of three experimental replicates, with five dishes per experimental condition and replicate. *: 0.01<p<0.05 **: 0.001≤p≤0.01. Student’s t-test.

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>No. of experimental replicates</th>
<th>G0/G1 phases</th>
<th>S phase</th>
<th>G2/M phases</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>3</td>
<td>101.3 ± 1.2</td>
<td>123.6 ± 5.7 *</td>
<td>87.7 ± 4.6</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>103.0 ± 0.5 **</td>
<td>82.0 ± 6.0 *</td>
<td>93.9 ± 2.4</td>
</tr>
<tr>
<td>42</td>
<td>3</td>
<td>103.3 ± 1.5</td>
<td>96.9 ± 12.5</td>
<td>90.7 ± 8.2</td>
</tr>
</tbody>
</table>

CONCLUSIONS
Electrically-induced changes in the expression of proteins controlling the cell cycle progression, cyclins A and D1, and p27kip1, are likely to be responsible for the reported partial arrest or deceleration in phases S and G1 of the cell cycle and for the observed decrease in cell proliferation. The present results provide partial support to the proposed electric and thermal synergy in the therapeutic effects of CRET treatments. The understanding of the cellular and molecular phenomena underlying the electro-thermal effects of CRET can contribute to significantly improve and extend the clinical applications of this therapy.

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RF-EMF and Stress Response: Effect of RF-EMF on Alternative Splicing of Acetylcholinesterase.

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INTRODUCTION

There is evidence that radio frequency electromagnetic fields (RF-EMF) elicit biological effects in a variety of cells. In the brain, two catalytically active acetylcholinesterase (AChE) isoforms with distinct functions in development and repair exist and are produced as a result of alternative splicing. The rare, read-through isoform, AChE-R, is preferentially induced by injury and appears to promote repair and protect against neurodegeneration. Overexpression of the more abundant, synaptic isoform, AChE-S, was shown to enhance neurotoxicity. The roles of the two AChE variants were reported in the response to neuronal injury and neurodegeneration [1, 2], physical trauma [3], and Alzheimer disease [4]. This research would contribute to study the effects of RF-EMF exposure on alternative splicing of AChE using neuronal cell lines in vitro.

MATERIALS AND METHODS

Cell culture: Cells were routinely maintained in DMEM supplemented with 10% horse serum, 5% FCS and antibiotics. Differentiation induced by NGF was performed over 7 days in collagen-coated culture vessels using 100ng/ml 7S-NGF. Heat shock and thapsigargin treatments: Undifferentiated PC12 cells were seeded 24h prior to heat shock or thapsigargin treatments at a density of 5×10⁶ cells per 60mm culture dish or at 2.5×10⁴ cells per coverslip treated either with APTS or coated with collagen. For experiments using differentiated PC12, cells were seeded at a density of 5×10⁴ cells per 35mm collagen-coated dish and cultured in NGF-containing medium, as described above. Cells were heat-shocked for 2h at 42°C and then allowed to recover at 37°C for 1h, 4h or 8h. Thapsigargin (TG) was added to the culture medium at a final concentration of 0.5 µM. As a control, DMSO alone (solvent) was used. The TG and DMSO treatments were carried out for 12h or 24h. RF-EMF exposure: RF-EMF exposures were performed using a sXc900 setup with exposure chambers in a cell culture incubator. For each double-blind run, cells in 35mm dishes (4 ml culture medium) were randomly exposed to either GSM basic (935 MHz; 217 Hz modulation) RF-EMF with an average expected SAR of 4 W.kg⁻¹ or sham-exposed. The total exposure time was chosen to be either 2 or 16h with 5min ON-10min OFF cycles. Temperature increase of the exposed cells was not allowed to exceed 0.1°C in order to prevent the induction of cellular heat-stress pathways. Primary antibodies: The following primary antibodies (Ab) were used: anti-AChE-S C-terminus Ab; affinity-purified custom-made anti-AChE-R C-terminus Ab; anti-α-tubulin Ab. Western blotting: Following experimental treatments the cells were recovered by pipetting, washed once with PBS and lysed with RIPA buffer supplemented with protease inhibitors. Protein concentrations were measured by the method of Bradford. Proteins were resolved by SDS-PAGE, blotted onto nitrocellulose membranes and processed using a standard protocol. Immunofluorescence analysis: Cells were fixed in 4% PFA for 20min at RT and post-fixed and permeabilized with methanol/acetone (1:1) at -20°C. Coverslips were blocked in PBS/5% BSA. Primary antibodies were applied for 1h at RT or O/N at 4°C in the same buffer, followed by appropriate Alexa Fluor-conjugated Ab.
RESULTS
PC12 neuroblastoma cells used in our study are a secondary rat cell line originally derived from a pheochromocytoma. Under standard culture conditions, they have properties similar to those of immature rat adrenal chromaffin cells. In the presence of nerve growth factor (NGF), PC12 cells outgrow neurites and acquire characteristics of sympathetic neurons. The temperature difference between the exposed and sham cells never exceeded 0.03°C, thus precluding an eventual contribution of thermal effects. In the experimental conditions we used, no alteration in the expression level or in the intracellular localization of the stress-associated AChE-R isoform was detected by western blot or by immunofluorescence analysis in undifferentiated cells. Similar results were obtained by western blot analysis of differentiated PC12 cells. The expression of the ‘synaptic’ AChE-S isoform was also unaltered in similar conditions. In order to check whether our methods were suited to detect changes in AChE-R form expression, cells were treated with thapsigargin (TG) for 12 or 24h and analysed by immunofluorescence and by western blot. The stimulating effect of TG on alternative splicing events leading to the overexpression of the AChE-R variant was only observed after 24h exposure to TG. Western blots of extracts from TG-treated undifferentiated and differentiated PC12 cells showed that AChE-R was clearly upregulated by TG since the 68 kDa AChE-R band was more intense in TG-treated cells than in solvent (DMSO)-treated cells. Irrelevant of the treatment applied, AChE-R was invariably detected by immunofluorescence as a punctuate pattern, being likely small vesicles dispersed throughout the cytoplasm, with a slightly more intense staining in TG-treated cells. In contrast, the main localization of the AChE-S isoform within the cell appeared to be perinuclear, in structures likely to be the ER and was not affected by TG. The expression of AChE isoforms was not altered in heat-shocked cells compared to cells maintained at 37°C.

CONCLUSIONS
The stress-associated AChE-R isoform did not appear to be up-regulated upon exposure of undifferentiated or differentiated PC-12 cells to up to 16h of 5min ON/10min OFF cycles of GSM basic RF-EMF. This suggests that RF-EMF may not trigger intracellular Ca2+ release and stimulate the protein kinase C (PKC) pathway that was reported to be involved in the regulation of AChE-R. However, we cannot exclude that our system lacked sensitivity to detect subtle effects of RF-EMF or that the RF-EMF dose applied to the cells was not sufficient to evoke a response. Experiments are underway that will tell us if this is the case.

ACKNOWLEDGEMENTS
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EFFECTS OF GSM-900 MHZ ON THE PROTEIN EXPRESSION OF
CHAPERONE-MEDIATED AUTOPHAGY COMPONENTS IN
CULTURED NEURONS AND ASTROCYTES

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INTRODUCTION

We analyzed in cultured neurons and astrocytes from the cerebral cortices rat embryos whether GSM-900 MHz radiofrequency (RF) fields, characteristic of mobile phones at non-thermal levels, alter the protein expression of the most known molecular components of Chaperone-Mediated-Autophagy: the constitutive heat-shock protein Hsc70 and the lysosome-associated membrane receptor LAMP-2A. Chaperone-mediated autophagy (CMA) is one of the processes of protein degradation in the lysosome. CMA is a relatively specific catabolic system, since only proteins that have a consensus peptide motif (KFERQ or KFRQ-Like) are recognized by the binding of the chaperone Hsc70, which forms a complex with several co-chaperones [1]. This substrate/chaperone complex then binds to the lysosome-associated membrane receptor type-2A (LAMP-2A), thus allowing the CMA substrate to translocate into the lysosome for degradation. By eliminating unwanted proteins, CMA represents a mechanism of cell defense. Therefore, it is not surprising that abnormalities of CMA might be associated with several pathologies including neurodegenerative disease like Parkinson’s disease [2]. To our knowledge, there are no available data concerning the effects of radiofrequency (RF) fields on the autophagy process.

MATERIALS AND METHODS

Neuron-enriched cultures were prepared from the cerebral cortex of Wistar rat embryos (E17) as previously described [3]. To obtain cultures enriched with astrocytes, neuron-enriched cultures were switched to a culture medium containing a high fetal calf serum (FCS) concentration (20%), which stimulates the proliferation of non neuronal cells (e.g. astrocytes) and is expected to kill neurons.

A previously described Wire Patch Cell exposure system was used [4]. Cells were exposed
continuously for 24 h to a 900-MHz GSM signal at a specific absorption rate (SAR) of 0.25 W.kg⁻¹.

Relative variations of Hsc70 protein, Hsp70, Hsp90 and LAMP-2A protein levels were determined by western blot semi-quantitative analysis according to our previously described protocol [5].

RESULTS

In our condition of exposure to GSM 900 MHz (average SAR 0.25 W.Kg⁻¹, 24 h), the protein expression of an inducible Hsp, Hsp90 was not significantly changed (see figure 1). Exposure to RF failed to induce apoptosis in both cell type cultures, as demonstrated by western blot of cleaved caspase-3 (the active form of caspase-3). These data confirm previously reported findings [6]. In both neuron- and astrocyte-enriched cultures, exposure to GSM 900MHz slightly increased Hsc70, whereas LAMP-2A had a tendency to decrease.

CONCLUSIONS

These preliminary data should be confirmed and statistically analyzed for significance. It also will be necessary to determine whether the changes in the protein expression of Hsc70 and LAMP-2A are linked to alterations in the CMA process. Additionally, the long term consequences of such eventual CMA alterations on cell fate should be determined.

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REFERENCES

Investigation of Potential Power-Dependent Effects of Millimeter-Wave Radiations on Various Aspects of Human Cell Functioning

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INTRODUCTION

The aim of this study was to investigate whether human skin cells respond to exposure to low-power millimeter-wave (MMW) radiations at 60 GHz. Currently under development, new broadband wireless communication systems will operate around this frequency and will provide high-definition multimedia streaming and high-speed multimedia transmissions. The frequencies around 60 GHz are naturally absent in the environmental electromagnetic spectrum and they represent a new anthropogenic factor in our environment.

Previous studies have reported that MMW radiations, which are non-ionizing, are not genotoxic [1]. Moreover, we have recently shown that, if precautions are taken to avoid thermal effects, low-power MMW exposures have no proteotoxic effects, as judged by the absence of detectable change in heat shock protein expression [2]. In the meantime, it was demonstrated that these radiations can modify the structural state of phospholipids layers in biomembranes [3, 4]. Accordingly, we recently evaluated if the membrane-rich organelle endoplasmic reticulum (ER) could be a potential target for MMW. We found that exposure to MMW radiations at various frequencies around 60 GHz, with an incident power density close to typically expected from wireless communication systems (0.14 mW/cm²), does not induce any detectable modification of ER homeostasis [5]. However, this work did not exclude that other exposure parameters, such as intensity, polarization, modulation or exposure duration may selectively impact cells. In the present study, we have investigated the role of power density on cell growth and viability, on cell cycle and finally, on gene expression of factors related to cellular stresses.

MATERIALS AND METHODS

An exposure system, operating at 60.4 GHz with an output power ranging from 0 up to 500 mW was specifically developed for exposure of in vitro cell culture. This exposure system will be presented in a distinct abstract during the meeting (Zhadobov et al., “Millimeter-wave exposure setup and dosimetry for in vitro studies”).

Human skin cell lines were used as an appropriate model since MMW are essentially absorbed in the superficial layers of skin. The human keratinocyte cell lines HaCaT and CCD1106, as well as the human melanoma cell line A375 were exposed to MMW with an incident power density (IPD) varying between 1 and 5 mW/cm², which correspond to the international safety standards and recommendations for the general public and professionals, respectively.

Cell growth and viability were studied by using the “cell growth determination kit” from Sigma, also known as MTT test. This assay allows determining the cellular metabolic activity, which is proportional to the number of viable cells. To complete this first approach, we then evaluated the impact of MMW exposure on cell cycle by flow cytometry experiments. Finally, to measure potential modifications of gene expression we used reverse transcription polymerase chain reaction (RT-PCR) analysis, as previously described (5). The
mRNA expression levels of stress-induced survival factors and inflammatory genes were measured by real-time PCR and normalized with housekeeping gene expression.

RESULTS AND CONCLUSION

The sensitivity to MMW exposure of three different human skin cell lines was examined to avoid particular cases. HaCaT, CCD1106 and A375 cells were exposed or sham-exposed to 60.4 GHz, for 1 to 24 h. Moreover, various incident power densities (IPD from 1 to 5 mW/cm²) were used in order to estimate the importance of the incident power density level.

Our experimental results demonstrate that for an incident power density below 2 mW/cm², MMW radiations do not modify cell growth and viability. Effect of higher IPD are currently under process and the data will be available at the meeting.

Furthermore, exposure of human skin cell lines at 60.4 GHz showed that for various IPD (1.1-1.4 mW/cm² or 1.7-2.1 mw/cm²), no statistically significant changes were observed for gene expression. As biomarkers, we used ER stress-sensor genes (BiP/GRP78 and ORP150/GRP170) and pro-inflammatory genes (CCL2, CXCL-1, CXCL-8), that are highly sensitive to environmental conditions and involved in various diseases. When compared, exposed and sham-exposed samples present the same cellular levels of BiP/GRP78 and ORP150/GRP170 mRNA, whereas cells treated with thapsigargin, a drug that triggers ER stress, showed a 13- and 8-fold increase, respectively. Relating to pro-inflammatory genes, expression of the chemokines CCL2, CXCL-1 and CXCL-8 was not changed in MMW exposed cells, whereas they are upregulated by interleukin-1β. Effect of higher IPD on these biomarkers gene expression is currently under investigation and will be presented at the meeting.

ACKNOWLEDGEMENTS

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REFERENCES

High Intensity Static Magnetic Field for in vitro Experiments

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INTRODUCTION

In the last years, the large diffusion of MRI systems in diagnostics and research has induced the scientific community to investigate on possible harmful effects due to such a kind of exposure in workers. Three types of EM sources are present inside a MRI system: RF field, gradient field and high intensity static magnetic field (0.2-3T in the more diffused systems). Although many studies showed that there is no prejudicial effect to the health due to RF fields exposure, the question concerning static magnetic field and gradient exposure is still under investigation. The WHO deemed that there are not enough scientific data and consequently the European Council Directive 2004/40/EC [1] about the workers protection has not came into force yet. This paper describes the design of an exposure system for in vitro experimental studies that allows contemporary exposure of biological samples in 4-8 Petri dishes to static magnetic field of different intensities (0.2-0.5T) in homogeneous conditions and in blind modality.

MATERIALS AND METHODS

The system is constituted by three fundamental parts: two permanent magnets generating a static magnetic field; a soft iron ring that enclosing the two sources of field by closing the magnetic circuit; an aluminium box embedded inside the magnetic circuit gap air to house Petri dishes during exposure.

The developed prototype is constituted by two neodymium-iron-boron (an alloy with a very high magnetic remanence, Br=1.21T) permanent magnets (dimensions 100x100x10 mm³) and faced in north-south configuration at a distance of 30 mm each other. The magnetic plates are enclosed in a soft iron structure that has the double function of increasing the field intensity and fencing it in the exposure area. The exposure area is inside an aluminium box (dimensions 150x150x25 mm³) embedded in the magnetic circuit; aluminium assures a very good mechanic resistance to huge magnetic force exerts by sources and due to its paramagnetic property does not interfere with them. The described structure is put in a further box to hide the nature of sources that could be of different thickness and/or material in function of the planned intensity field. This characteristic allows to expose biological samples in blind way. The Figure 1 shows a vertical section of the developed system.

Static magnetic field measurements inside the exposure area, have been performed using a teslameter (Group3 DTM-141) equipped with a monoaxial Hall probe (Group3-LPT 141-30-2S) and measuring the three field components by a scanning system controlled by an automatic procedure developed in Labview environment.
RESULTS

The measurements of magnetic flux density (B) show that the direction of the field is perpendicular to the magnets plane as expected, moreover a useful volume with a good uniformity in terms of B field and a high intensity exposure level can be realized. The Figure 2 shows the B-field pattern in a plane parallel between the two magnetic plates: the values have been measured in a 100x100 mm$^2$ region using a grid of 5 mm step. The graph shows a region of about 80x80 mm$^2$ where B varies between 0.41T and 0.36T (total uncertainty of about 20%). This pattern is the same for a height of about 10 mm.

CONCLUSIONS

The designed prototype presents suitable characteristics for \textit{in vivo} experiments: small dimensions (suitable for incubators), different intensities according to the chosen magnets, a consistent volume to expose a few Petri dishes, blind modality. It represents a low-cost solution to realize exposures to static magnetic fields with intensities comparable with the ones in magnetic resonance systems.

REFERENCES

Combination of Extremely Low Frequency Low Energy Electromagnetic Fields and Dynamic Compression and Shear on 3-D Constructs for Cartilage Tissue Engineering

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INTRODUCTION

Electromagnetic fields (EMF) are used in medicine to stimulate cell proliferation and tissue regeneration. The non-invasive application and simple usage make them interesting for \textit{in-vivo} treatment as well as for \textit{in-vitro} tissue engineering purposes. Earlier observations revealed the special electrical properties of cartilage during loading \cite{1} and the stimulating effect of EMFs on the matrix synthesis of chondrocytes\cite{2}. Therefore the application of EMFs might interact in a synergistic or an additive manner with the matrix-inducing effects of mechanical loading\cite{3}. We investigated the effects of single and combined treatment of bovine articular chondrocytes seeded on 3-D polyurethane constructs with an EMF and dynamic compression and shear.

MATERIALS AND METHODS

A pair of helmholtzcoils able to generate a homogeneous field in a volume of approximately 1000cm\textsuperscript{3} was designed and constructed. Chondrocytes from bovine calves (approx. 3 months old) were seeded into porous polyurethane scaffolds (8mm in diameter and 4mm high) used and evaluated before \cite{4}. Complex mechanical force was applied with a bioreactor \cite{5} for 2h every second day according to a standard protocol used in previous studies. In ‘’combined treatment’’ groups sinusoidal electromagnetic fields of 60 Hz and fluxdensities of 1mT, 2mT or 3mT were applied for 3h directly after mechanical loading. The outcome was analysed by measurement of sulfated glycosaminoglycan (GAG) per DNA content in scaffold and medium. Real time RT-PCR on various cartilage specific genes like collagen 1, collagen 2, SOX9, COMP, aggrecan, MMP3, MMP13, and PRG4 was also performed.

RESULTS

The results showed a high influence of EMFs on the production and release of GAG in the scaffold construct and medium. The group which was only exposed to the field of 2mT showed a 36\% higher amount of GAG/DNA than the loaded control and 47\% higher amount than the unloaded and unfielded control. This effect was even higher (61\% more GAG/DNA against unloaded control) amongst the scaffolds of the 3mT field and mechanical loading group (Figure 1). On the gene expression level a potent downregulation of collagen 1 in all fielded groups was noticed. Additionally there was an increase of PRG4 above the control in all loaded groups plus synergystic effects on PRG4 with the 2mT and 3mT field (ranging from 50\% to 246\% higher gene expression.
CONCLUSIONS

This study indicates that the impact of the single use of low energy electromagnetic fields on cellular metabolism might be comparable or even better than the use of other physical stimuli for chondrocyte matrix synthesis like dynamic compression or shear. Furthermore, synergistic effects on gene expression patterns of combined treatments with EMFs and dynamic mechanical load were observed \textit{in-vitro}. These effects can be used to culture optimized tissue in a shorter period of time. However the major advantage of EMF stimulation is the fact that it is non-invasive. The risk of contamination during cell culture is minimized and there is no risk of operation, radiation or medication to patients undergoing an electromagnetic treatment. Therefore we believe EMFs to be a very promising technique of cell stimulation and treatment.

ACKNOWLEDGMENTS

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Oxidative Stress Of 50 Hz Electromagnetic Fields In Combination With Chemical Exposure On A Human Monocytic Cell Line

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INTRODUCTION
Exposure to ELF-EMF may induce DNA damage by means of increasing levels of free radicals [1, 2]. Such a general cellular activation is compatible with the diverse nature of observed (secondary) effects. It is hypothesized that ELF exposure can cause both acute and chronic effects that are mediated by increased free radical levels. It is known that the modulation of signal cascades and regulatory pathways by oxidative stress can lead to cellular changes (e.g. immune response) that finally can lead to diseases such as inflammation, allergy, and, cancer [3, 4]. The aim of our work was to determine the oxidative stress induced by 50 Hz electromagnetic radiation on in vitro cultured monocytes. The cells were also submitted to additional oxidative stress induced by the chemical compound paraquat. This allowed estimating the impact of toxicity and oxidative stress induced by a combined chemical and physical stress.

MATERIALS AND METHODS
THP1 monocytic cells derived from a acute monocytic leukemia patient [5] were cultured in RPMI medium. The cells were seeded after overnight culture in fresh medium and exposed to varying concentrations of paraquat ranging from 0 to 5 mM. These cultures were exposed in a Helmholtz coil (diameter of 20 cm, length of 42 cm) in an incubator at 37 °C at 5% CO₂. The electric current was adjustable and allowed exposing the cultures to a magnetic field strength between 0.01 and 1.0 mT. Samples were collected at defined intervals to determine 1/general toxicity using the Alamar Blue test, 2/ (oxidative) DNA damage using the Comet assay, and 3/ gene expression using using oxidative stress focused PCR array from SABiosciences. The different experimental conditions were compared to their respective controls.

RESULTS
The addition of paraquat caused cytotoxic effects after a 24 h-incubation period in all cultures starting from 0.31 mM and the viability dropped to 10% at the concentration of 5.0 mM. The parallel exposure of the cell line to a 0.5 or 1.0 mT 50 Hz magnetic field caused additional cytotoxic effects. Cell growth as measured with the Alamar Blue test was increased when controls and cultures exposed to non-cytotoxic concentrations of paraquat were exposed to magnetic fields of 0.01 and 1.0 mT. Subsequently, the impact of paraquat and 50 Hz fields on the induction of DNA damage was investigated. THP1 cells that were exposed to 0.156 mM paraquat and/or 0.5 mT were submitted to the Comet assay. The exposure conditions were chosen based on the cytotoxicity assays and ensured that no cytotoxic events occurred because this might bias more subtle DNA damaging events. A 24 h-incubation exposure of the cells to 0.156 mM paraquat and/or 0.5 mT did not change the
DNA damage as measured as Median %DNA in tail. The classical Comet assay reveals single- and double-strand DNA breaks and not necessarily oxidative DNA damage, which is reflected in an increased amount of 8-oxoguanine (8-oxoG). The addition of formamidopyrimidine DNA glycosylase (fpg) in the Comet assay protocol results in the excision of 8-oxoG and the generation of additional single-strand breaks that can be measured using the Comet assay. The addition of fpg to cells that were pre-exposed to paraquat and 0.5 mT induced a significant rise in the Median %DNA in tail. The Median % DNA in tail parameter increased from about 15 to more than 20 indicating additional oxidative DNA-damage induced by the 50 Hz field exposure. The same experimental parameters (0.156 mM paraquat and 0.5 mT magnetic field) were applied to investigate the generation of reactive oxygen species (ROS) in the cells and to measure the expression of genes related to oxidative stress. After 4 h incubation, the cells were incubated with the fluorescent probe carboxy-H2-DCFDA. The relative fluorescence measured at a 520 nm increased in the cultures exposed to 0.5 mT. This phenomenon suggests an increased production of ROS. The gene expression data of cells taken at the same interval showed a differential regulation of 7 genes (out of the panel of 85) that are linked to oxidative stress. An upregulation of AOX1, GPR156, PTGS2, and TXNDC2; and a downregulation of ALOX12, GSS, PIP3-E was observed.

CONCLUSIONS

The in vitro results using a human monocytic cell line suggest an interplay between chemical exposure and 50 Hz electromagnetic radiation ranging from 0.01 to 1.0 mT. Evidence was collected under non-cytotoxic exposure conditions (0.156 mM paraquat and/or 0.5 mT 50 Hz magnetic field) that 50 Hz-fields induced additional oxidative stress. This was reflected in an increase of oxidative DNA-damage as measured with the Comet assay. Parallel to an increase of ROS, a subset of genes was differentially regulated. The results warrant further investigation into mechanisms that may cause this additional oxidative stress. Furthermore, the results should be related to the possible biological effects that are linked to 50 Hz-magnetic fields.

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REFERENCES

Reactive oxygen species formation is not enhanced by exposure to UMTS 1950 MHz radiation and co-exposure to ferrous ions in Jurkat cells

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INTRODUCTION

Recently, the Universal Mobile Telecommunication System (UMTS) signal, a digital technology of third generation (3G) cellular systems, has been developed as a standard, allowing multimedia services. At the moment it is the most widespread in Europe and it is expected that in the near future its use will be increased. Up to now few in vivo and in vitro studies have been published by employing UMTS signal and the results are still inconclusive. Among the possible biological effects of the exposure to radiofrequency (RF) radiation, oxidative stress is of crucial interest since it is a possible mechanism of action for non-genotoxic carcinogenesis [1]. Oxidative stress occurs when the production of ROS overrides the antioxidant capability of the target cell. This study was designed to investigate cell viability and ROS formation in human lymphoblastoid cells exposed to 1950 MHz, UMTS signal, for 1 h or 24 h exposure duration. The kinetics of ROS formation was also followed in the range of 5-60 min upon RF exposure and co-exposure to FeSO₄, a well known oxidative stress inducer.

MATERIALS AND METHODS

The signal used was generated by a series generator, amplified and fed through a bidirectional power sensor into a rectangular short-circuited waveguide whose feeding end was a coaxial waveguide adapter. An identical waveguide was used for sham exposures. Both waveguides were housed in a commercial incubator. The power sensor and signal generator were connected to a dedicated computer [2]. Preliminary experiments were carried out to monitor and recorded temperature time course during the exposure by means of a four-channel fibre-optic thermometer. Several experimental conditions were tested to measure ROS formation after RF exposure (SAR values of 0.5 and 2 W/kg) and co-exposure to 50 µM FeSO₄ in Jurkat cells. Cell viability was also measured by means of Neutral Red and Resazurin assays. Statistical analysis of ROS data was performed comparing, for each experiment, the cumulative distributions of cytometric raw data of treated and untreated samples [3]. Cell viability data were analysed by applying the ANOVA univariate to compare sham exposed and RF exposed groups.

RESULTS

RF radiation exposure did not alter spontaneous or 50 µM FeSO₄ induced ROS production for all the experimental conditions investigated. Treatments with FeSO₄ induced a significant and noticeable increase in ROS production, as expected, validating the sensitivity
of the method used. In Figure 1 representative flow cytometric histograms are reported. When cell viability was investigated, the Neutral Red uptake test and the resazurin assay did not reveal statistically significant differences among treatments (P>0.05 in all cases), indicating absence of cytotoxic effects due to 24 h exposure to RF radiation for both SAR values investigated.

Figure 1: Representative flow cytometric histograms of cells sham-exposed, exposed to RF radiation (0.5 and 2 W/kg) and treated with 100 µM FeSO₄ for 5 min as positive control.

CONCLUSIONS

The results presented in this study are consistent with most of the data reported in the literature on oxidative stress induced by RF radiation exposure alone or given in combination with known oxidative stress inducers, in the frequency range of 800-2000 MHz. Nevertheless, we would like to highlight that our findings are not directly comparable due to the substantial difference in the employed modulation (3G vs. 2G technologies). In fact, it has been suggested that the biological effects of RF radiation, when present, may be related not only to the frequency and SAR level investigated, but also to the type of modulation applied [4]. At present, to our knowledge this is the only study available on the induction of ROS after RF exposures/co-exposures employing the UMTS signal. Because we can not rule out the possibility that other oxidative stress parameters could be altered by RF exposure/co-exposure, further studies are needed either to investigate other endpoints involved in the oxidative cell metabolism and by using different stressors.

REFERENCES

INTRODUCTION

In earlier studies we showed a significant increase of free radical production after exposure to 50 Hz magnetic fields at a flux density of 1 mT in primary human umbilical cord blood derived monocytes, mouse bone marrow-derived macrophages and in the Mono Mac 6 cell line, indicating a cell-activating capacity of extremely low frequency magnetic fields (ELF-MF) [1,2]. The aim of this study is to investigate if 50 Hz MF can induce reactive oxygen species (ROS) release and influence antioxidant levels in human Mono Mac 6 cells, at lower flux densities (10-200 µT) and during co-exposure conditions (PMA, LPS).

MATERIALS AND METHODS

To analyse the cell-activating capacity of ELF-MF, human Mono Mac 6 cells were sham, PMA (1 µM), LPS (1 µg/ml) and/or co-exposed to 50 Hz MF for 45 min, at flux densities of 10, 25, 50, 100 and 200 µT. Helmholtz coil systems [3] were used for ELF-MF and sham exposure, which were located inside a CO2-incubator (37ºC, 5% CO2 in air). The background flux density in both sham and exposure incubators was 1–5 µT.

The release of total ROS was detected by using the dye dihydrorhodamine 123 (DHR), which is oxidized by hydrogen peroxide, hypochlorous acid and peroxynitrite anion to the fluorescence dye rhodamine. Rhodamine fluorescence intensity (X-mean) was measured at 525 nm emission wavelength by flow cytometry. Cells were characterised as total ungated cells, gated responding cells (60-65 % of total cell number) or non-responding cells (27-35%) to ELF-MF exposure, using the software EXPO32 vs. 1.2 analysis (Beckman Coulter, Germany). A total of 10,000 cells were analyzed in three parallel samples per exposure and treatment in at least tree independent experiments.

Furthermore, we investigated the possible effect of 50 Hz ELF-MF on the oxidative non-enzymatic cellular protection system in human Mono Mac 6 cells, by colorimetric measurement of reduced (GSH) and oxidised glutathione (GSSH) levels using the 5,5′-dithiobis(2-nitrobenzoic acid) (Ellman's Reagent) after 45 min MF exposure. To determine the cell activating capability and redox status we also examined the ROS and glutathione release using PMA as a receptor independent and LPS as CD14 receptor dependent activator in the Mono Mac 6 cells.

RESULTS AND CONCLUSION:

Analysing the ungated human Mono Mac 6 cells our results show a significant (p<0.05) increase in ROS release, up to 1.2 fold, after exposure of to 10, 25 and 200 µT ELF-MF for 45 min. After selective gating and analysis of the ELF-MF responding cells, we found an
additional 25-40 % increase in ROS release in these cells compared to results obtained after the non-gated analysis (Fig. 1). The positive controls (PMA, LPS) induced a statistically significant increase (up to 3fold) of free radical release compared to control. ELF-MF and LPS treatment of Mono Mac 6 cells show a similar response and peak distribution (responding and non-responding cells; rhodamine fluorescence) suggesting that ELF-MF act via the CD14 receptor or similar signal transductions pathways as LPS in Mono Mac 6 cells.

Regarding our analysis, we think that there are ELF-MF responding cells (around 60 %) and ELF-MF non-responding cells within the same cell line.

![Figure 1](image.jpg)

**Figure 1** Flow cytometric analysis of ROS production in Mono Mac 6 cells after exposure to 25 µT ELF-MF, TPA, LPS, and co-exposure to ELF-MF and LPS. X-mean describes the average value of the fluorescence intensity of gated cells.

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Characterization of Biological Effect of 1763 MHz Radiofrequency Exposure on Auditory Hair Cells

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INTRODUCTION

Radiofrequency (RF) is a non-ionizing radiation that does not have sufficient energy to destabilize electrons or break chemical bonds in DNA. Non-ionizing radiation is electromagnetic radiation that consists of waves of electric and magnetic energy. Electromagnetic waves have frequencies in the range of about 3 KHz to 300 GHz. Recently widespread concerns have been raised about the biological effects of RF radiation [1]. Radiofrequency (RF) exposure at the frequency of mobile phones has been reported not to induce cellular damage in in vitro and in vivo models. We chose HEI-OC1 immortalized mouse auditory hair cells to characterize the cellular response to 1763 MHz RF exposure, because auditory cells could be exposed to mobile phone frequencies.

MATERIALS AND METHODS

Conditionally immortalized HEI-OC1 mouse auditory cells were used in this study. Cells were exposed to 1763 MHz RF at a 20 W/kg specific absorption rate (SAR) in a code division multiple access (CDMA) exposure chamber for 24 and 48 h to check for changes in cell cycle, DNA damage, stress response, and gene expression.

RESULTS

We exposed log-phase HEI-OC1 mouse auditory cells to 1763 MHz RF at an SAR of 20 W/kg for 24 h and 48 h to investigate the possible effect of RF exposure on the cell cycle. The pattern of the cell cycle phases of RF-exposed cells was not different from that of sham-exposed cells (Fig. 1).

We checked DNA damage using the comet assay in HEI-OC1 auditory cells after 1763 MHz RF exposure at an SAR of 20 W/kg for 6, 24, and 48 h. We could not find evidence of DNA damage using the comet assay after 1763 MHz RF exposure at a 20 W/kg SAR for 48 h. Because RF exposure can be considered to be an environmental stressor, stress biomarkers such as heat shock proteins (HSP) and mitogen-activated protein kinases (MAPK) can be monitored. We could not detect any alterations in the levels of stress proteins or in the activation of MAPKs by RF exposure in comparison with the sham exposure (Fig. 2).
Figure 1: The biological effects of 1763 MHz RF on the cell cycle. HEI-OC1 cells after exposure to 1763 MHz at an SAR of 20 W/Kg for 24h (A) or 48h (B) were analyzed their distribution of DNA content using FACS.

Figure 2: Effects of RF exposure on HSP levels and MAPK phosphorylation in HEI-OC1 auditory cells. (A) Western blot analysis of HSP expression in HEI-OC1 auditory cells exposed to RF at 20 W/Kg for 6, 12, or 24h continually. After exposure, cells were harvested immediately and stored at -70°C for western blotting. (B) Western blot analysis of phosphorylated MAPK in lysates prepared immediately after exposure to RF for 15, 30, 60, and 120 min.

CONCLUSIONS

We used HEI-OC1 mouse auditory cells that were derived from long-term cultures of ‘Immortomouse’ cochleas [2]. These cells express several molecular markers that are characteristic of organ of Corti sensory cells. To examine the biological effect of 1763 MHz RF exposure from mobile phone use, we checked several parameters, such as changes in cell cycle, DNA damage, and the stress response, in RF-exposed HEI-OC1 cells. We also compared the gene expression patterns of RF-exposed cells against sham exposed cells using a microarray to monitor any alteration in transcription levels. We found that cell cycle phase and stress responses do not alter after RF exposure. RF exposure does not induce DNA damage.

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REFERENCES

Effect of radio frequency radiation on protein expression profile

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Aim of Work

Although many in vitro studies have previously been conducted to elucidate the biological effects of radio frequency (RF) radiation over the past decades, it has not been concluded whether RF radiation poses a health risk. In an effort to answer this question, we have monitored changes in protein expression profiles in RF-exposed MCF7 human breast cancer cells, using two-dimensional gel electrophoresis. Materials and Methods

MCF7 cells were exposed to either 2 W/Kg or 10 W/kg of an average specific absorption rate (SAR) of 849 MHz RF radiation for 1 h per day for three consecutive days. During exposure, the temperature in the exposure chamber was kept in an isothermal condition. Twenty-four hours after the final RF exposure, the protein lysates from MCF cells were prepared and two-dimensional electrophoretic analyses were conducted.

Results

The protein expression profiles of the MCF cells were not significantly altered as the result of RF exposure. None of the protein spots on the two-dimensional electrophoretic gels showed reproducible changes in three independent experiments. To determine effect of RF radiation on protein expression profiles more clearly, three spots showing altered expression without reproducibility were identified using electrospray ionization tandem mass spectrometry analysis and their expressions were examined with RT-PCR and Western blot assays. There was no alteration in their mRNA and protein levels.
Conclusions
As we were unable to observe any significant and reproducible changes in the protein expression profiles of the RF radiation-exposed MCF7 cells using high throughput and non-high throughput techniques, it seems unlikely that RF exposure modulates the protein expression profile.

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Keywords: RF radiation/ 2-D PAGE/ MCF7 cells
Health Risk Assessment In Occupational EMF Exposure

-POSTER PRESENTATION-

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SHORT SUMMARY

In our study we tried to evaluate the health estate of physiotherapists in relationship with occupational exposure.

EMF measurement were made in workplaces, we applied special questionnaires, performed micronucleus test from lymphocytes, and urinary thioethers assay. The results were compared to those of a control group by statistical analytical methods like logistic regression.

We found an overexposure of this profession to diathermy procedures and magnetodiaflux. Significant relationships were found for presented syndromes (asthenic-vegetative, neurological, cardiovascular), biological parameters (micronucleus, urinary thioethers) and values of exposure to RF EMF, respectively ELF EMF, and RF+ELF.

We conclude that physiotherapists are exposed to electromagnetic risk, that imposing adequate health monitoring and limiting exposure.
ABSTRACT

Introduction

Physiotherapy contains a group of widespread procedures used in medical therapy which can generate electromagnetic fields. In Romania was not made yet an adequate characterization of occupational exposure to EMF in this medical branch, nor a health risk assessment.

Objective

To assess preliminary health risk evaluation in chronic occupational exposure to electromagnetic fields.

Material and Methods

First, we proceeded to electromagnetic characterization of the workplaces, by making measurements of the fields components with an EMR 200 Wandel/Goltermann (with probes for electric field E and power density S) for RF fields, and with EFA 200 Analyzer for ELF fields.

We carefully evaluated the residential exposure in both groups, and eliminate those cases which could lead to errors and confusion factors (for example those which lived in the proximity of power lines).

The group taken into study consisted of 60 medical nurses in balneo-physiotherapy, middle aged (46,9±3,51 years), with more than 15 years of exposure(16,3±4,25). We applied a special individual questionnaire for electromagnetic fields, made clinical and paraclinical examination, performed micronucleus test, full blood count, and thioetters assay from urine.

The results of exams were compared to a control group, consisting of medical nurses from public health centres, not exposed to EMF, with 15,9±4,7 years length in service, and 44,8±2,59 years medium age.

The results were analysed and calculated by statistical regression models.

Results

Comparing to ICNIRP 1998 protective limits, we found an overexposure to ultrashort waves diathermy (up to >1000V/m) and magnetodiaflux procedures (>40 mT).

The measurements made established for overexposure reference two categories of values: one of ultrashort waves (RF) and the other of magnetodiaflux procedures (ELF magnetic fields). In workplaces of control group the values of EMF were below the detection of analyzers, which indicate 0. This value was established as reference value for control group exposure.

Special questionnaires registered the age, length of work, EMF exposure (years/months), type of exposure devices, personal and heredocollateral records. The reported symptoms were quantified by a range from 1 to 4.

The group taken into study presented affected health state (asthenovegetative syndrome, nervous system symptoms, cardiovascular) in significant relationship with exposure values. Were found significant reduced p values and odds ratios (with
95%CI) for 12 from 15 symptoms related to exposure RF values (asthenia, sleeping disorders, headache, cardiovascular disorders, increased values at micronucleus test, increased urinary thioethers); examples: asthenia (OR=43.21; CI=4.27-346.18; \(p=0.0009\)), headache (OR=8.24; CI=2.35-30.25; \(p=0.0019\)), sleep troubles (OR=10.52; CI=2.37-39.41; \(p=0.0031\)), concentration troubles (OR=7.18; CI=2.31-28.02; \(p=0.0043\)), depression (OR=31.24; CI=5.24-385.16; \(p=0.0076\)), cardiovascular disorders (OR=15.8; CI=2.52-127.64; \(p=0.0035\)), increased micronuclei values (OR=9.57; CI=0.41-9.84; \(p=0.0028\)).

In exposed group we found significant association between ELF fields values and 11 of 15 reported symptoms (ostheo-articular, cardiovascular, neurological syndromes, increased micronucleus values, increased thioethers values); the most powerfull correlations: sleep disturbances (\(p=0.0014; CI=3.71-54.17; OR=12.35\)), depression (\(p=0.0016; CI=4.52-421.32; OR=42.32\)), asthenia (\(p=0.0043; CI=3.42-253.17; OR=27.41\)), headache (\(p=0.0089; IC=1.14-53.15; OR=7.81\)), memory loss (\(p=0.0064; CI=1.69-18.35; OR=4.15\)), increased micronuclei values (\(p=0.0021; IC=3.16-39.21; OR=11.07\)).

At the logistic regression model for RF and ELF values two, we found significant correlation between 10 of 15 symptoms related to exposure. The more significant associations were: asthenia (OR=34.23; CI=3.95 - 303.57; \(p=0.0024\)), sleep disturbances (OR=12.35; CI=3.14-47.18; \(p=0.0025\)), depressive tendency (OR=37.23; CI=4.91-400.27; \(p=0.0049\)), headache (OR=8.15; CI=1.8-43.12; \(p=0.0060\)), concentration troubles (OR=4.15, CI=1.69-18.35; \(p=0.0064\)), increased micronuclei values (OR=10.74, CI=2.53 - 36.90, \(p=0.0025\)).

The values from micronucleus test were increased (SSD, \(P<0.05\)) comparing to control group. The urinary thioeters assay showed increased values at the group exposed to electromagnetic fields (\(P<0.05\)).

**Conclusions**

The exposure to increased values of electromagnetic fields of studied group - physiotherapists lead to the conclusion that these profession should be considered as “occupationally exposed to electromagnetic fields risk”. That impose a special health monitoring for this professional category and also special protective measures, including limitation of exposure.

Our results are suggesting a health impact of chronic exposure to EMF in studied group.

Affected heath estate associated with micronuclei increased values in both RF and ELF EMF exposures is suggesting that EMF (without excluding thermal effects) could act on health by an indirect process (possible free radicals), with possible genotoxic action.

The associate increased values of micronuclei and urinary thioeters suggests that these tests could be exposure and biological effect markers.

**Key words:** physiotherapy, electromagnetic fields, exposure risk, bioeffect markers.
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Subtypes of Idiopathic Environmental Intolerance with Attribution to Electromagnetic Fields – Differences in Symptom Picture and Psychological Aspects

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INTRODUCTION

Idiopathic environmental intolerance with attribution to electromagnetic fields, that is, symptoms reported in association with electromagnetic field (EMF) exposure, has been reported at least since the 70s. The symptoms may be attributed to single EMF sources (generally visual display terminals or mobile phones) or to electrical equipment in general. Research and clinical observations suggest differences between people with symptoms attributed to single EMF sources and people with symptoms attributed to electrical equipment in general (commonly denoted as electromagnetic hypersensitivity, EHS) concerning the number and the nature of the symptoms and the development of the condition over time as well as various psychological aspects [1, 2]. This study assessed symptom picture together with anxiety, depression, somatization, exhaustion, and stress in persons with mobile phone-related symptoms and EHS.

MATERIALS AND METHODS

Forty-five persons with mobile phone-related symptoms (MP group) and 71 persons with EHS (EHS group) were compared with a population-based sample (n=106) and a control sample (n=63), consisting of those in the population-based sample who reported no symptoms attributed to EMF. Number and type of symptoms as well as anxiety, depression, somatization, exhaustion, and stress were assessed using self-report questionnaires.

RESULTS

The EHS group reported more symptoms than the MP group, both symptoms attributed to EMF, and those not attributed to EMF. The MP group reported a high prevalence of somatosensory symptoms, whereas the EHS group reported neurasthenic as well as somatosensory symptoms. Both groups reported more symptoms, of both types, than did the population-based sample. As to self-reported personality traits and stress, there was a general tendency of the EHS group reporting higher levels than the MP group, except for perceived stress, which was reported to a higher extent by the MP group. However, in a direct comparison the groups differed significantly only on somatization and listlessness.

When compared with the two reference groups, the MP group reported significantly increased levels of exhaustion and depression but not of anxiety, somatization, and perceived stress; the EHS group reported significantly increased levels of all of these conditions except for perceived stress.

CONCLUSIONS

The findings support the idea of a difference between people with symptoms related to a
single EMF source (mobile phones) and people with general EHS with respect to the symptom picture and the psychological factors anxiety, depression, somatization, exhaustion, and stress. The differences may be pronounced enough to be of importance for the outcome of medical treatment and remedial activities. They should also be considered when performing research, both in the selection of subjects and in the interpretation of study results.

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INTRODUCTION

The power spectrum of HRV has been known as an effective quantitative method to evaluate the action of sympathetic and parasympathetic nerves of the autonomic nervous system [1]. LFP (low frequency power)/HFP (high frequency power) was used as an index for the balance of autonomic nerve activity in this mobile phone provocation study. Drowsiness occurred during our experiment approximately in half of the subjects, and we investigated how this drowsiness influenced on LFP/HFP.

MATERIALS AND METHODS

Total 37 subjects participated in the experiment: 18 EHS persons (8 males and 10 females; 26.1±3.4 years) and 19 non-EHS persons (10 males and 9 females; 25.0±2.3 years). Each subject was tested for sham exposure on the first day and for real exposure on the second day, or the other way round. No matter what came first, sham or real exposure, the second one was always given at approximately the same time of the day as the first one in order to have the subject keep the same physiological rhythm.

A conventional headset was modified to contain a folder-type CDMA phone (SCH-V300S, Samsung Electronics, Korea) on the left side. The lower part of the cellular phone with keypad was wrapped up with a 5 mm thick insulating material so that the subject could not be aware of whether the phone was operating through its generated heat. ECG data were collected for 5 minutes with the headset on the subject’s head at four different stages: pre-test rest (stage I), after 15 minutes exposure (stage II), after 31 minutes exposure (stage III), and 10 minutes after exposure termination (stage IV). The phone was set to the test mode that radiates continuous clipped sine waves with a maximal transmission power of 300 mW.

RESULTS

There were no significant differences between sham and real exposures in LFP/HFP at each stage for the EHS and non-EHS groups ($P > .05$) as shown in Figure 2. As for the EHS group in Figure 2A, statistically significant differences were found for LFP/HFP ratios obtained at some of the exposure durations ($P = .001$). By applying the Bonferroni multiple comparison test, there were significantly ratio differences between at rest and 15 min real exposure ($P = .038$), and between at rest and 10 min after sham exposure stop ($P = .017$). However, no difference was found between sham and real exposures ($P = .383$).
For the non-EHS group as shown in Figure 2B, statistically significant differences were found for LFP/HFP ratios obtained at some of the exposure durations ($P = .019$). By applying the Bonferroni test, there were significantly ratio differences between at rest and 30 min real exposure ($P = .039$), and between at rest and 10 min after sham exposure stop ($P = .002$). As in the EHS group, however, it did not show statistically significant differences between sham and real exposures ($P = .658$).

Even though the experiments were performed at day time, drowsiness was observed in approximately half of all subjects due to comfortable posture for more than one hour in a quiet room. When the examiner noticed any subject’s drowsiness, he made a noise to wake him up. Such a continuous increase of LFP/HFP from rest to 15 min, 30 min, and finish stages in the sham exposures of both groups is assumed to have been caused by sleep deprivation during the 64-minute long experiment. Zhong et al. [2] reported that sleep deprivation could increase LFP and LFP/HFP.

![Figure 2](image)

**CONCLUSIONS**

A method to minimize this unwanted phenomenon due to sleep deprivation should be searched in the future study. If a method is secured for future studies, HRV could be more reliable.

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Phase II Study Of Intrabuccally-administered Amplitude-Modulated Electromagnetic Fields in Patients with Advanced Hepatocellular Carcinoma

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INTRODUCTION
To assess the tolerability and effectiveness of amplitude-modulated electromagnetic fields administered by means of an intrabuccal spoon-shaped probe in patients with advanced hepatocellular carcinoma (HCC).

MATERIALS AND METHODS
From October 2005 to July 2007, patients with advanced HCC and Child-Pugh A or B were recruited in a phase II study. Three daily 60 min outpatient treatments were administered until disease progression or death. Imaging studies were performed every eight weeks. The primary efficacy end point was progression-free survival ≥ 6 months. Secondary efficacy end points were progression-free survival and overall survival.

RESULTS
A total of 41 patients were enrolled, 17 had Child-Pugh A, 20 Child-Pugh B disease. The median age was 64.0 years. Seventeen patients (34.1%) were progression-free for more than 6 months. Median progression-free and overall survivals were 4.8 months (95% CI 2.3-6.0) and 6.9 months (95 CI 4.8-11.1). As of January 2009, four patients are alive and two patients, who had progressive disease at the time of enrollment are still undergoing therapy, and remain progression-free for 32.8 and 32.5 months, respectively. Four patients had partial response (9.8%) and sixteen had stable disease for at least 12 weeks (39.0%) according to the RECIST criteria resulting in 48.8% disease control. There were no NCI grade 2, 3 or 4 toxicities. One patient developed grade 1 mucositis and one patient grade 1 fatigue.

CONCLUSIONS
In patients with advanced HCC and impaired hepatic function, treatment with amplitude-modulated electromagnetic fields is safe, well tolerated, and shows evidence of anti-tumor effects, which are long-lasting in some patients. The encouraging findings from this study warrant a phase III study to determine the impact of amplitude-modulated electromagnetic fields on overall survival and progression-free survival.
Carpal Tunnel Syndrome and Static Magnetic Field Therapy

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AIM OF WORK
Static magnetic field (SMF) therapy is a commonly-used self-care intervention for painful conditions, including carpal tunnel syndrome (CTS). The evidence base for therapeutic effectiveness of SMFs is limited and a wide variety of SMF dosing regimens have been applied. Our objectives in conducting this feasibility study were to: compare the effects of two different strength SMFs to a non-magnetic aluminum disk, and to explore whether electrophysiological recovery of the median nerve is associated with SMF application.

MATERIALS AND METHODS
A randomized 3–arm controlled trial compared delivery of 450G, 150G or 0mG (control) to our target tissue, the median nerve, which lies approximately 12 mm from the magnet surface within the carpal canal. Participants that were otherwise healthy were recruited from the community at large. Excluded were individuals who had previously used therapeutic magnets, wore electronic medical devices, did not meet specific symptomatic and electrodiagnostic levels of CTS disease severity or had concomitant medical illnesses. All participants provided informed consent. The institutional review boards approved the study protocol.

The treatment protocol consisted of nightly wearing one of 3 similar-appearing 1” diameter by 1/8” thick disks on the palmar base of the symptomatic hand. For 6 weeks devices were applied with tegaderm adhesive before going to sleep at night and removed before rising in the morning. The Symptom Severity Scale (SSS) of the Boston Carpal Tunnel Questionnaire (BCTQ) was the primary outcome. Secondary outcomes included the Functional Severity Scale (FSS) of the BCTQ and 5 median nerve conduction parameters.

Primary and secondary outcomes were analyzed using both parametric and non-parametric methods. Paired t-tests were performed for each group comparing BCTQ and median nerve conduction changes between baseline and 6 weeks, and analysis of covariance controlling for age and gender was used to test between-group differences. An ad hoc responder analysis was also performed. For the BCTQ subscales, participants were categorized as responders if they improved by 30% (considered clinically meaningful). For the nerve conduction measures, three responder categorizations, using cutoff points of 10%, 20%, and 30% improvement. The responder analysis employed Chi-square methods.

RESULTS
All three groups showed statistically significant within-group improvement for the BCTQ-SSS from baseline to end of treatment. There were no significant between-group differences. There were also no significant between-group differences in median motor and sensory nerve latencies from baseline to end of treatment. Substantial within-group variability in nerve conduction parameters was observed as shown in the figures below.
DISCUSSION

Few Phase I studies have confirmed safety or optimized SMF dosing parameters for specific medical conditions. Our study evaluated two SMF dosages delivered to the median nerve in the carpal canal and found no significant symptomatic or electrophysiological change compared with the application of a sham non-magnetic disk. Reportedly, median nerve conduction over a 2-year period deteriorates in 8% of untreated CTS patients, 67% have no change, and 25% improve [Ortiz-Corredor and others 2008]. No previous studies, however, have assessed the variability in median nerve sensory and motor distal latencies over 6 weeks. The improvement in the median sensory distal latency and combined sensory index observed in the supposed sham group from baseline to 6 weeks may reflect normal variability or may suggest that the sham disk was not inactive.

CONCLUSIONS

The nightly application of a 450G, 150G or a 0G SMF (supposed sham control) to the compressed median nerve in the carpal canal all provided statistically significant symptom relief from baseline to 6 weeks in patients with electrodiagnostically confirmed CTS. Static magnetic fields applied directly over the median nerve did not improve median nerve conduction parameters during a 6-week application. The application of a non-magnetic aluminum disk at the wrist may improve certain sensory nerve conduction parameters.

ACKNOWLEDGMENTS

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The Threshold Currents for Perception Determined by Two Different Threshold Tracking Methods

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INTRODUCTION

Our studies of perception threshold for 10 and 20 kHz sinusoidal currents in 6 normal subjects showed that the method of constant stimuli was better than the method of limits for threshold tracking[1]. In this investigation, we compared those threshold tracking methods for 50 and 100 Hz sinusoidal currents in addition to 10 and 20 kHz sinusoidal currents in 15 normal volunteers.

MATERIALS AND METHODS

15 normal adult male volunteers participated in the experiments for 10 and 20 kHz currents, and 12 of them for 50 and 100 Hz. The perception threshold was measured with two different methods in all of them.

Method of limits: The induced currents were increased linearly from the subthreshold level. The threshold was determined at the lowest level when the subject felt some currents in the skin.

Method of constant stimuli: Several different intensity currents were given in a random order, and the subject was asked whether he/she felt it or not. The threshold was determined as the lowest intensity to give perception in half trials.

The stimulation current was given through the electrodes fixed at the index finger tip with a home-made electric stimulator. The sinusoidal currents at the frequency of 10 k, 20 k, 50 or 100 Hz were given for one second. Each trial was separated by 10 seconds or longer from a preceding trial.

This procedure was approved by the ethics committee of the University of Tokyo, and no side effects were noted in any individuals.

RESULTS

The mean (+ SD) thresholds for the current perception were 2.8 (+0.9) mA in the method of limits and 2.2 (+0.5) mA in the method of the constant stimuli for 10 kHz currents. They were 6.2 (+1.3) mA and 4.9 (+1.0) mA for 20 kHz currents, respectively. For 50 Hz currents, they were 0.25 (+0.06) mA and 0.20 (+0.06) mA. For 100 Hz currents, they were 0.27 (+0.05) mA and 0.22 (+0.05) mA. For any frequency currents studied here, the threshold determined by the method of limits was significantly higher than those determined by the method of constant stimuli.
DISCUSSION

As expected, the threshold determined by the method of limits was higher than those determined by the method of constant stimuli. The method of constant stimuli must be appropriate for obtaining the physiological threshold that is the level at which some neurons are activated by the currents. The threshold of the method of constant stimuli (0.2 mA) corresponds to the lower level of the threshold (0.2 - 0.4 mA) described as a rational in the ICNIRP guidelines at 50 Hz. We therefore recommend that we should use the method of constant stimuli in the threshold tracking.

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REFERENCES

Idiopathic Environmental Intolerance attributed to electromagnetic fields - do subgroups exist?

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INTRODUCTION

In the last decades research has tried to establish an association between exposure to electromagnetic fields (EM fields) and symptoms in persons claiming electromagnetic sensitivity. So far no simple association has been verified. In a WHO-conference on this topic, in Prag 2004, the expression “Idiopathic Environmental Intolerance (IEI) with attribution to EM fields” was suggested as a label for symptoms related to being near equipment emitting EM fields. The question is; do different subtypes of IEI with attribution to EM fields exist, and, if so, do they need different handling and different medical treatment.

MATERIALS AND METHODS

In provocation as well as in epidemiological studies the selection criteria are often schematic, and not well defined, resulting in difficulties in classification of subgroups. However, a subdivision based on different attribution sources for the symptoms is a reasonable classification. Three possible subtypes that have been in focus for research; visual display terminal (VDT)-related symptoms, general electrical sensitivity (symptoms related to a large variation of electrical equipment and environments) and mobile phone (MP)-related symptoms.

RESULTS

In the beginning of the 80ies an increasing number of office workers reported skin symptoms related to VDT work. Reduction of VDT work, reduction of psychosocial workload, and changes of VDT screen technique, solved the problem in most cases. A possible influence of EM fields emitted from the VDT screen could not be confirmed. However, few cases are reported today, when compared to in the 80ies, at least in Sweden. Whether the introduction of low emission screens was of importance is not known but possible. The VDT issue is not a focus of research today.

People with more generalized electrical sensitivity are shown to have a less positive prognosis than those with VDT-related symptoms only, and the rehabilitation is usually more complicated. Studies have shown that there are people in this group with an imbalance of the autonomic nervous system, increased levels of anxiety and symptoms of “burn out”. This subgroup is very heterogeneous, and therefore the need for an individual approach in remedial activities and medical treatment is usually greater than for people with VDT-related symptoms. This should be considered in the action programs used in health care, social insurance offices etc.

The last subgroup that relate their symptoms only to MP use has so far not been studied over a longer period of time and the influence of EMF exposure is still an open question, but
the majority of available studies show no association with MP emissions. Reducing exposure by using hands free equipment is recommended in most countries, but for other reasons than that of reducing MP-related symptoms. Studies indicate that physiological reactions to work-related stress are a possible contributor and should be considered.

CONCLUSIONS

In conclusion groups of people with different subtypes of IEI with attribution to EM fields display differences in basic physiological characteristics, but also in their reaction to work related factors. It is likely that the differences between these subgroups as well as the heterogeneity within them are of consequence for the prognosis of individuals, and they should be considered in the choice of remedial activities and medical treatment

REFERENCES

Magnetic Field Shielding Facility to Study the Effects of a Hypogeomagnetic Environment on Humans
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INTRODUCTION
Previous experiments [1] [2] [3] with mice and snails have shown that repeated one hour daily exposure to an ambient magnetic field shielded environment induces analgesia (antinociception). Exposures have been carried out both in dark (< 0.05 W/m2) and in light (0.6 W/m2, 400-750 nm) during the mid-light phase of the diurnal cycle. However, in the presence of visible light, the analgesic effects of shielding were reduced or eliminated. What would the effects be on human whole body exposure to this shielded environment? Could shielding a patient before surgery be beneficial in reducing pain or dependence on post operative medication? Do the behavioral effects of exposure to magnetic fields depend on the ambient magnetic field? Is human EEG effected [4]?

OBJECTIVES
To provide a facility to determine the biological effects of repeated magnetic field shielding on humans.

MATERIALS AND METHODS
Two Models of STB-12 shielded rooms were built, assembled and installed onsite by Amuneal of Philadelphia PA at Lawson Health Research Institute in London Ontario. One cabinet is lined with 2 layers of 1.6mm thick 80% nickel, high permeability alloy mu-metal to provide greater than 276:1 shielding of DC to 5000 hertz magnetic fields. The second cabinet is lined with 2 layers of 0.76mm thick aluminum which provides negligible shielding to low frequency magnetic fields. Cabinet #1 is our active and #2 is our control (sham) environment. The cabinets are constructed with shielded ventilation ports as well as instrumentation ports. Both cabinets appear identical in all respects including the reclining leather easy chairs.

Each cabinet is fitted with four iW Profile g2, 24VDC LED lighting fixtures made by Philips Color Kinetics, to provide white ambient lighting. These lights provide variable light intensity as well as a variable white colour balance from 3000°K to 6500 °K.

An adjacent control room houses monitoring, recording and signal generating equipment. This includes two 64 channel EEG systems from Compumedics-Neuroscan Charlotte NC, lighting controls and power supplies, Techron gradient amplifiers, signal generators and computer equipment. The Techron power amplifiers and signal generators will be used for future exposure coils to be installed inside the cabinets.
RESULTS

Figure 1: MF shielded cabinet  Figure 2: Spectra of LED light

CONCLUSIONS

This unique facility will be the focal point for many years of research in magnetic shielding effects on humans.

ACKNOWLEDGMENTS

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REFERENCES


Measurement of Thermal Sensation Threshold for Converging Millimeter-wave Beam Exposure by Constant Method

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INTRODUCTION

The millimeter-waves will be more widely used for communication, sensing, or industrial purposes in near future. RF safety guidelines have been issued in order to avoid any adverse effects of millimeter-waves on humans. The exposure limits are based on the thermal effect such as thermal sensation, i.e., only well known biological effect of the millimeter-waves [1]. However biological and medical knowledge on the thermal sensation due to millimeter-wave exposure are not su cient [2].

In this paper, we conducted a thermal-sensation experiment in order to determine the relationship between millimeter-wave exposure and subjective sensation.

EXPERIMENT

We performed a thermal-sensation experiment using a constant method. In each experiment, the experimenter presented RF stimuli with different intensities to a subject in a random order, and the subject judged whether he had some sensation or no sensation for each stimulus. One exposure lasted 10 seconds with an inter-trial interval of 50 seconds. The subjects are 20 normal adult male volunteers. The experiment was approved by the ethics committee, and written informed consent was obtained from each subject prior to experiment.

The experimental system is shown in figure 1. A subject exposed his palm to 60GHz millimeter-wave focusing beam radiated from a lens antenna. The lens antenna was fed by a millimeter-wave oscillator through the attenuator and directional coupler. The power was controlled by the attenuator, and the power incident to the lens antenna was monitored by a power meter.

To evaluate the relation between millimeter-wave’s thermal sensation threshold and the size of exposure site, we determined the threshold at three points; just at the focal point, 20mm and 40mm away from the focal point. The experiment at 40mm point was conducted only with two subjects. We defined the exposure area as that of ellipsoid made by halfwidth of power distribution. In the present experiment, the exposure areas were 32mm$^2$, 45mm$^2$ and 76mm$^2$. The palm temperature was video-recorded by thermography. Two laser pointers indicated the right position of the palm to be placed.

ANALYSIS AND RESULTS

We assume that the probability of positive response of any senses follows the cumulative density function of the normal distribution:

$$f(z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}^2} \exp \left(-\frac{(z - m)^2}{2} \right) dz.$$  \hspace{1cm} (1)
The log likelihood function is calculated by
\[
L(m, \sigma) = \sum_{i:r(i)=1} \log(f(z_i)) + \sum_{i:r(i)=0} \log(1 - f(z_i))
\]  
(2)
where \(r(i) = 1/0\) corresponds to a positive/negative response to \(i\)-th stimulus \(z_i\). Then, the maximum likelihood estimates of \(m\) and \(\sigma\) were obtained as the maximizer of the above function. The resulting \(m\) represents 50% sensation threshold.

Figure 2 (a) shows the 50% sensation threshold for each subject, and (b) shows the same threshold for the mass of subjects for each exposure area. The latter indicates the strength of stimulus at which 50% of subjects make positive responses. In figure 2, vertical axis indicates the maximum power density on palm surface, and error bar indicates 90% Bayesian credible interval. One can see that the larger exposure area yields the lower thermal sensation threshold for most subjects.

CONCLUSIONS

We measured the thermal sensation threshold for millimeter-wave beam given to several exposure areas of the palm. The thermal sensation threshold evaluated in terms of the maximum power density on the palm negatively correlated with the exposure area. As future works, we will analyze the thermography data, and evaluate the relationship between thermal sensation and actual temperature.

REFERENCES


Study of Human Body Exposure to RF Signal at UHF Frequencies

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INTRODUCTION

The aim of this study is to determine the effects of realistic exposure of human body to RF signals from communication systems. Specific Absorption Rate (SAR) is used as a measure to characterise the level of exposure a human receives from an RF signal. In this paper, an electromagnetic model is designed to evaluate the SAR induced within the human body, especially the head, due to exposure to a Continuous Wave (CW) oscillating at 448MHz and 1.206GHz. The human is modelled with a homogeneous body and a multi-layered inhomogeneous head. The SAR within the head and body has been evaluated and hotspots are identified for the designed model at 448MHz and 1.206GHz. Difference of SAR distribution due to varying body postures is also analysed for straight arms and typing positions.

MATERIALS AND METHODS

The homogeneous part of the body has been defined by using a combination of primitive objects with tissue properties of muscle, resulting in a model close to a real human. The head volume has been specified using the inhomogeneous model comprising the skin, muscle, skull, brain and spinal cord tissues [1]. The body model is flexible in a way that allows it to shape the required position, memory efficient and re-structured in CST Microwave Studio® to represent the typing position by including a wooden chair and table [3] shown in Figure 1.

![Figure 1: Modeled human body in two postures, (a) Straight arms (b) Typing position](image)

The exposure system contains a transmitting horn antenna at one end of the room and the human body present on the other end. The far-field region of an antenna can be classified by using the distance $R$ from the antenna. A region is considered as the far-field for an antenna if it satisfies the condition:

$$ R > \frac{2D^2}{\lambda} $$

(1)
Where,  \( R \) = Distance from the antenna,  \( D \) = Largest dimension of the antenna,  
\( \lambda \) = Wavelength

The layout and calculations provide a basis to consider the human body in the far-field region of the transmitting antenna and to expose the modelled structure to a plane wave falling from the back side of the body at an angle of 77°.

RESULTS AND DISCUSSIONS

The modelled human body is exposed to a plane wave, incident at an angle of 77° with an incident power density of 0.631W/m². The SAR averaged over 1g volumes of the body is evaluated using the IEEE C95.3 [2] standard at 448MHz and 1.206GHz. Table 1 summarises the results obtained for SAR distribution for different body postures at two RF frequencies.

<table>
<thead>
<tr>
<th>Body posture</th>
<th>Frequency (MHz)</th>
<th>Maximum local SAR in brain (mW/kg)</th>
<th>Maximum whole body SAR (mW/kg)</th>
<th>Location of maximum SAR on the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straightened arm position</td>
<td>1206</td>
<td>2.14×10⁻²</td>
<td>1.42×10⁻¹</td>
<td>Left hand</td>
</tr>
<tr>
<td>Typing position</td>
<td>1206</td>
<td>2.10×10⁻²</td>
<td>1.28×10⁻¹</td>
<td>Back</td>
</tr>
<tr>
<td>Straightened arm position</td>
<td>448</td>
<td>2.54×10⁻²</td>
<td>1.02×10⁻¹</td>
<td>Middle left arm</td>
</tr>
<tr>
<td>Typing position</td>
<td>448</td>
<td>2.60×10⁻²</td>
<td>7.93×10⁻²</td>
<td>Upper left arm</td>
</tr>
</tbody>
</table>

Table 1 Maximum values of SAR on 1g averaged volume of whole body and corresponding locations on the body for the plane wave incident at different frequencies for different body postures

The presented results clearly indicate that change in body posture affects the SAR distribution by shifting the hotspots on the body. A shift in the location of maximum SAR is observed between the cases of straight arms and writing position. This effect is more prominent at the higher frequency as compared to the lower frequency exposure. The left arm receives the greatest exposure since the plane wave is closer to the left side of the body.

The results have also shown that the brain received a maximum SAR of 2.6×10⁻²mW/kg, at 448MHz, well below the occupational basic restriction level of 0.4W/kg in ICNIRP. The whole body SAR values were also well below the maximum allowed by the safety regulations [4].

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REFERENCES

Microwave Fields Cause Changes in Catecholamine Release from Chromaffin Cells

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INTRODUCTION

This study was undertaken to identify microwave (MW) exposure parameters in the frequency range 1 to 6 GHz that can induce non thermal changes in catecholamine (CA) release from bovine adrenal chromaffin cells. The free-space broadband in vitro exposure system used in these studies was previously described [1] and incorporated a cell perfusion apparatus (CPA) within which the cells were immobilized on a glass fiber filter (GFF) and continuously superfused with balanced salt solution (BSS) to allow continuous on-line monitoring of the release of CAs by an electrochemical detector (ECD) during MW exposure. Biological endpoints were effects on basal CA release that occurs by spontaneous depolarization, and release stimulated in response to activation of nicotinic acetylcholine receptors by the agonist 1,1-dimethy-4-phenylpiperazinium (DMPP). The results show that MW field-induced changes occurred mainly in the form of suppression of CA release stimulated by DMPP, and that a pulsed frequency sweep (PFS) with a 100 ms pulse width in the frequency range 5-6 GHz elicited this effect most often. Because chromaffin cells have been used as a model system to provide insight into the mechanisms of synaptic neurotransmission, these findings could potentially lead to clinical applications, such as the ability to modulate nervous system function non-invasively.

MATERIALS AND METHODS

Exposure system: Modifications to the free space exposure system described previously [1], included improvements to the DMPP delivery system, addition of meters to monitor the flow and pressure of BSS in the system, optimization of the performance of the ECD to ensure reliability of the responses recorded during MW exposure, complete automation of the system, replacement of the original CPA (diameter = 24 mm) by one having a smaller diameter (10 mm) and placement of the CPA in the near field of the broadband horn antenna to achieve maximum possible magnitude and homogeneity of the field and temperature distributions.

Control and MW Exposure Experiments. Cultured chromaffin cells [2] were transferred to a 1 ml glass syringe attached to the CPA, allowing the cells to be deposited onto and distribute evenly on the GFF. The syringe was removed and the CPA was connected to the perfusion system that automatically maintained the BSS flow rate at 1 ml/min and temperature at the BSS inlet at 36.5°C. A series of control and MW exposure experiments were conducted in which DMPP (75 μM concentration) was injected automatically every 10 min. to elicit CA release from the cells. The ECD responses to both basal and DMPP stimulated release were automatically monitored and recorded. At the end of each experiment, twice the amount of DMPP was injected to ensure that the cells were not desensitized and released twice the amount of CAs in response to the larger stimulus. In the MW experiments (30 min. MW field exposure), continuous wave, pulse keying, amplitude
modulation (AM), pulsed AM, phase modulation and Gaussian pulse exposures were utilized, as well as a more complex scheme called pulsed frequency sweep (PFS) in which both frequency and pulse width were actively changed during exposure. In PFS, the largest span width (1 GHz) was chosen so that the entire frequency range of interest could be covered in 5 experiments (1-2, 2-3, 3-4, 4-5 and 5-6 GHz). The sweep rate was set to the minimum possible value (500 ms) in order to introduce the maximum number of frequencies over the shortest period of time. Three different pulse durations, 10 ns, 100 µs and 100 ms, were used for each frequency sweep.

Statistical Analysis and Results
Changes in CA release due to MW fields were reflected by changes in the area under the CA peaks as measured by the ECD. Some peaks were significantly changed from their basal value while others were slightly or not changed at all. The statistical technique chosen to analyze the results was to use non-linear regression curve fitting to calculate a trend line whose characteristics were obtained from control experimental data. When a CA peak in a MW exposure experiment was outside the statistically estimated value or prediction band that provides the interval within which the peaks are expected to fall based on the corresponding control experiment, it was considered a “bioeffect”. The results of 51 experiments showed changes in CA release in response to DMPP mainly in the form of suppression during MW exposure with the effect lasting in some cases after the MW field was turned off. Fifty-five % of PFS exposures exhibited a change in CA release as compared to 26 % of other types of exposures. Seventy-two % of exposures using a 5-6 GHz PFS field elicited a bioeffect, while only 43 % of the exposures in the other four frequency sweep ranges combined showed bioeffects. These results indicate that effects on CA release occurred most often for the frequency range of 5-6 GHz. In addition, the magnitude of the effect was also greater, i.e., the change in the area under the CA peaks for 5-6 GHz PFS fields, was also larger than for PFS exposures in the other frequency ranges. Among the 5-6 GHz PFS exposures, the one using a 100 ms pulse showed the greatest change in the area under the CA peaks and hence the largest effect.

CONCLUSIONS
We conclude from this study that it is possible to induce changes in CA release in chromaffin cells by MW fields that produce complex E field patterns. Although the mechanism that elicits this effect is not clear, the results are indicative of a frequency and/or power density window and perhaps point towards the existence of a threshold value of the E field that can induce the effects.

ACKNOWLEDGMENTS
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REFERENCES
Exploring How Wound Cells Sense Electrical Guidance Signals: The Role of cAMP
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INTRODUCTION
Endogenous electric fields (EFs) play an important role in embryonic development and wound repair. They are the first guidance signal that wound cells will receive to indicate damage has occurred and stimulate the physiological responses required for the wound to heal. Indeed the center of the wound becomes the cathode of the endogenous EF, measured to be between 100-150mV/mm (1) In the epidermis, relatively sedentary cells at the edge of the wound must become migratory to move directionally across the newly formed fibrin clot to re-epithelialise the wound. In the dermis, endothelial cells must migrate, proliferate, elongate and align to form new blood vessels to supply the damaged tissue with oxygen and nutrients. Indeed, applied EFs stimulate EC physiological processes and induce VEGF secretion (2-4) to stimulate angiogenesis, which is essential for wound repair (5). Although we have begun to dissect the mechanism by which cells sense electric fields and have revealed some pieces of the puzzle, the "sensor" remains elusive and extensive further research is required to elucidate this important endogenous wound guidance system.

MATERIALS AND METHODS
Primary human dermal microvascular endothelial cells (Invitrogen) were cultured according to Invitrogen protocols. Three cell strains were used for this study. Cells were used between passage 3 and 7. Galvanotaxis was performed, as described (6). Cells were seeded onto collagen-coated glass, in custom chambers for 2-5 hours at 37°C. Chambers were placed in a custom, heated X-Y stage on an inverted Nikon microscope and images were captured every 10 minutes for 90 minutes using Volocity software (Improvision). Cells were tracked over time (Volocity) and the average true speed and directional factor (-1, anodal, 0 random, +1, cathodal) for each treatment group was calculated.
Treatments included: β-adrenergic receptor agonist (isoproterenol, 10µM), β2-adrenergic receptor agonist (salbutamol, 10µM), β-adrenergic receptor antagonist (timolol, 10µM), β2-adrenergic receptor antagonist, (ICI 118,551 1µM), forskolin (10µM) and sp-cAMP (100µM). Changes in global cAMP were determined by radio-ligand binding assay and enzyme immune assay (R & D Systems).

RESULTS
Keratinocytes express a high level of beta2-adrenergic receptors and we have previously demonstrated that their mechanism of electric field sensing is cAMP-dependent (6). In an applied EF of 100mV/mm, keratinocytes migrate at a speed of 1µM per minute towards the cathode, with a directionality factor of 0.68. While having no effect on cell speed, 0.1pM and 0.1nM β-adrenergic receptor agonist decreased directional migration by 52% and 75%, respectively. Higher concentrations of β-adrenergic receptor agonist (0.1µM) decreased both motility and directional migration. In contrast, the β-adrenergic receptor antagonist, timolol, increased keratinocyte directional migration by 26%. The decrease in directionality could be reproduced with forskolin or a camp analog, both capable of increasing intracellular camp and activating PKA (6). We have recently begun to investigate the mechanism for EF sensing in endothelial cells, using primary human dermal microvascular endothelial cells (DEC). DECs also express β-
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adrenergic receptors at a lower level than keratinocytes. In an applied EF of 100mV/mm, DECs migrate at a speed of 0.5µM per minute towards the cathode with a directionality factor of 0.65. Surprisingly, high concentrations (10µM) of β-adrenergic receptor agonists and antagonists have no effect on the speed or directional migration of DECs. In addition, forskolin or sp-cAMP also had no effect on the speed or directionality of DEC migration in an applied EF. To investigate this further we performed radioligand binding assays and an enzyme immune assay to observe β-adrenergic receptor-mediated changes in intracellular cAMP in both keratinocytes and DECs. While 0.01µM and 0.1µM β-adrenergic receptor agonist increases the concentration of cAMP 3-fold and 6-fold, respectively, no changes in intracellular cAMP levels could be detected in DECs. Indeed, we could also detect no cAMP changes upon forskolin addition.

CONCLUSIONS
Keratinocyte galvanotaxis is cAMP dependent, while DEC galvanotaxis appears to be completely independent of this important intracellular mediator. Sensing mechanisms in wound cells appear to be cell-type specific. Further investigation is required to determine the molecular mechanism for EF sensing in DECs.

ACKNOWLEDGEMENTS
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REFERENCES
Bacterial Growth and Survival and Changed Proton Transport and ATPase Activity under Millimeter Wave Radiation

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INTRODUCTION

Study of bacterial growth and survival and activity of membrane transport systems and enzyme under low intensity electromagnetic radiation of millimeter range and of different chemical reagents effects is of interest because: (1) millimeter waves in narrow ranges of wave lengths have widely used in telecommunication and expressed therapeutic effects too [1-2]; (2) electromagnetic radiation of millimeter range are shown to induce significant changes in bacteria causing both stimulating and depressive effects [3]; (3) there is a problem with changed bacteria having different metabolic pathways and antibiotic resistance. It is of significance to have clear effects of noise [4-5] and coherent [6-8] millimeter waves and some reagents on bacteria establishing membranous mechanisms of action. Establishing and comparison of the effects for different bacteria is the aim of the work.

MATERIALS AND METHODS

Escherichia coli K12 and Enterococcus hirae ATCC9790 were used. Bacterial growth in peptone medium under fermentation conditions and their survival in minimal salt medium as well as energy-dependent (upon glucose fermentation) proton efflux from whole cells and ATPase activity of membrane vesicles were determined as described elsewhere [6-8]. Chemical reagents like N,N'-dicyclohexylcarbodiimide (DCCD) (0.2 mM) and sodium azide (NaN₃) (1 mM) were used. The coherent electromagnetic radiation of the frequency of 51.8 and 53 GHz with low intensity (the power flux capacity of 0.06 mW.cm⁻²) produced by generator based on backward-wave oscillator of G-141 type was applied. Bacterial suspension with tickness of ~1 mM was radiated by the generator on the option of amplitude modulation with a frequency of 1 Hz; the other conditions were described before [8].

RESULTS

The millimeter waves radiation of the frequency of 51.8 and 53 GHz affected E. coli K12 and E. hirae ATCC9790 growth: a considerable decrease in the specific growth rate for both bacteria was determined. The lowering in the growth specific rate was increased in 2.2- and 1.6-fold (E. coli) and in 1.6- and 2.0-fold (E. hirae) for the frequency of 51.8 and 53 GHz, respectively, with radiation duration of 30 min to 60 min; the medium pH was of 7.5. The effects for these bacteria are similar with each other although differences in their growth and metabolic characteristics. These results are in good correlation with those reported before [6-7].

In addition, the marked changes in bacterial survival after radiation with 60 min exposure were also shown. Millimeter waves were stronger to suppress viable cells numbers for E. hirae than for E. coli. This could be already seen on the 1st day of survival.

This radiation enforced the inhibitory effects of NaN₃ and DCCD and on energy-dependent proton secretion from E. coli and E. hirae both: the frequency of 51.3 GHz than of 53 GHz was of stronger (~2-fold) effects. This complies that the frequency of 51.8 GHz is resonant for E. coli [3].

Moreover, radiation used significantly (~2-3-fold, depending on potassium ions content in the assay medium) decreased E. coli and E. hirae membrane vesicles ATPase activity.
Thus, this low intensity coherent electromagnetic radiation especially with the frequency of 51.3 GHz affects bacterial growth and survival. This might be applied in practical tasks solution in biotechnology and medicine. It is of interest to protect different products including food from bacteria too. In regards to action mechanisms, changed proton transport across plasma membrane and ATPase activity and increased effects of NaN$_3$ and DCCD, inhibiting H$^+$-transporting F$_0$F$_1$-ATPase, might point out membranous aspect suggesting a role of F$_0$F$_1$ in radiation effects. Further study with radiation and antibiotics and other chemical reagents effects evaluation for different bacteria [1-3] already started with E. coli [8] will lead to a novel viewpoint about the electromagnetic and chemical sensitivity and changed metabolic pathways giving bacteria with a specific role in different organisms and in biosphere, in general.

CONCLUSIONS
Millimeter waves of the frequency of 51.8 and 53 GHz have clear effects on E. coli and E. hirae growth and survival as well as on proton transport and ATPase activity. The effects of chemical reagents like NaN$_3$ and DCCD on bacteria might be enforced under millimeter wave radiation. The membranous aspects of action mechanisms are discussed among different pathways and effects.

ACKNOWLEDGMENTS
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REFERENCES
The Role of Hemichannels In Keratinocyte Galvanotaxis

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INTRODUCTION
Endogenous electric fields (EFs) play an important role in embryonic development and wound repair. It is the first guidance signal that wound cells will receive to indicate damage has occurred and stimulate the physiological responses required for the wound to heal. Indeed the center of the wound becomes the cathode of the endogenous EF, measured to be between 100-150mV/mm (1). In the epidermis, relatively sedentary cells at the edge of the wound must become migratory to move directionally across the newly formed fibrin clot to re-epithelialize the wound. Our lab is exploring the mechanism by which keratinocytes sense an applied EF in vitro. Keratinocytes express a range of P2X and P2Y receptors (2,3). We have discovered an essential role for purinergic signalling in keratinocyte galvanotaxis via both P2X and P2Y purinergic receptors. Here we further test our mechanism that applied EFs release ATP in a polarised fashion via hemichannels to establish the electric compass. We have revealed that both connexin and pannexin hemichannels mediate ATP release, essential for electrical sensing.

METHODS AND MATERIALS
Primary human dermal keratinocytes (Invitrogen) were cultured according to Invitrogen protocols. Three cell strains were used for this study. Cells were used between passage 3 and 7. Galvanotaxis was performed, as described (4). Cells were seeded onto collagen-coated glass, in custom chambers for 2-5 hours at 37°C. Chambers were placed in a custom, heated X-Y stage on an inverted Nikon microscope and images were captured every 10 minutes for 90 minutes using Volocity software (Improvision). Cells were tracked over time (Volocity) and the average true speed and directional factor (-1, anodal, 0 random, +1, cathodal) for each treatment group was calculated. Treatments included a range of connexin and pannexin hemichannel blockers and peptides.

RESULTS
In an applied EF of 100mV/mm, keratinocytes migrate at a speed of 1µM per minute towards the cathode, with a directionality factor of 0.68. While having no significant effect on cell speed, connexin channel blockers reduced directional migration by 70% and pannexin channel blockers completely blinded cells to the applied EF (100µM). We are currently using a range of specific hemichannel peptides to determine the identity of the hemichannels required for electrical sensing. We are also using time-lapse fluorescence microscopy to visualise the electric field induced release of fluorescent dyes through the hemichannels to visualise the EF-mediated opening and closing of hemichannels to initiate polarised purinergic receptor signalling, establish polarity and initiate electric field-mediated directional migration.

CONCLUSIONS
Here we begin to reveal the intricate signaling mechanisms that control keratinocyte galvanotaxis. Our investigations are revealing a complex picture of interacting membrane proteins and intracellular signalling mechanisms to establish the electrical compass with hemichannel-mediated ATP release playing a central role in the cascade. Real time fluorescence
imaging will now allow us to visualise spatially restricted changes within milliseconds of electric field application. Further work will hopefully reveal how the cell senses the applied electric field.

REFERENCES
Influence of Combined AC-DC Electromagnetic Fields on Cell Plasma Membrane

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INTRODUCTION

Exposure to electromagnetic fields is a research area that has generated conflicting results and thus uncertainty regarding possible adverse health effects. Accurate modeling and experimentation increases our understanding of the process. This study has investigated the problem of effect of charged particles according to three possibilities of electromagnetic fields: (i) Oscillating electric field and DC magnetic field. (ii) Oscillating electric field and oscillating magnetic field. (iii) Oscillating electric field and oscillating and DC magnetic field by considering AC and DC fields. We show numerical results and then discuss the behavior of the particle with different initial positions and velocities. We choose $E$ and $B$ arbitrarily to be at 90° with $E = (E_x, 0, 0)$ and $B = (0, B_{oy}, B_{oz})$ where $B$ is a constant, i.e. $B = B_0$ and $E$ is directed along x-axis and varies sinusoidally with time as $E = E_0 \sin \omega t \hat{x}$ where $E_0$ is a constant and $\omega$ is the angular frequency. Here DC magnetic field, for example the earth magnetic field, $B_0$, is in a vertical with $Y-Z$ plane and a uniform AC electric field $E$ in $x$ direction as in [1].

(i) Oscillating Electric Field and DC Magnetic Field

External field deploy a periodic force on each free ion which can pass across plasma membrane. Due to this force ion is displaced distance $x$ from its initial position [?]. Non-linear model is given by

\begin{align}
    x'' + \nu x' + \omega_0^2 x &= \omega_2 \sin t \sin x + y' \omega_{oz} - z' \omega_{oy}, \\
    y'' + \nu y' + \omega_0^2 y &= -\omega_{oz} x', \\
    z'' + \nu z' + \omega_0^2 z &= \omega_{oy} x',
\end{align}

where $\psi$ is the particle valence, $q$ is the electric charge of the particle of mass $m$, $E$ is the electric field, $B$ is the magnetic field, $\nu$ denotes the velocity of the particle at time $t$, $\omega_2 = \psi q E_0 / m$, $\omega_{oy} = \psi q B_{oy} / m$ and $\omega_{oz} = \psi q B_{oz} / m$. Thus the linear model for oscillating electric field and DC magnetic field will be

\begin{align}
    x'' + \nu x' + \omega_0^2 x &= \omega_2 \sin t \sin x + y' \omega_{oz} - z' \omega_{oy}, \\
    y'' + \nu y' + \omega_0^2 y &= -\omega_{oz} x', \\
    z'' + \nu z' + \omega_0^2 z &= \omega_{oy} x'.
\end{align}

where $\omega_{oy} = \omega_0 \sin \theta$ and $\omega_{oz} = \omega_0 \cos \theta$, where $\theta$ is the angle between AC and DC magnetic field.
(ii) Oscillating Electric Field and Oscillating Magnetic Field

For analysis purpose here we ignore DC magnetic fields. Non-linear model is given by

\[
\begin{align*}
 x'' + \hat{\nu} x' + \omega_0^2 x &= (-\omega_1/2) \cos x \sin y \sin t + \omega_1 \cos x \cos y \cos t \ y', \\
y'' + \hat{\nu} y' + \omega_0^2 y &= (\omega_1/2) \sin x \cos y \sin t - \omega_1 \cos x \cos y \cos t \ x', \\
z'' + \hat{\nu} z' + \omega_0^2 z &= 0,
\end{align*}
\]

where \( \omega_1 = \psi q B_1/m \). Linear model is given by

\[
\begin{align*}
 x'' + \hat{\nu} x' + \omega_0^2 x &= (-\omega_1/2) \cos x \sin y \sin t + \omega_1 \cos x \cos y \cos t \ y', \\
y'' + \hat{\nu} y' + \omega_0^2 y &= (\omega_1/2) \sin x \cos y \sin t - \omega_1 \cos x \cos y \cos t \ x', \\
z'' + \hat{\nu} z' + \omega_0^2 z &= 0.
\end{align*}
\]

(iii) Oscillating Electric Field and Magnetic Field and DC Magnetic Field

We can write non-linear model as second order differential equation (3) takes the form

\[
\begin{align*}
 x'' + \hat{\nu} x' + \omega_0^2 x &= (-\omega_1/2) \cos x \sin y \sin t + (\omega_1 \cos x \cos y \cos t + \omega_{oz}) y' - \omega_{oy} z', \\
y'' + \hat{\nu} y' + \omega_0^2 y &= -(\omega_1/2) \sin x \cos y \sin t - (\omega_1 \cos x \cos y \cos t + \omega_{oz}) x', \\
z'' + \hat{\nu} z' + \omega_0^2 z &= \omega_{oy} x',
\end{align*}
\]

where \( \omega_1 = \psi q B_1/m \), \( \omega_{oy} = \psi q B_{0y}/m \) and \( \omega_{oz} = \psi q B_{0z}/m \). Thus the linear model will be

\[
\begin{align*}
 x'' + \hat{\nu} x' + \omega_0^2 x &= (-\omega_1/2) \cos x \sin y \sin t + (\omega_1 \cos t \omega_{oz}) y' - \omega_{oy} z', \\
y'' + \hat{\nu} y' + \omega_0^2 y &= (\omega_1/2) \sin x \cos y \sin t - (\omega_1 \cos t + \omega_{oz}) x', \\
z'' + \hat{\nu} z' + \omega_0^2 z &= \omega_{oy} x'.
\end{align*}
\]

RESULTS & CONCLUSIONS

Figure 1: Linear model for oscillating electric field and DC magnetic field for cyclotron resonance with zero drag and \( \omega_1 = 0.1 \). Here \( x = 1, \ y = 1, \ z = 1, \ x' = 1, \ y' = 1, \ z' = 1 \).

As in Fig. 1 we investigated the influence of \( \theta \), angle between AC and DC magnetic field, and \( \omega_0 \) on particle displacement. Here initial position and velocity for all directions is assumed to be 1.

REFERENCES

Non-stationary EMF Surveying

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INTRODUCTION

Non-stationary electromagnetic field surveying creates lot of problems and doubts on its accuracy. Apart from errors typical for the near-field EMF measurements here appear additional errors resulted from meters calibration in CW excited standards and meters’ response due to their time constant, that is of primary importance while short trains of pulses are measured, for instance EMF of a radar beam.

The work presents two new solutions of the problem. The most accurate one requires an additional modulation of a pulse modulated excitation source of an EMF standard while the shape of the modulation reflects shape of the radiation pattern of a source that then will be investigated using calibrated meter. Simplified approach permits a replace of the modulator by a switch and keying the train of pulses such a way that RMS or mean value of the measured field is equivalent to the real one.

In both the cases a calibration of the meters is performed separately for any EMF source and requires its a priori data. This is a price that must be paid to change character of the measurements from qualitative to quantitative ones. An application of the approach is suggested for calibration meters devoted to AM modulated fields measurement.

MATERIALS AND METHODS

Electromagnetic field (EMF) surveying, performed mainly for labor safety and general public protection purposes, performed in majority in the near-field conditions and often leading to legal decisions (working time limitations, radiation limitation) are one of the least accurate amongst other polluting factors. Apart from factors limiting the accuracy and resulted from the specificity of the near-field one of the most important reasons of the accuracy degradation is inaccuracy of EMF standards that may well exceed 5%. The level is obtainable while an EMF standard is excited from a CW source. Then, such a way calibrated meters are applied for EMF measurements of different space-time variations. It was estimated that inaccuracy of the measurement may reach one order of magnitude while pulsed EMF is measured. It is almost impossible to estimate the accuracy while a non-stationary EMF is measured, for instance EMF generated by a radar beam in a point of observations. During the sweeping space by the beam in the point only several pulses may be observed during every rotation of the beam and level of the pulses is a function of the radar antenna radiation pattern. The train of pulses is repeated several times per minute and the train’s repetition time is a function of the rotations velocity of the radar antenna. Protection standards require a measurement of the E-field intensity or S averaged during a single train of pulses. Thus, apart from the standard’s parameters an important role here is played by the time constant of the applied meter. The constant is different for diode detectors and thermocouple ones that are usually applied in the meters.

Both the factors make that it is almost impossible to evaluate an error of non-stationary EMF measurements and it results in the change of the measurements character from quantitative to qualitative one.
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RESULTS

In order to lead the errors to the estimable level a new method of the meters calibration was worked out. Two versions of the method are discussed in the presentation. It includes the most accurate one and a simplified one. An idea of the accurate method is shown in Fig.1.

The method includes a pulsed modulated generator that excites a horn antenna EMF standard through an additional AM modulator in a form of a computer controlled attenuator. Pulses generated by the generator must be identical to that generated by a source which will be a subject of measurements while shape of attenuation reflects shape of the source radiation pattern. The pattern may be approximated by function: \(\cos^m\varphi\) (where \(\varphi\) is half-angle of the beam and \(m\) is a number; e.g.: for \(\varphi \approx 1^\circ\), \(m \approx 2500\)). The approach creates problems with generation trains of pulses in the shape: \(\cos^m\varphi\); moreover, attenuators are usually discrete than analog ones. The approach, almost ideal in theoretical aspect may create technical problems. In order to simplify the method the attenuator was replaced by a switch. The solution creates two possibilities: a generation of the trains of pulses of the same duration time as that generated by a source and then take into account appropriate correction factor or reduce duration time of the trains of pulses such a way that RMS or mean value of measured magnitude will be identical one to that of the source. Of course, the pulse modulation of the generator reminds identical to the source. The latter case is illustrated in Fig.2. \(\tau_r\) and \(\tau_s\) are durations of the real train of pulses and that of the standard respectively and \(\tau_r > \tau_s\).

CONCLUSIONS

Contrary to widely applied standardization methods that are almost universal ones, although create remarkable limitations in accuracy, the proposed ones are limited to only one source of radiation. \textit{A priori} data of the source are necessary for calibration a meter which will be then applied for measuring EMF around it. Sometimes, apart from the manufacturers’ data of the source, any additional measurements may be necessary in order to correct real radiation pattern in relation to the theoretical one, to take into account a presence of sidelobes of the pattern, reflections and multipath propagation, the pattern deformations due to the near-field conditions, presence of other radiation sources and others. With no regard to it the proposed method of the meters calibration assures a possibility to estimate a level of uncertainty of the measurements that is the main advantage of the method.

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Inter-laboratory 50 Hz EMF measurements

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INTRODUCTION

The objective of this measurement campaign was to compare methods and results for measurement of electric and magnetic 50 Hz fields.

Three different laboratories participated (RTE, LABORELEC and EDF R&D) the former two are accredited laboratories for 50 Hz EMF measurements.

The measurements were performed using corporate procedures, based upon national and international standards. They are used to assess conformity to European Directive 2004/40/EC and Recommendation 1999/519/CE and also national regulations.

MATERIALS AND METHODS

Methods and material for measurements are based upon IEC 61786, and are consistent with the recent CIGRE guide C4-203.

The all meters used by the different teams used isotropic probes commercially available:

- RTE: PMM 8053 + probe EHP 50C (E and B)
- EDF R&D: NARDA EFA 300 + probe E and probe B
- LABORELEC: PMM 8053 + probe EHP 50A (E and B)

During the inter laboratory campaign, EDF R&D also used EMDEX II meters held on the belt of the operator.

All measurement were performed at a height of 1 metre above ground.

For the electric field measurements, the probe is installed at the extremity of a horizontal offset rod supported by an insulating tripod. The E-field probe is connected to the meter by an optic fibber. Care was taken that measurement were not perturbed by weather conditions.

The HV substation of Domloup (France) was chosen for the measurements because of the presence of 400kV power lines. Before the measurements, the position of the measurements was defined exactly. Three different axis under power lines were chosen.

During the measurements, active and reactive power and voltage in the power lines were registered by RTE every minute.

RESULTS

After the measurements (which took place on the 18th and 19th June 2008), each laboratory sent its results to RTE who is in charge of the synthesis report.

Magnetic and electric field were measured every meter on the axes previously defined.
Electric measurements could not be performed everywhere because of bad weather conditions. The comparison of the results was done following the relevant metrological standards. The measurements will be compared to a EFC400 simulation.

CONCLUSIONS

The laboratories used different methods and field meters, and in addition to its metrological objective, the inter-comparison has shown significant difference in the time needed by the different laboratories to perform the same measurements. Consequently some general advices can be given to improve measurement practices:

- the use different probes for electric and magnetic field is time consuming because it imposes several go and back to record the different field profile
- nevertheless, if only magnetic field is considered the use of a probe fixed on the meter and not on the tripod allows quicker measurements
- the use of a tripod that can be blocked in a fixed position is recommended

The experiment was the first inter-laboratory comparison of electric and magnetic field measurements organised in France. Another experiment will be organised in 2009. Other laboratories, interested in this topic are invited to participate.
Biostimulation of Microorganisms Exposed to Multipolar EMF Systems

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INTRODUCTION

Previous work in our lab [1] has demonstrated experimentally a significant advantage of multipolar systems of AC EMFs, having a topologically symmetrical “star” configuration [2] for bacterial biostimulation. The overall goal of the work is to implement a system approach, based on assembly of interdependent emitters and generators, producing a multipolar system of EM fields or currents, applied to a media in a bioreactor.

MATERIALS AND METHODS

The output synchronous AC voltages with amplitudes 0.1-15 V and frequencies 0.05-3 kHz at each electrode of the 6-polar systems were generated by a symmetrical 2-cascade system of interdependent transformers, fed by an amplified function generator. A zone, formed by mutual compensation of the voltages from each electrode we call a “compensation zone”. The standard culture protocols and measurements are described in [1].

RESULTS

Figure 1 shows average colony area for treated and control samples with a similar number of colonies, demonstrating a near 2-fold stimulation. The saturated values for treated cultures are larger than the values for the control, indicating an improved survival rate in limited nutrient conditions. Continuous curves represent a logistic function fit, showing a deviation from the logistic function for the treated sample in comparison to the control sample data.

Figure 1: Growth curves of average E. coli colony area on Petri dishes under the treatment by a 6-polar EMF. Treated – circles, control – squares, logistic function fit – continuous lines.
The cultures in test tubes exhibited a significant decrease in turbidity after the saturation. Figure 2 shows a maximum difference between the growth curves, expressed in percent values, also demonstrating a considerable near 2-fold stimulation. The maximum stimulation was achieved at different AC frequencies at incubation times 3.2-5 hours under a continuous exposure, with a highest value near 150% at 2.1 kHz. A dependence on an AC frequency shows an increase at lower and higher values, which can be explained by resonant effects.

![Figure 2: Maximal increase of concentration of E. coli in test tubes, treated with 6-polar EMF at different AC frequencies (triangles) and corresponding incubation times (circles).](image)

**CONCLUSIONS**

A biostimulation effect of EMFs generated via systems of interdependent emitters in a near-field regime significantly accelerates bacterial growth. Although in industrial environments ecological monitoring of the net EMF in the compensation zone inside of such a system may show near-zero values, the biological effects have to be specifically tested. The biostimulation is especially strong under exposure to symmetric multipolar systems of EMFs, having a symmetrical “star” configuration. Experimental data based on growth curves for standard E. coli cultures demonstrates a 2-fold biostimulation effect, observed during the lag and log phases.

Although the stimulation mechanisms are under research, the applications of multipolar systems of alternating EMF and electric currents create a part of a new promising direction – a multipolar technology.

**ACKNOWLEDGMENTS**

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**REFERENCES**


DEVELOPMENT OF MEASUREMENT SYSTEM FOR MMW EXPOSURE TO AN EYE OF A RABBIT

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INTRODUCTION

It is expected that quasi-millimeter waves or millimeter waves (MMW) technology will rise due to the growth and need for high-resolution sensing and high-data transmission. Therefore there are concerns about effects caused by an exposure to millimeter waves. The eye is particularly vulnerable to micro wave (MW)-induced injuries. International protection guidelines limit local MW exposure to certain incident power densities (for example, Japan 3-300 GHz, 10 mW/cm² in public, United states of America, 15-300 GHz, and EU nations, 10-300 GHz). One of the rationale of the safety limits is based on reports of ocular thermal effects, e.g., cataract. To verify these guidelines, we developed a measurement system for MMW exposure to an eye of a rabbit.

MATERIALS AND METHODS

Fig.1 shows a measurement setup of the developed exposure system. The system consists of a MW signal generator (83650B Agilent technologies), 40W TWT amplifiers (18-26.5 GHz: K band, 26.5-40 GHz: Ka band, ETM ELECTROMATIC INCORPRATED) and a directional coupler which is used to monitor antenna input-power. We used two types of antennas i.e. a rectangular horn antenna and a lens antenna. Since MMW safety guidelines usually limit the incident power density, it is necessary to obtain the relationship between the antenna input-power and the power density at the exposure point for each antenna. In order to derive the power density, transmission characteristics are measured using open ended waveguides and a vector network analyzer (Agilent Technologies E8316) as shown in Fig.2. Power density D may be calculated from $D = \frac{4\pi}{\lambda^2} G T^* P [W/m^2]$. Where $\lambda$ is the wavelength in freespace, G is the calibrated absolute gain of the open ended waveguide, T is the measured transmission coefficient, and P is the power density.

RESULTS AND DISCUSSION

Transmission Coefficients and power-density distributions of each antenna were measured. The power density distribution at 11.5cm from the horn antenna is also shown in Fig.3A. Although it is not far field condition, the distribution is nearly homogeneous. However the obtained power density in the case of the horn antenna has larger uncertainly due to strong standing wave between the antenna and the exposure object. A ripple of the transmission coefficient due to the standing wave is about 1dB p-p.

The power density distribution at 13.5cm, the focal distance, from the lens antenna is shown in Fig.3B. It is shown that the high power density is focused in the center axis of the antenna. The power density of the lens antenna therefore depends on the averaging area. Fig.4 and Fig.5 show measurement results of temperature elevation due to exposure...
MMW(26.5,35,40GHz) to rabbit’s eye[1]. The power densities for the temperature measurement were evaluated as the peak value of the power density distribution(Fig.4A) and the average value of φ13mm, which nearly corresponds to rabbit’s cornea, in the power density distribution(Fig.4B). The highest temperature elevation was 40GHz (≈35GHz) followed by 26.5 GHz in Fig.4B, while the different trend was shown in Fig4A.

Figure 3A and 3B: Power density distributions of horn and lens antenna (40GHz)

Figure 4A and 4B: Corneal temperature elevation due to MMW exposure

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On microwave imaging of female breast

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INTRODUCTION

X-ray mammography is certainly the gold standard screening tool to detect breast cancer. However, despite the significant advances done, this technique still exhibits a significant false alarm rate and a reduced effectiveness when applied to radiographically dense breasts [1]. These limitations, which go beyond the problems related to the uncomfortable compression of the patient’s breast, justify the huge attention that has been recently deserved in exploiting new and complementary noninvasive diagnostic tools. Among these, microwave tomography is worth to be considered since it is in principle capable of providing both a morphological and a functional screening. As a matter of fact, by measuring the fields scattered by the breast when probed with known incident fields, one may retrieve its electromagnetic features and then detect and characterize anomalous inclusions possible present in it. However, this is not a trivial task since a nonlinear and ill-posed inverse scattering problem has to be solved [2]. As a consequence, the development of an effective screening tool is still an open issue and this communication aims at addressing some considerations on this topic.

MATERIALS AND METHODS

We will point out how, to provide, from the measured data, an accurate microwave image of the female breast, it is necessary to take into account the features of the inverse scattering problem at hand. This in turn entails to properly choice the number of transmitting and receiving probes, the working frequency range and also the coupling liquid, wherein the breast is immersed during the measurement stage. Provided practical realization constraints are considered, these parameters are degrees of freedom for the inverse scattering problem at hand and can contribute significantly in reducing/increasing its complexity. Therefore, a suitable definition of the measurement environment features is a key point for a successful microwave imaging. To address this issue, we have exploited our background in the solution of applied inverse scattering problems. In particular:

- the spatial bandwidth properties [3] of the electromagnetic fields have been exploited to chose the number of probes in such a way to collect as much as information as possible while being nonredundant;

- the degree of nonlinearity of the relationship among the data and the unknowns of the inverse scattering problem has been considered to properly fix the coupling liquid as well as the considered frequency range;

- the reflection coefficient at the liquid-skin interface has been taken into account to assure that a suitable fraction of the incident field strikes the inclusions and then contributes to the scattering process.

The scattering phenomena has been described by adopting the contrast source model and the imaging has been cast as an optimization problem, where the unknown electric
features of the breast are represented by means of Fourier harmonics and iteratively build up by minimizing a properly defined cost functional [4]. The starting guess of the iterative procedure has been fixed by using the linear sampling method to achieve a preliminary shape reconstruction of the breast. Finally, the frequency hopping strategy has been exploited, so that the reconstruction process starts at low frequencies to get a trend that is used as an initial guess for the inversion at higher frequencies. By doing so, one may achieve high resolution images increasing the robustness against false solutions occurrence.

RESULTS

For the sake of simplicity, we have considered the 2D geometry. Figures 1.a,b show a female breast having a percentage of adipose tissue ranging from 25% to 50%. The complex permittivity map of this numerical phantom has been achieved by converting a MRI image, wherein the breast is made of a thin skin layer and fibro-glandular and adipose tissues, into dielectric parameters (according to a Cole-Cole model)[5]. Following the above guidelines, a coupling liquid having relative permittivity equal to 18 and null conductivity has been chosen and the data have been simulated in the frequency range from 1 to 3 GHz, by assuming that \( N = 65 \) source and receiving points are uniformly located all around the investigated domain. These data have been corrupted by an additive Gaussian noise. Figures 1.c,d show the reconstructed profiles obtained by processing the synthetic multiview, multistatic and multifrequency noisy data.

CONCLUSIONS

Provided a proper design of the measurement environment is carried out, microwave screening is expected to be able of achieving functional images of the female breast.

REFERENCES

Selection of Measurement Technology for Field Strength Measurement and Dosimetry of Pulsed High Electric Field Strength Microwave Fields

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INTRODUCTION

Research into the bioeffects of radio frequency (RF) energy requires accurate description of incident electromagnetic fields and knowledge of interaction with tissues. The development of RF transmitters capable of creating electric field strengths in excess of 1 megavolt per meter (MV/m) challenges bioeffects researchers due to the lack of technologies for characterizing very high peak field strengths. A selection of technologies for measuring very high peak fields to supply accurate dosimetry data for bioeffects studies found that advances in electro-optical sensors with fiber optic transmission line are the most promising approach.

CRITERIA

The criteria for selecting a measurement technology include:

1. Measured data must be reliable and repeatable in order to allow correlation of effect to dose. This also allows replication by other laboratories in order to build scientific consensus on the validity of the dose-response relationship.

2. Measurement technology should be transportable and useful in a variety of environments because much of the data collection by our laboratory is in field locations. The use of equipment that requires a large number of discrete components, extreme care in placement of components for field orientation, or frequent recalibration of individual components is not desirable.

3. Technology should be able to measure 1 to 2 MV/m peak field strengths, 1-5 ns rise times, and 10-100 ns pulse widths in real time. The specification of a real time measurement allows capture of single pulses and nonperiodic waveforms.

4. Technology should be commercially available so further research and development is not necessary.

Traditional methods for measuring pulsed RF fields require use of discrete components such as horn antennas, B-dot and D-dot probes, microwave attenuators, crystal detectors, coaxial cables and connectors. Great care must be taken to ensure that the frequency response of each component is characterized and accounted for in the calibration of the system. Often, methods to increase attenuation such as use of open ended waveguides below cutoff increase measurement complexity and increase the possibility of error in data collection and analysis. New electro-optic approaches consist of integrated probe and transmission line systems that will require a simplified calibration and can be deployed in field environments without much concern for characterization of individual components.
Additionally, all traditional methods tend to perturb localized fields that might be found in the near field of an emitter or in enclosed exposure chambers such as TEM cells that are traditionally used for bioeffects research. The invention of extremely small (both electrically and physically) electro optic measurement probes with fiber optic leads promise to be minimally perturbing to the field allowing high resolution characterization of field patterns in near field situations and in enclosed research chambers.

Based on these criteria, it was determined that an electro-optic approach would allow direct measurement of electric field strength with nonperturbing probes. Electro-optic sensors are now available to measure field strength linearly in excess of 10 GW/m² with instantaneous bandwidths of several GHz.

**INDUSTRY SURVEY**

Based on communications with a number of experts and a review of literature, several manufacturers of electro-optic measurement systems were identified. These manufacturers were surveyed and a selection of technology made based on criteria including measurable peak field strength, time resolution characteristics, packaging, and commercial availability and affordability.[1,2,3,4]

**CONCLUSIONS**

Based on our criteria for peak field strength, response time, and small, nonperturbing detectors, an electro-optic measurement system was selected as the most promising candidate. Further work will be required to purchase and perform acceptance testing of the specified system.

**REFERENCES**


Electromagnetic Radiation Monitoring Time Series Analysis Based on Empirical Mode Decomposition

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INTRODUCTION
Monitoring of electromagnetic radiation at radio frequencies bands where most of wireless applications are present, poses challenging issues from scientific and social point of view. Surveys as well as long term measurement campaigns increase the amount of data available for post processing and initiate the procedure for result extraction by employing different signal processing techniques.

MATERIALS AND METHODS
A wide network of electromagnetic radiation monitoring is deployed in Greek territory measuring the effective value from the frequency band 100 KHz to 3GHz on 24 hours basis [1], [2], [3]. Time series concerning effective value at the aforementioned band as well as time series at sub bands along with environmental data are extracted for specific time intervals and processed using a new method, the Empirical Mode Decomposition [4].

The empirical mode decomposition (EMD) does not require any known basis function and is considered a fully data driven mechanism suited for signals originated from nonlinear and nonstationary processes. The goal of the procedure is the decomposition of the signal into components with well defined instantaneous frequencies.

RESULTS
The result of the EMD process produces N IMFs \((c_1(t), c_2(t), \ldots c_N(t))\) and a residue signal \((r_N(t))\) :

\[
x(t) = \sum_{n=1}^{N} c_n(t) + r_N(t) \tag{1}
\]

The corresponding intrinsic mode functions from the decomposition of an effective value 100KHz – 3GHz signal (Fig.1) is depicted in Fig.2.

![Fig. 1 One week effective value from site 1 at frequency bands 100 KHz – 3 GHz](image)
CONCLUSIONS

The application of EMD in electromagnetic field time series extracted from monitoring equipment produces IMFs which are related to signals or events with physical meaning. The method distinguishes time scales in order to separate series into large scale trend associated to oscillations in electromagnetic background and small scale fluctuations.

The approach adopted in this paper contributes to a better understanding of the dynamics of background electromagnetic fields in the range of 100 KHz – 3 GHz where most of the commercial applications are deployed. Long term time series analyzed by the proposed method reveal large scale and small scale trends of the monitored effective value of electric field.

REFERENCES

Flexible Measurement Setup for Electromagnetic Exposition of Biological Samples

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INTRODUCTION

Despite all efforts, the basic mechanisms of electromagnetic radiation in living cells are still not completely understood. The essential challenge in this area of research is the combination of biological requirements and well-defined RF test conditions in order to get reliable measurement results. At present, various setups for electromagnetic field generation are used for exposure of \textit{in vitro} cell cultures. Typically the field is generated in closed cabinets where standing waves with minima and maxima are unpleasant physical phenomena \cite{1}. Strictly defined specifications of the experimental setup, like a single type of culturing bin or a fitted exposition frequency are a way to overcome these problems.

To contribute an alternative, we designed a flexible, easy-to-use measurement setup for different culturing bins and a large range of frequencies and field strengths, respectively SAR levels. For this purpose we present an open TEM-cell in the form of a stripline.

MATERIALS AND METHODS

A stripline basically consists of two metallic elements, see Fig. 1., a ground plane and in a defined distance above, the septum. RF-energy is fed into the septum through one of the two coaxial connectors and generates an electromagnetic field between the two plates. This is the...
space where the sample can be positioned.

The main advantage of the stripline is the generation of a transversal and almost homogenous field (as long as only one mode can propagate inside). In consequence, the frequency range can theoretically be varied between 0 Hz and an upper frequency $f_{\text{lim}}$ without changing the position of the test objects or the measurement setup. The upper limit $f_{\text{lim}} = c/2h$ only depends on the plate distance $h$. The test setup is realized with a distance of 50 mm, which results in a upper frequency of 3 GHz. In practice this limit is high enough to test all current mobile phone wave bands up to 2 GHz. Another limitation is the maximum height of the test object, which should not be higher than one third of the plate distance [2]. In order to avoid any additional matching circuits, the other dimensions of the stripline were adapted to the input impedance of the setup by calculations based on Hammerstadt’s equations [3].

Due to the small plate distance, the field generation works very efficient: A RF power input of 1 W results in an electrical field strength of 140 V/m and high SAR values even with very low amplification. For controlled measurement conditions the consideration of the sample temperature inside the stripline is an important parameter. We use a local heating approach instead of keeping the whole environment at the desired temperature like within an incubator. The size of the stripline allows to put a small heating element inside to control the liquid sample temperature, while the lower ambient temperature avoids a positive temperature gradient during the field propagation (see Fig.1).

RESULTS

The setup has been constructed using biocompatible and disinfectable materials and has already been tested successfully with cultured rat cortical neurons. At present, the estimated field distribution and temperature constancy for different field strengths and configurations were verified by different sensor measurements as well as by a FEM simulation.

CONCLUSIONS

The elementary new aspect of the setup is the combination of three essential factors: Large usable homogenous field volume, variable frequencies and wide range of possible field strengths and SAR levels. This leads to a very high flexibility and offers an alternative to other available exposure systems.

ACKNOWLEDGMENTS

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Imaging of Wooden Art-Crafts at Millimetre Wavelengths

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INTRODUCTION

At the ENEA Frascati Research Centre a Compact Free Electron Laser (CFEL) [1-2], operating in the millimetre to Terahertz spectral range, has been realised and regularly running for applications in different scientific and technological fields. Recently [3] an innovative imaging system has been added to the source capable of recording reflectivity maps from samples placed on a XYZ translational stage, with applications in different scientific and technological fields, including cultural heritage conservation (THz-ARTE project [4]).

MATERIALS AND METHODS

Two Free Electron Laser sources have been developed at ENEA-Frascati and are available for a variety of applications: a Compact Free Electron Laser that provides coherent radiation in the frequency range between 90 and 150 GHz [1], and a second source, FEL-CATS, which utilizes a peculiar radio-frequency structure to generate coherent emission in the range 0.4 to 0.7 THz [2].

A reflective THz imaging system has been developed [3]: the FEL radiation is coupled into a focusing cone followed by a circular to rectangular waveguide transition, which
matches the cone output to a series of two WR6 directional couplers (see Figure 1). A microprobe end is attached to the second directional coupler directing the 130 GHz radiation to the surface of the sample under investigation. The side outputs of the two directional couplers provide a reference signal of the FEL radiation incident on the sample and the signal reflected by the sample respectively. Both signals are detected by Schottky diodes at room temperature. The sample under investigation is placed on top of a XY translational stage driven by piezo-motors with 50 mm travel range on both axes. Images of the sample can be acquired with a spatial resolution of about 0.2 mm, well beyond the diffraction limit. Scanning the sample along the Z axis also provides phase information, allowing accurate measurement of the complex reflectivity of the sample.

RESULTS

A recent application on ancient wood artifacts revealed interesting potential future developments for the analysis of the wood-worm effects. In Figure 2 a series of images is reported, obtained during preliminary tests; a hole generated by the worm is shown for different distances between the radiation source tip and the sample (Z-value). The different contrast between hole and plain wood is the first evidence, but a “ghost” image close to the hole itself can also be put in evidence possibly indicating the tube-eaten by the worm underneath the wood surface. These results can be exploited for subsequent microwave pest elimination, allowing more precise irradiation schemes and procedures.

![Images](image_url)

Figure 2 Images, taken at two different heights, of the wooden sample showing the worm hole and a “ghost” image. The two images shown different phase contrasts and positions of the worm-tube pattern

REFERENCES

Measurement Procedure for the Evaluation of the Electromagnetic Field Emitted by Wi-Fi Devices

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INTRODUCTION

In recent years wireless networks have been increasingly deployed inside home and in public areas. The huge diffusion inside places such as schools and hospitals has led to public concern about possible adverse effects on human health of the prolonged exposure to such a kind of electromagnetic (EM) fields.

As is known, the Wireless Fidelity (Wi-Fi) communication signal consists of several channels spanning the frequency band 2412-2484 MHz: central frequencies of each channel are 5 MHz away from each other. The frequency band of each channel is 22 MHz. The statements of the transmission protocols (IEEE 802.11b and IEEE 802.11g) result in stochastic characteristics, making Wi-Fi signal appear highly dynamic in time (depending on data traffic) and amplitude. This makes necessary the development of specific narrow-band measurement procedures for environmental EM field evaluation, which should require the employment of high quality instrumentation.

In this work, different spectrum analyzers (SAs) have been considered to check the goodness of their employment in such a kind of evaluation. Moreover, environmental measurements, both in anechoic chamber and in indoor scenarios, have been performed to evaluate the actual exposure levels.

MATERIALS AND METHODS

Some authors [1] suggest a measurement procedure requiring the employment of SAs provided with root-mean-square (RMS) detector and automatic channel-power (CHP) evaluation. Such requirements are not always available, thus we have investigated the possibility of employment of three SAs with different features by comparing their functioning in the same experimental conditions. Agilent E4440A has both RMS detector and CHP evaluation, Willtek 9101 has only RMS detector, and Hewlett Packard HP8592B neither of them. A commercial access point (AP) connected to a laptop via LAN and communicating with a PC was used as signal generator. The Wi-Fi communication has been assured by continuously transferring a batch file from the laptop to the PC. A single-channel transmission has been used, specifically channel 11, corresponding to the central frequency of 2462 MHz (2451-2473 MHz bandwidth). Comparisons have been performed by picking up the signal directly from the AP towards a power divider: each time its two outputs have been connected to the SAs to be examined.

The common settings for the SAs were: span 30 MHz, resolution bandwidth 100 kHz, video bandwidth 1 MHz, sweep time 200 ms. When RMS detector was not available, sample detector was used; when automatic CHP modality was not provided, a procedure, implemented in Labview 7.1 environment, evaluated the CHP according to the following relationship:
\[ CHP = 10 \log_{10} \left( \frac{B_s}{NBW} \left( \frac{1}{N} \sum_{i=1}^{N} P_i^{10} \right) \right) \]  

(1)

where \( B_s \) is the bandwidth of the signal (22 MHz), \( NBW \) is a parameter supplied by the firm, \( N \) is the number of samples of the acquired traces (401), and \( P_i \) is the \( i \)-th power sample.

For each comparison, five independent observations lasting six minutes have been considered for statistics, the sample step for the acquisition was 10 s. The outcomes of comparisons have been considered in agreement if differences in acquired CHP were less than 3 dB [2].

Measurements of the levels of the electric (E) field in air at 1 m from two APs (\textit{D-Link DSL-G624T} and \textit{Hamlet HNWS 254_R}) have been carried out in an anechoic chamber, operating up to 18 GHz. Analogous measurements have been performed in an actual indoor scenario on the same APs. A horn antenna with antenna factor of 29 dB/m at 2.45 GHz has been employed, both in horizontal and vertical polarizations.

RESULTS

The outcomes of comparisons among measurements obtained with the three SAs, shown in Table 1, prove that all the considered instruments can be used if correct procedures are followed.

<table>
<thead>
<tr>
<th>INSTRUMENTS</th>
<th>DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agilent E4440A vs Willtek 9101</td>
<td>0.67 dB</td>
</tr>
<tr>
<td>Agilent E4440A vs HP 8592B</td>
<td>0.15 dB</td>
</tr>
</tbody>
</table>

Table 1: Differences, in dB, among the evaluated CHPs.

For the E field measurement in air, the \textit{HP 8592B} SA has been used with the procedure set up during the previous step.

Results are shown in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>D-Link DSL-G624T</th>
<th>Hamlet HNWS 254_R</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textsc{anechoic chamber}</td>
<td>0.28 V/m ( \pm ) 4.70 %</td>
<td>0.41 V/m ( \pm ) 3.00 %</td>
</tr>
<tr>
<td>\textsc{indoor}</td>
<td>0.41 V/m ( \pm ) 7.00 %</td>
<td>0.42 V/m ( \pm ) 3.50 %</td>
</tr>
</tbody>
</table>

Table 2: E field measured in different scenarios from two APs.

CONCLUSIONS

In this work the possibility of using a not sophisticated instrumentation for the measurement of wideband digital signals, such as those emitted by Wi-Fi devices, has been proved. The E field generated by two APs has been measured in different scenarios: the found exposure levels are well below the ICNIRP 1998 guidelines [3].

REFERENCES


Reconstruction by Extrapolation of electric field distribution in phantom with Gaussian functions for SAR prediction

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INTRODUCTION

Currently, a full SAR measurement protocol based upon CEI or IEEE standard recommendations takes around a half day. There is a specific need for fast SAR assessment for post-production measurement and verification. In the literature, different approaches are exposed to reduce acquisition time [1] [2] [3].

From the measurement of the electric field \(E(x, y, d)\) in a reference plane \(z=d\), which can be chosen not especially where the SAR is maximum, it is possible to calculate the maximum electric field \(E(x,y,z)\) for another \(z\) positions, and then the PEAK SAR value considering the following simple relation.

\[
E(x, y, z) = E(x, y, d) e^{-\alpha(z-d)}
\]  

(1)

However, for the measurement of 1g-SAR and 10gSAR values, corresponding to 1cm\(^3\) and 10cm\(^3\) cubic volumes respectively, it is necessary to know the electric field distribution. A solution consist in extrapolating for each measurement point, the electric field around the maximum and then to average to calculate SAR 1g and SAR 10g, but this method is long. To reduce the calculation time, the idea is to describe the electric field distribution by a Gaussian function. This allows reducing the number of data acquisition points, like any other extrapolation methods, but the main interest is to describe the electric field distribution with only three parameters: peak, average and variance values. In addition, it is possible to define a simple relation (linear or polynomial) to describe the shape of the electric field distribution (variance) according to the distance of the transmit antenna or the distance of the measurement plane within the phantom. This approach is validated by a theoretically approach based on simulation (FEKO software) with a dipole antenna and a flat phantom and with measurements using mobile phones.

EXTRAPOLATION WITH GAUSSIAN FUNCTION

The following figures show the extrapolation of the electric filed distribution by a Gaussian function (Gaussian function parameters: \(\mu=0\) and \(\sigma=0.05\))

![Figure 1: measurement plane definition and Gaussian extrapolation](image-url)
The following figure shows the variation of the variance of the Gaussian function according to the distance \(d_{\text{plane}}\) of the measurement plane within the phantom (with respect to the inner surface \(z=0\) mm) and the distance \(d_{\text{dipole}}\) of the dipole antenna.

![Figure 2: Evolution of variance according to the distance \(d_{\text{plane}}\) and to the distance \(d_{\text{dipole}}\) in the x and y plane](image)

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Distance of plane in phantom</th>
<th>Distance of dipole antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polynomial interpolation in X plane</td>
<td>0.4%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Polynomial interpolation in Y plane</td>
<td>1.2%</td>
<td>1.15%</td>
</tr>
</tbody>
</table>

![Figure 3: maximum relative error](image)

We can observe an error prediction lower than 1.5% with the Gaussian extrapolation.

VALIDATION WITH A MOBILE PHONE SAR MEASUREMENT

This approach has been applied to the measurement of a set of mobile phones. We can observe a good approximation of the SAR distribution with a Gaussian function.

![Figure 4: Gaussian extrapolation on measurement data in x and y plane](image)

CONCLUSION AND PERSPECTIVES

A method based on a Gaussian extrapolation allows the description of the electric field distribution of a mobile phone according to the distance of the transmitting antenna and the distance of measurement planes. This method, exploiting the simple well-known relation of the E-field decrease within the tissues, could be applied to estimate SAR value with for example neural network that is more efficient with a low number of input parameter.

REFERENCES

RF Field Strength Measurement Method for Evaluation of Human Exposure in Modern Radio Frequency Spectrum Use

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INTRODUCTION

For the next mobile communication system, the 3GPP is currently discussing standardization of the Long Term Evolution (LTE), which is based on Orthogonal Frequency Division Multiplexing Access (OFDMA) as the radio access technology, and should attain the maximum information speed of approximately 100 Mbps [1]. The LTE provides options in regard to the signal occupied bandwidth, which has the range of 1.25 MHz to 20 MHz. Consequently, radio frequency spectra that have different occupied bandwidths will be observed in the LTE frequency range. Furthermore, the concept of the cognitive radio was presented to enhance further intelligent wireless communication systems [2]. A mature cognitive radio platform will automatically change radio parameters, e.g., signal occupied bandwidths and carrier frequencies, in accordance with variations in user demand, traffic condition, etc. to achieve higher utilization efficiency of radio frequency resources.

On the other hand, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published safety guidelines for human exposure to RF electromagnetic fields [3]. The guidelines describe the reference field power density for the radio frequency range of 100 kHz to 300 GHz. To verify compliance with the ICNIRP guidelines at the investigation point, the total normalized power density is generally estimated. The investigation point complies with the guidelines when the total normalized power density is less than one. The total normalized power density is the sum of the normalized power densities, which are ratios of the power densities at the investigation point to the reference power densities at each frequency. To measure the RF field power density, a frequency selective receiver such as the spectrum analyzer is generally used.

A resolution bandwidth (RBW) of a frequency selective receiver should be adjusted to cover the occupied bandwidth of the target radio source, e.g., a transmission signal from the radio base station, to evaluate the field power density accurately. However, this adjustment is bothersome because there are many radio signals that have different occupied bandwidths in a wide frequency range in current radio environments. Furthermore, the bandwidth and carrier frequency of the target radio source may change depending on time variations in future radio environments.

METHOD

Fig. 1(a) shows an example of the measured frequency spectra. The received signals, S(f₁) and S(f₂), are narrowband signals and S(f₃) and S(f₄) are wideband signals. Fig. 1(b) is a magnified section of the measured frequency spectrum around frequency fᵢ, which consists of a set of sampled points the number of which is M(fᵢ). At frequency fᵢ, the received level, S(fᵢ), is given by
When the number of detected radio signals is $N$, the normalized total power density is calculated by the above-mentioned procedure.

RESULTS

A modulated carrier, which is employed in the QPSK scheme, is prepared to show the validity of the proposed measuring procedure. The occupied bandwidth of the modulated carrier has the range of 1 kHz to 20 MHz, by the symbol rate changing from 1 ksps to 20 Msp/s when the root Nyquist filter with the roll-off factor of $\alpha=0.5$ is selected. Fig. 2 shows the deviation in the received level at the RBW of 1 MHz, which is measured using the proposed procedure, versus the occupied bandwidth. The deviation in the received level is less than +/-0.5 dB at the video bandwidth (VBW) of 100 Hz, while the deviation is less than +/-3 dB at the VBW of 1 MHz.

CONCLUSIONS

As radio communication technology evolves, radio signals that have different occupied bandwidths must coexist in the same radio frequency spectrum. The proposed method can measure the received radio signal level with a deviation of less than +/-0.5 dB, and is effective in evaluating the human exposure to EMF in current radio communication environments and those in the future.

REFERENCES

SAR Measurement of Birdcage Coil for MRI System Using Thermographic Method

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INTRODUCTION

Magnetic resonance imaging (MRI) is one of the noninvasive imaging techniques which can visualize inside human body based on nuclear magnetic resonance (NMR). This system is made of some important units including radio frequency (RF) technologies. The RF coil is one of the important parts in the RF unit. During imaging, the RF coil radiates electromagnetic (EM) pulse to the human body and receives the NMR signals emitted from the body. Therefore, it is necessary to estimate the specific absorption rate (SAR) in the human body due to the radiated EM energy from the RF coils [1]. Consequently, detailed evaluations of the SAR by numerical calculation have been explored. In addition, according to the International Electrothechnical Commission (IEC) standards, there are two methods that can measure the total absorption energy of human body. However, these are not able to measure detailed SAR distribution inside. Measurements of the SAR distributions are important for comprehending characteristics of conventional RF coils, reduction of the SAR during imaging etc. In this study, by use of thermographic method, detailed SAR distribution inside human body head model was intended to measure employing birdcage coil for MRI system.

MATERIALS AND METHODS

The RF coil employed in this study is a birdcage coil for 3.0 T MRI system which operates around 128 MHz. Figure 1 shows the structure of the coil. Two types of feeding are performed in this study. One is 1-port feeding which excite only in the \(\phi = 0\) position feeding gap. The other is 2-port feeding which has two feeding points 90\(^\circ\) apart with phase difference of 90\(^\circ\). Such excitation scheme is called “quadrature excitation” and is employed generally. Figure 2 shows the experimental setup for thermographic method [2]. In the SAR measurement, sinusoidal wave of approximately 100 W is fed to the feeding ports. After the short time exposure, the phantom is split into half and temperature rise is taken by a thermographic camera. The SAR at the observation plane is figured by the following equation:

\[
SAR = C \frac{\Delta T}{\Delta t} \quad [\text{W/kg}]
\]

where \(C \quad [\text{J/kg-K}]\) is the specific heat of the phantom, \(\Delta T \quad [\text{K}]\) is the temperature rise, and \(\Delta t \quad [\text{s}]\) is the exposure time.

RESULTS

Figures 3 and 4 show measured SAR distributions of 1-and 2-port feeding in \(xy\) plane at \(z\)
CONCLUSIONS

In this study, the SAR distributions by the birdcage coil are measured by the thermographic method. As a result, the tendency of the measured and the calculated SAR distributions agreed well. However, value of the SAR includes the error caused by the temperature diffusion. As a further study, reduction of measurement error will be considered by improvement of measurement scheme.

ACKNOWLEDGMENTS

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INTRODUCTION
In this study a mechanism-oriented approach for the investigation of potential interactions of EMFs on well-defined proteins is taken [1]. By using proteins the complexity of the investigated object is reduced from the cellular to the molecular level. To enable real-time observation of potential effects of EMFs on their structure, the exposure unit is placed directly in a spectropolarimeter recording their conformational equilibrium via their circular dichroism (CD) signal. Thus, the point of observation becomes identical with the potential interaction site in space and time that will allow for the detection of even small effects. Circular dichroism (CD) spectroscopy is a well-established and widely-used experimental method to investigate structural properties of proteins.

MATERIALS AND METHODS
In this study the thermosensor protein GrpE is exposed to EMFs whilst simultaneously monitoring its potential structural changes. The thermosensor GrpE belongs to the Hsp70 chaperone system of Escherichia coli. GrpE is involved in cell stress response and a similar protein exists in humans [4]. Since the α-helical content of GrpE is large, conformational changes can be sensitively monitored by changes in ellipticity in the far UV region. Given that all other physical parameters and solvent conditions are constant, its conformational equilibrium is exclusively defined by temperature. Provided that all thermal, electromagnetical, chemical and optical conditions within irradiated volume are known and controlled this configuration should allow for discrimination of non-thermally induced structural changes from those caused by temperature changes. The novel experimental unit facilitating the performance of strictly-controlled, real-time measurements is depicted in Fig.1. The design and preliminary evaluation has been reported [2]. Incorporated sensors and control loops ensure the specified physical conditions, e.g. the temperature measured at the spot is regulated by thermostated circulating water bath. Due to the polarity of water and free ions in the buffer solution in combination with high external electric fields, the most critical system uncertainty is constituted by induced additional heat at the irradiated spot. As a result of the exclusively temperature - CD signal relation of GrpE the overall system sensitivity is decreased. Thus, a limit for the maximum electric field strength is determined by exposure time and CD signal uncertainty (see [2]).

RESULTS
Initial measurements using test proteins - helix-bundle derived from the SIV envelope protein gp41; leucine zipper part of the GCN4 transcription factor - were conducted to

CD measurements provide information about the fractional population of different conformational states of macromolecules as function of the temperature. It is known that CD radiation itself is not invasive, i.e. it does not alter the covalent and non-covalent structure of the biomacromolecules [3].
evaluate the experimental setup. As depicted in fig. 1 the exposure unit does not change the CD measurement itself, in particular the EMF does not interfere with the CD signal. Further test runs detected EMF-induced temperature rise with time in the irradiated protein solution as predicted by simulations. For the tested proteins no measurable changes of their conformational equilibrium under EMF exposure at 1 – 2 GHz were observed. Measurements using protein GrpE are currently carried out.

CONCLUSIONS
A mechanism-oriented approach utilising circular dichroism measurements of biomacromolecules, like GrpE, whilst uniformly exposed to arbitrary composed electromagnetic field signals at specific temperatures, has been undertaken. The experimental setting allows for the distinctions between thermal and non-thermal effects of electromagnetic fields. If an effect induced by EMF can be detected, the molecular mechanism may be explored by studies with engineered variants of GrpE, e.g. mutants exhibiting different charge constellations or truncated variants.

ACKNOWLEDGEMENT
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REFERENCES
NEW METHODOLOGY FOR THE ESTABLISHMENT OF INTENSITY LEVEL MAPS OF ELECTROMAGNETIC FIELDS IN HOSPITALS

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INTRODUCTION

A large hospital currently presents a large variety of wireless telecommunications systems that generate electromagnetic fields (EMF) with different features and intensities. These systems range from the usual healthcare professionals tracking devices, such as pagers, DECT systems, WLANs or conventional mobile phones to medical equipment with telemetry systems or wireless networks for wireless distribution of medical record and diagnostic images in different plants of a hospital. Nowadays it is not infrequent to encounter radio frequency (RF) tracking devices.

On the other hand, the contribution of certain medical devices must also be considered. These medical devices can generate EMF that disrupt the radio environment of hospital areas where they are located. It is also possible that in certain areas of the health centre, high-frequency signals are detected as a result of pollution caused by radio-electric commercial stations broadcasting or communications systems of common use bands (walkie-talkies, radio ham or broadcast of security forces and civil protection), in addition to those received by mobile operators base stations [1-2].

All these EMF and RF signals can generate unwanted electromagnetic interference (EMI) in electro-medical equipment. They can alter both the normal operation and also the clinical signs recorded. This fact may result in adverse incidents for patients who are obtaining a diagnosis or treatment of their illnesses.

Large hospitals, especially if they are not new, generally consist of several old buildings with very different nature and constructive characteristics. Thus, it is difficult to establish standards for the EMF measurements in all their departments, even if they are dedicated to the same health-care activities using similar electro-medical equipment [3].

This work aims to establish procedures to provide a global and immediate overview through EMF maps levels in several units’ hospital in order to relate them with any electro-medical equipment failures and subsequent adverse incidents in patients [4] and also with exposure to general public [5].

MATERIALS AND METHODS

To begin, a plan of the units’ hospital is required. The program used to work with the plans has been a computer assisted design software, such as AUTOCAD. In each unit, a grid of 10 x 10 m2 is set. A first measurement is done in the centre of each grid, using the high frequency radiation monitor EMR-300 (Narda), with a probe E-FIELD from 100 kHz to 3 GHz.

Data collected were transferred to a simulation and computation software (Matlab) to draws contour lines and colours surfaces according to the previously measured levels of
intensity. In those areas where the difference of intensity level fields between two adjacent points was very large, a second set of samples in a denser grid of 5 x 5 m² was measured. Data was transferred to the software, obtaining more level curves for those areas with higher gradient fields.

RESULTS

Several graphs have been obtained with the measurements belonging to different units of hospitals. Level curves of the EMF found have been represented on them. Graphic designs have the advantage of setting up a graphical representation that allows an immediate and very accurate view of the situation according to the levels of EMF in different units of the hospital.

In this work, an exhaustive measurement and a graphic representation of the EMF levels in all the buildings and facilities of a large hospital have not been developed. The aim of this work only seeks to establish a standard procedure to get a uniform procedure for any health centre at any given time.

CONCLUSIONS

The computation of maps levels of EMF in a health centre can help to establish risks associated with EMI on electro-medical equipment exceeding electromagnetic immunity levels, with the logical negative consequences and impact on patient safety and also to limit the exposure of the general public to electromagnetic fields [5].

This basic premise should be compatible with a sufficient level of signal in wireless systems operating in each department. The security of the electro-medical systems must be compatible with the fact that these systems operate correctly.

Any manager who plans introducing a new wireless system in the hospital or installing new electrical equipment in a given area in a health centre will count on an important help if this tool for showing the electromagnetic situation of the hospital is available.

The methodology will be enhanced in subsequent works detecting the frequencies of the electromagnetic fields using a portable spectrum analyzer, and also using specific software such as SURFER 8 or similar for the design of the areas and surfaces.

REFERENCES

[5] Recommendation 1999/519/EC, of 12 July, on the limitation of exposure of the general public to electromagnetic filed (0 Hz to 300 GHz)
Laboratory Performance Testing of Personal RF Exposimetry Devices

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INTRODUCTION

The last decade has seen the proliferation of various mobile communication devices. Clearly, personal measurements of the actual field strengths are necessary, yet, until relatively recently there was no direct method to carry out these measurements in a convenient, standardized manner. The first compact, durable measuring devices specifically optimized to record electric field strengths in several pre-defined bands at the same time, in other words, Personal Exposimeters or PEMs were introduced a few years ago. However, the first field tests [1] of these devices raised concerns about their performance, especially their sensitivity and band selectivity. Also, it was hypothesized that the placement of the PEM relative to the subject’s body may significantly alter results. To answer such concerns, we decided to examine the performance of these PEMs in a controlled laboratory environment to characterize their usability in future real-life observation campaigns.

MATERIALS AND METHODS

The PEMs selected for this study were the Antennessa DSP 090, the Maschek ESM-140, and the Satimo EME Spy 121. The latter is essentially an upgraded version of the DSP 090. All measurements were carried out in a shielded, reflection-free chamber. Wideband synthesers were used as signal sources, coupled with separate power amplifiers centered at the 900 and 1800 MHz GSM bands. Calibrated field meters were utilized to provide reference values for field strength measurements. The PEMs were pre–programmed before experiments. A rotational table was used to test the isotropy of the devices. Furthermore, the effect of different measurement intervals was examined.

The effect of the placement of the PEMs on the subject’s body was also studied. The nominal wearing position for the DSP 090 and the EME Spy 121 is one clipped to the belt, while the ESM-140 is intended to be strapped to the exterior surface of the right arm. However, real-life testing [1] indicated that due to the somewhat bulky appearance of the DSP 090 users preferred to carry it in their backpacks. Testers of the ESM-140 also reported the nominal mode of usage (strapped to their arm) to be inconvenient. Therefore we have decided to test the PEMs in their nominal positions, as well as in the position the majority of the testers carried them (i.e. in a backpack). Furthermore, in the case of the uplink bands the position of the users’ phone relative to the PEM has to be considered. To this end, a real phone (model Nokia 6650, in test mode) was used as a radiation source in these experiments. This allowed for a realistic exposure scenario to be enacted, while the test mode ensured a constant level of RF power. First, the PEMs were mounted on the subject at their nominal locations. The test phone was placed at various positions, including in the pocket and backpack of the subject, near the head of the subject, as well as the pocket and backpack of the other person and finally near the...
head of the other person. Then the PEMs were relocated to the backpack of the subject and the experiment was repeated with the phone positions outlined above.

RESULTS

Several problems were identified regarding the fitness of the investigated PEMs for real-life data collection campaigns. The DSP 090 records between 0.05 V/m and 5 V/m, which raises the question of non-detects [2], while some high power spikes (common for hand-held phone operation) may escape detection. The EME Spy 121 doubles the upper limit, but the problem of the lower limit remains. The ESM-140 fares better in this regard, however, it suffers from poor frequency selectivity: inadequate band-pass filter performance causes significant adjacent-channel interference, rendering distinction of GSM900/1800 uplink and downlink difficult.

Selected results of the positional measurements can be seen in Table 1. Unsurprisingly, the placement of the PEMs significantly alters recorded values. The placement of the phone (relative to the PEMs) matters even more.

The PEMs’ resilience to ELF magnetic fields was also investigated. It was found that 50 Hz magnetic field with a flux density of up to 500 µT had no effect the PEMs.

<table>
<thead>
<tr>
<th>PEM Position</th>
<th>Nominal</th>
<th>Backpack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone position</td>
<td>DSP 090</td>
<td>ESM-140</td>
</tr>
<tr>
<td>Head of person sitting behind subj.</td>
<td>1.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Backpack of person sitting in front of subj.</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Head of subject</td>
<td>0.7</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 1: Comparison of field strengths (V/m) measured by DSP 090 and ESM-140: nominal vs. backpack positions coupled with different phone placements.

CONCLUSIONS

The issues with measurement limits and frequency selectivity are hardware-related; they may be fixed in future versions of the PEMs. However, field tests accumulating data about dozens of subjects are already underway [1].

The effects of positioning, however, depend on the actual usage protocols, but so far they haven’t been taken into consideration. For the purposes of a large-scale exposimetry survey, either the nominal wearing positions have to be enforced or every other position will have to be systematically modeled and measured in order to quantify their modification factors relative to the standard position.

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REFERENCES


Measurement Uncertainties For In-situ RF Measurements

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INTRODUCTION

It is well known that RF measurement results are affected by many factors, e.g. type of instrument, instrument settings, fading effects and characteristics of the measured signals. In this study, the variation of measured field strength in a controlled environment was compared with the variation for in-situ measurements. The purpose was to estimate how uncertainty factors can affect results of real-life measurement. The measurement data also allow some comparisons between different types of instruments and between different settings. The study was coordinated by the Swedish Radiation Safety Authority.

MATERIALS AND METHODS

The measurements were conducted by twelve independent measuring teams from the Nordic countries, using totally 20 separate measuring equipments.

The purposes of the controlled environment measurements were both to get a deviation reference for the in-situ measurements and to verify correct function of each measuring equipment. These measurements were performed in non-echoic chambers using calibrated signals at SP Technical Research Institute of Sweden, the Swedish national metrology centre for radio frequency fields. Four separate signals were used; 958 MHz CW, 958 MHz GSM, 2 140 MHz CW and 2 140 MHz UMTS. The exact field strength was unknown to the measuring teams. The uncertainty of the field strength was calculated to be 1.0 dB.

The in-situ measurements were performed in a regular conference room at the top floor of a seven-storey building. This site was chosen since it had a natural wide spectrum of RF signals with sufficient power density even for the less sensitive broadband instruments. Each team was alone in the room during their measurement and they were free to choose method and exact position. The purpose of these measurements was to find out how the type of instrument, instrument settings, time and exact position of the measurement may affect the result in general.

The following 20 measuring equipments were included in this study:
6 Narda broadband (EMR-30, EMR-300, etc.), 2 Narda frequency selective (SRM-3000), 5 Holaday broadband (with antenna HI-6005 or corresponding), 1 personal exposure meter (Antenna) and 6 different spectrum analysers (e.g. R&S, Anritsu) with separate calibrated antennas.

RESULTS

The results of the measurements performed in the calibrated controlled environment, where four different signals were set up and measured by each team, are presented in Table 1. For the CW signal at 958 MHz, all measurements were within +/-3 dB of the true level. The corresponding number for the CW at 2 140 MHz was +/-6 dB. This assured that all measuring devices in this study had normal functionality which was important for the reliability of the in-situ measurements.
Table 1: Signals and power densities in the controlled environment

<table>
<thead>
<tr>
<th></th>
<th>True time average mW/m²</th>
<th>Average of all time averaged measurements mW/m²</th>
<th>Median of all time averaged measurements mW/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW 958 MHz</td>
<td>38.3</td>
<td>38.9</td>
<td>36</td>
</tr>
<tr>
<td>GSM mod. at 958 MHz</td>
<td>14.4</td>
<td>18.8</td>
<td>13.2</td>
</tr>
<tr>
<td>3 of 8 time slots active</td>
<td>18.5⁴</td>
<td>13.3⁵</td>
<td></td>
</tr>
<tr>
<td>CW 2140 MHz</td>
<td>38.3</td>
<td>48.5</td>
<td>42</td>
</tr>
<tr>
<td>UMTS mod. at 2140 MHz</td>
<td>38.3</td>
<td>44.9</td>
<td>42</td>
</tr>
<tr>
<td>crest factor 10.7</td>
<td>38.4⁴</td>
<td>40⁴</td>
<td></td>
</tr>
</tbody>
</table>

⁴Weighted with regard to the offset of the measured CW level from the true CW level

During the evaluation of the measured modulated signal levels, the result for each instrument was also weighted with regard to the offset of the measured CW level from the true CW level which would cancel any calibration error associated with the measuring equipments. This did however only affect the results slightly, showing that most instruments used in this study were calibrated accurately.

The results also indicate that there was no significant difference if the instrument was tripod mounted or handheld. The average of handheld/tripod ratio for the instruments was 1.0 for all 958 MHz measurements and 1.1 for the measurements at 2 140 MHz.

In the second part of this study, the measurements were performed in the conference room. The median power density of all measurements was 1.0 mW/m². The measurements were compared to this level since the true level was unknown. All measurements, including max hold, time average and spatial average measurements were within +/-7 dB of the median, regardless of the measurement position. The strongest sources were GSM900, UMTS, GSM1800, police radio, DVB and FM-radio. Fix point measurements showed that the field strength varied during the time of the measurements.

CONCLUSIONS

In this study, twelve measurement teams have used totally 20 different measuring equipments. The deviation of the measured levels was found to be only +/-7 dB for the real-life measurements even though there were many sources of error, e.g. time variation of mobile phone signals, choice of exact measurement position (multipath fading in the room), the use or non use of tripod and differences regarding instruments and their specific settings. This deviation is surprisingly small in relation to the +/-3 dB and +/-6 dB for the measured CW signals in the controlled environment.

For detailed measurements of specific sources, it is of course important to use well adapted instruments and carefully chosen settings, but the results of this study indicate that when it comes to environmental assessment of radiofrequency fields in general, the type of instrument, instrument settings, time and exact measurement position might not be as crucial as we earlier believed.

ACKNOWLEDGMENTS

We would like to thank all measuring teams for participating, SP for setting up the controlled environment and the municipality of Borås for making premises available for the in-situ measurements.
DEVELOPMENT OF MULTIPLE-FREQUENCY EXPOSURE UNIT FOR IN VITRO EXPERIMENTS

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INTRODUCTION

Many studies have been performed on the possible biological effects of mobile phone electromagnetic field (EMF) exposure. Most of the studies were focused on the single frequency EMF exposure. People in real environment, however, are exposed by EMFs from various electromagnetic sources simultaneously. To our knowledge, there is no published result for multiple-frequency exposure yet. The objective of this study is to develop multiple-frequency exposure unit for in vitro experiments.

METHODS

For multiple-frequency exposure unit, we adopted a RTL structure terminated with an absorber at the outer edge of the RTL, which has been used widely for broadband EMF exposure system for in vitro experiment. The exposure unit is excited by a conical antenna with broadband characteristics. A code division multiple access (CDMA) signal at 836.5 MHz and a wideband code division multiple access (WCDMA) signal at 1,950 MHz are generated and the two signals are added after amplification. The signals are the real reference signals used for mobile phone tests. The combined signals are then fed to the antenna which is located at the center of the RTL as shown in Figure 1. The maximum input power is 60 W for each signal. Exposure level and exposure schedule can be controlled by computer manipulation. The external dimension of the exposure unit is 950 mm x 950 mm x 226 mm, as shown in Figure 1. The chamber is made of aluminum, which functions as electromagnetic shield as well as waveguide. The exposure system is specifically designed to satisfy the proper environmental conditions, including ventilation, humidity, and temperature, etc. To maintain CO₂ density and humidity inside the chamber, the gas from an incubator is circulated throughout the chamber. Additionally, a cooling system which circulates cooling water throughout the bottom of the cavity is used to prevent temperature rise of the culture medium. The SAR distribution inside the exposed medium was calculated for design purpose by the numerical simulation, using the commercial electromagnetic tools XFDTD (Remcom Inc, State College, USA). The actual performance of the exposure unit was characterized by measurement as described below. For finite-difference time-domain (FDTD) simulation, the cell size was \( \Delta x = \Delta y = \Delta z = 1 \) mm, and the local grid of \( \Delta x = \Delta y = \Delta z = 0.2 \) mm was used in the culture medium region. Time step was 0.580 ps. The inner diameter of the 100 mm petri dish was 85 mm, and the thickness of the wall was 1 mm. The inner diameter of the lid was 91 mm. The quantity of culture medium was 17 ml, corresponding to a height of 3 mm in the petri dish.

RESULTS AND DISCUSSIONS

The measured results are summarized below. The return loss of the conical antenna shown in Figure 2 was below -15 dB in the design frequency. The SAR distribution was measured at nine points inside a petri dish, using the LUXTRON 790 fluoro-optic thermal probe with a thermal resolution of 0.1°C. The mean and standard deviation of the SAR values for nine points were 0.105 ± 0.019 W/kg/W for the CDMA frequency and 0.262±0.055 W/kg/W for the WCDMA frequency. The measurement data were fairly consistent with the results of FDTD simulation: the mean SAR values from simulation being 0.084 W/kg/W for the CDMA frequency and 0.501 W/kg/W for the WCDMA frequency. The maximum measured SAR value for 60 W supplied power is 6.3 W/kg at the CDMA frequency and 15.72 W/kg at the WCDMA frequency.
CONCLUSION
In this paper, a multiple-frequency exposure system for in vitro experiments is described. This exposure system is currently used for in vitro experiments to study the effects of the multiple-frequency exposure in the mobile communication frequency band.

Figure 1. Multiple-frequency in vitro exposure system.

Figure 2. Return loss characteristics of the conical antenna in the exposure chamber.

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An improved [0.08-6GHz] portable dosimeter for epidemiologist studies

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Abstract

In order to answer the combined requests of the WHO and epidemiologists, selective epidemiologic dosimeters have been designed for evaluating the electromagnetic field of the general population, as well as occupation peoples. In this paper, we propose to carry on the results of a study aiming at improving these dosimeters, for both reducing their dimensions, and improving their performances (sensitivity,…) in an extended frequency range.

INTRODUCTION

In spite of the establishment of exposure thresholds and legislation decisions, most interrogations of the general public remain focused on the field levels radiated by base stations used with wireless networks (mobile phone, WIFI & WIMAX systems) as well as TV transmitters. To understand the real people exposure, it is essential to have tools allowing an accurate evaluation of the contribution of each services within the [80MHz-6GHz] spectrum. We propose in this paper a new miniaturized version, with extended frequency range, and improved performances (sensitivity and multi-signal response).

![Figure 1: New dosimeter (yellow/blue housing) - Comparison with the previous EME Spy121 (blue housing)](image)

Improvements basically address the antenna, which was not optimized for the first version. Indeed, the isotropy constraints, and the dynamic range involve a specific multi-axial antenna (for recovering the three spatial vectorial components of the measured electric field), while huge dimensions were required for enhancing the antenna factor for the lowest aimed frequencies (TV& FM bands). The new probe (Fig. 2) consists of three metal spheres (10mm in diameter) around a central sphere acting as a common ground plane (20mm in diameter). They are soldered on a Multilayer PCB for interconnecting the probe with the RF receiver.
Increasing the frequency bandwidth for considering new standards is quite an important issue also for future epidemiology studies. We have increased the operational bandwidth for considering emerging technologies. The covered frequency range is now ensured from 88 MHz (FM applications) up to 6GHz (Wifi 802.11.a, n (5150 MHz \(\rightarrow\) 5850 MHz), Wimax 802.16 (3400 MHz \(\rightarrow\) 3800 MHz)).

All these parameters bring quite severe constraints on the dosimeter, and we investigate on a new RF-architecture considering first, new available components (especially the detectors for dynamic range and bandwidth constraints), and consequently new thinkable dosimeter architectures (with a reduced number of cascaded amplifiers for improving the linearity and the DC power consumption).

The new design also involves new signal processing and interfaces, using fast sampling methods, especially considering appropriate analog to digital converter from microcontroller.

**CONCLUSION AND PERSPECTIVES**

The latest improvement will be detailed during the conference, with the new experimental results and performances.

**Acknowledgment**

This project is supported by the French Foundation “Santé et Radiofréquences”

**Figure 2**: a) Description of the new probe; b) assembled structure with microshielded transition

**Figure 3**: a) New RF receiver architecture; b) Response to a pulse GSM/DCS frame
Introduction

Recent advances in MRI have resulted in an increase in static and time-varying magnetic fields in and around MRI scanners. In extreme cases, the staff is exposed almost to the same extent as the patient. Exposure to time-varying gradient magnetic fields and movements in a strong static magnetic field both induce electric fields in tissues and may stimulate peripheral nerve cells and disturb the central nervous system [1], [2]. In this context, a particularly interesting new development is the magnetic field meter developed for the measurement of time rate of change of magnetic flux density \( \frac{dB}{dt} \) for the assessment of exposure to motion-induced electric fields [3].

In this study, we examined the assessment of occupational exposure to gradient magnetic fields and time-varying magnetic fields generated by motion in static magnetic field of MRI scanners. A measurement setup that detects the \( \frac{dB}{dt} \) was developed to measure these magnetic field components separately and also simultaneously. The measured \( \frac{dB}{dt} \) values can be compared with \( \frac{dB}{dt} \) reference levels derived from magnetic flux density reference levels given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [4].

Materials and Methods

The occupational exposure to magnetic fields generated by MRI scanners was assessed for two different devices: an open 1 T scanner and a closed (cylindrical) 3 T scanner. The magnetic field measurement setup used in this study was based on a specially-designed 3-axis magnetic field probe, four channel virtual oscilloscope and laptop computer. The probe was calibrated in a magnetic field of a Helmholtz coil. Weighted peak method was applied to enable easy comparison of the resultant \( \frac{dB}{dt} \) to the reference levels given by ICNIRP [5]. In weighted peak method, the measured waveform is modified with a filter whose function follows the frequency variation of the reference level. The weighted peak value is then compared to the derived reference level 0.22 T/s.

The probe was attached either to the head of a volunteer or to a fixed non-metallic holder during the measurements. The volunteer walked with a normal walking speed avoiding rapid movements and thus simulating the movements of a medical worker near an MRI scanner. The gradient magnetic fields were measured with the probe attached to the holder 20 cm above the patient bed.

Results

The derived reference level 0.22 T/s was exceeded for both MRI scanners when the volunteer moved in the vicinity of the scanners. The motion-induced \( \frac{dB}{dt} \) and the corresponding spectrum for the 3 T scanner are presented in figure 1. Static magnetic field was integrated from \( \frac{dB}{dt} \). The highest motion-induced \( \frac{dB}{dt} \) values were 0.7 T/s for the 1 T
scanner and 3 T/s for the 3 T scanner. Even higher value (6.5 T/s) was measured for simultaneous exposure to motion-induced $dB/dt$ and gradient fields (Fast Field Echo sequence) for the 3 T scanner.

![Figure 1](image)

**Figure 1.** (a) Measured resultant $dB/dt$ and $B$ integrated from $dB/dt$ when the volunteer moved in the static field of the 3 T MRI scanner and (b) the corresponding spectrum. In figure (a) $dB/dt$ (solid line) values are shown on the left y-axis and the $B$ (dash-dot line) values on the right y-axis.

The measured gradient $dB/dt$ also exceeded the derived ICNIRP reference level in positions where the medical staff has access during interventional procedures. In the case of the 3 T scanner the weighted peak $dB/dt$ was 1.6 T/s at the entrance to the bore of the magnet for Echo Planar Imaging (EPI) sequence. For the 1 T scanner the gradient $dB/dt$ for EPI sequence was 2 T/s at an axial distance of 50 cm from the isocenter of the scanner. At the edge of the scanner the value had decreased to 0.1 T/s.

**CONCLUSIONS**

The exposure caused by low frequency and static magnetic fields in the vicinity of MRI scanners can conveniently be measured with an induction coil setup that detects $dB/dt$. The measurement setup developed is able to measure simultaneously $dB/dt$ generated by gradient magnetic fields and motion in static magnetic field. Exposure to the magnetic fields of the two measured MRI units (1 T open and 3 T closed) significantly exceeded the derived ICNIRP reference level 0.22 T/s in positions where the medical staff can have access during interventional procedures. Highest values were measured for simultaneous exposure to motion-induced $dB/dt$ and gradient fields.

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**REFERENCES**


Millimeter-Wave Exposure Setup and Dosimetry for in vitro Studies

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INTRODUCTION

Today, the 57-64 GHz sub-band is of strong interest for high-data-rate short-range communications (e.g. wireless USB, wireless video, streaming data). A number of experimental efforts have been undertaken to evaluate potential biological and health impacts of these radiations. In this paper we describe an experimental setup recently developed for the investigation of biological effects of millimeter waves at the cellular level.

MATERIALS AND METHODS

A narrow-band exposure system for in vitro studies has been specifically developed for human cells exposure under near- or far-field conditions. Fig. 1 schematically represents the three main sub-units of this system, namely (1) the signal generation sub-unit, (2) the frequency and power control sub-unit, and (3) the exposure chamber.

A low-power continuous-wave signal is generated by a Gunn oscillator at the central frequency $f_c = 60.42$ GHz. This frequency value coincides with the maximum oxygen-induced absorption peak in V-band. A mechanical tuning system enables one to shift the resonant frequency by $\pm 150$ MHz around $f_c$. This signal is amplified and transmitted toward an antenna through a set of WR-15 rectangular waveguides and a directional coupler. Three antennas have been used and characterized depending on the study configuration: (i) pyramidal horn antenna with aperture dimensions equal to 22.2 $\times$ 16.7 mm, (ii) conical horn with the aperture diameter of 23.8 mm, and (iii) open-ended WR15 waveguide (3.8 $\times$ 1.9 mm). The maximum measured output power for the exposure system configuration equals to 500 mW taking into account losses in the waveguides. The system allows reaching general public exposure limits in terms of power density under far-field exposure conditions (1 mW/cm²) and occupational exposure limits under near-field conditions (5 mW/cm²).

The frequency and power control sub-unit allows to monitor in real-time during the exposure the radiated power, operating frequency, and signal spectrum. The use of a Gunn oscillator guarantees a very satisfactory frequency stability ($\Delta f_c = \pm 0.006$ GHz). Exposures of the cell layers located in tissue culture plates (8.5 cm $\times$ 12.7 cm) are performed within a temperature-controlled incubator at 37°C. Sham-exposures are performed under the same experimental conditions, but with the generator switched off.

The dosimetry study was performed considering two exposure scenarios. First, typical biological samples exposed by a pyramidal horn antenna under far-field conditions. Second, biological samples exposed by pyramidal horn antenna, conical horn antenna, or open waveguide in near-field zone. We consider below only the first scenario, as the second part of the study is currently in progress and complete results will be reported during the meeting.
**Dosimetry studies were performed for 6-well and 96-well tissue culture plates with a cell monolayer attached to the bottom of the well and covered by culture medium. The distributions of the electromagnetic field and SAR within the cell layers were computed using the FDTD method (XFDTD® software from REMCOM Inc.). We assumed the incident field to be a normally-incident linearly-polarized plane wave.**

**RESULTS**

Results of the dosimetry study showed that for the maximum power density of 1 mW/cm²:

1. the average SAR equals 21.4 W/kg and 17 W/kg for the central and corner wells, respectively, in the case of 6-well tissue culture plate;
2. the average SAR ranges from 26.2 W/kg (center well) down to 13.7 W/kg (corner wells) for 96-well tissue culture plates.

The exposure setup was validated in a series of bioelectromagnetic experiments at cellular and sub-cellular levels (cell viability, gene expression modifications, etc.).

**CONCLUSIONS**

A specific exposure system allowing to perform far-field or near-field exposures with power densities close to those expected from the near-future wireless communications in the 60-GHz band has been developed and characterized. The SAR for the typical biological samples used in bioelectromagnetic experiments were computed using the FDTD method.

**ACKNOWLEDGMENTS**

This study was supported by National Research Agency (ANR), France, under Grant № 2006 SEST 19 02 (HIMWR project) and by Health and Radiofrequency Foundation, France (StressOM project).
INTRODUCTION

There is ample literature which demonstrates effects of RF-EMF on structure and function of the genome of mammalian cells in vitro [1]. The European REFLEX-project and a subsequent study carried out at the Medical University of Vienna (MUW) impressively confirm the genotoxic effects of this kind of radiation [2,3]. In spring 2008 it was claimed that the findings obtained in Vienna would have been fabricated. The message which was aimed at the withdrawal of the respective publications from the scientific literature was distributed by major media all over the world. Since the clarification process at the MUW could not find any proof justifying this accusation, the editorial boards of the respective scientific journals had to ignore this request as unfounded. The authors of the publications feel obliged to inform the scientific community on this event accordingly.

MATERIALS AND METHODS

In the REFLEX study, human primary fibroblasts and granulosa cells of rats (GFSH-R17) were exposed continuously or intermittently (5 min on/10 min off) up to 24 h to 1800 MHz RF-EMF at a SAR of 2 W/kg and below without and with different system modulations (GSM basic, GSM talk). In a subsequent study, human primary fibroblasts were exposed continuously or intermittently (5 min on/10 min off; 5 min on/20 min off; 10 min on/10 min off; 10 min on/20 min off) up to 48 h to 1950 MHz UMTS at a SAR of 2 W/kg and below. In the REFLEX study [2], the samples were analysed with the alkaline and neutral comet assay by calculating the comet tail factor (CTF) as a measure for DNA strand breaks. In the subsequent study [3], only the alkaline comet assay and, in addition, the micronucleus test counting the micronuclei (MN) after blocking the cytokinesis with cytochalasin B were used for analysis. All EMF-exposed samples were compared with sham-exposed and negative and positive controls. All evaluations were performed under blinded conditions and by the same investigator (E.K.).

RESULTS

1800 MHz RF-EMF (CW, GSM basic, GSM talk) generated at a SAR of 1.2 and 2 W/kg after a continuous or intermittent (5 min on/10 min off) exposure for up to 24 h a significant increase in DNA strand breaks in both cell lines, the human fibroblasts and the granulosa cells of rats. Effects occurred after an exposure time of 16 h, without and with different mobile phone modulations, but could not be found after 4 h of exposure. After intermittent exposure to CW-RF-EMF the CTF was higher as compared to continuous exposure. This may indicate that the induced DNA damage is not based on thermal effects. A significant increase in the CTF was found with the alkaline comet assay at a SAR of 0.3 W/kg.

The UMTS exposure, too, significantly increased the CTF and in addition the number of micronuclei in human fibroblasts in a dose- and time-dependent manner. At a SAR of 0.1
W/kg the increase in the CTF was significant after 8 h of exposure (p<0.02), while the number of MN significantly rose after 12 h of exposure (p<0.02). A significant effect could already be seen at SAR of 0.05 W/kg, but in this case an exposure time of 24 h was needed. No UMTS effect was observed with lymphocytes, unstimulated or stimulated with phytohemagglutinin.

CONCLUSIONS

The proof of principle experiments which have been carried out by us and others, too, clearly demonstrate the genotoxic potential of RF-EMF. The numerous negative results in this area of research cannot be accepted as proof of the opposite. What is needed now, are biophysical and/or molecular-biological studies aimed at the detection of the basic mechanisms which are the underlying causes of the genotoxic effects.

REFERENCES


Proof of Principle Tests Confirm Genotoxic Potential of RF-EMF

Abstract

Human fibroblasts were exposed to 1800 MHz RF-EMF without and with different system modulations and to 1950 MHz UMTS at a SAR of 2 W/kg and below using different exposure times and patterns. The samples were analysed with the alkaline comet assay by calculating the comet tailfactor and with the micronucleus test by counting the micronuclei after blocking the cytokinesis with cytochalasin B. The experiments clearly demonstrate a significant increase in DNA strandbreaks and in micronuclei thus confirming the genotoxic potential of RF-EMF and its various modulations, but do not provide any insight into the mechanism of their genesis.
In vitro Studies of Low Frequency Electromagnetic Field Effects on Immune Cells using a Solenoid Coil Exposure System

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INTRODUCTION

Increased interest in modulation of disease resistance by low frequency electromagnetic fields (LF-EMF) has been evoked by several studies showing in vitro effects on cellular functions of immune cells [1-2]. Effects are however subtle and sometimes difficult to reproduce.

Studies with broiler chicken and fish have demonstrated a clear effect of LF-EMF on the health status of these animals. An improved feed conversion ratio, lower mortality and less infection-induced intestinal lesions were observed, suggesting immune stimulation. These effects were observed using extremely low field strengths [3-4].

As the underlying mechanisms remain unclear, extensive in vitro studies to elucidate the effects of weak LF-EMF on immune cells are essential. We hypothesize that LF-EMF acts as a stressor, promoting immune activity by increasing pro-inflammatory cytokine- and ROS-production, and consequently, stimulates the innate immune response to pathogens. To study this hypothesis, an innovative LF-EMF exposure coil was designed and applied to immune cells in vitro. Immunological assays and transcriptome analyses are used as the experimental read-outs for potential LF-EMF effects.

MATERIALS AND METHODS

A solenoid coil exposure system was developed. The exposure coil was built to fit inside a standard CO₂ incubator and to accept standard-sized tissue culture plates and 150 ml tissue culture flasks. This exposure system was especially designed for in vitro experiments with cell lines, isolated blood cells and tissues, and whole blood measurements. Optimization was performed with standardized hematopoietic cell lines (PLB-985 and HL-60), which were differentiated into either granulocytes or monocytes. Subsequently, immune activation assays were performed to characterize effects of LF-EMF. Read-out parameters include ROS-production, NO-production, genome-wide expression analysis (microarrays), intracellular calcium concentration and cytokine release.

RESULTS & CONCLUSION

The exposure system consists of a copper wire coil and a polymethylmethacrylate base cylinder. To exclude the possibility of fringe fields to unintentionally influence the control cells, our coil was designed with an inner cylinder onto which a truncated solenoid coil was placed, containing double windings at both ends. This resulted in a factor >5,000 reduced exposure field strength >1 meter away radially and/or >1.5 meters axially from the center. An outer cylinder with short solenoid coils at both ends counteracted the inside field. All geometric parameters were optimized simultaneously to yield high homogeneity (better than
0.6 %) in the exposure area of 130 x 90 x 20 mm. Together with signal generators built by Immunent BV, the system was able to generate electromagnetic fields with multiple simultaneously shaped waveforms from 0.1 µT to 1.5 mT.

Recently, the hematopoietic cell lines PLB-985 and HL-60, which were differentiated into either granulocytes or monocytes, were exposed to LF-EMF, and the effects on ROS-production, NO-production, genome-wide expression analyses (microarrays), intracellular calcium concentration and cytokine release are currently being analyzed. Importantly, the experiments are all performed in a dual-center fashion, allowing the possibility to directly verify findings for reproducibility and compare data between the corresponding laboratories.

ACKNOWLEDGMENTS

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REFERENCES


HALF-WAVE RESONANCE OF BACTERIA DNA IRRADIATED FROM 4 TO 8 GHz

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INTRODUCTION

A new theoretical concept is presented to explain the disruptive effects on some bacteria irradiated by an electromagnetic field. We suppose a half-wave resonance of their DNA. Proof-of-concept experiments by two electronic devices associated with various gas plasma antennas is given.

METHODS

It has been shown that AC conductivity of DNA in the millimetre range is largely ascribed to relaxational losses of the water dipoles in surrounding hydration layers. The total number of water molecules per nucleotide has to be correlated with the relative humidity. For instance the adsorption of water molecules per nucleotide is equal to 13 for a rate of humidity (R.H) equal to 84%, and 4 for R.H of 60%. For an R.H of 0% there are 3 water molecules per nucleotide which cannot be removed from the helix. The DNA conductivity of calf thymus at 100 GHz is equal to 25 S/m for a R.H of 84%. For a R.H equal to 0% the DNA conductivity is only of 1 S/m [1].

We suppose the DNA half-wave resonance at a frequency $F$ such as:

$$F = \frac{c}{2L} \left[ \varepsilon_r(F) \right]^{1/2} = \frac{c}{\left[ \varepsilon_r(F) \right]^{1/2} N_{PB} l_0}$$  \hspace{1cm} (1)

$N_{PB}$ is the base-pairs number, $l_0$ the distance between two consecutive bases counted along the helix strand, $c$ is the light speed in the vacuum, $\varepsilon_r$ is the relative permittivity of the water at the frequency $F$. The table 1 shows the various parameters for some bacteria.

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>$N_{PB}$</th>
<th>$F$ (GHz)</th>
<th>$L$ (mm)</th>
<th>$A$ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus aureus</td>
<td>2845890</td>
<td>7.80</td>
<td>2.32</td>
<td>2.20</td>
</tr>
<tr>
<td>Actinomyces</td>
<td>3042856</td>
<td>7.50</td>
<td>2.48</td>
<td>1.92</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>3218000</td>
<td>6.80</td>
<td>2.62</td>
<td>1.90</td>
</tr>
<tr>
<td>Mycobacterium leprae</td>
<td>3268203</td>
<td>6.70</td>
<td>2.67</td>
<td>1.86</td>
</tr>
<tr>
<td>Proteus mirabilis</td>
<td>4063606</td>
<td>5.10</td>
<td>3.32</td>
<td>1.59</td>
</tr>
<tr>
<td>Mycobacterium tuberculosis</td>
<td>4411532</td>
<td>4.75</td>
<td>3.60</td>
<td>1.44</td>
</tr>
<tr>
<td>Salmonella typhi</td>
<td>4830175</td>
<td>4.40</td>
<td>3.94</td>
<td>1.37</td>
</tr>
<tr>
<td>Escherichia coli K12</td>
<td>5126377</td>
<td>4.10</td>
<td>4.18</td>
<td>1.25</td>
</tr>
</tbody>
</table>

Table 1: Parameters for some bacteria

$A$ is the wave absorption into the water along the DNA strand. To explain the bacteria
destruction via their DNA, we refer to two enclosed gas plasma antennas lighted with a modulated RF electronic discharge. Plasma oscillation frequencies are generated very near of the ionic plasma frequency equal to:

\[ f_i = \left( \frac{e}{2\pi} \right) \left( \frac{\Delta n_f}{\varepsilon_0 m_i} \right)^{1/2} \]  

\( m_i \) is the ion mass, \( \Delta n_f \) the ion density related to the non-linear behavior of the plasma which depends on the modulation frequency, \( e \) the elementary electric charge and \( \varepsilon_0 \) the vacuum permittivity.

RESULTS

1) For the Rife-Bare device recalled in [2], the cylindrical plasma antenna is filled with argon gas at a pressure of 50 mm. The ion density \( /m^3 \) is equal to:

\[ \Delta n_f = 9.51 \times 10^{27}/(f_m)^2 \]  

(3)

\( f_m \) is the pulsed modulation frequency of the carrier of 27 MHz. With (2) and (3) we deduced with \( m_i = 6.63 \times 10^{-26} \) Kg:

\[ f_i = 3.24 \times 10^{12}/f_m \]  

(4)

When \( f_m \) is increasing from 405 to 810 Hz, \( f_i \) is decreasing from 8 to 4 GHz. The correlation between F on table 1 and \( f_i \) is right and shows that the Rife-Bare device is able to destroy the bacteria at the mortal modulation frequency \( f_i \).

2) For the Rife device (1939) recalled in [3], a spherical tube called phanotron filled with helium gas at 12 mm, radiates a carrier of 4.6 MHz modulated by a pure sinusoidal frequency. The neutral helium atom density \( n_0 \) is given in terms of the pressure \( P_0 \) by:

\[ n_0 = P_0/\varepsilon_0 T_0 \]  

(5)

With \( T_0 = 300K \) and an ionization degree of 1/100, the helium ion density is: \( \Delta n = 3.8 \times 10^{21}/m^3 \). With \( m_i = 6.64 \times 10^{-27} \) Kg, the maximum ionic plasma frequency was with (2): \( f_i M = 6.5 \times 10^9 \) Hz. This value is a right amount in comparison with the half-wave bacteria resonance frequencies F.

On the table 2 we present the mortal frequencies measured by Rife (1939), and the theoretical mortal frequencies deduced from (2) and (3) related to the Rife-Bare with \( f_i # F \).

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Theoretical mortal frequencies ( f_m ) (Hz)</th>
<th>Measured mortal frequencies by Rife (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus aureus</td>
<td>515</td>
<td>727</td>
</tr>
<tr>
<td>Actinomyces</td>
<td>520</td>
<td>784</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>530</td>
<td>757</td>
</tr>
<tr>
<td>Mycobacterium leprae</td>
<td>540</td>
<td>783</td>
</tr>
<tr>
<td>Proteus mirabilis</td>
<td>650</td>
<td>767</td>
</tr>
<tr>
<td>Microbacterium tuberculosis</td>
<td>700</td>
<td>803</td>
</tr>
</tbody>
</table>
From the high accuracy of the modulation frequency measured by Rife(1Hz) we deduced from (4): $df_i/f_i = df_m/f_m$, and then the high selectivity of the DNA bacteria at resonance.

**CONCLUSIONS**

The DNA half-wave resonance hypothesis of bacteria irradiated by frequencies between 4 and 8 GHz has been justified by experiments. It was necessary to know the base-pair numbers of the DNA bacteria surrounding by several hydratation layers.

**REFERENCES**


The damaging effect of different bands electromagnetic radiation on the rat testis and the mechanism study in the dysfunction spermatogenesis and spermiotelcosis

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Background: Electromagnetic radiation as an important pollution factor has threatened human health. The frequency of electromagnetic radiation in environment is composite, and frequency of radiation weapons in future battlefield is unknown. In order to resolve the question that if we can take universal prevention, diagnosis or therapy measures for electromagnetic radiation with different frequency, we take testis a hypersensitive target organ for electromagnetic radiation as breakthrough in this study. We investigate the differences among three kind of typical electromagnetic radiation with different frequency (EMP, S-HPM and X-HPM) in damaging effect on testis, and the roles of related genes in spermatogenesis includes c-fos, Cyclin A, Pp2A and the sex-determing region Sry gene of Y chromosome. The long-term (12m) study would be dynamic to reveal the damaging regule and the effect on the spermatogenetisis and the spermiotelcosis.

Methods: 174 male Wistar rats were exposed to EMP, S-HPM and X-HPM respectively. We determined the blood convention index, the data related to the function of kidney, liver and heart, the hormone contents in serum by radioimmunity meter and ELISA. Light microscope and scanning electron microscopy were employed for pathomorphological observation. The PCNA and apoptosis of spermatogenic cells were observed by IHC and TUNEL. Cell cycle of spermatogenic cells cultured primary by complex enzymatic digestion was detected by FCM. The related genes to the spermatogentisis and spermiotelsis were analysied quantitied by IHC and the stereology image system. The Sry gene was determined by PCR. So, we investigated the damaging effects of electromagnetic radiation on testis and the spermatogenesis by many methods to discuss the injury mechanism.

Results: (1) There were damaging on the kidney, liver and heart, and the index recovered to normal during the later time after radiation. (2) The Leydig cell damaged and induced the content of T decreased; with the increase of power density, the content of T decreased. (3) With the injury of testis morphous, the seminiferous tubules, the
spermatogenic cells and the interstitial tissue, their function were destroyed. There were common characteristics: produce quickly, a stable phase and distribute ununiformity. (4) The decreasing G0/G1 of spermatogonium and spermatocyte showed the slower DNA synthesis, proliferation activity(PCNA) decreased induced to apoptosis(6h ~ 6m). The whole spermatogenesis process was draw backed and the spermiotelcosis was inhibited(6h-6m). (5) The quantity of spermatod and spermatozoon, spermatogonium and spermatocyte, and the efficiency transferred from spermatogonium to spermatocyte and spermatod to spermatozoon reduced significantly. (6) The expressiones of c-fos and Cyclin A enhanced, the Pp2A weakend significantly. (7) The hyp-expression of Sry proved that Y chromosome spermatozoon had invalid function, that might be an important cause of the disorder ration of offspring sex. All the changes above showed an attenuating trend in the radiation groups as EMP, X-HPM, S-HPM.

Conclusions: To sum up, the damaging effects of testis structure, function and the failure in spermatogenesis, spermatoleosis and spermiotelcosis induced by three kind of electromagnetic radiations with different frequency possess general similarity. Main difference lies in injury degree, which shows a direct correlation with radiation frequency. This provides experimental basis for taking universal prevention, diagnosis and therapy measures for electromagnetic radiation with different frequency, molecular basis and target are also provided for new consideration path to research the mechanism of electromagnetic radiation result in the disorder sex ration.

Key words: electromagnetic radiation; testis; spermatogenesis; spermiotelcosis; Sry
A 0.2 mT, 50Hz magnetic field evoked reorganizations in microfilament cytoskeleton assembly of human amnion FL cell line, which was prevented by PD153035 and the elevation of extracellular Ca\(^{2+}\)

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Abstract

A 0.2 mT power frequency magnetic field (PFMF) was applied to FL cells, inducing cytoskeleton reorganization: decreases in assembly of cell central skeleton stress fibers in vivo, the efficiency of the F-actin assembly in vitro, and the height of cytoskeleton; and a time-dependent-new filopodias appeared at the cell periphery. The reorganization cytoskeleton could be greatly prevented by treating PD153035 plus EGTA prior to the exposed cells. These results suggest that the field exposure may disrupt the cytoskeleton organization mechanism which is defined by the EGFR-cytoskeleton signal pathway, and the extracellular Ca\(^{2+}\) plays a significant role in the disruption.

MATERIALS AND METHODS

MF exposure

The power frequency MF (PFMF) exposure system\([1]\) is placed in a CO\(_2\) cell culture incubator at 37°C. 10μg/ml G-actins or cells placed in plastic 6-well plates were randomly divided into three groups: the sham (Control), the MF (+MF) or the other leechdom-pretreated. The MF groups were exposed to a 50 Hz magnetic field for indicated time lengths. The sham was exposed for the same time in a MF exposure system with power off.

Immunofluorescence labeling and morphology observation

For immunofluorescent observation, FL cells on glass cover slips were fixed for 15 min at 37°C in 4% paraformaldehyde in PBS, after that put in 0.2% TritonX-100 in PBS for 15 min, and then blocked for 2 hrs in 10% goat serum in PBS. The resultant was incubated for F-actin labeling with the Phalloidin-TRITC (5μg/ml) at 20°C for 1 h, then were viewed and photographed by Olympus BX51.

For scanning microscope observation: cells were fixed in 1% OsO\(_4\) in Millonig’s buffer, dehydrated through a graded acetone series and critical point dried with CO\(_2\), then were coated with gold and observed on a JXA-840 scanning electron microscope.

Observing the assembly of F-actin fibers with atomic force microscope

G-actins were in F-buffer containing 2 mmol/L MgCl\(_2\), 100 mmol/L KCl, 1 mmol/L DTT, 1 mmol/L ATP, was dropped on a mica slit and were polymerizing, then exposed to MF for 30 minutes. After exposure, the samples were flushed then were dried for AFM (Nanoscope IIIa) examinations in tapping scanning mode.

PD153035 or EGTA pretreatment

1μM PD was added to and treated the cells for 2 hrs prior the sham or the field exposure. The Ca\(^{2+}\) concentration in extracellular matrix was set to 1mM or 10mM by adding 0.1mM or 1mM EGTA to the culture media containing 1.1mM or 11 mM CaCl\(_2\) at pH 7.1.
RESULTS

Tumor cells usually behave abnormal proliferation and abnormal migration, which are directly linked to the signal transduction pathways of cell cytoskeleton and that of growth factors. EGF binding or MF exposing to EGFR initiates responses including receptor activation, clustering and alterations in Ca$^{2+}$ fluxes [1-4]. In this research, efforts were put to reveal the effects of a 0.2 mT, power frequency magnetic field (PFMF) on microfilament assembly of human amnion FL cell line. It is observed that, after FL cells were exposed to the PFMF, (1) a decreases in the assembly of the central skeleton stress fibers of FL cells in vivo (Fig 1, 2), either the exposuring FL cells to a 0.2mT MF, and treating the cells with EGF, resulted in the disappearance of the central microfilament stress fibres (arrowheads) and in the appearance of filopodia (arrows)(Fig 1B and C), the appearance of filopodia and microfilament showed a time-dependent fashion (Fig 2 B-D). (2) a decrease in the efficiency of the F-actin assembly in vitro (Fig 3); (3) appearance of a time-dependent-new filopodias at the cell periphery; (4) the mean height of cell cytoskeleton decreased from (12.37±1.10)μm to (9.97±0.30)μm, presenting ~20% decrease (Table 1), along with occurrence of a “central hollow phenomenon” in cell skeletons with the appearance of flatter cells accompanied by the appearance of lamellipodia. The reorganization in cell assembly could not be obviously prevented either by an inhibitor of the EGFR tyrosine kinase, PD153035, or by chelating the calcium ions in the cultural medium by a Ca$^{2+}$ specific chelator Ethylen glycol-bis(β-aminoethyl ether)-N,N,N',N'-tetraacetic acid (EGTA) alone, but by an associated treatment of PD153035 and EGTA to the exposed cells. The treatments of PD153035 + 1 μM [Ca$^{2+}$]o presented obvious inhibitions of the field-induced-reorganization of stress fibers (Fig 4). These results suggest that the field exposure may disrupt the cellular skeleton function and actin recycle mode, which is defined by the EGFR-cytoskeleton signal pathway, and the cellular Ca$^{2+}$ plays a significant role in the disruption.

Figure 1. A 0.2 mT, 50 Hz power frequency magnetic field affects the microfilament cytoskeleton of FL cells. A: sham; B: exposed to 0.2mT MF for 30 min. C: treated with 100nM EGF without exposure to MF. Arrows: appearance of filopodia, arrowheads: the weakened central microfilament stress fibres. n=6.

Figure 2. Scanning Electron Microscopy analyzed the shape of FL cells. A: the sham exposed cells; B-D: cells were exposed to 0.2 mT MF for 15, 30, and 60min. This experiment was repeated 5 times. E: the positive control with 100ng/ml EGF. Arrow: appearance of lamellipodia. n=4.
**Table 1.** PFMF induces a decrease in cell mean height. n=10.

<table>
<thead>
<tr>
<th>Control mean height (μm)</th>
<th>+ MF mean height (μm)</th>
<th>Decrease (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: 12.4±0.7</td>
<td>9.9±0.3μm</td>
<td>19.4</td>
</tr>
</tbody>
</table>

P <0.05, n=15

**Figure 3.** The effect of 0.2 mT, 50Hz MF on the assembly of G-actins. A: The self assembling of G-actins were sham exposed. B: The self assembling of G-actins were exposed to 0.2 mT, 50Hz MF for 30 min. C: G-actins, without self-assembly. n=3.

**Figure 4.** PD153035 and 1μM [Ca²⁺], treatments influence the reorganization of microfilament. A: sham; B: with 1μM PD153035 for 2hrs, decreased the concentration of calcium in matrix from 1mM to 1μM with EGTA, then unexposed to 0.2mT MF for 30 min. C: with 1μM PD153035 for 2hrs, decreased the concentration of calcium in matrix from 1mM to 1μM with EGTA, then exposed to 0.2mT MF for 30 min. n= 4.

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In vitro approach of cardiac defibrillators immunity in low frequency electromagnetic environment

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INTRODUCTION
Cardiac implants are the most common medical devices. They are subject to specific international product standards. However, since the European directive 2004/40/EC on exposure of workers to electromagnetic (EM) fields, supplementing the EC recommendation-99, many questions remain still open. To establish a risk assessment procedure for workers bearing medical implant is very complex goal due to the diversity of the potential situations involving EM fields interactions in professional environment. Assessment of human exposure at the workplace for persons bearing active implantable medical devices (AIMD) in electromagnetic fields is thus a current challenge for all the concerned electrical industries.

These studies have shown that interference appear only for radiated fields above the limits recommended for the public and workers exposure. Studies were recently conducted on implantable cardiac defibrillators using the same protocol and the same frequencies. Further work on a larger number of implants is underway. A theoretical approach for establishing the electric potential at the tip of the probe catheter induced by an external magnetic field at the same frequencies was also developed.

In this paper we describe a method [1] for in vitro characterization of the immunity of implantable cardiac defibrillators (ICDs) to electromagnetic interference at low frequency (50 Hz-25 kHz). Provocative studies have already been conducted in vitro at the Laboratory of Electronic Instrumentation of Nancy (Nancy University) for frequency of 50/60 Hz, 10 kHz and 25 kHz for pacemakers.

MATERIALS AND METHODS
An experimental set up using an electromagnetic source for provocative interferences consists on a programmable BF generator connected to a power amplifier and a Helmoltz coil to simulate the radiated EM fields[2]. The instrumentation for data acquisition of telemetry signals provided by the manufacturer of the cardiac implants as well as an oscilloscope complete the bench. The signal disturbance is applied to the implant placed in a Plexiglas tank filled with an electromagnetic phantom. Dielectric and conductivity values of this phantom are close to those of biological tissues. Only the Helmoltz coil and the phantom of gelatin including the implant under test are placed in a Faraday cage. The whole set up is controlled by a PC with HP VEE to adjust voltage levels and frequencies. The acquisition of these parameters is synchronized with the clock of the telemetry of the implant. An oscilloscope control allows to check signals during routine settings.

The tests presented were made on a defibrillator with its probe. Other ICDs have also been studied and the results will be presented. The first parameter is the frequency the voltage level being fixed. It varies between 50 Hz to 25 kHz by steps of 50 Hz The second parameter is the level of voltage disturbances. We have studied the behavior of the DAI for each frequency, with voltage levels varying from 0.5 V to 4 V. The disturbing signal is applied over a period of 60 s and interrupted during the same period to ensure that the ICD can under
no circumstances fail to detect an event. The synchronization of clocks telemetry and PC, has
allowed us to establish a direct link between the temporal frequencies and arrhythmic events
detected by the defibrillator that we ordered.

RESULTS

A comparison was made between the file that contains the frequencies emitted at a given
time and the time of the occurrence of each event recorded by the DAI, which has allowed us
to deduce the frequency signal that caused false detections, and which would have been led to
inappropriate shocks. Once the measurements on all ranges of frequencies, we have plotted
the curves representing, in binary form, the presence of events detected as a function of
frequency and this for each level of voltage.

Beyond 1500 Hz, the defibrillator filter all the disturbances and no longer stop any event.

Inhibition of detections : at 50 Hz, the device detects ventricular fibrillation, when
disturbances are at low amplitude (less than 1 V), but it classifies correctly the two events
(ventricular tachycardia). Beyond 2500 Hz, the implant recognizes and classifies correctly
all the arrhythmias. We still remark at a given level of disruption, there is a frequency beyond
which the defibrillator detect all events and the threshold frequency of functioning increases
with the magnitude of disturbance. The influence of technology ICD is crucial in this regard.

For fields exceeding 1000µT and for the four frequencies of interest (50-60 Hz ; 10-25
kHz) no false detection nor deprogramming of the defibrillator was noticed.

CONCLUSIONS

In this paper we describe a method for in vitro characterization of the immunity of
implantable cardiac defibrillators (ICDs) to electromagnetic interference at low frequency (50
Hz-25 kHz). Provocative studies have already been conducted in vitro at the Laboratory of
Electronic Instrumentation of Nancy (Nancy University) for frequency of 50/60 Hz, 10 kHz
and 25 kHz for pacemakers. We still remark at a given level of disruption, there is a
frequency beyond which the defibrillator detect all events and the threshold frequency of functioning increases
with the magnitude of disturbance. The influence of technology ICD is crucial in this regard.

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EVALUATION OF MICRONUCLEUS FORMATION IN IN VITRO BY EXPOSURE TO INTERMEDIATE FREQUENCY MAGNETIC FIELDS
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INTRODUCTION
Last 25 years, intensive research has been conducting to examine whether electric and magnetic fields affect human health or not, especially in 50/60 Hz extremely low frequency magnetic fields as power frequency and radio frequency (0.8-2.45 GHz) in mobile telephony. These researches were motivated by the public concern of health effects such as association of exposure to extremely low frequency magnetic field and child leukemia. However, the biological effects of intermediate frequency (IF; from 300 Hz to 10 MHz) MFs have not been studied enough to estimate its health risk, although several technologies and equipments that generate IF-MFs have already used in public and occupational environments. In this study, we have investigated the mutagenic potential of the IF-MFs using in vitro micronucleus test.

MATERIALS AND METHODS
For IF-MFs exposure, an IF-MFs exposure device (Fig. 1), which use a resin CO₂ incubator (inside dimension of 200mm x 200mm x 200mm, water-jacket for temperature control) mounted over a plain coil (diameter of 160mm) was used. Sinusoidal IF-MFs were generated using this device and maximum density of magnetic field within exposure area was up to 0.8 mT at 2 kHz and 20 kHz, respectively. We used a 35mm disposable Petri dish to expose cells to the IF-MFs. Spatial distribution of magnetic field among the cells in a 35mm Petri dish was within 0.7 to 0.8 mT at maximum field strength.

The Chinese hamster V79 cells were exposed to up to 0.8 mT, 2 and 20 kHz IF-MFs for 24h at 37 °C in a 5% CO₂ resin incubator. After the exposure, cells were treated with cytochalasin B. Then cells were fixed 24h later after the cytochalasin B treatment. The ratios of micronucleus formation rates were estimated by counting micronucleus in approximately 1,000
RESULTS AND DISCUSSION

In the results, neither significant nor reproducible difference between MF exposed and unexposed control cells was found in the micronucleus formation rates in 2 kHz, 0.8 mT IF-MF and also 20 kHz, 0.8 mT IF-MF (Fig. 2), respectively. These results suggested that the IF-MFs used in this study did not induce micronucleus formation in in vitro micronucleus test using V79 cells.

Since previous reports showed similar results that 2, 20, 60 kHz, up to 1.1 mT IF-MFs did not show mutagenicity and co-mutagenicity in bacterial mutation assay\(^1\), and 23 kHz, 0.6 mT magnetic field did not have biological effects in mammalian cells\(^2\), it was suggested that IF-MFs are not likely to cause mutation.

CONCLUSIONS

Experimental results suggest that exposure to 2 and 20 kHz, up to 0.8 mT sinusoidal IF-MFs did not have any potential to induce micronucleus in V79 cells.

REFERENCES

Electromagnetic Field Effects On Malignant Cell Proliferation Are Dependent Upon Temporal Patterns

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INTRODUCTION

There is growing concern related to the risk of cancer incidence resulting from exposure to cell phones and electronic equipment. These devices emit electromagnetic fields (EMF) which have been shown to affect biological processes. Although most studies delineate the negative aspects of EMFs on health, EMFs can be used positively to target specific biological processes. “Thomas” is a frequency-modulated EMF pattern (25 Hz to 6 Hz) originally designed to target pain receptors (Fig 1). We have shown that exposure of cultured B16-BL6 cells, an aggressive murine melanoma, to the Thomas-EMF at 1-5 µT for 1 hour/day over the course of 6 days inhibited proliferation by approximately 50% (Fig 2a). In addition, we have shown that daily one hour exposures to Thomas-EMF significantly inhibited proliferation of three cultured malignant cell lines (MDA-MB-231 breast, MCF-7 breast and HeLa cervical) while having no effect on the proliferation of the three non-malignant cell lines (HBL-100 breast, HSG human salivary gland and 293T human embryonic kidney). Similarly, Thomas-EMF significantly restricted tumour growth in mice injected with 10^6 B16-BL6 cells.

The general consensus is that EMFs can influence biological processes, however there is controversy with regards to their ability to cause adverse health effects. These discrepancies across studies may be attributed to EMF-related factors such as differences in spatial complexity, temporal patterns, duration of treatments, intensity of the field, and homogeneity or heterogeneity of the field, or biologically-related factors such as differences in cell origin, age, and their ability to form differences in tumours. We hypothesize that the ability of EMFs to influence biological processes is dependent on the temporal (timing) patterns of the fields, similar to the way pharmaceuticals are dependent on their chemical structures.

MATERIALS AND METHODS

The optimal parameters within Thomas-EMF that are crucial to the inhibition of malignant cell proliferation have been examined. Exposure to the reverse form of Thomas-EMF (6Hz to 25Hz) as well as fragments of the Thomas-EMF pattern did not inhibit proliferation (Fig 2b). The effects were also dependent upon timing within the pattern. For example, the point duration in Thomas-EMF that had the strongest effect was at 3 msec while 1 and 2 msec showed smaller effects and 4 and 5 msec exhibited no effects (not shown). Four different EMF patterns were tested however none exhibited effects on malignant cell proliferation (not shown).
Cultured Bl6-BL6 cells, an aggressive murine melanoma, received daily 1 hour exposures to the specific EMF patterns. To measure the effects of EMF on cell proliferation, a replicate plate of cells was harvested each day and counted using the Trypan blue exclusion assay. Inhibition of proliferation was confirmed by MTT assay.

RESULTS

![Electromagnetic field patterns](image)

Figure 1: Electromagnetic field patterns A. The Thomas EMF pattern is a frequency modulated pattern composed of 849 points with each point programmed for 3 msec. The frequency modulation within the pattern ranged from 25 Hz during the first 200 msec of the pattern to 6 Hz during the last 500 msec of presentation. B. The Thomas reverse pattern is a frequency modulated pattern composed of 849 points with each point programmed for 3 msec. The frequency modulation within the pattern ranged from 6 Hz during the first 500 msec of presentation to 25 Hz during the last 200 msec of presentation.

![Proliferation of B16-BL6 melanoma cells exposed to either the Thomas-EMF pattern or Thomas-EMF reverse pattern](image)

Figure 2: Proliferation of B16-BL6 melanoma cells exposed to either the A. Thomas-EMF pattern or B. Thomas-EMF reverse pattern. B16-BL6 cells received either no EMF treatment (sham), were exposed to Thomas-EMF for 1 hour per day (forward or reverse) or 4 hours per day (forward only). Error bars represent 95% confidence intervals however there were no discernable differences between the eight replicates of each individual point.

CONCLUSIONS

These results strengthen the idea that EMF effects are dependent upon their specific temporal patterns. Spatial-temporal patterns are an absolute requirement inherent to many biological processes. For example, the appropriate spatial-temporal modulation of gene expression is critical for normal embryogenesis and development. Spatial-temporal patterns of brain activity are also required for many aspects of cognitive and motor processing. Therefore the notion that EMF effects are dependent upon their temporal patterns is consistent with a variety of physiological models.

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Development of Intermediate-Frequency Long-Term Magnetic Field Exposure System for In Vitro Studies

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INTRODUCTION

In recent years, induction heating (IH) cooktops, which are replacing gas and electric cooktops, have rapidly become popular in Japan and Europe. IH cooktops generate intermediate-frequency (IF) magnetic fields (MFs) of 20-90kHz from heating coils, and induction currents that heat metal pans are generated. The MFs generated by IH cooktops are not particularly strong. However, Fact Sheet 322 [1] recommended research programs to further reduce the uncertainty of scientific evidence on the health effects of extremely low frequency (ELF) MF (100kHz or less) exposure.

We had already developed an IF MF in vitro exposure system that could generate MFs of $532 \mu T_{\text{rms}}$ at 23kHz [2] and $6.25 m T_{\text{rms}}$ at 23kHz [3] for 2 hours. In this study, focusing on the long-term effect of the ELF MF reported in Fact Sheet 322 [1], we developed the IF MF in vitro exposure system that enables us to continuously expose cells to a MF for one week, and reported the design and the results of the evaluation.

MATERIALS AND METHODS

In this study, a relatively low sinusoidal magnetic field of $100 \mu T_{\text{rms}}$ (approximately 16 times the reference level at 23kHz for general public in the International Commission on Non-ionizing Radiation Protection (ICNIRP) guidelines [4]) at 23kHz is generated for one week. Consequently, maintaining the experimental environment under the same conditions for a long time, i.e., stability in terms of generated MF and temperature in the incubator, and the safety of the system without the presence of the researchers in charge have become problems. Furthermore, from the viewpoint of improving the research efficiency, the exposure space was enlarged to increase the number of Petri dishes simultaneously exposed to a MF; therefore, the uniformity of the MF applied to the Petri dishes was also a problem.

RESULTS

Figure 1 shows the in vitro exposure system. We used a Helmholtz coil considering the improvement of operability in terms of easy placement and removal of Petri dishes in the coil. In this study, it was planned that a total of 16 Petri dishes, i.e., four Petri dishes per tray, could be simultaneously placed in the in vitro exposure system from the viewpoint of experimental efficiency. To maintain the uniformity of the MF applied to the 16 Petri dishes within 5%, a sufficiently large coil diameter was required. However, a sufficient coil diameter could not be ensured because the coil was placed in the incubator. In fact, the results of the measurement of the uniformity of the MF applied to the Petri dishes revealed that the uniformity was not maintained within 5% in the case of the Petri dishes placed on the
bottom tray. Because the uniformity of the MF is a significant factor in the experiment on in vitro biological effects, only the upper three trays were used in the developed system.

We measured the stability of the MF and confirmed that it was stable throughout the experiment. It was also confirmed that the proportion of the harmonic component in the generated MF (Fig. 2) was 1% or less. The temperature stability was also confirmed to be 37.0±0.5°C.

The in vitro exposure system was composed of two units: an exposure system and a sham system. MF leakage of the exposure system was 0.64μT\(_{\text{rms}}\) at 50Hz and 0.02μT\(_{\text{rms}}\) at 23kHz, which were negligible compared with the generated MF.

To ensure the safety of the in vitro exposure system, power shutdown and automated notification systems with temperature sensors were installed.

**CONCLUSIONS**

We developed a MF exposure system for in vitro studies, which enables the generation of a sinusoidal magnetic field of 100μT\(_{\text{rms}}\) (approximately 16 times the reference level at 23kHz for general public in the ICNIRP guidelines [4]) at a frequency of 23kHz for one week.

It was confirmed that the uniformity of the MF in the exposed space containing 12 Petri dishes, i.e., four \(\phi10\)cm Petri dishes per tray with three trays, was maintained within 5%. It was also confirmed that the generation of MFs was stable throughout the one-week experimental period. The temperature around the Petri dishes in the incubator was successfully maintained at 37.0±0.5°C. Furthermore, the level of MF leakage from the exposure system was minimal.

As a result, we consider that our MF exposure system has a sufficiently high accuracy for in vitro studies of IF MFs biological effects.

**REFERENCES**


Relationship Between Duration of Heating and Temperature Threshold in Rat Hippocampal Slices

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INTRODUCTION

Previous studies have shown that changes in electrical responses in rat hippocampal slices in vitro [1] caused by exposure to low intensity radiofrequency (RF) fields are due to localised heating produced by interaction of the RF fields with the recording and stimulating electrodes [2]. This electrode-mediated heating artifact can be used to explore the effects of short pulses of localised heating on neurotransmission in brain tissue [3]. This abstract describes experiments to determine the relationship between duration of heating and the temperature rise required to produce changes in electrophysiological responses in brain slices.

MATERIALS AND METHODS

Porton Wistar rats were anaesthetised with halothane and decapitated; parasagittal slices of brain tissue (300 μm thick) containing the hippocampus were prepared using a Vibratome. The slices were maintained at 32.0 ± 0.1°C and perfused with artificial cerebrospinal fluid in a Haas type interface chamber. Responses were evoked every 30s by constant current pulses (70μs duration) delivered by a concentric bipolar stainless steel stimulating electrode placed in stratum radiatum. Extracellular field potentials were recorded in CA1 stratum pyramidale using glass microelectrodes filled with 2M NaCl. The slices were exposed to 380 MHz RF fields in a parallel plate transmission line [1]. An infrared camera (Cedip Infrared Systems Jade) was used to image the brain slice and the electrodes in order to measure the heating produced during RF exposure. This camera has a theoretical thermal resolution of 0.025°C and each pixel on the sensor corresponded to approximately 200μm at the brain slice target. The acquisition rate was 50 - 1000 frames.s⁻¹. Copper/constantan microthermocouples (Omega Engineering) were also used to record the heating produced during RF exposure.

RESULTS

Exposure to RF fields produced localised tissue heating around the tip of the stimulating electrode [2], which produced a decrease in the amplitude of the evoked field potential response in CA1 (Figure 1). At lower levels of RF exposure (smaller temperature increase), the change in the field potential was reversible, but at higher levels of exposure (greater temperature increase), the decrease in amplitude persisted after the end of the exposure. Shorter durations of exposure required higher intensities of RF (greater temperature increase) to produce the effects. The relationship between duration of heating and threshold temperature increase to produce changes in field potential response is being explored for durations of exposure between 1ms and 10 min.

The possibility of using microthermocouples both to induce the heating artifact and to measure the resulting temperature rise has been investigated. Infrared camera images showed that the RF-induced heating in the tissue slice around the tip of the
microthermocouple was similar to that seen around the tip of the stimulating electrode (Figure 2).

![Figure 1: Reversible (left) and persistent (right) decreases in evoked field potential amplitude produced by RF-induced heating through the stimulating electrode (indicated by the arrows).](image)

![Figure 2: RF-induced heating in tissue around the tip of the stimulating electrode (left) or around the tip of a microthermocouple (right).](image)

**CONCLUSIONS**

RF-induced heating artifacts can be used to characterise the effects of short pulses of localised heating on neurotransmission in brain tissue. The results of this study show that, for shorter durations of heating, higher temperature rises are necessary to produce changes in electrophysiological response. Characterisation of this relationship will help to provide a scientific evidence base for exposure standards for RF pulses.

Microthermocouples can be used both to induce the heating artifact and to measure the temperature rise in the tissue. This offers a lower cost alternative to the infrared camera system, which also has faster time resolution and is not limited to surface measurements.

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**REFERENCES**

INTRODUCTION

Whilst effects of exposure to radio frequency (RF) radiation due to heating are well established, there is continued interest as to whether other, more subtle, effects exist at lower intensities of exposure which may be hazardous to health. In order to address this issue, our laboratory is conducting studies to determine whether RF exposures induce altered genetic responses, such as up or down regulation of gene transcripts, in a human cell model using a range of pulsed signal exposures [1].

This abstract describes the exposure system used for these studies and the methods used for dosimetry. Determination of the specific absorption rate (SAR) by temperature measurement is inaccurate, due to the very small temperature changes involved. Accurate dosimetry therefore requires field strength measurements and numerical modelling.

MATERIALS AND METHODS

The exposure system is designed for an exposure frequency range of 400 MHz to 4.2 GHz. The exposure chamber is situated in an ISO container (3.7 m by 1.4 m by 1.7 m) lined with VHP18 NRL pyramidal RAM. Two incubators are used to keep the cells at 37°C: one of the incubators is housed in an electromagnetically screened box to provide a control non exposed cell group. Signals produced by an Agilent 4432B RF signal generator are amplified by an AR 25SG4A power amplifier (Amplifier Research) and a TWT 1 to 2GHz, 200 Watt power amplifier with a gain of 30 dB (Varian model numberVZI-6943G5) and fed to an AR AT4002A horn antenna. Temperature changes in the cell culture medium are measured using a Luxtron 790 thermoluminescent system. Custom written software (Mathshop, www.mathshop.co.uk) uses the formulae developed by Chou et al. [2] to calculate specific absorption rate (SAR) from these measurements. The software can use moving average or box average data to plot the temperature in real time. Additionally, the pre-exposure measurement time can be set to a slope of zero if desired.

A D-dot sensor (Prodyn AD-70 along with a Prodyn BIB-100G balun) is used to measure the electric field present in the chamber during the setup phase and during the exposure experiments. The D-dot sensor used is a differential probe: the balun combines both the positive and negative outputs from the sensor to one TX line that is connected to an Oscilloscope (Tektronix DPO7254) via fibre optic link (Point2Point). This configuration requires integration of the recorded output of the sensor before the data can be fed into the formula to produce the field strength:

\[ V_o = R \ A_{eq} \ \frac{d\phi}{dt} \]  \hspace{1cm} (3)

Where \( V_o \) is the output voltage, \( R \) is the impedance of the probe, \( A_{eq} \) is the equivalent area.
of the probe and D is the magnitude of the electrical displacement.

RESULTS

The temperature rises measured during exposure to RF fields (1.6 GHz, 550ns pulse width, pulse repetition rate 909 kHz, amplifier power output 200 Watts) were very small and therefore difficult to measure with the stated accuracy of 0.5°C for the Luxtron 790. Estimated rates of temperature rise were between 0.0001 to 0.0007°C s⁻¹. Even taking multiple measurements to provide a large number of data points and repeating the measurements with a number of runs could not provide a reasonable estimation of the actual SAR value, which ranged from 0.32 to 2.71 W kg⁻¹ for these temperature rises.

Measurements of E field intensity, in contrast, were consistent between similar exposures: the exposure produced a peak field strength of 315 V m⁻¹ in the incubator. Using a standard power calculation with the assumption that the impedance is 377 ohms, this represents a peak power of 263 W m⁻², and an average power of 132 W m⁻². These values can now be incorporated into numerical models of the exposure system.

CONCLUSIONS

These results demonstrate that the temperature rises induced by these exposures are much too small to allow accurate determination of SAR. Dosimetry must therefore be based on field strength measurements during exposure, supported by numerical modelling of the exposure system to provide estimates of SAR (in progress at Queen Mary University of London). Measurements with the Luxtron 790 SAR demonstrate that there is very little heating due to the RF exposure in these experiments. These measurements are also essential to determine whether the RF fields interfere with the thermostatic control of the incubators used to maintain a constant temperature in the cell cultures.

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REFERENCES

This abstract describes an exposure system used in studies on human T lymphocytes with pulsed RF and the methods used for dosimetry. Determination of the specific absorption rate (SAR) by temperature measurement is inaccurate, due to the very small temperature changes involved. Accurate dosimetry therefore requires field strength measurements and numerical modelling.
INTRODUCTION

The large exposure of the world population to cellular phones has led to a growing concern in the public about their health effects – mainly cancer. One of the hallmarks of cancer is the loss of control of the replication machinery in the cell leading to genomic instability through epigenetic mechanisms as evidenced by changes in replication timing. Replication of the genetic material needs to occur under a very tightly controlled temporal schedule, where each section has a specific time domain during the s-phase of the cell cycle at which it replicates. Replication timing is closely linked to the activity status (transcribed or not) of the DNA sequence in the tissue studied, where expressed sequences replicate early while unexpressed sequences replicate late [1].

MATERIALS AND METHODS

We exposed peripheral blood cells (PBLs) from young male volunteers to CW 800MHz radiation at SAR values of 2.9 and 4.1 W/kg. The exposure system was previously described in details [2]. We lowered the temperature of the incubator containing the exposure set up to 33.5°C in order to compensate for the increased temperature during exposure. We also determined the dependence of the replication timing and synchrony on temperature by culturing PBLs obtained from four donors at different temperatures in the range of 33.5–40°C for 72 h.

Peripheral blood cells from 10 male volunteers were exposed for the whole 72 hours of culturing and then harvested according to standard cytogenetic procedure. The mean age of the volunteers was 30.0±5.5 (23-39). In addition, we set up 5 independent exposure experiments (mean age 30.2±3.1 (28-33)) in which cells were exposed for 24 hours, cultured for 72 and harvested according to standard cytogenetic procedure. While series one (I) was exposed for the first 24 hours of culturing; series two (II) was exposed during the middle of the culturing period and series three (III) was exposed for the final 24 hours of culturing.

We used FISH for the centromeres (CEN) of chromosomes 11 and 17 to analyze changes in replication timing using the FISH replication assay. Manual analysis of about 600 interphase nuclei was performed on the automatically acquired FISH image galleries using the Metacyte image analysis system by coding as to their replication status according to the signal shapes. In the FISH replication analysis the signals are designated as belonging to one of four replication stages [3,4] in accordance with their progression through the cell cycle.

As there is inter individual variation in the level of asynchronous replication, we looked at the folds of induction of the effect and used the one sample t-test for analysis.

RESULTS

Our results (Fig 1) indicate that there is a statistically significant effect on the level of asynchronous replication in both chromosomes following 72 hr exposure to the higher SAR level of 4.1W/kg (p=0.014 and 0.027 for CEN 11 and 17, respectively). The centromere of chromosome 11 was more sensitive to the radiation and exhibited increased asynchronous replication even at the lower SAR level of 2.9W/kg (p=0.012).
Following 24 hrs of exposure (Fig. 1), no increased asynchronous replication was induced by the lower SAR (2.9W/kg) for either chromosome 11 or 17 at either of the three exposure periods. However, at the higher exposure level (4.1W/kg) we observed increased levels of asynchronous replication for centromeres 11 and 17 following exposure during period II (p=0.03 and 0.014, respectively) and III (p=0.02 and 0.014, respectively).

We found no statistically significant differences in the replication timing between cells incubated at 33.5°C, 37°C and 38.5°C. However, incubation at 40°C led to a significant increase in the level of asynchronous replication.

CONCLUSIONS

The present study suggests the existence of genetic instability, reflected by increased levels of asynchronous replication of centromeric loci in lymphocytes due to in vitro exposure to CW 800MHz radiation. These epigenetic changes are accompanied by genetic ones as reflected by previously observed increased aneuploidy of the same two chromosomes following identical exposure conditions for 72 hours [2]. Furthermore, the study suggests the possible existence of an athermal effect of RF radiation leading to increased genomic instability.

REFERENCES


Microwave Irradiation Effect On Peroxidase Activity Of Cytochrome c

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Apoptosis, a programmed cell death, plays an essential role in embryonic development, tissue homeostasis and various pathological conditions including inflammation and ischemia. Cytochrome c-driven cardiolipin (CL) oxidation in mitochondria membrane appears to be one of the key events at the initial stage of mitochondria-dependent apoptosis. Here, by using model system of cytochrome c (cyt c) and phospholipid membranes we demonstrated that microwave irradiation can stimulate cyt c-dependent oxidation of substrates in the water and membranes. Our results suggest that microwave irradiation may elevate sensitivity of cells to apoptotic stimuli.

INTRODUCTION

In the last decade it became apparent that mitochondria often play a central role in apoptosis. On one hand, mitochondria supply machinery involved in apoptosis with required energy; on the other hand, this organelle can produce reactive oxygen species (ROS), which participates in apoptosis development, and can release pro-apoptotic proteins, which directly initiate programmed cell death [1].

Mitochondrial protein cytochrome c can form complex with cardiolipin, a unique mitochondrial phospholipid. In this complex, cyt c turns from a mitochondrial electron carrier into a peroxidase which can oxidize small reducing substrates, protein tyrosines and CL itself. Hydrogen peroxide (H₂O₂), a reactive oxygen species, is a co-substrate and initiator of this catalytic oxidation. Accumulation of cardiolipin hydroperoxide induces detachment of cyt c from the membrane and stimulates mitochondrial outer membrane permeabilization [2]. These events lead to the release of pro-apoptotic proteins including cyt c from mitochondria into cytosole and to the induction of apoptotic program.

Microwave irradiation has been shown to affect various biological processes even at relatively low irradiation power. In particular, EHF irradiation can increase conformational flexibility of proteins, stimulate enzymatic activity, induce lipid peroxidation and affect cell proliferation [3-6]. However, mechanisms of biological and therapeutic effects of microwave irradiation remain poorly understood.

Here, we hypothesized that microwave irradiation may stimulate peroxidase activity of cyt c by increasing interface convection in water and by affecting protein conformational stability [3-5]. Later effect may stimulate binding of the protein to a membrane and increase accessibility of heme to substrates, while former process can hasten chemical reactions at the membrane interface. Thus, in addition to well recognized thermal effect, microwave irradiation can induce specific convectional and conformational effects on membrane-bound catalyst, and hence, significantly alter the course of the reaction.
MATERIALS AND METHODS

Gunn diode tuned to 39 GHz has been used as a source of EHF irradiation. Electromagnetic waveguide (section of 7.2x3.4 mm²) was designed to control an output in (0.1-10 mW/cm²) and irradiation frequency. Samples in the volume of 50 µl were irradiated in the quartz cuvette in the immediate vicinity of the waveguide horn for 10 min. Temperature in the samples was measured by using microthermodetector MT-4MO (Russia).

SUV were prepared from phosphatidylcholine (PC) and PC/CL (1:1). Membrane-bound horse heart cyt c was prepared by incubating purified protein with CL-containing SUV at protein/lipid molar ratio of 1:100 and 1:500 in Tris buffer (10 mM, pH 7.0).

Cyt c-catalyzed oxidation of Amplex red (AR) was determined on Hitachi F-2500 spectrofluorophotometer (Japan) using an excitation/emission wavelengths of 550/584 nm. C11-BODIPY oxidation was estimated by using excitation/emission wavelengths of 575 nm and 595 nm respectively for its reduced form and an excitation wavelength of 505 nm and an emission wavelength of 522 nm and 550 nm for the oxidized form.

RESULTS

We prepared membrane-bound and membrane free (globular) cyt c and analyzed peroxidase activity of cyt c in different states by using fluorescence probes. Nonfluorescent hydrophilic molecule AR is converted into fluorescent resorufin upon oxidation. We observed cyt c-dependent oxidation of AR in the presence of H₂O₂. EHF irradiation enhanced rate and yield of AR oxidation by cyt c in a dose dependent manner. At highest output of 10 mW/cm², the magnitude of the effect was ~40%.

C11-BODIPY is a hydrophobic ratio probe for lipid peroxidation. We found that it was efficiently oxidized in the presence of H₂O₂ by membrane-bound cyt c, while free cyt c was at least 40 times less effective. EHF irradiation enhanced C11-BODIPY oxidation by membrane-bound cyt c by 20%. An investigation of microwave irradiation effect on the programmed cell death induced by various stimuli is in progress in our lab.

CONCLUSIONS

We conclude that EHF irradiation at frequency of 39 GHz does not facilitate cyt c binding to membranes lacking CL. However, this irradiation can enhance oxidation of hydrophilic substrates by cyt c and may promote phospholipid oxidation by its membrane-bound form and, thus, may affect cell death pathways.

ACKNOWLEDGMENTS

REFERENCES

INTRODUCTION

Finland has an act giving recommendations on the exposure of the general public to electric and magnetic fields at the frequency range below 100 kHz [1]. This act is based on the recommendation (1999/519/EC) of the Council of the European Union [2]. The recommended reference levels of public exposure to electric and magnetic fields are 5 kV/m and 100 µT respectively [2]. Electric fields are of more significance than magnetic fields when we compare actual exposure to transmission lines to the reference level. Tampere University of Technology (TUT) has been studying the exposure of general public to electric and magnetic fields for several years.

The main aim of our project was to investigate exposure to electric and magnetic fields near 110 kV transmission lines in Tampere region. The measurements were planned so as to reflect the perspective of a person walking on the ground under the transmission lines.

MATERIALS AND METHODS

In this study measurements were made at 10 tower spans near 110 kV transmission lines. The measuring spans were selected based on how accessible they were for the measurement team. Measurement spans were not specifically selected for any expected high exposure values. Figure 1 shows the measurement points. We were not able to make any measurements at some spans as the transmission line was near a road or a building. Measurements were made at the height of 1 m above the ground and the meter used was a 3-axis EFA-3 meter (accuracy ±5%, RMS for electric field, ±8%, RMS for magnetic field).

RESULTS

Figure 2 shows both the electric and magnetic fields from portal towers. Figure 3 shows...
the corresponding results with triangular towers. The maximum measured electric field values were between 0.5 – 2.3 kV/m and for magnetic fields 0.6 - 6.0 µT. The mean value of maximum values ± standard deviation (SD) was 0.98 ± 0.56 kV/m and 2.98 ± 1.63 µT.

Figure 2: Measured electric field strengths (left) and magnetic flux densities (right) at portal towers (M refers to a performed measurement)

Figure 3: Measured electric field strengths (left) and magnetic flux densities (right) at triangular towers (M refers to a performed measurement)

DISCUSSION AND CONCLUSION

Measured values are clearly below the reference levels of 5 kV/m and 100µT. This was expected, considering the results from the previous measurements made near 400 kV transmission lines. Figure 2 shows results only from one side of the line. Maximum electric field value (2.3 kV/m) of all measurements was biased by the presence of 400 kV transmission line near the 110 kV line (M8). Excluding the M8 maximum value, second highest electric field value was 1.7 kV/m. In addition vegetation affected electric field measurements. The results are not fully comprehensive as the measurements were not made in entire Finland but in Tampere region only. In the actual measurement conditions roads and buildings quite often make it impossible to make any measurements farther away from the transmission line’s center line. Consequently those values are not present in the comparison of the results.

REFERENCES


Magnetic Field Exposure of 110 kV Underground Power Cables
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INTRODUCTION
Tampere University of Technology have previously studied the exposure for 20 kV cables and 400 kV power lines, but 110 kV cables haven’t been studied much before. When building new power lines, in some situations cables are considered as an alternative. Technically cables and transmission lines differ, although cable can be loaded as much as transmission lines. Finland has an act giving recommendations on the public exposure EMF at the frequency range below 100 kHz [1]. This act is based on the recommendation (1999/519/EC) of the Council of the European Union [2]. Reference level of public exposure to magnetic field is 100 µT [2]. The main aim of our project was to investigate public exposure to magnetic fields of 110 kV underground power cables.

MATERIALS AND METHODS
Measurement places were chosen by calling different electric utilities and asking how high currents were in their 110 kV cables. Cable routes from service areas of two utilities were chosen. Another factor that affected the selection was if the location was near Tampere. Measurements were made at six cable routes. Measurements were made for both sides of the cable route. At one of the cable routes were also investigated how the presence of 20 kV cable affects the results when it is near the 110 kV cable (measurements MP6 and MP7). Measurement MP4 also had another 110 kV cable near it which can be seen in the results. Measurement points were placed every 0.5 m, last point 5 m away from the cable. Current values were asked from the monitoring room in the beginning and the end of the measurements. The magnetic flux density was measured with a 3-axis EFA-3 meter (accuracy ±8%, RMS) and HIOKI-3470 meter (accuracy ±4%, RMS).

RESULTS
Table 1 shows summary of measurements. Maximum values at the height of 1 m from the ground was 1.7 µT and on ground surface 5.0 µT. Figure 1 shows measured magnetic flux densities at ground level and 1 m above the ground. Figure 2 shows magnetic flux densities from measurements MP6, where in the same channel was 20 kV cable (reversed current) along with 110 kV cable, and MP7 110 kV cable was alone (no 20 kV, figure 2).

Table 1: Summary of the measured underground power cables. (IB(RMS), IE(RMS), I(B(RMS), I(E(RMS)), IB(max), IE(max) are current beginning of measurement and current end of measurement. On parenthesis is percentage from theoretically maximum current (I(max)).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Meter</th>
<th>Bmax(0 m), µT</th>
<th>Bmax(1 m), µT</th>
<th>IB(RMS), A</th>
<th>IE(RMS), A</th>
<th>I(max), A</th>
</tr>
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<tr>
<td>MP1</td>
<td>EFA-3</td>
<td>1.9</td>
<td>0.7</td>
<td>134.0 (17.2%)</td>
<td>154.0 (19.7%)</td>
<td>780.0</td>
</tr>
<tr>
<td>MP2</td>
<td>EFA-3</td>
<td>0.7</td>
<td>0.2</td>
<td>43.0 (6.4%)</td>
<td>40.0 (6.0%)</td>
<td>670.0</td>
</tr>
<tr>
<td>MP3</td>
<td>HIOKI-3470</td>
<td>5.0</td>
<td>1.7</td>
<td>229.8 (34.3%)</td>
<td>229.8 (34.3%)</td>
<td>670.0</td>
</tr>
<tr>
<td>MP4</td>
<td>EFA-3</td>
<td>4.2</td>
<td>1.1</td>
<td>161.0 (24.0%)</td>
<td>161.0 (24.0%)</td>
<td>670.0</td>
</tr>
<tr>
<td>MP5</td>
<td>EFA-3</td>
<td>3.6</td>
<td>1.3</td>
<td>180.7 (27.0%)</td>
<td>180.2 (26.9%)</td>
<td>670.0</td>
</tr>
<tr>
<td>MP6</td>
<td>EFA-3</td>
<td>0.3</td>
<td>0.2</td>
<td>61.0 (9.1%)</td>
<td>61.0 (9.1%)</td>
<td>670.0</td>
</tr>
<tr>
<td>MP7</td>
<td>EFA-3</td>
<td>1.0</td>
<td>0.3</td>
<td>97.0 (14.5%)</td>
<td>92.0 (13.7%)</td>
<td>670.0</td>
</tr>
</tbody>
</table>
DISCUSSION AND CONCLUSION

Results are below the reference level 100 µT (1999/519/EC). Because there were so few measurements made, inclusive conclusions cannot be made from the results. Cables usually cause higher magnetic field maximum values than transmission lines with the same current, but the area of magnetic field exposure is significantly narrower than with transmission lines. Higher flux density is due to the closer proximity of cables to people compared to that of transmission lines. In cables the phase conductors are relatively near each other, causing the narrow exposure cone. When measurements are made farther than within the diameter of the whole installation, the measured magnetic flux density values decrease with the growing distance from the phase conductor bundle. Because the current values are quite small, that leads to small values for the magnetic field as well. However the results show that cables cause exposure to magnetic fields, so if transmission line is replaced by a cable, the magnetic field will not disappear and the exposure to it will remain and is usually even higher than in the case of transmission lines.

REFERENCES


Inténtación y seguridad ocupacional en el contacto con campos magnéticos estáticos de los escáneres de RM - estudio entre la población de trabajadores en Polonia

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INTRODUCCIÓN

La técnica de resonancia magnética requiere que los sujetos examinados sean expuestos a campos magnéticos estáticos y variables de campo electromagnético (EMF). Los exámenes de resonancia magnética están relacionados con un nivel relativamente alto de exposición a campos magnéticos estáticos (SMF) de los trabajadores de atención médica antes/after el examen. Solo un pequeño número de exámenes, significativamente menos del 1%, necesitan también el contacto del trabajador con los componentes variables del sistema de EMF emitido. 

Hay todavía muchos vacíos en el conocimiento sobre los efectos biológicos y de salud y los mecanismos de interacción de los campos electromagnéticos emitidos con los tejidos y el cuerpo humano [1, 2]. El análisis de la salud de la organización de la OMS sobre SMF [3] presentó la revisión de los espacios en el conocimiento sobre los efectos posibles de la salud y concluyó que, el trabajo realizado hasta la fecha no ha sido sistemático y a menudo se ha realizado sin la metodología adecuada y la información sobre la exposición.

MATERIALS AND METHODS

El estudio se centra en la identificación y caracterización de los escáneres de resonancia magnética en Polonia, así como los patrones de actividades de los trabajadores, así como la investigación del nivel de exposición personal de los trabajadores seleccionados. El objetivo del estudio es cubrir un 50% de los centros clínicos de resonancia magnética mediante la investigación del nivel de exposición personal de los trabajadores seleccionados.

El patrón de la exposición personal a SMF de los trabajadores seleccionados se registra mediante un monitor de pánico con un registro de datos. Este protocolo permite registrar la exposición durante las actividades normales mientras los trabajadores atienden a los pacientes examinados. Las exposiciones registradas se analizan a través de parámetros estadísticos, con atención al tipo de escáner de resonancia magnética, las características del trabajador (por ejemplo, género, altura, experiencia con el funcionamiento del escáner de resonancia magnética) y el tipo de examen del paciente (por ejemplo, examen de cuello o abdomen) y el estado de salud del paciente (relacionado, por ejemplo, con la duración de la asistencia cercana al bastidor del magnet para ese paciente).

RESULTADOS

Se identificaron más de 100 centros médicos activos en el uso clínico de la resonancia magnética. Se utilizan diversos tipos de escáneres de resonancia magnética de SMF de 0.2-3T, con 50% de 1.5T. El número de escáneres sigue aumentando, con un número creciente de magnet de campos más altos. SMF del magnet determinan el poder diagnóstico de un escáner, pero el nivel de exposición personal del trabajador no está correlacionado con este parámetro.

En el interior del local de la resonancia magnética, la exposición más alta del personal de atención médica (enfermeras, técnicos, radiólogos) ocurre en la proximidad inmediata de la casa del magnet, con SMF de una heterogeneidad espacial significativa [4]. Como consecuencia, se puede encontrar una variabilidad significativa del nivel de exposición personal durante la asistencia de un paciente (Fig. 1). El nivel de exposición personal del trabajador varía entre los centros médicos, los tipos de exámenes y entre los individuos en el mismo centro (Fig. 2). Los resultados de la campaña de medidas serán presentados.
CONCLUSIONS

The work presents new method of assessment of personal exposure to SMF among MRI workers, which can be useful to improve the quality of epidemiological study focused on health effects of occupational exposure among MRI workers, as well as routine exposure assessment for the purpose of occupational environment inspection. Obtained results from personal monitoring present significant variability of exposure level among workers population. The results of monitoring and method of personal monitoring of exposure pattern can be also useful for training MRI workers on how to avoid unnecessary exposure or to test working conditions among various types of MRI scanners to identify the most "worker's friendly" devices.

![Fig. 1. Example of pattern of health care worker's personal exposure to SMF during attendance of to the patient preparing to the spinal cord MRI examination in 1.5T MRI scanner (registration of exposure at the torso surface)](image1.png)

![Fig. 2. Example of workers' exposure while attendance to patients before examination in various MRI scanners of 1.5T (A, B, C) - registration of personal exposure level of 2 workers per scanner (worker 1 & 2)](image2.png)

ACKNOWLEDGMENTS

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REFERENCES


Electromagnetic Field Measurement Campaign in Urban Environment for Risk Assessment Of ELF And RF Exposure Of Children And Teenagers

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INTRODUCTION

Population exposure to electromagnetic (em) fields is a great scientific interest issue, for which a proper assessment is decisive for a correct awareness and risk perception. In this work we show the results of a ELF and RF radiation levels monitoring into or close to schools in some towns near Naples (Italy) with a high density of both population and electromagnetic sources. The aim is to evaluate the extended (>4h) exposure of children and teenagers that have a longer lifetime of exposure than adults and thus there is a great concern about unhealthy effects of non ionizing radiation on their developing nervous system [1].

MATERIALS AND METHODS

A campaign of broad band measurements of the background levels of both ELF and RF radiation has been carried out in more than 150 schools (outdoor and indoor measurements) in several towns of the province of Naples. Wide-band probes can satisfy the basic requirement for the monitoring campaign, that is, verifying the respect of the exposure limits over the whole frequency band. The equipment was made of radiation monitors, a tripod and a GPS receiver. For RF measurements basic broad band instrumentation comprised Wandel & Goltermann EMR-30 meter connected to the isotropic electric field probe Wandel & Goltermann type 8.2 (100KHz-3GHz). For ELF measurements Narda EFA 300 meter, connected to either magnetic or electric field probe (5 Hz – 32 kHz), was used. The Italian regulator adopted a more precautionary stance than most other governments concerning em field population exposure, abiding by the prudent avoidance principle; the Actuation Decrees (DPCM 8th July 2003) establish a multi-level protection: for mobile phone frequency range the limit of 20 V/m (1 W/m²) is adopted for the protection against acute health effects, while, for continuous sojourn for more than 4 hours, an attention threshold of 6 V/m (0.1 W/m²) is defined in order to take into account long-term effects. Similarly for the ELF field, the exposure limits are 5 kV/m and 100 μT, while the attention threshold is suggested only for the magnetic induction (10 μT) and a quality target of 3 μT is set if new infrastructures are installed. Measurements were performed following the procedure indicated by the Italian Electrical Committee [2] and results are reported adopting as reference the attention thresholds and the quality targets, then they are compared with the power density and magnetic induction that are tipically found in other european countries [1].

RESULTS

The objective of the project was to promote the monitoring activity in order to verify the respect of the exposure limits and give a widespread dissemination of the results, being known that where there is a good and well-distributed measurement campaign, citizens tend to have a minor risk perception and to be more confident in the actions carried out by the
administration in the em fields problem management [3]. The project started in December 2007 and data collection ended in January 2009; measurements were performed in towns with a high density of population (reaching 12,000 citizens/km²), during the morning (when the call traffic is higher), and overall in sensitive aerea (hospitals, public park, schools) with a particular attention to schools (Fig.1) in order to estimate the em field background of children and adolescents exposures. The results are reported in the histograms of Fig.2: they indicate that, respectively for RF and ELF measurements, 52% of samples is in the range 1mW/m²-2.6mW/m² (corresponding to 0.6V/m-1V/m), and below 0.1μT, while over 90% is below 24mW/m² (3V/m) and below 3μT.

**CONCLUSIONS**

Due to the concerns about the potential vulnerability of children to electromagnetic fields (they have a longer lifetime of exposure than adults, at RF their brain tissue is more conductive than that of adults due to the higher water content and ions concentration) an evaluation of background em field levels in schools has been performed. Results indicate that they are well below the quality target and, despite of high density of em sources, they are in good agreement with results found in other European countries [1].

**ACKNOWLEDGMENTS**

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**REFERENCES**

Numerical Estimations on Implantable Cardiac Pacemaker EMI due to mobile-radio in Elevator using Inhomogeneous Human Phantom Models

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2National Institute of Information and Communications Technology, Tokyo, Japan
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INTRODUCTION

The purpose of this study is to investigate the possible effect of cellular phones' signals on implantable cardiac pacemakers in elevators. Previously, we investigated it through the examination of the electromagnetic field (EMF) distribution inside elevator [1]. In this paper, in order to implement more detailed estimation, we carried out precise numerical simulations using inhomogeneous numerical human phantom models [2, 3] and examined the electric field strength inside the area of the human body in which pacemakers are implanted. The computed results of field strengths were compared with a certain reference level determined from the experimentally obtained maximum interference distance of implantable cardiac pacemakers.

METHODS

By using the FDTD method, the electromagnetic fields inside the elevator with cellular users were precisely calculated. An example of a 3-D representation of the numerical model is shown in Figure 1. This is a case in which one user is present in the elevator. High resolution anatomical human phantom models for Japanese and European adult males were used [2, 3] in this paper. The details of the FDTD analysis configurations are summarized in Table 1. A half-wavelength dipole antenna was used to represent a cellular radio and the antenna was set at 20 mm apart from the phantom’s head.

In order to estimate the EMI risks for implantable cardiac pacemakers, the E-field strength distributions in a certain area that was near the collar-bone where the pacemaker was implanted inside the body were extracted. The volume of the evaluation area became about 500 cm³ (3998 cells). The field strengths were also compared with the reference values obtained from the EMF strength at the maximum interference distance [4]. The maximum interference distances at which dipole antennas should be placed from cardiac pacemakers have been determined experimentally for each frequency band. Using these distances, the reference values were also calculated by FDTD analysis using pacemaker and torso phantom models [5]. By comparison with the reference value, an indication of the likelihood of occurrence of a pacemaker malfunction at that particular frequency was obtained.

RESULTS

Figure 2 shows an example of the 2-dimensional EMF distribution when 1 user (European adult male) was located in the center of the elevator. Also, Figure 3 shows an example of the EMI estimation results for 1 user, when the user position was in the center of the elevator and
in the corner of the elevator. In these cases, the averaged E-field values shown as histograms are about 10 dB higher than the free-space value. However, those are about 30 dB lower than the reference value for pacemaker EMI risks.

CONCLUSIONS
From our study using precise numerical analysis and the anatomical human phantom models, the E-field strength that might cause pacemaker malfunctions were not obtained in the elevator.

ACKNOWLEDGMENTS
This study was partially supported by the Electromagnetic Environment Committee of ARIB JAPAN.

REFERENCES

<table>
<thead>
<tr>
<th>Table 1: Computation parameters</th>
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<tr>
<td>Cell size (cubic)</td>
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<tr>
<td>Total problem space</td>
</tr>
<tr>
<td>Absorbing B. C.</td>
</tr>
<tr>
<td>Frequency</td>
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<tr>
<td>Elevator model</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Human phantom model [2,3]</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Required memory</td>
</tr>
<tr>
<td>Cellular radio</td>
</tr>
</tbody>
</table>

Figure 1: Numerical model of the elevator including human phantom model.

Figure 2: Example of E-field distribution inside the elevator with 1 user (2100 MHz).

Figure 3: Variation in $|E|$ field strength of the extracted area as the position of the user changes.
Measuring Exposure to Electric and Magnetic Fields at 110 kV substations in Tampere Region

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INTRODUCTION

Tampere University of Technology (TUT) has been studying public and occupational exposures to electromagnetic fields for several years. The European Parliament and the Council directive 2004/40/EC on the minimum health and safety requirements, regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) was published in the European Union on April 30, 2004. The Directive’s action values at 50 Hz are 10 kV/m for electric fields and 500 µT for magnetic flux density [1]. Previous studies at TUT concerning 400 kV substations show that 75 % of the measured eight substations had field strengths (max. 12.4 kV/m) that locally exceeded action values [2]. However, the limit value was not exceeded [3].

The main aim of our project was to investigate exposure to electric and magnetic fields at 110 kV substations. The measurements were designed from the perspective of a person walking on the ground of a substation.

MATERIALS AND METHODS

Five outdoor substations were selected based on their highest expected electric field exposure in Tampere region. Two of the substations were selected for closer inspection to get a clear overview of the exposure. In these substations the measurers selected a rectangle area of 75 m x 30 m in substation 1 and a 85 m x 25 m area in substation 2. Measurement points were placed evenly 5 m apart from each other, forming a grid in the area. At the point where the highest field was measured, more precise measurements were made in an area of 10 m x 10 m, with measurement points 1 m apart. The measurements were made at the height of 1 m from the ground. Another measurements were made inside the precise measurement area from a smaller area (3 m x 3 m) at the height of 1.7 m above the ground. The electric field strength was measured with a 3-axis Wandel&Goltermann’s EFA-3 meter (accuracy ±5%, RMS). Magnetic flux density was measured from the same points with a HIOKI-3470 magnetic field tester (accuracy ±4%, RMS). In the three other stations measurements were made at single points of the substation areas. The measurement points were located in positions where people walk and perform operations at substations. At these substations, electric field strength was measured with an EFA-3 meter, and magnetic field density with Narda ELT-400 meter (accuracy ±4% RMS).

RESULTS

Table 1 shows a summary of all the measurements. Figure 1 shows the cross-sections of the highest electric field strengths at substations 1 and 2. Electric field values in the figures are in kV/m. The highest electric field strength value in measurements was 4.5 kV/m and the highest magnetic flux density value was 23.4 µT.
Table 1: Summary of measured substations

<table>
<thead>
<tr>
<th>Substation</th>
<th>Date</th>
<th>Height, m</th>
<th>Meters</th>
<th>$E_{\text{max}}$, kV/m</th>
<th>$B_{\text{max}}$, $\mu$T</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>19.6.2008</td>
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<td>H</td>
<td>-</td>
<td>23.4</td>
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<tr>
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<td>EF</td>
<td>4.5</td>
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<tr>
<td>2</td>
<td>12.8.2008</td>
<td>1.0</td>
<td>H+EF</td>
<td>4.0</td>
<td>6.8</td>
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<tr>
<td>3</td>
<td>8.7.2008</td>
<td>1.5</td>
<td>EL+EF</td>
<td>1.4</td>
<td>8.6</td>
</tr>
<tr>
<td>4</td>
<td>8.7.2008</td>
<td>1.7</td>
<td>EL+EF</td>
<td>1.5</td>
<td>2.6</td>
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<tr>
<td>5</td>
<td>8.7.2008</td>
<td>1.7</td>
<td>EL+EF</td>
<td>4.1</td>
<td>7.0</td>
</tr>
</tbody>
</table>

1 H is HIOKI-3470, EF is EFA-3, EL is ELT-400

Figure 1: Electric fields (kV/m) cross-sections of substation 1 on the left and those of substation 2 on the right. Black lines describes busbars, white dots are circuit breakers and white dots with K are disconnectors.

DISCUSSION AND CONCLUSION

The measured values at substations are lower than the directive’s action values 10 kV/m and 500 $\mu$T. When analysing the results it should be noted that the measurements were only made at the height of 1 m and 1.7 m from the ground, these representing exposure in tasks at the ground level. The measurements do not give any information about exposure in tasks that require climbing onto a stand, for example. As for public exposure in substations, people other than staff can be exposed when visiting a substation, e.g. students on guided tours. Normally substations are restricted, fenced areas. When considering exposure to electric fields at substations, only outdoor substations are of significance as gas insulated substations (GIS) are enclosed and the structure reduces the electric field.

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ELF Magnetic Field Exposure During An Inner-City Hybridbus Ride

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INTRODUCTION

Hybrid drive systems are future key technologies not only for personal vehicle but also for public transportation means. Recently a few manufacturers have made available hybrid buses which are already in operation at several public transportation services. Current hybrid drive systems, utilize one or two inverter-fed electric machines working either as motor (to provide drive power), and/or generator (to transform mechanical power from the combustion engine or from braking-recupereation to electric power). Consequently, relatively high electric currents are flowing between the main components of the system, i.e. battery, inverter, and motor(s)/generator(s), which may be seen as potential sources of significant magnetic field exposure of the passengers. In order to assess the extent of magnetic field exposure inside such a vehicle magnetic field measurements during an urban bus ride were carried out and the results are compared to magnetic field exposure during typical train journeys.

MATERIALS AND METHODS

The investigated hybrid bus was the “Urbino18 Hybrid” (Solaris Bus & Coach S.A., Poland) which is already routinely operated by the public transportation service BOGESTRA (Bochum, Germany). Its hybrid system consists of two inverter-fed electric motors/generators 75 kW each and a battery located on the top of the bus cassis. Inside the bus 4 different passenger’s locations were considered for the measurements and 5 different spatially distributed measurement points were defined (feet, lower legs, upper legs, thorax, head) investigated in each location. Frequency selective magnetic field measurements in the range DC-100 kHz were carried in all mentioned measurement point during repeatedly riding a defined urban round-trip including all possible operating conditions of the bus. The measurements were done using the 3 channel (isotropic) analog outputs of the ELT400 system (Narda Safety Test Solution) and the magnetic field meter CA42/ field probe MF05 (Chauvin Arnoux). These, in total 6 analog signals were A/D converted and recorded at a sample rate of 200 kHz using an in-house measurement system based on the PXI system (National Instruments, Inc.) and a corresponding Labview™ user interface. Recording length in each measurement point was 1s during constant and repetition rate of the measurements was approximately 3 seconds. Postprocessing (FFT) and final rating of the recorded measurement data according to the ICNIRP reference levels [1] was done using an in-house developed software tool based on Labview™, which allows a phase-correct combination of multiple spectral components of exposure as described in [2].

For comparison additional, magnetic field measurements were also carried out during a typical train journey in Austria (train line voltage 15 kV, 16,67 Hz). For determining the position and the relative speed of the train a GPS data logger (Holux M-241) was used.
RESULTS

Figure 1 shows preliminary time averages of magnetic field exposure in the considered measurement points as percentage of the ICNIRP general public reference level. Error bars indicate the range of exposure. The final (extended and complete) set of results will be presented at the conference.

For comparison purposes the magnetic field in an electric train (15kV, 16.67 Hz) on a journey from Vienna (210m sea level) to Semmering (896m sea level) was measured.

CONCLUSIONS

In all considered situations and locations the measured field values were clearly below the corresponding ICNIRP general public limits.

ACKNOWLEDGMENTS

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Mobile Phone-Related Studies: Scientific Contents, Overviews, and Interactive Navigation

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INTRODUCTION

Within the framework of the internationally established internet information platform EMF-Portal (www.emf-portal.org), scientific studies on the effects of electromagnetic fields are continuously collected on a day-to-day basis and their individual contents systematically summarized by descriptors. The aim of this work was to develop an interactive structure for all mobile phone-related studies that easily guides the user through this huge amount of data to the topic of interest. Mobile phone-related articles are defined as articles with mobile phone exposure, i.e. studies dealing with all frequencies within the frequency range of mobile phones (800 MHz - 2000 MHz), and where the authors explicitly stated their intention to investigate the effects of mobile phone-related frequencies.

MATERIALS AND METHODS

All experimental medical or biological publications are categorized according to their endpoints, for example, blood-brain barrier, cognition, cancer, genotoxicity, hypersensitivity, etc.

Furthermore, comprehensive summaries are performed according to a standardized protocol (including aim of study, endpoints, exposure data, methods, results, etc.); thus, different studies are easily comparable. Currently, all recent studies of the mobile phone-related frequency range are summarized that way.

RESULTS

Based on approximately 500 currently available experimental medical or biological mobile phone-related studies an upper-level structure was created to present studies with similar endpoints and to easily enable the user to navigate through this enormous base of compendia (figure 1, www.emf-portal.org/overview.php). By clicking on a specific segment of the interactive graphics the user is intuitively guided to the chosen endpoint where all appropriate publications are listed, a synoptical table is offered, and for some endpoints further information is clarified (e.g. genotoxicity). If interested to see further details of a particular study the user just has to click on the author’s name and he is guided to the summary.
Mobile-phone related experimental studies of the broader category 'medical/biological'

This is an overview of all mobile-phone related experimental studies of the broader category 'medical/biological' (n=442 as of 01/28/2009).

Mobile-phone related articles are:
- studies with mobile phone exposure, i.e. studies dealing with all frequencies within the frequency range of mobile phones (800 MHz - 2000 MHz) and
- studies that were explicitly designed to investigate the effects of mobile phone-related frequencies.

CONCLUSIONS

The graphical reporting system is designed to summarize biological endpoints topics for the user using pie charts. This format dynamically communicates the prevalence of each endpoint in the article base to non-scientific subscribers.

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PLASMA MEMBRANE PERMEABILIZATION BY MULTIPLE
NANOSECOND ELECTRIC PULSES

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INTRODUCTION

In previous work, utilization of patch clamp technique to study plasma membrane permeabilization after nanosecond electric pulse (nsEP) exposure in living cells was introduced [1]. Most recently, it was found that for single nsEP, at two different pulse widths and various electric field amplitudes, absorbed dose adequately predicted the observed decrease in membrane resistance. This work aims to broaden the application of absorbed dose for quantification of nsEP plasma membrane permeabilization by exploring the impact of multiple pulse exposure.

MATERIALS AND METHODS

The effect of nsEP trains on cells was evaluated using patch clamp technique and fluorescent microscopy. GH3 cells were cultured, plated on a poly-l-lysine coated glass coverslip, and placed into a glass bottomed chamber mounted on an inverted microscope. Multiple nsEP were delivered using a bipolar electrode that was positioned 50 um above the coverslip [2-3]. Whole cell currents were recorded before and after nsEP exposure to quantify the change in membrane resistance. Thallium influx into the cell was used as an independent marker of membrane permeabilization and quantified by confocal fluorescent imaging [4].

RESULTS

In a preliminary experiment, cells were exposed to a train of 100 nsEP (5 Hz repetition rate) at several different electric field amplitudes. The electric field necessary for plasma membrane permeabilization was found to be lower than that for a single nsEP. This experiment was extended by varying both the electric field amplitude and pulse number. We found that increasing either the number of pulses or the pulse amplitude facilitates the permeabilization effect. Fluorescent imaging showed that exposing cells to single and multiple nsEP resulted in increased thallium influx into the cell.

CONCLUSIONS

The goal of this work was to quantify the effect of nsEP trains on plasma membrane permeability in cells. Increasing the number of pulses or the pulse amplitude was seen to enhance the permeabilization effect. However, the absorbed dose was no longer the universal metric that fully determined the exposure effect. Notably, the E-field threshold for multiple pulses was lower than for single pulse exposure; however, this was achieved at the expense of higher dose as compared to single pulses. These conclusions were verified using fluorescence imaging by monitoring the influx of thallium ions into the cell which directly correlates to permeabilization of the plasma membrane.
ACKNOWLEDGMENTS

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REFERENCES


Design and Fabrication of a Perfusion Microelectrode Chamber for High Intensity Electric Field Stimulation Using Rapid Prototyping Techniques

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INTRODUCTION

Experiments using ultra-short (<10 ns), high intensity (>1 MV/m) electric (E) fields have been conducted using microelectrode chambers produced by photolithographic techniques [1]. While these microelectrode chambers perform well in biological experiments, the cost and speed of fabrication is limiting their potential use to facilities with the required photolithographic fabrication equipment. A number of rapid prototyping techniques from the fields of microfluidics and MEMS (micro electromechanical systems) can be applied to the construction of such a microelectrode chamber at lower cost and in a fraction of the time.

MATERIALS AND METHODS

A recent technique [2] uses a commercial vinyl sign plotter to cut micro-scale structures in thin films. This process, termed Xurography, relies on equipment found in commercial graphic design workshops to directly cut structures, removing the need for costly and often unavailable clean room facilities. In addition, Xurographic methods lend themselves to the construction of microfluidic devices. In comparison with photolithographic methods, the addition of sealed channels for perfusing fluids is relatively straightforward.

Xurographic fabrication is performed by a vinyl plotter equipped with a 0.9 mm, 45º tungsten carbide blade (Graphtec CE5000-40, Graphtech America, Inc). The blade is capable of cutting materials with thicknesses down to 25 µm. The minimum resolution of the cut structures is limited by the physical properties of the material used as the thin film [2]. The material commonly used as the thin film for the majority of this work, Rubylith (Ulano Corporation), is capable of reliably forming channels smaller than 50 µm.

Biocompatibility of the microelectrode chamber is also achievable by isolating the interior of the chamber from the thin films with electroplated pure gold. Utilizing gold solves two potential problems as it provides excellent biocompatibility and serves as a good conductor for the propagation of the ultra-short E field pulses. In this work, gold was first sputtered (Hummer Technics II) to a thickness of 30 nm to form a seed layer on top of a glass slide substrate. The process used to sputter the gold is commonly employed in scanning electron microscopy.

Gold electrodes were plated on top of the seeded gold layer as formed by selectively cut and removed film. In addition, these electrodes formed mechanical barriers between the Rubylith thin film and the biological medium, in our case, balanced salt solution (BSS), intended for the experiments using this microelectrode chamber. Forming a mechanical barrier between the biological medium and the thin films avoids the necessity of toxicity studies in selecting materials, greatly simplifying the design of the chamber.

A sealed channel was established by sealing the chamber with an ordinary optical glass
cover slip to the chamber thin film and electrode structure. Silicone adhesive (Dow Corning High Vacuum Grease, Dow Corning) was used to bind and seal the structure together while maintaining biocompatibility.

RESULTS

A combination of numerical simulation techniques based on the Finite Element Method (Sonnet Professional Version 11.53, Sonnet Software) and Finite Difference Time Domain (FDTD) method (XFDTD Version 6, Remcom, Inc.) was used to model the geometry of the microelectrode chamber prior to prototyping. In the intended application, bovine adrenal chromaffin cells are exposed to ultra-short (< 10 ns), high intensity (> 1 MV/m) E fields. To maximize the spectral content of the pulse employed in the intended application, minimizing mismatch of the microelectrode chamber to the pulse excitation source is a priority. In order to provide a reliable and matched input, the chamber was designed with 50 Ω inputs to maximize power delivered to the cells. In addition, scattering (S)-parameters (in particular S_{11} that is a measure of the return loss) were numerically computed to ensure a known and reliable frequency response. In order to verify E-field homogeneity and magnitude in the region containing the cells, the chamber geometry was also simulated using XFDTD and the detailed E-field distribution was obtained. Measurements of the return loss were also made using a network analyzer (Hewlett-Packard model 8720B) to verify the frequency response.

The microfluidic channel in the chamber was also tested to ensure a sealed channel supporting a flow of BSS. Ensuring a sealed channel enables us to perform the intended biological experiments under constant perfusion of the BSS over the cells, hence maintaining them at physiological temperatures.

CONCLUSIONS

The S_{11} measurements and the corresponding values obtained from the XFDTD simulations, support the use of the microelectrode chamber for the intended biological experiments. In addition, cost, fabrication time, resources required and technical skill needed are all reduced in this design. These factors combine to enable biological and physiological laboratories to begin experimenting with ultra short, high intensity E fields without relying on prohibitively expensive external photolithographic fabrication services.

Furthermore, the known frequency response of the chamber may enable future experiments in pulse shaping and pulses of specific spectral content. Moreover, the ability to perfuse cells will enable greater flexibility in experimental investigations by allowing temperature changes and switching between different solutions during exposures.

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REFERENCES


Manipulation of 3T3-cells by nanosecond pulsed electric fields

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INTRODUCTION

Pulsed electric field technology is a way of affecting cells with an externally applied pulsed electric field. This externally applied electric field can affect the cell membrane but also the intracellular structures, depending on the field strength, pulse shape and pulse duration. This technology is under investigation for biomedical purposes [1]. With short duration pulsed electric fields it is possible to make the cell membrane temporarily permeable so that drugs can be locally delivered. Ultra short duration pulsed electric fields can induce apoptosis, which is interesting for the treatment of cancer [2].

This paper will discuss a novel method to generate intense pulsed electric fields to affect biological cells (patent is applied for, so no details of this method can be given now). It will also be shown that the method can be used to enhance the growth of 3T3 cells.

MATERIALS AND METHODS

3T3 cells originate from the primary mouse embryonic fibroblasts and are cultured by the protocol 3T3 [3]. Fibroblasts are mammal cells, eukaryote type, and are an important part of connective tissue. They make structural fibers and ground substance of connective tissue and play a major role in wound healing.

The 3T3 cells were cultured and then transferred to well plates and after 2-3 days in culture the cells were counted and transferred to Ependorf tubes to be tested. A so called dose response test was done for various treatment times, where other parameters, such as field strengh and pulse duration, were kept constant. The treatment times used are 1, 2, 3, 4, 5, 10, and 15 minutes which corresponds to between 400 and 6000 pulses. During these tests the pulses electric field was repeated at 7 pulses-per-second. After treatment both the untreated and treated cells were put back into an incubator and pictures of the cells were taken at regular times during this incubation. This is a quick method to see if the cells are affected by the pulsed electric field.

RESULTS

Figure 1 shows a small selection of the pictures. The entire set of pictures shows that cells treated between 1 and 5 minutes show an increase in cell growth as compared to the control sample. Experiments of cells treated between 10 and 15 minutes show a decrease in cell growth compared to the control sample. Cell counting confirms an increase of the number of cells at a treatment time of 2, 4 and 5 minutes and a decrease of the number of cells at a treatment times of 10 and 15 minutes.

Clearly, the cells are affected by the pulsed electric field. Therefore the same dose experiment was done where the cells were counted every day after treatment by a NucleoCounter (which detects fluorescent signals bound to a cell nuclei). An example is
shown in Figure 2. The results show again an increase in cell growth after 3 and 4 minutes of treatment time and a decrease in cell growth around 10 and 15 minutes of treatment time.

CONCLUSIONS

The 3T3 cells are clearly affected by the pulsed electric field. Depending on the treatment time a noticeable effect on the cell growth was observed. For treatment times of about 2-5 minutes the cell growth increases as compared to the control samples. For longer treatment times (10-15 minutes) the cell growth significantly reduces, as compared to the control samples. The underlying mechanism of these findings is not known and requires further research.

REFERENCES

Synergistic Effect of the Specific Pulsed Electromagnetic Fields Stimulation on the Osteogenesis in Murine Mesenchymal Stem Cells

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INTRODUCTION

Mesenchymal stem cells (MSCs) have been considered to be a promising cell type for regenerative medicine and tissue engineering applications. A large number of studies demonstrate that MSC osteogenic differentiation is enhanced by appropriate growth factors or chemical supplements. However, physical stimuli such as pulsed electromagnetic fields (PEMFs), which have been widely used in orthopedics for at least three decades, have not yet been evaluated for their potential effects on MSCs. The intent of this study was to characterize and compare the synergistic effect of PEMFs on the osteogenic differentiation of murine MSCs with/without osteogenic supplements in vitro.

MATERIALS AND METHODS

Cell Culture. Murine MSCs were isolated from the bone marrow of femorae and tibae obtained from 6–8-week-old Wistar rats in an aseptic and modified procedure. Briefly, the adherent cells were maintained as monolayer cultures and expanded for further studies.

Osteogenic Differentiation. To induce the osteogenic differentiation of MSCs in vitro, cells were cultured in an osteogenic medium supplemented with 100 nM dexamethasone, 50 μg/ml L-ascorbic acid, and 10 mM β-glycerophosphate.

PEMF Experiments. MSCs at P3 were cultured in 8-well chamber slides for 2 days at the initial cell density of 1,000 cells/cm² before exposing to PEMF stimulation. Cells were divided into 6 groups as shown: Control, OS (osteogenic supplements), PEMF(1.3G), PEMF(1.9G), PEMF(1.3G)+OS and PEMF(1.9G)+OS. All PEMF-treated groups were placed into the center of solenoid coils and exposed to daily PEMF stimulation with induced electric waveform consisting of single, narrow 300 μs quasi-rectangular pulses with a repetition rate of 7.5 Hz. The average flux density of the magnetic field produced within the solenoids was set at 1.3 G and 1.9 G. Cell viability, alkaline phosphatase (ALP) activity, and osteocalcin (OCN) concentration were determined at days 0, 3, 7, 10 and 14.

RESULTS

The cell viability of each group was normalized and compared to the Control group (Fig. 1, left) and OS group (Fig. 1, right), respectively. It showed that the PEMF-treated cells have more significant proliferation than the Control and OS groups, especially at the exposure of 1.9 G. ALP, one of the early osteoblast marks, was determined at each time point (Fig. 2). It showed that the osteogenic differentiation of MSCs occurred only under the OS medium. Besides, PEMF-treated cells with OS expressed higher ALP activity compared to others. PEMF-treated cells also showed significant osteocalcin concentration under the OS treatment (Fig. 2).
CONCLUSIONS

It indicated that PEMF has the potential on stimulating the MSC proliferation in vitro, irrespective of the osteogenic supplements. Moreover, the higher magnetic flux density (i.e. 1.9 G) showed more significant proliferation. Also, the osteogenic differentiation was greatly enhanced during the PEMF treatment with the osteogenic supplements. It concluded that the specific PEMF stimulation may play a synergistic role on modulating the proliferation and osteogenic differentiation in murine MSCs in vitro.

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REFERENCES

Tests of Four Pulse Waveforms to Elicit Limb Responses in a Swine Model of Electromuscular Incapacitation

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INTRODUCTION

Electrical stimulation of nerves can elicit a muscular response. Nerve stimulation has been studied theoretically in terms of the relative efficiency of different pulse waveforms and muscle responses have been studied with stimulation of specific local nerves. However, limb responses to different pulse stimulus waveforms applied away from the limb, as for electromuscular incapacitation, have not been evaluated. Here, four waveforms and four pulse durations were applied in a swine model of electromuscular incapacitation to investigate the relative energy and charge of the waveforms to elicit the same force at the limbs.

MATERIALS AND METHODS

Four Yorkshire swine weighing 50-57 kg were used. Anesthesia was maintained throughout the experiment with 2-3.5% isoflurane in oxygen. Animals were positioned in dorsal recumbency and each limb was connected to a force sensor. Two barbed electrodes were inserted on the ventral surface of the animal: one 7.6 cm left of the umbilicus (caudal electrode) and one 12.7 cm rostral and 5.1 cm right of the xiphoid. Each electrode penetrated the skin, but not the underlying tissue.

A custom-made high voltage stimulator (James Franck Institute, University of Chicago, USA) amplified programmed pulse waveforms from an Agilent 33250A arbitrary waveform generator. Applied pulses were negative at the rostral electrode referenced to the caudal electrode. The connection between stimulator and rostral electrode passed through a Pearson Model 110 current monitor. Stimulus selection and response recording were implemented in LabVIEW (v8.5, National Instruments).

Four pulse waveforms were tested. Square and Gaussian pulses had durations of 20, 50, 100, and 250 µs. Increasing exponential and decreasing exponential pulses had durations of 50, 100, and 250 µs. Applied voltage and current were measured by a Tektronix TDS5104 oscilloscope and were stored for calculation of pulse energy and total charge. A 100 µs square pulse was applied to obtain a reference response at the beginning of, and periodically during, an experiment. Equivalent stimulation by a subsequent waveform was determined by delivering it with different amplitudes that gave responses larger than or smaller than the reference. This was done until 3-4 crossings of the reference value were obtained. The pulse amplitude for an equivalent response was computed as the average of the last 4-6 pulse amplitudes.

A linear mixed model with pulse type and duration as fixed effects and animal as a random effect was used to test for differences in pulse energy and charge. When appropriate, this was followed by pair-wise testing with Tukey-Kramer correction for multiple
comparisons. Testing was done using SAS (v9.1) and a p-value of less than 0.05 was considered to indicate a significant difference.

RESULTS

A total of 27 reference responses were used and 4-5 equivalent responses were determined for each pulse type-duration combination tested. For each animal, pulse energy and pulse total charge for the different waveforms was normalized to the respective value for the reference response. Energy decreased with longer pulse durations for each waveform. Energy of the square pulse was (1) the smallest at 20, 50, and 100 µs and (2) the same as energy of the Gaussian pulse and smaller than energy of the exponentials at 250 µs. Total charge increased or remained the same for successively longer pulse durations for each waveform. Total charge was the same for square and Gaussian pulses at 20 µs and the same for all pulse types at 50 µs. Total charge of the square pulse was the largest, and total charge of the decreasing exponential the next largest, at 100 and 250 µs.

CONCLUSIONS

The results of this experiment using a swine animal model indicate that for the pulse waveforms tested, less energy and more charge are required for longer pulses that elicit the same limb response. Of the waveforms tested, the square pulse required the least energy to elicit equivalent responses, with smaller energy required at longer durations. However, the square pulse required more charge at longer durations. Thus, a square pulse might be preferred based on energy considerations. A Gaussian or an exponential pulse might be preferred based on charge considerations, especially at longer durations.

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TMS Apparatus for Treating Migraine with Aura: Mapping of the Current Induced in a Human Head

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INTRODUCTION

According to Mohammad et al. from Ohio University (48th meeting of the American Headache Society, 2006), a single TMS pulse applied at the back of the head could help manage migraine with aura. The TMS pulse can interfere with the development of the attack and in a significant number of cases even stop it completely. An apparatus was designed in our laboratory to test the modalities of this therapy in a coming clinical assay. The purpose of the present work was to characterize this apparatus in its ability to stimulate the tissues and primarily the motor cortex.

MATERIALS AND METHODS

A simple TMS apparatus was designed, with an 11 cm diameter circular coil. The pulse is a 200 µs sinusoid with both polarities available and maximum field strength of ca. 0.7 T close the coil centre. Full and half-sine pulses are available. This parameter, along with the level and the polarity of the TMS pulse, can be adjusted by the clinician.

For the characterization of the apparatus, the motor threshold of the right thumb was determined in a group of volunteers from our laboratory. Starting with the coil centre positioned above the vertex, the coil was moved around looking for the location where the lowest amplitude of the magnetic pulse induced a reaction of the thumb in 5 trials out of 10. The coil position, the pulse polarity and amplitude were noted.

A segmented IRM scan of a human head provided by the National Library of Medicine, with 11 different tissues, was used to compute the current induced by the coil of the TMS apparatus. A code based on the resolution of node and mesh equations had been designed and validated in our laboratory. Another code was developed for computing the magnetic induction in the head volume. This allowed for the mapping of the eddy currents in the head model by calculating the induced E field in the tissues with known conductivities [1-5]. The primary motor cortex of the right thumb was located in the head model and the induced current density was calculated at that location, and compared with the known current density at motor threshold [6, 7].

RESULTS

The mean motor threshold for the group of volunteers was found for a 69% setting of our apparatus. Given the mean location of the coil in the group, i.e. 2 mm in front of the vertex and 4 mm towards the left side of the subject, peak current density was found to be 19.9 A/m² at the left primary motor cortex of the (right) thumb. The peak value expected for this pulse duration [6] was 12 A/m².

CONCLUSIONS

The value of the peak current density found was about 1.66 times the expected value. This
may be due in part to an overestimation of the conductivity of gray matter.

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REFERENCES


Elucidation of Membrane Transport Processes in the Giant Marine Alga *Valonia utricularis* by Employing the Charge Pulse Relaxation Technique

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**INTRODUCTION**

An overview is given on the effect of osmotic stress on membrane transport processes in the giant marine alga *Valonia utricularis* as studied with the charge pulse relaxation technique. Charging of the cell occurs by injecting a current pulse (duration: 1 µs; amplitude: ~20 mA) via a microelectrode inserted into the central vacuole that occupies >95% of the cell volume. A separate microelectrode is introduced to monitor the subsequent voltage relaxation (within a few ms) that is exclusively mediated by charge movement through the tonoplast (that surrounds the central vacuole) and the plasmalemma. The charge pulse relaxation technique was employed to study the regulation of the membrane RC properties, e.g. upon a reduction or increase of the osmotic pressure of the bath (an osmotic shock); the turgor pressure (i.e. the hydrostatic pressure inside the cell) was also recorded. Information on the cellular organisation of this coenocytic alga, on the perception of osmotic stress and on transport processes involved in turgor re-adjustment was obtained.

**MATERIALS AND METHODS**

The experimental setup used in these studies has been described in detail elsewhere [1-3]; Briefly, two borosilicate microelectrodes (tip diameter about 30 µm) were inserted into the central vacuole of a *V. utricularis* cell. Microcapillaries were filled with artificial vacuolar sap (AVS) containing 420 mM KCl, 210 mM NaCl, 3 mM CaCl₂, 3 mM MgCl₂ (osmolality 1210 mosmol kg⁻¹; pH 6.3). Cells were usually immersed in artificial sea water (ASW) containing 545 mM NaCl, 12 mM KCl, 11 mM CaCl₂ and 10 mM MgCl₂. The microelectrode for charge-pulse injection consisted of a 10 µm-thick platinum wire that was moved deeply into the vacuole. The wire was connected to a fast pulse generator (model 214B; Hewlett Packard, Palo Alto, CA, USA) through a diode with a reverse resistance >10¹⁰ Ω. The microelectrode for recording the vacuolar membrane potential contained an Ag/AgCl wire surrounded by a small glass capillary filled with 3 M KCl.

Integrated pressure transducers additionally allowed measurements of turgor pressure. The setup also allowed to replace the vacuolar sap by artificial media, using the microelectrodes as inlet and outlet, respectively.

The voltage decay following the injection of a charge pulse could be fitted with a sum of two exponential functions. It was shown previously [1] that this biphasic voltage relaxation reflected the electrical response of both the tonoplast and the plasmalemma that are arranged in series; the fast component of the biphasic relaxation originates from the plasmalemma and the slow one arises from the tonoplast. Accordingly, the capacitance, resistance and conductance of the plasmalemma (Cₚ, Rₚ and Gₚ, respectively) and of the tonoplast (Cₜ, Rₜ and Gₜ) are calculated according to:
with $Q$ being the charge, $A_{\text{cell}}$ being the surface area of the cell, $V_1$ and $V_2$ being the amplitude of the fast and the slow voltage relaxation, respectively, and $\tau_1$ and $\tau_2$ being the respective time constants.

**RESULTS**

When $V_{\text{utricularis}}$ cells are challenged with a hypo- or hyperosmotic shock (dilution or up-concentration of ASW), a biphasic response of the turgor pressure is elicited. The initial phase is due to water flow into or out of the vacuole. During the second phase turgor pressure is regulated predominantly by vacuolar uptake or release, respectively, of Cl$^-$ and K$^+$. Regular injections of charge pulses revealed that the tonoplast conductance always responded most rapidly to a turgor pressure changes, indicating that this membrane is crucial for sensing of turgor pressure changes and initiates subsequent back-regulation of pressure. In case of hypo-osmotic regulation, a rapid drop in the tonoplast conductance was observed upon turgor pressure increase, whereas the plasmalemma conductance hardly responded to the osmotic shock. When a hyperosmotic shock was applied, $G_t$ dropped transiently, whereas $G_p$ increased with a slow time course; under these conditions, external application of Ba$^{2+}$ that inhibits K$^+$ transport, and 4,4$'$-diisothiocyanatostilbene-2,2$'$-disulfonic acid (DIDS), a blocker of Cl$^-$ transport, reduced $G_p$ by about 46% and 38 %, respectively. Hyperosmotic turgor regulation was also reversibly inhibited by Ba$^{2+}$ and DIDS, whereas hypo-osmotic regulation was hardly affected by these blockers and other effects that reduced $G_p$ and/or $G_t$.

**CONCLUSIONS**

It has been demonstrated that the charge pulse relaxation technique allows to record electrical properties of plasmalemma and tonoplast separately in $V. \text{utricularis}$. In that respect, it is superior to voltage clamping that did not allow to identify the contribution of both membranes to the obtained current voltage profiles with certainty [4]. Charge pulse studies indicated that hyperosmotic turgor regulation is mediated by electrogenic K$^+$ and Cl$^-$ uptake, but KCl efflux during hypo-osmotic regulation occurs partly via electrically silent transport.

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Transmembrane Potential Measurements on Plant Cells Using the Voltage-Sensitive Fluorescence Dye ANNINE-6

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INTRODUCTION

Recently, effects of pulsed electric fields on plant cells have become an interesting research topic in plant electrophysiology. Systematic measurements using *Nicotiana tabacum* L. cv. Bright Yellow 2 (BY-2) protoplasts stained with the fast voltage sensitive fluorescence dye ANNINE-6 have been performed using a Pulsed Laser Fluorescence Microscope (PLFM) setup with a time resolution of 5 nanoseconds. Application of an external electric field leads to membrane charging up to a distinct transmembrane potential, where a strong membrane permeability increase prevents further membrane charging. A common explanation for this increased permeability is the enhanced formation of pores in the lipid bilayer. The measured saturation of the fluorescence intensity is a clear sign for the limitation of the membrane charging by the formation of pores.

MATERIALS AND METHODS

The experimental setup used for the presented experiments is similar to the one described by Frey et al. [1]. Protoplasts prepared from the cell line *Nicotiana tabacum* L. cv. Bright Yellow 2 (BY-2) have been stained with ANNINE-6, a fast voltage-sensitive dye which exhibits fluorescence intensity changes based on electronic transitions due to the molecular Stark effect within a subnanosecond time range [2]. For the excitation of the fluorescent dye, a 5 ns laser pulse with a wavelength of 468 nm delivered by a Nd:YAG-pumped dye-laser has been used. The voltage pulse driving the external electric field is provided by a microscope-based Blumlein-line generator. Transmembrane potential dependent fluorescence changes caused by the applied external electric field have been recorded using a fast intensified CCD camera. To obtain the basic fluorescence $F_0$, the fluorescence response of ANNINE-6 has been recorded without external electric field. For the measurement of the field strength dependent fluorescence intensity $F$, an external electric field $E$ has been applied and the fluorescence image has been acquired at a certain point of time $t$ relative to the onset of the pulse. The obtained relative fluorescence change $F/F_0$ has been converted to transmembrane potential values $\Delta V_M$ using a calibration curve of the voltage-sensitive dye obtained by spectroscopic measurements on leech neuron cells [3].
RESULTS

The experiments presented in this work have been performed using a 1 µs rectangular pulse with field strength amplitudes in the range of 0.05 kV/cm to 30.0 kV/cm. The recordings of the fluorescence intensity changes have been acquired at t = 500 ns after the onset of the electric field pulse.

A. FIELD STRENGTH DEPENDENCE OF THE TRANSMEMBRANE POTENTIAL

With increasing external electric field an increase of the fluorescence intensity (shift to more negative transmembrane potential) at the hyperpolarized pole and a decrease (shift to less negative or even positive transmembrane potential) at the depolarized pole could be measured. The field strength dependence of the protoplast’s transmembrane potential $V_M$ shows an asymmetric curve progression. At the depolarized cell hemisphere (cathode) the transmembrane potential saturates at an external electric field of ~1.0 kV/cm, while at the hyperpolarized pole (anode) saturation sets in at a lower field strength of approximately 0.3 kV/cm.

B. AZIMUTHAL DEPENDENCE OF THE TRANSMEMBRANE POTENTIAL

The azimuthal dependence of the transmembrane potential, measured in angular intervals of 10° along the circumference of the cell, shows a nearly cosinusoidal curve progression with a flattening and a slight decrease at higher fields at the pole regions due to enhanced pore formation. Additionally, at the hyperpolarized cell pole a statistically verified polarization reversal could be observed at an external field strength of approximately 1.0 kV/cm.

CONCLUSIONS

A. FIELD STRENGTH DEPENDENCE OF THE TRANSMEMBRANE POTENTIAL

The field strength dependence of the protoplast’s transmembrane potential $V_M$ shows strong asymmetric saturation characteristics due to the high resting potential of the plants plasmalemma. With the assumption of a resting potential value of -150 mV, the results allow the calculation of the critical transmembrane potential where pore formation effects limit a further charging of the membrane to a value $|V_M|$ of ~ 300 mV.

B. AZIMUTHAL DEPENDENCE OF THE TRANSMEMBRANE POTENTIAL

The sudden drop of the transmembrane potential at an external electric field of 1.0 kV/cm might be attributed to a fast charge transfer through the membrane at the hyperpolarized pole. Recent theories explain this behaviour by the activation of voltage-gated ion channels. The existence of hyperpolarisation-activated Ca$^{2+}$-channels in plant cells, which control the membrane depolarisation needed for physiological functions, has been confirmed by several authors [4].

REFERENCES

Enhancement of the Expression of Genes Electrotransferred in Cells in Culture and in Skeletal Muscle by Nanosecond Electric Pulses

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INTRODUCTION

Electric pulses in the range of 100 µs to 100 ms and 25 to 1500 V/cm are known to permeabilize the cell membrane and they are used to allow genes or molecules entering the cells (in electrochemotherapy for example). A new kind of electric pulses, nanosecond electric pulses (nsPEF) is actually under study. nsPEF are ultra-short pulses (10 to 300 ns) with higher electric field strength (10 to 150 kV/cm) that do not increase the temperature of the exposed cells [1].

Several studies have been published on nsPEF effects on animal cells, reporting an induction of apoptotic markers [2,3] and a release of calcium [4,5]. Within these papers [2,3], one experiment showed that the application of 1 nsPEF (10 ns, 150 kV/cm) 30 min after the electrotransfer of the GFP reporter gene into cells in suspension allows an increase of three-fold of the GFP expression compared to DNA electrotransfer only.

The objective of this study was to explore whether nsPEF affect electrotransferred gene expression, not only in vitro but also in vivo, and to explore the parameters affecting such effect to start the analysis of the underlying mechanisms.

MATERIALS AND METHODS

The experiments were performed in vitro (on DC-3F cells) and in vivo (on skeletal muscle).

In vitro: DNA coding for the luciferase was electrotransferred using classical procedures with Cliniporator™ (IGEA, Italy). Then nsPEF (10 ns duration) were delivered or not with a nsPEF generator (FID Technology, Russia).

In vivo: DNA coding for the luciferase was electrotransferred into skeletal muscle (tibialis cranialis) of mice using combinations of microseconds (HV) and milliseconds (LV) pulses [6]. Then tissues were exposed or not to nsPEF with a new exposure technique using insulated electrodes. Muscles were processed 48 or 72 hours after.

Measurement of the luciferase expression were performed using a luminometer and results were expressed as pg luciferase/µg total protein (in vitro) or pg luciferase/mg muscle (in vivo).

RESULTS

In vitro, we determined that some parameters have an important impact. An increase of three-fold of the luciferase expression in the extracts can be achieved with the application of 20 nsPEF (10 ns, 1 Hz, 60 kV/cm) 60 minutes after plasmid electrotransfer, in an electroporation cuvette with 2 mm of gap between the electrodes. The effects are also dependent of the nsPEF repetition frequency: 100 Hz are more effective than 1 Hz. Contrary
to these parameters, others do not seem crucial, as for example the time between DNA electrotransfer and nsPEF delivery, or the amount of DNA per cuvette. No loss of viability is associated to the exposure to these conditions.

In vivo: When nsPEF were delivered immediately after or before DNA electrotransfer (combination of HV and LV), a statistically significant increase of about seven- to eight-fold in the luciferase activity was observed in the muscles treated by DNA electrotransfer + nsPEF compared to DNA electrotransfer only. In contrast, when nsPEF were delivered 60 min after DNA electrotransfer, we observed a non significant increase of about two-fold in muscles treated by nsPEF compared to DNA electrotransfer only. In muscles exposed to 30000 nsPEF without HV and LV, no difference in the luciferase expression was observed with respect to the DNA injection alone.

CONCLUSIONS

In this study we demonstrate that cell manipulation by means of electric nsPEF delivery may increase the overall efficiency of gene electrotransfer. An increase of three-fold in the production of the reporter gene was achieved in vitro and of seven- to eight-fold in vivo.

Studies on nsPEF mechanisms are still ongoing, but our preliminary results seem to show that nsPEF does not have an effect on nuclear pore. Moreover, nsPEF does not seem to destabilize enough the plasma membrane to allow plasmid DNA to enter inside the cells.

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REFERENCES

Radiofrequency Ablation in Breast Cancer: A Critical Review of Clinical Studies

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INTRODUCTION
Tumor ablation is defined as the direct application of chemical or thermal therapies to a tumor to achieve eradication or substantial tumor destruction. Ablative and minimally invasive percutaneous excisional treatments for early stage breast cancer are being investigated by various groups involved with this research. Currently, these include ablation by laser, cryotherapy, microwave, and radiofrequency. During radiofrequency ablation (RFA), alternating current is sent into the tissue through needle electrodes. The alternating current generates ionic movement and agitation as ions oscillate at the applied frequency. Localized friction results in tissue heating, which leads to cell death; histologically tissue shows coagulation necrosis and protein denaturation after RFA. The aim of this review is compared the currently used RFA in breast cancer.

MATERIALS AND METHODS
This report summarizes and compares nine clinical studies of RFA in the treatment of breast cancer published since 1999. The report shows the results of the following parameters: Number of patients, eligibility criteria (age range, tumor size, tumor characteristics and site of tumor), RFA devices (antenna, generator, power level and frequency), techniques (protocol, feedback control impedance/temperature, periods, time, image guidance and anesthesia) and results (ablation zone, failures, cosmesis and complications).

RESULTS
In the last 10 years, nine clinical studies using RFA in breast cancer have been published [1-11]. These reports were compared according several parameters mentioned in material and methods. The results include success, failures and complications of 169 tumors (size ranged from of 0.5 mm to 7 cm) in 167 patients aged 37-89 years, using different commercial RFA devices and protocols.

The first report analyzed was published in 1999, Jeffrey et al. treated with RFA a small series of five women, aged 38 to 66 years, with locally advanced (stage III) breast cancer or tumors larger than 5 cm. While patients were under general anesthesia and just before surgical resection, a 15-gauge insulated multiple-needle electrode (LeVeen needle electrode; RadioTherapeutics Corp, Mountain View, Calif) was inserted into the tumor under sonographic guidance. The multiple-needle electrode was connected to the RF-2000 generator (RadioTherapeutics Corp), and a return electrode pad (Valley Lab, Boulder, Colo). Radiofrequency energy was applied at a low power by a preset protocol for a period of up to 30 minutes. The ablated area measured 0.8–1.8 cm diameter and non-viable tumor was found within this area in four patients. Currently, Medina et al. (2008) treated Twenty-five patients, aged 42 to 89 years with invasive breast cancer <4 cm (range 0.9–3.8 cm). Under ultrasound
guidance, a 17-gauge probe (Elektrotom 106 HiTT, Berchtold, Germany) was inserted in the center of the tumor. The needle electrode was attached to a 500 kHz monopolar RFA generator. RF energy was applied to the tissue with initial power setting of 30 W, for three cycles of 3 minutes each. The energy was increased with increments of 5 W to a maximum power of 50 W. Radiofrequency was delivered until the tumor was completely hyperechoic with the aim of obtaining a safety margin of 1 cm around the tumor. Of the 25 patients treated, NADPH stain showed no evidence of viable malignant cells in 19 patients (76%), with significant difference between tumors <2 cm (complete necrosis in 13 of 14 cases, 92.8%). Additionally others protocols from different authors were considered in order to compare its results.

CONCLUSIONS
Radiofrequency ablation seems to be a promising new tool for minimally invasive ablation of breast carcinoma. Additionally, it was difficult to analyze these studies because several different devices were used in different ways. Nevertheless successful cases for different protocols were obtained for smaller tumors with a low failures and complication rate. A large randomized control study is required to assess the long-term advantages of RFA compared to the current breast conserving therapies. Further research will be necessary to establish the optimal technique, and to demonstrate the long-term oncologic and cosmetic effects of radiofrequency ablation.

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MODYFYING EFFECT OF ELECTROMAGNETIC RADIATION IN BRAIN NEURODYNAMICS INFLUENCED BY NIFEDIPINUM

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INTRODUCTION
The central nervous system plays a significant role in adaptive reactions of an organism. The problem is to investigate the integrative activity of central nervous system influenced by electromagnetic fields and irradiation. Using of pharmacological remedies in the treatment process may be insufficiently effective. Because of this, for monitoring of various constantly occurring in the organism the determination of the combined effect exerted by electromagnetic waves and pharmacological remedies is necessary.

The goal of this work was to reveal the peculiarities in the bioelectric brain activity under the combined effect of Nifedipinum and electromagnetic waves by a nonlinear analysis of the activity.

Nifedipinum was specifically selected due to its wide application in medical practice for the cardiovascular system treatment.

MATERIALS AND METHODS
The experimental animals were 24 white rats. The gilded electrodes (0,8 mm in diameter) were placed with stereotaxis into the somatosensory cortex of both hemispheres upon the introduction of urethane narcosis (1 G/ kG, intraperitoneally). Nifedipinum was introduced with a dose of 4 mG/ kG, subcutaneously. The animal head was exposed to the millimeter range electromagnetic radiation (frequency of 42,2 GHz; spectral power density 150 W/ cm²) in the pulse modulation mode (1 GHz frequency modulation, on-off time ratio of 30). Processing of the bioelectric brain activity was performed with the help of our automated experimental information-measuring system [1].

The recorded electrocorticograms were processed and analyzed by the nonlinear dynamics and traditional spectral correlation methods. The main advantage of the nonlinear dynamics method is the possibility to build a phase portrait of the central nervous system by changes in the parameters which are dependent on a single variable, namely: correlation dimension and Kolmogorov entropy. The Grassberger-Proccacia algorithm was used to calculate the correlation dimension and Kolmogorov entropy. To perform analysis of the recorded electrocorticograms, the algorithm for the nonlinear dynamics method was modified. During processing of the relevant bioelectric information the following parameters of the nonlinear dynamics and spectral correlation methods were calculated: correlation dimension \( d \); Kolmogorov entropy \( K \); spectral power density \( S \) of spectral components over the delta-rhythm, theta-rhythm, alpha-rhythm, beta-rhythm, gamma-rhythm. Reliability of the parameters determined by nonlinear dynamics method, including the correlation dimension \( d \) and Kolmogorov entropy \( K \), was confirmed additionally with the help of the discrimination statistics method.
RESULTS

During this study, the recorded electrocorticograms were processed and analyzed. The effect of Nifedipinum has led to the enriched rhythm components in the high-frequency region, that was confirmed by spectral correlation analysis of the electrocorticograms. A great increase in the intensity of beta-rhythm was observed. The theta-, alpha-, and gamma-rhythms also increasing. The correlation dimension value was practically constant with increasing Kolmogorov entropy $K$. This was indicative of the fact that the brain as a dynamic system went into the instable state.

Microwave irradiation of the rats influenced by Nifedipinum lead to insignificant variations in the correlation dimension $d$. It was found that in the process of time the only one of the nonlinear dynamics parameters was still informative: Kolmogorov entropy $K$. Under the effect of microwaves, by the 5th minute, the Kolmogorov entropy was practically halved. The beta-rhythm intensity was growing at a rather high value of the delta-rhythm. The Kolmogorov entropy went very low by the 10th minute of irradiation. The beta-rhythm intensity was lowered contrary to the delta-rhythm that was growing. Inhibition processes in the brain became prevalent. Electromagnetic waves modified the effect of Nifedipinum with a tendency to inhibition of the animal bioelectric processes. When in 10 minutes the microwaves were switched off, the electrocorticograms were greatly changed. The activity of the brain processes was increased, this state of the central nervous system being less stable, however. The rats subjected to microwave radiation after the introduction of Nifedipinum revealed insignificant variations in the correlation dimension.

CONCLUSIONS

In this way the effect of electromagnetic waves on the organism influenced by Nifedipinum leads to inhibition of the brain processes. This is quantitatively confirmed by a nonlinear analysis of the recorded electrocorticograms. The results obtained are interesting from the viewpoint of the side-effects during the treatment of cardiovascular diseases.

REFERENCES


MODYFYING EFFECT OF ELECTROMAGNETIC RADIATION IN BRAIN NEURODYNAMICS INFLUENCED BY NIFEDIPINUM

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SHOT SUMMARY

The peculiarities found in the influence of microwaves and Nifedipinum on the bioelectric brain activity demonstrate the possibility for the correction of this activity and look very interesting from the viewpoint of side-effects exerted by the compounds used in treatment of cardiovascular pathologies.
SIGNIFICANT IMPROVEMENT FOLLOWING A THREE MONTH PEMF TREATMENT IN A CLINICALLY DEFINITE PERMANENT HEMIPLEGIC SUBJECT AFTER A ROAD ACCIDENT

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INTRODUCTION

It has been well described in the literature that PEMF stimulation, a non-invasive therapy, is a powerful tool used in many medical conditions, like non-union bone fractures, osteoarthritis and osteoporosis [1,2,3] and more recently, transcranial magnetic stimulation to enhance brain functions and neuronal regeneration [4,5,6,7,8]. In this respect, PEMF treatment was strongly recommended in a hemiplegic subject after a clinical diagnosis involving neurological and psychiatric investigations defining permanent aftereffects. In fact, following a road accident, an extremely severe cranio-cerebral trauma was diagnosed with injuries involving the pyramidal motor system and cognitive disturbances predominantly related to frontal cortex in a woman of 50 years of age. In spite of all possible efforts in rehabilitation for a period of more than two years since the road accident, the final conclusions were that all observed aftereffects are permanent from a clinical point of view. At the time of those conclusions, a local and whole body PEMF treatment, five days a week, at home, was prescribed. Three months later, significant improvements were observed on motor motility as well as cognitive and sensorial performances such as vision, language, attention and vigilance. Such a successful response after a daily repetitive PEMF stimulation during three months is new and important enough to be reported in order to go further in the implementation of such a therapy in clinical longitudinal studies.

MATERIALS AND METHODS

It was suggested to use the PEMF stimulator Bio-Stim System. The system consisted of a) a PEMF generator with four controls which offer a great versatility: Amplitude (A) 1 to 9, Frequencies (F) 2 to 60 Hz, Modulations (M) 0 to 9, Timer (T) 1 to 30 minutes and b) two types of applicators: a pair of Helmholtz Hoops and a pair of Helmholtz Pads with 22cm diameter and 5 x 9cm, respectively. The prescribed dosimetry was with the Pads: A4, F60, M2, T15 and with the Hoops: A6, F60, M2, T15. The prescribed posology was fixed at two treatments per day, 5 days a week. In the morning the patient used the Pads under the feet, one Pad under each foot, North side to the foot. In the evening the patient used a whole body treatment with the Hoops, sitting in one Hoop and placing the second at breast level, North side to the head. The intensity of the magnetic field was 12.5 micro-Tesla and 11.1 micro-Tesla with the Hoops and the Pads, respectively.

RESULTS

After three months of treatment with the PEMF stimulator, the following improvements were observed: a) A significant increase in motor activities, motility, security and strength as the subject, by herself, was now able to walk at ease with a deambulator; b) The sensorial aspects were also enhanced particularly the vision allowing the subject to move inside and outside without fear of falling. Both eyes are shiny and suggest alertness. The perceptibility on the left side has increased allowing, for instance, to take and hold a pencil; c) The subject could now speak fluently with accurate and rapid answers to several type of questions including emotional questioning involving familial and individual relationships with her two
adolescents having specific emotional and affective reactions following the accident and the aftereffects; d) The cognitive disturbances were improved. In respect to vigilance, attention and concentration observed by her capacity to read and retain information; e) The sleep period is normal and long enough, 8 hours, to recover without having a nap during the day without dream recall; f) The contact with animals (rabbit, dog and horse) related to zootherapy is improving in regards to their needs, to take them and realize their beneficial effects on moods and emotions thus, encouraging her to expect to ride a horse in next spring time.

The patient is also quite aware that the following improvements such as breathing, hydration, food intake, emotional and relational events are necessary to maintain the progressive efforts and to bring about more beneficial effects in the next three months of PEMF stimulation.

CONCLUSIONS

It is important to specify that after twenty years of expertise with PEMF stimulation for non-union bone fractures, osteoarthritis, osteoporosis and other medical problems, it was the first time that I had the opportunity to address a PEMF treatment in a hemiplegic patient. After more than one year of stable condition with clinically permanent deficit, the PEMF stimulation contributes significantly to the improvement of such a severe cranio-cerebral trauma case. The present results contribute to support the studies done in patients affected of neurodegenerative disorders such as Parkinson and Alzheimer diseases favoring the cell regeneration within the brain. They also suggest that cranio-cerebral trauma has to be treated with PEMF stimulator as soon as possible after the traumatism to accelerate the healing of the brain and diminish the clinically permanent deficit as observed too often.

ACKNOWLEDGMENTS

We thank the patient who has accepted that her clinical situation be presented to the medical community, to help other patients in the future.

REFERENCES

Low Intensity Millimeter-Wave Electromagnetic Radiation (EMR) Effect on Erythrogenesis

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INTRODUCTION

Revealing the effects which electromagnetic radiation at millimeter wavelengths has on the organism and its biological significance serve as a basis for using microwave exposure as a physiotherapeutic procedure for treating various diseases. Penetrating into the organism this radiation is transformed into information-carrying signals performing guidance and adaptation control or rehabilitation processes in the organism. Erythron plays an essential role in development of such processes, as it actively contributes to the maintenance of functional state of the organism. This investigation has the aim to study the characteristics of regenerative processes in the circulatory system under the effect of electromagnetic radiation.

MATERIALS AND METHODS

Experiments were carried out on rabbits of the same weight, age and sex. The animals underwent 30-day EMR exposure with frequency of 50.3 GHz, in correspondence with resonance frequency of vibrations of hexagonal structures of water. A whole-body EMR exposure of rabbits was conducted in the far-field zone of antenna. Incident power density in the plane of exposed object was of $50 \mu\text{w/sm}^2$. Calculated value for the SAR is about 2W/kg. Animals of the control group were sham-exposed by placing them into the exposure zone when the generator was turned on but the output power was attenuated to zero. Duration of the exposure and sham-exposure was 60 minutes. Normally, 24 hours after the bone marrow extraction and on the 5th, 10th, 15th, 20th, 25th, 30th days and 2 weeks after the exposure the following features of erythropoiesis were analyzed: the quantity of erythrocytes (ERT), reticulocytes, hemoglobin (HEM), maturation rate of reticulocytes, the cellular content of the bone marrow, colour index. In order to assess the functional alternations of erytroid branch, the bone marrow index of erythronormoblasts protoplasm maturation has been revealed.

RESULTS AND DISCUSSION

Hypochrome changes of ERT and HEM amounts were observed without irradiation during 24 hours after the bone marrow withdrawal. As compared to the starting point, the amount of ERTs had fallen by 13.5%, HEM by 21.33%. Thus the color index changed to value 0.68. The latter was accompanied by increase in relative and absolute quantities of reticulocytes, as well as their maturation rate. On the 5th day of irradiation, normochrome decrease of ERTs and HEM content was observed. Reticulocytosis and high level of their maturation rate were the same in the mentioned period. In the phase of marrow extraction, the amount of myelocaryocytes and erythroid branch cells was low. The myelocaryocytes level is $95300 \pm 3115$ and erythroid branch cells $38.0 \pm 1.2$ in normally. On the 5th day of irradiation...
they were respectively 68000 ± 2045 (p < 0.001) and 27.0 ± 0.678 (p < 0.001). However, the marrow index of erythronormoblasts protoplasm maturation remained unchanged (0.6). On the 10th day of the experiment, moderate increase of ERTs and HEM amount has been observed. On mentioned time the increase of cells, not containing HEM proerythroblasts and erythroblasts was seen in marrow, which confirms the acceleration of proliferative processes. On the 15th day of irradiation, the growth of ERT and HEM quantities continued. The quantity of reticulocytes and their maturation rate were high. On the 20th day of studies the ERT and HEM quantities were within the limits of physiological vibration 94.48%, 94.28%. As compared to the 15th day, the absolute and relative amounts of reticulocytes had decreased, but still were on the high level compared to the starting point. The observed variations in the peripheral red-blood indices are likely to be related with intensification of marrow proliferative and maturation processes. This fact is confirmed by high activity of erythroid cells in the extracted marrow domain and the growth of HEM-containing normoblasts quantity. During 25 to 30 days after exposure the quantities of ERTs and HEM have not undergone any essential changes compared to the 20th day. The absolute and relative amounts of reticulocytes on the 30th day varied within the limits of starting point. In 2 weeks after stopping the irradiation, all parameters of erythropoiesis have returned to the initial values. It should be noted that the marrow index of cytoplasm maturation of erythronormoblasts have not changed during the whole investigation period.

CONCLUSIONS

The results obtained show that, after removal of the marrow, repeated application of electromagnetic millimeter waves activates the erythropoiesis, enhances the long-lasting reticulocyte maturation process, increases the ERTs and HEM content. Stability of ERTs and HEM quantities during 20 to 30 days after extraction and irradiation of marrow, strong intensification of reticulocyte maturation process, as well as the acceleration of proliferative branch erythroids and maturation processes allow us to conclude that multiple exposure of living organism to electromagnetic radiation mobilizes its preservation power. The latter tends to enhance the regenerative processes and broaden the capacities of compensational mechanisms, as a result of which the removal of marrow does not seriously affect erythropoiesis. Our obtained results agree on the literature, according to which in case of combined action of electromagnetic millimeter waves and anti-tumor preparations the impairment of hemopoietic system decreases significantly and stimulates the proliferative activity of stem cells of marrow, as compared with isolated effect of the mentioned drugs.

Figure 1: The change by percent amount of erythrocytes in 1 ml blood (black) and amount of hemoglobin (gram/%) (white) under influence of electromagnetic radiation (EMR)

Figure 2: The change by percent relative amount of reticulocytes (%(%) (black) and the rapidity of reticulocytes ripening in an hour (white) under influence of electromagnetic radiation (EMR)
EMP Exposure Enhanced Chemotherapy Agent (Lomustine) Delivery to Rat Brain Tumor

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INTRODUCTION

Glioma is the most common brain tumor in adults, which usually occurs in frontal lobe of cerebral cortex. Unfortunately, adequate delivery drugs to the tumor tissue have been a major obstacle to clinical success because of the presence of the blood-brain barrier (BBB). Specifically, it is well documented that systemic administration of lomustine(CCNU), routinely used for treating brain tumors, exhibits a dose-limiting toxicity of delayed myelosuppression and nephrotoxicity[1]. Previously we found that exposure to electromagnetic pulses (EMP) at 200 kV/m for 400 pulses transiently increased the permeability of BBB in cerebral cortex and without damage to neurons in rats [2], whether EMP exposure could potentially aid in the delivery of chemotherapy agents in brain tumors? To answer this question, we studied the effect of EMP exposure on the delivery of chemotherapy agent (CCNU) into brain tumors using a rat glioma model.

MATERIALS AND METHODS

The rat C6 glioma model was used as brain tumor model. Male Sprague–Dawley rats (200–250 g) were placed on a stereotactic head holder and intracranially implanted $10^5$ C6 glioma cells at frontal lobe of cerebral cortex.14 days later, magnetic resonance imaging (MRI) examination was used to confirm the tumor implantation. Then tumor-bearing rats were randomly allocated to either receive an injection of CCNU or EMP+CCNU. The animals (normal rats and tumor-bearing rats) were sham or whole-body exposed to EMP at 200 kV/m for 400 pulses, the repetition rate was 1 Hz. The exposure conditions produced a rise in rat rectal temperature less than 0.2 °C. At 1h after sham or EMP exposure, CCNU (50 mg/kg) was administered i.p. to animals. Blood, cerebral cortex and tumor tissue were collected at different time points after dosing. The content of CCNU in blood and tissues was determined by high-performance liquid chromatography (HPLC) [3].

RESULTS

Content of CCNU in rat cerebral cortex with or without initial EMP exposure As shown in Fig1, the CCNU concentration in normal rats cerebral cortex tissue in EMP+CCNU group was significantly higher than that in CCNU group at 10 and 30min time points after CCNU administration (p<0.05). The CCNU concentration in normal rats plasma in EMP+CCNU group was significantly lower than that in CCNU group at 60min after CCNU administration (p<0.05). These data indicate that much CCNU was delivered from plasma to cerebral cortex with the aid of EMP exposure.
Figure 1. Time courses of CCNU concentration in cerebral cortex tissue (A) and plasma (B) in normal rats after single-dose treatment of CCNU (50 mg/kg, i.p) with or without initial EMP exposure (200kV/m, 400pulses), n=3 at each time points.

**Content of CCNU in rat cerebral cortex with or without initial EMP exposure** To study the effect of EMP exposure on the delivery of CCNU into brain tumors, the rat C6 glioma model was set up firstly (Fig2A), then according to the results from normal rats, the content of CCNU in rat brain tumor at 30 min after CCNU administration was determined. As shown in Fig 2C, the CCNU concentration in tumor tissues in EMP+CCNU group was significantly higher than that in CCNU group at 30 min after CCNU administration (p<0.05).

Figure 2. (A) MRI showing C6 glioma mass (arrow) in a rat brain, (B) HPLC chromatograms of the extract of rat brain tumor at 30min after CCNU (50 mg/kg, i.p) administration and (C) CCNU concentration in rat brain tumor with or without initial EMP exposure (200kV/m, 400pulses), n=3 for each group.

**CONCLUSIONS**

The evidences present here indicate that EMP exposure ((200kV/m, 400pulses) could enhance chemotherapy agent (CCNU) delivery to rat brain tumor, which suggests the possibility of using EMP in facilitating chemotherapy of brain tumors.

**ACKNOWLEDGMENTS**

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**REFERENCES**


On The Optimal Choice Of The Magnetic Field And Nanoparticle Parameters For The Selective Heating Of Cancerous Tissues By Means Of Hyperthermia

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INTRODUCTION

One of main goals for improving Magnetic Particle Hyperthermia (MPH) [1] effectiveness is to reduce as much as possible the dosage, \( C \), of magnetite nanoparticles (MNPs) to be administered in the treatment to achieve the therapeutic heating of the tumour with the desired degree of selectivity [1]. To reduce \( C \) one must increase the SAR of MNPs, which, in principle, can be attained by properly choosing the Magnetic Field (MF) amplitude, \( H \), the working frequency, \( f \), and the MNP-size, \( d \). However, this task is not straightforward because at the same time it is required to guarantee the selectivity of heating. For instance, SAR could be increased by increasing the product \( Hf \), but the higher \( Hf \), the higher the Joule losses due to the Electric Field (EF) in the healthy tissues, and consequently the lower the degree of the heating selectivity of the treatment. Although the optimal choice of \( H, f, \) and \( d \) represents a crucial step to improve MPH, so far this question has been mostly faced with an empirical approach. As a matter of fact, to limit the heating produced in the healthy tissues by the EF, to the best of our knowledge, in all the experiments described in literature \( H \) and \( f \) are chosen by requiring that their product does not exceed the safety value \( 4.85 \times 10^8 \) A/m/s, obtained by clinical trials [1]. However, due to its empirical character, such condition underestimates the actual values of \( H \) and \( f \) exploitable in MPH and consequently the possibility of reducing \( C \).

The paper aims to present a criterion for the optimal choice of the MF and MNP parameters to be used in MPH, i.e. the values for \( H, f \) and \( d \), say \( H_0, f_0 \) and \( d_0 \), minimizing \( C \). The proposed approach determines \( H_0, f_0 \) and \( d_0 \) by estimating the mean values, over the irradiated tissues, of the magnetic and electric power densities to be supplied to the cancerous and surrounding healthy tissues to achieve the therapeutic heating of the tumour with a desired degree of hyperthermia and selectivity. These quantities, in the following denoted with \( p_m \) and \( p_e \), are of concern since their knowledge allows the estimation of the actual constraint on the product \( Hf \). Once \( p_m \) and \( p_e \) have been evaluated, \( H_0, f_0 \) and \( d_0 \) are determined by exploiting the models relating \( H, f \) and \( d \) to \( p_m \) and \( p_e \) [1].

MATERIALS AND METHODS

As well known, in MPH the therapeutic heating of the tumour should be as selective as possible. Ideally, a temperature distribution where all the diseased area is at a therapeutic temperature, \( T_1 \), and all the healthy tissue is at the metabolic temperature \( T_0=37^\circ C \) should be attained. However, due to the finite thermal conductivity of biological tissues and the unselective heating generated by the EF in the healthy tissues, the actual profile of temperature, \( T \), is always characterized by a non null transition region, surrounding the tumour, wherein \( T \) decreases from \( T_1 \) to a smaller, safety, value of temperature \( T_2 \). Accordingly, at least in principle, \( p_m \) and \( p_e \) should be determined by requiring that \( T \) is as
close as possible to the ideal profile. Indeed, \( p_m \) and \( p_e \) can be conveniently determined simply by requiring that the transition region width has an assigned extension, representing the desired degree of heating selectivity. This is basic idea of the criterion proposed here to estimate the values of \( p_m \) and \( p_e \). In detail, if a linear description for the thermal balance within the irradiated regions can be adopted and a uniform temperature \( T=T_0 \) is kept at the boundary of the irradiated tissues, the following expression for \( T \) in the steady regime holds:

\[
T(r) = p_m f_m(r) + p_e f_e(r) + q_{met} f_{met}(r) + T_0
\]  
(1)

In eq. (1) \( r \) is the position vector, \( q_{met} \) the metabolic heat generation and \( f_m(r), f_e(r), f_{met}(r) \) are the solutions of the problem describing thermal balance within the irradiated regions for \((p_m, p_e, q_{met})=(1, 0, 0) \) w/m\(^3\), \((p_m, p_e, q_{met})=(0, 1, 0) \) w/m\(^3\) and \((p_m, p_e, q_{met})=(0, 0, 1) \) w/m\(^3\), respectively. It is worth noting that \( f_m(r), f_e(r) \) and \( f_{met}(r) \) are known once the electromagnetic, thermal and metabolic features of the applied field and the irradiated tissues are given.

Then, according to the proposed criterion, \( p_m \) and \( p_e \) are determined by imposing simultaneously that: \( T(r) \geq T_1 \) for \( r \in V_1 \) and \( T(r) \leq T_2 \) for \( r \in V_2 \), where \( T(r) \) is given by eq. (1) and \( V_1 \) and \( V_2 \) denote the volumes of the diseased tissue and the healthy tissue outside the transition region, respectively. Once \( p_m \) and \( p_e \) have been determined, \( H_f, f_o \) and \( d_o \) are evaluated by exploiting the models relating \( H, f \) and \( d \) to the mean magnetic power density dissipated by the MNPs, namely \( p_m \), as well as the expression of mean electric power density dissipated by the EF over the irradiated tissues, namely \( p_e \) [1].

**RESULTS**

As an example, later on are reported the results of the criterion applied to a 2D, circular geometry consisting of a tumour of radius \( R_1=5 \) mm and a surrounding healthy tissue with a radius \( R_2=50 \) mm. The Pennes BioHeat Equation in steady regime [2] has been exploited to describe the thermal balance. Moreover, uniform electrical and thermal properties have been assumed for the irradiated tissues. Their values have been chosen within the range of values typically quoted for human tissues [2]. Concerning the applied field, a uniform, axial MF and an EF given by the Faraday’s law have been adopted in the calculation. The assigned temperature requirements are: \( T_1=42^\circ\text{C} \) (mild hyperthermia) and \( T_2=39^\circ\text{C} \). The radius of the transition region is set to \( R=15 \) mm. The obtained results are: \( p_m=184 \) kw/m\(^3\), \( p_e=5.5 \) kw/m\(^3\), \( H_f=1.25 \times 10^9 \) A/m/s, from which one obtains, by assuming \( H_{max}=H_o=10 \) kA/m, \( f_o=125 \) kHz and \( d_o \approx 17 \) nm. The corresponding amount of MNPs is \( C=1.5 \) mg/ml. This value is about ten times smaller than that usually used in the experiments to heat tumours of comparable size.

**CONCLUSIONS**

A criterion to identify the optimal values for \( H, f \) and \( d \) to be used in MPH has been proposed. The results of the criterion applied to a 2D geometry have been presented. Preliminary results of the criterion applied to a 3D geometry will be presented at the meeting.

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**REFERENCES**


Electromagnetic Compatibility Issues between Vehicular Mounted Antennas and Implantable Medical Devices

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INTRODUCTION

Vehicular mounted antennas are integral parts of communication systems for law enforcement and public safety vehicles. To guarantee reliable communications, the emitted electromagnetic energy levels from these antennas are typically much higher than from most other wireless devices, such as cell phones. Depending on the operating frequency, the maximum output power in some mobile radio products can be close to 120 W in VHF band, 50 W in parts of UHF band and 5-10 W in 700-900 MHz band. Such high level of electromagnetic emission can lead to significant energy deposition in bystanders as well as passengers and all mobile radio products must comply with applicable exposure compliance limits. An accurate estimation of such exposure for product compliance evaluation purposes is subject of research within IEEE 1528.2 standards development process. The developed numerical techniques allow evaluation of the Specific Absorption Rate of RF energy produced in the human body in such conditions.

With the increased usage of medical implantable devices, additional safety consideration on human subjects with medical implantable devices shall be studied more carefully. Such investigations are critical for two reasons. First, when a medical implantable device is implanted within human subjects, metallic cases of implantable devices can lead to higher electromagnetic energy depositions in the vicinity of these devices, in particular, in the vicinity the tip of metallic leads. In addition, many of these medical devices are now equipped with wireless capability for telemetry applications. Some of these devices operate at 900 MHz as the carrier frequency. If particular frequency overlaps with the operating frequency of vehicular mounted antenna it could be susceptible to electromagnetic interferences from that antenna. Careful electromagnetic studies are necessary to understand the potential hazard of electromagnetic interference related to the vehicular mounted antennas to nearby human subjects with medical implantable devices.

METHODS

The Finite-Difference Time-Domain (FDTD) method is used to analyze the interactions between vehicular mounted antennas and implantable medical devices. The Planar Inverted-F Antenna (PIFA) is designed on top of an implantable device model. Both bystander positions and passenger positions are studied as shown in Figure 1. In all cases, the implantable devices are placed at the left pectoral region.
RESULTS
In the first study, we investigate the variation of specific absorption rate (SAR) near the heart region with and without the presence of an implantable device. The SAR values at three specific frequencies with/without the implantable device are tabulated in the Table 1 (vehicular antenna input power is normalized to 1 W). As indicated in the table, these regional SAR values increase when the implantable device is presented.

The electromagnetic interference from vehicular mounted antenna to the implantable device receivers are characterized by the transmission coefficient (S21) between the excitation port on the vehicular mounted antenna and the antenna port on the implantable PIFA. Figure 1 shows the interference between the vehicular antennas and the PIFA as the bystanders moves away from the vehicular. As expected, the large distance reduces the interface level but higher operating frequency tends to cause a higher level of electromagnetic interference.

Table 1. 1g averaged SAR near the heart region with /without implantable device

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>SAR with Device (W/kg)</th>
<th>SAR W/O Device (W/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 MHz</td>
<td>0.0028</td>
<td>0.0020</td>
</tr>
<tr>
<td>450 MHz</td>
<td>0.0041</td>
<td>0.0034</td>
</tr>
<tr>
<td>900 MHz</td>
<td>0.0077</td>
<td>0.0067</td>
</tr>
</tbody>
</table>

CONCLUSIONS
In this paper, we investigate the electromagnetic compatibility/interference issues related to the human subject with medical implantable devices located in the vicinity of vehicle mount antennas. Numerical investigation shows that the implantable device can lead to increased SAR in the vicinity of the implant. The wireless receivers on these devices tend to be more susceptible to electromagnetic interference at higher operating frequency.
Body-Centric Antennas for Body Area Networks

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INTRODUCTION

In this study, mutual coupling between body-centric antennas for wireless cardiac monitoring is investigated by mounting the antennas on a human torso covered with three layered tissue (skin-fat-muscle) mimicking gel. Particle Swarm Optimization (PSO) algorithm is used to optimize the dimensions of body-centric antennas operating at Industrial, Scientific, and Medical (ISM) (2.40 GHz - 2.48 GHz) band. The antennas are first mounted on a plane covered with three layered tissue mimicking gel, and mutual coupling measurements are performed by varying the position of the antennas. The mutual coupling is minimized by placing the antennas with 90 degree phase difference at 4 cm distance. In order to test the performance of the antennas, a female mannequin torso is used. The mutual coupling measurements and the recipes regarding the tissue mimicking gels will be presented.

BODY-CENTRIC ANTENNAS AND GEL CHARACTERIZATION

Electrocardiogram (ECG) monitoring is important to diagnose heart abnormalities and treat patients with cardiac related diseases. Current ECG monitoring systems employ at least three electrodes where the electrodes are collecting data and wired back to a central monitoring system for data transmission. In a traditional monitoring system the wires can be tangled up which causes the electrodes to be dislodged from patients body. The current systems also are not suitable for out-patient care. To improve patient’s comfort, developing a wireless cardiac monitoring system is vital. Designing body-centric antennas is a key component to develop such systems. Antennas are required to be miniaturized and have sufficient gain to transmit data to required distance. Furthermore, the mutual coupling between body-centric antennas should be minimized, and the mutual coupling between central unit and body-centric antennas should be maximized for accurate data transmission.

This study is a complementary for mutual coupling of body-centric antennas proposed in [1]. Using distilled water, oil, ultra ivory, and agarose a fat mimicking gel is characterized and formerly characterized muscle and skin mimicking gels in [2] are used to form the three layered tissue mimicking gel. The dimensions of serpentine shaped body-centric antenna operating at ISM (2.40 GHz – 2.48 GHz) band is optimized with PSO. Fig. 1 shows the dimensions and Fig. 2 shows the return loss of the antenna. A mannequin torso is covered with three layered tissue mimicking gel and the antennas are mounted on the female mannequin’s torso. Then the mutual coupling measurements are taken for different configurations. Note that all measurements are performed with
Agilent’s 85070E dielectric probe kit and E8362B PNA network analyzer. The measurement set-up for plane surface and the mutual coupling measurements for 90 degree phase difference at various distances are shown in Fig. 3 and Fig. 4 respectively.

RESULTS

CONCLUSIONS

In this study, mutual coupling measurements of body-centric antennas mounted on a female torso are performed. The configuration to minimize the mutual coupling between antennas is to position the antennas with 90 degree phase difference with enough distance. The future work will be to perform the measurements on a children and male torso. Results regarding the measurements will be presented.

REFERENCES


Numerical and Experimental Validation of a Circuital Model of a UWB Radar for Breath Activity Monitoring

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INTRODUCTION

Monitoring of breath activity is conventionally achieved by means of bandage systems placed in contact with the skin or by airtight jackets worn by the patient. In many cases these techniques can be uncomfortable for the patients and do not allow a continuous monitoring of the vital signals. By using electromagnetic radiation in the microwave region it is possible to monitor the respiratory activity in a non-invasive and continuous way. Many works have shown that ultrawide band (UWB) radar systems can be used for contact-less vital-signs monitoring [1]; to this purpose experimental prototypes have been realized and tested [2-3]. However, few complete models of UWB radars for the monitoring of the respiratory activity have been developed [4-5]. In this paper, the model proposed in [5] is validated both numerically and experimentally by using a commercial CAD (Microwave Studio - MWS) and an experimental set-up based on an indirect time domain reflectometry system.

MATERIALS AND METHODS

Fig. 1 shows the proposed model of the UWB radar for monitoring the breath activity [5]. The model takes into account the UWB source, the antenna, characterized by its radiation impedance and its effective height ($h_{\text{EFF}}$), the air propagation, and the body scattering.

![Figure 1: Model of the UWB radar for monitoring the breath activity.](source)

This model has been implemented inside the commercial CAD Microwave Office (MWO). The radiation impedance of the antenna is modeled through a complex impedance whose values are assigned in the form of a table. For taking into account the transmitting properties of the antenna the far field equation has been considered. The air propagation is modeled by means of a lossy transmission line which takes into account the field spherical attenuation with the distance. The interaction with the subject is considered through a subcircuit that allows to insert the radar cross section (RCS) at various frequencies. Finally the scattered field $E_S$ reaching the antenna is multiplied by $h_{\text{EFF}}$ and gives rise to the late time content of $V_S$. The numerical validation has been performed by using the EM software MWS based on the FIT technique. The experimental validation has been carried out with a set-up using a vector network analyzer (Agilent PNA E8363B) controlled by means of a PC in order to implement an indirect time domain reflectometry (TDR) system. Measurements have been carried out using a Seibersdorf PCD 8250 biconical antenna as radiating structure, and a
rectangular copper panel (45×30 cm) as scattering target. LabVIEW controlling software generates the monocycle and, after measuring the complex reflection coefficient of the antenna, is able to reconstruct the time behavior of the reflected signal.

RESULTS

The time behavior of the free space electric field produced by a dipole (30 mm length) excited by a monocycle has been investigated. Fig. 2 (a) shows a comparison between the electric field obtained with the proposed model and the field simulated by MWS at a distance of 80 cm from the dipole. As expected from the theory, the electric field time behavior is the second derivative of the exciting monocycle.

![Figure 2: Free space electric field at a distance of 80 cm from the dipole (a). Received voltage (V_S) due to a target placed at a distance of 50 cm from the biconical antenna (b).](image)

The received voltage due to the target reflection (50 cm far away from the antenna) has been measured by using the experimental set-up and evaluated with the model by considering the measured frequency behaviors of the radiation impedance and h_EFF of the used antenna [Fig. 2 (b)]. The Figure shows a good agreement in the early time contents and the presence of the environmental clutter, that is not considered in the model, in the late times.

CONCLUSIONS

A circuital model of a UWB radar for the study of breath activity has been validated both numerically and experimentally. The electric field in free space and the received voltages have been reproduced with a good agreement between the model and the other techniques.

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REFERENCES

Study of dielectric properties of human skin in millimeter wave range and its correlation with physiological condition

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INTRODUCTION

Modern imaging techniques such as magnetic resonance and ultrasound have been responsible for significant advances in medical science. In recent years the interaction of electromagnetic signals with the human body has been studied intensely for health and safety applications as well as diagnostic and therapeutic purposes. However, the field of dielectric spectroscopy of biological materials at high microwave frequencies (above 20GHz) is relatively unexplored but would seem to offer several important benefits to the real-time monitoring of human health. In this work the dielectric properties of human tissues, specifically skin and blood, in the millimetre wave band (30-300GHz) are studied. Such research would contribute towards our understanding of the electromagnetic properties of both normal healthy tissues and tissues exhibiting various abnormalities in this band. This, in turn, would enable the development of fast and non-invasive methods of monitoring human health. Such methods would be safe and offer a real-time monitoring of dynamic life processes. Study the interaction between electromagnetic radiation in the millimetre wave (MMW) band and the human body are carried out in vivo and in vitro. The main parameter of interest which is indicative of the response of the human body is the complex dielectric permittivity. It is frequency dependent quality. MMW are strongly absorbed by human tissues and therefore only penetrate the skin. Experimental studies of human skin in vivo will be used to develop a model of the dielectric properties of skin and to study of mechanisms of dielectric relaxation and polarisation of human skin in MMW band. The data will be used to search for correlations between dielectric properties in MMW band and physiological conditions of human body.

MATERIALS AND METHODS

Materials: we have studied human organism by investigation of complex dielectric permittivity of living human skin in vivo using reflection coefficient of electromagnetic wave only [1] and of a single sample of excised human skin fixed in formaldehyde at body temperature [2].

Methods. The reason for usage of MMW for bioelectromagnetic study are follow. Skin is tissue with high water content. In this case: 1. The sensitivity to the content of water and other dipole liquids in different media increases with frequency (e.g., a free space absorption of MMW in water a > 40 1/cm is much greater than that in all monitored host materials; as wavelength decreases, the absorption in water increases more rapidly than the absorption in these host materials). 2. MMW practically are not sensitive to conducting impurities in liquids. 3. MMW allow one to realize non-destructive, real-time, in-flow measurement of the dielectric properties of media. These properties are closely related to the chemical composition of substances under test.
Investigation of correlation of dielectric properties of skin in millimeter (MM) frequency range and its physiological parameters demand own methods for investigations. We have elaborated and realized the original methods for measurements of dielectric parameters for materials, media and tissue. In detail, quasi optical methods of measurements in non-reflected beam waveguides. This method allows: a) to eliminate errors because of reflections in experimental setups; b) to work with the samples much more smaller as with the usual quasi-optical methods allow, i.e. with the cross-section area about some wavelengths; c) in comparison with the usual methods, that use metal waveguides, in our method it is not needed to make the cross-section area of the samples exactly suitable to the cross-section area of waveguides; d) because of in our method experimental setups are open, then there is no problem to place the samples under investigation in every place of the setup, e) there is no problem to realize influence of external factors like temperature, electrical and magnetic fields, light, mechanical pressure. The main original method proposed to human skin is non-destructive (non-invasive) method for determination of complex dielectric permittivity with the use of measurements of minimal reflection coefficient and the frequency, in which this coefficient is obtained. The reflection is connected with the special dielectric with known parameters. This method is much more easy and much more accurate then usual non-invasive methods, that use measurements of the module and phase of reflection coefficient. The reason for this high accuracy is the next: the accuracy of frequency measurements is much more higher then one for the measurements for reflected wave [1].

RESULTS

The method [1] for investigation skin in vivo was realized in frequency range 28—150 Ghz and at frequency about 10 GHz. The next measurements were carried out. Dielectric properties of glucose solutions with concentrations of W from 5 to 0.25% wt. are measured in the frequency range 30–93 GHz and at 10 GHz. Dielectric properties of blood (using one drop) are investigated in vivo at frequencies of 42 and 66 GHz. The measurements have shown that the method developed in this project can be used for the real-time determination of the glucose content in blood without strips used in optical invasive glucometer after oral glucose tolerance test (OGTT).

Dielectric properties of skin excised human skin fixed in formaldehyde was studied in frequency range from 90 up to 100Ghz. The experimental results have been used to determine the parameters of a Cole-Cole function which gives the best fit to the measured data. The measured skin data has also been used to calculate power deposition in skin exposed to millimetre wave radiation. This work concludes that a skin surface temperature rise of only 0.20C results from a thirty second exposure to signals of 100W/m².

CONCLUSIONS

It is shown that our results allow, to create a non-invasive measurement method for skin water content for different strata of skin, and in principle, for the glucose content in blood determination, at least after OGTT and some parameter of human organism.

REFERENCES

Magneto-hydrodynamic simulations for non-invasive cardiac blood flow measurement

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INTRODUCTION

The overall goal is to develop a method to non-invasively characterize cardiac blood-flow dynamics, including stroke volume and cardiac output along with spatial resolution of flow profiles. The research develops techniques to gather information about blood flow that can supplement present non-invasive ultrasound techniques for the evaluation of heart failure. This additional blood flow information is based on a new physiological marker. This marker is the magneto-hydrodynamic (MHD) signal recorded on the ECG (Electrocardiogram) while the subject is exposed to a strong static magnetic field. The MHD signal is caused by induced electrical currents in the blood due to the blood flow in the magnetic field and is detected as distortion in the electrocardiogram (ECG).

Therefore, we hypothesize that the MHD signal is capable of rapid and non-invasive measurement of blood flow characteristics that are necessary for evaluating heart failure, particularly diastolic heart failure. Such signals have been collected in both animals and humans by other investigators [1]. Analysis of the MHD signal recorded with the 12-lead ECG in conjunction with physiological measurements will require electromagnetic modeling to determine the exact location of the sources of the signals (i.e., ventricle, aorta, pulmonary circulation, coronary arteries, and carotid arteries) and the size of the magnetic field needed to obtain useful physiological signals. Electromagnetic modeling using anatomically accurate models of the human has been done [2]. Currently available anatomical models, such as Virtual Family [3], will permit the exact calculation of the MHD signal locations as vectors that may be used as functional biomarkers for cardiac blood-flow dynamics.

The main focus of this abstract lies on the mathematical implementation of the MHD equations as a finite element code, preliminary simulations results, and the comparison of the MDH solver results to literature data.

MATERIALS AND METHODS

The blood flow is simulated using the flow simulator Fluent [4]. Our method makes two simplifying assumptions. (1) The electromagnetic (EM) field follows the different flow conditions fast enough to be considered instantaneous. (2) Our model neglects the flow reduction due to the coupling with the magnetic field because it is less than 1% at 2 Tesla [5]. Because of the extent and the low blood velocities, the induced currents in the blood do not contribute significantly to the overall magnetic field, i.e., the resulting magnetic field is the external B-field and considered to be constant. With these assumptions, the equation for the unknown potential \( \phi \) and phenomenological Lorentz force \( \sigma \mathbf{v} \times \mathbf{B} \) is:

\[
(1) \ \text{div} \ \sigma \ \text{grad} \ \phi = - \text{div} \ \sigma \ \mathbf{v} \times \mathbf{B}
\]
where $\sigma$ is the electrical conductivity, $v$ is the blood velocity field and $B$ is the constant external magnetic field. Equation (1) is implemented using the finite element technique with linear nodal elements for the potential. The solver is embedded in the simulation platform SEMCAD X [6]. The velocity field on the unstructured grid of the flow simulation is interpolated on quadrature points of the EM simulation grid. This grid is implemented as a non-uniform but rectilinear grid in 3-D.

RESULTS

Two simulations were run using SEMCAD X and the newly developed MHD solver to compare our results with literature [7]. The simulation parameters are chosen to be similar to those found in [7]. The models used in the simulations are a model with single aorta and a model with both ascending and descending aorta. The applied magnetic field strength is 1T.

The field distribution of the resulting induced voltage and current density are similar to the distribution found in [7]. Despite the fact that the geometries of our simulations differ slightly from the geometry found in [7], the values at each locations are in good agreement.

CONCLUSIONS

The developed MHD solver is able to calculate the induced current distribution and the equi-potentials in simple geometries. Preliminary validation of the MHD solver shows good agreement with values found in the literature [7]. The implemented MHD solver is also able to calculate the induced fields in highly accurate models of the human anatomy. In the future, an exact model of the geometry used in [7] will be simulated and compared. In addition, an experimental validation to compare the MHD solver results with actual measurements will be done. Future simulations will also include the calculation of the MHD signals for all four models of the Virtual Family with varying the orientation of the static magnetic field to determine an optimized location for the measurement of the MHD signal. The optimal location for measuring the MHD signal is a location on the surface of the patient which maximizes the signal strength and optimizes the correlation of the MDH signal to the blood flow. In addition, the ECG signal, obtained with no magnetic field, can be subtracted from the MHD-ECG to obtain a pure MHD signal for analysis. The volunteers based on which the Virtual Family models were developed (two adults and two children) will be used to measure the ECG signal and the combined ECG + MDH signal. We will correlate the computational MHD results with the actual measurement. Based on this information we hope to develop a MHD based biomarker to non-invasively estimate spatially localized blood flow for the evaluation of heart failure.

DISCLAIMER

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

REFERENCES

Test Setup for Revealing Pacemaker Interference with Low Frequency Magnetic Fields

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INTRODUCTION

The number of workers with cardiac pacemakers and implantable cardiac defibrillators (ICD) is increasing rapidly as the mean age of workers is rising. Therefore, management of possible pacemaker interference issues at work places is a challenge for many employers. It is especially unclear how sensitive modern ICD’s are to strong low frequency magnetic fields which may occur at various work places. The European EMF directive (2004/40/EC) requires employers to consider specifically the factors that affect the health and safety of workers at particular risk, like those with pacemakers. This creates great challenges especially in industrial work environments, where high magnetic fields can be found [1,2].

In this study several cardiac pacemakers and ICD’s from three different manufacturers were exposed to high intensity magnetic fields in Helmholtz coil system using different waveforms and frequencies (2 Hz - 1 kHz). The goal was to find the thresholds where the malfunctions appear with various waveforms and frequencies. Previous pacemaker studies have been focused mainly to the frequencies near 50 Hz [3,4].

MATERIALS AND METHODS

Two Helmholtz coil systems were used to produce the magnetic fields. The bigger coil had 22 turns and a radius of 48 cm, and the smaller one had 40 circles and a radius of 9 cm, respectively. The test setup was computer-controlled utilising the Agilent Vee Pro 7.5 program, a KEPCO power amplifier and an Agilent waveform generator. The current was recorded with Agilent multimeter equipped with a 30 A current shunt.

The tested pacemakers and ICD’s were manufactured by three pacemaker companies: Medtronic, St. Jude Medical, and Boston Scientific. The pacemakers were either used ones from standard replacement operations due to nearing end of operating time, or they were demo pacemakers intended for teaching purposes but still having all the same qualities and behavior as those implanted in patients. The pacemakers and ICD’s were exposed to different magnetic fields varying in waveform, intensity, and frequency. The waveforms used were sine, pulse, ramp, and square waves, as well as sine sweep and burst waves. The frequencies ranged from 2 Hz to 1 kHz. Magnetic field intensities varied from less than the ICNIRP occupational reference values to ca. 4 mT. The pacemakers/ICD’s were situated in clinical NaCl-solution in order to uphold an impedance similar to the human one (200-600 Ohm). With every pacemaker/ICD prober electrode leads were used and arranged to match the worst case scenario in real life, so that the lead loops were as long as possible. Each pacemaker/ICD was pre-programmed to as sensitive state as possible, and after the exposures carefully recorded to find out all the possible interferences caused by the magnetic field. The measurements were conducted in three orthogonal directions to find out possible significance.
the direction of the magnetic field.

RESULTS

About 30 different pacemakers and ICD's have been tested to determine the malfunction thresholds for more than 40 different combinations of waveforms and frequencies, all with several different intensities. The results indicates that there can be found differences between the thresholds of different pacemakers/ICD's.

Pacemaker/ICD malfunctions seem to appear in magnetic fields that are well above the ICNIRP reference levels for public exposure. Nevertheless, malfunctions were found to appear below occupational reference levels for magnetic fields. A malfunction start almost immediately when interfering exposure starts, as shown for one ICD in the figure 1. The ICD detects magnetic field interference as ventricular fibrillation and treats it by giving a high voltage defibrillating therapy shock, as it has been programmed to function. When the magnetic field exposure stops, the ICD returns to normal ventricular pacing and detects sinus rhythm without interference.

Figure 1. Example of an ICD experiencing interference. A square-wave magnetic field (25 Hz, 3.9 mT) produces an artifact of ventricular fibrillation and evokes the ICD to give high voltage defibrillating therapy shock. The interference lasts 10 s which is the same time that the magnetic field was applied.

CONCLUSIONS

The Helmholtz coil system appears to be advantageous method in exposing pacemakers to alternating magnetic fields. It gives specific information about the used parameters in every exposure situation, and makes the experiment conditions well comparable with real life conditions.

ACKNOWLEDGMENTS

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REFERENCES

Assimilatory Pigments and Nucleic Acid Concentrations of Vegetal Tissue Exposed to Low Level 900MHz Controlled Field

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INTRODUCTION

Numerous non-thermal biological effects of radiofrequency (RF) fields were reported in the last decades [1]. They were observed at various cellular or molecular levels in living tissues. However, no clear interaction mechanism was yet proved [2]. Data also show that modulation of RF field may play a role [3]. Vegetal tissue proved to be a proper target for investigating such effects at environmental levels of RF fields. Unfortunately, many experiments with plants suffer from poor expo-dosimetric characterization. In this regard, present work aimed at tracing variations of some common biochemical parameters of vegetal tissue, in controlled exposure conditions. Chlorophylls and carotenoids content together with nucleic acids concentration due to exposure to low-intensity electromagnetic field in the 900MHz band (both continuous wave – CW and modulated wave) were traced. Plant seeds (Zea mays) were exposed inside a TEM cell and dosimetric characterization followed. The plantlets developed from irradiated seeds where further biochemically investigated.

MATERIALS AND METHODS

A TEM cell model IFI CC 104 SEXX (Instruments for Industry Inc, USA) was used for experimental exposure of the vegetal tissue - Zea mays (corn) seeds, in an experimental configuration presented in fig. 1. Expoisometric characterization of the interest area in the cell (E-field uniformity) was made prior to exposure, both experimentally (measurements with a calibrated E-field probe model Scan EM-EC connected to a spectrum analyzer) and computationally (finite element model, Comsol Multiphysics software) [4]. Several 40 seeds samples were successively exposed in the same place of the TEM cell, inside a glass Petri dish, 9cm in diameter. Three types of RF signals were applied to different samples: a) CW, f=900MHz, P_{inc}=20mW; b) AM, f_c=900MHz; P_{inc}=5mW; shape=sin; f_{mod}=100kHz; AM depth=100%; f_{step}=500kHz; level step=0.5dBm; f_{mod step}=100Hz; c) FM, f_c=900MHz; P_{inc}=20mW; shape=sin; f_{mod}=10kHz; FM f_{dev}=200kHz; f_{step}=1 MHz; level step=2dBm; f_{mod step}=1kHz. The samples were exposed continuously for fixed durations, in the range 4 to 72 hours. Control samples were also provided. After the exposure, the seeds were put aside to germinate on watered porous paper support in Petri dishes, in darkness and 22°C temperature. The plant growth was conducted in controlled conditions of temperature (22±0.5 °C), moisture (70% humidity), illumination (dark/light cycle of 14/10 hours) and the culture medium of young plantlets was daily watered with the same amount of deionized water. The biochemical quantifications were applied after 12 days of plant growth. Dosimetric comparative assessment was made: a) experimentally, by using differential power method – CW case (see fig. 1); b) theoretically, TEM cell modeling and simulation of the CW case with Comsol Multiphysics – FEM method [4]. Spectrophotometric assays were applied for
determination of pigment contents (Lichtenthaler & Welburn’s method, JASCO V530 UV-VIS spectrophotometer). Spirin’s method was applied for average nucleic acid content calculation. Plant individual length was measured with 0.1 cm precision; sample weight was measured with $10^{-5}$ g accuracy.

![Figure 1: Exposure set-up and TEM cell model in Comsol Multiphysics](image1)

**RESULTS**

The average incident E-field measured in the exposure area was 5 V/m for CW, 3.4 V/m for AM and 2.1 V/m for FM signal respectively. Simulations showed an average E-field level of 5.5 V/m for the CW case, in good agreement with the measurements. Dual experimental and computational dosimetric assessment showed that SAR$_{avg}$ < 12 mW/kg.

Biological effects: A slight stimulatory influence on the plants growth, for all exposure durations, independent on the waveform was evidenced. Assimilatory pigments concentration is dependent by both exposure duration and waveform. Photosynthesis process efficiency was stimulated by short exposure duration and for CW, but was slightly inhibited for modulated signals, independent by exposure duration. Nucleic acids content was increased by the CW, while for modulated signals a decreasing trend appears.

**CONCLUSIONS**

Controlled exposure to low level 900 MHz field of *Zea mays* seeds, for duration in the order of hours…tens of hours, induce traceable changes in the assimilatory pigments concentration and nucleic acid content. Plantlets developed from earlier exposed seeds grew faster than the not-exposed ones, after the 12 days period of development.

**REFERENCES**


Comparing Effects of Electromagnetic Fields (60 HZ) On Seed Germination And Developmental Growth In Higher Plants

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INTRODUCTION
The identification of potential simulative effects of ELF-EM on growth and function of plants is of special importance. Pulsed EMFs can be more active biologically than continuous one[2]. Kavi found that seeds exposed to a magnetic fields absorbed more moisture[1]. In the present study we aim to determine effects of different intensities of pulsed EMFs (60 HZ), duration of exposure and their interactions as a stress on C4 (maize) and C3 (canola) plants in different states of seeds.

MATERIAL AND METHOD
Exposure to EMFs was performed by a locally designed EMF generator. The electrical power was provided by a 220 V, AC power supply with variable voltages and currents. This system consisted of one coil, cylindrical in form, made of polyethylene with 12 cm in diameter and 50 cm in length. The number of turns is 1000 of 0.5 mm copper wire. A fan was employed to avoid the increase of temperature (22±1ºC). Calibration of the system as well as tests for the accuracy and uniformity of EMFs (60 HZ) were performed by a tesla meter with a probe type of hall sound. Three replicates, with 30 seeds in each one were used. They were spread in moist filter paper (for wet seeds) on Petri dishes. They were placed in the coil. Analogous groups were used as control. The same numbers of seeds were soaked in the water 12 hours before treatment. Then the same conditions were applied. The wet and dry seeds were exposed to pulsed EMFs (15 min on, 15 min off) by magnitude of 1 to 7 mT in steps of 2 mT and the highest intensity was 10 mT for 1 to 4 hours in steps of 1 h. Then dry seeds in Petri dishes were moistened and all Petri dishes were placed in germinator with 23 ºC temperature. The number of germinated seeds was registered on the 2nd and 6th days after moisturizing in canola and maize. Five 7 days seedlings from each replicate were randomly taken for measuring shoot and root length in cm. Then fresh weights of them were measured. Subsequently, they were dried in an oven at 60 ºC for 24 hours and dried weight of them was measured too. The data was analyzed using the software SPSS12. The variance analyses ANOVA and DUNCAN tests were used to calculate the level of differences of all measured traits among EMFs, duration of exposure and their interaction (P < 0.05)

RESULTS
The results showed that in both C4 and C3 plants, when seeds were imbibed in water 12 hours before exposure (1 mT, different duration of exposure)fresh biomass in 7 days seedlings increased significantly and dried biomass decreased significantly comparing to control. On the other hand wet treated seeds and dry pretreated seeds showed increase in both fresh and dried biomass weight by the same treatment. Seed germination rate of wet treated seeds in maize and dry pretreated seeds in canola showed significant differences between all intensities of EMFs, duration of exposure and their interaction(Fig1). Other developmental growth parameters including: root and shoot length of 7 days seedlings (Fig 2, 3). Fresh and dried biomass weights in canola showed just significant differences between intensities of EMFs(Fig4, 5). On the other hand in maize most of developmental growth parameters in seedlings grown from both wet and dry pretreated seeds showed significant differences between intensities of EMFs, duration of exposure and their interaction (Fig2, 3, 4, 5). The most
significant difference observed at 10mT (p<0.05) In canola, seedlings grown from dry pretreated seeds showed the most significant increase in developmental growth at 10 mT and seedlings grown from wet treated seeds showed the most significant decrease in developmental growth at 10mT comparing to control (p<0.05). In canola, seedlings grown from dry pretreated seeds showed the most significant increase in developmental growth at 10 mT and seedlings grown from wet treated seeds showed the most significant decrease in developmental growth at 10mT comparing to control (p<0.05).

Figure 1: Treated by 10 mT
Figure 2: Treated by 10 mT
Figure 3: Treated by 10 mT
Figure 4: Treated by 10 mT
Figure 5: Treated by 10 mT

CONCLUSIONS
Water consumption of C4 plants are considered to be more efficient than C3 plants. Furthermore in low concentration of CO2 and high temperature, photosynthetic efficiency of C4 plants is higher than C3 plants. Generally, C4 plants are assumed to be more evolved than C3 plants[3]. Fresh biomass weight of seedling grown from imbibed seeds in water 12 h before treatment (by 1 mT) increased significantly comparing to control. In contrast, dried biomass weight from the same seedlings decreased significantly. It is elicited that EMFs exposure increased capacity to absorb moisture. It also stimulate metabolism. These would cause more substances consumption. As a result protein synthesis decrease. Consequently, dried biomass weight decreased. But in seedlings grown from dry and wet treated seeds with 1 mT both fresh and dried biomass increased significantly, which shows augmentation in protein synthesis. Based on these results the rest of experiments carried out on dry pretreated seeds and wet seeds, which were exposed to EMFs immediately after moisturizing. All experimental data and statistic calculations have attracted attention to interaction of EMFs and exposure time. It indicates that certain combination of EMF and duration like 10mT for 3 h in maize seedlings grown from wet treated seeds has highly effects on enhancing most of developmental growth. Therefore, it would be deduced that C4 plants function more precisely than C3. Furthermore, in canola EMFs intensities were highly effective in enhancing or avoiding growth parameters. There is a window at 10mT in wet treated seeds of canola, which negatively interacts and reduce the seedlings growth traits compared to control. Beside, at the same intensity of EMF, seedlings grown from dry pretreated seeds were highly effective in enhancing growth parameters. Therefore in canola two states of seed treatment showed different results. However, we observed an overall stimulating effects of EMFs in maize with respect to developmental growth characteristics. In conclusion, maize as a representative of C4 plants is more resistant than canola (C3) against EMFS as an abiotic stress.

REFERENCES

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A PRELIMINARY STUDY ON THE ROLE OF LIPID RAFTS AND ACID SPHINGOMYELINASE IN RECEPTOR CLUSTERING INDUCED BY 50-HZ MAGNETIC FIELDS  Y. Wang, D.Q. Lu, H. Chiang, and W.J. Sun*. Bioelectromagnetics Lab., Zhejiang University School of Medicine, 388 Yuhangtang Road, Hangzhou 310058, China.

Objective: To investigate the relationship among a 50-Hz MF-induced epidermal growth factor receptor (EGFR) clustering, lipid rafts and acid sphingomyelinase (ASM), and explore the possible mechanism of receptor clustering induced by 50-Hz magnetic field (MF). Methods: Human amnion FL cells were exposed to 50-Hz, 0.4 mT MF for 15 min. EGF treatment was used as positive control. Nystatin was employed to study lipid rafts since it can disrupt lipid rafts structure. The EGF receptors, ASM and lipid rafts were labeled with polyclonal anti-EGFR antibody, anti-ASM antibody and FITC-Cholera toxin subunit B, respectively. The images were observed by laser confocal scanning microscope. Results: Both EGF treatment and 50 Hz MF exposure can induce EGFR clustering. However, nystatin pretreatment could inhibit this effect. MF exposure caused ASM (labeled with Cy3) translocation from a diffused state into a concentrated state on the cell membrane, and co-localized with lipid rafts (labeled with FITC). Conclusion: Based on these results, it suggested that the EGFR clustering induced by 50-Hz MF depended on intact lipid rafts on cellular membrane, and the ASM might participate in the process of EGFR clustering.

[Keywords]: Magnetic fields/electromagnetic fields, Epidermal growth factor, Receptor, Clustering, Lipid rafts, Acid sphingomyelinase (ASM).
INTRODUCTION

The CNS has been shown to have the greatest reactivity to the actions of electromagnetic radiation, particularly, to the extremely high frequency electromagnetic radiation (EHF EMR) [Lebedeva, Kotrovskaya, 2001]. The investigations of responses of the hypothalamic structures, such as supraoptic nucleus of hypothalamus (SON), which provide both adaptation to the changes of environmental factors and maintenance of homeostasis of organism at optimal level in conditions of external and internal factors’ influences are of great interest. Our investigation was aimed at the revealing of effects of 10 days of exposure low-intensity EHF EMR on the spontaneous spike activity of the rats’ SON neurons.

MATERIALS AND METHODS

In acute experiment conditions in vivo extracellular recordings were made from cells of SON of hypothalamus in male albino rats. Rats weighing between 250 and 300 g were anaesthetised with Nembutal at a dose of 40 mg/kg I.P. The stereotaxic orientation of electrodes was performed according to Paxinos and Watson’ atlas [Paxinos and Watson, 2005]. The localization of the electrode tip in the SON was determined at the end of the experiment by histological control. The animals were subdivided into two groups: control and experimental. As a control (6 rats, 78 neurons) we have used data from intact animals because the parameters of spontaneous activity of SON’ neurons of intact and sham-exposed animals were analogously. The impulse activity of supraoptic cells after 10-day-long exposure to the low-intensity EHF EMR was investigated in the experimental group of animals (6 rats, 75 neurons).

Exposure of experimental animal’s head was performed daily for an hour. The long axis of the animal’s head was parallel to the E vector. For irradiation, the animals were not anesthetized. As a source of monochromatic EHF EMR we have used a G4-141 high-frequency generator (Russia). Radiation was performed at room temperature (19-22°C) at the frequency of 42.2 GHz in a continuous generation regime. Power intensity value at the level of the animal was 0.19 mW/cm². The animal’s head was exposed in the vertical direction at a distance of 40 cm from the generator horn with an aperture of 30 mm x 30 mm, i.e., in the far-field zone of the horn of pyramidal antenna. Calculated by formula [Gapeev et al., 2008] value for the specific absorption rate (SAR) is received about 1.5 W/kg on the surface of skin of animals head. The analysis of spike activity of registered cells by the distributions of neurons by the degree of regularity, dynamic structure of neuronal streams and different frequency ranges, as well as the mean spike frequency and the coefficient of variation of interspike intervals (ISIs) in naive control and after treatment was carried out. The evaluation of reliability of changes in distributions of ISIs of supraoptic neurons after 10-day-long exposure compared with control was assessed by $\chi^2$ test. Student’s $t$-test was made to divulge significant differences in changes of the mean spike frequency and the coefficient of
variation of ISIs.

RESULTS

Analysis of autocorrelograms of stationary supraoptic cells by the grade of regularity has shown a predominance of irregular activity registered in control (79.5%); the amount of cells with intermediate-regularity and non-stationary impulse activity was 11.5% and 9% respectively. “Regular” neurons have not been registered in norm. 10 days of exposure to low-intensity EHF EMR was followed by significant (p<0.01) shifts in the distribution of SON’ neurons in terms of the grade of regularity of spike activity. We observed 3.1-fold increase in the quota of neurons with intermediate grade of regularity and 1.5-fold decrease of the proportion of irregular neurons in comparison with the control. The determination of serial correlation coefficients has revealed different types of dynamic structure of current flows. More than half of all recorded in norm impulse flows were characterized by local changes in discharge frequency (56.6%). Among 33.3% of SON’ neurons the train-group activity was observed. Neurons with coincident sequencing of ISIs (2.6%) and monotonic (7.7%) changes in discharge frequency were registered. 10-day-long radiation led to significant (p<0.01) shifts in distributions of supraoptic cells by the dynamics of ISIs sequencing. The changes were mainly noted in increase of proportion of units with coincident (3-fold) and monotonic (2.3-fold respectively) changes of sequence of ISIs. The abrupt decrease in quote of neurons with train-group activity (2.8-fold respectively) was observed as well. The coefficient of variation of ISIs and the mean spike frequency of intact animals’ supraoptic cells were respectively 94.6±3.3% and 22.7±1.9 imp/s. The analysis of SON’ neurons distribution by different frequency ranges has shown a prevalence of mid-frequency cells in control (50.7%). The low- and high-frequency units were observed 22.5% and 26.8% respectively. The significant decrease of mean spike frequency to 17.5±1.5 imp/s (p<0.05) was observed after the 10-day influence of factor. It was accompanied by appropriate, although non-reliable, changes in distribution neurons by the different frequency ranges. The increase in proportions of low- and mid-frequency cells to 28.9% and 55.1% respectively, as well as decrease in share of high-frequency units to 16.0% were observed. The value of ISIs’ coefficient of variation was changed insignificantly (to 97.7±3.1%).

CONCLUSIONS

Our study has revealed changes in the spike activity of SON’ neurons after 10-day-long influence of low-intensity EHF EMR, concerning both of internal structure and of statistic parameters of the registered impulse streams. The 10-day-long influence of EHF EMR led to the changes of neurons excitability which is manifest as the suppression of spike activity of supraoptic neurons.

REFERENCES
DIRECT INTERACTION OF ELECTROMAGNETIC FIELD WITH LONG RANGE ELECTRON TRANSFER. A KEY TO BIOLOGICAL EFFECTS?

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INTRODUCTION

It is suggested that harmful biological effects may be related to non ionizing radiation through enhancing a damage already done by ionizing radiation, when the range of charge migration in protein is increased under the influence of time dependent electric field. Calculations of time dependent electronic wave function at donor-bridge-acceptor system in presence of static and oscillatory electric field, oversimplified by ignoring all effects of intervening medium, support that assumption. Main result is that the strength of field counts at the location of interaction with the biological material and not the energy absorbed. Non thermal biological effects are rendered possible.

BACKGROUND

Long range electron transfer (LRET) is related in the literature to health damage. LRET of unpaired electron may extend the target size for radiation-induced damage of subcellular structures [1]. DNA damage produced e.g. by direct effect of ionizing radiation or chemical oxidation involve transfer of electron away from the DNA[2a]. Migration of charge over long molecular distances should be considered with respect to DNA damage[2b]. A conjecture of Szent-Gyorgyi [4], on the contrary, is that hindering electron flow is hazardous. Typically the electron transits from donor D to empty acceptor A by tunneling through intermediate high lying empty electronic states ("bridge"- B) [5,9].

RESULTS OF CALCULATION

Demonstrate the effect of static and oscillating electric field on the tunneling process for two values of barrier height separating the donor and acceptor. The electron is treated quantum mechanically. Time dependent electric field is treated as a classical variable. Time dependent wave function at the donor(0), acceptor(N) and the intermediate sites\(\{n\}\) is

\[
\Psi(t) = C_0(t)|0\rangle + \sum_{n=1}^{N-1} C_n(t)|n\rangle + C_N(t)|N\rangle
\]  

(1)

Equations of motion for the amplitudes \(C(t)\) at donor, acceptor and intermediate sites are(h=1)

\[
\dot{C}_0 = -iE_0C_0 - iAC_1, \ C_0(0)=1
\]

(2)

\[
\dot{C}_n = -iE + V(n-1)\cos(\omega t)C_n - iA(C_{n-1} + C_{n+1}) , \ C_n(0)=0 \quad n=1,N-1
\]

(3)

\[
\dot{C}_N = -iE_0 + V(N-1)\cos(\omega t) - iAC_{N-1} , \ C_N(0)=0
\]

(4)

\(E-E_0\) is the barrier height referring to \(0<n<N\). Intersite coupling \(A\) is taken to be equal for all next neighbors. Unit of energy is electron volt. \(V=eFa(eV), F\) is the field strength in Volt per Å, \(e\)-electron charge, \(a=distance\ between\ neighbors\ in\ Å\), \(\omega\) is frequency. Only \(V\) is an explicit parameter here.

Results are presented in Figs. 1-2. At barrier height of 7 eV (Fig.1), static field of about \(10^3\) eV/Å, (still huge macroscopically - see "FINAL REMARKS" section), strongly reduces the electron tunneling as far as the frequency is below 1THz. At 10THz the field loses its effect completely. Fig 2 shows that at barrier height of 0.5 eV and A=0.1eV, there is no tunneling at all in absence of field ,but sinusoidal field with parameters given in the plot , enables strong transfer to 12\(^{th}\) site. Not shown here is that time at which acceptor’s population reaches its maximum is inversely proportional to \(\omega\) since it depends on the phase \(\omega t\), so lower frequencies are effective at longer tunneling time.
FIG. 2

a) donor occupation without a field.

Intersite interaction=0.1eV , barrier height=0.5eV

b) donor and 12th site occupation

Field strength =10^-3 Volt per intersite interval. \( \omega = 3 \text{THz} \)

FIG 1. Population of initially unoccupied 6th site as function of time in units of 10^-15 sec.

Intersite interaction=1eV, barrier height =7eV

Field strength=10^-3 Volt per interval length.

Frequencies are as shown.

CONCLUSIONS

1) Non-ionizing radiation may extend the range of electron migration along protein chain or even be responsible for its very existence. Thereby may cause damage related to ionizing radiation by means of enhancing the effects of the later. 2) The above said effects are non thermal, be the strength and frequency of radiation as high as they are. Energy is not absorbed into the intervening medium. 3) In case of high barrier and low enough frequencies (Fig 1) transfer is blocked ; thereby, according to [4] damage may be done to the cell.

FINAL REMARKS

The high values of field obtained in the calculations refer to D-B-A system in air. Rate of ET will be modified by local EM environment. Lorentz model for local field in a dielectric medium [3], reliable for gas, is surprisingly successful experimentally in solids [7,8]. Assuming that the D-B-A system is located in a cavity inside a biological material with very high values of the imaginary part of dielectric constant at low frequencies [6,3] the magnification of the external field can be so huge that 100V/m external field leads to the value shown in our calculation; seems to be gross overestimation but a motivation for further research based on analytical and numerical calculation of local field inside biological material [10] and the overall role of the medium in large range of frequencies[7,8 ].

REFERENCES

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The Effects of Water Structures, on Its Electrical Properties and Biological Systems
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University of Colorado at Boulder
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INTRODUCTION
In this paper some of the structures that water forms will be reviewed as a starting point for understanding how they affect the electrical properties and how water molecules shield ions and bind to biological molecules. The unique behavior of water is largely due to dynamic hydrogen bonded networks that exist when water is in its liquid form. Hydrogen bonds are weak at room temperature, so the clusters due to hydrogen bonds are constantly forming and breaking up [1]. They form many different structures with lifetimes on the order of $10^{-7}$ seconds. These structures modify the dielectric constant and conductivity of water and the mobility of ions in solution. Hydrogen bonds are a controlling force for the configuration of biological molecules.

MATERIALS AND METHODS
Recent advances in computer modeling have made it possible to generate models for many of the dynamic structures that water molecules form. Coupling some of these recent results with earlier work in the literature provides some insight into the measured values for the mobility of various ions and thus the conductivity and dielectric constants. The material presented is based on an extensive review of the literature.

RESULTS
Computer calculations show that water molecules can form a wide variety of structures some of which are shown below in Figure 1[3].

Figure 1: Some of the many water molecule clusters.
Reference [2] suggests that the most stable form of (H2O)6 is a cage-like structure and many larger clusters have also been simulated. Some simulations for the water molecules surrounding ions are shown in Figure 2[4].

\[
\text{Na}^+(H_2O)_{20} \quad \text{Cl}^-(H_2O)_{17} \quad \text{Na}^+(H_2O)_{100}
\]

**CONCLUSIONS**

If the average mobility that are shown in Table 1 of these dynamic structures is taken into account one can begin to understand the relative conductivities. For example proton transfer through water structures that are held together by hydrogen bonds leads to a very high mobility for the H+ and OH- ions and thus their high conductivity and the relative mobility for ions such as Na+ and K+ are reduce by the structure of the water molecules surrounding them. Farther information will be presented on how hydrogen bonds and water molecules effect the configurations of protein molecules and their mobility.

<table>
<thead>
<tr>
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<tr>
<td>Na⁺</td>
<td>[Fe(CN)₆]⁴⁻</td>
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<tr>
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<td>7.63</td>
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<td>[N(CH₃)₄]⁺</td>
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<td>Zn²⁺</td>
<td>SO₄²⁻</td>
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<tr>
<td>5.47</td>
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</table>

Table 1: Ionic mobilities in water at 298 K, \(u/(10^8 \text{ m}^2 \text{ s}^{-1} \text{ V}^{-1})\)

**REFERENCES**


Characterization of Micelle System in Presence of an External Electric Field: a Molecular Dynamic Study

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INTRODUCTION

Recently, colloidal carrier systems as micelles have been receiving much attention in the field of drug delivery and gene targeting because of their high loading capacity for chemicals [1]. In particular, intelligent drug delivery systems are mostly based on stimuli-responsive polymers, which sense a change in a specific variable (as for example an electric field) and activate the delivery [2]. Moreover, it is well known that the use of high intense electric fields pulses applied to cell membranes may reversibly modify the lipid membrane permeability [3]. A similar response could be hypothesized for micellar systems. The objective of the present work is to understand, by means of molecular simulations, if an exogenous electric field could interact with molecular nano-carriers modifying their capacity to entrap nano-particles.

MATERIALS AND METHODS

Molecular dynamic (MD) simulations of a water-micelle system have been performed using GROMACS MD package [4], which treats complex systems by means of classical physics structure at atomic-level. Interactions between atoms are modeled by a potential function including both inter and intra-molecular interactions. The simulated system includes a single zwitterionic micelle made up of 55 lipids (TDDNO: N, N-dimethyl-tetradecylamine-N-oxide) and 14123 water molecules (considered as SPC: Simple Point Charge). Simulations have been performed at T=300K with the isokinetic temperature coupling [5] (step of 2 fs) and with the Particle Mesh Ewald (PME) [6] method for treating long-range electrostatics.

RESULTS

Initially all lipid molecules have been placed at the centre of the simulation box (cubic, side 7.66 nm) and an energy minimization followed by thermal convergence has been carried out, letting the micelle to reach a stable condition (Fig. 1). Successively a simulation has been performed for a 50 ns time-length, considered as a suitable time to study the dynamical properties of the system. Simulations in exposure conditions included the presence of a homogenous static electric field, at intensities of 10^5 and 10^6 V/m, typical of the nano-pulses electric field applications. All simulations allow free rotation of the micelle.

Micelle geometry and its fluctuations have been studied by means of the 3x3 Covariance matrix, whose elements stand for covariances among the vectors representing the cartesian coordinates of the lipidic ensemble. The eigenvectors correspond to the geometric principal axis of the micelle (geometrically approximated by an ellipsoid) with the eigenvalues providing a measure of the axis lengths. The time-behaviour of the micelle eigenvalues is shown in Fig. 2 and indicates that the micelle structure maintains its ellipsoidal shape over the whole 50 ns time-length. Note that for all the external electric fields intensities we obtained,
within the thermal noise, identical behaviour. In Fig. 3A is reported the water density profile along the radial direction from the micelle centre towards the bulk water. The inset of the figure reporting the water density ratio between unexposed and exposed case, shows how the external field ($10^5$ V/m), influencing the arrangement of water molecules inside, depletes the idrophobic core of the micelle. An overall difference in Helmholtz free energy up to 4 kJ/mol (Fig. 3B) is obtained with this kind of exposure. Such results suggest that water molecules (and, in principle, even other types of solute molecules) are pushed away from micelle’s core when an electric field is applied, whereas are caught inside when field disappears. It is also interesting to investigate the electric potential profile along micelle’s principal axis (Fig. 3C), whose gradient represents the local field acting on micelle’s system.

CONCLUSIONS

A rigorous molecular description of a water/micelle system has been obtained; results seem to show a direct effect of an exogenous homogeneous electric field on water molecules distribution inside the micelle’s environment, as well as a thermodynamics effect.

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PEMF Potentiates the Induction of Nitric Oxide by Glutamate and 6-Hydroxydopamine in a Neuronal Cell Line

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INTRODUCTION

Nitric oxide (NO) is essential for neuronal viability, but it can also be toxic in high concentrations. Generally, neuronal nitric oxide synthase (nNOS) produces NO that participates in survival signaling pathways. During inflammation, inducible NOS (iNOS) produces 10-fold greater amounts, resulting in toxicity. Using a cell line of rodent dopaminergic neurons, we used glutamic acid, a neurotransmitter and excitotoxin, and 6-hydroxydopamine (6-OHDA), an oxidative stressor, to model the initiating events of the neurodegenerative process. Both of these insults cause a transient increase in cytosolic free Ca2+, which activates resting calmodulin (CaM), a calcium binding protein. This is known to rapidly activate the Ca2+-dependent NO cascade as the body attempts to control inflammation. In this study we tested the effects of specific PEMF signals configured to enhance Ca2+ binding to CaM to activate the synthesis of NO in the presence of both neurotoxins.

MATERIALS AND METHODS

MN9D, a rodent dopaminergic hybrid cell line, was provided by Dr. Alfred Heller at the University of Chicago. Cells were dissociated, plated in 35 mm culture dishes, and allowed to attach for at least 24 hours before treatment. For experiments, cultures were equilibrated in Krebs buffer for 10 minutes, after which 30 µM 6-OHDA, 100 µM glutamic acid, or buffer alone were added. A PEMF signal, configured a priori to accelerate the kinetics of Ca2+ binding to CaM, and consisting of 5 msec bursts of 27.12 MHz sinusoidal waves at 5 bursts/sec and 0.05 Gauss peak amplitude, was administered beginning two minutes prior to the addition of toxin. Control cultures were subjected to “null” signals under identical conditions. NO levels were measured by an electrochemical detection system (WPI) in real time from equilibration in Krebs buffer until the effects of the added toxins or buffer were no longer detectible. NOS inhibitors were added at least 30 minutes prior to toxins and PEMF signals. NO levels were calculated from the maximum change in current induced by toxin ± PEMF treatment minus the values obtained by adding buffer alone. Data were compared by ANOVA and Fischer’s PLSD post-hoc tests.

RESULTS

The selective dopaminergic neurotoxin 6-OHDA produced a rapid 500 nM increase in NO within 10 seconds. NO production decayed over 2 minutes, returning to baseline levels. When PEMF signals were applied to culture dishes prior to and during the addition of toxin, this increase was potentiated more than 200%, with measured NO concentrations of 900 nM. To confirm that this increase was due to NO synthesis, treatments were repeated in the...
presence of 3.3 mM L-NAME, a non-selective NOS inhibitor. Results indicate that L-NAME diminished NO levels to 33\% of cultures treated with 6-OHDA alone, and to 24\% of NO levels induced by 6-OHDA + PEMF. Similar results were obtained in the presence of glutamate, an established endogenous neurotransmitter that acts on dopaminergic neurons through both ionotropic and metabotropic receptors. With this stimulant, the increase in NO production was lower in magnitude, increasing NO levels less than 100 nM. PEMF signals potentiated this increase by 133\%. Neither 6-OHDA nor glutamate were toxic over this time course.

CONCLUSIONS

Our results demonstrate very rapid and transient effects of PEMF signals on NO synthesis in a neuronal cell line in two models of dopaminergic cells death. While higher concentrations of toxins and longer incubations may result in toxicity, the effects observed here are immediate early events in response to toxic challenge. While 6-OHDA causes oxidative stress, there is also an inflammatory response to this compound in vivo and in vitro that may be inherent to dopaminergic neurons themselves even in the absence of other cell types. In contrast, glutamate-mediated cell death involves the influx of calcium ions through receptor ion channels. Importantly, relatively low-level increases in NO production have been shown to initiate neuroprotective signaling cascades that could increase resistance to both of these insults. Experiments to distinguish the role of inflammatory events and calcium influx in the mechanism by which PEMF affects NO signaling are in progress.

ACKNOWLEDGMENTS

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Anomalous Heating in a Living Cell with Dispersive Membrane Capacitance under Pulsed Electromagnetic Fields.

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INTRODUCTION

The specific capacitance of living cell membranes may be frequency-dependent [1],[2]. In the spectral bands where the membrane specific capacitance drops significantly, most of the absorbed power can be dissipated in the membrane. For pulsed fields acting on timescales (much) shorter than those of thermal diffusion across the cell, this may result into rapid increase of the local membrane temperature up to possible biological damage, even at low perhaps non-thermal field levels [3].

In order to obtain an estimate of cell membrane heating under such circumstances, a semi-analytic solution of the electromagnetic + full heat-diffusion problem for a homogeneous spherical cell with (linearized, dispersive) membrane admittance embedded in a homogeneous lossy half-space and exposed to a pulsed-electromagnetic field is derived, under a quasi-static approximation. Numerical simulations using a toy membrane dispersion model are presented.

EM HEATING IN A SPHERICAL LIVING CELL

We consider an insulated spherical cell with radius $R$ embedded in a uniform unbounded medium exposed to a $\hat{z}$-polarized electromagnetic field. In the quasi-static approximation the average power dissipated in the membrane ($P_m$) and cytoplasm ($P_c$) is given by [4]:

$$P_m(\omega) = \frac{3\pi}{2} R^4 \frac{\sigma(\omega) E^{(inc)}(\omega)}{\sigma(\omega) + (3/2) R Y_m(\omega)} \left| \text{Re}[Y_m(\omega)] \right|^2,$$

and

$$P_c(\omega) = \frac{\sigma(\omega)}{2} \int_{(cytoplasm)} |E^{(inc)}|^2 dV = \frac{2\pi}{3} \sigma(\omega) R^3 \left| -\frac{\sigma(\omega)}{\sigma(\omega) + (3/2) R Y_m(\omega)} \right|^2 |E^{(inc)}|^2.$$

where $\delta_m$ is the membrane thickness, $\sigma_m(\omega)$ and $\sigma(\omega)$ are the cell membrane and cytoplasm conductivity, respectively, while $Y_m(\omega) \equiv \sigma_m(\omega) \delta_m^{-1} + j\omega \tilde{C}_m(\omega)$ denotes the cell membrane complex specific admittance for which we adopt the following toy model membrane (specific) capacitance:

$$\tilde{C}_m(\omega) = \tilde{C}_{\text{max}} + \tilde{C}_{\text{min}} - \frac{\tilde{C}_{\text{max}}}{2} \text{Erfc}\left[-\left(\frac{\omega - \omega_0}{\Delta\omega}\right)^2\right].$$

where $\omega_0$ is the center frequency of the dispersion band, $\tilde{C}_{\text{min}}$ and $\tilde{C}_{\text{max}}$ are the minimum and maximum values of the membrane specific capacitance, while $\Delta\omega$ and $q$ affect the width and steepness of the dispersion window. The ratio between (1) and (2) can be a very large number if $|\sigma(\omega)| >> R|Y_m(\omega)|$ [4].

SIMULATION AND RESULTS

We solve numerically the inhomogeneous heat diffusion equation
\[ \rho_{m,c} C_{p,m,c} \frac{\partial T_{m,c}}{\partial t} - \frac{k_{m,c}}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial T_{m,c}}{\partial r} \right) = \dot{Q}_{m,c}, \quad (4) \]

under the following boundary conditions:
\[ n \cdot (k_{m,c} \nabla T_{m,c}) = 0 \text{ on the outer boundary of the extracellular medium (Fig.1)} \]
\[ T_m(r, t) \big|_{r=0} = T_c(r, t) \big|_{r=0} = T_0 \quad r \in (0, R + \delta_m) \]
\[ T_m(r, t) \big|_{r=R} = T_c(r, t) \big|_{r=R} \]

Here the suffixes \( m \) and \( c \) refer to the membrane and cytoplasma, respectively; \( \rho, C, k \) are the density, heat capacity and thermal conductivity, respectively; \( T \) is the temperature, and the problem’s geometry is shown in Fig.1.

In Fig.2 we show the temperature in the cell membrane (continuous lines) and cytoplasma (dotted line) vs time for an electromagnetic pulse with duration \( 10^{-9} \)s and SAR \( 10^8 \)W/kg. The red line refers to a pulse with the same energy and duration \( 10^{-8} \)s. It is interesting to note that increasing the pulse duration at constant pulse energy produces a slower temperature raise. The temperature increase in the cytoplasma is negligible insofar as the thermal time constant of the membrane is comparable with the pulse duration, the thermal time constant of the cytoplasma being larger by a factor \( \sim (R/\delta_m)^2 \).

CONCLUSIONS

The possible effect of dispersion in the membrane specific capacitance on the spatial localization of the power dissipated in a spherical cell exposed to an incident EM field has been investigated. Strong absorption peaks and fast heating in the membrane may occur at frequency bands where the membrane would be unaffected in the absence of dispersion. Numerical simulations suggest that, at fixed pulse energy, the shorter the pulse duration, the higher the membrane temperature increase.

REFERENCES

Genetic Thermometry Demonstrates Intracellular Heating Is Not Responsible For Bacterial Inactivation In Low Power Electromagnetic Fields

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INTRODUCTION

In the context of low power EMF exposures, the extent and consequences of intracellular heating has been a tenuous topic in the field of bioelectromagnetics. We present an in-situ method to observe cytoplasmic heating during EMF exposure, by measuring color intensity associated with the activity of intracellular proteins genetically engineered to report temperature increases between 1-2°C increments. A mutant E. coli culture, hosting a stable temperature sensitive plasmid which controls galactosidase activity, experienced no significant increases in cytoplasmic temperature, through a range of lethal EMF exposures.

MATERIALS AND METHODS

The LacI-ts protein controls expression of β-galactosidase (β-gal or LacZ) by binding to a specific operator sequence (lacO) located in plasmid DNA. β-gal production can be reliably assayed in bacterial culture, as it catalyzes the conversion of X-gal (5-bromo-4-chloro-3-indoyl-beta-D-galactopyranoside) to insoluble blue (5,5’-dibromo-4,4’-dichloro-indigo), which has its peak absorbance at 630nm. The ts mutant plasmid we utilize (pA199A2-Its241Z) is stable in E. coli, and was developed to reduce costs for transgenic protein production [1]. We have adapted this plasmid for the express purpose of reporting intracellular heating in response to different environmental challenges— including EMFs. Of note, LacI-ts is an intercellular protein whose binding to lacO predictably denatures in response to cytosol temperature (i.e. sensing); this makes the assay of activity a true measure of intracellular temperature effects.

E. coli carrying pA199A2-Its241Z are maintained in a constant log-phase growth condition in a chemostat fed with sterile nutrient broth amended with carbenicillin. Cells are harvested by centrifugation and resuspended, in either phosphate buffered saline (PBS) for later culturing, or PBS including 1%v/v dimethylsulfoxide (DMSO) and 0.08mg/mL Xgal for temperature assay. Cells are then immobilized on sterile 25mm diameter filter coupons incubated in parallel under otherwise identical conditions at room temperature (- control); 40°C (+ control); or in a low power EMF. After 1 hour, the coupons are removed and cells eluted with PBS including 0.01% tween 80, counted by direct microscopy, and plated to nutrient agar with carbenicillin. Parallel filters with Xgal are extracted (beadbeater) in acetone (1mL CH3COCH3) using 500µL 0.2mm diameter glass beads for 1 min, and the extract spectrophotometrically assayed at OD630.

RESULTS

We have demonstrated that this colorimetric assay is robust with respect to β-galactosidase activity and linear over a broad temperature range, 25-45°C (R²=0.99), spanning above and below the optimal growth temperature of E. coli, 37°C (Figure 1). As temperature based inactivation of E. coli begins at 42°C, the dynamic range of this assay is appropriate for these inactivation studies. We observed greater than a 2 log inactivation of E. coli in an electrically enhanced filter hosting field strength of approximately 4 kV/cm for an hour, while there was no concomitant increase in β-gal activity in those same cells above a
room-temperature control. A parallel positive control heated to 40°C showed a 250% increase in β-gal activity as judged by insoluble blue production (Figure 2). These results suggest that no intracellular temperature increases were realized in *E. coli* cells subject to extended EMF exposure conditions.

**CONCLUSIONS**

We conclude that utilizing a temperature sensitive mutant, we can accurately assay intracellular temperature increases in near real time regardless of environmental challenge. Further, we observe no intracellular heating, even in cases of acute bacterial inactivation resulting from electromagnetic field exposures in field strengths less than 4kV/cm.

**ACKNOWLEDGMENTS**

StrionAir Incorporated, Louisville, Colorado.

**REFERENCES**

Physiological Responses of ELF Electric Field Exposure during the Mental Work Load Task
- Study on the Mechanism of the Field Effects -

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INTRODUCTION

In our previous study, we have found that the local exposure of ELF electric field suppressed the natural decrease of skin temperature [1]. This suggested the effect of field exposure on autonomic nerve response. To clarify this mechanism, the palm perspiration was measured in the same protocol as the skin temperature measurement. The results showed the suppression of the palm perspiration which indicated the suppression of the skin sympathetic nerve activity [2]. As we put the finger on one mechanism of the field effects, we conducted the new type experiment introducing a mental work load task to confirm the mechanism.

METHODS

Skin Conductance Change (SCC): In the experiment, the temporal change of the SCC was measured instead of palm perspiration which appears in strain condition as mental sweating. The SCC is used in the study of psychophysiology to evaluate the skin sympathetic nerve activity. The measurement method of the SCC was followed by the advice of the Society for Psychophysiological Research. The relation between the SCC and the palm perspiration was studied using perspirometer and the variations of two parameters agreed well.

Telemeter: The small size SCC telemeter (40x52x17 mm\textsuperscript{3}) was developed and the feasibility was verified. The sensor parts of the SCC telemeter were placed on the index finger and the middle finger of a subject’s left hand. The case of the telemeter was shielded and ELF noise reduction circuit was installed.

The ECG telemeter (60x80x18 mm\textsuperscript{3}) was developed and the feasibility was verified also. The ECG electrodes were placed focally on a chest over a heart and the telemeter case was placed on the electrodes. Further, the telemeter and the electrodes were covered with a copper film as the shield.

Experimental condition and protocol: Experiments were carried out from 1 p.m. to 6 p.m. in a controlled environment. The room temperature and the humidity were 22.5-23.5 degrees C and 30-50 %, respectively. The subjects were 20-22 years old healthy male volunteers.

Prior to the experiment, the purpose, the possible risks and the procedure of the experiment were explained to each subject, and the consent was obtained. The experiments were carried out in the double-blind method.

To confirm the suppression effect on the sympathetic nerve activity of the ELF electric field exposure, the well-known Kraepelin test was introduced as a mental work load task to raise the subject’s sympathetic nerve activity. The responses of the SCC and the heart rate under execution of the Kraepelin test were confirmed before the experiment. Each parameter showed the increase of the sympathetic nerve activity.

The time course of the experiment was as follows. A subject sat on the chair of the therapeutic device and kept rest for 10 minutes. Then he was instructed to execute the Kraepelin test for 20min. and kept rest again for 10 minutes. An electric field was applied to
him for 20 minutes from the start of the Kraepelin test.

The 50 Hz electric field was exposed to the subject using the therapeutic device. With this device we could apply 30 kV to the soles of the subject through an insulating plate. As a result, the field up to 300 kV/m was exposed to his head and about 100 kV/m to his hand. The electric field was applied without any noticeable cue following the rest period. Then the electric field was switched off without any cue, as well.

The temporal changes of the SCC and the ECG were measured to monitor the autonomic nerve response. The physiological parameters were measured in 200 Hz sampling rate. The data were divided into 8 analyzing sections (rest 1, rest 2, expo.1, expo.2, expo.3, expo.4, rest 3, rest 4) of 5 minutes period.

RESULTS

Figure 1 shows the temporal changes of the SCCs. The measured values were averaged in each time section and normalized individually as the ratio to the value of the "rest 2" period. The SCC increased when the subject executed the Kraepelin test in both condition and decreased slightly after the test. Because the subject was forced to keep same posture with his left arm fixed through the experiment, physical and mental stress was applied to the subject, and the increase of the SCC as a mental sweating lasted even in the later rest periods. Comparing with the exposed case and the sham exposed case, the SCC was suppressed on the former case in the Kraepelin test period without statistical significance.

Next, the heart rate was analyzed by measured ECG. The data were also normalized as the way mentioned before for comparison. Each heart rate was increased with the execution of the test and returned to previous level after the test on both experimental conditions. Then no difference was observed between both conditions in the heart rate variations.

These results of the SCC and the heart rate suggested that the field exposure supposed to suppress the response from the skin sympathetic nerve system but had no effect on the response from the heart sympathetic nerve system.

CONCLUSIONS

To confirm the mechanism of the ELF electric field effect on a human body, the well-established Kraepelin test was introduced as a mental work load task to raise the sympathetic nerve activity. Using this test, the SCC due to the mental perspiration and the heart rate were analyzed. As a result, the increase of the SCC supposed to be suppressed by the field exposure under the mental work load condition. This suggested that the ELF electric field suppressed the skin sympathetic nerve activity. Further study was required to confirm the mechanism.

REFERENCES

Exposure to 60Hz ELF in Apartment Building with Built-in Transformer Stations in Korea

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INTRODUCTION

The International Agency for Research on Cancer[IARC, 2002] has classified extremely low frequency(ELF) magnetic fields (MF) as a possible human carcinogen (class 2B). This classification was based on limited evidence from epidemiological studies of an association between residential ELF MF exposure and childhood leukemia. Apartments in multi-level residential buildings located above transformer stations (TRS) might offer the possibility of conducting epidemiological studies of residential MF exposure that include higher exposure levels than previous studies, avoid selection bias and minimize confounding factors. Thus, an epidemiological study focusing on populations living in apartment buildings with transformer stations is likely to reduce the uncertainty surrounding the association between ELF MF and childhood leukaemia [1].

The aim of the study is conducted to characterize ELF MF exposure profile in indoor space and above transformer that are located in the apartments.

MATERIALS AND METHODS

Measurements are being in 30 apartment buildings, 20 multi complex building. To get a more representative sample, measurements were taken in Seoul, Korea. In each building, one apartment directly above the transformer station was included in the study. The transformers were selected as a random sample, but technical details of the transformer stations were obtained from the utilities to be able to study the relationship between structural characteristics and MF exposure level. In each building, three apartments were selected for measurements. The apartments with room or rooms directly above the transformers were selected as exposed or index apartments in the same buildings, half of them on the same floors as the “exposed” apartments, randomizing the location on that particular floor.

Measurements are being between January and April 2009. Short-term spot measurements were taken in every room of the residence using ELF MF meter (EMDEX II, Enertech, Campbell, CA, USA). Broadband (Bb 40–800 Hz) component of MF was measured at selected measuring points. In each room, one measurement was taken at the centre of the room and four measurements at 1.4 m away from the corners, at the height of 0.5 m. For further analysis, the average of these five measurement data was to be considered as the data of the room exposure. In the bedroom(s), an additional measurement was taken at the centre of the beds. In addition, one short-term spot measurement was taken at the front door of each apartment. A 24-h MF measurement was taken in the bedroom in four buildings at the height of 0.5 m with a statically placed recording MF meter set to register field strengths every 5 s.
RESULTS

The results of spot measurements of values in apartments on the same floor as the index apartments, but not immediately above transformer rooms, tended to be similar to those in apartments on higher floors. In the apartments above the transformers, the highest values were observed in the living rooms and the bedrooms and lower values were observed in the kitchens and second bedrooms, probably reflecting the relative location of these rooms to the bus-bars or low-voltage cables. This study is being conducted to characterize ELF MF exposure profile in indoor space and above transformer that are located in the apartments.

REFERENCES


EFFECTS OF 53.37 GHz RADIATION ON CATIONIC LIPOSOMES

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INTRODUCTION

As reported in literature biological response to millimeter waves (MMW) appears deeply related to the frequency range and the level of power radiation [1-2]. A part from the thermal effects that occur at high powers (>10 mW/cm²), it was conjectured that the interaction between MMW and most systems could involve resonant/non-thermal mechanisms at very low powers [3-5]. Recently we have observed that low-intensity 53.37 GHz radiation of giant vesicles results in physical changes, induced diffusion of fluorescent dye di-8-ANEPPS, and increased attraction between vesicles. These effects are reversible and occur only during irradiation with a “switch on” of the effect requiring a short time [6]. In order to obtain more information on these phenomena, here, we used cationic liposome loading carbonic anhydrase to reveal real-time changes on lipid bilayer permeability induced by low-intensity 53.37 GHz radiation.

MATERIALS AND METHODS

Cationic liposomes consisting of dipalmitoylphosphatidyl choline, cholesterol and positive charged stearylamine (SA) at 5:3:2 molar ratio, entrapping Carbonic Anhydrase (CA) were used [7]. The influx of the substrate p-nitrophenyl acetate (p-PNA) across intact DIA liposome bilayer was followed by means of spectrophotometric measurement of CA enzymatic activity. The vesicle suspension was placed in a dish of the exposure chamber and subjected to either 53.37 GHz radiation or sham exposure, i.e. when the 53.57 GHz radiation was turned off. The irradiation was intermittently turned on and off during the measurements of the CA activity carried out in real time by mean of an optical probe inserted into the dish (Fig.1). An upward irradiation was applied on the samples by using a conical horn antenna (IMG-53.37, Micro Med Tech, Russia) with 34 mm of maximal diameter (D) and an output power of 39 mW. The distance (R) of the centre of the exposure dish from the horn antenna was 8 cm and the incidence angle was 35°. As 53.37 GHz has a free space wavelength (λ₀) of 5.6 mm, the above cited distance R was less than the minimum distance (R_ff) required for the far field condition to hold, that is R_ff = 41 cm, where R_ff = 2D²/λ₀. However, our conditions of R > D and R >> λ₀ are generally accepted as defining the far field, thus locally, and for our purposes, the wave may be considered as being a plane wave. The exposure chamber was simulated and used to numerically calculate the power density and the absorbed power distribution inside the aqueous sample by using a commercial code (CST-MWS2008 from GmbH, Lautenschlagertstr. 38, D-64289 Darmstadt) based on the Finite Integration Technique (FIT) [8].

RESULTS

We assume that at 53.37 GHz the relative permittivity of the sample is ε_r=14-j24, the skin depth (δ) is 0.34 mm, the conductivity σ is 71.2 S/m, the mass density ρ is 1000 Kg/m³ and the wavelength (λ) in the medium is 1.22 mm. Simulation data demonstrated that, as expected due to the high conductivity of the water, power density and SAR average levels (SAR_avg) had
their maximum values on the surface of the sample. They were calculated both for the whole sample and for different layers, more details on this method are reported elsewhere [9]. They resulted to be 0.085 W/Kg for the whole sample and 0.53 W/Kg for the upper layer, so that 3.3 mW/cm² power densities over sample surface is revealed.

The CA is mainly encapsulated (80%) into the aqueous interior of liposomes. When the substrate (p-NPA) is added in the bulk aqueous phase, upon its permeation across the lipid bilayer, it can reach this trapped CA to be converted into the reaction product (p-nitrophenolate anion). Thus the substrate hydrolysis rate, expressed as ΔA/min, can be used to track bilayer permeability changes. On a CARY 50 spectrophotometer we followed, for four minutes, the appearance of reaction product at its peak absorbance at λ = 400 nm. The value of ΔA/min in sham liposomes (i.e. no irradiation) was 0.0028 ± 0.0001 (n=12), indicating that an amount (20%) of the total CA is sticking onto their external surface. To determine the total amount of CA (100%) a detergent treatment was carried out to completely disrupt the liposomes. Preliminary results showed that when liposome samples were subjected to intermittent irradiation (MMW-on for 1.5 min- off for 1.5 min) during the kinetic measurements no significant changes on the substrate hydrolysis rate resulted. Further experimental and theoretical studies are ongoing.

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INTRODUCTION

When risks are unclear or highly controversial, precautionary measures are called for to reduce the potential for risks and also oftentimes to primarily affect risk perceptions. Understanding how risk perceptions are influenced by precautionary measures is a critical component of the efforts to improve risk communication strategies and, indeed, risk management practices [1-3]. In a multi-national (9 +3 nation) research project, survey experimental studies were performed to obtain crucial scientific data related to understanding trust, risk and benefit perception of mobile communication technology by the general public in regards to the issue of precautionary measures towards both mobile phones and base stations. Contrary to the prevailing assumption that implementation of precautionary measures, or more precisely communicating or informing about taking such precautionary measures, will increase trust, alleviate fears, and reduce risk perceptions in the general public, previous findings from Western & Middle European countries [2-4] indicated that the opposite effect may be observed. Data analyses for the ISEP study in these countries support the previous observations. Various theoretical hypotheses may be posited to explain this countervailing effect.

MATERIALS AND METHODS

To verify whether this effect holds true across larger sample sizes and across different cultures and countries, an international comparative study was performed in nine countries using a standardized survey experiment that, however, was culturally adapted. Survey variables included the information about the level of precautionary measure, the basic intention behind implementing it, and the order of addressing base stations and mobile phones. 400 respondents in each country rated their perceived risks, trust in public health protection, and benefits, and in addition self-reporting their own mobile phone usage patterns.
RESULTS
While the data for the Western & Middle European countries, and in addition the United States data, supports our hypothesis of a countervailing effect (i.e. increased risk perceptions) for information about precautionary measures, other countries have shown an effect more in line with prevailing assumptions. India, specifically, demonstrated an opposite effect – namely a reduction in risk perception – compared to observed effects in Germany, United Kingdom, Netherlands, and the USA.

Statistically significant effects were seen across the study for the survey measures of personal threat (risk perception) and trust in public health protection, for some but not all the countries. Fig. 1 serves as an example of the effect on risk perception.

CONCLUSIONS
Our multi-national, cross-cultural study emphasizes the significance of understanding and incorporating risk perception knowledge in the development of country-/culture-specific risk communication strategies. Information about certain precautionary measures must be carefully designed so as to affect risk and trust perceptions in risk communication challenges to the expected extent and direction. Consequently, decisions on precautionary risk management options need to be cognizant of potentially countervailing impacts on risk and trust perceptions for radiation-emitting mobile telephony technologies.

ACKNOWLEDGMENTS
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REFERENCES


Hand Position Effect on SAR and Antenna Pattern in RF Exposure Study of a Human Head Model.

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INTRODUCTION
While studying the exposure of the human head to electromagnetic field one the most important quantity to evaluate is SAR inside the head and its distribution. Consideration of only head model interacting with antenna is not enough because other nearby objects such as hand holding the transmitter changes the distribution of the EM field and SAR as well as affects the radiation pattern. These effects are investigated through numerical simulations in this work.

METHODOLOGY OF THE SIMULATION
The numerical investigation of EM interaction between the portable transmitter and human head model requires extensive computer simulations. At the same time due to difference in anatomical details of different people the characterization of average properties of such interaction is useful. The simplified homogeneous or partially homogeneous head models are used in this case study. In addition a simplified hand model is also employed to investigate it’s the effect of its proximity to the head and transmitter. The simulations where carried out at 900 MHz. All models are simplified to the degree that the Method of Auxiliary Sources (MAS) [1] could be used to conduct very efficient computer simulations which are much faster than FDTD computations with the same geometry.

SIMULATION RESULTS
Two cases with different distances between head and antenna have been considered. Simulations with head only and head and hand have been conducted and the SAR results have been compared. In addition radiation pattern was also evaluated and compared in those configurations. In addition to those to configurations the partially homogeneous head model was also used for similar simulations. This model features an additional shape representing the brain tissue in the head as well as additional feature representing the mouth. Simulations of those different configurations can help understand the major effect in EM interaction between the transmitter and the head and hand model. The results show influence of transmitter to head distance on SAR and radiation pattern. The presence of the hand model had mostly strong effect on radiation pattern.

CONCLUSIONS:
Simulation results show that consideration of hand interaction with the portable transmitter and head is important to study antennas transmitting next to the user’s head. Both radiation pattern and near field distribution change significantly depending on the transmitter distance and hand position. The front-to-back ratio of the radiation pattern is increased as the transmitter moves toward the head.

REFERENCES:
Computational Dosimetry Models to Assess Exposure to Low Frequency Electromagnetic Fields

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INTRODUCTION

Increasing public concern about human exposure to electromagnetic fields led to the development of exposure Standards, which reflect the actual scientific knowledge on this subject. Existing exposure limits are based on maximum admissible fields or induced currents inside human bodies. Since those physical quantities can not be readily measured, they must be estimated using techniques of computational dosimetry. These techniques rely on accurate computational modelling of human bodies to establish the relation of external field (electric / magnetic) to induced current (internal field).

While nowadays the available models for human Body simulation (FEM, FDM, …) are reasonably accurate, the determination of tissues characteristics (permittivity and conductivity) the simulation of induced currents on real transmission line conditions require some further developments. In current studies the electrical characteristics (permittivity and conductivity) of tissues are based on values which were obtained form measurements done on dead bodies. However those values may not represent adequately the behaviour of living tissues. In this paper a research designed to characterize the permittivity of human body tissues is presented, consisting on measurements and simulations designed to determine, using indirect methods, the electrical behaviour of living tissues. An application of computational dosimetry techniques to a real transmission situation is presented, where the special case of live line workers is discussed.

ABSTRACT

The methodology presented takes three steps to undertake a field exposure evaluation in order to ensure compliance to International Standards, in the sense that basic restrictions are not exceeded.

The first step in the assessment is to calculate both the electric and the magnetic fields in the vicinity of the transmission line, where people can be exposed. At each point in space three spatial components of both the electric and the magnetic field must be calculated in intensity and phase angle, since due to the elliptical polarization pattern of those fields, the actual induced current is resultant from the combined effect of all those components. Naturally if those field values are below limits, the simplified approach can be taken and compliance to the Standard is assured.

In this work the calculation of EM fields in the vicinity of transmission lines is done using an implementation of boundary elements method [3]. Since the methodology is intended to be applied to real situations, it is recommended to use a tri-dimensional model, in order to
account for conductor sagging, towers, nearby objects, constructions, vehicles, etc.

In the second step, in order to calculate the currents induced inside the human body by an external field it is required to have a model of a human. This model must be as accurate as possible in what regards both the geometry and the characteristics of materials (human tissues). Since available data for permittivity and conductivity of human body tissues are based on measurements on dead bodies, a research work designed to evaluate the behavior of living bodies is presented. The permittivity was evaluated through an indirect method, measuring the distortion of electric field around the body, and comparing the resulting field pattern with simulated patterns calculated with a finite element model. In this way the values of permittivity that gave the best adherence to the measured field values were identified.

![Figure 1: Indirect characterization of human body permittivity - comparison of measured and calculated field values along longitudinal profiles.](image1)

With the first two steps accomplished, it is routine to apply the field values as external conditions to the FEM human model and obtain the values of induced currents inside the body. This third step is illustrated by an exposure evaluation of live line work conditions on an actual transmission line, using the computational dosimetry techniques described. In the case presented it was necessary to provide a special shielding to the electric field, in order to maintain internal induced currents below basic restrictions of ICNIRP Standard.

![Figure 2. Map of internal induced current densities around a 500kV transmission line – electrostatic field shielded.](image2)
CONCLUSIONS

The proposed methodology, consisting of several computational models, used in sequence, is a valuable tool to the design and operation of transmission lines, allowing the establishment of different regions near the line, in order to assure compliance to Exposure Standards, considering different situations (circulation, agricultural activities, live line work, sensitive areas, etc.).

This methodology can be quitey useful when analyzing constructive alternatives designed to reduce electric/magnetic fields, such as electrostatic shielding. This calculation process deals directly with the field components and can quickly give the result in terms of field exposure, in order to verify the compliance to Standards.

The ongoing research, designed to determine electric characteristics of human bodies, will provide more accurate data in order to guarantee the sound application of the modeling.

REFERENCES


Nonlinear, Temperature Based Optimization for Hyperthermia Treatment Planning Using PDE Constrained Interior Point Optimization

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INTRODUCTION

Hyperthermia is a promising, relatively new treatment modality for various types of cancer. It aims at heating the tumor using EM fields. Antenna arrays are usually used to focus the energy. However, the difficulty of controlling the deposition has so far hindered the acceptance of hyperthermia, and hyperthermia treatment planning tools would therefore be very valuable. A comprehensive tool should include a powerful EM simulation package, a thermal model which correctly handles blood flow, a fast field optimizer for antenna arrays and a segmentation toolbox. The treatment planning tool has to permit modeling and planning at a very high level of detail, accuracy and reliability. This is required to reduce hotspots and guarantee a good coverage of the tumor area.

Such a treatment planning tool has been presented previously at BEMS [1]. However, essentially only linear optimization could be performed, which limits the possible optimization functionals and the underlying thermal model. This work examines the applicability of nonlinear interior point optimization to remove these limitations.

MATERIALS AND METHODS

The underlying electromagnetic fields are computed per antenna using FDTD on a non-uniform mesh [2]. Hardware acceleration is used to achieve acceptable speed at high resolution. Conformal corrections and singularity models improve the numerical accuracy. Subsequently, the antenna parameter (amplitudes and relative phases) optimization is performed jointly with the temperature distribution determination (e.g., contrary to the approach in [1], no previous execution of \( n^2 \) temperature simulations is required – where \( n \) is the number of antennas). For this, interior point optimization software (IPOPT [3]) is used. A finite differences based discretization of the Pennes Bioheat equation defines constraints for the values of the temperature field in the optimization which, together with the antenna parameters, are treated as free variables (state and control variables). The fine discretization of the model (~2-20 million voxels) gives rise to a large-scale optimization problem.

PARDISO [4] is employed to solve the resulting equation systems. Both the direct (less convergence issues) and the iterative solver (smaller memory requirements, suitable for larger problems) have been tried.

RESULTS

The presented approach is able to simultaneously solve the optimization problem and the temperature calculation. It can be applied to highly resolved simulations. The implemented solution has various benefits:

- It permits the use of nonlinear thermal models: This is especially relevant considering
the strong temperature dependence of perfusion, which is now considered.

- It permits the use of nonlinear functionals: Hot-spots and underexposure of tumor regions can be penalized more strongly. In addition, optimization for treatment outcome (based on Arrhenius tissue damage model) becomes possible.

- Modulated Hyperthermia: The framework offers a straightforward way of determining multiple antenna settings between which rapid switching is performed. This multifocus approach improves coverage of large tumors and reduces the average hot-spot exposure.

- Constraints: It is trivial with this method to use point-wise constraints to ascertain that certain tissue-specific thresholds are never exceeded in healthy tissue.

Figure 1: Temperature distribution for temperature based optimization of antenna settings.

CONCLUSIONS

The PDE constraint interior point optimization method offers various benefits when aiming for nonlinear temperature based optimization. It considerably extends the range of possible optimization functionals and thermal models.

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REFERENCES


Design and SAR Analysis of Trapezoidal Ring Monopole Antenna by Using Conductor-backed CPW for Broadband Characteristics

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INTRODUCTION

In this paper, a newly designed antenna using a trapezoidal ring monopole antenna with H-shaped parasitic patch for broadband operation is described as shown in Fig. 1. The proposed antenna is stabilized by the conductor-backed coplanar waveguide-fed because the coplanar waveguide-fed would decrease a significant change of the return loss or the impedance matching. Besides the conductor-backed CPW has been broadened the bandwidth to compare with the CPW fed antennas because H-shaped parasitic patch is added[1]-[3]. The mobile communication unit which used in very close distance to the human body is restricted by the SAR. The standard SAR value in Korea is not exceeded 1.6 W/kg. The SAR values were measured and analyzed.

MATERIALS AND METHODS

Fig. 1 presents the structure of the proposed antenna. The antenna dimensions are 35 mm(W) × 70 mm(L) × 1 mm(T), and the substrate uses the FR-4 having dielectric constant 4.62. The trapezoidal patch is removed to make the ring shape of which leaves only the base of 3.5 mm, the upper side 3.5 mm, and both sides 3.2 mm. The existence and nonexistence of the parasitic patches lead to very different results that the existence cases are more enhanced return loss and operation band than the nonexistence case. Moreover, for the variation pattern of the return loss by the antenna thickness, the existence, or nonexistence, of the H-shaped parasitic patch, ground plane sizes, etc., are calculated using computer simulations.

To evaluate the human effects, the specific absorption rate (SAR) is measured by the equipment, ESSAY-3 of EMF Safety co. The cellular phone was modeled in the absorbing boundary condition which has the perfectly matched layer using commercial program, SEMCAD. The medium of the SAM phantom is used the uniform model to the characteristic of human tissue provided by FCC[4].

Fig. 1 The structure of the proposed antenna  Fig. 2 The return loss of the proposed antenna
RESULTS

The graphs of the simulated and measured results are compared using the optimized antenna parameters in Fig. 2. For the -10 dB return loss, the first resonance in the measured results is in the 1.5 GHz to 1.7 GHz bands, and the second resonance is in the 2.2 GHz to 4.6 GHz bands. In addition, only the band of around 2.4 GHz is used for WLAN and Wibro communication services. As the experimental measured results show, the peak gains in the wireless service bands are 2.74 dBi at 2.3 GHz and 1.56 dBi at 2.4 GHz. Fig. 3 presents the measured radiation patterns of the designed antenna at 2.4 GHz.

As the results of the SAR measurement, SAR value at 2.4 GHz is 0.529 W/kg(1g) and 0.273 W/kg(10g). The designed antenna is satisfied with the SAR guideline of 1.6 W/kg(1g) and 2.0W/kg(10g) as shown Fig. 4.

CONCLUSIONS

The design and optimization of the trapezoidal ring monopole antenna has been described for broadband operation. The H-shaped parasitic patch is inserted in the antenna for impedance matching, and to enhance the bandwidth. The antenna works well for frequencies from 1.5 GHz to 1.7 GHz, and 2.2 GHz to 4.6 GHz as confirmed by measurements, and these can be applicable to Wibro and WLAN communications of 2.4 GHz. The radiation pattern of the proposed antenna has an omnidirectional shape as that of planar monopole antenna.

For the human effect, the specific absorption rate is analysis by the measurement. The measured SAR values are satisfied the guidelines in Korea.

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REFERENCES

Dose assessment of radiofrequency exposure on fast petrol boats in the Royal Norwegian Navy

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INTRODUCTION

In connection with the WHO International EMF project, Repacholi [1] pointed out that satisfactory dosimetry has been a shortcoming in many epidemiological studies. Presently, regarding radiofrequency field (RF) in epidemiological studies there are more questions about what constitutes a dose than there are answers. Bortkiewicz et al. [2] and Wilén et al. [3] have calculated dose based occupational lifetime RF exposure of electric (E) field’s measurements for use in epidemiological studies.

The Royal Norwegian Navy (RNoN) has since the 1980’s measured E-fields from the communications equipments and radars aboard the Navy ships. The measurements from fast petrol boats (FPB) of Hauk-class formed the basis for an approach to make a dose assessment for occupational exposure onboard these ships.

MATERIALS AND METHODS

The FPB of the Hauk-class were equipped with two high frequent (HF) whip antennas, (HF1 and HF2) and from 1995 a Link 11 in addition. The frequency band for the HF transmissions has mainly been between 2.1 MHz and 4 MHz. The output power from the antennas ranged from 10 W to a maximum of 250 W. There were two radars; Navigation radar (9.4 GHz) and Weapon control radar (9.1 GHz) with peak power of 25 kW.

Exposure was measured using stationary equipments, for the E-field probe (Wandel & Goltermann Type 8, 100 kHz - 3 GHz). Measurements were performed for each step of 0.5 MHz from 2.1 MHz to 4 MHz.

The HF-antennas were measured at 13 different places onboard the FPB; two at upper bridge, seven amidships, four abaft all above deck. The distance to the antennas ranged from 1.2 m to 6 m. The measurements were done when the antennas transmitted with a power of 125 W (HF1 and Link 11) and 110 W (HF2). Based on the measurements arithmetic mean of the different frequencies (2.1-4 MHz) and also an arithmetic mean of all the different places were calculated. A total mean exposure was calculated as a mean of both frequencies and places. Exposure from the two HF-antennas was combined in a mean value while exposures from Link11 were added to the exposure.

Both radars were measured at 9 different places. Two measurements were done at upper bridge, four in front, one amidships and two abaft; all above deck. The distance to the radars varied from 2.6 m to 18 m. Exposures from the two radars were added. A mean exposure of the different places for each of the radars were calculated.

Measurements and information about transmitting pattern were used to make a dose assessment for the FPB. An exposure dose (eq. 1) and also a square E-field dose (eq. 2) were
calculated for each of the equipment.

\[
E-(\text{equipment}) = (\text{Mean } V_m^{-1}) \times (\text{transmission in minutes})/60 \quad (1)
\]

\[
E^2-(\text{equipment}) = (\text{Mean } V_m^{-1})^2 \times (\text{transmission in minutes})/60 \quad (2)
\]

An exposure measure for each of the equipments was calculated. For combining this into a dose we converted the E-field to an equivalent power density and took the ratio to the ICNIRP guidelines. These values will be used together with transmission time of the equipments to assess a dose in various areas of the ship.

RESULTS

Results from the measured E-fields from the HF varied from 1.8 V/m at the upper bridge and a mid ship to 43 V/m a mid ship, with mean values at upper bridge 3.5 V/m and 16.7 V/m a mid ship. The mean E-field value from Link 11 a mid ship was 19.3 V/m and aft 81.9 V/m.

The measurements from the radars were highest at the upper bridge and forward where total E-field from both radars were 2.6 and 3.0 V/m respectively.

These values will be used in the dose calculations and examples will be shown at the meeting.

CONCLUSIONS

The approach to an E-field dose assessment will be used in epidemiological studies where occupational RF exposure and different health outcomes will be studied.

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REFERENCES


Investigation of the feasibility of magnetic cardiac stimulation

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INTRODUCTION
The aim of the present work is the preliminary investigation on the feasibility of the cardiac stimulation with a magnetic pulse. Magnetic pulses are widely used to stimulate brain cortex and nerves because this technique is painless and less invasive than the corresponding electric stimulation. On the base of the experience achieved from the analysis of the magnetic brain stimulation, we started to explore the capability of the magnetic pulse to stimulate the cardiac region; in fact a further advantage is the contact-less application of the pulse and therefore the possibility to stimulate a dressed patient. An accurate numerical model has been developed to evaluate the current density flowing into the heart; in fact this electrical parameter represents the design constraint of the whole system. Many technical and technological problems have to be solved; the induced current density, according to the Faraday law, will be a compromise between the strength of the induction magnetic field and the pulse rise time. In this contribution some preliminary numerical results, obtained for a virtual human body [1] are presented.

MATHEMATICAL MODEL
The electromagnetic problem is to calculate electric fields and current density distribution induced in biological tissues by time-varying fields. The problem has been simulated by a 3D numerical model that was developed using the Scalar Potential Finite Difference (SPFD) algorithm [2]. This tool provides an accurate description of the source and of the volume, including the magnetic applicator, and the complex conductivity of the human body [3]. The method used to solve the electromagnetic problem concerns the application of the Faraday’s law and the continuity equation, both in their integral form. For common values of conductivity of the biological tissues, the field scattered by the induced current density is much smaller than the external field $\vec{B}_0$, so that its contribution can be neglected in the total field computation. The discretization of the equations leads to a 3-D linear electric network, where the electric field (or the current density) in each branch is the problem unknown and the electromotive force induced in each mesh by the external field is the forcing term. Our simulation procedure is developed through the following steps: subdivision of the volume in elementary homogeneous cells, assignment of dielectric characteristics to each cell, generation of the linear system, solution of the linear system using a method based on LU factorization for sparse matrix, graphical representation of the results.

RESULTS
Two type of applicators are considered. The applicator of type 1 is constituted by 30 metallic coils each one with a wire of 1 mm diameter section. The applicator of type 2 is constituted by two applicators of type 1 linked as a butterfly. The simulator is able to
Figure 1: Current density distribution \([A/m^2]\) on a vertical section of the human body at a distance of 0.05 m under the magnetic applicator of type 1

Figure 2: Current density distribution \([A/m^2]\) on a vertical section of the human body at a distance of 0.05 m under the magnetic applicator of type 2

determine different electromagnetic parameters. For example the current density distribution in the whole human body as shown in Fig. 1 and in Fig. 2 for a vertical section of the human body at 0.05 m from the applicators of type 1 and type 2 respectively, that are sided on the thorax.

CONCLUSIONS

A numerical 3-D model is implemented able to determine, to compute and to plot the electromagnetic parameters induced in every biological volume, including the whole human body, from a whatever type of magnetic applicator.

REFERENCES


Simulation of In-vehicle SAR Levels at 900 MHz for a Car with Various Transmitter Positions and Human Occupancy Configurations

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INTRODUCTION
The impact of source location and human occupancy configurations on in-vehicle SAR levels due to 400 MHz on-board transmitters has previously been investigated using numerical models [1–2]. These results suggest that the ICNIRP [3] whole-body average SAR limits for general public exposure would be reached at lower power levels than the localized SAR limits, and that the average field levels over the empty vehicle interior would be approaching twice the field reference levels at the power associated with the average SAR limit in the worst case. This paper reports on an extension of this work to 900 MHz sources.

MATERIALS AND METHODS
A 3D numerical model was used to compute the electromagnetic field distribution over the passenger compartment of a car for horizontal and vertical dipoles located inside the cabin and for an external monopole mounted at the rear of the roof. Human simulants of realistic shape but homogeneous dielectric properties were added to the empty vehicle model in order to compute SAR for a driver and up to three passengers, resulting in nine simulations for each antenna configuration. The vehicle model was based on the major metallic parts of the car, including the bodyshell, doors, seat frames, steering gear and rear window heater array. Broadband simulations were carried out using a TLM (transmission line matrix) full wave field solver [4], and spatial field and SAR distributions were obtained at 900 MHz.

Electric and magnetic field data was extracted at more than 19 million points over the passenger compartment, and SAR values (averaged over 10 g of contiguous tissue) were obtained at more than 430,000 points for each of the four human simulants. These data sets were used to obtain average field levels for the empty vehicle and to determine the whole body average and maximum SAR values for each of the human simulants. The results were also normalized to 1 W CW radiated power in order to allow direct comparison between source/occupancy configurations and for convenient scaling to other radiated power levels.

RESULTS
The whole-body average SAR limit was found to be reached at lower power levels than the localized SAR limits, for all source positions and occupancy configurations. The results presented in Table 1 indicate the empty vehicle average internal electric fields at radiated power levels corresponding to the whole-body average SAR limit relative to the free space reference level. In Table 1 DR, FP, RD and RP denote the driver, front passenger, passenger behind the driver, and rear passenger behind the front passenger, respectively. The worst case over all of the occupancy configurations for each of the three source positions is indicated in bold. Thus, the SAR limits would be reached at radiated power levels producing average empty vehicle fields of 1.93 times the field reference levels for the roof-mounted antenna: for
the internal dipoles this factor is 2.002 for the vertical case, and 2.278 for the horizontal case.

<table>
<thead>
<tr>
<th>Vehicle occupancy case</th>
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<th>Internal horizontal dipole</th>
<th>Roof-mounted monopole</th>
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<td>FP</td>
<td>RD</td>
</tr>
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<td></td>
<td>2.547</td>
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<td></td>
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</table>

Table 1: Safety factors provided by free space electric reference level at 900 MHz for in-vehicle whole-body average SAR over all source locations and human occupancy configurations investigated

CONCLUSIONS

At 900 MHz, comparing the average field over the interior of the empty vehicle with the field reference levels of [3] appears to give a reasonable safety factor for exposure risk assessments. These results are very similar to those found in earlier 400 MHz investigations.

The power balance method [5] has been shown to provide good estimates for the average fields over the interior of a car for the band 1–2 GHz [6]. This approach is expected to be increasingly successful at higher frequencies and for larger systems, where 3D numerical simulations may be impracticable. These observations suggest that initial risk assessments for in-vehicle human exposure could be achieved using relatively simple analytical calculations requiring very little geometrical data (only the window areas and glazing construction).

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REFERENCES

Modeling Electromagnetic Field Effects on Natural Antioxidant Systems in Tissues via Genetic Algorithm

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INTRODUCTION

Exposures of magnetic fields with various frequency and intensity can change the antioxidant activity of human and animal bodies [1, 2]. In vivo exposure effects of Extremely Low Frequency (ELF) Electromagnetic Fields (EMFs) on Glutathione (GSH) levels of brain, and hearth tissues of experiment animals have been investigated [2]. In this sense, this study focuses on the modeling and formulation of these biological effects for brain and hearth using Genetic Programming (GP) based on experimental values. The performances of prediction of the proposed GP formulation versus actual experimental values are found to be quite satisfactory in terms of standard deviation and correlation coefficient. It is concluded that the GP application serves to form a data base for the researchers in this field, without using too many guinea pigs and exposing tissues to EMF.

MATERIALS AND METHODS

In the experiments, forty seven guinea pigs were exposed to 50 Hz, 1mT, 2mT, and 3mT fields with the exposure periods of 4h/day and 8h/day for 5 days. Nine subjects were handled as control group. The GSH levels of brain and hearth tissues were determined by modified method of Aykaç et al.[3]. Mann Whitney-U test was used for statistical analysis.

Genetic programming (GP) proposed by Koza [4] is defined as a domain-independent problem-solving approach in which computer programs are evolved to solve problems based on the Darwinian principle. Gene expression programming (GEP) software which is used in this study is an extension to GP that evolves computer programs of different sizes and shapes encoded in linear chromosomes of fixed length [5]. The experimental values are evaluated by GEP and it is formulated explicitly.

RESULTS

The GSH levels of heart tissues were found increased with the effects of 1, 2 and 3 mT for the exposure period of 4 hours with respect to controls. However, it was increased only for 2 mT field at 8h while a decreased level for 1 mT. Increases have been observed in brain tissue for 1 mT with both of the exposure periods and decreases for 2 mT, 8h and 3 mT, 4h groups.

The GEP model formulation for GSH in brain is found as a function of $d_0$, $d_1$ and $d_2$ show Magnetic field (mT), Time (hr) and Control Value, respectively;

$$GSH_{brain} = (\ln(d_0^{G_C_0}) + d_0^{G_C_1}) + \ln(\frac{G_C_0 + d_0^{G_C_1}}{d_0}) + \ln(\frac{G_C_0}{d_0} + d_0^{G_C_1}) + (\ln(\ln(G_C_1) \cdot d_1)) + (\cos(\frac{G_C_0}{d_1} \cdot d_0))$$ (1)
where the constants are \(G_{C_0} = 46.467926, G_{C_1} = -88.9581, G_{C_2} = -14.149475, G_{C_3} = -47.51355, G_{C_4} = 91.538178\).

The performance of test results versus GP is shown in Figure 1.

![Performance of Test Results vs. GP for GSH in Brain](image)

Figure 1: Performance of Test Results vs GP for GSH in brain

Similarly, the GEP model formulation for GSH in hearth is formulated as

\[
GSH_{\text{hearth}} = \sqrt\left(\frac{d_1 + \sin^3(d_2))d_3}{d_1} + \ln\left(\frac{(d_4 + G_{2}C_0)}{d_4} + \sin^3(d_5) \cdot \frac{G_{3}C_1 - G_{3}C_0}{d_5}\right)\right)
\]

where the constants are \(G_{1}C_{0} = 51.256103; G_{2}C_{0} = -66.129425; G_{3}C_{1} = 91.805664; G_{3}C_{2} = 28.214081\).

CONCLUSIONS

In this study, the GSH activity in brain and hearth tissues of guinea pigs exposed to 50 Hz magnetic fields of 1 mT, 2 mT and 3 mT were formulated using GP. The accuracies of the proposed GP models are quite high where standard deviation and correlation coefficient are 0.32 and 0.24, and 0.84 and 0.78 for GSH levels of brain and hearth, respectively. It can be concluded that GP can be effectively used to model complex relationships especially where no valid models exist as in the case of the GSH activity considered in the study.

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Software Tools for Finite Element Meshing in Bioelectromagnetics

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INTRODUCTION

The finite difference methods commonly used in numerical dosimetry are problematic for small structures such as the retina. Existing dosimetric methods can calculate the spatially averaged ELF electric fields and currents in the neighbourhood of the retina, but cannot accurately predict peak values in the retinal layer which can trigger the perception of phosphenes. HPA is developing a new finite element model which incorporates all the tissues of the head together with a new fine-scale model of the eye and its surroundings. This requires conversion of the existing voxels models to CAD formats for editing.

In the past, computational bioelectromagnetics has been performed using segmented voxel phantoms derived directly from medical imaging data. There is now an increasing interest in using sophisticated mathematical descriptions of body shape (for example, [1]). The construction of these phantoms from medical imaging data or pre-existing voxel datasets requires a certain amount of manual intervention. In this study we have integrated a range of open-source and commercial software tools to simplify the process.

SOFTWARE AND METHODS

The starting point for the model was the existing set of HPA voxel datasets, including NORMAN and a 1 mm resolution head. The organ surfaces were extracted using the Visualization Toolkit (VTK), an open source software system for 3D computer graphics, image processing, and visualization. A script written in the Python language was used to create an image processing pipeline containing VTK modules. For each organ, the isosurface was generated by marching cubes, and the VTK modules vtkWindowedSincPolyDataFilter and vtkQuadricDecimation were subsequently used to smooth the mesh and reduce the triangle count. At present, the resulting organ surfaces are stored as triangle meshes in STL (stereolithography) files. In subsequent work, the model will be converted to NURBS (non-uniform rational B-splines) using techniques similar to those in [1].

An in-house C++ program is used to construct a complete CAD model of the head from the component organ models (STL or NURBS). It assembles the model using various “constructive solid geometry” functions from the OpenCASCADE library, which implement the boolean operations intersection, union and difference. This program also contains a sophisticated user interface for manual scaling and registration, so that multiple data sources can be used in the construction of the model.

A three-dimensional finite element mesh of the head was produced using gmsh, an automatic 3D finite element grid generator with a built-in CAD engine and post-processor. It contains support for two open source 3D meshers: Netgen and Tetgen. Tetgen uses the technique known as constrained Delaunay triangulation [2] and this allows non-uniform mesh sizes to be specified by fields defined throughout the volume, as well as by characteristic lengths attached to the boundary points in the input.
RESULTS

To evaluate the performance of the algorithms, the skin surface of the whole-body phantom NORMAN was extracted, smoothed and decimated. Using the windowed sinc filter [3] with a pass band of 0.1 and 100 iterations, and decimating the mesh by 95%, Figure 1 was obtained. The surface area of this mesh is 1.937 m², which is just 2% greater than the ICRP reference value 1.9 m². This suggests that the staircasing of the original voxels has been almost completely eliminated by these filters.

To assemble a complete head model, OpenCASCADE boolean operators were applied to the individual organs. This proved to be very time-consuming for high-resolution triangle meshes. To mitigate this problem, we are investigating (1) converting the organ surfaces to NURBS; or (2) using a spatial storage scheme for the triangle meshes, so that only nearby triangle pairs need be tested for intersection.

CONCLUSIONS

A combination of open source and in-house software has been demonstrated which effectively converts existing voxel models to smooth triangle meshes suitable for subsequent use in finite element/boundary element techniques.

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REFERENCES

Effects far from equilibrium in electromagnetic heating of tissues

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INTRODUCTION

Local and regional heating of the tissues and body-parts, (hyperthermia, HT), in fact is one of the very first treatment “technology”, starting in early ancient cultures. It had various applications from the well-known common cold, to the oncology. Despite of its extremely long history, the medical practice does not accept HT like conventional treatment. The main reason of the loathing is its numerous controversial results and pure control of the processes. Having aversion of HT is certainly huge in oncology, which deals with a fatal disease, and the seeking for new treatments is one of the most preferred medical research nowadays. The basic problems of any applications are the missing of appropriate selective, controllable safe deep heat-delivery. The balanced physiological feedback, the sophisticated transport, and the very heterogenic tissue structures block to apply the simple applications and practices. This situation primary emphasizes the bioengineering tasks to satisfy the medical explanations. The modern heating technologies made a huge step ahead in this complex field, but not enough yet to solve some crucial problems in deep heating [1]. One of the most perspective heating applications is the electromagnetic one, using various technical solutions. The commonly applied microwave and high frequency (RF) radiation is challenged by the magnetic and capacitive heating techniques. Heating by the dielectric loss of the body (electro-hyperthermia, EHT) makes possible to select by the variations of the dielectric properties of the tissues. At the constrained RF-current conduction changes of the complex impedance determines the direction of the current and could make microscopic heterogeneity in the treated tissue [2].

MATERIALS AND METHODS

The relatively low frequency RF-current dominantly flows in the extracellular electrolyte, and creates a temperature gradient through the cellular membrane. This gradient drives non-equilibrium processes by constrained heat-flow through the membrane, [3]. The thermodynamic consequences (definite ion- and mass-flows) could be well approached by Onsager’s theory, while the polarization conditions discussed in frame of β-dispersion. The chemical effects determine the dose of the action [4] instead of the temperature. The actual realization of EHT is capacitive coupled heating, using the constrained conduction of 13.56 MHz RF [5], amplitude modulated by time-fractal pattern (mEHT) [6], which is not limited by the thermal-energy [7]. The in vitro and in vivo experiments were accomplished on identical 42 °C reference temperature by conventional HT and mEHT methods, respectively. The experimental systems are in vitro cell-lines (HT29, B16, HepG2, A431) and their in vivo xenografts in nude mice. The changes of the adherent connections the cell membrane-
associated effects (activation of the apoptotic signal transduction pathways, heat shock protein mediated stress-responses) were studied in vitro, while the cell-destruction mechanisms were investigated in vivo.

RESULTS

The conductance differences (due to the change of metabolic activity) between the cell-culture/tissue-parts automatically control the focusing on cellular/tissue level and acts selectively, which was proven in co-culture experiments. The emergent thermal- and electric-gradients force higher membrane permeability, larger intracellular pressure, imbalance of the ion-exchange, and finally challenges the membrane stability. An over-expression of HSP70 on the outer membrane was detected by immunhistology, and the longer recovery after mEHT made heat-shock compared to HT was measured by PCR and by luciferase indicated gene measurements. Significant reconstruction of adherent connections of the cells could be detected after mEHT, due to the polarization conditions by field gradients, but this was not observed by HT. Experiments by stain the double strains of DNA (DAPI) and enzymatic labeling of the strand-break of DNA (TUNEL-FICT) had shown the high rate of apoptotic cell deaths caused by mEHT compared to the dominantly necrotic HT. This observation was supported with the Western-blot and with follow-up the β-catenin development during 24h. Significant difference between HT and mEHT was measured in vivo as well. Effective characteristic cell-destructions of tumor lesions was observed in such low temperature where HT was ineffective. Experiments by combination of the heating methods with various drugs (mitomycine, liposomal-doxorubicine, Tc-labeled liposomes, etc.) also emphasize the definite advantages mEHT versus HT.

CONCLUSIONS

The non-equilibrium thermodynamics makes mEHT feasible to go over the difficulties of the problem of the selective deep-heating, and could be a candidate in the branch of modern therapies in medical practice. It could be applied in various biomedical fields where the selection and the drug-targeting as well as the personalized treatment are important requests.

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On the Combined Use of MPI Code and a Subgridding Algorithm to Solve Maxwell’s Equations in Large and Complex FDTD Domains

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INTRODUCTION

The Finite Difference Time Domain (FDTD) method is widely adopted as a suitable numerical technique to efficiently solve the Maxwell equations both in free space and in presence of lossy media, like a human being. In non ionizing electromagnetic fields radioprotection, it is well known that the computer simulation is the only feasible approach to describe the detailed SAR distribution inside the whole human body or selected districts of it. Spatial resolutions on the order of 1-2 mm are now easily achievable regarding the tissues complex permittivity maps [1], [2]. Therefore to describe a human body, a complete 3-dimensional FDTD grid requires a large number of cubic cells, typically on the order of $10^7$-$10^8$, which cause an unmanageable request of computer RAM and long running time on a single processor. To overcome these drawbacks we propose a parallel MPI (Message Passing Interface) implementation [3] of the subgridding algorithm as described in [4] with the aim of sharing the RAM request and spatial iterations of the FDTD grid among a number of processors.

As practical example here we show the MPI parallelization of a large FDTD domain, in which five human bodies are simultaneously frontally illuminated by a 1800 MHz DCS antenna in the near field situation.

MATERIALS AND METHODS

Five standing men on a perfectly conducting ground plane are exposed to the e.m. near field of an 1800 MHz DCS antenna. The whole modeled space volume has sizes of: 2.80 m (Height, x-axis) × 1.40 m (Width, y-axis) × 2.80 m (Depth, z-axis). Five sub-lattices contain, at a refined level the relative dielectric constant and conductivity (Siemens/m) data values for the standing man (875 × 252 × 147 cubic cells – 2 mm space step), as described in [2]. The remaining one contains data for the antenna metallic structures (700 × 154 × 112 cubic cells – 2 mm space step). The antenna operates at a frequency of 1862.5 MHz and is made of a double array (for a double polarization of $\pm 45^\circ$) of radiating elements, each array consisting of 8 dipole pairs. A metallic shield is positioned on the back side. The coarse domain (air) space step is 14 mm: therefore the embedding/sublattices refinement factor is $r = 7$. The total number of cubic cells is 182,205,100 amounting to 8.5 GBytes of requested RAM (single precision floating point). Figure 1 reports the y-z layout of the domain.

The MPI parallelization of the FDTD code was implemented on High Performance Computing machines (IBM SP5 and IBM BCX clusters) of the CINECA Consortium Supercomputing Group (located in Bologna, Italy). Two slices were used for the coarse grid (z slicing directions) and three slicing values for the human and antenna sublattices (x slicing directions). Table 1 reports the slicing data. To each slice is assigned a single processor. The three configurations ran for 1200 time iterations.
RESULTS

Figure 1 shows the E-field distributions in the middle y-z plane of the FDTD domain. In Figure 2 are shown the E-field distributions in three planes of the coarse domain, with a perspective view from the antenna side.

Table 1: FDTD domain slicing

<table>
<thead>
<tr>
<th></th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nr. of slices in the coarse grid</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Nr. of slices in the refined grid (for each human)</td>
<td>15</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Nr. of slices in the refined grid (for the antenna)</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>Total number of parallel processes</td>
<td>105+7</td>
<td>140+2</td>
<td>350+2</td>
</tr>
</tbody>
</table>

CONCLUSIONS

In this paper we presented the feasibility of combining MPI computing techniques with subgridding algorithms, to realize realistic FDTD simulations of complex geometries such as several human bodies close to radiofrequency sources.

REFERENCES

Development of the wavelet analysis algorithm for assessment of subcutaneous microvasculature alterations after ELF EMF action in vivo

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INTRODUCTION
The wavelet transform-based correlation analysis has been used to study microvasculature alterations after ELF EMF action. Microcirculatory changes in arterioles were examined in mice exposed to low frequency-electromagnetic fields (EMF), by direct, continuous intravital microscopy. Spectral analysis of the variations in mice skin vascular tone provides useful information about regulatory mechanism influencing skin microcirculation. These regulatory factors can be analyzed more precisely by means of the wavelet analysis of blood vessel diameter oscillations registered by real time intravital video-fluorescent microscopy. Some authors proposed wavelet analysis of blood flow oscillations registered by laser Doppler flowmetry (Kvernmo et al. 1998; Stefanovska et al. 1999; Soderstrom et al. 1999, 2003; Aalkjaer C, and Nilsson H 2005; and Podtaev et al. 2008) and the others based their wavelet analyses on the data obtained by arterial blood pressure and heart-rate variability (HRV) signals. According the data from laser-Doppler flowmetry five subintervals of blood vessel oscillations are measured (heartbeat (0.5-2 Hz), respiration (0.14-0.5 Hz), intrinsic myogenic activity (0.05-0.14 Hz), neurogenic activity (0.02-0.05 Hz), and endothelial function (0.0095-0.02 Hz). According our previous investigations of intravital microscopy data of microcirculation, Arterioles between 45 and 80 μm in diameter were measured. Spectral range of oscillations from 0.0095 to 1.2 Hz, and four subintervals are revealed, (0.0095-0.02 Hz), (0.02-0.05 Hz), (0.05-0.14 Hz) and (0.14-1.2 Hz), by FFT analysis. In this work our group applied wavelet Daubechies analysis.

MATERIALS AND METHODS
Conscious BALB/c mice (n=34) assigned to 1 of 4 groups were exposed to EMF for 10min: at 10, 16 or 50Hz (28mT), or no exposure (sham). Dorsal skin-fold chamber implanted mice, were injected with FITC-Dextran-250, 2.5% in PBS, via caudal vein. Epillumination of arterioles (45-80μm diameter) was monitored continuously over 33min, that included: 3 min preliminary preparation and 10min pre-, 10min EMF-exposure, and 10min post-exposure. In vivo alterations in vasomotion were measured using a high-speed digital-video recording and image enhancement system, employing an edge-gap detection algorithm (389ms sampling time), to calculate arteriole diameters. Captured signal images were filtered and amplified to eliminated background fluorescence noise. Changes in frequency band magnitudes were determined by FFT (Fourier coefficients) and consequent wavelet analysis.

RESULTS
Sham-exposed mice exhibited no significant changes in vessel diameters amplitude changes,
during the 33min evaluation. However, 16Hz EMF significantly increased vasodilatation at post-exposure, period compared with pre- and exposure periods. No significant change with 10Hz or 50Hz exposure on vessels was seen throughout the monitoring, using Friedman’s Chi-Square analysis. This on-line, automated and real-time methodology enables improved, advanced analysis of single frequency components among the compound signals monitored in vasomotion, toward better understanding signal transduction pathway interactions/factors related to the mechanisms of microvascular regulation and change.

After FFT analysis Daubechies wavelet analysis were applied. Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform. With each wavelet type of this class, there is a scaling function (also called father wavelet) which generates an orthogonal multiresolution analysis. In our investigations we applied Daubechies orthogonal wavelets from D1 to D3. Main idea of daubechies analysis is to find time interval with maximal amplitude variations at certain frequencies.

Wavelet analysis show significant in comparison with the control, increase of the values of high frequency vasomotion (0.14-1.2 Hz). This frequency component were detect in time interval between 20-th and 30-th min., after exposure for 10 min with 16 Hz ELF EMF 25 mT. In all other investigated frequencies (10 and 50 Hz ELF EMF) this components were not significant in comparison with the control.

Obtained frequency domain (0.14-1.2 Hz), probably is related with elasticity of blood vessel wall and related with the heart rate.

CONCLUSIONS
Non-linearity state and stationary state condition of the processes is one of the main manifestation of the life itself.
Our approach in investigation of changes of blood vessel diameter is to attempt to elucidate possible regulatory mechanism of skin microcirculation. First step in adequate interpretation of the data from the single blood vessel diameter changes, is signal processing. Signal, obtained by means real time intravital video-fluorescent microscopy, was processed by means consequent FFT and wavelet signal analysis.

The correlation wavelet analysis of oscillations was used to describe the spectral composition and to determine the correlation degree and the phase shift for two signals at each vasomotion frequency (scale). Simultaneous recording of skin microvasculature oscillations at 33 min at sham/exposed and exposed with ELF EMF animals obtained within spectral ranges corresponding to myogenic (0.05-0.14 Hz), neurogenic (0.02-0.05 Hz), and endothelial (0.0095-0.02 Hz) regulation mechanisms, which agree with other results by other authors work with Doppler flow metric data.

Simultaneous analysis of obtained control and exposed signal data by blood vessel diameter changes allow to isolated specific frequency domains (mechanisms) related with certain processes during and after exposure in ELF EMF.
16 hz ELF EMF induce significant changes in blood vessel diameter in comparison with the control in frequency domain related with neurogenic, and endothelial regulation mechanisms and blood vessel elasticity. These data analysis need additional analysis.

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Standardized Methods for the Evaluation of the Numerical Uncertainty of Dosimetric Assessments with the Finite-Difference Time-Domain Method

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INTRODUCTION

For many dosimetric applications, numerical methods are the only means to quantify the absorption in the exposed subject. Among the simulation techniques for radio frequency (RF) electromagnetic fields, the Finite-Difference Time-Domain (FDTD) method has the most prominent role in this area [1]. It owes this to its high flexibility with respect to the representation of highly inhomogeneous dielectrics, such as the human body, and to its moderate hardware requirements for large numbers of unknowns, which permits the efficient use of latest advances in numerical processing power.

Findings of dosimetric simulations reported in the scientific literature are recognized by international standardization bodies and used to determine limits for RF safety and compliance. Although the results of most publications throughout the field of computational dosimetry are consistent, their accuracy is not evaluated routinely, which is in obvious contrast to what is usually expected from measurement results. The gap between these different policies for numerical and experimental studies motivated an effort by the Technical Committee 34 of the International Committee on Electromagnetic Safety (IEEE/ICES) to develop methods for the assessment of the quality of the implementation of a numerical method, to give guidelines for its correct use for different numerical applications and to evaluate the numerical uncertainty of the simulation results.

OBJECTIVES

IEEE/ICES TC 34 is developing a series of standards for the numerical evaluation of the compliance with RF safety limits of trunk mounted antennas and cellular phones. Fundamental guidance for the ascertainment of the accuracy of numerical results is given in the first part IEEE 1528.1 [2]. In detail, the objectives of [2] are to define standardized methods

- to validate the accuracy of the different components of an implementation of the FDTD algorithm and those postprocessing routines which are required for dosimetric evaluations and

- to assess the uncertainty of the simulation result with respect to the numerical parameters of the simulation.
METHODS and RESULTS

Various methods were developed to validate the correct implementation and to accurately determine the numerical properties of an FDTD code. These methods evaluate propagation in different dielectrics, boundary conditions at planar and staircased material interfaces as well as spurious reflection at absorbing boundary conditions for well-defined numerical benchmarks. Analytical solutions of the FDTD update equations are used as reference. Post-processing routines, e. g., for the interpolation of field components or the averaging of the specific absorption rate (SAR) according to [3] can be tested using particularly defined geometries or against benchmark results of methods other than FDTD.

For the evaluation of the uncertainty, various methods were defined which permit the assessment of the impact of a) numerical contributions, e. g., the grid resolution, the power budget, etc. and b) the accuracy of the modeling, such as correct representation of the electrically relevant parts, dielectric parameters. For particular applications, the experimental validation of the transmitter model is indispensable. Appropriate guidelines for simple test configurations for the experimental validation are given.

The validation of the implementation of the numerical code and post-processing routines is independent of the actual application and can be performed once by the manufacturer for each software release. The numerical uncertainty need be evaluated in particular for each application.

CONCLUSIONS

The methodology defined in [2] represents the first systematic approach to validate the accuracy of simulation results obtained with the FDTD method considering aspects of implementation, modeling and numerical parameters. Although the main goal of IEEE/ICES TC 34 is the dosimetric evaluation of wireless devices, the guidelines developed here are not restricted to this range of applications, but they can contribute to increasing the accuracy of numerical results in general and the confidence in them.

DISCLAIMER

The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.

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Design and SAR Analysis of Spiral Slot Antenna fed by Coplanar Waveguide Using the Magnetic Phase Difference

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INTRODUCTION

In the last years, there are various demands for high capacity wireless systems. One of the demands is to the broadband operation characteristic. This paper describes a new design of a spiral slot antenna, using the magnetic flow in the slots for UWB (Ultra Wide Band: 3.2 ~ 10.6 GHz). The characteristics of the spiral antenna are wider bandwidth and radiating circular polarizations. Because of these things, although spiral antennas have long been used as the efficient radiators at microwave frequencies, there has not been the research of the specific absorption rate (SAR). The international organizations are actively progressed a research about the effect of the electromagnetic wave to the human body for the advanced prevention. Especially, the mobile communication unit which used in very close distance to the human body is restricted by the SAR. The standard value in Korea does not exceed 1.6 W/kg. The SAR values were simulated [1].

ANTENNA DESIGN AND SAR ANALYSIS

The structure and the return loss of the proposed antenna is shown Fig. 1. The antenna dimensions are 75 mm × 45 mm × 1 mm, and the substrate is FR-4 whose dielectric constant is 4.62. The proposed antenna, which is composed of a symmetrical line without balun circuits, is added in the shorted CPW feed that retains the higher inductance and lower resonance frequency. The bandwidth of the realized antenna is 2.7GHz ~ 12 GHz below the return loss of -10dB, the gain of this antenna is values from 3.4 to 6.1 dBi, and the 3dB bandwidth of the axial ratio is 4.2GHz ~ 4.7GHz, 5.9GHz ~ 6.8GHz.

Figure 1: Structure and return loss of the proposed antenna

To evaluate the human effects, SAR is measured by the equipment, ESSAY-3 of EMF Safety co. The SAR is defined by:
SAR = \frac{\sigma}{2\rho} |E|^2 [W/kg] \tag{1}

Where \( \sigma \) is the electric conductivity [S/m], \( \rho \) is the density of an organization [kg/m\(^3\)], and \( E \) is the electric field strength [V/m]. The portable devices were modeled in the absorbing boundary condition which has the perfectly matched layer using commercial SEMCAD. Fig. 2 is the result of the SAR simulation. The simulated value of 1 g and 10 g averaged peak SAR at 3.5 GHz on human head caused by the proposed antenna on a folder-type device was analyzed and discussed. As a result, the simulated 1 g peak SAR value is 1.119 W/kg and 10 g peak SAR value is 0.562 W/kg at 3.5GHz. The results are smaller than the reference SAR limit values that are respectively 1.6 W/kg and 2 W/kg on 1 g and 10 g averaged SAR values [2].

CONCLUSIONS

The design and optimization of the spiral slot antenna fed by coplanar waveguide has been described for UWB operation. The bandwidth of the realized antenna is 2.7GHz ~ 12 GHz below the return loss of -10dB, the gain of this antenna is values from 3.4 to 6.1 dBi, and the 3dB bandwidth of the axial ratio is 4.2GHz ~ 4.7GHz, 5.9GHz ~ 6.8GHz. The simulated 1 g peak SAR value is 1.119 W/kg and 10 g peak SAR value is 0.562 W/kg at 3.5GHz. The results are smaller than the reference SAR limit values that are respectively 1.6 W/kg and 2 W/kg on 1 g and 10 g averaged SAR values.

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Design and SAR Analysis of Broadband Monopole Antenna

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INTRODUCTION

A small broadband monopole antenna having a dual resonance characteristic was designed. To compensate narrow bandwidth characteristic, we added the patch of the diamond shape and induced the current in various directions for acquiring broadband characteristic. Frequency characteristic is optimized with various design parameters. By the measurement results, the bandwidth of the antenna is 1.66 – 3.04 GHz. It could be applicable to PCS/IMT-2000/WLAN in Korea. For the human effects, the analysis of SAR values is important factor. The SAR values are simulated and analyzed.

MATERIALS AND METHODS

We proposed a novel broadband printed antenna in Fig. 1. First of all we proposed a dual band antenna, and then added a diamond patch for non-resonant band between existing dual bands in Fig. 2. This antenna satisfy PCS, IMT-2000 and WLAN band in Korea. The antenna dimension is 30 × 60 × 1 mm3, and the substrate is FR-4 having dielectric constant 4.62. The ground size is 30 × 45 mm2, the patch size is 30 × 10 mm2.

To evaluate the human effects, the specific absorption rate (SAR) is necessary. The SAR analyzed by simulation and measurement. The simulation is used to computer program, SEMCAD, and the measurement is used to ESSAY-3, EMF Safety co.

RESULTS

Fig. 3 shows the comparison of the simulation and measurement result of the proposed antenna. The measured result coincided with the simulated result, but the bandwidth in the measured result was smaller and more efficient than that in the simulated result. By the result, the bandwidth of -10 dB return loss has the broadband characteristic. The resonant bandwidth is 1.66 to 3.04 GHz.
For effect in human bodies, the WHO recommends the SAR measurement. The guideline of the 1g avg. SAR is 1.6 W/kg. This antenna could be applicable to PCS, IMT-2000 and WLAN, therefore the SAR measurement is necessary. By the simulation using SEMCAD, the 1 g-SAR value is 0.707 W/kg.

CONCLUSIONS

In this paper, a new designed broadband antenna was proposed for PCS/IMT-2000/WLAN bands. The bandwidth is 1.66 – 3.04 GHz, and the peak gain in PCS, IMT-2000 and WLAN bands are 1.959 dB, 3.488 dB and 3.78 dB respectively. The simulated SAR value is 0.707 W/kg that is not exceeded in guidelines.

ACKNOWLEDGMENTS

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Anatomical-Based Deformation Of 3-D CAD High-Resolution Human Models For Complex Electromagnetic Simulations

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INTRODUCTION

Several techniques have been presented to deal with skeleton driven deformation of 3-D skin models for visual purposes only. The work presented here extends and combines these techniques to deal with high-resolution anatomical full-body models, including deformation of all tissues and organs surrounding the rigid bones in an efficient way. This work also focused on a visual system to set up the hierarchical system of bones that drive the anatomical deformation in an easy way.

MATERIALS AND METHODS

The goal of this work was the development of a system which takes a high-resolution anatomical model and allows a visual setup of the influencing bones. It furthers allows positioning of the underlying bone structure taking into account user-defined joint constraints and movement limits. The next step is the actual computation of the deformation with immediate visual feedback to the user. The posed anatomical models are finally used to simulate exposure to and interaction with electromagnetic radiation.

The crucial part of the skeleton based deformation of anatomical models is the setup of the influence regions of the bones. For this a tool has been developed and integrated into the existing electromagnetic simulation platform SEMCAD X. The user defines a set of bones as a hierarchical structure. Such a structure consists of a set of rigid bones connected with joints.

Every bone defines a volume of influence and a spatial weight distribution attached to it. The tool allows the user to manipulate the influence volume such that it matches the bone and the tissues surrounding it. Bones may have regions with overlapping influences. Every vertex in the model has a set of weights for every bone with an influence on it. The resulting transformation of the vertex is computed using two different methods. The first non-iterative method uses Dual Quaternions described in [2] which computes the interpolation of a set of transformations in the space of Dual Quaternions. The second one is iterative and uses a divergence-free deformation vector field induced by the skeletal motion which generates volume-preserving deformations.

The bone hierarchy allows propagation of transformations through a whole limb if the user moves the parent bone, on the other side the tool makes use of known methods to solve the Inverse Kinematics problem to achieve a desired pose of the bone structure while satisfying defined joint constraints. This work uses a non-iterative method based on Lagrange multipliers described in [1] to simulate the articulation of the bone system which gives to the user a fast and intuitive way to define a pose.
RESULTS

All the methods described in this work have been implemented and integrated into the software package SEMCAD X. Models with millions of triangles have been imported and posed, e.g. high resolution anatomical human whole body models from the Virtual Family project [3]. A lot of effort was spent on the user interface for setting up the bone influence regions since this step was found to be the most crucial part. This step was addressed by generating automated adaptive influence volumes as an initial configuration which can be further edited by the user.

![Figure 1: Shows a posed hand grabbing a phone](image)

CONCLUSIONS

This work presents methods inspired by computer graphics based animations applied to the physiological postures of high resolution inhomogeneous anatomical human models. Whereas in computer based animation the sole purpose is usually to deform an empty skin, this novel approach was implemented in the context of electromagnetic simulations with anatomical models.

In particular addressing complex exposure situations, it turned out to be highly valuable to put the anatomical model of interest into the posture being addressed in the investigation, e.g., standing, sitting, operating or being exposed to an EM radiation emitting device, e.g., the influence of a hand holding a mobile phone. Application of the novel methods presented in this work to a variety of inhomogeneous high resolution models in different exposure situations have proven to be successful.

ACKNOWLEDGMENTS

REFERENCES

Efficient Low Frequency EM Human Body Simulations

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INTRODUCTION

In the last decades, the finite-difference time-domain method (FDTD) \cite{1} has proven to be an efficient and powerful numerical tool. Especially for interactions of complex human body models and electromagnetic (EM) fields, the FDTD method is highly valuable to assess electromagnetic compatibility at radio frequencies. However, at lower frequencies the FDTD method becomes inefficient due to the explicit time integration scheme. The use of quasi-static approximations of Maxwell's equations can lower the computational burden considerably. A novel approach and effective implementation was therefore the objective of this study.

MATERIALS AND METHODS

The electro and magneto quasi-static approximations (EQS and MQS) to Maxwell's equations have been implemented using the finite element method (FEM) in frequency domain. The EQS model neglects the temporal change of the magnetic flux, whereas the MQS model neglects the temporal change of the displacement current. The non-uniform but rectilinear computational grid of the FDTD method has been re-used to benefit from the model discretization and post-processing capabilities of the graphical user interface SEMCAD X \cite{2}. Another important reason for rectilinear grid is the usage of very detailed human body models \cite{3}, which can be only discretized efficiently on this kind of grid (almost one hundred distinguished tissues). Thus, these models are immediately applicable for the low frequency solver, which is an essential feature of this study.

RESULTS

The new low frequency solver package was applied to highly complex human body configurations. The EQS model was used in assessing the impact of a person touching a power line at 50 Hz. Figure 1 shows the current distribution of the person touching with her right hand a 600 MΩ rod connected to the power line. Future versions of virtual family members will allow the positioning of each part of the model individually (ongoing research).

A special MQS model addressed the safety of workers operating close to a MRI machine, i.e., the magnetic fields of the gradient coils operated at 1 kHz. Again the current distribution was of major interest.

CONCLUSIONS

The numerical approach of this study has proven to be very effective in assessing interactions between detailed human body models and electromagnetic fields at low frequencies. Real-world simulation results are presented.
ACKNOWLEDGMENTS

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Figure 1: Preliminary result: a person holds a rod connected to a power line. The EQS model (ohmic current dominated) is used to assess the current distribution (right) inside the body.
Estimating General Public Exposure to Electromagnetic Fields generated by Cellular Phone Base Stations

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INTRODUCTION

Often, public exposure to electromagnetic fields of public telecommunication systems is only assessed for compliance, resulting in merely the highest values reported at a given location. On the other hand, determining the distribution of the exposed population in function of field levels requires a myriad of measurements or calculations. Such distributions can be used for general information, for analyses over time or between different regions, or even as forecast tool for new technologies. A relatively simple model is described in [1]. It requires, however, detailed knowledge of the base stations. This data is commercially sensitive and, therefore, difficult to obtain from all concerned operators. But standardized base station data [2] is already available for frequency coordination purposes at many European regulators. A new simple model using this data is described here. It was compared with [1] and validated by drive test measurements within a region typical for Switzerland.

MATERIALS AND METHODS

[1] describes a relatively simple method to calculate the distribution of the exposed population in function of field strength: at all locations within a certain geographical area where people live according to the official population census data, the cumulative field strength of all relevant base stations was calculated, and the distribution of the exposed population determined. The detailed base station data, in particular the antenna specifications, of just one operator has been used for this model.

Base station data is available at the regulator for frequency coordination purposes [2]. This data is simplified with respect to antenna diagrams, which are categorized for each transmission plane by a type and two numerical values. The advantage is that this information is readily available and standardized within 17 different European countries. This allows independent calculations, which are, in addition, comparable between these countries.

A new, simple calculation model was thus developed using Matlab. It incorporates free field propagation and flat topography (with the possibility to subsequently add a terrain model). Shadowing, diffraction, reflection and absorption have not been taken into account. The base stations are modelled by effectively radiated power (ERP), antenna height, main beam direction of the antenna and its radiation pattern according [2]. Furthermore, average transmission power is modelled in function of traffic channels for GSM and of estimated power load for UMTS. The fields were calculated 1.5 m above ground only, since in [1] only small variations in function of height above ground were observed for key results (i.e. median of exposure). Only base stations for mobile communication systems were looked at.

In order to verify the model, the distributions were compared to results according [1]. For these calculations the updated base stations information for one single operator have been
used in both approaches. The same geographical region as in [1] was used, since it includes rural, urban and sub-urban parts, as well as some hilly terrain and water flows. Furthermore, the distributions for all operators were also calculated (Figure 1). These results were validated by drive measurements along a typical track within the geographical range.

RESULTS

The calculation with the new model showed only minor differences to the results of [1] (below 10% in respect of field strength). However, compared to calculations with the inclusion of shadowing, the results were - as one would expect - consistently higher (about 60%). Terrain height on the other hand did not matter much for the key results. The measured and calculated distributions along the measurement track show similar forms.

![General public exposure Bern North](image)

Figure 1: Distribution of exposed population in function of the electric field strength, 1.5m over ground

CONCLUSIONS

The distribution of the exposed population in function of field strength is a robust model for the estimation of the general public exposure to EMF generated by mobile phone networks. It is possible to use standardized data bases of mobile telecommunication systems available at the regulator for rapid calculation with this simple model. These results can be compared between countries as well as over time. It could be possible to single out exposed and less exposed regions. Finally, the future development of the exposure due to newly introduced technologies can be estimated.

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Electromagnetic/Thermal Co-simulation of RF Thermal Ablation

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INTRODUCTION

Liver metastases are unfortunately a frequent side-effect of various types of cancer. Due to the position and spreading deep in the liver, approximately 70% of patients are considered to have inoperable cancer. Untreated, the average lifetime of the patient is reduced to less than 12 months. This has led to the development of minimally invasive treatments which directly apply energy to the tumor using methods such as Radio Frequency Thermal Ablation (RFTA). The subsequent heating of the region destroys the tumor and tissue in a small circumferential region around the tip of the RF electrode.

Testing and development of RFTA devices are limited by the fact that all measurements need to be performed on living tissue, since both current distribution and resulting temperatures depend heavily on blood flow inside the body. In this article it is shown that a combined 3D electromagnetic and thermal simulation, which includes the bio-heat equation [1], makes an accurate prediction of the resulting localized heating inside a tumor when exposed to an RF signal, feasible.

SETUP AND SIMULATION

An electrode for monopolar RFTA [2] is applied to a human body model, which is based on anatomical data of the Visible Human Project®. In Fig 1, the setup, which includes the neutral electrode at the bottom and the exciting electrode placed in a catheter in the liver, is shown. An input signal of 40 W at a frequency of 375 kHz is applied to the device. To avoid damaging the healthy tissue along the electrode, the outside of the electrode is externally cooled to room temperature.

In order to numerically determine the temperature distribution in the liver due to the electromagnetic fields in the body, a co-simulation was performed using the programs CST Microwave Studio® and CST EM Studio® [3], both based on the Finite Integration Technique. To calculate the electromagnetic losses, the transient high frequency solver of CST MWS was used. The power loss density is shown on the left of Figure 2. It can be seen that the loss is especially high near the tip of cathode, but there are also significant currents near the neutral electrode. The temperature distribution was calculated with both the stationary and the transient thermal solvers of CST EMS. In Figure 2 (right side), two
thermal simulations neglecting the bio-heat equations (considering effects like blood flow) and including this formulation are compared. It becomes very obvious, that blood perfusion changes the temperature distribution significantly and needs to be considered in order to deliver realistic results.

The results show a maximum temperature near the cathode of about 106°C, which agrees very well to results known from experience. The volume of the tissue, which experiences a temperature in excess of 50°C and will be coagulated by the treatment, is measured to be approximately three cm in diameter. This agrees well with data supplied by the manufactures of the probe used in this study [3]. In order to validate the results, additional measurements will be performed and shown in the final presentation.

Treatment lasts for several minutes, and maximum temperature is typically reached after about 2 minutes. A deeper understanding of this process is obtained by looking at the transient heating profile around the probe. Figure 3 shows the temperature distribution within the first 100 s after switching on the RF power.

CONCLUSION

Minimally invasive methods such as RF Thermal Ablation are very successfully used for cancer treatment. Electromagnetic-thermal co-simulation has been shown to be a very helpful tool for designing RFTA devices and for understanding effects during the operation inside the biological tissue which are not easily accessible for measurements. The results were studied both in a steady state and in transient conditions and show very good agreement to already published references. Own measurements will be performed and presented later.

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SOFTWARE TOOLS FOR EDITING ANATOMICAL MODELS

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Aim of Work

Modeling and Simulation (M&S) techniques, such as the Finite Difference Time Domain (FDTD) method, are commonly used to assess the interaction of electromagnetic energy with biological media. In the radio frequency region of the spectrum, these techniques are commonly used to predict energy absorption throughout a human or animal body. These human body simulations are often used to assess the consistency of RF safety standards, while animal simulations are used to determine the dosimetry in laboratory research experiments. In either of these cases, it is critical to have highly-resolved and accurate digital anatomical models.

In the past, anatomical models for M&S purposes were often created by a manual tissue identification and coding process. Two-dimensional slices of the anatomy, often from magnetic resonance imaging (MRI) scans, were considered independently and hand coded. These slices were then stacked in order to form the complete three-dimensional model. Inconsistencies in this coding process often led to discontinuous tissue interfaces in the model. Furthermore, artifacts inherent when creating full-body MRI images became incorporated into the final model. In this work, image processing techniques and software are developed to substantially reduce these errors, to improve the model creation process, and to perform morphological operations on existing models.

Materials and Methods

Two software packages have been created for this work. The first is an in-house C language code that performs smoothing operations on existing anatomical models. This software is used to improve the continuity of tissue boundaries for models that were coded by hand.

The second software package, called Maverick, is a workflow based environment for image segmentation. Maverick is a collection of C++ classes that allow the user to perform various image processing and segmentation tasks in a sequential manner. These tasks ultimately lead to a final desired product, which in this case is a fully segmented anatomical model.
Results

The Maverick framework includes tools to perform a wide variety of image segmentation tasks. These tools can be used for:

- Tracing organ boundaries
- Auto-segmenting organs
- Refining existing models to better match MRI data
- Combining anatomical features from one model into another model
- Visualizing MRI data, corresponding labelmaps, and specific absorption rate data simultaneously
- Computing organ-specific SAR measures
- Performing morphological operations on models

To date, Maverick has been used in the creation of a 2mm resolution swine model based on MRI data, improving the alignment of human body models with their image datasets, morphing the size and shape of a human body model, and registering a 0.1mm eye model within a 1mm head model.

The in-house smoothing algorithm has been used to correct discontinuities in tissue boundaries within the Brooks Man Model, which was derived from the Visible Human dataset. We anticipate that is will also be useful for existing laboratory animal models.

Discussion and Conclusions

The software approaches presented here are aimed at 1) optimizing the continuity of tissue boundaries in already existing models, 2) performing morphological and editing operations on models, and 3) semi-automating the process of creating models in the future. The result will be better anatomical models leading to improved RF simulation accuracy.
New Powerful FDTD Source Based on Huygens Surface: Highly Complex EM Simulations Performed on an Ordinary PC

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INTRODUCTION

A wide range of powerful electromagnetic simulation tools are available today that are based on different methods of computational electromagnetics developed over the past four decades. Each of these software packages can simulate real world problems of large complexity but is limited to a certain problem category. These categories can be characterized as spatial dimensions in terms of wavelength. Examples are wave propagation in cities (Ray-Tracing), electrically large antennas and scatterers (MoM=Method of Moments), mobile phone mounted on the body (FDTD=Finite-Difference Time-Domain), micro-devices implanted inside the body or structures on semi-conductors (FEM=Finite Element Method).

For example, the FDTD method is well-suited for problem extensions between 0.01 to 10 wavelengths whereas the computational effort scales with the power of 4 (time step x number of cells) and the memory requirements with the power of 3 with respect to spatial refinements. To reduce the overall computational effort, one can

- minimize the number of cells,
- increase smallest spatial step (therefore the time step), and/or
- decrease the resonant characteristic of the model (therefore smaller physical end time of simulation, i.e., less time steps needed to reach it).

Thus, these three items are the target of the novel Huygens FDTD source and are explained in detail in the next sections.

METHODS

Figure 1 shows a possible simulation scenario, where the subsystems antenna, antenna-human and human are very weakly coupled. Therefore, it is sufficient to simulate one subsystem after the other in the sense of a unidirectional subgridding. The novel Huygens source can therefore act as a powerful hybridization platform linking other methods (e.g. MoM, FEM, ray-tracing, etc.) to FDTD or as an FDTD-FDTD subgridding scheme. The key point was to generalize the total field scattered field (TFSF) plane wave excitation [1] and therefore enable virtually any incident field to be used as an excitation field.

Practically speaking, this approach breaks down the simulation into two stages: (1) primary simulation of incident field: a simulation of source region to determine the incident field distribution on the Huygens box region. Typically characterized by coarse mesh and a large time step and therefore short simulation times. Another strategy is to use other possibly more appropriate numerical EM tools during this step. (2) secondary simulation of Huygens box region: unidirectional subgridding using the Huygens source with incident field as the excitation. Typically characterized by fine mesh resolution and small time step, but small
overall mesh size result in average simulation times. Furthermore, the model is mostly less resonant and the simulation times reduces further.

The advantage of this approach is that the limitation of a very long FDTD simulation with many time steps is overcome by running a faster, coarser simulation followed by a smaller, detailed simulation. The immediate benefit being a tremendous saving in computation time and memory consumption compared to overall simulation.

**Figure 1:** Left side: in this example, a MoM solution is used as input for the FDTD solvers. Different anatomies and postures can be analyzed without solving the entire problem. The effectiveness of the spatially diverse antennas for different antenna configurations and posture.

**RESULTS**

Currently, one of the most challenging problems in medical device simulation is the research and design of active medical implants which cause heating when exposed to the RF fields of an MRI scanner. Both patients and industry would largely benefit from MRI safe implants. But simulation of a complex implant, embedded in an inhomogeneous body and surrounded by a large electrical resonator with micrometer resolution is a challenging task. SEMCAD X [2] is used in this case study to highlight the benefit of applying the Huygens source approach to simulate an RF MRI birdcage including a patient with generic implant and lead pass. This particular example will show the substantial benefit in computational requirements that the Huygens source offers with respect to both RAM memory and overall simulation time (wall clock time): a factor of 8 times reduction in simulation time is achieved and almost five times less RAM is required. In other cases the benefit may be much more.

**CONCLUSIONS**

This article demonstrated the effectiveness of a novel FDTD source called Huygens source. The source uses a generalized TFSF implementation and enables straightforward FDTD unidirectional subgridding with tremendous savings in CPU time and memory consumption. Furthermore, the incident field can be provided by other numerical EM tools like MoM and the new FDTD Huygens sources acts as a powerful hybridization between the two methods.

**REFERENCES**


DATA OF EMF EXPOSURE IN BULGARIA AND LEGISLATION POLICY

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Introduction
A lot of measurements of electromagnetic fields (EMF) have been performed in Bulgaria in working and living environment. Epidemiological studies carried out in different occupations show where overexposure and professional risk could be found. For instance, higher risk exists amongst professions in energetic, metallurgy, metal processing, plastic industry, physiotherapy, nuclear magnetic resonance (NMR), radars, radiobroadcast and communication. In other hand, many new technologies are in a process of tremendous development as mobile communication technologies (3G, 4G, WI-MAX, WI-FI), medical diagnostics (NMR), energetic and others. The existing uncertainties in scientific literature concerning the thresholds, long-term exposure and fears amongst workers and general population, especially “sensitive” groups, require conducting careful policy for assessing and reducing EMF health risks. The International Commission of Non-Ionizing Radiation Protection (ICNIRP) guidelines give the countries any possible way to limit exposure on the base of evidences about the possible adverse effect. Unfortunately, the ICNIRP guidelines are based only on short-term effects, chronic or long-term effects are not considered in setting exposure limits.

The aim of the study is to present the EMR policy that we propose to be followed in Bulgaria as an EU member country on the basis of our experience of EMF exposure assessment for general public and different professional groups.

Materials and Methods
Sources of EMR exposure
Exposure in living environment: Mobile communication base stations - 900 MHz; 1800 MHz; 2100 MHz; transformers in dwellings - 50 Hz.

Occupational exposure: Sound recording studios – static electric field; power stations - 50 Hz: 110 kV, 220 kV, 400 kV; electric transport: railway and trolley cars - ELF; induction metal heating: generators - 66 kHz; plastic welding - 27.12 MHz; mobile communication base stations - 900 MHz; 1800 MHz; 2100 MHz; video display units (VDUs) - frequency ranges 20 Hz to 300 kHz; radiobroadcast, physiotherapy - 27.12 MHz; 2450 MHz; NMR imaging – static magnetic and time varying EMF (0.5 T, 1 T).

Measuring methods are based on some international and national standards, also on our own experience. Some of the methods used are standardized by the Ministry of Health for such measurements. For exposure assessment of EMR are used both spot and “dosimetric” methods: scenario method and individual dosimetry.

Risk assessment of exposure to EMF is performed according to ILO recommendations. The risk rating (RR) is determined as well as the measures of priority to be taken by the employer. The risk coefficient related to the number of subjects exposed to electromagnetic field only in power stations is evaluated apart. Considering these two risk indices we determined the decision-making priorities, proposals and recommendations for work conditions improvement.

For risk assessment we used TWA and energetic values calculated for different professional groups (energetic loads), as well.

Results and Discussion
Some results of measurements in different occupations and living areas are presented in relative units of average levels measured according both to the Bulgarian national standards and ICNIRP exposure limits proposed by WHO/EU for occupational and residential EMF exposure.

It is ascertained that there is a risk from EMF exposure for people working in factories for induction heating, plastic welding, also for those working in the close proximity of broadcasting or base station antennae, in physiotherapy and power substations. For a part of these occupational groups
the risk is evaluated on the basis of the EMF values measured above the limits: plastic welding, induction heating, broadcasting, base station antennae, high voltage power stations, NMR, and for the other part the risk is assessed on the exposure dose (including the time duration of the working shift) or specific operations in the close proximity of emitting sources: radars in physiotherapy, power lines for transport and in power stations. Bulgarian legislation allows such determination of the maximal permissible time duration of exposure at which the risk for harmful effect is insignificant.

Compared to the limit values recommended by the European Union/ICNIRP Guidelines which consider only the short term effects some of these professional groups are not at risk: physiotherapy, transport, radio broadcasting, hydropower stations, and operators maintaining base stations.

There are cases where the ICNIRP limit values are more stringent than the national legislation, for example, for a part of radiofrequency range (up to 10 MHz), especially for the limits for magnetic field.

For the general public the measured EMF values rarely exceed the hygienic limit values according to the national legislation. Compared with EC recommendation (1999/519/EC) they are hundred times lower than the limit values and could not create health risk.

The policy for providing public health in the field of EMF exposure on national level should follow not only the possible risk for the people and also the level of public fears and concern about such risk. For some time past the main problem in our country is fear amongst the general public concerning the risk of EMF effects by mobile communication antennae. Some reasons for this are:

- lack of good legislation to regulate obligations of the industry for ensuring health for the general public as well as citizens’ rights to make use of EMF sources and to receive information regarding the exposure;
- economical interests as by side of the citizens (rent relations with the operators) and by firms (companies) as well considering assuring general public health as a business;
- approaching elections by reason of the problem is being used to create tension /strain amongst the general public.

In this situation, we consider that an implementation of a Law on EMF Protection, based on “Model Legislation for Electromagnetic Fields Protection” of WHO will help us to solve the problems with the general public to great extent.

We propose development of specific national legislation according to the requirements of European Union and WHO. Generally, the main aspects of such legislation are:

1. To form an expert working group (WG) to develop a draft document for implementing a Law for EMF safety up to the end of this year (2009).
2. To make changes and supplements in the Health Law in force towards better and more strict control of technologies and products emitting EMR.
3. The framework of the draft for an EMF law for protection the people should be considered according to the requirements of WHO/EU, and with all requirements for control of sources of radiation used in member countries as follows:
   - By calculations – health evaluation of the safety zone for permitting the area of mounting any antenna;
   - By measurements – checking the safety zone around any stationary source of radiation.
4. One obligation of the expert WG should be to implement the Precautionary Principle in the legislation. This requirement is a result of the uncertainty in science, and the lack of enough information about the health effects of EMF that arise the public concern.
PHYTOMETER AND ENVIRONMENTAL GEOMAGNETIC FIELDS
ΔGMFS FOR INVESTIGATION OF RESTING-PLACE IN PLEASURE-GROUND

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Key words: phytocenosis; electromagnetics; taxonomy.

INTRODUCTION

The structure of magnetic fields on the Earth surface (ΔGMFs) does not correspond to model computations based on Gauss’ geocentric axial dipole hypothesis. It is conjugated with regional and local magnetic heterogeneities of lithosphere. They are visible on ΔGMFs maps in form of anomalous values (secular variations of declination \(D^\circ\), inclination \(I^\circ\) and inductional vector of magnitude \(B\)). This natural ΔGMFs property determines evolutionary processes in biosphere as well as biological health of plants and animals [1].

The local geobotanic peculiarities of terrestrial phytocenoses can be coming from impact of anomalical GMFs characteristics. It is obvious that scientific and applied tasks are incorporated in this problem. The represented report is devoted to the results of ecological state monitoring of Saint Petersburg State Polytechnic University campus.

MATERIALS AND METHODS

The recreational zone and its phytocenosis were used as the natural model in vivo. The nature foliaceous and coniferous trees were taken as the test-object and the anomalies of ΔB_z were presumed to be unfavourable for life and biological health of these plants.

For the first time the complexal magnetoecological method was set forward by author for monitoring of park zone using the main preference of method – its expressivity.

The compositional parts of the common proposed method are the following:

- **The biomagnetic estimation** of phytocenosis condition (the method is confirmed physiologically);
- **The geobotanic landscape mapping** of park zone phytocenosis (mycosis, bacterial pathologies, distraction of wooden mass by insects, etc.), the determination of forest taxonomic characteristics in according to the taxonomy of dangers;
- The magnetometric revealation of local steady anomalies ΔGMFs in recreational zone with consideration for background geomagnetic normal field \(B_0\) before 2000 year.

RESULTS

1. The mapping (scale 1:500) of values ΔB_z, \(\mu T\) was done on the nodes of a square 10 m on side to within the experimental error of \(\delta=50\ \text{nT} (0,1\%)\).

These data in program Delta graph were depicted on maps for two levels: one at surface (0 m), other at 0.7 m above it. The variations of induction |ΔB_z| not upheigthenig 80 nT (\textit{id est...})
0.02% mean diurnal alternation) were expelled.

2. The phytocenosical (geobotanic) survey of forest plants was conducted with the accounting of taxonomy of danger: type of tree, diameter of trunk, height, Kraft class, category of condition morbidity, a level of a damage. This survey were carried out on chosen lot using the St. Petersburg Forest Technical Academy methodic. The category of condition was rated on the 6-ball scale in accordance with Russian Federation sanitary norms of forest tree usage. These points were put into electronic data base in program Mapinfo.

The following diseases of tree species were discovered:

- *Taphrina betulina, Uncinula, Nectria cinnabarina, Nectria galligena, Rhytisma acerinum, Melampsoridium betulae, Melampsora populina, Hypoxylon pruinatum, Ionotus obliguu, Armieliariella mellea, Lepzites betulina* (foliaceous);
- *Lachnellula welcommii, Peridermium pini, Genangium abietis* (coniferous)

3. By means of GIS-technologies the park territory field survey data was compiled into integrated informational space:

- The trees with “*Nectria galligena*” disease
- The magnetometric data within limits of localized ΔGMFs anomalies, *id est* ΔBz.

**CONCLUSIONS**

The collected data permit:

To establish the fact of 80%-connection of plants morbidity with localized anomalies ΔGMFs, their sources located near subsurfacial layer of soil or more deep stratum.

To strive for increasing reliability of survey by using expensive high-tech magnetometer (type *Superconducting Quantum Interference Device*) with protection from sources of dangerous action (EM-hindirances).

To plan the perspective cleaning of recreational zone territory from sources of dangerous impact ΔBconst.

**ACKNOWLEDGMENTS**

State Polytechnic University budgetary funds.

**REFERENCES**

INTRODUCTION
The study results of the power frequency (50 Hz) magnetic field (PF MF) intensity and temporal characteristics under non-occupational conditions are presented. The study was conducted to determine the PF MF intensity and temporal characteristics in general public areas with uncontrolled access. Some particular features of modern PF MF sources are demonstrated.

MATERIALS AND METHODS
Living quarters, public and business premises and residential areas located close to detectable PF MF sources such as 0.4-500 kV overhead and cable power lines, built-in and detached transformer substations, switchboards, etc. were objects of inquiry. Measurements were made at 415 different objects.

Measurement method consisted of two basic stages – mapping of the PF MF intensity in a room and PF MF monitoring in localized maximum point. Simultaneously spatial orientation of magnetic flux density $B$ vector and dominant frequency were recorded. PF MF measurements along selected direction were made at residential areas. In total measurements were conducted at 10818 points. Short-term (up to 4 hours) and 24-hour monitoring PF MF monitoring was provided on 73 and 9 objects correspondingly.

Then the unbalanced currents in 0.4 kV cable lines were the main PF MF sources oscilloscopic recording with the following current spectrum analysis was used.

Root-mean-square (RMS) magnetic flux density $B$ values in the frequency range 5-2000 Hz (50 Hz and higher harmonic components) were measured using Narda EFA-3 electromagnetic field analyzer (Pfullingen, Germany) with external $B$-field probe ($A = 100 \text{ cm}^2$).

For every object magnetic flux density $B$ maximum and averaged values were defined and maximum, minimum and averaged values were defined during PF MF monitoring.

Hygienic Norms GN 2.1.8/2.2.4.2262–07 "Maximum permissible levels of 50 Hz magnetic fields in dwellings, public premises and residential areas" introduced in the end of 2007 was used as a criterion for the PF MF assessment. This standard places a PF MF maximum permissible level (MPL) of 5 $\mu$T for dwellings and 10 $\mu$T for public and business premises and residential areas.

RESULTS
Generalized data of PF MF measurements results is presented in Table 1. Analysis of study results demonstrates variety and specific character of the general public PF MF exposure in uncontrolled environment. There was a wide range of measured magnetic flux density $B$
values – from less than 0.04 µT up to 100 µT (more than 2500 times) and the averaged value was about 1 µT.

Table 1. Generalized PF MF measurements results

<table>
<thead>
<tr>
<th></th>
<th>Over all objects</th>
<th>Living quarters, public and business premises</th>
<th>Residential areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum registered value of magnetic flux density $B$, µT</td>
<td>98.70±2.96</td>
<td>98.70±2.96</td>
<td>10.080±0.303</td>
</tr>
<tr>
<td>Averaged value of magnetic flux density $B$, µT (95% CI)</td>
<td>1.252±0.057</td>
<td>1.260±0.060</td>
<td>1.003±0.125</td>
</tr>
</tbody>
</table>

The PF MF intensity locally exceeded MPL at 16.4 % of surveyed objects. For 2.6 % of objects averaged magnetic flux density $B$ values exceeded MPL for PF MF.

The most common sources of PF MF significant levels were unbalanced currents over 0.4 kV cable power lines, current-carrying parts of built-in transformer substations and switchboards.

Unbalanced currents over pipelines and building metal constrictions appear due to technical errors in power-supply systems.

Predominance of the third harmonic of the fundamental frequency (50 Hz) – 150 Hz – was recorded in the magnetic field spectrum at 88 of 415 objects (21.2 %). Pronounced presence of the higher harmonic components, especially 150 Hz, is determined by nonlinear electrical load distribution in modern power-supply systems.

PF MF monitoring showed different types of magnetic flux density $B$ changes in time related to differences in current load characteristics. Thus, general public PF MF exposure has a pronounced intermittent pattern.

CONCLUSIONS

Obtained data shows that a part of Russian population has a contact with PF MF, whose intensity exceeds MPL. However maximum measured magnetic flux density $B$ value did not exceed MPL recommended by ICNIRP (100 µT). Registered appearance of higher harmonics of fundamental frequency 50 Hz requires application of appropriate instrumentation and measuring methods. It also should be taken into account then planning experimental studies of PF MF biological effects. Preliminary computation and measurements of PF MF levels have to be made during the design and placing of stationary electric power transmission and distribution facilities to ensure electromagnetic safety of the population.
MOBILE COMMUNICATION AND CONDITIONS OF EMF RF EXPOSURE FOR POPULATIONS: NON-ADEQUACY OF CURRENT EMF SAFETY STANDARDS

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INTRODUCTION:

The general postulate: Hygienic standards are developed for protection of health of the population, taking into account concrete conditions of factors harmful or potentially dangerous to health under the obligatory conditions of probable contact of the population with these factors [1, 2].

RESULTS AND DISCUSSION

All international EMF RF safety standards continue to be based on THERMAL, ACUTE and PATHOLOGICAL biological and clinical effects (ICNIRP Guidelines 1998, IEEE Stand. C95.1-2005, CENELEC EN 50166-2.2000). These contradict real conditions EMF of mobile communication exposure of population. Most people usually do not contact EMF of thermal intensity at work or at home and have no acute contacts with EMF of such high intensity. All population in the world has contact with low levels of electromagnetic fields and radiation; and daily chronic irradiation is the rule. The important critical system of is organism is a brain of the user of mobile communication.

There are no scientific bases for extrapolation of these international standards to real conditions of the population. There are no publications which show how one passes from acute exposure at thermal levels to normal exposures: to chronic long-term EMF exposure and to weak, non-thermal informational levels of exposure.

The EMF safety standards of the RUSSIA/USSR (EMF Sanitary Rules, SanPiN) have another way of basing safety limits, assuming

- non-thermal levels;
- a chronic EMF exposure of all population;
- absence of a threshold level on pathological effects.

However Russian EMF standards also do not take into account up-to date EMF daily exposure of the brain of people who have a mobile phone, including children.

The necessity of development of the standards for children, as new group of risk. The potential risk to children’s health is very high and is a completely new problem. As WHO Backgrounder N 3 (2003) states, "CHILDREN ARE DIFFERENT FROM ADULTS. Children have a unique vulnerability. As they grow and develop, there are 'windows of susceptibility': periods when their organs and systems maybe particularly sensitive to the effect of certain environmental threats".
CONCLUSION

Both foreign EMF standards and Russian standards have become outdated because not correspond to the facts conditions of an EMF exposure of population. Existing EMF safety standards cannot guarantee safe healthy development of new generation of peoples.

New research is necessary. It is also necessary to introduce a precautionary principle actively.

REFERENCES


INTRODUCTION

When a worker is implanted with an active cardiac implant, as a pacemaker (PM) or implanted defibrillator (ICD), occupational physician has to define his work aptitude. The implant may be perturbed by magnetic field, and the risk has to be evaluated.

The objective of this paper is to illustrate the application of a methodology to do this risk assessment. For this, we have to evaluate the functioning of the PM or ICD in the presence of a magnetic field of 50Hz in a occupational area. EDF had to managed 3 cases of workers implanted with an ICD since 2005: the first worked in a hydroelectric plant, the second in a nuclear power plant and the third in an high voltage substation. In these circumstances the workers are potentially exposed to higher magnetic fields than the general public. These three examples illustrate our approach to define the work fitness. These situations are rare, that is why we propose to do a particular workplace assessment.

MATERIALS AND METHODS

We performed an assessment of the ICD functioning at various workplaces. The protocol consists in measuring magnetic field in the presence of implanted worker. A pluridisciplinary team should perform the study:
- the occupational physician
- the employee
- the cardiologist with cardiac reanimation material
- the ICD constructor to question the ICD with the telemetry material
- the engineer to perform magnetic field measurements

All areas where the worker could work or even cross have to be visited and the ICD (or PM) has to be questioned in all situations.

It is important to visit workplace in a cautious way, in order to limit possible interferences for the worker. For this, the measurements should begin with the areas of lowest magnetic field, which correspond to daily life exposure.

RESULTS

In the hydroelectric power plant, the occupational physician decided to perform directly measurements with the patient. In the different areas, 50Hz magnetic field has been measured from 0 to 650µT at the ICD location. No dysfunction of the ICD has been observed with the bipolar mode.

In the nuclear power plant, the occupational physician decided to perform measurement
without the patient in a first step. The magnetic field measured was lower than 200µT. In the areas where the magnetic field is lower than 10µT, no additional assessment is needed. Measurements of magnetic field with the patient and the telemetry material have to be performed in the other areas.

In the high voltage substation, the occupational physician decided to perform directly measurements with the patient. In the different areas, 50Hz magnetic field has been measured from 0 to 80µT at the ICD location. No dysfunction of the ICD has been seen.

CONCLUSIONS

Theses three examples of workplace assessment show different way to conduct a particular risk assessment for implanted cardiac devices. They demonstrate the interest of measuring magnetic field and questioning the implant in the same time, at the different working places, in order to evaluate risks of ELF magnetic field interference and to help the occupational physician to define the work aptitude. The decision of the method to adopt comes under the occupational physician.
**50 Hz Electric and Magnetic Field Measurements in High Voltage Substations**

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**INTRODUCTION**
The European Directive 2004/40/EC requires from the employer to make a risk assessment. The first step of this one is to assess the exposure of the workers to electromagnetic fields. Concerning exposure to 50 Hz electric and magnetic fields, RTE and EDF have performed extensive measurements in a representative sample of production, transmission and distribution facilities. The present paper focuses on transmission substations in France, all operated by RTE.

**MATERIALS AND METHODS**
All measurements were performed using commercially available field meters (PMM 8053A and EFA300), regularly checked and calibrated. RTE’s measurement laboratory is accredited for 50 Hz electric and magnetic field measurements under power lines and has developed a dedicated calibration procedure. EDF’s measurement team uses similar procedures.

For magnetic field assessment, in addition to the spot 50 Hz measurements, an EMDEX II meter was used, allowing a continuous recording broadband (40 - 800 Hz) and harmonics (100 – 800 Hz) compounds of the magnetic field.

For electric field, the probe was installed at the extremity of a horizontal offset rod supported by an insulating tripod, at the height of 1 meter above the ground. The E-field probe is connected to the meter by an optic fibber. Care was taken that measurements were not perturbed by weather conditions.

RTE operates more than 2600 HV substations in France, and they are spread on quite large areas. It is obviously not feasible to measure field everywhere and in every substation. Nevertheless, these stations are highly standardised, with similar designs, and it is therefore possible to find repetitive structures in each substation, what reduces the area of investigation.

In order to comply with directive 2004/40/EC, it is necessary to look for maximal exposure. That is why measurements at ground level were performed at regular intervals following selected axis under the bus bars, but also on specific workplaces identified as possible “hot spots”.
RESULTS

Results of measurements in 63 kV, 90 kV, 150 kV, 225 kV, and 400 kV substations will be presented. 400 kV with and without GIS will be distinguished.

Electric field is maximal under bus bars, depending of the height of conductors but also of the phases arrangement. Maximal values between 15 and 17 kV/m were measured in 400 kV overhead substations, between 10 and 12 kV/m in 225 kV substation. Electric field is less than 7 kV/m in 150 kV substation, less than 4 kV/m in 90 kV substation and less than 2 kV/m in 63 kV substation. Within GIS, electric field is less than 1 kV/m.

Maximum measured magnetic field was 77 µT, except some localised places closed to air core reactors.

CONCLUSIONS

Measurement results will be discussed with regard to the action values and exposure limits set up by the European Directive 2004/40/CE, and also with regards to the relevant standards.
**Hygienic Standardization of Power Frequency Electromagnetic Fields in Russia**

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**INTRODUCTION**

Power frequency EMF sources are various types of power objects - high-voltage substations and transmission lines, devices containing current wires, including electrical transport, the industrial and medical equipment, home appliances, etc. Personnel of power networks first of all, of extremely and ultra high voltage open switchyard and overhead transmission lines are most occupationally exposed by PF EMF, and also the personnel which is carrying out service of cable transmission lines.

General public can be exposed by PF EMF in the open territory near overhead and cable transmission lines (OTL and CTL), transformer and distributive substations, and also electrical transport. At home the main sources of PF EMF are different home appliances and in garages and on summer residences – electric tools, pumps and so forth. Besides in inhabited and public buildings general public can be exposed by PF EMF from nearby OTLs and CTLs, distributive and transformer substations, and other permanent functioning sources. Human health hazard PF EMF effects protection is actual issue.

**MATERIALS AND METHODS**

The principles of human health protection from adverse PF EMF effects include 3 principles:

- **Protection by time.** It is applied when there is no opportunity to reduce EMF intensity up to all day (or all working day) maximal permissible levels. This principle is realized in hygienic norms both for occupational and general public exposure;

- **Protection in distance.** In case of occupational exposure it consists in deducing staff of a zone of raised EMF levels. It is carried out by means of mechanization, automation, use of remote control, manipulators, accommodation of workplaces in view of emission direction and properties. In case of general public exposure it is realized by the maximal removal of population places of residing (constant stay) from EMF source. In particular, for general public protection from OTL electric field, will be organized sanitary-protective zones.

- **Protection by protective means (collective and individual).** As collective protective means for occupational conditions the devices limiting receipt of electromagnetic energy on workplaces (shielding) are used. Individual protection from PF electric field provides by screening clothes.

The basis of PF EMF hygienic norms (maximum permissible levels (MPL) are the complex of hygienic, clinical and physiological, epidemiological, experimental researches (and last years epidemiological studies). The main basis of EMF norms setting are the experimental data of EMF exposure hazard effects threshold determination.

Special experiments directed on development of general public PF magnetic field hygienic norms were carried out in mice and rats under long term (4 months and one month post exposure period) under 100; 400 and 2,000 μT and sham every day exposure. Experiments aim were to determine the exposure hazard effect threshold to nervous, immune...
systems, generative function. Using extrapolation from animal to human body principles and introduction of hygienic safety factor as well as data of hygienic investigation data and analyses of scientific publications new PF hygienic norms have been developed.

RESULTS

Now in the Russian Federation there are some statutory-methodical documents of PF EMF exposure limits.

According to SanRaN 2.2.4.1191-03 and GOST 12.1.002-84 permissible level of electric field (EF) occupational exposure is from 5 kV/m (all working day) to 25 kV/m (up to 10 min per day). Work in EF intensity more than 25 kV/m without protective means is not supposed. Hygienic norms of PF magnetic fields occupational exposure are from 100 μT (all working day) to 2,000 μT (<1 h/day) total exposure (with special norms for extremities).

Until recently 50 Hz EF levels from overhead transmission lines 330 kV and above voltage were regulated only. Thus established MPL were differentiated depending on possible time of stay of the population - from 0.5 kV/m (inside of residential buildings and constructions), 1 kV/m (in territory of a housing estate) up to 20 kV/m (in remote district). In addition in the document requirements on delimitation of sanitary-protective zones of OTL and maximum level of EF intensity on its border - 1 kV/m contain.

As a results of last years investigations were developed new Hygienic Norms 2.1.8/2.2.4.2262-07 “50 Hz magnetic fields maximum permissible levels in premises of inhabited and public buildings and residential territories”. Maximal permissible levels are from 5 μT (premises inside of the buildings inhabited is equal to), 10 μT (outside of residential buildings and in territory of housing estate zone); 20 μT (temporary stay, including works by persons who professionally don’t connected with power installations), and 100 μT. (not occupied and remote district with incidental stay of people).

For the control of PF EMF created by various sources, settlement and tool methods are used. There are various PC programs, that allow calculate EMF levels.

In case of impossibility of PF electric and magnetic field reduce for maintenance of permissible limit values in staff workplaces, and in places of general public residing, power equipment technical improvement, allowing reduce of EMF intensity, is possible.

The main PF MF sources under occupational conditions are transmission lines with their switching equipment and reactors without closed ferromagnetic core. Cable transmission lines play especially important role as until recently they were not considered as potential source of PF MF human health adverse effect.

For human health safety under conditions of PF MF exposure questions decision, RAMS Institute of Occupational Health in collaboration with Branch of Open JSC “Federal Power Network Company” “Main Power Networks of the Centre” were developed:

- the principle of cable lines configuration on a method of rapprochement of virtual cables axes, allowing to lower created by cable lines MF intensity in 50 - 1000 times,
- designs of air reactors and electromagnetic screens to the reactors, allowing to reduce MF intensity in 5 - 50 times.

CONCLUSION

Complex activity on PF EMF hygienic regulation, development its levels decrease measures (including collective, and individual means of protection), and also introduction of new technical decisions on decrease in PF electric and magnetic field levels at workplaces and inside of inhabited and public buildings and in territory of zone of housing estate can serve for the decision the problem of human health electromagnetic safety.
Assessing Exposure to Electromagnetic Fields at Railway Work in Finland

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INTRODUCTION

Time-varying extremely-low-frequency (ELF) electromagnetic fields (EMFs) are utilized in electric railway transportation. Therefore, both workers and passengers are exposed in various situations to EMFs of 50 Hz, which is the operating frequency by electric trains in many European countries.

Exposure of railway workers to EMFs was previously assessed in Finland in the beginning of 1990s [1]. It was noticed that workers may chronically be exposed to EMFs higher than background levels. Also, it was estimated that general public may occasionally be exposed to higher EMFs than recommended by the protection guidelines. Due to the new current supply systems used in electric railways, as well as the recent public debate and general concern on possible adverse health effects of EMFs, it was decided to further assess the EMF exposure levels at electric railway surroundings. With new, versatile measurement equipment and methods it is possible to determine exposure levels more precisely and reliably than before.

MATERIALS AND METHODS

In this study Narda ELT-400 and Narda EFA-300 were used for measuring magnetic and electric fields, respectively, at railway network surroundings administered by the Finnish Rail Administration. Measurement points were selected so that they represented well the occupational exposure at different work tasks at fixed installations. The measurements were made both at areas open to the public (railway stations) and at areas restricted only to workers (supply stations, standby power plant, railway construction areas, etc). No measurements were taken at electric trains or locomotives.

The aim was especially to assess the exposure levels in situations where workers are potentially exposed to higher EMFs than normally. Also, personal dosimeters (Combinova FD3) were used for assessing the exposure of individual workers to magnetic fields at different work tasks.

The exposure of general public was estimated by performing measurements at places with open access e.g. on platforms where waiting for the arriving train. The measured field strengths were compared separately to the international recommendations given for occupational and general public exposures [2, 3, and 4].

RESULTS

The results of this study indicated that the strengths of EMFs at railway work do not exceed the limit values given for occupational exposure, provided that the working instructions are followed and appropriate safety zones respected. Also, the general public using railway stations and platforms are protected from the health risks arising from electromagnetic fields.
Figure 1: Exposure of workers to magnetic fields in the installation work of railway switch heaters was less than 1 % of ICNIRP reference level which is 500 μT at 50 Hz. At the working site the electric field strength at the height of 150 cm was 2 700 V/m where the occupational guideline for 50 Hz electric fields is 10 kV/m.

CONCLUSIONS

The EMF measurements taken at railway network surroundings indicated that ELF fields do not exceed the recommended exposure levels, and hence there is no need for further actions at the moment. It should be emphasized that the results do not refer to ELF fields inside electric trains or locomotives.

ACKNOWLEDGMENTS

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REFERENCES


The EMF Exposure Risks From Functional Magnetic Resonance Imaging May Outweigh Its Benefits

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INTRODUCTION

The use of FMRI on human volunteer subjects has become fairly common in neural and psychological research. Most of these studies address important issues in neuroscience or neurology, but some others tend to be less cogent issues. Human “volunteer” subjects used in these studies often have little understanding of the biophysical basis and side effects of FMRI—including the physiological action of the magnetic fields applied to the brain (and adjacent body parts). In order to achieve higher spatial resolution, FMRI technology is evolving towards using higher and higher magnetic field strengths; sometimes approaching the level at which “magnetostimulatory” effects would be seen. At such levels, the FMRI is clearly dangerous and is proscribed for use on human subjects---but levels somewhat below this still produce EMF within the brain which may be of a “neuromodulatory” nature. Given even the possibility of such effects, it seems that more attention should be paid to assessing potential risks to the human subjects used in FMRI research--and this should then be weighed against the limited benefits of that technology.

METHODS

Our current study focuses on the risk side of the issue and is based on estimating the EMF fields that are imposed by FMRI exposure at the neuronal level where they might be influencing ongoing neuro-electrical processes. For that purpose we employ techniques we have used in our earlier studies of the cellular impact of Frequency (ELF) fields. First each region of the brain is viewed as a “macro-conductor” of, more or less, uniform conductivity and the local tissue current densities are estimated. The “microdistribution” of these currents at the cellular level is then estimated using non-uniform models of neuron interiors, neural membranes and intracellular spaces. Finally, the likely impact of these induced “micro currents” is assessed by comparing their magnitude and frequency content with those of the endogenous neuro-electric currents (produced by ambient brain activity).

RESULTS

Our dosimetric estimates indicate that neuronal level fields induced by exposure of the human brain to FMRI field are far greater those produced by endogenous neural activity. By comparison, they are also far stronger than cellular level fields we had previously calculated for humans exposed to fields from “High Current Configuration” power lines and other EMF sources. Induced neural fields from FMRI are not likely to produce direct “neurostimulatory” effects but could potentially alter the pattern of ongoing neuro-electric activity and could also burden neural metabolic functions such as the active transport of ions. Induced currents result when conducting tissue moves even in a static (DC) magnetic field. Such movements can include the flow of blood through the brain, the rapid (“saccadic”) motions of the eyeballs as
well as unavoidable “twitches” and other head motions. In multi-Tesla fields, induced electric fields can produce currents having densities that exceed the normal extracellular fields surrounding active neurons. The FMRI also involves a smaller “gradient” field that switches its direction frequently during the course of an exposure and thus introduces a substantial dB/dt. This is the basis for magnetostimulators (usually in the form of “figure eight” coils driven by rapid onset pulses), which are also used in brain research (mainly on animals). In addition to direct, short term, magnetostimulatory actions, induced currents, either from tissue motion in the large static field, or from time varying gradient fields, can have longer-term effects on brain metabolism. Any exogenous currents which cross the neuronal membrane (such as those induced by FMRI) can add to intracellular ion concentration increases which must be compensated for by increased activity of metabolically driven ion pumps (“active transport”). This is especially true if the neurons are exogenously driven to increased action potential firing rates. Moderate elevation of active transport over short times (minutes) would not unduly stress the neurometabolic machinery of the brain, but cumulative effects over many hours, at excessively high fields, are likely to have deleterious effects—especially if the brain metabolism is already stressed by the evoked brain responses that are an inherent part of the experimental protocol in many of these experiments. The FMRI also uses pulsed radio frequency (RF) fields to excite protons to resonate (at their Larmor frequency which is 63.76 MHz for a magnetic field of 1.5 Tesla and would increase to 382.56 MHz for a 9 Tesla magnet). These RF exposures of brain tissue during the FMRI experiments are far more widespread throughout the whole brain and more intense than those SARs produced by RF fields from cell phones held to the ear.

CONCLUSIONS

c) The consent of “volunteers” to be human test subjects is often more “misinformed” than “informed.” There is often little appreciation by these

This analysis points to three main areas of concern regarding the use of human “volunteer” subjects in FMRI research:

a) The exposures to the magnetic and RF fields that are inherent to the FMRI can have distinct physiological effect on brain function. For higher field levels (up to 9 Tesla) and multiple hours of cumulative exposure these could lead to long-term detriments to brain function.

b) The scientific cogency of FMRI based research studies is sometimes questionable. In part this is due to a lack of understanding on the part of P.I.s concerning the basic limitations of the FMRI technology (particularly in terms of limited spatial and temporal resolution). Occasionally, it is even due to the whimsical nature of the issues being addressed.

volunteers—or by their supervising investigators—of the biophysical impacts and potential risks from the EMF exposures they are being subjected to.

Given the substantial risks of FMRI exposures and the limited benefits derived (when compared to less dangerous methods such as EEG or MEG), the use of FMRI as an experimental tool on human subjects needs to be more carefully scrutinized and regulated.
Practical aspects of transposition of requirements given by the directive 2004/40/EC into occupational health and safety legislation

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INTRODUCTION
The permissible level of occupational exposure to electromagnetic fields (EMF) is in force in Poland since 1972 (last amended in 1999; current issue: DzU 2002; No 217, item 1833; terminology and harmonized measurement methods regarding this exposure limitations given by PN-T-06580:2002). Relevant rationale documentation was adopted by the Polish Interdepartmental Commission for Maximum Admissible Concentrations and Intensities for Agents Harmful to Health in the Working Environment [1]. Draft for new issue of this law was developed in the context of requirements of the directive 2004/40/EC.

MATERIALS AND METHODS
As it is necessary to transpose the requirements of the European Directive 2004/40/EC into the Polish occupational health and safety law, the series of field investigations on pattern of realistic EMF workers exposure and series of computer modeling on assessment of EMF exposure represented by numerical models of EMF sources and human body have been performed. The results provided rationale background for amendment drafted for provisions of the regulation of the Minister of Labour and Social Policy on permissible level of exposure to EMF, to be better harmonized with the directive 2004/40/EC provisions. This recommendations were adopted by the Interdepartmental Commission [2].

RESULTS
The review of the results of research carried out in recent years on the effects of EMF on humans reveals grounds justifying that occupational safety and health regulations should continue to consider worker protection against the effects of chronic exposure to EMF although the minimum requirements of the Directive 2004/40/EC are less strict and refer only to the effects present in exposed body during the continuance of exposure. It is therefore necessary to maintain to the highest possible degree the existing system of better protection than required by the directive on the protection of workers against excessive exposure to EMF, based on permissible level of exposure to electric and magnetic field, protective zones, and exposure factor of worker and protective zones reach factor.

To obtain better harmonization of the limit of prohibited exposure (limit of dangerous zone) with the requirements of Directive 2004/40/EC for internal measures of exposure to EMF, the following new permissible level of exposure to electric and magnetic field presented in Table 1 and Table 2 can be applied. At the same time the current definitions of parameters, measured to assess workers’ exposure following PN-T-06580:2002 were maintained (worker’s exposure to EMF is assessed on the base of the maximum value measured over workers body vertical axe).
Table 1. Permissible exposure level proposed for static and time-varying electric field

<table>
<thead>
<tr>
<th>No.</th>
<th>Frequency range</th>
<th>$E_0(f)$, V/m</th>
<th>$E_1(f)$, V/m</th>
<th>$E_2(f)$, V/m</th>
<th>$Dd(f)$, (kV/m)$^2$h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>static electric field</td>
<td>10000</td>
<td>20000</td>
<td>40000</td>
<td>3200</td>
</tr>
<tr>
<td>2.</td>
<td>$f \leq 300$ Hz</td>
<td>5000</td>
<td>10000</td>
<td>20000</td>
<td>800</td>
</tr>
<tr>
<td>3.</td>
<td>$0.3$ kHz $&lt; f \leq 1$ kHz</td>
<td>100/(3f)</td>
<td>100/f</td>
<td>1000/f</td>
<td>0.08/f$^2$</td>
</tr>
<tr>
<td>4.</td>
<td>$1$ kHz $&lt; f \leq 1$ MHz</td>
<td>100/3</td>
<td>100</td>
<td>1000</td>
<td>0.08 (kV/m)$^2$h</td>
</tr>
<tr>
<td>5.</td>
<td>$1$ MHz $&lt; f \leq 5$ MHz</td>
<td>100/(3f)</td>
<td>100/f</td>
<td>1000/f</td>
<td>0.72/f$^2$ (kV/m)$^2$h</td>
</tr>
<tr>
<td>6.</td>
<td>$5$ MHz $&lt; f \leq 300$ GHz</td>
<td>20/3</td>
<td>20</td>
<td>200$^2$</td>
<td>3200 (V/m)$^2$h</td>
</tr>
</tbody>
</table>

Table 2. Permissible exposure level proposed for static and time-varying magnetic field

<table>
<thead>
<tr>
<th>No.</th>
<th>Frequency range</th>
<th>$H_0(f)$, A/m</th>
<th>$H_1(f)$, A/m</th>
<th>$H_2(f)$, A/m</th>
<th>$Dd(f)$, (A/m)$^2$h</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>static magnetic field</td>
<td>2666</td>
<td>8000</td>
<td>80000</td>
<td>512 (kA/m)$^2$h</td>
</tr>
<tr>
<td>2.</td>
<td>$f \leq 50$ Hz</td>
<td>100/3</td>
<td>100</td>
<td>1000</td>
<td>80000 (A/m)$^2$h</td>
</tr>
<tr>
<td>3.</td>
<td>$0.05$ kHz $&lt; f \leq 1$ kHz</td>
<td>5/(3f)</td>
<td>5/f</td>
<td>50/f</td>
<td>200/f$^2$ (A/m)$^2$h</td>
</tr>
<tr>
<td>4.</td>
<td>$1$ kHz $&lt; f \leq 100$ kHz</td>
<td>5/3</td>
<td>5</td>
<td>50</td>
<td>200 (A/m)$^2$h</td>
</tr>
<tr>
<td>5.</td>
<td>$0.1$ MHz $&lt; f \leq 10$ MHz</td>
<td>0.5/(3f)</td>
<td>0.5/f</td>
<td>5/f</td>
<td>2/f$^2$ (A/m)$^2$h</td>
</tr>
<tr>
<td>6.</td>
<td>$10$ MHz $&lt; f \leq 300$ GHz</td>
<td>0.05/3</td>
<td>0.05</td>
<td>0.5</td>
<td>0.02 (A/m)$^2$h</td>
</tr>
</tbody>
</table>

Notes:
- $f$ - frequency of time-varying electric field, in units given in “Frequency range” column
- $E_0$ ($H_0$) - limit of occupational exposure to EMF - values of electric (magnetic) field strength for limit between intermediate zone and exposure permissible for workers non-informed on EMF hazards;
- $E_1$ ($H_1$) - limit of occupational exposure to EMF permissible for 8 hours per day - values of electric (magnetic) field strength for limit between intermediate and hazardous zones;
- $E_2$ ($H_2$) - limit of prohibited occupational exposure to EMF - values of electric (magnetic) field strength for limit between hazardous and dangerous zones
- # - following the principles for worker’s exposure factor assessment according to PN-T-06580, exposure exceeding 100 V/m is evaluated as overexposure

CONCLUSIONS

EMF is an environmental factor that is subject to compulsory assessment in the working environment because of the risk it may cause to the workers. The level of workers exposure is assessed by measurement or with the use of computer simulation results. Both methods play various roles. Measurements of EMF may be performed at each individual work place, so they make it possible to make individual assessment of exposure level for each worker, with the use of criteria given by Table 1 and 2. They can also be used in developing data necessary to design numerical models of the workplace or verification of selected calculation outcomes. Computer simulations require specialist software, high-performance computers, and a highly skilled user. As they are time-consuming and entail high costs, it is especially justified to conduct them as part of scientific research aimed at analyzing exposure level that may be permitted by regulations. Such approach may significantly reduce the costs of workers protection against excessive EMF exposure.

REFERENCES

[1] H. Korniewicz et al. Electromagnetic fields and radiation in the frequency range of 0 Hz ÷ 300 GHz. Documentation of a draft amendment of maximal admissible values of occupational exposure. PiMOŚP. 17(2); 97–238, 2001 (in Polish)

EMF Measurement and Communication Activity: the BluShuttle Project

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INTRODUCTION

During year 2002 the Italian Ministry of Communications established the Italian national Electromagnetic Field (EMF) monitoring network with the technical support of Fondazione Ugo Bordoni (FUB) and in collaboration with the local Environmental Protection Agencies of all Italian regions.

The technical part of the project ended in year 2006 but the related communication activities still go on, in particular the measurement campaigns performed using the BluShuttle vehicle which are still appreciated by Municipalities and citizens.

MATERIALS AND METHODS

The network and the related public communication campaign had a multiplicity of aims:

- inform the public about the current scientific knowledge and about the current Italian regulation;
- demonstrate that the exposure to radio-frequency EMF is well below the prescribed limits in the vast majority of cases;
- activate procedures to reduce the exposure levels when they exceed the attention thresholds;
- create and support a dialogue between administrators, general public and scientists on EMF related topics.

After the end of the project it was decided to go on with the communication activity. This activity was performed using the BluShuttle vehicle; a mini car equipped with a PMM8053B wide band portable EMF meter and an autonomous control centre.

The BluShuttle vehicles can move easily and faster from a place to another inside a city and in each point a short monitoring campaign (lasting no more than half an hour) is performed.

During the last part of year 2007 and the whole year 2008 the BluShuttle visited about 45 towns all over the national territory performing more than 300 measurements. Every time the BluShuttle visited a town newspaper articles were published and meetings were organized.
RESULTS

Preliminary results are shown in figures. The situation for what concerns EMF levels is extremely reassuring: in about 89% of the sites the EMF level was lower than 1 V/m. The communication campaigns feedback show that in Italy there is still a strong interest in EMF monitoring activity in fact each time the mini car visited a town lots of articles appeared on local newspaper and 51% of the times the organization of a meeting was required by the Administrators.

CONCLUSIONS

In Italy the risk perception on electromagnetic fields effects is still a problem. Citizens are worried about the presence of antennas and for the Municipality Administrator is difficult to create a dialogue on this topics. Monitoring and communication campaign are a good way to deal with this situation and to create a dialogue which in most of the cases is absent.

REFERENCES

INTRODUCTION

In 2000 Greece implemented [1] the EU Recommendation [2] / ICNIRP Guidelines [3] for general public protection from electromagnetic fields in the vicinity of antenna stations. The Greek Legislation, however, asked for the application of an extra reduction factor of 80% on EU/ICNIRP limits, without mentioning the quantities where it should be applied. As a result the most obvious solution was selected: application directly on the reference levels. Unfortunately, this brought an inconsistency at the Greek limits because the derived electric and magnetic field strength reference levels were not equivalent with the power density one (in far field conditions the application of an 80% reduction factor on the values of the reference levels for the electric or the magnetic field strength is equivalent with the application of a 64% reduction factor on the values of the reference level for the power density) and also the purpose of the reference levels as easily measured quantities to show compliance with the and the basic restrictions was lost!

In February 2006, the Greek Parliament voted a new Law [4] reducing the limits for general public exposure to electromagnetic fields to 70% of the ICNIRP’s limits in general, and to 60% of them for antenna stations located closer than 300 meters from the perimeter of schools, kindergartens, hospitals or eldercare facilities. For the implementation of this new Law, a different but more scientifically sound approach was selected for the application of the reduction factors. In order to avoid any inconsistencies, the Greek Atomic Energy Commission, as the competent National Authority for the protection of the general public from non ionizing radiation and for checking compliance with the established limits in Greece, decided [5] that the application of the reduction factors on ICNIRP’s limits should concern principally the basic restrictions and new reference levels have to be derived for showing compliance with them.

DERIVED GREEK REFERENCE LEVELS

The Greek reference levels for the electric or magnetic field values are derived after the direct application of the 60% and 70% reduction factors on the corresponding ICNIRP’s values when electro-stimulation effects are considered and on their square values when thermal effects are considered. The occurring Greek reference levels are shown in Table 1. It is noted that the transition from electro-stimulation effects to thermal ones occurs in ICNIRP’s reference levels for general public and considering sinusoidal fields, at 1 MHz for the electric field and 150 kHz for the magnetic field; whereas for the Greek limits occurs at 1.66 MHz and 174 kHz for the 70% reduction factor and 1.43 MHz and 188 kHz for the 60% reduction factor, for the electric and magnetic field reference levels, respectively. This shift in the transition frequencies is caused by the uneven reductions of field strength reference levels when different effects are considered.
Table 1. Greek reference levels after the application of 70% and 60% reduction factors

<table>
<thead>
<tr>
<th>Reduction factor</th>
<th>Frequency range</th>
<th>Electric field strength $(V/m)$</th>
<th>Magnetic field strength $(A/m)$</th>
<th>Magnetic flux density $(\mu T)$</th>
<th>Equivalent plane wave power density $(W/m^2)$</th>
<th>Maximum contact current $(mA)$</th>
<th>Induced current in limbs $(mA)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>70%</td>
<td>1 – 2.5 kHz</td>
<td>$175/f$</td>
<td>3.5</td>
<td>4.375</td>
<td>-</td>
<td>0.35</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2.5 – 3 kHz</td>
<td>$175/f$</td>
<td>3.5</td>
<td>4.375</td>
<td>-</td>
<td>0.14$f$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3 – 100 kHz</td>
<td>$60.9$</td>
<td>3.5</td>
<td>4.375</td>
<td>-</td>
<td>0.14$f$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>100 – 174 kHz</td>
<td>$60.9$</td>
<td>3.5</td>
<td>4.375</td>
<td>-</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.174 – 1.43 MHz</td>
<td>$60.9$ $0.61/f$</td>
<td>0.77$f$</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.43 – 10 MHz</td>
<td>$72.8/\sqrt{f}$ $0.61/f$</td>
<td>0.77$f$</td>
<td>-</td>
<td>-</td>
<td>14</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>10 – 110 MHz</td>
<td>$23.4$</td>
<td>0.061</td>
<td>0.077</td>
<td>1.4</td>
<td>14</td>
<td>37.6</td>
</tr>
<tr>
<td></td>
<td>110 – 400 MHz</td>
<td>$23.4$</td>
<td>0.061</td>
<td>0.077</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>400 – 2000 MHz</td>
<td>$1.15/\sqrt{f}$ $0.0031/\sqrt{f}$ $0.005/\sqrt{f}$ $f/286$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>60%</td>
<td>1 – 2.5 kHz</td>
<td>$150/f$</td>
<td>3.3</td>
<td>3.75</td>
<td>-</td>
<td>$0.12f$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2.5 – 3 kHz</td>
<td>$150/f$</td>
<td>3.3</td>
<td>3.75</td>
<td>-</td>
<td>$0.12f$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>3 – 100 kHz</td>
<td>$52.2$</td>
<td>3.3</td>
<td>3.75</td>
<td>-</td>
<td>$0.12f$</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>100 – 188 kHz</td>
<td>$52.2$</td>
<td>3.3</td>
<td>3.75</td>
<td>-</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>0.188 – 1.66 MHz</td>
<td>$52.2$ $0.565/f$</td>
<td>0.71$f$</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.66 – 10 MHz</td>
<td>$67.4/\sqrt{f}$ $0.565/f$</td>
<td>0.71$f$</td>
<td>-</td>
<td>-</td>
<td>12</td>
<td>34.9</td>
</tr>
<tr>
<td></td>
<td>10 – 110 MHz</td>
<td>$21.7$ $0.0565$</td>
<td>0.071</td>
<td>1.2</td>
<td>12</td>
<td>34.9</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>110 – 400 MHz</td>
<td>$21.7$</td>
<td>0.0565</td>
<td>0.071</td>
<td>1.2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>400 – 2000 MHz</td>
<td>$1.065/\sqrt{f}$ $0.00287/\sqrt{f}$ $0.00356/\sqrt{f}$ $f/333$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>2 – 300 GHz</td>
<td>$47.2$</td>
<td>0.124</td>
<td>0.155</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: $f$ as indicated in the frequency range column

CONCLUSIONS

The 60% and 70% reduction factors provisioned in the new Greek Legislation about general public’s exposure to electromagnetic fields in the vicinity of antenna stations should be applied on ICNIRP’s basic restrictions and not on its reference levels. This way, the new Greek reference levels for electric and magnetic field strength occur after the application of the reduction factors directly on ICNIRP’s reference levels when electro-stimulation effects are considered and on their square values when thermal effects are considered.

REFERENCES


German Mobile Telecommunication Research Programme – Conclusions and Perspectives

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INTRODUCTION
The German Mobile Telecommunication Research Programme (DMF) was carried out between 2002 and 2008 under the leadership of the Federal Office for Radiation Protection (BfS). A financial volume of 17 million Euro was available to fund a total of 54 research projects in the fields of biology, dosimetry, epidemiology and risk communication so as to investigate relevant questions on potential adverse health effects and the public’s risk perception of high frequency electromagnetic fields. The DMF was able to contribute significantly towards an improved risk assessment and communication with the public.

MATERIALS AND METHODS
The BfS took overall responsibility for the implementation of the research programme. At first, research needs were identified by means of an open discussion between the BfS, the German Radiation Protection Commission and the public, and the topics of the particular projects were defined. The projects themselves were performed by German and international scientists. The focus of research was on:

• Action mechanisms of high frequency electromagnetic fields;
• Effects on animals and human beings;
• Determination of exposure;
• Risk perception and Risk communication.

The results of the DMF were discussed in expert workshops focusing on dosimetry, risk communication, acute health effects, action mechanisms and long-term effects; final results of the DMF were presented at an international conference in June 2008 in Berlin.

RESULTS
In dosimetry, the research focused mainly on three objectives: the development of measurement and calculation methods to determine the exposure of the public, the determination of actual everyday exposure to electromagnetic fields as well as the solution of dosimetric problems during the exposure of research subjects in laboratory studies, and the classification of exposure in epidemiological studies. It proved that the exposure of the public in the investigated mobile communication frequency bands is on average well below the limit values. Exposure values approaching these limits can only be reached when using sources close to the body, such as mobile telephones.

As part of the research in the areas of biology and epidemiology, possible acute and chronic health effects of mobile communication fields were investigated.

Acute health effects were primarily analyzed by means of clinical studies. Those studies
focused on the question whether high frequency electromagnetic fields affect sleep, cognitive performance, memory or the processing of visual and acoustic stimuli. Overall, this was not the case. This was confirmed by cross-sectional population based studies, which showed no association between the measured electromagnetic fields from mobile phone base stations and several health complaints among adults and also no acute health effects due to measured fields of mobile telecommunication networks among children and adolescents. Regarding the question of electromagnetic hypersensitivity, increased evidences demonstrated that there is no causal connection between exposure to electromagnetic fields and unspecific symptoms such as sleep disorders, concentration disruptions or headaches.

To investigate possible impacts of a chronic exposure to high frequency electromagnetic fields, long-term studies were carried out on animals, exploring the blood-brain-barrier, the induction of tinnitus, different cancers as well as reproduction and development. These studies did not yield indications of an “athermic” impact due to high frequency electromagnetic fields.

Studies on several generations of animals do not support the hypothesis of a particular sensitivity during early developmental stages. Nevertheless, the question whether the health risk as a result of long-term exposure is higher for children than for adults, either due to age differences or due to a longer lifetime exposure, could not be answered conclusively by the DMF studies.

Epidemiological studies so far have not found evidence for an increased risk of brain cancer or uveal melanoma for mobile phone users. A study on powerful radio and television transmitters found no evidence for an association between estimated field intensities and a risk of childhood leukaemia. The question of long-term effects (a period of use of more than 10 years) remains an open issue, due to the long latency periods for cancer and the comparably short-term use of mobile communication technology by the general public.

Several research projects looked further into the perception of mobile communication in society and found improvement possibilities for information and communication. It became clear that the mobile communication and health topic does not play a major role compared to other possible health risks for the majority of the public. Within certain groups, however, a major concern about electromagnetic fields as well as a subjectively and strongly perceived impairment through electromagnetic fields, do exist. Information and communication offers must be tailored to the information need of specific groups.

CONCLUSIONS

The DMF’s findings give no reason to question the protective effect of current limit values. However, as some studies found minimal physiological reactions and indications that children could be more exposed than adults, along with the constantly open question on health risks from long-term exposure for adults and in particular for children, make it necessary to continue dealing carefully with wireless communication technologies. Further research on the still opened endpoints is planned.
European Health Risk Assessment Network On Electromagnetic Fields Exposure: The EC Project EFHRAN

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INTRODUCTION

EFHRAN (European Health Risk Assessment Network on Electromagnetic Fields Exposure) is a three-year project (2009-2012) of the European Commission in the framework of the Programme of Community Action in The Field of Health (2008-2013), Health 2008. EFHRAN is coordinated by Paolo Ravazzani and involves 7 additional partners (see the author list) from different European countries. More than 15 European research centers, universities and other stakeholders have already expressed their preliminary interest in the activities of this project.

GENERAL OBJECTIVE

The general objective of EFHRAN is to establish a network for performing health risk assessments of exposure to electromagnetic fields (EMF). This network will make use of the risk analysis of the completed project EMF-NET CA (EC FP6).

STRATEGIC RELEVANCE

Exposure to EMF diffusion is such that possible health consequences can generate a domino effect, that has consequences for all sections of society both directly and indirectly. The establishment of the most appropriate health risk assessment process related to EMF, as proposed by EFHRAN, is not only desirable but essential at the European level. The effort is too great to be managed at the level of individual countries, where the full set of highly specialised experts or infrastructure are not available. Furthermore, only supranational authorities, such as the EC, can develop recommendations needed by Member States.

MAIN METHODS AND MEAN

EFHRAN will implement the following tasks: i) Risk analysis and hazard identification, that will consist in complementing the existing EMF-NET risk analysis; ii) Exposure assessment estimation, i.e. how much and how long people in Europe are exposed to EMF; iii) Dose-response assessments, to estimate the amount of EMF exposure that is likely to result in a particular health effect; iv) Risk characterization, to characterize the risk for the population; v) Give input to risk management and communication, by identifying priority areas where intervention/communication is needed.
EXPECTED OUTCOME

EFHRAN will provide the EC and the EU with a health risk assessment on exposure to EMF that will allow these bodies to react to the concerns in full understanding of the scientific issues. EFHRAN is also expected to provide input for future risk management steps. The established network is an added value for the EC, being an infrastructure capable of providing updated assessments in the future.

ACKNOWLEDGEMENTS

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The purpose of this paper is to show that the history and evolutionary record of EMF standard setting among participating nations of the world has resulted in divergent approaches: Broadly defined, one approach adheres to a thermal based safety limit, recommended by international standard setting groups; the other considers non-heating effects by adopting a health based standard that applies the Precautionary Principle to set a lower safety limit. It is proposed that, while harmonization of EMF standards internationally is a good idea in principle, when more weight is given to technology innovation and expansion over adopting a lower threshold that acknowledges non-heating effects based on scientific and medical evidence and accepted standards of protection, the outcome can be less government involvement and more resistance to a harmonized standard.

For over twenty years, there has been an international campaign to “harmonize” thermal based EMF standards, driven by the technical interests of the utility industries and the military. As a result of a 1984 agreement, many nations started adopting national standards that only addressed one health issue, avoiding tissue heating from acute, short term, exposure from a single EMF source. In contrast, the standards adopted by nations that have lower safety thresholds include Italy, Switzerland, Belgium, Slovenia, Greece, Poland, Russia, and China. These nations not only give more consideration to the science and medical evidence on non-heating effects, but are more inclusive and have greater cooperation among political leaders and the industries to be regulated. The standards themselves, however, are internally divergent. For example, only Italy has set standards to regulate cumulative RF exposure levels including all transmitters (AM-FM, TV-radio broadcast, cellular, WiFi, WiMax and military). The first chart below illustrates the Italian standard compared to the EU standard (Rec. 1999/519/CE).

While European Council of Ministries adopted the above quoted Recommendation, the EU Parliament on March 10 1999, adopted a resolution asking the EU Commission to not reference ICNIRP but to modify the proposal taking into account the Precautionary Principle, recalled in the EU Parliament Resolution on May 5 1994.

Italy has also taken the lead in setting up exposure monitoring systems and has in the past spent government funds to investigate and remediate exposure when compliance problems occur. The Italian standards are supported by environmental and health groups, particularly those groups who are concerned about health problems, such as cancer and electrical hypersensitivity which appear to be relate to excessive EMF exposure; and, the number of these cases are increasing.

The European Parliament will shortly be considering a resolution submitted by the Committee on the Environment, Public Health and Food Safety to reduce its recommended EMF exposure standards, issued in 1999, which conform to the international harmonization standards. Over the past two years, there has been a call for the development of biologically based EMF standards. While the scientific evidence may not be complete enough, this approach can incorporate what is known about established basic mechanisms of effect, including calcium efflux, heat shock protein loss, permutation of the mammalian blood brain barrier and, DNA and mitochondrial changes. Whatever standards are eventually determined will necessarily be a compromise between maximum exposure protection and high performance technology.
In sum, it is proposed that when nations adopt more protective EMF exposure standards and apply principles of scientific integrity, transparency and effective oversight in ensuring the health protection of the public and workers, but especially children, a stronger bond of trust can emerge between national government and its constituency. This understanding is confirmed by recent Eurobarometer surveys about EMF health risks.

Chart #1. NOTE: In the graph, electric field values are referenced: meanwhile, we can derive magnetic field and power density values from comparable equations for far field exposures.

<table>
<thead>
<tr>
<th>Country</th>
<th>Head Exp. SAR (W/kg)</th>
<th>Magnetic Field (µT)</th>
<th>Power Density MHz (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>900 – 2450 MHz</td>
<td>900 – 50-60 Hz</td>
<td>0,1-30</td>
<td>0,024</td>
</tr>
<tr>
<td><strong>Switzerland</strong> (Limits to the plant, Ord. Dec. 23rd 1999)</td>
<td>1,02</td>
<td>0,2</td>
<td>0,024</td>
</tr>
<tr>
<td><strong>Belgium</strong> (Arrête. Royale Apr. 29th 2001)</td>
<td>2.0††</td>
<td>0,50</td>
<td>0,50</td>
</tr>
<tr>
<td><strong>Russia</strong> (Ord. 2003/1340)</td>
<td>1,01</td>
<td>1,01</td>
<td>0,10</td>
</tr>
<tr>
<td><strong>China</strong> (UDC 614.898.5, Jan 6 2008)</td>
<td>2.0††</td>
<td>0,26</td>
<td>0,45</td>
</tr>
<tr>
<td><strong>Italy</strong> (Cumulative Long Term Exposure: Decree Jul 8th 2003, Decree 1999/381)</td>
<td>2.0††</td>
<td>10</td>
<td>0,10</td>
</tr>
<tr>
<td><strong>USA</strong> (FCC Dec. 1997: average on 1 g tissue)</td>
<td>1,6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†† Average on 10 g of continuous tissue. Italy and Belgium follow the EU Rec. 1999/519/CE just for partial exposure.

Chart #2. NOTE: These data are only used as a reference, authors will be not responsible for anything.
Continuous Electromagnetic Radiation Monitoring in the Environment: Analysis of Results in Greece

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INTRODUCTION

In several European countries (Portugal, Malta, Italy, Greece, Germany) there are networks installed, which comprise of monitoring stations that register electromagnetic radiation in the environment on a 24-hour basis. The Radiocommunications Laboratory of the Aristotle University of Thessaloniki is responsible for more than 60 monitoring stations in the northern part of Greece, belonging to three such networks (one of them has commenced operation in 2003 and is continuously expanding). Although the radiation monitors were initially installed as a reaction to public concerns about electromagnetic radiation emitted from base station antennas, it appears that they can now provide valuable information about the temporal evolution and spatial behavior of the electromagnetic environment. In this work we present the statistical analysis of the measurement data collected by these networks until now.

MATERIALS AND METHODS

Radiation monitors operate on a 24-hour basis. They measure the electric field at the point of their installation, usually in a broadband fashion (from 150kHz to 3GHz). However, different models are used in the networks, some of which allow measurement of electric field in separate narrow bands of the above spectrum. A 6-minute average (according to ICNIRP Greek legislation) is calculated by instantaneous measurements. The total of 240 average values are communicated once per day to the control station (a dedicated PC) via the GSM network, using wireless modems and the short messaging system (SMS). The measurements of electric field (together with the associated measurements of temperature, humidity and battery voltage) are saved in a database (realized with MySQL on an Apache platform) and are presented on the internet in relevant sites. Until now more than 6.5 million measurement records are available.

RESULTS

A statistical analysis of the results has shown that classification of stations to those installed in densely populated urban areas, urban areas and rural areas is possible by observing the mean value of measured electromagnetic field strength (Figure 1a). The mean value in these areas is 1.86V/m, 1.22V/m and 0.69V/m, respectively. This result is statistically significant at a level of \( p<0.1 \) (Student's \( t \)-test with unequal sample sizes and variance). Additionally, the processing of records with autocorrelation (Figure 1b) has revealed that the electric field has a full day periodicity (fluctuating between day and night). The latter can be attributed to the telecommunication traffic served by base stations of mobile telephony systems, since the study of the range of electric field values (maximum and
minimum value per day) resulted in a higher daily variation for stations whose records are
derived from high frequency (GSM and UMTS) bands. Other findings of the results from
monitors installed in the vicinity of base stations include short-term variations of the electric
field, like higher values during the first (two) hours of New Year’s Day, lower values during
the month of August (vacation month) in urban areas (the opposite effect in rural areas) and
higher values during periods of heavy snowfall. In the densely populated area of Thessaloniki
(the second largest city in Greece) it appears that broadcasting stations are the main
contributors to the electromagnetic environment, whereas in other areas mobile telephony
networks are prevailing.

![Figure 1: (a) The mean value of electric field is different (in a statistically significant manner), depending on the installation site of the monitor. (b) The correlogram shows that there is period of 240 samples in the signal registered by the monitor. This number of samples corresponds to the total of measurements collected in a day.](image)

CONCLUSIONS
Radiation monitoring networks were originally deployed as a response to local public concerns about exposure to electromagnetic fields. The measurements have shown that reference levels foreseen by Greek legislation have never been reached. Apart from this result though, the data collected by the monitors can give valuable information about the short- and long-term variation of the electric field at a position, especially close to base station antennas.

ACKNOWLEDGMENTS
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An Australian Exposure Standard for ELF Electric and Magnetic Fields

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INTRODUCTION

Exposure to electric and magnetic fields in the extremely low frequency (ELF) range, 0 – 3 kHz, is widespread among both workers and the general public but exposure levels are usually very low compared with the thresholds for established biological effects. In contrast, exposure to some patients and specialist staff in magnetic resonance imaging (MRI) facilities can often exceed current guidelines and fall within range where undesirable biological effects might be expected in some people. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), the national radiation protection body in Australia, has recently prepared a new human exposure standard for ELF and static fields [1] and tried to address the need to provide a high degree of protection while avoiding unnecessary restriction of worthwhile activities. In particular, the challenges faced have included:

- The need for science-based limits to provide protection against established health effects, including significant discomfort and pain, as well as life-threatening phenomena, in a diverse population,
- The wish to take into account the widespread and strong public concern about the unproven but suspected health effects of prolonged exposure to low levels of ELF fields, such as the apparent increased risk of childhood leukaemia,
- The need to avoid unnecessarily interfering with the reliable delivery of electrical power to the community and with the provision of life-saving procedures to patients.

STANDARDS DEVELOPMENT PROCESS

The ELF standard has been developed by established procedures aimed at achieving consensus, transparency and stakeholder participation. A working group of experts in the fields of physics, biophysics, epidemiology, radiation protection and regulation have reviewed the literature and developed a science-based draft standard [2,3]. As in the case of the RF standard developed by ARPANSA and published in 2002, the draft ELF stand includes extensive annexes giving an explanatory rationale for the limits and summarizing the evidence from epidemiology and laboratory experiments. The draft standard was then made available for the public and submissions invited.

Nearly 70 submissions were received from Australia and overseas and included extensive submissions from affected industries such as power supply and distribution and MRI. There were also submissions from regulators and experts setting standards in other countries offering technical advice.

The public consultation process highlighted the inherent difficulty of ELF standard setting given the very wide margin between the existing limits protecting against established effects and the relatively low field values associated with increased risk of childhood leukaemia in
epidemiological studies. The submissions made clear the confusion in the minds of some between the need for numerical limits on instantaneous field levels that can be based on experimental results and the general desirability of reducing prolonged exposures to fields in case they may be harmful at low levels.

Following the public consultation process and further discussions with stakeholders, the standard has been modified to strengthen its precautionary section and to address the need, in some industries, for some reduction in conservative safety factors.

RESPONSES TO CONSULTATION SUBMISSIONS

The proposed ARPANSA ELF standard, expected to be published in mid 2009, now includes two distinct aspects. First, the standard includes basic restrictions and reference levels, based on scientific examination of biological responses to ELF fields and which provide the expected high degree of protection against established harmful effects. Second, there is an explicit recognition that people who through their activities, ownership or operation of equipment, or through the conduct of their business, intentionally or otherwise, increase the exposure of people, particularly children to ELF electric or magnetic fields, have some obligation to assess the possible exposure and address mitigating measures.

It is intended that annexes will provide guidance on precautionary measures and that practical advice of ways to reduce exposures will be made available through other means. Details on likely consequences of exceeding limits are also to be provided to those who need to make risk-based decisions in special circumstances. This is particularly important to the MRI community where well supervised exposures above existing and proposed limits may be justified in terms of lives saved.

CONCLUSIONS

The community expects governments to provide strong guidance on how to protect against harmful effects of electric and magnetic fields and to ensure workplaces and residences are safe. Industry and the medical community also wish to be able to use modern technology where there is no evidence of harm. However, the uncertainty about possible health effects means that it is difficult to provide numerical limits that satisfy both requirements and some additional measures, taking into account specific risks and benefits, are necessary if the best outcome is to be achieved.

ACKNOWLEDGMENTS

The authors wish to acknowledge the considerable efforts of the ELF standard working group in preparing the ARPANSA standard and the important contributions made by the consultative group members and public in providing extensive submissions.

REFERENCES


Deeper RF Energy Penetration In Heads Of Children Than Adults Using Mobile Phones?

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INTRODUCTION

In recent media reports and in presentations of those promoting precautionary measures in using mobile phones, a figure of numerically-computed color SAR patterns for 5 yr, 10 yr and adult heads is shown that was published in 1996 by Gandhi et al. [1]. Figure 1 shows a dramatic increase of penetration depth in smaller heads. This information has been used extensively as one of the reasons that children should restrict their use of mobile phones.

MATERIALS AND METHODS

In 1999, I pointed out to the first author of the 1996 paper that the size and color SAR scales were not properly done, which led to the incorrect result that the smaller heads appear to have much deeper penetration depths. Gandhi and Kang [2] redid the calculations and published a follow-up paper in 2002, with proper scaling and color presentation, showing a different result from their findings in 1996, that is, the penetration depth in the three head models are about the same (see Fig 2). The authors still claim that the smaller heads have deeper penetration; however, this statement is true only if the authors are referring to relative RF penetration in the heads of different sizes. In a collaborative study with Bill Guy, University of Washington, and Jian-Qin Wang and Osamu Fujiwara, Nagoya Institute of Technology, we determined SAR distributions in the same scaled human head models as used by Gandhi et al. [1].

RESULTS

We found that penetration depths in heads of children and adults are about the same (see Figure 3 from [3]) similar to the results of Gandhi and Kang [2]. Our results that the RF energy penetration is about the same in heads of children and adults are consistent with other recent publications [4-11]. The results published in 1996 (Fig 1) are not valid as shown by the results in Fig 2 published by the same lab and all other studies [3-11] that have investigated SAR patterns in heads of people of different sizes. Peak SAR measured in the Specific Anthropomorphic Mannequin (SAM) phantom as described in the international mobile phone compliance standards are conservative for the various head sizes as verified in an international project [9]. Therefore all phones tested to be within the compliance limits are safe to use for all users including children.

Figure 1: Original 1996 study showing distinct differences in SAR patterns in scaled heads of children and adults [1] (different SAR distributions based on incorrect scaling)
CONCLUSIONS

The deeper penetration figures published in 1996 are erroneous. All other studies show similar SAR patterns regardless of the head size. It is unfortunate that the incorrect information continues to get attention and the correct information is ignored.

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Supported by Motorola, Inc.

REFERENCES


**Purpose:** Validation of SAR estimation using power loss density data obtained from 3-D EM simulations remains an important goal for RF coil designers. Although the RF transmit magnetic field ($B_1^+$) can be measured with MRI, SAR cannot be directly determined. $B_1^+$ information is insufficient for SAR calculation because two different electrical fields, conservative and non-conservative, must be considered, neither of which is MRI-measurable. The first is the E-field penetrating from the distributed capacitors commonly used in high field coils, the second is the E-field that accompanies the propagating magnetic field. The temperature within a phantom can be measured using MRI. However, temperature change versus time in a phantom depends not only on power loss density, and the power applied to the coil input, but also on the thermal conductivity and thermal radiation losses. Our goal was to investigate conditions in which SAR/power loss estimation using the thermal profile can provide reasonable accuracy.

**Method:** A 3-D EM model of a commercially available 7 T multi-channel coil, which includes all construction details for the resonance elements, was simulated in Ansoft HFSS with realistic dimensions and material electrical properties, so that the simulated trim capacitor values are equal to the actual values. Transient thermal co-simulation was performed with the aid of Ansoft ePhysics software using both mesh refinement alternatives: a) mesh linked to the HFSS simulation - suboptimal for thermal simulation, but requiring no interpolation of power loss density, and b) mesh designed by thermal solver itself - more suitable for thermal simulation, but power loss density must be interpolated. Heating of the phantom and measurement of its thermal profile must obviously be as fast as possible. However, most RF coils have limited power handling capacity, and the speed of the MRI-based thermal mapping methods available is about 100 seconds per slice. To investigate the effect of these time delays, a simulation of two cycles – each consisting of a 800W heating stage for 100 seconds, followed by 100 seconds of thermal mapping – was performed.

**Results and Discussion:** Fig. 1 and 2 show that the thermal profile at the 360 second time point is similar to the power loss density profile, as expected from previous studies [1]. The same is true for earlier time steps. Detailed analysis of temperatures at different locations (Fig. 3) reveals that the thermal profile change during the thermal mapping stage is smallest for areas where the power loss density is close to maximum (change less than 2%). By contrast, areas with a relatively low power loss density have temperature changes as large as 100%. Thermal mapping as a guide to SAR can thus vary in accuracy, depending on power loss density. This may not be a serious problem, because the hot spots, with maximum power loss density, are clearly most significant in regard to safety investigations defining coil SAR operation limits. The influence of thermal conductivity and thermal radiation losses on the linear relationship between thermal and power loss density profiles depends on the duration of the thermal mapping procedure. The available speed of about 100 seconds per slice does not allow full 3-D thermal mapping, which would enable reliable calculation of 3-D power loss density data. However, the good agreement between simulated power loss density and measured thermal profiles for slices through the most dangerous hot spots (predicted by 3-D EM simulation) may be adequate for reliable coil safety approval. We found no significant influence of mesh refinement strategy or transient simulation time step (if less than 0.5 second) on thermal data (Fig. 3).

**Conclusion:** Simulated results show that at RF hot spots the heat loss due to thermal conduction and thermal radiation has little effect on SAR estimation. Thermal mapping may become an important tool for validation of SAR and power loss profiles obtained from 3-D EM simulations for complex RF coils.