Ple-2 **CELL ELECTROMANIPULATION *IN VITRO* AND *IN VIVO*: BIOMEDICAL APPLICATIONS**

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New biomedical applications of the electric pulses are emerging and reaching the clinical stage. They arise from the knowledge of the effects of the electric field at the level of the cell membranes, knowledge that allows cell electromanipulation both in vitro and in vivo, in animals and even in humans.

The purpose of this lecture will be to give an overview of the biomedical and biotechnological applications based on the electromanipulation of the cell membrane, namely electropermeabilization and electroendocytosis. In the case of the membranes electropermeabilization, either the external or the internal membranes of the cell can be affected, depending on the intensity of the electric field and the duration of the pulses. Electroendocytosis can also be obtained with pulsed electromagnetic fields like those constituting the GSM mobile phone signals.

The biomedical applications develop mainly in two different areas, cancer treatment and gene therapy. The type of pulses necessary for these applications are very different, as well as the concerns of the electric pulses delivery. In the case of the gene transfer mediated by the electric pulses, safety is a very important issue and thus cell viability preservation is mandatory.

In the case of the anticancer treatments, several options are being developed: cell membrane reversible electropermeabilisation combined with non-permeant drugs (electrochemotherapy), cell membrane irreversible electropermeabilisation, and internal membranes electropermeabilisation. The mechanisms of action of these three approaches will be discussed.

Electrochemotherapy is already used in the clinics as accepted treatment of the cutaneous and subcutaneous metastasis of any origin, with excellent results. The treatment is simple, safe, efficient, and with a good cost/benefit ratio. It can be delivered when classical treatments fail, it can be repeated, and it has good cosmetics effects.

Recent data on electrochemotherapy will be presented, as well as the mechanisms of gene electrotransfer, which is a new and efficient non viral gene therapy approach that is rapidly developing nowadays.

Keywords: electrochemotherapy, DNA electrotransfer, gene electrotransfer, electroendocytosis, electroporation, electropermeabilisation, electropermeabilization.

Tut-2 **EPIDEMIOLOGICAL STUDY DESIGNS AND THEIR APPLICATION IN THE FIELD OF MOBILE PHONE USE AND THE RISK OF BRAIN TUMORS**

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The widespread use of mobile phones throughout the world has raised concern about possible adverse health effects. In a number of epidemiological studies, the possible association between mobile phone use and the risk of brain tumors was investigated.

Registry-based studies are observational studies in which time trends or geographical distributions of brain tumor incidence or mortality rates are calculated in order to examine whether this correlates with the distribution of the mobile phone usage patterns. Such ecological studies are based on aggregated exposure information and are regarded as hypothesis generating.

Most studies in this research field were case-control studies. In case-control studies a group of brain tumor patients and a suitable group of subjects without a brain tumor are selected and their past use of mobile phones is obtained and compared. The first case-control studies on this topic were conducted in the 1990s, but the time between first exposure and the diagnosis of the tumor was rather short. Taken together, these studies showed no association between mobile phone use and brain tumor risk. A series of case-control studies from Sweden showed strong associations between mobile phone use and brain tumor risk, both for benign and malignant tumors and already after non-extensive cumulative use. The Interphone study is a multinational case-control study conducted according a joint study protocol in 13 countries. Results are already available from some of the countries. Overall, no increased risks for brain tumors were seen, but a small to moderate risk increase in long-term users cannot be ruled out.

In cohort studies, the study population is divided into different exposure groups by amount of mobile phone use, and the cohort is followed up for brain tumor incidence. The only cohort study on this topic is a retrospective cohort study in Denmark, based on mobile phone subscribers between 1982 and 1995. A recent follow up showed no overall increased brain tumor risk, but the study gives no information by amount of use.

A major challenge of the case-control studies is the exposure assessment through questionnaires, as it is difficult to recall past mobile phone use, particularly when affected by a brain tumor. It is also difficult to guarantee the suitable control group, as some studies have shown links between mobile phone use and study participation. In the retrospective cohort study, subscription information had to be used as an exposure measure, which predicts mobile phone use only to some extent. Prospective cohort studies overcome limitations of both the case-control studies and the retrospective cohort study, but they need to be based on a huge sample size with a long follow up period.

In all, the balance of epidemiologic evidence suggests that mobile phone use of less than 10 years does not pose any increased risk of cancer. For longer use, fewer data are available and any conclusions therefore are tentative. From the available data, it does appear that there is no substantially increased risk of brain tumors, however, more data are needed for long-term, heavy users.

S-1-1 **EVALUATION OF THE CHRONIC EFFECTS OF 50-HZ MAGNETIC FIELDS ON HUMAN IMMUNE FUNCTIONS**

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The relationship between exposure to 50-Hz magnetic fields (ELF) and human health is of increasing interest since this exposure has been implicated in many different diseases including cancers in epidemiological studies, though the results are controversial. The identification of possible mechanisms of interaction between ELF and biological systems that could provide a biological plausibility to the observed effects has failed so far. In this study we investigate the possible chronic effects of exposure to ELF in humans. We examine the circadian rhythm of CD_3, CD_4, CD_8, NK cells and B cells in 15 men (38.0 ± 8.9 yrs) exposed chronically and daily for a period of 1-20 years, in the workplace and at home, to a 50-Hz magnetic field in search of any cumulative effect from those chronic conditions of exposure. The weekly geometric mean of individual exposures ranged from 0.1 to 2.6 mT. The results are compared to those for 15 unexposed men similar in age (39.4 ± 1.2 yrs), with the same synchronisation and physical activity who served as controls (individual exposures ranged from 0.004 to 0.092 mT). Blood samples were taken hourly from 2000 to 0800. This work shows that subjects exposed over a long period (up to 20 years) and on a daily basis to magnetic fields experienced no changes in their plasma immune variables.
Our data suggest therefore that magnetic fields have no cumulative effects on immune functions, at least for the variables under study.

S-1-2 **INCREASED FREQUENCY OF MICRONUCLEI IN LYMPHOCYTES OF WORKERS FROM A HOT DIP GALVANIZING PLANT**

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Although there is now a significant body of genotoxicity data from experiments with low frequency electromagnetic field (ELF-EMF) exposure of various cell types in vitro and of rodents in vivo, the findings do not present a consistent picture. In addition, no biomonitoring study so far has revealed a link between exposure of humans to ELF-EMFs and the induction of DNA damage. In the present study we determined frequencies of micronuclei in lymphocytes of workers from a hot dip galvanizing plant with induction heating with the aim to identify a possible association of genotoxic effects with exposure to 50 Hz-EMF.

Eighteen male workers (46±10 years, 12 smokers, 1-21 exposure years) from a hot dip galvanizing plant have been monitored for micronucleus frequencies. Three series of monitoring have been performed, and all probands were their own controls: monitoring 1 was done immediately before exchanging the heating system for furnacing from induction heating into gas heating. The second monitoring session was performed three months after replacement of the induction heating system. To ensure that the latter was not associated with a significant variation of other parameters of the workplace environment (most prominently exposure to lead), we measured metal concentrations in blood and urine (Pb, Cd, Hg, Mn, As, Cu, Zn, Ni, Cr) of workers before and after change of the heating system. A third session of monitoring was performed six months after the first examination.

High levels of micronuclei were found in the workers when the induction heating system was in use (21.4± 12.2 MN / 500 bn cells). A significant lowering of the micronucleus frequency was observed three months after replacement of this source of ELF-EMF exposure. The blood lead concentrations were not affected by the exchange of the heating system. No further significant decrease of micronuclei was found in the third monitoring, the mean level of micronuclei being still elevated as compared to controls (Fig. 1). Using a centromer-specific probe we were able to demonstrate that the significant decrease of micronuclei after induction heating cessation could be exclusively attributed to a decline of acentric fragments. However, no association of micronucleus frequency with exposure years was observed.

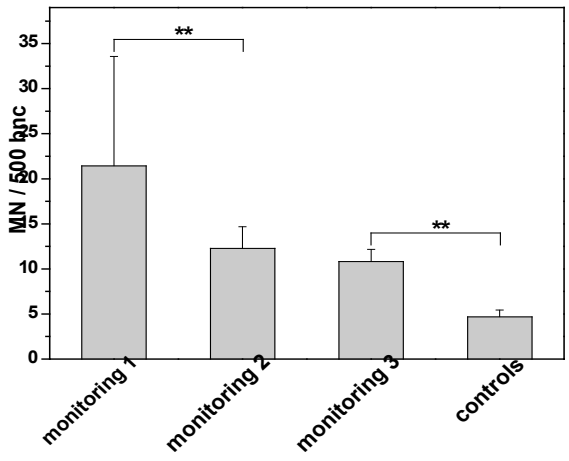

Fig.1

Our findings indicate, for the first time, that chronic exposure to ELF-EMF ≤ 2.5 mT may induce genotoxic effects in humans. This points to the clear need to investigate the underlying mechanisms and to consider effective protective measures.

S-1-3 EXPLANATIONS FOR "ELECTROMAGNETIC HYPERSENSITIVITY": A LITERATURE REVIEW

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Aim of the work :
Some individuals attribute symptoms to electromagnetic fields, some exclusively to fields from specific devices such as visual display units (VDUs) or mobile phones, and some claim to get symptoms when being near or using various sources of low frequency and of high frequency fields.
The symptoms as well as the severity of the symptoms attributed to the fields differ between individuals. In the most severe cases the symptoms lead to long term sick leaves or disability and even social isolation because of the avoidance of electromagnetic fields. As a part of a process to gain more knowledge on how the public health service could assist this group of people, the Norwegian health authorities gave me the task to review scientific literature. One of the main objectives was to explore reasons for the symptoms, and the possible effect of electromagnetic fields was focused. The evaluation of possible reasons for the symptoms based on scientific literature is also the aim of this presentation.

Materials and methods :
The possible role of low frequency and high frequency fields were evaluated separately and primarily based on results from provocation studies, but also epidemiology studies were reviewed. In addition, scientific papers that might suggest alternative explanations for the symptoms were included. The literature survey in connection with the task for the Norwegian Health Authorities (Oftedal, 2006) was finished in Jan. 2006. For this presentation also later provocation studies have been reviewed. Among the methods used to identify relevant literature was searches in literature data bases and in references in original papers, review articles and reports.

Results :
Most epidemiological studies suggest a correlation between the use of VDUs and skin symptoms, but no association between the electromagnetic fields from the VDUs and the symptoms. With a few exceptions the provocations studies did not give any evidence that the low frequency electromagnetic fields influence symptoms or physiological variables. An association between the use of mobile phones and headache and other symptoms is suggested by epidemiological studies, whereas provocation studies have not demonstrated any confirmed effect of the fields from the mobile phones neither for symptoms nor for physiological responses. There are indications that the group of people attributing symptoms to electromagnetic fields is heterogeneous with respect to the reason for their symptoms. Among causes that are suggested in the scientific literature are dust in combination with electrostatic fields, flickering light, and stress in connection with VDU work. Some "electromagnetic hypersensitive" individuals have been diagnosed with known diseases, and some studies indicate an abnormal autonomic nervous system regulation of "electromagnetic hypersensitive" individuals. Normal psychological mechanisms may explain the attribution of the symptoms to sources of electromagnetic fields even if there is no physical relation between the symptoms and the fields. This may be the case regardless of the primary or original reason for the symptoms.

Reference :
Oftedal G. El-overfølsomhet – utredning om årsaker og mulige tiltak og behandlingsopplegg. (Electromagnetic hypersensitivity - a review of reasons for and possible measures and treatments.) Trondheim: Høgskolen i Sør-Trøndelag (Sør-Trøndelag University College) HiST/AFT-rapport nr 1 2006, 2006.

S-1-4 **SUBJECTIVE SLEEP IMPAIRMENT IN THE VICINITY OF MOBILE-PHONE BASE STATIONS**

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Abstract

To investigate a potential causal role of environmental RF EMF in sleep disorders, at 44 worst cases out of 500 volunteers the subjective sleep quality of total 261 nights was investigated. The investigations were performed in the sleeping rooms of the volunteers, 6 of them aborted the investigation prematurely due to several reasons. The aim of the double-blind crossover designed study was to investigate potential reactions to shielding of environmental fields rather than to provoked exposure by additional fields. A mobile shield of electric conducting tissue was used. The subjective sleep status was assessed by PSQI. Daily sleep quality was characterised by the Self Rating scale for Sleep and Awaking Quality (SSA). Subjective sleep quality, awaking quality and sleep efficiency were assessed by standardised morning questionnaires. Shield conditions were compared with unshielded control and sham shields. RF EMF were continuously monitored during all the nights. Results were statistically analysed and positive, negative, placebo effects and side-effects by the setup differentiated.

S-1-5 EFFECTS OF ELECTROMAGNETIC FIELDS EMITTED BY COMMUNICATION SYSTEMS ON HUMAN COGNITION

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Two studies were conducted to investigate the effects on human cognitive performance of exposure to radiofrequency (RF) electromagnetic fields (EMF) used in communication systems. In the first, a total of 48 male participants completed a battery of cognitive tests on three separate test days whilst being exposed to a 29.725 MHz field, a 75.9 MHz field (peak SAR of 1.7 W/kg and 1.5 W/kg, respectively), and under a sham control condition. On the majority of the cognitive tests there were no significant differences between conditions. Results did indicate that exposure to a 29.725 MHz EMF field decreased reaction time and increased error proneness on a sustained attention task. However, these effects did not reach significance after family-wise error correction.

The second study investigated two further fields using an identical experimental design. Forty-one male participants completed the same battery of cognitive tests whilst being exposed to a 448 MHz field, a 1206 MHz field (peak SAR 0.9 W/kg and 0.7 W/kg, respectively) and a sham control. There were no statistically significant differences in cognitive performance between conditions.

The results of both of these studies indicate that the EMF fields investigated do not have a robust sustained effect on cognitive performance at these power levels. Furthermore, this lends support to recent studies of EMF cognitive effects which have found similar non-significant results.

S-1-6 **MOBILE PHONE HEADACHE: A PROVOCATION STUDY OF SUBJECTS ATTRIBUTING SYMPTOMS SPECIFICALLY TO THE PHONES**

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Aim of the work: Some people experience symptoms in connection with mobile phone calls, and epidemiological studies suggest a relation between the use and the occurrence of symptoms. Except from heat sensations, headache is the most frequently reported symptom (Oftedal et al., 2000). The aim of this provocation study was to test whether the radio frequency (RF) fields from mobile phones may cause pain or discomfort in the head of individuals who regularly experienced these symptoms when using mobile phone but who did not report hypersensitivity to electricity in general. We also wanted to test possible effects on blood pressure and heart rate.
Subjects and methods: The inclusion procedure was designed to recruit a highly selected group in which the chance to find an association between symptoms and the RF exposure would be high, if such an association exists. Individuals were selected based on interviews, questionnaires, and eventually an open provocation test. Only individuals who in this test got symptoms similar to those they usually experienced when using mobile phones were accepted for the double blind study. Seventeen subjects took part in at maximum four pairs of trials, each pair consisting of an RF and a sham exposure session in random order. In total 65 pairs of trials were conducted. The exposure lasted 30 min, and there were at least two days between any of the sessions. The amplified signal from a GSM 900 mobile phone was emitted by one of two dipole antennae mounted symmetrically on the sides of the subject's head. Peak SAR_{1g} was 1.0 W/kg. During a sham exposure the signal was absorbed by a resistive load. Tests on healthy subjects were conducted to ensure proper blinding of the exposure conditions. Symptoms were registered at various times using visual analogue scales (VASs). Separate VASs were used for headache and "other symptoms". The primary effect variable, decided *a priori*, was the maximal change in degree of head pain and discomfort (with pre-exposure values as baseline) during or within the first hour after the exposure. We also tested for headaches and "other symptoms", separately. The diastolic and systolic blood pressure and the pulse rate were continuously registered and changes during and after the end of exposure were analyzed.
Results: Most symptoms were mild, and they resembled the symptoms reported by the subjects for real mobile phone calls. When a symptom occurred, it usually came during the exposure, and its maximum usually occurred during exposure. The severity of symptoms did not depend on the order of the eight trials. The difference in symptom severity between RF and sham sessions was not statistically significantly (Table). Likewise, there were no statistically significant differences in blood pressure or pulse rate between the RF and sham sessions during or after the exposure (*p:* 0.30-0.88).
In conclusion, the study gave no evidence that RF fields from mobile phones cause head pain or discomfort or influence heart rate or blood pressure even if the subjects were selected to increase the chance to detect possible effects. The most likely reason for the symptoms is negative expectations, i.e. a nocebo effect.

Table. Maximal degree of symptom (means) relative to the pre-exposure value

	Mean values		*p* (paired t-test)
	RF	Sham	
Head pain or discomfort	10.1	12.6	0.30
Headache	7.4	10.3	0.22
Other symptoms	8.1	11.6	0.19

Reference:
Oftedal G, Wilén J, Sandström M, Mild KH. Symptoms experienced in connection with mobile phone use. Occup Med-Oxf 2000;50(4):237-245.

A REVERBERATION CHAMBER FOR THE EXPOSURE OF RODENTS TO RADIO FREQUENCY ELECTROMAGNETIC FIELDS: DESIGN AND PERFORMANCE

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INTRODUCTION

This paper presents the design and experimental results for a reverberation chamber based exposure setup for individually housed unconstrained rodents suitable for exposure over extended periods. The idea of using reverberation chambers for animal exposure to electromagnetic fields was first suggested by the National Institute of Standards and Technology (NIST) in a special session at BEMS 2001. A preliminary study involving an experimental investigation performed by NIST and a preliminary numerical dosimetry study performed by IT'IS, both funded by the National Institute of Environmental Health Sciences (NIEHS) in the USA. The results of this preliminary study were very encouraging and in January 2006 the main study to evaluate the potential toxicity and carcinogenicity of cell phone RF radiation in laboratory animals was issued by NIEHS under the National Toxicology Program. These results constitute the out come of the chamber prototype development and evaluation phase of the study.

METHODS

The design of the reverberation chamber had to encompass both the electrical design and animal housing issues. The application demanded a design that could house up to 108 rats or 214 mice and provide good ventilation and lighting. From the animal husbandry view point non-toxic materials must be used that can be readily disinfected without corrosion or other problems, this resulted in a stainless steel design. The electrical design had to achieve the required shielding and excellent field uniformity, to this end the chamber has a fully welded construction and utilizes two mode stirrers designed using EM modeling tools.

RESULTS

The important performance metrics for a reverberation chamber used for animal exposure are: the field uniformity and isotropy, the SAR uniformity, and the efficiency. Using E-Field probes the measured electric-field uniformity (one standard deviation) in the empty chamber measured on a 300mm 3D grid was 0.6dB and the field isotropy 0.85dB and in the fully loaded chamber, over a reduced number of points, 0.74dB and 1.3dB respectively. Figure 1 shows one slice of the E-field uniformity results. The SAR uniformity measured in rat and mouse phantoms, using the temperature method, were 0.46dB and 0.40dB respectively. The design achieves an overall efficiency of ~70% for adult rats and 45% for adult mice.

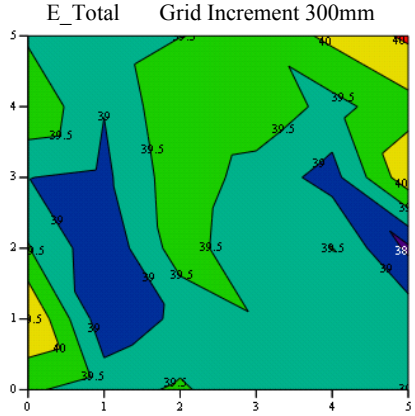

Figure 1, E-field uniformity (0.5dB Contours)

DISCUSSION

Overall, the performance across all the criteria of the reverberation chamber for animal exposure is excellent, with all target performance metrics being met or exceeded. The performance of this exposure environment is comparable to the best exposure setups using constrained animals. In addition exposure periods can extend from a maximum of 4 hours for a rat to ≥20 hours per day

ACKNOWLEDGEMENT

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S-2-2

A New 900 MHz Ridged-Waveguide Microwave Exposure Equipment to Achieve High Power Density Irradiation for In Vitro Experiments

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INTRODUCTION

Authors conducted in-vitro experimental investigations into free-radical production in human cells due to microwave exposure, especially focusing on mobile radio frequencies [1]. In the experiment, cultured or treated human cells are irradiated by high-level RF waves for a few minutes. Several kinds of exposure systems that make use of rectangular waveguides have been reported for in-vitro studies so far [2]. To achieve high duty RF exposure of cells at 900 MHz, we developed ridged-waveguide microwave exposure equipment.

MATERIAL AND METHODS

The exposure system is shown in fig. 1. This system consists of a vector signal generator, 100 Watts transistor amplifier, stub tuner, the ridged waveguide and terminator. In manufacturing the 900 MHz ridged-waveguide exposure equipment, rectangular waveguides (WRJ-1: 740 MHz-1.12 GHz) that have the cross-sectional dimensions of 247.65 × 123.83 mm are used. As shown in the figure, the two tapered ridged parts and ridged waveguide that has dimensions of 185.5 × 61.5 mm are employed to increase the duty of electromagnetic fields on irradiated sample tissue.

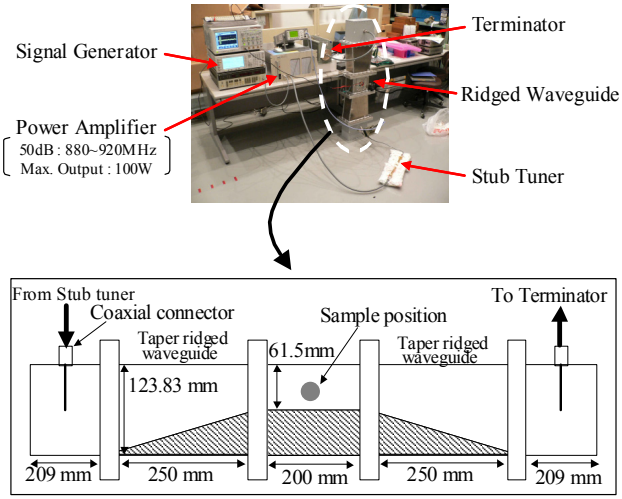

Fig. 1: Ridged waveguide exposure system

RESULTS

This equipment can achieve about 1.5 times higher exposure on samples in comparison with conventional rectangular waveguides and it is also available without special degradation of the impedance matching caused by the scattering waves from the samples.

ACKNOWLDEGMENT

This work is supported by Grant-in-Aid from the Ministry of Internal Affairs and Communications (MIC) of Japan.

REFERENCES

[1] Hikage et al., “Experimental Investigations on the Biological Free Radical Production in Human Fibroblasts due to Microwave Exposure”, The Bioelectromagnetics Society the 28th Annual Meeting P-B-78, 2006. [2] Schonborn et al., “Design, Optimization, Realization, and Analysis of an In vitro System for the exposure of Embryonic Stem Cells at 1.71 GHz” , Bioelectromagneticas 21 :372-384, 2000.

S-2-3

RF EXPOSURE OF CELLS IN VITRO USING FINLINES FOR THREE DIFFERENT FREQUENCY BANDS

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AIM OF THE WORK

This project performed within the frame of the "German Mobile Telecommunication Research Programme" is designed to investigate possible effects on the auditory system due to RF signals from the cellular mobile communication networks GSM 900MHz, GSM 1800MHz or UMTS. To do so, parts of the so-called Cortian organ of the cochlea of mice are prepared and kept in vitro and the Ca^{2+}-ion flux through the cell membrane of an isolated inner hair cell is measured with help of the patch clamp technique. Simultaneously, the cells are exposed using new exposure devices based on a finline concept. This contribution reports about the properties of the exposure set-up and presents results of the electromagnetic fields and specific absorption rates within the biological system.

MATERIALS AND METHODS

For each of the three frequency bands a specifically dimensioned finline made of brass was developed which means in principle a rectangular waveguide with two internal metal fins attached to the side walls, thus guiding a shielded slot line wave with a field concentrated to the area close to the slot. There were some important requirements:

- Since the exact location of the biological cells is not known a priori, a homogeneous field distribution over the central volume of the vessel filled with nutrient solution and with the sample must be achieved.
- The distance between the condensor lens for illumination and the microscope objective for observation of the contact between cell and patch clamp electrode is only a few millimeters, and the exposure field must propagate through this gap.
- The structure must be open for the microscope objective, the patch clamp electrode and two perfusion tubes.
- The dimensioning of the finlines as well as the construction of excitation must allow for a stable single-mode operation of the devices.
- SAR values of 0.02, 0.2, 2, and 20 W/kg should be reached without producing thermal effects. Analytical and numerical computations, field and temperature measurements were applied to find a suitable solution.

RESULTS

As an example, figure 1 shows the exposure device for GSM 1800MHz. The above mentioned requirements are completely attained. For UMTS exposure (2 GHz) the maximum desired SAR of 20 W/kg is achieved for a total input power of 120 mW with heating below 0.4 °C. A good agreement between field measurements and calculations is obtained. More details will be given in the presentation.

Fig. 1: Photograph of the implemented exposure device for GSM 1800MHz

S-2-4 FDTD SIMULATION OF DOSIMETRY FOR BENT RATS EXPOSED TO GSM-900 SIGNALS IN A TEM CELL

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Aim of the Work

Salford et al. reported in 2003 that the GSM-900 signals induced an albumin leakage due to disruption of blood-brain barrier function in rats. The dosimetry of the TEM (transverse electromagnetic) cell used in his experiment, however, remains unclear. The uncertain exposure conditions may cause unexpected influences on the exposed rats and then confuse the interpretation of the actual result. Replication studies of his result are being performed on an international collaboration basis, and a high-precision dosimetry evaluation was a necessary step for the replication experiment. The researchers at Brooks City Base recently reported their dosimetry results mainly based on localized and whole-body-averaged SAR measurements in the Salford-used TEM cell. However, the finite-difference time-domain (FDTD) simulation suggests some discrepancies with the measurement. A possible reason is being attributed to the accuracy of TEM cell modeling. In this paper, we newly developed a detailed FDTD-based TEM cell model for the dosimetry of rats exposed to GSM-900 signals. We also employed a bent rat model, just as used in the Brooks City Base simulation, and incorporated it into the TEM cell model. We then conducted a dosimetric analysis by means of the FDTD simulation and attempted the comparison with the reported brooks City Base results.

Method

The FDTD method was employed in the dosimetric analysis. The FDTD TEM cell model, with the same structure and dimensions as Salford used, was constructed of 2-mm cubic cells. It consists of a section of rectangular coaxial transmission line tapered at each end to adapt to standard coaxial connectors. The rectangular coaxial transmission has a length of 15 cm and a cross-section of 15 x 15 cm. The coaxial connector parts were adjusted to have a characteristic impedance of 50 ohm. This was validated by FDTD simulation in which we obtained a value of 54.9+j0.3 ohm.

The TEM cell is cramped for the rats exposed to GSM-900 signals. The rats have to be in a bent shape usually because of the small TEM cell space. We therefore employed a bent rat model, provided by Brooks City Base, in the FDTD simulation. The bent rat model has a mass of 279 grams and a volume of 1322 cm^3. It consists of 36 tissue types. We employed the dielectric properties for the bent rat model from the 4-cole-cole extrapolation of Gabriel's data. Both the absorbed total power and the local specific absorption rate (SAR) distribution were numerically derived.

Results

The FDTD-calculated total power absorbed in the bent rat was compared with measured results to further confirm the validity of the TEM cell model. Then the local SARs in various arrangements of the bent rat in the TEM cell were calculated to demonstrate the possible SAR distributions in actual exposed rats. Finally, for the bent rat exposed to GSM-900 signal in the TEM cell, the whole-body-averaged SAR and the brain-averaged SAR were given in a statistical sense in view of the various arrangements of rat.

Acknowledgment

The authors would like to thank Dr. P.A. Mason and his colleagues at the Brooks City Base, USA, for providing us with their bent rat model and measured data.

S-2-5 USING PLANAR MODELS TO COMPARE LOCAL SAR TO INCIDENT POWER FLUX DENSITY AS THE BEST METRIC FOR BASIC RESTRICTIONS BETWEEN 1 AND 10 GHz

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Aim: The aim of this study is to provide a more rigorous basis for the specification of localised 10g average SAR (SAR_{10g}) and incident power flux density (S_{inc}) as RF safety exposure metrics in the frequency range of 1-10 GHz. In particular, we seek to establish the optimal frequency crossover point (or range) for these two metrics using maximum induced tissue temperature rise as a common gauge for comparison.

Materials and Methods: The point SAR distribution and tissue temperature rise were calculated in three tissue (skin/fat/muscle) planar models exposed to 10 W/m² plane waves ranging in frequency from 1 to 10 GHz. Thousands of models were formulated by Monte Carlo analysis to explore the effects of varying thermal environmental conditions and statistical variation in tissue layer thicknesses. Our statistical distributions for skin and fat tissue layer thickness were developed from a meta-analysis of the available literature, and included estimates of population variation for varying age, sex and body location. For each model that we analysed, we recorded the peak 10g average SAR and the maximum tissue temperature rise. The incident power flux density and 10g average SAR were then normalised to a constant value of maximum tissue temperature rise (1°C) to enable meaningful comparison between the S_{inc} and SAR_{10g} metrics.

Results: The results of our analyses were sorted into normalised SAR_{10g} and S_{inc} histograms for each combination block of body location, frequency and thermal conditions. By examining the distribution spread of each histogram, we were able to best judge which basic restriction exposure metric, S_{inc} or SAR_{10g}, provides the best indicator of maximum tissue temperature rise in the frequency range of 1 to 10 GHz.

STATISTICAL ASSESSMENT OF SAR TYPOLOGY ON THE SAM HEAD

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The maximum averaged Specific Absorption Rate (SAR) in 10g is currently the unique parameter characterizing a mobile phone, in terms of radiated power in the user's head. In any case, it is the only physical parameter under regulation, through the standards and the current SAR level recommendations. Beside the knowledge of the averaged SAR value, it could be interesting to represent the SAR maximum location on the phantom head, to give an idea of the head regions exposed to the mobile phone radiation. In this study, we have exploited the huge amount of mobile phones measured in the Supélec accreditated SAR measurement laboratory, on a SARA2 (Indexsar) facility. The 150 phones taken into account here have been measured since October 2004 until October 2006. We will focus on the SAR maximum localisation on the head (Specific Anthropomorphic Mannequin) and the surface defined by iso-SAR curves.

All the phones considered in this study have been measured in the Supélec facility according to the EN50361 SAR measurement standard[1]. For each phone, 12 different configurations were measured, depending on the frequency (900 MHz and 1800 MHz bands), the position with the Specific Anthropomorphic Mannequin (SAM) phantom (close to the cheek, or tilted 15° away) or the side of the SAM head. The SAR measurement procedure consists in roughly determining the location of the maximum local SAR in a surface close to the SAM head boundary, and then explore with a fine mesh this region in 3 dimensions, to get accurate results for SAR measurement. We use here the first planar information, consisting in a large local SAR surface surrounding the phone shape, with a coarse mesh (approximately 120 x 100 mm with 12 mm square mesh). Each measurement data file have been reprocessed and local SAR data interpolated to 1mm square mesh to get the following information : i) maximum local SAR coordinates, ii) levels and associated surface where local SAR is higher than 90%, 75% and 50% of the maximum local SAR and iii) the SAR curve associated to the surface corresponding to the 10g SAR cube side. The maximum local, 1g and 10 averaged SAR values, with the test position and frequency information are also associated to the previous results.

The results of this study will be presented as maps of SAM head showing localisation of maximum local SAR for different phones categories or frequencies. Three different phone shape categories are considered: bar, slide and clam-shell. With the rise of clam-shell phones shape, the localisation of maximum local SAR is now more often in the cheek, near the mouth region, while the bar-phones are located around the ear region. The statistical assessment of the relation between maximum SAR values and surface SAR extension gives additional information, showing the need to consider also such parameters in the SAR characterisation of a mobile phone.

[1] EN50361, Basic standard for the measurement of Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz – 3 GHz), CENELEC TC211 European standard, Bruxelles, June 2000.

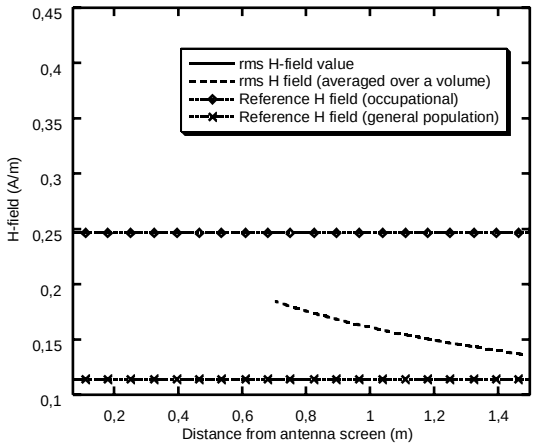

Fig. 1: rms field value and averaged value on a volume equivalent to the human body, compared with the reference value for occupational exposure and general population. a) E field; b) H field.