Joint Workshop of URSI Commission K and ICNIRP

Abstracts

Telecom Institute - Telecom Paris Tech (the School of Telecom Engineering)

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PROGRAM (Day 1)

	Opening	
10:00	**Welcome Address**	A Sibille (URSI France , Mines Telecom Paris Tech) F. de Fornel (President of URSI France)
10:20	**Introduction** URSI Commission K ICNIRP	 M. Taki (URSI -K) R. Matthes (ICNIRP)
10:40	**Coffee break**	
11:00	**EMF and Health (Chair: C. Ohkubo)** View of WHO View of IARC View of ICNIRP	 E. Van Deventer (WHO) I. Deltour (IARC) R. Matthes (ICNIRP)
12:30	**Lunch**	
13:30	**Human Exposure assessment (chair. M. Taki)** Gaps and Inconsistencies of the Safety Guidelines Stochastic dosimetry and human exposure On Temperature Elevation Computation for RF Far-field and Near-field Exposures Risk and exposure perceptions vs. assessment: The EMF case Public Perception of EMF Risks and Risk Communication in Japan	 N. Kuster (IT'IS), invited J. Wiart (WHIST Lab) invited A. Hirata (NIT), invited P. Wiedemann (KIT), invited C. Ohkubo (JEIC), Invited
15:10	**Coffee break**	
15:40	**Standards (chair: N. Kuster)** IEC 62232 ITU IEC 62209 IEEE 1528 SAR measurement standard and IEC/IEEE 62704-x numerical exposure standards	 M. Wood, invited A.Zeddam, invited J. Keshvari, invited M. Douglas, invited

17:00	**Regular session (Chair: S. Watanabe)** Photonic technologies applied to evaluation of the human exposure to electromagnetic fields Metrology for next-generation safety standards and equipment in MRI – A joint research project within the European Metrology Research Programme Personal Human exposure vs Human Population exposure to EMF SAR evaluation in fetuses at 13th, 18th and 26th gestation ages due to a typical tablet computer	 T. Onishi (NTT DoCoMo), Invited B. Ittermann (PTB), Invited N. Varsier (Orange labs, Whist lab) A. Tateno (Chiba Univ)
18:20	**Discussion (Chair J.wiart)**	
18:50	**End of 1st day meeting**	
18:50	**URSI-K Business Meeting**	
19:30	**End of URSI-K Business Meeting**	
20:00	**Social Event**	

PROGRAM (Day 2)

9:30	**Medical Application of EMF (chairs: S. Ueno and F. Prato)** Recent advances in biomagnetic stimulation and imaging by transcranial magnetic brain stimulation and magnetic resonance imaging Simultaneous Magnetic Resonance Imaging and Positron Emission Tomography: Challenges and Opportunities of a New Medical Imaging Hybrid Technology	 S. Ueno (Univ of Tokyo), invited F. Prato (Lawson Health Research Inst), invited
10:30	**Coffee break**	
11:00	**Regular session (Chair: R. Matthes**) Topical issues in assessment of occupational exposure to EMFs A Questionnaire Survey of Physical and Mental Symptoms during routine MRI operations Teratological Study in Pregnant Rats being Locally Exposed to Their Abdomen of Intermediate Frequency (21kHz) Magnetic Fields Numerical Assessment Method for Implantable Cardiac Pacemaker EMI Triggered by 10MHz-band Wireless Power Transfer Coils	 J. Karpowicz (CIOP), Invited S. Yamaguchi (JNIOSH) A. Ushiyama (NIPH) T. Hikage (Hokkaido Univ.)
12:20	**Lunch**	
13:20	**Blue Light (chair: P. Söderberg)** Blue light and the eyes and the skin Radiometry and human hazard evaluation of blue light sources	 P. Soderberg (Uppsala University), invited P. Boulenguez (CSTB), Invited
14:20	**Regular Session (Chair: P. Söderberg)** Ocular damage differs by frequency difference (40 or 95 GHz) to rabbit eye Heat transport on rabbit eyes exposed to millimeter waves considering flow in the anterior chamber	 M. Kojima (Kanazawa Medical Univ.) Y. Suzuki (TMU)
15:00	**Discussion (Chair: M. Hietanen)**	
15:30	**Closing (Chair: M. Taki**)	J. Wiart (URSI K) , R. Matthes (ICNIRP)
16:00	**End of the Meeting**	

Introduction

EMF and Health
(Chair: C. Ohkubo)

Human Exposure Assessment

(Chair: M. Taki)

Stochastic dosimetry and human exposure

J. Wiart, E. Conil, N Varsier, A.Hadjem, M Jala, , P. Kersaudy, T Sarrebourse and A Gati

Orange labs , Whist Lab Issy les Moulineaux France

The wireless communications are increasingly used since 20 years. Such trend is also accompanied with a large versatile use of such technology. If in the 90's the GSM phones were used mainly close to the ear, in a voice call usage, today the manners of use of a mobile phone are multiple. With the GSM Edge technology mobile phone users have been able to surf on the Internet. The 3G and after that the 3G+ have offered more capacity and mobility to use the Internet on mobile phones, computers and tablets. Today the new technology LTE is offering a full mobility for internet users with for them the same capacity than the one offered today to fixed DSL users. Wifi technology is also able, without real mobility capability, to be used for voice call and Internet access. Tomorrow offloading combining Wifi and 3G or LTE will increase the capacity offered to users. Several studies have shown that the number of SIM cards, requested to use a mobile, overtook the 100 %. A recent survey, performed in France, reports that in 2011 more than 80 % of the population owned a mobile phone and 100 % of the age segment 18-25 years old have a mobile. In spite of such important use, this wireless use trend is accompanied with fears about possible sanitary effects associated to the Radio Frequency (RF) electromagnetic fields (EMF). To respond to this concern, large research effort has been conducted since the 90's. Based on current scientific knowledge, ICNIRP has recommended protection limits. Technical standards such as IEC, IEEE or CENELEC have been established and adopted to check the compliance of RF systems put on the market or put into service. While studies relating to compliance could settle for a conservative approach using worst-case scenario, the public concern about the day-to-day exposure as well as epidemiological studies request the estimation of the “real exposure”. As explained previously technologies and usages have evolved. As a consequence the exposure depends on several variable parameters such as technology, usage, posture … a worst case approach while useful to check the compliance can not be used anymore to assess a day-to-day exposure with such variable patterns.

The stochastic dosimetry has defined methodologies involving statistical modeling to assess such exposure and estimate the statistical distribution of the output of a process induced by the variations of the input parameters and the sensitivity analysis. To perform such analysis Monte Carlo method is often used and has shown its efficiency. In the numerical dosimetry domain the human exposure assessment has been improved. Millimetre resolution human models, including child, fetus and pregnant women models have been built. Parallel computer architecture, graphic process unit GPU have allowed to improve the computation performances and reduced the time computation of finite difference in time domain (FDTD) method. In spite of such improvement the pre-processing and computation time do not allow to use directly methods such as Monte Carlo method in human exposure assessment.

To overcome this difficulty, surrogate model or response surface can be used to approximate the human exposure. Such models allowing quick calculation can be used in usual Monte Carlo. The key question is therefore to built, in a parsimonious way, the response surface. This paper reviews the methods, planning experiment, regression and complementary methods that can be used to build surrogate models based on Polynomial Chaos expansion. This paper is also providing examples illustrating the method.

On Temperature Elevation Computation for RF Far-field and Near-field Exposures

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1. Summary

In the ICNIPR (International Commission on Non-Ionizing Radiation Protection) guidelines and IEEE standards, the whole-body average specific absorption rate (SAR) is used as a measure of human protection for radio-frequency (RF) whole-body exposure. The basic restriction or the limit for occupational exposure is 0.4 W/kg. One of the rationales for this value is based on the fact that RF exposure of laboratory animals in excess of approximately 4 W/kg revealed a characteristic pattern of thermoregulatory response, and a reduction factor of 10 was then applied. Additionally, decreased task performance by rats and monkeys has been observed at SAR values in the range of 1-3 W kg. These phenomena would be caused by core temperature elevation. However, some difference between these small animals and human would exist, especially because the physiological heat loss mechanisms of the small animals are limited.

For RF localized exposures, the guidelines/standards are based on peak spatial-average SAR for any 10g of body tissue. However, physiological effects and damage to humans due to RF absorption are induced by the temperature elevation, similar to whole-body exposures. A temperature elevation of 4.5 ^{o}C in the brain has been noted to be an allowable limit which does not lead to any physiological damage (for exposures of more than 30 minutes).

Although a temperature elevation in the human is a dominant factor due to microwave exposure, the relationship between incident electromagnetic fields, whole-body average SAR, and temperature elevation was not well quantified until recently. This study reviews briefly our computational study on the temperature elevation in anatomically based human head models for RF exposures. Computational examples are given to explain the difference of the temperature elevations between localized and whole-body exposures.

Public Perception of EMF Risks and Risk Communication in Japan

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Electromagnetic fields (EMFs) have been present in industrialized countries since the late 19th century and a considerable amount of knowledge has been accumulated as to possible health effects. EMFs are unavoidably produced wherever electricity is used, and are thus inherent in modern societies. Throughout the world, the general public concerned that exposure to EMF from such sources as high voltage power lines, radars, mobile telephones and their base stations could lead to adverse health consequences, especially in children. As a result, the construction of new power lines and mobile telephone networks has met with considerable opposition not only in Japan but in many countries. Lack of knowledge about health consequences of advances in EMF technology may not be the sole reason for social opposition to innovations. Ignorance of differences in risk perception that are not adequately reflected in risk communications of EMFs among scientists, governments, industry and the general public, is also to be accused.

The scientific evidence on EMFs and their potential health effects has been reviewed many times, mostly by the World Health Organization (WHO). In 2007, the World Health Organization (WHO) issued the Environmental Health Criteria monograph 238 and Fact Sheet 322 on extremely low frequency (ELF) electromagnetic field (EMF)s for supporting the needs of the health ministries of Member States of the WHO International EMF Project and one of its aims is to help the relevant national authorities develop their risk commination strategies.

Public perception of EMF risks in Japan is very high. It was shown in a survey conducted in 2003 that perceived risk of EMFs is higher than that of smoking. The Ministry of Economy, Trade and Industry (METI) formed a Working Group on Electric Power Facility and EMF Policy in June 2007. The Working Group compiled their report in which their recommendations to the METI were incorporated.

To address issues related to possible long-term exposure effects of ELF-EMF, the Working Group recommended that a neutral and permanent EMF information center should be established to promote risk communication and facilitate peoples' understanding based on scientific evidences. In response to this recommendation, the Japan EMF Information Centre (JEIC) was established in July 2008. The JEIC is funded by the Japan Electrical Safety & Environment Technology Laboratories (JET) that was established in 1963 as an authorized testing body, designated by the Government of Japan under the Electrical Appliance and Material Control Law. JEIC has been financed from donations by stakeholders and governmental funds. The Administration Audit Committee was founded in order to ensure and monitor the neutrality and transparency of JEIC operations.

The JEIC institutional system is determined to develop itself into a world-class risk communication center with expertise in EMFs. Challenge is to provide an accurate translation of scientific information and terminology for the media, policy-makers and the general public. JEIC's philosophy and purpose are to provide easy-to-understand scientific information on EMFs and its possible health effects and minimize the gap of risk perception among stakeholders and promote risk communication from a fair perspective. Because established of JEIC was triggered by one of recommendations of the METI's Working Group Report and the METI is the ministerial agency responsible for authorization of electric power facilities, JEIC's activities have been mainly focused on ELF-EMF issues generated from power facilities; however, there are queries relating health effects due to exposure to all EMF frequencies from the general public. JEIC's work to achieve its purposes includes

(1) creating an EMF information database including EMF research,
(2) communication with mass media,
(3) organizing public meetings and
(4) Q&A by telephone and email.

Besides the JEIC activity, risk communication activities on EMFs are also conducted in several governmental bodies (the METI, the Ministry of Internal Affairs and Communications, and the Ministry of the Environment). They have been disseminating information of EMF risks on their websites, publishing brochures (booklets), consulting the public or organizing public meeting all over Japan.

Outlines of the EMF risk communication activities in Japan will be introduced at the meeting.

Standards
(Chair: N. Kuster)

Regular Session
(Chair: S. Watanabe)

Photonic Technologies Applied to Evaluation of the Human Exposure to Electromagnetic Fields

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1. Introduction

This paper describes photonic technologies for use in evaluating human exposure to electromagnetic fields. For the safe usage of radio waves, exposure assessment is required for both terminals and base stations. Photonic technologies such as Electro-Optic (EO) probes have low level of invasiveness and the capability to measure both amplitude and phase. In this paper, a small EO probe and application of assessment for terminals and base stations are introduced. It is shown that these methods are effective in shortening the measurement time maintaining accuracy.

2. Exposure assessment methods

2.1 Application for Terminals

The SAR estimation method employing the EO probe that enables us to omit theoretically the 3-D measurement was proposed [1]. The method is based on the equivalence theorem and image theory so that the 3-D E-field can be calculated from 2-D measurement data. Figure 1 shows the calculated and estimated SAR distributions on the phantom surface at 900 MHz. As shown in Fig. 1 the estimated SAR distribution agrees well with the calculated results. The estimated 1-g or 10-g average SAR shows a difference of less than a few percent compared to the original SAR values.

2.2 Application for Base stations

The near field to far field (NF/FF) transformation technique is a useful methods in estimating the electric field distribution to reduce the measurement time. For the calculation, the NF/FF technique also requires the amplitude and phase of the electric field. In this study the amplitude and phase are calculated using the fast Fourier transformation (FFT) from the time-varying measured RF field that is employed by the modulation scheme of the mobile system [2]. Figure 2 shows that the field calculated from the measurement with respect to the LTE downlink (Fig. 2 (a)) agrees well with that of the CW (Fig. 2 (b)).

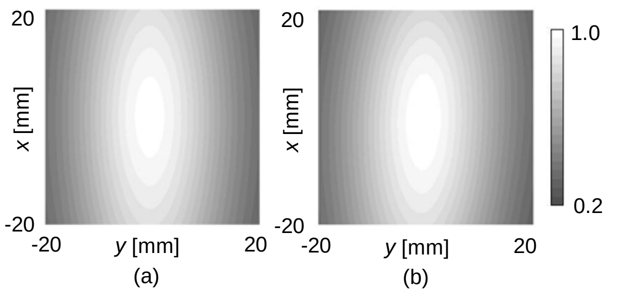
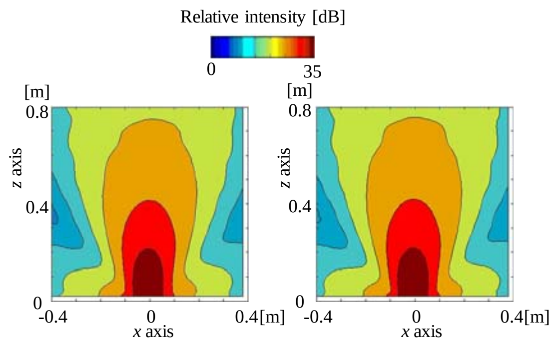


Figure 1. SAR distributions on phantom surface from 900 MHz half-wave dipole. (a) Calculated. (b) Estimated results based on measured results [1].



(a) LTE downlink (b) CW

Figure 2. Radiated near- and far- field calculated from measured near E-field [2].

3. References

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Metrology for next-generation safety standards and equipment in MRI – A joint research project within the European Metrology Research Programme

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1. Introduction

During an magnetic resonance imaging (MRI) scan the patient is exposed to three different types of electromagnetic fields: i) the static magnetic field from the superconducting MRI magnet, ii) switched (magnetic) gradient fields, and iii) strong radio-frequency (RF) pulses. At globally about 100 million exams per year, MRI is arguably the most relevant source of exposure to intense electromagnetic (EM) fields in the industrialized world. Normally, only patients are exposed to the RF and switched gradient fields but the strong static (stray) field affects MR personnel as well. But exceptions to this rule exist, most notably the case of MRI guided surgical interventions.

All three types of MRI related EM fields are potentially hazardous and a variety of guidelines, standards and regulatory documents [1-3] exist defining exposure limits in order to protect exposed human subjects. This approach is presently without alternative but nevertheless it comes with two fundamental questions: i) how do we know the precise physiological effects when biological tissue is exposed to EM fields, and ii) how can we reliably determine these EM fields *inside* the human body, in the first place? The first question is a physiological and bio-physical one and worldwide a host of researchers from these communities are trying to address it. The second one is about metrology – the art and science of measurement.

The questions are pressing as the existing safety limits are already limiting the performance of modern MRI scanners. *Insufficient* safety limits cannot be tolerated but *unnecessary* restrictions have to be avoided as well as they result in images of reduced diagnostic value, longer scan times and higher costs for our health care systems.

2. The EMRP joint research project on MRI Safety

In April 2012 a joint research project within the European Metrology Research Programme (EMRP) took off aiming to contribute to the answer of the second question about determining MRI related EM fields inside the human body. The partners are research groups from National Metrology Institutes (PTB, Germany; INRIM, Italy; VSL Netherlands) and academia (King's College London, UK). The project is built upon two fundamental propositions: i) quantitative numerical simulations are at present the most powerful and most promising tool to achieve the intended goal, and ii) a sound experimental validation is an indispensible prerequisite before any safety decisions can be based on numerical simulations. Two basic workpackages are devoted to develop the theoretical and numerical as well as the experimental techniques and instrumentation required for this project. Building upon on these two basic ones there are four "applied" workpackages trying to use the developed tools to address specific problems:

- WP 3 "*Motion induced LF fields and currents*" applies EMF simulations to determine the *E* fields and currents induced inside a human body when moving around an MR magnet.
- WP 4 "*Emerging technologies: parallel transmission and ultrahigh fields*" is specifically concerned about new challenges posed my recent trends in MRI hardware development.
- WP 5 "*Emerging technologies: MRI-accelerator*" is the only part of the project which is related to ionizing rather than electromagnetic radiation. An innovative approach to combine an radiation therapy (RT) accelerator with an MRI scanner opens unprecedented opportunities for MRI guided RT but also poses new challenges for photon dosimetry in strong magnetic fields.
- WP 6 "*Metallic implants in MRI*" aims to explore the additional safety hazards which one particular group of potential MRI patients, subjects carrying a conductive medical implant is facing.

The project's first results after 15 months of operation will be presented and discussed.

4. References

1. ICNIRP, "Guidelines on limits of exposure to static magnetic fields,".*Health Phys* **96**, 2009, pp. 504-514

2. IEC, "Medical electrical equipment - Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis", *IEC-60601-2-33* ed. 3, 2010

3. European Commission, "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)"

Personal Human exposure vs Human Population exposure to EMF

N. Varsier, E. Conil, A.Hadjem, T Sarrebourse, A. Gati and J. Wiart

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Wireless networks traffic has experienced unparalleled growth in recent years, and this trend is expected to continue: users are increasingly reliant on pervasive wireless connectivity, and the amount of data shared wirelessly is forecast to grow exponentially, with an increasingly varying type of content. This will be compounded by the proliferation of the machine-to-machine communication and cloud computing paradigms, which will see the connection of tens of billions of objects to the Internet over the next 10 years, much of it wirelessly. Measures to meet the growing demand, such as traffic offloading, mean that small wireless cells will become omnipresent. While this allows for user devices to transmit at lower power, it also moves the transmitters closer to the user. Moreover, dedicated wireless systems will emerge to carry new services, thereby contributing to the increase in transmitter sites, especially in urban environments. In summary, the density of all the radio connected objects and their proximity to users will result in a potential increase in electromagnetic field (EMF) levels in the radio-frequency (RF) range.

Stringent regulations exist that protect users from RF-EMF exposure [1]. However, the main focus of most exposure evaluation is conformance to the existing EMF standards at the stage when wireless networks are first deployed and mobile terminals manufactured, using worst-case assumptions (i.e. maximum power emitted), as opposed to day-to-day network functioning and management. Having said that, the exposure limits are valid throughout the life of a network and in-situ measurements are performed even after the networks are first deployed to ensure this. Nevertheless, RF-EMF exposure is a cause of recurring public concern [2].

European Union has specifically addressed the need for low-EMF technologies in its Seventh Framework Programme (FP7, ICT Call 8), by designating the following (among others) as a target outcome: “R&D targeting new radio transmission paradigms and system designs taking into account the need for radical cost and energy per bit reduction and lower electromagnetic field exposure”. This target outcome recognises that there is a clear need for new network topologies and management which reduce the EMF levels of exposure without compromising the user’s Quality of Service (QoS). In response to this need, 17 leading telecommunications operators, manufacturers, research centres and academic institutions have launched LEXNET (Low EMF Exposure Networks) project [3], a research endeavour which aims to pave the way for low-EMF networks of the future.

The preliminary results of a LEXNET-devised survey illustrate the biased view of the public on RF exposure, overestimating exposure from far-field sources (i.e. base station and access points) and underestimating exposure from near-field sources (e.g. mobile terminals). However, measurements on real networks have shown a strong correlation (Figure 1) between the power emitted by personal devices and received from base station antennas [4].

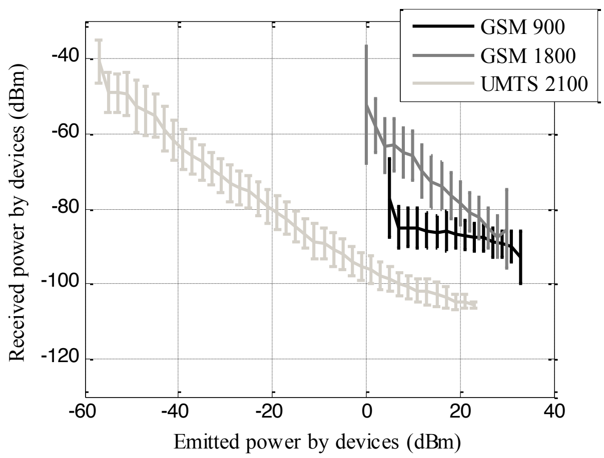

Figure 1 Duality between emitted and received powers by mobiles during voice calls measured on the 3G Orange France network.

The question of RF-EMF exposure has so far been focused on the individual user, handling the exposure induced by personal devices and that of the network equipment separately. LEXNET will change this by putting the issue of the exposure not at the individual level but at the network level and by introducing exposure into network optimization.

In this paper we start by discussing the user perception of exposure to RF-EMF and shed new light on this issue by presenting preliminary results of original, LEXNET-devised surveys. We then present the key concepts of LEXNET—population exposure due to both personal devices and network transmitters—and how networks could be designed with a view to minimising this exposure and in line with the pervasive trend towards human-centric computing and networks. In this part we present an important concept of LEXNET, that is the formulation of a new exposure metric, which we term the Exposure Index, that would be associated with a given wireless telecommunication network. This Exposure Index merges the exposure incurred by personal devices with that attributable to access points or base stations, thus becoming a new parameter to be reduced as part of network optimization. We continue by presenting a simplified example of calculation of this exposure index. And lastly, we present concluding remarks and outline the key goals of LEXNET.

References

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SAR evaluation in fetuses at 13th, 18th and 26th gestation ages due to a typical tablet computer

***Akihiro Tateno*[1], *Kensuke Tanaka* [1], *Tomoaki Nagaoka*[2], *Kazuyuki Saito*[1], *Soichi Watanabe*[2], *Masaharu Takahashi*[1], *Joe Wiart*[3] and *Koichi Ito*[1]**

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[2] National Institute of Information and Communications Technology, 4-2-1 Nukuikita-machi, Koganei, Tokyo 184-8795, Japan
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1. Introduction

Recently, wireless radio terminals such as mobile phones and tablet computers are increasing and developing rapidly. As tablet computers are frequently used close to the abdomen, the electromagnetic source is near to a fetus. In this study, we estimated the maternal and fetal SARs when the tablet computer is placed in vicinity of the abdomen of pregnant females.

2. Materials and methods

In this study, the pregnant female models at 13th, 18th and 26th gestational weeks [1] were employed. Figure 1 (a) shows a typical tablet computer model with the high-resolution cell of 0.5 mm × 0.5 mm × 0.5 mm [2]. Three antennas are built into the tablet computer model (Global Positioning System, 3rd generation mobile communication system and Wireless Fidelity). We focused on the antenna for the 3rd generation mobile communication system in the tablet computer model because of high radiation power. The operating frequencies are 900 MHz and 2 GHz, the radiation power is 0.25 W. The tablet computer model is placed horizontally and the distance between the pregnant female and the terminal is 10 mm. The height of feeding point is the center of a fetal head. The median line of pregnant female models corresponds to the bisector of short side of the tablet computer model. We performed the calculations by XFdtd ver.7 [3].

3. Results

Figure 1 (b) shows the peak 10-g-averaged SARs in pregnant female (maternal 10-g-averaged SAR). The SARs at 2 GHz is approximately 1.3-3.5 times higher than those at 900 MHz. The highest SAR value is 1.35 W/kg in 26th gestational week model. Figure 1 (c) shows the peak 10-g-averaged SARs in the fetus (fetal 10-g-averaged SAR). The SAR is highest in 26th gestational week model at 2 GHz (0.17 W/kg). This highest fetal SAR value is approximately one eighth of the maternal SAR. Fetal 10-g-averaged SARs become higher as the gestation age progresses. This is because of the shortened distance between the fetus and the terminal due to the growth of the fetus and the extension of the maternal abdomen. Comparison with frequencies, the fetal 10-g-averaged SARs at 2 GHz are higher than those at 900 MHz. In addition, we confirmed all calculated SARs were below the ICNIRP safety guideline for RF energy exposure (2 W/kg).

4. Acknowledgment

Part of this work was supported by the Strategic International Cooperative Program (Joint Research Type), of the Japan Science and Technology Agency.

5. References

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3. Remcom Inc. (http://www.remcom.com)

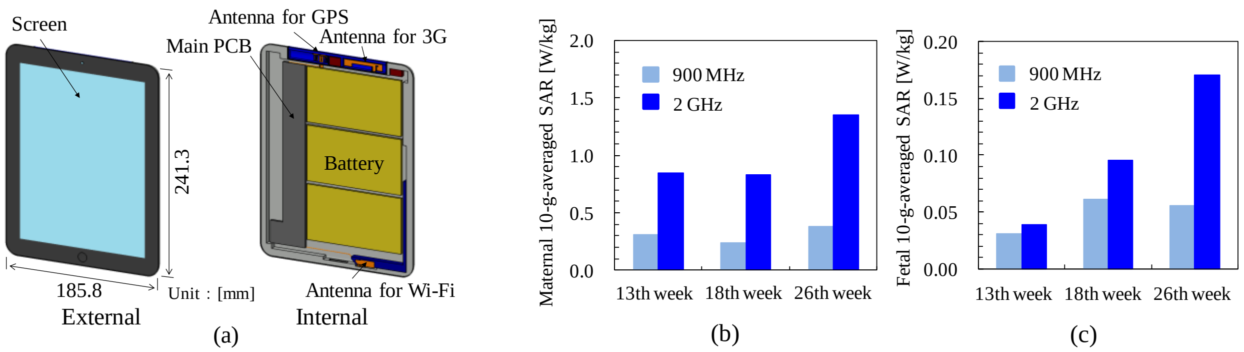

Figure 1 (a) Tablet computer model (b) Maternal 10-g-averaged SAR (c) Fetal 10-g-averaged SAR

Medical Application of EMF

(Chairs: S. Ueno and F. Prato)

Recent advances in biomagnetic stimulation and imaging by transcranial magnetic brain stimulation and magnetic resonance imaging

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[3] Professor Emeritus, the University of Tokyo, Tokyo 113-8654, Japan

1. Introduction

The techniques of transcranial magnetic stimulation (TMS) of the human brain and magnetic resonance imaging (MRI) have opened new horizons in brain research and medicine in these decades. This paper reviews the recent advances in biomagnetic stimulation and imaging by TMS and MRI. In TMS studies, scientific bases for therapeutic applications are discussed, introducing the experiments of hippocampus functions in the rat brain. Various coil configurations are also introduced and discussed towards the deep brain stimulation. In MRI studies, imaging of impedance or conductivity in the brain and imaging of electrical currents in the brain are discussed towards the MR- based neuronal current imaging, or, MR neuroimaging.

2. Biomagnetic stimulation by transcranial magnetic brain stimulation

Transcranial magnetic stimulation (TMS) is a technique to stimulate the human brain transcranially by pulsed magnetic fields generated by a coil positioned outside of the head. A method of localized TMS with a figure-eight coil has enabled us to stimulate the human cortex within a 5-mm resolution [1, 2]. Promising applications of TMS for cognitive science and medical treatments have been widely studied. We have studied hippocampus functions in the rat brain treated by repetitive TMS (rTMS) to obtain scientific bases for therapeutic applications. A series of the experiments suggest that rTMS modulates memory function and contributes to learning and memory, neuronal plasticity, prevention of neurons against injury, recovery of injured neurons, and the acquisition of tolerance against cerebral ischemia [3, 4].

For the deep brain stimulation, various coil configurations have been proposed such as multi-channel coil array, H-coil and Halo coil systems. We discussed the focality of stimulation by these coils, calculating the spatial distributions of electric fields in the brain induced by the stimulation of these coil configurations.

3. Biomagnetic imaging by magnetic resonance imaging

Magnetic resonance imaging (MRI) is a powerful tool in medicine today. Conventional MRIs, however, give no information of electrical properties such as electrical impedance and currents in the brain. Imaging of impedance or conductivity in the brain based on MRI, called impedance MRI, and imaging of neuronal electric currents based on MRI, called current MRI or MR neuroimaging, have been studied in recent decades [5-8]. We proposed three different methods for impedance MRI. One of them is a conductivity MRI based on diffusion tensor MRI. The results show that the signals in corpus callosum exhibit high anisotropy due to the alignment of neuronal fibers. Regions with high anisotropic conductivity are also observed in the white matter. We estimated a theoretical limit of sensitivity of 10^{-8}-10^{-9} T for current MRI, and obtained a transient decrease in signal intensity in the rat brain using a 4.7 T MRI system [7]. Since the signal-to-noise ratio is essentially low in current MRI, the issues of fundamental factors such as RF inhomogeneity and the dielectric resonance effect need to be investigated. We proposed a method of RF inhomogeneity correction in MR imaging.

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Simultaneous Magnetic Resonance Imaging and Positron Emission Tomography: Challenges and Opportunities of a New Medical Imaging Hybrid Technology

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1. Introduction

Positron emission tomography or PET detects the annihilation of antimatter of short lived positron emitting radioisotopes. PET can image the human body with a spatial resolution of 4mm x 4mm x 4mm (64mm^3) and can detect sub picomolar concentrations of injected PET probes to disease specific biomarkers. PET technology holds the promise to detect disease early enough to allow curative therapy. Magnetic Resonance Imaging or MRI has a sensitivity of only millimolar but for human body imaging a resolution of one mm^3. In the past when a subject was imaged sequentially the PET and MRI images would be superimposed (i.e. registered) with software. However exact superposition was not always possible and comparing how the images simultaneously changed with time was impossible. The bringing together of PET and MRI so that simultaneous imaging over the same volume of the human body is possible has had to surmount significant challenges but the opportunities for positive impact to reduce the worldwide burden of chronic disease are substantial .

2. Challenges

The main engineering goal was to integrate PET and MRI without compromising the performance of either technology. As existing PET technology was very sensitive to magnetic fields, PET systems were redesigned and in the process significantly improved. As the PET signal must be corrected for attenuation new MRI sequences were developed and PET compatible MRI RF coils were designed. The result was a PET/MRI hybrid platform wherein the engineering goal was exceeded as the performance of the PET component exceeds what was available in the past [1, 2].

3. Opportunities

Hybrid PET/MRI, through early detection, will impact all the major human chronic diseases which currently are a burden worldwide [3]. In oncology the effect will at least be incremental in adult patients but significant in pediatric patients. In neurology the impact of early detection of neurodegenerative disease will first have a major impact on research into cause of disease and then, once there are more effective treatments for dementia, a very significant impact on patients. It has already been demonstrated that PET/MRI can detect changes in the brain more than 10 years before symptoms of cognitive decline can be detected [4]. In cardiology (the greatest chronic disease burden worldwide) the impact will be immense as there is no other way to adequately image heart tissue changes that result in heart failure [5].

4. Remaining Opportunities and Challenges

To achieve these very important opportunities a number of non-engineering challenges remain:

a) MRI surrogates of tissue changes such as oedema , hemorrhage and inflammation need to be callibrated and validated against PET
b) New PET probes to disease specific biomarkers are needed particularly in cardiology
c) New approaches to simultaneous acquisition protocols are needed that effectively integrate the strengths of the two modalities
d) A convergence in training is needed for radiologists, imaging technologists and medical physicists.
e) The possible deleterious effect of combined exposure to ionizing (PET) and non-ionizing (MRI) radiation needs to be investigated [6].

There is much that remains to be done and Commission K members have a unique opportunity to make significant contributions.

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Regular Session
(Chair: R. Matthes)

Topical issues in assessment of occupational exposure to EMFs

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Some technologies emitting electromagnetic fields (EMF) require detailed investigation of exposure of humans – in the workplace, where many installations and devices are emitting stronger EMF than acceptable in the public accessible environment some cases are likely to be a reason of non-compliance with the exposure limitations (usually linked with organizational or technical dysfunctions). Usually only trained and authorized workers are involved in occupational activities in highly exposed workplaces where warning signs and labeling of EMF sources are use, but to establish properly the rules of such activities it is a need for a good quality EMF exposure assessment and proper understanding of the nature of occupational hazards caused by EMF exposure.

In European Countries occupational safety and health legislation on EMF exposure of workers and related hazards is based on the general provisions of European Framework directive 89/391/EEC, supplemented by the directive focused on the EMF hazards - 2004/40/EC (replaced by 2013/35/EU on June 26, 2013). In every European country it is also required to establish national labour legislation which introduce workers protection against EMF exposure - no less restrictive than following the provisions of the above-mentioned directive. The deadline for such new legislation is July 1, 2016.

Exposure limits of the Directive 2013/35/EU is based on the guidelines of the International Commission on Non-Ionizing Radiation Protection (from 1998 is applicable to the 100 kHz – 300 GHz frequency range, from 2009 and 2010 are applicable to the static fields – 10 MHz, and it is declared that for movement related hazards caused by static magnetic fields new guidelines will be also introduced to the directive). For the static electric fields no limits are provided, but it is mentioned that electric charge is a proper measure of such hazards. It is also declared, that as long the directive do not provide detailed provisions, the concept of ICNIRP guidelines should apply in the exposure assessment details.

The new significant changes in the new directive is the many levels exposure limitations (linked with various provisions regarding work organization). It created many new challenges in the area of exposure assessment strategy and protocols to be urgently solved before establishing above-mentioned national legislations transposing directive 2013/35/EU into legal system of particular EU countries. The other significant new elements in the directive are voluntary use of European Standards and the need to consider uncertainty of measurements and calculations in EMF exposure assessment.

The examples of practical problems created by a structure of new ICNIRP guidelines and directive 2013/35/EU cover among others: the assessment of movement in static magnetic fields, the assessment of non-sinusoidal and pulsed exposures to low frequency EMF, the assessment of contact and induced currents at the workplace (without any hazards for workers), the assessment of exposure in the transient frequency range 100 kHz – 10 MHz. Special attention is needed to the relation between measured and calculated parameters of EMF exposure, which are taken by the directive as equivalent but in practice they differ much more than uncertainty of their assessment. Very important challenge is also the rules of numerical modeling for the occupational exposure assessment, to be acceptable for enterprises (in the costs) and acceptable for the workplace inspections (in the quality). In both calculations and measurements many practical problems are created by "non-fixed scenarios" of exposure - high level exposures may be a whole body or localized exposures.

The proper understanding of how far the results of assessment of EMF emission is applicable for the workers exposure assessment (without replication of calculations or measurements) is one of the most important challenges for "real life" of EMF directive and legislations regarding occupational EMF exposure together with proper identification of highly EMF exposed workplace.

Among non-technical challenges in the transposition of EMF directive, the rules of health surveillance and monitoring of long-term exposure health hazards (required by 2013/35/EU directive) may be identified.

The above mentioned topics of occupational EMF exposure will be discussed based on the examples discussed in the papers listed below.

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A Questionnaire Survey of Physical and Symptoms during routine MRI operations

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1. Introduction

Occupational exposure to the static field during magnetic resonance imaging (MRI) examinations raises concerns of adverse health effects [1]. In this study, we conducted a questionnaire survey on the physical and mental symptoms in the operation of MRI systems, particularly among users of 1.5 T and 3 T MRI systems. Relationships between the rate of self-reported claims and work environments (field strength, job contents, frequency, and years of experience in operation) were analyzed.

2. Methods

We sent questionnaires to 217 workers in 16 key hospitals asking about background job stress level (Brief Job Stress Questionnaire), exposure opportunity of ionizing radiation and electromagnetic source (e.g. PHS), and work environments (type of occupation, job contents, and presence of the night shift). Respondents of MR workers (N=82) were asked to proceed to further questions of MRI operations (field strength, job contents, number of scans per month, and experience), occurrence of the physical and mental symptoms during MRI operations. Statistical analysis was performed using SPSS 19 (IBM Japan).

3. Results and Discussion

The response rate was 57.1 % (N=124) and the number of valid response was 117. The responders' occupations were radiological technologist (96.6 %) and nurse (3.4 %). The exposure opportunity of ionizing radiation was 94.0 % and that of electromagnetic source was 84.6 %, indicating that most of all responders were co-exposed to ionizing and non-ionizing radiation. The number of MR worker was 82 responders.

Brief Job Stress Questionnaire was implemented to examine the responders' background job stress levels ("tiredness", "anxious", "feeling", "depressiveness", and "physical complaints"). MR workers showed lower scores at each stress category than non-MR worker. However, the score of "tiredness" was higher in MR workers with the night shift (N=69) compared with MR workers only day shift (N=13). This result suggests that the night shift possibly influences results.

Results of the working environments in MR workers were as follows; "field strength of MRI": 1.5 T (81.7 %) and 1.5 T and 3 T (17.1 %), "job contents": routine use (59.8 %) and occasionally use (37.8 %), "number of scans per month": less than 50 scans (42.7 %), 51-100 scans (34.1 %), more than 101 scans (19.5 %), and "operation experience": less than 10 years (63.4 %) and more than 11 years (34.1 %).

Approximately 11 to 27 percent of MR operators reported the increase of physical symptom (vertigo/ dizziness (17.6 %), head-ringing (14.1 %), headache (15.9 %), sudden sleepiness (16.6 %), tiredness (27.1 %), and muscle twitching (11.8 %)) after routine operations. Then, complaints were stratified by age, sex, presence / absence of shift work, and work environments to examine possible factors underlying the complaints. MR operators who use routinely more frequently reported the increase of "tiredness". "The field strength of MRI" and "job contents" positively correlated with the rate of occurrence in "vertigo / dizziness" (chi-square test, $p < 0.05$ and $p < 0.01$). "Number of scans per month" showed the strong connection to several complaints. Effect of the shift work was observed only in "muscle twitching" (chi-square test, $p < 0.05$). Sex and age had no effect on the complaints.

4. Conclusion

This study performed a questionnaire survey of physical and mental symptoms during routine MRI operations. Several complaints were reported by MR workers and "Number of scans per month" possibly increased the rate of physiological symptoms.

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Teratological Study in Pregnant Rats being Locally Exposed to Their Abdomen of Intermediate Frequency (21kHz) Magnetic Fields

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1. Introduction

The WHO Environmental Health Criteria No.238 requires the need for biological studies on hazard identification and health risk assessment of IF-MFs. The induction heating cooking hob emits such IF-MFs (20-90 kHz) and is recently wide spreading in some countries including Japan. When people use the IH cooking hob, abdomen is close to the hob. Therefore, reproductive and developmental effects are one of the main public concerns. Although it is reported that there are lack of teratological effects in rats due to 20 or 60 kHz MFs exposure [1], rats are whole-body exposed with relatively low intensities. In this study, we evaluated teratological effects of abdominal local exposure at higher level of IF-MFs during the period of organogenesis of rats.

2. Materials and Methods

Ten weeks old female rats (Splague Dawley) were mated with males and the day when observed positive vaginal smear defined as gestation day 0. Pregnant rats were randomly divided into three groups (n=20 each): IF-MF exposure, sham exposure, and cage control group, respectively. For the abdominal exposure, we used originally developed apparatus, which have the spiral coil and emit sinusoidal MFs with 21 kHz [2]. We set MFs intensity to 10.3 mT at the center of abdominal surface. Exposure (or sham exposure) was done for 1hr/day from gestation day 7 up to 17. During exposure, dams were fixed in an acrylic holder except cage control group. On the gestation day 20, their fetuses were excised and weighed. The number of live fetuses, dead fetuses, and implantation sites were recorded. Half of fetuses were placed in Bouin's fixative and examined for external and internal abnormalities. Other half of fetuses were eviscerated then fixed in alcohol, and their skeletons were stained with Alizarin red S and Alcian Blue 8GX to examine skeletal abnormality. All teratological evaluations were conducted in a blind fashion.

3. Results and Discussion

In this study, we examined numeral dosimetry using a pregnant rat model of gestation day 16 rat. Induced electric field of each fetus ranged between 0.611 to 5.74 V/m (mean 3.01V/m) depending on the spatial position to the spiral coil. The mean value is higher than the basic restriction to general public exposure (2.83 V/m at 21 kHz) of ICNIRP guidelines [3].

Regarding dams, no significant difference among groups was observed in the hematological and blood chemistry examinations at the gestation day 20. Total 767 fetuses from 60 dams were eviscerated and subjected to teratological examination. No significant difference was observed in dams' body weight, average weight of fetuses, number of fetuses per dam and number of implantation sites. The incidence of external, visceral, and skeletal malformations in the fetuses also did not indicate significant differences among the groups.

In conclusion, high level of 21kHz IF-MFs which emits high induced electric field compared to ICNIRP guidelines, does not show teratogenicity under the present experimental conditions.

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Numerical Assessment Method for Implantable Cardiac Pacemaker EMI Triggered by 10MHz-band Wireless Power Transfer Coils

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1. Introduction

Wireless power transfer (WPT) technologies using magnetic resonance have been attracting attention [1]. The technologies are expected to achieve charging and power supply functions for home appliances, electric vehicles, and other electric systems and devices. However, there is a concern that, when an implantable medical device patient is close to WPT coils, the electromagnetic fields (EMF) may be strong enough to impact pacemaker operation. The strength of EMF created by an antenna/coil usually decreases with distance, however, the EMF generated by WPT system based on magnetic resonant coupling is complicated and varies with the coupling condition (e.g. frequency, air-gap)[2]. This paper presents a numerical assessment methodology of pacemaker EMI triggered by magnetic resonance WPT coils. A numerical EMI estimation model that consists of magnetic resonant coils and a human torso phantom is constructed. The interference voltage induced at the connector of the pacemaker is calculated using the finite element method (FEM). As an example, we examine WPT coils operating in the frequency band of 10 MHz in this paper. FEM analyses of numerical models are conducted.

2. Estimation Model for Pacemaker EMI due to WPT Coils

The human torso phantom model for numerical estimation, which contains the implantable-cardiac pacemaker model, is shown in Fig.1. As shown in the figure, the lead wire is connected to the pacemaker’s terminals. The interference voltage is evaluated at the register on the terminal. The dielectric constants and electric conductivities of each material used in the phantom model are summarized in ref.[2]. As shown in Fig.2, WPT coils and the human torso phantom are combined to obtain the interference voltage. The WPT coil model is based on that shown in ref. [1]. When the distance between the Tx and Rx coils is 1 m, the resonance of the coils occurs close to 10 MHz and the resonant frequency splits into two peaks under this coupling condition. Simulated power transfer efficiency was 70 % at 10.3 MHz (f_{low}) and 83.2 % at 10.4 MHz (f_{high}). The two resonant modes created different distributions of magnetic field around the coils. When the distance between the Tx and Rx coils is 1.5 m, the resonant frequency occurs at 10.35 MHz and efficiency decreases to 59 %.

3. Results and Conclusion

Normalized interference voltages at the pacemaker connectors were obtained as a function of the distance (L) between the antennas and the torso phantom. When the distance between the Tx and Rx coils is 1.0 m, the interference voltage at the resonant frequency f_{low} became higher than that at f_{high} in a short distance ($L < 30$ cm). When the distance between the Tx and Rx coils is 1.5 m, the voltage at resonant frequency became 20 % higher than that obtained when the coil distance D was 1.0 m.

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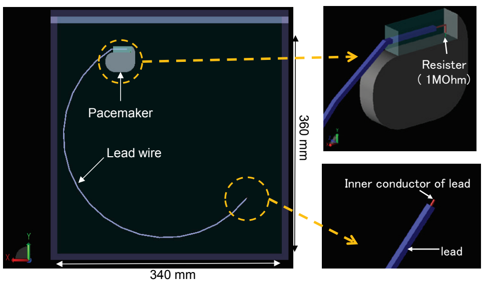

Fig. 1. Numerical torso phantom model.

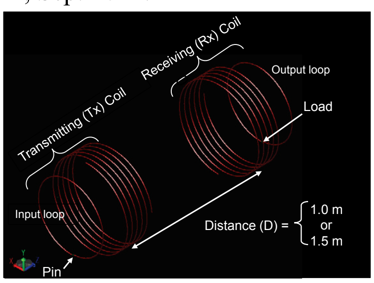

Fig. 2. EMI estimation set-up consists of wireless power transfer coils and a human torso phantom.

Blue Light
(Chair: P. Söderberg)

Regular Session
(Chair: P. Söderberg)

Ocular damage differs by frequency difference (40 or 95 GHz) to rabbit eye

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1. Purpose

Millimeter waves (MMW) are prevalent in high-speed wireless communication, automobile collision prevention systems and high-resolution radar imaging. We examined frequency (40 and 95 GHz) dependent differences of corneal damage in rabbit eye.

2. Methods

Pigmented rabbits (N=48, Dutch, 13-16 week-old) were exposed unilaterally to 95 GHz MMW at 200 mW/cm^2 for 6 or 10 minutes, and 40 GHz MMW at 200, 300, 400 mW/cm^2 for 6 min by lens antenna [1]. Systemic anesthesia during exposure and ocular examination was induced by medetomidine hydrochloride (0.5 mg/kg). Ocular changes were evaluated by slit-lamp microscope. Corneal surface temperature during exposure was recorded by thermograph camera (R300, NEC Avio). Microencapsulated thermochromic liquid crystal (MTLC) [2] was injected into the anterior chamber prior to exposure, and color change recorded by video camera during exposure revealed heat transport [3].

3. Results

Corneal surface temperature following 95 GHz 200 mW/cm^2, 6 and 10 min exposure was 42.6±2.1℃ and 43.2±1.3℃, respectively (NS). Representative ocular damage was diffuse corneal epithelial cell damage immediately after exposure, and corneal epithelial defect and corneal edema 1 day after exposure. Exposure for 10 min caused more severe corneal epithelium defect (12/12 eyes) than for 6 min (4/7 eyes). Maximum corneal surface temperatures by 40 GHz at 200, 300 and 400 mW/cm^2 were 41.4±1.1, 42.5±1.1, and 45.5±2.1℃, respectively. Exposure for 6 min to 40 GHz at 200 mW/cm^2 caused transient corneal diffuse damage (3/6 eyes) and at 300 mW/cm^2 diffuse corneal epithelial damage (6/6 eyes). Diffuse corneal epithelial cell damage occurred immediately following exposure at 400 mW/cm^2 (3/5 eyes), and corneal epithelial defect (2/4 eyes) and corneal edema (2/4) 1 day after. Morphological evaluation showed 95 GHz at 200 mW/cm^2 and 40 GHz at 400 mW/cm^2, for 6 min, caused similar damage. Corneal surface penetration depth of 40 and 95 GHz was 0.59 and 0.31 mm, respectively. MTLC analysis revealed that 40 GHz exposure transported heat to iris and lens by aqueous humor convection within 20 sec, compared to 52 sec by 95 GHz.

4. Conclusions

Ocular heat effects by 40 and 95 GHz MMW differed with 95 GHz being more severe. MMW penetration depth, heat transport, and dissipation from cornea play important roles in ocular damage.

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Heat transport on rabbit eyes exposed to millimeter waves considering flow in the anterior chamber

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1. Purpose

The purpose of this study is to investigate the heat transport mechanism caused by the millimeter-wave (MMW) exposure for the eye through the experiment and the computer simulation. We discuss the dependence of heat transport mechanism on the incident power density by comparing experimental results with the numerical results.

2. Methods

We use Micro-encapsulated thermo-chromic liquid crystal (MTLC)[1] to measure temperature and flow velocity for the in-situ measurement within the anterior chamber. This method is effective for measuring the temperature and the flow velocity because of its high temporal and spatial resolution. Temporal resolution is about 33 µs, and spatial resolution is 19 x 19 µm2.

Numerical coupled analysis system on electromagnetic field (EMF) with heat transport (HT) including convection model is developed to understand the mechanism of temperature elevation. 3D incident EMF distributions generated by the lens antenna is reconstructed from measured 2D EMF distributions by the plane wave spectrum (PWS) [2] method. Induced EMFs in the rabbit eye is calculated from the reconstructed 3D EMF by the scattered-field FDTD method. The geometrical rabbit eye model based on the MRI image is used to obtain induced SAR distributions. Heat transport patterns due to induced SAR distributions are calculated by the simplified marker and cell (SMAC) method [6].

3. Results

To investigate the effect of heat convection, numerical simulation is performed with and without heat convection. When the only heat conduction is considered, temperature elevation is larger than the heat convection is considered. This result suggests that the convection in the anterior chamber suppresses the increase of temperature.

We examine the heat transport mechanism depending on the incident power density by measurement and simulation. In the case of 75GHz irradiation, for example, when the incident power density is 50 mW/cm^2, the flowing pattern becomes complex flow with disturbance. For the low power irradiation, “heat conduction” is dominant. When the incident power density is 150 mW/cm^2, the flowing pattern becomes the ordered (laminar) flow from cornea to lens. Therefore, “heat convection” is dominant for high power irradiation.

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4. References

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