System for Animal EM Exposure with well Defined Dosimetry

Jan Vrba, David Vrba, Jan Vrba jr., Frantisek Vožeh, Jan Barcal, Luca Vannucci

[1]Czech Technical University in Prague, Faculty of Electrical Engineering, Dept. of EM Field, Prague, Czech Republic, (vrba@fel.cvut.cz)

[2]Czech Technical University in Prague, Faculty of Biomedical Engineering, Dept. of Biomedical Technique, Kladno, Czech Republic (david.vrba@fbmi.cvut.cz , jan.vrba@fbmi.cvut.cz)

[3]Charles University in Prague, Medical Faculty in Pilsen , Dept. of Patophysiology, Pilsen, Czech Republic,

[4]Czech Academy of Sciences, Institute of Microbiology, Prague, Czech Republic

Abstract

The whole-body exposure system for unrestrained mice was designed in order to analyze the influence of electromagnetic field. The setup operating at 900MHz was designed with respect to induced uniform field, external radiation elimination, absorbed power determination, sufficient space for mice movement together with even mice exposure and costs. The main aim of this paper is to assure that the dosimetry results reached by computer simulations can be used for determination of absorbed power in the unrestrained mouse. The whole-body exposure chamber with anatomical mouse model was simulated by two different numerical methods: finite-difference-time-domain method (FDTD) and Finite Integration Technique (FIT) and its dosimetry results were compared by computed SAR values. In our contribution we will describe our first results dealing with observed biological effects of EM field, obtained by real exposures of experimental animals.

1. Introduction

In our modern world various sophisticated devices emitting microwave electromagnetic field are ubiquitous. These devices are used in many branches such as industry, medicine and particularly communication. The advent of a wide penetration of mobile communications has arisen the concern whether the exposure to electromagnetic field could be adverse to the exposed users. The increasing daily exposure has raised the research activities in order to determine the effects of exposure to the electromagnetic radiation of mobile phones. Although a lot of researches have been accomplished, no adverse health effects of cellular phones have been confirmed yet. The main aim of this work was to design exposure chamber for in vivo studies where the impact of electromagnetic field on biological organisms is analysed. In our contribution we will describe our first results dealing with observed biological effects of EM field, obtained by real exposures of experimental animals.

2. Methods

The whole-body exposure system for unrestrained mice was designed in order to analyze the influence of electromagnetic field. The setup operating at 900MHz has been designed with respect to following conditions:

- induced uniform field,
- external radiation elimination,
- accurate absorbed power determination,
- sufficient space for mice.

These conditions are grounded on requirements for exposure system from [1]. Such conditions assure an accurate determination of Specific absorption rate (SAR) together with the elimination of stress induced in mice. The major advantage of the system is the capability of direct measurement the whole-body averaged SAR which is performed by analysis of measured scattering parameters.

As the basic structure of the exposure chamber a waveguide was chosen. The advantage of the waveguide structure is a shielding of electromagnetic field generated inside in order to protect the operators and also generated outside the system in order to eliminate outer radiation. Dimensions of the exposure chamber were calculated in order to use desired frequency of operation and the volume needed to exposed mice. The exposure chamber is made of copper plate with dimensions of 1650mm length and 240mm diameter. The chamber is terminated by matched loads at both ends. In order to avoid reflection and assure an attenuation of power the loads must be made of lossy dielectric material and must have a suitable shape. The electrical resistance of the shape should grow linearly in a direction of the wave propagation. The designed matched loads are conical, 500mm long and are made of RF absorber. The reflection loss of the matched load is more than -20 dB at 900 MHz. The circular polarized wave TE_{11} is excited in the waveguide (Fig.1).

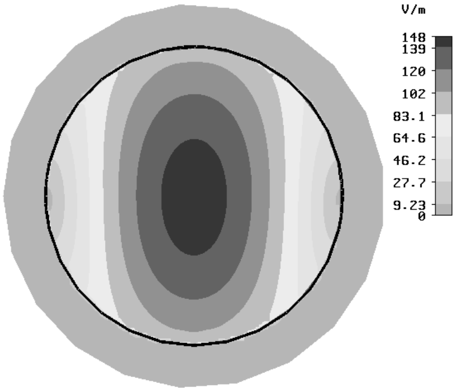

Fig.1. Distribution of electric field strength of TE_{11}

This wave is comprised by two monopoles which have mutually orthogonal orientation and the distance between them is equal to one-fourth of wavelength. Circular polarized wave provides relatively constant coupling of the field to each mouse regardless of its position, posture or movement.

The exposed mice are kept in a box which is made of Styrofoam. Styrofoam has a dielectric constant of 1.03, i.e. very close to that of air, and thus the disturbance of exposure and measurements is negligible. The box provides space for two separated mice. Punctured slit-like holes are set on the cover and side of the box for air ventilation. In the study the mice are hold in the chamber only during RF exposures and therefore, no food or drinking water is necessary.

Efficient ventilation is necessary to maintain constant temperature and good air quality in the chamber. The air exchange is realized by a ventilation system which consisted of a fan installed outside the chamber and a tube attached to the ventilation hole. The exchange air come towards mice through the ventilation hole placed below the styrofoam box and flow towards the second opposite ventilation hole placed above the box.

Basic properties such as electromagnetic field distribution and impedance matching of the designed chamber were optimized and verified by a 3D electromagnetic field simulator SEMCAD X [5].

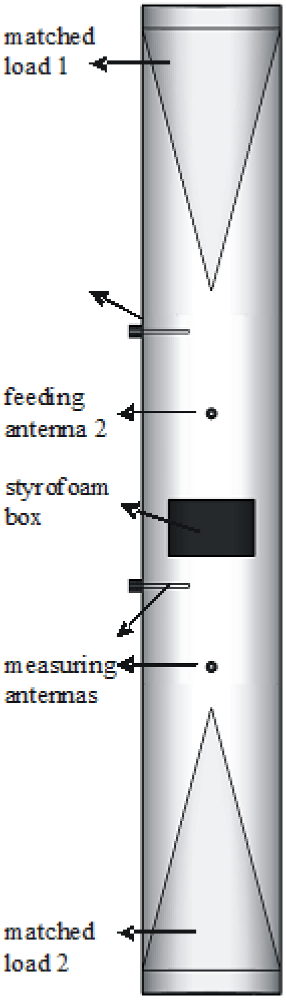

Fig.2. Exposure chamber

Dosimetry is an inherent task for exposure setups. Dosimetry is the quantification of the magnitude and distribution of absorbed electromagnetic energy within biological objects that are exposed to electromagnetic fields. At RF, the dosimetric quantity, which is called the specific absorption rate, is defined as the rate at which energy is absorbed per unit mass. The SAR is determined not only by the incident electromagnetic waves but also by the electrical and geometric characteristics of the irradiated subject and nearby objects. It is related to the internal electric field strength as well as to the electric conductivity and the density of tissues. Therefore, it is a suitable dosimetric parameter, even when a mechanism is determined to be “athermal.” SAR distributions are usually determined from measurements in animal tissues or from calculations. It generally is difficult to measure the SAR directly in a living biological body, and therefore dosimetry efforts are forced to rely on computer simulations [2].

An anatomically based biological model is essential for numerical dosimetry. Such a numerical model is developed commonly from MRI or CT scans. In order to develop a model for numerical dosimetry original gray-scale data must be interpreted into tissue types which is known as a process of segmentation. Segmentation is the task of partitioning the data into contiguous regions representing individual anatomical objects. Segmentation is a difficult task because in most cases it is very hard to separate the object from the image background. This is due to the characteristics of the imaging process as well as the grey-value mappings of the objects themselves.

The most common medical image acquisition modalities include computer tomography (CT) and magnetic resonance imaging images (MRI).

MRI or CT provides gray-scale image data as many transverse slices, at a designated spacing, from the head to the feet of the biological body. The resolution in each slice is on the order of several millimeters.

CT scans for mouse model development were obtained from the project Digimouse [3][4]. The CT raw data can be downloaded directly from the web site http://neuroimage.usc.edu/Digimouse_ download.html. The mouse model (Fig.3.) has the resolution 0,1mm, meaning voxel size 0,1 x 0,1 x 0,1 mm. Each voxel was assigned to one of 14 different tissue types, such as bone, muscle, brain, etc.

Fig.3. The numerical mouse model based on CT scans

For dosimetry with the numerical voxel models, proper permittivity and conductivity values must be assigned to each tissue. The data from 10 MHz to 6 GHz, which were derived from 4-Cole-Cole extrapolation based on measurements for small animals [7], constitutes the most widely accepted database for this information. The data are recommended by various international standardization organizations and can be accessed from the web site http://www.fcc.gov/fcc-bin/dielec.sh.

3. Results

In order to verify and rely on numerical dosimetry results, the simulations of exposure chamber is desired to be performed in different electromagnetic field simulators using different numerical methods. As 3D simulators using different numerical methods were chosen SEMCAD X [5] which uses Finite Difference Time Domain (FDTD) method and CST Microwave Studio [6] which uses Finite Integration Technique (FIT) method. For the purpose of results comparison the model of the mouse was chosen homogenous phantom with anatomical shape of the mouse. The model dielectric parameters were set the same like muscle tissue. The simulations were performed for three positions of mouse in order to verify an even exposure which should be assured by circular polarized wave. The first and the second position of the mouse was chosen perpendicularly to one of the feeding antenna and the third position was chosen generally (Fig.4.).

From the Fig.5. it is obvious that the reached simulation results for both numerical methods are in a good agreement. Further, it was verified that the circular polarization provides constant coupling of the field to each mouse regardless of its position or movement.

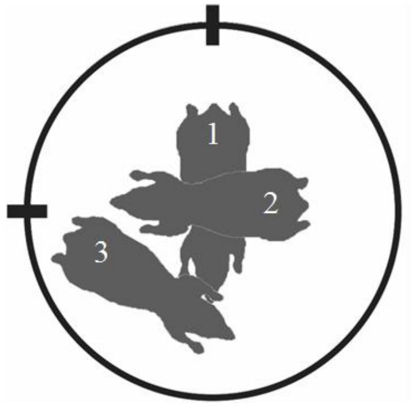

Fig.4. Positions of mouse inside the box

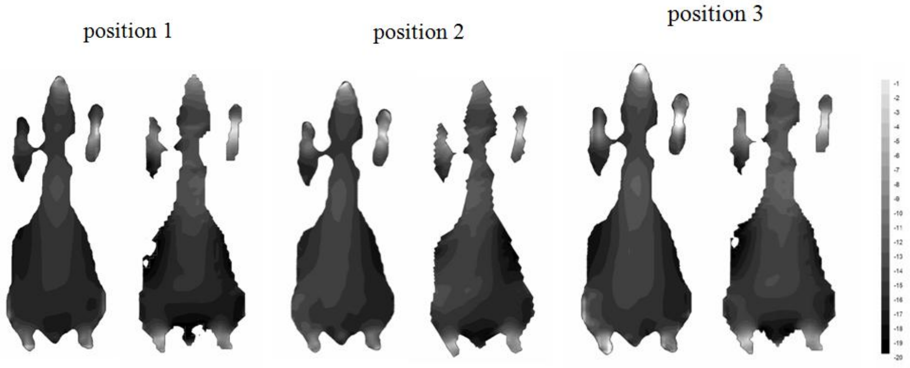

Fig.5. SAR distribution in middle cutting plane (top view) for three positions of mouse

4. Conclusion

It was designed the exposure chamber working at 900MHz serving for researches of effects of electromagnetic field. The chamber was optimized by aid 3D simulator of electromagnetic field. In order to verify simulation results, the numerical dosimetry was computed in two different electromagnetic field simulators with two different numerical method. The simulation results were compared and reached results were in a good agreement. The designed exposure chamber is suitable for researches of effects of electromagnetic field. In our contribution we will describe our first results dealing with observed biological effects of EM field, obtained by real exposures of experimental animals.

Acknowledgement

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