Exposure chambers for verification of microwave influence on biological systems

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Abstract

The main aim of our work is to design and simulate an exposure chamber in order to analyze the influence of electromagnetic field on mice which can simulate mobile phone emission patterns. We use two types of structures and compare their properties to find the best design for our future work.

1. Introduction

In today's modern world various sophisticated devices emitting microwave electromagnetic field are ubiquitous. These devices are used in many fields such as industry, medicine (for therapeutic and diagnostic purposes) and communication. Almost everyone has a mobile phone or a wi-fi card in her notebook. The pervasiveness of electromagnetic pollution and its possible impact on human health therefore raises a growing concern in our society.

There are two general classes of microwave effects: thermal and non-thermal. The difference is obvious. For thermal effect applies – the intensity of exposure produces heating of tissues due to energy absorption leading to a temperature rise. And what about non-thermal effect? Due to an increasing daily exposure of humans many researchers focus on non-thermal effects and investigate its influence on biological tissues – experiments with mice or rats. To determine the exact impact of electromagnetic field it is required to eliminate some conditions affecting the results such as stress and to accurately determine the exposure. Although many researches have achieved significant results, we point out some flaws below.

First, to determine the exposure of animals, tabular values of absorption are used. However, by mere putting on the emitting device and use of tabular values it is not possible to determine how much energy is in fact absorbed. Some part of the energy is reflected and by using mobile phones as emitting source a part of energy is also radiated to the surroundings. Second, animals are fixed to emitting device in such a way that they can't move. This condition induces stress in the animals and the stress itself can affect the results. Also anesthesia isn't a good solution because of its stressful influence.

2. Materials and Methods

The main goal of our work is to design and simulate an exposure chamber in order to analyze the impact of electromagnetic field on mice which can simulate mobile phone emission patterns and also eliminate the conditions mentioned above. We follow the following assumptions: working frequencies 900MHz and 1800MHz, dimensions to assure enough space for mice movement due to a non-stressful condition, possibility to measure reflected and transmitted power and homogenous electromagnetic field distribution to assure an accurate exposure. To accomplish these requirements we decided to design two types of exposure chambers and compare their properties in order to find the best solution for our future work. As the most appropriate chambers we choose parallel plate and waveguide structures.

The first chamber consists of a parallel plate structure (Fig.1) terminated by a matched load. The chamber is supplied by N-connector and the energy passes through parallel plate line into matched load (Fig.3). Because of energy transmission the dimensions of parallel plate line should guarantee a value of impedance in correspondence to N-connector, i.e. 50 Ohms. We set the dimensions in accordance with formula (1): $d = 2.5$mm and $W = 18.85$mm.

$$Z_0 = \frac{d}{W}\sqrt{\frac{\mu}{\varepsilon}} \tag{1}$$

The tapered lines are used as a linear impedance transformer. Because of zero reflection coefficient magnitude a length of taper lines is chosen $L_1 = k \bullet \lambda$ where λ is a wavelength in the parallel plate structure and $k = 1$ (for 900MHz), $k = 2$ (for 1800MHz).

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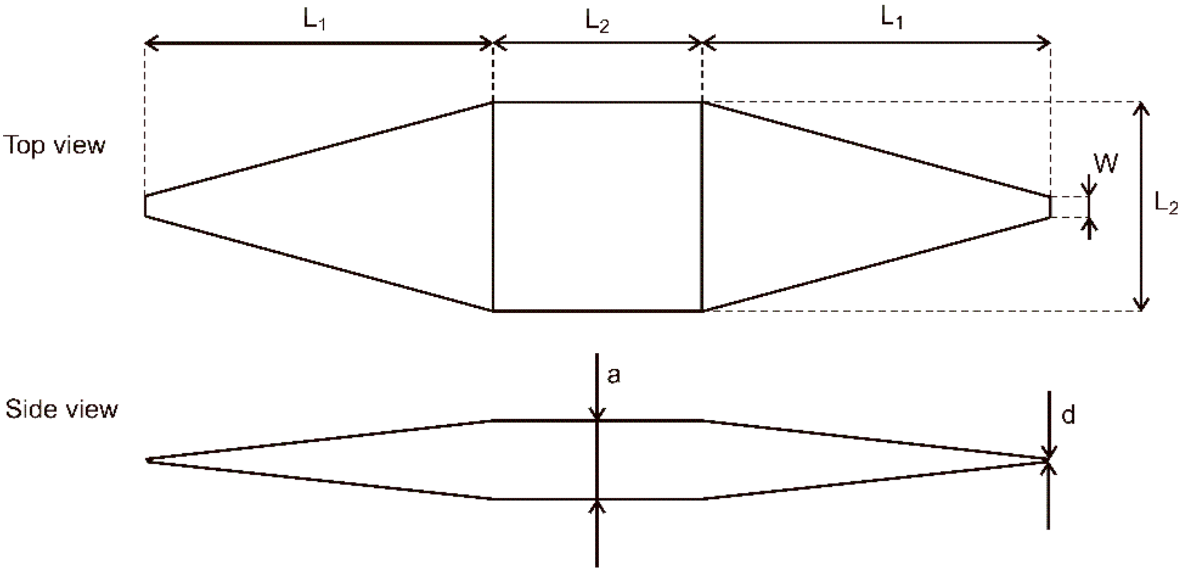

Fig.1. Parallel plate structure.

There were many modes possible to excite. And so exposure chamber dimensions were computed and chosen so that only TEM mode is excited for both frequencies. We chose TEM mode because of constant power extending over the whole aperture. To avoid excitation of the next mode TE_{10} it is needed to reach its cutoff frequency f_c greater than 1800MHz (for TEM mode for both frequencies $f_c = 0$) in accordance with formula (2).

$$f_{cTE_{10}} = \frac{1}{2a \cdot \sqrt{\mu\varepsilon}} \tag{2}$$

We set a dimension a = 75mm and a dimension L_2 = 200mm in such way to assure enough space for mice movement. For measuring the power passed it is possible to connect a power meter to the matched load.

The second chamber is a rectangular waveguide resonator (resonant frequencies 900MHz and 1800MHz). It consists of two identical waveguides connected together (Fig.4). To achieve a homogenous electromagnetic field distribution it is possible to excite TE_{10} mode only. Due to this requirement we are not allowed to design one waveguide exposure chamber for both frequencies. According to a waveguide cutoff frequency formula (2) we set dimensions a = 250mm, b = 125mm for 900MHz and a = 125mm, b = 62.5mm for 1800MHz (Fig.2). For our application the support of mode TE_{103} in a resonator is the most advantageous.

$$f_{r,mnp} = \frac{c}{2\pi\sqrt{\varepsilon_r \mu_r}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{p\pi}{l}\right)^2} \tag{3}$$

By analyzing formula (3) we get dimension $l = 3\lambda/2$. We locate a feeding connector in a distance $l_1 = \lambda/4$ from a shortcut end of the waveguide. The second connector is used for measuring passed power. Due to air and light supply a row of gaps was made in lateral sides. Gap dimensions were chosen in a way not to influence the inner electromagnetic field distribution and to avoid emission in the surrounding space – width 2mm and height $h = 2b/3$ (spatially oriented in the line of the surface current flowing). The row length is 200mm.

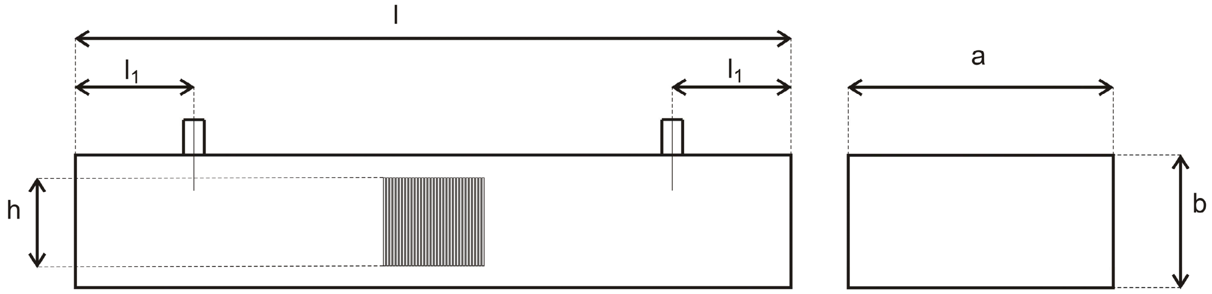

Fig.2. Waveguide structure.

3. Results

To verify the basic properties of the designed chambers such as electromagnetic field distribution and impedance matching and to choose the best solution for further research by their comparison, we simulated both structures by aid of 3D electromagnetic field simulator.

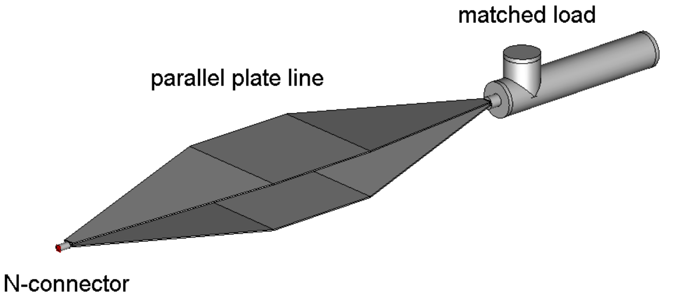

Fig.3 Simulation model of a parallel plate chamber

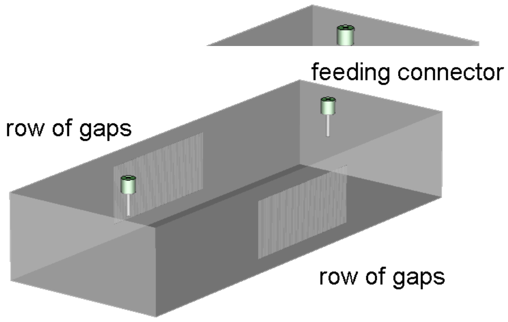

Fig.4 Simulation model of a waveguide chamber.

We divided the analysis into two parts. In the first part exposure chambers were optimized and we verified their properties and in the second part we investigated their behavior after putting into a homogenous mouse model and compared the results. As a mouse model we used a homogenous cylinder with radius 25mm and length 60mm as a body and a cone with length 25mm as a head. We use electrical parameters $\varepsilon_r = 45.8$ and $\sigma = 0.76$ S/m for both parts of the model.

Significant simulation results were mostly similar for both frequencies and we therefore show only results for 900MHz.

Parallel plate Fig.5 displays the impedance matching reached in an empty chamber. Parameter $S_{1,1}$ is equal to -18.96 dB. After putting the mouse model into chamber and changing its position, the parameter $S_{1,1}$ ranged from -17dB to -20dB.

Fig.6 shows the distribution of electromagnetic field intensity. It is obvious that a considerable part of energy is emitted in the surrounding space and after putting the mouse model into chamber the amount of emitted energy has grown as we can see by comparing Fig.7 and Fig.8.

Fig.5 Impedance matching of parallel plate structure

Fig.6 Distribution of electromagnetic field intensity in longitudinal cutting - top view

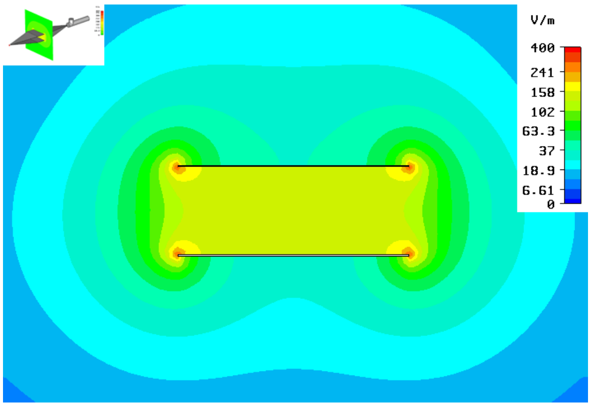

Fig.7 Distribution of electromagnetic field intensity without mouse model in a transverse cutting – front view

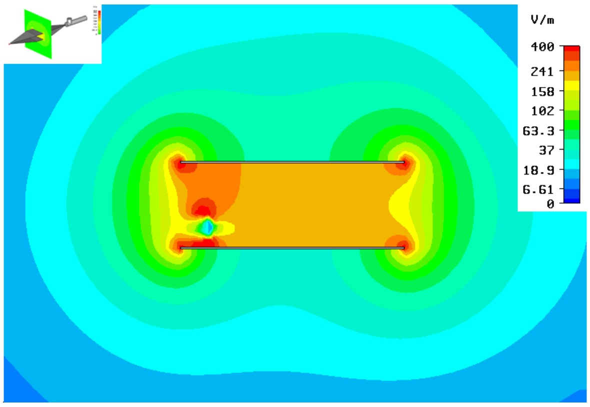

Fig.8 Distribution of electromagnetic field intensity with mouse model in a transverse cutting – front view

Waveguide Fig.9 displays the impedance matching reached in an empty chamber. Parameter $S_{1,1}$ is equal to -19.12 dB. After putting the mouse model into chamber the resonance frequency has changed significantly (value $S_{1,1}$ = -0.5dB) and we had to reach again resonance frequency. But during next "mouse movement" some positions caused a significant change of a resonance frequency. Fig.10 displays the distribution of electromagnetic field intensity and ed in the surrounding space.

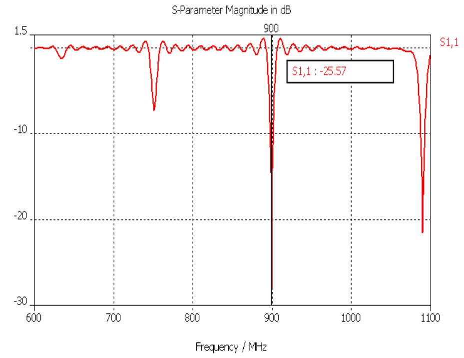

Fig.9 Impedance matching of waveguide resonance structure

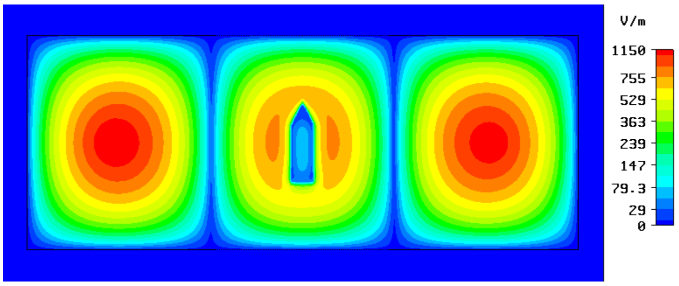

Fig.10 Distribution of electromagnetic field intensity with mouse model in a longitudinal cutting – top view

4. Conclusions

In the designed parallel plate chamber it is possible to excite both frequencies within one structure. Constant power is extended over the whole aperture (Fig.7) and thus we can use the whole space for mice and mice movement does not have an impact on the impedance matching. On the other hand, open lateral sides emit inconsiderable amount of energy in the surrounding space and we are not allowed to measure accurate power balance.

We need one special waveguide chamber for each frequency. Power is concentrated in the centre of aperture. We can use only 50 percent of this aperture. Impedance matching is strongly influenced by mouse movement. Insignificant amount of power is emitted in the surrounding space. Waveguide chamber has a problem only with impedance matching. A solution to this problem could be to add a loss material to enlarge the resonance band width or a usage of a non-resonance microwave structure.

The main aim of this work was to find a direction for our future progress in the design of an exposure chamber. This problem is very complex and a lot of issues remain unsolved.