Design of an Exposure Chamber for Biological Experiments

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Abstract—The main aim of this work is to design and to simulate an exposure chamber which can simulate mobile phone emission patterns in order to analyze the influence of electromagnetic field on small animals. During our previous research we found the most suitable type of an exposure chamber for this purpose. The basic properties such as electromagnetic field distribution and impedance matching of our designed chamber were optimized and verified by the aid of a 3D electromagnetic field simulator. As a result of our effort a cylinder waveguide chamber with a working frequency 900 MHz has been designed. In the cylindrical structure a circular polarization is excited in order to even the exposure. The chamber is terminated by matched loads on both lateral sides which serve for preventing a possible resonance between sides and the animal.

1. INTRODUCTION

In a modern world various sophisticated devices emitting microwave electromagnetic field are ubiquitous. These devices are used in many fields such as industry, medicine and particularly communication. An increasing daily exposure has raised the research activities in order to determine the effects of exposure to the electromagnetic radiation of mobile phones.

Therefore, many experiments on animals have been accomplished. In many cases the animals were fixed to the emitting device in such a way that they could not move. This condition induces stress in the animals and the stress itself can affect the results. Also anesthesia is not a good solution because of its stressful influence. In other cases the elimination of perturbative external electromagnetic field was missing. This condition can also affect results. For these experiments the development of an exposure system where an accurate exposure determination and elimination of stressful conditions are possible is required.

Our motivation is based on the improvements in methods to determine an accurate exposure together with the elimination of external influences which can affect results, such as stress and, of course, external electromagnetic radiation.

2. MATERIALS AND METHODS

The main aim of this work is to design and to simulate an exposure chamber in order to analyze the impact of electromagnetic field on small animals and to simulate mobile phone emission patterns.

To design such an exposure system it is important to satisfy the following requirements which arise from the specific purpose mentioned above:

- a working frequency of 900 MHz
- a shielding of electromagnetic field
- enough space for the animal’s movement
- an even exposure
- a possibility to measure the exposure accurately
- for a long-term exposure providing illumination and ventilation

The basic structure of the exposure chamber consists of two cylindrical waveguides connected to each other. This structure provides a shielding of electromagnetic field generated inside in order to protect the operators and also generated outside the system in order to eliminate parasitical radiation. Dimensions of the exposure chamber were calculated having in mind two endpoints: desired frequency of operation and the volume needed to expose small animals. The dimensions of the chamber components were computed starting from the waveguide radius because it is a critical value which can affect electromagnetic field excitation and distribution. It is needed to choose radius so that a suitable electromagnetic field distribution can be excited. As the most appropriate mode TE11 was chosen (see Fig. 1).
By analysis of a waveguide cut-off frequency formula (1) a value of the radius was chosen with respect to the TE$_{11}$ mode and the request of large volume for the animal exposure.

\[
f_{c11} = \frac{c \cdot p'_{11}}{2\pi r \sqrt{\mu_r \varepsilon_r}}
\]

where \(c\) is the speed of light, \(r\) is the desired radius of the waveguide, \(\mu_r\) is the relative permeability, \(\varepsilon_r\) is the relative permittivity and \(p'_{11}\) is the value 1.84 (see Lit.1).

In order to even the animal’s exposure we have chosen a cylindrical structure where a circular polarization can be excited. Electromagnetic field is excited in the chamber by the aid of two capacity screws. There were two possibilities of how to approach the design. First, both capacity screws could be situated perpendicularly in one cutting plane and the signal amplitude being the same on both screws but exciting signal phase shifted to 90 degrees on one of them. Or second, the capacity screws could be at one-fourth of the wavelength distance. Signal amplitude and phase would then be the same on both screws. Screws’ lengths itself were chosen to be one-fourth of the wavelength.

To measure an accurate exposure it is desirable to avoid resonance between the terminating sides and the animal. Matched loads on both lateral sides can serve this purpose. 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’s propagation. According to previous conditions the shape was designed as a cylinder with a cone gap (see Fig. 2).

We set the length of the cylinder to one wavelength. The dielectric material properties were set to \(\varepsilon = 17 + 1.2j\) and \(\mu = 3 + 0.39j\).

A power balance is determined by the aid of power reading screws which are situated in the same mutual position like the exciting screws. Because the circular polarized wave can be backwards divided into linear polarized waves the power balance can be determined by analysis of \(S\) parameters between measurements of an empty chamber and a chamber with animals and simultaneously
between the corresponding screws. In this way it can be accurately determined how much energy is, in fact, absorbed by the animals.

The exposure chamber was designed to allow long-term exposure of small animals like mice and rats. The waveguide sides are provided with two small holes continuing outside with small waveguides. They serve for a softened illumination and ventilation support. A radius of these two waveguides was chosen to be 20 mm and therefore working like evanescent. Through evanescent waveguides the outside radiation is eliminated.

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

3. RESULTS

We have designed a cylindrical waveguide chamber where a circular polarization can be excited. By analysis of formula (1) with respect to frequency 900 MHz and a propagation in the air, the radius of the cylinder waveguide was obtained. The computed value is 120 mm. The length of the waveguide was set in such a way that enough space for animal movement is assured. Its value was set to 650 mm. There were two possible configurations of the exciting screws — in one cutting plane or shifted. First of them was not a suitable solution because the transmission between screws took a high value — approximately $-3 \text{ dB}$. The second configuration reached usable values. Transmissions between screws took a low value — approximately $-26 \text{ dB}$ (see Fig. 3).

![Figure 3: Transmission between exciting screws.](image)

The value of impedance matching for the exposure system is a very important parameter. Values reached are displayed in Figs. 4 and 5.

![Figure 4: Impedance matching for the first exciting screw.](image)

![Figure 5: Impedance matching for the second exciting screw.](image)
Figure 6 displays a complete view on the configuration of the designed exposure system.

Figure 6: A configuration of designed chamber-longitudinal cutting plane.

4. CONCLUSIONS
As a result of our efforts a cylinder waveguide chamber was designed which satisfies all the requirements for accurately emulating the effects of mobile phone emission on animals. In order to even animals exposure it was chosen cylinder structure where can be excited a circular polarization. The chamber is terminated by matched loads on both lateral sides. These loads serve for preventing a possible resonance between sides and animals and therefore the accurate exposure can be determined. The next important issue is to assure a suitable milieu for animals (support air and light). Evanescent waveguides can serve for this purpose well.

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