LETTER

Dosimetry Evaluation of a Whole Body Exposure Setup for Small Animal at 2.45 GHz

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SUMMARY An attempt to derive the lethal dose for mice was made at 2.45 GHz for whole body exposure. Based on a numerical dosimetry result and an experimental death rate investigation, the lethal dose was estimated to be a whole body averaged specific absorption rate (SAR) with a level at double the mouse's basal metabolic rate.

key words: *microwave, biological effect, lethal dose, mouse, dosimetry*

1. Introduction

A large-scale research for the microwave biological effects on animals' genes, cells and organs was conducted in Tohoku and Tohoku Gakuin Universities, Japan, as a project of Telecommunications Advancement Organization of Japan (TAO) in 1997–1999 [1]. For whole body exposure to microwave at 2.45 GHz, an experimental attempt to derive the lethal dose for mice was made, while accurate dosimetry on the mice was unclear. In general, dosimetry indicates quantifying the specific absorption rate (SAR, in a unit of W/kg) in a biological body. In this paper, a numerical approach was made to quantify the SAR for these exposed mice. With the employment of the finite-difference time-domain (FDTD) method together with an anatomically based mouse model, the SAR in mice was evaluated with a reasonable accuracy, which enabled one to estimate the lethal dose.

2. Analysis Method

Figure 1 shows a numerical model of the exposure setup. The exposure setup had a construction similar to a microwave oven. A horn antenna at the top of the box was fed via a waveguide at 2.45 GHz. The exposure box had a dimension of $30 \times 40 \times 26$ cm, and was made of aluminum plates. Its insides, except for the metallic front door, were inlaid with planar rubber ferrite absorber with a thickness of 8 mm and complex relative permeability and permittivity of 2.3-j1.9 and 22.0-j1.9, respectively. Figure 2 shows an anatomically based numerical model of the mouse [2]. It was simplified to a homogeneous one (muscle tissue) with a resolution of 2 mm and a weight of 19.6 g. In the FDTD analysis for the dosimetry evaluation, cubic cells with a size of 2 mm were employed to model the exposure setup and the mouse. The excitation was made inside the waveguide with a TE_{10} mode. The metallic parts of the exposure setup were simulated as a perfect conductor, and the others were simulated as lossy materials with their complex permittivity and permeability. The second order Mur absorbing boundary condition was applied to the top of the waveguide for absorbing the outgoing scattered waves.

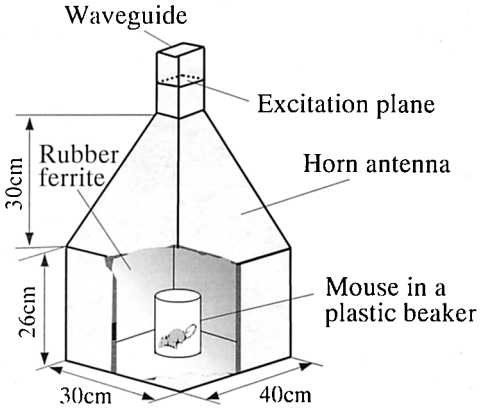

Fig. 1 Numerical model of exposure box.

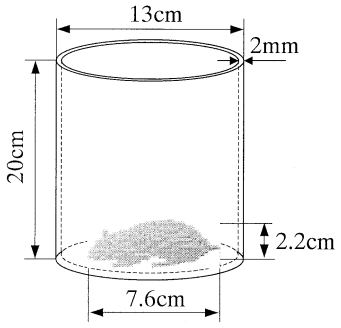

Fig. 2 Numerical mouse model in a plastic beaker. The mouse model had a resolution of 2 mm. The circular plastic beaker was approximated with staircase representation.

3. Validation

Figure 3 shows measured and FDTD-calculated elec-

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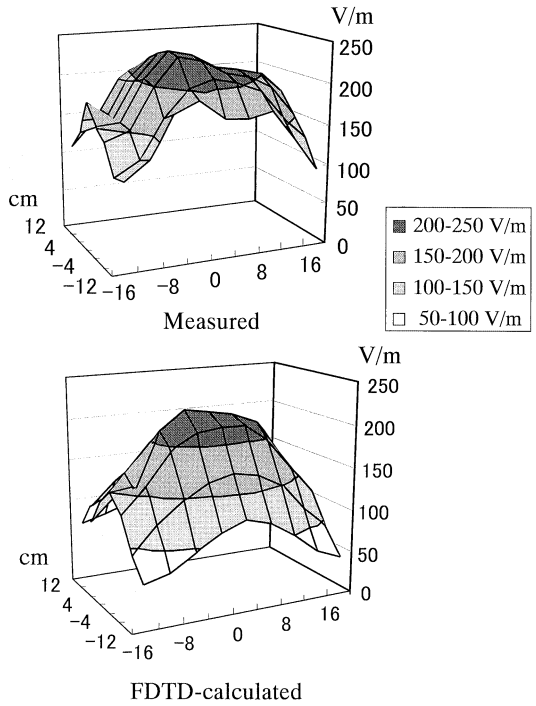

Fig. 3 Electric field distributions at a horizontal plane inside the exposure box with a distance of 2.5 cm from the bottom. The antenna power is 40 W.

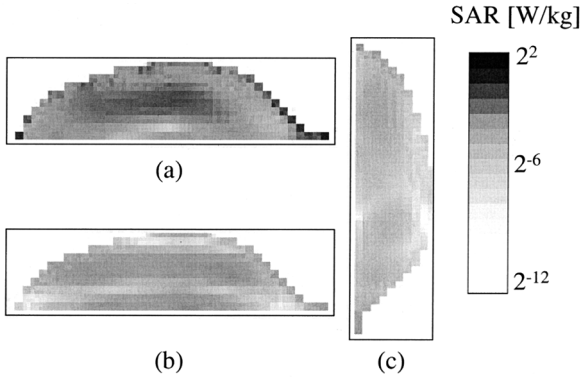

Fig. 4 SAR distributions inside the mouse for an antenna power of 1 W. (a) parallel orientation, (b) facing orientation, and (c) standing up straight.

Table 1 Calculated whole body averaged SAR for mouse.

Mouse situation	Whole body averaged SAR
Parallel orientation	0.47 W/kg
Facing orientation	0.32 W/kg
Standing up stright	0.29 W/kg
Average	0.36 W/kg
	Antenna power: 1 W

tric field (E-field) distributions at a horizontal plane with a height of 2.5 cm from the exposure box bottom. The antenna output was 40 W. The mouse was removed from the exposure box. The E-field probe was a dipole antenna. As can be seen from Fig. 3, the calculated E-field had a distribution similar to the measured one. At the center of the E-field distribution where the mouse would be placed, good agreement on the E-field level was observed between the calculated result (235 V/m) and measured result (237 V/m). These results demonstrated that the numerical modeling for the actual exposure setup had an acceptable accuracy. The discrepancy in the corners and front was considered to be due to the influence of modeling errors in the ferrite absorber and the somewhat open door for passing through the cable of the E-field probe in the measurement. Since the door was as far as 1.6 wavelength from the box center, it is unlikely to have a significant influence on the E-field level at the center location.

4. Result and Discussion

In the exposure the mouse was placed in a 2000 cc plastic beaker. Since the mouse could move freely inside the beaker, three typical exposure situations were considered in the numerical dosimetry analysis. In the first situation, the mouse had an orientation so that its long axis was parallel to the front door (parallel orientation). In the second and third situations, the mouse faced to the front door (facing orientation) and stood up straight, respectively. Figure 4 shows the FDTD-calculated SAR distributions in the mouse. From Fig. 4, the strongest exposure was found in the situation of parallel orientation. The high SAR areas were found not only at the top surface of the mouse but also inside the internal body. In the situation of facing orientation, however, the SAR distribution was quite different from that in the above situation. The high SAR areas were under the back of the mouse and in the abdomen. The difference between the two situations was due to the TE_{10} excitation in which the E-field was parallel to the mouse in the former and perpendicular to the mouse in the latter. The former, therefore, exhibited higher electromagnetic absorption characteristics due to a resonance with the mouse length at 2.45 GHz. In the situation of upright pose, the highest SAR area was in the mouse head due to its close distance to the horn antenna. The whole body averaged SAR in the three typical exposure situations were tabulated in Table 1 with normalization to an antenna power of 1 W. From Table 1, an average for the whole body averaged SARs was derived as 0.36 W/kg in the three typical situations, which may be considered approximately as an average SAR during the whole exposure period of 30 minutes for a mouse. The variation among them ranged up to 0.18 W/kg.

In the TAO research it was found that the mice had a death rate of 100% for an antenna power of 60 W but a death rate of 0% for an antenna power of 40 W with the exposure time of 30 minutes. It seems that there is a sharp threshold for the lethal dose of mice. Referring to Table 1, the whole body averaged SAR should range

from 17–28 W/kg (average: 22 W/kg) for the death rate of 100% and 12–19 W/kg (average: 14 W/kg) for the death rate of 0%. Since a mouse has a basal metabolic rate of 13 W/kg [3], a whole body averaged SAR level at double the mouse's basal metabolic rate may be considered as the lethal dose at 2.45 GHz.

5. Conclusion

Numerical dosimetry of a 2.45 GHz exposure setup for mice, employed in the TAO research project, has been conducted. The dosimetry results indicated that the exposure setup gives a whole body averaged SAR of 0.29–0.47 W/kg for an antenna power of 1 W. Based on the finding, the lethal dose for mice was estimated to be a whole body averaged SAR level at double the mouse's basal metabolic rate. The future subjects are experimental dosimetry evaluation and further validation of the above finding, including the use of other means except for microwaves in order to cause the energy absorption in mice' bodies.

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