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CALCULATION OF ENERGY DEPOSITION INSIDE RATS EXPOSED TO NEAR FIELD BY A MONOPOLE ANTENNA

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1 Introduction

Recently, the number of portable telephone has been increasing explosively. Operators are often exposed to near field produced by the antenna, and some of them are afraid if electromagnetic (EM) exposure may cause any harmful effect such as cancer promotion. Therefore, it is necessary to establish the scientific evidence to clear whether near field exposure by portable phones could be harmful for health or not.

Animal experiments are an authentic approach to evaluation of health risks of exposure to physical agents such as EM radiation. Carcinogenesis of EM exposure has been examined through animal experiments using rodents [1, 2] in the ELF region.

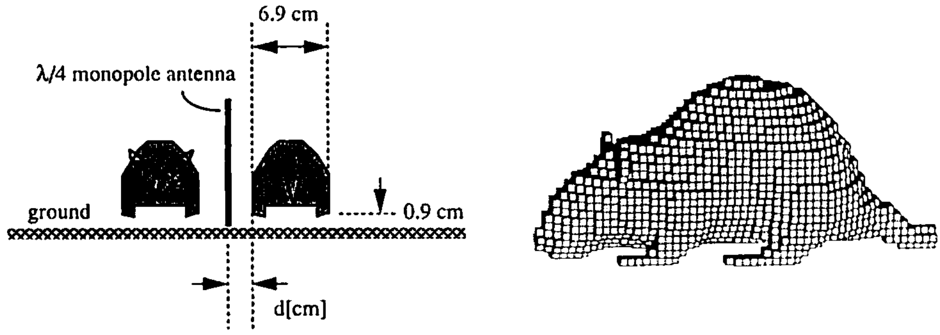
Similar studies on carcinogenesis of EM near field of portable telephones are also necessary. In designing an exposure equipment for this purpose, it is necessary to simulate a partial-body exposure condition encountered in the exposure to radiation by a portable phone. That is, we must achieve an exposure condition where the local peak SAR is considerably large while the whole-body averaged SAR is small enough.

To examine the achievement of this condition it is required to evaluate the energy deposition inside the animal body during exposure to EM wave from the simulated portable phone. This paper therefore calculates the specific absorption rate (SAR) inside small animals using finite difference time domain (FDTD) method, and discusses their distance dependence from antenna. We choose in vivo rat liver as the target organ for partial-body exposure in this study as this organ has been chosen in another experiment in ELF region[2] and the method of assessment has been well-developed[3].

2 Method

For the numerical simulation of EM exposure, we used FDTD method [4]. The calculated space is a rectangular box of 36x60x30 cm, constituted from 120x200x100 cubes with sides of 3 mm. The base boundary is a perfect conductor, and other five boundaries are absorbing wall using Mur's the second approximated equation[5]. A $\lambda/4$ monopole antenna is placed at the center on the ground plane. The antenna wire is modeled by a pillar of cells which approximates a wire with 3 mm diameter. Figure 1 (a) illustrates the configuration of rats and antenna. The rat model used in our calculations is shown in Fig.1 (b).

The antenna is driven at a frequency of 929 MHz. Table 1 shows the electric constants in tissues which the heterogeneous rat model consists of[6]. A homogeneous rat model is also considered which consists of tissue with electric constants of the high water content tissue. Mass densities of the tissues are assumed 1000 kg/m^3 for simplicity.



(a) (b)

Fig.1 Rat model and $\lambda/4$ monopole antenna

Table 1 The electric constants in tissues (900 MHz) [6]	bone	liver	skin	high water content
relative dielectric constant	8	46	35	51
conductivity [S/m]	0.05	0.98	0.6	1.6

3 Result

3.1 SAR distribution

SAR is calculated from internal electric field strength in tissue, conductivity, and mass density. Figure 2 shows SAR distributions in the homogeneous and heterogeneous models at a frequency of 929 MHz. Antenna input power P_a is 1 W, and the distance between antenna and rat d is 1 cm.

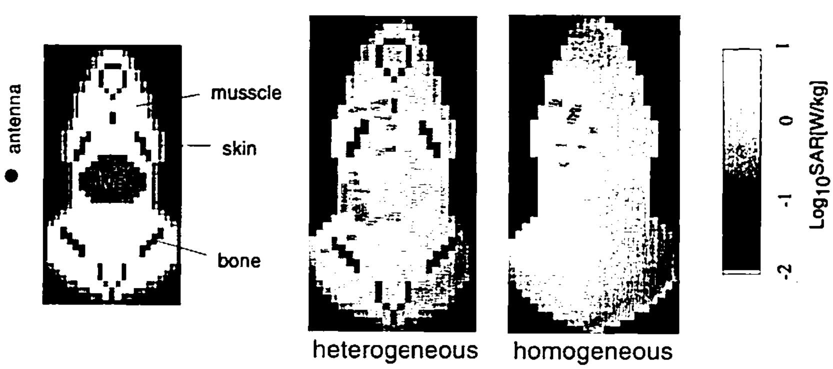
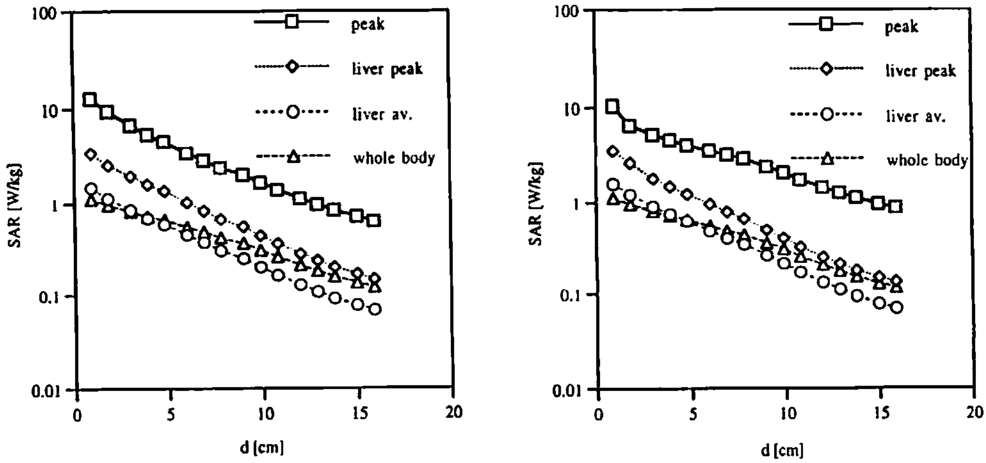


Fig.2 SAR distributions in the rat models(d=1 cm, P_a=1 W)

Peak SAR appears at the surface of right foreleg in the homogeneous model, while it concentrates around the bone of foreleg in the heterogeneous model. It is clear that the homogeneous model is not suitable to evaluate the distribution of energy deposition around skin and bone.

3.2 Distance dependence of SAR

Figure 3 shows the distance dependence of various SARs in each rat model, where antenna input power is 1 W. Whole body averaged SAR, the peak SAR in the whole body, the SAR averaged over liver, and the peak SAR in the liver are evaluated.



(a) heterogeneous (b) homogeneous

Fig.3 Distance dependence of SAR in rat model (P_a=1 W)

All SARs decrease with the distance. The peak SAR in the whole body is higher than the peak SAR in liver as the peak does not appear in the liver but in the foreleg. The SAR averaged over liver is comparable to the whole body SAR. The SARs except the peak SAR in the whole body are approximately the same for the heterogeneous and homogeneous models. It should be noted that the peak SARs in liver show little difference between these two models in spite of the difference in heterogeneity.

3.3 Distance dependence of SAR ratio

In general, the ratio of the whole body SAR to the peak SAR indicates the effects of near field or partial-body exposure. Figure 4 shows the distance dependence of various SAR ratios. We obtain the ratio of the peak SAR to the whole body SAR, and the ratio of the peak SAR in liver to the SAR averaged over liver.

The 'peak SAR/whole body SAR' ratio in the homogeneous model is approximately constant for the distance of 2 cm and over, while the others tend downward depending on distance. The 'peak SAR in liver/whole body SAR' ratio is from 2 to 3. The 'SAR averaged over liver/whole body SAR' ratio is lower than 1 for the distance of 4 cm and over.

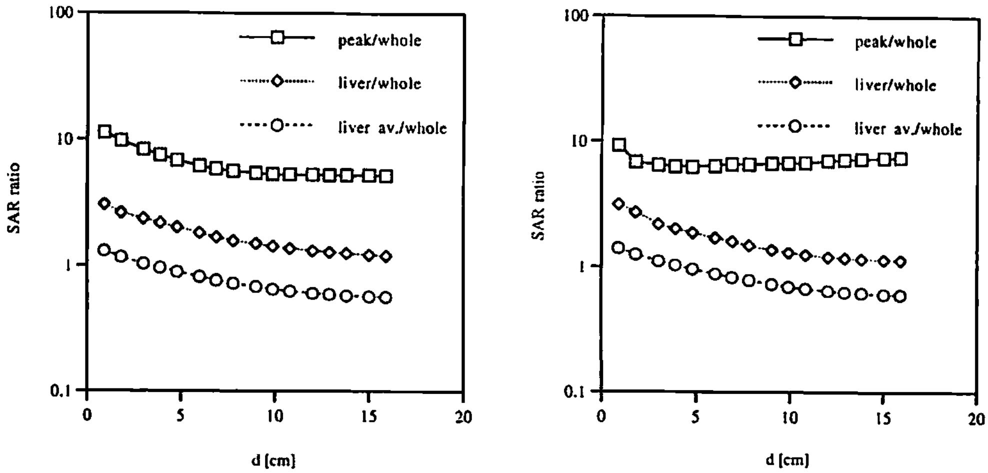
4 Discussion

We have compared the SARs in the heterogeneous model to that in the homogeneous model. Homogeneous model is not suitable to evaluate energy deposition around skin and bone, but approximates to the heterogeneous model with regard to SAR in liver.

On the SAR ratios, we have obtained the following results:

(1) 'peak SAR/whole body SAR'=7-11,

(2) 'peak SAR in liver/whole body SAR'=2-3,



(a) heterogeneous (b) homogeneous

Fig.4 Distance dependence of SAR ratio in rat model

(3) 'SAR averaged over liver/whole body SAR'=0.8-1.4.
Especially, SAR averaged over liver is lower than whole body SAR for the distance of 4 cm and over. It is necessary to put the animal as close to antenna as possible (< 2 cm) for experiment using rat to achieve the near field exposure condition.

In the exposure of rats to the field by wire antenna, the body size of rat is comparable to the wavelength and penetration depth of the EM wave at 900 MHz. Therefore the energy deposition is not localized within a small part of body but occurs the over whole body of rats. The difference in the exposure condition between small animal and human head should be noted. To achieve more localized exposure in animal experiments, it is necessary to use higher frequency or bigger animals.

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