A PRECISE MEASUREMENT METHOD FOR THE LOCAL PEAK SAR ESTIMATION BY USING THE SOLID PHANTOMS

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1. Introduction

Recently, many researches have been conducted on the interaction between a human body and electromagnetic (EM) waves radiated from an antenna near the human body [1], [2]. The main purposes of the research are to improve antenna performance for mobile communication devices considering a safety or a health issue and to develop better antennas or applicators for medical applications such as thermal therapy. The rate of EM energy deposition, called the SAR (specific absorption rate), is usually used to evaluate potential health effects and compliance with safety standards such as the ANSI and to estimate heat generation inside the human body for thermal therapy. However, numerical simulation techniques employed for estimating the SAR may require considerable time and large computer memory for calculation. In addition, they cannot take all the cases of the complex environment of mobile equipment in use into account. Therefore, precise means of experimental evaluation for the SAR are necessary. One of the effective techniques is the thermographic method in which a superficial SAR as well as an internal SAR distribution of arbitrary shaped media can be measured [3]. In the thermographic method, however cooling dawn on phantom surface arises an error. Hence to obtain more precise measurements, it is indispensable to minimize the error and to be closely approximate the electrical characteristics of the phantom model for the human body. We consider that phantoms covered with insulation can minimize the error. To confirm this expectation, we used the urethane foam that could be formed into arbitrary shape such as insulation, whose thickness was assumed to be constantly 5mm.

In this paper, more precise measurements for the local peak SAR of modeled human body using the tissue-equivalent solid phantom are presented at 900MHz. First, the characteristics of the biological tissue-equivalent phantom developed in our laboratory are presented. Next, the SARs of the canonical model phantoms covered with a 5mm thick urethane foam on phantom surface in the vicinity of a dipole antenna are measured and compared with the results of the FDTD calculation. Finally, to investigate the effect of cooling dawn on phantom surface by the 5mm thick urethane foam, we measure the temperature decrease on phantom surface by using an optical fiber thermometer after microwave exposure.

2. Characteristics of Biological Tissue-Equivalent Phantoms

2.1. Features of the Tissue-Equivalent Phantoms

Biological tissue-equivalent phantom is indispensable to experimental evaluation of the SARs. The followings are features of the biological tissue-equivalent phantom developed in our laboratory:

- easy to obtain materials and no special equipments is necessary to fabricate
- adjustable to almost the same complex dielectric constant as homogeneous tissue of not only high water content but also low water content at 900MHz
- have sufficient mechanical strength and is supportable by itself without container
- easy to cut and manufacture to arbitrary shape
- have sufficiently large specific heat and small thermal conductivity
- sufficiently stable so as to keep the electric characteristics for more than a half year in room temperature

2.2. Materials and Composition of the Phantom

The ingredients of the phantom for the human model realized the same relative permittivity and conductivity as human muscle [2]. The phantom, which has the same dielectric constants as the human muscle, is realized using ingredients as shown in Table 1 [4].

Figure 1 shows the complex dielectric constants of this phantom, which almost equal the values of the human muscle at 900MHz. We confirmed that the electrical characteristics of the phantom kept unchanged for a half year.

Table 1 Composition of muscle-equivalent phantom.

Glycerol	2000[g]
Deionized Water	2134[g]
NaCl	66[g]
Agar	200[g]
Polyethylene Powder	100[g]

<A batch is approximately 3800cm^3>

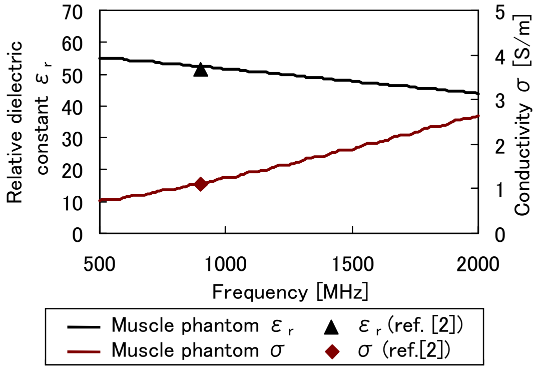


Fig. 1 Electric constants of muscle-equivalent phantom.

3. Evaluation of the SAR

3.1. Effect of EM Waves on Human Body

As personal communication devices that are usually used in the vicinity of the human body become popular, a need to evaluate interaction between the human body and EM field increases. How EM waves affects the human body depends on its frequency. In the microwave region, the EM wave mainly contributes to a heat effect produced by absorption of the energy. In practice, characteristics of heat effect are evaluated by the absorbed electric power per unit mass in tissue, i.e. the SAR [W/kg]. The SAR is defined as

$$\mathrm{SAR} = \frac{\sigma E^2}{\rho} \quad [\mathrm{W/kg}]$$

where E [V/m] is amplitude of electric field (rms value); σ [S/m] is electric conductivity of the tissue; ρ [kg/m^3] is density of the tissue.

3.2. Measurement of the SAR

The thermographic method is one of measurement methods for the SAR. Figure 2 shows a configuration for the thermographic method using an infrared camera and a split phantom.

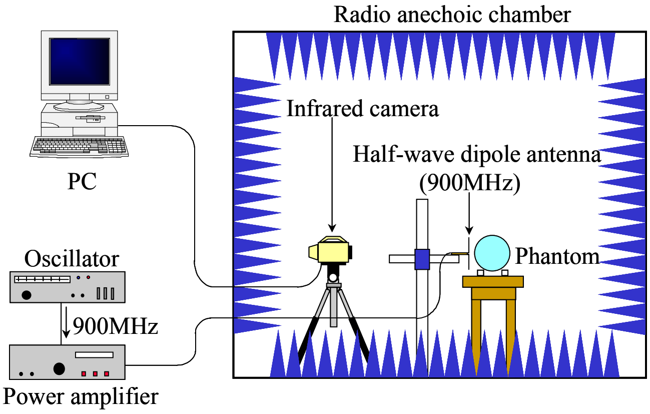


Fig. 2 SAR measurement system.

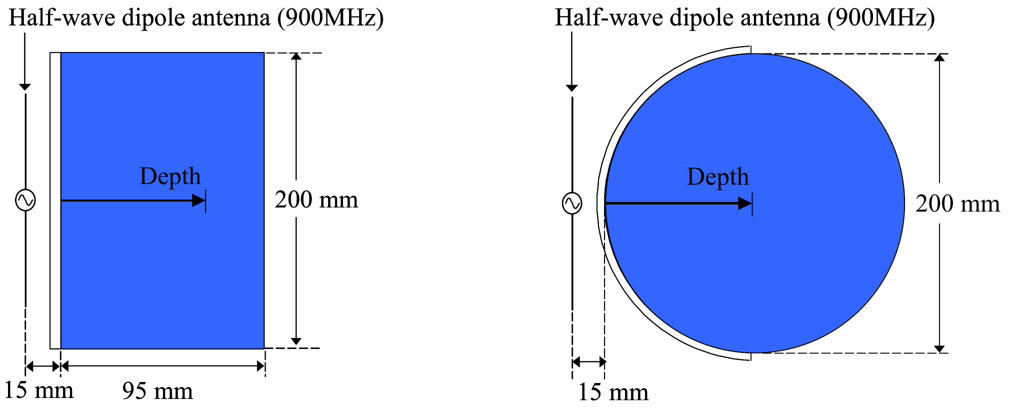
The split phantom is exposed by the microwave radiated from a dipole antenna. The change in the thermal distribution on a cross section of the phantom is observed using the infrared camera after separating it half. To minimize the heat diffusion, exposure duration must be as short as possible within a range that makes the heat distribution observable. If the heat diffusion and exposure duration are negligibly small, the SAR at an arbitrary point is given directly by

$$\mathrm{SAR} = c\frac{\mathit{\Delta} T}{\mathit{\Delta} t} \quad [\mathrm{W/kg}]$$

where c [J/kg·K] is specific heat of phantom material; $\mathit{\Delta} T$ [K] is temperature rise at the point; $\mathit{\Delta} t$ [s] is exposure duration.

3.3. Canonical Phantoms Covered with the Insulation and Radiated with Dipole Antenna

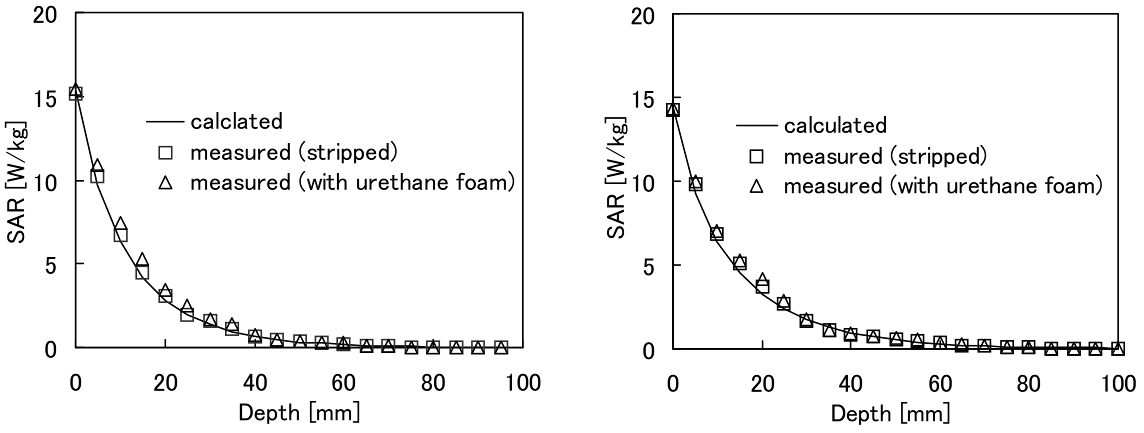
Figures 3 (a) and 3 (b) show a dipole antenna and two different muscle-equivalent phantom models (a rectangular parallelepiped and a sphere) covered with the 5mm thick urethane foam on phantom surface. The dimensions of the rectangular parallelepiped and the sphere are 200×200×95mm^3 and 200mm in diameter, respectively.



a) The rectangular parallelepiped b) The sphere

Fig. 3 Canonical phantom models covered with the 5mm thick urethane foam on phantom surface.

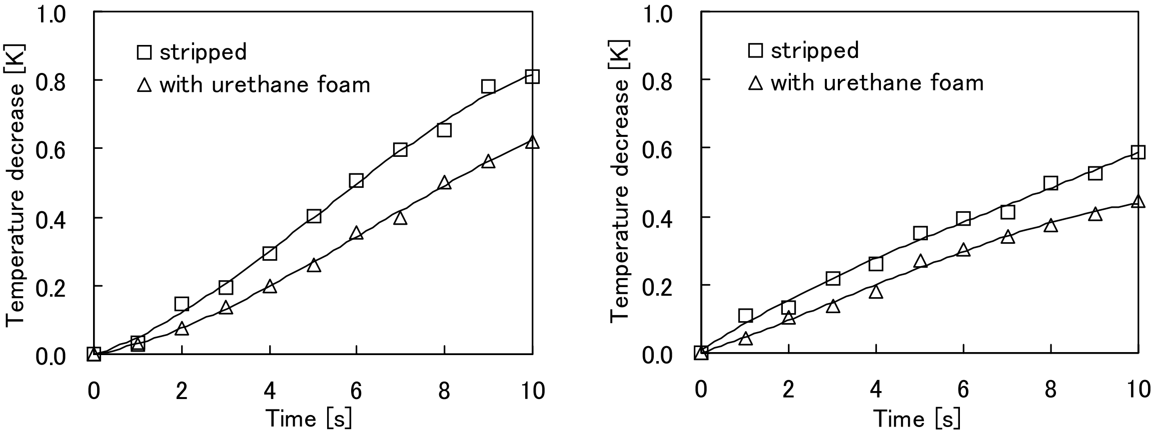
Figures 4 (a) and 4 (b) show a comparison between calculated and measured SAR distributions using the thermographic method. The calculated value was simulated by the FDTD method. Here, the input power is normalized to 1W. Good agreement between the calculated and measured results is obtained. Moreover, it has been confirmed that the 5mm thick urethane foam does not influence SAR distribution.



a) The rectangular parallelepiped b) The sphere

Fig. 4 SAR distribution in muscle-equivalent phantom.

For real-time measurement of cooling down on phantom surface after microwave exposure we have used the optical fiber thermometer. Then a probe stub of the optical fiber thermometer was inserted into the point where the EM wave power is mostly absorbed on phantom surface. The condition for estimation of the SAR is equal to measurement in the foregoing paragraph. Figures 5 (a) and 5 (b) show measured results of cooling down on phantom surface by using the optical fiber thermometer after microwave exposure. Hence we have confirmed that phantoms with the urethane foam can reduce the temperature decrease in comparison with that of stripped one. However, these results of the temperature decrease are much larger than those in the thermographic method. This is because in the thermographic method the infrared camera averages the temperature at time.



a) The rectangular parallelepiped b) The sphere

Fig. 5 Cooling down on phantom surface after microwave exposure.

4. Conclusions

Precise measurements for the local peak SAR of the modeled human bodies have been conducted using the tissue-equivalent solid phantoms covered with the insulation. The electric and thermal characteristics of the biological tissue-equivalent phantom developed in our laboratory have been presented. In addition, SARs of the canonical model phantoms covered with the 5mm thick urethane foam in the vicinity of the dipole antenna have been measured and compared with the results of the FDTD calculation. As a result, it has been confirmed that the 5mm thick urethane foam does not influence SAR distribution. Furthermore, to investigate the effect of cooling dawn on phantom surface by the 5mm thick urethane foam, we have measured the temperature decrease on phantom surface by using the optical fiber thermometer after microwave exposure. As a result, we have confirmed that phantoms with urethane foam can reduce the temperature decrease in comparison with that of stripped one. From these results we conclude that phantoms covered with the insulation can estimate more precise evaluation of the local peak SAR.

As a further study, the same examination as above should be done using smaller volume models.

5. References

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