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The SAR estimation by the optical fiber thermometer

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1. Introduction

Recently, the manufacturer was obligated to specify a biological effect of own mobile communication devices. An indication of the biological effect is defined by specific absorption rate (SAR). The guideline for the SAR is coerced at the government level in each country. Therefore, it is necessary to establish the experimental evaluation technique of the SAR.

The SAR evaluation technique used internationally is the electric field probe scanning method [1]. This method estimates the SAR from the electric field intensity in the liquid phantom. By substituting the electric field intensity for expression (1), then the SAR is calculated.

$$\mathrm{SAR} = \frac{\sigma \cdot E^2}{\rho} \quad \mathrm{W/kg} \tag{1}$$

where σ (S/m) is the electric conductivity of the body tissue, E (V/m) is the electric field intensity, and ρ $(\mathrm{kg/m^3})$ is the density of the body tissue.

However, it is thought that the SAR evaluation by a physically different technique is necessary for the calibration and the uncertainty evaluation of the above-mentioned system.

In this paper, the SAR estimation method by the calorimetric method is introduced. In this method, the optical fiber thermal sensor and the solid phantom are used. Because it is thought that the electromagnetic field disturbance in phantom with the optical fiber sensor is small. If thermal diffusion is negligibly small, the SAR is given by

$$\mathrm{SAR} = \frac{C \cdot \Delta T}{\Delta t} \quad \mathrm{W/kg} \tag{2}$$

where C $(J/kg \cdot K)$ is the specific heat of the phantom material, ΔT (K) is a temperature rise amount observed at the position where a thermal sensor is installed, and Δt (second) is the exposure duration.

2. The $\mathrm{SAR_{1g}}$ estimation

Fig.1 shows the measurement system of the temperature rise in the solid phantom caused by the electromagnetic irradiation. To measure an average temperature rise in the mass of 1 gram (or, 10 grams), two or more thermal sensors are installed (Fig.1 : in case of 1 gram mass.).

The thermal sensor has been inserted in parallel to polarisation of the electric field (see Fig.1).). To minimize the disturbance of the electromagnetic field in phantom, the thermal sensor has been inserted in parallel to polarisation of the electric field [2].

The measurement point locations are showed in Fig.2. The density of the solid phantom is 1029 kg/m3, and the space size of 1g mass becomes almost 10 mm x 10mm x 10mm. Measurement points is set to the center and the edge of A-plane and B-plane (see Fig.2) of the space which corresponds to 1g mass at intervals of 5mm. The purpose to use 5mm interval for the sample points is almost similar the probe scanning interval used by DASY.

The method of evaluating $\mathrm{SAR_{1g}}$ is described as follows. First of all, the temperature rise at 18 points shown in Fig.2 is measured. At the next stage, the average temperature rise of the space which corresponds to 1g mass (ΔT_{1g}) is calculated from the measurement data of 18 points. $\mathrm{SAR_{1g}}$ can be obtained by substituting the average ΔT_{1g} for expression (3).

$$\mathrm{SAR} = \frac{C \cdot \Delta T_{1g}}{\Delta t} \quad \mathrm{W/kg} \tag{3}$$

where C $(J/kg \cdot K)$ is the specific heat of the phantom material, ΔT_{1g} (K) is average temperature rise in 1g mass, and Δt (second) is the exposure duration.

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3. Experimental and numerical techniques

A. Shape and material of phantom

The shape of the phantom is 200 x 100 x 200 (width x depth x height)mm which is compliant with COST244 model (see Fig.3). COST244 model is a kind of the canonical model by which the human head is assumed, and an original size is 200mm x 200mm x 200mm. However, because the penetration depth of the electromagnetic energy is shallow in 2GHz, the depth of phantom has been compressed into 100mm.

The solid phantom used for the measurement is a homogeneous structure synthesized to have the electric constant approximated to the average brain tissue of which FCC notifies [3]. The material and the composition ratio of the solid phantom are shown in Table 1. The dielectric properties and material properties of the brain-equivalent solid phantom are listed in Table 2. The relative permittivity and conductivity were measured with 85070C permittivity probe manufactured by Agilent Technologies Ltd.. The date of the density and specific heat is due to the measurement of Agne technical center Ltd..

B. Experimental technique

The SAR measurement system is expressed in Fig.4. The optical fiber thermometer used for the measurement is FL-2000 manufactured by Anritu meter Ltd.. The procedure of SAR measurement with the optical fiber thermometer is as follows. The electromagnetic wave is exposed to the brain-equivalent solid phantom for a short time, and, as a result, the temperature rise caused in the phantom is measured with an optical fiber thermometer.

The exposure frequency assumed 2GHz, and used the half wavelength dipole antenna for the radiation source. The distance between the antenna and the phantom is 15mm.

The irradiation electric power is 20W. The reason is that some temperature rise is necessary when measuring it with an optical fiber thermometer.

It is thought that the influence of thermal diffusivity can be disregarded if temperature rise is proportion to exposure time. Then, the result of measuring the temperature rise VS. exposure time characteristic is shown in Fig. 5 as a preliminary experiment. Exposure duration was while 40 seconds from 10 seconds in as a result of a preliminary experiment, temperature rise and exposure time were in the proportion relation. Therefore, the irradiation condition is as indicated above.

C. Simulation technique

The finite-difference time-domain (FDTD) method is used as an analysis method to compare it with SAR_{1g} obtained from the measurement. The parameters of the FDTD calculation employed in this paper are as follows. The cell size is 1mm. The time step of the FDTD calculation is 1.926ps. The absorbing boundary condition is Liao. The relative permittivity, conductivity, and density of the phantom used to calculate are listed in Table2.

4. Result and discussion

The experimental result of the SAR_{1g} estimation from the temperature rise in 18 measurement points shown in Fig.2 is 16.05W/kg. The FDTD analytical result of the SAR_{1g} is 17.24W/kg. The SAR measurement system with the optical fiber thermometer becomes possible the SAR_{1g} estimation by the difference of about 6%. The transition of dielectric property in the solid phantom and the location accuracy of the optical fiber sensor are thought by the error factor. To prevent the dielectric property transition of phantom, the plastic film stores the phantom. The error in relative dielectric constant and the conductivity of the solid phantom after one month is about 1% and 4% respectively. Therefore, it is thought that the location accuracy of the optical fiber sensor is a main error factor. It is necessary to improve the location accuracy of the optical fiber sensor to reduce the error.

5. Conclusion

In this paper, the establishment of the SAR measurement system with the optical fiber thermometer to estimate SAR_{1g} was tried. Because the SAR_{1g} estimation was possible by the difference of about 6%, the effectiveness of this SAR measurement system was confirmed.

References

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[3] FCC web site, http://www.fcc.gov/fcc-bin/dielec.sh.

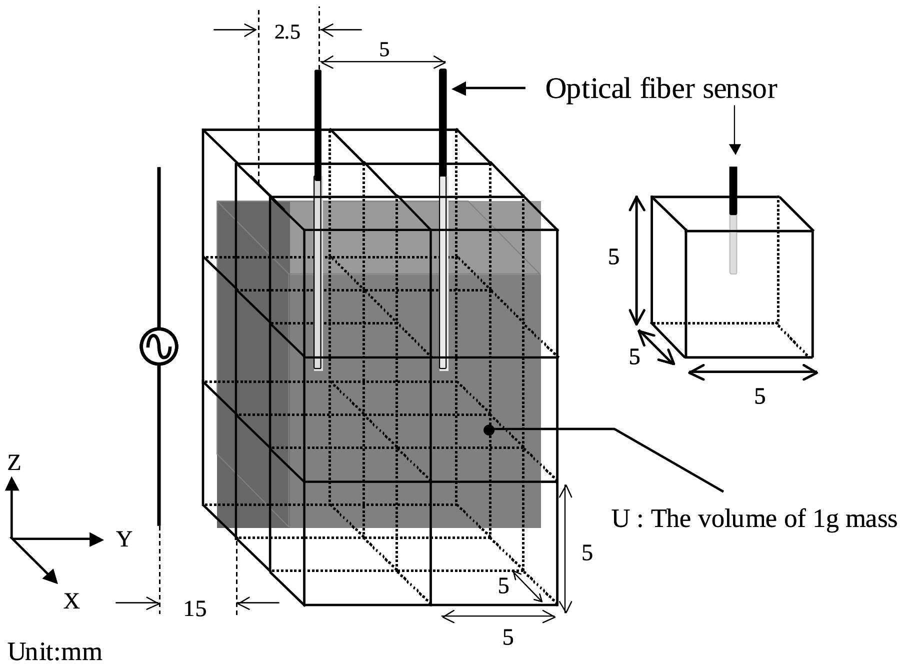

Fig.1 The location of an optical fiber sensor

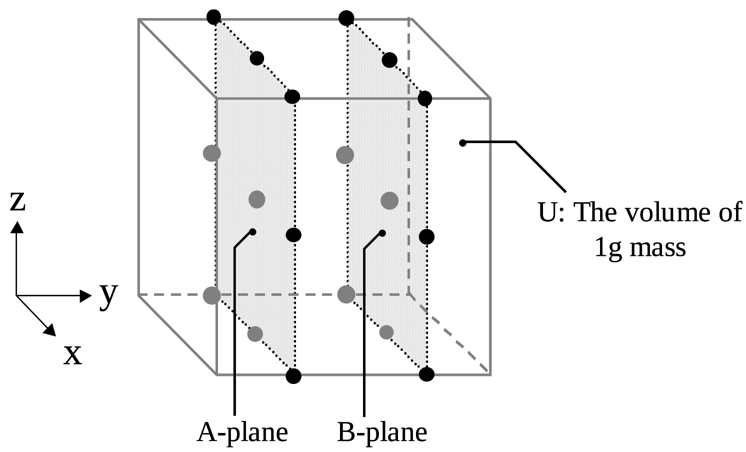

Fig.2 measuring point

Table1 Composition of the brain-equivalent solid phantom

Material	Weight ratio [%]
Silicone Emulsion	46.5
Deionized Water	27.6
Glycerin	20.9
Agar	4.7
Sodium benzoate	0.3

Table2 Dielectric properties and material properties of the brain-equivalent solid phantom at 2GHz

Tissue type	Brain
Relative dielectric constant	45.52
Conductivity [S/m]	1.24
Density [kg/m^3]	1029
Specific heat [J/g K]	3.21

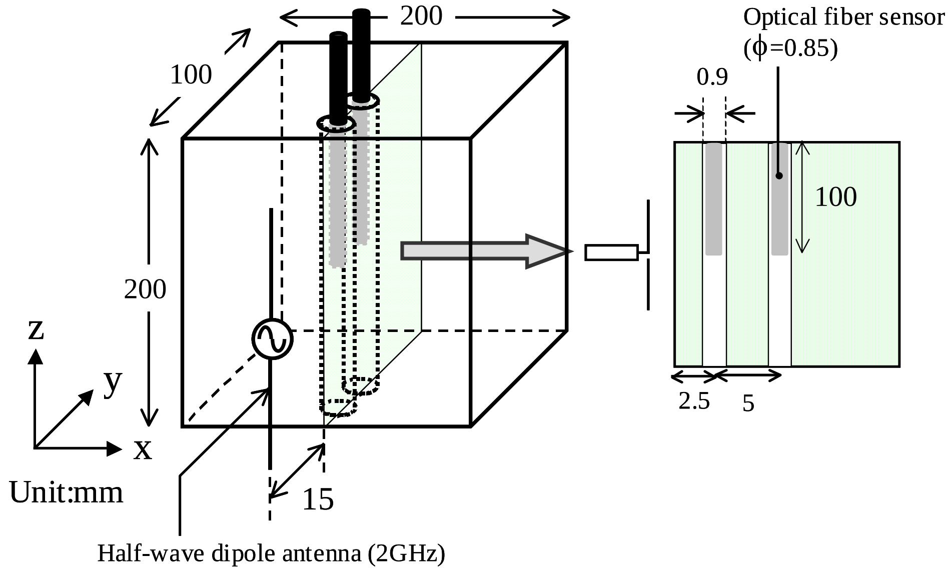

Fig.3 The phantom model

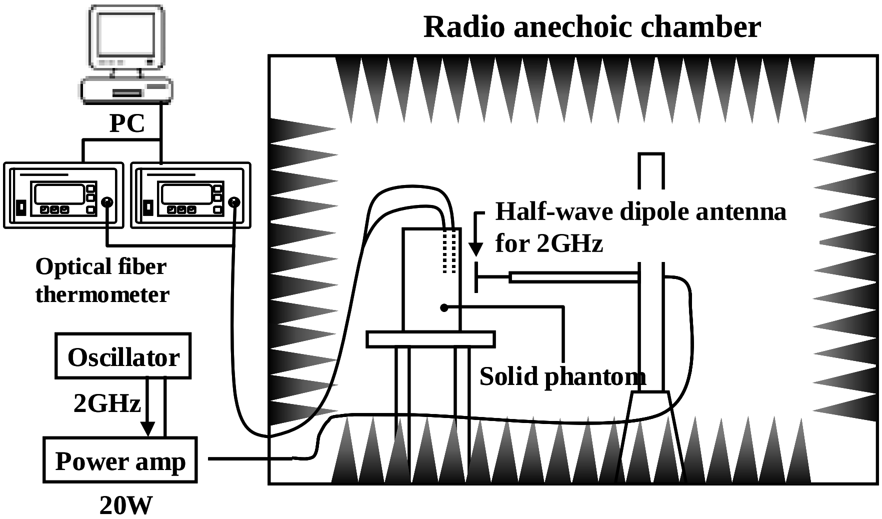

Fig.4 The SAR measurement system

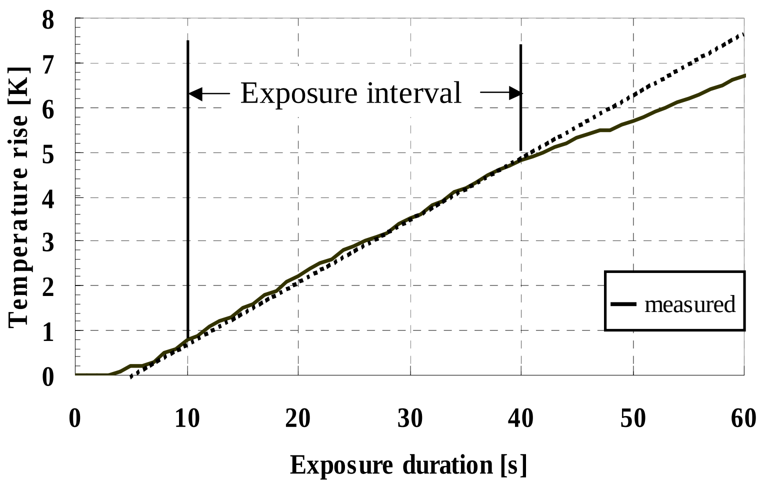

Fig.5 Relation between exposure time and temperature rise