NOVEL SPECIFIC ABSORPTION RATE MEASUREMENT METHOD USING FLAT-PLANE SOLID PHANTOM – ABSOLUTE SAR VALUE AND ARRAYED PROBES -

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Abstract: A Specific Absorption Rate (SAR) measurement method using a flat-plane solid phantom that provides stable dielectric properties and easy handling of the phantom is presented, in which the E-field probes are fixed in the flat-plane solid phantom and the radio device is scanned. This method can also be used as an alternative to that employing flat liquid phantoms. This paper compares the absolute SAR values measured using the solid phantoms, the liquid phantom recommended by the International Electrotechnical Commission (IEC), and those calculated using the Finite Difference Time Domain (FDTD) method for a standard dipole antenna. The measurement results agree extremely well with each other, and the calculation results confirm the adequacy of the experiments. Moreover, a fundamental evaluation of arrayed probes is presented that confirms that the distance of 20 mm (corresponding to approximately one wavelength in the phantom) between two holes for probe insertion obtains SAR measurement within the variation of ±10% at 1950 MHz.

Key words: E-field probe, dielectric properties, shell, SAR distribution

1. Introduction

Specific Absorption Rate (SAR) measurement procedures for hand-held mobile wireless communication devices have been established in Europe [1] and Japan [2], and are being drafted in the USA [3] and by the International Electrotechnical Commission (IEC) [4]. These procedures employ the same realistic shaped phantom filled with a liquid that simulates the dielectric properties of human tissue, and an E-field probe that spatially scans the inside of the phantom. They enable a highly accurate SAR measurement. A SAR measurement system based on such procedures has been commercially available as presented in [5]. Some studies for simplifying the system have also been carried out such as in [6].

However, changes in dielectric properties of the liquid over time due to evaporation and deposition are unavoidable. The recommended human-tissue simulating liquids in [4], which include organic solvents, require strict procedures for storage and ventilation. In addition, the liquids require a container called a shell. Therefore, although the use of the liquid phantom provides accurate SAR measurement, these factors require complex handling procedures.

A realistic shape reproduces the actual layout of the human head and any radio devices. However, radio devices are used not only in conjunction with the human head, but also with the torso, palm, and other PC attachments in practical situations. The IEC has started to investigate SAR measurement methods using a flat phantom in order to accommodate such varied situations.

Therefore, we proposed in [7] the use of a solid phantom to address the complex handling of the liquid, and the use of a flat phantom as indicated by the IEC. Instead of scanning the E-field probe in the liquid, the radio device is scanned over a flat-plane solid phantom and E-field probes are fixed inside the phantom. Using the solid phantom is advantageous because the dielectric properties and shape do not change over time [8], [9]. In addition, a shell is not required and it is easier to deal with.

The dimensional design of the phantom and the normalized SAR distributions obtained using the proposed method have already been reported in [7]. This paper compares the absolute SAR values measured using the solid phantoms, the liquid phantom recommended by the IEC, and those calculated using the Finite Difference Time Domain (FDTD) method generated for a standard dipole antenna. The application of the arrayed probes is also presented. The considered frequency is 1950 MHz.

2. Experimental Configuration

Figure 1 shows the experimental configuration for the SAR measurement. The flat-plane solid phantom, in which an isotropic E-field probe is fixed, is placed on top of a wooden table. The support adjusts the height of the E-field probe, and an industrial robot (RX-90, Stäubli AG, Horgen, Switzerland) is used to scan the radio device (a dipole antenna is depicted in Fig. 1).

The solid phantom comprises ceramic powder, graphite powder, and bonding resin [8], [9]. The dimensions of the flat-plane solid phantom are 400 mm, 800 mm, and 150 mm in *W*, *H*, and *D*, respectively. These dimensions are sufficiently large to simulate an infinite flat-plane phantom above 900 MHz when the RF source is scanned over the flat-plane solid phantom [7]. In this experiment, the frequency is 1950 MHz. The solid phantom has the relative permittivity of 41.8 and the conductivity of 1.40 S/m at 1950 MHz. The differences from the target values described in [4] are +4.5% and ±0%, respectively.

The isotropic E-field probe (ET3DV6, Schmid & Partners Engineering AG, Zürich, Switzerland), which has the diameter of 12 mm, is inserted and fixed in the flat-plane solid phantom. The distance between the probe tip and the detection elements is 2.7 mm. The probe is calibrated in the liquid, which is based on the composition recommended by the IEC [4] at 1950 MHz.

3. Measurement of Absolute SAR Value

As a fundamental validation, the SAR distributions generated by a standard dipole antenna in the flat-plane solid and liquid phantoms are measured at 1950 MHz. The liquid has the relative permittivity of 40.0 and the conductivity of 1.40 S/m at 1950 MHz. The E-field probe scans the inside of the liquid while the antenna remains fixed. On the other hand, the standard dipole antenna is scanned over the flat-plane solid phantom while the E-field probe remains fixed. To simulate the same configuration as that for the liquid phantom, a dielectric board (bakelite), which is 2-mm thick and has the relative permittivity of 4.5, covers the flat-plane solid phantom.

Figure 2(a) illustrates the definition of the axes. Figure 2(b) shows the measured SAR distributions along the antenna element for x = 2.7 and 7.7 mm.

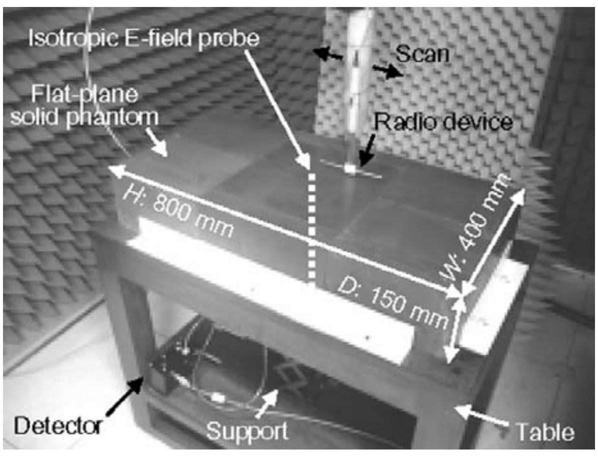

Fig. 1. Photograph of the experimental configuration using flat-plane solid phantom.

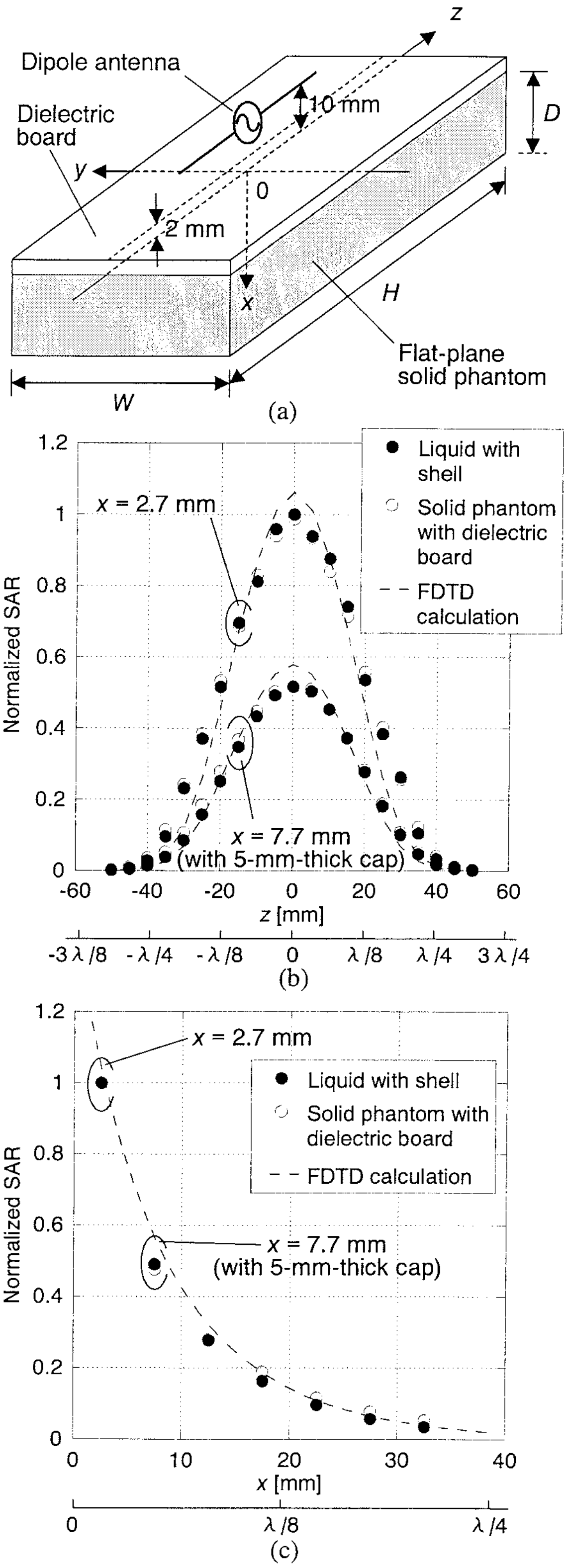

Fig. 2. Comparison of the SAR distributions using the flat plane solid phantom, liquid phantom, and calculated using the FDTD method. RF source is a standard dipole antenna at 1950 MHz. (a) The definition of the axes, (b) Along z axis, y = 0, x = 2.7 and 7.7 mm, (c) Along x axis, y = z = 0.

Here, y = 0. When x = 2.7 mm, only the dielectric board covers the E-field probe tip. A 5-mm-thick cap comprising the same material as the solid phantom occupies the surface of the phantom in the case of x = 7.7 mm. Figure 2(b) also illustrates the calculated SAR distribution using the FDTD method with the cell size of 1.0 mm. The calculation model simulates the measurement configuration without the probe and the hole. The measured and calculated SAR distributions as a function of the depth in the phantoms are shown in Fig. 2(c). All the plots and lines in Figs. 2(b) and 2(c) indicate the SAR normalized to that obtained in the liquid phantom for x = 2.7 mm when the probe faces the antenna feeding point. The same RF power is radiated from the standard dipole antenna for the measurements and calculations. The good agreement between the SAR distributions measured using the phantoms and that calculated using the FDTD method indicates that the experiments are adequately conducted. Moreover, the SAR distributions obtained using the flat-plane solid phantom agree extremely well with those obtained using the liquid phantom, and we confirm that the proposed method using the flat-plane solid phantom enables the SAR measurement with an absolute value.

4. Application of Arrayed Probes

To shorten the measuring time, one solution is to insert a number of probes in the flat-plane solid phantom. A comparison of the SAR at the observation point obtained using the FDTD calculation method and the measurement using the flat-plane solid phantom is conducted at 1950 MHz for two holes for E-field probe insertion. Figures 3(a) and 3(b) illustrate the FDTD calculation model for two holes on the y and z axes, respectively. The diameter of the holes is 12 mm corresponding to that of the probe used in the measurement. The experimental configuration around the holes is displayed in Fig. 3(c), where the dielectric board is not shown. The center hole contains the E-field probe, and the other four holes are located 15, 20, 25, and 30 mm away from the center hole. Cylinders comprising the same material as the solid phantom occupy some holes when needed. The observation point is facing the feeding point of the fixed standard dipole antenna. Figure 3(d) illustrates the SAR at the observation point calculated using the FDTD method and measured using the flat-plane solid phantom as a function of the distance between the two holes. All the plots and lines in Fig. 3(d) indicate the normalized SAR to that obtained at the observation point when only one hole is constructed. In any case, the same RF power is radiated from the standard dipole antenna. The results are in good agreement. To obtain the SAR within the variation of ±10%, the distance between the two holes at 1950 MHz should be greater than 20 mm, which corresponds to

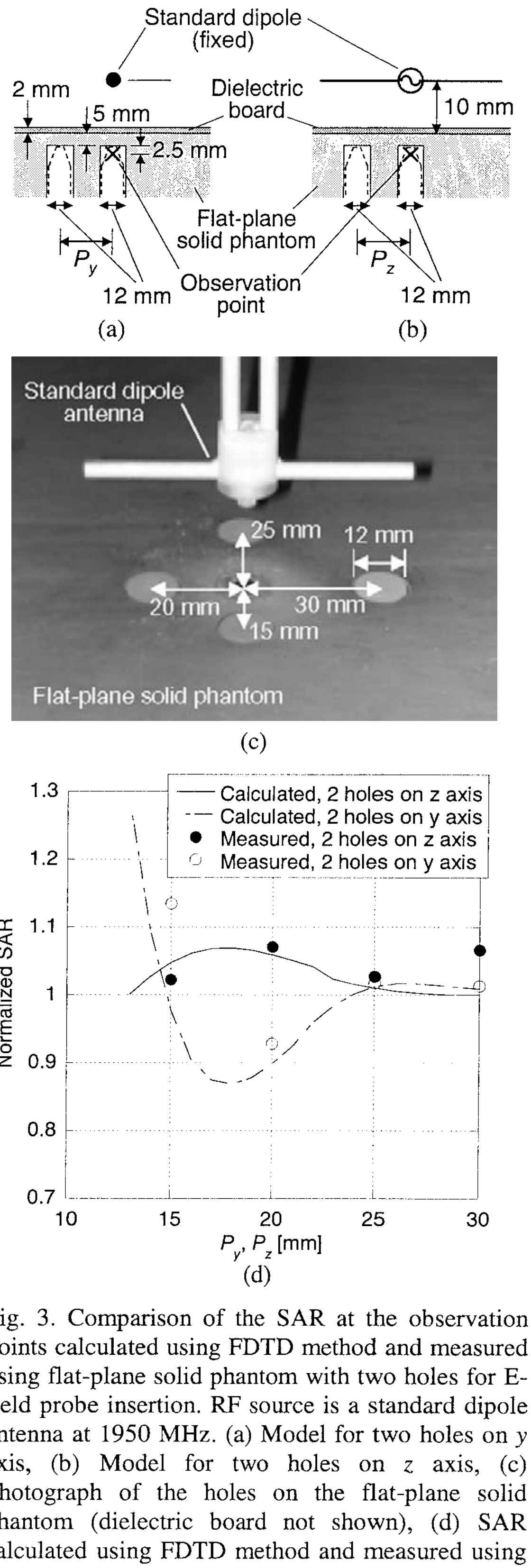

Fig. 3. Comparison of the SAR at the observation points calculated using FDTD method and measured using flat-plane solid phantom with two holes for E-field probe insertion. RF source is a standard dipole antenna at 1950 MHz. (a) Model for two holes on y axis, (b) Model for two holes on z axis, (c) Photograph of the holes on the flat-plane solid phantom (dielectric board not shown), (d) SAR calculated using FDTD method and measured using flat-plane solid phantom related to the distance of two holes.

approximately one wavelength in the phantom, when using 12-mm-diameter probes.

5. Conclusion

A Specific Absorption Rate (SAR) measurement method that provides stable dielectric properties and easy handling of the phantom was presented, in which the E-field probes are fixed in a flat-plane solid phantom and the radio device is scanned. The method can also be used as an alternative to that employing flat liquid phantoms. The SAR values obtained using the proposed method were examined based on the experiments using the solid and liquid phantom, and FDTD calculation method. The absolute SAR values obtained using the flat-plane solid phantom agreed extremely well with those obtained using the liquid phantom and those obtained using the FDTD method confirmed the adequacy of the experiments. This method is applicable to SAR measurement of radio devices and provides easy handling of the phantom with a simple shape. The arrayed probes, which are accurately designed, will decrease the measuring time while maintaining a reasonable level of SAR measurement accuracy. Therefore, our method has various other applications such as in measuring the SAR radio devices during mass-production or during various test production stages.

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