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Development of a Liquid-Type Human-Body Equivalent Antenna Using NaCl Solution

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1. Introduction

Biological effects due to radio wave exposure are dependent on frequency, and thermal effects are dominant in high frequency region higher than about 100 kHz. Furthermore, whole body resonance phenomena arise in VHF band (30-300 MHz) when the electric field is parallel to the human body's height and the wavelength is about twice the human body. Because the power absorption by the human body could be maximum at the whole-body resonance, the radio-frequency (RF) safety guidelines recommend the most strict exposure limits in VHF band [1][2].

When a human body stands on the ground plane, local SAR becomes very high at ankles and sometimes exceeds the guideline limits in terms of the local SAR for extremities. The guidelines set additional limits in terms of the induced ankle current because the local SAR at ankles can be estimated from the induced ankle current. Measurement methods of induced ankle current have not been established nor standardized yet although some induced current methods using clamp type current meters or parallel type ones have been proposed.

Because of ethical issues, furthermore, it is necessary to use a surrogate of a human body in measuring the induced ankle current for very high-strength exposure conditions. Although some human-body equivalent antennas have been developed [3], it is difficult to manufacture or optimize the antenna for various exposure conditions.

We therefore propose a human-body equivalent antenna, which is easy to manufacture and optimize for various frequencies and body heights, for measurement of the induced ankle current. In this presentation, we demonstrate the design of the antenna based on the numerical results and the measured results.

2. Methods

2.1 Human-body equivalent antenna

Figure 1 shows a human-body equivalent antenna proposed in this study. This antenna consists of acrylic boards on metal board. The size of the metal board is 20 cm square and the thickness of the board is 5 mm. The height of the acrylic board is 180 cm. The horizontal cross-section of the antenna is 25 cm^2. Tissue-equivalent liquid is filled in the antenna. The height of tissue-equivalent liquid in the antenna is 170 cm for simulating an adult human body.

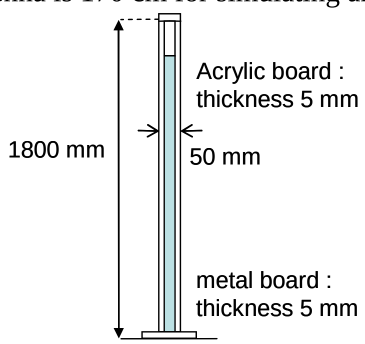

Figure 1: Human-body equivalent antenna proposed in this study

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2.2 Numerical human model

Figure 2 shows a numerical human model which is used for determining the reference values of the induced ankle current. The realistic-shape homogenous human model consists of cubes with 5 mm on a side. The electric properties (relative permittivity and conductivity) are set with 5 those of 2/3-muscle. In this study, the ankle induced current of the human-body equivalent antenna is compared with the reference value.

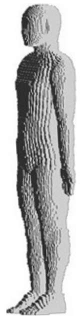

Figure 2: Realistic-shape homogenous human model

2.3 Calculation method and models

The finite-difference time-domain (FDTD) method is used to evaluate the ankle induced currents of the human-body equivalent antenna and the realistic human model. The calculation model for each exposure condition is described below.

Exposure to near-field of a monopole antenna: Figure 4 shows a calculation model for exposure to the near-field of a monopole antenna. The distance of the monopole antenna to the human-body equivalent antenna is 3 m. The realistic human model is also set at the same position of the human-body equivalent antenna shown in Fig. 3. The cell size of the calculation region is 5×5×5 mm^2. Computational domain is 800×400×500 [cell]. Absorbing boundary conditions are PML.

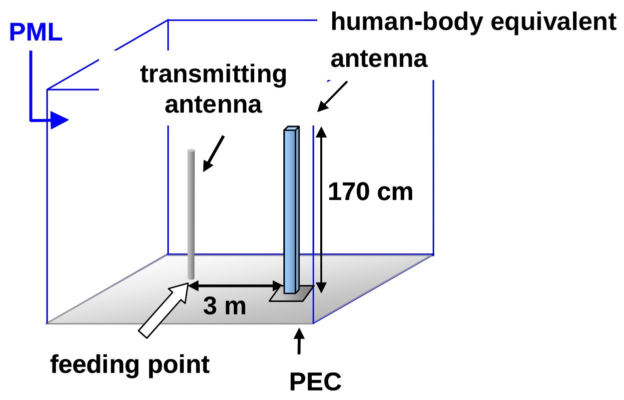

Figure 3: Calculation model of exposure to the near-field of a monopole antenna

2.4 Measurement method of ankle induced current

A clamp-type induced current meter (HI-3702) is used to measure the induced ankle current of the human equivalent antenna, as shown in Fig. 4. Although the current meter is designed up to 110 MHz, we calibrate the current meter by the comparison with the numerical calculation (MoM) [4]. The correction factors of the read out of the current meter are shown in Fig. 5.

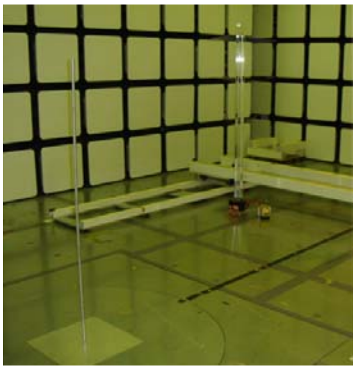

Figure 4: Human-body equivalent antenna and the monopole antenna in the anechoic chamber and the human-body equivalent antenna with a clamp-type induced current meter (HI-3702) at the base of the antenna.

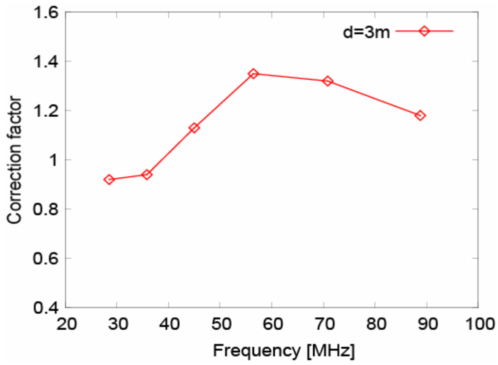

Figure 5: Correction factors of the readout of the induced current meter (HI-3702)

3. Results and discussion

In this section, we investigate NaCl solution for tissue-equivalent liquid filled in the human-equivalent antenna because NaCl solution is easy to prepare and is often used for tissue-equivalent liquid.

The relative permittivities and conductivities of NaCl solution were measured with a coaxial cell (National Physical Laboratory, UK). The applicable frequency of the coaxial cell is from 15MHz to 1GHz. Table 1 lists the measured electrical properties of 2.6 % concentration NaCl solution at frequencies in VHF band. The temperature of the NaCl solution was at 21 degree C.

Figure 6 shows the ankle induced currents of the realistic human model, i.e., the reference values, and the measured and calculated ankle induced currents of the human-body equivalent antenna using of 2.6 % NaCl solution for the tissue-equivalent liquid. The near-field of the monopole antenna which is resonant at each frequency is irradiated to the models. The antenna input power of the monopole antenna is 25 W.

Table 1: Measured Relative Permittivities And Conductivities of 2.6 % Concentration NaCl Solution (21 Degree C)

Frequency (MHz)	relative permittivity	conductivity (S/m)
36	83.9	3.85
45	82.8	3.86
56	81.9	3.87
70	80.8	3.88
88	79.9	3.92

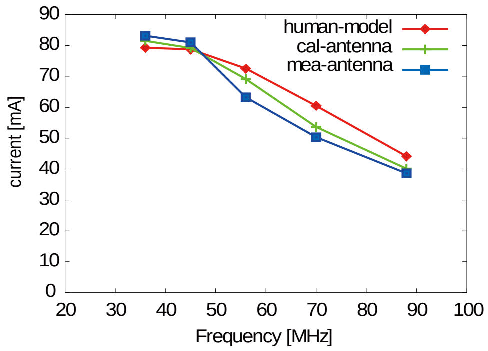

Figure 6: Ankle induced currents of the realistic human model and of the human-body equivalent antenna using of 2.6 % NaCl solution for the tissue-equivalent liquid

Figure 7 shows the errors of the measured and calculated ankle induced currents of the human-body equivalent antenna from those of the realistic human model, i.e., the reference values. This result proves that the human-body equivalent antenna using of 2.6 % NaCl solution for the tissue-equivalent liquid, which is optimized at 45 MHz, can estimate the ankle induced current within 20 % error from 36 MHz to 88 MHz.

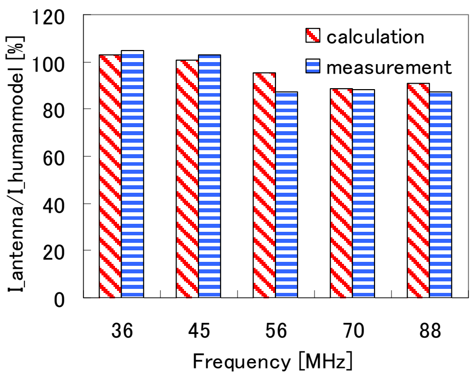

Figure 7: The errors of the measured and calculated ankle induced currents of the human-body equivalent antenna with 2.6 % NaCl solution from those of the realistic human model, i.e., the reference value

4. Conclusions

We have investigated the human-body equivalent antenna for estimation of the induced ankle current. Consequently, we demonstrated the human-body equivalent antenna using of 2.6 % NaCl solution for the tissue-equivalent liquid at 21-degree C can estimate ankle induced current within 20 % error.

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