A Liquid-Type Human-Body Equivalent Antenna with Improved Induced Current Distribution

#Akira Itou [1,2] , Ally Y. Simba[2], Takuji Arima[1], Lira Hamada[2],
Soichi Watanabe[2], and Toru Uno[1]
[1] Graduate School of Engineering, Tokyo University of Agriculture and Technology, 2-24-16, Koganei, Tokyo, 184-0012, Japan, a-itou@nict.go.jp
[2] National Institute of Information and Communications Technology, Nukuikitamachi 4-2-1, Koganei, Tokyo, 184-8795, Japan

Abstract

We investigate the human-body equivalent antenna with improved induced current distribution. The human-body equivalent antenna is designed based on the numerical analysis. The induced current of the antenna shows good agreement with that of numerical human model. The validity of the numerical result is verified by comparison with experimental result. Consequently, effectivity of the proposed antenna is shown.

Keywords: The human-body equivalent antenna induced current distribution

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 [1]. Furthermore, whole body resonance phenomena arise in VHF band (30-300 MHz) when the electric field is parallel to the human bodyȏs height and the wavelength is about twice the height of 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.

The whole-body resonant frequency is about 70 MHz for an adult human body in free space. The resonant frequency shifts to about 40 MHz due to the mirror effect when the human body stands on the ground [2], [3]. At the whole-body resonance for a human body who 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. So it is necessary to measure induced ankle current.

However the measurement methods for the induced ankle current have neither been established nor standardized. Furthermore, considering the ethical issues; for very high-field strength exposure we cannot use human subjects in measurements. Therefore, the use of a surrogate of a human body in measuring the induced ankle current for very high-strength exposure conditions becomes necessary. Although some human-body equivalent antennas have been proposed and developed. We focus attention on a liquid type human-body equivalent antenna [4].

We therefore propose a liquid type human-body equivalent antenna with improved induced current distribution. The NaCl solution was employed as a liquid for the antenna because it is easy to make and control its electrical properties. The developed antenna consists of several acrylic rectangular blocks which are filled with NaCl solution. The developed antenna is easy to manufacture and adjust electric properties. In this presentation, we demonstrate the design of the antenna based on the numerical simulations and the comparison with the numerical results and the measured.

2. Numerical analysis of human-model equivalent antenna

2.1 **Numerical human model and proposed antenna model**

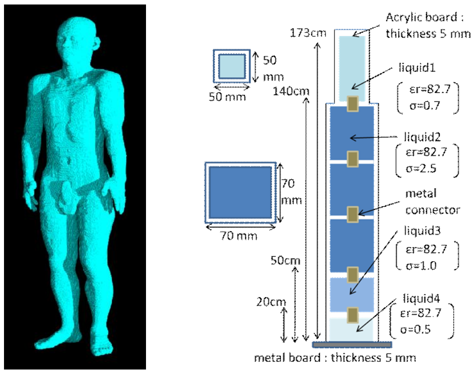

Figure 1: Realistic-shape human model of Japanese adult male (left),
The proposed human-body equivalent antenna (right)

Figure 1 shows realistic-shape heterogeneous human model of Japanese adult males of average height and weight [5]. The model consists of cubes with 2 mm on a side and is segmented into 51 anatomic regions. The electrical properties corresponding to the tissues are taken from different studies [6]. In this study, the induced current of the human-body equivalent antenna is compared with the reference value.

The human-body equivalent antenna, as shown Figure 1, is designed based on the numerical analysis that the induced current on conductivity and cross section area of the antenna.

2.2 **Calculation methods and conditions**

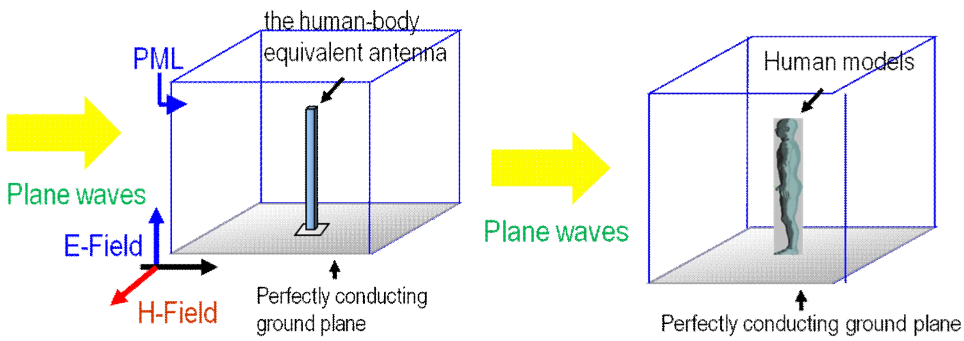

Figure 2: Calculation model of exposure to E-polarized plane wave.

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

Exposure to plane wave: Figure 2 shows a calculation model for exposure to E-polarized plane wave. The incident power density is 1 mW/cm^2, which is the reference level for occupational exposure to electromagnetic fields in the VHF band [1]. The realistic human model is also set at the same position of the human-body equivalent antenna shown in Figure 2. The cell size of the calculation region for the human-body equivalent antenna and the homogenous human model is 5×5×5 mm^2 and that for the heterogeneous human model is 2×2×2 mm^3. Perfectly-matched-layer (PML) boundary conditions (8 layers) [7] are employed as absorbing boundary conditions. The PML boundary conditions are set 200 mm apart from the nearest parts of models. A frequency is set at 40MHz which is the whole-body resonant frequency for a Japanese adult male on the ground. In this study, induced ankle current is calculated as

$$I(t) = \oint H \cdot ds \tag{1}$$

2.3 **Result**

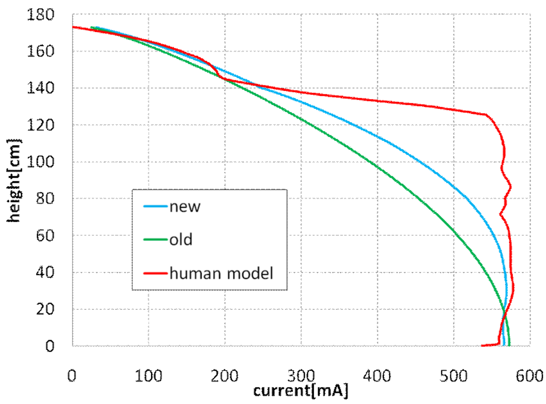

Figure 3: Induced current distribution of the human-body equivalent antennas and their corresponding human models at frequency of 40MHz.

Figure 3 shows that the induced current distribution of the antenna better with that of numerical human model than the previous antenna [8]. The model of the previous antenna is a rectangular acrylic case and used only one liquid. This result shows that the using several different liquid and changing cross section can improve an induced current distribution of the antenna.

3. Experimental validation using monopole antenna

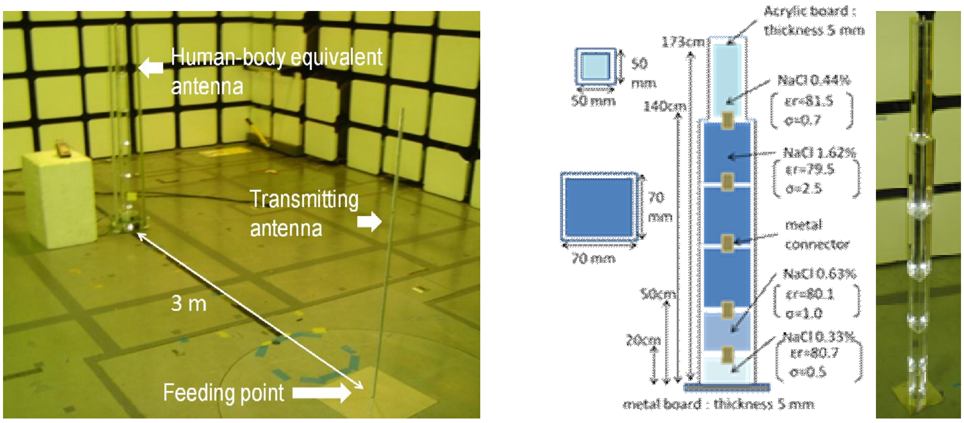

Figure 4: Measurement system (left), the human-body equivalent antenna (right)

In order to validate the performance of the proposed antennas, we carried out experiment when the equivalent antennas are exposed to electromagnetic fields from nearby monopole antenna. The measurement system is shown in Figure 4(left). The monopole antenna whose height is a resonant length (1577 mm) of 45 MHz is used as a transmitting antenna. The output power is 5 W. The induced currents were measured using clamp-type induced current meter, HI-3702, ETS-LINDGREN (9 kHz-70MHz). The human-body equivalent antenna is shown in Figure 4(right). The antenna is filled with four NaCl solutions different. The antenna is comprised of six antenna blocks. There are four kinds of antenna blocks and is made of acrylic and metal.

3.1 **Comparison with the numerical analysis and experiment**

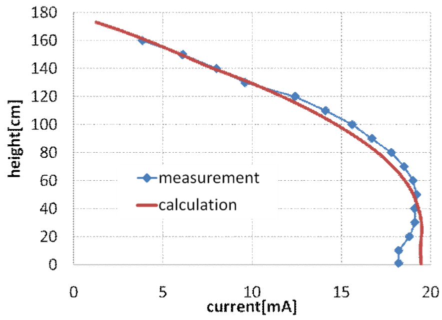

Figure 5: Calculation and measured values of the induced current of the human equivalent antenna exposed to the near-field of the monopole antenna.

Figure 5 shows the induced current distribution of the numerical result is good agreement with that of the experimental result. This result confirms the validity of the numerical assumptions used in this work and the performance of the proposed antenna

4. Conclusion

This paper has an investigation of the human-body equivalent antenna for estimation of the induced current. First, the human-body equivalent antenna was designed based on a result of the numerical analysis of the changed conductivity and cross section. The result of numerical analysis showed that the induced current distribution of the antenna better agreement with that of numerical human model than that of the previous antenna. Second, the validity of the numerical result verified by comparison with experimental result. Consequently, effectively of the proposed antenna is shown.

References

[1] ICNIRP Guidelines, ñGuidelines for limiting exposure to time-varyingelectric, magnetic and electromagnetic fields (up to 300GHz), Health Physics Society, vol. 74, no. 4 pp. 494ï 522,April 1998

[2] O. P. Gandhi, ñUse of the Finite-Difference Time-Domain Method for Calculating EM Absorption in Man Model, ò IEEE Trans. on Biomed. vol. 35, No. 3, pp.179-186, 1988.

[3] O. P. Gandhi, J.-Y. Chen and A. Riazi, òCurrents Induced in a Human Being for Plane-Wave Exposure Conditions 0-50 MHz and for RF Sealers,ò IEEE Trans. Biomed. Eng., 33, 8, pp.757-767, 1986.

[4] H. Takahashi et al, ñDEVELOPMENT OF A HUMA-BODY EQUIVALENT ANTENNA WITH TISSUE-EQUIVALENT LIQUIDò Abstract of BEMS, pp 292- 295, June . 2007

[5] T. Nagaoka et al, ñDevelopment of realistic high-resolution whole-body voxel models of Japanese adult males and femails of average height and weight, and application of models to radio-frequency electromagneticfield dosimetryò,Phys. Med. Biol.,vol. 49,pp. 1-15,2004.

[6] Gabriel S et al, ñThe dielectric properties of biological tissues: III.Parametric models for the dielectric spectrum of tissues,ò Phys. Med.Biol., vol. 41, pp. 2271-2293,1996.

[7] Berenger JP, ñA perfectly matched layer for the absorption of electromagnetic wavesò ,Journal of computational physics, pp.185-200,1994

[8] Y. Takahashi, T. Arima, P. Pongpaibool, S. Watanabe, and Toru Uno, ñDevelopment of a Liquid-Type Human-Body Equivalent Antenna UsingNaCl Solution,ò International Zurich Symposium on Electromagnetic Compatibility, BIO2-5, Sep, 2007