Application of Electromagnetic Simulation Techniques based on FDTD Method in Human Body Healthcare

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***Abstract*—In this study, the radiation efficiency of a dipole antenna inside human body is calculated from 300 MHz to 2 GHz to evaluate the transmission characteristics of electromagnetic wave propagating through human body. Simulation is completed mainly by the finite-different time domain (FDTD) method.**

***Keywords*—electromagnetic simulation techniques, FDTD, GPU, in-body antenna, radiation efficiency**

I. Introduction

Body-centric wireless communications (BCWCs) system is becoming more and more important in human body healthcare applications [1-4]. In-body communication means communications from the inside of body to the outside by using implantable devices. Generally, there is a limit on the size of the implantable devices, for example, a swallowable capsule endoscope has a maximum length of 20 mm and a maximum diameter of 10 mm [2], and it is considered that the transmitting power of antennas is extremely low caused by its physical size. The electric properties of the human body tissues and the propagation channels around the body extremely are depend on frequencies, it is necessary to choose an appropriate frequency band for individual applications in terms of radiation performance, which is a useful method for designing and optimizing the wireless communication system for in-body applications.

In this study, the radiation efficiency of a dipole antenna inside human body is calculated from 300 MHz to 2 GHz to evaluate the transmission characteristics of electromagnetic wave propagating through human body.

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II. Simulation Model

In the electromagnetic simulation, software SEMCAD X is used which is developed and provided by SPEAG [5]. The hardware accelerate GPU Tesla C2075 is used to improve the computing speed and reduce the calculation time. The simulation hardware is shown in Tab.1, and the simulation settings are shown in Tab.2.

The torso-shaped phantom is shown in Fig. 1, the phantom is filled with homogenous human body equivalent liquid. A *y*-polarized dipole antenna with the length of l_1=20 mm is placed inside the human body as the position of the stomach. The FDTD method is used with considering the dispersive effect of liquids. Fig. 2 shows the relative permittivity and the conductivity of the human body equivalent liquid which is similar to the muscle provided by S. Gabriel [6]. Two cases are calculated to compare with each other: dipole antenna with human body and dipole antenna without human body.

III. Results And Analysis

According to the view of conservation of energy, we can obtain

$$P_{in} = P_r + P_l \tag{1}$$

Here, P_{in} is the power delivered by the sources; P_r is the power radiated to the space; P_l is the power lost to heat in the volume whose definition is

$$P_l = \frac{1}{2}\int_V \sigma\left|\vec{E}\right|^2 dv \tag{2}$$

The definition of the radiation efficiency is

$$\eta_{rad} = \frac{P_r}{P_{in}} \tag{3}$$

TABLE I. SIMULATION HARDWARE

Hardware	Details	Numbers
CPU	Intel(R)Core(TM)i7-4820K@3.70GHz	×1
GPU	Tesla C2075	×1
Memory	32708 MB	

TABLE II. SIMULATION SETTINGS

Excitation	Broadband
Frequency band	0.3-2 GHz
Simulation time	100 periods
Boundary layers	13
Cell size	2 mm
Number of cells	31.27 M

Figure 3 shows the simulation results: in the case of without human torso-shaped phantom, the radiation efficiency is 0 dB in the frequency band, which means all the input power is radiated to the space; in the case of with human torso-shaped phantom, the radiation efficiency is around -40 dB, a local maximum of -34 dB is appeared in the frequency of 700 MHz, which is corresponding to the half-wavelength of the in-body dipole antenna. It is considered that below 700 MHz the radiation efficiency is decreased with the decrease of the frequency for the reason that the radiation efficiency of electrical small antenna is small; while above 700 MHz the radiation efficiency is decreased with the increase of the frequency for the reason that the conductivity loss of human body is increased with the increase of the frequency. It is shown that when the in-body antenna operating at the half-wavelength resonant frequency, the radiated power to the outside is relative large.

IV. CONDLUSION

In this study, the radiation efficiency of antennas inside human body is calculated from 300 MHz to 2 GHz to evaluate the transmission characteristics of electromagnetic wave propagating through human body. There is a local maximum at the half-wavelength resonant frequency.

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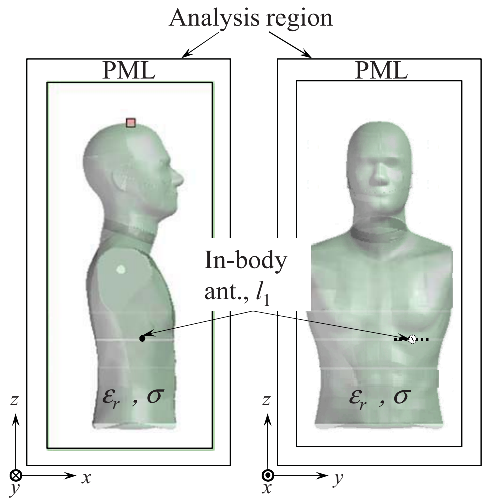

Fig. 1. Analysis model.

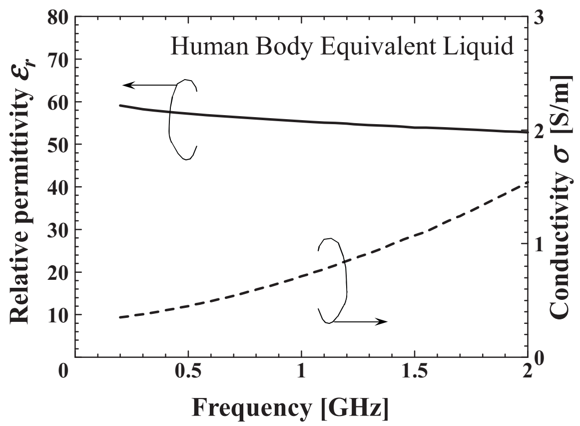

Fig. 2. Relative permittivity and conductivity of human body equivalent liquid.

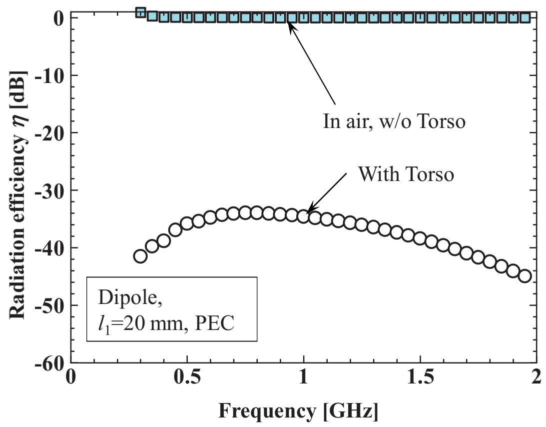

Fig. 3. Radiation efficiency of in-body antenna.