DETAIL DOSIMETRIC ASSESSMENT OF A HUMAN HEAD EXPOSED TO NEAR-FIELD OF VARIOUS SOURCES USING ADVANCED NUMERICAL HYBRID TECHNIQUES

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ABSTRACT

An investigation has been done for the dose characteristics in a human head exposed to the near field of various fundamental sources by the finite-difference time-domain (FDTD) method. It's shown that the dominant direction of the internal E- and H-field in the human head can be quite different in the case of the different source-type. To improve the approximation error of a helical antenna structure due to the Cartesian meshing, a hybrid method, which combines the FDTD and the method of moment (MoM) calculations, has been used. The obtained results will be compared with those by a conventional FDTD method.

INTRODUCTION

Explosive increase of cellular telephone users has caused public concerns with the health effect of the human head exposure to near field of a cellular telephone. In order to evaluate the health risk of the near-field exposure to the cellular telephone accurately, the World Health Organization (WHO) encourages strategic researches under the international harmonization. The International Agency of Research on Cancer (IARC) has recently begun the international epidemiological study between the brain tumor and the use of cellular telephones [1].

Most studies described above employ specific absorption rate (SAR) as a measure of the dose. However, the SAR values are not always an appropriate assessment factor when unknown health effects of the cellular telephone are caused by non-thermal mechanisms. Even if any non-thermal effects causing a significant health impact have not been established, the strength and the direction of the E- and H-field as well as the current density induced in the exposed head may be similarly important as SAR. It is therefore necessary to evaluate the exposure characteristic in terms of the various dose parameters.

It is also known that the dose of the human head exposed to the near field of a cellular telephone depends on various factors, such as frequency, modulation, type of the antenna, and shape and position of the handset [2, 3, 4]. Measurement methods of SAR in a human head exposed by a cellular telephone using a homogeneous head phantom and a small isotropic E-field probe, have been standardized internationally. Using these standard measurement methods, the statistical data of the exposure levels by various types of cellular telephones, can be obtained. In Japan, it is reported in a survey of 76 Japanese cellular telephones, that two different antenna settings (retracted or extended) yield 2dB statistical difference of the maximum local SAR. When the antenna is retracted, the helical portion works as a main radiator. On the other hand, when the antenna is extended, the wire portion works primarily as a radiator. This suggests that various antennas may cause the significant difference in the dose characteristics.

It is our aim to investigate numerically such dose characteristics in a human head exposed to the near field of some fundamental sources. For this numerical calculation, one may utilize the FDTD method in which anatomically-based numerical head models can be easily implemented. In this paper, we shall present the numerical results by the FDTD method for fundamental sources (Half wavelength dipole, Infinitesimal electric dipole, and Infinitesimal magnetic dipole), and compare the SAR, the electric field, the magnetic field, and the current density distributions excited by three sources.

SIMULATION MODELING

The FDTD is one of the powerful numerical methods and it can be used for evaluating various scattering/radiation field distributions. In our calculation, the FDTD voxel size is chosen as $2 \times 2 \times 2$ [mm], and the calculation region is $148 \times 159 \times 158$ [cells] with second-order approximations of Mur's absorbing boundary condition. Three fundamental sources are used here for comparison. A half wavelength dipole serves as a reference antenna. An infinitesimal electric dipole may be considered as a typical wire antenna tip, while an infinitesimal magnetic dipole is used to simulate a helical antenna of a retracted cellular handset. These sources are located at the distance of 6 mm from the temporal surface of the head and are oriented along the Z direction. The operational frequency is assumed as 900 MHz. As a heterogeneous numerical human head model, we choose the one, with 25 tissue types, based on Visual Human Project and developed by the U.S. Air Force [5] (see Fig. 1).

RESULTS AND DISCUSSIONS

Let us show some cross-sectional distributions in the human head exposed to the near field of three different sources. In the following figures, the distribution is shown in XY plane containing the feed point (Z=98th cell). The numerically calculated values in the human head are first normalized by its peak value independently, and coloring is made in logarithmic scale. Accordingly, those figures show relative distribution.

Figure 2 shows the SAR distribution described above. While the peak SAR position is located at the same point (nearest phantom surface to the feed) for all three cases as one naturally expects, each distribution pattern is rather different. Illumination by a half wavelength dipole (Fig. 2(a)) causes somewhat broader SAR distribution than the other two cases.

The distributions of the internal E- and H-field, and the current density in the human head model are shown in Figs. 3, 4, and 5, respectively. In these figures, we also show each X, Y and Z component of the field/current as well as the total values. No significant difference in the distributions has been found between results by the half wavelength dipole and the infinitesimal electric dipole. The dominant components of the E-field and the current density are those parallel to the Z axis while the dominant component of the H-field is the one parallel to the Y axis. On the other hand, the dose characteristics by the infinitesimal magnetic dipole are pretty different from the other sources. The dominant components are interchanged from the previous case.

Since above results show that the dominant directions of E-field and of H-field are opposite to each other, the internal E-field as well as current density and SAR are mainly caused by the internal H-field. It is also suggested that because the H-field within non-magnetic human tissues is almost same as the incident H-field, the internal electromagnetic fields are closely related with the near field of those simple sources. It should be noted, however, that the dose characteristics of actual source models are not cleared yet since simple source models are assumed in the above calculation. If one can calculate the detailed dose characteristics of human head exposed by more realistic/complex-shape antennas, the result would be useful to understand the possible non-thermal effects. For example, the direction of the E- and H-field may play an important role for possible resonance phenomena. Although the FDTD method has been applied to the complicated antenna geometries [6, 7, 8], substantial errors might occur in the numerical results. In order to overcome this deficiency, hybrid method such as the FDTD/MOM method [9] could be used. Some numerical results by a conventional FDTD algorithm and a hybrid numerical technique will be shown for the helical antennas in the presentation.

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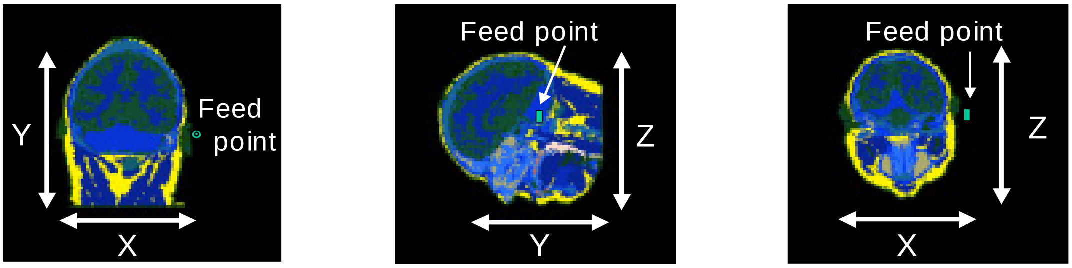
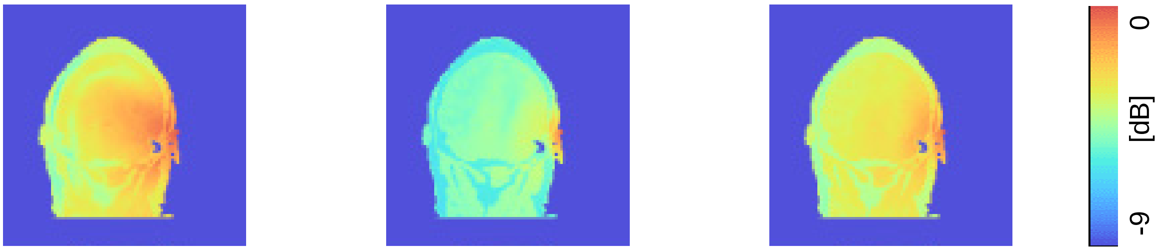


(a) XY-plane : Z=98th cell (b) YZ-plane : X=74th cell (c) ZX-plane : Y=85th cell

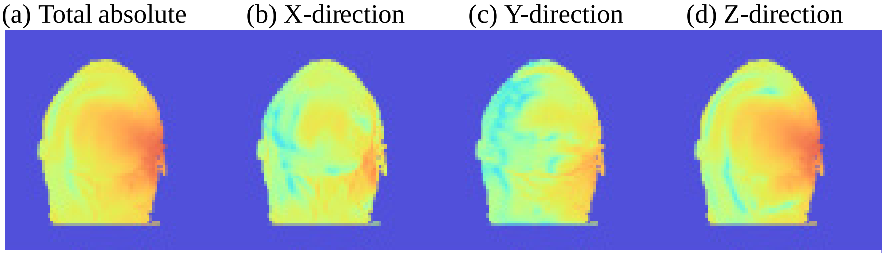
Figure 1: Numerical head model.



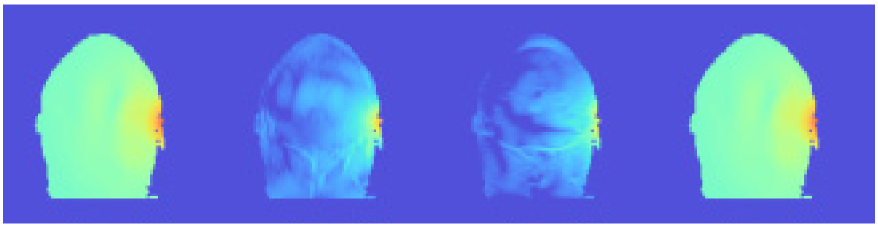
(a) Half wavelength dipole (b) Infinitesimal electric dipole (c) Infinitesimal magnetic dipole

Figure 2: Relative SAR distribution. Log scale. XY-plane. Feed in Z-direction.

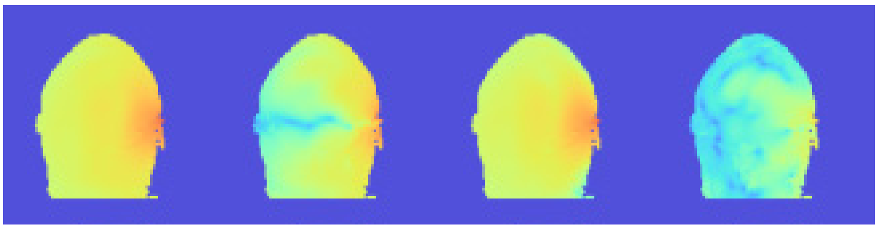
(a) Total absolute (b) X-direction (c) Y-direction (d) Z-direction



Half wavelength dipole.



Infinitesimal electric dipole.



Infinitesimal magnetic dipole.

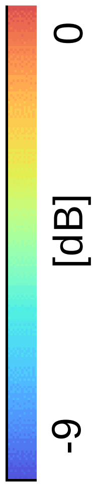


Figure 3: E-field distribution. Log scale. XY-plane. Feed in Z-direction.

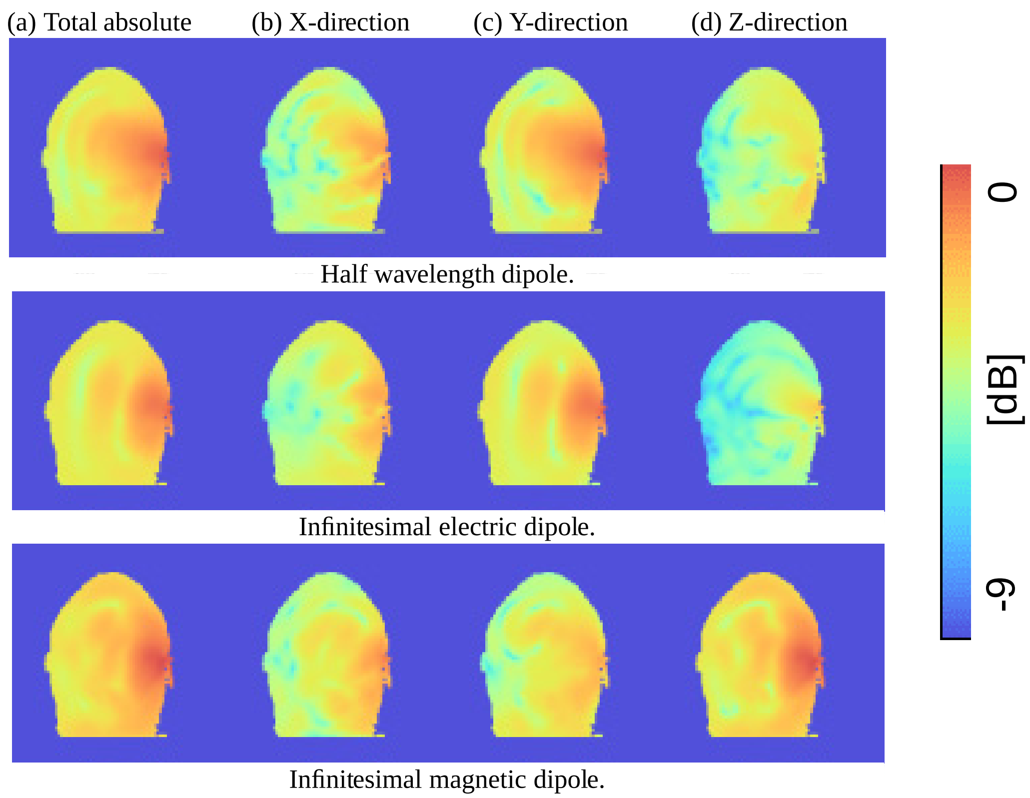


Figure 4: H-field distribution. Log scale. XY-plane. Feed in Z-direction.

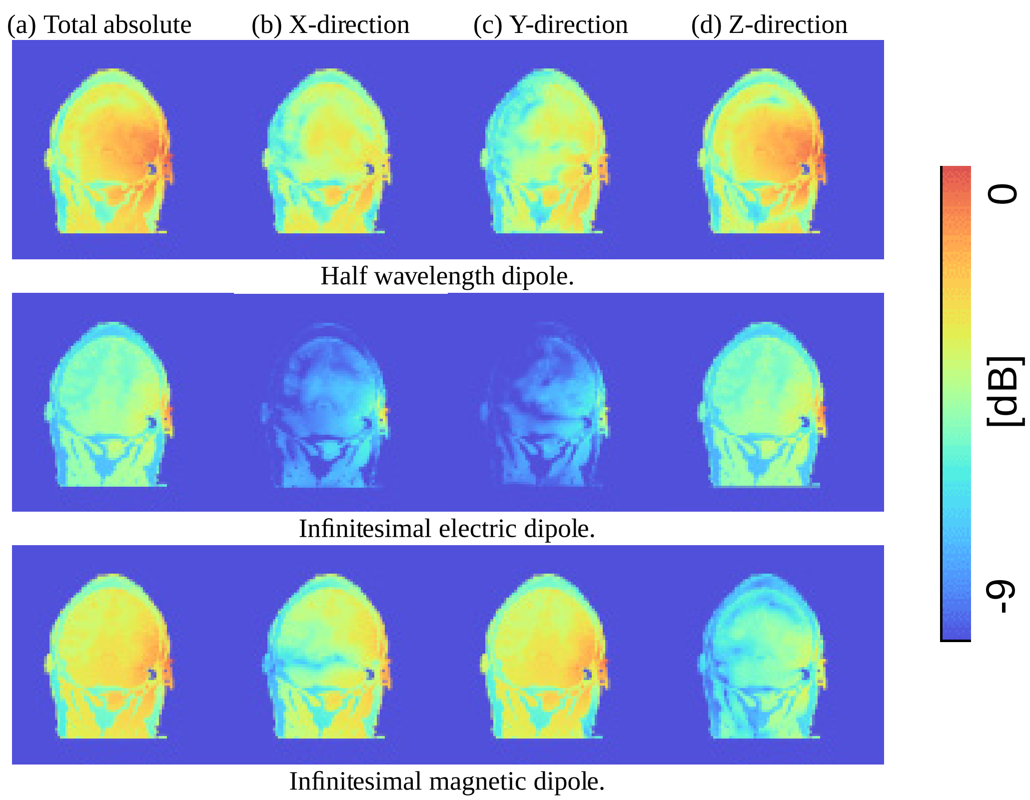


Figure 5: Current density distribution. Log scale. XY-plane. Feed in Z-direction