MODELING OF INTERACTION OF ELECTROMAGNETIC FIELDS FROM A CELLULAR TELEPHONE WITH HEARING AIDS

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Abstract

The use of digital modulation in the new generation of cellular telephones and other personal communication services (PCS) poses new problems and challenges in interactions with the human body. Among them is electromagnetic interference (EMI) with medical devices. We have evaluated the electric and magnetic fields in the ear canal at 900 MHz for a typical monopole antenna on a metallic handset, an equivalent dipole and a plane wave using the FDTD method. The results are of importance and used in developing performance standards and practical testing methods for various types of hearing aids.

Introduction

A number of studies have shown that digital telephones and other PCS devices disrupt the proper operation of hearing aids due to the electromagnetic interference (EMI). Evaluation of EMI can be done experimentally and protocols for testing are being developed, e.g. in the Center for Devices and Radiological Health, FDA (M. Skopec and H. L. Bassen, personal communication). However, the experimental test procedures can be greatly simplified, if the levels of the electric and magnetic fields in the ear at the location of specific types of the hearing aids are known. Furthermore, it would be beneficial if for testing purposes a plane wave could be used, and the results could be scaled for various near field sources.

In this work, we used the finite-difference time-domain method (FDTD) to compute the electric and magnetic fields behind the ear and in the ear canal, as relevant to the in-the-ear and the completely in-canal type of hearing aids.

Models and Methods of Analysis

An anatomically correct model of the human head comprising some 20 tissues was used. A particular attention was paid to the correctness to the anatomy of the outer and inner ear. The head model was based on the image segmentation of the CT and MRI scans [1] with additional manual corrections of the reconstructed anatomy as required. The model resolution was 1.1 mm. For the modeling of the fields in the ear canal we developed a guiding tool (the so-called "electronic worm") that allowed us to find automatically, locations in the center of the ear canal. This was essential, as otherwise it would have been tedious and unreliable to find the points at which the fields were relevant to the problem investigated.

The FDTD method was used for the analysis because of its flexibility and efficiency in solving complex heterogeneous geometries. The Yee-cell rectangular computational grid [2] and the total-field formulation [3] were used. The computational space was truncated by a perfectly matched layer (PML) [4] of 7 cell thickness with a parabolic profile to ensure reflections below at least 40 dB. Two mesh sizes were used; 3.4 mm everywhere except the volume surrounding the ear, where 1.7 mm was used. The fine resolution was obtained with a subgridding algorithm [5].

A special automatic algorithm was also used to handle dielectric objects with shapes and/or voxels that do not coincide with the FDTD mesh. This algorithm was based on the field-continuity conditions and the integral form of Maxwell's equations in a sub-cell regime. Using fast integration and logical functions the weighted flux averages were computed and look-up tables of the dielectric constant and conductivity were assembled for each field component separately.

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This algorithm increased the accuracy of computations. In the cases where the metal surfaces did not coincide with the mesh, an algorithm was used that allows for accurate treatment of fields near these surfaces [6]. Computations were performed on a Hewlett-Packard workstation HP9000/735.

Results of Modeling

Computations were performed at 900 MHz for a plane wave, a dipole and a monopole on a dielectric insulated metal box representative of a cellular telephone. One important general finding, characteristic of all three sources investigated, is that the electric field in the ear canal is quickly attenuated. Similar exponential profiles are obtained for all three exposures investigated with slower attenuation for the plane wave, as illustrated in Fig. 1. The magnetic field has a significant penetration into the ear canal and develops a standing wave-like pattern. There are considerable differences in the profile of the magnetic field in the ear canal between the three exposures, as illustrated in Fig. 2. The dependence of the fields on the distance for the dipole and monopole was also investigated. Scaling coefficients for comparison of the internal fields for plane wave exposures and those from the monopole and dipole have been derived. The finding that the magnetic field is much less attenuated than the electric field is important, as hearing aids have coils that are directly susceptible to this field.

References

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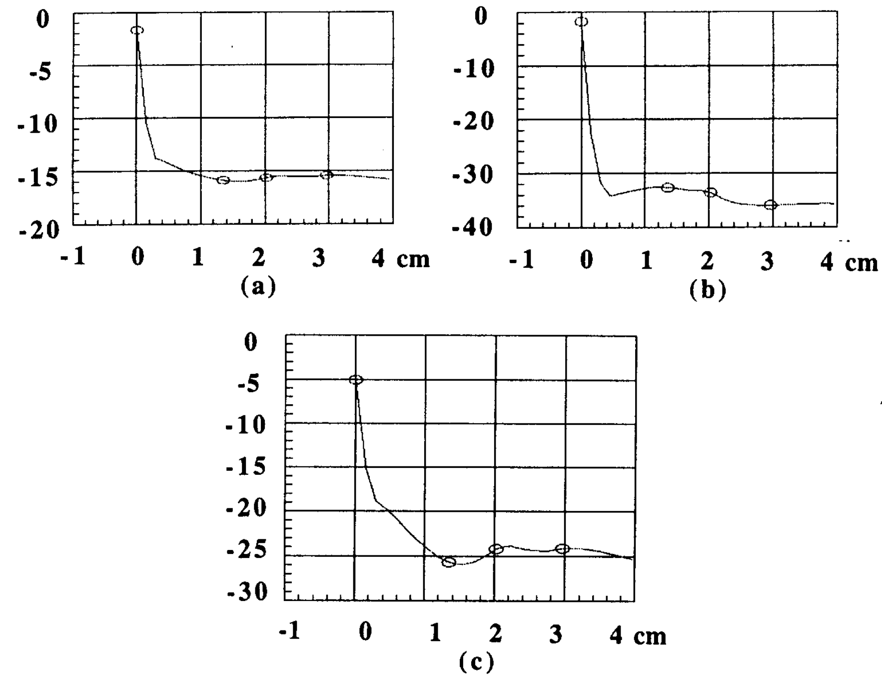

Fig. 1 Normalized total electric field in the ear canal as a function of distance from the canal entrance: (a) plane wave, (b) dipole, and (c) monopole on the handset.

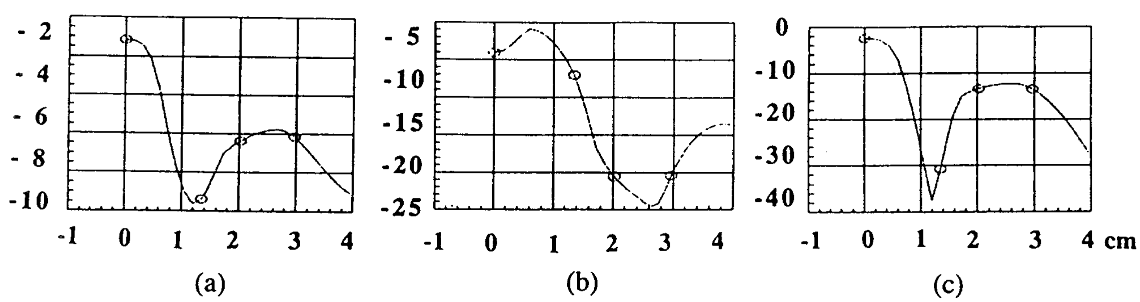

Fig. 2 Normalized total magnetic field in the ear canal as a function of distance from the canal entrance: (a) plane wave, (b) dipole, and (c) monopole on the handset.

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