ACCURACY STUDY OF FDTD CALCULATIONS OF A DIPOLE ANTENNA IRRADIATING A LOSSY SPHERE

W. Heyvaert, N. Ilijasevic, and L. Martens

INTEC, University of Gent, Sint-Pietersnieuwstraat 41, 9000 Gent, Belgium
tel.:+32 9 264 3333, fax:+32 264 3593, e-mail:martens@intec.rug.ac.be

ABSTRACT

An accuracy study of electromagnetic calculations for the determination of fields inside the human head of the user of mobile telephone has been performed. Because of the simplicity of the set-up we used a dipole antenna as radiator and a homogeneous lossy sphere as absorber of the fields. Even in this case we found that grid sizes of maximal 2.5 mm are needed for accurate SAR calculations. The effect of the antenna model and of the uncertainty of dielectric properties has also been studied.

INTRODUCTION

There are many concerns about the health effects produced by the electromagnetic fields of mobile telephones. Safety limits have been proposed by standardization organizations such as CENELEC and IRPA. For mobile telephones the Specific Absorption Rate (SAR) in the head of the user is the quantity to be determined. Electromagnetic calculation is a candidate for certification of mobile telephones with respect to the limits proposed for the SAR averaged over a certain weight of tissue (e.g. 10 g) and over a time interval (e.g. 6 minutes).

Today, many laboratories through the world investigate the electromagnetic calculation of the fields in the human head irradiated by a mobile telephone. This is however a very complicated problem due to the complex inhomogeneous geometry of the head and of the mobile telephone. Moreover, the head is in the near-field of the mobile telephone. The near-field is very sensitive to the details of the mobile telephone and the head. Many calculations of the fields of the mobile telephone with complex models of the human head have been done by several authors e.g. [1]. The accuracy of these calculations has never been reported. This is however a prerequisite if one wants to compare the calculated fields with the proposed safety limits. In this paper, we present a study of different parameters that determine the accuracy of the electromagnetic calculations. As modeling tools we used the Finite Difference Time Domain (FDTD) method and the Method of Moments (MoM) (only used for simulating the antenna in free space).

MEASUREMENT SET-UP

We have selected a dipole antenna irradiating a half sphere at 900 MHz (GSM frequency) as canonical case and built up the measurement set-up of figure 1 to compare simulated results with measured ones. The set-up essentially consists of the dipole antenna (length 15 cm, radius 1.82 mm, gap width 2.5 mm), a half sphere filled with liquid with electrical parameters σ=0.83 S/m and ε=43 at 900 MHz,

0-7803-4471-5/98/$10.00 (c) 1998 IEEE

an electric field probe and a robot for scanning the fields in the half sphere.

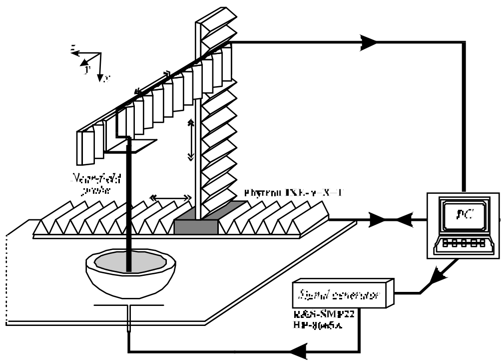

Figure 1. Set-up for measurement of SAR distribution in the half-sphere irradiated by a dipole antenna.

The exact dimensions and positions of the half sphere and dipole antenna are shown in figure 2. All values of the SAR are related to a 2 W power radiated by the dipole antenna (equal to the power of a GSM mobile telephone). All results are shown on a line perpendicular to the antenna and going through the center of the gap and in a plane defined by a line perpendicular to the antenna and the dipole antenna.

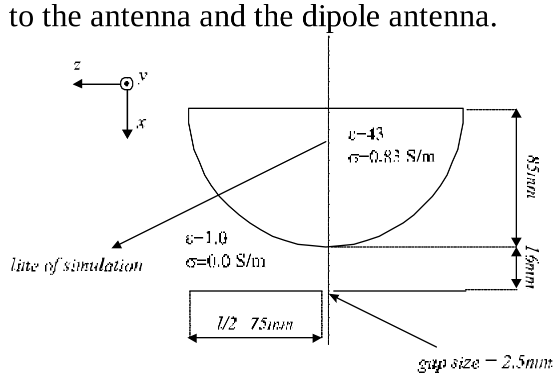

Figure 2. Dimensions and positions of half sphere and the dipole antenna in the measurement set-up.

RESULTS

First of all simulations are done in free space. We performed a study of the cell size used for the FDTD-simulations. We found that it is important to exactly simulate the gap width equal to 2.5 mm. As we used one cell for the gap, the grid size along the antenna dz was set to 2.5 mm. dx=dy was changed from 4 mm to 2 mm and to 1 mm. We found that these grid dimensions were not that important in free space for distances larger than 10 mm as shown in figure 3. We found a good convergence of all three results. However in the lossy sphere dx and dy are much more important.

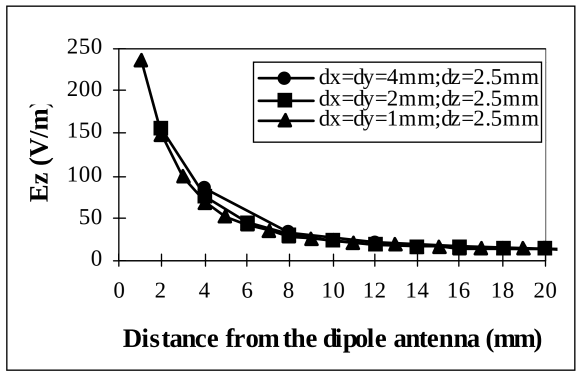

Figure 3. Comparison of FDTD results in free space using three different grid sizes.

We also compared the results to the MoM calculations and measurements with a loop antenna.

As shown in figure 4 we find excellent agreement between measurements and the two simulations at a distance of 1 cm or more.

Closer than 9 mm to the antenna no measurements are available due to the size of the loop antenna (radius 4.5 mm).

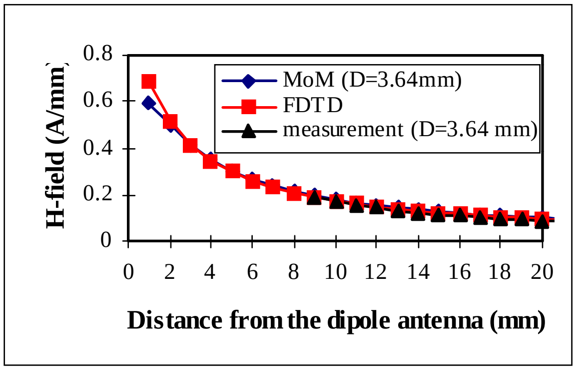

Figure 4. Comparison of MoM results, FDTD results (dx=dy=1 mm; dz=2.5 mm) and measurement in free space.

We found larger differences between the MoM and FDTD calculations close to the antenna mainly due to differences in the exact antenna configurations in both tools. In the FDTD-calculations we used the square antenna approximation while the MoM calculations can handle the exact form of the circular antenna.
The SAR was also calculated for different grid sizes. We only found results with acceptable accuracy when a grid of dx=dy=2 mm (or less) was used. Comparison of the SAR for different grid size cells is shown on figure 5.

Results here show that it is important to use a smaller grid, because the variation of the maximum value of the SAR going from 4 mm grid size to 1 mm grid size is approximately 13%. The SAR values are averaged over 6 minutes (the dipole antenna is powered over 1/8 of the time such as in GSM with a peak radiated power of 2 W).

We also made a study on the influence of the electrical parameters ε and σ to the results.

As the SAR is proportional to σ, this parameter has the largest influence on the variations of the SAR.

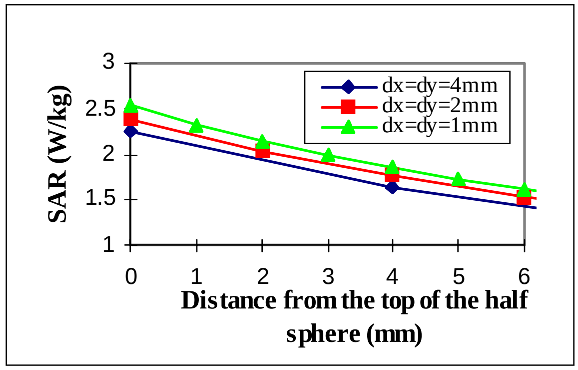

Figure 5. Comparison of the SAR in the half sphere using different grid size (dz=2.5 mm).

Changes of ε do not influence the final result of SAR. Variation of σ over 10% results in approximately same variations of the SAR. The averaged maximum value of the SAR over 10 g of tissue and 6 minutes is calculated for dx=dy=1 mm; dz=2.5 mm grid and is 1.48 W/kg. This value is acceptable with respect to the normative references proposed by CENELEC (2 W/kg for the general population and 10 W/kg for workers). However the situation given here is not the real situation (we are using a dipole antenna, instead of the mobile phone).

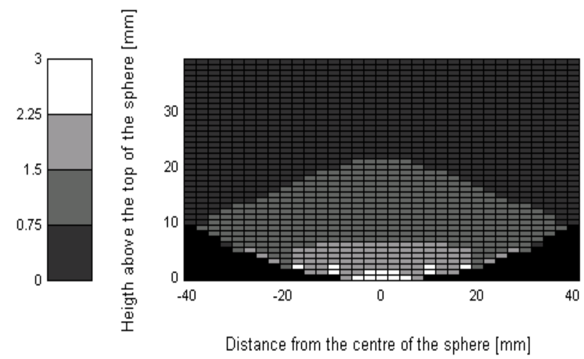

Figure 6. SAR (W/kg) distribution in a central plane through the antenna (dx=dy=1 mm; dz=2.5 mm).

Figure 6 shows SAR distribution in a central plane through the antenna and the center of the half sphere.

Comparison between the measurement and the simulation is given in figure 7.

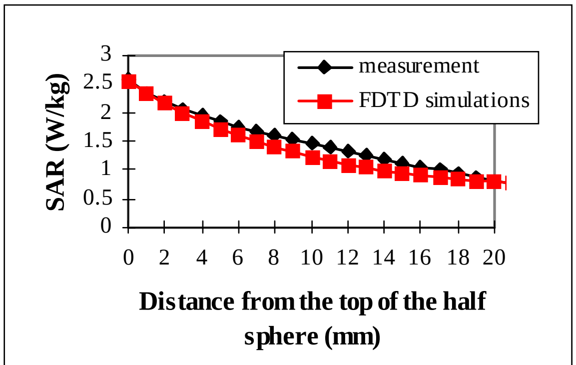

Figure 7. Comparison between measurement and FDTD simulation (dx=dy=1 mm; dz=2.5 mm).

Results show that the simulation and the measurement deliver nearly equal values for the maximum value of SAR at the top of the sphere. Going further away from the top of the sphere, we find differences that are due to small differences in the measurement set-up and simulated set-up. The antenna geometry in the simulation and in the measurements is not perfectly equal. The dielectric properties also may differ slightly. The stair-case approximation of the sphere in the simulations may also contribute to the differences.

The reported results already show that the accuracy of the modeling method for calculation of electromagnetic fields in the simple configurations must be carefully investigated. A procedure is needed to verify the accuracy of the tools. Canonical cases can help for this verification.

Reference

[1] L. Martens, J. De Moerloose, D. De Zutter, J. De Poorter, C. De Wagter, Calculation of the electromagnetic fields induced in the head of an operator of a cordless telephone," Radio Science, vol. 30, no. 1, pp. 283-290, Jan. - Feb.1995