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Dosimetry at GSM Frequencies

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ABSTRACT

The purpose of this paper is to calculate the specific absorption rat (SAR) distribution in a human head exposed to electromagnetic field emitted from a handheld cellular phone operating in the 900 MHz and 1800 MHz rang in a partially closed environment. The HFSS code has been used to evaluate the SAR in realistic anatomically based model of the human head for different antenna-head distances.

Key words : SAR, GSM, HFSS, Human head, FDTD, Dipole antenna.

1. INTRODUCTION

When electromagnetic waves hit a biological tissue, the wave is absorbed, refracted and diffracted. The physical modification of matter after interaction can have a biological effect. Thus, the microwave heating of tissue, constituted in great part of water, causes a damage of the tissue if the temperature elevation is too intense or prolonged [1]. The interaction depends on the dielectric matter properties (conductivity and permittivity) and the rate between the wave-length and tissue dimensions [2-3].

In practice, characteristics of the heat effect are evaluated by the absorbed electric power per units mass in the tissue, i.e., the specific absorption rate (SAR) (in watts per kilogram). The local 1-or 10-g average SAR has been used for the primary dosimetric parameter of the electromagnetic waves' exposure [4]. These SARs are generally estimated from numerical simulation [5] and experimental evaluation based on the E-field and thermal measurement [6-9].

In this paper, we present the simulation results of this interaction permitted to analysis the absorption of RF energy in the biological tissue in the case of the cell phones. The Ansoft HFSS method with boundary conditions and assigned excitations by an antenna dipole (0.5λ) is used as the cell phone. The human head is simulated by HFSS at GSM frequencies 900 MHz and 1800 MHz.

2. USED METHOD AND MODELLING

Two models used for the human head were. The first model was a sphere consisting entirely of material with the electric properties of brain-equivalent tissue with parameters εr and σ (figure1).

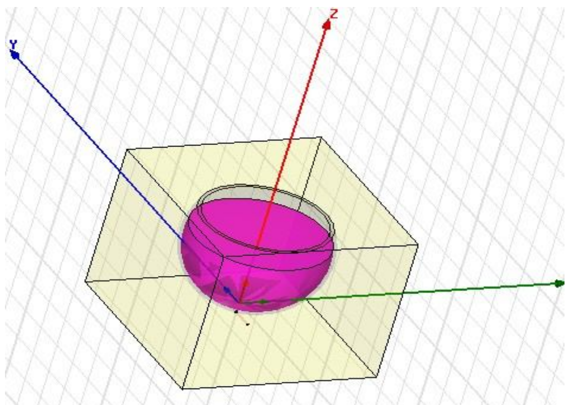


Figure 1: Homogeneous sphere with cylindrical boundary conditions

The sphere is irradiated by a dipole antenna of length 2L (L depends on the frequency) with a gap width δ of 1 mm located at different distance from the sphere. The conducting medium is surround by a no conducting glass shell with at thickness of 5 mm and dielectric constant εr =4.6 representing the recipient of the brain-equivalent liquid in testing situations. The radiated power of the dipole in presence of the sphere is 1W (continuous-wave mode). The second model comprised three layers are considered. The spherical model had a uniform content at its core (representing the human brain) and the core was surround by two spherical shells representing the skull (bone) and the muscle and the skin(skin) with their respective electromagnetic properties (figure 2). The properties of the materials used in the simulations are presented in table 1 [10].

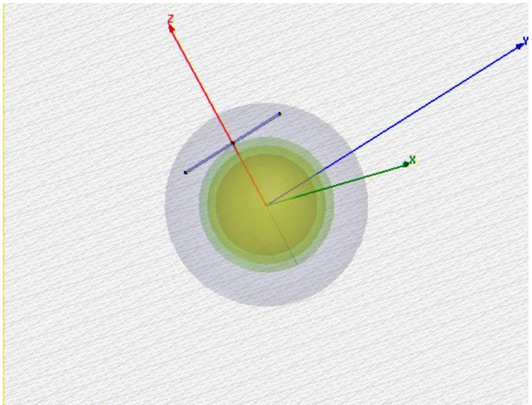


Figure 2: Layered sphere

Table 1: The properties of the materials used in the simulations

Material	900 MHZ ε	900 MHZ σ	1800 MHZ ε	1800 MHZ σ	Mass Density ρ (Kg/m^3)
Skin	39.5	0.7	38.2	0.9	1080
Bone	12.5	0.17	12.0	0.29	1180
Brain (cortical)	56.8	1.1	51.8	1.5	1050
Dielectric phone cover	2.7	0.0016	2.7	0.003	-

The distribution of the local SAR values can be calculated directly from the electric field distribution, which results from the HFSS code. The rate at which the energy is absorbed in tissue par unit mass is called the specific absorption rate (SAR) (W/kg):

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{\sigma.|E|^2}{2\rho}$$

Where E is the total electric field in V/m, σ is the conductivity in mhos/m, and ρ the density of the tissue in kg/m3 (this is usually given in units of g/cm3), e.g., for water, ρ=1g/cm3). SAR is calculated as a function of position from the estimates of local fields and tissues properties. An integral of SAR over a volume of tissue containing a given mass gives the absorbed power. This is typically expressed in units of mW/g, or mW/cm3 (for a given tissue density) averaged over 1 g of tissue.

3. FDTD COMPUTATIONS

The spherical bowl and the dipole were modelled in a cubical FDTD grid [11] with grid step equal to 2.5 mm, as shown in Figure 3. This grid step was chosen as suitable for computing distances 5, 25 and 50 mm between the bowl and the antenna but also giving moderate modelling errors for the dimensions of both structures. Obviously, in order to have a symmetrical antenna, the length of the antenna model is always an odd number of cells and therefore the diameter of the bowl also has to be an odd number of cells if the antenna is to be placed in a true centred position below the bowl. This requires though that the antenna is modelled as a bar of cells rather than by a thin filament of FDTD components if the models are to be symmetrical also in the plane perpendicular to the antenna axis. However, when modelling the case with a asymmetrically positioned antenna the tip of the dipole is not possible to placed directly under the outer south pole but it will be a half grid step offset from this position. The FDTD components in the glass-liquid boundary, i.e. on the inside of the bowl, were computed with the material parameters set equal to those for the liquid since the pyrex glass has a zero conductivity. In the 2.5 mm grid, the bowl has an outer diameter of 89 cells, i.e. 222.5 mm, and an inner diameter of 85 cells, i.e. 212.5 mm. The antenna is represented by two bars each 33 cells long with a one by one cell cross section giving an overall length, including the voltage source gap, of 67 cells or 167.5 mm.

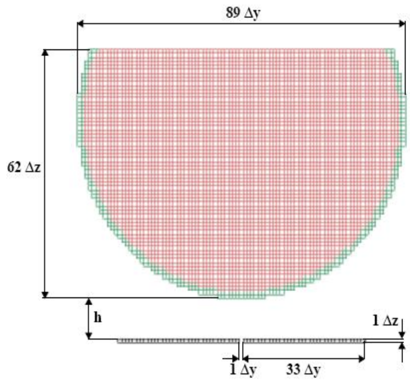


Figure 3: The dimensions of the FDTD models. The separation h between the bowl and the dipole, was 2, 10 and 20 cells corresponding to distances 5, 25 and 50 mm

The bowl and the half wave dipole were placed in the FDTD grid with a minimum distance to the Liao boundary of l/3 giving a total computational volume of 165x165x165 cells for the computations with the dipole in a cantered position and 165x190x165 cells for the case when it was placed asymmetrically.

4. RESULTS

The spherical phantom is a glass bowl with an opening at it northern hemisphere. The opening allows a probe to move within the liquid. It has been determined that the opening does not alter the fields in the southern hemisphere: Inner radius = 106.5±5mm, thickness = 5±0.5mm, opening =d2=170mm and εr =4.6. At 900 MHz, the first model (homogeneous sphere), the conducting medium has an εr of 41.5 and a σ=0.97 S/m. The Inner radius=106.5±5mm, thickness =5±0.5mm, opening =d2=170mm. The following liquid dielectric properties were measured are: ε_r=43.32 ±5%,σ=0.862±10%,ρ=1.33 kg/m3 (For the SAR evaluations, the density will be assumed to be 1 kg/m3),Level = d1 = 13.4 cm. The gap between dipoles = 1mm and wire diameter = 3.6mm. The length *L* of on arm of the antenna is 74 mm. At 1800 MHz, the conducting medium has an ε_r of 40.5 and a σ=1.40 S/m. The length *L* of on arm of the antenna is 35.5 mm. The figure 4 gives the local and average SAR variation in the first model. Figure 5 gives the distribution of SAR in the second model (layered sphere: Brain (60mm), Bone (70mm), and Skin (80mm)). The HFSS evaluation method of the local and average SAR is based on distribution on the Electric field. These SARs are calculated when depth *d* varied and normalized to maximal value. Notice that the SAR is higher in homogeneous head phantoms than in nonhomogeneous.

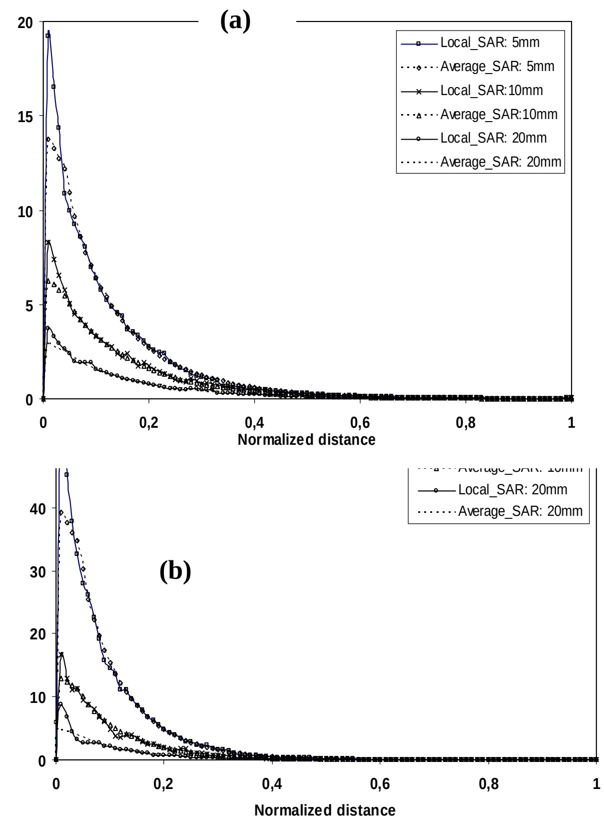
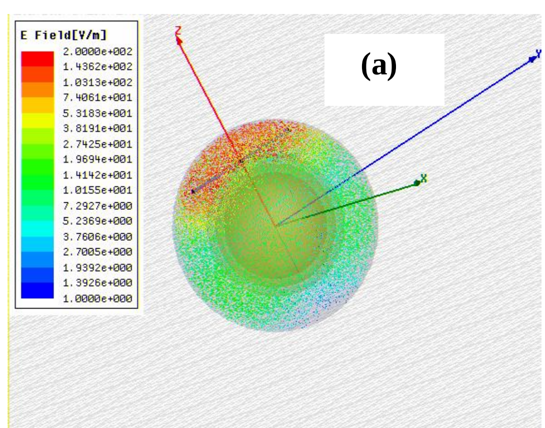


Figure 4: Local and average SAR variation, at different antenna-head distances:
(a) 900 MHz
(b) 1800 MHz



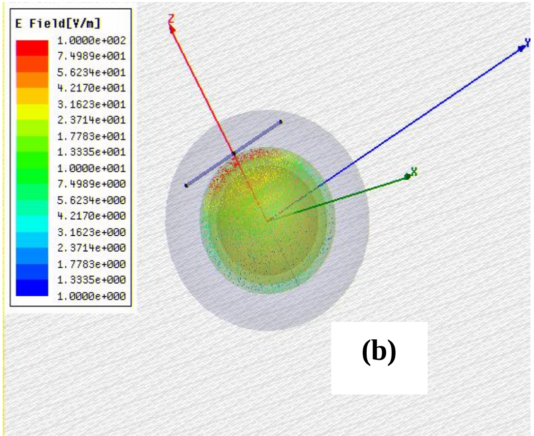


Figure 5: SAR distribution in phantom as layered sphere:
(a) Brain (60mm), Bone (70mm) and Skin (80mm), f=900 MHz, antenna at 10mm
(b) Skin (60 mm), f=1.8 GHz, antenna at 10 mm

We note that the level of the SAR has important values if the antenna is too close to the sphere (the head) and poor when it is a bit far. If we increase the frequency of 900 MHz to 1800 MHz, the SAR value increases.

We note that the highest level of SAR is in the muscle. So, it absorbs more radiation than the other layers. As for absorption in the bone, it is almost zero. Concerning the brain, it absorbs a lot of radiation, but since it is a bit far from the radiation source and the wave is degraded through the skin, muscle and bone, it absorbs less. So these layers somewhat protect the brain.

In order to properly compare the measured, the FDTD computed SAR distributions in the bowl, and the HFSS simulation, the FDTD values had to be calculated by averaging over several computational cells and E-field components [12-13]. All SAR values were normalized to 1W of radiated power. The FDTD computed local SAR on the axis of symmetry in the spherical bowl when the antenna was placed symmetrically below it is shown in Figure 6.

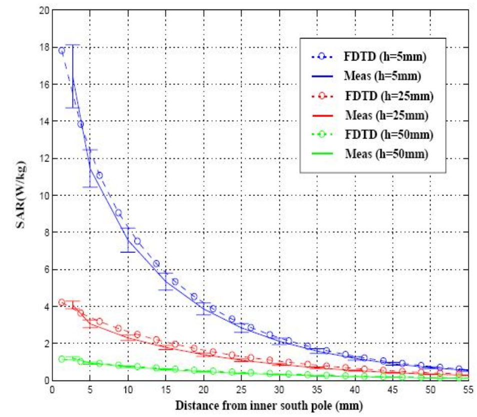


Figure 6: FDTD computed SAR on the axis of symmetry for the spherical bowl. (Dipole was placed as centred 5, 25 and 50 mm below the outer south pole)

5. CONCLUSION

In conclusion, the important parameters affecting the absorbed energy in the human head exposed to cellular phone radiation were the type antenna considered at the given frequency (900 MHz or 1800 MHz) and the distance between head and antenna. The feature of this study will be interested to a no homogeneous phantom radiated by patch antenna.

Numerical modelling of human head-cellular phone is a very important problem. The importance of the problem has just been re-evaluated in a special session of an IEEE AP-S conference [14], where the most recent studies of the well-known groups were presented and discussed. In that conference, the points listed below were especially mentioned by all of the researches:

- There is a great demand to build a canonical head, hand, neck and phone models, where the results of all the algorithms may then be compared on the same platform.

- Since it does not account for the tissue dosimetry, the FDTD based SAR calculations should be evaluated in connection with the medical research society.

- Accuracy of these numerical simulations strongly depends on the reliability of electrical parameters of the tissues. Therefore, parallel studies should be continued with groups who conduct measurement researches.

- Finally, long term measurements, simulations and statistical evaluations should be done before making any declarations related to public health and safety.

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