DETERMINATION OF ELECTROMAGNETIC FIELD ABSORPTION IN A HUMAN HEAD MODEL PRODUCED BY DIFFERENT TYPES OF ANTENNAS USED IN CELL PHONES

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***Abstract**: The development of recent sources of electromagnetic fields used for individual, industrial, commercial or medical purposes brought with it concerns about the possible health risks associated with their use. The manifestation of these concerns focused on the evaluation of risk associated with using mobile phone, long living in the vicinity of power lines and use of portable installation for police RADARS. To determine the absorption of the electromagnetic field by the human body can use three types of methods of investigation: the experimental, analytical and numerical methods. Experimental methods consume much time and sometimes the results are subject to hazard and do not allow much flexibility in changing parameters. Field evaluation lead to accurate solutions by using analytical methods or to approximate solutions by numerical methods. But to get the correct results these methods should be combined as without experiments we can not validate any theory.*

***Keywords**: human head, SEMCAD, FDTD, mobile phones, SAR..*

1. INTRODUCTION

In order to calculate the dose of electromagnetic field induced by a cell phone in a head model we should consider the following elements: the mathematic method used to perform modeling, depend on the available computing facilities; according to the latter element it is necessary to partition the geometric domain represented by the human skull; the geometry of the emission antenna: monopoly, dipole, helical, internal, or other configurations; the relationship between the skull size and emission frequency of the device; the geometrical characteristics of the human head and the dielectric properties of various fields which compose it.

2. USING FINITE DIFFERENCE TIME DOMAIN METHOD (FDTD) FOR DETERMINING DOSIMETRY

FDTD method was the first time introduced by Yee, and then developed by Taflove and others. Finite difference method essentially consists of replacing the differential equations in finite difference equations. The method involves the following steps:

- meshing the spatial region in a network of nodes / cells (grid);
- approximating the differential equations with finite difference equations;
- solving the algebraic equations in terms of imposing certain values on the border and / or initial;
- getting the values of variables (unknown) in different network nodes, depending on their values in neighboring points.

To solve the problem we apples Maxwell's theory for linear, homogeneous and isotropic in rest medium. It starts from Maxwell's equations:

$$\begin{cases} \Delta \times \overline{H} = \dfrac{\partial}{\partial t}\varepsilon\overline{E} + \sigma_E \overline{E} \\ \Delta \times \overline{E} = -\dfrac{\partial}{\partial t}\mu\overline{H} - \sigma_H \overline{H} \end{cases} \tag{1}$$

where: σ_E and σ_H are the electrical and magnetic losses for the chosen configuration in space and time.

Relations linking between the two components of the field are:

$$\begin{cases} \overline{D} = \varepsilon_0 \varepsilon_r \overline{E} \\ \overline{B} = \mu_0 \mu_r \overline{H} \end{cases} \tag{2}$$

The area / subject of investigation must be a discrete space, and scale must be very small compared to the wavelength (distance <0.1 λ) and smaller than the smallest irregularities of the model. The material structure of the field can be very precisely specified at all points, through dielectric and magnetic material parameters.

Yee cell: In the three-dimensional domain the space for a particular object can be decomposed into a sum of cubes:

$$G = \{(x_i, y_j, z_k)\}\ i = 1 - I,\ i = 1 - J,\ k = 1 - K$$

The total number of items is $N = I \times J \times K$. Alongside each edge of the cube a certain potential difference is supposed to act and each side of it is crossed by a magnetic flux (figure no. 1). Each Yee cell will contain six components of the field $E_x, E_y, E_z, H_x, H_y, H_z$. The unit cell has the dimensions $\Delta x, \Delta y, \Delta z$.

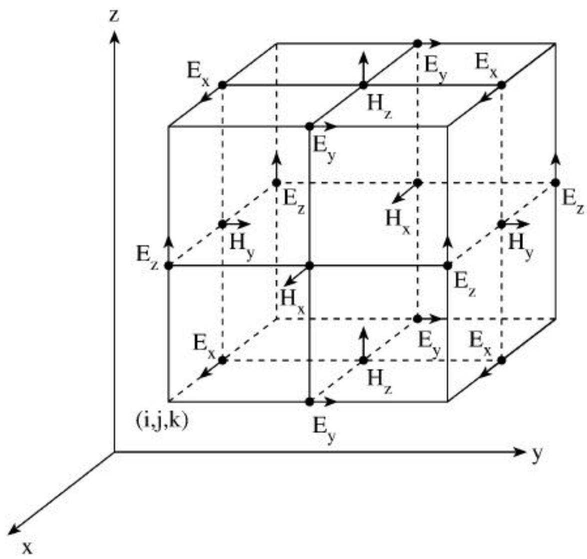


Fig. 1: Yee Cell

The rotational equations of Maxwell's equations system (1) are discretized using finite differences of second order both in space and time through a balanced spatial network. The first partial derivatives in space and time lead to:

$$\begin{cases} \dfrac{\partial F(i,j,k,n)}{\partial x} = \\ \dfrac{F^n(i+1/2,j,k) - F^n(i-1/2,j,k)}{\Delta x} + O\left[(\Delta\Delta x^2\right] \\ \dfrac{\partial F(i,j,k,n)}{\partial t} = \\ \dfrac{F^{n+1/2}(i,j,k) - F^{n-1/2}(i,j,k)}{\Delta t} + O\left[(\Delta\Delta x^2\right] \end{cases} \tag{3}$$

Where :

- F-electric field E (magnetic H) at the moment $n\Delta\Delta$;
- i, j, k are indices of spatial network;
- $O\left[(\Delta\Delta x^2\right], O\left[(\Delta\Delta t^2\right]$ are error terms;

Applying equations (1) centered differences, for a proposed allocation of the fields in space and time resulting equation (4) for E_x component:

$$\frac{E_x\big|_{i,j,k}^{n+1} - E_x\big|_{i,j,k}^{n}}{\Delta t} = \frac{1}{\varepsilon_{i,j,k}} \left(\begin{array}{l} \dfrac{H_z\big|_{i,j+1/2,k}^{n+1/2} - H_z\big|_{i,j-1/2,k}^{n+1/2}}{\Delta y} \\ -\dfrac{H_y\big|_{i,j,k+1/2}^{n+1/2} - H_y\big|_{i,j,k-1/2}^{n+1/2}}{\Delta y} \\ -\sigma_{i,j,k} E_x\big|_{i,j,k}^{n+1/2} \end{array} \right) \tag{4}$$

Approximation is considered

$$E_x\big|_{i,j,k}^{n+1/2} = \frac{E_x\big|_{i,j,k}^{n+1} - E_x\big|_{i,j,k}^{n}}{2} \tag{5}$$

Equation (4), applying the (5) approximation, can be reduced to the unknown E_x^{n+1} of the new step in time:

$$E_x\big|_{i,j,k}^{n+1} = \left(\frac{1 - \dfrac{\Delta t \sigma_{i,j,k}}{2\varepsilon_{i,j,k}}}{1 + \dfrac{\Delta t \sigma_{i,j,k}}{2\varepsilon_{i,j,k}}} \right) E_x\big|_{i,j,k}^{n} + \left(\frac{\dfrac{\Delta t \sigma_{i,j,k}}{\varepsilon_{i,j,k}}}{1 + \dfrac{\Delta t \sigma_{i,j,k}}{\varepsilon_{i,j,k}}} \right) \tag{6}$$

$$\left(\frac{H_z\big|_{i,j+1/2,k}^{n+1/2} - H_z\big|_{i,j-1/2,k}^{n+1/2}}{\Delta y} - \frac{H_y\big|_{i,j,k+1/2}^{n+1/2} - H_y\big|_{i,j,k-1/2}^{n+1/2}}{\Delta z} \right)$$

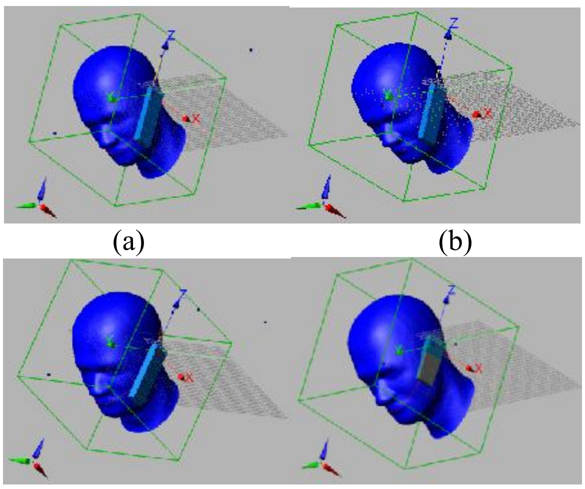
Following this procedure, the (1) rotational equations can be derived and discretized in explicit expressions for all six field components. Components E and H are calculated for alternative times respectively at intervals ½ of calculation step. Once the subject of study was defined in geometrical and electrical terms, simulation can start by introducing excitation (incident radiation, voltage or current) (A. Taflove and K.R. Umashankar, 1981: 83–113; A. Taflove (1980):191–202; K.S. Yee, (1966): 302–307; Sadiku Matthew N. O., 2000).

3. THE MODELING OF THE ELECTROMAGENTIC ABSORTION RADIATION EMITTED BY CELL PHONES IN A HUMAN HEAD

To solve the problem stated there is calculated the SAR (Specific Absorption Rate) in a specific anthropomorphic mannequin (SAM), performed according to the requirements of Standards Coordination Committee of the IEEE (SCC34-SC2) and CENELEC, pr.EN50360. SEMCAD programming environment is developed by Schmid & Partner Engineering AG.

Stages of work:

a. The modeling:



(a) (b) (c) (d)

Fig. 2: The phantom of the four phones positioned and with applied sensors for four models of phones

- the modeling of the phone: (the mobile phones with monopole, helical and patch antenna at 900 MHz frequency and with monopole antenna at 1800 MHz frequency);
- shaping source and adding sensors;
- import the phantom;
- location of phone in call position in contact with the left ear.

Figure 2 shows the human head model (phantom) with four types of phones placed in contact with the left ear and with appropriately placed sensors.

b. Simulation:

- grid generation, grid setting parameters and the type of material for each element solid model;
- setting parameters for simulation using a sine wave with frequency of 900 MHz, 1800 MHz, respectively, during the simulation period =10 at border using Mur absorbing condition of order 2; phone source is a source of sinusoidal voltage, 10V, 50Ω, the material parameters used are the following: the fluid that fills the phantom has $\varepsilon_r = 41.5$, $\mu_r = 1$, $\sigma_E = 0.97\left[\frac{1}{\Omega m}\right], \sigma_H = 0\left[\frac{1}{\Omega\ m}\right]$, $\rho = 1000\left[\frac{kg}{m^3}\right]$ and phantom shell is $\varepsilon_r = 4.5, \mu_r = 1$, $\sigma_E = 0\left[\frac{1}{\Omega\ m}\right]$, $\sigma_H = 0\left[\frac{1}{\Omega\ m}\right]$, and the environment has $\varepsilon_r = 1$, $\mu_r = 1$.

c. Generation network computing

The generated model SEMCAD is not restricted previously defined grid. To generate a clear numerical representation of the model, create a irregular linear network model adapted to the details of model. In SEMCAD network lines are calculated from a set of baseline. These baselines are located on the material discontinuities of model in sensor and source locations. The intervals between the base lines are filled with additional lines, by considering a minimum and maximum step.

Figure 3 shows human head model with four phones in the right ear, with sensors attached of near and far field and with grid computing obtained. It can be seen that grid computing is used symmetrical, more dense in the area where the phone is positioned.

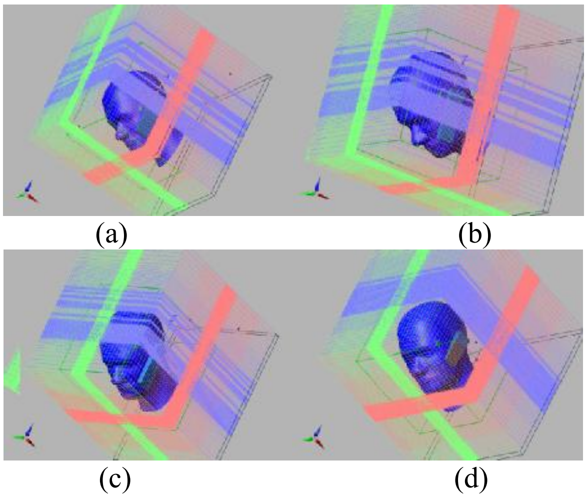


Fig 3: Phantom of the four mobile grid computing applied to four model phones

d. Results obtained:

In Figure 4 is the spatial distribution of far electric field and in Figure 5 is the distribution of SAR (10g) normalized to the maximum value for the four cell phones in the human head model three-dimensional plan for the four mobile phones.

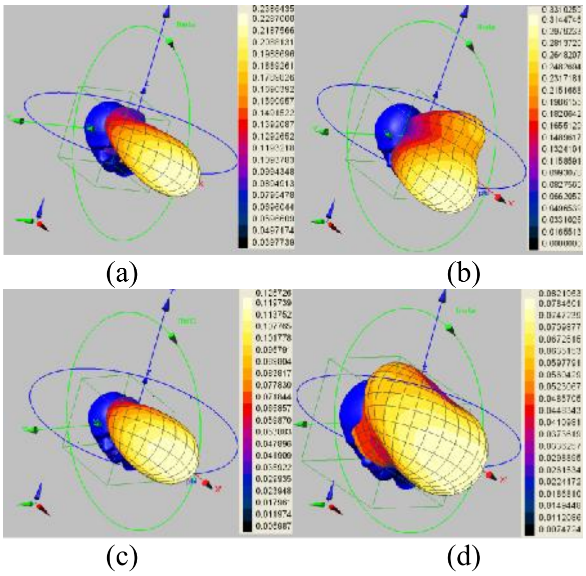


Fig 4: Far electric field for (a) telephone with monopole antenna at 900 MHz, (b) telephone with monopole antenna at 1800 MHz, (c) helical antenna phone at 900 MHz, (d) phone with internal antenna (patch) to 900 MHz

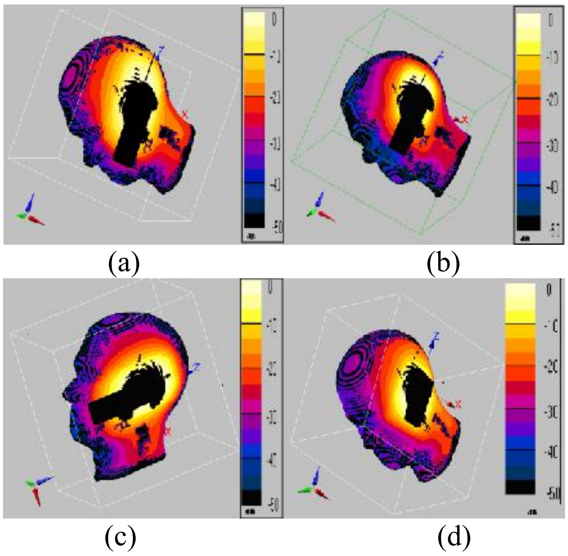


Figure 5: Representation of SAR - normalized to the maximum value for (a) telephone with pole antenna at 900 MHz, (b) telephone with pole antenna at 1800 MHz, (c) helical antenna phone at 900 MHz, (d) telephone with internal antenna (patch) to 900 MHz

In Table 1 are presented the maximum SAR values (10g) obtained from near field sensor in the human head model for the four model phones and in Table 2 are presented the average values of SAR (10g) obtained from near field sensor in the human head model for the four model phones (Jeler Grigore Eduard, 2010).

Table1: Output data for near field sensor for phantom with phone (Jeler Grigore Eduard, 2010)

Output data for near field sensor for phantom with phone	
Type of antenna	Maximum value of SAR mW/g
monopole antenna at 900 MHz	5.503
monopole antenna at 1800 MHz	9.24468
helical antenna at 900 MHz	7.5808
internal antenna la 900 MHz	5.8527

Table 2: Output data for near field sensor for phantom with phone (Jeler Grigore Eduard, 2010)

The output data near field sensor for phantom with telephone			
Type of antenna	Mean SAR's mW/g	Volume up to ± 3dB %	Volume up to ± 5dB %
monopole Antenna to 900 MHz	0.15578	8.63	14.9
monopole antenna to 1800 MHz	0.13976	5.68	10.13
Helical Antenna to 900 MHz	0.1798	7.15	12.14
internal antenna to 900 MHz	0.1234	8.407	14.57

4. CONCLUSIONS

From the study of SAR values induced by the four mobile phones, some conclusions are derived, namely:

- induced SAR in human head model is close in value to your rod antenna and helical antenna and the smaller phone with internal antenna (patch). One explanation is the model of antenna used, more powerful, and placing the internal antenna behind the phone. The conclusion is that the new internal antenna models significantly reduce the SAR.

- using helical antenna has not led to lower SAR, but its use was justified in obtaining a more pleasing design and achieve a more compact aspect of the phone, however stick antenna is used because of simplicity and low cost of manufacture;

- the maximum SAR values are very high, respectively: 5.503, 9.24468, 7.5808, 5.8527 mW/g SAR and average values are 0.15578, 0.13976, 0.1798, 0.1234 mW/g. These low average values can be explained as follows: the results and graphs can be seen that the SAR concentration in human head model is grouped around your ears where the phone is positioned, and then falls very much in the rest of the head. In fact, more than 80% of head SAR is less than 10% of the maximum SAR value for all four cases, because during the propagation of electromagnetic energy is rapidly dissipated;

- average values of SAR (10g) are less than 2mW/g and the same order of magnitude between them, the highest value being for model helical antenna - 0.1798 mW/g, then stick antenna at 900 MHz - 0.15578 mW/g, antenna pole at 1800 MHz - 0.13976 mW/g, the lower the internal antenna - 0.1234 mW/g.

- basing on the obtained results in this study, it can be concluded that the recommended standard values are satisfied (mean values) in all four types of phones.

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