Modelling SAR of Mobile Phone Inside User' Head

Dejan Jovanović, Vladimir Stanković, Dejan Krstić, Nenad Cvetković

Abstract - This paper represents distribution of electric field which obtained inside a human head from source of electromagnetic radiation, i.e. the mobile phone. Also Specific Absorption Rate (SAR), within a user' head due to exposure to electric field from mobile phone was presented. For this research different models of human head were used. The first model was created as a phantom model, second one was created as model with a few layers (multilayers model) and the last one was created as a realistic model of head with all actual biological tissues and organs. In every case simulations were performed for the frequency of 900 MHz, which are the most common used in mobile communications. The parts of the human head are based on their electromagnetic properties (conductivity, electric permittivity, and magnetic permeability). In order to obtain the electric field distribution and SAR within head, the numerical calculation based on the Finite Integration Technique (FIT) and Finite Element Method (FEM) was performed.

Keywords - Nonionizing radiation, Electric field, Specific Absorption Rate, Finite integration technique, Finite element method.

I. Introduction

In order to make our everyday life more comfortable, various wireless devices used for transfer of different multimedia content and for regular daily activities at home have been developed. The common characteristic of all such devices is that they are sources of electromagnetic radiation.

The main expansion of mobile device use turned the focus towards the research of microwave impact on the human body for the purpose of assessing human health risk.

Compared to base stations located far from humans, mobile phone is source of electromagnetic (EM) radiation located close to the human head or body.

Such intense use, mostly among the younger population, can cause concern about health effects. In order to obtain relevant data, it is necessary to perform continuous research of the effects of EM radiation on human health.

In order to obtain the most realistic results of EM field distribution and values of SAR, we made a 3D human head model with size which corresponds of an average person and which consists actual biological tissues and organs.

Because of that it was necessary to make a model that would represent the human head structure as truly as possible (Fig. 1). [1, 2, 3, 4]

Dejan Jovanović, Vladimir Stanković and Dejan Krstić are with Faculty of Occupational Safety, University of Niš, Čarnojevića 10a, 18000 Niš, Serbia, E-mail: {dejan.jovanovic, vladimir .stankovic, dejan.krstic}@znrfak.ni.ac.rs.

Nenad Cvetković is with the Faculty of Electronic Engineering, University of Niš, A. Medvedeva 14, 18000 Niš, Serbia, E-mail: nenad.cvetkovic@elfak.ni.ac.rs.

This paper presents the distribution inside the human head of an EM field originating from mobile phones for operating frequency of 900MHz.

II. Electromagnetic Properties of Tissues

In order to describe the characteristics of biological tissue, it is necessary to define features that are as close as possible to the actual tissue. The real biological tissues are nonhomogeneous, nonlinear, and dispersive. Since the human body consists of different organs, each of the organs or tissues has to be described by adequate electromagnetic parameters that are used for biological tissues.

TABLE I
Electromagnetic Properties of model A and model B for $f = 900\text{MHz}$

Tisuue	ε_r	σ (S/m)	ρ (kg/m^3)	Heat Capacity (kJ/kgK)	Thermal conductivity (W/m°C)
Cortical Bones	12,45	0,143	1850	1,313	0,32
Brain	45,805	0,7665	1030	3,630	0,51
Cerebrospin Fluid	68,60	2,410	1007	4,096	0,57
Fat	11,30	0,109	1020	2,348	0,21
Cartilage	42,70	0,782	1100	3,568	0,49
Pituitary Gland	59,70	1,040	1053	3,687	0,51
Spinal Cord	32,50	0,574	1075	3,630	0,51
Muscle	55,00	0,943	1040	3,421	0,49
Eyes	49,60	0,994	1060	3,615	0,53
Skin	41,40	0,867	1100	3,391	0,37
Tongue	55,30	0,936	1090	3,421	0,49
Teeth	12,50	0,143	2180	1,255	0,59

TABLE II
Electromagnetic Properties of model C for $f = 900\text{MHz}$

Tissue	ε_r	σ(S/ m)	ρ(kg/m3)
Shell	45.5	0,0016	1100
Fluid	41.4	0.145	1000

The influence of the dispersive characteristic is eliminated with the electromagnetic characteristic of tissues at a certain frequency. The following electromagnetic

parameters have to be correctly defined for every organ: electric conductivity, permittivity, heat capacity, density and thermal conductivity. For model A and model B which consist a different biological organs and tissues, the values of electromagnetic parameters are given in Table I. while the values of electromagnetic parameters for model C (phantom model) are given in Table II. [5] The proper boundary conditions at separation areas of the domains that connect individual organs have to be taken into consideration (model A and Model B).

III. Numerical Models of Human Head

Modeling of 3D models (Model A, Model B and Model C) was performed in two stages. First external look of models (Fig.1) and every tissues and organs was created in 3D Max Studio [6]. The second step was creating full model with actual tissues and organs and connecting certain electromagnetic properties with adequately tissues and organs (Table I and Table II) by using software package CST Microwave Studio [7]. The same software has been used for simulation of electromagnetic field and its influence on human head. Numerical calculation method which is used in this software is based on the Finite Integration Technique [8].

External look, horizontal and vertical cross-section with actual tissues and organs are shown in Fig. 1 and Fig. 2.

When using FEM analysis software, the key step before any computations is to create the mesh of elements. Finer mesh means the greater number of elements and thus the results will be more accurate.

Model C was also created with the same size as Model A and Model B (Fig. 1 and Fig. 2) while the electromagnetic characteristics of tissues were modeled only with two layers. Model B (phantom model) contains only two layers with electromagnetic properties as shown in Table II.

For this research actual smart phone (Fig. 3) has been used as a source of electromagnetic radiation. The current mobile phone consists of following parts: planar inverted F antenna (PIFA), display and mobile housing. The planar inverted F antenna (PIFA) as a source of electromagnetic radiation was modeled for the frequencies of f=900MHz as one of most common used frequency in telecommunication system, with power of P=1W [9] and impedance of Z=50Ω.

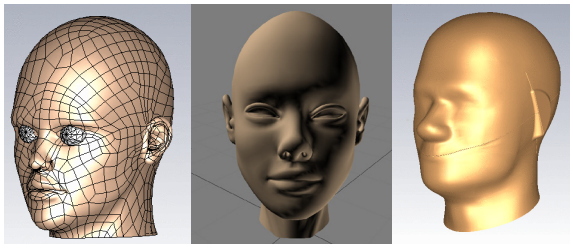
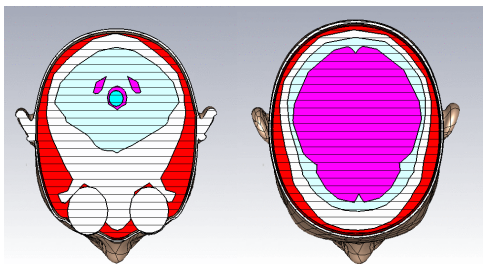
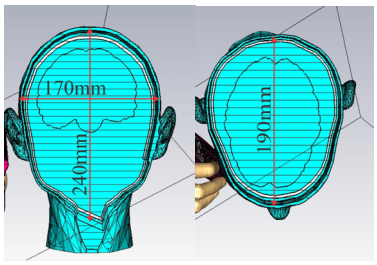


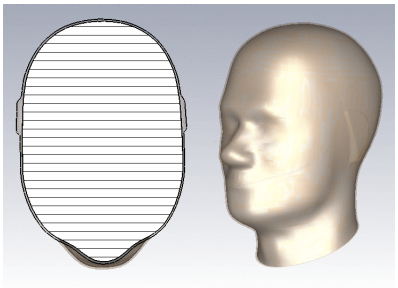
Fig. 1 - External looks of human head models: A-Realistic Model, B-multilayers Model and C-Phantom Model.



Model A



Model B



Model C

Fig. 2 – Horizontal and vertical cross-sections of the models with organs and tissues

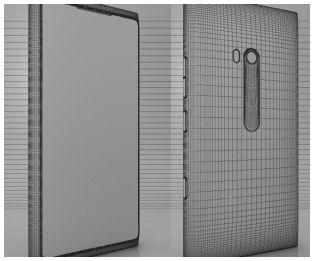


Fig. 3 - Model of actual smart phone

IV. Results

A. Electric Field Distribution

Calculation of the EM field in the head is based on the finite element method. The electromagnetic properties of head tissues for a 900MHz frequency are shown in Table I and Table II.

On the Fig. 4, in accordance with color at the surface of model we can observe that the greatest values of the electric field are just around the radiation source, where there is also the biggest influence of radiation and penetration of the electric field. The field decreases dramatically moving away from the source.

The Fig. 5. represent the maximum electric field distribution at $f = 900\text{MHz}$ for different models. Electric field levels are represented by different colours, whose values are shown by a colour palette on the right in each figure. Based on Fig. 5, (Model A, B and C) one can conclude that the envelope of electric field strength decreases with the distance from the area of field penetration into the head model. Therefore, the biological effects of radiation are more significant in the skin, subcutaneous fat tissue, head muscles, and the part of the brain closer to the radiation source.

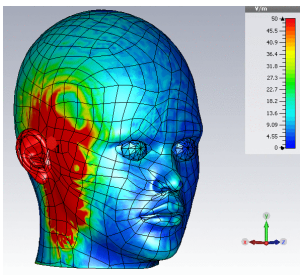
B. Specific Absorption Rate (SAR)

If biological tissue is in the path of EM wave propagation, the wave penetrates the tissue and a portion of the wave energy is absorbed in the tissue. A force affects the charged particles due to electric and magnetic components of the EM field. The internal energy increases and, consequently, the temperature increases and thermal energy dissipates. The difference of input and output wave energy at the boundaries of an object represents absorbed energy. The SAR quantity has been introduced to precisely define absorbed energy.

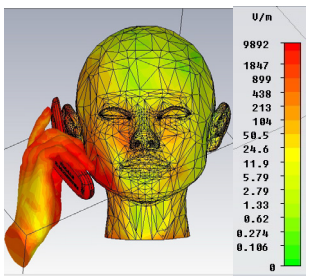
SAR is the power converted into heat in a body per unit mass, i.e.

$$\text{SAR} = \frac{P}{m} = \frac{\sigma E^2 V}{\rho_m V} = \frac{\sigma E^2}{\rho_m} \qquad (1)$$

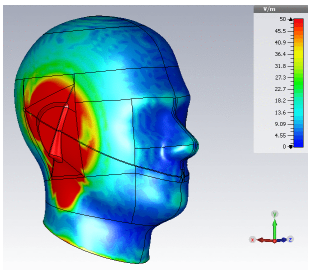
This simulation represents the local SAR value in the human head (Fig. 6) which is calculated by using (1) for the frequency of 900MHz for Model A, Model B and Model C.



Model A

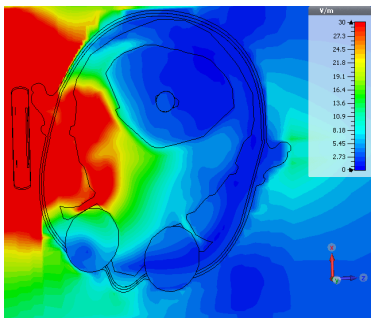


Model B

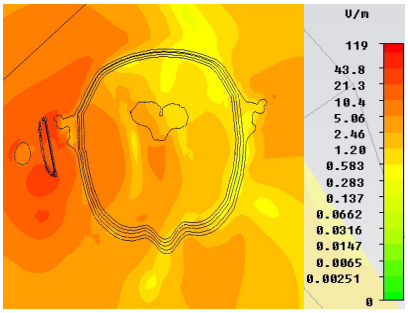


Model C

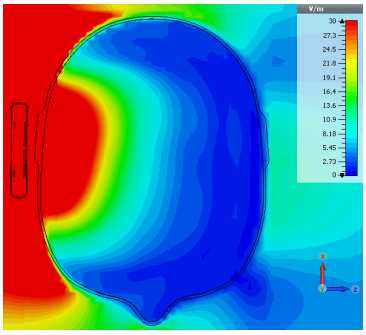
Fig. 4 - The distribution of the electric field E [V/m] at the surface of human head models.



Model A

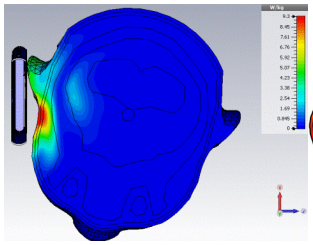


Model B

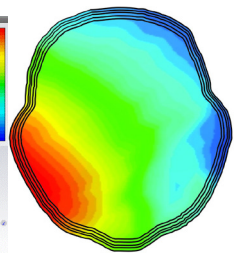


Model C

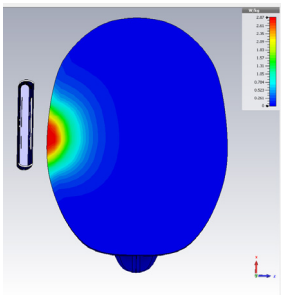
Fig. 5 – Electric field strength distribution inside human head



Model A



Model B



Model C

Fig. 6. - SAR [W/kg] inside different models

Those results are obtained for output power of the mobile phone P = 0.25W. It should be noted that in the worst case for output power of P = 1W [10], values of SAR would be much greater than values shown in previously figures.

V. Conclusion

The aim of this study was to examine the influence of mobile phone radiation on human head by numerical calculation. To achieve this aim different models of human head have been used: realistic model with organs and tissues, multilayers model and phantom model with only two layers.

It was possible to graphically represent the features of electromagnetic wave penetration through the head models. Graphical representation showed the electric field strength distribution and SAR values in the human head for different models for frequency of 900MHz.

The results represent where the maximum value of absorbed energy is, how the field penetrates, and how much it weakens as the distance from the radiation source increases. Naturally, the highest radiation level is in the area next to the phone antenna, and it gradually decreases with every subsequent area.

The results for different cases of exposure showed disagreement between both the simulations used previously described models (Model A, Model B and Model C). In the case of a phantom model (Model C) can be seen from Fig. 5 that the penetration depth of electric field is deeper than in case with Model A and Model B (Fig. 5). This can be explained with higher volume of brain in case of phantom model and homogeneous characteristics of only one layer that supposed to simulate all biological tissue inside head.

More realistic and accurate results were obtained by using realistic model (Model A) due to this model is taking into consideration all biological organs and tissues with adequately electromagnetic properties (Table I). Because of these advantages of this Model A, its usage allows defining absorbed energy and electric field in each organs or tissues. This date can be used for medical purpose in order to describe dose and biological sensitivity of biological mater.

The realistic model (Model A) of human head provide exceptional assistance to researchers, with a new idea of connecting the simulation results obtained using this model the real structures of the human head, as shown in the paper.

Acknowledgement

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