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3D-FDTD Head Model Exposure to Electromagnetic Cellular Phones Radiation

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Abstract: According to the increasing of mobile phone radiation exposure. Many research has been evaluated the specific absorption rate which is the power dissipation rate normalized by material density in human life tissue exposure to the radiation. Therefore, in this work, the electric field, magnetic field and specific absorption rate generated inside a three human life tissue of head model are studied. The electromagnetic radiation can be measured in terms of specific absorption rate. The human head exposed to global system for mobile communication frequency bands of 900MHz. The radiation absorption analyzed through simulations by using three dimension finite difference time Domain method and computer software program. The penetration of the fields and power density were computed inside the model of human head. Results show that electromagnetic fields penetrate the life tissues and attenuate fast to reach zero at the brain layer, the peak is smaller than because the electric field strike the bone tissue. The absorbent power and specific absorption rate show maximum at the skin layer. Preliminary results show good agreement with previous published using numerical and software technique. Also the results suggest that three layer human model and simulation can help to understand the specific distribution of mobile phone electromagnetic fields inside the human head.

Keywords: Finite Difference Time Domain (FDTD), Cellular Phone Radiation, Human Head, Specific Absorption Rate

1. Introduction

The ever rising diffusion of cellular phones has brought about an increased concern for the possible consequences of electromagnetic radiation on human health. The diffusion of mobile phones has brought about an increased concern for the possible consequences of electromagnetic radiation on human health, in particular for children. As a matter of fact, when a cellular phone is in use, the transmitting antenna is placed very close to the user's head where a substantial part of the radiated power is absorbed. In the last decade, several research projects have been conducted in order to evaluate the possible biological effects resulting from human exposure to such an electromagnetic radiation [1]. It is difficult to experimentally measure SAR or EM field distributions inside human body. Therefore, various numerical techniques play significant roles to calculate EM field components and SAR inside human body. FDTD method [2] is one of the widely used techniques to simulate the EM field distributions in three dimensional structures [3-9]. The FDTD method is currently the leading method for numerical assessment of human exposure to electromagnetic waves [12]. The specific absorption rate (SAR) in scaled human head models has been analyzed to study possible differences between SAR in the heads of adults and children and for assessment of compliance with the international safety guidelines, while using a mobile phone [10]. The finite-difference time-domain method (FDTD) has been used for calculating specific absorption rate values for models of both children and adults, at 900 and 1800 MHz. In this work the computation of the electric, magnetic fields and specific absorption rate generated by cellular phone inside a three-tissue phantom head model is presented. The phone was considered working at 900MHz Global System of Mobile Communication (GSM). The penetration of the E-fields and averaged SAR values were computed inside the model of human head model using three dimension Finite Difference Time Domain (FDTD) technique.

2. Theory and Modeling

In order to consider the effects of electromagnetic waves produced from mobile phone, a planar three-layer body model has been chosen such as skin, bone and brain as shown in figure 1. It assumed that a plane electromagnetic wave is incident vertically upon the plane-layered slabs of medium in z- direction, which electric field is in x-direction. The model consist of three layer having dielectric properties for each layer differ according the frequency consider.

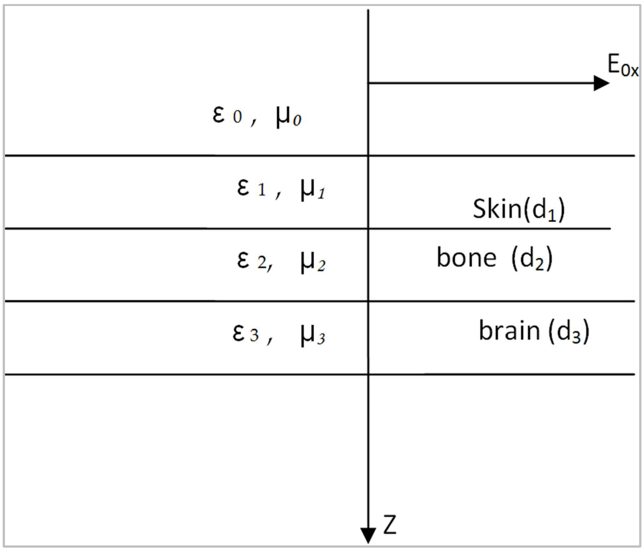

Figure 1. *Model of layered dielectric slab.*

There are many media that have a loss term specified by conductivity. This loss term results in the attenuation of the propagating energy. Once more we will start with the time-dependent Maxwell equation, but we will write them in amore general form, which will allow us to simulate propagation in media that have conductivity are

$$\varepsilon\frac{\partial E}{\partial t} = \nabla\times H - J \tag{1}$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0}\nabla\times E \tag{2}$$

J is the current density which can also be written

$$J = \sigma.E \tag{3}$$

where σ is the conductivity., we get

$$\frac{\partial E}{\partial t} = \frac{1}{\varepsilon_o\varepsilon_r}\nabla\times H - \frac{\sigma}{\varepsilon_o\varepsilon_r}E \tag{4}$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_o}\nabla\times E \tag{5}$$

The constants ε_0 and μ_0 are known as the permittivity and permeability of free space and ε_r is the relative permittivity of the material. The equations reduced to

$$\frac{\partial E_x(t)}{\partial t} = -\frac{1}{\varepsilon_0\varepsilon_r}\frac{\partial H_y(t)}{\partial z} - \frac{\sigma}{\varepsilon_0\varepsilon_r}E_x(t) \tag{6}$$

Take the FDTD formulation, the central difference approximations for both the temporal and spatial derivatives are obtained at $z = k\Delta z, t = n\Delta t$. Implementing the changing of variables we have the electric and magnetic component as

$$H_x^{n+1}(i, j+\tfrac{1}{2}, k+1/2) = H_y^{n}(i, j+\tfrac{1}{2}, k+1/2) - \frac{1}{\sqrt{\varepsilon_o\mu}}\frac{\Delta t}{\Delta z}$$
$$\left\{\frac{\tilde{E}_y^{n+1/2}(i,j+\frac{1}{2},k+1)-\tilde{E}_y^{n+1/2}(i,j+\frac{1}{2},k)}{\Delta z} - \frac{\tilde{E}_z^{n+1/2}(i,j+1,k+\frac{1}{2})-\tilde{E}_z^{n+1/2}(i,j,k+\frac{1}{2})}{\Delta y}\right\} \tag{7}$$

$$H_y^{n+1}(i+\tfrac{1}{2}, j, k+\tfrac{1}{2}) = H_y^{n}(i+\tfrac{1}{2}, j, k+\tfrac{1}{2}) - \frac{1}{\sqrt{\varepsilon_o\mu}}\frac{\Delta t}{\Delta z}$$
$$\left\{\frac{\tilde{E}_z^{n+1/2}(i+1,j,k+\frac{1}{2})-\tilde{E}_z^{n+1/2}(i,j,k+\frac{1}{2})}{\Delta x} - \frac{\tilde{E}_x^{n+1/2}(i+\frac{1}{2},j,k+1)-\tilde{E}_x^{n+1/2}(i+\frac{1}{2},j,k)}{\Delta z}\right\} \tag{8}$$

$$H_z^{n+1}(i+\tfrac{1}{2}, j+\tfrac{1}{2}, k) = H_y^{n}(i+\tfrac{1}{2}, j+\tfrac{1}{2}, k) - \frac{1}{\sqrt{\varepsilon_o\mu}}\frac{\Delta t}{\Delta z}$$
$$\left\{\frac{\tilde{E}_x^{n+1/2}(i+\frac{1}{2},j+1,k)-\tilde{E}_x^{n+1/2}(i+\frac{1}{2},j,k)}{\Delta y} - \frac{\tilde{E}_y^{n+1/2}(i+1,j+\frac{1}{2},k)-\tilde{E}_y^{n+1/2}(i,j+\frac{1}{2},k)}{\Delta x}\right\} \tag{9}$$

And the electric fields components are

$$\tilde{E}_x^{n+1/2}(i+\tfrac{1}{2},j,k)=\frac{1-\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}{1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\tilde{E}_x^{n-1/2}(i+\tfrac{1}{2},j,k)-\frac{1/2}{\varepsilon_r 1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\left\{\frac{H_z^n(i+\frac{1}{2},j+\frac{1}{2},k)-H_z^n(i+\frac{1}{2},j-\frac{1}{2},k)}{\Delta y}-\frac{H_y^n(i+\frac{1}{2},j,k+\frac{1}{2})-H_y^n(i+\frac{1}{2},j,k-\frac{1}{2})}{\Delta z}\right\} \quad (10)$$

$$\tilde{E}_y^{n+1/2}(i,j+\tfrac{1}{2},k)=\frac{1-\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}{1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\tilde{E}_x^{n-1/2}(i,j+\tfrac{1}{2},k)-\frac{1/2}{\varepsilon_r 1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\left\{\frac{H_x^n(i,j+\frac{1}{2},k+\frac{1}{2})-H_x^n(i,j+\frac{1}{2},k-\frac{1}{2})}{\Delta z}-\frac{H_z^n(i+\frac{1}{2},j+\frac{1}{2},k)-H_z^n(i-\frac{1}{2},j+\frac{1}{2},k)}{\Delta x}\right\} \quad (11)$$

$$\tilde{E}_z^{n+1/2}(i,j,k+\tfrac{1}{2})=\frac{1-\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}{1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\tilde{E}_x^{n-1/2}(i,j,k+\tfrac{1}{2})-\frac{1/2}{\varepsilon_r 1+\frac{\Delta t.\sigma}{2\varepsilon_o\varepsilon_r}}\left\{\frac{H_y^n(i+\frac{1}{2},j,k+\frac{1}{2})-H_y^n(i-\frac{1}{2},j,k+\frac{1}{2})}{\Delta x}-\frac{H_x^n(i,j+\frac{1}{2},k+\frac{1}{2})-H_x^n(i,j-\frac{1}{2},k+\frac{1}{2})}{\Delta y}\right\} \quad (12)$$

we use the computer program and simulates a sinusoidal wave hitting a human body tissue that has a dielectric constant and conductivity according the frequency which considered. In Program we choose $\Delta t=\frac{\Delta z}{3c_0}$ where c_0 is the speed of light in free space. Since the human tissues are nonmagnetic, it has been assumed that $\mu_i=\mu_0$, where i stands for 1, 2 and 3 which represents the three layers. The free space is assumed for the exterior of the model with wave number $k_0=\omega\sqrt{\varepsilon_0\mu_0}$. And the dielectric properties for mobile phone frequency are illustrated in table (1)

Table 1. *Dielectric properties for human body at frequency 900MHz.*

Tissue name	Conductivity [S/m]	Relative permittivity	Loss tangent	Wavelength [m]	Penetration depth [m]
Skin	0.86674	41.405	0.41809	0.050714	0.04023
Brain	0.94227	52.725	0.35694	0.045182	0.041536
Bone	0.34	20.788	0.32667	0.072128	0.07211

3. Results and Discussion

The FDTD method has been used for many applications including calculating specific absorption rate and induced currents in the human body and etc. The electrical properties of various biological tissues, permittivity and conductivity are very important by specific absorption rate calculating. Permittivity and conductivity depend on frequency. Various parameters by specific absorption rate calculating with EMF from mobile phone are operational frequency and antenna power, mutual positions of the device and head design of the device and size of human head. In this work the relation between electric field, power of absorption and specific absorption rate have been evaluated in life tissue where the power density (W/m^3) absorbed in the conductivity σ_i along the ith layer from the sinusoidal field of the amplitude E_i is given

$$P_i=\frac{|E_i|^2\sigma_i}{2} \quad (13)$$

And specific absorption rate in units of (W/kg) is the most important dosimetric parameter for the evaluation of the exposure hazard at radio and microwaves frequencies [11, 13]. It is the biological electromagnetic estimation. It is defined as the power dissipation rate normalized by material density

SARs are plotted with respect to time steps in three human layers as skin, bone and brain. Figures 2, 3 represent the electric field in skin and brain in three dimension, it has the maximum peak. In figure 3 the peak is smaller than because the electric field strike the bone tissue, its effect is appear smaller than the skin. Figure 5 illustrate the simulated of specific absorption rate in skin tissue, the skin thicknes is 0.04 mm, permittivity =41.4 and conductivity =0.866, the mobile phone is matched for operation in free space at distant 20cm. In Figure 6 the specific absorption rate in bone tissue is at maximum value 0.7nW/kg. Specific absorption rate in brain tissue has been shown in Figure 7. The brain thickness is 0.041m, permittivity =52.7 and conductivity =0.9422. The mobile phone is matched for operation in free space at distant 20cm. The maximum amplitude in brain tissue is 0.04nW/kg, it is less than the amplitude is bone tissue. The power density simulation in skin, bone and brain are shown in figures 8, 9, 10, the maximum value of power density in brain tissue is 0.03µ W/m^3 as in Figure 10. The brain thickness is .041m, permittivity =52.7 and conductivity =0.9422. The mobile phone is matched for operation in free space at distant 20cm.

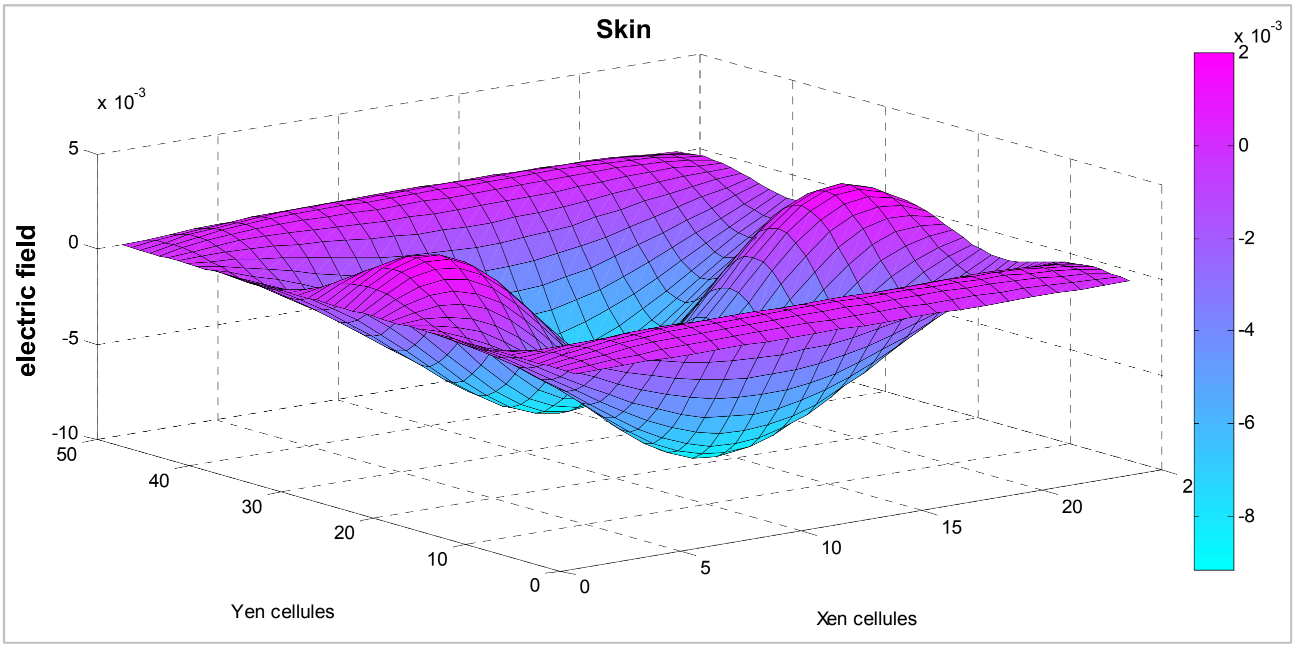

Figure 2. *Electric field in skin tissue*

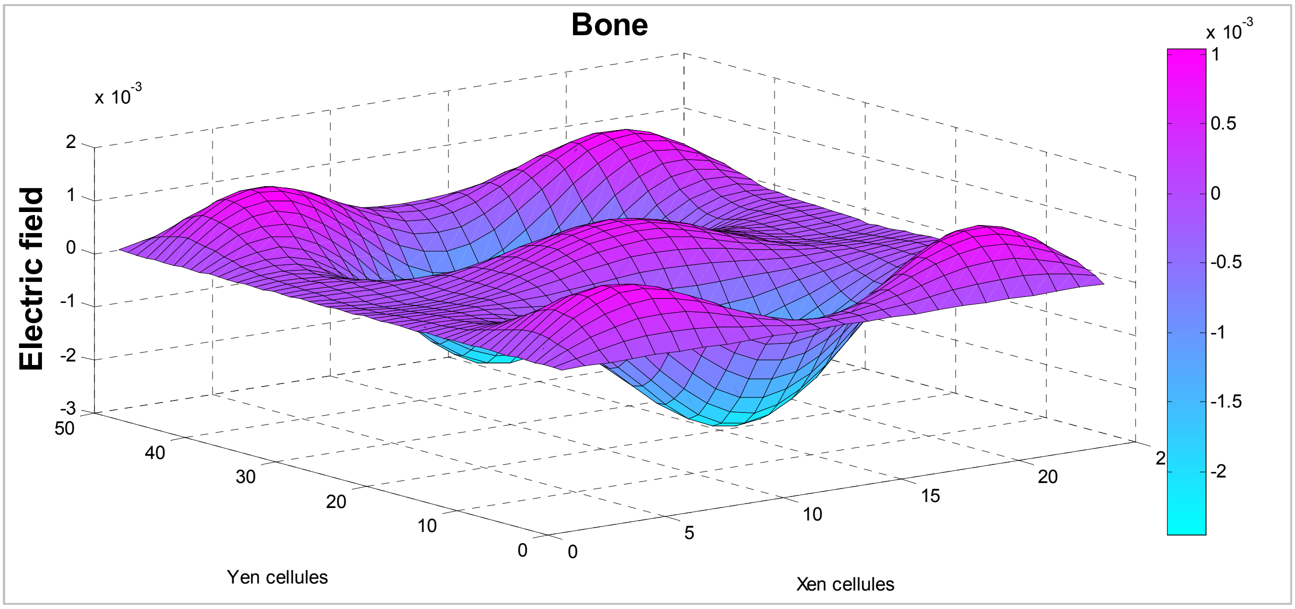

Figure 3. *Electric field in bone tissue.*

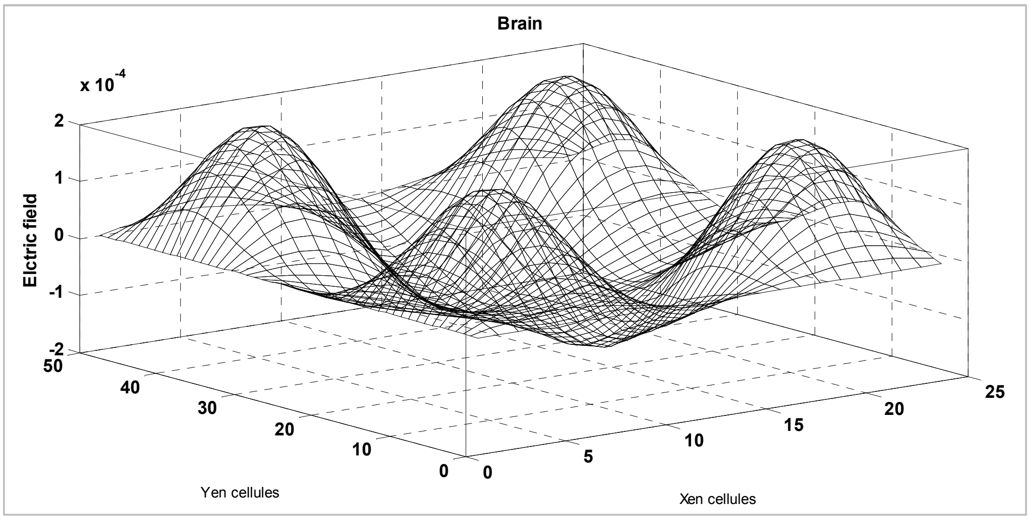

Figure 4. *Electric field in brain tissue . The brain thickness is .041m, permittivity =52.7 and conductivity =0.9422. The mobile phone is matched for operation in free space at distant 20cm.*

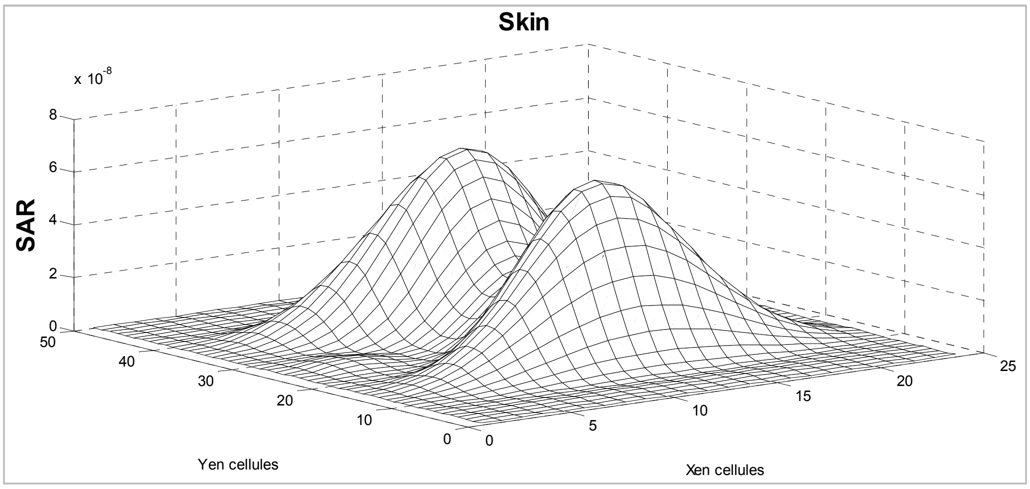

Figure 5. *The simulated of Specific absorption rate in skin tissue . The skin thickness is .04 mm, permittivity =41.4 and conductivity =0.866. The mobile phone is matched for operation in free space at distant 20cm.*

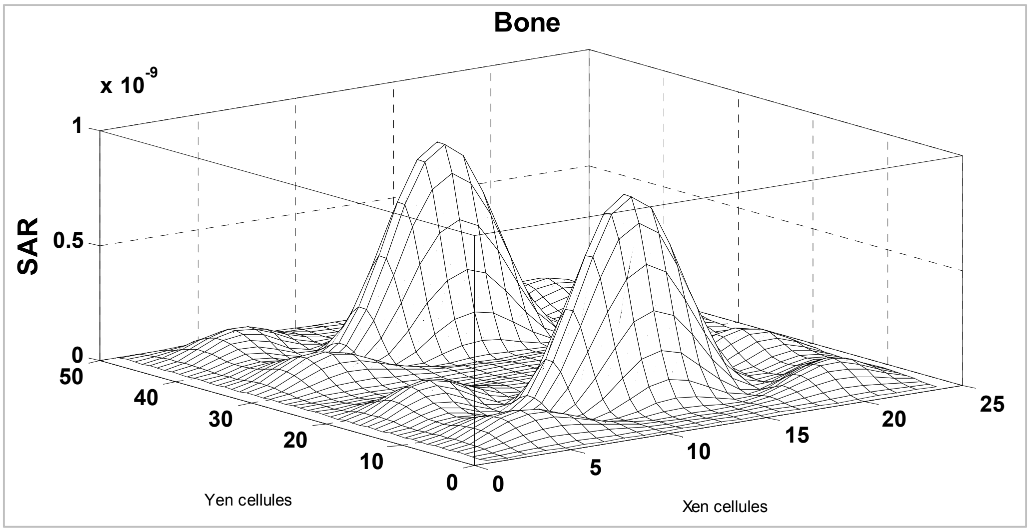

Figure 6. *Simulation of specific absorption rate in bone tissue . The bone thickness is .072 m, permittivity =20.7 and conductivity =0.34. The mobile phone is matched for operation in free space at distant 20cm.*

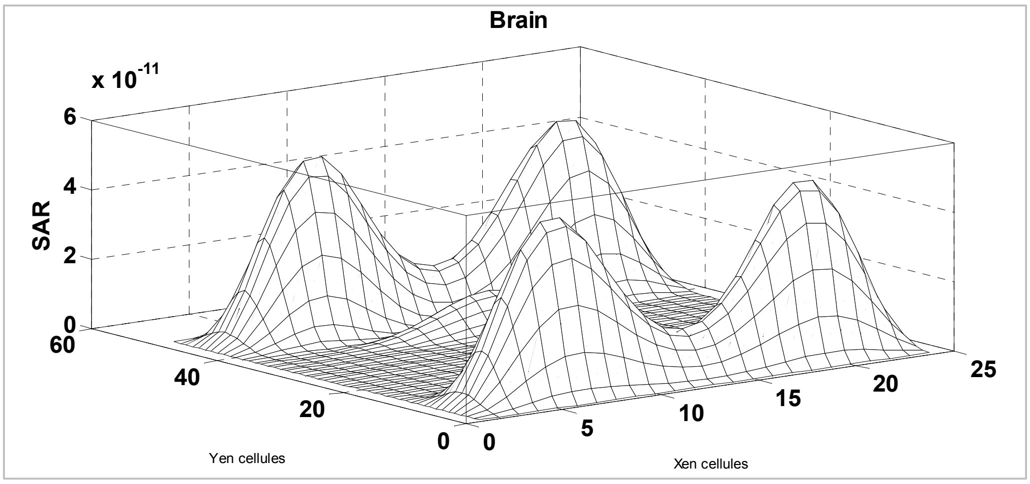

Figure 7. *Specific absorption rate in brain tissue . The brain thickness is .041m, permittivity =52.7 and conductivity =0.9422. The mobile phone is matched for operation in free space at distant 20cm.*

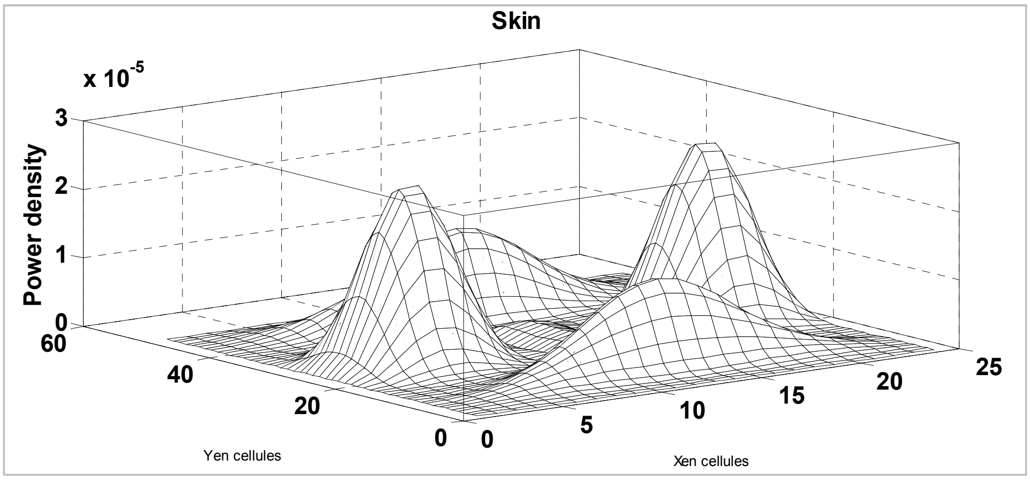

Figure 8. *The simulated of power density in skin tissue . The skin thickness is .04 mm, permittivity =41.4 and conductivity =0.866. The mobile phone is matched for operation in free space at distant 20cm*

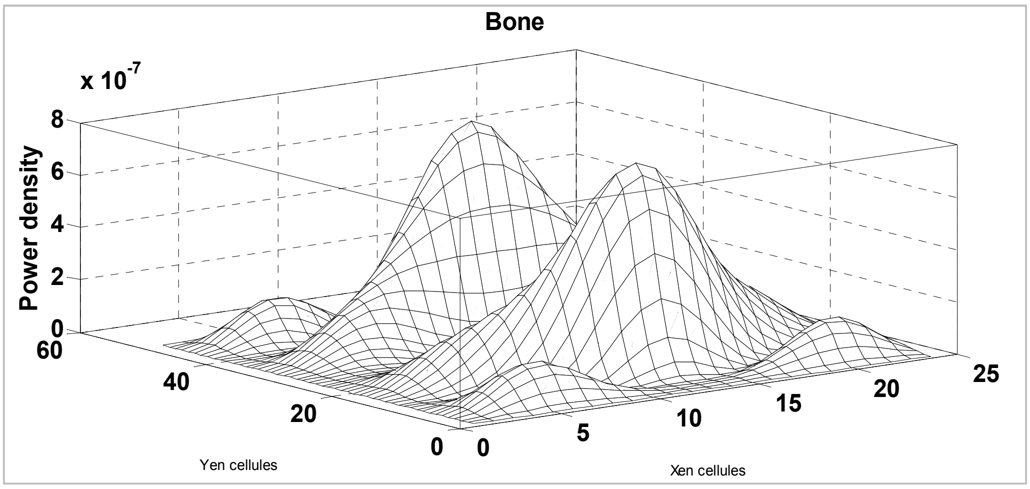

Figure 9. *Simulation power density in bone tissue . The bone thickness is .072 m, permittivity =20.7 and conductivity =0.34. The mobile phone is matched for operation in free space at distant 20cm.*

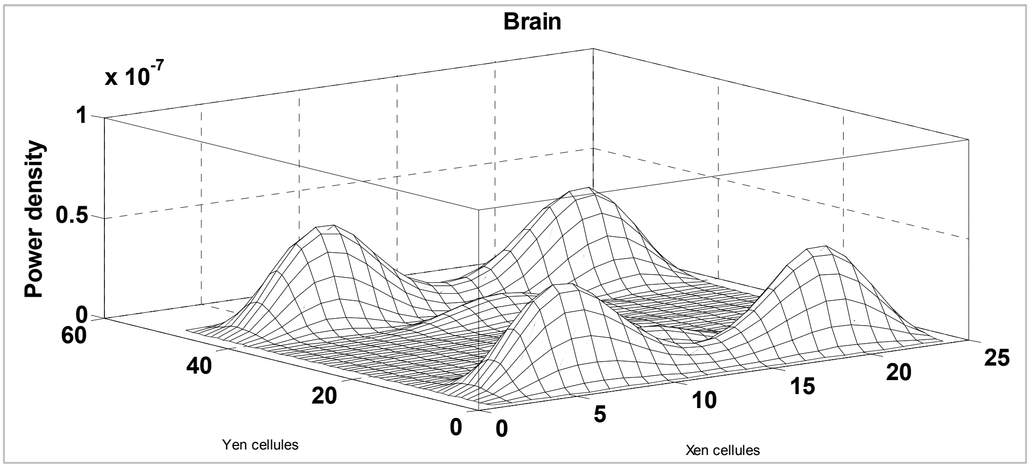

Figure 10. *Power density in brain tissue. The brain thickness is .041m, permittivity =52.7 and conductivity =0.9422. The mobile phone is matched for operation in free space at distant 20cm.*

4. Conclusion

This paper deals with numerical modeling of electromagnetic field effects on the human body (especially calculation of the specific absorption rate (SAR) distribution in human body using FDTD method in three dimensions. The penetration of the electric field, averaged SAR and power density values were computed inside the model of human head model using three dimension finite difference time domain (FDTD) technique. Results show that electro magnetic fields penetrate the life tissues and attenuate fast to reach zero at the brain layer. The absorbent power and SAR show maximum at the skin layer.

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