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FDTD Computation of Prostate Tissue Exposure to Cellular Phones Radiation

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***abstract* - The Finite-Difference Time-Domain (FDTD) is the most often used method for evaluating of electromagnetic fields in human tissue. The ever-rising diffusion of cellular phones has brought about an increased concern for the possible consequences of electromagnetic radiation on human health. This paper presents a study of electric , magnetic fields distribution in human prostate tissue . Concerning numerical modeling, the power absorption and specific absorption rate (SAR) in a prostate are generally computed using FDTD methods in one and two dimension . Results show that mobile radiation penetrate the prostate tissues and attenuate fast to reach zero at the inner of tissue. The absorbent power and SAR show maximum at the interface .**

***Key words*- FDTD method, life tissue, cellular phone radiation .**

I. Introduction

Computation of electromagnetic field inside a tissue at mobile communication has been studied, which presents a new approach to calculate the electromagnetic field inside a tissue, composed of electrically excitable cell by means of the FDTD (finite difference time domain method) [1-2]. the simulation results of the absorption of RF energy in the biological tissue in the case of the cell phones has been evaluated . The Ansoft HFSS method with boundary conditions and assigned excitations by an antenna dipole, an antenna monopole and patch antenna are used as the cell phone. The human head is simulated by HFSS at GSM frequencies 900 MHz and 1800 MHz. In order to evaluate the ability of the HFSS code, we use the FDTD computations and the measurement results of the SAR distribution obtained from the spherical glass bowl filled with different liquids and either a wired dipole antenna[3]. The classical FDTD was modified by using an unsplitting field formulation which can combine the simulated physical domain and an artificial absorbing layer as a single computational domain [4]. the simulation of electromagnetic interaction in the human head model using the FDTD with a modified PML investigated .

The simulated physical domain contains a dipole antenna, a high-resolution human head model and a metal wall. In the simulation, a dipole antenna acts as a mobile phone operated at 900 MHz and 1.8 GHz[5]. In general, IEEE standard required that the SAR 1-g of handheld wireless phones not exceed 1.6 watts/kg, averaged over 1-g mass of tissues [6]. Although the SAR 1-g is determined at the highest power level, the actual SAR 1-g value while operating depends on factors such as the proximity of the antenna to the human head while in use. M, Burkhardt et al has been modeled The ear, including skin- and cartilage-layer, by using two layers in the multi layered superquadric ellipsoid[7]. The skin-layer (of the ear) is modeled by thickness of one FDTD cell. SAR simulation in wireless communication and safety discussions in the society discussed [8], numerical simulation in cellular phone study by powerful time techniques(TD) and the transmission line matrix(TLM).A finite element thermal model of the head has been developed to calculate temperature rises generated in the brain by radiation from cellular telephones and similar electromagnetic devises. Martinez-Burdalo et al. further analyzed SAR depositions in different-aged human heads exposed to electromagnetic radiation resulted from a mobile phone [9]. electromagnetic waves interactions with human bodies has been studied by M. F. Wong[10]. The Changes in the dielectric properties of rat prostate ex vivo at 915 MHz during heating has been evaluated[11]. It found that the temperature coefficients can be utilized in microwave treatment planning programmers to provide insight into the effects of dielectric changes that arise during microwave thermal therapy of prostate cancer. In this work we studied the effect of electromagnetic waves produce from mobile phone on human prostate tissue, computation FDTD Simulations were run for mobile phone radiation of the human prostate which frequency was 0.9 GHz continuous wave form source . FDTD method implemented in MATLAB program was used to compute the distribution of electric , magnetic fields, specific absorption rate and power density in the prostate tissue.

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II. MODELLING AND COMPUTATIONAL METHOD

It assumed that electromagnetic radiation from mobile phone is incident vertically upon the interface prostate tissue with dielectric properties shown in table(1).

TABLE I
DIELECTRIC PROPERTIES OF PROSTATE TISSUE AT FREQUENCY 900MHz

Tissue name	Conductivity σ[S/m]by 900MHz	Relative permittivity by 900MHz	Penetration depth [m]	Density ρ[kg/m^3]
Air	0	1	1	1.229
Prostate	1.2096	60.553	0.034802	1100

The dielectric properties of a life tissue are different according changing frequency. The function of the prostate is to secrete a slightly alkaline fluid, milky or white in appearance[12], that usually constitutes 20–30% of the volume of the semen along with spermatozoa and seminal vesicle fluid the electric field and the magnetic field are found to satisfy the equations

$$\left.\begin{aligned}(\nabla^2 - \gamma^2)E &= 0,\\ and\\ (\nabla^2 - \gamma^2)H &= 0,\end{aligned}\right\} \qquad (1)$$

The electric field is assumed to propagate in the z direction with polarization at the x direction. Now we present the Maxwell's equations in one dimensions. We suppose the absence of magnetic or electric current sources, and the existence of absorbing materials in the space under study .The finite difference time domain (FDTD) method is powerful solution for solving Maxwell's equations, introduced by K.S. Yee [13]. The algorithm involves direct discriminations of Maxwell's equations by writing the spatial and time derivatives in a central finite difference form.

The time-dependent Maxwell's curl equations in general form, which will allow us to simulate propagation in media that have conductivity

$$\nabla \times E + \mu \frac{\partial H}{\partial t} = 0 \qquad (2)$$

$$\nabla \times H - \varepsilon \frac{\partial D}{\partial t} = \sigma E \qquad (3)$$

Where the displacement vector D is related to the electric field through the complex permittivity . In 1-D, we consider only E_x and H_y are not equal to zero and traveling in the z-direction [14] . In addition, we assume that the fields do not vary in the x-y plane, i.e. $\frac{\partial}{\partial x} = 0$ and $\frac{\partial}{\partial y} = 0$. However, the dielectric properties of prostate are donated with the complex permittivity as

$$\varepsilon_r^*(\omega) = \varepsilon_r - j\frac{\sigma}{\omega\,\varepsilon_0} \qquad (4)$$

Where ω is the angular frequency, and ε_r is the real relative part of the permittivity, σ is the conductivity and ω is the radial frequency of the signal. The quantity $\sigma/\omega\varepsilon_0$ is called the loss tangent. It describes the looseness of the medium. Since the human tissues are nonmagnetic, it has been assumed that $\mu_1 = \mu_0$. The free space is assumed for the exterior of the model with wave number $k_0 = \omega\sqrt{\varepsilon_0\mu_0}$.

Then Equations (2,3) can be reduced to [

$$\frac{\partial E_x(t)}{\partial t} = -\frac{1}{\varepsilon_0\varepsilon_r}\frac{\partial H_y(t)}{\partial z} - \frac{\sigma}{\varepsilon_0\varepsilon_r}E_x(t) \qquad (5)$$

$$\frac{\partial H_y(t)}{\partial t} = -\frac{1}{\mu_0}\frac{\partial E_x(t)}{\partial z} \qquad (6)$$

In the FDTD formulation, the central difference approximations for both the temporal and spatial derivatives are obtained at $z = k\Delta z$ and $t = n\Delta t$ for the first equation

$$\frac{E_x^{n+1/2}(k) - E_x^{n-1/2}(k)}{\Delta t} = -\frac{1}{\varepsilon_0\varepsilon_r}\frac{H_y^n(k+1/2) - H_y^n(k-1/2)}{\Delta z} - \frac{\sigma}{\varepsilon_0\varepsilon_r}\frac{E_x^{n+1/2}(k) + E_x^{n-1/2}(k)}{2} \qquad (7)$$

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and

$$\frac{H_y^{n+1}(k+1/2)-H_y^{n}(k+1/2)}{\Delta t}=-\frac{1}{\mu_0}\frac{E_x^{n+1/2}(k+1)-E_x^{n+1/2}(k)}{\Delta z} \quad (8)$$

Where n is the time index and k is the spatial index, which indexes times $t = n\Delta t$ and positions $z = k\Delta z$. The time index is written as a superscript, and the spatial index is within brackets. Equations (7 and 8) can be rearranged as a pair of 'computer update equations', which can be repeatedly updated in loop, to obtain the next time values of $E_x^{n+1/2}$ (k) and H_y^{n+1} (k + 1/2), corresponding the $E_x(t+\Delta t/2, z)$ and $H_y(t+\Delta t, z+\Delta z/2)$. As a result, E_x and H_y will differ by several orders of magnitude.

the changing of variables, equations (7and 8) become

$$\tilde{E}_x^{n+1/2}(k)=\frac{1-\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}}{1+\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}}\tilde{E}_x^{n-1/2}(k)-\frac{1/2}{\varepsilon_r\left(1+\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}\right)}[H_y^{n}(k+1/2)-H_y^{n}(k-1/2)] \quad (9)$$

$$H_y^{n+1}(k+1/2)=H_y^{n}(k+1/2)-\frac{1}{\sqrt{\varepsilon_0\mu}}\frac{\Delta t}{\Delta z}[\tilde{E}_x^{n+1/2}(k+1)-\tilde{E}_x^{n+1/2}(k)] \quad (10)$$

Stability and the FDTD method: For stability purposes, we need to choose the cell size Δz to allow 10 to 15 points per wave length. We used in all our simulations a time step $\Delta t=\frac{\Delta z}{2c_0}$ where c_0 is the speed of light in free space. The most important points in FDTD calculations are the stability and numerical dispersion [15].

III. NUMERICAL RESULTS AND DISSCUSION

A one dimensional finite difference model for predicting electric and magnetic fields in living tissues such as prostate tissue undergoing microwave heating is presented. .

For cell phone radiation studies, the simulated radiation source is a continuous waveform (CW) of .9GHz, The values of electrical parameters, relative permittivity and electric conductivity for this frequency, are adopted from [16]. The SAR IS a measurement used to quantify and the localized deposition of microwave energy. The SAR units are watts per kilogram (W /kg). As a dosimetric quantity, the SAR denotes the time rate of electromagnetic energy absorption at a given location in the tissue. The expression for the SAR is as follows:

$$SAR=\frac{\sigma E^2}{2\rho} \quad (11)$$

Where E is the electrical field (V/m), σ is the electrical conductivity (S/m) of the tissue and ρ is the mass density of the tissue (kg/m),and the power density is

$$p=\frac{\sigma E^2}{2} \quad (12)$$

Simulations were run for mobile phone radiation of the human prostate which frequency was 0.9 GHz continuous wave form source . In equation (9) the appropriate mesh sides Δx = .01and time steps Δt = .04 are considered for calculations H, E . FDTD method implemented in MATLAB program was used to compute the distribution of electric , magnetic fields, specific absorption rate and power density in the prostate tissue. Figure (1) represent the electric field in prostate tissue vs time steps, the electric field is maximum and decrease exponentially towards the inner tissue. The magnetic field penetrate in prostate tissue from mobile radiation is illustrated in figure(2). It shows that the amplitude of the magnetic field is more than electric field amplitude and decrease fast by much time steps through the tissue.in figure (3) we run MATLAB program using one dimension FDTD method to plot the specific absorption rate (SAR) in prostate tissue. The SAR and power density is directly proportional according the density of the tissue as in equation (11,12), so the minimum value in the case of SAR and power is at 35 time steps. In figure(4) the power density was plotting with respect to time steps and the figure show a maximum peak is less than amplitude more SAR curve peaks. Two dimension FDTD method illustrated in figure (5,6). The curves shows the electric field sticking prostate tissue in tow dimension by using bone and lines shape. This results denote that the mobile phone radiation is effect on human tissue and caused specific absorption rate according the dielectric properties of tissue which is changing by changing the frequency.

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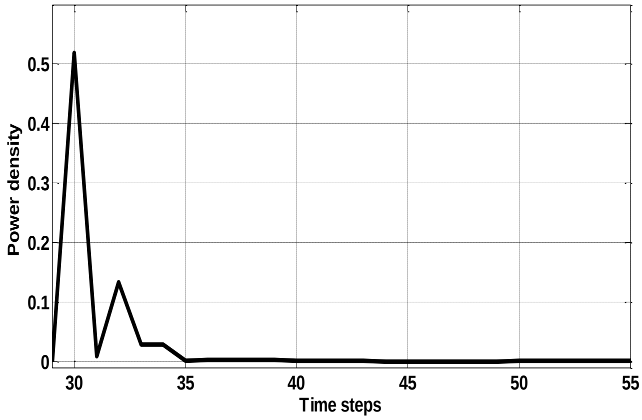
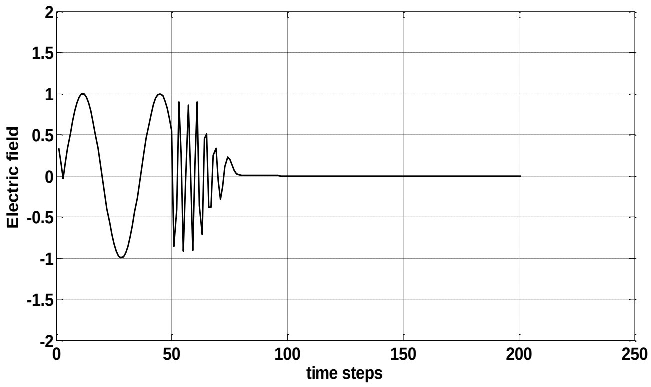
VI. CONCLUSION

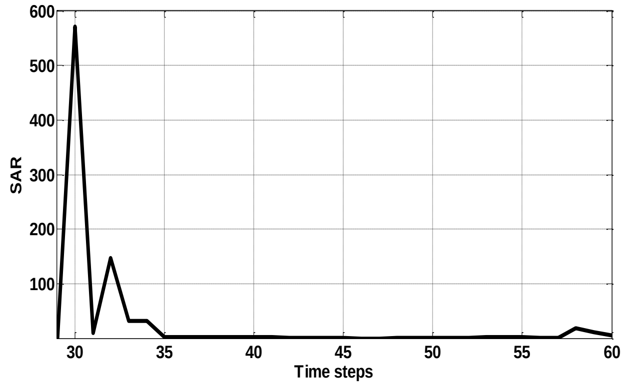
prostate human tissue representing simplified model life tissue irradiated by plane waves produced by mobile phone is investigated.. FDTD is used to study the distribution of the electromagnetic fields in the prostate tissues, the absorbent power, and SAR distribution. It is found that the fields penetrates the interface of tissue and attenuated rapidly till they reach zero at inner layer. Absorbent power and SAR have maximum values at the interface of tissue . According to the result from the graphs , notice that the there are the effect of frequency 900MHz by mobile phone Global System Mobile (GSM) is more at the first time steps through the cell of tissue. The dielectric properties for tissue are different according the change in frequency. This model enabled us to make simulations with very small cell size, and thus, figuring out the effect of thin layers on the SAR distribution was possible in a small simulation time.



Figure(3) power density in prostate tissue by one dimensional FDTD method



Figure(1) Eclectic field in prostate tissue by one dimensional FDTD method



Figure(4) SAR in prostate tissue by one dimensional FDTD method

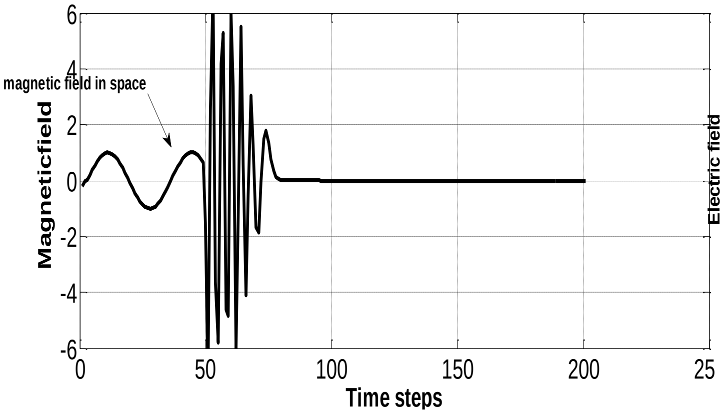
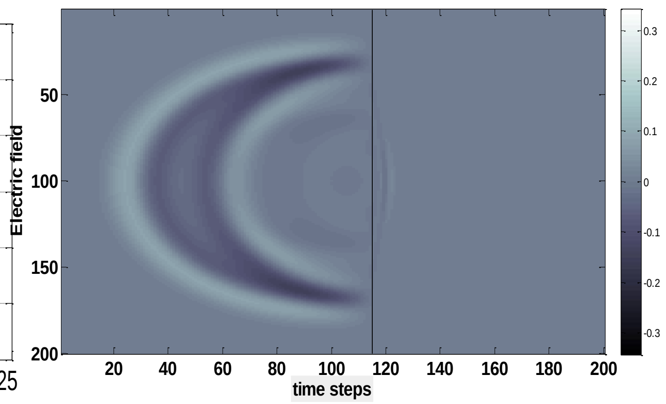


Figure (2) Magnetic field in prostate tissue by one dimensional FDTD method



Figure(5) 2D EM propagation -striking a prostate tissue (bone color)

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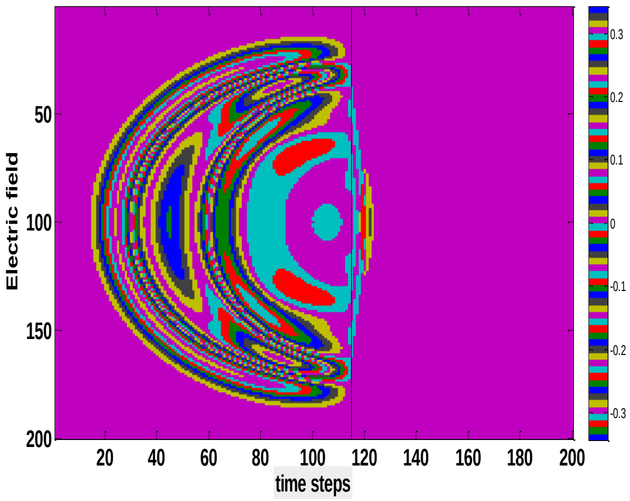

Figure(6) 2D EM propagation -striking a prostate tissue (lines)

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