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Numerical Study The Dielectric Properties And Specific Absorption Rate Of Nerve Human Tissue At Different Frequencies

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Abstract

The study of electromagnetic radiation effects on human body is a very important subject, due to the possible health effects, these electromagnetic waves can cause in life tissue. In this paper, the dielectric properties and specific absorption rat (SAR) distribution in nerve human tissues exposed to electromagnetic radiation with different frequencies is studied . We modeled nerve tissue by layered system. Finite difference time domain (FDTD) computations were used to evaluator the electric, magnetic field, and specific absorption rate. Results show the dielectric properties as conductivity, relative permittivity and penetration depth of nerve tissue plotted with different frequencies. A one dimensional FDTD algorithm has been built, some simulations for electromagnetic wave through the nerve tissue is made. Results show that electromagnetic fields penetrate the life tissues and attenuate fast to reach zero at large time steps. SAR show maximum at the first boundary of tissue and becomes less value by using high frequency. Also, the result appear that penetration depth and relative permittivity decreased by increasing frequency.

Keywords: Electromagnetic radiation; nerve human tissue; Finite difference time domain method.

1. Introduction

Increasing development of electromagnetic communication causes an increase in public concern about health risks from electromagnetic energy emitted from many sources [1]. Also, a raise using a high power electromagnetic waves results in the necessity to identify the limits of safe exposure with respect to thermal hazards. The amount of energy absorbed by tissue depends on many factors including frequency, dielectric property of the tissue, irradiating time exposure, intensity of electromagnetic radiation, and water content of the tissue. For this reason, public organizations throughout the world have established safety guidelines for electromagnetic wave absorption values. Since specific absorption rate (SAR) is a physical quantity, which causes the tissue heating because of RF exposure, the safety guidelines on localized SAR for wireless applications should be determined in relation to temperature rise in the head. This is because the biological hazards are mainly owing to temperature rise in the tissue. Although temperature elevation is an important parameter, little is known about it. Different head models were presented in the literature. A semi-infinite homogeneous plane of tissue has been considered by Riu and Foster [2]. S Gabriel et al have been studied a parametric model to explain the difference of dielectric properties of tissues as a function of frequency. The experimental spectrum from 10 Hz to 100 GHz was modeled with four dispersion regions. The development of the model was based on recently acquired data, complemented by data surveyed from the literature. Their purpose is to enable the prediction of dielectric data that are in line with those contained in the vast body of literature on the subject. Parameters are given for 17 tissue types[3]. The effects of operating frequency and leakage power density on distributions of specific absorption rate and temperature profile within the human body are investigated[4]. The study focuses attention on organs in the human trunk. The specific absorption rate and the temperature distribution in various tissues, obtained by numerical solution of electromagnetic wave propagation coupled with unsteady bio heat transfer problem, are presented. The real effects of the fields and the sensitivity of human model to electromagnetic radiation generated by mobile antenna has been studied[5].

When a human body is exposed to the electromagnetic radiation, because human body contain 70% of liquid, and it contain more liquid near of head, heart, abdomen (near of Thai). It is similar to that of cooking in the Microwave oven. The finite difference time domain (FDTD) method is widely used as a computational tool to simulate the electromagnetic wave propagation in biological tissues. The FDTD method has been used for calculating SAR (specific absorption rate) values on human model by varying the EM radiation at frequency 1.47 GHz. Electromagnetic field effect showing at different position of the human model. The propagation of radio frequency signals through different layers of human tissue is analyzed. In contrast to other research the complex characteristics of human tissue are included for both received signal strength and time of arrival methods [6,7] A multilayer model is developed to investigate the influences of different tissue layers on the absolute signal attenuation and travel time for signal propagation from in-body to on-body for in-body communication allocated frequencies: 403.5 MHz,916.5MHz, and 2.45 GHz. The analysis results show that the attenuation and delay in small intestine and muscle tissues have more influence on the total values than in fat tissue. In this paper , the dielectric properties and specific absorption rate (SAR) distribution in nerve human tissues exposed to electromagnetic radiation with different frequencies is studied . We modeled nerve tissue by layered system. Finite difference time domain (FDTD) computations were used to evaluator the electric, magnetic field, and specific absorption rate.

2. Theory and model

The possible effect of electromagnetic radiation for the human body is increasing in for our society [8]. We have been investigated and simulation of radio frequency produced from mobile phone with different frequencies as 900 MHz and 1800 MHz. The extent of reflection, absorption and transmission from an incident radiofrequency field depends on the type of material and its thickness with relation to the wavelength. When electromagnetic fields are incident on highly conducting such as metal surfaces, reflection is the dominant process, some absorption will occur and there will be almost no transmission. In the case of biological materials, there will be some reflection and the relative proportions of absorption and transmission will depend on the thickness of the material. Radio waves at telecommunications frequencies generally penetrate into the body tissues for a few centimeters before having been almost completely absorbed by the tissues. Suppose that electromagnetic radiation with different frequencies is incident vertically upon the interface nerve human tissue with dielectric properties shown in table (1).

Table 1. Dielectric properties of nerve tissue at frequency 900MHz and 1800MHz

Tissue name	Frequency (MHz)	Conductivity σ[S/m] at 900MHz	Relative permittivity at 900MHz	Penetration depth [m]	Density ρ[kg/m^3]	Wavelength [m]	Loss tangent
Nerve tissue	900	0.57369	32.531	0.053567	1100	0.057543	0.35223
Nerve tissue	1800	0.8429	30.867	0.035309	1100	0.029708	0.2727

Radio frequency radiation research may be modeled as boundary value problems control by partial differential equations subject to initial boundary values. The spatial domain of the boundary value problem may be complicated in general, and the direct analytical solution. The study of a heterogeneous model for human tissue is a difficult theoretical task. Maxwell's equations are the basic equations to simulate human life tissue by FDTD method[9]. There have been used special models and techniques, each valid only in a limited range of frequencies or other parameters. A combination of techniques has been used to obtain SAR for different models as a function of frequency and time. The permittivity and conductivity of nerve tissue are different according changing frequency. The electric field is assumed to propagate in the z direction with polarization at the x direction. Where only E_x and H_y are not equal to zero and traveling in the z-direction [10,11]. Maxwell's equations considered in one dimensions. The time-dependent Maxwell's curl equations in general form as

$$\nabla \times E + \mu \frac{\partial H}{\partial t} = 0 \tag{1}$$

$$\nabla \times H - \varepsilon \frac{\partial D}{\partial t} = \sigma E \tag{2}$$

Where $D = \varepsilon E$ is the displacement vector. Also, we suppose that the fields do not vary in the x-y plane. However, the dielectric properties of nerve human tissue are change according difference frequencies. Using some theoretical technique equations (1,2) becomes:

$$\frac{\partial E_x(t)}{\partial t} = -\frac{1}{\varepsilon_o \varepsilon_n}\frac{\partial H_y(t)}{\partial z} - \frac{\sigma_n}{\varepsilon_o \varepsilon_n} E_x(t) \tag{3}$$

$$\frac{\partial H_y(t)}{\partial t} = -\frac{1}{\mu_o}\frac{\partial E_x(t)}{\partial z} \tag{4}$$

Where σ_n, ε_o and ε_n are nerve conductivity, free space permittivity and relative permittivity of nerve tissue, respectively. By using FDTD formulation, the central difference approximations for both the temporal and spatial derivatives are obtained at $z = k\Delta z$ and $t = m\Delta t$, we have

$$\frac{E_x^{m+1/2}(k) - E_x^{m-1/2}(k)}{\Delta t} = -\frac{1}{\varepsilon_o \varepsilon_n}\frac{H_y^m(k+1/2) - H_y^m(k-1/2)}{\Delta z} - \frac{\sigma_n}{\varepsilon_o \varepsilon_n}\frac{E_x^{m+1/2}(k) + E_x^{m-1/2}(k)}{2} \tag{5}$$

and

$$\frac{H_y^{m+1}(k+1/2) - H_y^m(k+1/2)}{\Delta t} = -\frac{1}{\mu_o}\frac{E_x^{m+1/2}(k+1) - E_x^{m+1/2}(k)}{\Delta z} \tag{6}$$

where m is the time index and k is the spatial index, which indexes times t = $m\Delta t$ and positions $z = k\Delta z$. Equations (5) and equation (6) can be rearranged as a pair of 'computer update equations', which can be repeatedly updated in loop, to obtain the next time values of $E_x^{m+1}(k)$ and $H_y^{m+1}(k + \frac{1}{2})$, corresponding the E_x (t +Δt/2, z) and H_y(t +Δt, z + Δz/2) as:

$$\tilde{E}_x^{m+1/2}(k)\left(1+\frac{\Delta t.\sigma_n}{2\varepsilon_0\varepsilon_n}\right)=1-\frac{\Delta t.\sigma n}{2\varepsilon_o\varepsilon_n}\tilde{E}_x^{m-1/2}(k)-$$

$$\frac{1/2}{\varepsilon_n\left(1+\frac{\Delta t.\sigma_n}{2\varepsilon_o\varepsilon_n}\right)}\left(1+\frac{\Delta t.\sigma_n}{2\varepsilon_0\varepsilon_n}\right)[H_y^m(k+1/2)-H_y^m(k-1/2)] \tag{7}$$

$$H_y^{m+1}(k+1/2)-H_y^m(k+1/2)=-\frac{1}{\sqrt{\varepsilon_0\mu}}\frac{\Delta t}{\Delta z}[\tilde{E}_x^{m+1/2}(k+1)-\tilde{E}_x^{m+1/2}(k)] \tag{8}$$

3. Results and Discussions

Numerical study the electromagnetic simulation with different frequencies are used to calculate the electric and magnetic field distribution in nerve human tissue. Also, Power density of absorption and specific absorption rate have been evaluated in nerve tissue where the power density (W/m^3) absorbed in the conductivity σ along the supposed slab layer tissue from the sinusoidal pulse is given $P=\frac{|E|^2\sigma}{2}$. And specific absorption rate (SAR) in units of (W/kg) is the most important parameter for the evaluation of the exposure hazard at radio and microwaves frequencies [12]. It can be shown that: $SAR=\frac{P}{\rho}$, where ρ (Kg/m^3) is the density of the tissue.

FDTD Methods have become almost the most important time domain simulation techniques used in broad range of electromagnetic problem. FDTD method implemented in soft ware program was used to compute the distribution of electric and magnetic fields in nerve life tissue. The cell size has been calculated by taking into consideration the wavelength in the tissue with the highest relative dielectric constant, because this has the corresponding shortest wavelength. In our assumption, the highest relative dielectric constant is for the nerve tissue which is 32.531 at 900MHz. Thus the cell size is calculated to be 10th the wavelength at this layer as follows

$$\text{cell size}=\frac{1}{10}\frac{c_o/\sqrt{32.531}}{900000000},$$

and the number of electric field samples is 201 position. A sinusoid pulse adding the pulse at the start of the grid in our model. Figure (1) illustrated the conductivity for nerve human tissue at different frequencies, it seems that for increasing frequency the conductivity increased at frequency range (10-40GHz), and in the interval 60-100GHz, the increased of is very small. There are inversely proportional between relative permittivity and frequency as shown in Figure(2). Loss tangent is frequency dependent For microwave engineering[13,14], lossy materials are given with dielectric constants ε_r and loss tangent (tan δ). As $\varepsilon=\varepsilon_o\varepsilon_r(1-J\tan\delta)$, For lossless material, there is no loss and tan δ = 0, the permittivity is real and is simply $\varepsilon=\varepsilon_o\varepsilon_r$, the complex permittivity of the material can be reconstructed as the relation between frequency and lose tangent is directly in the frequency range(0-40) GHz but the relation becomes inversely if the frequency change from (70-100) GHz as illustrated in Figure (3). The wavelengths are plotted for different frequencies as in Figure (4) for nerve human tissue. In Figure (5) Penetration depth for nerve human tissue at different frequencies has been evaluated. Electric field for nerve human tissue at1800MHz frequencies ,500 time steps is shown in Figure (6) . the maximum first peak value is 0.2 V/m while in figure (7) is 0.4v/m when the frequency is 900MHz. It means that the electric filed is high at low frequency in nerve tissue. The comparative discussion to magnetic field according different frequencies is obvious in Figure(8) and Figure(9). It is shown that the magnetic field at low frequency is more than at high, Also, it is clear that the magnetic field at 900MHz and 1800MHz are 2.6T and 1.25T respectively. It is evident that the magnetic field attenuate very fast in nerve tissue until it is deep after many time steps . Specific Absorption Rate (SAR) for nerve human tissue at ,900 and 1800MHz frequency are shown in figures(10,11). It is obvious from the graph and according the program use that the amplitude in less than in the case of higher frequency.

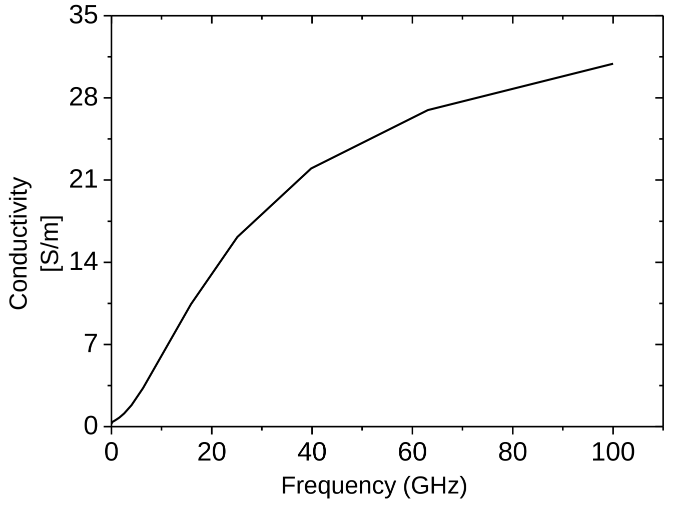


Fig 1 : Conductivity for nerve human tissue at different frequencies

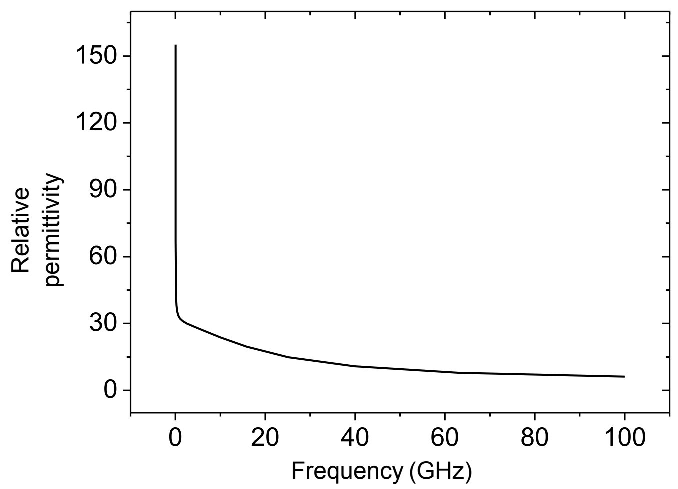
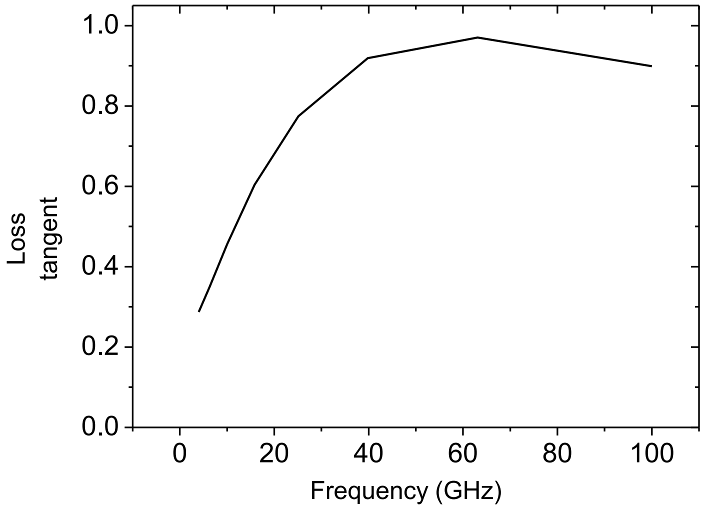


Fig 2: Relative Permittivity for nerve human tissue at different frequencies



. Fig 3: Loss Tangent for nerve human tissue at different frequencies

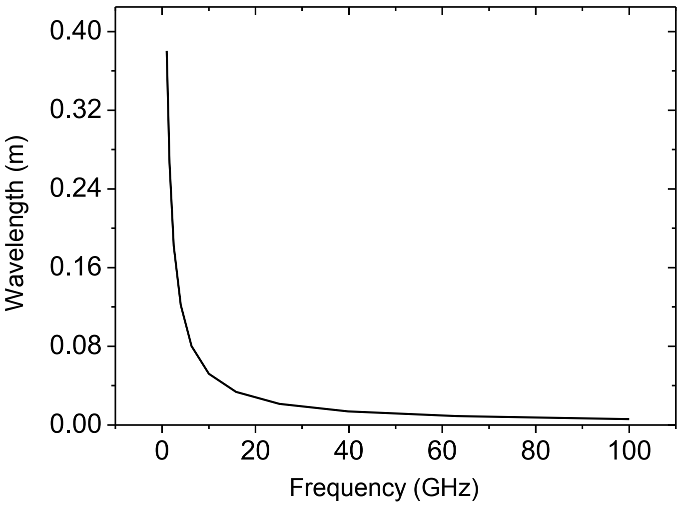


Fig 4: Wavelength for nerve human tissue at different frequencies

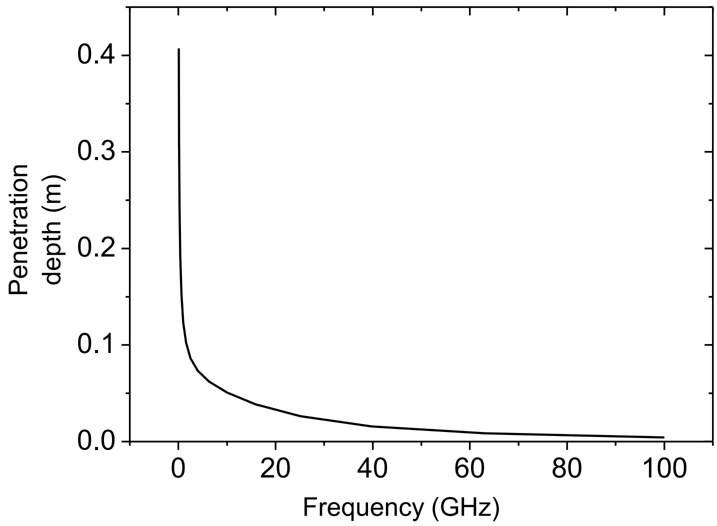


Fig 5: Penetration depth for nerve human tissue at different frequencies

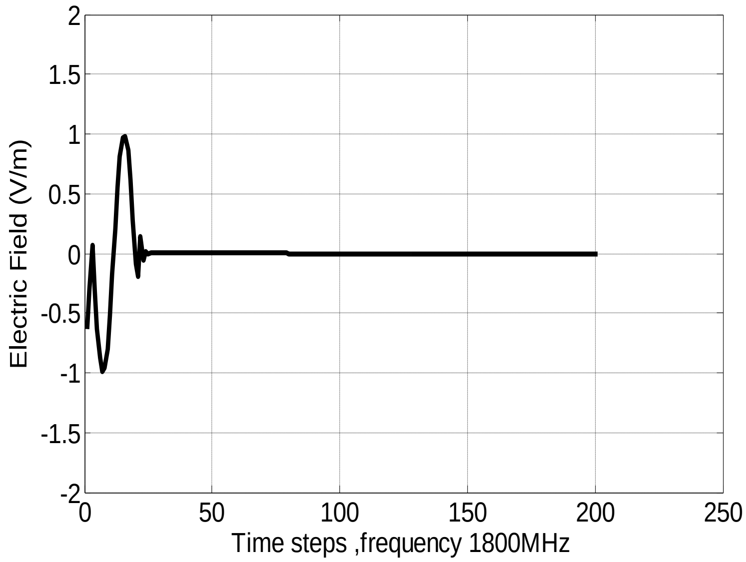


Fig 6: Electric field for nerve human tissue at1800MHz frequencies, 500 time steps

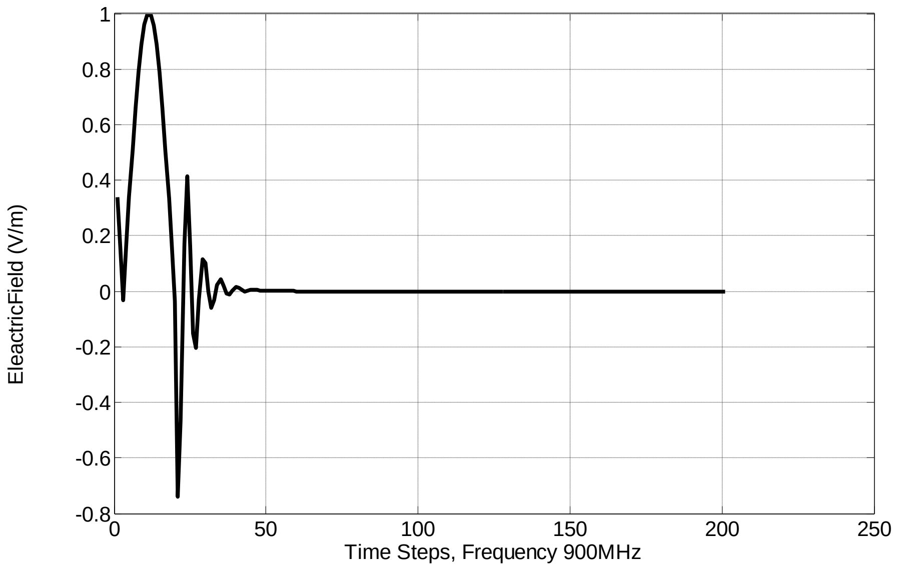


Fig 7: Electric field for nerve human tissue at 900MHz frequencies, 500 time steps

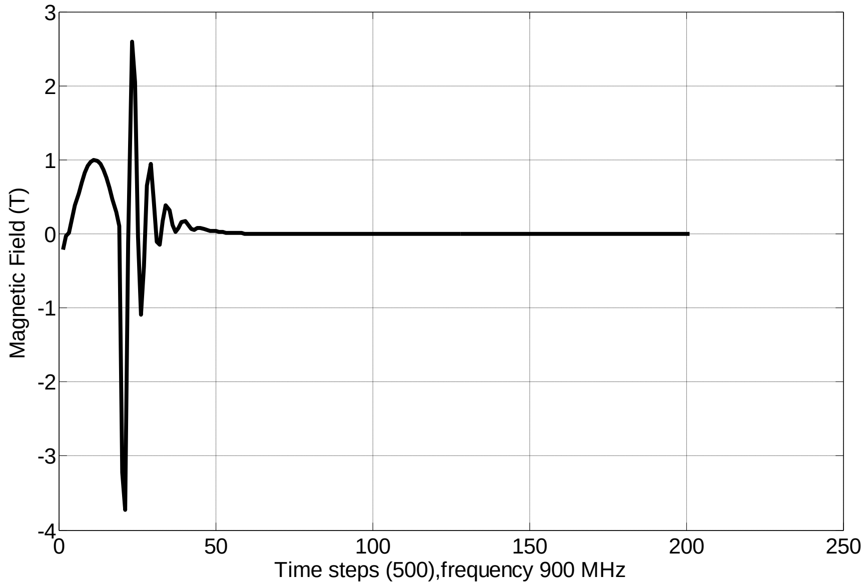


Fig 8: Magnetic field for nerve human tissue at 900MHz frequencies, 500 time steps

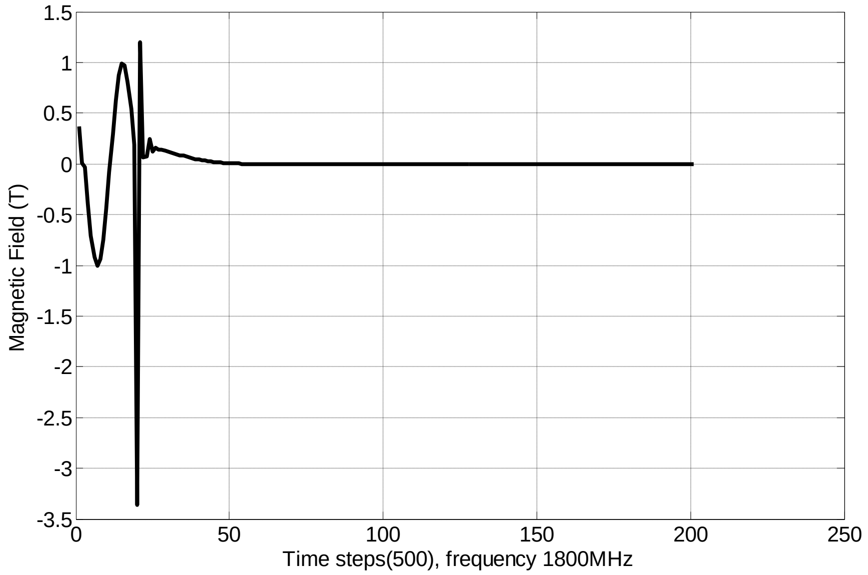


Fig 9: Magnetic field for nerve human tissue at 1800MHz frequencies, 500 time steps

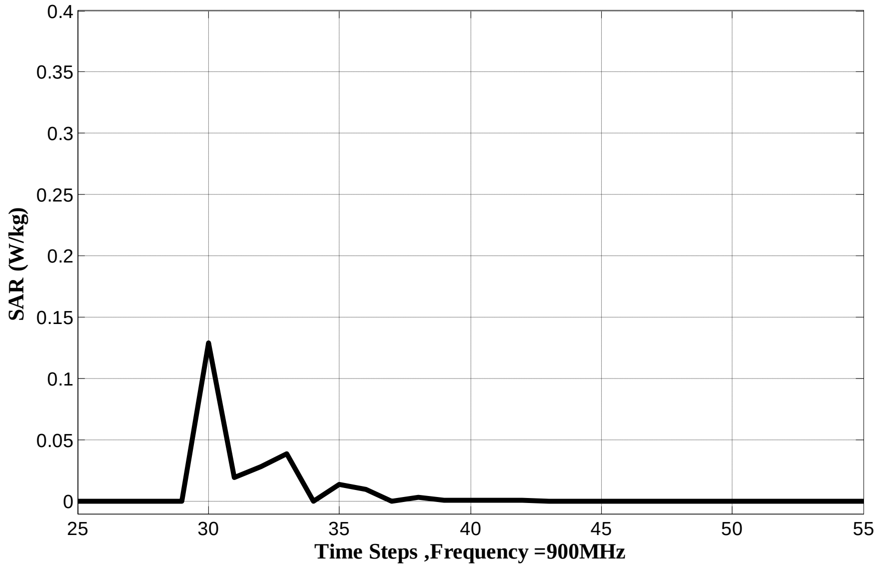


Fig 10: Specific Absorption Rate (SAR) for nerve human tissue at 900MHz frequencies, 150 time steps

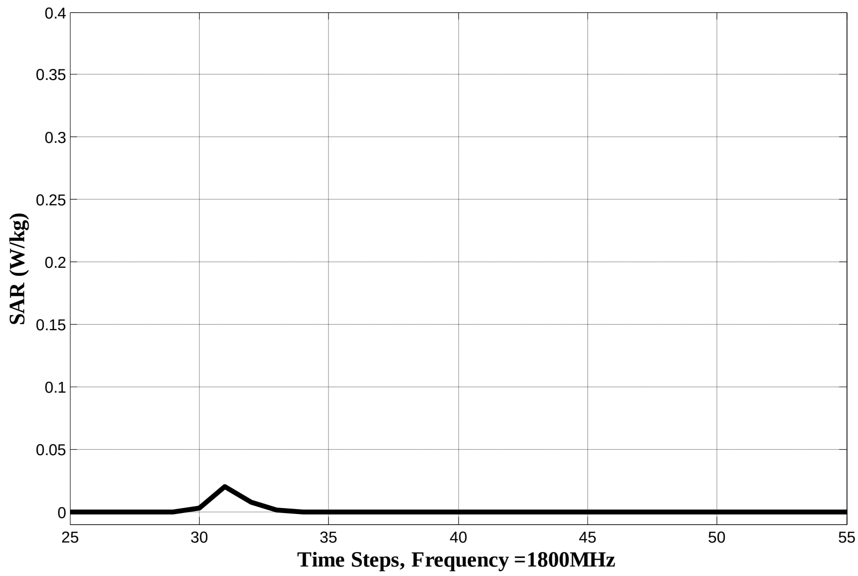


Fig 11: Specific Absorption Rate (SAR) for nerve human tissue at 1800MHz frequencies, 150 time steps

4. Conclusion

the dielectric properties , electromagnetic fields and specific absorption rat (SAR) distribution in nerve human tissues exposed to electromagnetic radiation with different frequencies is studied . Finite difference time domain (FDTD) computations were used to evaluator the electric, magnetic field, and specific absorption rate. Results show the dielectric properties as conductivity, relative permittivity and penetration depth of nerve tissue plotted with different frequencies. A one dimensional FDTD algorithm has been built, some simulations for electromagnetic wave through the nerve tissue is made. Results show that electromagnetic fields penetrate the life tissues and attenuate fast to reach zero at large time steps. SAR show maximum at the first boundary of tissue layers. Also, Specific Absorption Rate (SAR) for nerve human tissue at 1800MHz frequency is less amplitude than lower frequency. Furthermore, the result appear that penetration depth and relative permittivity decreased by increasing frequency.

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