

# Electromagnetic Fields in Tissue-Equivalent Liquids for Different Frequencies by Means of Flux Density

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**Abstract:** It is possible to use the dielectric parameters (effective permittivity and equivalent conductivity) of tissue equivalent liquids to evaluate electric and magnetic field for different electromagnetic wave frequencies. The electric and magnetic field in tissue equivalent liquids has been evaluated by means of flux density. Electromagnetic waves with different frequencies has been simulated used the finite difference time domain method. Found that the electric field amplitude decrease by increasing the frequency. The results reveal many interesting properties for measuring specific absorption rate.

**Keywords:** electromagnetic waves- Tissue equivalent liquid-FDTD-flux density

## I. INTRODUCTION

The daily exposure of hundreds of thousands of people to electromagnetic fields of electromagnetic waves intensity is without precedent, much concern and interest has been expressed in the possibility, that there could be associated health risks. Biological effects due to radio wave exposure are dependent on frequency [1-2]. Excitation was provided in the model by assuming a electromagnetic waves modal structure or static field distribution. The structure under test was taken to be a homogeneous cube with permittivity and conductivity equal to that of muscle tissue. Additional work on an engineering design approach of the electromagnetic waves cell using the finite-element method was reported in [3]. The dielectric properties of tissue are determined by a number of dispersion phenomena which are described[4]. Additional, lower frequency, dispersions are known to exist but have little bearing at microwave frequencies, however, excellent reviews have been provided by Pethig [5-6]. Specific absorption rate is generally obtained by measuring the electric field in a phantom made of a shell filled with a tissue-equivalent liquid. Based on the dielectric characteristics of the human body, such as the permittivities and conductivities of various tissues, and further investigations [7]. Tissue equivalent materials have a variety of uses, including routine quality assurance and quality control in both diagnostic and therapeutic physics. They are frequently used in a research capacity to measure doses delivered to patients undergoing various therapeutic procedures. However, very few tissue equivalent materials have been developed for research use at the low frequencies. Derived limits in terms of power flux density or in terms of electric field strength  $E$  (V/m) and magnetic field strength  $H$  (A/m) has been derived [8]. At operating frequencies of mobile communications base stations in far-field conditions, the measurement of the electric field strength is sufficient. A simple equation described the correlation to power flux density. K. Fukunaga et al evaluated the time dependence of dielectric properties of tissue-equivalent liquids recommended in the standard documents, and found that the permittivity and the conductivity decrease with time due to the evaporation of water [9]. Development of a Liquid-Type Human-Body Equivalent Antenna Using NaCl Solution has been investigated. NaCl solution for tissue-equivalent liquid filled in the humanequivalent antenna because NaCl solution is easy to prepare and is often used for tissue-equivalent liquid. The relative permittivities and conductivities of NaCl solution were measured with a coaxial cell (National Physical Laboratory, UK). The applicable frequency of the coaxial cell is from 15MHz to 1GHz. Different substances have been used as tissue-simulating materials [10-14]. Of these, the sugar-based liquids described in [10] are common because they have low toxicity and are easy to obtain. For these liquids, sugar (sucrose) is used to lower the permittivity of water and sodium chloride is added to increase the conductivity. In this study, common granulated cane sugar, salt (NaCl), and deionized water were used. In this paper, the form of flux density useied to evaluate the electric and magnetic field simulated in a tissue

equivalent liquids as diethylen glycol monobuthyl . FDTD method has been used to determine electric and magnetic field for different frequencies .

## II. THEORY AND MODEL

Figure 1 shows source of electromagnetic waves as sinusoidal waves with determine frequency. The source is at distance 30 cm from the boundary of The mixture of de-ionized water diethylene glycol monobuthyl ether (DGBE) [9]. Diethylene glycol monomethyl ether (DGME) is a colorless liquid at room temperature with a mild, ether-like odor. It is highly soluble (miscible) in water. This product is manufactured by the reaction of methanol and ethylene oxide. Its Applications is a good solvent for many classes of dyes including basic chrome, naphthol, and stabilized reduced vat dyes.

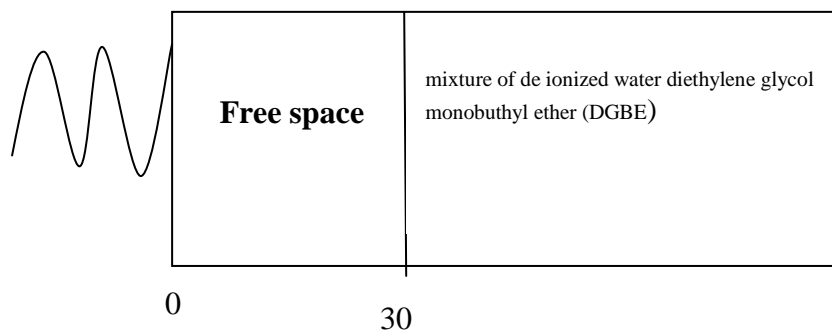


Figure (1) electromagnetic waves incident upon a tissue equivalent liquid exposed to electromagnetic waves

in this study. Tables 1 show the target values and the recipes recommended in the standard [15], for 900, 1450, 1950, and 2450 MHz

We use the form of flux density into the simulation. Its importunacy is apparent in problem of frequency dependent materials. Maxwell's equation in firm of flux density are

$$\frac{\partial \mathbf{D}}{\partial t} = \nabla \times \mathbf{H} \tag{1}$$

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

where  $\mathbf{J} = \sigma \cdot \mathbf{E}$  is the current density, and

$$\mathbf{D}(\omega) = \epsilon_0 \cdot \epsilon_r^*(\omega) \cdot \mathbf{E}(\omega) \tag{3}$$

We assume the dielectric properties of tissue are donated with the complex permittivity  $\epsilon_r^*$ ,

$$\epsilon_r^* = \epsilon_r + \frac{\sigma}{j \omega \epsilon_0} \tag{4}$$

where  $\epsilon_r$  is the real relative part of the permittivity,  $\sigma$  is the conductivity and  $\omega$  is the radial frequency of the signal[ 16 ].

Substituting equatiin (4) in (3), then

$$D(\omega) = \epsilon_r \cdot E(\omega) + \frac{\sigma}{j\omega\epsilon_0} E(\omega) \tag{5}$$

Taking the first term into the time domain is not problem, because it is simple multiplication. In the second term. Fourier theory tells us that  $1/j\omega$  in the frequency domain is integration in the time domain ,so equation (5) becomes[16].

$$D(\omega) = \epsilon_r \cdot E(\omega) + \frac{\sigma}{\epsilon_0} \int_0^t E(t) \cdot dt \tag{6}$$

The integral approximated as a summation over the time steps  $\Delta t$  are

$$D^n = \epsilon_r \cdot E^n + \frac{\sigma \cdot \Delta t}{\epsilon_0} \sum_{i=0}^n E^i \tag{7}$$

we solve for  $E^n$  given the value of  $D^n$ , so separating the  $E^n$  term from the result of summation

$$D^n = \epsilon_r \cdot E^n + \frac{\sigma \cdot \Delta t}{\epsilon_0} E^n + \frac{\sigma \cdot \Delta t}{\epsilon_0} \sum_{i=0}^{n-1} E^i \tag{8}$$

The electric field  $E^n$  can be written as

$$E^n = \frac{D^n - \frac{\sigma \cdot \Delta t}{\epsilon_0} \sum_{i=0}^{n-1} E^i}{\epsilon_r + \frac{\sigma \cdot \Delta t}{\epsilon_0}} \tag{9}$$

Choose the new parameter as

$$I^n = \frac{\sigma \cdot \Delta t}{\epsilon_0} \sum_{i=0}^n E^i \tag{10}$$

Substituting in equation (9) we have

$$I^n = I^{n-1} + \frac{\sigma \cdot \Delta t}{\epsilon_0} E^n \tag{11}$$

At every time steps  $n$ , simply adds the value  $E^n$  times the constant term to the previous values of the summation  $n-1$ . The dielectric properties for four frequencies are illustrated in table (1)

Frequencies (MHz)	Relative permittivity $\epsilon_r$	Conductivity $\sigma$ [S/m]
900	41.5	0.79
1450	40.5	1.20
1950	40	1.40
2450	39.2	1.80

Table(1) dielectric properties for mixture of de-ionized water diethylene glycol monobutyl ether at four frequencies

### III. RESULTS AND DISCUSSION

The electric and magnetic fields have been calculated numerically. The finite-difference time-domain (FDTD) method is used to evaluate the electric and magnetic field for different values of permittivity and conductivity of tissue equivalent liquid. It is a method of numerical analysis. The mixture of de-ionized water diethylene glycol monobutyl ether (DGBE) has been used. We have changed the formulation slightly and introduced the use of flux density into the simulation.

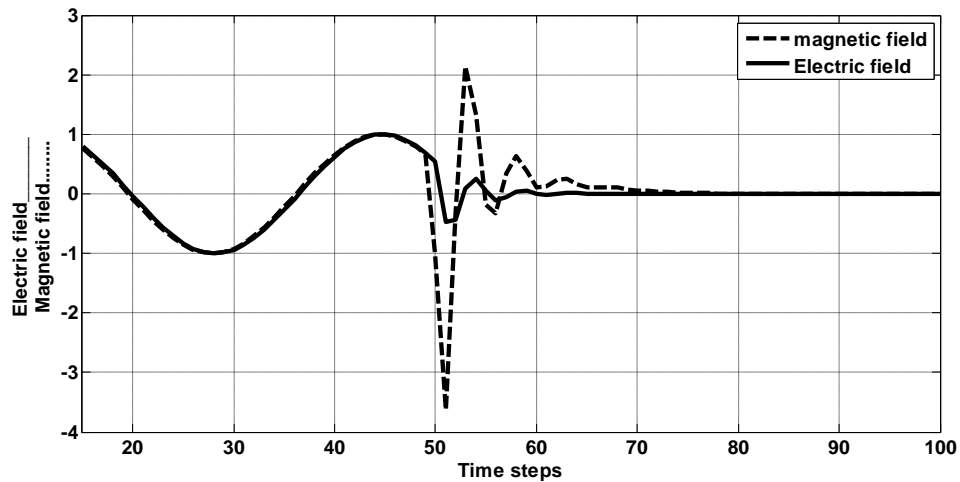


Fig. 1. Electric and magnetic field in tissue equivalent liquids - mixture of de-ionized water diethylene glycol monobutyl ether, frequency is 900 MHz,  $\epsilon_r=41.5$ ,  $\sigma=0.79$  S/m

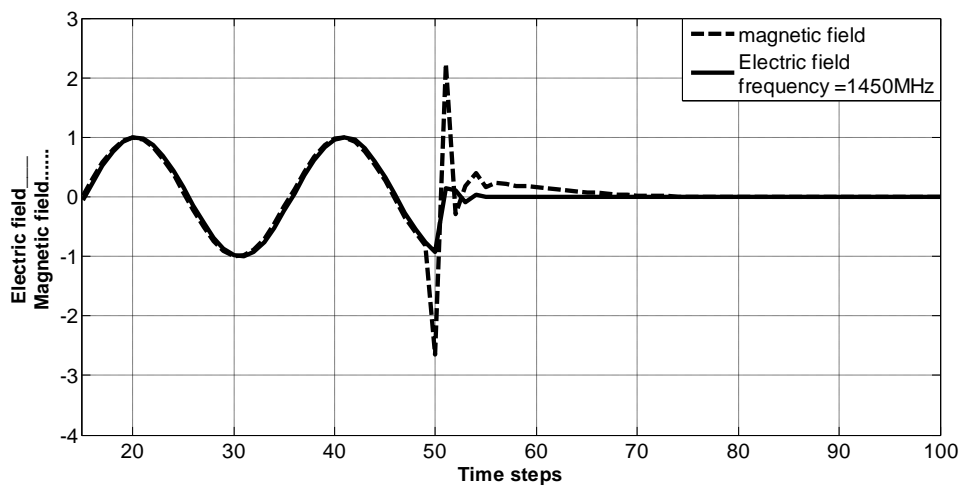


Fig. 2. Electric and magnetic field in tissue equivalent liquids - mixture of de-ionized water diethylene glycol monobutyl ether, frequency is 1450 MHz,  $\epsilon_r=40.5$ ,  $\sigma=1.20$  S/m

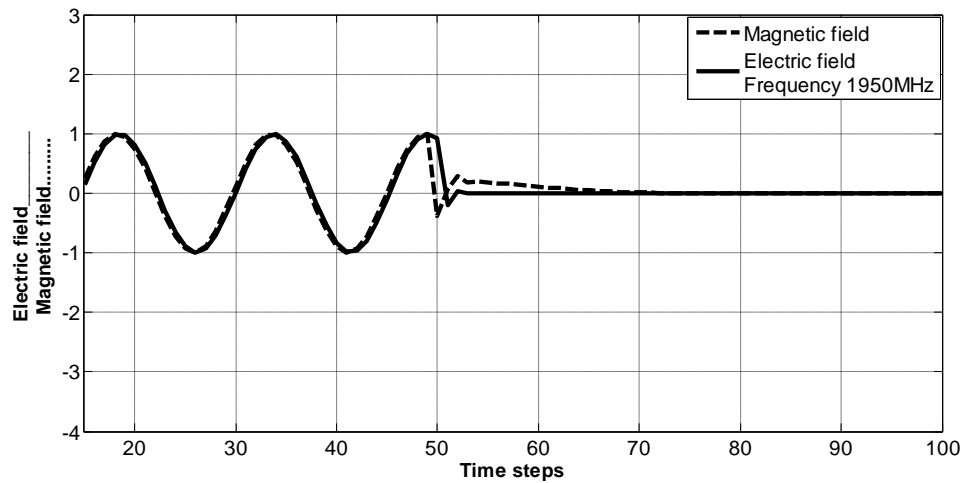


Fig.3. Electric and magnetic field in tissue equivalent liquids - mixture of de-ionized water diethylene glycol monobuthyl ether, frequency is 1950 MHz , $\epsilon_r = 40$  , $\sigma = 1.40$  S/m

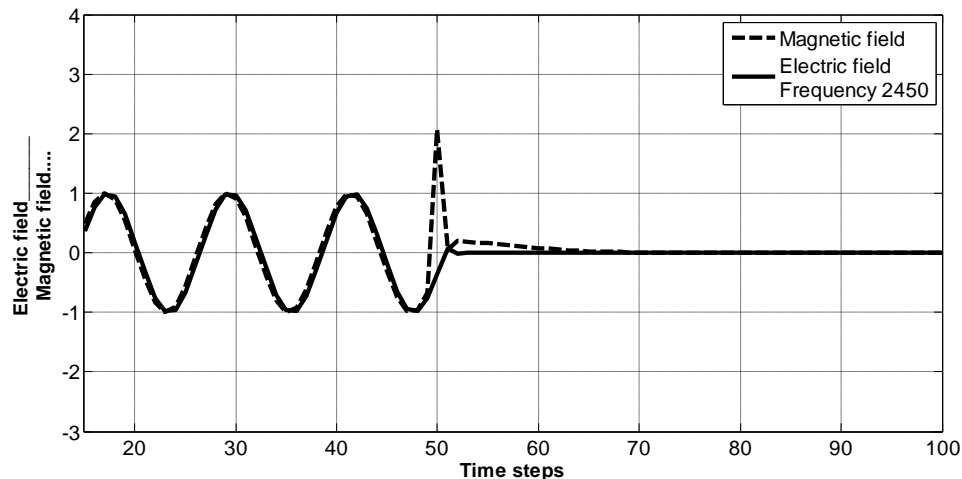


Fig. 4. Electric and magnetic field in tissue equivalent liquids - mixture of de-ionized water diethylene glycol monobuthyl ether, frequency is 2450 MHz , $\epsilon_r = 39.2$  , $\sigma = 1.80$  S/m

#### IV. CONCLUSION

For different electromagnetic wave frequencies . The electric and magnetic field in tissue equivalent liquids has been evaluated by means of flux density. It has been simulated using the finite difference time domain method (FDTD) . Found that the electric field amplitude decrease by increasing the frequency. The results of this research reveal many interesting properties for measuring specific absorption rate.

The Benefits of DGME has low odor and high solvency and can fill a wide range of solvent requirements.

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