Investigation on the MHz-THz Radiation Field Regime Absorption in Cancer-Health Cell Tissue

Muhamad Hamdi, Usman Malik

Physics Dept, Math and Science Faculty, University of Riau Pekanbaru, Tel.+62 761 63273, email : muh4hamdi@yahoo.com

ABSTRACT

This paper focuses on the thermoregulation rise due to exposure of the MHz-THz radiation field regime in cancer-health cell tissue. In fact it may occur some processes such as absorption, transmission, reflection and scattering when this radiation interacts with tissue. It depends on the exposure power source. During in cell tissue there is basically the existence of this radiation field contribution to the cell tissue bioelectric and bio magnetic field result in heat production rate. It has a source from excitations of cell macromolecule photonic-phonon vibrations. The self cell tissue has the periodic bio potential with a small cellular volume results in the bioelectric field. This main reason we investigate and solve the simultaneous equations using Maxwell, heat conduction and sinusoidally modulated intensity equation with spectral method. We assume a small tissue piece to form the spherical or cylindrical cell membrane layer. Absorption involves the extraction of vibration energy from MHz-THz radiation regime field by a cell macromolecular species; the vibration must cause a change in the cell electric dipole moment. Energy absorption is the primary mechanism that allows radiation field of MHz-THz source to produce physical effects on tissue for treatment purposes. While transitions between two energy levels of a molecule that are well defined at specific THz wavelengths could serve as a spectral fingerprint of the cancer molecule for diagnostic purposes

Keywords :*MHz-THz radiation, absorption, cell tissue , macromolecule, excitation, photonic-phonon vibration*

INTRODUCTION

The MHz-THz region of the electromagnetic spectrum lies in the range between microwaves and infrared. This so-called 'phonon-photon gap' has historically been defined specially for THz frequency range by the relative expensive sources, detectors, and systems for its wave generation.This paper focuses on use of MHz-THz radiation regime for fundamental studies in cellular organization and as tools in medical practice. More detail information relating to the modes of interaction of the MHz-THz radiation field regime energy with cancer-normal cell tissue structures is continually being soughtThe next analysis pursuing our individual research interest have been employing the MHz-THz radiation regime method in biologically oriented studies [1,2]. In this tissue layer the penetration of the MHz-THz radiation regime is the way by which the energy of phonons or photons is taken up by level of cell macromolecules, typically in the molecules of a macromolecule in cell [1]. Thus, this radiation energy is transformed to other forms of energy for example, to heat.

This paper investigates and solves a heat conduction, sinusoidal modulated intensity and Maxwell equation simultaneously, which includes the calculation of low scattering factors that affect the ratio of bioelectric field and bio magnetic amplitude change per unit cylindrical or spherical volume in cancer cell tissue (mW/mm^2)[3]. Because the interaction between MHz-THz radiation regime and cancer-health cell tissue involves phonon-photon radiation absorption and scattering, the most important parameter is power density (mW/mm^2), which is a function of the power delivered by the source and the spot size [1]. In fact, the product of fluence and absorption coefficient equals the heat from the source, which is the amount of energy deposited in a unit volume of cancer cell tissue. Basically more complicated configurations of cancer cell tissues and interfaces may arise in practice. However, the effects on the magnetic and electric field intensity amplitude of its penetration within a cancer cell medium as choice has been considered in this discussion dealing with the physical mechanisms of penetration [3] .

This model analyzes the power effect on the MHz-THz radiation regime penetration in cancercell tissue by analyzing the scattering, which depends on the angle and wavelength [1]. We validate our model using the experiment data in the MHz-GHz radiation frequencies while the THz frequencies have the submillimeter wavelengths in the range from 0.1 mm to 10 or 30 mm used for testing model. The good agreement is found in this frequency range. It analyzes numerically the dependence of dielectric constant on this frequency for the higher frequencies range such as the 0.1-10 of MHz and THzrange. Besides it analyzes the behaviours of bioelectric and bio magnetic field intensity amplitude in normal for tangential and normal component, energy flux per unit area at an interface of the cancer cell tissue layer. The cancer cell tissuemedium properties for simplicity are a suitable formulation can be derived. For requirement of charge cancer cell in tissue layer assumes their characteristic of in tissue layer such as non linier, anisotropic and dielectric loss media. It is derived the boundary ('jump') conditions on the field vectors at an interface between the first and second tissue layer [3].

THEORETICAL CONSIDERATION

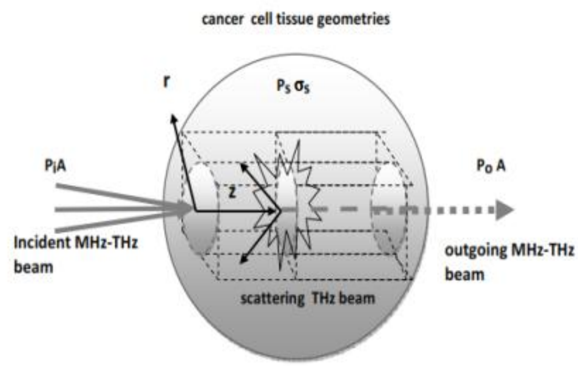
The simultaneous Maxwell and heat conduction equation in the cancer cell tissue layer

The radiation absorbed by sample according to the Bouguer-Lambert-Beer Law decreases its intensity in depth x. The energy absorbed or scattered by the sample , and therefore also the portion thereof which its transformed into heat. For sinusoidally modulated light, with the modulated amplitude ranging ΔI, the incident radiation intensity I_o with its change given [4]

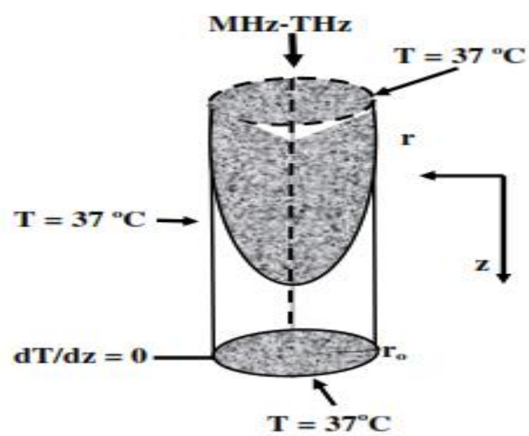
$$dI_{abs} = \beta(\frac{1}{2} I_o (1 + \sin \omega t) e)^{-\beta x})dx \qquad (2.1)$$

Where β is scattering parameter, ω frequency and in time t. The time-dependent process of heat conduction in Figure 2.2 with conditions of boundary , it shows the penetration of MHz-THz radiation regime field in the cancer cell tissue slab which results in heat transfer. This analysis can be described by the thermal diffusion equation

$$\nabla^2 T = \frac{1}{\alpha} \nabla T - \frac{\eta}{\chi} \frac{dI_{abs}}{dx} \qquad (2.2)$$



(a)



(b)

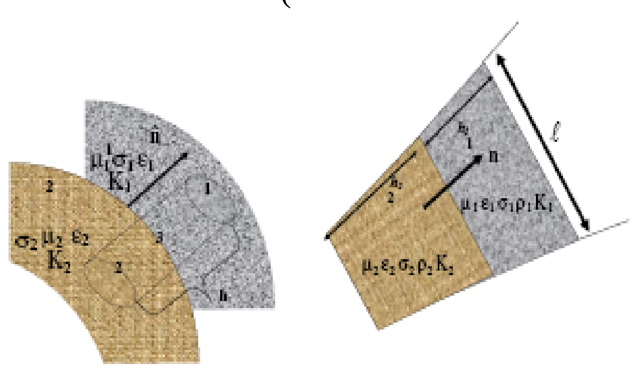


Figure 2.2. (a) A small sphere tissue with) scattering factor (b)a small cylinder in normal direction of an axial and radial width in the depth boundary, (c) the space of spherical and cylindrical tissue form between 1 cancer and 2 health tissue with biological properties $\sigma, \varepsilon, \mu, K$.

Which gives the change of temperature T in a cancer cell tissue of temperature. Where it involves constant of diffusivity conductivity α, thermal conductivity η and absorption coefficient χ . For the simple reason the physical magnetic and electric field intensity Maxwell's equations are set in the time-domain is the most natural approach. It starts with solving the following main Maxwell's equations together the heat conduction equation simultaneously,

$$\frac{\sigma}{\varepsilon}\frac{\partial E}{\partial t} = \frac{1}{\mu\varepsilon}\nabla^2 E + \frac{1}{2} E H + Q(x, T) \qquad (2.3)$$

$$\frac{\sigma}{\varepsilon}\frac{\partial H}{\partial t} = \frac{1}{\mu\varepsilon}\nabla^2 H + \frac{1}{2} E H + Q(x, T) \qquad (2.4)$$

$$\rho C\frac{\partial T}{\partial t} = \nabla^2 T + \frac{1}{2} E H \quad (2.5)$$

Fields arise from currents and charges on the source. In this condition, the electric (E) and magnetic (H) field intensity, current density are three-dimensional vector fields that are dependent on both time and space.

Interface of the cancer-health tissue layer

The study has been concerned with the MHZ-THz radiation regime fields which can be quantitatively described in terms of a " nonlinear "analysis. That is, it is assumed that the change in the density of the cancer cell tissue layer is linearly proportional to the change in the pressure which waves are of infinitesimal radiation field intensity amplitude. Radiation pressure a can exert steady forces on interfaces between tissue layers having different values of radiation velocity and/or density. In Figure 2.2a, it shows a radiation penetrationwith scattering factor. Figure 2.2 b the use of Maxwell and heat conduction equation solve the first boundary conditions using Dirichlet and Neumann conditionsat the interface between two tissue layersin Fig2.2c having forms of spherical and cylindrical geometry, respectively. It uses the important integral theorem or a divergence theorem. If this theorem used on the surface integral of magnetic field normal line component, then each of part of this integral is zero.The magnetic field equation in terms $\rightarrow 0$ when loop shrink for parts from H_{1n} to H'_{2n} and rest of from the previous reason $B_2 = 0$, $H_{21} = 0$ and dielectric constant does not depend on frequency , then ratio

$$\frac{H_{1t}}{E_{1n}} = \frac{h}{2}(\sigma_1 - j\omega K_1\varepsilon_o) + \frac{h}{2}(\sigma_2 - j\omega K_2\varepsilon_o)\frac{E_{2n}}{E_{1n}} \quad (2.6)$$

Energy flux **S** in interface of two biological tissue layers has been derived with using some approximations. Energy flux in W/m2 sec and at the higher frequencies such as THz radiation range penetrating in biological tissue layers for its depth and heat transformation depends on kinds of tissue layers. If THz radiation electric field intensity amplitude has a source from an oscillating electric dipole , $p = p_o e^{-j\omega t}$ located at the origin then the radiated power unit solid angle $S \bullet \hat{r}\ r^2$.

EXPERIMENTAND MODELING

Design of a setup in MHz-GHz experiment for a comparison

The process of generation and detection of photo acoustic signals is presented in this section although a detailed derivation of the theory can be omitted. The cancer-health cell tissue sample using the rat cancer cell tissue to be investigated is irradiated with the microwave and ultrasound radiation, modulated by chopper, for

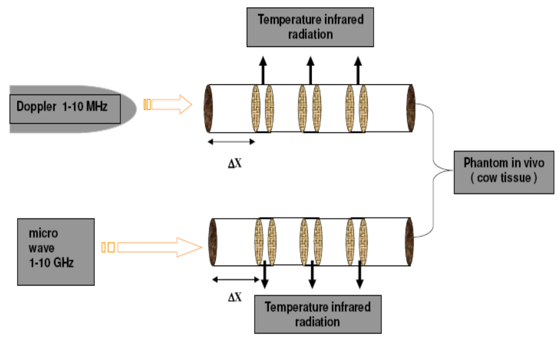


Figure 3.1. A schematic diagram of the process in a photo acoustic cell for cow cancer cell tissue in experiment using range of frequencies in MHz and GHz

example, at Δx at a frequency $\omega/2\pi = \upsilon$ as comparison for studying penetration of THz radiation in cancer cell tissue. It is as shown in Fig. 3.1assumed the sample is optically and thermally homogenous. In addition, it is required that incident radiation intensity and the flow of heat both be perpendicular to the surface of the sample. Upon absorption of radiation intensity the energy of excitation is transformed into heat through radiationless transitions with a fractional yield . This leads to local periodic heating of the sample. By means of thermal diffusion the heat spreads through the sample and reaches the surface, where it is partly transferred to the free space present in the sample chamber. A schematic diagram of the process of penetration THz radiation in cancer cell tissue in model uses 1-

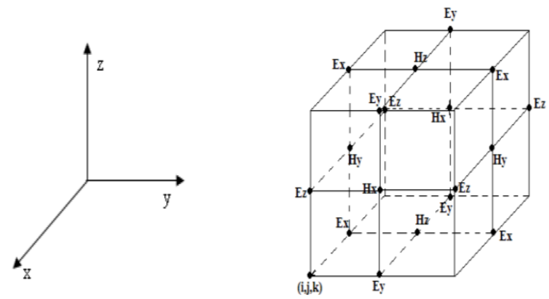
10 MHz-GHz range in width and depth boundary.

1.1. Numerical methodology- finite difference time domain method

There are a few popular computational electromagnetic methods such as the finite element method (FEM), the method of moments (MOM), and the finite difference time domain method (FDTD). The FEM is a numerical technique for finding approximate solutions of partial differential equations and integral equations. It is usually used in the frequency domain and each solving of the equations gives the solution for one frequency. The MOM method is based on integral equations and Green's functions. MOM is usually used in the frequency domain, and it has the advantage of dealing easily with long thin wires or thin patches. A function *F* of space and time is evaluated at a discrete point in the grid and at a discrete point in time as in Figure 3.2b.

$$F^n(i,j,k) = F(i\Delta x, j\Delta y, k\Delta z, n\Delta t) \quad (3.1)$$

where *x*, *y*, *z* and *t* are the steps in the x y and z directions and the time step. The updated value of the E (or H) field



(a) (b)

Figure 3.2.Yee cell shows the spatial and radial (a) relationship of E and H. (b)

It could be gotten the basic FDTD updating equations for *E*and H inFigure 3.2 b given

$$E_x^{n+1}(i+1/2, j, k) = \left(\frac{2\varepsilon - \sigma e\Delta t}{2\varepsilon + \sigma e\Delta t}\right)E_x^{n}(i+1/2, j, k) + \left(\frac{2\Delta\Delta}{2\varepsilon + \sigma e\Delta t}\right)$$
$$\left\{\frac{1}{\Delta y}[H_z^{n+1/2}(i+1/2, j+1/2, k) - H_z^{n+1/2}(i+1/2, j-1/2, k)] - \right.$$
$$\left.\frac{1}{\Delta z}[H_y^{n+1/2}(i+1/2, j, 1/2+k) - H_y^{n+1/2}(i+1/2, j, k-1/2)]\right\}$$

(3.2)

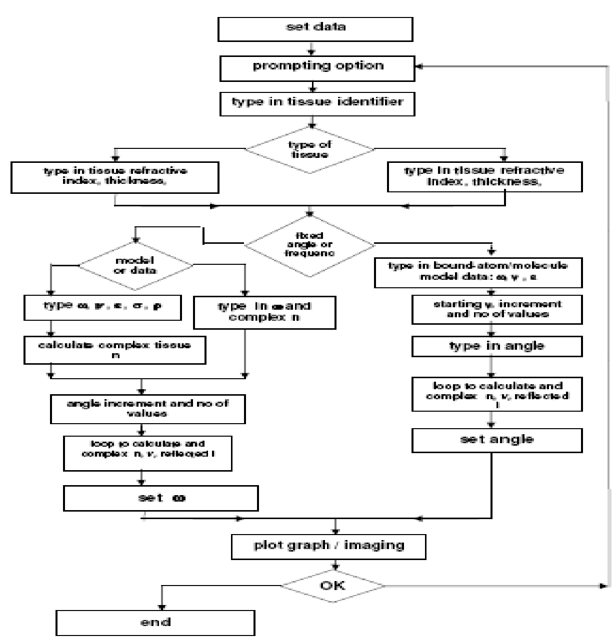


Figure 3.3. A schematic diagram of the process in modeling using range of MHz-THz frequency in the width and depth boundary.

Component is a function of its previous value (one time step before) and the previous value (half time step before) of the surrounding H(or *E*) fields at half spatial steps away. Power absorbed in the loads is calculated from equation

$$Power = \Delta x(i,j,k) \times \Delta y(i,j,k) \times \Delta z(i,j,k) \times \sum_i \sum_j \sum_k [\frac{1}{2}\sigma_{(i,j,k)} \times (E^2_{x(i,j,k)} + E^2_{y(i,j,k)} + E^2_{z(i,j,k)})]$$

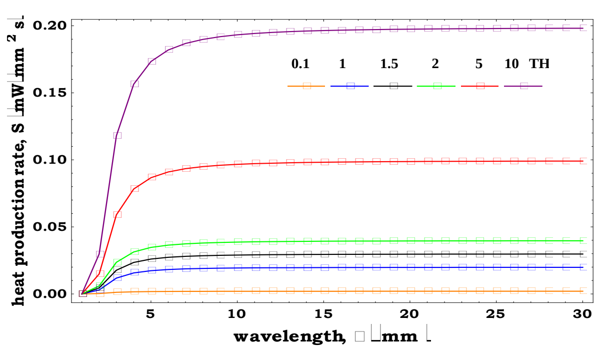
(3.3.)

Where $\sigma_{(i,j,k)}$ (S/m) is the conductivity of the FDTD cell at the *(i,j,k)* location; E_x, E_y and E_z(V/m) are the magnitudes of the electric field components in the *x*, *y*, and *z* directions, respectively; Δ*x (i,j,k)*, Δy *(i,j,k)* and Δz *(i,j,k)* are the dimensions of each FDTD cell at location *(i,j,k)* and the summation is performed over the hole volume of the load. In Figure 3.3. a flow diagram shows the procedure for the estimation of tissue grid types. The computer program consists of a number of subroutines are done in succession and the flow-chart is shown in Fig. 3.3. The process involves the building up of the element, structural tissue type, refractive index, thickness, density, conductivities and the determination of response values

RESULTS & DISCUSSION

The low scattering factor and heat production in THz regime radiation absorption

When macromolecules absorb MHz-THz radiation regime, in principle some type of coupling might be expected meanwhile transitions occur between vibration energy levels. However, this is not the case because this transition occurs much more rapidly than the time scale of nuclear motions [1,2]. The next discussions have just attempted to produce a approach result of modelling to experiment. The MHz-THz frequency range having a terahertz gap ranges



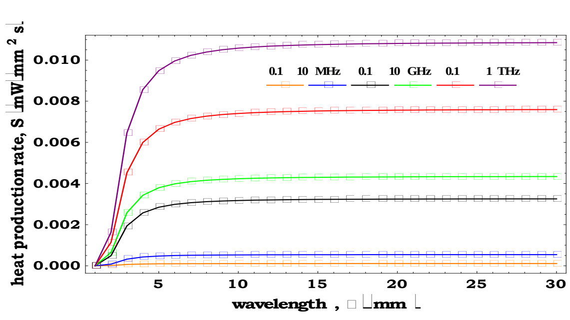
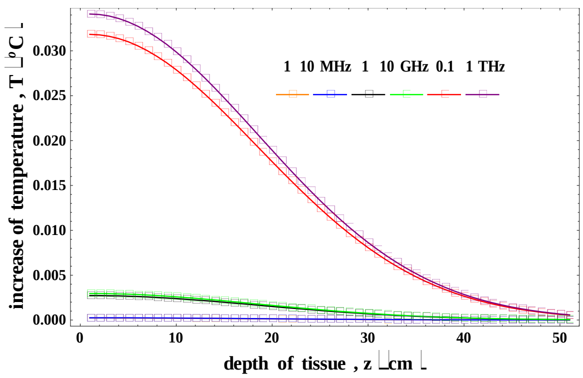


Figure 4.1.The change from a MHz to THz wavelength in THzFigure 4.2.The change from a shorter to a longer wavelength inradiation regime absorption shows a significant change of theTHz radiation regime absorptionincreases the heat production heat production rate in a cancer cell tissue volume rate in a cancer cell tissue volume



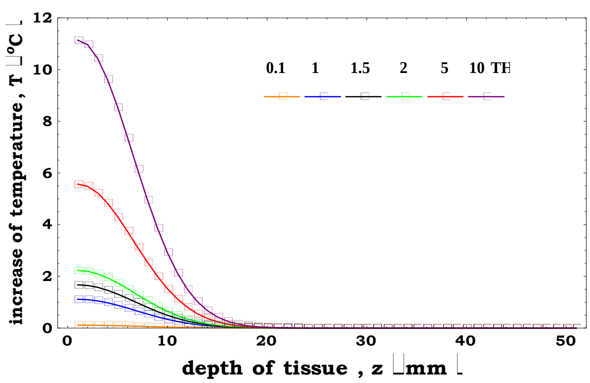


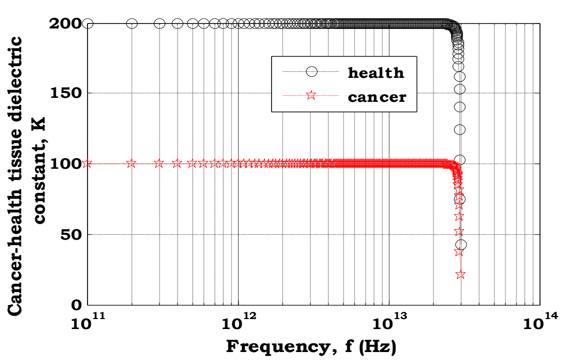
Figure 4.3. The increase of temperature with variation of frequencyFigure 4.4. The increase of temperature with a depth of cancer

range and depth in cancer cell tissue cell tissue for various THz frequencies

are studied . It can be seen in Fig. 4.1 and then compared with MHz and GHz ranges. There is a significant difference of THz radiation regime absorption in cancer cell tissue between ultrasound or microwave frequencies and THz frequencies in heat production. The heat production rate of THz radiation regime is higher than MHz-GHz frequencies because of the power source. The Fig.4.2 shows that the change from a shorter to a longer wavelength increases the heat production rate in a cancer cell volume slightly (measured in mW/mm^2).This means that shorter wavelengths contribute to the heat production more than the longer wavelengths. It also indicates that the longer wavelengths remain constant. In Fig.4.3 shows that in with variation of MHz-THz frequency range and tissue depth due to penetration of THz photon radiation variation about d = 50 mm reduces temperature change to zero and alsodue to properties of tissue optical depth, δ = 1 mm. Other factors include the variation of the THz radiation power source P and the variation of the wavelengthλ, as well as the radiation photon incidence angle θ. They also give effect on rise of temperature in cancer cell tissue. The effect of various THz power source describes the rise of temperature with a depth of cancer cell tissue in Fig.4.4. It means the THz radiation regime in range 5-10 THz which indicates the highest peak from heat increase in tissue. The higher heat production is caused by the THz radiation regime beam for 5 THz and 10 THz propagating through the tissue with strong water absorption, the intensity is attenuated exponentially, due to the low scattering factor.

The dielectric constant and electromagnetic field analysis in THz regime radiation absorption

In Fig.4.5, the higher range (0.1-10 THz) in near infrared frequencies shows that dielectric constant K depending on frequency for cancer and health tissue, respectively. The result of dielectric constant for cancer tissue K = 100 and normal tissue K = 200 show remain constant for all frequencies in ultrasound and microwave ranges which describe the independence of dielectric on frequency. The change of K occurred when this radiation



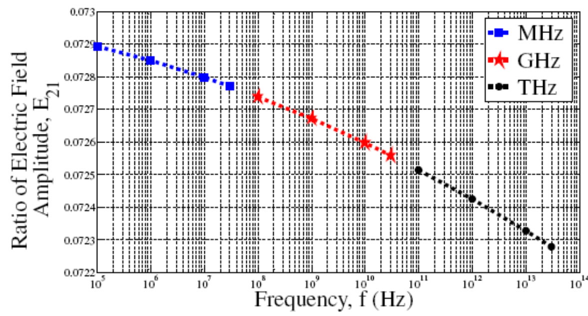
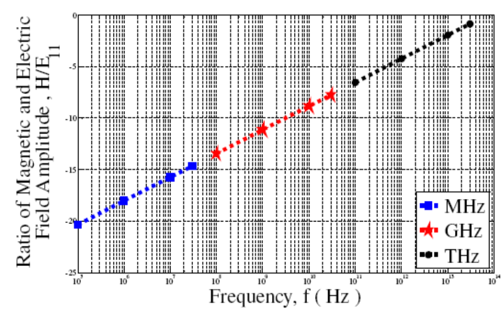


Figure 4.5. Dielectric constant as frequency function in THz range Figure 4.6. The ratio of the tangential electric field amplitude as for cancer and healthy tissue frequency function in THz range for cancer and healthy tissue



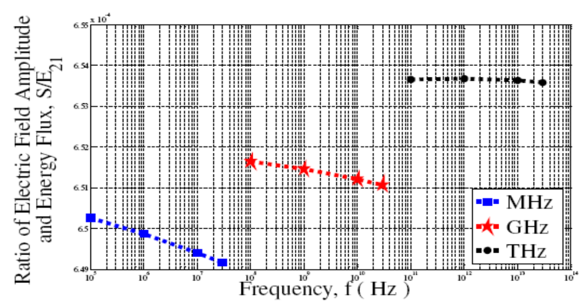
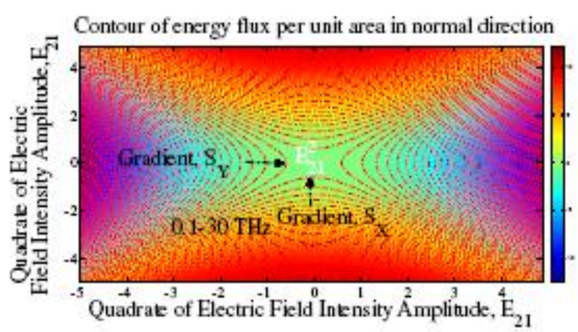


Figure 4.7. The ratio of magnetic and electric field amplitude asFigure 4.8. The electric field amplitude and energy flux ratio

frequency function in THz range for cancer and healthy tissue as frequency function in THz range for cancer and healthy tissue

penetrates in cancer cell tissue specific for frequencies of THz ranges form 0.1 THz to 30 THz. The sharp decrease of K is in this specific THz range due to its phenomena to absorb water strongly in near infrared vibrational spectra. It indicates that cancer cell tissue included a kind of dielectric medium loss. In addition to in fact the cancer cell tissues consist of most of glucose contained discrete tissue structures relate to water content. The result of the numerical calculation in Fig. 4.6 , THz-MHz radiation penetrates at the interface of cancer-normal tissue layer to show the reduced tangential electric field amplitude ratio . It indicates decrease when its frequency increases. The changes of electric field intensity amplitude ratio values tend to decrease from the MHz to THz range. This reduction is caused by properties of dielectric loss tissue from cancer cell tissue (K = 100) to health tissue (K = 200) and also this radiation absorbs water strongly in the liquid contained tissues. Line-of-sight propagation in a boundary of cancer-health tissue layer refers to THz electro-magnetic radiation or MHz and GHz range acoustic wave propagation in Fig 4.7.This graph describes the ratio of magnetic and electric field intensity amplitude a rise linearly with increasing ranges of the higher frequencies. This fact caused besides the higher frequency the higher magnetic field intensity, also THz radiation transmission includes light emissions travelling in a straight line. Fig.4.8 the terahertz radiation penetrating at the boundary of cancer-health tissue layer can reduce its electric field intensity amplitude which consequences, of course, decrease its energy flux. This reduction factor is many causes of its loss ; the losses actually may have a source from diffraction, refraction, scattering, transmission or absorption. Frequencies between approximately 0.1 and 30 THz, can penetrate through



(a)

(b)

Figure 4.9. (a). Contour of gradient of energy flux per unit area at interface of cancer-healthy tissue in normal direction, (b) a position of cancer cell tissue

Cancer-health tissue layer, thus giving THz radiation transmissions in this range a potentially global reach. Again along multiply diffracted curve lines are in ratio of electric field intensity amplitude and energy flux quadrate. It is for distribution of energy flux per unit area as a complex function as can be seen in Fig.4.9. The effects of multiple diffraction lead to macroscopically "quasi-curved paths". The complex equation of real part in energy flux rate S for the THz (0.1-10) radiation range is described in gradient contour for flow in normal direction in area of S_x and S_y component , respectively. It show that image of flux lines change as quadrate of electric field intensity amplitude at boundary of cancer-healthy tissue layer. Accounting for penetration effects in terahertz radiation is important because a reduced electric field intensity amplitude can affect the quality of the image produced. By knowing the penetration that THz radiation experiences travelling through a tissue medium, one can adjust the input signal amplitude to compensate for any loss of energy at the desired imaging depth.

CONCLUSION

Use of the MHz-THz range about (0.1-10 MHz, 0.1-10 GHz, and 0.1-10 THz shows that THz range having the low scattering factor compared to the MHz-GHz range. THz radiation regime absorptiondescribes the change from a shorter to a longer wavelength to increase the heat production rate in a cancer cell volume slightly. Meanwhile MHz-GHz range shows the high scattering which it generates the low heat production. It also indicates that the decrease of temperature with a depth of cancer cell tissue for various frequencies or powers. Besides thatthe result of dielectric constant Kdepends on frequency for cancer and healthy tissue, respectively. The 0.1-10 THz gapradiation frequency range is used for realistic theoretical analysis while it is compared to the 0.1-10 MHz and 0.1-10 GHz radiation frequency range. The penetration intwo tissue layer is analyzed by means of numerical analysis. The energy flux rate in complex function as a function of electric field intensity amplitude quadrate penetrates at an interface of a cancer-health cell tissue layer. Since any biological tissue layer mainly consists of water, it behaves as a dielectric with losses. Dielectric constant of cancer and normal tissue also show that in these specific radiation frequencies they are highly depending on the frequency. The most useful interaction information of terahertz radiation with tissue occurs due to strong absorption and scattering. This is in fact that if it really absorbs water in any tissue layer which it penetrates with the motion of groups of relatively large groups of molecules; in consequence, such applications sensing to medicine and biology.

REFERENCES

[1] Muhamad Hamdi, Yusof Munajat, 2012. Penetration of THz Radiation in Biological Tissue . USA Wolfram Demontrations Project , http: demonstrations.wolfram.com/

[2] Muhamad Hamdi, Yusof Munajat,2013. 1 D Heat Conduction through Biological Tissue . USA Wolfram Demontrations Project, http: demonstrations.wolfram.com/

[3]Muhamad Hamdi, Investigation on Bio electromagnetic Field of Terahertz Radiation Behaviours at Interface of Brain-Fat Tissue. J. Innovative Science. Islamic University of Indonesia Vol.1No.2,5-2012.ISSN 2089-3086

[4] Hamdi Ilham, *Introduction to Biophysics*, 1st ed., Pekanbaru, Riau, Indonesia: RUEDC-Press, 2007.

[5] W. Hoppe, W. Lohmann, H. Markl, and H. Ziegler, *Biophysics*, New York: Springer-Verlag, 1983