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Analysis of Field Exposure in Skin Cells at Terahertz Frequency Range

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Abstract—Terahertz frequency spectroscopy (10^{12} Hz) has its application in Tele-communication, Medical, Security and it is also an extension of microwave and millimeter wave bands. Those cells in the human body which have selective wavelength interaction when exposed to terahertz frequency will absorb, reflect or scatter light that is based on tissue water content. Therefore it is essential to ensure safety limits for its radiation exposure in tissue. Monte Carlo simulation method is being used to find dosimetry calculations for terahertz frequency radiations. This method is applicable for normal and cancer tissue. The final result is plotted graphically for number of frequencies and compared with each other in terms of variation parameters such as diffuse reflectance, diffuse transmittance and photon probability fluence in order to know about the difference absorption and reflectance in the photon penetration at skin layers in these regions in human cells or biological tissue
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Keywords- *Terahertz radiation, Skin cells, water content, Monte-carlo simulation*

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I. INTRODUCTION

The Terahertz radiation is in the range between Far-infrared and microwaves in the Electro-Magnetic Spectrum [1]. The Growth of terahertz radiation is used in various applications fields such as dermatology, oncology, oral health care, medical imaging, pharmaceutical industry and security [2]. It is mainly used in therapeutic and diagnostic applications such as medical and pharmaceutical industry due to its ability of light to penetrate a tissue and its components depositing energy through the optical absorption properties of the tissue. The optical properties in a light transport model used to predict the light distribution and energy deposition. The information about the optical properties of human tissue at terahertz frequencies should be useful for predicting the feasibility of proposed applications, optimizing acquisition protocols, providing information about variability of healthy tissue and supplying data for studies of the interaction mechanism [3, 4]. The skin appearance is linked to water content in skin layers. This water content of the stratum corneum, outer most layer of skin influences its permeability and elasticity. The Water is main absorber in terahertz region. The role of water is important in distinction between the diseased and normal tissue. For this frequency region according to corresponding wavelength optical constant of water content in tissue is given in the work of Hale and Querry [5]. Water is the major thing important to all living things; 90% of body weight is contributed from water content for certain organisms. Water content for adult human body is about 60% and for human adult women body it is about 55% which means that 2/3rd of our body made up of water. But recently born babies have more water content than adults, on growing (i.e.) after one year its water content drops to 65%. The Percentage of water content in human body parts is given in Table I [6,7]. People with more fatty tissue have less water than less fatty tissue people.The basic structural unit of any living thing is cell. Every cell is like a building block and a little miniature factory to process the food of its own body regulating functions [8].

Table I. Water content in parts of human body

Percentage of water Content (%)	Organs
73	Heart and Brain
83	Lungs
64	Skin
31	Bones

Human skin is a complex tissue consisting of several distinct layers, each consisting of their own components and structure. The various layers of skin are stratum corneum, living epidermis, dermis and subcutaneous fat, each varying in few millimeters in thickness [9]. Water content and hydration level in the central part of stratum corneum is higher than in the superficial and deeper cell layers. Water domains are mainly present within the corneocytes and not in the intercellular regions [10]. The thickness of the epidermis varies in different types of skin [11].

II. MONTE CARLO SIMULATION

Photon propagation in tissue is simulated by the Monte Carlo simulation technique. The simulation is based on the photon travel through tissue by sampling for particular bin size and angular deflection at incidence of the photon. There are so many algorithms to implement Monte Carlo simulations of light transport. Monte Carlo simulations are available in various computer languages [12, 13]. Here standard C implementation of Monte Carlo multilayered (MCML) modeling of photon transport is developed to calculate the diffuse reflectance, absorbance and photon probability fluence for various frequencies in the terahertz radiation region.

A. MCML

MCML is a steady state Monte Carlo simulation program for multilayered turbid media. The infinitely narrow photon beam serves as the light source. Each layer has its own optical properties of absorption, scattering, anisotropy and refractive index. The simulation is 3D, but the results are stored in an r-z array in cylindrical coordinates denoting radial and depth positions [14]. The final output shows its radial position, fluence rate within the multilayered medium of tissue, diffuse reflectance and absorbance. The program can be easily modified in an input text file specified for the simulation and another text file as output is obtained. Dynamic allocation of data is followed for MCML program, therefore the number of tissue layers and grid elements can be varied by user at run time. It is used to solve various problems related to laser tissue interaction. Monte Carlo simulated diffused reflectance can be used to differentiate and deduce the optical properties of cancerous tissue from normal tissue. The optical energy deposited inside the tissue by photon transmission is used to analyze light dosage for photodynamic therapy. Each layer of tissue is described using the parameters: the thickness, the refractive index, the absorption coefficient μ_a (cm^{-1}), the scattering coefficient μ_s (cm^{-1}) and anisotropy g. The refractive index for medium above and below the tissue is to be given as well. The layers of tissue are parallel to each other. The absorption coefficient μ_a is defined as the probability of photon absorption per unit infinitesimal pathlength. Absorbant is the ratio of the absorbed intensity to the incident intensity. The scattering coefficient μ_s is defined as the probability of photon scattering per unit infinitesimal pathlength.

B. Absorption coefficient of water

Water absorption spectrum is based on the work of Hale and Querry [5]. The water absorption during the exposure of high energy laser pulses, report of Cummings and Walsh gives detailed discussion about mid-IR water absorption, the peak absorption decreases as pulsed laser energy deposition in the water increases. The absorption coefficient of water changes, by as much as two orders of magnitude, during a high irradiance laser pulse is given in Table II. Total absorption coefficient is the product of percentage of water content in tissue and absorption coefficient of water at corresponding frequency is

$$\mu_a = W*\mu_{a\ water} \quad (1)$$

Water content percentage of skin tissue value varies between 20% to 45%, according to layer and type of tissue in cancer research [15].

Table II. Absorption coefficient of water at THz frequency

Frequency (THz)	Absorption coefficient of water (cm^{-1})
1	200
1.5	317
3	669

III. RESULT AND DISCUSSION

A. Depth of penetration

The tissue depth of penetration varies based on the type of tissue layer and it is given as

$$\delta = 1/ [3*\mu_a*(\mu_{a+} \mu_s*(1-g))]^\wedge(1/2) \quad (2)$$

TABLE III. PENETRATION DEPTH FOR VARIOUS FREQUENCY

Frequency (THz)	Tissue depth (cm)
1	0.0291
1.5	0.0117
3	0.0045

When the photon incident on the tissue layer it will get absorbed, reflected or scattered based on its water content. The depth of penetration of photon decreases with increases in frequency of light incident on it which implies that most of the photons are absorbed. The maximum photon penetration depth is given based on Table III.

B. Reflectance and Transmittance

Reflection occurs between the two medium whenever light is incident on the biological tissue. Then the amount of reflectance is the ratio of reflected power to incident power. Total reflectance is subdivided into specular reflectance and diffuse reflectance. Specular reflectance is amount of light reflected regularly on the surface of the tissue and the diffuse reflectance is amount of light diffused or scattered on the tissue surface. The Transmission is the light passing through the medium by unidirectional beam. The transmittance of a tissue amount is the ratio of transmitted power to incident power [17]. The calculated value for reflectance and transmittance in normal and cancer tissue for different frequency in terahertz radiation is displayed in Table IV and the graph is plotted for the various frequency in normal and cancer tissue in Figure 1.

Table IV. Reflectance value obtained for Skin tissue at Terahertz frequency

Tissue type	Frequency (THz)	Specular Reflectance	Diffuse Reflectance	Transmitta nce
Normal	1	0.0672154	0.000365217	2.18791E-007
	1.5	0.0672154	0.000265894	0
	3	0.0672154	0.000132967	0
Tumor	1	0.0672154	0.000427315	8.95249E-008
	1.5	0.0672154	0.000200921	0
	3	0.0672154	0.000103553	0

The reflectance of tissue also varies when the incident angle of photon is varied this can be understood and also the difference between the normal and cancer tissue for various terahertz frequencies are also easily viewed graphically by seeing the figure 2, The incident angle is varied between 0^o to 180^o.

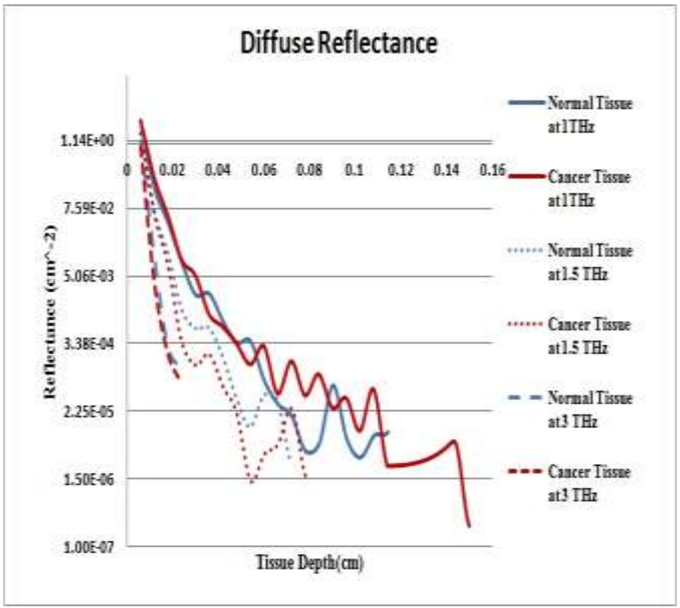

Figure 1: Variation of diffuse reflectance based on Tissue depth at various frequencies

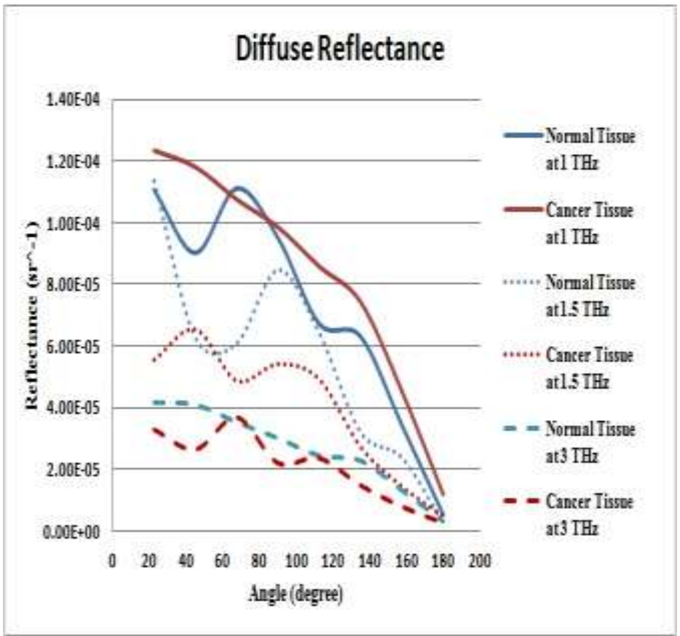

Figure 2: Variation of diffuse reflectance based on angle of incidence at various frequencies

C. *Absorbance at skin layers*

The ratio of the amount of intensity absorbed to the amount of intensity incident on the tissue is called absorbant. The absorption degree is quantified by Beer Lambert law. The inverse of absorption coefficient is referred as absorption length L; it is the measure of distance z in which intensity has dropped into $1/e^{th}$ value of its initial intensity. The table V is about the amount of photons absorbed in tissue layer and comparison between normal tissue layers and cancer tissue layers at 1 THz, 1.5 THz and 3 THz frequencies of terahertz radiation [1].

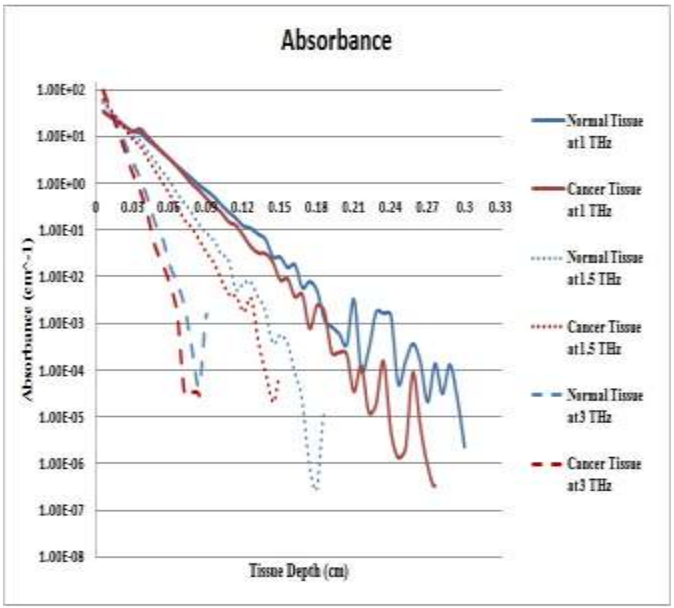

Figure 3: Variation of absorbance based on Tissue depth at various frequencies

The absorbance value for various tissue types such as normal and cancer tissue at different frequencies of terahertz radiation is plotted graphically on Figure 3 where blue line in graph denotes the Normal tissue and red line in graph denotes cancer tissue. The Absorbance value goes on decreasing when photon penetrates deeper the tissue i.e. most of the photons are absorbed in outermost layer.

Table V. Absorbed fraction of photons in layers of skin tissue at Terahertz frequency

Tissue type	**Frequency (THz)**	**Absorbed fraction in Tissue layers**		
		Epidermis	***Dermis***	***Subcutaneous Fat***
Normal	1	0.6745	0.2578	7.426E-005
	1.5	0.8115	0.121	1.624E-007
	3	0.921	0.01165	0
Cancer	1	0.6532	0.2791	1.763E-005
	1.5	0.8504	0.08222	0
	3	0.9268	0.005889	0

IV. CONCLUSION

The terahertz radiation has wide range of applications in both science and technology. To analyze the defects in cells and tissues at deeper level and things which are hidden from the human vision can be viewed by terahertz spectroscopy.

REFERENCES

[1] Thomas Kleine-Ostmann, Christian Jastrow, Kai Baaske, Bernd Heinen, Michael Schwerdtfeger, Uwe Karst, Henning Hintzsche, Helga Stopper, Martin Koch and Thorsten Schrader, "Field Exposure and Dosimetry in the THz Frequency Range", IEEE Transactions on Terahertz science and Technology, Vol 4,12 – 25,2014.

[2] Ashish Y. Pawar, Deepak D. Sonawane, Kiran B. Erande, Deelip V. Derle, "Terahertz technology and its applications", journal of Sciverse ScienceDirect, drug invention today, pp 157-163, March 2013.

[3] A.J. Fitzgerald, E. Berry, N.N. Zinov'ev, S. Homer-Vanniasinkam, R.E. Miles, J.M.Chamberlain And M.A. Smith, "Catalogue of human tissue optical properties at terahertz frequencies," Journal of biological physics 129: 123 – 128, 2003.

[4] Steven L Jacques," Optical Properties of Biological Tissues: A Review", IOP Publishing, Physics In Medicine and Biology, 58, R37 – R61, 2013.

[5] G. M. Hale and M. R. Querry, "Optical constants of water in the 200nm to 200µm wavelength region," Applied Optics, 12, 555--563, 1973.

[6] Http://water.usgs.gov/edu/propertyyou.html

[7] http://hubpages.com/hub/The-Healthy-water-body

[8] http://www.chemcraft.net/wbody.html

[9] F.M. Hendriks, D. Brokken, C.W.J. Oomens, F.P.T. Baaijens, J.B.A.M. Horsten, "Mechanical properties of different layers of human skin".

[10] Joke A Bouwstra, Anko de Graff, Gert S Gooris, Jaap Nijsse, Johann W Wiechers and Adriaan C van Aelst, "Water distribution and related morphology in human stratum corneum at different Hydration levels", Journal of investigative Dermatology, 120,750 – 758,2003.

[11] http://training.seer.cancer.gov/melanoma/anatomy/layers.html

[12] http://omlc.org/software/mc/

[13] Lihong Wang, Steven L. Jacques, Liqiong Zheng, "MCML – Monte Carlo modeling of light transport in multi-layered tissues", Computer methods and programs in biomedicine 47, 131 – 146, 1995.

[14] Lihong Wang, Steven L. Jacques, Liqiong Zheng, "CONV – convolution for responses to a finite diameter photon beam incident on multi-layered tissues", Computer methods and programs in biomedicine 54, 141 – 150, 1997.

[15] Ion-Christian Kiricuta, Virgil Simplaceanu, "Tissue Water content and Nuclear magnetic resonance in Normal and Tumor tissues", Cancer research 35,1164 – 1167, May 1975.

[16] S. A. Prahl, M. Keijzer, S. L. Jacques, A. J. Welch, "A Monte Carlo model of light propagation in tissue", SPIE Institute Series Vol. IS 5, 102 – 11, 1989.

[17] http://www.lightmeasurement.com/reflectionabsorption/