EM Wave Effects upon the Human Body Using UWB Antennas

Bader Saadi Fadhel and Muhammad Ramlee Kamarudin

***Abstract*—This paper presents a calculation of Electro Magnetic Wave and its effects on a part of the human body by using a Finite Difference Time Domain (FDTD) code. The analysis is on the electromagnetic field penetration and a thermal effect of radiofrequency signal in structures, which represent estimates of human biological tissue. A model of human hand was created by using CST Microwave Studio and an irradiation by microwaves of frequency range used by UWB antenna of (3.1 – 10.6GHz) was simulated. The thermal distribution in the model was calculated and numerical estimates of the Specific Absorption Rate (SAR) inside the body tissue were compared for different frequencies and positions.**

***Index Terms*—Biological tissue, CST microwave studio, specific absorption rate (SAR), ultra-wideband (UWB) antenna.**

I. Introduction

As wireless portable devices increase in complexity providing improved functionality, higher data rate communication has captured the public concerns about possible harmful effects on human health was taken into consideration [1][2]. The extensive usages of such devices are accompanied by The EM Wave radiation caused by these devices.

A study of electromagnetic field generated by two Ultra-Wideband (UWB) antennas and the distribution into the exposed human body are considered [3]. The researchers will consider only a part of designated human body. Localized human exposure to electromagnetic field in microwave frequency range is associated to the usage of wearable devices, detection and positioning systems; one of its applications can be used for medical devices [4]. There are studies on transmitters on micro wave (MW) range and their effects on mankind. Some of the energy in the electromagnetic waves emitted by a device worn is absorbed by a user, mostly in superficial tissue. The direct effect is the heating of the tissue. H is thermal effect usually quantified by the Specific energy Absorption Rate (SAR) [Wkg-1]

$$SAR = \frac{\sigma . E^2 \max}{2.\rho} \qquad (1)\ [5]$$

where, E max is the maximum value of the electric field [Vm-1], σ is the electric conductivity [Sm-1] and ρ is the mass density [kg.m-3].

Most SAR probes are currently measuring E-field in volts per meter (V/m1), which allows SAR to be calculated. In addition to the E-field present, SAR is also dependent on the conductivity and permittivity of the tissue simulant. The equation used to calculate temperature-change SAR relates directly to the one used in current measurements. A lot of efforts has been considered in improving the capabilities of computer simulations, such as CST Microwave Studio (CST MWS) to quantify the absorbed EM Wave from these devices.

Lastly, this research aimed to present and evaluate simplified numerical models for dosimetric studies in the microwave domain. This work is concentrated on the construction of a 3D model that is appropriate to the study of EM Wave penetration and the estimation is focused on SAR computation of the thermal effect in the human's wrist as a sample of the human body.

II. Model Construction

With increasing demands for high data rate in wireless communication systems, engineering designers faced a challenge of designing compact antennas. Recently, printed monopole antennas have gained popularity due to their low cost, low profile, ease of fabrication, large bandwidth and radiation properties.

III. Antenna Design

The ultra-wideband commonly refers to signals or systems that either have a large relative or a large absolute bandwidth. The FCC (Federal Communications Commission) issued a ruling in 2002 that allowed intentional UWB emissions in the frequency range between 3.1 and 10.6 GHz [6].

Our redesigned UWB antenna illustrated in in Fig. 1. For probe purposes include circular patch [7]. The antenna is designed on FR4 substrate with thickness of 1.6mm. The specifications of the substrate for dielectric permittivity, εr are 4.7 and tangent loss is 0.019. All the simulations are carried out using CST software [8]. The circular patch antenna is redesigned to operate at two testing points namely 3 & 7 GHz and therefore the radius calculated is 7mm. The dimension of the substrate use is 30 × 30 mm2. The waveguide port feeding technique is used in the simulation where the dimension of feeding is 2.9 × 15.4 mm2 in order to match to the patch for 50Ω. Partial grounded plane method is used for both original and modified circular.

Manuscript received September 8, 2013; revised December 2, 2013.

Bader Saadi Fadhel is with Faculty of Engineering and Technology, Management and Science University, Selangor, Malaysia (e-mail: bader_saadi@msu.edu.my).

Muhammad Ramlee Kamarudin is with Faculty of Electrical Engineering, Wireless Communication Centre (WCC), Universiti Teknologi Malaysia, Johor, Malaysia.

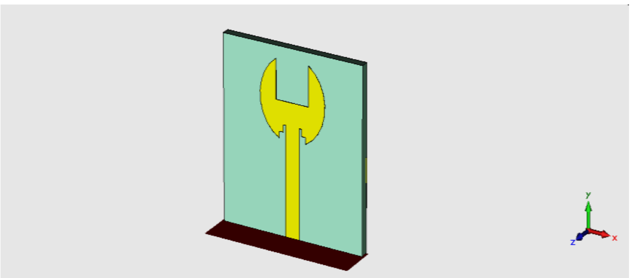

Fig. 1. The re-designed modified UWB circular antenna.

IV. Design a Part of Human Arm

A. Design Single Layer Homogeneous Body

The research heeded of using the modified UWB antenna to know the overall radiation effects on human body as shown in Fig. 2. A simplified parallel microstrip line exposure system has been considered for the RF exposure scenario within the ultrawide-band range system.

The need for a reliable computation model in microwave for radiation measurement related to the worn body devices technology led us to try several approaches to simulate the human's wrist and the EM Wave source. It is of a common practice to generate simplified 3D models of the human's wrist in a cylindrical single layered structure.

In general, the body specification can be considered in terms of electromagnetic energy absorption rate and the dielectric properties of materials are generally defined in terms of their relative permittivity (ε) and conductivity (σ). These two parameters respectively represent the charge and current densities induced in response to an applied electric field of unit amplitude. Thus, the factors taken into consideration for Electrical permittivity are $\varepsilon = 54.4176$ F/M, the Magnetic permeability $\mu=1$ and the Electric conductivity are 1.88201 S/m and material density is P (Rho)=1040 kg/m3.

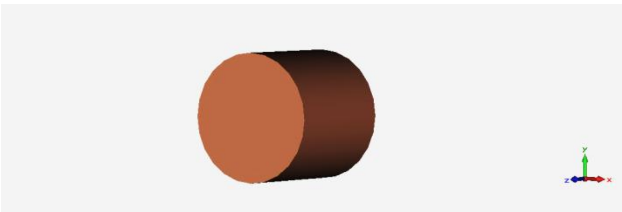

Fig. 2. Designed homogeneous body.

B. Design Multi-Layer Homogeneous Body

Another design to compute electromagnetic field distribution in a four-layered tissue structure is shown in Fig. 3. Is a homogenous one. Setting the electrical properties of tissues is quite complicated, in respect of the significant change for the existing values among the considered literature for our studies. The studies used a conductivity and relative permittivity values of a real human arm tissues. The dielectric properties which has already exist is as an example from on-line database, CST microwave studio software.

The design considered a part of human being's wrist which consists of the bone, blood, skin and Skeleton Muscle as shown in Fig. 3, the dielectric properties of materials are generally defined in terms of their relative permittivity (ε) and conductivity (σ) as shown in the Table I for the frequency of 3.1 GHZ. In general, our criterion is conducted by creating a new procedure.

TABLE I: Shows the Dielectric Properties of a Multi-Layer Homogenous Body

	Permittivity (ε) [F/m]	Conductivity(σ) [S/m]
Blood	57.187332	3.149209
Bone	17.838749	1.04397
Skin(Wet)	41.982449	2.016814
Muscle (Parallel Fiber)	53.507809	2.420193

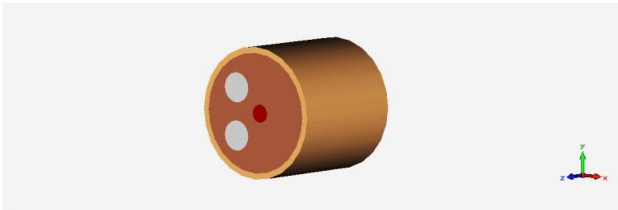

Fig. 3. Designed multi-layer homogeneous body.

V. CST Software Implementation

The simulated return loss for the modified UWB antennas obtained from the UWB frequency which operates from 3.1GHz-10.6GHz and it witnessed four S-parameters cases due to antennas facing each as shown in Fig. 4.

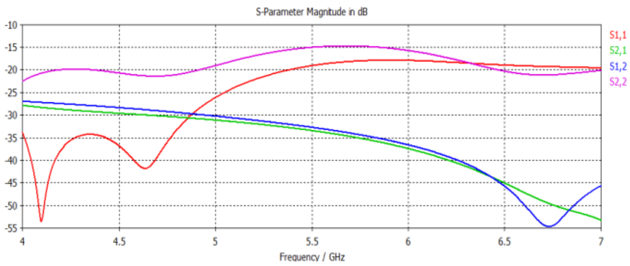

Fig. 4. The simulated return loss of modified UWB antennas.

A modified UWB models are used in our studies. The distance is chosen to be 94.2 mm between each one of the antennas to the designed sample of the wrist. Since the FCC (Federal Communications Commission) set the frequency range of the UWB system between (3.1 - 10.6) GHz, Our designed wearable device considered two identical antennas functioning as the transmitter and receiver, the human's wrist sample should be surrounded by the UWB antenna system in the study as shown in Fig. 5.

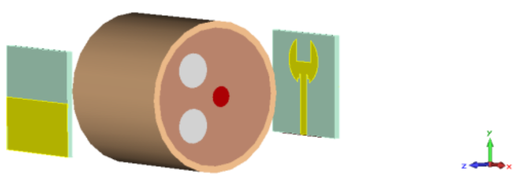

Fig. 5. A body exposure due to re-designed antennas.

During the SAR measurement, the two frequencies are chosen within the UWB range are 4GHz and 7GHz for probing purposes, to understand the differences between the single layer and the multi-layer designed body and comparing the results within two unit standards: American that takes a volume containing a mass of 1 gram of tissue and European which averages it over a 10 g of tissue.

VI. Results

The thermal distribution was computed caused by RF signal inside the human's wrist model, where the most affected area which is the nearest to the transmitter as shown in Fig. 6.

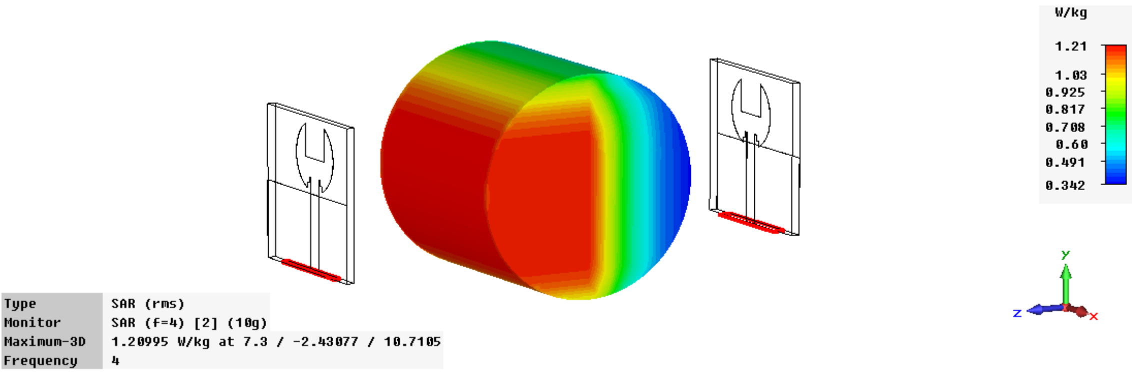

Fig. 6. Thermal distribution at operating frequency 4GHz.

The most affected area is represented in red color and the gradient in colors ended with the least affected area or non-affected represented with blue color. The maximum temperature is calculated as shown in Fig. 6, the SAR is defined as exposition on the whole body in the interval not to be higher than 0.08 Wkg-1 for cell phone users [9].

At the frequency of 4GHz, the maximum temperature increases and the SAR were calculated automatically through the CST software and the result is 0.0216 W.kg-1 and 0.944 W.kg-1 for the American and European standards respectively. As a maximum value, the effect decreases as shown for the color gradient to reach 0.342 W.kg-1.

For the frequency of 7GHz, the maximum temperature increased to make the SAR values reach up to 2.752W.kg-1 and 1.038 W.kg-1 for the American and European standards respectively. Antenna 2 is considered as an example while the same changes are available for antenna 1, since they are symmetrical antennas.

TABLE II: Shows the Difference between Single Layer and the Multi-Layer Homogenous Wrist with Two Different Frequency Ranges

			Single Layer		Multi Layers	
Frequency \ Average Mass			1g	10g	1g	10g
4 GHZ	Antenna	1	1.857	1.099	1.745	0.901
		2	2.115	1.209	2.102	0.944
7 GHZ	Antenna	1	1.765	0.903	2.394	0.983
		2	1.931	0.97	2.752	1.038

The results is computed in terms of SAR factor, watts/ Kg for each 1g mass unit and 10g mass unit in terms of each American and European standards respectively, as shown in Table II.

VII. Conclusions

The main target of this research is to study the interaction of electromagnetic waves with the human body. The first model is created as a simplified one layer and the other model was simplified to four homogenous tissue layers. Thermal losses are caused by radiation and perfusion. Only the thermal conduction was calculated in terms of SAR factor. We found out that for a low frequency of 4GHz, the one layered sample would be more absorbable to the energy while it would be the opposite case for the frequency of 7GHz.

The extreme conditions were taken in consideration, and our results can be considered for precaution cases. The direct effect of RF signal is focused on the heating exposed to human body tissues. Therefore the maximum security should be taken against this energy. Moreover, the human head is considered as the most sensitive part and it should be considered for our next research.

References

[1] P. Futter, N. Chavannes, and R. Tay *et al.*, "Reliable prediction of mobile phone performance for realistic in-use conditions using the FDTD method," *IEEE Antennas and Propagation Magazi*ne, vol. 50, no. 1, pp. 87-96, 2008.

[2] L. Xu, Max Q.-H. Meng, and H. Ren, "Effect of subject size on electromagnetic radiation from source in human body following 2450mhz radio frequency exposure," in *Proceedings of the 2007 IEEE International Conference on Integration Technology*, March 20 - 24, 2007, Shenzhen, China.

[3] S. I. Al-Mously and M. M. Abousetta, "Effect of the hand-hold position on the EM Interaction of clamshell-type handsets and a human," in *Proc. the Progress in Electromagnetics Research Symposium (PIERS)*, 18-21 August, pp. 1727-1731, Moscow, Russia (2009).

[4] M. Zhang and A. Alden, "Calculation of whole-body SAR from a100MHz dipole antenna," *Progress In Electromagnetics Research*, vol. 119, pp. 133-153, 2011.

[5] M. Morega and A. Machedon, “Specific Conditions for EMF modeling in human exposure from mobile phone technology,” presented at Advanced Topics in Electrical Engineering ATEE 2002, Bucharest, Romania, Nov. 2002.

[6] A. F. Molisch, *Ultra-Wideband Antennas and Propagation for Communications, Radar and Imaging*, Wiley, 2007.

[7] C. C. Chiaw and M. R. Kamarudin, “Novel Design of Circular UWB Antenna,” in *Proc. IEEE Microwave Conference*, APMC, 2009, pp. 1977-1979.

[8] A. H. M. Alam, M. R. Islam, and S. Khan, “Design and analysis of UWB rectangular patch antenna,” in *Proc. IEEE Asia-Pacific Conference on Applied Electromagnetics*, 2007, pp. 1-3.

[9] C. X. Sun, Y. Liu, and F. Liu, “The research of 3G mobile phone radiation on the human head”, in *Proc. IEEE 2nd International Conference on Artificial Intelligence, Management Science and Electronic Commerce (AIMSEC)*, 2011, pp. 4869-4872.

Bader Saadi Fadhel is a lecturer at Management and Science University (MSU) He obtained bachelor degree BSc. in Electronic and Communication Engineering from University of Technology (UoT)/ Iraq – 2004. Then he continued further studies to do a master of Science. MSc. In Communication Engineering, from University of Technology (UTM)/ Malaysia- 2012, he worked as a teaching assistance during his studies in Digital Electronic Lab- UTM, the he joined the Management and Science University in 2012, as an Electronic and Communications Engineering. Bader has also a membership in the Society Digital Information and Wireless Communications (SDIWC). He has attended the International Conference on and Technology ICEnT. 2012- Malaysia. Some more he has a published papers. Currently he’s a lecturer at MSU University, his responsibility is to teach and also to supervise a numbers of BSc. students.

Muhammad Ramlee Kamarudin is an associate professor and obtained his first degree from Universiti Teknologi Malaysia (UTM), Malaysia, with Honours, majoring in electrical and telecommunication engineering, graduating in 2003. He was then joined UTM as a tutor at Wireless Communication Centre (WCC), Faculty of Electrical Engineering (FKE), UTM. He has been awarded a scholarship from the government of Malaysia to further study in the United Kingdom. He received the M.Sc in Communication Engineering in 2004, He then obtained his Ph.D in 2007 from University of Birmingham, UK under supervision of Professor Peter Hall. Dr Kamarudin is an author of a book chapter for book entitled “Antennas and Propagation for Body-Centric Wireless Communications”, and has been published more than 30 technical journals including an IEEE Transaction on Antenna and Propagation, an IEEE Antenna Magazine, Progress in Electromagnetics Research (PIER), Microwave and optical Technology Letters (MOTL), Electronics Letters and more than 50 of technical conference papers on antennas performance and design for wireless applications, on-body communication systems and antenna diversity. He is also a reviewer for IEEE Transaction on Antenna and Propagation Journal, IEEE Antenna and Propagation Magazine, Progress in Electromagnetics Research (PIER) Journal, IET Microwaves, Antenna and Propagation Journal, Electronics Letters, Elektrika Journal (UTM), currently he’s in Communication Centre (WCC), Faculty of Electrical Engineering (FKE) at UTM University.