Ultra-Wideband (UWB) Antenna Radiation on Action Potentials in Human Nerve Fibers

M. S. N. Azizi, N. R. Mohamad, A. Salleh, A. Othman, A. Aris, N. Hassan
Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia
syafiqnoorazizi@yahoo.com

***Abstract*—The increasing and rapid development of wireless communication technology such as mobile phone, radio base station, power transmission line, medical devices and microwave antenna are being concerned to all parties due to its electromagnetic fields exposure to human. Some of these devices have been classified as extremely low frequency (ELF) non- ionizing radiating devices. These electromagnetic fields will transform into microwave radiation or electromagnetic radiation that can lead to biological hazardous effects, thus affects human health. A human nervous system which the main part of the human body also can't escape from being exposed to electromagnetic radiation. Therefore, this study is to investigate the effect of microwave radiation from Ultra-Wideband antenna frequency towards human arm action potentials (AP) in nerve fibers. In this paper, a CPW-fed modified circular patch antenna for UWB application is proposed. This antenna is designed by using biocompatible Poly (methyl methacrylate) (PMMA) substrate with dielectric constant, Ɛr = 2.8 and substrate's thickness, h = 1.6mm. The simulation is done by using Computer Technology (CST) software. The antenna operates at frequency range 2.930-19.032GHz. The antenna also has the nearly omnidirectional result that is suitable for UWB application. The homogeneous human arm model with the presence of other human tissues such as fat, muscle, skin, bone and nerve are designed which is expected to improve the understanding of radio propagation inside the human body. The UWB antenna will be implanted in skin. CST Microwave Studio is one of the EM modeling code which can be used for bio electromagnetic purpose.**

***Index Terms*—Action Potentials; Nerve Fibers; Ultra-Wideband (UWB); Antenna; Human Model.**

I. INTRODUCTION

Nowadays, the development of wireless technologies has provided a lot of benefit to the user in term of wireless voice and data transmission. These types of technologies usually use electromagnetic waves in the range of frequencies from 300MHz to 300GHz which has been broadly used in telecommunication, medical, military fields, agriculture, and transportation [1]. Furthermore, the demand in this modernization era has led to increasing usage of wireless communication devices such as microwave antenna, radio base station and mobile phones which are placed in human surroundings. However, this technological ability also had it side effect where people are being exposed to electromagnetic radiation (EMR). As a result, the human body will get frequently exposed to the microwave energy from those devices. Some of these devices are classified as a non-ionizing radiating device which is low-frequency radiation produced by electromagnetic, electric and magnetic fields. Although, non- ionizing electromagnetic radiation does not alter the atomic structure, yet it still has a lot of effects on the human body [2]. Non-ionizing radiation (NIR) can cause headaches, fatigue, stress, eczema, dermatitis, cataracts, glaucoma, Parkinson's disease, miscarriage, insomnia, impotence and cancer that depend on the exposure time to this radiation [3]. Therefore, The International Committee on Non-Ionizing Radiation Protection (ICNIRP), which was recognized in 1992, published guidelines which refer to limiting exposure to time- varying electric, magnetic and electromagnetic fields to an acceptable level. The guidelines must be published in order to avoid opposing health effect. Nevertheless, the guideline for radio frequency and microwave in ICNIRP is still ongoing. Therefore, initial results of this research should be well- thought-out as an involvement in setting proper guidelines in this field [4].

Human body especially the nervous system also can't escape from being exposed to electromagnetic radiation from those non-ionizing radiating devices. The nervous system is the main part of human body which controls and coordinates the activities of another organ system by activating the muscle movement, regulates the depth and rate of breathing, controls the secretion of hormones and also modulates plus regulates a multitude of the physiological process. Thus, in order to make these functions perform successfully, the nervous system depend on neuron which transmits information from one cell to another cell. Neuron plays a role by directing electrical impulses as well as secreting chemical neurotransmitters. It is communicated by a combination of electrical and chemical signaling. The information is processed and transmitted along the single neuron processed electrically and transmitted chemically to the target cell [5]. Neuron encrypts different inputs from the dendrites by producing diverse patterns of action potentials and interprets information by the axon [6]. An action potential is a type of electrical signal which flows through over a long distance without changing its amplitude. Moreover, action potentials play a key role in information coding. It is also influenced by a regenerative wave of opening and closing of the voltage-gated ion channel in the membrane [5]. For that reason, it is possible for electromagnetic radiation to interrelate with action potentials and later disturbing the system functionality of the human body. Figure 1 shows the actual action potentials with it phases.

Balaguru et al. investigated the effect of an incoming electromagnetic field towards the spinal cord which acts as a natural antenna through a Finite Difference Time Domain (FDTD). The authors observed based on simulation results which showed peak voltage and current response in the range of FM radio range. The authors also display the early result where the incident electromagnetic frequency in the FM radio range around 100MHz which shows response on the spinal cord structure increased by generating a voltage of 8mV.

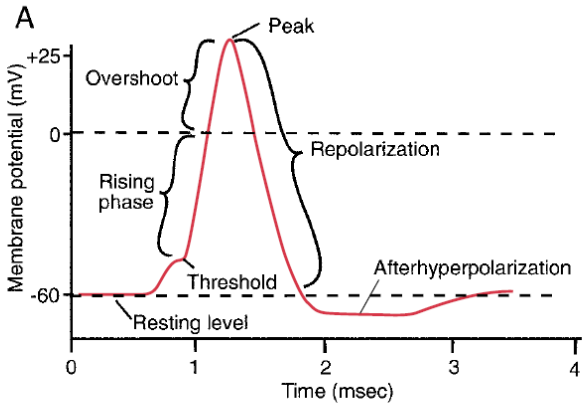


Figure 1: The action potentials phases [5]

Therefore, the authors said that the increased response could have a potential impact on the central nervous system process [7].

Besides that, Adib et al. investigate the effect of mobile phone radiation towards action potential in brain-arm nerve fibers of a human body. Adib et al. modeled the brain-arm nerve fibers as wire-type transmission lines and they simulate the models with and without interference source. The authors shown that the GSM phone radiation is capable of disturbing the action potential based on the simulation result. The authors also introduce the bursting spikes on action potential when the distance between the phone and the human arm model is 9mm and they conclude that the altered action potential might interrupt the function of the human arm [4].

Moreover, Schneider and Pekker investigate the effect of non- thermal of a weak microwave on nerve fiber activity. Schneider and Pekker also state that in the range of 30-300GHz, there are strongly prominent resonances which associated with the excitation of ultrasonic vibrations in the membrane. This is the result when there is an interaction with microwave radiation. Therefore, the authors said that the threshold of the action potential excitation in the axon is changing due to rearrangement of the protein transmembrane channels. The protein transmembrane channels redistribution is caused by the pressure created from the forced of vibrations [8].

Therefore, in this study, we concentrate on the Ultra-wideband antenna radiation on action potential in human nerve fibers. The human arm is a model in term of the homogeneous model in that can observe and analyze in order to obtain a result which can be related to the actual human arm. The homogeneous human arm consists of three models with a different age. Then, the Ultra-wideband (UWB) antenna that acts as radiation source will be located inside of homogeneous human arm model. The Ultra-wideband antenna radiations effects towards the action potential of each model will be observed and analyze in term of different age and distances. The main reason for using UWB frequency is due to its ability to penetrate through walls or obstacles which are in this study, the human body.

II. Homogenous Human Arm Modelling

In this study, we model the simplest form of a human arm section with flat shapes used for simulation. The homogeneous human arm model is designed in a three-dimensional simulation software package known as CST Microwave Studio. The homogeneous human arm model consists of five layers, which are the skin, fat, muscle, bone and nerve. After finish modeling, the defining material must be done by selecting the bio-tissue in the material folder and set the age for each homogeneous human arm model. The flat homogeneous human arm model is designed with different age which is a child (7years), adolescent (26years), adult (38years) and each model have different thickness of tissue layer. Note that, the gender of the three models is not specified in this study. The detailed thicknesses and dielectric properties of the simplified model layers are summarized in Table 1, 2 and 3. Figure 2 shows a homogeneous arm model with flat shape; (a) child-7 years, (b) adolescent-26 years, (c) adult-38 years while in Figure 3 shows the UWB antenna implanted in the skin layer of homogeneous arm model with flat shape; (d) child-7 years, (e) adolescent-26 years, (f) adult-38 years.

Table 1
Dielectric Properties of Human Arm Tissue at 3.9 GHz for Child (7 years)

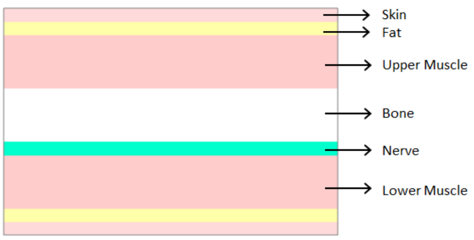
Tissue	Width (mm)	Permittivity (Ɛr)
Skin	2	38.077
Fat	2	5.654
Upper Muscle	8	51.822
Lower Muscle	15	51.822
Bone	8	10.581
Nerve	2	30.132

Table 2
Dielectric Properties of Human Arm Tissue at 3.9 GHz for Adolescent (26 years)

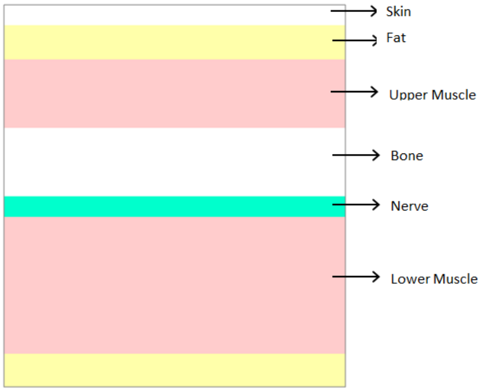
Tissue	Width (mm)	Permittivity (Ɛr)
Skin	3	36.857
Fat	5	5.203
Upper Muscle	10	51.061
Lower Muscle	20	51.061
Bone	10	10.581
Nerve	3	28.998

Table 3
Dielectric Properties of Human Arm Tissue at 3.9 GHz for Adult (38 years)

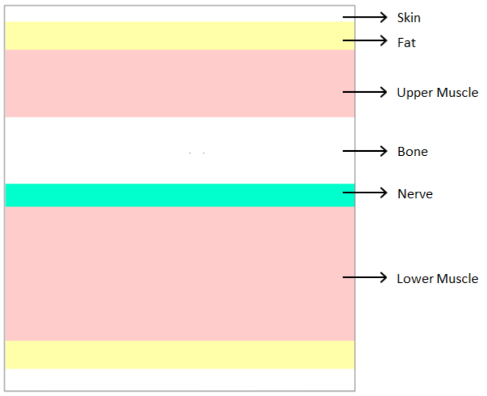
Tissue	Width (mm)	Permittivity (Ɛr)
Skin	4	36.713
Fat	5	5.151
Upper Muscle	12	50.971
Lower Muscle	24	50.971
Bone	12	10.581
Nerve	4	28.865



(a)

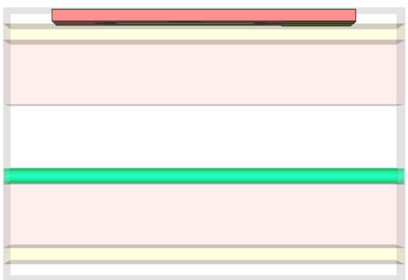


(b)

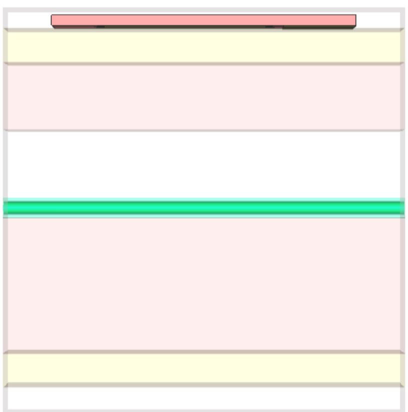


(c)

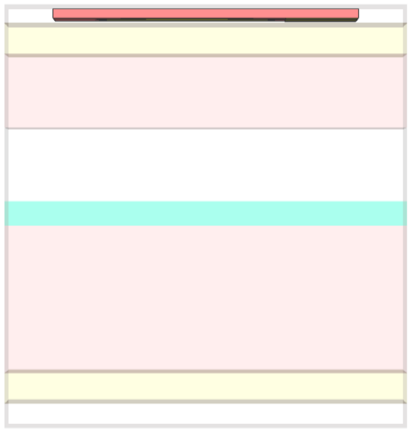
Figure 2: Homogeneous arm model with flat shape, (a) child-7years, (b) adolescent-26years, (c) adult-38 years



(d)



(e)



(f)

Figure 3: UWB antenna implanted in skin layer of homogeneous arm model with flat shape, (d) child- 7 years, (e) adolescent- 26 years, (f) adult-38 years

III. ANTENNA CONCEPT

Initially, a circular patch antenna has patch radius of 14mm regarded at a size substrate 36.0mm x 38.0 mm. This antenna designed using bio-compatible Poly (methyl methacrylate) (PMMA) substrate with dielectric constant, Ɛr = 2.8 and thickness h= 1.6mm. The designed antenna is for UWB application. The specifications of the antenna are listed in Table 4. A strip line 50 ohm has feed length, Lf=10 mm and feed width, Wf=3.0mm connected with antenna patch. The gap between the feed line and the ground plane, d is 0.5 mm while the dimension of the ground plane is 15.5 mm x 9 mm.

Figure 4 shows front view of CPW fed circular patch antenna while in Table 4 shows the antenna design specification. Figure 5 shows the return loss in dB for CPW fed circular patch antenna in free space. The antenna operates at frequency range 2.930-19.032 GHz. The antenna also has nearly omnidirectional result that is suitable for UWB application.

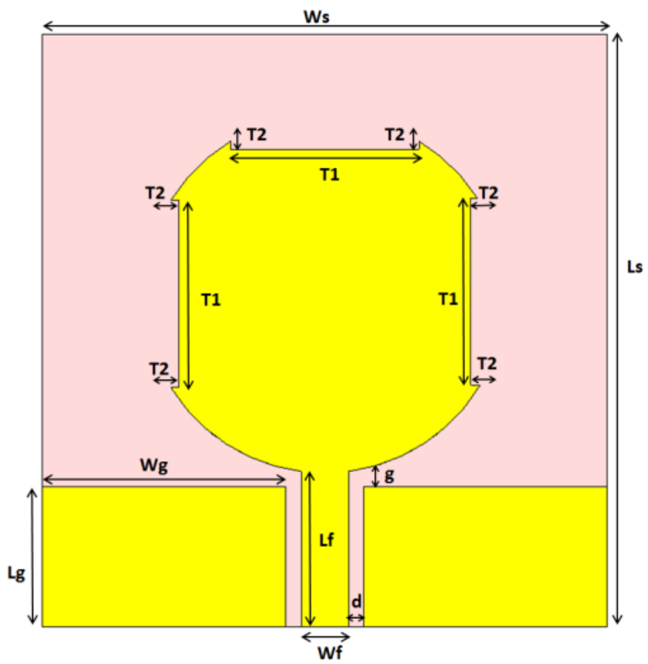


Figure 4: Front view of UWB antenna.

Table 4
Design Parameter of UWB Antenna

Optimized Design Parameter	Value (mm)
Width of substrate, Ws	36
Length of substrate, Ls	38
Width of ground plane, Wg	15.5
Length of ground plane, Lg	9
Width of feed line, Wf	3
Length of feed line, Lf	10
Feed gap, d	1
Feed height, g	1
Truncation Length, T1	12
Truncation Length, T2	0.5

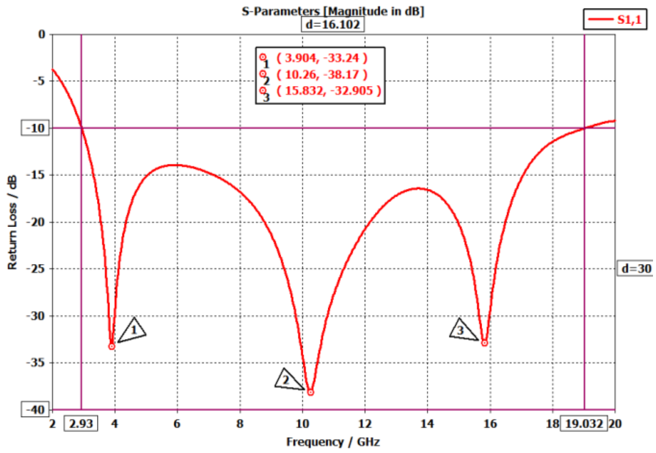


Figure 5: S-parameter for CPW fed circular patch antenna in free space

IV. Nervous System As An Electric Circuit System

The nervous system and electric circuit are similar in that, they both work on electric charges plus the nervous system has a central CPU (brain), like a circuit could have. In order to observed and analyzed the attain results that can be related to real life situation, the homogeneous human arm is model into electrical system. This is due to people usually use arm to handling thing, hence, human arm is more exposed to microwave radiation. Neuron narrowly correlated to human arm movement since it transports action potential signal from brain to arm muscle in order to direct the muscle whichever to reflex or extend. Hence, the action potential is representing as a voltage source of an electric circuit.

Figure 6 show the homogeneous arm model with fully electric circuit around it. The nerve with cylindrical shape acts as conductors of wire for conducting electricity which has the starting point and the ending point. Figure 7 shows the schematic circuit of nervous system in human arm model.

V. Creation of Action Potential Signal

Figure 8 shows the action potential signal data in .csv format imported into transient simulation task in Computer Simulation Technology (CST) design studio. The action potential signal data is obtainable from executing of Izhikevcih's MATLAB programming which has created points of voltage that converts into input data for both continuous piecewise linear voltage sources to generate the action potential.

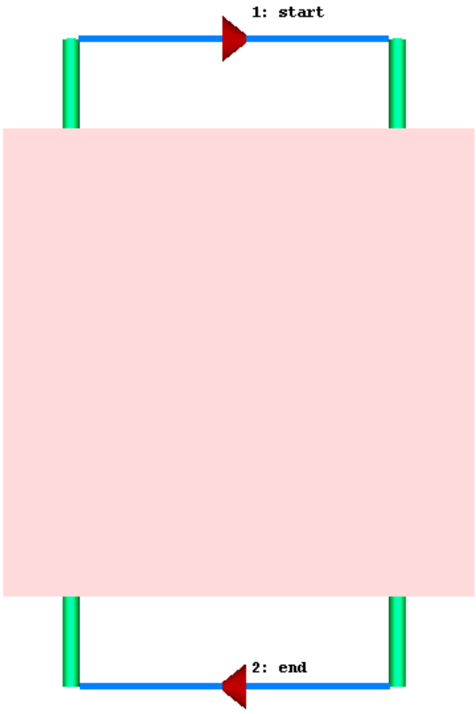


Figure 6: The action potentials phases

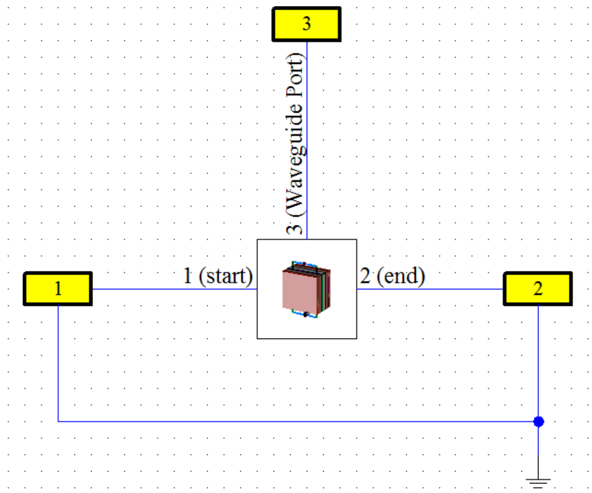


Figure 7: The schematic circuit of nervous system in homogenous human arm model

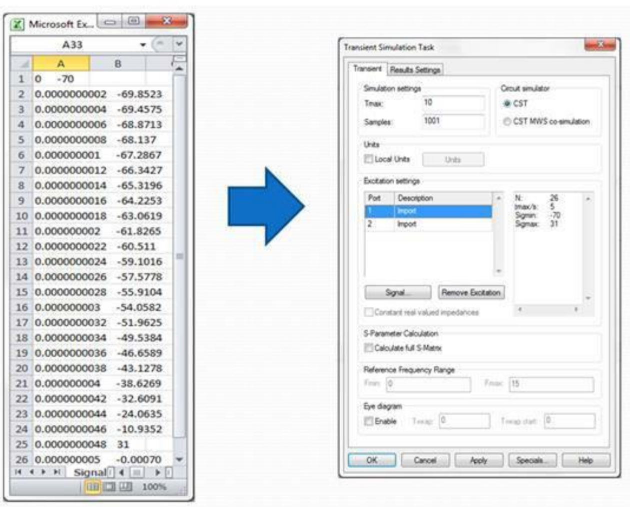


Figure 8: Imported action potential signal data into transient simulation task in CST design studio

Figure 9 shows the created action potential signal once the data is being imported into transient simulation task.

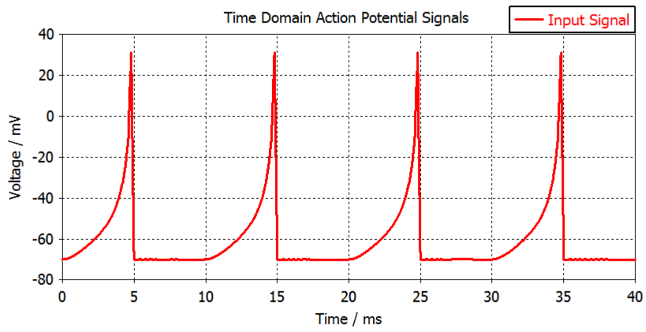


Figure 9: Created Action Potential Signal

VI. RESULT AND DISCUSSION

Figure 10, 11 and 12 show the action potential signal behavior of 7, 26 and 38 years old subject when the action potential signal is being exposed to UWB antenna frequency radiation. Figure 13 shows the overall action potential signal interference of 7, 26 and 38 years old subject. It can be observed that the major difference result is at the amplitude of the AP signal.

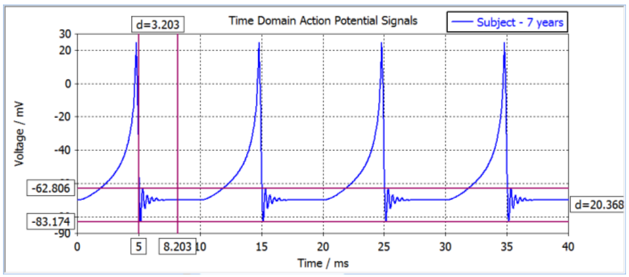


Figure 10: Action Potential Signal Interference of 7 years old subject

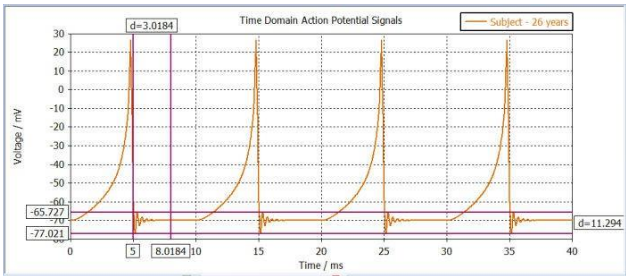


Figure 11: Action Potential Signal Interference of 26 years old subject

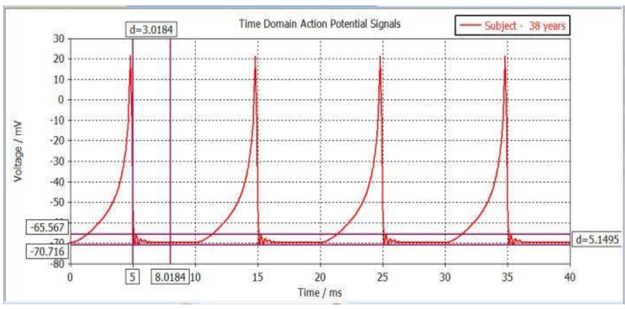


Figure 12: Action Potential Signal Interference of 38 years old subject

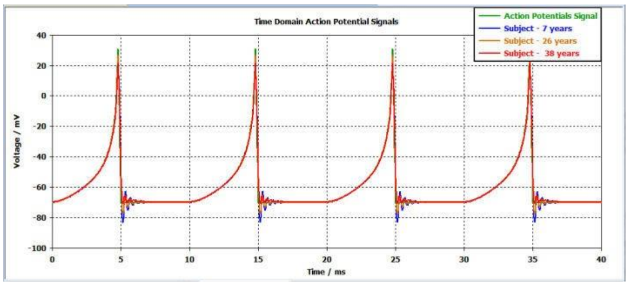


Figure 13: Overall Action Potential Signal Interference of 7, 26 and 38 years old subject.

Table 5 shows the time range of distortion signal (ms) and Peak-to-peak amplitude (mV) of action potential signal of human homogenous arm model in term of age. We can see that the 7 years old subject action potential signal produce larger spikes in amplitude compared to other subjects which are 20.37mV with the time range of distortion signal from 5.00ms to 8.20ms. For 26 years old subject, we can be seen that the time range of signal distortion is from 5.00ms to 8.02ms while the peak-to-peak amplitude of the distortion signal is 11.30mV. The 38 years old subject shows less interference on action potential signal which is it time range of signal distortion is from 5.00ms to 8.02ms while the peak-to- peak amplitude of the distortion signal is 5.15mV.

Table 5
The Time Range of Distortion Signal (ms) And Peak-To-Peak Amplitude (mV) of Action Potential Signal of Human Homogenous Arm Model in Term of Age

Human homogenous arm model	Time range of distortion signal (ms)	Peak-to-peak amplitude (mV)
7 years subject	5.00 – 8.20	20.37
26 years subject	5.00 – 8.02	11.30
38 years subject	5.00 – 8.02	5.15

The action potential signal peak-to-peak amplitude of 7 years old subject is larger due children absorb more microwave radiation than adults. Morgan state that, it was found ICNIRP's 2 W/kg, 10 g spatial peak SAR results in 2.3-3 times higher SAR than FCC's 1.6W/kg, 1 g spatial peak SAR [9]. Moreover, it is also influenced by the different thickness of various tissue layer and the dielectric properties of the tissue. The dielectric properties which refer to the permittivity of children are higher than adults. Gandhi stated that higher dielectric properties of the tissues will further increase the aforementioned higher SAR for children [10].

VII. CONCLUSION

It can be concluded that the modeling of the simplest human arm model in layers of cylindrical solid has been successfully accomplished. The homogeneous model can give brief results on the electric field and magnetic field magnitudes absorbed by the nerve layer and therefore assisted in recognizing the induction sources value introduced by UWB antenna frequency. The effects of UWB antenna frequency radiation has verified that it can alter the AP signal as shown in time domain signal of CST design simulations. This alteration might affect the human arm harmonious function.

ACKNOWLEDGMENT

We are grateful to Centre for Telecommunication Research and Innovation (CeTRI) and Universiti Teknikal Malaysia Melaka (UTeM) for supporting us to complete this study using the grant RAGS/1/2014/TK03/FKEKK/B00064 and supplying the electronic components and equipment's from the laboratory.

REFERENCES

[1] Y. Hao, L. Zhao and R. Peng, "Effects of microwave radiation on brain energy metabolism and related mechanisms", *Military Med Res*, vol. 2, no. 1, p. 4, 2015.

[2] A. Othman, N.R. Mohamad, M.Z.M. Jenu, "Mobile Phone Radiation Effects on Action Potentials in Brain-Arm", *International Journal of Applied Engineering Research*, vol. 10, no. 17, pp 38177-38182, 2015.

[3] P. Cmara, "Effect of exposure to non-ionizing radiation (electromagnetic fields) on human system: a literature review", *Journal of Interdisciplinary Histopathology*, p. 1, 2014.

[4] A. Othman, N.R. and M.Z.M. Jenu, "Preliminary Study on the Effects of Microwave Radiation on Action Potentials in Human Arm", *Malaysian Technical Universities International Conference on Engineering & Technology (MUiCET)*, 2011.

[5] C.J. Forehand, "The action potential, synaptic transmission, and maintenance of nerve function", Medical Physiology: Principles for Clinical Medicine (Rhoades RA, BD, eds., Lippincott Williams & Wilkins, a Wolters Kluwer business, ed). pp 38-64, 2009.

[6] Y. Liu, "Action Potential Initial Dynamical Control of a Minimum Neuron Model", *4th International Conference on Biomedical Engineering and Informatics (BMEI)*, vol. 4, no. 11, pp. 1820-1824, 2011.

[7] S. Balaguru, R. Uppal, R. Vaid and B. Kumar, "Investigation of the spinal cord as a natural receptor antenna for incident electromagnetic waves and possible impact on the central nervous system", *Electromagnetic Biology and Medicine*, vol. 31, no. 2, pp. 101- 111, 2012.

[8] S. MN and P. M, "Non-thermal Influence of A Weak Microwave on Nerve Fiber Activity", *Journal of Physical Chemistry & Biophysics*, vol. 4, no. 5, 2014.

[9] L.L. Morgan, "Why children absorb more microwave radiation than adults", *Journal of Experimental and Clinical Medicine 30*, no. 3, 2013.

[10] O.P. Gandhi, "Yes the Children Are More Exposed to Radiofrequency Energy from Mobile Telephones than Adults", *IEEE Access, 3*, pp.985- 988, 2015.