Jurnal
Teknologi

Full Paper

NON-IONIZING (ULTRA-WIDEBAND FREQUENCY) ELECTROMAGNETIC RADIATION EFFECT ON NERVE FIBER ACTION POTENTIAL OF HUMAN BODY

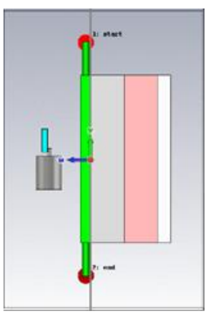
Article history
Received
22 June 2015
Received in revised form
7 September 2015
Accepted
17 December 2015

Muhammad Syafiq Noor Azizi*, Azahari Salleh, Adib Othman, Nor Azlan Mohd Aris, Najmiah Radiah Mohamad, Maisarah Abu, Nornikman Hasan, Mohamad Hafize Ramli

Department of Telecommunication Electronics, Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka (UTeM), Malaysia

*Corresponding author
syafiqnoorazizi@yahoo.com

Graphical abstract



Abstract

In modern telemedicine systems the physiological data of patients can be measured with the aid of electronic sensors located on and inside the human body. The collected medical data is then transmitted wirelessly to an external unit for processing, thereby enhancing the health monitoring, diagnosis, and therapy of the patients. In biomedical application, the process requires transmitting data, images and videos from inside the body taken by a radio system of a size of a pill seems to be the way. The use of non-ionizing electromagnetic radiation in various areas like medical application has arisen the electromagnetic radiation problem. The services provided by this type of application can cause either good or bad effects on human body depending on the power level, frequency and the way it being used. The implant antenna with ultra-wideband (UWB) frequency will be used by inserting it into the nerve of human arm in term of homogenous model. Ultra-wideband (UWB) is a wireless technology that potential applications in variety of medical areas such as implant wireless sensors, microwave hyperthermia, imaging and radar. It can transmit digital data over a wide frequency spectrum with very low power and at very high data rates. Hence, this paper present the non-ionizing electromagnetic radiation effect on electrical nerve fiber of human arm model with the presence of other human tissues such as fat, muscle, skin and etc. at ultra-wideband frequency which is expected to improve the understanding of radio propagation inside human body hence contribute to more advance and innovative medical implants. CST Microwave Studio is one of the EM modeling code which can be used for bio electromagnetic purpose.

Keywords: Ultra-wideband antenna, radiation, nerve fiber, action potential signal

1.0 INTRODUCTION

Non-Ionizing radiation (NIR) refers to radiative energy that producing charged ions when passing through matter and it has sufficient energy only for excitation. However, it is identified to cause biological effects to living systems [1]. The effects of non-ionizing electromagnetic (EM) radiation on human have been studied for more than 50 years. The World Health Organization (WHO), over its International Electromagnetic Field (EMF) Project, has conducted a series of in-depth international reviews of the scientific literature on the biological and health effects of exposure to electromagnetic fields. The studies accomplish their discoveries based on indication collated from epidemiological, animal or in vitro studies.

This non-ionizing radiation spectrum is separated into two main regions which is optical radiations and electromagnetic fields. Non-Ionizing radiation initiates from numerous sources which is natural origin such as sunlight or lightning discharges etc. and man-made like we seen in wireless communications, industrial, scientific and medical applications.

Karen A. Massey expressed that, non-ionizing electromagnetic radiation have the capacity to bother human wellbeing perilously in two ways. Firstly, this non-ionizing recurrence might enter into human body and interrelate with the living systems. Furthermore, the radiation will causes impedance with and physical debasement of electronic systems [5].

Non-ionizing radiations (NIR) cover the long wavelength (> 100 nm), low photon energy (<12.4 eV) portion of the electromagnetic spectrum, from 1 Hz to 3 x 10^{15} Hz. With the exception of the narrow visible region, NIR can't be seen by any of the human faculties unless its force is great to the point that it is felt as heat. The ability of Non-ionizing radiations to infiltrate the human body, the sites of absorption, and the resulting health effects are very much frequency dependent.

A biological effect occurs when a change can be measured in a biological system after the introduction of some type of stimuli. However, the observation of a biological effect, in and of itself, does not necessarily suggest the existence of a biological hazard or health effect. Biological effects could be physiological, biochemical changes instigated in a life form, tissue or cell. Non-ionizing radiations usually interact with tissue through the generation of heat. The hazards rely on upon the capacity to enter the human body and the retention attributes of various tissues [1]. High power densities of non-ionizing radiation can led to potential health hazards such as cancer, tumors, headaches, fatigue, Alzheimer's and Parkinson's disease. Notwithstanding, most specialists are uncertain of to what extent the impacts coming due to exposure of non-ionizing radiation [2].

There is also study for different frequency of non-ionizing electromagnetic radiation on action potential in a nerve. McRee *et al*. has undertaken a study and an experiment where they exposed the spinal cords of cats to 2450 MHz continuous wave electromagnetic radiation. The authors study the effect on reflex response and synaptic function on action potentials. Therefore, an action potentials recorded from the ventral root nerve were amplified 500 to 2000 times from its original signal with presence of electromagnetic radiation [4].

Moreover, human nervous system is the electrical system of human body which is the neurons is the basic unit of the nervous system that conveys electrical heartbeats known as action potentials (AP). This AP helps in term of communication and coordination functions of nervous system with other systems in human body. Lots of research in neurons and AP has formed biophysical electrical equivalent circuits plus mathematical models which express the behavior of AP inside neurons. The graph of membrane potential versus time shows the actual action potential signal.

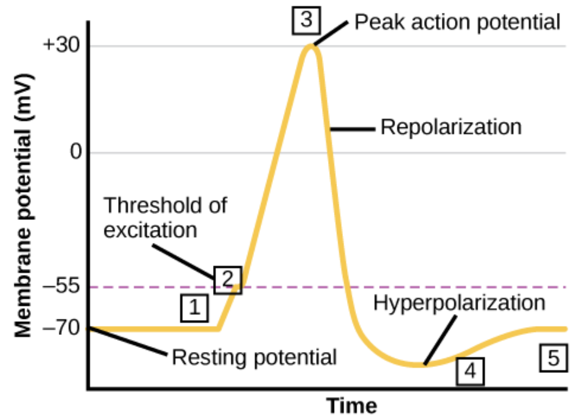


Figure 1 Actual action potential signal [7]

In nerve cells, human electricity energy is produced by chemical processes. Billions of nerve impulses travels go all through the human brain and nervous system. A nerve impulse is a wave of electrical activity that goes starting with one end of nerve cell then onto the next. Each impulse is the same size it; it is the frequency, impulses per second, that transfers information about the concentration of the nerve signal. Neurons are accountable for sending, receiving, and interpreting information from all parts of the body. Everything from proliferation to contaminations to repairing a separated bone happens at the cellular level l [3].

This paper presented the non-ionizing electromagnetic radiation effect on electrical nerve fiber of human arm model with the presence of other human tissues such as fat, muscle, skin and nerve at ultra-wideband frequency. UWB rectangular slotted micro strip patch antenna is designed. The reason of using UWB antenna is it potential applications in variety of medical areas such as implant wireless sensors, microwave hyperthermia, imaging and radar. Moreover, it can transmit digital data over a wide frequency spectrum with very low power and at very high data rates [6].Then, the UWB antenna will be simulate 10mm from the nerve to study the behavior of action potential signal effect based on the antenna radiation. The simulated result for the UWB antenna in free space and the behavior of action potential signal are compared and discussed.

2.0 HOMOGENOUS ARM MODEL MODELLING

The homogenous human body used in the simulation consists of five layers which is skin, fat, muscle, bone, and nerve. All the layers are lossy dielectrics with specific thicknesses and complex permittivity which refer to CST voxel family due to these models accurately represent the electromagnetic characteristics of body tissues. A whole "family" of voxel models, which represents different sizes and ages and includes children and a pregnant woman, is available for the analysis of biological effects and medical equipment [8].

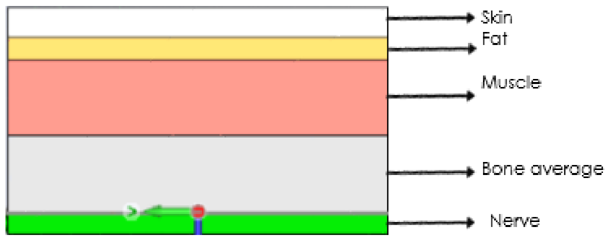
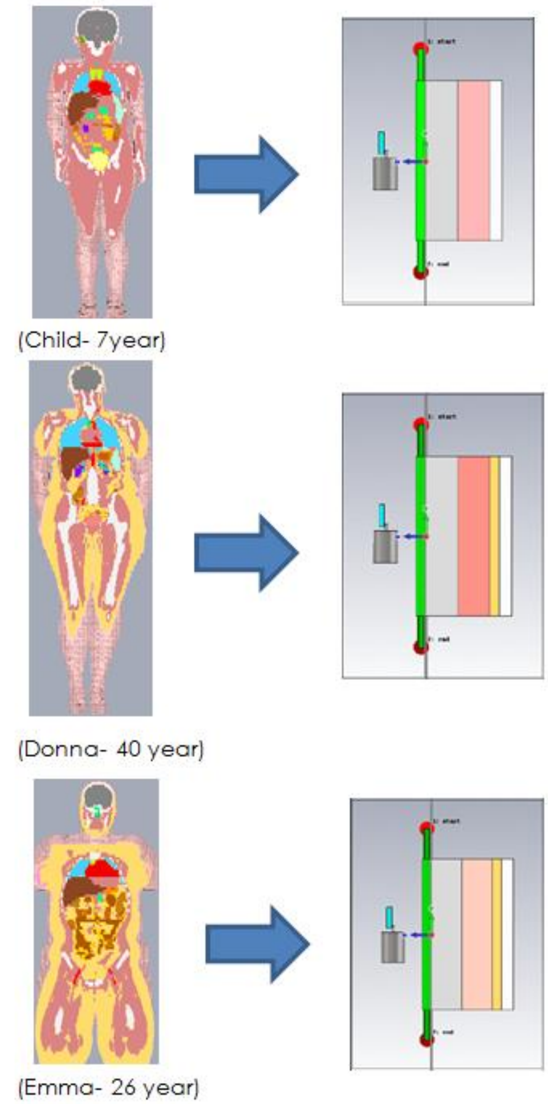


Figure 2 Axial view of Homogenous Voxel model

Figure 2 show an axial view of homogenous model based on voxel model in CST studio which include skin, fat, muscle, bone average and nerve with different thickness.



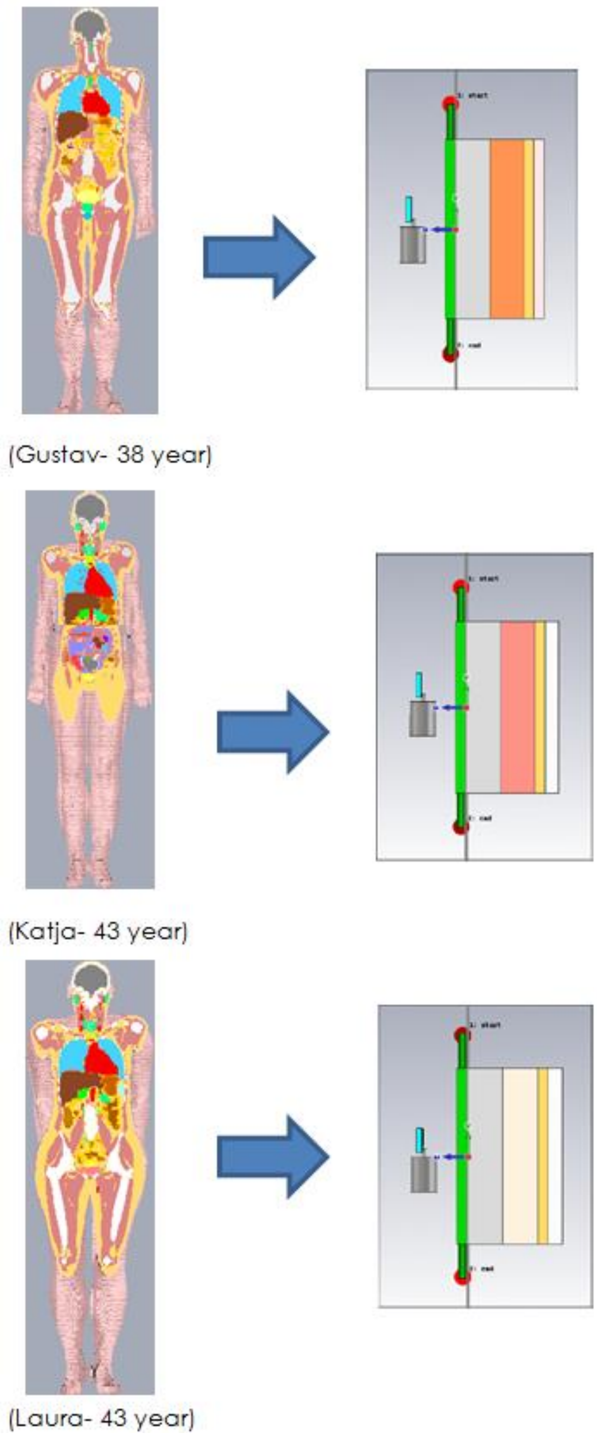


Figure 3 A homogenous voxel model which represent whole "family" of voxel in different sizes and ages which includes children and a pregnant woman

Figure 3 represents the family of voxel model in different sizes and ages. All the data in term of properties is collected and imported into homogenous model. The Ultawideband antenna are placed 10mm from the nerve fiber of homogenous voxel model.

Table 1 Human arm organs and tissue properties

Voxel model	Organs	Thickness (mm)	Relative permittivity	Electric Conductivity (S/m)
Child	Skin	3	72.93	0.4912
	Muscle fat average	4	36.02	0.3720
	Bone	8	15.28	0.0643
	Nerve	2	47.27	0.3382
Donna	Skin	4	72.93	0.4912
	fat	5	6.074	0.0363
	Muscle	10	65.97	0.7076
	Bone	10	15.28	0.0643
	Nerve	3	47.27	0.3382
Emma	Skin	4	72.93	0.4912
	fat	5	6.074	0.0363
	Muscle	10	65.97	0.7076
	Bone	10	15.28	0.0643
	Nerve	3	47.27	0.3382
Gustav	Skin	4	72.93	0.4912
	fat	5	6.074	0.0363
	Muscle	12	65.97	0.7076
	Bone	12	15.28	0.0643
	Nerve	4	47.27	0.3382
Katja	Skin	4	72.93	0.4912
	fat	5	6.07	0.0363
	Muscle	10	65.97	0.7076
	Bone	10	15.28	0.0643
	Nerve	3	47.27	0.3382
Laura	Skin	4	72.93	0.4912
	fat	5	6.074	0.0363
	Muscle	10	65.97	0.7076
	Bone	10	15.28	0.0643
	Nerve	3	47.27	0.3382

3.0 ANTENNA CONCEPT

The antenna is designed on a Poly(methyl methacrylate) (PMMA) substrate of dielectric constant 2.1, with an overall size of 25 × 7 × 1.6 mm^3. The antenna compromises a 2:1 voltage standing wave ratio (VSWR) bandwidth from 3.38 to 12.94 GHz. The reason of using Poly(methyl methacrylate) (PMMA) as a substrate is due to its good degree of compatibility with human tissue and it also being used in medical technologies and implant.

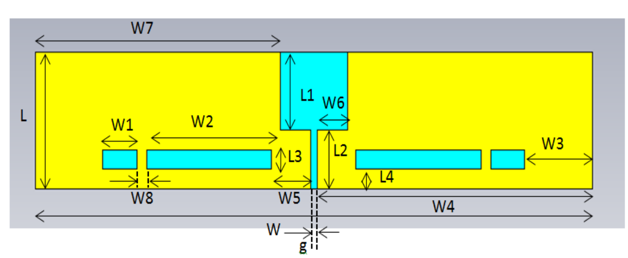


Figure 4 Geometry of UWB antenna

Table 2 below shows the dimensions of the UWB antenna and Table 3 shows the performance result – return loss (gain).

Table 2 The dimensions of the UWB antenna

Parameters	L	L1	L2	L3	L4	
Values (mm)	7	4	3	1	1	
Parameters	W	W1	W2	W3	W4	
Values (mm)	33	2	7.4	4	16.3	
Parameters	W5	W6	W7	W8	h	g
Values (mm)	2	1.8	14.5	0.6	1.6	0.4

Table 3 Performance result – return loss (gain)

Antenna	Resonant frequency (GHz)	Return loss (dB)	Gain (dB)
Simulation	5.100	- 46.845	2.59
	9.836	- 23.428	4.45
	12.155	- 13.595	5.38

Figure 4 show the performance result in term of return loss and gain for frequency of 5.100 GHz, 9.836 GHz and 12.155 GHz. Based on the simulation result, it can be seen that when the frequency increase, the return become decrease and the gain increase.

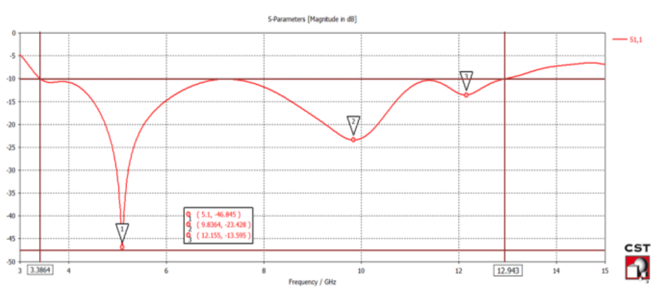


Figure 5 Simulated and measured return loss against Frequency of ultra-wideband Coplanar stripline-fed compact antenna in free space

Figure 5 show the simulated and measured return loss against frequency of ultra-wideband Coplanar stripline-fed compact antenna in free space. The optimal result of this coplanar ultra-wideband antenna 5.100 GHz, 9.836 GHz and 12.155 GHz with a gain of 2.598 dB, 4.452 dB and 5.383 dB and the return loss of – 46.845 dB, - 23.428 dB and – 13.595 dB .

4.0 ACTION POTENTIAL SIGNAL

Figure 6 show the action potential signal data in .csv format imported into transient simulation task in CST design studio. The action potential signal data is available from Izhikevcih's MATLAB programming has produced points of voltage that becomes the input data for both continuous piecewise linear voltage sources to create action potential.

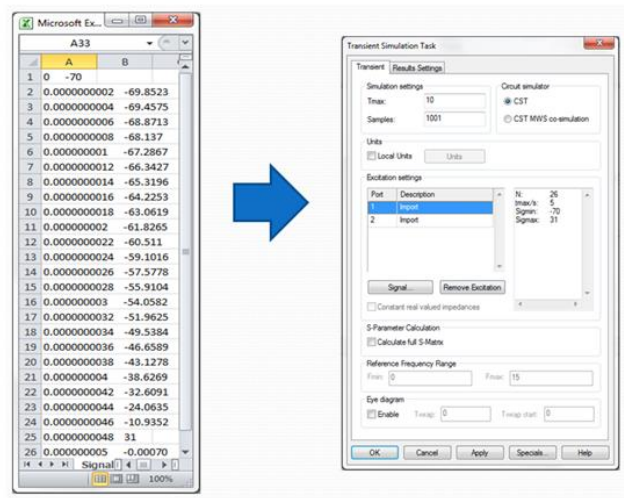


Figure 6 Imported action potential signal data into transient simulation task in CST design studio

Figure 7 show the created action potential signal after the data is being imported into transient simulation task.

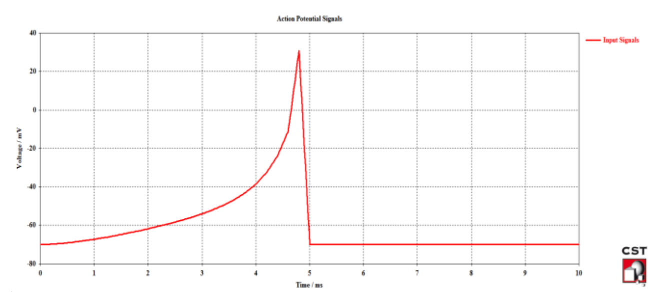


Figure 7 Created Action Potential Signal

5.0 RESULT AND DISCUSSION

Figure 8 shows the action potential signal behavior of a child when the action potential signal received from the frequency of ultra-wideband antenna. Based on the signal, we can that the time range of signal distortion is larger than other voxel model which is from 5.00ms to 9.78ms while the peak-to-peak amplitude of the distortion signal is 11.38mV. This is due to the thickness layer of a child which is thinner than other voxel model.

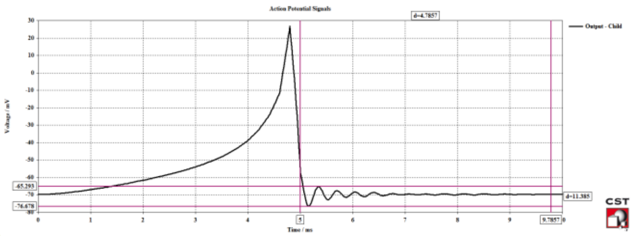


Figure 8 Action potential behavior of a child when placing UWB antenna 10mm from nerve

Figure 9 shows the action potential signal behavior of a Gustav model when the action potential signal received from the frequency of ultra-wideband antenna. It can be seen that the time range of signal distortion is from 5.00ms to 6.32ms while the peak-to-peak amplitude of the distortion signal is 9.17mV.

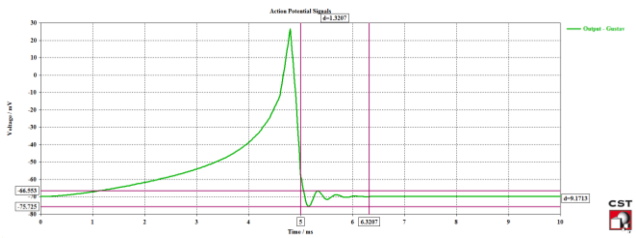


Figure 9 Action potential behavior of Gustav when placing UWB antenna 10mm from nerve

Figure 10 shows the action potential signal behavior of an Emma model when the action potential signal received from the frequency of ultra-wideband antenna. It can be seen that the time range of signal distortion is from 5.00s to 6.36s while the peak-to-peak amplitude of the distortion signal is 8.47mV.

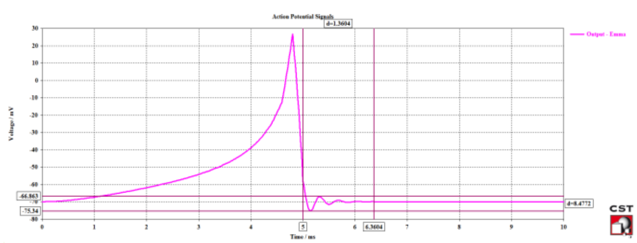


Figure 10 Action potential behavior of Emma when placing UWB antenna 10mm from nerve

Figure 11 shows the action potential signal behavior of a Donna model when the action potential signal received from the frequency of ultra-wideband antenna. It can be seen that the time range of signal distortion is from 5.00ms to 6.27ms which the difference is 1.27ms, while the peak-to-peak amplitude of the distortion signal is 8.40mV.

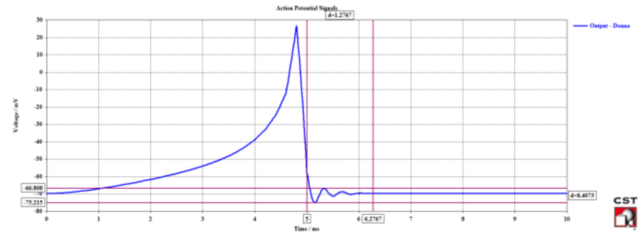


Figure 11 Action potential behavior of Donna when placing UWB antenna 10mm from nerve

Figure 12 shows the action potential signal behavior of a Laura model when the action potential signal received from the frequency of ultra-wideband antenna. It can be seen that the time range of signal distortion is from 5.00s to 6.33s while the peak-to-peak amplitude of the distortion signal is 8.12mV.

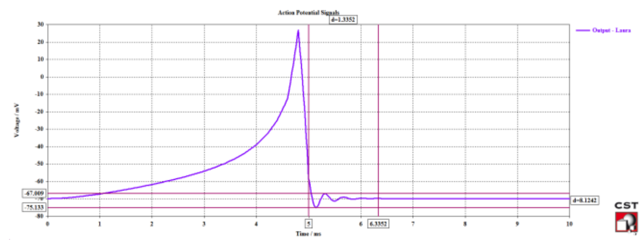


Figure 12 Action potential behavior of Laura when placing UWB antenna 10mm from nerve

Figure 13 show the action potential signal behavior of Katja model which is a pregnant woman, when the action potential signal received from the frequency of ultra-wideband antenna. It can be seen that the time range of signal distortion is from 5.00ms to 6.71ms while the peak-to-peak amplitude of the distortion signal is 8.29mV.

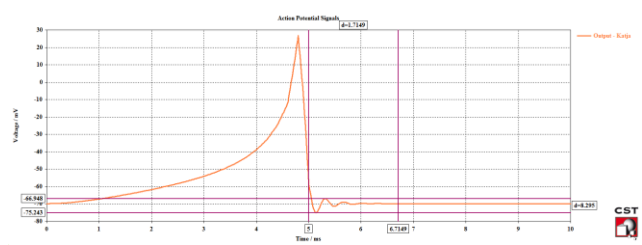


Figure 13 Action potential behavior of Katja when placing UWB antenna 10mm from nerve

Figure 14 shows the action potential signal behavior of all the family of voxel model, when the action potential signal received the frequency or radiation from the ultra-wideband antenna.

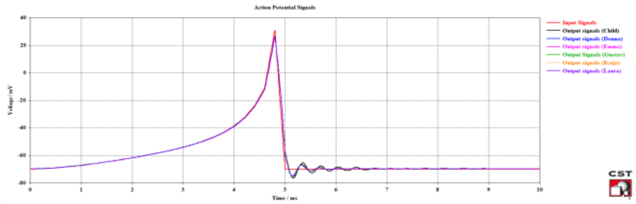


Figure 14 Action potential signal behavior of CST voxel family when antenna being placed 10mm from nerve

Table 4 The time range of distortion signal (ms) and Peak-to-peak amplitude (mV) of action potential signal

Human Voxel model	Time range of distortion signal (ms)	Peak-to-peak amplitude (mV)
Child	5.00 - 9.78	11.38
Gustav	5.00 – 6.32	9.17
Emma	5.00 - 6.36	8.47
Donna	5.00 - 6.27	8.40
Laura	5.00 – 6.33	8.12
Katja	5.00 - 6.71	8.29

Table 4 show the time range of distortion signal (ms) and Peak-to-peak amplitude (mV) of action potential signal when it prone to radiation effects from the ultra-wideband antenna. The time range of distortion signal for a child is the largest among the other human voxel model which the difference is 4.78ms and the peak-to-peak amplitude of 11.38mV. The lowest Time range of distortion signal is Donna which is from 5.00ms to 6.27ms while the lowest Peak-to-peak amplitude is Laura which ios 8.12mV.

6.0 CONCLUSION

The modeling of the simplest human voxel model in layers of homogenous solid has been successfully achieved. Hence, the human voxel homogenous model with nerve fibers is prone to radiation effects from the ultra-wideband antenna. The effects of ultra-wideband antenna radiation have proven to alter the AP as shown in time and frequency domains simulations. This alteration might interfere with the human nerve harmonious function. It can be conclude that, the ultra-wideband antenna radiation is possible to interfere with harmonious function of human nerve fiber that maybe become hazardous threats in long period of time.

Acknowledgement

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/B00064and supplying the electronic components and equipment's from the laboratory.

References

[1] Kwan-Hoong N. 2003. *Non-Ionizing Radiations–Sources, Biological Effects, Emissions and Exposures. Non-Ionizing Radiations – Sources, Biological Effects, Emissions and Exposures.* 20-22 Oct. Web. 8 Oct. 2014. 1-5.

[2] Zamanian, A., Hardiman, C. Electromagnetic Radiation and Human Health. [Online]. From: http://www.highfrequencyelectronics.com/Jul05/HFE0705_Zamanian.pdf.[Acessed on 24 November 2014].

[3] Health Effects of Artificial Electromagnetic Fields and Effective Solutions for the Problem (n.d): n. Pag. Web. 7 Oct. 2014.

[4] McRee, D. I., Elder, J. A., Gage, M. I., Reiter, L. W., Rosenstein, L. S., Shore, M. L., Galloway, W. D., Adey, W. R. and Guy, A. W. 1979. Effects Of Nonionizing Radiation On The Central Nervous System, Behavior, And Blood: A Progress Report. *Environmental Health Perspectives*. 30: 123-131.

[5] Karen, A. M. 1979. *The Challenge of Nonionizing Radiation: a Proposal for Legislation*. 105: 115.

[6] Abbasi, Q. H., and Sani, A., Alomainy, A., Yang Hao. 2009. Arm Movements Effect on Ultra-Wideband On-body Propagation Channels and Radio Systems. *IEEE Xplore*. IEEE, 16-17 Nov. 2009. Web. 8 Oct. 2014.

[7] Nerve Impulse Transmission within a Neuron: Action Potential. 2016.Boundless.[online]Availableat:https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the nervous-system-35/how-neurons-communicate-200/nerve-impulse-transmission-within-a-neuron-action-potential-762-11995/ [Accessed 22 Feb. 2016].

[8] CST STUDIO SUITE. 2016. Bio-Electromagnetics Medical Device, Exposure, and SAR Simulation. [online] Available at: https://www.cst.com/Content/Media/CST-BioEM-Flyer.pdf [Accessed 22 Feb. 2016].