ISSN 2347 - 3983
Volume 8. No. 6, June 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter56862020.pdf
https://doi.org/10.30534/ijeter/2020/56862020

Electromagnetic Radiation Effect of Action Potential Based on Different Antenna Position in Homogeneous Human Arm Flat and Cylindrical Shape Model using Ultra Wideband Coplanar Stripline-Fed Antenna

A. Salleh[1], M. Z. A. Abd. Aziz[1], Z. Zakaria[1], M. H. Misran[1], N. M. Z. Hashim[1]
[1]Centre for Telecommunication Research & Innovation (CeTRI), Fakulti Kejuruteraan Elektronik & Kejuruteraan Komputer (FKEKK), Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, 76100, Durian Tunggal, Melaka, Malaysia, azahari@utem.edu.my

ABSTRACT

This paper proposes simulation of non-ionizing electromagnetic radiation effect of Action Potential (AP) signal in the electrical nerve fiber of the human arm model by using the Computer Simulation Technology (CST) software. In this case, the primary challenge to model the human bodies and tissues and to simulate the propagation and introduce radiation of an implanted antenna from inside the human bodies. Thus, the main contribution of this work is the AP signal has been created with different antenna positions in the homogeneous human arm flat and cylindrical shape model using Ultra Wideband (UWB) coplanar stripline-fed antenna. The design of UWB antenna is based on Computer Simulation Technology (CST) software and Poly (methyl methacrylate) (PMMA) substrate, which operated from 3.1 GHz to 10.6 GHz. The process of AP signal creation including the consideration of the human arm model in the complete electrical circuit system based on the schematic circuit of the nervous system and implementing of Izhikevcih's MATLAB programming. The simulated antenna manages to realize 10.71 GHz bandwidth at two resonance frequencies, 5.27 GHz and 9.45 GHz. Overall, the proposed system offers the AP signal analysis with difference antenna position in the multilayer human arm model and the significant effect of radiation is in the cylindrical shape model.

Key words: UWB Antenna, Action Potential, CST Software, Human Arm Model,

1. INTRODUCTION

In the era of modernization, people remain exposed to electromagnetic radiation in their daily lives due, for example, to the continuous development of the use of wireless communication devices, mobile telephones as well as base stations which are broadly set in the human environment. This causes exposure to electromagnetic radiation from those devices to occur constantly in the human body. A variety of literature shows the concern that microwave radiate systems can affect the health of animals and humans [1]–[9]. Thus, the understanding of a human nervous system and its physiology is important including the process to produce the equivalent circuit of a neuron network. The nervous system can control the human body with its nerve and cell network complex and collects all the information from the senses and is processed through the nerves and the brain. Neuron directs the electrical impulses and the chemical neurotransmitters are secreted. An Action Potential (AP) is an electrical impulse that transfers information from the cell body to the terminal buttons via the axon, which is the means of communication within a neuron [10]–[13].

The external exposure effects of an electromagnetic frequency towards the human body and its cells are being influenced mostly by electromagnetic frequency and magnitude. Hence, the EM radiation will induce voltages and currents in a human body which are associated with the AP signal. When the interfering currents and voltages interact and exposed to the AP signal over a long period, the electrical system of the human body which is the nervous system will be disturbed due to the confusion. A small size UWB antenna has been designed for body implanted application to study the radiation effect [14]–[21]. The UWB frequency was chosen because of the uniqueness of high data transfer rate, smaller size, and low cost of production. However, the technical challenge happens when the performance of the antenna is different when in free space and the human tissue [22]–[24]. In [25] the effect of radiation on the nervous system was investigated using the cell phone but did not discern the age of the sample and the frequency used was also different. Therefore, the CST software was used to model human tissues and introduce radiation from the inside of human bodies from the implanted antenna.

In this paper, the AP acts as a source of the circuit in the nervous system of the human body. The design and simulation of the UWB Coplanar Stripline-Fed antenna by using CST software. Then, the analysis of the behavior of the AP signal was conducted when the radiation source from the UWB antenna ranging from 3.1 to 10.6 GHz frequency appeared. The electromagnetic radiation was produced by implanting antenna in the homogeneous model of the human arm (flat and cylindrical shape). The main focus of the paper is to analyze the AP signal based on different positions of the antenna in both models.

2. DESIGN CONFIGURATION

In this research, the UWB coplanar stripline-fed compact antenna had been designed to test the electromagnetic effect of AP of the human body. The antenna has little losses, low fringing, low mutual coupling, good variation in achievable impedance levels, high gain for a given size, and low likelihood of launching a trapped wave in the dielectric slab. The antenna designed with size 35mm x 11.67mm is based on a bio-compatible substrate material of the polymer known as Poly (methyl methacrylate) (PMMA). The permittivity or dielectric constant, $\mathcal{E}_r$ of this substrate was equivalent to 2.8, tangent loss, *tan δ* was equivalent to 0.04. The thickness of the substrate, *h*, was 0.8 mm. Figure 1 shows the structure of the antenna.

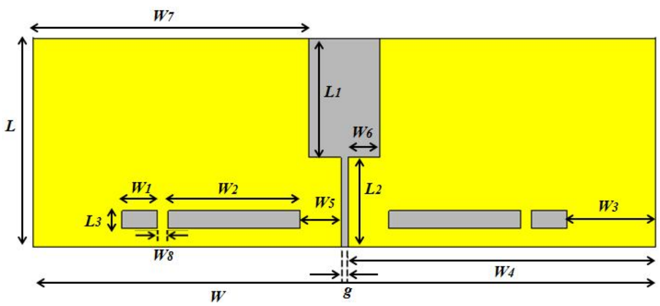

Figure 1: UWB Antenna Structure (Front View)

The initial step is to model the simplest form of the actual human arm in CST Microwave Studio software with its corresponding radiation source. This step is very important to know how much the intensity of radiation is being absorbed by the nerve fibers. Then, the radiation intensity is transformed into an induced source for the Transmission Line (TL) circuits.

The cylindrical homogeneous human arm model is designed with the age of 26 years old. The human arm model designed in the simulation consists of nine layers as shown in Figure 2. All the layers are lossy dielectrics with specific thicknesses and complex permittivity which refer to the propagation of electromagnetic waves. The electrical properties of human arm organs and tissue including thickness, relative permittivity, and conductivity at 3.9 GHz and 5.27 GHz is considered.

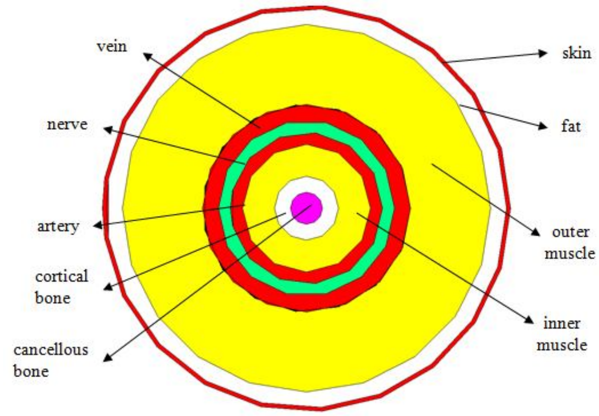

Figure 2: Human Arm Cylindrical Shape Model

The flat homogeneous human arm model is designed with different age comprises a child (7 years old), adolescent (26 years old), adult (38 years old), and every model has a dissimilar thickness of tissue layer. Figure 3 shows an example of the human arm flat shape model for a child. The electrical properties of human arm organs and tissue for child 7 years old child is shown in Table 1.

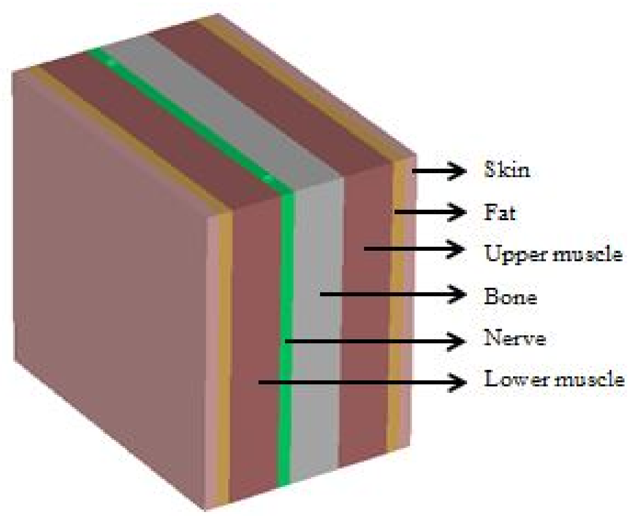

Figure 3: Human Arm Flat Shape Model

Table 1: Electrical Properties of Child (7 year old)

Tissue	Width (mm)	Relative Permittivity at 3.9 GHz	Relative Permittivity at 5.27 GHz
Skin	2	38.077	33.1299
Fat	2	5.6540	5.1160
Upper muscle	8	51.822	44.3977
Bone	15	51.822	44.3977
Nerve	8	10.581	8.2924
Lower muscle	2	30.132	25.4113

The nervous system and electric circuit are similar in that, they both work on electric charges plus the nervous system has a Central Processing Unit (CPU) which acts as a brain, as a circuit could have. To observed and analyzed the accomplish results that can be related to the real-life situation, the homogeneous human arm is modeled as an electrical circuit system. Figure 4 shows the homogeneous arm model of both flat and cylinder shapes with a fully electric circuit system. The nervous system is equipped with bio-electrical cable known as nerve fibers.

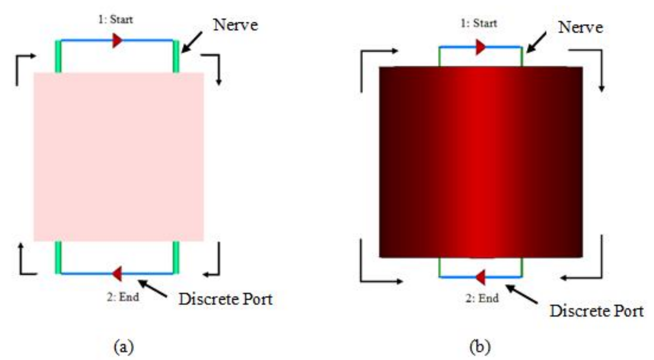

Figure 4: Human Arm Model (a) Flat Shape (b) Cylindrical Shape as Electrical Circuit System

Figure 5 shows the schematic circuit of the nervous system in the human arm model in the CST software. It can be seen that the simulation blocks which can be combined to accumulate a system. To build a complete circuit, the simulation blocks can be linked together which contain the simulated results.

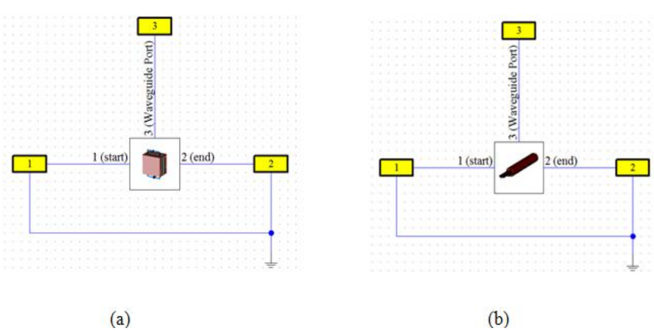

Figure 5: Schematic Circuit of Nervous System (a) Flat Shape (b) Cylindrical Shape

From the .csv format, the AP signal needs to convert through transient simulation in CST software. The AP signal data can be obtained from the implementation of the Izhikevcih Matrix Laboratory (MATLAB) programming that developed voltage points that were converted into input data for both continuous linear voltage sources to produce the AP signal. The UWB signal interaction with the human body has been studied through a layered body model, which based on tissue frequency dependence. Figure 6 shows a free view of the UWB antenna embedded into the constructed homogeneous human arm model with the cylinder and flat shape. Firstly, we radiated the homogeneous arm model with the UWB antenna which is implanted into the skin. The antenna characteristics in the biological tissue environment are different from the antenna characteristics in free space. The electrical properties of the homogeneous human arm model are available in the CST software database to depend on the operating frequency.

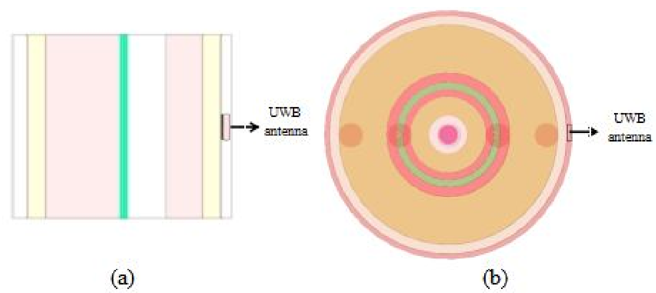

Figure 6: Human Arm Model with UWB Antenna in Vertical Orientation (a) Flat Shape (b) Cylindrical Shape

The effect of UWB antenna radiation is based on the position of an antenna in each tissue layer of the arm model. To study the effect of antenna position in dissimilar tissue layer towards the AP, the UWB antennas are placed at the center of each tissue starting from the skin to the bone as shown in Figure 7 and Figure 8 respectively.

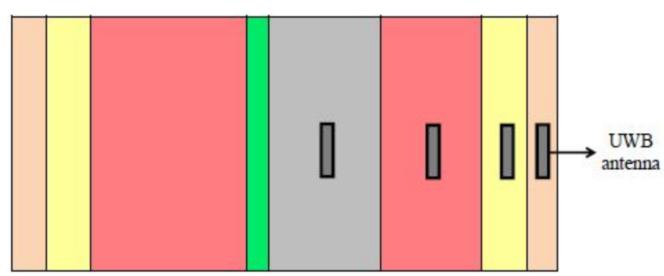

Figure 7: The position of the UWB antenna embedded in each layer of tissue (Flat Shape)

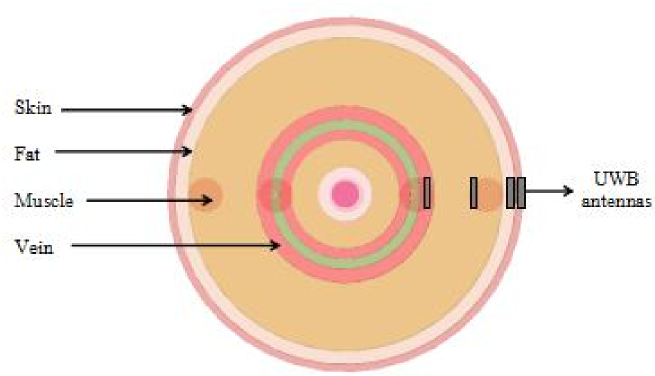

Figure 8: The position of the UWB antenna embedded in each layer of tissue (Cylinder Shape)

3. RESULT AND ANALYSIS

Figure 9 shows the result of the return loss of the UWB antenna allocated in different spaces which includes the subject in free space, 7 years old, 26 years old and 38 years old. The performance of the various age in the human arm is poor due to distracting by the complexity and inhomogeneity of the biological tissue 's loss medium due to antenna radiation.

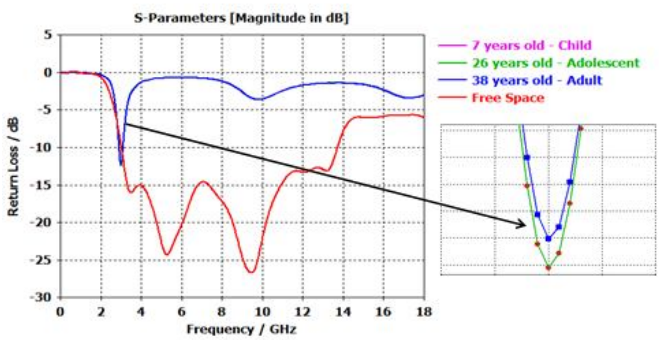

Figure 9: The Comparison of Return Loss of Antenna in Free Space and with Homogeneous Human Arm Model at 5.27 GHz (Flat Shape)

Figures 10, 11, and 12 show the combination of AP signals interference by UWB antenna in terms of different ages based on flat shape model. It can be seen that different positions of an antenna in each tissue will give a different result of AP signal interference especially the amplitude signal.

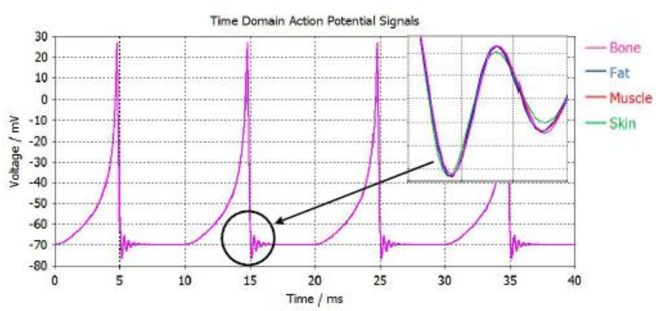

Figure 10: Combination of AP signal interference in each layer of 7 years old model (flat shape)

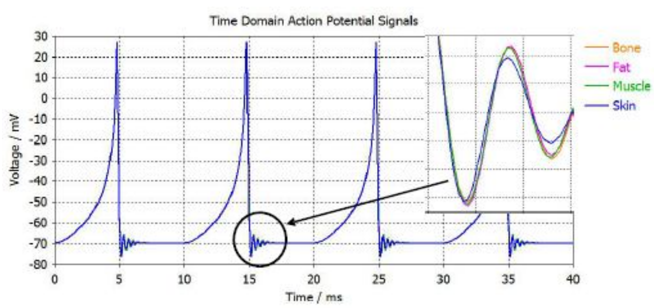

Figure 11: Combination of AP signal interference in each layer of 26 years old model (flat shape)

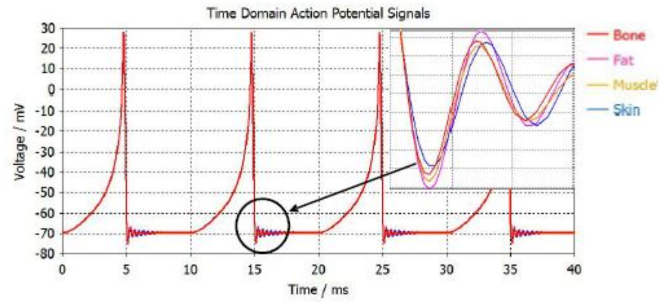

Figure 12: Combination of AP signal interference in each layer of 38 years old model (flat shape)

Table 2 comprises the time range of distortion signal (ms) and peak-to-peak amplitude (mV) of action potential signal of human homogenous arm model in terms of different tissue layers when it was exposed to UWB antenna in flat shape model. It is found that the peak-to-peak amplitude of fat is higher compared to other tissue in the three types of age which is 11.32 mV of 7 years old model, whereas the peak-to-peak amplitude of 26 and 38 years old model is 11.24 mV and 8.43 mV, respectively.

Table 2: AP Signal Properties in Different Layers and Model (Flat Model)

Human Model Arm (Age)	Layer	Time Range of Distortion Signal (ms)	Peak to Peak Amplitude (mV)
7 years old	Skin	5.00-7.19	11.05
	Fat	5.00-7.26	11.74
	Muscle	5.00-6.78	11.31
	Bone	5.00-6.87	11.22
26 years old	Skin	5.00-7.58	11.13
	Fat	5.00-7.52	11.24
	Muscle	5.00-7.73	10.99
	Bone	5.00-7.19	10.84
38 years old	Skin	5.00-7.19	7.09
	Fat	5.00-7.19	8.87
	Muscle	5.00-7.19	8.43
	Bone	5.00-7.19	7.22

The cylindrical arm model has more layered tissue than a flat arm model, therefore, based on the AP of amplitude signal is different when the UWB antennas are placed in a different medium as shown in Figure 13. In the cylinder arm model, the peak-to-peak amplitude in fat tissue is larger compared to other tissue in the arm model which is 11.05 mV, whereas the lowest peak-to-peak amplitude is in skin tissue with only 10.04 mV, followed by muscle as well as vein with 10.84 mV and 10.55 mV. All the signal properties is summarized in Table 3.

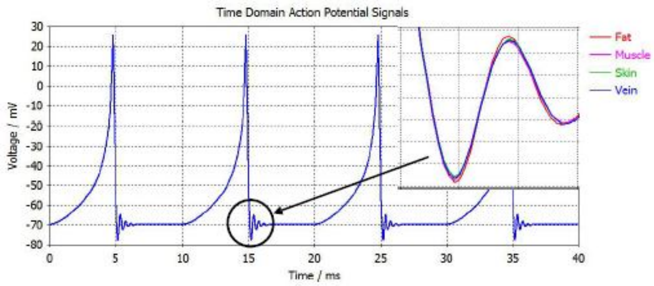

Figure 13: Combination of AP signal interference in each layer of 26 years old model (cylindrical shape)

Table 3: AP Signal Properties in Different Layers for Cylindrical Model)

Human Model Arm (Age)	Layer	Time Range of Distortion Signal (ms)	Peak to Peak Amplitude (mV)
26 years old	Skin	5.00-7.26	10.04
	Fat	5.00-7.67	11.05
	Muscle	5.00-7.74	10.84
	Bone	5.00-6.82	10.55

4. CONCLUSION

The electromagnetic radiation effect of AP signal in the nerve fiber based on UWB coplanar stripline-fed antenna using homogeneous human arm (flat and cylindrical shape) has been successfully simulated through CST software. The main concern is the effect of AP signal properties especially the time range of distortion signal and peak-to-peak amplitude in different antenna positions and ages. The radiation effect is more significant in the cylindrical shape model. For the validation process in the future, this method can be applied to the low cost actual human arm model.

ACKNOWLEDGMENT

The author would like to thank Universiti Teknikal Malaysia Melaka (UTeM) for financial support.

REFERENCES

1. C. L. Russell **5G wireless telecommunications expansion: Public health and environmental implications**, *Environmental Research.*, Vol. 165, pp. 484-495, 2018. https://doi.org/10.1016/j.envres.2018.01.016
2. A. H. Elgazzar and N. Kazem, **Biological effects of ionizing radiation**, in *The Pathophysiologic Basis of Nuclear Medicine*, Springer, Cham, pp. 715-726, 2015.
3. E. Kivrak, K. Yurt, A. Kaplan, I. Alkan, and G. Altun, **Effects of electromagnetic fields exposure on the antioxidant defense system**, *J. Microsc. Ultrastruct.*, *5*(4), pp.167-176, 2017. https://doi.org/10.1016/j.jmau.2017.07.003
4. L. N. Medeiros and T. G. Sanchez, **Tinnitus and cell phones: The role of electromagnetic radiofrequency radiation**, *Brazilian Journal of Otorhinolaryngology*, 82(1), pp.97-104, 2016 https://doi.org/10.1016/j.bjorl.2015.04.013
5. World Health Organization (WHO), **Ionizing Radiation, Health Effects and Protective Measures**, *World Heal. Organ.*, 2016.
6. M. L. Pall, **Wi-Fi is an important threat to human health**, *Environ. Res.*, 164, pp. 405-416, 2018.
7. W. J. Zhi, L. F. Wang, and X. J. Hu, **Recent advances in the effects of microwave radiation on brains**, *Military Medical Research*, 4(1), pp. 29, 2017. https://doi.org/10.1186/s40779-017-0139-0
8. P. Chauhan, H. N. Verma, R. Sisodia, and K. K. Kesari, **Microwave radiation (2.45 GHz)-induced oxidative stress: Whole-body exposure effect on histopathology of Wistar rats**, *Electromagn. Biol. Med.*, 36(1), pp. 20-30, 2017.
9. A. B. Sharma and O. S. Lamba, **A Review : Source and Effect of Mobile Communication Radiation on Human Health**, *Adv. Wirel. Mob. Commun.*, 10(3), pp. 423-435, 2017.
10. M. Chappell and S. Payne, **The Action Potential**, in *Biosystems and Biorobotics*, pp. 35-45, 2020.
11. D. Pramanik and D. Pramanik, **Action potential,**" in *Principles of Physiology*, 2nd Edition, Academic Publishers, 2015, Chp 1, pp. 66-70.
12. S. Rao and J. C. Chiao, **Body electric: Wireless power transfer for implant applications**, *IEEE Microw. Mag.*, 16(2), pp. 54-64, 2015. https://doi.org/10.1109/MMM.2014.2377586
13. M. S. N. Azizi, N. A. Aris, A. Salleh, A. Othman, N. R. Mohamad. **Non-ionizing electromagnetic radiation effect on nerve fiber action potential of human body – A review**. *J. Teknol.*, 77(7), pp. 31–362, 2015.
14. M. Ghafari, P. Brennan, and M. Ghavami, **UWB power propagation for bio-medical implanted devices**," in *17th International Conference on E-Health Networking, Application and Services (HealthCom)*, pp. 483-487 2015.
15. K. Yekeh Yazdandoost, **UWB antenna for body implanted applications**, in Proc. *European Microwave Conference (EuMC 2012)*, pp. 932-935, 2012.
16. N. A. Aziz, N. R. Mohamad, M. Abu, and A. Othman, D**esign of ultra-wideband (UWB) implantable antenna for biomedical telemetry**," *ARPN J. Eng. Appl. Sci.*, 11(5), pp. 3249-3252, 2016.
17. M. Abu, N. R. Mohamad, A. Othman, N. A. M. Aris, S. Indra Devi, and N. H. Izahar, **Propagation characterization of implantable antenna at UWB frequency – A review**, *Jurnal Teknologi*, 77(7), pp. 85-89, 2015
18. M. S. Noor Azizi, A. Salleh , A. Othman, N. A Mohd Aris, N. R. Mohamad, M. Abu. **Non-ionizing (ultra-wideband frequency) electromagnetic**

radiation effect on nerve fiber action potential of human body., J Teknol., 78(5–6), 131–137, 2016. https://doi.org/10.11113/jt.v78.8651

19. A. Don, M. Africa, I. J. Volume, A. D. M. Africa, F. X. Asuncion, R. Miguel. **PCB / Microstrip Antenna Design and Simulation**. Int J Emerg Trends Eng Res., 7(8), pp. 157–162, 2019. https://doi.org/10.30534/ijeter/2019/09782019
20. A. D. M. Africa, A. M. S. Alejo, G. L. M. Bulaong, S. M. R. Santos, J. S. K. JUy . **Effect of dielectric substrate on dipole antenna directivity,** Int. J. Emerg. Trends Eng. Res., 7(8), pp. 170–177, 2019; https://doi.org/10.30534/ijeter/2019/11782019
21. K. Vamsi, I. Journal, K.V. Krishna, H. Khan , K. K. Naik. **A Compact Rectangular Shaped Dipole Array Slot Microstrip Antenna with DGS for Multiband Applications**, Int J. Emerg. Trends Eng. Res. 8(2), pp. 408-413, 2020. https://doi.org/10.30534/ijeter/2020/28822020
22. H. Bahrami, S. A. Mirbozorgi, R. Ameli, L. A. Rusch, and B. Gosselin, **Flexible, Polarization-Diverse UWB Antennas for Implantable Neural Recording Systems,** *IEEE Trans. Biomed. Circuits Syst*, 10(1), pp.38-48, 2016.
23. J. Charthad, M. J. Weber, T. C. Chang, and A. Arbabian. **A mm-Sized Implantable Medical Device (IMD) With Ultrasonic Power Transfer and a Hybrid Bi-Directional Data Link**, *IEEE J. Solid-State Circuits*, 50(8), pp.1741-1753, 2015.
24. E. Miralles, C. Andreu, M. Cabedo-Fabres, M. Ferrando-Bataller, and J. F. Monserrat, **UWB on-body slotted patch antennas for in-body communications**, in *11th European Conference on Antennas and Propagation, EUCAP 2017*, pp. 167-171, 2017. https://doi.org/10.23919/EuCAP.2017.7928598
25. A. Othman, N. R. Mohamad, and M. Z. M. Jenu, **Mobile phone radiation effects on action potentials in brain-arm nerve fibres of human**, *Int. J. Appl. Eng. Res.*, vol. 10, no. 17, pp. 38177–38182, 2015.