VOL. 11, NO. 5, MARCH 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

DESIGN OF ULTRA-WIDEBAND (UWB) IMPLANTABLE ANTENNA FOR BIOMEDICAL TELEMETRY

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ABSTRACT

Implantable medical device (IMD) is one of the latest developments in biomedical telemetry which allows the transmission of physiological signal at a distance either through wired or wireless communication. Commonly, this IMD is used at medical implant communication service (MICS) band. But, it have limited range of communication and suffers from low data rates which make low quality and precision of the patient record. So, this paper proposes an implantable planar antenna which operates at UWB frequency band. The total dimension of the antenna is 25 mm × 30 mm and by adding two strips at right top of antenna patch will increase the performance of the antenna. The results indicate when the antenna is embedded inside the human arm, the return loss is slightly shifted to the right. Presence of the conductive material in the human arm, the antenna gain is reduced to be negative due to the losses from the signal towards human arm tissue.

Keywords: biocompatible, implantable antenna, ultra-wideband (UWB).

INTRODUCTION

In the new global technology, lots of new inventions had been developed in biomedical telemetry. One of them is implantable medical device (IMDs) [1]. IMDs have the competency to communicate wirelessly with an exterior device, and have received enormous attention for attaining real time and stored physiological data in biomedical telemetry. It is also capable in a number of applications, for instance, temperature monitors [2], blood-glucose sensor [3], cochlear [4] and retina implants [5], as well as pacemakers and cardioverter defibrillators [6]. An implantable antenna is a main element towards radio frequency (RF)-linked IMDs. However, it comes with many limitations due to the low data rates, restricted range between the implant and exterior monitor, as well as not user-friendly for home monitoring. So, to overcome these limitations, some research is currently oriented towards implantable antenna for biomedical telemetry.

Commonly, implantable antennas are used at medical implant communication service (MICS) band, in which it have its own frequency range (402-405 MHz) as stated by Federal Communication Commission (FCC). However, there are some limitations in transmitting the signal as it has very low power and also has short range of bandwidth. Nevertheless, there are also frequency bands that have been suggested which are industry, scientific and medical (ISM) bands which start from (2.4-2.5 GHz). However, in medical field application, it required for high data rates in order to upload and transfer the huge data of patient to the base station. So, ultra-wideband (UWB) is introduced in this implantable antenna design due to their advantages in which can penetrate through obstacles, and produce high bandwidth communication which can allow high data rate throughout for communication device. FCC standard had allocated the UWB frequency band starting from (3.1-10.6 GHz), which having a fractional bandwidth larger than 0.2 or at least 500 MHz of bandwidth.

In fact, an implantable antenna inside the human body had faced with a variety of challenges like biocompatibility and miniaturization. Biocompatibility is an important factor in designing the implantable antenna in order to avoid the rejection of the implant and protect the patient safety. Also, due to the fact that human tissue is conductive material, so there would be a problem of short circuit if they were allowed to be in direct contact with its metallization. Furthermore, used with high permittivity of substrate material like ceramic alumina [7], Rogers 3210 [8], and Silicon [9] would shorten the effective wavelength and thus, lower resonance frequency.

In this paper, the design of implantable planar antenna is proposed at UWB frequency band. The proposed antenna has simple and compact structure. Details of the implantable antenna design, and the results before and after embedding the antenna inside the human arm are discussed in the next step.

ANTENNA DESIGN

Figure-1 shows the proposed implantable UWB planar antenna, which is designed on the biocompatible polydimethylsiloxane, PDMS substrate (ε_r = 2.2) with thickness of 1.5 mm. Total dimension of the antenna size is 25 mm × 30 mm. The square radiating patch antenna which sized 15 mm × 15 mm is then added by with two strips at the right top of the patch antenna. These two strips are used to increase the gain of the antenna thus making the performance of antenna a better one. The upper layer of substrate is made up of copper layer with thickness of 0.035 mm which works as radiating elements. The opposite side of the substrate is partial ground plane. The antenna is then fed with inset feed method. Matching the mode impedance of the planar antenna to 50Ω is obtained by tuning the width of feed line. The optimum parameters of the proposed antenna in Figure-1 were listed in Table-1.

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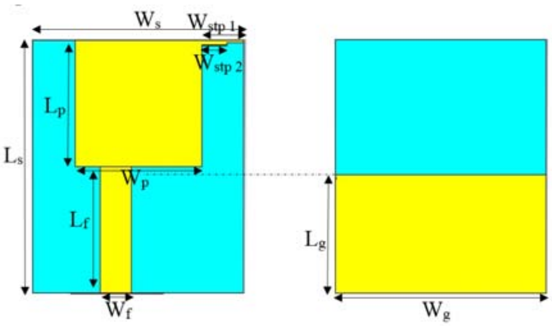

Figure-1. Antenna design.

Table-1. Antenna design parameters.

Parameters	Dimension (mm)
Ls	30
Ws	25
Lp	15
Wp	15
Lg	14
Wg	25
Lf	15
Wf	4.7
L_{stp1}	5
W_{stp1}	0.3
L_{stp2}	3
W_{stp2}	0.3

RESULTS AND DISCUSSION

The implantable antenna is then embedded into homogeneous arm model as shown in Figure-2. There are four layers in homogeneous arm model which are skin, fat, muscle and bone layer, and each thickness of tissue layer is based on previous research in [10][11]. Note that, the dielectric properties in the homogeneous arm model tissue must be same as dielectric properties in actual human being. Table-2 shows the dielectric properties of the human arm tissue at single frequency, 7.7 GHz.

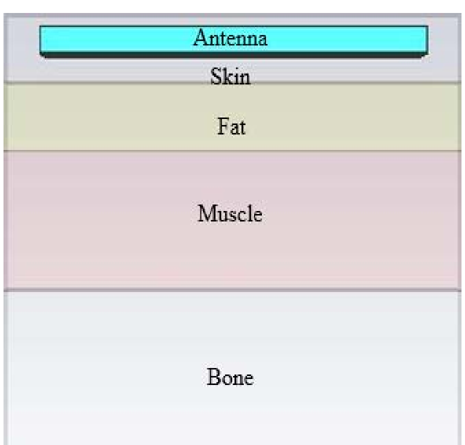

Figure-2. Homogeneous arm model.

Table-2. Dielectric properties of human arm tissue at 7.7 GHz.

Tissue	Permittivity (ε_r)	Conductivity (S/m)
Bone	14.026	2.9413
Fat	4.7874	0.422
Muscle	45.908	7.3897
Skin	33.458	5.5147

As seen in Figure-3, the return loss of the antenna in free space drop at resonant frequency of 7.7 GHz by having wide bandwidth which is cover enough the entire of UWB frequency range. When an implantable antenna is mounted at 2.4 mm depth of skin layer tissue inside homogeneous arm model, there are changes in return loss which is slightly shifted to the left due to the conductivity of the human arm tissue which affect the impedance matching as shown in Figure-3. The impedance matching is reduced from 50 Ω to 35 Ω. As shown in Figure-3 also, the bandwidth of the antenna became quite wider after implanting the antenna inside the human arm tissue.

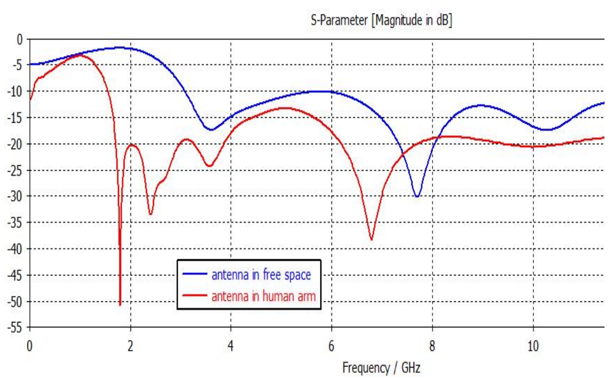

Figure-3. Return loss.

Figure-4 shows the schematic for matching circuit while Figure-5 shows the result of return loss before and after doing the circuit matching in order to make it match back the impedance matching to 50Ω at 7.7 GHz.

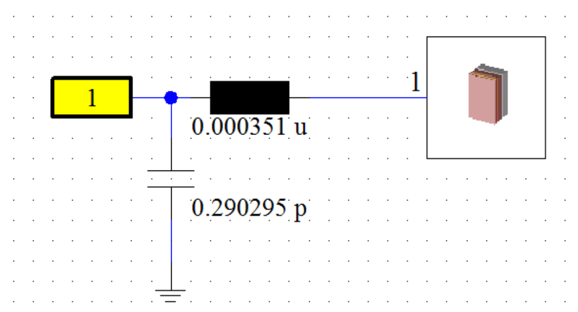

Figure-4. Schematic for matching circuit.

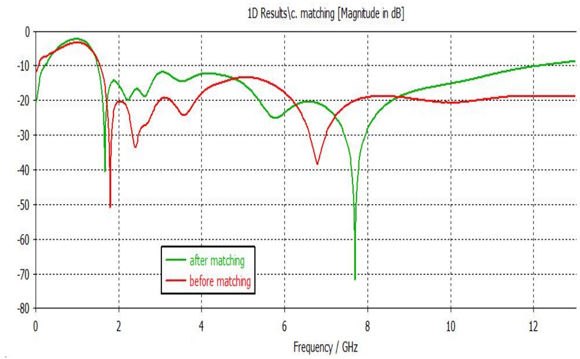

Figure-5. Return loss before and after matching circuit.

As shown in Figure-6, the antenna gain in free space is about 3.271dB at 7.7 GHz. It is noted that, the performance of the antenna in free space is not the same as the antenna inside the human body. This is because, human body contains lot of water which will produce some energy losses of the transmitted signal. So, as seen in Figure-7, when the antenna is implanted inside human arm model, the gain is absolutely changed to negative dB (-7.095dB) due to the significant attenuation of the tissue when the UWB signal is passing through by different layer of tissue. It can be seen that, the gain of the antenna before and after implant the antenna inside human arm are reduced about 1.93%.

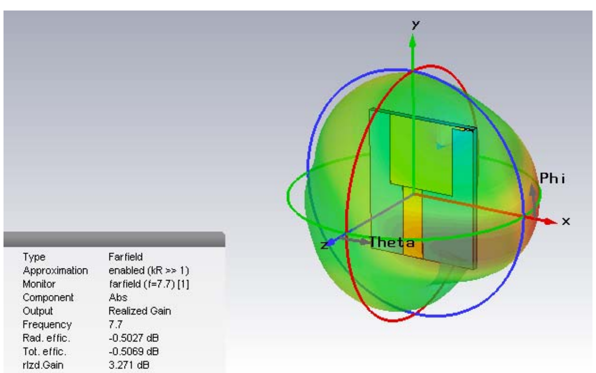

Figure-6. Antenna gain in free space at 7.7 GHz.

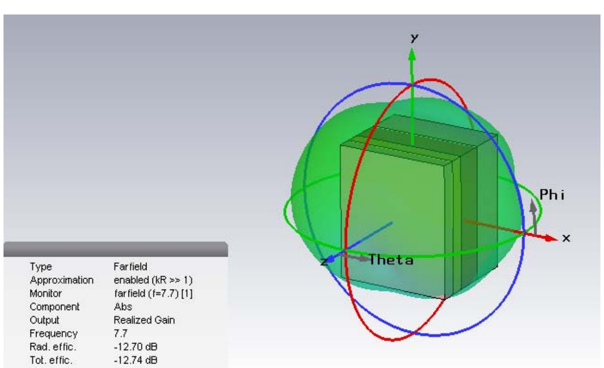

Figure-7. Antenna gain when embedded inside human arm tissue at 7.7 GHz.

CONCLUSIONS

The implantable planar antenna is presented with a compact sized of 25 mm×30 mm by using biocompatible PDMS substrate with thickness of 1.5 mm. The proposed antenna was analyzed by using CST Microwave Studio Suite and this antenna is operated at UWB frequency band with resonant frequency of 7.7 GHz. Since human arm is a conductive material, so there are changed in impedance matching thus affecting the result of return loss. The attenuation from the significant tissue produced some losses thus, giving the antenna gain become negative decibel.

ACKNOWLEDGEMENTS

The authors wish to thank the Centre for Research and Innovation Management (CRIM) of Universiti Teknikal Malaysia Melaka (UTeM) for the support of this work under the grant number of PJP/2013/FKEKK (48C)/S01277.

REFERENCES

[1] Kiourti and K. S. Nikita. 2012. A review of implantable patch antenna for biomedical telemetry: Challenges and solution. IEEE Antennas and Propagation Magazine. 54(3): 210-228.

[2] W. G. Scanlon, N. E. Evans and Z. M. McCreesh. 1997. RF performance of a 418 MHz radio telemeter packaged for human vaginal placement. IEEE Transactions on Biomedical Engineering. 44(5): 427-430.

[3] M. C. Shults, R. K. Rhodes, S. J. Updike, B. J. Gilligan and W. N. Reining. 1994. A telemetry-instrumentation system for monitoring multiple subcutaneously implanted glucose sensors. IEEE Transactions on Biomedical Engineering. 41(10): 937-942.

[4] T. Buchegger, G. Obberger, A. Reisenzahn, E. Hochmair, A. Stelzer and A. Springer. 2005. Ultra-wideband transceivers for cochlear implants. EURASIP Journal on Applied Signal Processing. 18: 3069-3075.

[5] K. Gosalia, G. Lazzi and M. Humayun. 2004. Investigation of microwave data telemetry link for a retinal prosthesis. IEEE Transactions on Microwave Theory and Techniques. 52(8): 1925-1932.

[6] D. Wessels. 2002. Implantable pacemakers and defibrillators: Device overview and EMI considerations. Proceedings of the IEEE International Symposium on Electromagnetic Compatibility (EMC 2002).

[7] A. Kiourti, M. Christopoulou and K. S. Nikita. 2011. Performance of a novel miniature antenna implanted

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in the human head for wireless biotelemetry. IEEE International Symposium on Antennas and Propagation, Spokane, Washington, USA.

[8] Kiourti and K. S. Nikita. Miniature scalp-implantable antennas for telemetry in the MICS and ISM bands: Design, safety considerations and link budget analysis. IEEE Transactions on Antennas and Propagation.

[9] K. Y. Yazdandoost. 2006. Antenna for body implanted applications. Proceedings of the 9th European Radar conference. Amsterdam, the Netherlands. pp. 606-609.

[10] M. L. Scarpello, D. Kurup, H. Rogier, D. V. Ginste, F. Axisa, J. Vanfleteren, W. Joseph, L. Martens and G. Vermeeren. 2011. Design of an implantable slot dipole conformal flexible antenna for biomedical application. IEEE transactions on antennas and propagation. 59(10): 3556-3564.

[11] S. Ashok Kumar and T. Shanmuganantham. 2014. Design of implantable CPW fed monopole H-slot antenna for 2.45 GHz ISM band application. International journal of electronics and communications (AEU). 68: 661-666.