Gain Enhancement of Implantable Antennas Using Patch Slots

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Abstract : Implantable antennas are of great importance in designing various implantable sensors and medical devices. In this paper, we have designed a compact size implantable antenna with the crossed slots at the patch area and its design considerations along with the modification done on the patch have been thoroughly discussed. ISM band between 2.4GHz and 2.48GHz MHz has been considered for the operating frequency of the antenna. A 50ohm impedance matching has been done by the insertion of the coaxial probe to have maximum power delivered to the device. For conserving the patient's tissue from coming close in contact with the radiation emitted from the patch, a supersubstrate layer has been applied over the patch. The antenna is simulated in muscle. Then patch slot extension from one has been done to analyze the overall changes in the parameters of the antenna. The designed antenna depicts considerably improved performance at various muscle depths by having excellent gain and a return loss less than -10 dB at the desired ISM band. The analysis of simulations done on HFSS software makes it suitable for insertion in the human body.

***IndexTerms* - Implantable antenna, Implantable Medical Devices (IMDs), biocompatibility, miniaturization, patient safety, Bio-medical telemetry, patch Antenna, crossed slots.**

I. INTRODUCTION

The evolving development of wireless communication with increasing multiple service abilities has received great focus towards a wider range of applications in various wireless technologies. One of the major application areas of wireless communication technologies is in the biotelemetry domain. In the biomedical domain, the implantable device placed into the human body by the surgical methods has the main function of performing the various diagnostic and therapeutic functions for transmitting the biological and physiological signals strongly to the controlling and the monitoring unit that is placed in the exterior of the human body. The area of implantable medical devices (IMDs) has been highlighted a lot with the advancement in the biotelemetry fields. use of Lower-frequency inductive links in biotelemetry fields for implantable medical devices results in poor data rates (1-30 kbps) due to limited distance of communication which is less than 10cm and sensitivity increase due to the requirement of coil antenna within the specified communication range. to solve this problem, the research work is presently focused on radiofrequency (RF)-linked implantable medical devices. many people across the world are dependent upon implantable medical devices for bracing and improvising their overall lifestyle. RF-linked implantable medical devices have various applications in measurement of the temperature of the human body, pacemakers and cardioverter-defibrillators devices used for giving electric shocks to the heart for the rhythmic beating of heart, functional electrical stimulators (FES) that provides the application of electric charges to the damaged or weakened muscle for getting back the usual; movement of that muscle, blood-glucose sensors for diagnosing the blood sugar level in patients body, and cochlear for effective hearing and retinal implants for getting a proper vision. For smooth functioning of the implantable devices. various bands of frequencies are available to keep the human body safe during diagnosis and treatment that are The Medical Implant Communication System (MICS), Wireless Medical Telemetry Service (WMTS), industrial, scientific, and medical (ISM) bands, and so on .with the advancement in technology new variations are being done to the implantable medical devices, to improvise their functionality and increase their use.

In this paper, an antenna has been designed for biomedical purposes. A detailed description of the designed implanted antenna system has been presented in section 2. Section 3 deals with the parameters that were being simulated on the software HFSS at the operating frequency of the ISM band between 2.4Ghz and 2.48 GHz.

II. ANTENNA DESIGN

Patients' safety has been the major concern for the designing of implantable devices due to their placement inside the complex body. Hence, the overall designing aim of the antenna is to have a desirable miniature size with desired resonance and radiation characteristics at the ISM band (2.4GHz-2.48GHz). Human muscle is a highly dielectric material, Rogers 3010 ($\varepsilon r = 10.2$, $\tan\delta = 0.0035$), which has been usually deployed as substrate and supersubstrate. This material is used for the prevention of the radiation emitting from the antenna to be exposed to lossy tissue, thereby increasing the tissue temperature. To, miniaturize the overall size of the device, the patch antenna's ground is trimmed to achieve the miniaturized size. As shown in Fig. 1 shows patch antenna in muscle box of volume 216000m^3(60m x60m x60) was placed at the 4.27mm depth of the muscle tissue. Both substrate and superstrate have a thickness of 0.635mm. The input to the antenna is provided by a 50-Ω impedance matching of coaxial cable which has been achieved at a 9.5mm distance from the center of the patch and ground, both with a radius of 10mm. To improve the overall impedance matching the crossed slots have been introduced as shown in fig 2.

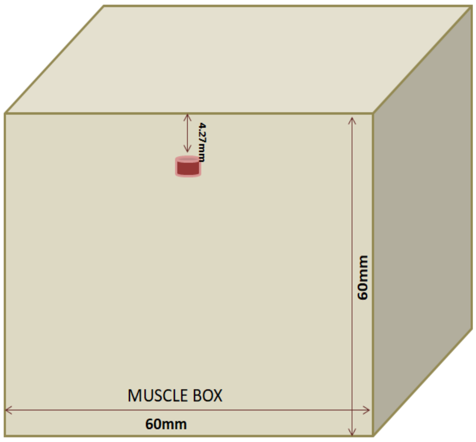


Fig 1: Antenna with crossed slots placed at the depth of 4.27mm

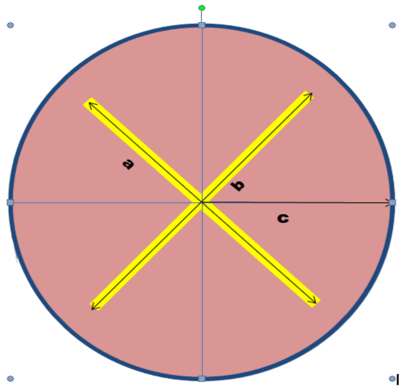


Fig 2:Antenna with crossed slots

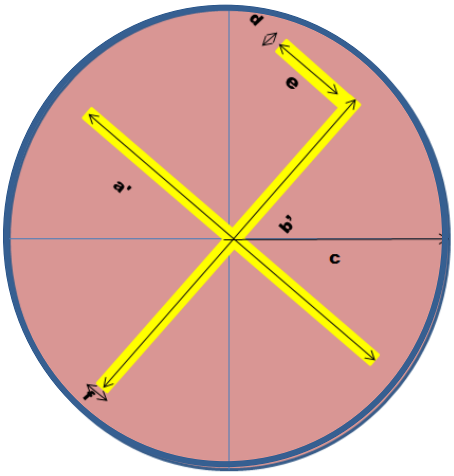


Fig 3: Antenna slot extended in a horizontal fashion

Parameters	Length (mm)
a	14.9
b	15.1
a’	13.9
b’	13.8
c	10
d	0.3
e	1.36
f	0.2

Table 1: Parameters defined for antenna

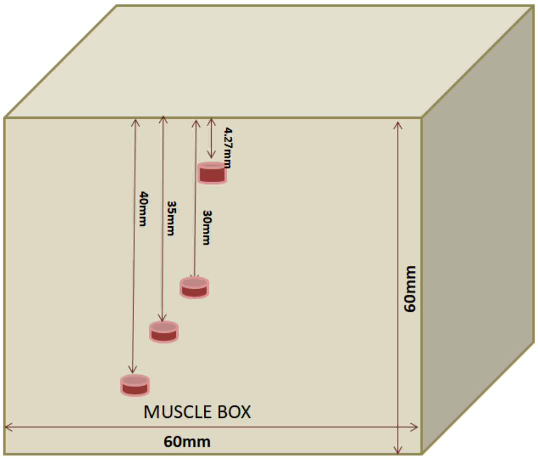


Fig 4: Extended Slot antenna patch placed at various muscle depths.

To improve the overall antenna performance for the diagnostic applications, the slot has been horizontally extended from one side as shown in fig 3. The overall dimensions of the patch have been illustrated in table 1.
Antenna with the extended slots ie the proposed antenna have been shown in Fig 3 has been placed at the various skin depth of 4.27mm, 30mm and 40mm. so with horizontally extending the slot from one side towards the edge of the patch and slight trimming in the length of crossed slots, brings the two orthogonal modes to move closer which will lead to the maximization of the overall resistance.

III. Results And Discussions

3.1Return Loss

Return loss represents how much power is being delivered to our antenna and how much of it is reflected. Fig 5 represents the return loss at various skin depths for the extended slot patch antenna and with crossed slot patch antenna. As per the observation from the plots, it has been seen that the return loss of -14dB for the crossed slot has been achieved at 2.44GHz resonating frequency. With the extended slots, the value of return loss has been decreased consecutively at 4.27mm and 30mm, and 40mm. It has slightly increased at 35mm but is within the desired range. Due to the lossy nature of the muscle tissues, there has been a slight shift of resonant frequency within the desired ISM band range.

The range of return loss (also called reflection coefficient) should have to less than -10db. This implies that the lesser the value maximum amount of the antenna power is transferred to the medium (around 90%) and near about 10% of the power is reflected. The return loss for various depths of the muscle of the proposed antenna has been shown in these figure5.

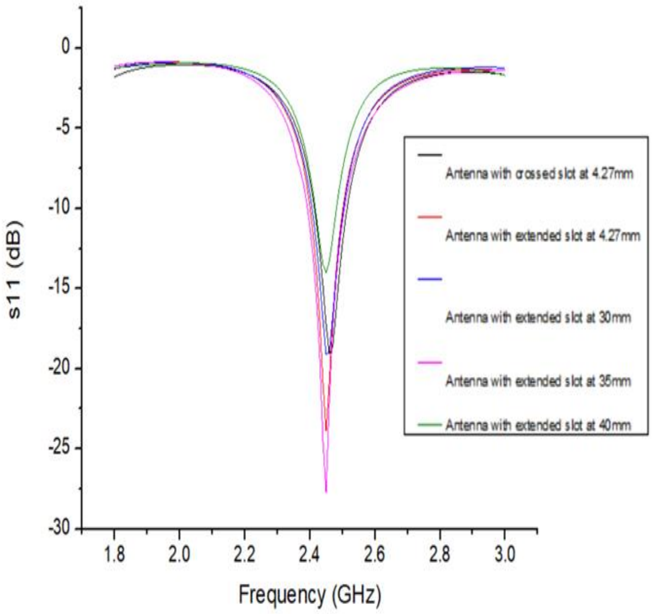


Fig 5: Return loss at various muscle depths.

Hence, at the skin depth of 4.27mm ,30mm 35mm and 40mm gives a very good return loss at -27dB, -29dB, -19dB and -23dB.Thereby making it safer for the patient's body.

3.2 Radiation Pattern And Gain

The overall antenna gains for crossed slots and extended slots through the radiation pattern have been simulated. Inside the various muscle depths, the introduction of these crossed slots resulted in increased gain because of the increased antenna bandwidth. This increase in the bandwidth of the antenna is due to the power that is absorbed from the patch.

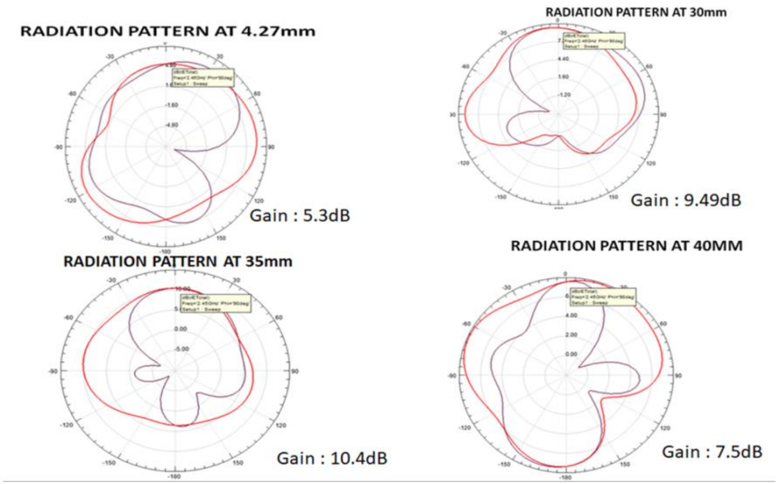


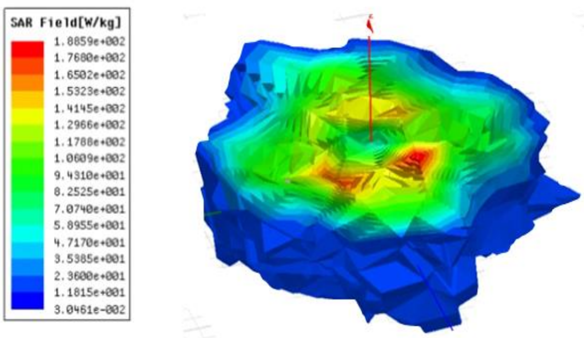
Fig 6: a) radiation pattern of crossed slot patch antenna at 4.27mm. b) radiation pattern of extended patch antenna at 4.27mm b)radiation pattern of extended patch antenna at 30mm c) radiation pattern of extended patch antenna at 35mm d) radiation pattern of extended patch antenna at 40mm

The proposed antenna gain depicts the overall performance of the antenna has enhanced on increasing the depth of penetration of the antenna within the muscle tissue.

The increased gain of the proposed antenna through the radiation pattern has resulted in improving the overall efficiency within the operating frequency band for the human body.

3.4 Specific Absorption Rate (SAR)

SAR of the crossed slot antenna as well as extended crossed slot antenna patch has been within the considerable range. This has been shown in fig 8 depicting the SAR for the proposed antenna. The SAR should be less than 180w/g averaged over the 1g of tissue. Since the human tissue is lossy so the SAR value should be within the considerable range. If it won't be within the considerable range, then the tissues may absorb the radiations emitted from the antenna to a larger extent and this may lead to tissue damage or could be fatal as well. Hence, with the considerable range, there is no compromisation with their safety.



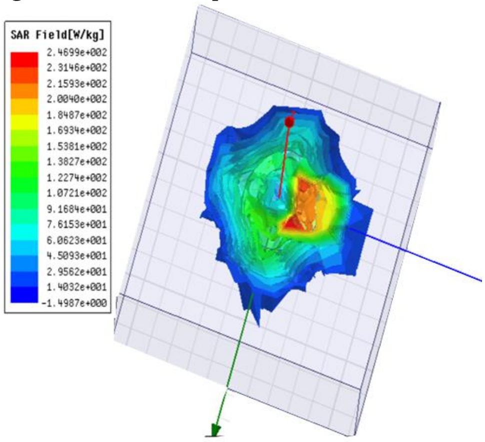
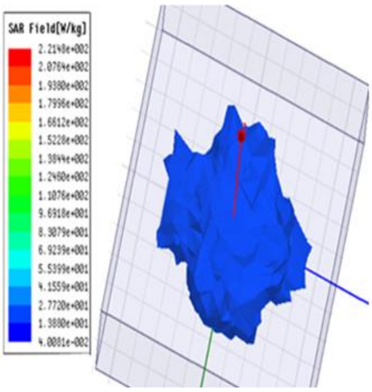


Fig 8:a) SAR of crossed slot patch antenna at 4.27mm Fig 8:b)SAR of extended slot patch antenna at 4.27mm



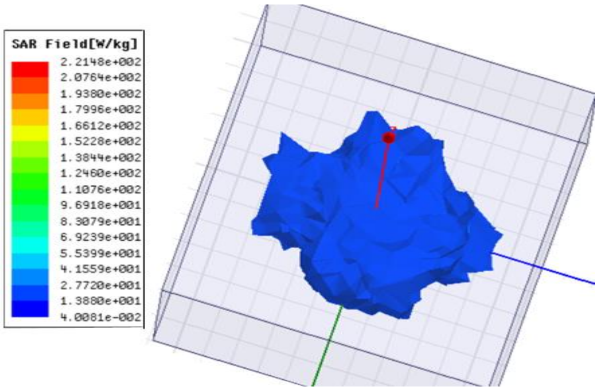


Fig 8:c) SAR of extended slot patch antenna at 35mm Fig 8:d)SAR of extended slot patch antenna at 30mm

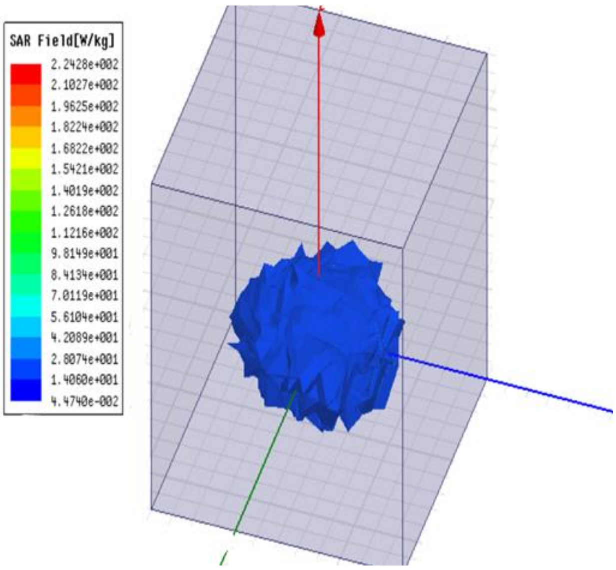


Fig 8:e) SAR of extended slot patch antenna at 40mm

So, tabulating all the parameters for various depths has been illustrated in table 2. From table 2, it can be seen that the value of return loss and gain has been improved concerning the reference antenna. Then, the value of SAR has been slightly increased but it is within the considerable limit.

Table 2: overall comparison of the extended slot antenna patch parameters concerning antenna with crossed slots.

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Depth of Antenna from Skin (mm)	Return Loss (dB)	Resonating Frequency (GHz)	Gain (dB)	SAR (w/kg)
4.27	-14	2.44	-13	188.8
4.27	-29.9	2.46	5.3	246
30	-27.7	2.45	9.49	221.48
35	-19	2.45	10.4	213.6
40	-23.8	2.45	7.5	224

IV. ACKNOWLEDGMENT

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REFERENCES

[1] Damla Alptekin, Lale Alatan, Nevzat G. Gencer "DUAL BAND PIFA DESIGN FOR BIOMEDICAL APPLICATIONS'', Electrical and Electronics Engineering Department, Middle East Technical University, Ankara, Turkey,10th European Conference on Antennas Year of publication:2016

[2] Asimina Kiourti and Konstantina S. Nikita, "Implantable Antennas" School of Electrical and Computer Engineering, National Technical University of Athens, Athens, Greece Digital Object Identifier 10.1109/MMM.2014.2308765 Date of publication: 7 May 2014

[3] Asimina Kiourti and Konstantina S. Nikita, A Review of Implantable Patch Antennas for Biomedical Telemetry: Challenges and Solutions, BIOSIM Laboratory, Faculty of Electrical and Computer Engineering National Technical University of Athens 9, Iroon Polytechniou Str., 15780 Zografos, Athens, Greece IEEE Antennas and Propagation Magazine, Vol. 54, No. 3, June 2012

[4] Nabeel Ahmed Malik and Tahmina Ajmal "A Compact Size Implantable Antenna for Bio-medical Applications", Department of Computer Science and Technology, University of Bedfordshire.

[5] A. Kiourti and K. S. Nikita, "A review of implantable patch antennas for biomedical telemetry: Challenges and solutions," IEEE Antennas Propagat.Mag., vol.54, no.3, pp.210–228, June 2012.

[6] Merli, Implantable antennas for biomedical applications (PhD thesis), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland, 2011.

[7] Adel Damaj, Hilal M. El Misilmani, and SoubhiAbou Chahine, "Implantable Antennas for Biomedical Applications: An Overview on Alternative Antenna Design Methods and Challenges", IEEE Electrical and Computer Engineering Department, 2018.

[8] Z. Duan, Y.-X. Guo, R.-F. Xue, M. Je, D.-L. Kwong, Differentially fed dual-band implantable antenna for biomedical applications, IEEE Trans. Antennas Propagation 60 (2012).

[9] Hall. P, kiourti. Y (2012). "Antennas and propagation for body-centric wireless communications", Norwood: Artech House.

[10] Dinesh.S Vivek Priyan. R Mrs. R. lothichitra," Design of Implantable Patch Antenna for Biomedical Application"," IEEE Sponsored 2nd International Conference on Innovations in Information Embedded and Communication Systems ICIIECS'15".

[11] A. Kiourti, K. A. Psathas, and K. S. Nikita, "Implantable and ingestible medical devices with wireless telemetry functionalities: A review of current status and challenges," Wiley Bioelectromagn., vol. 35, no. 1, pp. 1–15, Jan. 2014

[12] Topsakal E., "Antennas for medical applications: Ongoing research and future challenges" Electromagnetics in Advanced Applications, IEEE, 2009.

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