Performance Enhancement in Gain, SAR of Implantable Antenna using Slots and Sorting Pin

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***Abstract*— In this communication, a compact size rectangular implantable dual-band patch antenna for biomedical applications is proposed. Rogers RT6010 material is employed as substrate and superstrate material. Reference antenna resonates at two bands but with very low gain and a large value of SAR. 50-ohm microstrip line is kept exciting the proposed implantable antenna. With the introduction of Slots and Sorting pin, the gain has been enhanced from - 48.7 dB, -52.4 dB to -43 dB, -41 dB at 0.6 GHz and 2.4 GHz frequency, respectively. SAR value of reference antenna also enhanced from 1685 W/Kg to 263, 142 W/Kg at 0.6 GHz and 2.4 GHz frequency, respectively. A superstrate layer is placed on the top surface of antenna to fend physical contact touch between the radiating patch and human body tissues. The antenna is simulated in the fat layer model. The simulated results show that this proposed antenna is well suitable for biomedical applications.**

Keywords—Biomedical application, flexible,gain enhancement, compact, implantable antenna, wideband.

1. INTRODUCTION

For designing implantable antenna for biomedical application, compact, low specific absorption rate (SAR), and large bandwidth are the concerned parameters. In biomedical device, implantable antenna has maximum size among RF circuitry, bio-data sensor, battery etc. So, to ensure proper implantation of IMD, size of implantable antenna must be as small as possible. Implantable medical devices play a significant preface in health industries in the world now a days. Such devices establish the link for monitoring health data of patient with external receiving station [1-2]. For example, capsule endoscopy, blood glucose monitoring, blood sugar level monitoring, etc. [3-9].

In all such devices, the antenna is a key component which is supposed to set up the wireless link for communication purpose. So, device performance directly depends on the working of implantable antenna. Poor performance of antenna leads to affect the performance of the whole device and system connected to it [10-11]. If the antenna operates at a higher frequency or lower frequency, then it will suffer from interference or large size respectively. Patient's health tissues are also crucial consideration for designing such antennas to ascertain safety. So, the size selection and design of antennas for implantable applications is a defying task. Since antenna is conducting material so implantable antenna may give some harmful reaction to human body. The battery life of implantable devices should be of large span of time otherwise frequent surgery for replacing battery would be least preferred. Dual band antenna makes battery charged through one band with wireless power transfer technique. Hence overall designing of implantable antenna is big task to do. According to the literature, several antennas have been introduced for implantable biomedical applications. A wideband circularly polarized implantable antenna for ISM band bio-medical application was investigated in [10]. Rogers RT/duroid is implemented as substrate and super substrate with thickness of 0.635 mm. It has electrical properties (Er = 10.2; tan δ = 0.0023). The proposed antenna is having volume of 122 mm3 at 2.4 GHz. Skin layer phantom is utilised to test the proposed antenna's performance. Introduction of slots on patch surface with 2 sorting pins, resonating frequency has been adjusted. The proposed antenna exhibits low value of gain due to lossy environment of human body. In this paper, dual band, small size, high gain, and low SAR value implantable antenna is presented. This paper is structured as follows: In Section, 1 detail the literature of recent research on implantable antennas. In section 2 the design of the proposed antenna is given. Section 3 deciphers the results and analysis. Conclusions are drawn in the last section.

2. IMPLANTABLE ANTENNA DESIGN

Substrate thickness of 0.25 mm is taken to design implantable antenna. Rogers RT/duroid 6010 is used for substrate with electrical properties ie. Er = 10.2; tan δ = 0.0023. The superstrate layer is also used for isolation purpose from human tissue hence to avoid any chemical reaction. The superstrate layer material and thickness are the same as the substrate. The side view of the implantable antenna is shown in Fig. 1. Reference antenna's top and bottom view are shown in Fig. 2 (a) and Fig. 2(b).

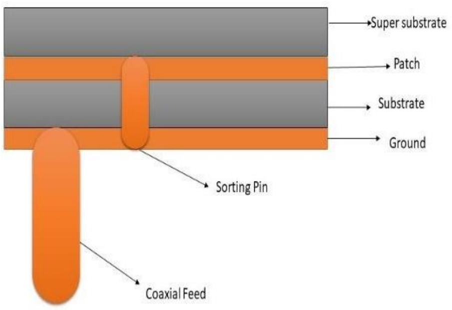

Fig.1. Side View of Implantable Antenna.

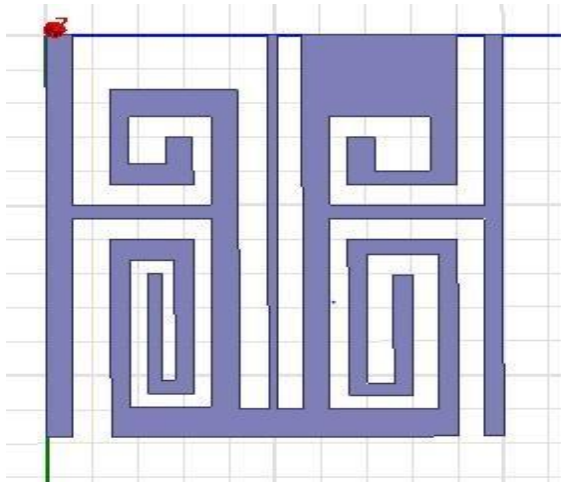

Fig. 2(a) Reference Antenna Top (patch) Surface [12].

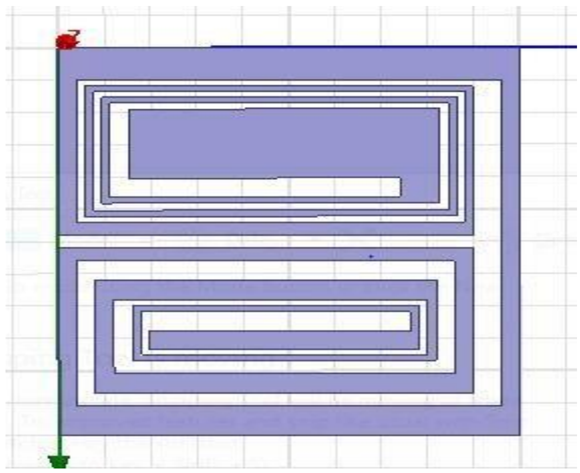

Fig.2 (b) Reference Antenna Bottom Surface [12].

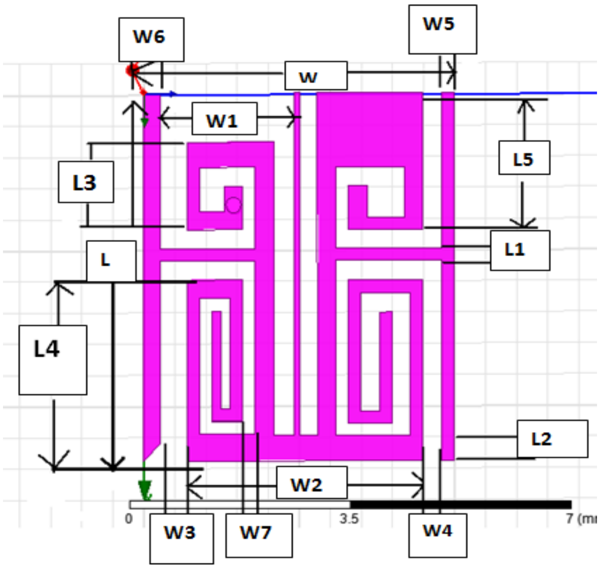

Fig.3. (a) Proposed Antenna Patch Surface Design.

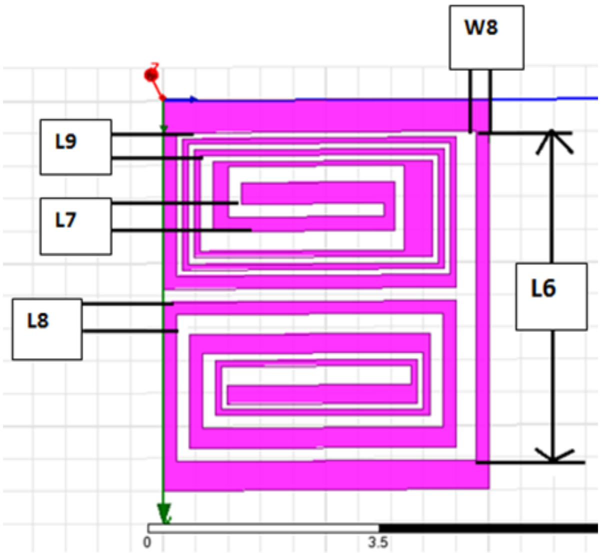

Fig.3 (b) Proposed Antenna Ground Surface Design.

Top and bottom surface of implantable antenna has perfect E Plane. 50-ohm microstrip line is used to make excitation for the implantable antenna. Overall dimensions of the proposed implantable antenna are 6 mm×5 mm×0.5 mm i.e.,15 mm^3. In Fig.3(a) and (b) Slots are introduced to change the current distribution on top surface of antenna which makes antenna electrically large with physically small dimension. The insertion of slots in the patch and ground introduces more electrical resistance which is reduced by a shorting pin P (1.8, 1.45) of radius 0.12 mm. The shorting pin also helps to alter the current distribution along the conducting surface of antenna. Slots are also introduced in the ground plane to adjust the resonant frequency and to improve the gain of the antenna. The simulated antenna is placed inside the fat layer of 60mm x 60mm x 60mm at depth h (1mm, 2mm, 3mm, 4mm, 5mm). The specific properties of Fat layer have been taken from reference work [12]. In the shown fig.4 the antenna is placed in h=3mm from the top surface of fat layer. we analysed the simulated antenna at all depths (1mm, 2mm, 3mm, 4mm, 5mm) from the top surface of the fat layer.

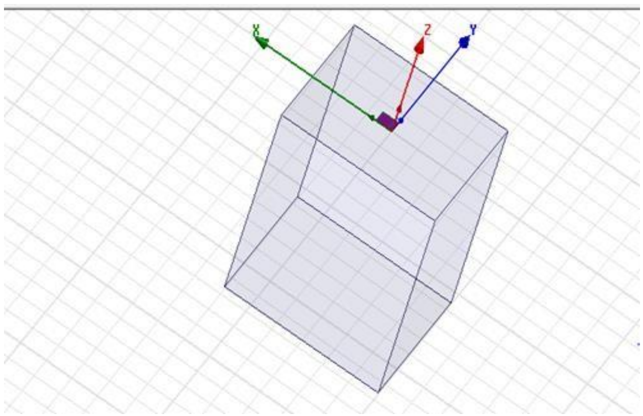

Fig.4 Proposed Antenna in Fat box layer.

The specific dimensions of the patch and ground plane of proposed antenna are shown in Table 1.

Table 1: Proposed Antenna Dimensions

Parameter	**Unit (mm)**	**Parameter**	**Unit (mm)**	**Parameter**	**Unit (mm)**
L	6	L7	0.3	W4	0.3
L1	0.2	L8	0.2	W5	0.2
L2	0.1	L9	0.9	W6	0.275

L3	1.4	W	5	W7	0.2
L4	2.9	W1	2.151	W8	0.3
L5	2	W2	3.8	W9	2.95
L6	5.05	W3	0.425		

3. RESULTS AND DISCUSSION

3.1) Return Loss

The reflection coefficient (S1,1) of an antenna is a measure of reflected power to the transmitted power. The lower value of S11 ensures to have lower value of reflected power due to impedance mismatching. Standard value is assigned which ensure 90% of transmitted power radiated by the antenna ie, -10 dB or below. The return loss of the reference antenna in fat layer at 4mm depth of penetration is shown as below in fig 5.

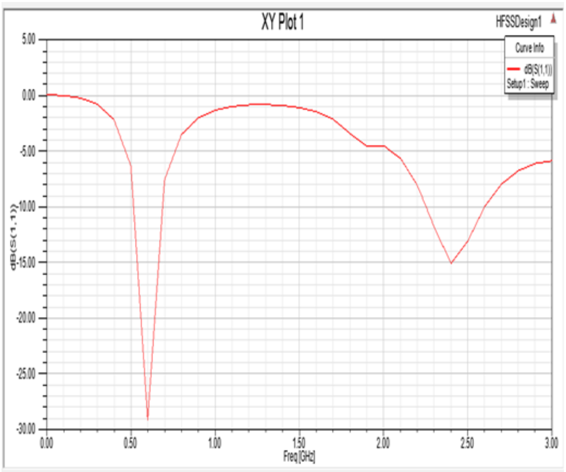

Fig. 5 (a) Return Loss of Reference Antenna.

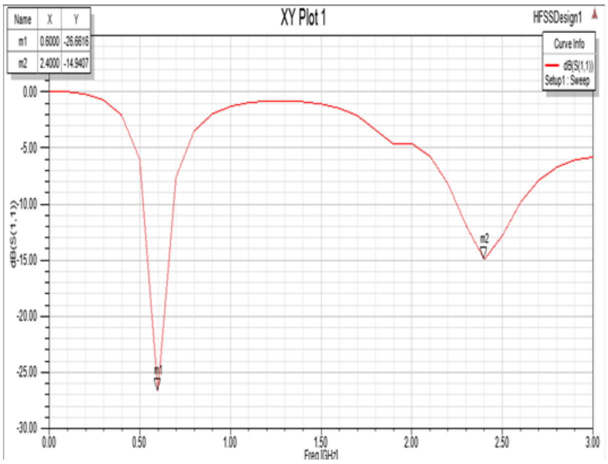

Fig.5 (b) Return Loss of Proposed Antenna.

It can be seen in Fig. 5(a) and (b) that the antenna is resonating on two frequencies which are 0.6 GHz, 2.4 GHz when implanted inside the fat layer. The available bands in reference antenna remains as it is after introducing slots and sorting pin. The resonating frequency at 0.6 GHz and 2.4GHz exhibits return loss -27dB and -15 dB, respectively. . A little impedance bandwidth is varied after imposing slots and sorting pins on reference antenna. 1st band shows impedance bandwidth of 200 MHz from 0.5 GHz to 0.7 GHz and 2nd band (ISM Band) shows impedance bandwidth of 300 MHz from 2.2 GHz to 2.5 GHz

3.2) Radiation Pattern and Gain

The implantable antenna generally suffers from high lossy medium inside of human body. Human body itself is a good conducting medium so it degrades the performance of implantable antenna. Several parameters affect the antenna radiation pattern such as position, penetration, and tissues.

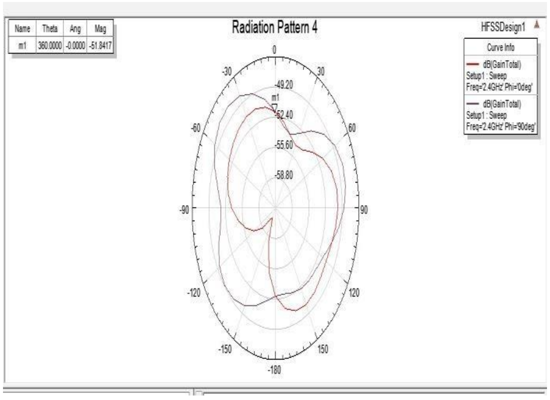

Fig.6 (a) Radiation Pattern of Reference Antenna at 2.4 GHz.

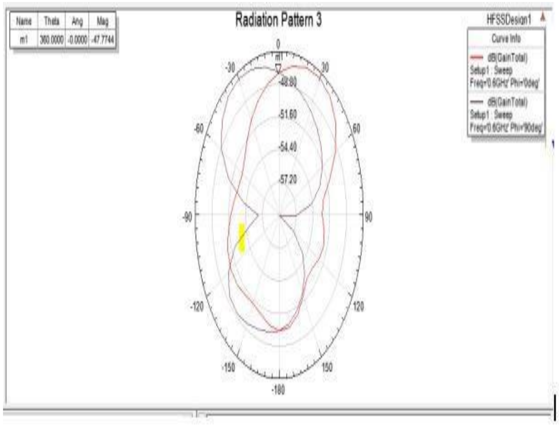

Fig.6 (b) Radiation Pattern of Reference Antenna at 0.6 GHz.

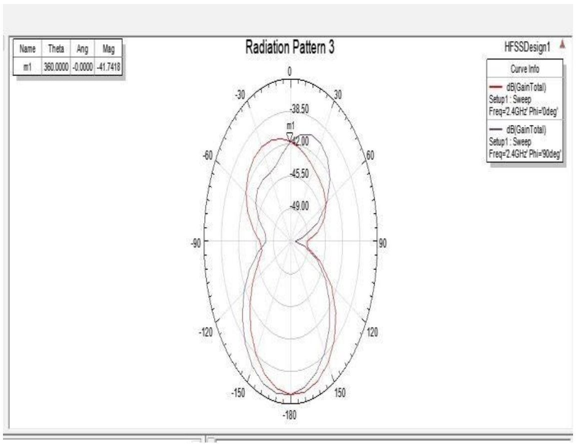

Fig. 6(c) Radiation Pattern of Proposed Antenna at 2.4 GHz.

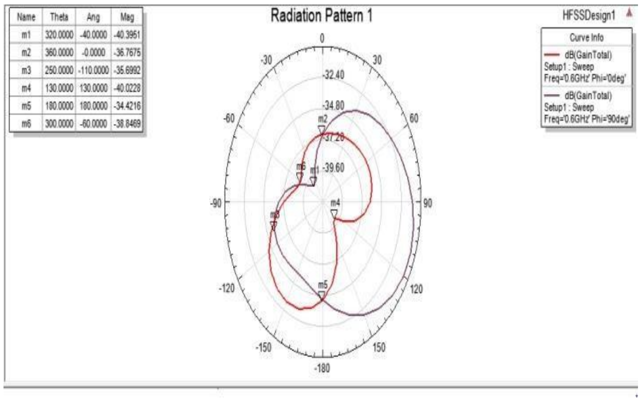

Fig. 6(d) Radiation Pattern of Proposed Antenna at 0.6 GHz.

From fig 6(a) we can see that our reference antenna gain is -52db and from fig.6 (c), the gain of the proposed antenna is -41.74dB at ISM band of frequency 2.4 GHz when the antenna is simulated in the fat layer box. A significant enhancement of gain is observed due to slots and sorting pins. These slots at a specific position (patch as well as ground) on the reference antenna introduce new current distribution which eventually matches its impedance and enhanced the gain of the antenna. The gain of the reference antenna in fig 6(b) also improved from -48 dB to -43 dB in fig 6(d) at the 2^{nd} band 0.6GHz frequency.

3.3) SAR

The electromagnetic radiation from the implantable antenna causes heating effect during telemetry sessions. Due to such heating effect, temperature may increase in the surrounding tissues. Such phenomena can be extremely dangerous for patient's health. According to IEEE C95.1-1999 standard and IEEE C95.1-2005 standard, the SAR value must be less than 1.6 W/kg averaged over 1g and should be less than 2 W/kg averaged over 10g cubic volume of the tissue.

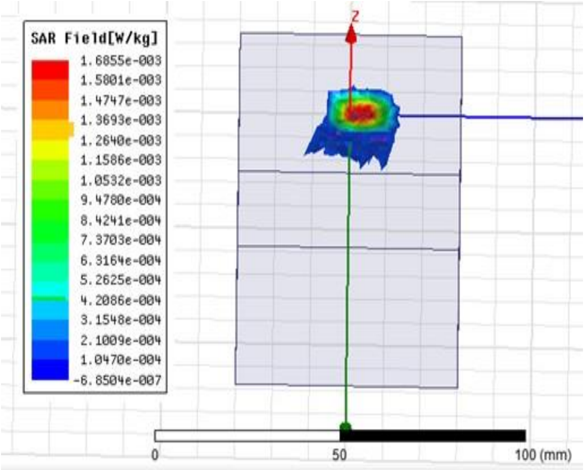

Fig. 7 (a) SAR distribution of Reference Antenna at 0.6 GHz and 2.4GHz.

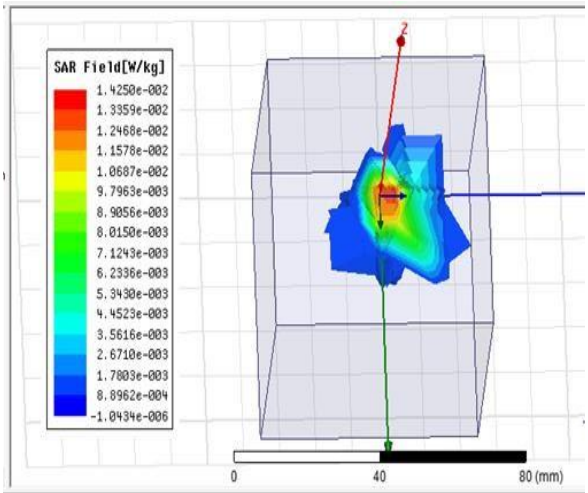

Fig. 7(b) SAR distribution of Proposed antenna at0.6GHz.

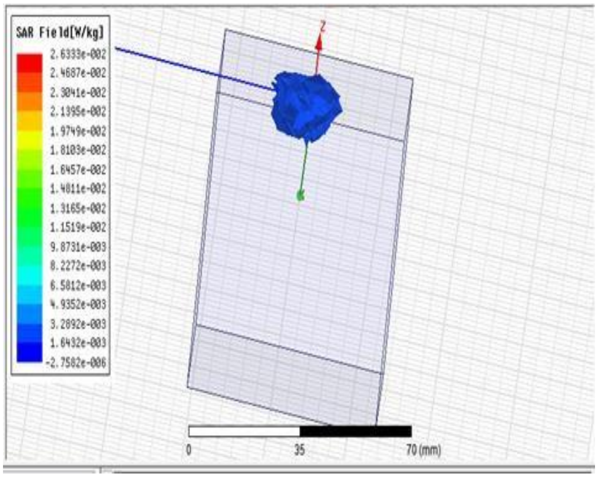

Fig. 7 (c) SAR distribution of Proposed Antenna at 2.4 GHz.

From figure 7. (a) The SAR value of the reference antenna has exceeded the standard limit as per SAR guidelines by IEEE. It shows 1685 W/Kg which may cause serious damage to human organs. So eventually Slots on patch and ground along with sorting pin are introduced on the reference antenna. With this introduction, the SAR value has dropped up to a large extent due to changes in current distribution and the effective impedance of the antenna. The value of SAR of the proposed antenna at 0.6 GHz and 2.4 GHz is 263 W/kg, 142W/kg respectively. Now proposed antenna can perform safe operation during telemetry sessions.

A comparison between the reference antenna and the proposed antenna is presented in the comparison table shown below.

Table.2 Comparison Table

Size (6x5x0.5) mm^3	OBSERVATION		
	Resonating Frequencies (GHz)	**Gain(dB)**	**SAR for 1 gram of tissue**
Reference Antenna	0.6. 2.4	-48 dB, -53dB	1653
Proposed Antenna	0.6, 2.4	-43dB, -41dB	263, 142

4. CONCLUSION

A miniaturized dual-band implantable antenna operating at 600 MHz, 2.4 GHz for biotelemetry applications is presented successfully. Slots are embedded on the patch and ground surface to match antenna impedance which enhanced antenna parameters like gain and SAR. Further sorting pin is implemented through the substrate to enhance antenna results. The antenna performance was deeply analysed in a fat layer model. The proposed antenna shows a peak gain of -41dB and-43 dB at 0.6 MHz & 2.4 GHz Frequency respectively with accepted range of SAR values. The antenna can be used for wireless data transmission, wake-up signal, and wireless power transfer in its two frequency bands.

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