A Compact Wideband Flexible Circularly Polarized Implantable Antenna for Biotelemetry Applications

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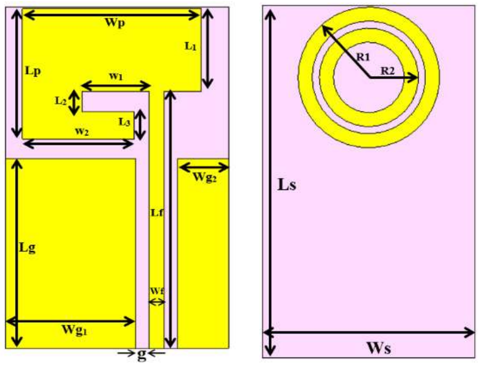
***Abstract*--Flexible implantable antennas have got much attention in the field of biotelemetry applications. So, a circularly polarized compact size wideband implantable antenna for the applications of biomedical telemetry is presented in this research work. The proposed design is being operated in ISM (industrial scientific, and medical) band at 5.8 GHz for medical applications. The antenna consists of the discrete ground circular patch and a CPW (coplanar waveguide) fed radiating patch printed on a Polyimide substrate. The overall size of the design is 5×3×0.15mm^3. The antenna covers the bandwidth from 3.4 GHz to 7 GHz (3.6 GHz). The design is being simulated inside human tissues like skin, fat, and muscle. The antenna gives circularly polarized behaviour at 5.8 GHz. This proposed design is well-suited for medical implantable applications.**

I. Introduction

Recently, an implantable medical device (IMD) has got the interests of scientists in the area of biomedical telemetry applications. Biomedical telemetry allows doctors to transfer the data from the implantable gadget inside human tissues to an outdoor communicating device. They can help the doctors to display the blood pressure and the human body temperature of a patient. They can also be used for tablets endoscopic, such as pacers, cardioverter-defibrillators, as devices for retinal implants and blood glucose. The implantable antenna must have low specific absorption rate (SAR) values, stretchy for patient's protection, and low profile [1]. A flexible antenna resonating at 2.45 GHz and 6 GHz made up of FR-4 substrate is reported in [2]. The superstrate and a substrate made up of fluid crystal-like polymer of Roger (ULTRALAM) dual-ISM-band in-body antenna. The dual-band implantable communicating device working at 3.5 GHz, and 5.8 GHz is presented in [3]. The wideband in-body antenna has improved gain and low SAR value. A wideband CP (circularly polarized) in-body antenna is presented in [4] for biotelemetry implementations. This wideband CP implantable antenna is printed on a Roger 3010 substrate operating at 910 MHz, with a gain of -21.9 dBi in a vacuum and -15.18 dBi in human tissues. Another wideband microstrip patch implantable antenna working at 2.4 GHz to get dual loops to achieve greater bandwidth of the impedance. The circular polarization behaviour of the antenna for biotelemetry implementations is presented in [5].



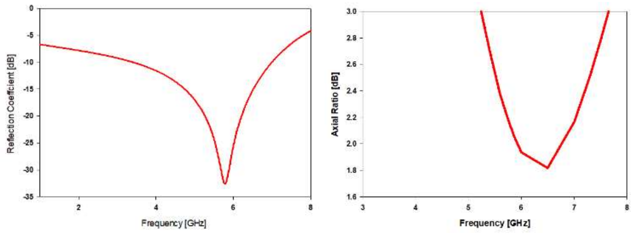
(a) (b)

Figure 1. Dimensions of the proposed design; (a) Front view, (b) Back view. *Ls=5mm;Ws=3mm;Lg=2.78mm;Lf=3.77mm;wf=0.2mm;L1=1.21mm;L2=0.3 mm;L3=0.4mm;Wg1=1.75mm;Wg2=0.69mm;wp=2.4;g=0.18mm;R1=1mm; R2=0.7mm;ts=0.15mm*

In this article, we have designed a circularly polarized, compact size wideband implantable antenna printed on a Polyimide substrate for biotelemetry applications. The peak-gain of the proposed design is achieved (-1.2 dBi) with an overall size is 5×3×0.15mm^3. This paper is categorized as follows: Antenna design and methodology is discussed in section II, in-body antenna results in section III, and at the end conclusion part is presented in section IV.

II. Antenna Design and Methodology

The proposed antenna is configured with a modified coplanar waveguide (CPW) technique, so its response to the greater bandwidth and reduced antenna radiation. A low-profile implantable antenna is proposed for biomedical telemetry utilization at 5.8 GHz operating frequency. To make it flexible, a semi-flexible material is used as a substrate. The performance of the proposed system is improved, reducing the back radiation of the antenna and the proposed system is investigated by physical layers by the regular relative permittivity. The S_{11} and axial ratio results of the proposed design is presented in Figure 2.

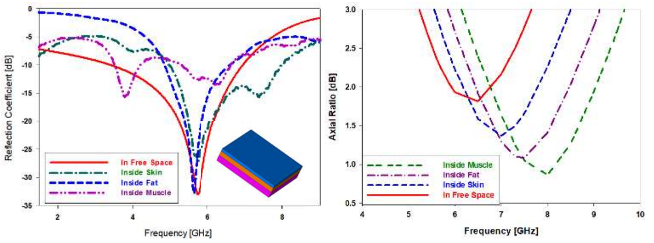


(a) (b)

Figure 2. Proposed Design, (a) |S11| , (b) Axial Ratio vs Frequency

III. IN-BODY ANTENNA RESULTS

To evaluate the robustness to human proximity effect, the antenna is placed inside multilayer human body model. The antenna with compact size is kept inside skin ($\varepsilon_r = 41.4$ and $\sigma = 0.88$ s/m). The size of the phantom box is 20×20 mm^2, and human tissues used for simulations are of three layers like skin, muscle, and fat. Return loss ($|S_{11}|$) and the radiation pattern of the antenna under the proximity of human tissues are simulated. The axial ratio bandwidth of the proposed antenna inside skin, fat and muscle and the return loss are presented in Figure 3.

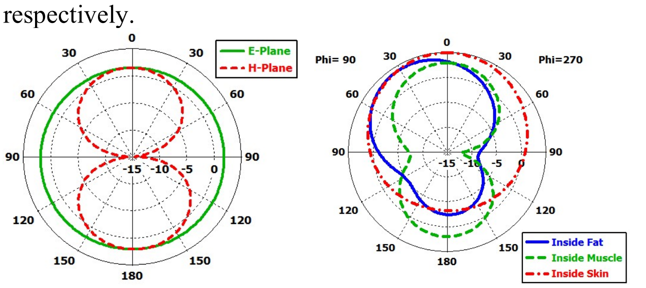


(a) (b)

Figure 3. (a) |S11| at 5.8GHz, (b) Axial ratio inside Human tissues.

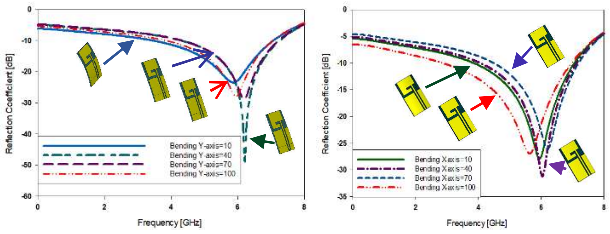
The proposed antenna has been simulated in human body layers in two ways, i.e., testing inside skin and testing inside the muscle. CST MW Studio is used for testing the proposed antenna. The 2D radiation pattern of the antenna in free space and in human tissues are presented in Figure 4.

The antenna in-body implantable situations depend on the twisting during the real-time applications. So, the bending analysis of the antenna along x-axis and y-axis in free space are presented in figure 5. From the figure, the antenna has negligible effects on the reflection coefficient when it is bending along x- and y-axis. Hence, we can say the antenna shows good agreement during the bending analysis. During y-axis and x-axis bending analysis, we noticed the gain -1.23 dBi and -1.24 dBi, respectively.



(a) (b)

Figure 4: (a) 2D Radiation Pattern of the antenna in Free Space, (b) 2D Radiation Pattern inside Human Tissues



(a) (b)

Figure 5: Bending Analysis of the design; a) along y-axis; b) along x-axis

TABLE 1. COMPARISON WITH PREVIOUS RESEARCH

Ref. No.	Frequency (GHz)	Size (mm^3)	Substrate Material	Gain (dBi)
[1]	5.8	7.8 × 7 × 0.15	Polyimide	------
[2]	2.4 & 6	10 × 10 × 1.6	FR-4	5.8
[3]	3.5 & 5.8	36 × 18 × 0.1	Rogers ULTRALAM	6.8
[4]	2.4 & 5.8	35 × 20 × 0.1	Rogers ULTRALAM	3.17
[5]	2.4 & 5.8	30 × 27 × 1.6	FR-4	6.83
[6]	5.8	8.5 × 5.5 × .25	Rogers 6010LM	-3.2
This Work	**5.8**	**5 × 3 × 0.15**	**Polyimide**	**-1.25**

IV. CONCLUSION

A compact size implantable wideband circularly polarized antenna for biotelemetry application has been presented in this research article. The proposed antenna is operating in the ISM band at 5.8 GHz for medical utilization. The antenna consists of the discrete ground circular patch and a CPW (coplanar waveguide) fed radiating patch printed on a polyimide substrate. The overall size of the design is 5×3×0.15mm^3. The antenna covers the bandwidth from 3.4 GHz to 7 GHz (3.6 GHz). The design is being simulated inside human tissues like skin, fat, and muscle. The antenna gives circularly polarized behaviour at 5.8 GHz. This proposed design is a perfect candidate for medical implantable applications.

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