URSI AP-RASC 2019, New Delhi, India, 09 - 15 March 2019

A Compact Co-planar Waveguide fed Circularly Polarized In-body Antenna for Medical Devices

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Abstract

In this paper a simple CPW (co-planar waveguide) fed circularly polarized (CP) antenna is proposed in ISM band (2.4-2.48 GHz) for implantable applications. The footprint of the proposed antenna is 10 × 10 × 0.3 mm^3. To achieve desire CP operation, two T-shaped slots are inserted into the ground plane. The simulated 10 dB impedance bandwidth (IMBW) is around 26.5%, and 3 dB Axial Ratio bandwidth (ARBW) is around 5.26%.The radiation and specific absorption rate (SAR) performance of the antenna is also evaluated.

1. Introduction

In the recent past implantable antenna technology is receiving considerable attention for medical diagnosis and therapy where patients can be monitored remotely. Significant research on antennas for medical applications has been reported owing to the antenna size barrier of implantable devices. Some research works are based on the adoption of multi layer configurations to reduce the antenna size [1-3]. On the other hand, to ensure the mobility of the patients with an implanted system, a healthy communications between the implant system and the peripheral device is very much obligatory. To achieve this, it is enviable to employ a circularly polarized (CP) implantable antenna, as it is sovereign of the orientation of the transmitter and the receiver [4-6]. In [7], a broadband non-superstrate monopole CPW-fed implantable antenna operating at the Medical Implant Communication Service (MICS) frequency band (402-405 MHz) is developed on ceramic material. The advantages of such ceramic non-superstrate antenna are compact, low profile and wide measured bandwidth. Due to CPW feed, the antenna has uni-planar geometry and thus easier to fabricate. Also it has low radiation loss and the less dispersion in comparison to a microstrip feed. The vantage of CPW feed and CP thus motivated to propose a CPW fed CP implantable antenna in this study..

In this paper a simple spiral monopole fed CP implantable antenna operated in ISM band (2.4-2.48 GHz) has been proposed. A method of T slot on the ground was used to design a CP implantable antenna. Details of the antenna design and simulation results are presented and discussed.

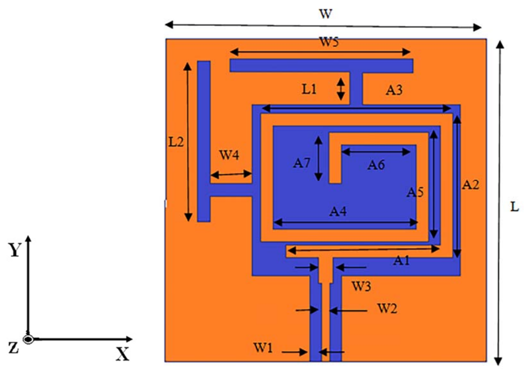

Figure 1. Configuration of the proposed antenna.

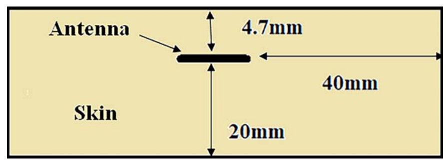

Figure 2. Simulation setup of the antenna in skin phantom.

Table 1. Dimension of proposed antenna (unit: mm)

L	L1	L2	W	W1	W2	W3	W4
10.0	1.00	5.00	10.0	0.36	0.28	0.48	1.30
W5	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
5.70	4.80	4.50	6.0	4.44	3.40	2.32	1.60

2. Antenna Geometry

The geometrical structure of the proposed antenna is shown in Figure 1 A Rogers 3010 substrate (thickness = 0.3 mm, ε_r=10.2, and loss tangent = 0.0035) is used for implementation. The overall dimension of the antenna is 10 × 10 × 0.3 mm^3. A CPW line is used for feeding purpose. Figure 2 shows the simulation model of the proposed implantable antenna. The proposed antenna is embedded in single skin layer phantoms. The dielectric properties of the skin tissues at 2.4GHz is ε_r = 42 .92, σ =1 .562S/m.

3. Results

3.1 Resonance Characteristics and CP Realization

Figure 3 shows the simulated S parameters and axial ratio. As from Figure 3, the S_{11} of the proposed antenna covers the entire ISM band with a bandwidth of 640 MHz (26.5%). ARBW of the antenna is 130MHz (5.26%) covering the entire ISM band.

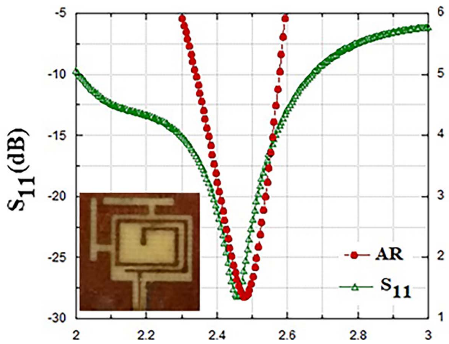

Figure 3. S_{11} and AR of proposed Antenna in skin.

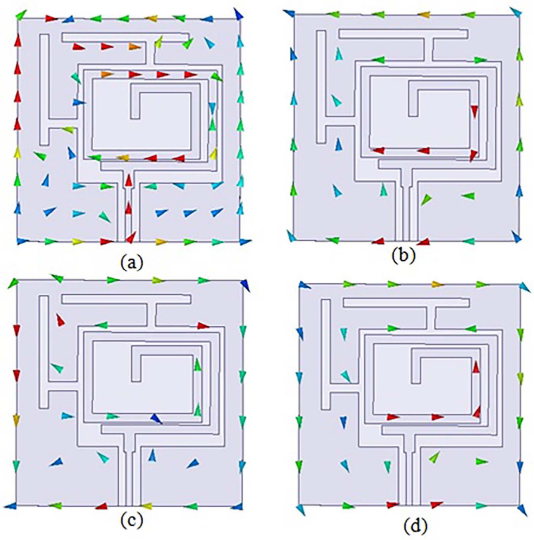

Figure 4. The current distributions of the proposed antenna at 2.45 GHz (a) 0 ˚ (b) 90 ˚ (c) 180 ˚ (d) 270 ˚.

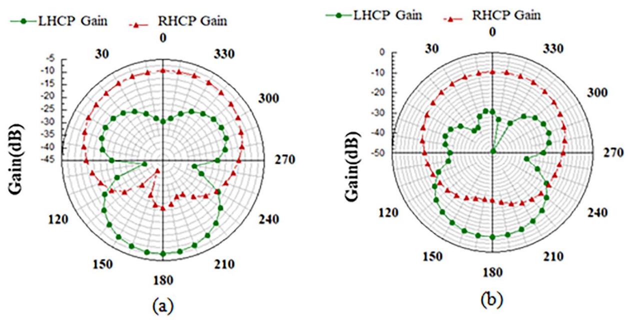

Figure 5. Simulated radiation patterns at 2.45 GHz in (a) XZ -plane (b) YZ -plane.

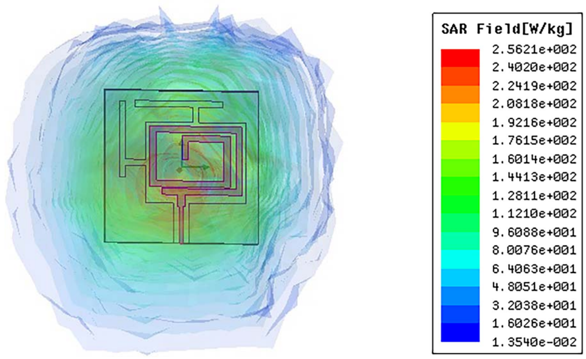

Figure 6. Average SAR analysis for proposed antenna.

In order to construe the CP mechanism, the simulated surface current distributions are analyzed. Figure 4 shows the current distributions of the antenna at 2.45 GHz for phases of 0˚, 90˚, 180˚ and 270˚. For 0˚ phase, the principal radiating currents are in +x direction. It is obvious from Figure 4 that the rotation of the current is in the anti-clockwise direction and hence it exhibits the right-hand circular polarization (RHCP).

3.2 Radiation Characteristics

The simulated radiation patterns in XZ-plane and YZ-plane at 2.45 GHz is plotted in Figure 5. The antenna radiates a bidirectional wave with the opposite circular polarization which can be verified from Figure 5. The RHCP is substantiate in the +z direction, while LHCP in the -z direction. The simulated peak gain of the proposed antenna is -7.8 dBi.

3.3 SAR Distribution and Restrictions

Figure 6 represents the average SAR distribution of the proposed antenna in the single layer tissue model. For 1W of input power, the highest SAR value obtained in our analysis is 256 W/Kg. Hence, the input power must be limited to 6.25mW in order to satisfy the most restrictive SAR regulation (i.e, SAR < 1.6W/kg).

Table 2. Comparison of some implantable antennas

Ref.	Vol mm^3	% of IMBW	% of ARBW	Peak Gain dBi	feed	SAR (W/Kg)
[8]	153.6	8.30%	2.49%	- 22.7	coax	733.5
[9]	127.0	16.15%	6.09%	- 22.3	coax	254.7
[10]	91.7	12.20%	2.40%	- 17.0	coax	210.8
[5]	127.0	7.740%	1.63%	- 22.0	coax	213.0
Our work	**30.0**	**26.50%**	**5.26%**	**- 7.8**	**CPW**	**256.0**

Compared to other similar implantable antennas [5], [8], [9], [10] as shown in Table II, the proposed ISM band antenna reveal the highest gain (-7.8 dB) and the maximum impedance bandwidth (26.5%) with minimum volume. Moreover, compared to other antennas, the fabrication process is easier because of the use of CPW-fed structure. It is also observed that the SAR (W/Kg) of the proposed antenna is quite good and has an acceptable value.

4. Conclusion

This paper presents a compact implantable CP spiral monopole CPW fed antenna in the 2.45-GHz ISM band. First, the characteristic of an implantable spiral monopole antenna with CPW fed was studied. Second, two T-slot are employed in ground to have good impedance matching and also to achieve the desired band CP for the proposed antenna. The simulated impedance, AR, radiation pattern and SAR are studied simulation models in skin phantom in HFSS. Simulated results showed good agreement with impedance bandwidth and polarization property. The maximum SAR value satisfies the ANSI / IEEE SAR regulation. Thus it is a competent candidate for in-body biomedical applications.

6. Acknowledgements

Authors like to acknowledge UGC and Indian Institute Engineering Science & Technology, Shibpur (I.I.E.S.T) for providing necessary support in this research work.

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7. References

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