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Circular Patch on Rectangular Slits loaded Antenna with DGS for Biomedical Applications

Gopi Dattatreya, K. K. Naik

Abstract*: The analysis has been carried out on conformal circular patch antenna for MICS, ISM, WMTS applications. The proposed antenna is considered with flexible polyimide substrate material. The circular patch antenna with rectangular slits loaded has considered on top of the substrate and concentric circular ring slots has considered on the ground plane of substrate. The proposed antenna is tested in on-body and in-body characteristics of human tissue simulation model by considering the electrical properties. The proposed antenna operates at 0.41GHz (0.34 –0.52GHz), 1.24GHz (0.77–1.43 GHz) dual-bands for on-body mode with reflection coefficient of -14.2dB, -26.3dB. For in-body mode the antenna operates at 0.80GHz (0.65–0.92GHz), 1.42GHz (1.27–1.61GHz) with reflection coefficient of -21.1dB, -18.1dB respectively. Specific absorption rate (SAR), gain, radiation patterns are presented in the results.

Index Terms*: Dual-band, defected ground structure (DGS), industrial, scientific and medical (ISM), in-body, medical implant communication service (MICS), on-body, specific absorption rate (SAR), wireless medical telemetry services (WMTS).

I. Introduction

Recent growth in flexible antennas has been desired in the direction of bio-integrated electronics which match with arched surfaces of human/animals skin, organs, and tissues for reliable measurements and harmless use. Implantable antennas are the new era in the modern medical communication applications like monitoring blood pressure, brain imaging, glucose levels, tracking of people and pets, although the existing approaches restricts for certain clinical applications due to lack of wireless communication ability and to power the devices from short distance. Dual-frequency single-feed and single-layer microstrip antennas have been proposed [1], [2]. The limitations of patch antenna, is low efficiency. The bandwidth enlargement and gain can be increased by employing slots in the ground plane. In literature, some models of on-body antenna are proposed. On-body wearable devices are used to minimize the power consumption of implanted antenna [3]. A monopole C-shaped patch antenna [4] for bio-medical applications is proposed, the antenna is simulated by considering human tissue model. A compact patch antenna [5], which works for both MICS and ISM bands. Dual-band dual-mode antenna [6] proposed for on-/off-body communication. An on-/off-body switchable antenna [7] proposed for ISM-band and wireless body area networks (WBAN) applications.

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Some flexible, implantable antennas are proposed for ISM, WiMAX applications in [8, 10]. A compact dual-band implantable antenna is proposed [9] for MICS and ISM band applications. A compact square ring patch antenna [10] is proposed for bio-medical applications.

In this paper, the optimized dual-band rectangular slit loaded circular patch antenna is proposed for on-body and in-body bio-medical applications. The antenna performance is analyzed by considering the RSCP antenna in human muscle tissue simulation model and three layer tissue simulation models. The antenna offers 220MHz, 660MHz impedance bandwidths in on-body mode and 270MHz, 340MHz impedance bandwidth for in-body mode which covers MICS, ISM, WMTS applications.

II. Proposed Antenna Design

The proposed rectangular slit loaded circular patch (RSCP) antenna is presented in Fig. 1.. The proposed antenna is polyimide material with ε_r is 3.5 and δ is 0.008.

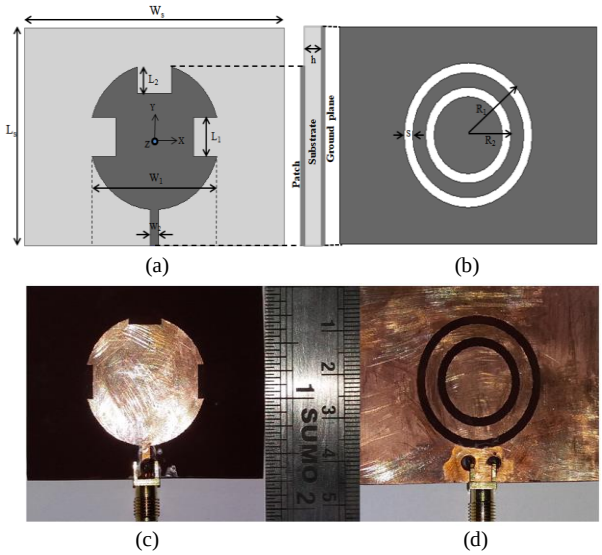

Fig. 1. Rectangular slit loaded circular patch (RSCP) antenna with defected concentric ring on ground plane (a), (b) top view. (c), (b) bottom view.

The dimensions of the substrate is $W_s \times L_s$. Fig. 1(a) shows the top layer and it is loaded with rectangular slits with dimensions $L_1 \times L_2$ on a circular patch with diameter W_1. A 50-ohm feed line with width W_2 is used to feed the antenna. Fig .1(b) shows the ground plane with defected concentric rings with outer, inner ring radius R_1 and R_3 to enhance the gain and bandwidth.

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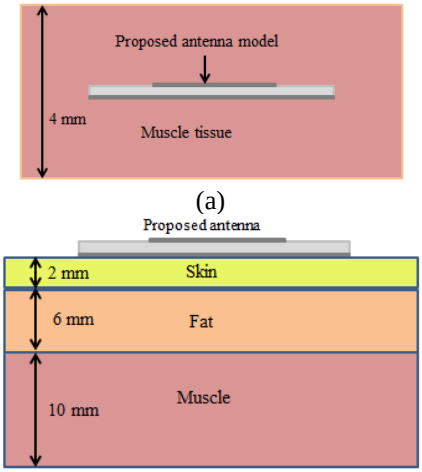
The optimization of the RSCP antenna has been proposed using CST software and dimensions are tabulated in Table I.



(a)

(b)

Fig. 2. RSCP antenna, (a) in human muscle tissue, (b) On-body three layer human tissue simulation models.

Table I. Optimized values of RSCP antenna.

Parameters	Values in (mm)
W_s	60
L_s	45
W_1	30
L_1	8
W_2	2
L_2	5.4
R_1	15
R_2	10
S	2

Fig. 2(a) represents the human muscle tissue simulation model with implanted antenna. The proposed antenna is implanted in muscle tissue with a thickness of 8mm. Fig. 2(b) shows the three layer human body models of RSCP antenna. The dielectric properties and thickness [16] of each tissue at MICS, ISM band is reported.

III. RESULTS AND DISCUSSIONS

The reflection coefficients (S11) are presented in Fig. 3. As it can be observed the proposed antenna operates at two bands 0.41GHz, 1.24GHz for on-body mode and 0.80GHz, 1.42GHz for in-body mode with reflection coefficients -14.2dB, -26dB and -21.1dB, -18.1dB for both on-body and in-body modes .

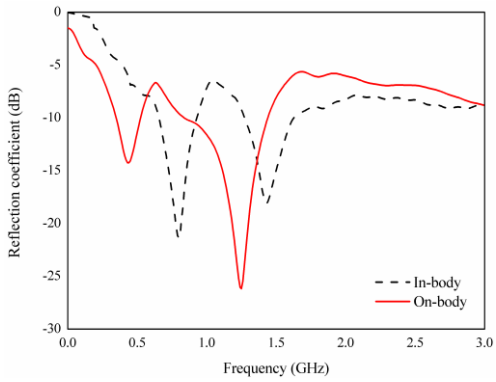
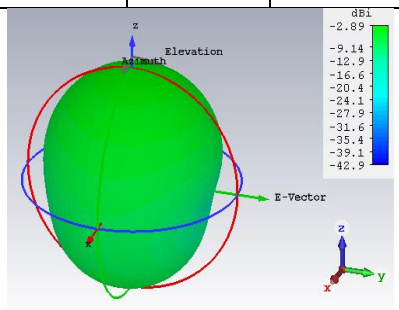


Fig. 3. Reflection coefficient response of the rectangular slit loaded circular patch antenna.

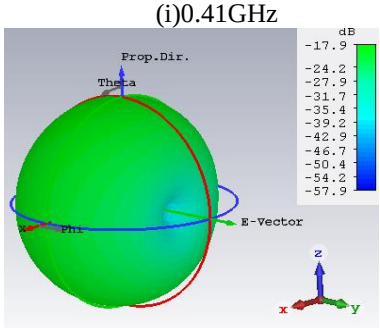
It is observed from Fig. 3 that the frequency is shifts towards higher for in-body mode. The performance of RSCP antenna is shown in Table II.

Table II. RSCP antenna characteristics.

Model	Operating frequency (GHz)	Reflection coefficient (dB)	Bandwidth (MHz)	Gain (dBi)
Three layer (On-body)	0.41	-14.2	220MHz	-2.28
	1.24	-26.3	660MHz	3.46
Muscle tissue (In-body)	0.80	-21.0	270MHz	-29.9
	1.42	-18.2	340MHz	-17.9

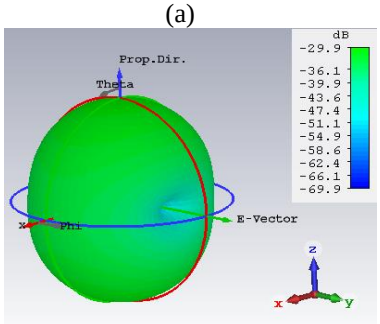


(i)0.41GHz

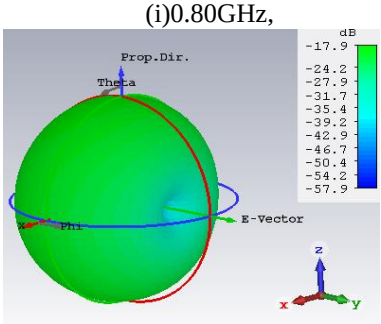


(ii)1.24GHz

(a)



(i)0.80GHz,



(ii)1.42GHz

(b)

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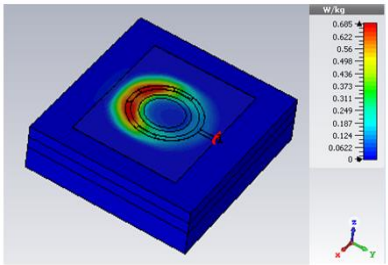
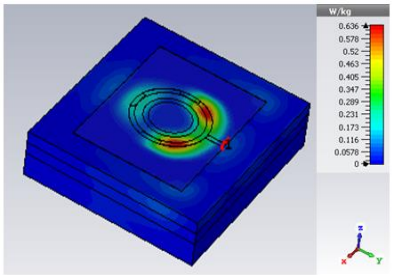
Fig.4. 3D gain patterns of RSCP antenna over, (a) three layer human tissue model, (b) Muscle tissue simulation model.

The SAR value is observed for RSCP antenna for both on-body and in-body conditions are shown in Fig 5. It is important to evaluate the specific absorption rate (SAR) to ensure the safety of the human body caused by the implanted antenna. The SAR standard is regulated by IEEE. Under the C 95.1-2005 standard, the 1g averaged SAR is less than 1.6 W/kg. Fig 5(a) shows the on-body SAR distribution using input power of 1mW at 0.41GHz, 1.24GHz frequencies. Maximum obtained value of SAR is 0.68W/kg, 0.63W/kg for both frequencies. Similarly, Fig. 5(b) shows the in-body SAR distribution using input power of 1mW at 0.80GHz, 1.42GHz frequencies. Maximum obtained value of SAR is 0.93W/kg, 0.87W/kg for both frequencies and it is below the standard level.

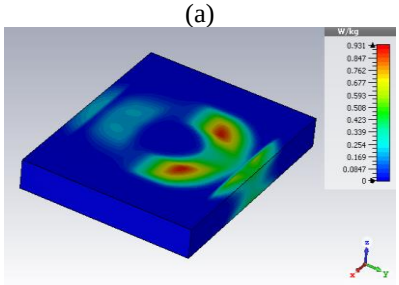


(i)0.41GHz

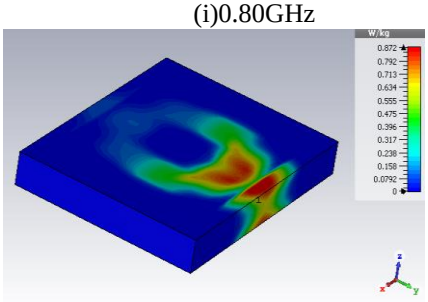


(ii)1.24GHz

(a)



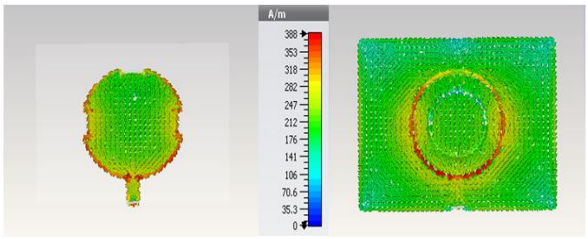
(i)0.80GHz



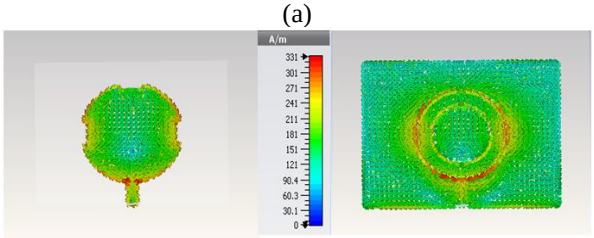
(ii)1.42GHz

(b)

Fig. 5. SAR of the RSCP antenna over, (a) three layer human tissue model, (b) Muscle tissue simulation model.



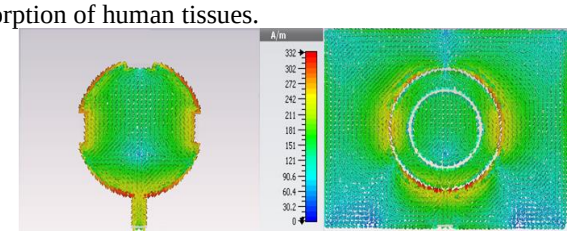
(a)



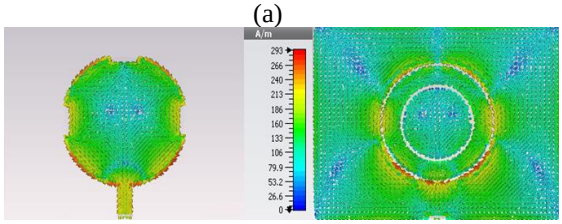
(b)

Fig.6. Surface current distributions of RSCP antenna on three layer human tissue model at (a) 0.41GHz, (b) 1.24GHz frequencies.

Fig. 6 presents the on-body condition surface current distributions of RSCP antenna. On three layer human tissue model as shown in Fig. 2(a), from Fig. 6(a) it is observed that the current distribution is 388A/m resonates with a gain of -2.28dBi. The current concentration is high at the circular patch, outer ring slot on ground plane and this leads to the first resonant frequency. In Fig. 6(b) the current distribution is 331A/m resonates with a gain of 3.46dBi, current concentration is high at some portion of the circular patch, as well as inner, outer ring slot on ground plane and this leads to the second resonant frequency. For higher frequencies the current concentration lowers due to the absorption of human tissues. Fig. 7 shows the surface current distributions of RSCP antenna at in-body condition (as shown in Fig. 2(b)), from Fig. 7(a) it is observed that the current distribution is 332A/m resonates with a gain of -29.9dBi. In Fig. 7(b) the current distribution 293A/m resonates with a gain of -17.9dBi, the maximum current concentration leads to the two resonant frequencies of RSCP antenna. For higher frequencies the current concentration lowers due to the absorption of human tissues.



(a)



(b)

Fig.7. Simulated surface current distributions of RSCP antenna in human muscle tissue model at (a) 0.80GHz, (b) 1.42GHz frequencies.

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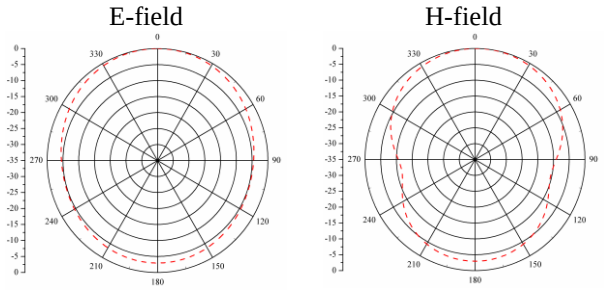
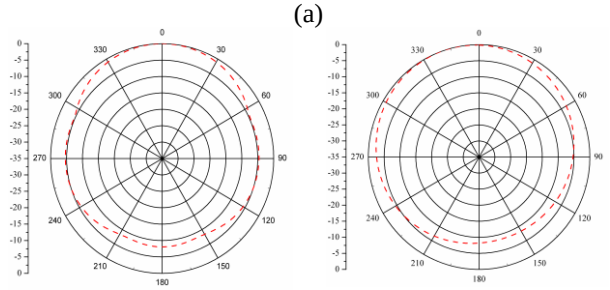


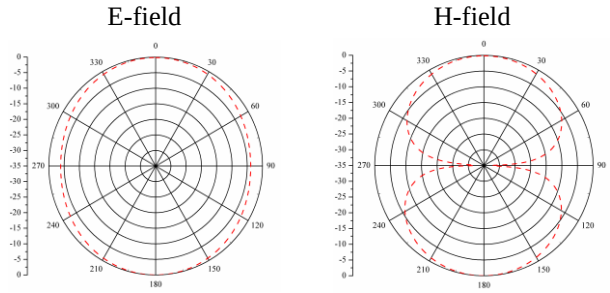
(a)



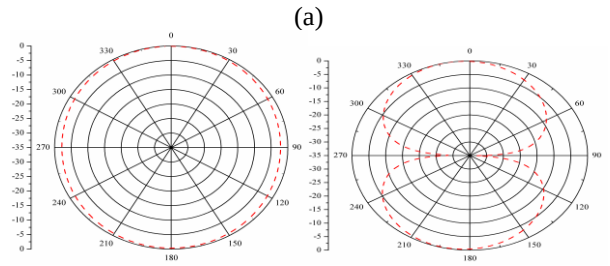
(b)

Fig. 8. Normalized E-field, H-field radiation patterns of RSCP antenna on three layer human tissue model at (a) 0.41GHz, (b) 1.24GHz frequencies.

The on-body simulated E-plane and H-plane radiation patterns of RSCP antenna are presents in Fig. 8. Fig 8 (a) is observed that in E-plane the antenna radiation plot is semi omni-directional with maximum directivity is focused on 0° and a -3 dB beam width of about 60° is observed, In H-plane the radiation plot is bi-directional and the maximum directivity is focused on 0° and 180° with -3 dB beam width of about 55°. Similarly, Fig 8 (b) shows that in E-plane the antenna radiation pattern is directional with maximum directivity is focused on 0° and a -3 dB beam width of about 57° is observed, In H-plane the radiation plot is directional and the maximum directivity is focused 330° with -3 dB beam width of about 75°.



(a)



(b)

Fig. 9. Normalized E-field, H-field radiation patterns of RSCP antenna in human muscle tissue model at (a) 0.80GHz, (b) 1.42GHz frequencies.

The in-body simulated E-plane and H-plane radiation plot is RSCP antenna are presents in Fig. 9. Fig 9 (a) is observed that in E-plane, H-plane the antenna radiation plot is semi omni-directional and bi-directional with maximum directivity is focused on 0°-180° and a -3 dB beam width of about 50° and 45° is observed. Similarly, Fig 9 (b) shows the semi omni-directional and bi-directional patterns for both E and H-fields with -3 dB beam width of about 70° and 45°. From Fig. 9(a), (b) the patterns remain same with small changes in beam widths are observed

IV. CONCLUSION

The investigation is carried out on rectangular slit loaded circular patch (RSCP) antenna for biomedical applications. The RSCP antenna operates for MICS, ISM, WMTS at on-body and in-body modes. The RSCP antenna has resonated with 0.41GHz (0.34 –0.52GHz), 1.24GHz (0.77–1.43 GHz) for on-body mode with S11 of -14.2dB, -26.3dB respectively. For in-body mode the RSCP antenna is resonates at 0.80GHz (0.65–0.92GHz), 1.42GHz (1.27–1.61GHz) with S11 of -21.1dB, -18.1dB respectively. The SAR is observed about 0.68 W/kg, 0.63 W/kg for on-body mode and 0.93 W/kg, 0.87 W/kg for in-body modes respectively

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