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Design of 3.1GHz/4.1GHz/5.1GHz/9.8GHz tetra band microstrip antenna for wireless applications

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In this paper, a novel engineered tetra band microstrip antenna is designed for wireless applications. The proposed antenna is printed on flame-retardant fiberglass epoxy (FR-4) substrate with the dimensions of 40*mm*x40*mm*x1.6*mm* and ground plane etched with rectangular split ring defected ground structure (RSRDGS). The RSRDGS unit cell is used to miniaturize the designed antenna as well as for multiband resonance. The proposed antenna resonates at tetra band frequency points i.e., 3.1GHz, 4.1GHz, 5.1GHz, and 9.8GHz with satisfactory bandwidth of 209MHz, 313MHz, 168MHz, and 195MHz respectively. The total peak gain at tetra band frequency points are 8.54dB, 7.65dB, 1.79dB, and 4.65dB as well as 48% of virtual size miniaturization is achieved. The proposed antenna results make it suitable to use for S-band to X-band wireless applications.

Keywords: Microstrip antenna, Rectangular split ring defected ground structure (RSRDGS), Total peak gain

1 Introduction

The recent growth in the wireless system has resulted in a high data rate and low latency with compact layout is the most demanding requirements[1]. The emerging wireless technologies such as artificial intelligence, data science, RFID, based smart parking systems, cyber physical systems, and the internet of things, have more demands on antennas to operate multiband resonance with wideband characteristics[2]. To achieve these requirements and fit on to the compact layout of the wireless devices is a more challenging task. In literature to overcome these drawbacks, several techniques have been reported[3]. The most recommended technique is a geometrical slot defected on the ground plane of antenna layout is referred to as defected ground structure (DGS)[4]. These structures possess the band stop characteristics and higher slow wave rate due to that antenna bandwidth enhancement as well as miniaturization is achieved[5]. The main objective of this paper is to provide a novel approach to the design of tetra band microstrip antenna for wireless applications.

2 Materials and Methods

The conventional rectangular microstrip antenna (CRMA) has been designed by using formulas discussed in[6] and optimized by using ANSYS Inc HFSS electromagnetic simulation software of version 15.0. Figure 1, shows the geometry of the conventional rectangular microstrip antenna (CRMA) with a center-fed 50Ω microstrip line feed printed on FR-4 substrate. The dimensions of conventional rectangular microstrip antenna are as given in Table 1.

Further, the study is carried out by modifying the ground plane of the conventional rectangular microstrip antenna (CRMA) by embedding the following defected ground structure such as Rectangular split ring defected ground structure (RSRDGS). The DGS is made by etching the copper in the shape of RSRDGS from a copper sheet in the ground plane of the CRMA. Figure 2, shows the

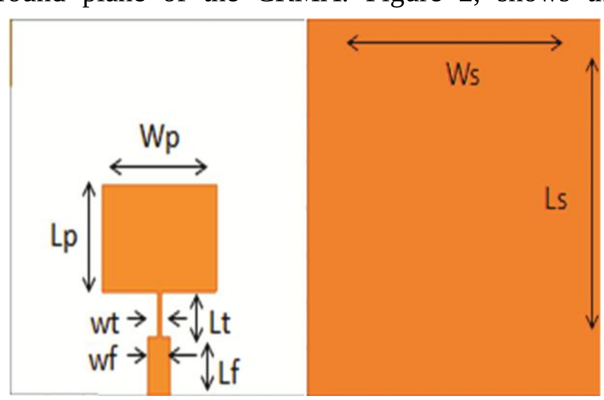

Fig. 1 — Geometry of conventional rectangular microstrip antenna (CRMA).

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Table 1 — Dimentions of conventional rectangular microstrip antenna (CRMA)

Parameters	Ls	Ws	Lp	Wp
Dimensions (*mm*)	40	40	11.35	15.25
Parameters	Lt	Wt	Lf	Wf
Dimensions (*mm*)	4.9	0.5	6.15	3.06

Table 2 — Dimensions of rctangular split ring defected ground structure (RSRDGS)

Parameters	Notation	Dimensions (*mm*)
Length of the ring	L1	20*mm*
Width of the ring	W1	20*mm*
Gap between the ring	G1	2*mm*
Split gap between the ring	G2	2*mm*

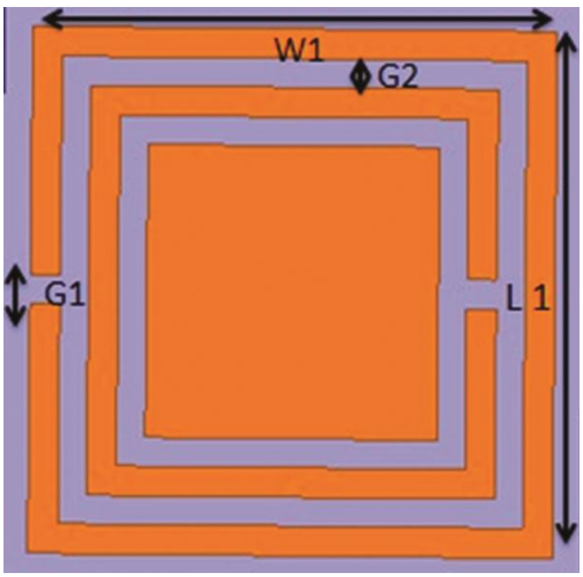

Fig. 2 — Geometry of rectangular split ring defected ground structure (RSRDGS).

enlarged geometry of the RSRDGS unit cell and their finalized dimensions are as given in Table 2.

In this study by using the above optimized RSRDGS geometry, loading to the CRMA ground plane and it is named as CRMA-RSRDGS. Figure 3, shows the enlarged geometry of CRMA- RSRDGS.

The detailed simulation study was carried out for CRMA-RSRDGS, a significant size reduction, multiband resonance, and high peak gains are obtained as compared to CRMA.

3 Results and Discussion

The conventional rectangular microstrip antenna resonates at 5.9 GHz with a bandwidth of 204 MHz is shown in Fig. 4. The simulated results are summarized in Table 3.

The peak gain of an antenna decides the area of coverage and link budget of the system. Figure 5, shows the 3D radiation peak gain pattern of the

Table 3 — Summarized Results of CRMA

Antenna Prototype	Resonating Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
CRMA	5.9	-20.65	204

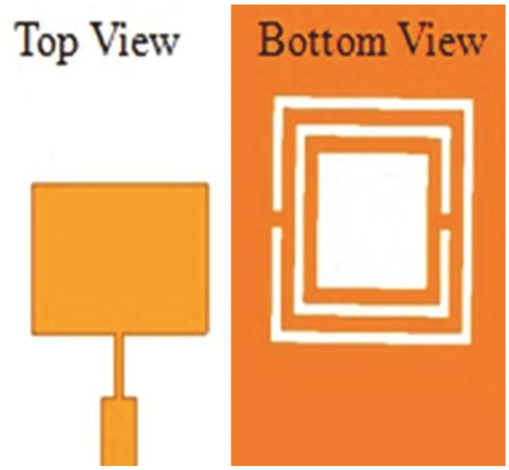

Fig. 3 — Geometry of CRMA-RSRDGS.

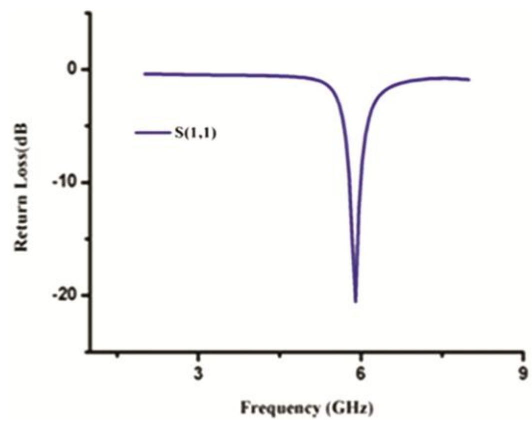

Fig. 4 — Return loss characteristics of CRMA.

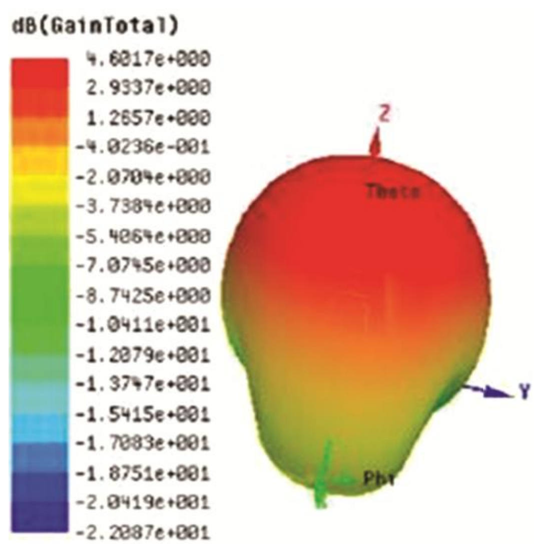

Fig. 5 — Total Peak Gain of CRMA at 5.9 GHz.

proposed CRMA. The designed antenna has a peak gain of 4.6dB at 5.9 GHz.

Figure 6, shows the CRMA-RSRDGS return loss characteristics. The antenna resonates at four particular frequency points i.e., 3.1 GHz, 4.1 GHz, 5.1 GHz, and 9.8 GHz with a bandwidth of 209 MHz, 313 MHz, 168 MHz, and 195 MHz along with the minimum return loss of -13.21 dB, -23.26 dB, -15.23 dB and -17.2 dB respectively.

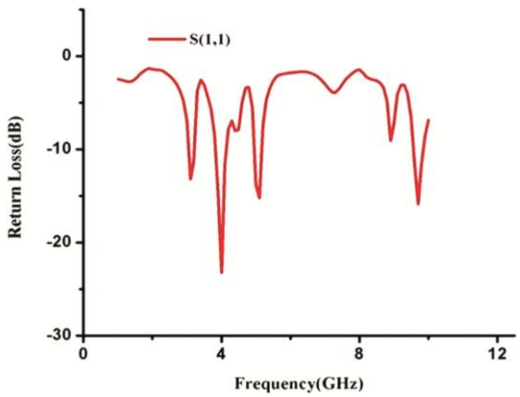

Fig. 6 — Return loss characteristics of CRMA-RSRDGS (a) 8.54dB at 3.1GHz (b) 7.65dB at 4.1GHz (c) 1.7dB at 5.1GHz, and (d) 4.65dB at 9.8GHz.

Due to the inclusion of RSRDGS type defected ground structure, it suppresses the unwanted surface wave and enhance the antenna parameters interns of tetra band resonance, with bandwidth enhancement, as well as virtual size reductions are obtained as compared to CRMA. So from Eq. (1) virtual size reduction of the proposed antenna is calculated[7].

$$\text{Virtual Size reduction (\%)} = \left(\frac{L_C - L_{RA}}{L_C}\right) x100 \quad \ldots (1)$$

where, L_{RA} is the patch length of the reference (CRMA) antenna, L_C is the patch length of the antenna resonating at that frequency or reduced resonant frequencies of the proposed antenna (CRMA-RSRDGS). But the width of the patch is same at both designed and actual resonating frequencies. So that by using RSRDGS the proposed antenna (CRMA-RSRDGS) virtual size reduction of 48% is obtained.

The 3D radiation peak gain of CRMA-RSRDGS antenna at four particular frequency points are 8.54 dB, 7.65 dB, 1.79 dB and 4.65 dB are shown in Fig. 7.

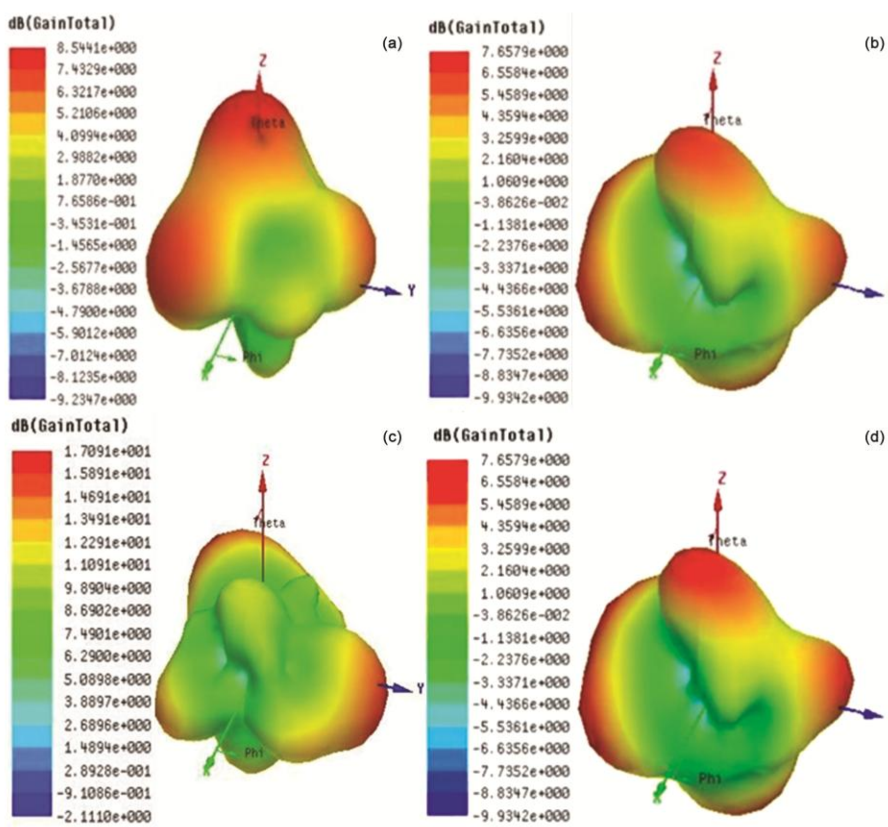

Fig. 7 — Total Peak Gain of CRMA-RSRDGS (a) 8.54dB at 3.1GHz, (b) 7.65dB at 4.1GHz, (c) 1.7dB at 5.1GHz, and (d) 4.65dB at 9.8GHz.

Table 4 — Comparison results of previously published methods and proposed methods[7, 8, 9]

Antenna Prototype	Resonating Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)	Total Peak Gain (dB)
	1.2	-30.1	78	4.2
	1.6	-15.5	125	1
	2.4	-17.2	110	1.5
	2.6	-28	175	2
	2.9	-13.4	112	4.2
	4.58	-22.3	153	3.5
	2.8	-17.8	198	4
	5.8	-19.5	201	3.5
	10.7	-22	48	5.8
CRMA	5.9	-21.3	204	4.6
CRMA-RSRDGS	3.1	-13.21	209	8.54
	4.1	-23.26	313	7.65
	5.1	-15.23	168	1.79
	9.8	-17.2	195	4.65

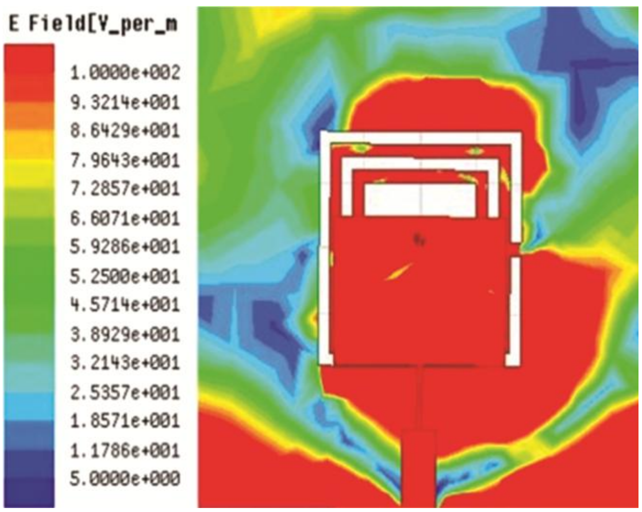

Fig. 8 — E-Field Magnitude of CRMA-RSRDGS.

Figure 8, shows the simulated E-field magnitude plot for the proposed CRMA-RSRDGS. It is observed that the combined effect of split ring loop elements of RSRDGS is providing a lower frequency band.

It has been observed that, proposed CRMA-RSRDGS is resonated tetra band frequency points i.e., 3.1GHz/4.1GHz/5.1GHz/9.8GHz with the highest bandwidth of 209MHz/313MHz/168MHz/ 195MHz as well the size reduction of 48% obtained. Hence this CRMA-RSRDGS gives novel design made in our work as compared to CRMA and other antennas available so for in the literature. Table 4, depicts the comparison of the results of previously published methods with the proposed method.

4 Conclusion

This work presents the miniaturized tetra band microstrip antenna for wireless applications. The proposed CRMA-RSRDGS antenna is resonated at tetra frequency points i.e., 3.1 GHz/4.1 GHz/5.1 GHz/ 9.8 GHz with a bandwidth of 209 MHz/313 MHz/ 168 MHz/195 MHz respectively. This antenna offers total peak gain at tetra band frequency points are 8.54 dB, 7.65 dB, 1.79 dB, and 4.65 dB and also gives 48% of virtual size reduction. The proposed CRMA-RSRDGS antenna results show that are acceptable to the S-band to X-band wireless applications.

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