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Design and Analysis of Complementary Split Ring Resonator with Slot on Rectangular Patch Antenna for Wireless Applications

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Abstract: *A design of the rectangular patch antenna (RPA) with complementary split ring resonator (CSRR) is presented in this paper for wireless communications. The four CSRR with one small slot is considered at radiating patch to operate the antenna at dual frequency. The proposed antenna resonates at 4.8GHz and 5.39GHz frequencies with reflection coefficient -29.05dB and -14.86dB. A maximum gain of 8.28dBi is observed at 4.8GHz frequency. The directional characteristics are also presented of CSRR patch antenna in results. The proposed antenna is used at wireless communications for high data transceiver the signals.*

Index Terms: *CSRR, rectangular microstrip patch antenna, wireless applications.*

I. INTRODUCTION

In the world of rapidly growing wireless communication, devices capable of operating in different frequency bands are required. These devices must be able to receive multiple services provided by multiple wireless technology networks. These requirements cause the need for a multiband antenna [1]. The need can be overcome by microstrip antenna, split ring resonator (SRR) [2] and complementary split ring resonator (CSRR) structures [3] became obsessed with antenna designers, due to the ability to change direction and generate new resonance. The CSRR structure electromagnetic behaviour is based on the dual magnetic resonance SRR structure and for this reason SRR and CSRR are widely used in antenna designs. Compact broadband circularly polarized antennas with low axial ratio bandwidth and compact size has been studied [4]. Microstrip patch antennas with slots for 5G wireless communication [5], with CSRR loaded on the ground plane for ISM band application [6] for satellite communication [7] is presented. Patch antenna arrays for mutual coupling reduction [8], printed MIMO based slot antenna for 5G sub millimetre wave application and satellite communication [9]. Corrugated Y-shaped patch antenna for tripleband operation with enhanced gain has been studied [10]. Bandwidth expansion using patch antenna based on CSRR, SRR antenna has miniaturized for triple band applications at 4GLTE [11] is presented.

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In recent years, the techniques of miniaturize CSRR patch antennas has been studied [5],[6]. However, these attempts rely on loading the CSRR into the microstrip patch element, but others can miniaturize the CSRR randomly from the metal ground plane was achieved. However, such techniques will increase the complexity of the design and will make an effort to optimize the optimal position of the CSRR.

In order to obtain a compact multiband antenna, a conventional radiating patch with a CSRR is used in this paper. The geometry of the proposed antenna and its surface current distribution, gain and radiation pattern are studied and analyzed in the following section.

II. ANTENNA DESIGN

Figure 1 represents the RPA design with CSRR slots. The substrate material used for antenna design is Rogers RT/duroid 5880 (ε_r=2.33) with a height (h) of 1.59mm. The dimensions of the substrate material are $l_1 \times w1$. A rectangular patch with length and width $l_2 \times w_2$ is metalized on the top of the substrate material. A circular shape and rectangular shape CSRR are etched at four corners from the radiating patch. A rectangle shape slot with dimensions c_1 and d_1 is etched near to the feed line which is having an input impedance of 50Ω. The length and width of the feed line are $l_3 \times w_3$ respectively.

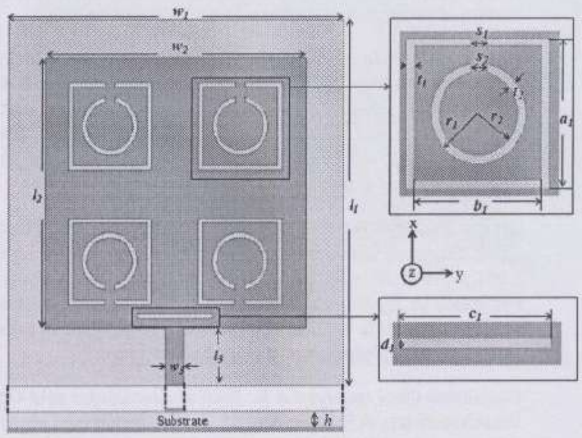

Figure 1. The proposed patch antenna geometry

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The slot widths of the rectangular and circular CSRR are t_1 and t_2 as shown in Figure 1. The inner radius is r_1 and outer radius of the circular CSRR is r_2. Similarly, the length is a_1 and width is b_1 for the rectangular slot. The split gap of s_1 and s_2 are considered for rectangular and circular CSRR. A plane ground surface is coated on the bottom layer of the substrate material. The radiating patch thickness and ground plane thickness is 0.01mm. The detailed optimized dimensions of the proposed antenna are shown in the Table I.

TABLE I OPTIMIZED DIMENSIONS OF PROPOSED ANTENNA

Parameters	Values in (mm)	Parameters	Values in (mm)
l_1	38	d_1	0.5
w_1	36	a_1	9
l_2	28	b_1	8
w_2	28	s_1, s_2	1
l_3	6	t_1, t_2	0.5
w_3	2	r_1	3
c_1	8	r_2	2.5

III. RESULTS AND DISCUSSIONS

The analysis of the designed antenna with CSRR on radiating patch is proposed with CST tool. The simulated reflection coefficient (S_{11}) of the proposed antenna with and without slot at two resonant frequencies is shown in Figure 2, some frequency shift is observed for two cases. This antenna resonates at 4.88GHz frequency with S_{11} of -29.05dB and a bandwidth of 90MHz (4.84-4.93GHz). The second band resonates at 5.39GHz frequency with S_{11} of -14.86dB and a bandwidth of 60MHz (5.36-5.42GHz). It is observed that there is an improvement in S_{11} and gain for antenna with slot compare to without slot. The analysis data is shown in Table II.

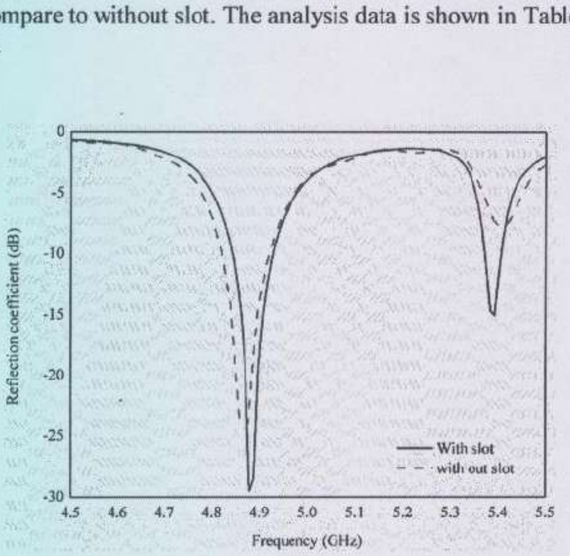
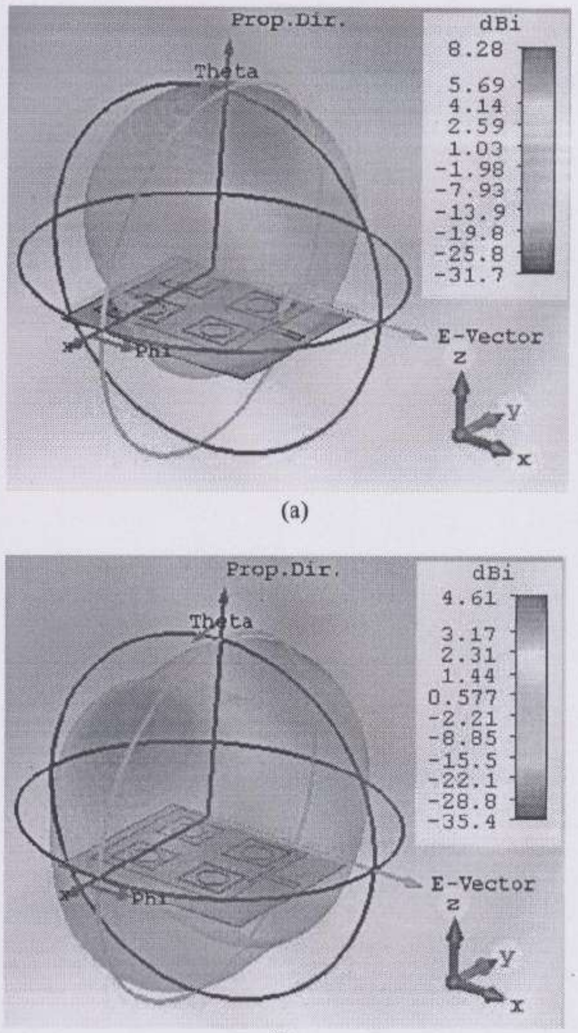


Figure 2. Reflection coefficient (S_{11}) is presents for two operating frequencies of the proposed antenna.

TABLE II. OPERATING FREQUENCY, REFLECTION COEFFICIENT, BANDWIDTH AND GAIN OF PROPOSED ANTENNA

	Operating frequency (GHz)	Reflection coefficient (dB)	Bandwidth (MHz)	Gain (dBi)
Simulated without slot	4.84	-24.1	100	-
Simulated with slot	4.88	-29.05	90	8.28
	5.39	-14.86	60	4.61

Figure 3 presents simulated 3D gain plots of the proposed antenna with obtained values. From the Figure 3, it is observed that the gain is high 8.28dBi for antenna at first resonant frequency and the gain is 4.6dBi for second resonant frequency.



(b)

Figure 3. 3D gain patterns of the proposed antenna at (a) 4.88GHz (b) 5.39GHz.

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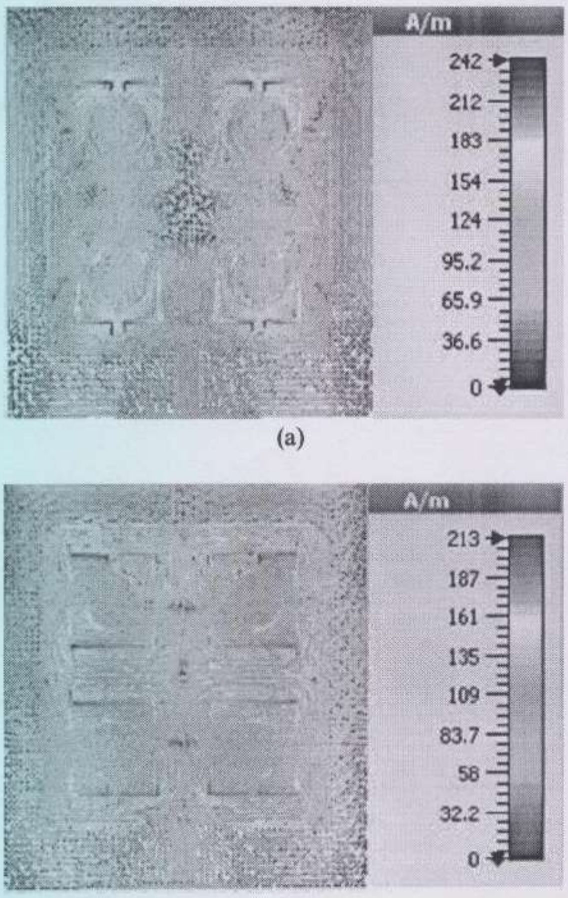


(a)

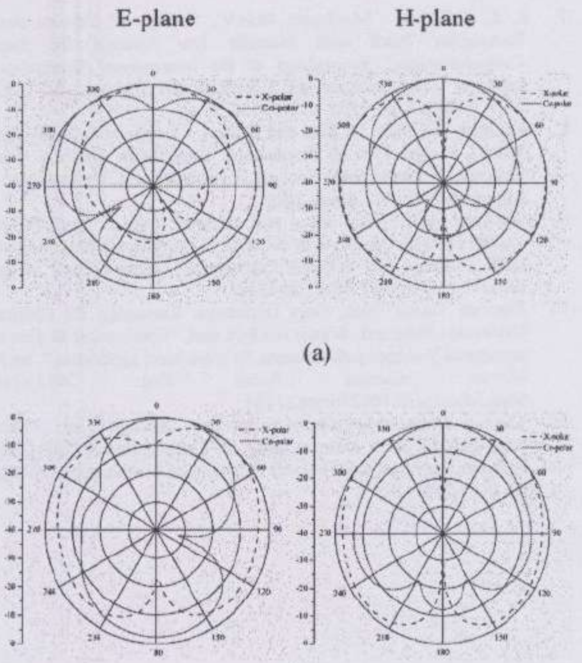
(b)

Figure 4. Surface current distributions at (a) 4.88GHz, (b) 5.39GHz frequency is presents of proposed antenna.

Figure 4 shows the current distributions of proposed antenna at two resonant frequencies. The maximum current concentrates at inner edges split circles with 241.5A/m which leads to the resonance of 4.88GHz frequency. The current distribution is 212.5A/m resonates at operating frequency 5.39GHz frequency with a maximum current concentration is observed at the edges of split rectangles.

Simulated normalized radiation patterns of the proposed antenna at two operating frequencies are given in Fig 5. From the results it is shown that for 4.8GHz E-plane the radiation patterns are unidirectional with a -3dB beamwidth of 65°,52° with front-to-back ratio of 18dB, 24dB for both co-polarization (Co-polar) and cross-polarization (X-polar). Similarly for H-plane bi-directional radiation pattern is observed for X-polar and a -3dB beamwidth of 60° with front-to-back ratio of 3dB. Unidirectional radiation pattern is observed for co-polarization with 70° beamwidth and 18dB front-to-back ratio.

From Figure 5(b) it is observed that the E-plane radiation patterns of 5.39GHz are bi-directional in both broadside and end-fire directions. Co-polar and X-polar are observed with 50°, 65°beamwidths and 3dB, 15dB front-to-back ratios. The Co-polar and X-polar of H-plane radiation patterns are bi-directional and uni-directional with a -3dB beam widths of 50°, 60°and a 3dB and 12dB front-to-back ratios.



(a)

(b)

Figure 5. Radiation pattern of the proposed antenna at (a) 4.88GHz frequency (b) 5.39GHz frequency.

IV. CONCLUSION

A rectangular patch antenna with complementary split ring resonator (CSRR) is presented for wireless communication applications. The antenna resonates at 4.88GHz, 5.39GHz frequencies with a reflection coefficient of -29.05dB, -14.86dB. The simulated bandwidths of 90MHz, 60MHz is observed. The radiations are bidirectional and unidirectional with a gains of 8.2dBi, 4.6dBi respectively.

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