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Design of Multiband Patch Antenna using CSSR for C-Band

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Abstract—This manuscript represents a complementary Split ring Resonator CSRR antenna which is used for multiband (Four Band) of operation in C band of 4 to 8 GHz. Although we have analyzed the antenna performance for 2 GHz to 8 GHz but our frequency range of interest is entire C band. Here we present three design with different split ring structure, second design and third proposed design is almost identical but with different feed point dimension on the other hand first design is having only one band of operation on the other hand second design has only two band of operation. The paper presented here is a modified CSRR based microstrip antenna in which the final design is modified form of second design. This paper presents the design of patch antenna and its simulation results using ansys HFSS software. The performance analysis of proposed antenna is based on result parameters like Number of operating frequency bands, VSWR, Return Loss, Bandwidth and Peak gain. The frequency range under observation is between 2 GHz to 8 GHz.

Keywords- Complementary split ring Resonator (CSRR); Multiband;VSWR; Return Loss; FR4.

I. INTRODUCTION

Microstrip patch antenna is widely used in communication systems to meet the increasing requirement for multiband frequency of operation in various applications, such as MIMO and radar systems. In recent times, subsequent developments of these systems, the demand for multiband Microstrip patch antennas has been gradually increasing. Accordingly, the techniques for obtaining improved performances in theses domains have become an attractive field of research. The needs for single antenna working for wide range of applications motivate us for designing of a multiband antenna with better performance parameters. Thus in this paper we proposed three novel design based on CSRR concept of patch, which is used in multi frequency range the observation for C band application of 4 GHz to 8 GHz of frequency. All the three design presented here is developed on glass epoxy FR-4 substrate (ε_r=4.4) of thickness 1.6 mm. The rest of the paper is ordered in the different section, section II represents theory and various important concept of split ring resonator used in microstrip patch antenna designing. Section III represents Physical design of different proposed antenna, for multiband application in the frequency range of 2 to 8 GHz. Section IV represents the simulation result of the proposed designs, in section V conclusion and future work is reached.

II. THEORY OF CSRR AND PATCH ANTENNA

The CSRR and SRR are different method of achiving metamaterials structure which behaves like as an externally driven LC resonant circuit. The resonance frequency of the SRR unit cell is determined by the self-inductance L and capacitance per unit length C_{ul}. The resonant frequency (f_0) of the square SRR is given by

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

where L and C are the total inductance and capacitance of the split ring resonator structure. The total capacitance C can be expressed as

$$C = (C_s+C_g)/2 \quad (2).$$

Where C_s and C_g are series and gap capacitance respectively, where their values are as follows:

$$C_g = \varepsilon_0 wt/g \quad (3)$$

Where t and w are the thickness and width of the metal rings on the other hand g is the split gap.

$$C_s = (4a_e-g)c_{ul} \quad (4)$$

Where a_e is the radius of split structure.

The total inductance of the proposed circuit model can be calculated by using the following relation:

$$L = (0.0002)l(2.303 \log_{10}\frac{4l}{w} - 2.853) \quad (5)$$

III. DESIGN

In this part of the manuscript we have presented three designs, first design is a simple split ring resonator grown on 1.6 mm thick FR4 substrate. The second design is CSRR antenna with 6 mm and 0.5 mm opening as shown in design B and the final proposed design is modified version of second design in which we have change the strip line position by 2 mm and feed line is reduced by 1.65 mm as shown in design C in the following sub-section. We use same substrate material for all of the three designs of thickness of 1.6 mm.

A. Design A of SRR Model

The first design is a split ring resonator based patch in which we use rectangular ring with a gap of 0. 5 mm and dimension of ratangular ring is 17 mm by 12 mm of thickness of 3 mm as shown in figure 1. The substrate and ground plane has same area of dimension 32 mm x 26 mm and height of substrate is 1.6 mm. the ground plane is simple basic copper based rectangle with no modification as shown in figure 2.

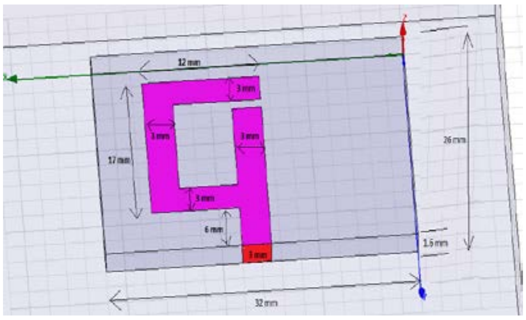

Figure.1 Top view of Design *A* of SRR model.

B. Design B CPA Model

In the second design we use a CSRR antenna with 6 mm and 0.5 mm opening and the dimension of ratangular ring slot is 17 mm by 12 mm of thickness of 3 mm as shown in figure 2. The antenna is excited by a feed line of dimension 6 mm x 5 mm. The substrate and ground plane has same area of dimension 32 mm x 26 mm and height of substrate is 1.6 mm. with ground plane of dimension 32 mm x 26 mm PEC.

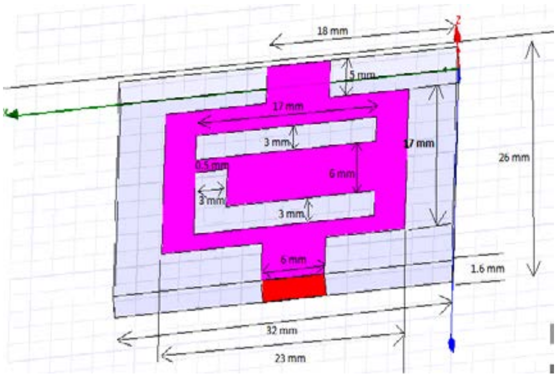

Figure.2 Top view of Design *B* of CSRR model.

C. Design C of modified *CSRR Model*

The third and final design is a modified form of second design in which we have change the strip line position by 2 mm and feed line is reduced by 1.65 mm. In the final proposed design we again have a CSRR antenna with 6 mm and 0.5 mm opening and the dimension of rectangular ring slot is 17 mm by 12 mm of thickness of 3 mm as shown in figure 3. The antenna is excited by a feed line of dimension 6 mm x 5 mm. The substrate and ground plane has same area of dimension 32 mm x 26 mm and height of substrate is 1.6 mm. with ground plane of dimension 32 mm x 26 mm PEC.

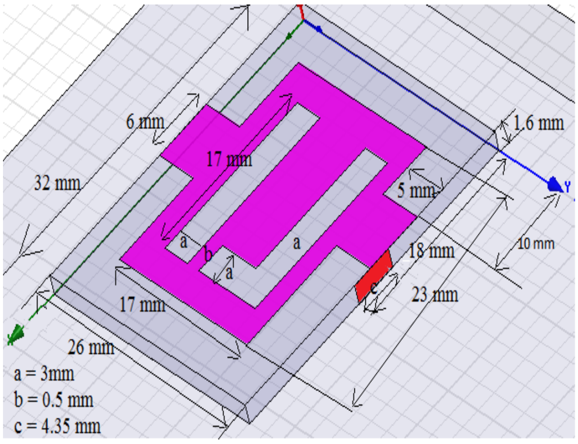

Figure.3 Top view of Design *C* of Modified CSRR model.

IV. RESULTS AND DISCUSSION

In this part of the paper we discuss about the foremost performance parameter of proposed antenna such as S_{11} Return Loss, VSWR, Bandwidth, Number of operating band and Peak Antenna Gain. For first design (Design A) we get only one band of operation with bandwidth of 600 MHz at center frequency of 5.4 GHz. On the other hand for second design (Design B) we get two band of operation of bandwidth 400 MHz and 312.5 MHz at 4.7 GHz and 5.7 GHz respectively. Finally in Third proposed design (Design C) we achieve multiple band of operations i.e four band of radiation at different frequencies, the overall results obtained by all of the three designs are shown in table 1.

Table I: Result analysis of Proposed antennas.

Design	***Radiating Frequency (GHz)***	***BW (-10dB) (MHz)***	***Gain (dB)***	***Return Loss***	***VSWR***	***Axial Ratio (dB)***
A	5.4	600	+0.488	-18.50	1.269	16.40
B	4.7	420	-5.56	-19.19	1.249	20.50
	5.7	312.5	-2.90	-25.26	1.770	17.72
C	4.4	231	-5.02	-16.31	1.36	7.00
	5.0	210	-4.85	-16.12	1.37	13.52
	6.0	334	-0.72	-16.87	1.33	19.75
	7.9	300	1.90	-17.33	1.31	8.46

The figure 4, 5, 6 and 7 presents the above discussed parameter such as return loss S11, -10 dB Bandwidth, gain, VSWR and Axial Ratio respectively for design A. on the other hand The figure 8, 9, 10 and 11 represents the above parameter for design B and figure 12, 13, 14 and 15 represents the above parameter for design C respectively.

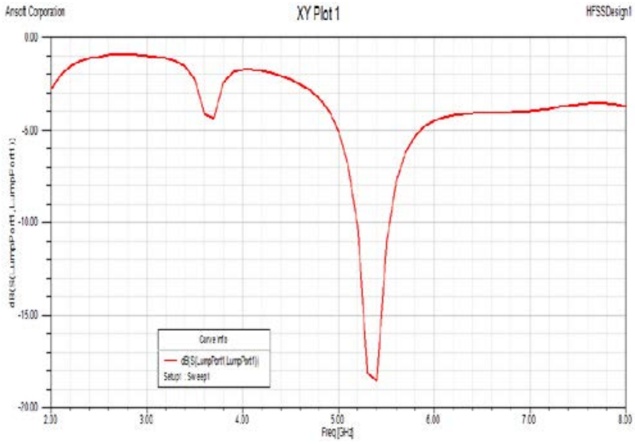

Figure 4. S11 For Design A

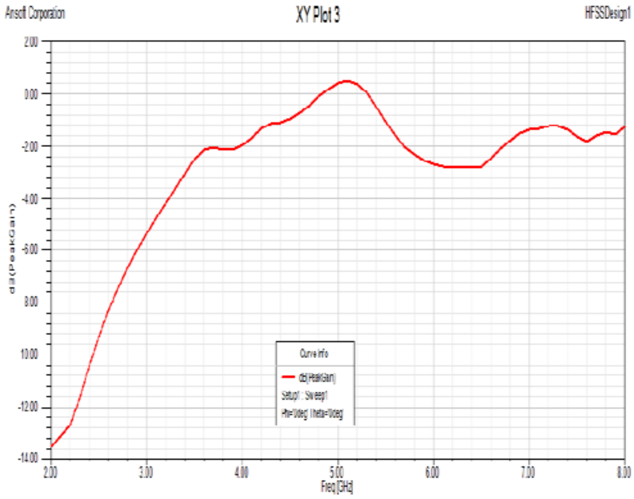

Figure 5. Gain For Design A

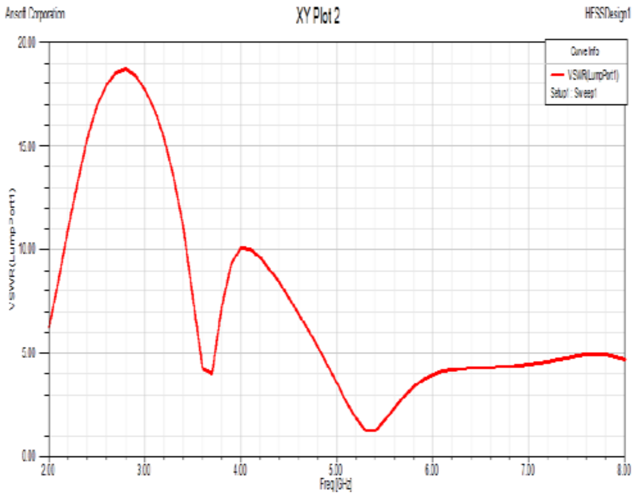

Figure 6. VSWR For Design A

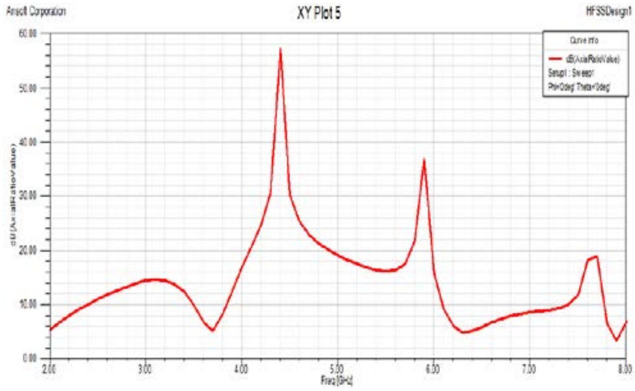

Figure 7. Axial Ratio For Design A

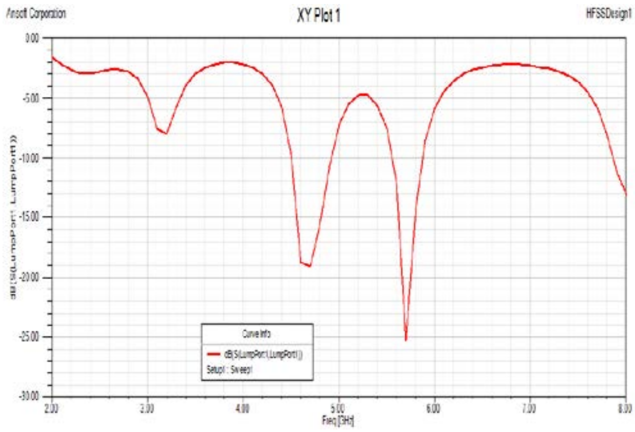

Figure 8. S11 For Design B

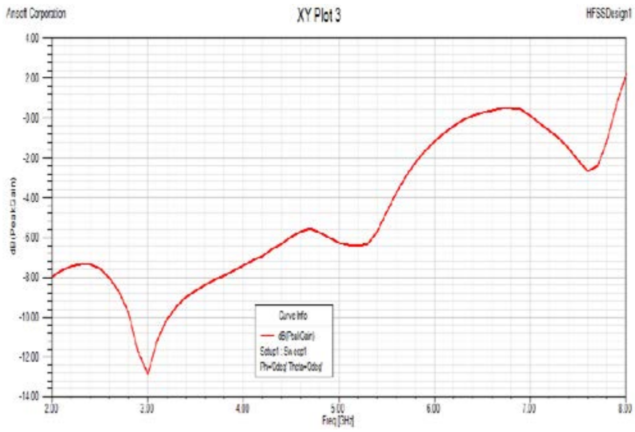

Figure 9. Gain For Design B

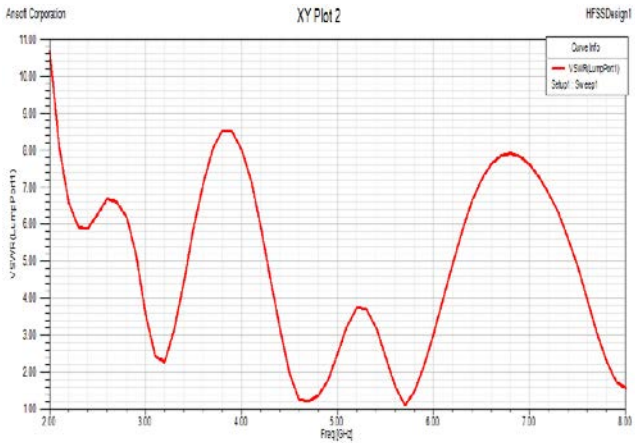

Figure 10. VSWR For Design B

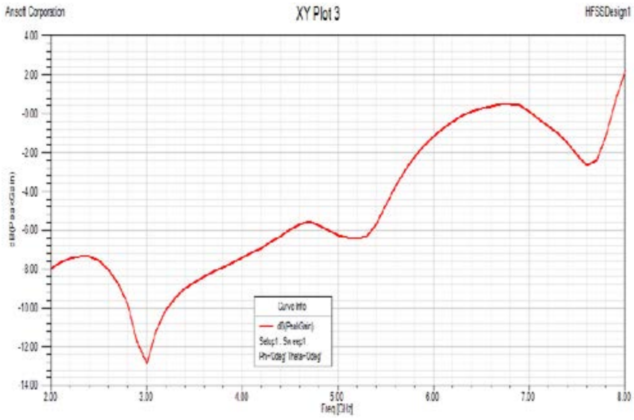

Figure 11. Axial Ratio For Design B

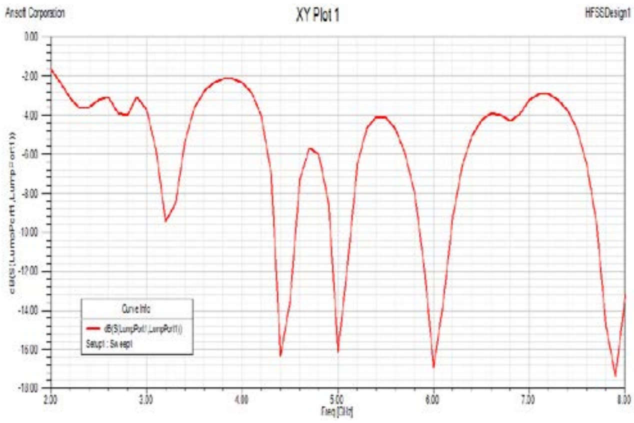

Figure 12. S11 For Design C

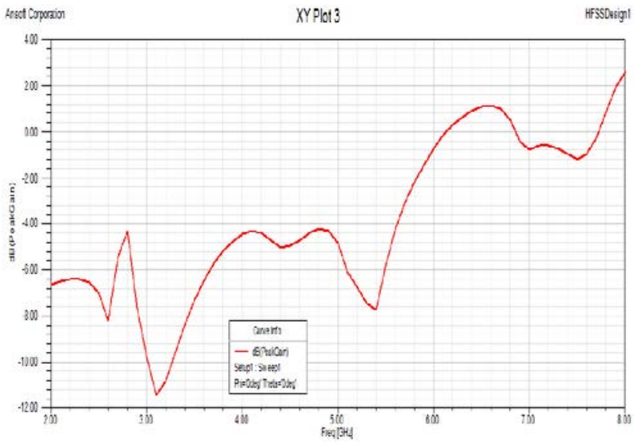

Figure 13. Gain For Design C

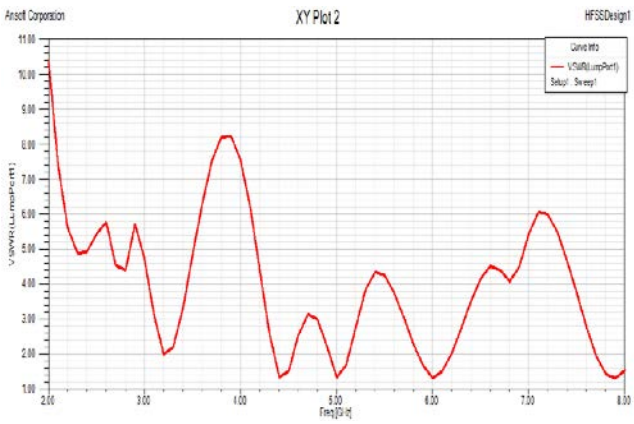

Figure 4. VSWR For Design C

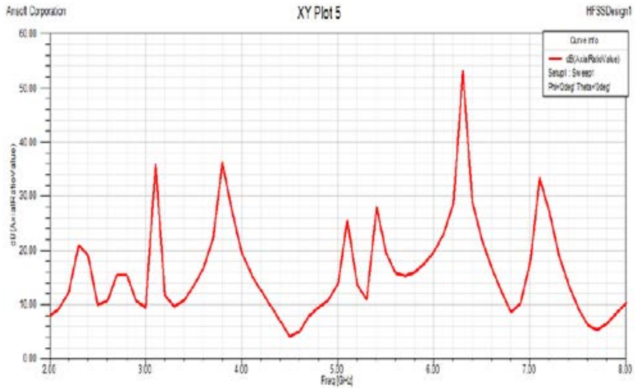

Figure 15. Axial Ratio For Design C

V. CONCLUSION AND FUTURE WORK

In this paper we presents three split ring resonator patch antenna, For first design (Design A) we get only one band of operation with bandwidth of 600 MHz at center frequency of 5.4 GHz. On the other hand for second design (Design B) we get two band of operation of bandwidth 400 MHz and 312.5 MHz at 4.7 GHz and 5.7 GHz respectively. Finally in Third proposed design (Design C) we achieve multiple band of operations i.e four band of radiation of bandwidth 231 MHz, 210 MHz, 334 MHz and 300 MHz at 4.4 GHz, 5.0 GHz, 6.0GHz, and 7.9 GHz as center frequencies respectively. We also observed that the peek Gain is achieved at 7.9 GHz that is +1.90 dB. After analyzing the results in table 1 we can conclude that the introduction of CSRR patch cavity improve the multi-band and high Gain with acceptable bandwidth and return loss.

In future the research can be extended for improvement of axial ratio and gain improvement so that we can achieve circular polarization for the same.

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