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Design of Triple Band Microstrip Patch Antenna Loaded with CSRR

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***Abstract*- The aim of the paper is to design a wide band and multiple band rectangular Microstrip Patch Antenna with complementary split ring resonator center shorted to ground. In this paper, method of moments based IE3D software is used to design a Triple Band Microstrip Patch Antenna Loaded with Complementary Split ring resonator. The proposed antenna with square slot etched on patch can be operated at a frequency band with center frequency 3.96 GHz (with a bandwidth of 57.58%) and antenna loaded with CSRR can be operated at three frequency band with center frequencies 2.17 (with a bandwidth of 2.76%), 3.91 (with a bandwidth of 56.26%) and 5.285 GHz (with a bandwidth of 3.02%). So this antenna can be used for both mobile and satellite communication purpose.**

***Keywords*- Microstrip patch antenna, CSRR, Bandwidth, Return loss, Efficiency.**

I. INTRODUCTION

Due to the rapid growth in wireless communication, the need of multiband frequency is raised. Thus, an antenna with multiband operations is required. Multiband antennas are developed for various wireless applications so that any equipment can employ several applications at a time. These applications can involve data transfer, video, audio, radio [1]. In multiband antenna, one part works for one band while another part works for different band. A Multiband antenna can have lower than average gains. These are manufactured to work at high frequencies from MHz to several GHz.

A circularly polarized antenna allows stable data transmission and not depends on the orientation of transmitter and receiver. Hence, it is most suitable for portable and handheld mobile devices. Circular polarization (CP) in a conventional patch antenna can be achieved by simultaneous excitation of two orthogonally polarized modes with a 90 degree phase difference [2]. In literature, there exist a large number of techniques of achieving CP in a microstrip patch antenna using both single and dual-feed configurations [2]. However, the single-feed design is more popular as it avoids the use of an external power divider. Recently, the use of complementary split ring resonators(CSRR) to achieve multiband performance in the conventional microstrip antennas has become very popular [3][4]. Loading metamaterial resonators in addition to the conventional edge trimming and cutting slots in patch antennas to achieve circular polarization are also gaining wide attention [6]–[12]. In [12], the orientation of the gap of a CSRR relative to the feed point in the patch is utilized to achieve a CP for the CSRR-loaded patch antenna.

The Microstrip patch antennas are similar to parallel plate capacitors and microstrip antennas are attractive due to their light weight and low profile and low cost. The patch width, w is usually in the range $\lambda_o/3 < W < \lambda_o/2$, ratio of L/W>2 is not advised, L is the path length. Thickness of the dielectric constant substrate is less effective on the resonance frequency compared to dielectric constant, $0.003\lambda_o \leq h \leq 0.1\lambda_o$ is generally used.

In this paper, a square slot is cut out along the diagonal of the patch at a specific distance from the center. After that a CSRR with center shorted to ground is placed into the square-shaped slot etched along the diagonal of a patch antenna to achieve triple-band operation.

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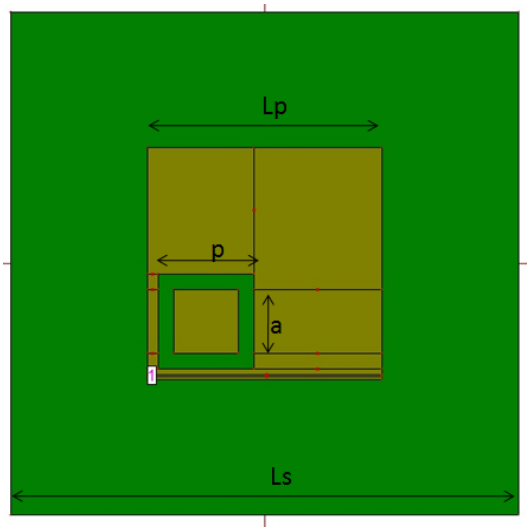
II. ANTENNA DESIGN METHODOLOGY

A conventional square patch antenna operating at around 3.5 GHz is chosen as the reference design. Low-cost FR4 epoxy substrate (ε_r= 4.4, tan δ = 0.02) with copper trace of 20µm is used for the antenna design. The length of square patch, L_P is 30mm and the length of square substrate or ground plane, L_S is 65mm. The thickness of the dielectric substrate (h) is 1.6mm. The probe feed is used for excitation of this antenna. The location of probe feed in reference patch antenna is (-14.5,-14.5) mm from the centre of patch.

A. Wideband slotted antenna design

A square slot is cut out along the diagonal of the patch at a distance of $L_1$from the center. Antenna is feed at the point (-14.5,-14.5) and simulated and result is obtained that is higher frequency is 5.1GHz, lower frequency is 2.82GHz and bandwidth is calculated as 57.58% which is increased as compare to simple conventional patch antenna. Fig.1 shows the geometry of slotted microstrip patch antenna. Detail specification of slotted patch antenna is given in table 1.



(a)

(b)

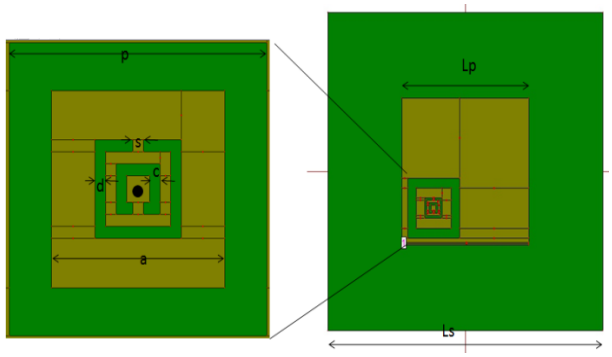
Fig.1. (a)Top view,(b)side view of slotted microstrip patch antenna

Table 1. Design specification of slotted patch antenna

Parameter	Value (mm)
L_P	30
L_S	65
H	1.6
P	12.2
A	8.2
L_1	7.5
Feed location from center	(-14.5,-14.5)

B. Triple band antenna design

A slotted patch antenna further loaded with a complementary split ring resonator in which the centre shorted with ground so this design is called mushroom shape design. Fig.2 shows the geometry of slotted patch antenna with CSRR in which center shorted to ground. Table.2 shows the design specification of this antenna. In table.2 v is diameter of shorting wire between patch and ground plane.



(a)

(b)

Fig.2. (a)Top view,(b)side view of slotted patch antenna with CSRR in which center shorted to ground

Table 2. Design specification of slotted MPA loaded with CSRR

Parameter	Value (mm)
L_P	30
L_S	65
h	1.6
p	12.2
a	8.2
L_1	7.5
d	0.5
s	0.5
c	0.5
v	0.6
Feed location from center	(-14.5,-14.5)

III. RESULT AND DISCUSSION

The proposed antenna has been designed using IE3D software. The IE3D is a full-wave, method of moment (MOM) simulator solving the current distribution on 3D and multi-layered structures of general shape. The performance of antenna has been analyzed in terms of resonant frequency, return loss(S_{11}), bandwidth, gain(dB), directivity (dBi), VSWR and antenna input impedance.

Fig. 3 shows the return loss plot of slotted patch antenna. From the s parameter display the operating frequency is centered at f_c= 3.96 GHz with S(1,1) = -17.6dB

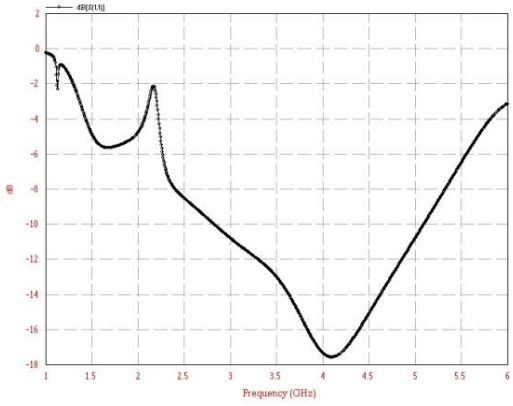


Fig.3. Return loss vs frequency curve for slotted patch antenna

and the resonance frequency is 4.12GHz. The bandwidth percentage of this antenna is 57.58%.

Bandwidth Calculation

f_L =2.82GHz, f_H = 5.1GHz, f_c= 3.96GHz

Bandwidth = $\frac{5.1-2.82}{3.96} \times 100$ =57.58%

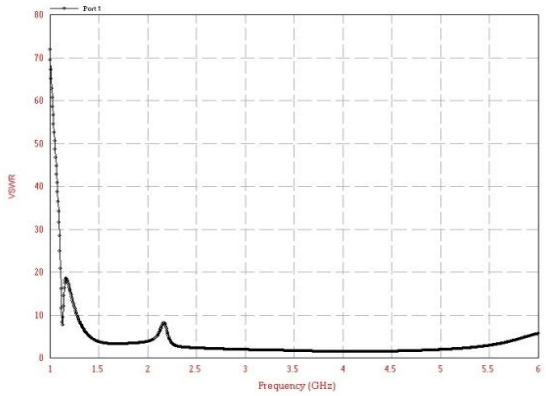


Fig. 4. VSWR vs frequency graph of slotted patch antenna

Fig. 4 shows the VSWR plot of slotted patch antenna. This graph shows that the value of VSWR can be seen to be within 1 to 2 in the operating range. Fig.5 shows the gain vs frequency graph of slotted patch antenna.

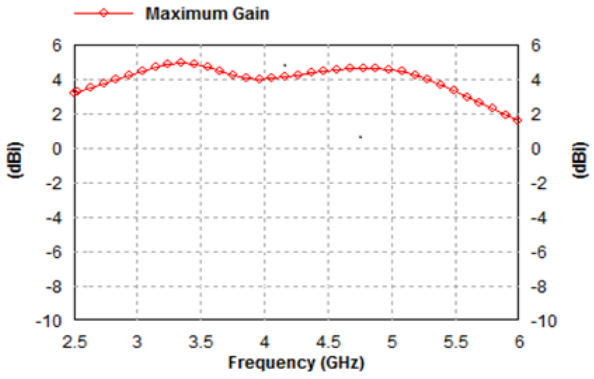


Fig. 5. Gain vs frequency graph of slotted patch antenna

When slotted patch antenna loaded with a CSRR the return loss characteristics is shown in fig.6. This slotted patch antenna loaded with CSRR is operated in three frequency bands. The all results are shown in table 3.

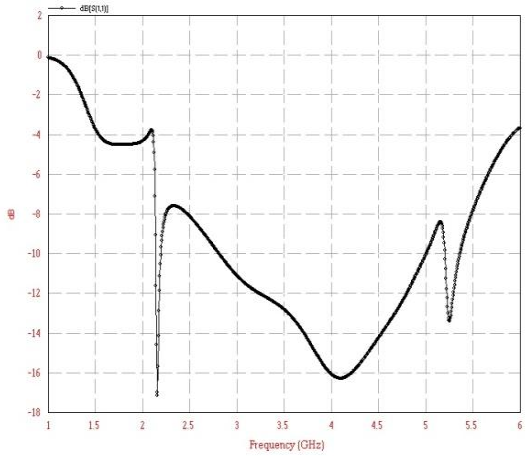


Fig. 6. Return loss vs frequency curve for slotted patch antenna loaded with CSRR

Bandwidth Calculation

For 1st band

f_{L1} =2.14GHz, f_{H1} = 2.2GHz, f_{c1}= 2.17GHz

Bandwidth = $\frac{2.2-2.14}{2.17} \times 100$ = **2.76%**

For 2nd band

f_{L2} =2.81GHz, f_{H2} = 5.01GHz, f_{c2}= 3.91GHz

Bandwidth = $\frac{5.01-2.81}{3.91} \times 100$ = **56.26%**

For 3rd band

f_{L3} =5.205GHz, f_{H3} = 5.365GHz, f_{c3}= 5.285GHz

Bandwidth = $\frac{5.365-5.205}{5.285} \times 100$ = **3.02%**

Table 3. Results at three bands of slotted patch with CSRR

Parameter / Band	Lower cutoff frequency f_L (GHz)	Higher cutoff frequency f_H (GHz)	Center frequency f_c (GHz)	Bandwidth (%)	Return loss (dB)
1st band	2.14	2.2	2.17	2.76	-17.15
2nd band	2.81	5.01	3.91	56.26	-16.30
3rd band	5.205	5.365	5.285	3.02	-13.43

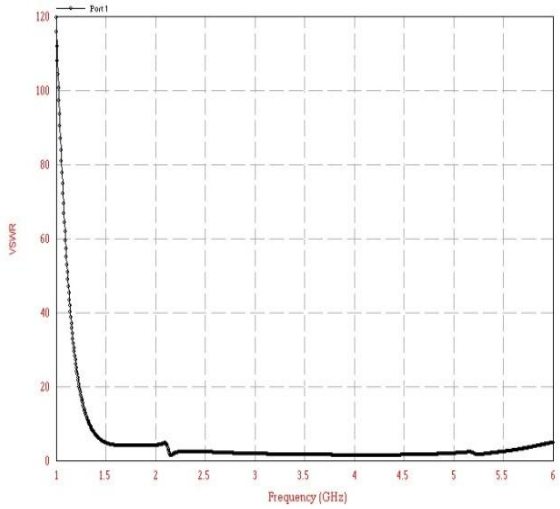


Fig. 7. VSWR vs frequency curve for slotted patch antenna loaded with CSRR

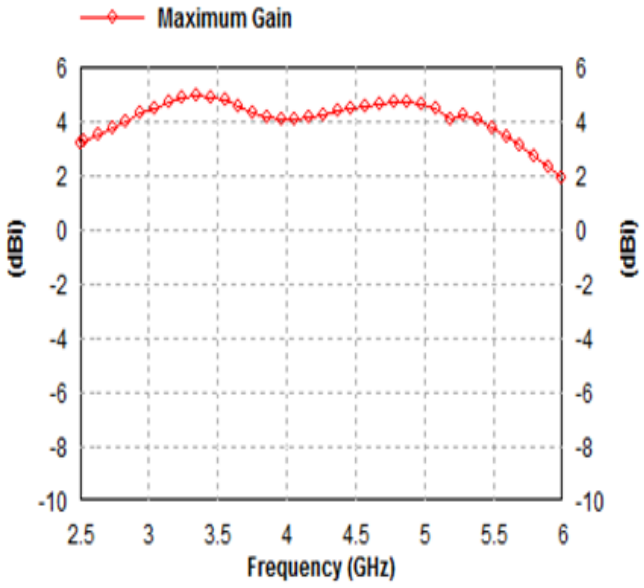


Fig. 8.Gain vs frequency curve for slotted patch antenna loaded with CSRR

Fig.7 and Fig.8 shows the VSWR and gain with respect to frequency. Fig.7 shows that the value of VSWR can be seen to be within 1 to 2 in the operating range. Fig.9 shows the 2-D radiation pattern of triple-band patch antenna at φ 0 and 90 degree.

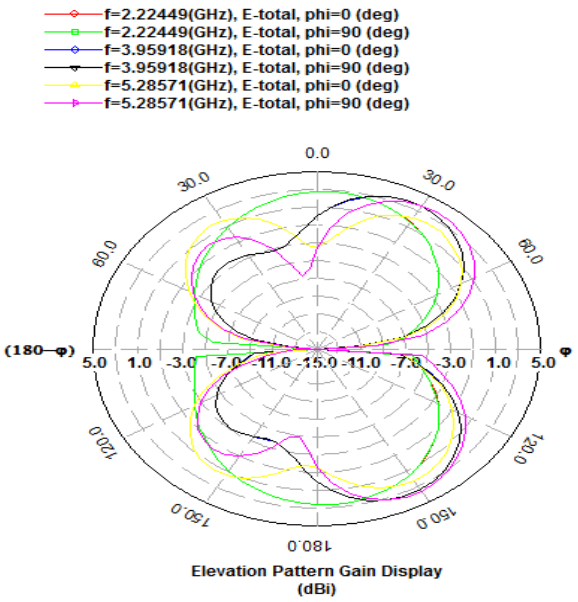


Fig. 9. 2-D radiation pattern of triple-band patch antenna

IV. CONCLUSION

A triple band Microstrip Patch Antenna has been successfully designed. It can be concluded from the above results that, the effect of etching square slot on patch and slotted patch loaded with CSRR are studied under great details with the help of experimental results. The proposed patch field desirable results throughout the operating frequency range.

The designed antenna with square slot etched on patch can be operated at a frequency band with center frequency 3.96 GHz (with a bandwidth of 57.58%) and antenna loaded with CSRR can be operated at three frequency band with center frequencies 2.17 (with a bandwidth of 2.76%), 3.91 (with a bandwidth of 56.26%) and 5.285 GHz (with a bandwidth of 3.02%). So this antenna can be used for both mobile and satellite communication purpose.

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