# Dual Band Circular Patch Antenna based on Metamaterials

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**Abstract.** A novel dual-band circular patch antenna with a circular mushroom unit cell is proposed. A circular slot is etched along the diagonal of the circular patch antenna, which is loaded with the circular mushroom unit cell to achieve dual-band operation. Three other mushroom unit cells are designed simulated and studied. The negative order modes with Linear Polarization (LP) are observed from each mushroom unit cell, so these modes are combined to get Circular Polarization (CP) at a single frequency. To validate the results obtained from the simulation, one of the four antennas which are having good radiation characteristics is fabricated. The close relationship between simulation and measured results establish the usefulness of the antenna.

Keywords: Dual band, Split Ring Resonator, mushroom unit cell, Circular Polarization

## 1. Introduction

A microstrip patch antenna is compact, low profile and portable is the most wanted candidate for modern-day wireless communication applications [1]. Furthermore, dual-band patch antennas are attractive to operate at several communication systems [2- 5]. An antenna with circular polarization is mostly suitable for handheld devices because it is independent of the orientation of the receiver and transmitter. By exciting two orthogonally polarized modes with a phase difference of $90^0$, circular polarization can be achieved [6]. Single feed, circularly polarized antennas for multiband performance are most popular in printed antennas.

Circular polarization with more compactness can be obtained by using Metamaterials because of their backward wave properties [7-17]. Metamaterials are artificial materials which are having electromagnetic properties which are not available in nature. Most of the antennas proposed in the existing literature have less 10-dB return loss bandwidth at each resonance frequency and have more physical size this is not favourable for portable devices. The proposed antenna resonates at three bands with linear polarization, the rightmost band (n=+1 mode) is due to the circular patch which is called as patch mode band and the leftmost band (n=-1 mode) is called as negative order mode band and middle band (n=0 mode) is called as zeroth order mode band. By optimizing the position and size of the complementary square split ring resonator (CSSRR) loaded mushroom unit cell with respect to circular patch, the two left-handed bands (n=-1 mode and n=0 mode) are combined at a single frequency which results in CP.

In this paper, a CSSRR etched circular mushroom unit cell loaded circular microstrip patch antenna is reported to get dual band dual polarization operation. Along with proposed mushroom unit cell, three more mushroom unit cells are designed and simulated. Commercially available Ansys HFSS simulator tool is used to design and simulate the proposed circular patch antenna.

## 2. Proposed antenna geometry and simulation results

The structure of the proposed circular patch antenna loaded with CSSRR etched circular mushroom unit cell is shown in Figure 1. A conventional circular microstrip patch antenna is chosen as reference design which is resonating at 2.5 GHz. Low cost FR4 epoxy dielectric material with permittivity of 4.4 is used for the design of proposed patch antenna. The design parameters of the proposed antenna are given in the Table. 1.

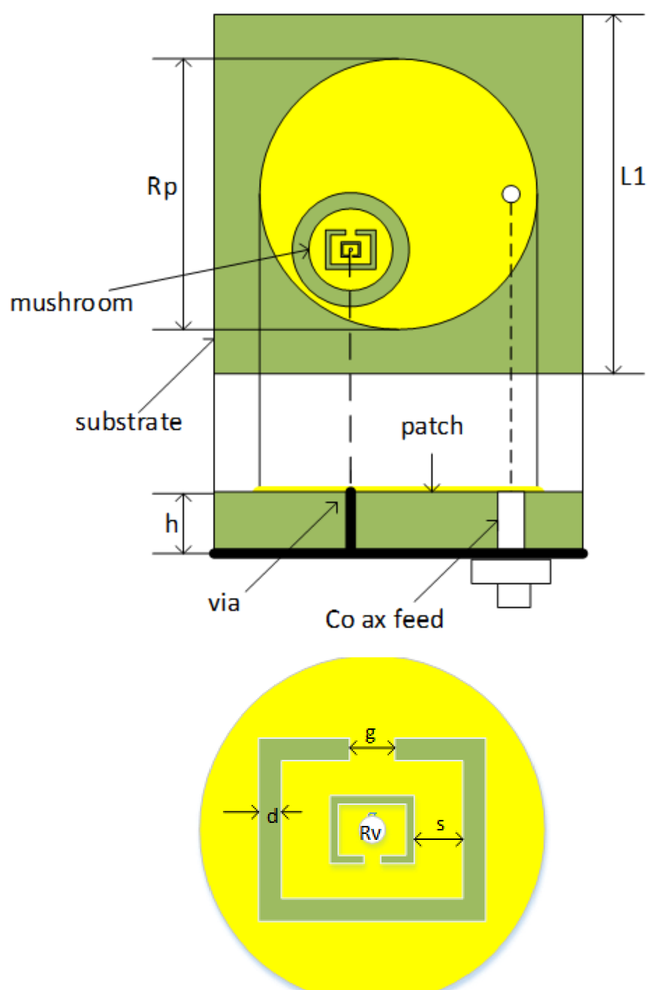



Fig. 1. Geometry of the proposed antenna and CSSRR etched mushroom unit cell

**Table 1**: Parameter values

| Parameters | Values in mm |
|---|---|
| L1 | 60 |
| rp | 16 |
| h | 1.6 |
| g=d=s | 0.4 |
| rv | 0.3 |

Initially, the proposed antenna is loaded with a complementary square split ring resonator (CSSRR) etched circular mushroom unit cell which results in a triple band (n=-1, n=0, n=+1 modes) with LP. The triple band resonance occurs due to the split ring resonator presented in the mushroom which will acts as the permeability negative metamaterial and the via between ground and patch which will act as effective negative permittivity metamaterial. By optimizing the size of the mushroom unit cell the left modes are combined together orthogonally and produce CP at a single frequency. The return loss characteristics of the above antenna with parametric optimization of radius of the mushroom and feed position are shown in Figure 2.

From the Figure 2, three bands with LP appear when the radius of the mushroom is closer to the radius of the slot. When the radius of the mushroom unit cell is decreasing the leftmost band is moving closer towards zeroth mode and at r=4.2 mm both modes are combined and produce CP at a single frequency.

In the same way, the return loss characteristics are observed for remaining three mushroom unit cells which are shown in Figure 3 by loading individually into the proposed antenna and are shown in Figure 4.

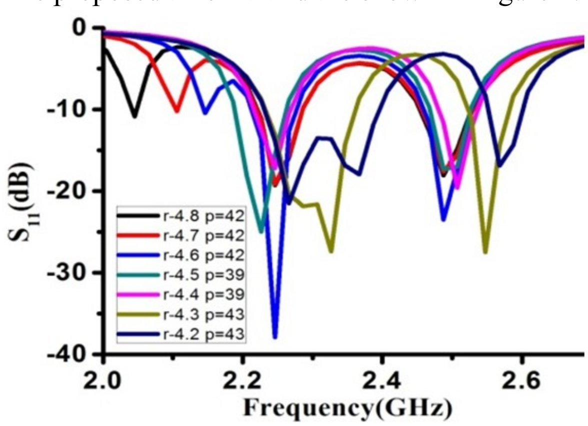



Fig. 2. Return loss characteristics of the proposed patch antenna with CSSRR loaded circular mushroom unit cell

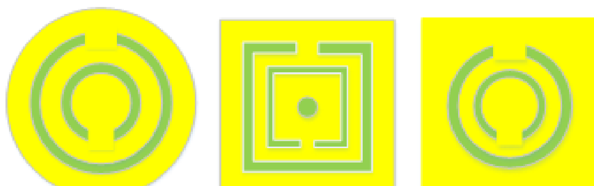
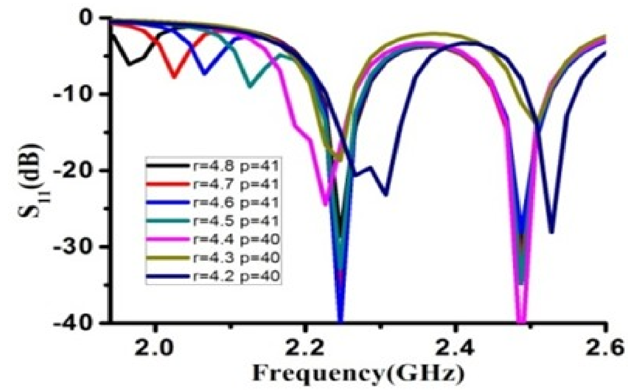
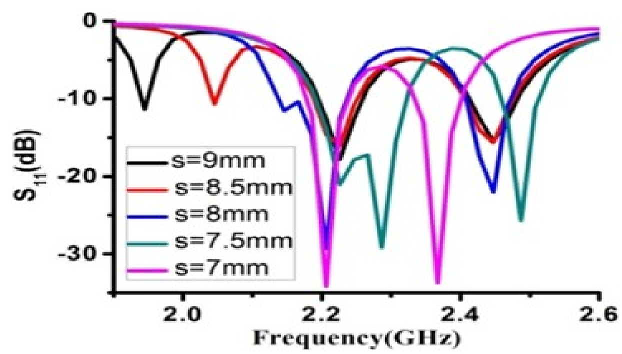


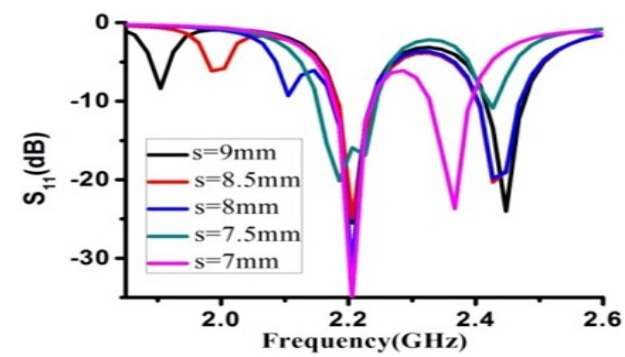
Fig. 3. CCSRR etched circular mushroom unit cell, CSSRR and CCSRR etched square mushroom cells




(a)




(b)




(c)

Fig. 4. Return loss characteristics of (a) CCSRR etched circular mushroom (b) CSSRR etched square mushroom (c) CCSRR etched square mushroom

A circular mushroom unit cell with CCSRR and the square mushroom unit cell with CSSRR and CCSRR are the remaining three mushroom unit cells. Out of four mushroom unit cells the circular mushroom unit cell with CSSRR is giving good return loss characteristics with good bandwidth and CP. The return loss characteristics of four antennas which are producing dual band dual polarization are compared and tabulated in Table. 2.

## 3. Experimental results

The proposed antenna with CSSRR etched circular mushroom unit cell is printed on the FR4 epoxy substrate. The fabricated antenna is shown in Figure 5. The measured and simulated results of the proposed antenna are portrayed for comparison in Figure 6. The feed position is at (13.4, 0) from the center of the patch.

**Table 2**: Return loss bandwidth

| Type of mushroom | Return loss bandwidth | |
|---|---|---|
| | At left hand band | At patch mode band |
| CSSRR etched circular | (2.24- 2.38 GHz) 6.06% | (2.54- 2.58 GHz)1.56% |
| CCSRR etched circular | (2.24- 2.38 GHz) 6.06% | (2.56- 2.58 GHz) 0.71% |
| CSSRR etched square | (2.20- 2.30 GHz) 4.4% | (2.46- 2.50 GHz) 1.61% |
| CCSRR etched square | (2.16- 2.22 GHz) 2.73% | <1% at 2.42 GHz |

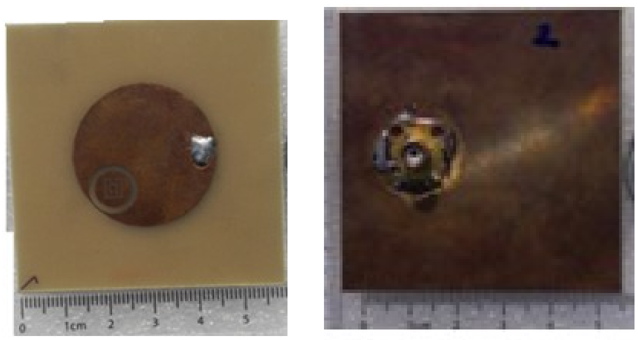


Fig. 5. Top view and bottom view of the fabricated antenna

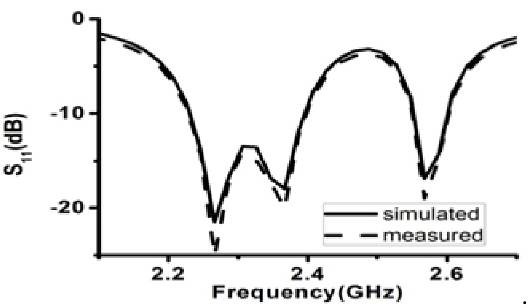



Fig. 6. Return loss characteristics of the fabricated antenna

The first resonance frequency (patch mode band) is at 2.56 GHz (2.54 - 2.58 GHz) with a 10-dB return loss bandwidth of 1.56%. The second resonance frequency (the combined left handed bands) is at 2.4 GHz (2.24 GHz- 2.38 GHz) with a 10-dB return loss bandwidth of 6.06% is due to the mushroom unit cell. The measured and simulated axial ratio plots of proposed antenna at CP band are shown in Figure 7. The measured 3-dB axial ratio bandwidth at the second resonance frequency is 1.71% (2.32 GHz- 2.36 GHz).

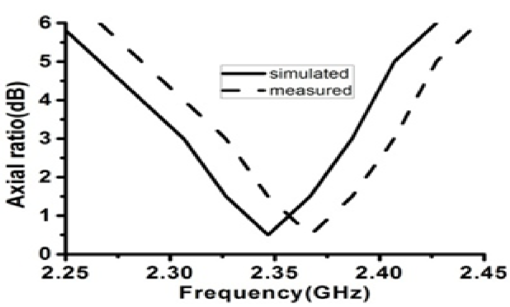
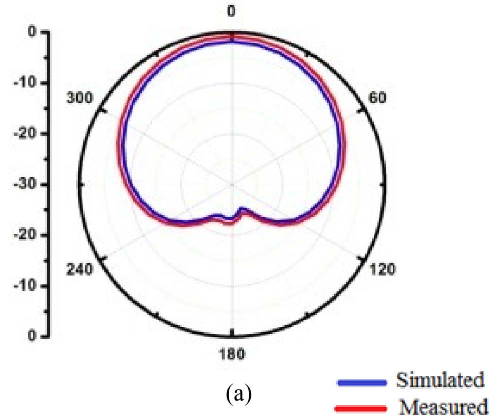
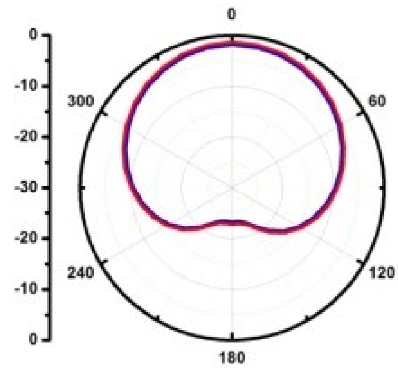



Fig. 7. Axial ratio characteristics of the proposed antenna

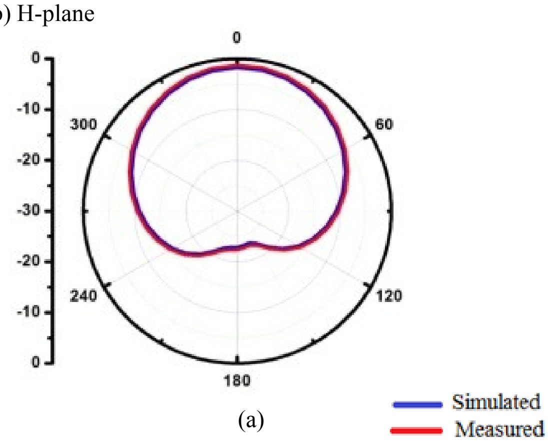



(a)

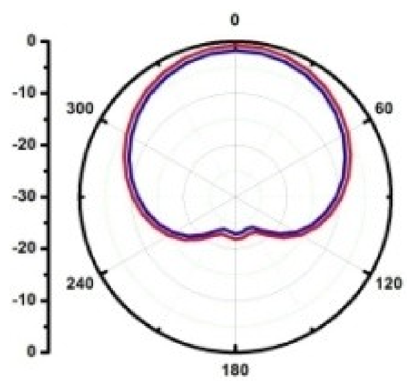


(b)

Fig. 8. Radiation patterns of proposed antenna at 2.34 GHz (a) E-plane (b) H-plane




(a)



(b)

Fig. 9. Radiation patterns of proposed antenna at 2.54 GHz (a) E-plane (b) H-plane

## 4. Conclusion

Single probe fed circular patch antenna loaded with circular mushroom unit cell has been tested and presented. Circular patch antenna with different polarizations has been studied and designed. The simulated and measured results are in good agreement. Several wireless communication bands can be achieved, by varying the dimensions of the patch and mushroom unit cell.

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