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ANALYSIS OF CIRCULARLY POLARIZED NOTCH BAND ANTENNA WITH DGS

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ABSTRACT

A compact printed wideband antenna with circular polarization is analyzed in this work. A basic structure of rectangular monopole is converted into a trapezoidal shape with tapered step ground. Different iterations of radiating element as well as defected ground structures are examined in this work to analyze the circular polarization characteristics of the antenna. A peak realized gain of 4.3dB and peak directivity of 3.8dB is attained from the current designed models. The design models are simulated on HFSS tool and the optimized dimensions are prototyped on FR4 substrate for measurement validation. By incorporating Split ring resonator (SRR) notch band characteristics are attained in the proposed wideband antenna.

Keywords: circular polarization (CP), defected ground structure (DGS), notch band, split ring resonator (SRR), wideband antenna.

1. INTRODUCTION

Circular Polarization has acknowledged as one of the extremely required characteristics of an ultra-wideband antenna [1-2]. Though, circular polarization which is the restricting instance of the most common elliptical polarization is fairly hard to accomplish because of the stringent demands on the phase and is understood just in the vicinity of two orthogonal components of the electric field vector in exact phase quadrature [3-8]. Generally, circularly polarized antennas were utilized for point to point satellite communications and accordingly, the antennas used to understand circular polarization had no space restrictions and could offer to be large [9-12]. Crossed dipoles, Archimedean Spirals and Yagi-Uda's gave the required circular polarization characteristics. The quick development in wireless communications attached with extensive practice of the cellular phones and other portable devices directed to a bout of research in the area of microstrip antennas. Additionally, the issue of spectrum by Federal Communications Commission (FEC) for Personal Area Network (PAN) operations has employed an increasing demand on the flexibility of the basic microstrip patch antenna need to be compact in size, robust in design and almost omnidirectional in radiation while in the meantime providing a large impedance bandwidth to fit for a numerous applications in the ultra-wideband region [13-18].

In this paper, basic structure of rectangular monopole is converted into trapezoidal shape with tapered step ground. Different iterations of radiating element as well as defected ground structures are examined in this work to analyze the circular polarization characteristics of the antenna. A defected structure etched in the metallic ground plane of a microstrip line is one of the smart solutions. It provides deep and extensive stopband, sharp cutoff with its compact size to encounter evolving applications.

In this paper, a compact ultra-wideband uses an individual split ring resonator which is exited by a monopole antenna.One of the most important features of SRR is to achieve negative electric permittivity and magnetic permeability in a certain frequency range. SRR is used to achieve the band reject filter characteristics of the designed antenna models.

2. ANTENNA GEOMETRY

In Figure-1, the antenna model 1 shows the trapezoidal shape slot antenna on defected ground structure. The antenna is designed on FR4 substrate of dimensions 60 x 50 x 1.53 mm. A ground is also printed in the same side of substrate along with radiating patch element. A rectangular slot of dimensions 40 X 23 mm is etched on ground plane and is excited by CPW feed line. The feed line is ended with a trapezoidal shaped tuning stub extended into the center of slot. The rectangular slot is cut into two circular arcs at lower left corner and upper right corner and having different radii to serve as perturbations required for recognizing circular polarization. The distance between the stub and the ground plane is represented as 'S' and the spacing between the feed line and the ground plane is represented by 'G'. The trapezoidal shape stub has widths of Ws1 and Ws2and has length as Ls. The parameter values are shown in Table-1.

From the antenna model 1 shown in Figure-1, the slot perimeter S_{per} and the stub height h_s can be calculated as

$$S_{per} = 2L + 2W - 2R_1 - 2R_2 + \frac{\pi}{2}(R_1 + R_2) \quad (1)$$

$$h_s = S + \sqrt{L_s^2 - \left(\frac{W_{s1} - W_{s2}}{2}\right)^2} \quad (2)$$

The slot perimeter can be assessed to two guided wavelengths at the lower resonant frequencies.

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Table-1. Antenna model 1 dimensions.

Parameter	Dimensions(in mm)
Wg	60
Lg	50
W	40
L	23
R1	6
R2	10
Lf	16.62
Wf	2.8
S	3.68
G	0.85
Ws1	7
Ws2	14
Ls	7.5
H	1.53

The lower resonant frequency is given as f1 and on the upper side, the monopole like operation of antenna takes place and the upper resonant frequency is given by

$$f_1 = \frac{2c}{S_{per}\sqrt{\varepsilon_{r,eff}}} \quad (3)$$

$$f_2 = \frac{c}{4h_s\sqrt{\varepsilon_{r,eff}}} \quad (4)$$

In the above expression 'c' is the velocity of light in free space and ε_{reff} is the effective relative permittivity of the substrate and it is given by the

$$\varepsilon_{r,eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-1/2} \quad (5)$$

Antenna model 1 is modified further to improve impedance bandwidth and circular polarization characteristics. Accordingly, the two modified version of antenna model 1 are designed they are named as antenna model 2 and antenna model 3. The antenna model 2 has step size 11 X 2 mm is added to trapezoidal shaped tuning stub, two rectangular slots of dimensions 3 X 4 mm are cut in the ground plane. In the antenna model 3, one more step is added to the tuning stub and a slit of dimensions 2x0.2 mm is cut at the center of trapezoidal tuning stub. The modified dimensions of antenna model 2 and antenna model 3 are shown in Table-2.

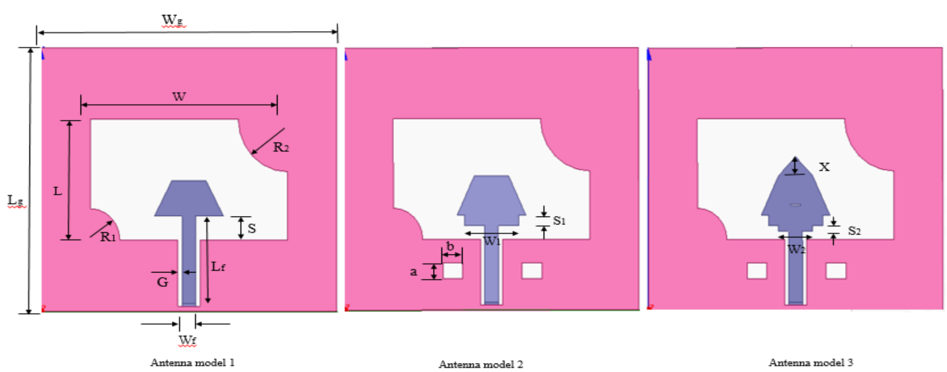

Figure-1. Tapered ground monopole, (a) Trapezoidalmonopole, (b) Trapezoidal stub monopole with DGS, (c) Trapezoidal stepped stub monopole with DGS.

Table-2. Modified dimensions (in mm) of antenna model 2 and antenna model 3.

Parameter	W1	S1	W2	S2	X	a	b
Antenna model 2 dimensions	11	2	-	-	-	3	4
Antenna model 3 dimensions	11	2	7	1	3.685	3	4

3. RESULTS AND DISCUSSIONS

The designed models are simulated with HFSS and the results are presented in this section. Figure-2 show the reflection coefficient of the antenna iterations shown in Figure-1. Antenna model 1 is giving a bandwidth of 4.8GHz and antenna model 2 is giving the bandwidth of 5.4 GHz. By changing the radiating element shape and by incorporating defected ground structure we attain additional resonant band for antenna model 2. To improve the bandwidth characteristics of the designed antenna model, we incorporated additional changes in the patch element by taking tapered step structure. Antenna model 3

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is providing bandwidth enhancement of 7.2 GHz which is almost double to the basic antenna model 1.

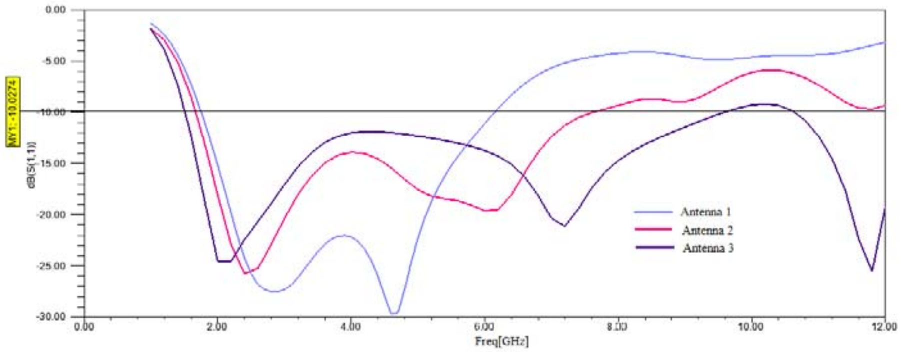

Figure-2. Reflection coefficient of antenna models 1, 2 and 3.

An impedance bandwidth of 120% is attained from the modified structure of antenna model 3. Figure-3 shows the impedance characteristics of the antenna models in Figure-1. All the models are showing an average impedance of 40 Ω.

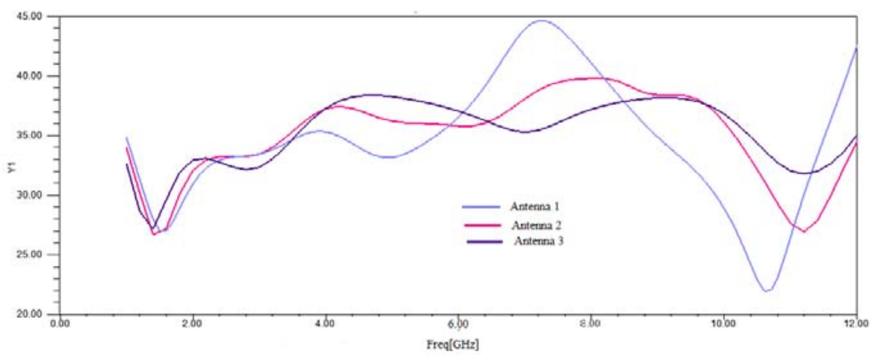

Figure-3. Impedance Vs Frequency of antenna models 1, 2 and 3.

Figure-4 shows the gain characteristics of the designed antenna models with respect to operating frequency band. Model 1 is showing peak realized gain of 3dB whereas model 2 is showing 3.5dB and the modified model 3 is providing the peak gain of 4.2 dB.

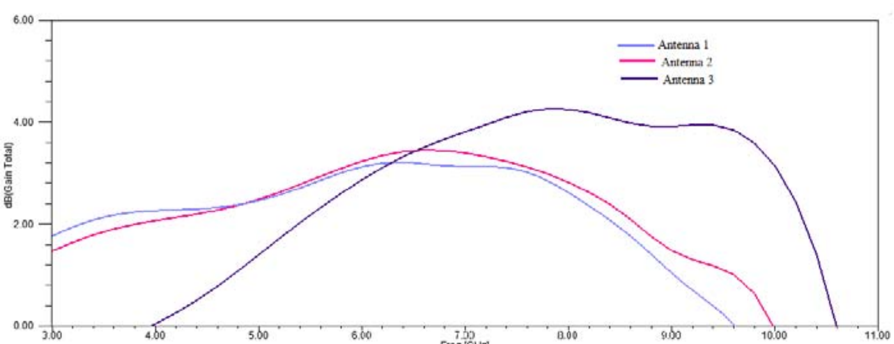

Figure-4. Gain of antenna models 1, 2 and 3 with respect to resonant frequency.

Figure-5 shows the directivity of the antenna models with a change in frequency. Antenna model 2 is giving superior directivity value when compared with the other models. A peak directivity of 3.5dB is attained from model 2.

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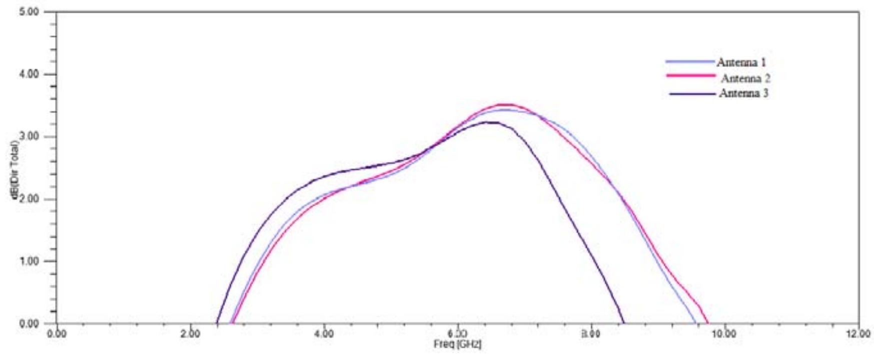

Figure-5. Directivity of antenna models 1, 2 and 3 with respect to resonant frequency.

The circular polarization characteristics of the designed models can be observed through axial ratio curve of Figure-6. In the operating band of this antenna models only at certain frequency bands, the designed antennas are showing circular polarization characteristics. 3 dB cutoff circular polarization characteristics at certain frequency bands can be observed from Figure-6.

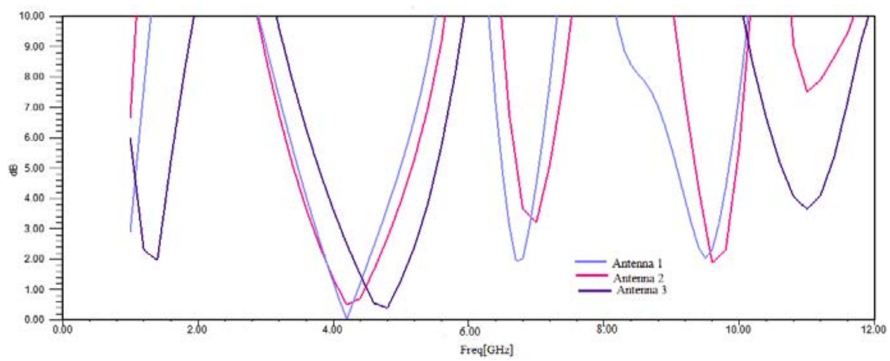

Figure-6. Axial ratio of antenna models 1, 2 and 3 with respect to resonant frequency.

Figure 7, 8 and 9 shows the radiation characteristics of the designed antenna models at center resonant frequency in the operating band. All these models are providing almost omnidirectional radiation pattern in H- plane and monopole like radiation in the E-plane.

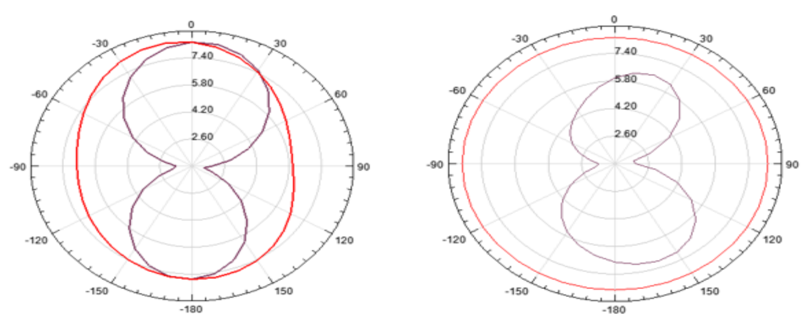

Figure-7. Radiation pattern of antenna model 1 at 4 GHz.

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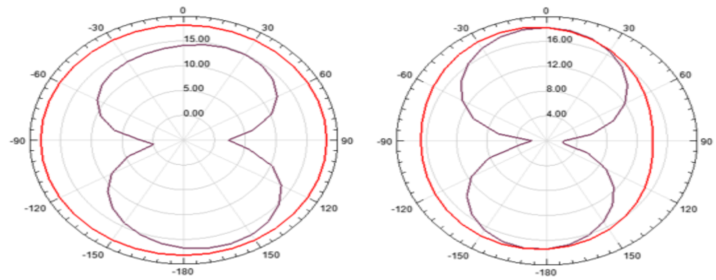

Figure-8. Radiation pattern of antenna model 2 at 4 GHz.

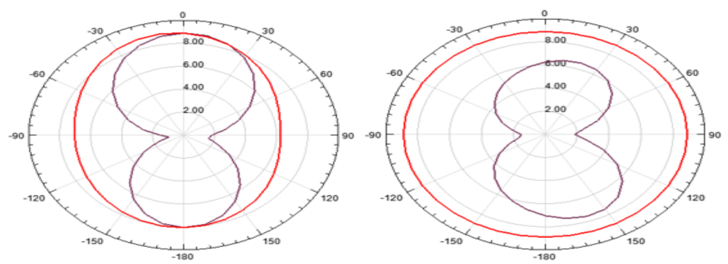

Figure-9. Radiation pattern of antenna model 3 at 4 GHz.

Figure 10 shows the surface current distribution of designed antenna models and by analyzing current distribution characteristics at different phases; we examined the circular polarization from these models.

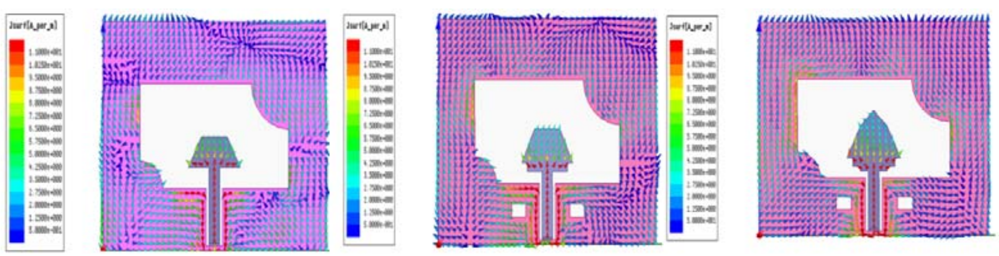

Figure-10. Current distribution of antenna models 1, 2 and 3 at 4 GHz.

4. MODIFIED MODELS WITH SRR

Figure-11 shows the modified antenna structures of basic models of 1, 2 and 3. In the modified structures, resonant frequencies are notched in the wide band by incorporating a split ring resonator shaped slots on the radiating element. The initial designs are modified by using a split ring resonator (SRR) which is placed almost on the radiating element to notch a particular band of frequencies and to observe the notch band characteristics in the designed wideband antenna.

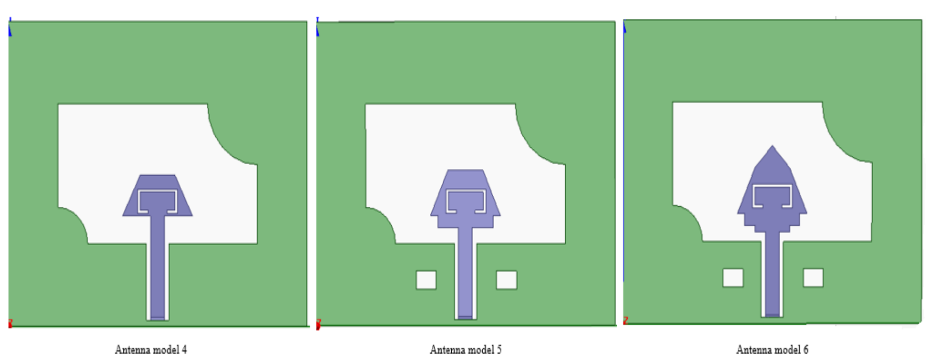

Figure-11. Modified antenna models 4, 5 and 6, (a) Trapezoidal monopole with SRR, (b) Trapezoidal stub monopole with SRR and DGS, (c) Trapezoidal stepped stub monopole with SRR and DGS.

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Figure-12 shows the corresponding reflection coefficient characteristics of the notch band antennas. The notching is occurred between 5 to 6 GHz which is popularly known for WLAN communication band. With the antenna model 6 we obtained a perfect notch band between 5.4 to 5.8 GHz (WLAN). The impedance characteristics of modified notch antennas can be observed from Figure-13.

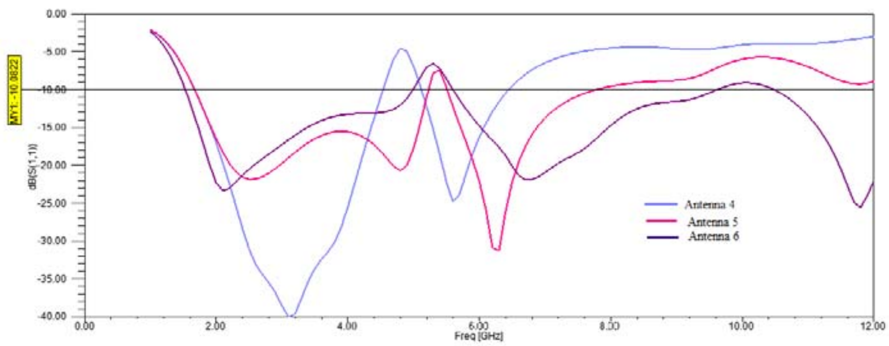

Figure-12. Reflection coefficient of antenna models 4, 5 and 6.

Figures 14 and 15 shows the gain and directivity plots of the modified notch antennas. At notch band frequencies we can observe the reduction in gain and directivity from these Figures. Figure-16 shows the axial ratio versus frequency plot of the notch band antennas. Except at notch band, at other operating bands antenna models are providing 3 dB axial ratio.

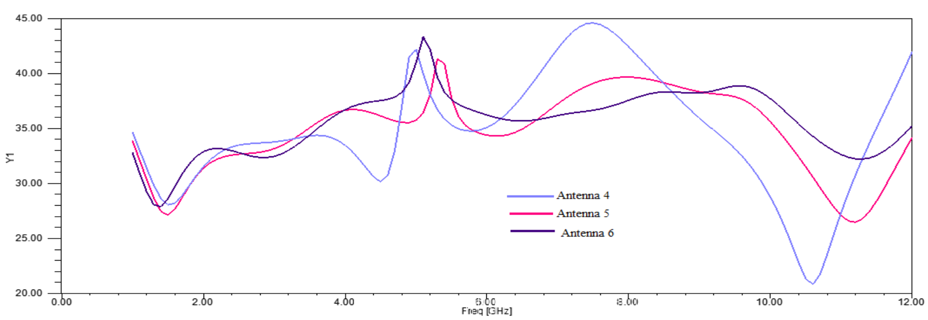

Figure-13. Impedance Vs Frequency of antenna models 4, 5 and 6.

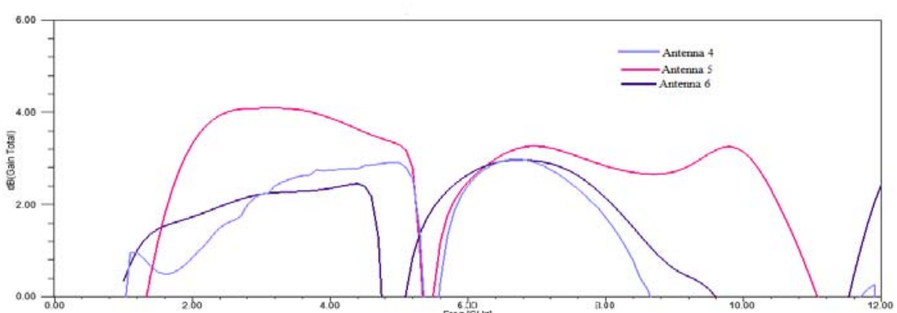

Figure-14. Gain of antenna models 4, 5 and 6 with respect to resonant frequency.

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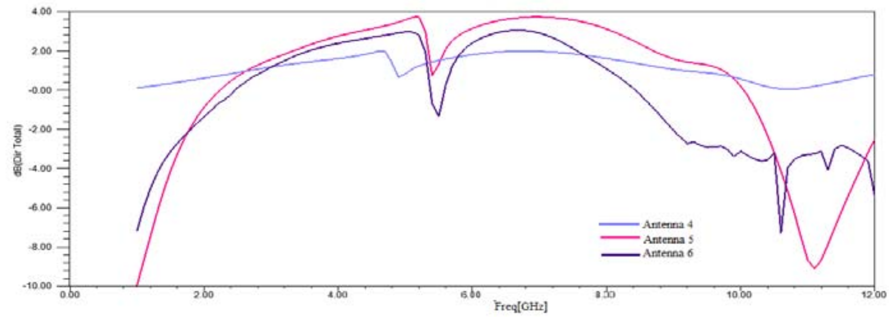

Figure-15. Directivity of antenna models 4, 5 and 6 with respect to resonant frequency.

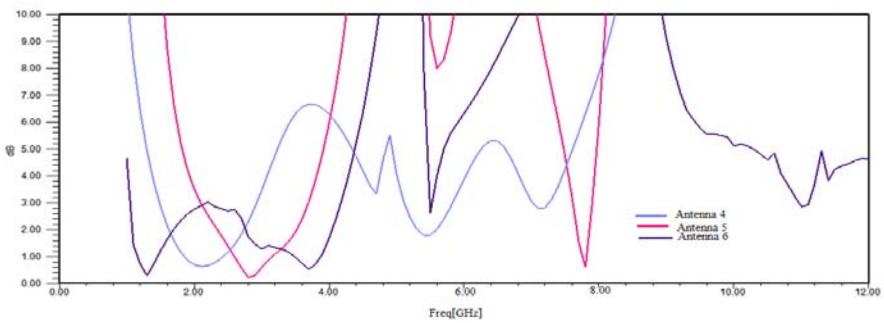

Figure-16. Axial ratio of antenna models 4, 5 and 6 with respect to resonant frequency.

The radiation characteristics of these notch band antennas can be observed from the Figure-17 and current distribution plots from Figure-23.

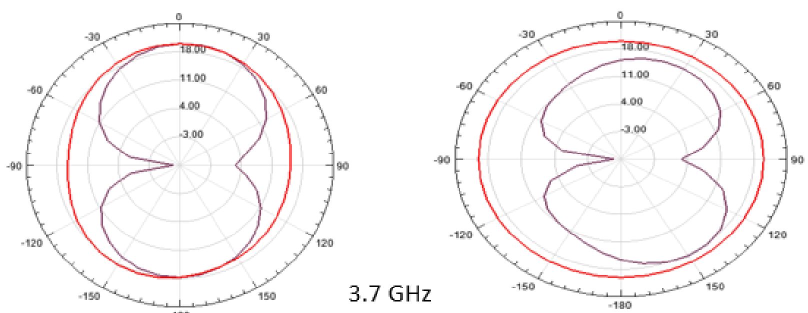

Figure-17. Radiation pattern of antenna model 4 at 3.7 GHz.

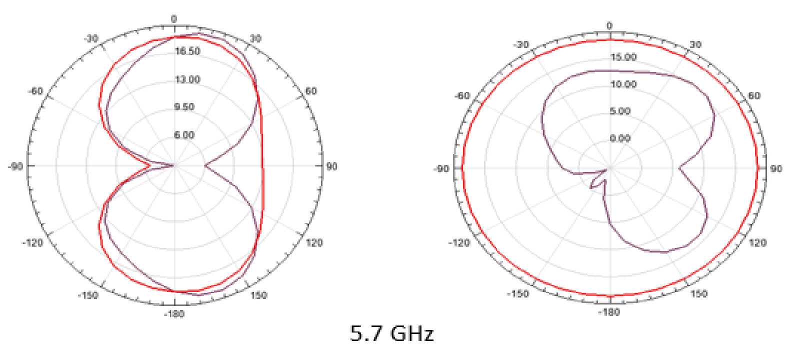

Figure-18. Radiation pattern of antenna model 4 at 5.7 GHz.

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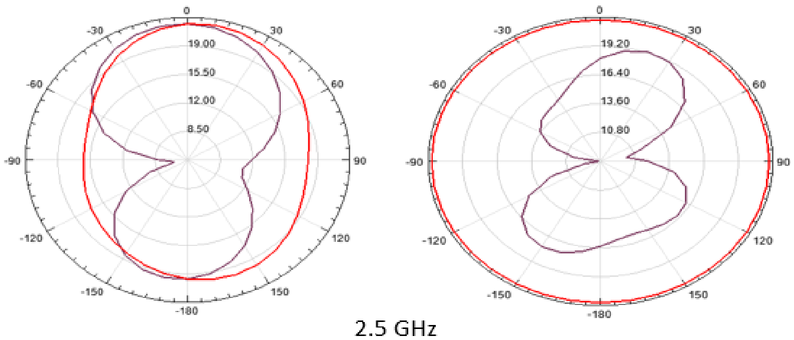

Figure-19. Radiation pattern of antenna model 5 at 2.5 GHz.

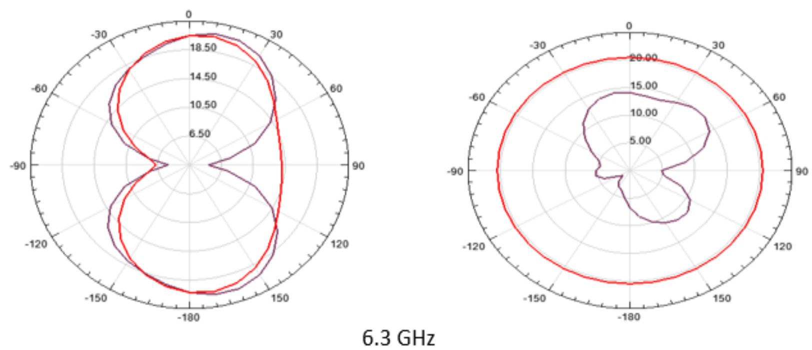

Figure-20. Radiation pattern of antenna model 5 at 6.3 GHz.

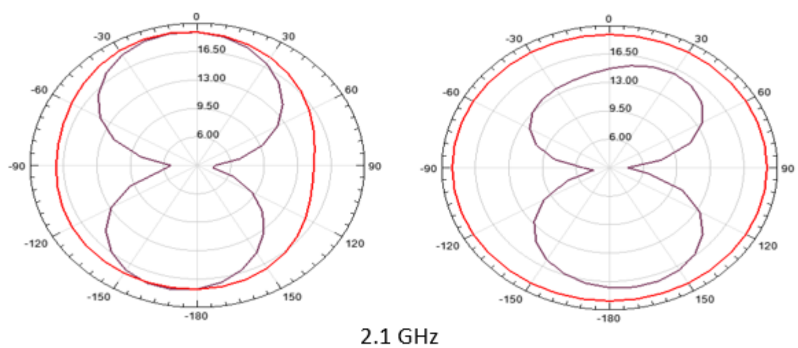

Figure-21. Radiation pattern of antenna model 6 at 2.1 GHz.

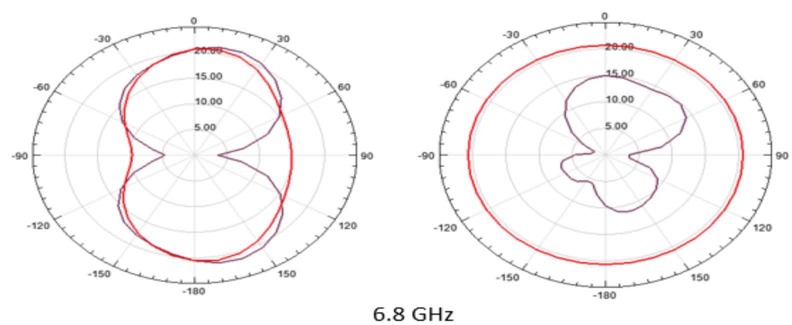

Figure-22. Radiation pattern of antenna model 6 at 6.8 GHz.

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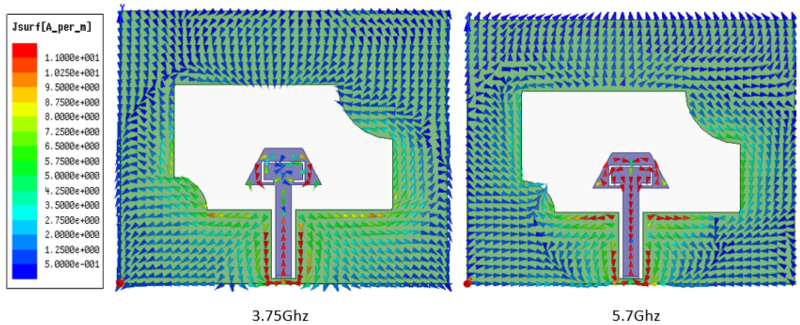

Figure-23. Current distribution of antenna model 4 at 3.7 and 5.7 GHz.

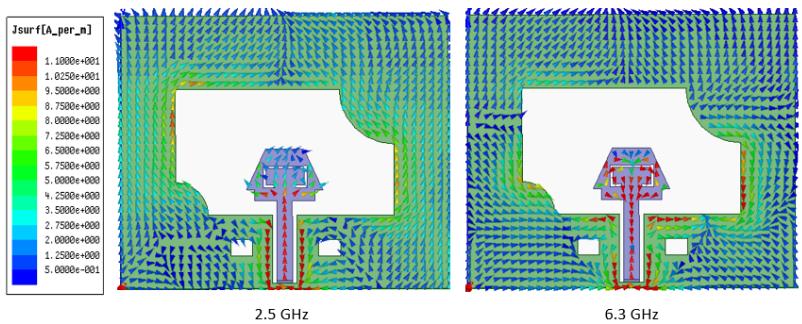

Figure-24. Current distribution of antenna model 5 at 2.5 and 6.3 GHz.

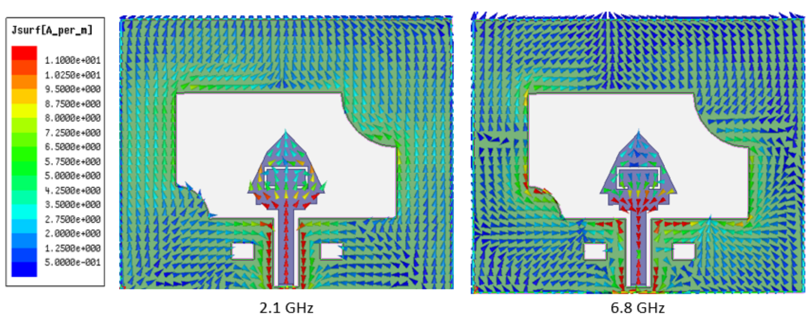

Figure-25. Current distribution of antenna model 6 at 2.1 and 6.8 GHz.

Figure-26. Fabricated antenna, (a) Prototype on FR4 Substrate, (b) Measured results of S11 on ZNB 20 VNA.

CONCLUSIONS

A circularly polarized notch band antenna is designed with defected ground structure in this work. Basic trapezoidal shaped monopole is modified with stepped stub and all the iterations are analyzed with respect to reflection coefficient, gain and radiation patterns. The modified structure of trapezoidal monopole with split ring resonator is tested for notching characteristics and circular polarization. The proposed optimized antenna model is fabricated on FR4 substrate and tested for reliability on ZNB 20 vector network analyzer. Measured reflection coefficient is showing bandwidth of 3.8 GHz at first resonant band and 4 GHz at second resonant band. The measured results are in very good agreement with simulated results taken from HFSS.

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