

**CIRCULARLY POLARIZED MRPA WITH DEFECTED GROUND
STRUCTURE FOR S-BAND & C-BAND APPLICATIONS**P. Ram Prasad¹, P. Poorna Priya²¹Department of ECE & Dadi Institute of Engineering & Technology, ramprasad@diet.edu.in²Department ECE & Dadi Institute of Engineering & Technology, ppriya@diet.edu.in

Abstract— *The endeavour presents the microstrip rectangular patch antenna for S –band and C – band applications. In order to achieve the circular polarization, defected ground base structure has been incorporated in the design. By employing iterations in the coplanar structure of the antenna, parameters like gain, directivity, reflection coefficient are observed. The antenna is simulated using FR4 Epoxy as a substrate material with a dielectric constant of 4.4. Entire design process has been done using the HFSS.*

Keywords — *Circular polarization, defected ground structure, FR4 Epoxy, HFSS, Microstrip rectangular patch antenna.*

I. INTRODUCTION

Antenna engineering, being an important part of the emerging wireless technology, has enjoyed a very successful period during the 1940s-1990s. Responsible for its success have been the introduction and technological advances of some new elements of radiation, such as aperture antennas, reflectors, frequency independent antennas, and microstrip antennas. The antenna engineering area has been made more interesting by advancement of low frequency and high frequency asymptotic methods which have been instrumental in analysing many problems that were hard to analyse in the past. However, there remain some problems and challenges in the antenna engineering field.

Microstrip patch antenna consists of a conducting metallic patch placed over a grounded substrate. In aircraft, satellite and missile applications where size, weight; cost, performances are constraints, and low profile antennas may be required. To meet these requirements micro strip antennas may be used. These are low profile, conformable to any type of surface and easy to manufacture and install. Few disadvantages of patch antennas are low efficiency, low power and narrow frequency bandwidth. Hence, these can be used only in applications which require narrow bandwidth [1]. Microstrip antennas are an extension of microwave circuits, this feature has given rise to microstrip integrates active antennas in which circuit functions are integrated with the antenna function to produce compact transceivers and in spatial power combiners to overcome power limitations of solid-state devices. Many of the antenna applications for satellite links, mobile communications, dual-frequency operation, frequency agility, polarization control, radiation pattern control and so on. These functions can be achieved by suitably loading simple microstrip antennas, and hence these antennas are becoming more commonly used.

The basic operating principle of a patch antenna is that the space between the patch and ground plane acts like a section of parallel plate waveguide. Neglecting radiation loss, the edge of the patch is an open circuit, so that energy reflects and remains below the patch [2]. The patch antenna is therefore a resonant cavity with relatively high quality factor. One disadvantage of a high-Q system is narrow bandwidth, so patch antennas have limited bandwidth, meaning that the input impedance of the antenna only remains near the desired value for a small range around the designed center frequency.

II. DEFECTED GROUND STRUCTURE

The defected ground structure (DGS) and the Electromagnetic band gap structures (PBG) are the two different types of the generic structures mostly used for the design of compact and high performance microwave components [3]. These structures are employed to reject unwanted frequency and circuit size reduction. DGS is an etched lattice of certain shape located on the ground plane. The performance of microstrip antennas and their array can be enhanced by introducing the defects in the ground plane. The shape of the defect may be changed from the simple shape to the complicated shape for better performance [4]. The DGS equivalent circuit consists of a parallel tuned circuit in series with the transmission line. The different shapes of DGS structure have the same role and same characteristics of slow wave effect and high impedance, band rejection, miniaturization of size with the same equivalent circuit. However to improve the circuit performance of antenna the shape of DGS can be further change or modified. In this work we have employed DGS in metallic ground plane for antenna miniaturization. When DGS is introduced in a microstrip antenna, the defect geometry etched in the ground plane disturbs its current distribution. In other words, introducing DGS in a microstrip antenna can result in an increase of the effective capacitance and inductance which influences the input impedance and current flow of the antenna thus reducing its size with respect to a given resonance frequency.

III. ANTENNA MODEL

The design procedure of microstrip patch antenna has been carried out by using the transmission line model equations. These equations are finite time domain analysis. Knowing the value of relative permittivity of the substrate material is the key for the calculation of dimensions of the antenna.

$$f_r = \frac{1}{2L\sqrt{\epsilon_{\text{reff}} \mu_o \epsilon_o}} \quad (1)$$

$$W = \frac{\lambda_0}{2} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (2)$$

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-1/2} \quad (3)$$

$$L = \frac{1}{2 f_r \sqrt{\epsilon_{\text{reff}} \mu_o \epsilon_o}} - 2\Delta L \quad (4)$$

Slot parameter is given by the following equation $\text{Sper} = 2L + 2W - 2R_1 - 2R_2 + \pi/2 (R_1 + R_2)$, Where f_r is the resonant frequency, W is the width of the patch, L is the effective length of the patch. Fringing effect should be taken into consideration to determine the actual length of the antenna [5]. Circular polarization of an antenna can be achieved by either adding the varactor diode, or by introducing slots on the ground plane. Here in this design the slots are imprinted on the coplanar ground structure making it as a defected ground base structure. Generally the slots can be of any arbitrary shape. Two trapezoidal slots of 7mm and 14mm were made. In order to maintain the perfect impedance matching, stubs are also added in the design. Rectangular slot of width 40mm and length of 23mm is made on the ground. Stub and ground plane are separated by a reasonably gap of 3.68mm, similarly the feed line and ground plane are separated by 0.85mm

TABLE I
 DIMENSIONS OF THE MRPA WITH DGS

S. No	All dimensions are in millimetres		
	Parameter	Definition	Dimension in mm
1	Wg	Width of the Ground	60
2	Lg	Length of Ground	50
3	W	Width of Rectangular slot	40
4	L	Length of Rectangular slot	23
5	R1	Length of Lower truncation	6
6	R2	Length of Upper Truncation	10
7	Ls	Length of Substrate	7.5
8	L _f	Length of Feed Line	16.62
9	W _f	Width of Feed Line	2.8
10	S	Distance Between Stub and Ground Plane	3.68
11	G	Spacing Between Feed Line and Ground	0.85
12	W _{s1}	Width of Trapezoidal slot	7

The following figures depict the circularly polarized microstrip patch antenna with defected ground structure. It is a coplanar structure which means ground; substrate and patch are located on the same plane. Fig. 1 shows the microstrip patch antenna two truncations namely R1 and R2. Fig. 2 shows the MRPA with single trapezoidal slot whereas the Fig. 3 displays the MRPA with dual trapezoidal slots with appropriate dimensions.

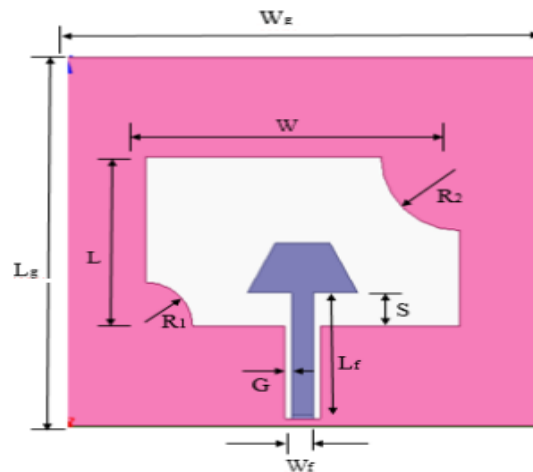


Fig.1 MRPA with defected ground structure

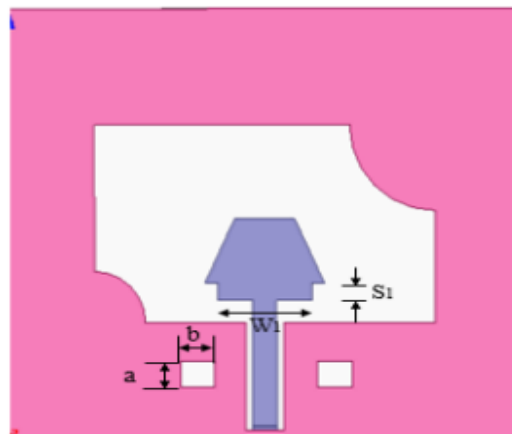


Fig.2 Antenna structure with single trapezoidal slot

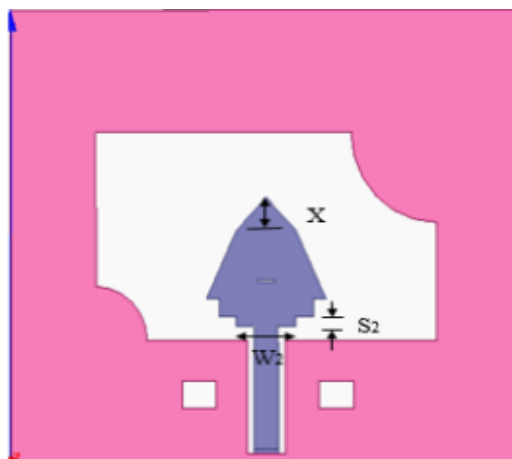


Fig.3 Antenna structure with dual trapezoidal slot

IV. RESULTS AND ANALYSIS

Fig. 4 shows the reflection coefficient of the antenna iterations shown in Figure 5.1. Antenna model 1 is giving a bandwidth of 4.3GHz and antenna model 2 is giving the bandwidth of 4.7 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, additional changes are incorporated in the patch element by taking tapered step structure. Antenna model 3 is providing bandwidth enhancement of 6.34 GHz which is almost double to the basic antenna model 1. The antenna shows the maximum S_{11} at 2.5GHz with -49db. The antenna provides maximum bandwidth which is suitable many wireless applications.

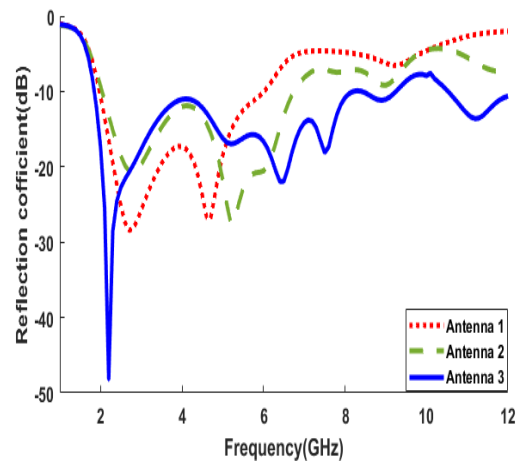


Fig.4 Reflection coefficient of antenna models 1, 2 and 3

An impedance bandwidth of 127% is attained from the modified structure of antenna model 3. Figure 5.3 shows the impedance characteristics of the antenna models in Fig 5. The impedance characteristics of the antenna is observed at the resonating frequencies with minimum values at resonating frequencies the impedance curves touch the 50Ω at resonating frequencies. All the models are showing an average impedance of 50Ω .

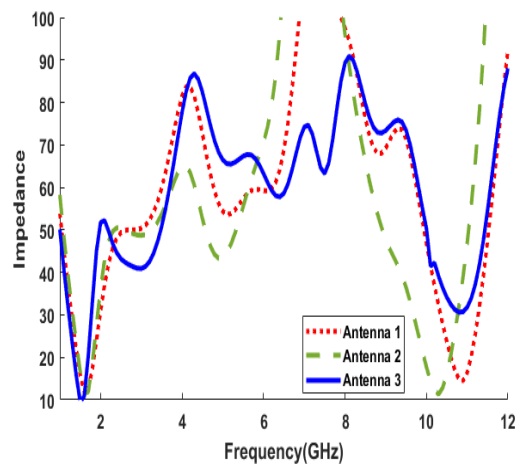


Fig.5 Impedance vs frequency of antenna models 1, 2 and 3

Fig. 6 shows the gain characteristics of the designed antenna models with respect to operating frequency band. Model 1 is showing peak realized gain of 5.6dBi whereas model 2 is showing 5.4dB and the modified model 3 is providing the peak gain of 6.2 dB. The peak gain variation of the antenna is ranging from 4-6.4dBi.

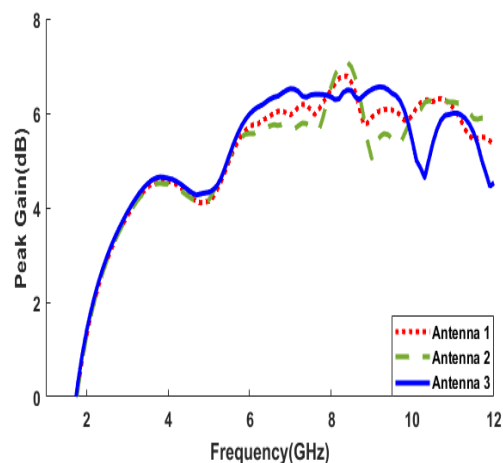


Fig.6 Peak gain of antenna models 1, 2 and 3 with respect to resonant frequency

Fig. 7 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.

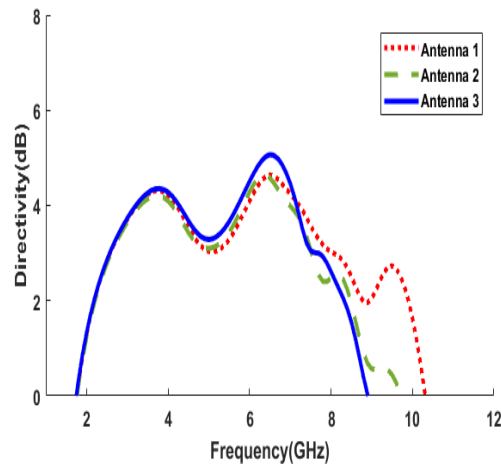


Fig.7 Directivity of antenna models 1, 2 and 3 with respect to resonant frequency

The circular polarization characteristics of the designed models can be observed through axial ratio curve. In the operating band of this antenna models only at certain frequency bands, the designed antennas are showing circular polarization characteristics of 3 dB cut off circular polarization characteristics at certain frequency bands can be observed from Fig. 8. For the antenna model 1 antenna has resonating peaks of axial ratio in operating bands. As the model 1 operating in the 1.9-6.2GHz but the axial ratio 3dB less is observed at 4GHz only. Similarly, for the Antenna model 2 antennas operate from the 2-6.2GHz but 3dB less is observed at the 4.2GHz and 10.5GHz only. For the antenna model 3 antenna operates in multiple frequencies even the 3db axial ratio is covered by the antenna in multiple frequencies.

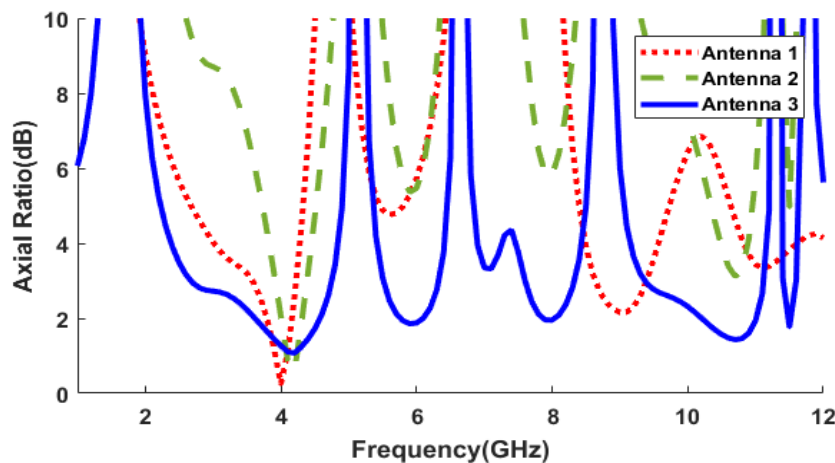


Fig.8 Axial ratio of antenna models 1, 2 and 3 with respect to resonant frequency

S. No	All dimensions are in millimetres					
	Iteration of antenna	Operating frequency	Fractional bandwidth %	Resonating frequency	Gain in dBi	Radiation efficiency
1	Antenna 1	1-9-6.21	106	2.7,4.7	5.6	93
2	Antenna 2	2.0-6.71	108	2.7,5.2	5.4	92
3	Antenna 3	1.8-8.14	127	2.1	6.2	95
		8.4-9.2	9	6.4	6.18	95
		9.8-12.1	105	7.5	6.17	94

V. CONCLUSIONS

A novel structure of trapezoidal monopole antenna with defected ground structure is designed in this work. After analysis, the characteristics of the proposed antenna are given as follows, obtained a -49dB return loss for the antenna with dual trapezoidal slots. The antenna provides maximum bandwidth which is suitable many wireless applications. All the designed models have a average impedance of 50ohms. The peak gain variation of the antenna is ranging from 4-6.4dBi. A peak directivity of 3.5dB is attained from model 2. All the three models exhibit multiple axial ratios in different frequency bands. The performance of the antenna can be still improved by incorporating complimentary split ring resonators in the substrate which can serves as the future scope of this work.

REFERENCES

- [1] Balanis, C.A. 2005, "Antenna Theory Analysis and Design", Textbook 3rd Edition. New Jersey : John Wiley and Sons.
- [2] K. Gi-Cho, et al., "Ku-band high efficiency antenna with corporate series-fed microstrip array", in Antennas and Propagation Society International Symposium. IEEE, 2003, pp. 690-693 vol.4, 2003.
- [3] D. M. Pozar, "Microstrip Antennas", Proceedings of the IEEE, Vol. 80, No. 1, 1992, pp. 79-81.
- [4] Brajraj Shrama, V Sharma, K B Sharma and D Bhatnagar, Broadband Semielliptical Patch Antenna with Semicircular Ring Slot for WiMax Application, Chinese Journal of Engineering, 2014, Article ID 379073.
- [5] Vijay Sharma and M M Sharma, Dual Band Circularly Polarized Modified Rectangular Patch Antenna for Wireless Communication, Radio Engineering, 2014, Vol. 23, No. 1, p. 195-202.