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Circularly Polarized Rectangular Microstrip Patch Antenna with Finite Ground Plane

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ABSTRACT

In this paper a new geometry of patch antenna is proposed with improved bandwidth and circular polarization. The radiation performance of circularly polarized rectangular patch antenna is investigated by applying IE3D simulation software and its performance is compared with that of conventional rectangular patch antenna. Finite Ground truncation technique is used to obtain the desired results. The simulated return loss, axial ratio and smith chart with frequency for the proposed antenna is reported in this paper. It is shown that by selecting suitable ground-plane dimensions, air gap and location of the slits, the impedance bandwidth can be enhanced upto 10.15 % as compared to conventional rectangular patch (4.24%) with an axial ratio bandwidth of 4.05%.

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1. INTRODUCTION

Microstrip antennas have become increasingly popular for microwave and millimeter wave applications, because they offer several advantages over conventional microwave antennas. These advantages include robust structure, easy to fabricate, small size, availability in various shapes, lightweight and conformability with the hosting surfaces of automobiles, aircraft, missiles and direct integration with the microelectronics [1, 2]. Microstrip Antenna consists of radiating conducting patch, a conducting ground plane, a dielectric substrate sandwiched between the two, and a feed connected to the patch through the substrate [3]. The miniaturizations in electronic designs have generated tremendous demand for compact and efficient antenna geometries. However, these types of antennas have several limitations like low gain, impurity in polarization, poor bandwidth and low radiation efficiency which cannot be ignored [4]. Among the conventional patch geometry rectangular and circular patches are widely used as its ease of design and its analysis. Usually the requirement for a compact antenna is associated with a reduction in ground plane size to the extent that antenna performance becomes strongly dependent on the ground plane dimensions and position. Its is already investigated in past that the grounded dielectric supports a finite number of surface wave modes (SWMs) which propagate in a direction parallel to the air-dielectric interface [5].

The effects of change in finite ground plane dimensions on antenna impedance have been investigated and several techniques to enhance bandwidth and achieve dual polarization is reported [6, 7]. The effect of different shapes of ground structure on polarization and cross polarization radiation is also investigated in past [8, 9].

In this communication, we present novel patch antenna geometry for achieving circular polarization and improvement in bandwidth by truncating the dimensions of finite ground plane and additions of slits in patch geometry. We have used Method of Moments (MOM) for the analysis of proposed antenna although some other methods such as transmission line model, cavity model, Spectral Domain Full Wave Analysis, Mixed Potential Integral Equation Analysis, Finite-Difference Time-Domain Analysis (FDTD), Finite Element Method (FEM) etc. exist. Results show that by selecting suitable ground-plane dimensions and location slits, the impedance bandwidth can be enhanced upto 10.15% and axial ratio bandwidth of 4.05% can be achieved.

The rest of the paper is organized as follows. In section II the proposed antenna geometry is discussed. Simulation results have been discussed in section III. The conclusions are given in section IV.

2. RESEARCH METHOD

Patch antennas having rectangular, circular or their minor variations, are generally used. A conventional rectangular patch is shown in figure 1. The conventional patch is modified by introduction of slits at 45^0 along the edges and at the center of the patch. An air stacking of 0.8 mm is also added between the patch and ground plane the modified structure is shown in figure 2.
Here conventional rectangular patch antenna is considered the reference antenna to compare the results of that simulated from modified proposed geometry.

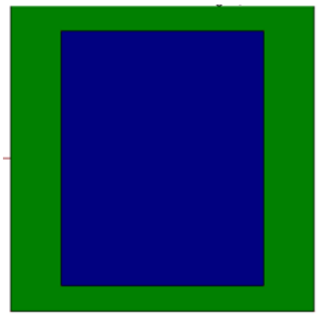

Figure 1. Conventional rectangular microstrip patch antenna

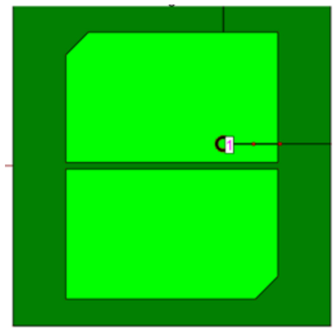

Figure 2. Proposed modified geometry of rectangular microstrip patch antenna

The patch has dimensions as 20×25mm and finite ground dimension as 30×30mm. A 50Ω coaxial probe is used to connect the microstrip patch at coordinates and it is made fixed for both the conventional and modified geometry.

The dimensions of the modified patch as 20×25mm and finite ground dimension as 30×30mm. The patch was loaded with slits of 5× 5mm at the two diagonal corner of the proposed patch with 45^0 degree elevation. A slit of L=20 mm and W=0.6 mm is also introduced at the center of the patch.

The proposed geometry is designed on glass epoxy FR4 substrate having thickness h=1.59 mm, substrate dielectric constant ε_r=4.4, substrate loss tangent tanδ= 0.024, and relative permeability μ_r=1 with an air-gap of 0.8 mm. Circular polarization with simple topology and improvement in the other antenna radiation parameters are the main advantages of this geometry. Many simulations are done for optimizing the length; width and location of the slits and best results are obtained with defined length and width of the slot. Due to existence of the slot, the current distribution changes and another mode is excited. Each mode has its own cut-off frequency and thus the modified geometry has a new resonant frequency which is different from the conventional patch resonant frequency.

3. RESULTS AND ANALYSIS

The simulation results of conventional rectangular patch and modified proposed geometry are obtained using IE3D Software [10].

Radiation Pattern: A plot through which it is visualizes where the antenna transmits or receives power. The microstrip antenna radiates normal to its patch surface. So, the elevation pattern for φ= 0 and φ= 90 degrees are important for the simulation.

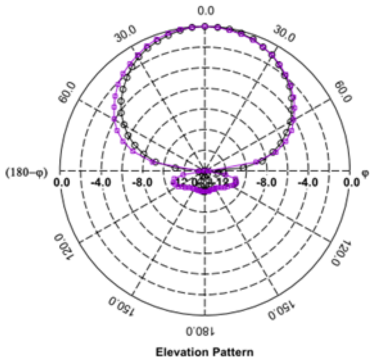

Figure 3. Computed 2D Radiation Pattern for the conventional geometry

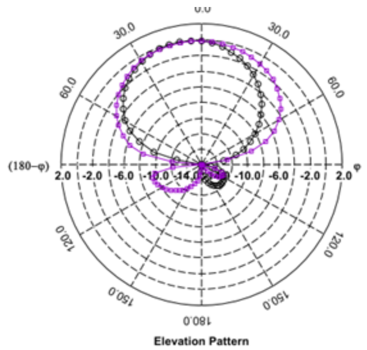

Figure 4. Computed 2D Radiation Pattern for the proposed modified geometry

The simulated E-plane pattern i.e. the 2D pattern-view of the geometries are illustrated in Figure 3 and 4. Radiation pattern are smooth and uniform over the band of frequencies.

Return Loss and Bandwidth: Return Loss is a measure of how much power is delivered from the source to a load and is measured by S_{11} parameters. The range of frequencies over which the antenna can operate effectively is characterized by Bandwidth. It can be calculated by going 10 dB down in return loss.

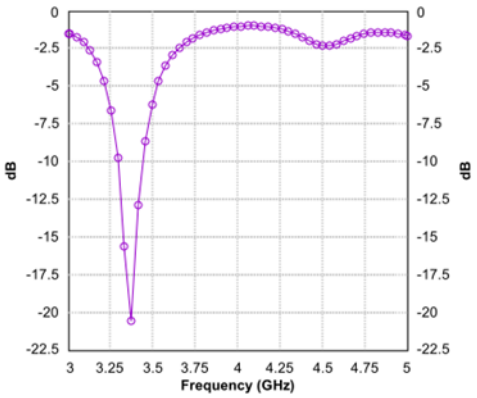

Figure 5. Computed variation of return loss with frequency for conventional geometry

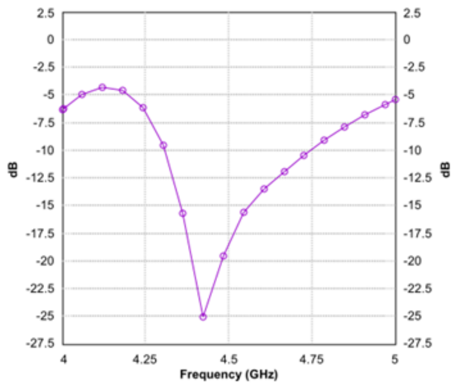

Figure 6. Computed variation of return loss with frequency for modified proposed geometry

Return Loss shown in Figure 5 of the conventional rectangular patch antenna is -20.85 dB at resonating frequency of 3.37 GHz and the bandwidth obtained is 4.24%.

Return Loss shown in Fig. 6 of the modified rectangular patch antenna is -25.12 dB at resonating frequency of 4.42 GHz and the bandwidth obtained is 10.15%.

Smith Chart*:* Smith Chart provides the information about the polarization and the impedance-matching of the radiating patch. The smith chart for the conventional antenna is given in Figure 7.

Simulated input impedance matching data of the design is shown by smith chart in Figure 7 and 8. From this, the circle passes through the centre of the smith chart represents the impedance match of (41.4+j0.77) ohm for conventional patch as shown in Figure 7 and (51.3-j5.49) ohm for modified geometry as shown in Figure 8 with the coaxial transmission line and it shows that modified geometry has better impedance matching than conventional patch.

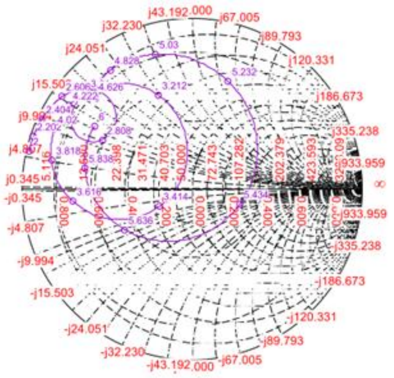

Figure 7. Variation of input impedance with frequency for conventional geometry

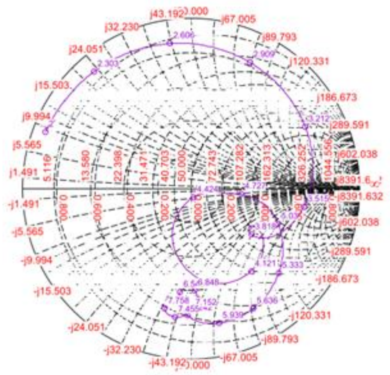

Figure 8. Variation of input impedance with frequency for modified geometry

Axial Ratio: This is related with quality of circular polarization of an antenna and axial ratio bandwidth is obtained by calculating the range of frequencies falling between 0 dB to 3 dB.

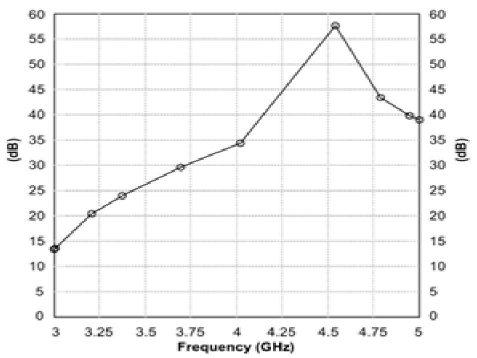

Figure 9. Variation of axial ratio with frequency for conventional geometry

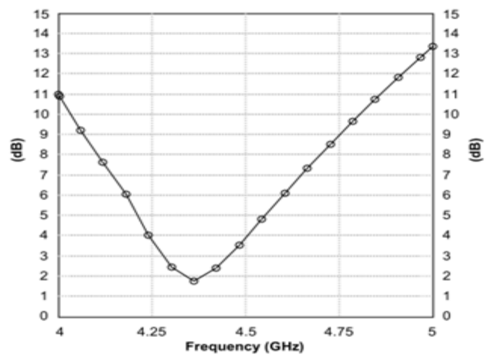

Figure 10. Variation of axial ratio with frequency for modified proposed geometry

Table 1. Comparison of conventional and modified geometry

Sr. No.	Parameters	Conventional Patch	Modified Patch
1.	Resonant Frequency (GHz)	3.37	4.42
2.	Return loss (dB)	-20.85	-25.12
3.	Bandwidth (%)	4.24	10.15
4.	Axial Ratio (dB)	23.97	1.77 (4.05% Axial-Ratio BW)

The axial ratio observed for the conventional geometry clearly shows that the conventional geometry is not circularly polarized with axial ratio as 23.97 dB at resonant frequency.

The axial ratio observed for the modified geometry clearly shows that it is circularly polarized with axial ratio as 1.77 dB at resonant frequency and axial ratio bandwidth of 4.05%.

4. CONCLUSION

This paper presents the radiation performance of circularly polarized rectangular microstrip patch antenna. The performance of proposed geometry has been compared with conventional geometry. Simulated results indicate that the antenna exhibits axial ratio bandwidth upto 4.05% by optimizing the length, width of slits and air gap in proposed antenna geometry. There is also improvement in bandwidth upto 10.15%. The radiation pattern is found to be stable over the entire bandwidth. Finally, we found the proposed geometry to be circularly polarized which is a great advantage in modern communication system.

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