RESEARCH ARTICLE OPEN ACCESS

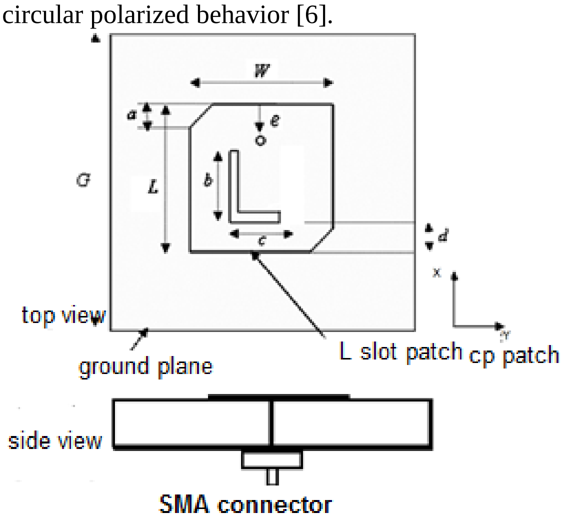
A Wideband Single Fed L Slot Circularly Polarized Antenna

Nisha,Meenakshi saini,Ms. Susila chahar
M.Tech. Student, Dept. of Electronics & Communication, JNIT Jaipur,
M.Tech., Dept. of Electronics & Communication, NIET, Greater Noida,
Assistant Professor, Dept. of Electronics & Communication, JNIT Jaipur

Abstract
A single-fed circularly polarized (CP) patch antenna is designed and built using L-slot loaded patch technique. The antenna is designed on a high dielectric constant (εr = 10.02) substrate which achieves a reasonable bandwidth and axial ratio bandwidth with respect to a U slot antenna. At the operating frequency of 1.575 GHz with the size of the patch is 25mm X 25mm, while ground plane of 60mm X 60mm and the thickness of the substrate is 9.12mm. Bandwidth is enhanced to 18.42% and Axial Ratio Bandwidth by 4% by this design. The other Parameters of antenna like return loss and radiation pattern are also analyzed using HFSS software.
Key Words— Circularly polarized (CP), patch antenna, L-slot

I. INTRODUCTION

Microstrip Patch Antenna (MSA) has several advantages such as simple structure, low profile, and low cost, it is often used in various applications. One of the disadvantages of the traditional MSA is its poor impedance-bandwidth. As the bandwidth enhancement techniques for the MSA, the MSAs with parasitic elements, and the L-shaped probe-fed MSA are well known [1]. With the rapid development of the satellite communication and positioning system, more and more consideration has been paid to circularly polarized (CP) antennas. The Global Positioning Satellite (GPS) system operates at 1575 and/or 1227 MHz with RHCP signals [2]. . Circularly polarized antenna is well-known for its feature of relative insensitivity to transmitter and receiver orientations. CP radiation is generated when two degenerate orthogonal linearly polarized modes, of equal amplitude and 90 phase difference are independently attractive Patch antenna is one attractive candidate for Parameter producing circular polarization owning to its characteristics of wide bandwidth, high gain, low profile and low cost. For a single feed patch antenna, truncating a pair of corners and cutting a diagonal slot are two conventional ways to generate CP radiation. However, narrow axial ratio bandwidths of less than 1% are normally obtained. To enhance the CP bandwidth, some techniques, such as a probe-fed corner truncated patch with L-shaped slot with ground plane, a meandering p robe truncated corners stacked patch antenna, and L-shaped probe-fed patch antenna with a cross slot were proposed respectively[3]. If the patch shape is like the square or the circle, the bandwidth is the same and proportional to its size. The deviations start when the shape changes drastically and becomes a narrow or wide rectangle. If the radiation edge becomes narrow, decreases the radiation loss and increases the antenna Q, reducing the bandwidth. For a patch with a large radiating edge, the reverse is true [4]. In general, the advantages and drawbacks of patch antennas with high permittivity substrate are a controversial problem and some interesting results. In this paper we have performed an exploration on patch antennas built on a high permittivity substrate [5]. To obtain the high bandwidth a fork-like L-probe is used. The dimension of the patch as well as the position of the probe feed is optimized leading to a wideband circular polarized behavior [6].



Parameter	a	b	c	d	e	h	G	L	W	ε_r
Unit(mm)	6	10	10	7	2	9.12	60	25	25	10.02

Fig. 1 Geometry of the antenna

II. ANTENNA GEOMETRY AND DESIGN

The antenna geometry is shown in Fig. 1. This antenna is designed to operate at around 1.575

GHz. The truncated square patch of length and width is printed on a microwave substrate (with dielectric constant 10.02) for exciting two orthogonal modes for CP radiation. A L-shaped slot (with 1-mm width) is cut in the truncated patch. The function of the L-slot is to introduce a capacitance that can suppress the inductance due to the vertical feeding probe so as to enhance the impedance bandwidth. The feeding probe is connected to an SMA launcher that is mounted underneath the ground plane. As discussed, L-slot enables the use of thicker substrates to obtain larger impedance bandwidth. The total height of the dielectric is 9.12 mm, and the dielectric is made up of six layers of thin substrates. Designing and simulation is performed by using high frequency simulation software (HFSS).

III. RESULTS

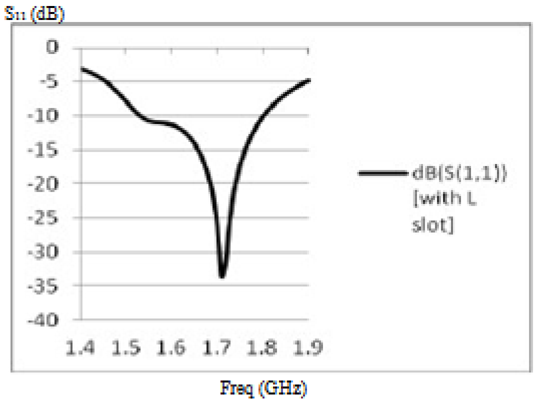
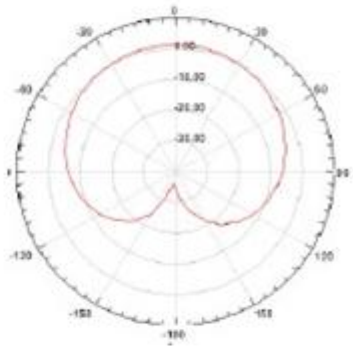


Fig. 2 Return loss



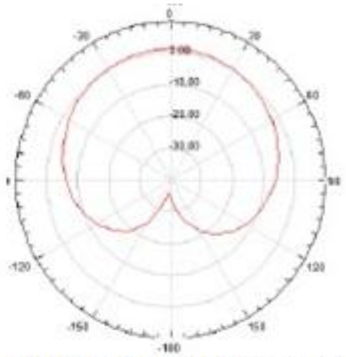


Fig.3 LHCP Radiation pattern at 1.575 GHz (□=90o, 0o)

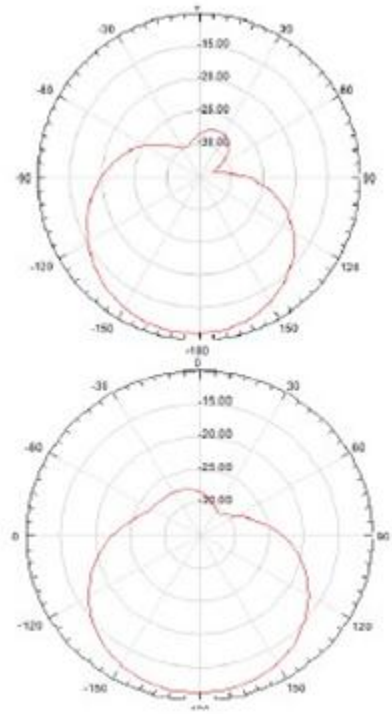


Fig. 4 RHCP Radiation pattern at 1.575 GHz (ɸ=90o, 0o)

The measured return loss is shown in Fig.2.The impedance bandwidth is 18.5% with 10 dB between 1.52–1.80 GHz. Fig. 3 and Fig. 4 show the measured radiation patterns at 1.575 GHz. The 3-dB beam widths are 92 and 90 in ɸ=900 and ɸ=00 planes respectively. It can be observed that in the plane, the cross polarization is 25 dB below the co polarization above the ground plane. In the plane, it is 25 dB below the co polarization. Referring to the operating frequency of 1.575 GHz, the patch dimensions are about 25X25 square patches and the substrate thickness is about 9.12mm. For real application of GPS, the receiving antenna should be designed as a right- hand circularly polarized (RHCP) antenna. In this design, it is easy to adjust the antenna with RHCP operation by changing the truncated corner of the patch to another diagonal axis.

IV. SIMULATION

This simulation is carried out by using an electromagnetic (EM) commercial software tool, HFSS. For small antenna design, the size of the ground plane is a very important parameter to be considered. In this section, a study for an impedance bandwidth response with different ground plane sizes is carried out. (For this simulation, the size of the ground plane is equal to the substrate size). The square-shaped ground plane with a length varied from 40 to 60 mm is investigated.

Fig. 5 depicts the return loss responses for the L-slot CP antenna with different ground plane sizes. The result indicates that when the size of the ground plane is too small, the impedance bandwidth of this antenna would significantly reduce. When Ground plane is 60 mm the impedance bandwidth is 18.5% whereas, the bandwidth decreases for 40 mm Ground plane. Fig. 6 illustrates responses of the AR with different ground plane sizes. When G=60 mm, the minimum value of the axial ratio for the antenna is maximum. However, if the ground plane size is reduced, the value of AR is deteriorated. For the antenna gain, a smaller ground plane size would also cause the decrease in gain. Since L-slot loaded technique is employed for improving the bandwidth performance for a small CP antenna, a study of changing the values of L-slot parameters are carried out to show the effect of the L-slot in the CP antenna. Two parameters b and c are investigated.

Fig.7 shows the impedance bandwidth response with different and fixed b=10 mm. For this antenna, when the value of b is selected between 8–12 mm, the antenna has good and wide bandwidth characteristic. However, as b is increased (b>12) mm, the overall impedance bandwidth is deteriorated as considerable mismatch occurred.

Fig.8 shows the impedance bandwidth response with different c and fixed b=10 mm. The value of c is varied from 9 to 12 mm. It is observed that it cannot be either too small or large; otherwise the antenna would have a narrow impedance bandwidth.

Finally, a comparison for a CP antenna with-L/with U-slot is given in Table 1 and shown in Fig.9. The simulated return loss and axial ratio for CP antenna is measured and reported. It is observed that the presence of L-slot gave a significant bandwidth enhancement in the impedance bandwidth but only less improvement in the axial ratio bandwidth. However, since a thick substrate is employed in the proposed CP antenna, the absence of the L-slot would generate very high inductance from the feeding probe and would causes the impedance bandwidth and axial ratio bandwidth not to overlap. For a CP antenna, the usable bandwidth is the range of frequencies for s11≤10 dB. Therefore, if the patch antenna is designed using thick substrate material, the use of the L-slot loaded technique can provide bandwidth enhancement, but also ensure both axial ratio and impedance bandwidth to overlap.

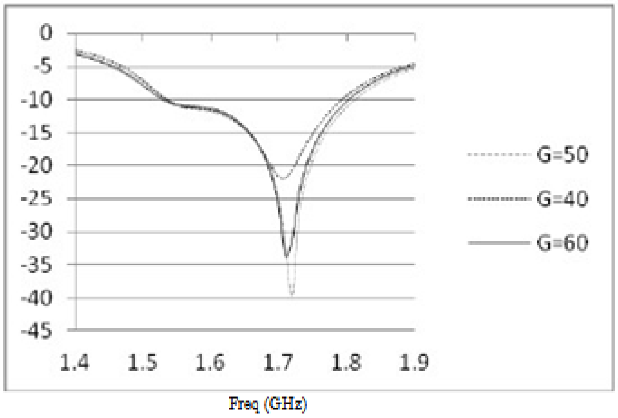


Fig.5 Return loss with different size of ground plane with L slot

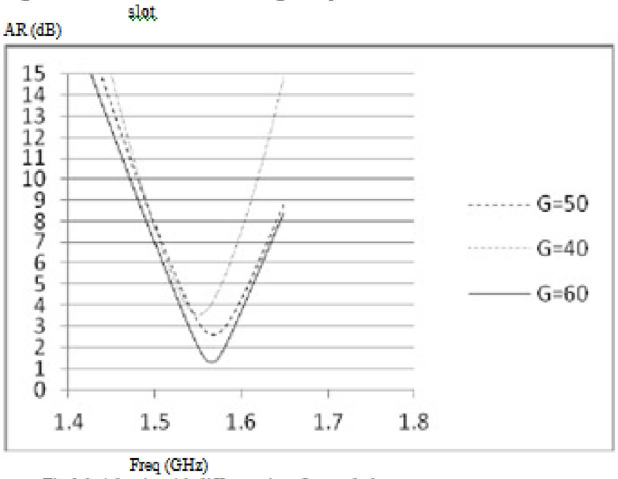


Fig.6 Axial ratio with different size of ground plane

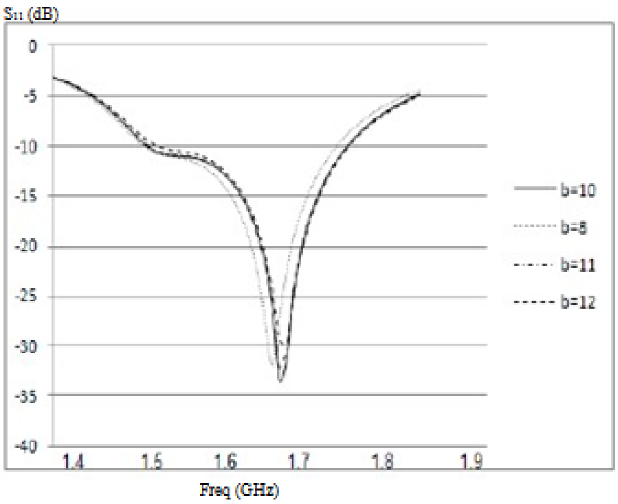
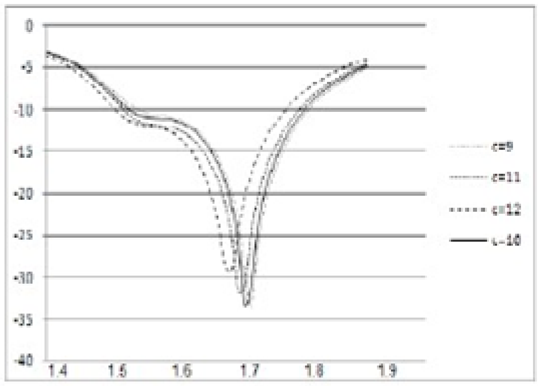


Fig. 7 Simulated Return loss with different size of b

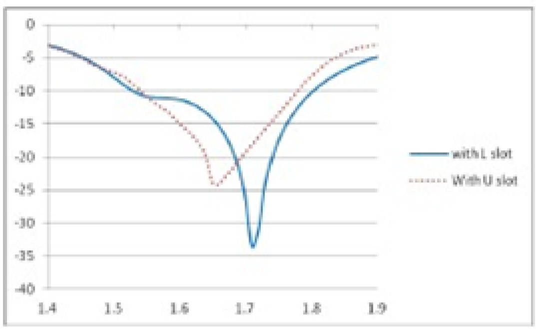
S_{11}(dB)



Freq (GHz)

Fig.8 Simulated return loss with different size of ground plane

S11 (dB)



Freq (GHz)

Fig.9 Comparison of return loss with different U/L slot

TABLE I. SUMMARY FOR SIMULATED IMPEDANCE BANDWIDTH AND AXIAL RATIO BANDWIDTH FOR CP ANTENNA WITH U SLOT AND L SLOT

CP Antenna	Imp. BW(S11 ≤-10dB)	AR BW(AR≤ 3dB)
With U Slot	15.11% 1.53GHz to 1.78 GHz	3.16% 1.56 GHz to 1.61 GHz
With L Slot	18.42% 1.52 GHz to 1.80 GHz	3.92% 1.53 GHz to 1.59 GHz

V. CONCLUSION

A miniature circularly polarized patch antenna has been designed which consists of one L-slot square patch with truncated corners supported by a substrate with dielectric constant of 10.02 for achieving small size. The operating frequency, square patch size, ground plane size and thickness of substrate are 1.575 GHz, 25X25, 60X60, 9.12mm successively. Measured results show that this single-feed CP patch antenna attains bandwidth of 18.5% in the frequency range 1.52–1.80 GHz and axial ratio ratio bandwidth is 3.92%, which is within the impedance bandwidth. This small antenna can be used for a number of wireless communication applications, including GPS receivers.

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