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A Comparative Analysis of a Single Feed Circularly Polarized Micro-strip Patch Antenna with U-Slot & L-Slot

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Abstract

This paper compares the different parameters for a single feed circularly polarized Micro-strip patch antenna with U-slot and L-slot. The proposed antenna 1 contains a U-Slot and designed with DGS technique to reduce the size of antenna and proposed antenna 2 contains a L-slot and designed with DGS technique to reduce the size of antenna. The antenna with L-slot is designed on a high dielectric constant (εr = 10.2) 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 50mm X 50mm and the thickness of the substrate is 10.2 mm. Bandwidth is enhanced to 19.99% and Axial Ratio Bandwidth by 3.5% by using L-slot as compared to U-slot. The parameters of antenna like return loss, axial ratio, RHCP and LHCP, gain are analyzed using CST MSW Software.

Keywords*: Circularly Polarized (CP), Defected Ground Structure (DGS), L-Slot, Patch Antenna, U-Slot.*

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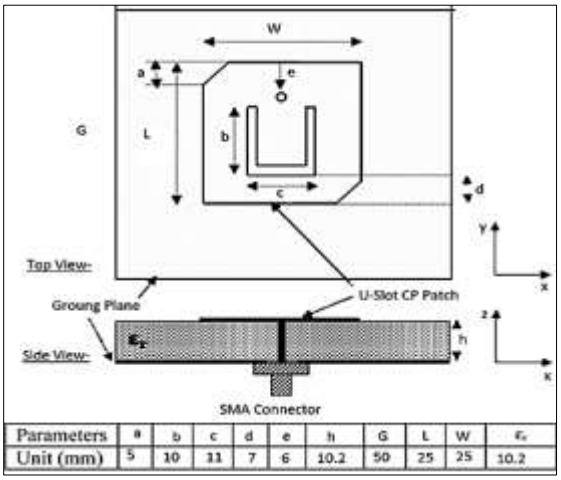
INTRODUCTION

Micro strip patch antennas have appreciated use in numerous circularly-polarized applications because their low-profile and useful radiation features. In the previous period, the growth of modern wireless systems has encouraged enlarged investigation on micro strip radiators, with specific consideration paid to refining recital and diminishment[1]. These U-slot antennas are simple in structure and are easy to fabricate. It was demonstrated that U-slot patch antennas with linear polarization have good electrical characteristics including wide bandwidth, high gain, and quite stable gain across the operating frequencies[2]. Recently, it was found that U-slot patch antennas can also be operated with circular polarization (CP).For example ,by cutting a symmetrical U-slot with equal arms in a square patch with truncated corners, an axial-ratio (AR) bandwidth of about 4% can be obtained[3]. To improve the CP bandwidth, several techniques, such as a probe-fed corner truncated patch with L-shaped slot with ground plane, a twisting p robe truncated corners stacked patch antenna, and L-shaped probe-fed patch antenna with a cross slot were proposed respectively[4].

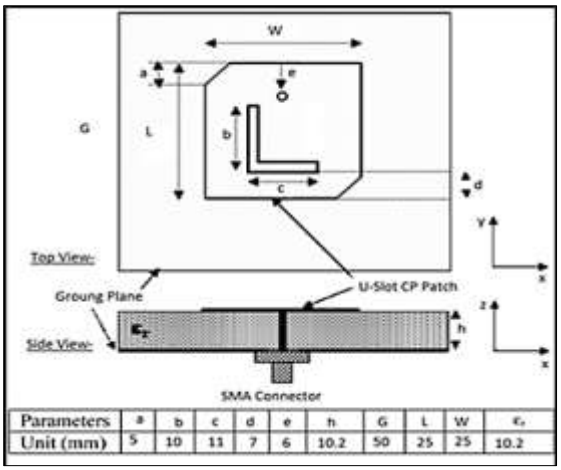
If the patch shape is like the square or the circle, the bandwidth is the same and proportional to its size. The deviations start when the shape changes radically and turns into a narrow or wide rectangle. If the radiation edge develops thin, reduces the radiation loss and upsurges the antenna Q, dropping the bandwidth. For a patch with a large radiating edge, the reverse is true[5]. 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[6].To obtain high bandwidth a U-Slot 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[7]. In this wideband CP slot antenna with L shaped is reformed from the design in[8] which have the asymmetric L-slot designed on square metallic layer. In our design a symmetric L-slot, this is designed on a metallic layer with truncated corner. A wider BW and more gain are achieved. As we know the antenna is characterized by its length, width, Input Impedance, gain and radiation pattern.



Parameters	a	b	c	d	e	h	G	L	W	ε_r
Unit (mm)	5	10	11	7	6	10.2	50	25	25	10.2

Fig. 1: *Geometry of Proposed U-Slot Patch Antenna.*



Parameters	a	b	c	d	e	h	G	L	W	ε_r
Unit (mm)	5	10	11	7	6	10.2	50	25	25	10.2

Fig. 2: *Geometry of Proposed L-Slot Patch Antenna.*

In this paper, we present the simulated results of a probe-fed CP patch antenna with U-shaped slot and L-shaped slot using high dielectric-constant material of relative permittivity 10.2. The square patch has truncated corners to generate CP radiation. It will be demonstrated that U-slot & L-slot CP patch antennas on high dielectric substrate has the attractiveness of small size and good axial-ratio bandwidth. This miniature CP antenna has many wireless communication applications.

ANTENNA GEOMETRY AND DESIGN

The geometry of proposed U-slot antenna is shown in Figure1 and geometry of proposed L-slot antenna is shown in Figure 2. This antenna is designed to operate at around 1.521 GHz. The truncated square patch of length L and width W is printed on a microwave substrate (with dielectric constant 10.2) for exciting two orthogonal modes for CP radiation.

A U-shaped slot (with 1 mm width) is cut in the truncated patch. The function of the U-slot is to introduce a capacitance that can suppress the inductance due to the vertical feeding probe so as to enhance the impedance and axial-ratio bandwidths. The feeding probe is connected to an SMA launcher that is mounted underneath the ground plane. As discussed in[10] ,the U-slot enables the use of thicker substrates to obtain larger impedance bandwidths. 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 which subdues the inductance owing to the vertical feeding probe so as to enhance the impedance bandwidth. As discussed, L-slot enables the use of thicker substrates to obtain larger impedance bandwidth. The total height of the dielectric is 10.2 mm, and the dielectric is made up of six layers of thin substrates. After optimizing the various antenna parameters with the help

of CST Transient solver, a prototype with the parameters listed in Figure 1 and 2 was designed and simulated.

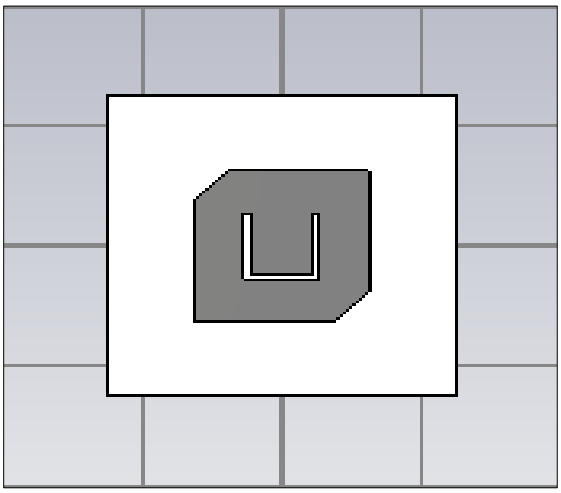


Fig. 3: *CST Design of Proposed U-Slot Patch Antenna for Circular Polarization.*

SIMULATED RESULTS

This simulation is carried out by using Transient solver method, CST MSW. For small antenna design, the size of the ground plane is a very important parameter to be considered. For this simulation, the size of the ground plane is equal to the substrate size. The square-shaped ground plane with a length G varied from 40 to 50 mm is investigated. The simulation of circularly polarized U-Slot & L-slot Patch antenna with dielectric constant 10.2 and height of substrate 10.2 mm are used in design. The results obtain after the simulation (CST software[13] of Circularly Polarized U-Slot & L-Slot Patch Antenna are shown in Figure 5 and 6 respectively.

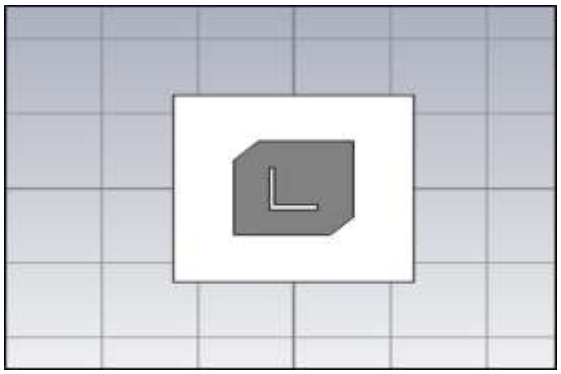


Fig. 4: *CST Design of Proposed L-Slot Patch Antenna for Circular Polarization.*

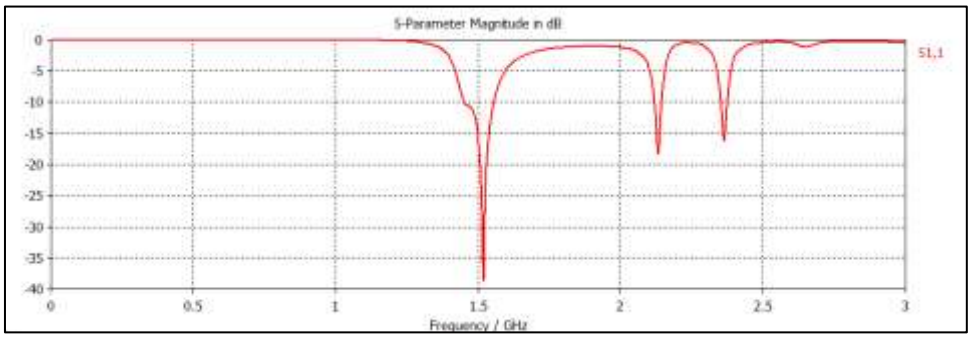


Fig. 5: *Graph of S11 with U-Slot.*

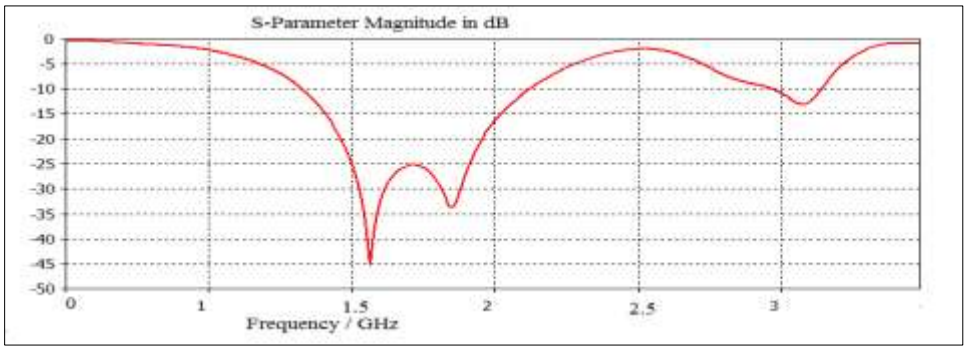


Fig. 6: *Graph of S11 with L-Slot.*

The graph shown in figure 5 shows the cut off frequency at 1.521 GHz. The return loss at cut off frequency is 38.6 db. The graph shown in Figure 6 shows the return loss at cut off frequency of L-slot antenna. Figure 7 shows the Axial Ratio at cut off frequency of U-Slot antenna and Figure 8 shows the Axial Ratio at cutoff frequency of L-slot antenna. The Axial Ratio of L-slot at 1.521 GHz is obtained 1.021 dB and the Axial Ratio of U-slot at 1.521 GHz is 1.35224 dB.

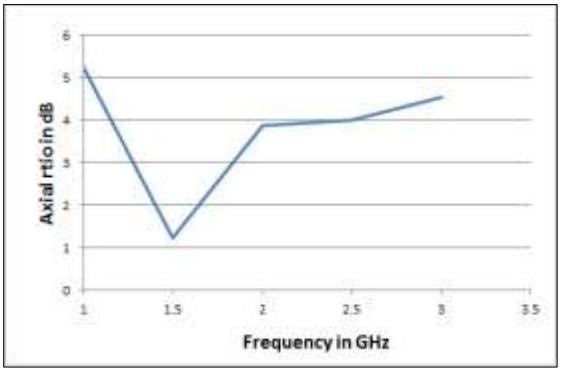


***Fig. 7**: Graph of Axial Ratio with U-Slot.*

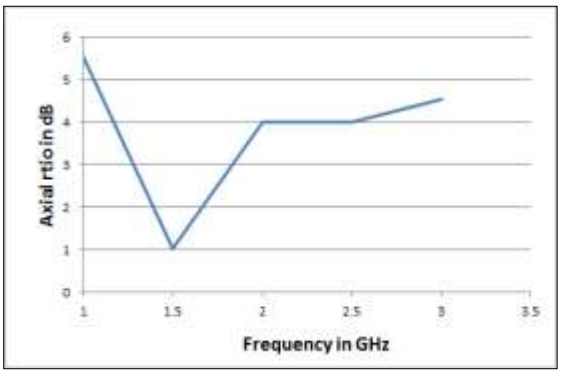


***Fig. 8:** Graph of Axial Ratio with L-Slot.*

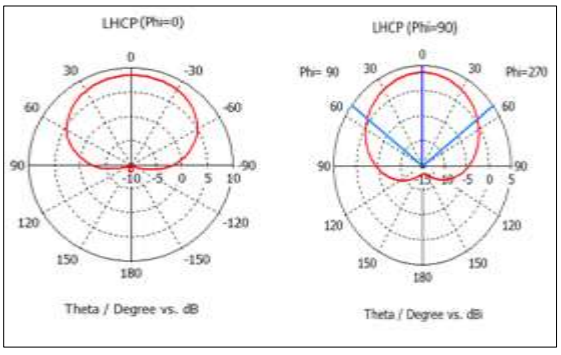


***Fig. 9:** LHCP of proposed U-Slot Patch Antenna for phi=0 Degree & phi=90 Degree at 1.521 GHz*

Figure 9 shows the LHCP of proposed U-slot antenna at phi=0 degree & phi=90 degree.

Figure 10 shows the RHCP of proposed U-slot antenna at phi=0 degree & phi=90 degree.

Figure 11 shows the LHCP of proposed L-slot antenna at phi=0 degree & phi=90 degree.

Figure 12 shows the RHCP of proposed L-slot antenna at phi=0 degree & phi=90 degree. For real application of GPS, the receiving antenna should be designed as a Right-Hand Circularly Polarized (RHCP) antenna.

In this design, the antenna is easy to adjust with RHCP operation by changing the truncated corner of the patch to another diagonal axis. Then, the antenna can operate with RHCP[2].

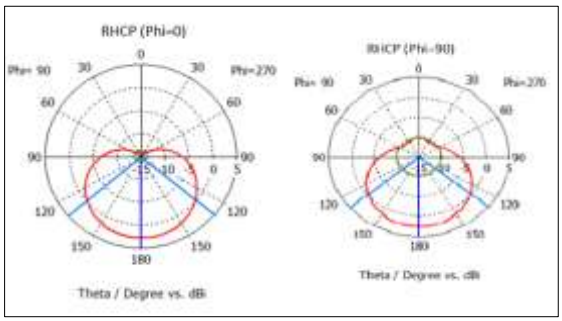


***Fig. 10:** RHCP of Proposed U-Slot Patch Antenna for phi=0 Degree & phi=90 Degree at 1.521 GHz.*

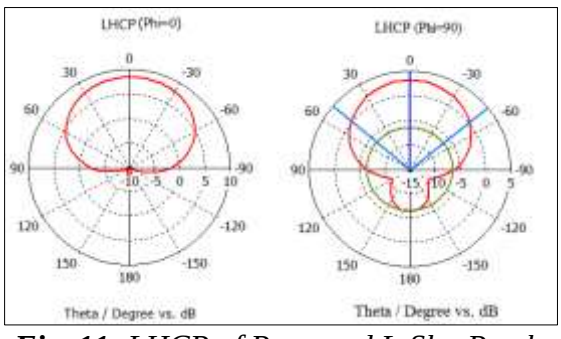


***Fig. 11:** LHCP of Proposed L-Slot Patch Antenna for phi=0 Degree & phi=90 Degree at 1.521 GHz.*

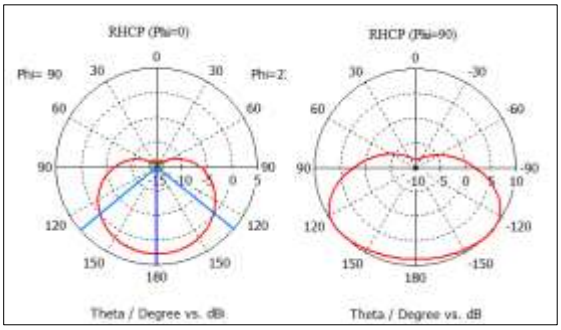


Fig. 12: *RHCP of Proposed L-Slot Patch Antenna for phi=0 Degree & phi=90 Degree at 1.521 GHz.*

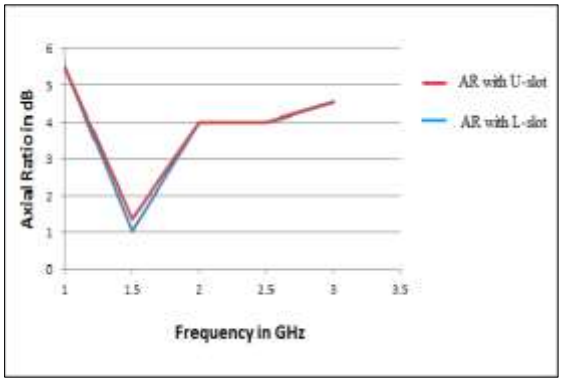


Fig. 13: *Compared Graph of Axial Ratio of CP Antenna with U-Slot & L-Slot.*

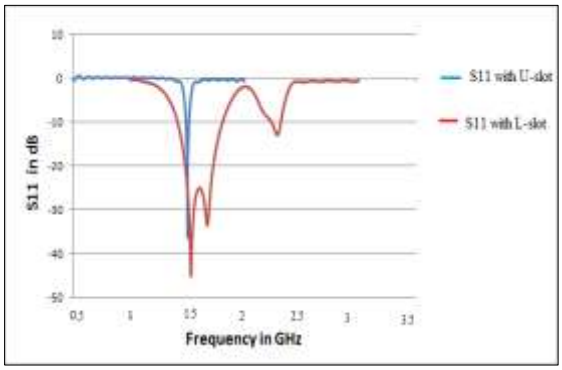


Fig. 14: *Compared Graph of S11 of CP Antenna with U-Slot & L-Slot.*

COMPARISON

Finally, a comparison for a CP antenna with-L/with U-slot is given in Table 1 and shown in Figure 13 and 14. 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.

Table 1: *Summary for Simulated Impedance Bandwidth and Axial Ratio Bandwidth for CP Antenna with U-slot & L-slot.*

CP Antenna	Impedance BW (S11≤10 dB)	Axial Ratio BW (AR≤3 dB)
With U-Slot	13.56%	2.95%
With L-slot	19.99%	3.5%

CONCLUSION

Antenna performance is obtained by CST Microwave Studio 2010 have been analyzed. A circularly polarized patch antenna has been designed and simulated. The antenna is designed with truncated corners and consists of a U-Slot & L-Slot with dielectric constant of 10.2 for achieving small size. The operating frequency is 1.521 GHz. The antenna gives better return loss, axial ratio with L-slot as compared to U-slot. The length of the proposed square patch is reduced by about 70 % in comparison to the antenna using air/foam substrate. The bandwidth is 86.8 MHz. This small antenna can be used for a number of wireless communication applications, including GPS receivers.

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antenna with compact size and small frequency ratio. *IEEE Trans. Antennas Propag*. July 2007; 55(7): 2104–07p.
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