A Novel Compact CPW-Fed Antenna with Circular Polarization Characteristics for UWB Applications

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Abstract **─** A novel compact antenna with Circular Polarization (CP) characteristics is presented. The antenna structure includes an asymmetrical rectangular radiating patch from which a semi-circle shaped slot is cut. A 50 Ω Co-Planar Waveguide (CPW) feed line with two rectangular slots feeds the antenna. Two inverted L-shaped strips and also two spiral shaped slots are embedded on opposite corners of the ground plane to further enhance the antenna bandwidth and also generate the circular polarization property. The antenna is printed on a compact size FR4 substrate with the total dimensions of 20×20×1.6 mm^3. The proposed antenna operates over the frequency range of 3-14.5 GHz for VSWR<2 and exhibits CP in 5.35-7.65 GHz (35%).

Index Terms **─** Circular polarization, CPW-feed line, Ultra-Wideband.

I. INTRODUCTION

The assignment of 3.1-10.6 GHz as UWB frequency range by Federal Communication Commission (FCC), can be considered an evolution in antenna design realm. As antenna is an essential component of every communication system; since then, a vast variety of antennas have been designed and published to be used in UWB frequency band [1]-[5]. One category of the antennas which has recently gained great popularity is circularly polarized antennas. By the use of CP antennas, there will be no need to consider the orientation between the transmitter and receiver. Apart from this, higher performance and better mobility and weather penetration with respect to the Linearly Polarized (LP) antennas are of the other CP antennas features [6]-[7]. Recently, a lot of CP antennas have been proposed. For instance in [8], placing of two spiral slots in the ground plane results in circular polarization generation. In [9], Chen, et al., propose a CPW-fed antenna with a widened L-type strip which exhibits CP about 17%. Three L-shaped strips are embedded on corners of the ground plane of antenna in [10] to get the desired CP operation. A simple antenna with inverted L-shaped strip is introduced in [11] that shows circular polarization characteristics in L-band. In this paper, we propose a novel structure of a CP antenna. The study antenna is printed on a cheap FR4 substrate with dimensions of 20×20×1.6 mm^3 and exhibits CP in 5.35-7.65 GHz. A simple radiating patch with a semi-circle shaped slot along with a ground plane with two spiral shaped slots and also two inverted L-shaped strips on two corners, comprise the antenna's configuration. A slotted CPW feed line feeds the antenna. Small size, wide impedance and Axial Ratio (AR) bandwidth are of advantages of this antenna. The remainder of the paper is outlined as follows: The structure and design process of the antenna are discussed in Section II. The simulation results of parametric study, measured results and their comparisons are presented in Section III. Finally the conclusion of the paper is presented in Section IV.

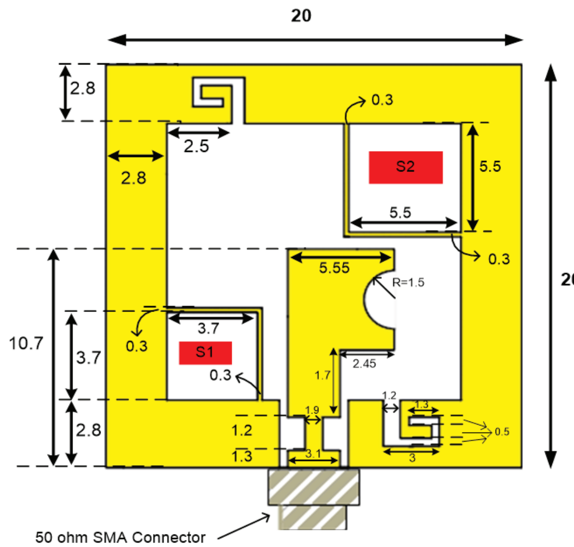
II. ANTENNA DESIGN

The schematic of the proposed CP antenna is shown in Fig. 1 (a). The fabricated antenna is also shown in Fig. 1 (b). The proposed antenna is printed on a cheap FR4-epoxy substrate with permittivity of 4.4, loss tangent of 0.002 and

Submitted On: July 20, 2013
Accepted On: September 6, 2014

thickness of 1.6 mm. A CPW feed line with the length and width of 4.2 mm and 3.1 mm respectively, is adopted to feed the study antenna; of course two rectangular slots with dimensions of 1.2mm×0.6mm are cut from both sides of the feed line. Two inverted L-shaped strips with inner areas of 5.5×5.5 mm^2 and 3.7×3.7mm^2 on top-right and bottom-left corners of the antenna structure play the main role in CP generation. Also, two spiral shaped slots are removed from the antenna ground plane on two corners opposite to the location of L-shaped strips. To better analyze the antenna performance, four prototypes are introduced in Fig. 2 until reaching the antenna's final structure. As it is seen, Ant. I includes a simple feed line and an asymmetrical radiating patch. In Ant. II, two inverted L-shaped strips are added to the top-right and bottom-left corners of the antenna ground plane and form two square slots with the areas of 5.5×5.5 mm^2 and 3.7×3.7 mm^2 respectively. Ant. III contains two spiral shaped slots cut from the ground plane top-left and bottom-right corners (opposite of the inverted L-shaped strips' locations), and finally in Ant. IV that shows the final structure, two rectangular slots are cut from the feed line and also a semi-circle with the radius of 1.5 mm is removed from the right side of the radiating patch. The four introduced antennas have been simulated and VSWR and AR results relating to these antennas are plotted in Fig. 3 (a) and (b).

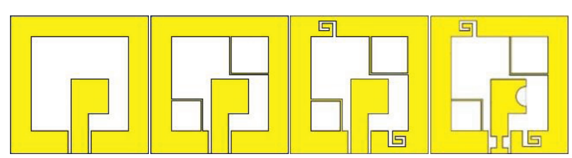
As it is seen from Fig. 3, Ant. I does not have good impedance matching and also no circular polarization is seen for this structure. In Ant. II, by the addition of two inverted L-shaped strips to the top-right and bottom-left corners, the antenna impedance matching has improved noticeably at higher frequencies. The reason is laid in the fact that by the addition of these L-shaped strips to the antenna structure, a new path is made for the current. Figure 4 shows the surface current flow through the L-shaped strips. As the current flows in the newly created path, new resonances at 8 GHz and 10.4 GHz are excited and the antenna bandwidth has improved. In this stage, still there is poor impedance matching problem in lower frequency edge and UWB spectrum is not fully covered. Ant. II generates circular polarization in 6-7.3 GHz. The problem of poor impedance matching at lower frequencies is overcome by the inclusion of the spiral shaped slots in Ant. III, but the same problem is seen at 8 GHz. By this change, the lower and higher frequency edges of AR curve are shifted toward lower and higher frequencies respectively, and a wider AR bandwidth at 5.65-7.4 GHz is obtained. Finally in Ant. IV, shows better performance at around 8 GHz. The poor impedance matching problem is completely overcome. UWB frequency range if fully covered and CP is generated in 5.6-7.4 GHz.



(a)

(b)

Fig. 1. (a) The schematic geometry of the proposed antenna, and (b) the fabricated antenna.



(a) (b) (c) (d)

Fig. 2. (a) Ant. I, (b) Ant. II, (c) Ant. III, and (d) Ant. IV.

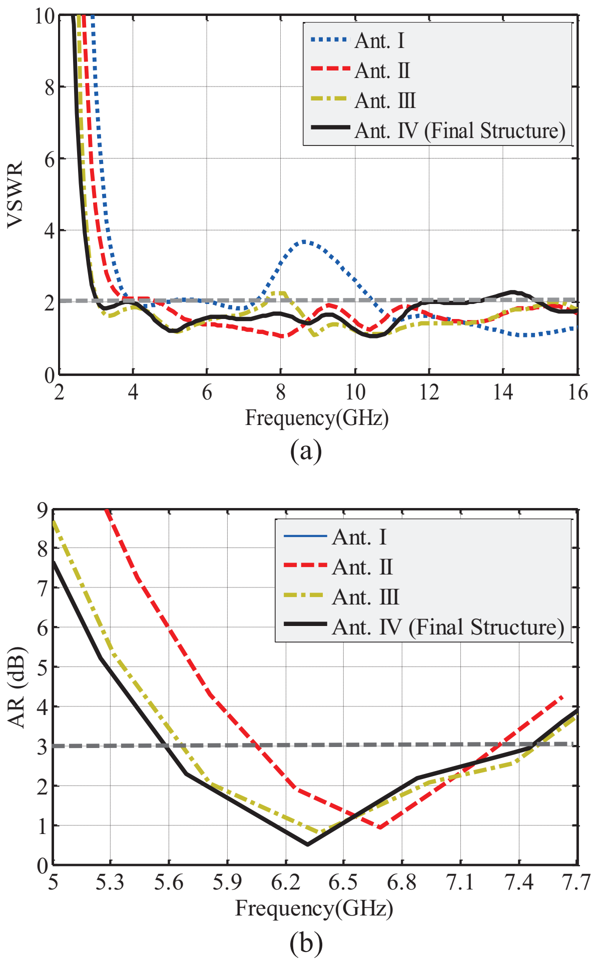


Fig. 3. (a) VSWR curves for the four mentioned antennas, and (b) AR curves for the four mentioned antennas.

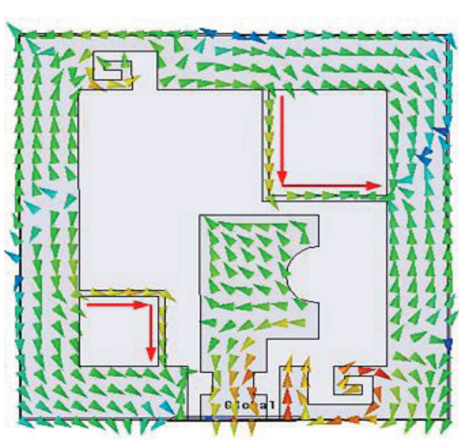
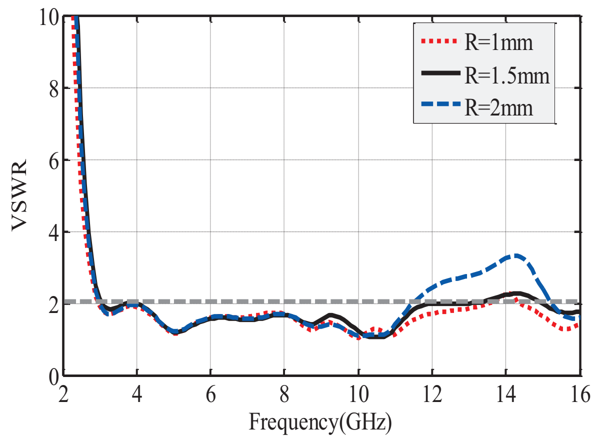


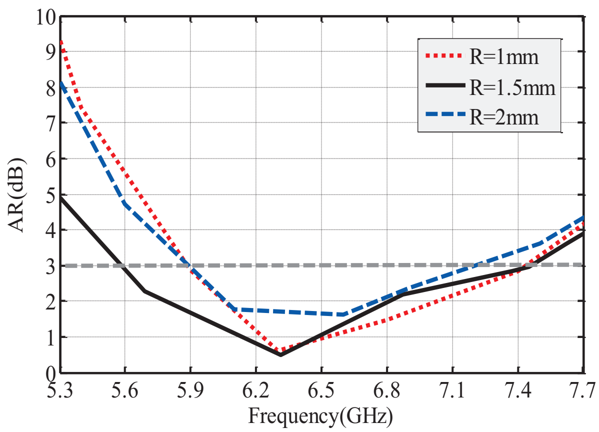
Fig. 4. Surface current distribution on the antenna at 8 GHz.

To further investigate the antenna performance, a parametric study is also carried out. Figure 5 (a) and (b) show the simulated VSWR and AR curves for three values of the semi-circle radius that is removed from the radiating patch. The semi-circle radius named as "R" is varied from 1 mm to 2 mm with a step of 0.5 mm. Simulated results clearly show that changing of R does not influence the lower frequency edge of VSWR curves but the upper frequency edge shifts toward lower frequencies, which means the bandwidth reduction. This parameter also affects AR. It is seen from Fig. 5 (b), that when R=1.5 mm, wider AR bandwidth is obtained for the antenna respect to the other two cases. The other parameter that is studied is the inner area of two square slots on two corners of the antenna named as S_1 and S_2. Figure 6 (a) and (b) show VSWR and AR curves for different values of these parameters. Three values are chosen for S_1 and S_2. As it is seen from simulated results of Fig. 6, both lower and higher frequency edges of VSWR are sensitive to the variation of S_1 and S_2. With S_1=3.2mm×3.2mm and S_2=5.2mm×5.2mm, poor impedance matching is seen in VSWR curves around 8 GHz. By increasing the areas with a step of 0.3mm×0.3mm, the VSWR value goes under 2 and leads to impedance matching enhancement at this frequency. When S_1 and S_2 are adjusted in 3.7mm×3.7mm and 5.5mm×5.5mm respectively, the widest frequency range is covered by the proposed antenna. These areas also affect the AR curve. Figure 6 (b) shows that for the first case when S_1=3.2mm×3.2mm and S_2=5.2mm×5.2mm, circular polarization is not generated and when S_1=4mm×4mm and S_2=5.8mm×5.8mm, circular polarization is seen in 6.45-7.15 GHz. The best and widest CP is seen in black color, when S_1 is 3.7mm×3.7mm and S_2 is 5.5mm×5.5mm.

Antenna CP mechanism is explained in Fig. 7, using surface current distribution at 0, 90, 180 and 270 degree phases. It is observed that the surface current distribution in 180 and 270 has equal magnitude but they are opposite in phase of 0 and 90. From the results, It is seen that the surface current rotates counter clockwise on the antenna, so the antenna shows Left-Hand Circular Polarization (LHCP) in 6.5 GHz.

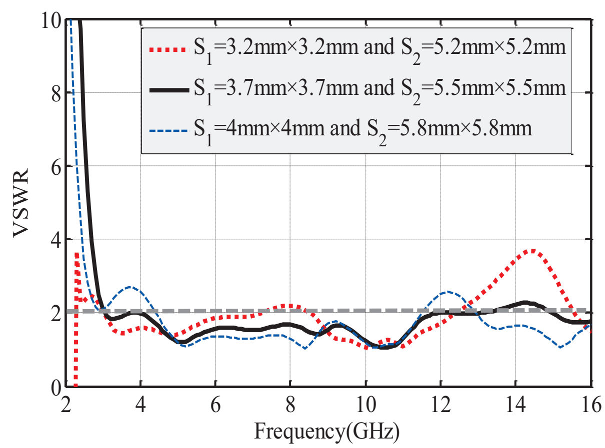


(a)

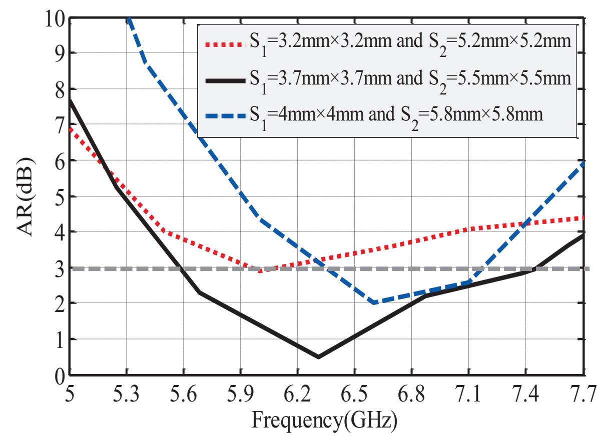


(b)

Fig. 5. (a) VSWR curves for three values of parameter "R", and (b) AR curves for three values of parameter "R."



(a)



(b)

Fig. 6. (a) VSWR curves for different values of S_1 and S_2, and (b) AR curves for different values of S_1 and S_2.

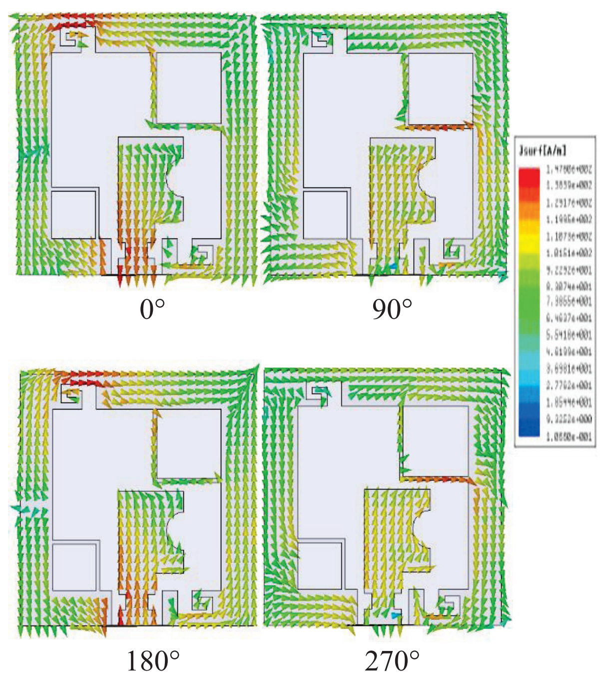
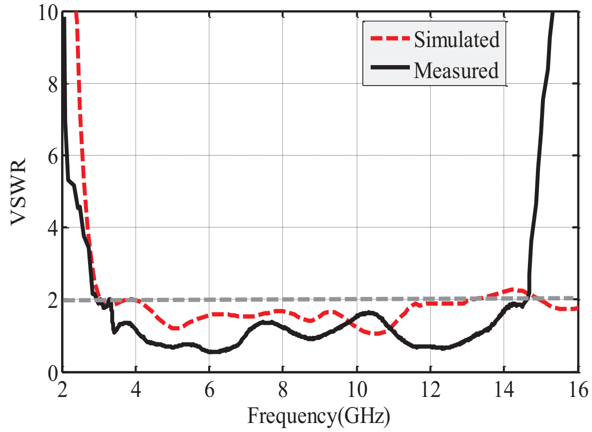


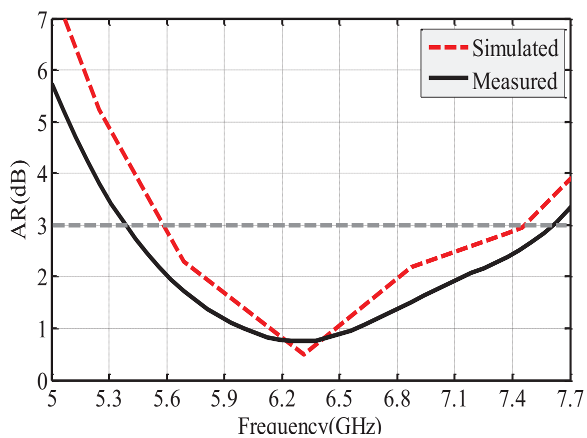
Fig. 7. Surface current distribution at 6.5 GHz.

III. RESULTS AND DISCUSSIONS

The proposed antenna with the given values in Fig. 1, has been fabricated and tested. Figure 8 (a) shows the simulated and measured VSWR curves. From the measured results, the frequency band of 3-14.5 GHz is covered by the antenna, which is a little more than the bandwidth obtained from simulation. Also, the simulated and measured AR curves are plotted in Fig. 5 (b), 5.35-7.65 GHz is under 3 dB Axial Ratio that is in good agreement with the results from HFSS. The difference between the simulated and measured results may be due to the SMA connector that is used in measurement process and also the effect of soldering the SMA connector to antenna.



(a)



(b)

Fig. 8. (a) Simulated and measured VSWR of the proposed antenna, and (b) simulated and measured AR of the proposed antenna.

In addition to VSWR and AR, antenna gain is also measured and is plotted in Fig. 9. As it is seen, both the antenna simulated and measured gains vary in acceptable ranges.

Measured LHCP and RHCP radiation pattern of the antenna is plotted in Fig. 10 at 6.2 GHz and 7 GHz. Suitable pattern is obtained for the proposed antenna.

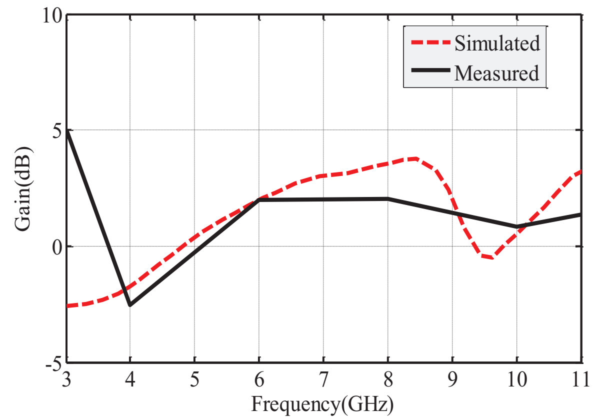


Fig. 9. Simulated and measured gain of the proposed antenna.

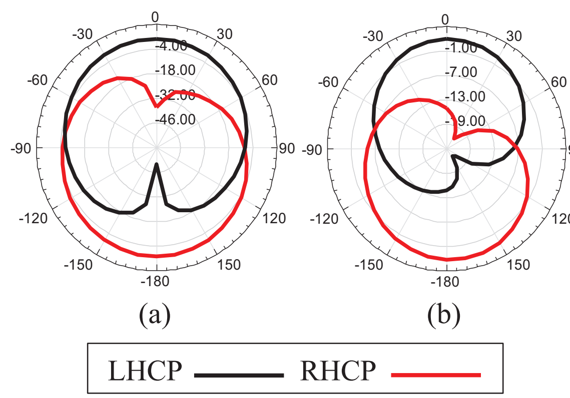


Fig. 10. Measured radiation pattern at: (a) 6.2 GHz, and (b) 7 GHz.

IV. CONCLUSION

A novel compact CPW-fed antenna with CP characteristics is introduced in this work. Antenna geometry is composed of a slotted CPW feed line, a radiating patch with a semi-circle slot, two inverted L-shaped strips and also two spiral shaped slots on the ground plane. The combination of these elements and properly adjusting their dimensions lead to impedance bandwidth extended from 3 GHz to14.5 GHz, and CP in 5.35-7.65 GHz (35%). The presented antenna is printed on FR4 substrate with the size of 20×20×1.6 mm^3. Small size, wide impedance and AR bandwidth, acceptable gain range and suitable radiation patterns are of the merits of the presented antenna, which makes it a good choice for UWB systems.

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