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WIDEBAND CPW-FED CIRCULARLY POLARIZED ANTENNA WITH MODIFIED FEEDING LINE AND SYMMETRIC ELLIPSE-APERTURE

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Abstract—This paper presents a new design for wide slot circularly polarized (CP) antenna (WSCPA). The proposed design possesses much larger return loss bandwidths and CP bandwidths than existing WSCPA. The main features of the antenna structure include a modified CPW feeding line and a wide and symmetric ellipse-aperture along the diagonal axis. By properly tuning axial ratio of ellipse-aperture and parameters of feeding line, wideband return loss and CP radiations can be achieved. The measured bandwidths of 10-dB return loss and 3-dB axial ratio (AR) are as large as 112.5% (2.1–7.5 GHz) and 109% (2.3–7.8 GHz), respectively. The improvement process of the AR and S_{11} properties is completely presented and discussed in this paper.

1. INTRODUCTION

Circularly polarized (CP) antennas [1–35] have been receiving much attention for the applications on wireless communications because they are not only able to overcome the multipath fading problem but also provide better mobility and weather penetration than linearly polarized antennas (LP). Because of advantages of low profiles, many microstrip antenna [1–3] designs have been proposed to generate LP and CP radiation by using single feed. However, the achieved 3-dB AR bandwidths for related designs are narrow and less than 3%. Printed slot antennas have been receiving much attentions, because they not only have the same low profiles as microstrip patch antennas, but also have larger impedance bandwidths and 3-dB AR bandwidths. CP printed slot antennas can be divided into two categories according to the structures: wide and ring slot types

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(WSCPA and RSCPA). For comparison, the 3-dB AR bandwidths of the WSCPA [4–9, 13, 14, 16, 17, 22] tend to be larger than those of RSCPA [10–12, 15]. However, the areas of the WSCPA seem to slightly larger than RSCPA.

Advantages of CPW feed are wide bandwidth, a single metallic layer only, low radiation loss and less dispersion. Recently, most of CP antennas are designed by using CPW-fed [9, 13, 14, 22], the AR bandwidths can be improved greatly through the method of reshaping the feeding structure and inserting the inverted-L grounded strips as

Table 1. Comparison of CP slot antennas.

Reference	Antenna Type	10-dB Return Loss Bandwidths	3-dB AR Bandwidths
[1]	MSCPA	3.4%	0.65%
[2]	MSCPA	4.6%	1.2%
[3]	MSCPA	Not Mentioned	1% and 1.03%
[4]	WSCPA	15%	12%
[5]	WSCPA	39.6%	12.4%
[6]	WSCPA	52%	25%
[7]	WSCPA	45%	45%
[8]	WSCPA	51%	23%
[9]	WSCPA	35%	30%
[10]	RSCPA	1.3%	4.3%
[11]	RSCPA	23%	6%
[12]	RSCPA	23%	10.5%
[13]	WSCPA	132%	32.2%
[14]	WSCPA	110%	85%
[15]	RSCPA	56%	46.7%
[16]	WSCPA	107%	68%
[17]	WSCPA	48.8%	8.9%
[18]	monopole	65.6%	71.4%
[19]	monopole	87.3%	95%
[20]	DRA	24.5%	25.4%
[21]	microstrip	43%	43%
[22]	WSCPA	83.2%	71.1%
Proposed	WSCPA	112.5%	109%

perturbation structure.

This paper presents a new design for wide slot circularly polarized antenna. A new structure consists of a wide ellipse symmetric-aperture along the diagonal axis acting as perturbation structure, and a modified CPW feeding line. Wider return loss and AR bandwidths can be obtained by optimizing the parameters of the structure. The 10-dB return loss impedance bandwidths are as large as 112.5% (2.1–7.5 GHz) and the achieved AR bandwidths is up to 109% (2.3–7.8 GHz). To the authors' knowledge, the achieved AR bandwidths for the proposed antenna are relatively much better than the presently available circularly polarized printed slot antennas [1–22], which has been compared in Table 1. The proposed antenna is designed, fabricated and measured. The measured performance of the antenna is compared with simulated results by HFSS software.

2. ANTENNA DESIGN

Figure 1 presents the geometry of the proposed single-layer CPW-fed CP antenna. As shown in the figure, the proposed antenna consists of a square ground plane with size of $G \times W$, a wide symmetric aperture, and a vertical stub. The wide symmetric aperture consists of two ellipse-shaped apertures, which is rotated by 45° from the feeding line axis that can produce two equal-amplitude resonant modes that have a phase difference (PD) of around 90°. A CPW feeding line has been optimized to enlarge the impedance bandwidths. All the antenna

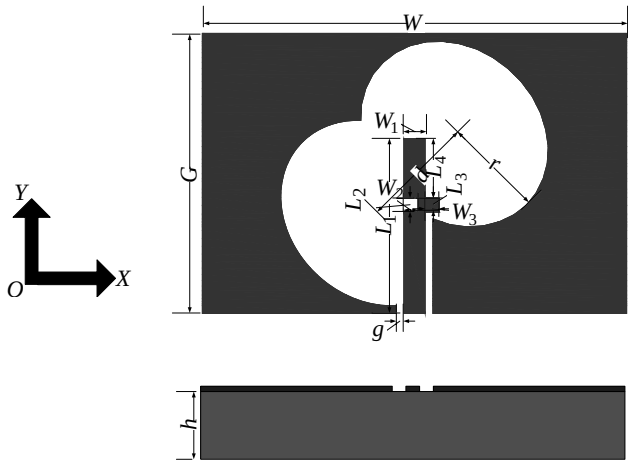


Figure 1. The geometry of the designed antenna.

Table 2. The parameters of the antenna.

W	G	r	d	g	h	W_1
60 mm	40 mm	12 mm	8 mm	1 mm	1.6 mm	3 mm
L_1	W_2	L_2	W_3	L_3	L_4	k
25 mm	2 mm	2 mm	2 mm	2 mm	8.5 mm	1.2

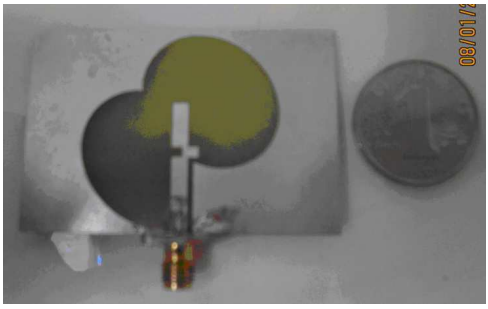


Figure 2. The photo of the designed antenna.

parameters are placed in the Table 2. The antenna is fabricated on a low-cost FR-4 substrate with a thickness of $h = 1.6$ mm and relative dielectric permittivity $\varepsilon_r = 4.4$. The photo of the designed antenna is shown in Figure 2. The designed antenna can generate right- and left-handed circular polarized (RHCP and LHCP) radiations in the $+Z$ and $-Z$ directions simultaneously. The opposite sense of the CP radiation can be achieved if the symmetric aperture is placed along the other diagonal axis of ground plane.

3. RESULT AND DISCUSSION

The performances of the designed antenna at parametric studies have been investigated to find optimized parameters using the Ansoft High Frequency Structure Simulator Software (ver.11). In explaining the design process of antenna, three prototypes of the proposed antenna are defined as follows, which can be seen in Figure 3: Antenna 1 includes only a single strip as feeding structure, and two symmetrical ellipse-apertures cut in the ground plane. The antenna design begins with determining the axial ratio of the ellipse-aperture (k) and the length of main axis (r). As indicated in Figure 4, the return loss of the Antenna 1 less affected by k. However, the performances of AR for Antenna 1 have been greatly affected by k, which can be seen in Figure 5. Figure 6 shows the return loss of the antenna affected by the main axis of the ellipse-aperture (r), it is clear that when the value

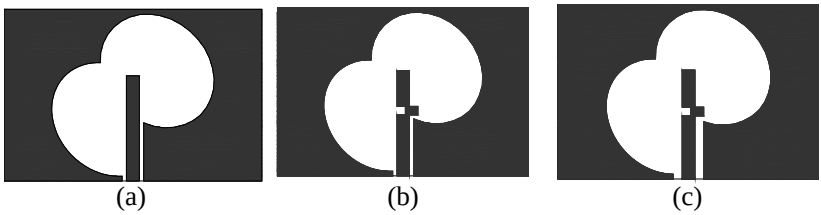


Figure 3. Three prototypes of the proposed antenna. (a) Antenna 1. (b) Antenna 2. (c) Antenna 3.

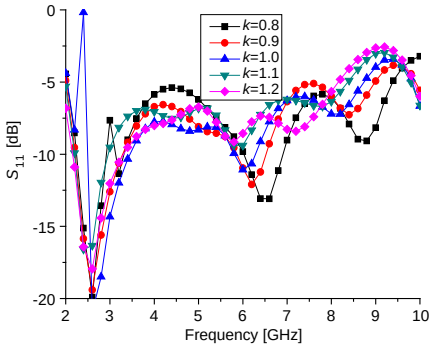


Figure 4. Simulated return loss of the antenna affected by the axial ratio of the ellipse-aperture (k).

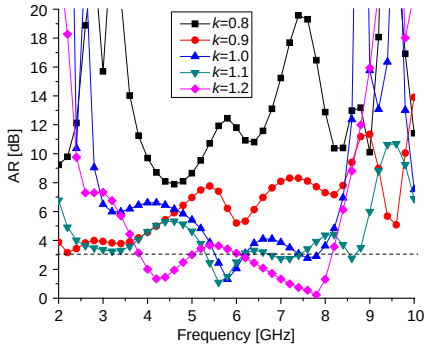


Figure 5. Simulated AR of the antenna affected by the axial ratio of the ellipse-aperture (k).

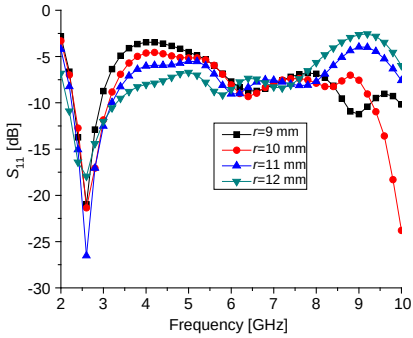


Figure 6. Simulated return loss of the antenna affected by the main axial of the ellipse-aperture (r).

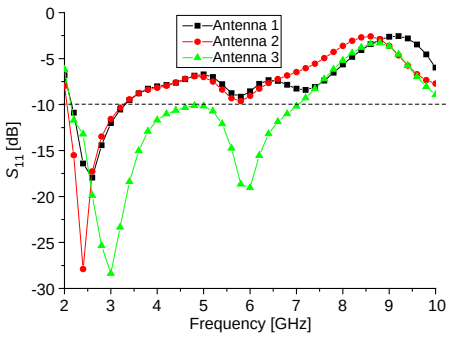


Figure 7. Simulated return loss of three types of antenna.

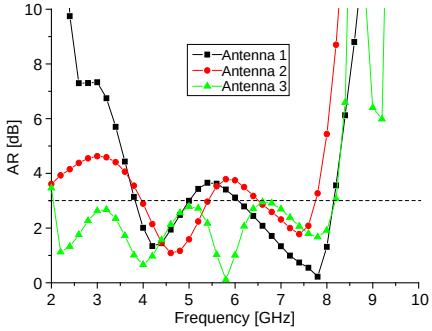


Figure 8. Simulated AR of three types of antenna.

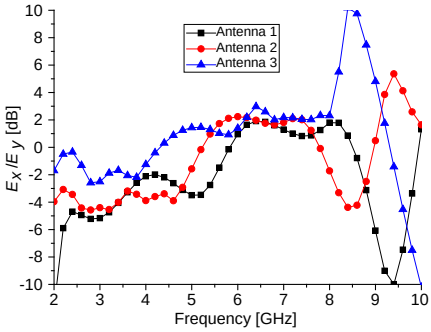


Figure 9. Simulated amplitude ratios for Antenna 1, 2 and 3.

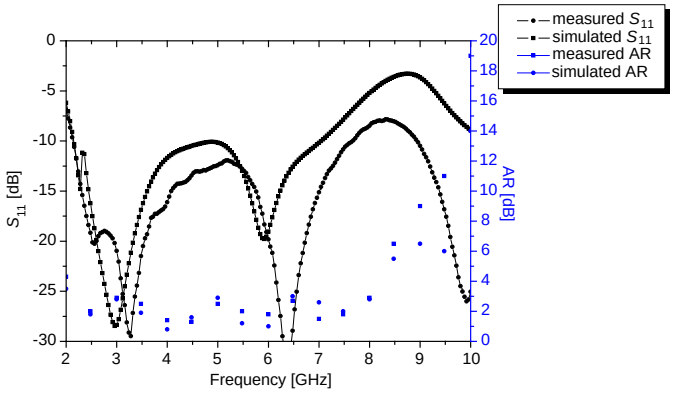
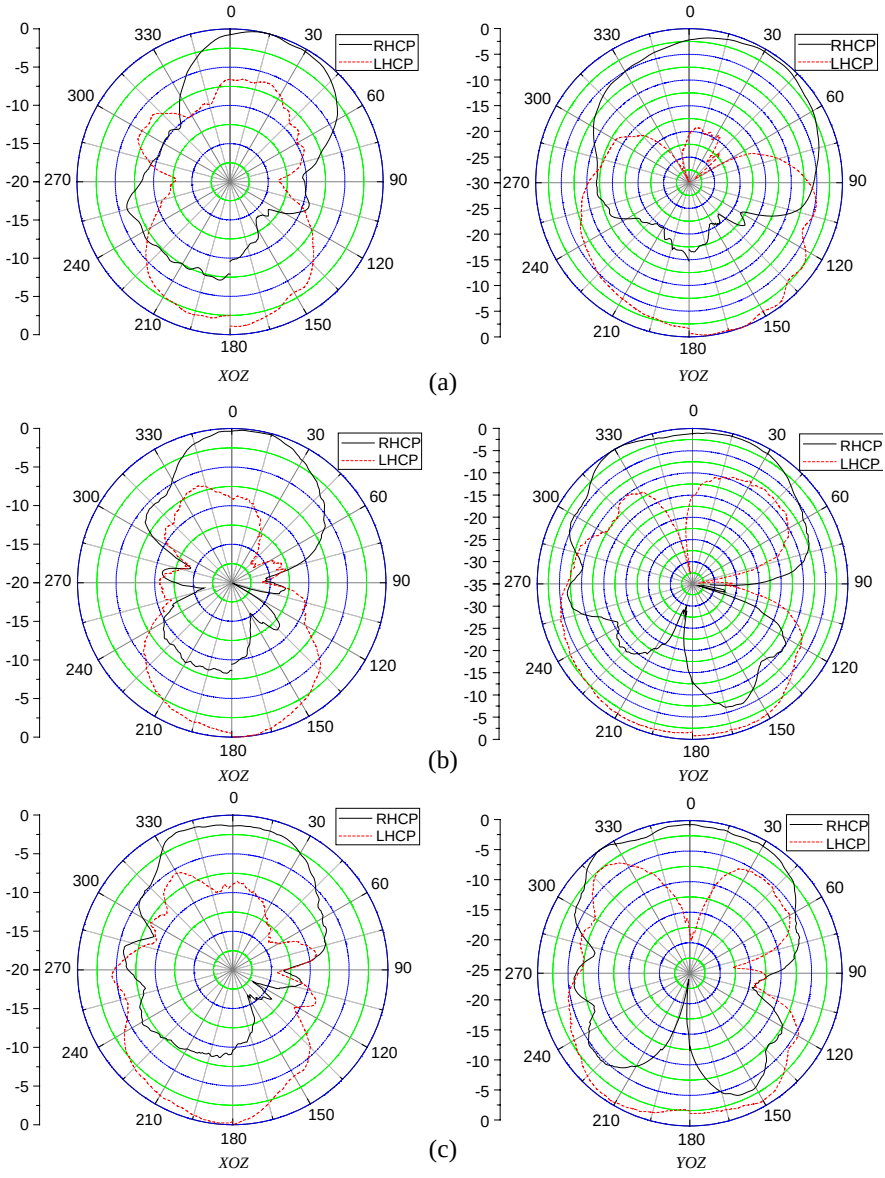


Figure 10. Simulated and measured return loss and AR of the designed antenna.

of r is 12 mm, the return loss at low frequency is better than that for other values of r. Therefore, the values of k and r are determined as 1.2 and 12 mm for the original design respectively. Antenna 2 contains a modified CPW feeding line. As a result, the simulated return loss of Antenna 2 change a little compared with Antenna 1, but the AR curve of Antenna 2 becomes smoother than Antenna 1, which can be seen in Figure 7 and Figure 8 respectively. Figure 9 shows the simulated amplitude ratios for Antenna 1, 2 and 3 respectively. It is found that the amplitude ratios are around 0 dB for Antenna 2 and 3. In order to further improve the return loss and AR bandwidths, the width of the gap between the feeding line and the ground plane (g) has been optimized. When the value of g increases to 1 mm, as indicated in

Figure 7, the simulated return loss of Antenna 3 have an operating frequency range from 2.1 to 7.1 GHz. Antenna 3 also attains 3-dB AR bandwidths from 2.1 to 8.2 GHz (Figure 8).

Figure 10 shows the measured and simulated frequency responses of return loss comparison for the proposed antenna. The experimental



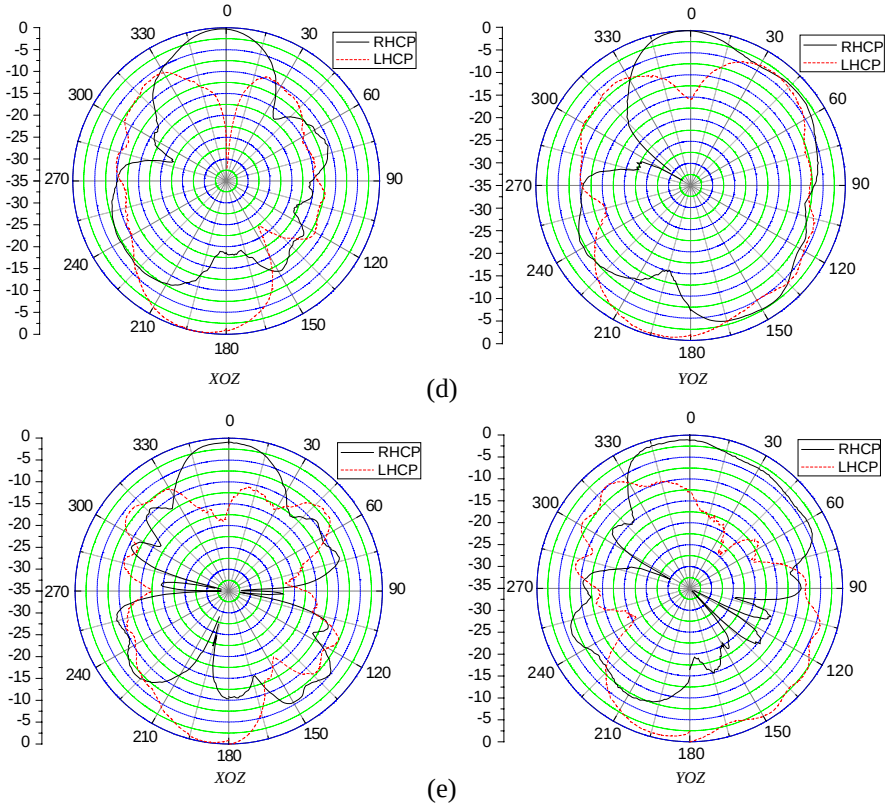


Figure 11. Measured radiation patterns of the designed antenna. (a) 3 GHz. (b) 4 GHz. (c) 5 GHz. (d) 6 GHz. (e) 7 GHz.

results agree well with the simulated data, the measured impedance bandwidths are as large as 5.4 GHz (2.1–7.5 GHz) or about 112.5% with respect to the center frequency at 4.8 GHz. Figure 10 presents the simulated and measured axial-ratio values at the boresight direction. It is seen that the measured 3-dB AR bandwidths are about 5.5 GHz (109%) from 2.3 to 7.8 GHz. Radiation patterns of the antenna are measured and computed by synthesizing two orthogonal polarization. Figure 11 shows the measured radiation patterns in both X-Z and Y-Z planes at 3, 4, 5, 6 and 7 GHz. The proposed antenna has bidirectional radiations, for $+z$ direction, the antenna is RHCP radiation and for $-z$ direction, the antenna is LHCP radiation. The simulated and measured antenna gains have been shown in Figure 12, and it is observed that the peak antenna gain is about 3.8 dBi.

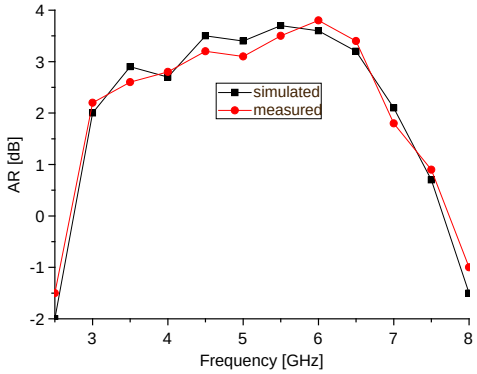


Figure 12. Simulated and measured gain of the designed antenna.

4. CONCLUSION

A design procedure has been developed for designing a novel broadband CP symmetric ellipse-aperture antenna in this paper. The experiment results show that the proposed antenna can achieve an impedance bandwidths of about 5.4 GHz (112.5% relative to the center frequency) and a 3-dB AR bandwidths of 5.5 GHz (109% relative to the center frequency), which are greater than the presently available single-feed circularly polarized printed slot antennas. In addition, excellent CP radiation patterns have been observed in the broadside directions, with RHCP and LHCP radiation at boresight and backside direction, respectively. The maximum antenna gain was measured and found to have a maximum value of 3.8 dBi.

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