A Compact Wideband Dual-Circular Polarization CPW-Fed Slot Antenna

Zhao Neng Jiang [1], Shi Chun Huang [1], Zhi Xin Wang [1], Xiao Yan Zhao [1], and Ting Wan [2]

[1] Department of Information Engineering
Hefei University of Technology, Hefei, 230009, China
jiangzhaoneng@hfut.edu.cn

[2] College of Telecommunications & Information Engineering
Nanjing University of Posts and Telecommunications, Nanjing, 210003, China
want@njupt.edu.cn

Abstract ─ A compact wideband coplanar waveguide (CPW) excited slot antenna with dual-circular polarization (DCP) is presented and fabricated in this paper. Two inverted-L-shaped patches are implanted in a square slot to achieve wideband DCP characteristic. The feed line is terminated on an inverted-L-shaped patch. Moreover, two rectangular slots are added on the corners of the antenna to improve the bandwidth of axial ratio (AR) and the voltage standing wave ratio (VSWR). The simulated results show that the designed antenna can generate a good impedance bandwidth of 70.4% and a 3-dB AR bandwidth of 48.6%, respectively. This antenna possesses the qualities of small size, simple structure, and good dual-circular polarization.

Index Terms ─ Compressed Block Decomposition (CBD) preconditioner, Multilevel Simply Sparse Method (MLSSM), object with fine structures.

I. INTRODUCTION

With the development of satellite communication, the dual-circular polarization (DCP) antenna has attracted more and more attention due to its characteristics such as the polarization, isolation, anti-multipath effect, and so on. In the existing literatures, the microstrip antennas are often used in the multi-layer configurations to achieve the double-circular polarization [1-2]. The microstrip antenna has the advantages of small size, light weight, low attitude, and so on, which has been widely used in communication equipments. In [1], a double-circular polarization antenna is proposed, which consists of two identical two-element Vivaldi antenna arrays that cross vertically with each other along the z-axis, but its dimension becomes much larger. In reference [2], a multi-layer configuration is applied to achieve the double-circular polarization, so that the two patches work in different circular polarization direction. However, such a multi-layer configuration processing is complicate and costly. In recent years, many single-layer microstrip antennas [3-6] have been developed to achieve the double-circular polarization. However, they all have the defects of narrow impedance and axial-ratio (AR) bandwidths.

In recent years, many structures of CP slot antenna fed by the CPW is proposed to improve the impedance and axial-ratio bandwidths [7-13]. These antennas have the advantages of compact, low cost, and easily manufactured. They obtain the characteristics of the right-hand CP and the left-hand CP simultaneously with the various structures. In [7-9], the L-shape grounded strips are embedded around the square slot. In [10], a regular-hexagonal slot antenna is proposed to achieve the circular polarization, whose size is much smaller than that of [7]. The antenna with the L-shaped monopole slots and rotated-parasitic patches is proposed in [11]. The design in [12] is embedded in the square slot of two nearly mirror-symmetric L-shape strips. Besides, a wide rectangular-slot has been etched on the ground plane of a dielectric substrate to obtain the circular polarization [13]. The details of these antennas are listed in Table 1.

Table 1: Circular-polarization bands and sizes of some existing wide-slot antennas

Ref.	f_c (GHz)	10-dB Return Loss BW (GHz/%)	3-dB ARBW (GHz/%)	Gain (dBic)	Dimension (mm×mm×mm)
[7]	4.5	5/111%	3/85.7%	--	70×70×0.8
[10]	3.15	2.7/86%	1.5/50%	2.5	62×62×3.0
[11]	2.42	1.38/57%	0.97/39.4%	3.4	100×120×0.762
[12]	3	2/62.5%	2.1/64%	2.0	117×39×3.8
[13]	2.1	0.2/9.5%	0.6/26.7%	5.0	62.8×72.8×1.5
This paper	3.0	2.5/70.4%	1.35/48.6%	3.95	80×80×2.0

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In this paper, a compact wideband-CPW-excited slot-antenna with the dual-circularly polarization is presented and fabricated. Two inverted-L-shaped patches are implanted in a square slot to achieve the wideband DCP characteristic. Two rectangular slots are embedded on the corners of the antenna to effectively improve the impedance bandwidth. The simulated and measured results show that there are about 70.4% of impedance bandwidth lower than -10 dB and 48.6% of AR bandwidth lower than 3 dB. At the same time, the proposed antenna has the advantages of relatively small loss, being easy to integrate with the active devices, simple-fed structure, and so on.

II. THE PROPOSED SCHEME

Figure 1 shows the geometry structure of the proposed antenna, which is printed on the 2-mm-thickness substrate with the loss tangent tan δ = 0.02 and the relative permittivity ε_r = 4.4. The proposed antenna consists of a square ground-plane with a dimension of L×L and a square slot with the dimension of L1×L1 etched on the ground plane. Two inverted-L-shaped strips with the length of long arm of L3+L4 and short arm of W2 are protruded into the square slot. The antenna is fed by a 50-Ω inverted-L-shaped strip from the feed line of width W5 and two identical gaps of width g2. By notching two rectangular slots of W1×L2 on the corners of the antenna, it can effectively improve the impedance-matching bandwidth of the proposed antenna. Meanwhile, the circular-polarization antenna utilizes the perturbation current to separate two geometries by the equal amplitude and 90° phase-difference to obtain a good circular-polarization. Two inverted-L-shaped strips are the main factor to generate two geometries with the equal amplitude and 90° phase-difference to produce the left- and right-circular polarized radiations (RHCP and LHCP). The DCP bandwidth of this antenna can be generated by properly adjusting the dimension of two rectangular slots and inverted-L-shaped strips. Figures 2 (a)-(b) show the proposed antenna is tested in the Microwave Anechoic Chamber. The photograph of the proposed antenna is shown in Fig. 2 (c), its size is relatively small to meet the needs of miniaturization in modern society.

Figure 3 (a) shows that the development process of the proposed antenna. The Type1, Type2, and the proposed antenna are with the same dimension of 80mm × 80mm. Compared with the Type 1, an inverted-L-shaped ground-strip is protruded into the square slot in Type 2. This strip and the inverted-L-shaped strip from the feed line have the identical size. From Fig. 3 (a), the impedance matching of the antenna remained unchanged and the DCP performance becomes better in Fig. 3 (b). However, the axial ratio bandwidth is still narrow. To improve the axial ratio bandwidth of this antenna, two rectangular slots are notched on the corners of the proposed antenna, which is the proposed antenna. After a series of simulated and optimized experiments, this antenna can obtain the good impedance and DCP characteristics. Figure 4 shows the simulation results of the surface current distribution in 0°, 90°, 180°, 270° phase for the antenna. It can be seen that the proposed DCP antenna is able to generate an RHCP in the +z-direction and an LHCP is produced in the -z-direction.

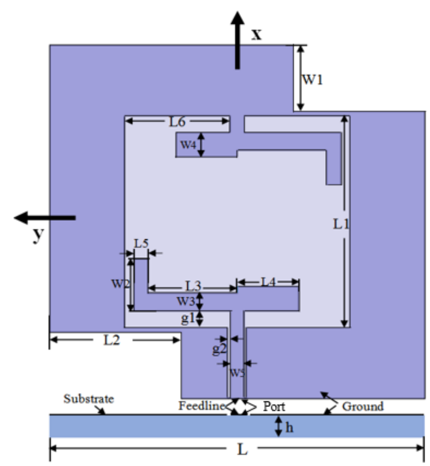


Fig. 1. Geometry of the proposed CPW-Fed antenna.

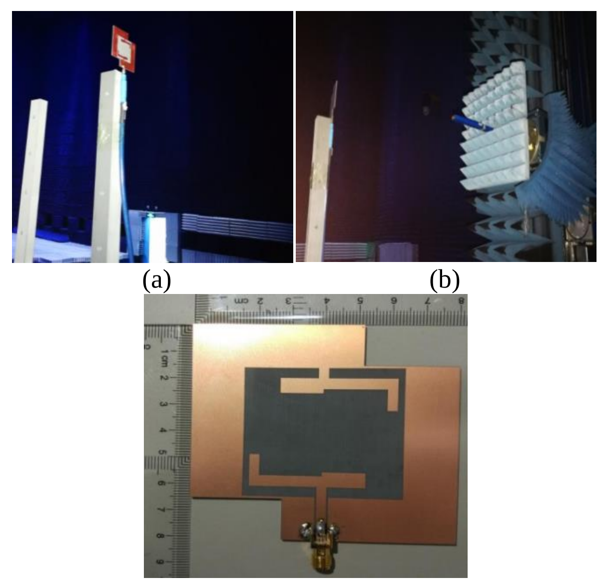
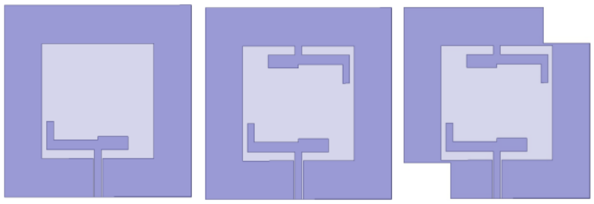
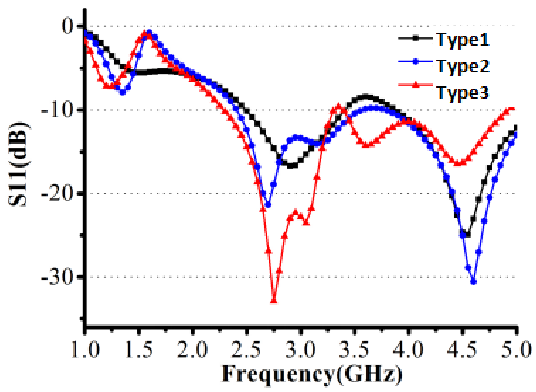


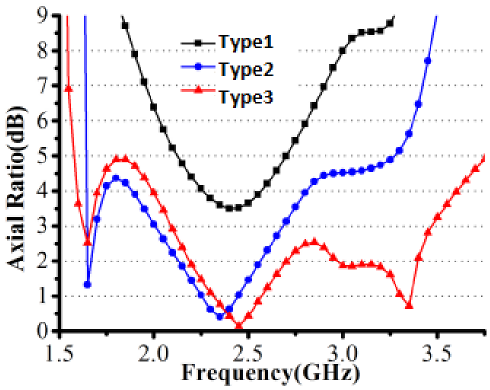
Fig. 2. Front view photograph of the proposed antenna.



Type1 Type2 Type3 (proposed)

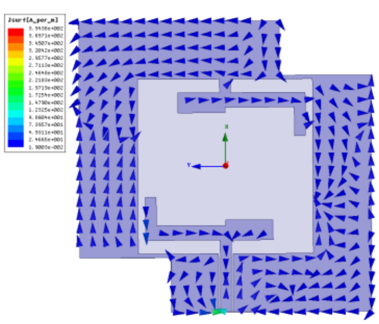


(a)

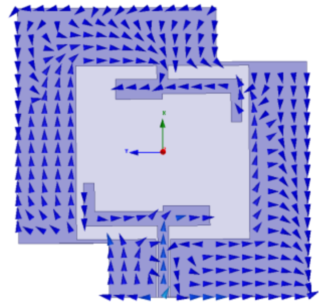


(b)

Fig. 3. Simulated (a) S11 parameter and (b) axial ratio for Type 1, 2, and 3.



(a)



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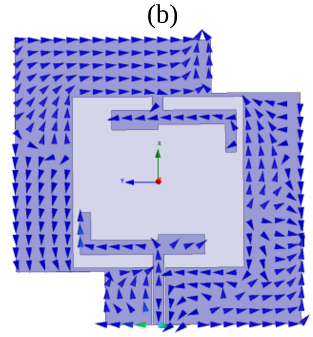
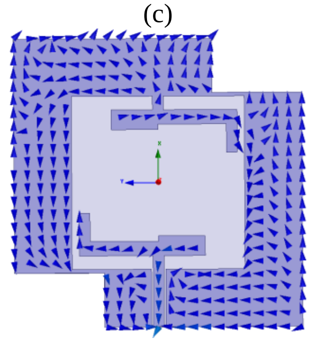


(c)



(d)

Fig. 4. Simulated surface-current distribution of the proposed antenna at 3 GHz for the different phase instants ((a) 0°, (b) 90°, (c) 180°, and (d) 270°).

III. NUMERICAL RESULTS

In order to verify the circular-polarization performance of proposed antenna, the main physical parameters which affect its performance are analyzed and optimized by the electromagnetic simulation software Ansoft HFSS 15.0 and the suitable dimensions of proposed antenna are thus obtained. It is found that the gap widths (g1 and g2) and the dimensions of two inverted-L-shaped strips and two rectangular slots have a certain impact on the DCP performance. With the simulation and optimization of these design parameters, the influence can be obviously asserted. Finally, the optimized antenna has been fabricated and tested.

A. Step one: The effects of the two gap widths

Figure 5 and Fig. 6 show the simulated axial ratio of the gap width of g1and g2 for the Type 3. As the inverted-L-shaped strip from the feed line is near the ground plane, it exists a strong coupling effect. The simulation and optimization of two gaps of width g1 and g2, it is found that two gap widths play the primary role to the circular-polarization characteristic of the proposed antenna. Through the adjustment of g1 and g2, respectively, the return loss of the proposed antenna remains unchanged. As can be seen from Fig. 5 and 6, when g1 = 3.75 mm, and g2 = 0.5 mm, the axial-ratio bandwidth of the designed antenna can reach the standard of wideband antennas.

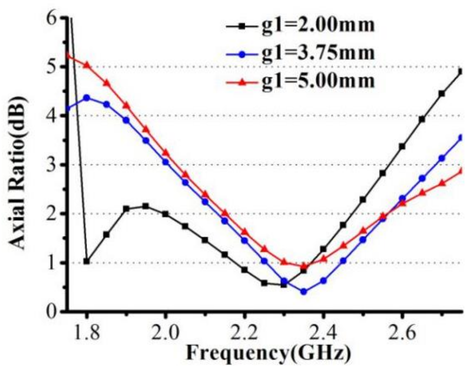


Fig. 5. Simulated axial ratio of the gap width of g1.

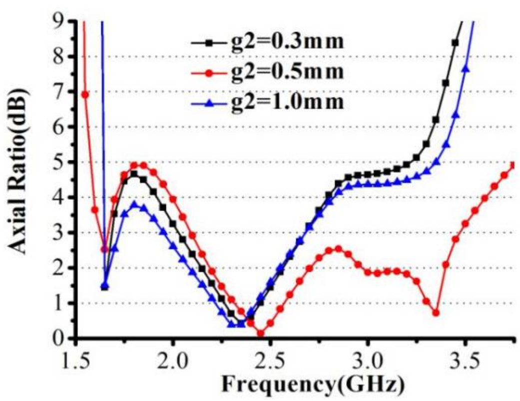


Fig. 6. Simulated axial ratio of the gap width of g2.

B. Step two: The effects of the inverted-L-shaped strip

Figure 7 shows the effect of the inverted-L-shaped strip on the Type 2 performances. The simulation results show that the influence of short arm of the inverted-L-shaped strip on the DCP performance. When the long-arm (L3 + L4) length changes, the DCP performance remain unchanged. As the length (W2) of short arm increases, the circular-polarization performance of the proposed antenna gradually gets better. In view of comprehensive consideration, the length of short arm is set at 11.85 mm.

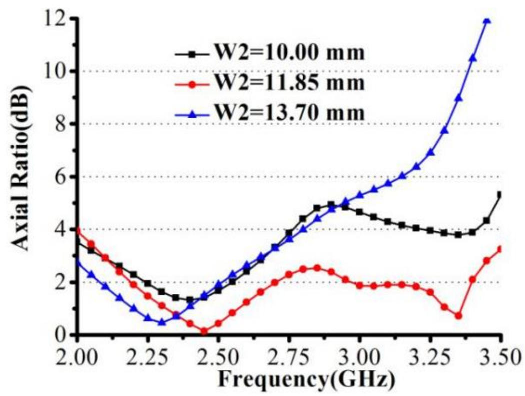
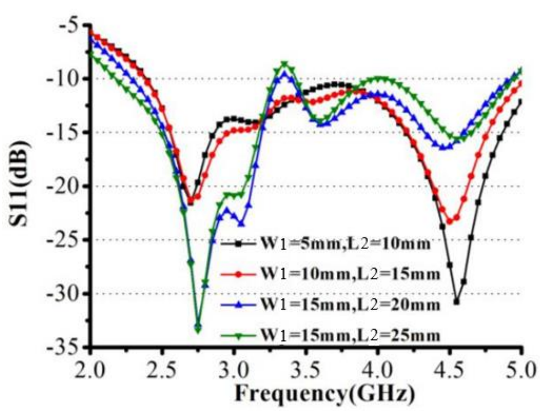


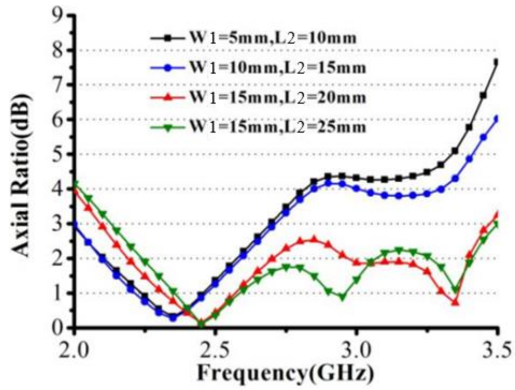
Fig. 7. Simulated axial ratio of the width of W2.

C. Step three: The effects of two rectangular slots

As can be seen from Fig. 8, the impedance-matching performance of the Type 2 is poor. In order to improve the impedance-matching performance, two rectangular slots are embedded on the corner of the proposed antenna. Figure 8 shows the effect of the dimension of the slots on the impedance matching and DCP characteristics of the antenna. When the size of two rectangular slots increases, the S11 parameter gets worse. However, it can be seen that the AR bandwidth gets better from Fig. 8. Through the adjustment and optimization of the size of two rectangular slots, it is set at 15 mm×20 mm.



(a)



(b)

Fig. 8. Simulated (a) S11 parameter and (b) axial ratio of the size of two rectangular slots

IV. SIMULATION AND MEASUREMENT RESULTS

The final optimized dimensions of the proposed antenna are listed in Table 2. Thereof, the simulated and measured results of the S11 parameter and ARBW of proposed antenna are shown in Fig. 9 and Fig. 10, respectively. Based on the final optimization, the simulated results are in a good agreement with the measured results. The simulated and measured return-loss bandwidth is from 2.3-4.8 GHz while the relative bandwidth is about 70.4%. The simulated and measured 3-dB AR bandwidth is from 2.1-3.45 GHz while the relative bandwidth is 48.6%. The overlapped operation bandwidth of the proposed antenna is about 40%. The calculation formula of relative bandwidth is shown in formula (1). Among them, fh is the highest frequency, fl is the lowest frequency, fc is the center frequency. fc $= (fh + fl)/2$:

$$\text{the relative bandwidth} = [(fh - fl)/fc] \times 100\%. \quad (1)$$

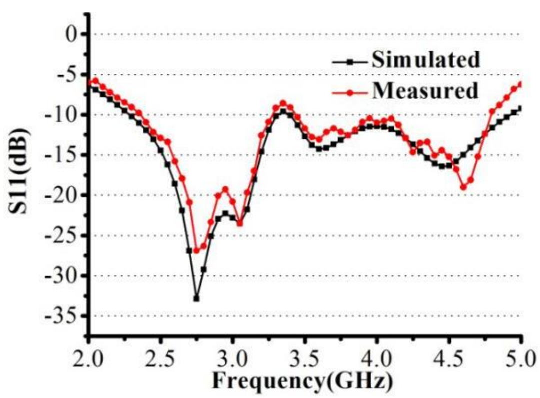


Fig. 9. Simulated and measured S11 parameter of the proposed antenna.

The measured radiation patterns of the proposed antenna at 2.30, 3.00, and 3.45 GHz are shown in Figs. 11-13. The simulated radiation patterns of the proposed antenna at 3.00 GHz are shown in Figs. 14. It can be found that the simulated radiation patterns at 3.0GHz is agree well with that of measured radiation patterns. The simulated and measured gains of the antenna in the DCP bandwidth are shown in Fig. 15.

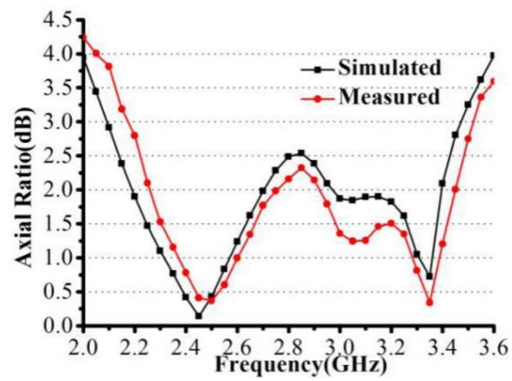
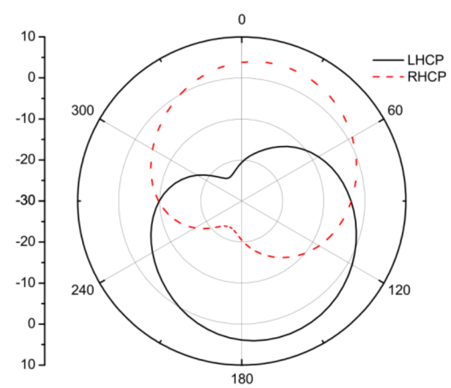


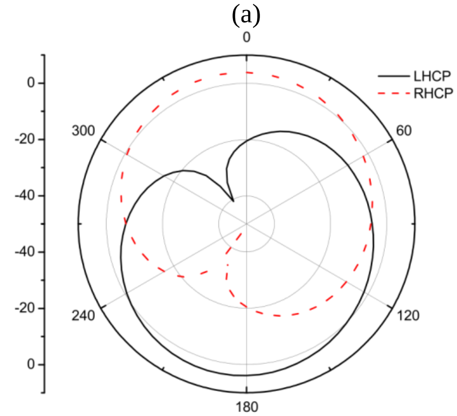
Fig. 10. Simulated and measured axial ratios of the proposed antenna.

Table 2: Dimensions of the proposed antenna (Unit: mm)

L	L1	L2	L3	L4	L5	L6	G1
80	48	20	19	13	3	22.5	3.75
W1	W2	W3	W4	W5	G2	h	
15	11.85	4	5.5	3	0.5	2	

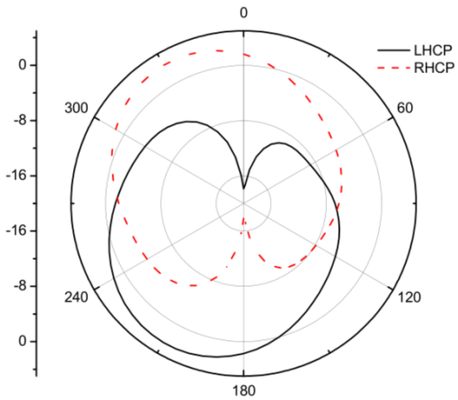


(a)

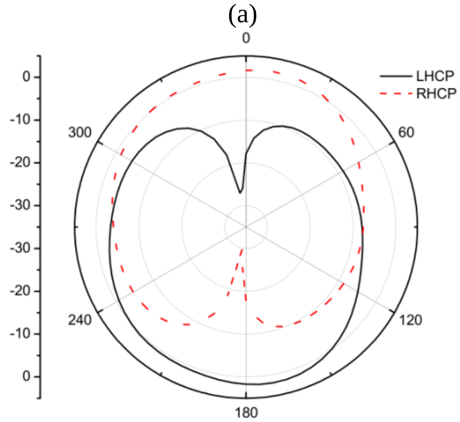


(b)

Fig. 11. Measured radiation patterns of the proposed antenna at 2.30 GHz ((a) Phi=0°, (b) Phi=90°).

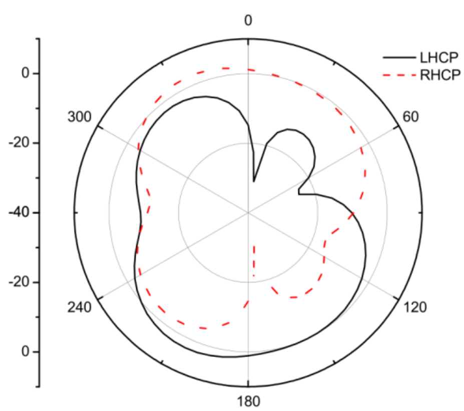


(a)

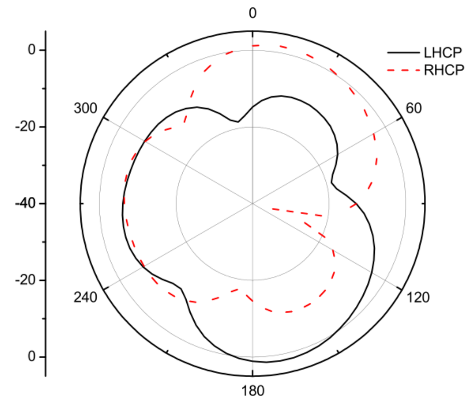


(b)

Fig. 12. Measured radiation patterns of the proposed antenna at 3.0 GHz ((a)Phi=0°, (b) Phi=90°).

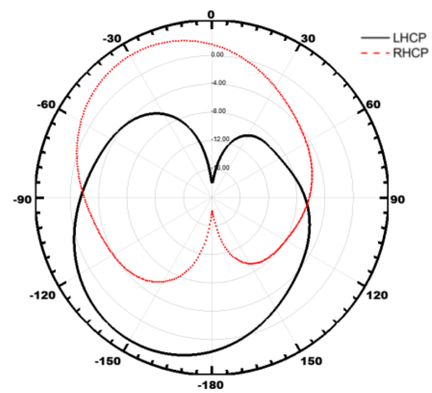


(a)

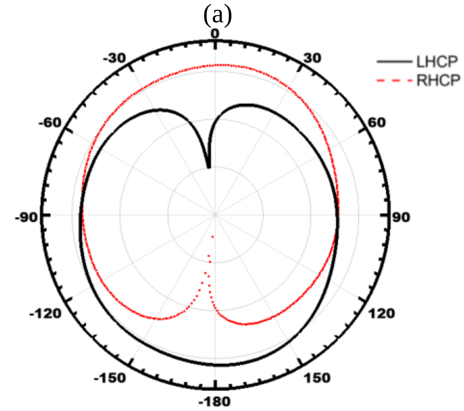


(b)

Fig. 13. Measured radiation patterns of the proposed antenna at 3.45 GHz ((a) Phi=0°, (b) Phi=90°).



(a)



(b)

Fig. 14. Simulated radiation patterns of the proposed antenna at 3 GHz ((a) Phi=0°, (b) Phi=90°).

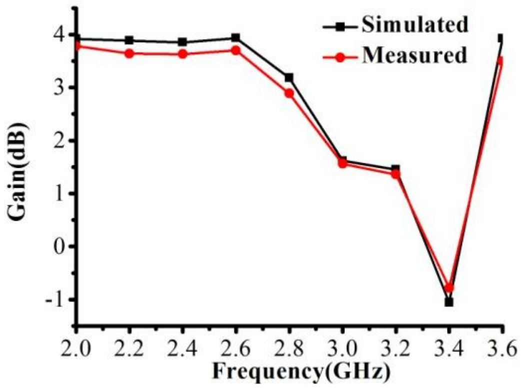


Fig. 15. Simulated and measured gain in +z-direction of the proposed antenna

VI. CONCLUSION

By analyzing the circular-polarization characteristics of CPW-fed slot antenna, a compact wideband dual-circular polarization CPW-fed slot antenna is presented in this paper. Two rectangular slots are respectively embedded on the corners of the antenna. By protruding into two inverted-L-shaped strips in the slot, the proposed antenna obtains a good impedance bandwidth of 70.4% from 2.3 to 4.8 GHz and 3-dB AR bandwidth of 48.6% from 2.1 to 3.45 GHz. The maximum gain of the proposed antenna reaches 3.95 dB. The proposed antenna can be applied for Bluetooth/WLAN (2,400-2,484 MHz) and WiMAX (2.5-2.69 GHz and 3.2-3.8 GHz) and the other wideband communication systems.

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