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Broadband Circular Polarized Antenna Loaded with AMC Structure

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Abstract—In this paper, a novel broadband circular polarized (CP) antenna for mobile communication is proposed. The antenna is constructed by a square ring patch with a gap and coplanar waveguide (CPW) feed structure. To achieve a broadband CP wave, a cross patch is embedded at the center of the slotted square ring patch to excite two orthogonal resonant modes with equal amplitude and 90° phase difference for CP radiation. Furthermore, on one side of ground a stub is embedded to match impedance bandwidth that can cover the whole CP bandwidth completely. Loading the AMC (Artificial magnetic conductor) structure on the back of the antenna achieves directed radiation of circular polarized waves. An antenna was fabricated based on simulation and optimization. The simulated and measured results show that the bandwidth with $S_{11} < -10\,\text{dB}$ is 66.9% from 1.82 GHz to 3.65 GHz, and the 3 dB axial ratio bandwidth is 52.8% from 1.95 GHz $\sim$ 3.35 GHz.

1. INTRODUCTION

With development of the newest wireless communication systems in recent years, narrow band antennas have been difficult to meet the needs of people. Acquiring high speed and efficient data become increasingly important. The research on broadband circularly polarized antenna has attracted much attention in the application of modern communication [1]. The advantage of circularly polarized antenna is that the polarization matching problem cannot be considered in the process of electromagnetic wave transmitting and receiving. It has been widely used in communications, radar, RFID, and sensor systems. Many of the circularly polarized antennas using single or double fed structures excite two orthogonal modes with a phase difference of 90 degrees [2, 3]. However, the axial ratio bandwidth of these antennas is very narrow, less than 3%. To obtain a wider axial ratio bandwidth, some researchers have proposed cross dipole antennas [4, 5], and the axial ratio bandwidth of this antenna can reach 25%. However, the disadvantage is that the size of the antenna is relatively large.

The coplanar waveguide structure has many characteristics, such as single metal layer, feed and radiation units in the same plane and easy integration with an active device. Therefore, this structure has been widely used in many wideband circularly polarized antennas. CPW-fed slot antennas for improving axial ratio bandwidth are presented in [6–8]. [6] shows that two inverted L structures with unequal sizes are inserted in the two corners of a coplanar waveguide feeding slot, and two orthogonal resonant modes are generated to form circularly polarized waves, and the bandwidth ratio is 32.2%. For a single slot antenna, coplanar waveguide is fed on a hexagonal structure in the slot. The antenna in [8] uses two diagonal arc structures on the diagonal to broaden the bandwidth of axial ratio, so the antenna's relative axial ratio bandwidth is 28%.

The concept of AMC structure comes from the reflection phase characteristics of an electromagnetic band gap structure. This structure has the characteristic of ideal magnetic wall in a certain frequency range. In other words, it is possible to realize the same phase reflection between the incident

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electromagnetic wave and reflected electromagnetic wave. At present, although the antenna design of the same kind of AMC structure has been designed at home and abroad such as [9–12], there is little research on the antenna fed by CPW with an AMC structure.

In this paper, we propose a novel design of a CPW-fed circularly polarized square slot antenna. The feed microstrip line is directly connected to the slotted ring structure. Meanwhile, a vertical cross patch is added to the center of the square ring structure to attain wider axial ratio bandwidth. A metallic strip of width 5 mm is protruded and on the side of the CPW structure to match the bandwidth of antenna. The AMC structure is loaded on the back of the antenna to realize the directed radiation of the antenna. Electromagnetic simulation software is used for simulation and design, then the structure is optimized in a appropriate way. Finally, 52.8% of the axial ratio bandwidth is acquired.

2. ANTENNA DESIGN

2.1. AMC Structure

Compared with the traditional coplanar waveguide antenna, the loaded AMC structure antenna has the advantages of directed radiation antenna wave and high gain. The following is the AMC structure designed in this article in Figure 1. From top to bottom, the structure contains 8×8 square metal patches with 6 mm length, an FR4 dielectric substrate and a metal plane plate.

An AMC works as a perfect magnetic conductor at resonant frequencies with 0° phase of the reflected wave when being illuminated by a normally incident plane wave. The waveguide simulation

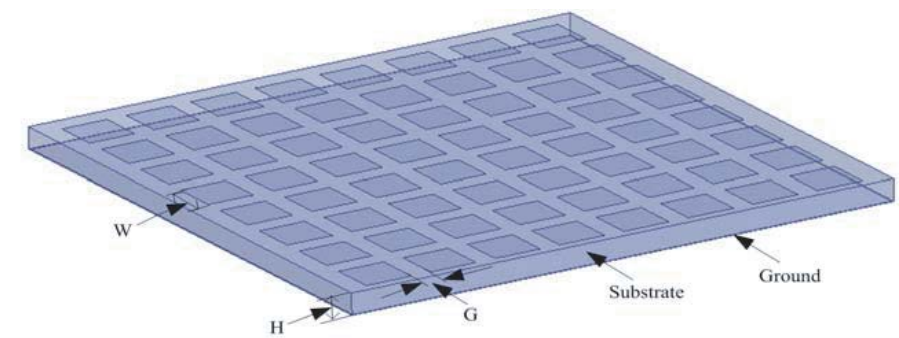


Figure 1. The AMC structure.

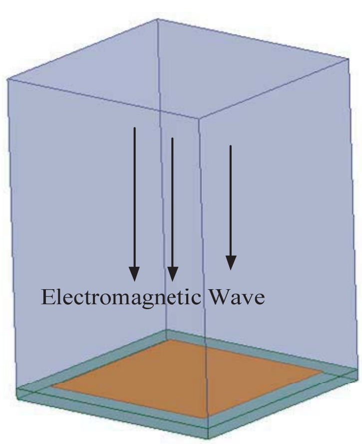


Figure 2. The AMC unit cell.

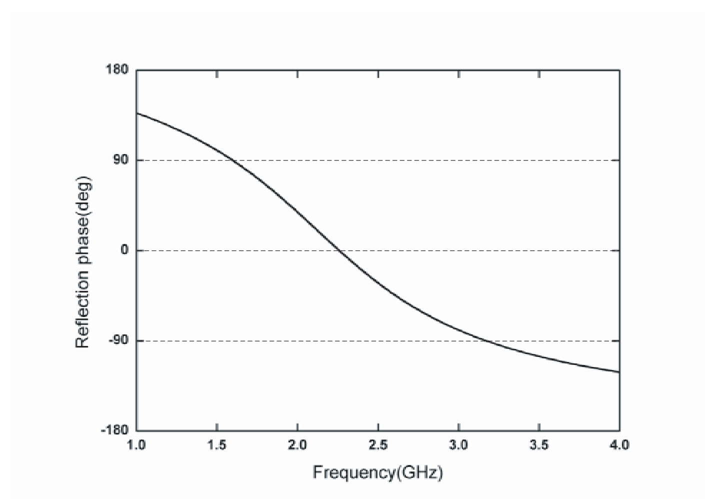


Figure 3. Reflection phase diagram of AMC structure.

setup of the proposed AMC unit cell is shown in Figure 2. Its bandwidth is defined as the frequency range over which the phase of the reflection coefficient is between ±90°. As we can see from Figure 3, the proposed structure's 0 degree reflection phase frequency is near 2.3 GHz, and the in-phase reflection phase bandwidth is 1.60 GHz–3.25 GHz.

2.2. Antenna Structure

The traditional loop antenna can radiate circularly polarized wave when there is a slot at the appropriate position of loop antenna. The geometric structure of the broadband CPW-fed circularly polarized antenna is presented in Figure 4. The radiating patch and grounding strip are located on the same layer of the dielectric substrate. The intersecting patch is placed at the center of the ring patch, and the wider axial ratio bandwidth is obtained by optimizing the length and width of the patch. The medium substrate used in this design is FR4 with thickness of 1 mm and dielectric constant of 4.4. The size of the antenna is 72 mm × 70 mm × 1 mm. A characteristic impedance of 50 Ω CPW with a protruded central

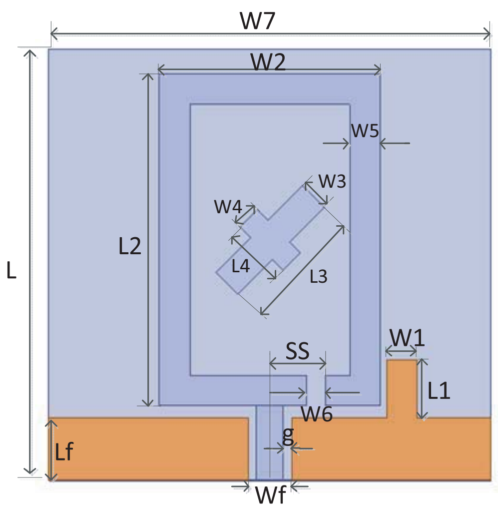


Figure 4. The antenna structure.

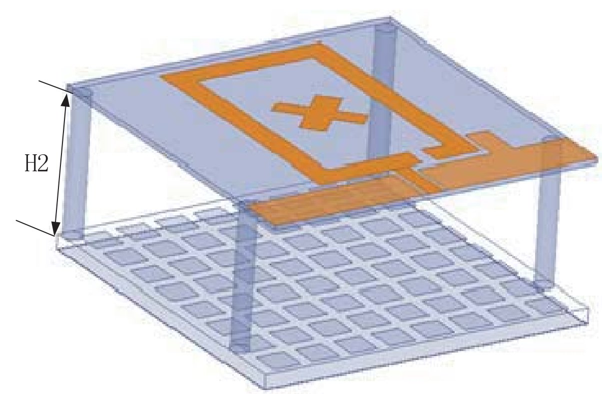


Figure 5. The integral structure of the antenna.

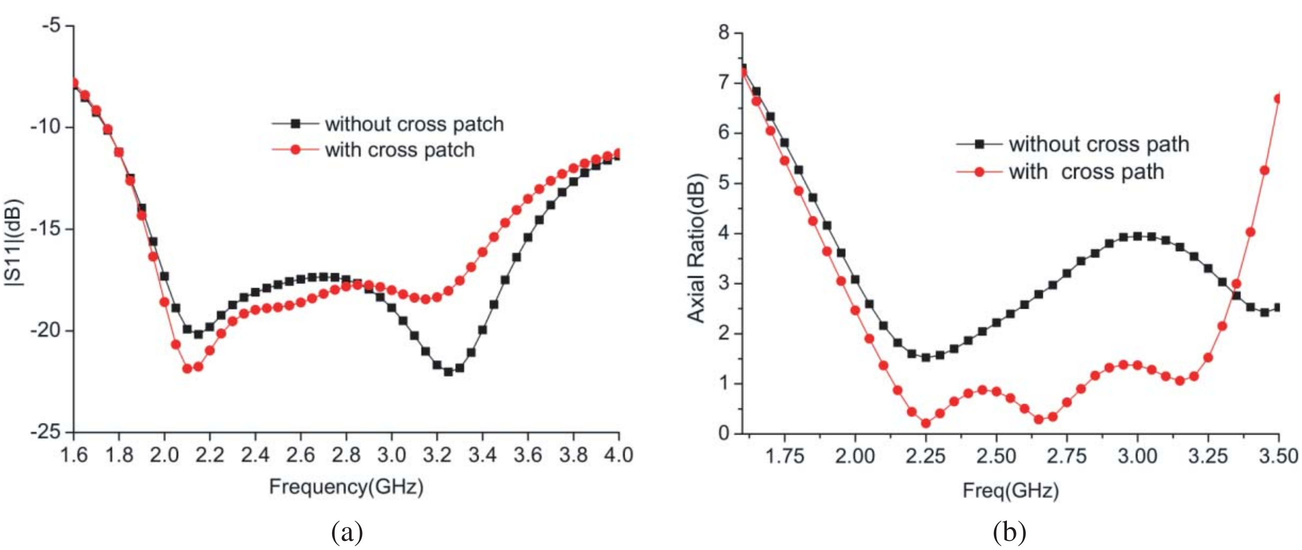


Figure 6. (a) $|S_{11}|$ patterns for antennas with and without cross patch. (b) AR patterns for antennas with and without cross patch.

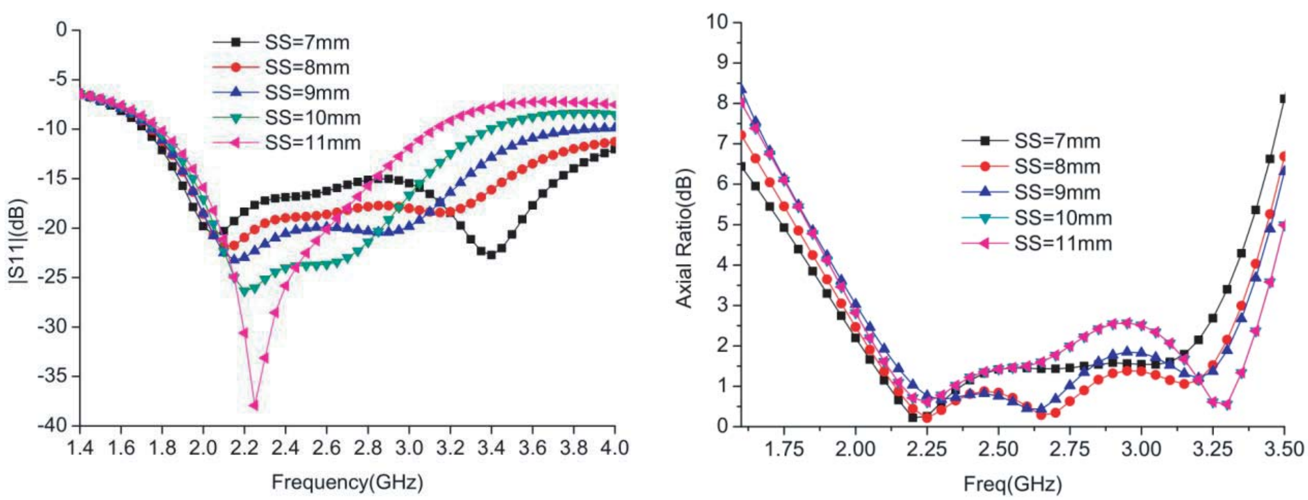
strip is used to feed the antenna. The central strip of the CPW is narrowed to a width of $Wf = 3.4\,\mathrm{mm}$ and a gap of spacing $g = 0.8\,\mathrm{mm}$ between the central strip and the coplanar ground plane. The length of the coplanar ground plane is $Lf = 10\,\mathrm{mm}$, and the central strip is 12 mm.

The integral antenna structure is shown in Figure 5. From top to bottom, the structure is the antenna, air medium layer and AMC structure. The antenna structure and AMC structure are supported by four plastic columns with the length of 27 mm.

3. PARAMETER ANALYSIS

The key factors affecting the performance parameters of the antenna designed in this paper rely on cross metal patch at the center of square ring patch and the position of slot on the square ring patch. Simulation analyses with and without the cross patch are given in Figure 6. To verify the effect of slot position on axial ratio bandwidth, simulation analysis of the position of slot has been done under the condition of changing only one parameter once and keep other parameters fixed. Figure 7 shows S_{11} and AR pattern of various SS.

The cross metal patch has a great influence on the axial ratio of the antenna as can be seen from Figure 6(b). When the patch is loaded, the current on the ring is coupled to the cross metal patch. Adjust the length of the metal patch to excite a pair of orthogonal modes with equal amplitude and phase difference of 90 degrees for circular polarization waves. From Figure 6(b), the axial ratio bandwidth of the antenna without cross patch is 2 GHz $\sim$ 2.4 GHz and that with cross patch is 1.95 GHz $\sim$ 3.35 GHz.



(a) (b)

Figure 7. (a) Simulated $|S_{11}|$ pattern for various SS. (b) Simulated AR pattern for various SS.

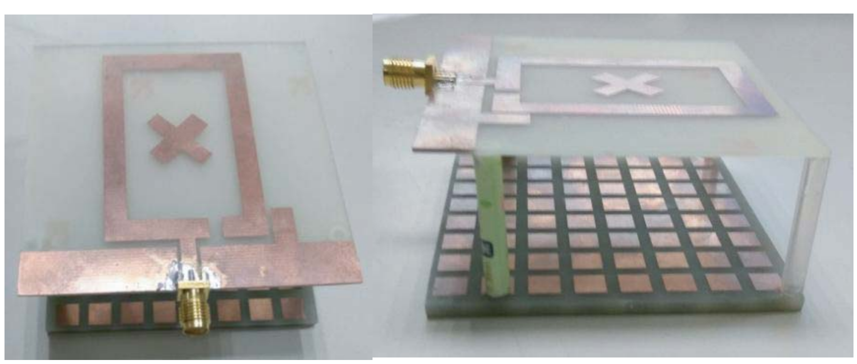


Figure 8. Photograph of the fabricated antenna.

Therefore, loading the metal cross patch can widen the axial ratio bandwidth of the antenna.

In Figure 7(a) and Figure 7(b), as SS increases the antenna working frequency becomes higher, and impedance bandwidth increases. 3 dB AR bandwidth increases and then decreases quickly when $SS = 10$ mm. As a result, when $SS = 8$ mm we could get a wider axial ratio bandwidth.

4. SIMULATION AND EXPERIMENTAL RESULTS

As shown in Figure 8, the proposed antenna was fabricated to validate our simulation data. Detailed parameters for this fabrication are listed in Table 1.

Table 1. Parameter of the proposed antenna (unit: mm).

W	H	G	L	$W7$	$L1$	$W1$	$L2$	$W2$	$L3$
6	3	2.5	70	72	9	5	54	36	15.8
$W3$	$L4$	$W4$	$W5$	$W6$	Lf	Wf	SS	g	$H2$
5	17.6	4	5	3	10	3.4	8	1.3	27

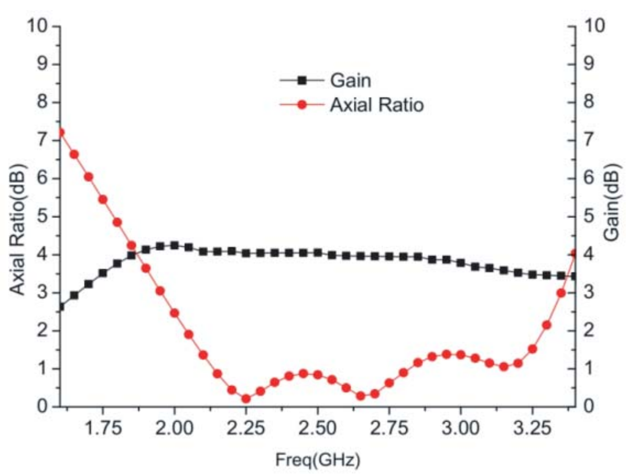


Figure 9. Gain and axial ratio of antenna.

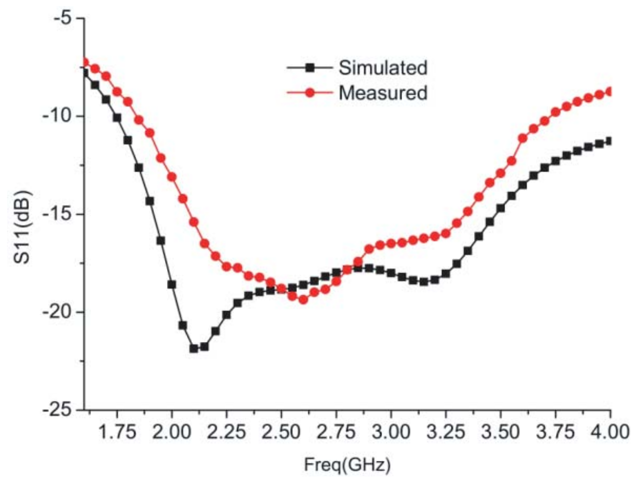
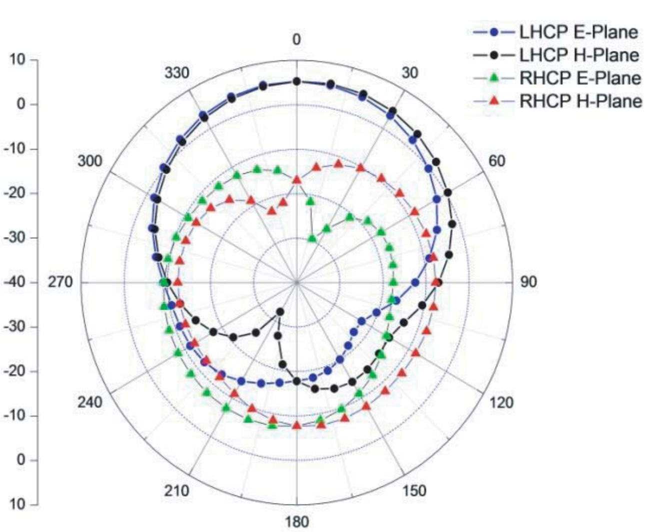
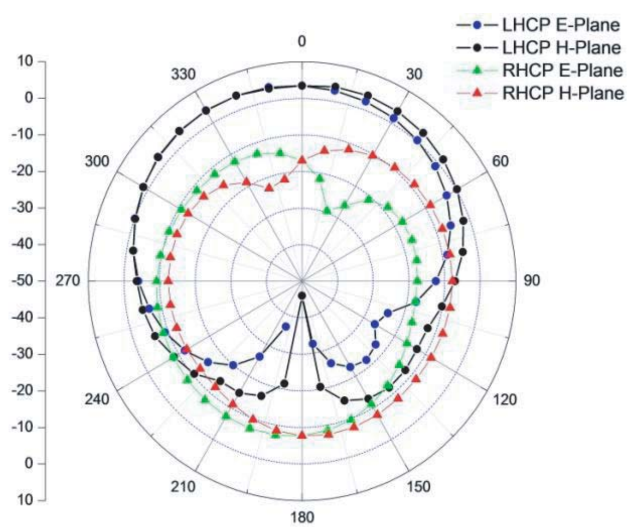


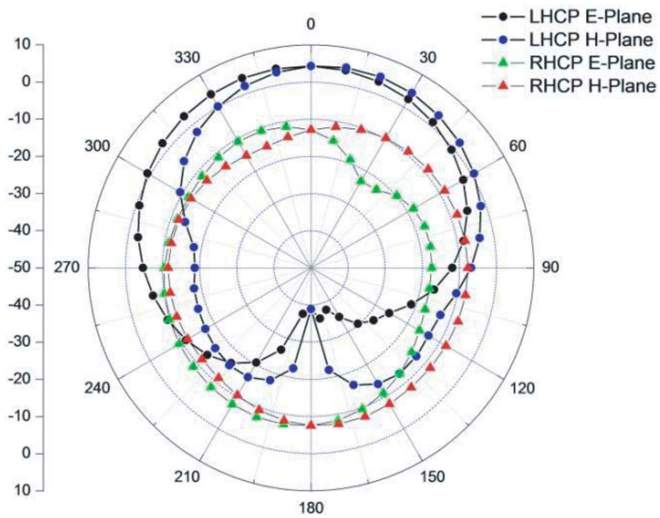
Figure 10. Measured and simulated $|S_{11}|$ results.



(a)



(b)



(c)

Figure 11. Simulated LHCP and RHCP radiation patterns of the proposed antenna. (a) 1.95 GHz. (b) 2.45 GHz. (c) 3.2 GHz.

The measured results of gain and axial ratio bandwidth are shown in Figure 9. The simulated impedance bandwidth is 56% for VSWR < 1.5 from 1.91 GHz to 3.45 GHz, and the measured impedance bandwidth is 68.2% for VSWR < 2 from 1.82 GHz to 3.75 GHz. In Figure 10, both of them can cover the frequency needed for 3G/LTE/WLAN application. The simulated radiation patterns at frequencies of 1.95, 2.4, and 3.2 GHz at the E-plane and H-plane are plotted in Figure 11.

The radiation patterns of the antenna at 1.95 GHz, 2.45 GHz and 3.2 GHz are shown in Figure 11. It is concluded that the proposed design with AMC structure gives left-hand circularly polarized (LHCP) and right-hand circularly polarized (RHCP) radiations. Compared with LHCP radiation, the RHCP radiation is very weak from Figure 11. A novel coplanar antenna has been integrated with the AMC reflector. By using the AMC reflector, the proposed antenna realizes directed radiation.

5. CONCLUSION

A broadband circularly polarized antenna is presented in this paper. The antenna consists of an annular structure with a slot, a vertical cross structure and AMC structure at the back of the antenna. Through the CPW feeding and optimization of the parameters, the circular polarization characteristics of the antenna in the 1.95 GHz $\sim$ 3.35 GHz bands are achieved in an unidirectional radiation. This band perfectly covers 3G/LTE and WLAN mobile communications in the present. The designed antenna has the advantages of simple structure, low cost, wide frequency band, etc. It also provides a new choice for the design of broadband circularly polarized antenna.

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REFERENCES

1. Karamirad, M., F. Samadi, C. Ghobadi, et al., "A very small broadband CPW-fed circular polarized antenna with two semicircles etched on ground plane," *IEEE International Symposium on Telecommunications*, 442–446, 2017.
2. Feng, D., H. Zhai, L. Xi, et al., "A broadband low-profile circular polarized antenna on an AMC reflector," *IEEE Antennas & Wireless Propagation Letters*, Vol. 99, 1-1, 2017.

3. Qi, S. S., W. Wu, and D. G. Fang, "Singly-fed circularly polarized circular aperture antenna with conical beam," *IEEE Transactions on Antennas & Propagation*, Vol. 61, No. 6, 3345–3349, 2013.
4. Baik, J. W., T. H. Lee, S. Pyo, et al., "Broadband circularly polarized crossed dipole with parasitic loop resonators and its arrays," *IEEE Transactions on Antennas & Propagation*, Vol. 59, No. 1, 80–88, 2011.
5. He, Y., W. He, and W. Hang, "A wideband circularly polarized cross-dipole antenna," *IEEE Antennas & Wireless Propagation Letters*, Vol. 13, No. 1, 67–70, 2014.
6. Pourahmadazar, J., C. Ghobadi, J. Nourinia, et al., "Broadband CPW-fed circularly polarized square slot antenna with inverted-L strips for UWB applications," *IEEE Antennas & Wireless Propagation Letters*, Vol. 10, No. 6, 369–372, 2011.
7. Cao, R. and S. C. Yu, "Wideband compact CPW-fed circularly polarized antenna for universal UHF RFID reader," *IEEE Transactions on Antennas & Propagation*, Vol. 63, No. 9, 4148–4151, 2015.
8. Krishna, R. V. S. R. and R. Kumar, "A CPW fed hexagonal patch — Slot antenna for circular polarization," *2013 IEEE MTT-S International Microwave and RF Conference*, New Delhi, India, 2013.
9. Li, G., H. Zhai, L. Li, et al., "AMC-loaded wideband base station antenna for indoor access point in MIMO system," *IEEE Transactions on Antennas & Propagation*, Vol. 63, No. 2, 525–533, 2015.
10. Gupta, G. and A. R. Harish, "Circularly polarized antenna using a double layered via-less high impedance surface," *Microwave and Optical Technology Letter*, Vol. 58, No. 2, 340–343, 2016.
11. Li, F., Y. Cui, and R. Li, "A novel broadband AMC surface for lowering the height of planar antennas," *IEEE International Symposium an Antenna and Propagation & USNC/URSI National Ratio Science Meeting*, 1110–1111, 2015.
12. Li, B., W. Hu, J. Ren, et al., "Low-profile dual-polarized patch antenna with HIS reflector for base station application," *Journal of Electromagnetic Waves & Applications*, Vol. 28, No. 8, 956–962, 2014.