An Improved Broadband Circularly Polarized Cross-Dipole Antenna With An AMC Reflector

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***Abstract*—In this paper, we present an improved design method to significantly reduce the volume of circularly polarized (CP) cross-dipole antenna. Unlike the commonly used approaches, the distance between the antenna and the reflector is largely narrowed to only 0.13λ_0 in this work. The proposed cross-dipole antenna achieves low profile and broadband characteristics by using stepped rectangular patch arms, parasitic strips and artificial magnetic conductor (AMC). And CP radiation for the proposed antenna can be generated effectively by connecting two arms of each dipole via a vacant-quarter ring. The overall size of the proposed antenna is 0.88λ_0 $\times$ 0.88λ_0 $\times$ 0.13λ_0. Simulation results show that a broadband impedance bandwidth (for S11 $<$ -10 dB) of 47.3% (1.81 to 2.93 GHz), a wide 3-dB AR bandwidth of 25.3% (2.16 to 2.78 GHz), the peak gain of 7.8 dBic and the average CP gain of whole operating frequency band of 7.5 dBic are obtained.**

***Index Terms*—Artificial magnetic conductor, broadband, circularly polarized, cross-dipole antenna, low profile.**

I. Introduction

For the advantages of low multipath interference, superior performances of transceivers and high polarization matching, circularly polarized (CP) antennas have attracted wide-spread attention in modern wireless communication applications, such as the global navigation satellite system (GNSS), radio frequency identification (RFID), and Internet of thing (IOT) [1]–[3]. Many methods including single fed patch antenna with cross slot or U-slot [4], [5], magneto-electric (ME) dipole [6] are mentioned to achieve CP radiation and wide axial ratio (AR) bandwidth.

In the past few years, the cross-dipole antennas to achieve broadband CP radiation have been extensively studied due to their low complexity structure and simple CP radiation mechanism [7]–[9]. In [7], a wider rectangular patch cross-dipole antenna is proposed to obtain 3-dB AR bandwidth of about 27% AR bandwidth. In [8], four parasitic loops are added to the printed cross-dipole giving an AR bandwidth of 25.2%. Besides, asymmteric crossed bowtie dipole with a wide AR bandwidth of 43.5% is reported in [9]. Although all the aforementioned cross-dipole antennas have achieved broadband CP radiation, they suffer from relatively high profiles of approximately 0.25λ_0, which are not suitable for using in low profile applications such as RFID terminals and other integrated devices. To reduce the profile of cross-dipole antenna, an artificial magnetic conductor (AMC) is used as reflector [10], [11]. Similar to the introduction of AMC, the antenna in [10] has achieved a low profile 0.088λ_0, and its AR bandwidth is only 8%. Although a 3-dB AR bandwidth of 19% and the profile of 0.14λ_0 is realized in [11], its gain is relatively lower.

In this paper, an improved cross-dipole CP antenna with an AMC structure is proposed to achieve low profile and broadband AR bandwidth simultaneously. Two adjacent resonant modes are excited to obtain a wider operating frequency bandwidth by using the stepped rectangular patch arms and parasitic strips. What's more, an AMC reflector is added above the ground plane to meet a low profile requirement.

The remainder of this paper is organized as follows. Section II is antenna design. Section III gives simulation results and analysis. Section IV draws the conclusion.

II. Antenna Design

The geometry of the proposed antenna is shown in Fig. 1. As shown in Fig. 1, the proposed antenna consists of two stepped rectangular patch arms, four parasitic strips, an AMC surface as the reflector and a semi-rigid coaxial cable. Two cross dipoles are respectively printed on both sides of a 55 $\times$ 55 mm^2 FR-4 substrate with a thickness of 1.6 mm, a relative permittivity of 4.4, and a loss tangent of 0.02. In this way, two CP modes are generated between the stepped rectangular patches and parasitic strips. By choosing a proper gaps between the arms of the dipole and the parasitic strips, both the impedance bandwidth and AR bandwidth can be expanded. In Fig.1(a), the AMC reflector is composed of 9 $\times$ 9 unit cells where each unit cell consists of a square patch with side length of w_{p} =11.5 mm (0.09λ_0, where λ_0 is the guide wavelength at the center frequency of 2.45 GHz) and a pair of crossed-stubs inside the ring slot on the patch, and the gap between adjacent unit-cells is p. Therefore, The side length of the square AMC reflector is W_g=108 mm. The top view of one cross dipole of proposed antenna is also shown in Fig.1(a). The bottom view of the other cross dipole of proposed antenna is similar to [7]. Two cross dipoles in [7] are replaced by two stepped rectangular patch arms and four parasitic strips in this work. Fig. 1(b) shows the side view of the proposed antenna. By choosing a proper distance between the antenna

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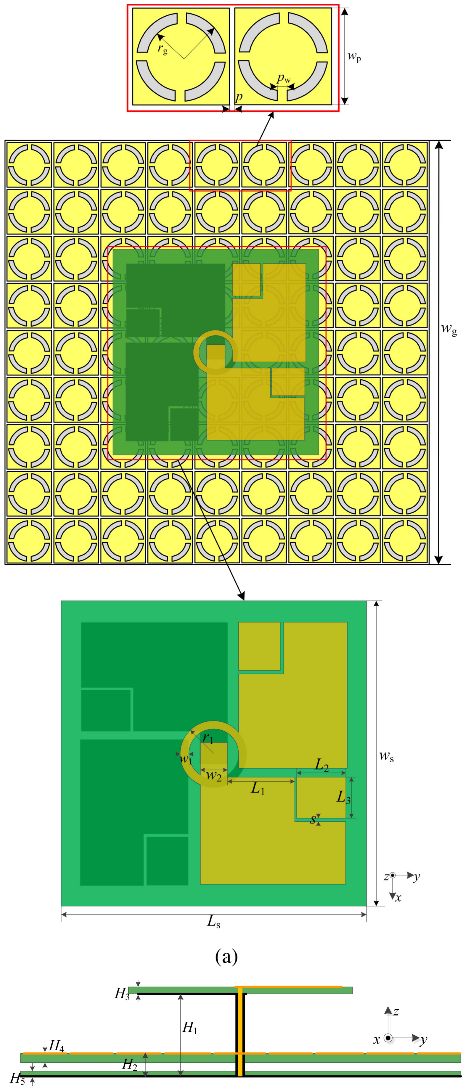


(a)

(b)

Fig. 1. Geometry of the proposed antenna (a) top view (b) side view.

TABLE I
ANTENNA PARAMETERS (MM)

H_1	H_2	H_3	H_4	H_5	w_s	w_1	w_2	r_1
15	5	1.6	2	1	55	1.5	5	6
L_s	s	L_1	L_2	L_3	w_p	p	r_p	r_g
55	0.5	12	9.2	7.5	11.5	0.5	5	4

and the AMC reflector, optimal antenna performance can be obtained. The dipole and AMC reflector surface are placed at height of H_1=15 mm and H_2=5 mm, from the ground plane, respectively. Therefore, the overall height of antenna is 16.6 mm, which is $0.13\lambda_0$. The detailed parameters of the proposed antenna are listed in Table I.

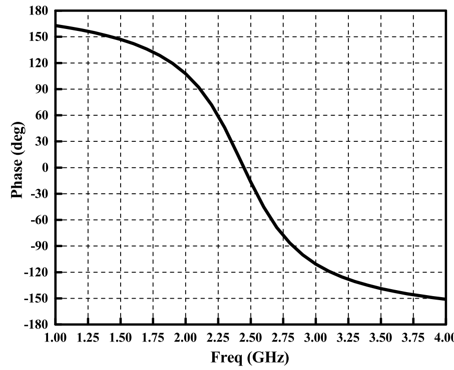


Fig. 2. Reflection phase of an AMC unit cell.

III. SIMULATION RESULTS AND ANALYSIS

Simulation results of the proposed antennas are obtained in this section. Figure 2 shows the reflection phase of an AMC unit-cell. As shown in Fig. 2, the AMC structure has a resonant frequency of 2.45 GHz, its reflection phase is 0°, and a frequency bandwidth of 2.1 to 2.8 GHz with the reflection phase varing from 90° to -90°. The fabricated prototype of the proposed antenna is shown in Fig. 3. Figure4 shows S_{11} of the proposed antenna. Simulated impedance bandwidth is 47.3% for S_{11}<-10dB, covering the frequency band from 1.81 to 2.93 GHz, and the measured S_{11} agrees reasonably with the simulated result. The simulated and measured ARs and gains are presented in Fig. 5, where the simulated 3-dB AR bandwidth is about 25.3%, from 2.16 to 2.78 GHz, and the measured 3-dB AR bandwidth covers from 2.21 to 2.85 GHz. As shown in the Fig. 5, the peak gain is 7.8 dBic at 2.45 GHz, and the average CP gain of 7.5 dBic is maintained within the whole operating bandwidth, and the measured results are consistent with the simulated results. The simulation and measurement radiation patterns of the proposed antenna in the *xoz* and *yoz* at 2.45 GHz are shown in Fig. 6, where the right hand circular polarization (RHCP) fields at boresight direction are always stronger than that of the left hand circular polarization (LHCP) counterparts by more than 15 dB, which also illustrated the proposed antenna is a RHCP antenna.

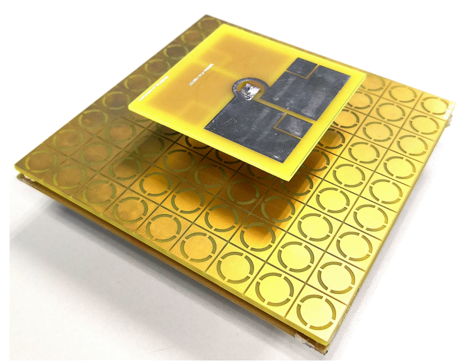


Fig. 3. The fabricated prototype of the proposed antenna.

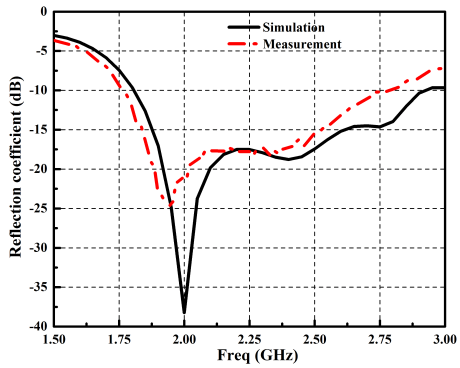


Fig. 4. The reflection coefficient of the proposed antenna.

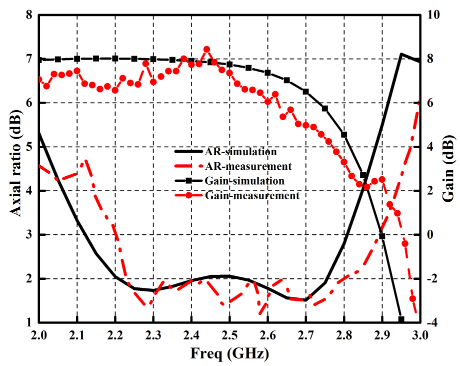
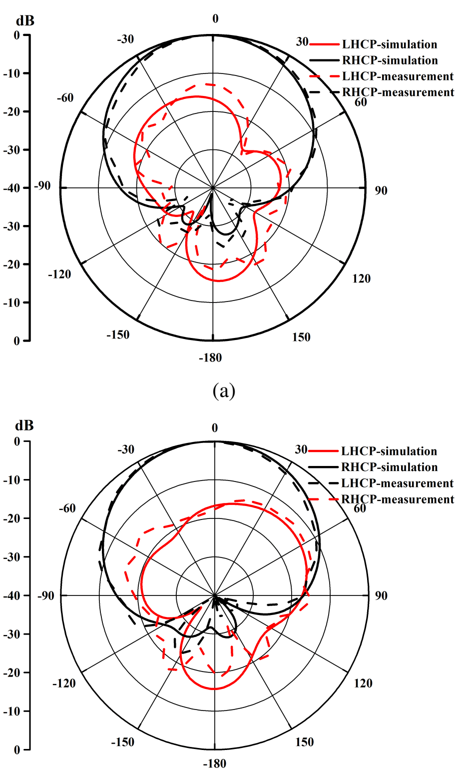


Fig. 5. The axial ratio and gain of the proposed antenna.



(a)

(b)

Fig. 6. Radiation patterns of the proposed antenna at 2.45 GHz (a) xoz plane (b) yoz plane.

IV. Conclusion

An improved broadband CP cross-dipole antenna with an AMC reflector has been proposed. The proposed antenna is composed of two stepped rectangular patches, four parasitic strips and an AMC reflector, which helps enhance the impedance bandwidth and AR bandwidth, and reduce the profile of antenna simultaneously. The overall size of the proposed antenna is only $0.88\lambda_0 \times 0.88\lambda_0 \times 0.13\lambda_0$. The proposed antenna achieves an impedance bandwidth (for $S_{11} < -10$ dB) of 47.3% (1.12 GHz, 1.81-2.93 GHz), and 3-dB AR bandwidth of 25.3% (0.62 GHz, 2.16-2.78 GHz). Besides, the average CP gain of 7.5 dBic is maintained within the whole operating bandwidth and the maximum gain of 7.8 dBic is achieved. Due to the low profile and broadband CP characteristics, the proposed antenna is suitable for various RFID antenna applications.

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