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Low Profile Dual-Polarized Circular Patch Antenna with an AMC Reflector

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Abstract—A coax-feed low profile dual-polarized circular patch antenna with ±45° polarization is presented. The antenna consists of a dual-polarized circular patch excited by two coax-lines and an AMC reflector. By using the AMC reflector as the ground plane of the patch antenna, the profile of the antenna is reduced to $\lambda/8$ of the operation frequency, which is much lower than that of the conventional dual-polarized patch antenna. The experimental results show that the proposed design obtains a wide bandwidth (2.12–2.77 GHz) and a high isolation (> 35 dB) over the entire band. In addition, the front-back radio of the antenna is improved significantly by using the AMC reflector. The wide bandwidth, low-profile and high front-to-back ratio make the antenna a good candidate as a base station antenna for WLAN, WiMAX and LTE applications.

1. INTRODUCTION

In recent years, with the rapid development in commercial communication systems, dual-polarized patch antennas have aroused considerable attention. The dual-polarized antennas are usually used to combat the multipath fading problem. At the same time, channel capability of the system can be enhanced as the antennas are able to provide double transmission channels. In previous works, various kinds of dual-polarized antennas have been developed [1–9]. In [1–3], aperture coupling has been adopted to achieve wide bandwidth and high port isolation, but the cross-polarization levels are not low enough. In order to obtain low cross-polarization levels, the dual-feed systems with a phase difference of 180° are proposed [7]. In addition, the electromagnetic feeds are also used to wider the bandwidth of the dual-polarized antennas.

Nevertheless, all of the antennas mentioned above have a high profile which is about $\lambda/4$ at the operation band. To get a low profile, in [10], we have proposed a low profile antenna with high front-back ratio by using AMC reflector. As the AMC or HIS can mimic a perfect magnetic conductor (PMC) within a certain frequency range, the antenna is allowed to be placed closer to the ground plane with good impedance matching and high efficient radiation. Due to these reasons, the AMCs are widely used to enhance the performance of the conventional antennas, such as low profile antennas [11–13], circularly polarized antennas [14] and high gain antennas [15]. By using HIS reflector as the ground plane, the antenna proposed in [10] has a profile less than $\lambda/8$, and the front-back ratio is better than 35 dB. However, the rectangle patch antenna proposed in [10] has a big size, which limits the applications of the antenna, especially for the array applications.

In this paper, a coax-feed low profile dual-polarized circular patch antenna with ±45° polarization is presented. The antenna has a compact size, and by using the AMC as the ground plane of the conventional antenna, the profile of the antenna is reduced to about $\lambda/8$ at the operation band. The prototype of the proposed antenna is fabricated and measured. The experimental results show that a

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wide operation band, high port isolation between the two feeding ports and good dual linear polarization can be obtained. In addition, after using the AMC reflector, the front-back radio of the antenna is improved significantly. Details of the proposed antenna design and both theoretical and experimental results are presented in following sections.

2. ANTENNA DESIGN AND WORKING MECHANISM

The illustration of the proposed antenna is shown in Figure 1(a). The antenna consists of a dual-polarized circular patch excited by two coax-line and an AMC reflector. The patch antenna consists of a pair of folded dipole antennas, which are printed on the opposite side of the FR4 substrate. The substrate has a relative permittivity of 4.4 with the thickness of 0.8 mm. The dipole antennas are placed perpendicularly to each other and in order to obtain $\pm 45°$ polarization, the patch antenna and AMC reflectors all has a rotated angle of 45° as shown in Figure 1(a).

The antenna is fed by two coax-lines which are placed along the diagonals of the radiating patch and are located at a distance of P from the patch center. The outer conductor of one coax-line is directly connected to point A, and the inner conductor is bended to connect to point B. Similarly, the other coax-line is connected to the points of C and D. Such structures described above form two air crossover bridges. Therefore point A and B (the same as point C and D) are excited in the same strength with a 180° phase difference. Moreover, in order to improve the isolation between the input ports, two short pins connected to point B and point D are introduced in this design.

The AMC reflector is placed under the antenna to act as the ground plane of the antenna. The geometry for the AMC reflector is shown in Figure 1(a). The square metal patch has a dimension of $B \times B\,\text{mm}^2$ and a period of A mm. To get a wide bandwidth, the substrate with high relative permittivity and high thickness is chosen and the AMC reflector was printed on the substrate with relative permittivity of 10.2 and a thickness of 2.34 mm.

According to the work principle of the AMC reflector [12], the reflecting phases of the AMC at interesting band is between $-180°$ to $180°$. This can counteract the phased of the mirror image, which can make the antenna's profile low. The distance H between the patch and the AMC reflector is set about $\lambda/8$ at the operation frequency, which is lower than conventional design.

Figure 2 depicts the current distributions of the antenna at 2.4 GHz with port 1 excited. It is obvious that the current mainly distributes along the slots and the antenna radiate electromagnetic wave like the folded dipole. In addition, the current is symmetrical with 45° direction. This enhanced the 45° linearly polarized wave and reduced the cross polarization of the antenna.

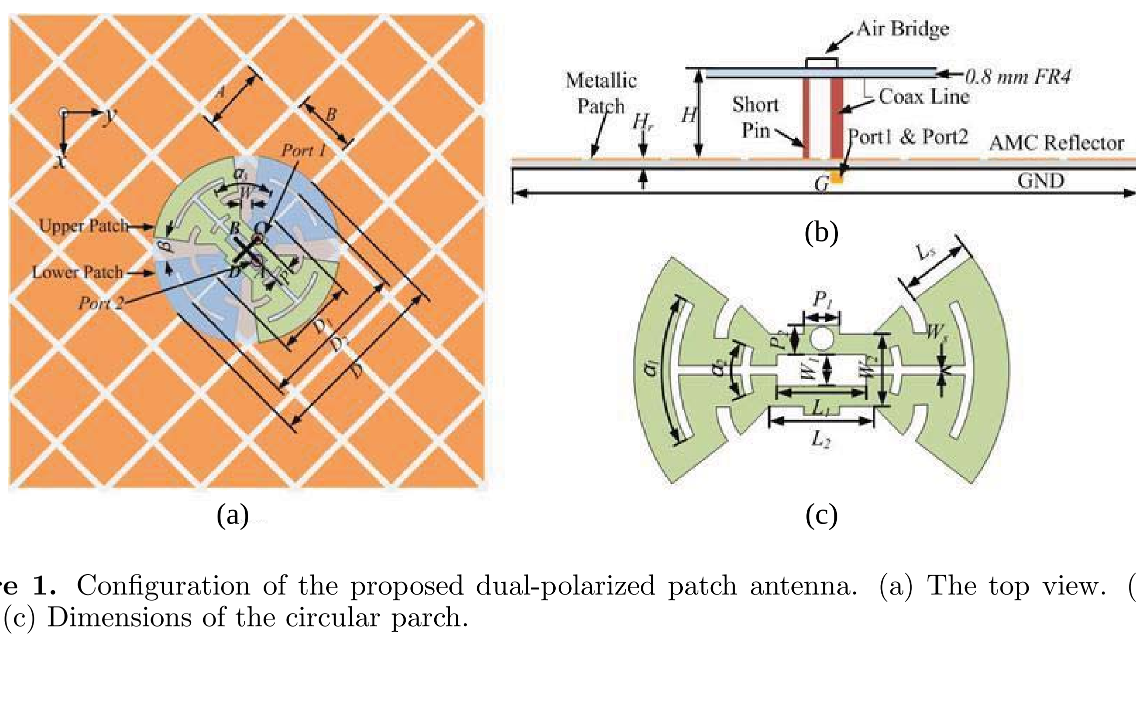

Figure 1. Configuration of the proposed dual-polarized patch antenna. (a) The top view. (b) Side view. (c) Dimensions of the circular parch.

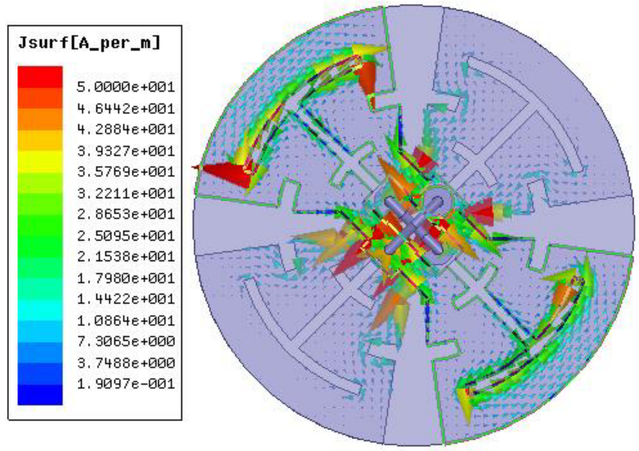

Figure 2. Current distributions of the antenna at 2.4 GHz.

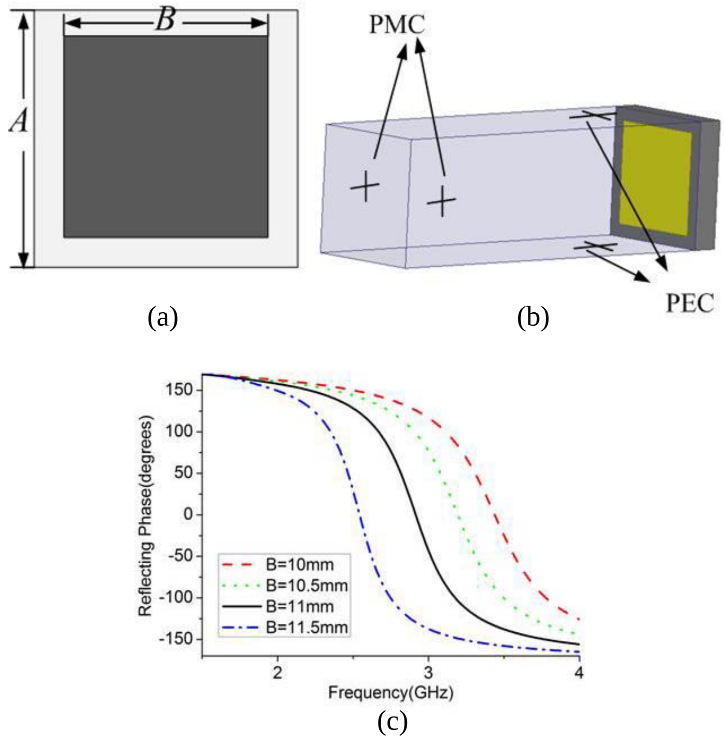

Figure 3. (a) The dimensions of AMC unit. (b) The simulation setup in HFSS. (c) The simulated reflecting phases of the AMC unit with different B.

3. THE AMC REFLECTOR DESIGN

There are several types of AMC reflectors that have been proposed in the open literature, such as "mushroom" type, uniplanar EBG, Peano curve type and Hilbert curve type [16]. Different type of AMC has different characteristic of bandwidth and reflected phases. To get the widest operation band, the modified "mushroom" AMC proposed in [17] is used. Usually there are vias between the square patched and the ground plane. However for normal incidence, the vias have little effect on the performance of the AMC reflector [18]. So the vias are removed for the simplification of the AMC reflector fabrication.

A unit cell of the proposed AMC reflectors is shown in Figure 3(a). The performance of an infinite repetition of the square patch cell was simulated by using ANSYS High Frequency Structure Simulator (HFSS). The model of the structure is shown in Figure 3(b) and the proper boundary condition (PEC is on the planes perpendicular to the polarization of the incident field, and PMC is on the planes parallel to the polarization of the incident field) is applied. Figure 3(c) gives the reflecting phase of the unit cell with different dimensions of the square patch. Here the period A is fixed to 12 mm. As can be seen, with the increase of B, the operation band of the AMC decreases and the operation bandwidth keeps constant, which show a $+90°$ to $-90°$ bandwidth of 14%. To meet our design operation band, here B was chosen as 11 mm.

4. RESULTS AND DISCUSSION

The proposed dual-polarized circular patch antenna was fabricated and measured. The final optimized dimensions of the antenna are given in Table 1. To validate the proposed technique, the measured

Table 1. Design parameters of the antenna shown in Figure 1.

Parameters	G	H	P	W	D	D_1	D_2	L_s
Unit	118.8 mm	14 mm	3.2 mm	2.5 mm	42 mm	17 mm	33 mm	8 mm
Parameters	L	L_2	W_1	W_2	P_1	P_2	W_s	
Unit	10 mm	11 mm	3.5 mm	8 mm	4 mm	3.5 mm	1 mm	
Parameters	α	α_2	α_3	β	H_r	A	G_r	
Unit	11°	27°	40°	8°	2.54 mm	12 mm	11 mm	

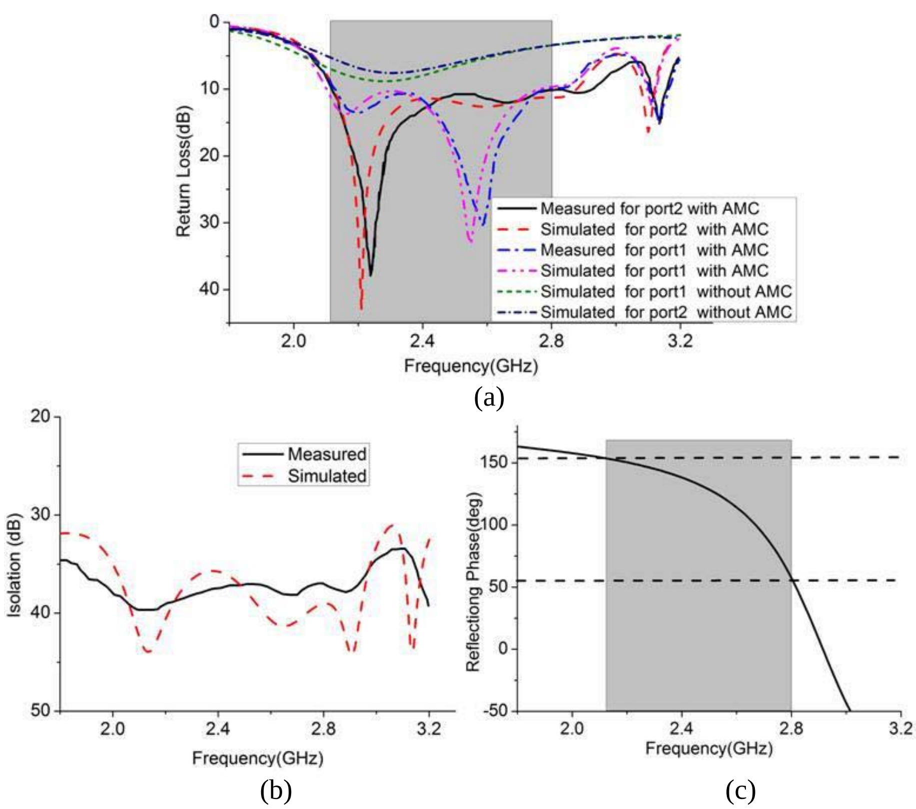

Figure 4. (a) Simualted and measured return loss of the proposed antenna. (b) Simualted and measured isolation of the proposed antenna. (c) Simulated reflecting phase of the AMC feflector (Grey area is the operation band of the antenna).

results are compared with the simulations. Figure 4(a) shows the simulated and measured return losses of the antenna. As can be seen, the measured impedance bandwidth for the $S_{11} < -10\,\text{dB}$ reflection coefficient covers a frequency range from 2.12–2.77 GHz (650 MHz) and 2.12–2.92 GHz (800 MHz) for port 1 and port 2, respectively, which indicates a similar impedance characteristic of the two ports and a percentage bandwidth of 26.5% (2.12–2.77 GHz) for the proposed antenna. The antenna can cover the WLAN 2.4 GHz band and WiMax 2.3–2.7 GHz band. In addition, the reflecting phases of the AMC are given in Figure 4(c) and the grey area is the antenna operation band for $S_{11} < -10\,\text{dB}$. In the antenna

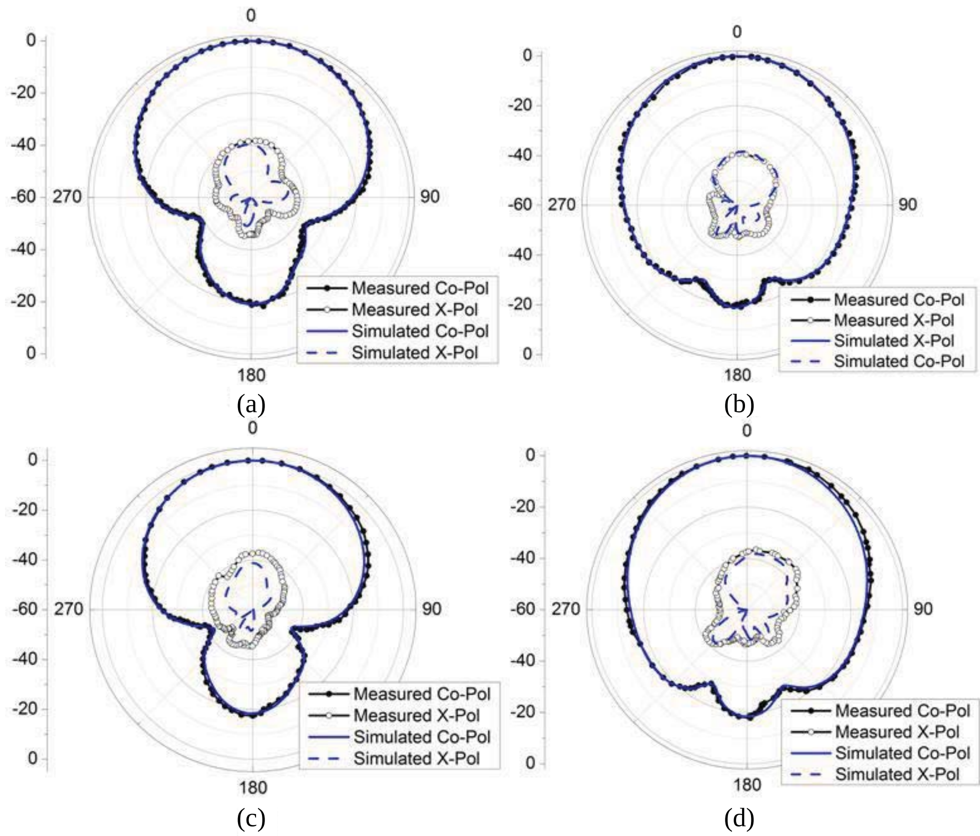

Figure 5. Measured and simulated radiation patterns at 2.4 GHz for the proposed antenna. (a) E-plane for port 1. (b) H-plane for port 1. (c) E-plane for port 2. (d) H-plane for port 2.

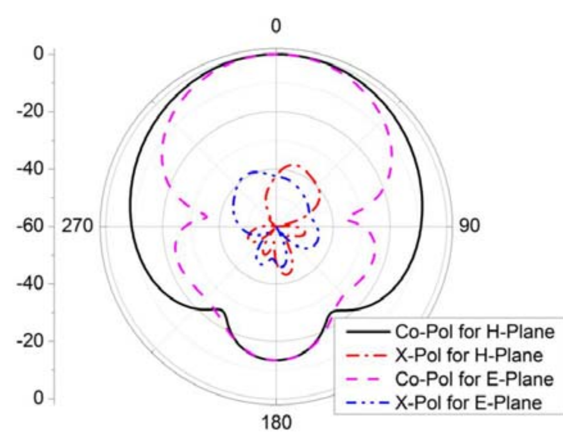

Figure 6. Simulated E-plane and H-plane radiation patterns at 2.4 GHz for the antenna without AMC reflector.

operation band, the reflecting phases varied from 53° to 154°. This is in good agreement with the conclusions proposed in [12] which indicate that the antenna shows a good return loss in the frequency region where the reflection phase of the EBG surface between $90° \pm 45°$. Besides, Figure 4(b) shows the port isolation of the proposed antenna. From the results, it also can be seen that the port isolation keeps better than 35 dB in the whole bandwidth.

Figure 5 shows the measured and simulated radiation patterns for E-plane ($phi = 135°$ for port 1 and $phi = 45°$ for port 2) and H-plane ($phi = 45°$ for port 1 and $phi = 135°$ for port 2) at 2.4 GHz, respectively. When port 1 is excited, port 2 is terminated with a 50-Ω load, and vice versa. For a comparison, the simulated radiation patterns without the AMC reflectors are shown in Figure 6. It can be seen that the cross polarization within the main lobe remains less than −38 dB. In addition, as the profile of the antenna is reduced and the AMC reflector can suppression the surface wave [18], the front-to-back ratio remains better than 20 dB, which is about 7 dB higher than that without the AMC reflector. Besides, the half-power beam width of the antenna is about 68° in E-plane and 64° in H-plane. The gain of the antenna is stable at about 8.7 dB in the whole bandwidth with the efficiency about 83%.

5. CONCLUSION

A coax-feed low profile dual-polarized circular patch antenna with ±45° polarization is presented. By using the AMC reflector as the ground plane of the patch antenna, the profile of the antenna is reduced to $\lambda/8$ at the operation band, which is much lower than that of the conventional dual-polarized patch antenna. At the same time, the front-back radio of the antenna is improved about 10 dB. The wide bandwidth, low-profile and high front-to-back ratio make the antenna a good candidate as a base station antenna for WLAN, WiMAX and LTE applications.

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