High-efficiency Wideband and Compact Circularly Polarized Microstrip Antenna with Wide Beamwidth

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***Abstract*—A novel compact circularly polarized (CP) microstrip antenna is presented. The antenna introduces a square radiation patch with a crossed slot to improve the impedance matching and reduce the antenna sizes. In addition, the proposed radiation structure makes the antenna a good CP property in the normal direction and also in the horizontal direction, so a super wide beamwidth of the axial ratio (AR) is obtained. Low-loss substrate and no-resistor feeding network are utilized to maximize the antenna radiation efficiency. Based on the above design, The profile and the length of the antenna are $0.073\lambda_0$ and $0.275\lambda_0$ respectively (λ_0 is the wavelength in free space). The impedance bandwidth for VSWR≤2 is 21.9%, and the AR bandwidth for AR≤3dB is 9.1%. In the overlap band, the radiation efficiency can reaches more than 97%, and the gains are over 5.1dBic. Especially, the beamwidth for AR≤3dB can cover more than 190°.**

Keywords—Circularly polarization microstrip antenna, miniaturization, wideband, wide beamwidth, cross slot, series feeding network.

I. Introduction

The compact circularly polarized (CP) microstrip antennas (CCPMA) are always a research topic because of their low-profile advantage in the applications of satellite navigation, radio frequency identification (RFID) and other mobile communication systems [1, 2]. In present researches, the design of the CCPMA mainly involves two approaches. One is to employ the high-permittivity substrate to reduce antenna sizes directly, which often has a simple structure but narrow bandwidth and low radiation efficiency. The other is to introduce the power dividing network feeding to the miniaturized radiation patch, which usually obtains a flexible design but a complex structure [3]. The miniaturized radiation patch is usually realized by the shorting and coupling structures, which usually leads to the Q factor rising and bandwidth droping [4]. The feeding network with resistors could facilitate wideband CP operation, because the resistors could absorb the reflected energy [5, 6]. However, the bandwidths of gain and radiation efficiency of the antenna will shrink obviously.

In addition, the wide-beamwidth property of the CP antenna is also desired in some applications. For a CP antenna, the beamwidth is not only the beamwidth of the radiation pattern (RP) but also that of the AR RP, i.e. the angle range of AR≤3dB. Although the RP beamwidth could be enlarged through reducing antenna sizes or increasing surface wave, the 3dB-AR beamwidth does not increase easily as desired [7].

In this paper, a high-efficiency wideband CCPMA with the much wide 3dB-AR beamwidth is designed. A novel compact crossed-slot radiation patch structure is proposed, and a larger area of the effective current distribution is obtained on the patch, which has different properties from the other similar antennas. Besides getting the CP property in the normal direction of the antenna, the CP property at horizontal is improved obviously, so the antenna has a much wide 3dB-AR beamwidth (more than 190°). A sufficiently series feeding network is introduced to excite the compact patch.

II. Antenna Design

The configurations of the proposed antenna are shown in Fig.1. The antenna is mainly composed of three components: the top PCB, bottom PCB and the side PCB. All the PCBs adopt 1mm-thick PTFE substrate, whose relative permittivity ε_r is 2.65 and loss tangent is 0.002. The top one is the main radiation component (fig. 2(a)). A square patch cut with a crossed slot along the diagonals is printed on the upper surface of the PCB. Also, the patch could be seen as four isosceles right triangle patches divided by the crossed slot. The length of the square is labeled as L_1, and the width of the slot is labeled as W_s. The top PCB is connected to the bottom PCB by four side PCBs. The feeding patch with the shape of right triangle is printed on the side PCB (fig. 2(b)), which contains a shorting stub. By tuning the position of the shorting stub L_2, the impedance matching can be solved. The width of the shorting stub is 2mm.

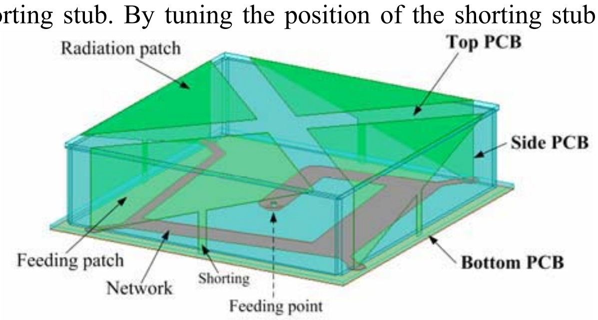

Fig. 1. Configuration of the proposed antenna.

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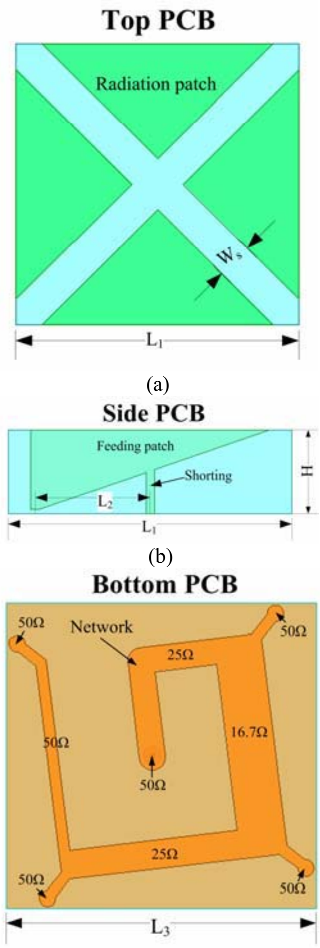


(c)

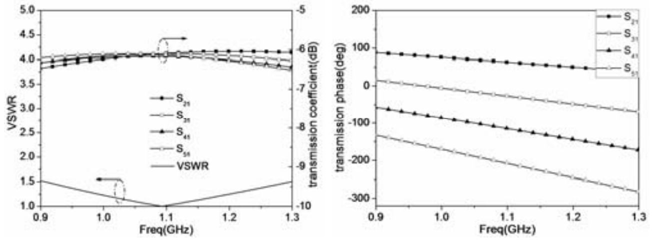
Fig. 2. Three components of the proposed antenna. (a) Top PCB. (b) Side PCB. (c) Bottom PCB.

The space between the top and bottom PCBs is labeled as H. The bottom PCB is a microstrip feeding network, which is a clockwise rotation for LHCP operation (fig. 2(c)). For low loss and compact layout, the network is a square series line, whose feeding port is at center and four connecting ports are at four corners. The length of each line between two adjacent ports determines the 90° phase difference of the output. All the five ports are designed to match with 50Ω, and then the characteristic impedance of each line is calculated and labeled in Fig. 2(c). Fig. 3 shows the simulated performances of the network. The band of VSWR ≤ 1.5 almost covers 0.9~1.3GHz. Therefore, the bandwidth of the entire antenna will be mainly dominated by that of the radiation component.

III. RESULTS AND DISCCUSION

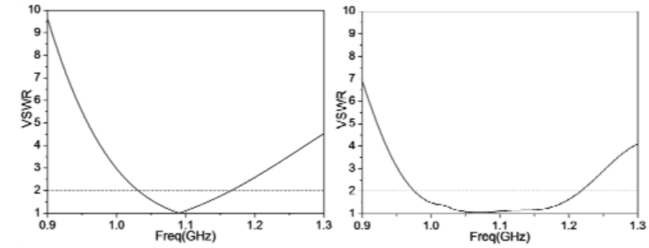
According to the above antenna, the performances of the antenna are calculated and optimized by the Ansoft HFSS. The optimized parameters are obtained as follow: L_1=72mm, L_2=40mm, H=20mm, L_3=75mm, W_s=5mm.

Firstly, the VSWR curve of the antenna without network is shown in fig. 4(a), and the bandwidth of VSWR ≤2 coves 1.033~1.166GHz, 133MHz. Fig. 4(b) shows the VSWR of the



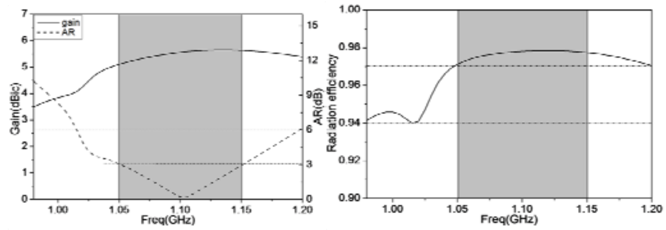
(a) (b)

Fig. 3. Performances of the network (a) VSWR and transmission coefficient. (b) Transmission phase.



(a) (b)

Fig. 4. (a) VSWR without network. (b) VSWR of the entire antenna.

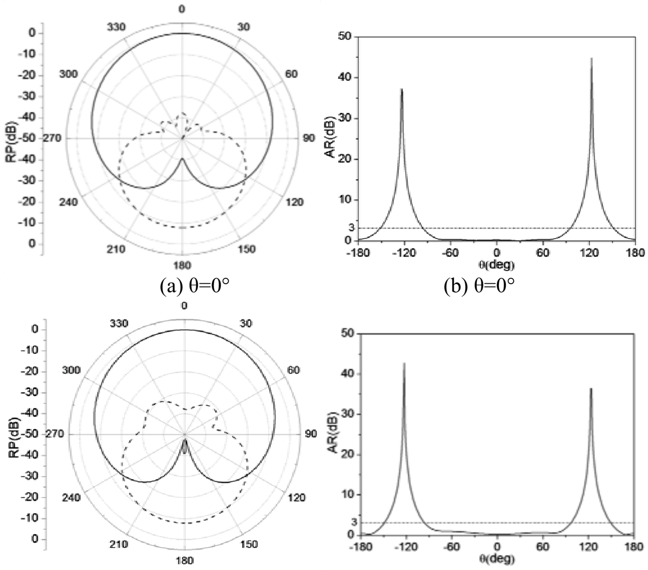


(a) (b)

Fig. 5. (a) Gain and AR of the proposed antenna along along z-axial direction. (b) Radiation efficiency.

entire antenna. The bandwidth for VSWR≤2 covers 0.976~1.217GHz, i.e. 241MHz, which implies the relative bandwidth of 21.9%. A perfect impedance matching is acquired around 1.1GHz. The bandwidth for VSWR≤1.5 covers 0.999~1.192GHz, the relative bandwidth of 17.5%. Such a wide impedance bandwidth benefits from the employing of the series feeding network but no resistor on it. The obtained impedance bandwidth is wider than that of other compact CP antenna without resistor [8]. Then, the high radiation efficiency can be achieved. Fig. 5(a) depicts the co-polarization gain and AR curves verse frequency along z-axial direction. The bandwidth of the AR below 3dB is 1.05~1.15GHz, i.e. 100MHz, and the relative bandwidth is 9.1%. In this band, the measured co-polarization gains are above 5.1dBic, and the peak gain is 5.6dBic. Fig. 5(b) shows the radiation efficiency of the band is more than 97% in the whole band. If the requirement of the AR is allowed to 6dB, a wider AR bandwidth of 1.015~1.2GHz, a relative bandwidth of 16.8%, could be obtained. The corresponding radiation efficiency is also beyond 94%. In most communication systems, the performances are also acceptable.

Fig. 6 shows the RPs and AR RPs in elevation plane at 1.1GHz. The planes of θ=0° and 90° are given separately. The 3dB-beamwidths of the co-polarization (LHCP) RPs in two planes are 104.0° and 104.4° respectively, so it indicates a



(a) θ=0° (b) θ=0°

(c) θ=90° (d) θ=90°

Fig. 6. RPs and AR RPs of the proposed antenna at 1.1GHz.

very well symmetry of the radiation characteristic. In addition, a good CP property is acquired. The AR RPs are presented in fig. 6(b), (d). Very large 3dB-AR beamwidth are obtained in two planes, and the angle range are -95.5°~94.8°and -95.9°~97° respectively. From these results, the proposed antenna has an excellent CP property in almost entire upper-half space, especially at low elevation angle.

IV. CONCLUSION

A compact CP microstrip antenna is proposed in the paper. The square radiation patch of the antenna is divided by a cross slot, which brings a miniaturized structure and a wide-beamwidth CP property in almost entire upper-half space. Meanwhile, due to the application of the low-loss substrates and no-resistor series feeding network, the radiation efficiency of more than 97% is obtained in the operating band. Based on the good CP property and the low-profile structure, the proposed antenna is the good choice for the mobile communications.

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