Wideband Microstrip-Line-Fed Circularly Polarized Slot Antenna with Open Slot Structure

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***Abstract*—A new wideband circularly polarized (CP) slot antenna with open slot structure using a microstrip-line for feeding is presented. The proposed antenna consists of an open C-slot with a straight slit on the ground plane, and a microstrip-line with a semi-circle-shaped patch on the other side of the substrate. The antenna size is reduced by about 35% compared with the circular slot antenna. By using the semi-circle-shaped patch to disturb the magnetic current distribution on the open C-slot, a wider CP bandwidth can be achieved. The measured results show that the proposed antenna can provide a 3 dB axial ratio (AR) bandwidth of 40% (4.1-6.2 GHz) and a 10 dB return loss impedance bandwidth of 107% (2.3-7.6 GHz).**

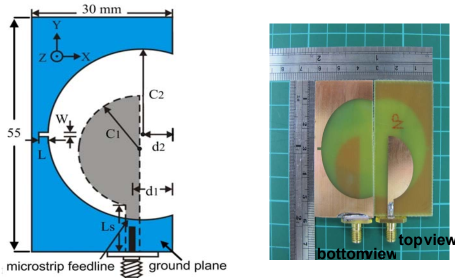
Keywords—circularly polarized (CP); open C-slot; semi-circle-shaped patch; magnetic current; axial ratio (AR)

I. INTRODUCTION

Circular polarization is an important polarization scheme in current wireless communications to enhance system performance. The main reason is because it can provide better mobility and less sensitivity to the orientation between transmitter and receiver and multipath interference than the linear polarization [1]. Recently, several planar slot antennas have been proposed to achieve the desired wideband CP performances [2-6]. Among these antenna designs, the antenna structures containing a symmetric slot can be made perturbation effect by embedding some short-circuited stubs on the slot and using a special shape feedline, such as a square slot [2], a circular slot [3] and an irregular slot [4]. Another type of the slot antenna is an open slot (monopole slot) antenna that not only possesses the advantages of the slot antenna, but also need only half operation wavelength for a narrow or wide slot structure. Several researchers have devoted to design a wider CP bandwidth for the narrow open slot antenna with a quarter-wavelength resonating characteristic. In [5], an L-shaped monopole slot antenna with a single C-shaped feed is used to achieve the 3 dB AR bandwidth of 23%. In [6], a modified open cross-slot on the ground plane is fed by a coplanar waveguide feeding structure, which can provide the AR bandwidth of 8.9% and impedance bandwidth of 48.8%. In this paper, we report an open C-slot antenna with a slit by using a microstrip-line with a semi-circle-shaped patch for excitation. The proposed antenna has a compact size of 30 × 55 × 1.6 mm^3 compared with the circular slot CP antenna [3] that requires a larger size of 110 × 110 × 1.6 mm^3. The AR bandwidth is 2.1 GHz (4.1-6.2 GHz, 40%) and the measured impedance bandwidth is 5.3 GHz (2.3-7.6 GHz, 107%).

II. ANTENNA DESIGN

The proposed antenna is excited by a 50 Ω microstrip-line as shown in Fig. 1(a), which is printed on an FR4 substrate with thickness of 1.6 mm and relative permittivity of 4.4. The width of the microstrip-line is fixed at 3 mm. The antenna structure consists of a microstrip feedline with a semi-circle-shaped patch and an open C-slot with a straight slit on the ground plane. A conducting ground plane with a width of 30 mm and length of 55 mm is placed on the other side of the substrate.



(a) (b)

Fig. 1 Geometrical configuration of antenna: (a) proposed antenna and (b) fabricated antenna photograph.

For the design of CP characteristics, the radius C1 of the semi-circle-shaped patch and the radius C2 of the open C-slot are set 13 mm and 20 mm, respectively. By using the semi-circle-shaped patch to disturb the magnetic current distribution on the open C-slot, CP characteristics can be achieved. In addition, the impedance bandwidth can be improved by tuning the straight slit with dimensions L and W on the open C-slot. After a thorough parametric study, the optimum design parameters were set as follows: d1 = 8.5 mm, d2 = 6.5 mm, L = 2 mm, W = 1 mm and Ls = 6.5 mm. The antenna prototype was fabricated as shown in Fig. 1(b).

III. SINULATED AND MEASURED REULTS

Fig. 2 shows the magnetic current distribution for the proposed antenna at 5.5 GHz, as obtained from the HFSS simulation software. It can be observed that the magnetic current distribution is displayed on the open C-slot for the four phase angles of 0^o, 90^o, 180^o, and 270^o, respectively. At the phase angle of 0°, the stronger magnetic current mainly flows in the +x direction. Note that the magnetic current along the upper half-plane of the open C-slot has the strongest distribution. Then, it flows in the -y direction at the phase angle of 90°. The magnetic current flows in the -x and +y directions at the next two phase angles of 180°, and 270°, respectively. The instantaneous magnetic current varying as a function of time exhibits a clockwise flow, which likes a left-handed circularly polarized (LHCP) behavior.

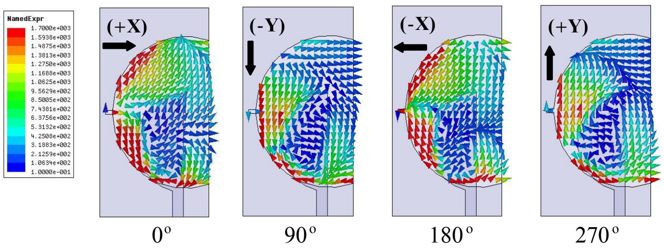


Fig. 2 Simulated magnetic current distributions for the proposed LHCP antenna at 5.5 GHz with four phase angles of 0°, 90°, 180°, and 270°.

Table I lists the simulated and measured results for the 10 dB impedance bandwidth and 3 dB AR bandwidth of the straight slit with varying dimensions L and W on the open C-slot. It can be seen that the AR bandwidth exhibits less variation than the impedance bandwidth. This because the magnetic current distribution on the open C-slot was little affected by the straight slit with a small size (W = 1 mm and L = 2 mm). Note that the impedance bandwidth can be improved by fine tuning the straight slit with the width W.

TABLE I. SIMULATED AND MEASURED RESULTS FOR THE CENTRAL FREQUENCY, IMPEDANCE BANDWIDTH (10 DB RETURN LOSS) AND AR BANDWIDTH (3 DB AXIAL RATIO)

Geometrical parameters	Unit (mm)	Central freq. (GHz)	Bandwidth (GHz, %)	AR bandwidth (GHz, %)
L	0	6.05 (4.1-8)	3.9, 64.5	2.3, 43.8
	1	6.0 (4.0-8)	4.0, 66.6	2.3, 43.0
	2	4.95 (2.3-7.6)	5.3, 107.1	2.1, 40.8
	3	5.75 (3.9-7.6)	3.7, 64.3	1.3, 26.8
W	0.5	5.9 (3.8-8)	4.2, 71.2	2.3, 43.0
	1	4.95 (2.3-7.6)	5.3, 107.1	2.1, 40.8
	1.5	5.85 (3.7-8)	4.3, 73.5	2.0, 39.2
	2	5.85 (3.8-7.9)	4.1, 70.01	1.4, 29.2

Figs. 3(a)-(b) show a good agreement between the measured and simulated results for the return loss and axial ratio. The impedance bandwidth for 10 dB return loss reaches 5.3 GHz (2.3-7.6 GHz) and corresponds to a fractional bandwidth of 107% for the central frequency at 4.95 GHz. The 3 dB AR bandwidth is 2.1 GHz (4.1-6.2 GHz) and corresponds to a fractional bandwidth of 40% at the central frequency of 5.15 GHz. Fig. 4(a) shows the measured and simulated far-field radiation patterns in the H- and E-planes at 5.5 GHz. The measured radiation patterns are performed inside an anechoic chamber. The radiation patterns in the 3 dB AR bandwidth have the broadside directions (i.e., ±z directions). They are mainly LHCP for z > 0 and RHCP for z < 0. Note that the proposed antenna is designed to produce a LHCP radiation at broadside direction (+z direction), while a RHCP radiation is considered to be the cross polarization. From Fig. 4(a), it can be observed that the 3 dB beamwidth of the H-plane (x-z plane) is broader than that of the E-plane (y-z plane). This is because the proposed antenna is an asymmetric structure. Also, the measured gain variation is from 2.8 to 4.3 dBic in the 3 dB AR bandwidth and the gain difference is within 1 dB between the simulated and measured results, as shown in Fig. 4(b)

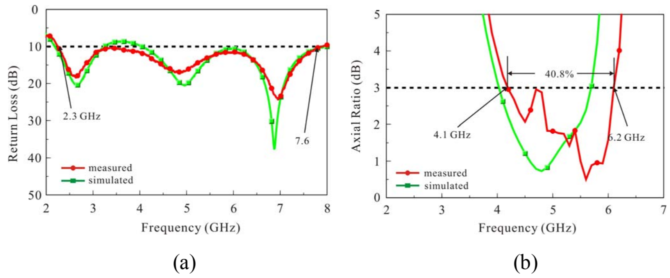


Fig. 3 Measured and simulated results: (a) return loss and (b) axial ratio.

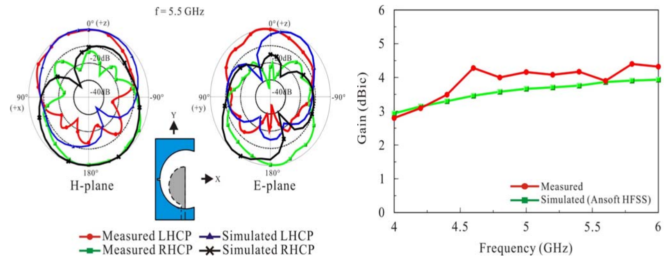


Fig. 4 Measured and simulated results: (a) radiation patterns (b) antenna gain.

IV. CONCLUSION

A printed open C-slot antenna with a semi-circle-shaped patch for size reduction is proposed and investigated. Using the open C-slot structure and the semi-circle-shaped patch fed by a microstrip-line, the proposed antenna can achieve a wider circularly polarized bandwidth of 40% for 3 dB axial ratio and has a compact size of 30 × 55 mm^2. In addition, the proposed antenna has a wider impedance bandwidth of 107% for 10 dB return loss.

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