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A Simple V-Shaped Slot Antenna with Broadband Circular Polarization

Hui-Fen Huang* and Bin Wang

Abstract—In this paper, a simple broadband circular polarization (CP) V-shaped slot antenna is developed. The CP antenna consists of Z-shaped feedline with a stub and a patch, and symmetrically etched two right-angled V-shaped slots (an open slot and a closed slot) along the center line. The stub is introduced for multi-resonances to obtain broadband. The broad CP and impedance bandwidths overlap by the symmetrically etched right-angled V-shaped closed slot along the center line and the Z-shaped feedline placed in a proper position. The measured results show that the proposed antenna has a broad overlapped 3-dB axial ratio (AR) bandwidth and -10 dB impedance bandwidth of 71% (2.19–4.6 GHz).

1. INTRODUCTION

Nowadays, circularly polarized antennas have received much attention since they require no strict orientation between transmitting and receiving antennas and can mitigate the Faraday rotation effect as well as multipath interference. CP antennas can be applied in many wireless systems such as GPS, RFID, WLAN and WIMAX [1, 2]. A wide bandwidth antenna is very popular for high data rate wireless communication. CP antennas require wide overlapped bandwidth of VSWR/axial ratio (AR) while keeping a compact size. A slot antenna has the advantages of simple structure, low profile, light weight, easy impedance matching, broad bandwidth, and good radiation efficiency. Broad CP bandwidth can be achieved by utilizing square slot antennas [3–7]. In [4], the corners of the slot antenna are connected to achieve 35.7% CP bandwidth with a compact size. In [7], two asymmetric T-shaped feedlines and an inverted-L grounded strip with three straight strips are introduced to a slot antenna to obtain 60% CP bandwidth. Owing to the performance and compactness, open-slot (or monopole slot) antennas attract much attention. The length of a conventional closed-slot antenna is usually half wavelength; however, the length of an open-slot antenna is usually about a quarter-wavelength [8, 9]. Many works for CP open-slot antennas have been proposed [10–15]. In [11], an L-shaped open-slot antenna with CP is first presented to operate at the GPS band of 1.57 GHz. In [12], the L-shaped open-slot achieves a wide CP bandwidth of 64% by introducing two rotated parasitic patches. In [13], a microstrip-fed open-slot antenna with a bent feeding structure and three slots achieves dual-band circular polarization. A stair-shaped dielectric resonator and an open-ended slot ground are introduced for -10 dB return loss and 3-dB AR bandwidths of 71.7% (3.84–8.15 GHz) and 46% (4.15–6.63 GHz), respectively [14]. An open slot and a patch-protruded feeding topology provide 3-dB AR bandwidth 76% (2.00–4.47 GHz) and -10 dB impedance bandwidth 133% (1.22–5.97 GHz) [15].

In this paper, a simple low-profile right-angle V-shaped slot antenna is developed with broad overlapping bandwidth 71% for both -10 dB impedance and 3-dB AR. The paper is organized as follows. Section 2 gives the antenna design. Section 3 provides the simulated and measured results. The conclusion is in Section 4.

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2. DESIGN OF THE ANTENNA

2.1. Antenna Configuration

The structure of the proposed antenna is shown in Fig. 1. The proposed antenna is made on an FR4 substrate with size $44 \times 42 \times 0.8$ mm, relative permittivity 4.4 and loss tangent 0.02. Fig. 2 shows the prototype for the developed CP antenna. The design is done using high frequency structure simulator (HFSS), and the optimized geometry dimensions are shown in Table 1. The proposed antenna is composed of a Z-shaped feedline with a stub and a patch symmetrically etched two right-angled V-shaped slots (an open slot and a closed slot) along the center line. The Z-shaped feeding line is located at a proper position of the open slot A'-A in Fig. 2(b) for CP excitation.

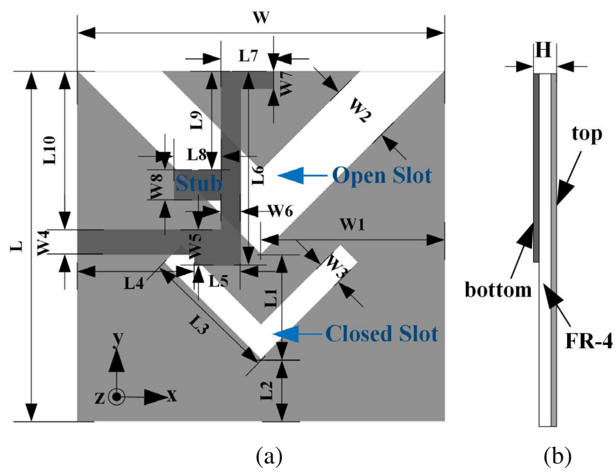

Figure 1. Geometry of the proposed antenna, (a) top view, (b) side view.

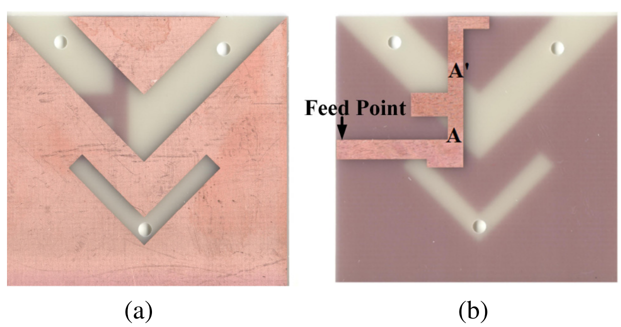

Figure 2. Prototype of the proposed antenna, (a) top view, (b) bottom view.

Table 1. The detail parameters of the proposed antenna (mm).

L	W	H	$L1$	$L2$	$L3$	$L4$	$L5$
42	44	0.8	12.6	7.4	16.5	14	5.5
$L6$	$L7$	$L8$	$L9$	$L10$	$W1$	$W2$	$W3$
23.2	6.3	5.6	11.8	19	22	7.2	3
$W4$	$W5$	$W6$	$W7$	$W8$			
2.9	4.2	2.3	2	3.6			

2.2. Design Process

Three steps of improving the developed antenna are shown in Fig. 3 from Antenna-1 to Antenna-3. Antenna-1: Patch with etched right-angled V-shaped open slot + Z-shaped feeding line. Antenna-2: Patch with etched right-angled V-shaped open slot + (Z-shaped + stub) feeding line. Antenna-3: Patch with etched right-angled V-shaped (open + closed) slots + (Z-shaped + stub) feeding line.

The simulated imaginary parts of impedance, return loss and axial ratio for Antenna-1, 2 and 3 are shown in Fig. 4. For Antenna-1: The total length of the open slot is 48 mm about half wavelength of 1.9 GHz, and only one resonance at 2.25 GHz is excited. For Antenna-2: After the stub is introduced, resonances at 2.7 GHz, 3.6 GHz, 4.1 GHz and 4.4 GHz are generated, forming two impedance bands at 2.4 GHz, and 4.2 GHz, as can be seen in Fig. 4(a). For Antenna-3: A symmetrical right-angled V-shaped closed slot is introduced, and the length is about 33 mm, about half wavelength of 2.8 GHz. The impedance bandwidth at 2.4 GHz keeps unchanged, but the resonances for 3.6 GHz and 4.4 GHz shift to 3.48 GHz and 4.5 GHz, respectively. Then broadband impedance bandwidth from 2.19 to 4.6 GHz is formed. The etched closed slot introduces a perturbation for the orthogonal electric fields along the diagonals of the patch. The length of closed slot L3 is swept to achieve a 90-degree difference between the orthogonal electric fields. Finally, CP radiation is excited in whole band.

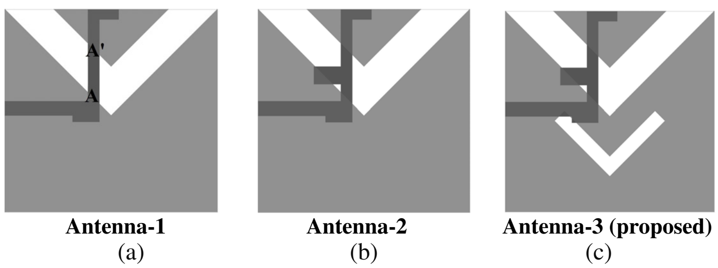

Figure 3. Antenna design process from Antenna-1 (a) to Antenna-3 (c).

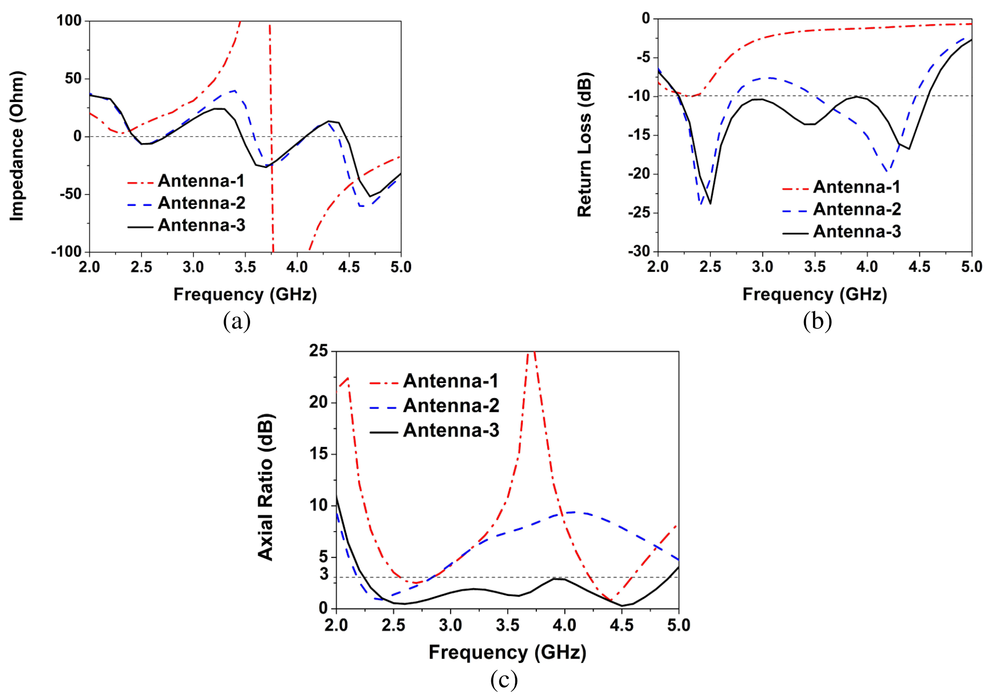

Figure 4. Simulated (a) impedance imaginary part, (b) return loss and (c) AR for Antenna-1, 2, and 3.

3. EXPERIMENTAL RESULTS

A prototype of the proposed antenna is fabricated as shown in Fig. 2. Simulated and measured results of the return loss of the proposed antenna are shown in Fig. 5. The simulated and measured -10 dB return loss bandwidths are 71.4% (2.18–4.6 GHz) and 76.5% (2.05–4.61 GHz), respectively. The simulated and measured results of AR of the antenna are illustrated in Fig. 6. The simulated and measured 3-dB AR bandwidths are 76% (2.2–4.9 GHz) and 71% (2.19–4.6 GHz), respectively. The measured overlapped -10 dB return loss bandwidth and 3-dB axial ratio bandwidth is 71% (2.19–4.6 GHz). Fig. 7 shows the gain in $+z$ axis of the antenna versus frequency. The gain of the antenna varies between 1.9 and 2.8 dBic in the CP band. The measured results agree well with the simulated ones.

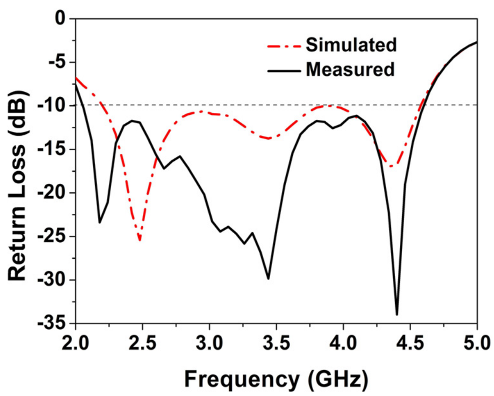

Figure 5. Simulated and measured results of return loss.

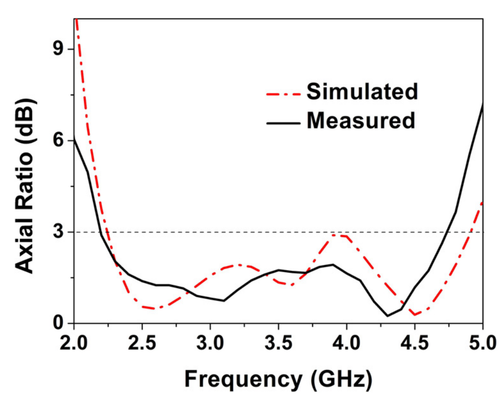

Figure 6. Simulated and measured results of axial ratio.

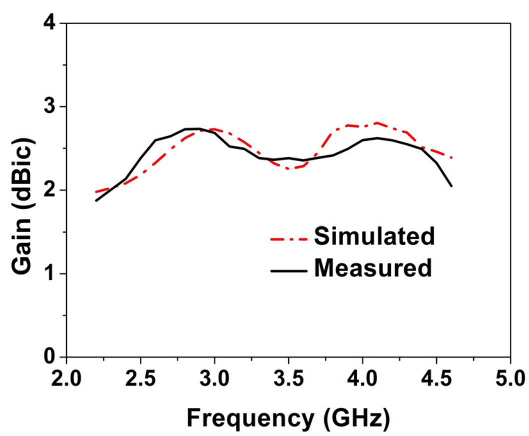

Figure 7. Simulated and measured results of gain.

Figure 8 shows surface current distributions of the proposed antenna at 2.8 GHz for four different time phases, from 0° to 270°, with an interval of 90°. The currents rotate in counter clockwise direction to generate a right-hand CP (RHCP) wave in $+z$ direction. The measured normalized CP radiation patterns in the xz-plane and yz-plane at 2.6, 3.5, 4.4 GHz are shown in Fig. 9. The red lines represent RHCP (Right-hand CP), and blue lines represent LHCP (Left-hand CP). In Fig. 9, the radiation pattern shows a good bidirectional characteristic: RHCP wave radiates in the $+z$ direction of the antenna, and LHCP radiates in $-z$ direction.

Table 2 compares the proposed antenna with reported wideband CP antennas. λ is the free-space wavelength at the lowest frequency of the 3-dB AR bandwidth. As can be seen, the proposed antenna has compact size and wider CP bandwidth.

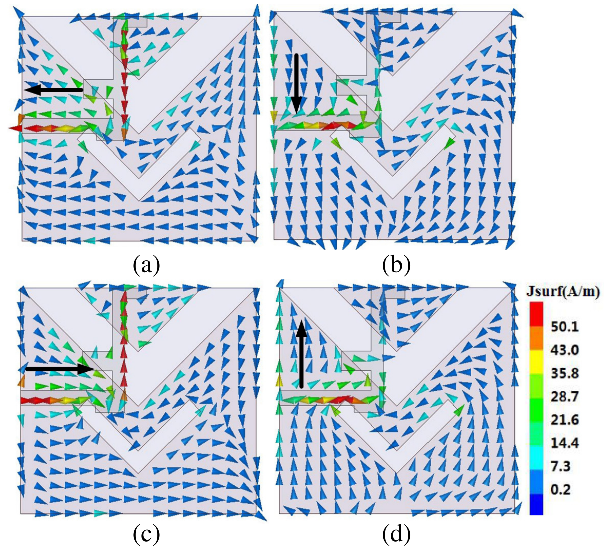

Figure 8. Simulated surface current distributions of the antenna at 2.8 GHz, (a) 0°, (b) 90°, (c) 180°, (d) 270°.

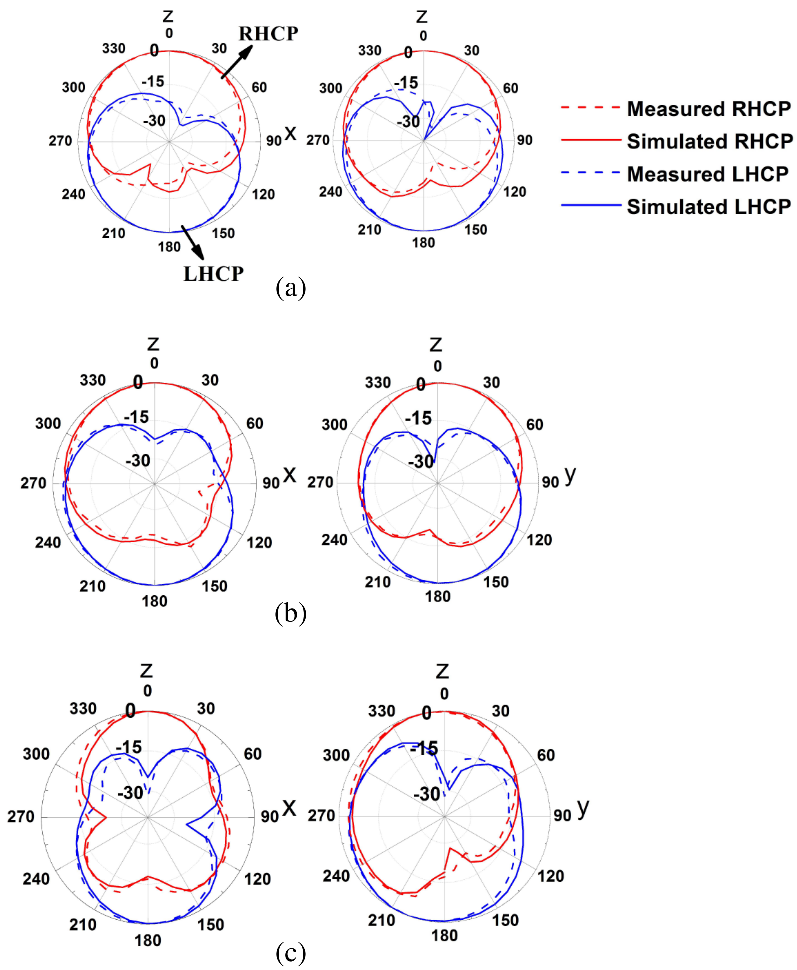

Figure 9. Simulated and measured radiation patterns in x-z plane and y-z plane at (a) 2.6 GHz, (b) 3.5 GHz, (c) 4.4 GHz.

Table 2. Performance comparisons with reported antennas.

Ref.	Patch size (λ^2)	Height (mm)	CP bandwidth (%)	Center frequency (GHz)	Peak gain (dBic)
[4]	0.25×0.25	0.8	35.7	5.4	4.2
[6]	0.32×0.32	0.8	34.7	0.96	3.4
[7]	0.4×0.4	1.6	60	2.85	3.6
[12]	0.61×0.29	3.8	64	3.3	2
[14]	0.37×0.34	3.8	46	5.39	3.9
[15]	0.44×0.31	0.8	76	3.24	3.9
proposed	$\mathbf{0.32 \times 0.31}$	**0.8**	**71**	**3.39**	**2.8**

4. CONCLUSION

In this paper, a simple broadband CP right-angled V-shaped slot antenna is proposed. The proposed antenna is composed of a Z-shaped feedline with a stub and a patch, and symmetrically etched two right-angled V-shaped slots (an open slot and a closed slot) along the center line. After introducing the stub in the Z-shaped feeding line, multi-resonances are obtained, and broad impedance bandwidth is achieved. The overlapped broad -10 dB impedance and 3-dB AR bandwidths 71% are obtained by the Z-shaped feedline placed in a proper position and the symmetrically etched right-angled V-shaped closed slot along the center line.

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