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# WIDEBAND CAVITY-BACKED CROSSED DIPOLES FOR CIRCULAR POLARIZATION

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**Abstract**—A novel circularly polarized cavity-backed antenna (CBA) excited by crossed bowtie dipoles is presented in this paper. It is fed by a transition from a microstrip line to doubleslot lines. The crossed dipoles consist of a top-loaded triangular and a filleted rhombic to achieve the required input impedance relations for circularly polarized radiation. After optimization, a simulated 3-dB axial-ratio bandwidth of 50% and a broadside gain in a range of 7 to 9 dBi are achieved while the standing wave ratio is kept below 2.

## 1. INTRODUCTION

Circular polarization (CP) is getting more attention because of its capabilities to reduce polarization mismatch and to suppress multipath interferences. Meanwhile, the unidirectional radiation patterns and a large operating bandwidth are expected in many cases of modern wireless communications, e.g., radar and satellite systems.

There are many methods to construct circularly polarized antennas, e.g., single feed truncated corner antenna [1, 2], crossed dipoles [3] and dielectric resonator antenna [4, 5]. However, their axial-ratio (AR) bandwidths are generally very small. Comparatively, slot antennas can present a bandwidth as large as 33% for AR $\leq 3$ dB by changing the slot shapes and the feeding strips [6–9]. However, the radiation patterns are bidirectional, and the gains are generally below 6 dBi.

By contrast, cavity-backed crossed dipole antennas (CBCDAs) can provide unidirectional radiation patterns and higher gains [10, 11]. The CP realized by the crossed dipoles is a straightforward way, which employs two orthogonally crossed dipoles individually fed by

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two sources with equal magnitude and 90° phase difference. Generally, the feeding network is complicated, e.g., the antenna in [10] employs a Wilkinson power divider to excite two orthogonal resonant modes.

In 1961, it was reported that the single-fed crossed dipoles connected in parallel could generate the CP radiation if the real part of their input admittances are equal and their phase angles differ by 90° [12]. According to these conditions, a wideband circularly polarized CBCDA was constructed [11]. That antenna can achieve a broadside gain of 8–10.7 dBi and rotationally symmetrical radiation patterns over the whole frequency band. However, the 3-dB AR bandwidth is only 39%. This paper presents a new design of a circularly polarized CBCDA following the techniques in [11] to improve the CP bandwidth. Finally, a 3-dB simulated AR bandwidth of 50% is achieved.

## 2. GEOMETRY

Figure 1 shows geometries of the proposed CBA, which consists of a cylindrical cavity, crossed dipoles as an exciter, a transition from a microstrip line to double slot lines (DSL), and an SMA connector placed under the cavity to feed the antenna. Fig. 2 shows the geometry of the exciter and its parameters in detail, which consists of a rhombic bowtie dipole (Dipole I) with rounded corners and a triangular bowtie dipole (Dipole II) loaded by two narrow rectangular strips. The exciter is built on a substrate with thickness 0.5 mm and a relative permittivity $\varepsilon_r = 2.2$ for easy fabrication and support.

Detailed geometry of Dipole I is shown by the inset at the lower right corner of Fig. 2. Two narrow rectangular strips, placed along with the $x$ axis, are introduced as a top loaded component of Dipole II to reduce the physical size. For the parallel connection of the two dipoles, Dipole II is separated by a small distance along with the $x$ axis to connect one arm of Dipole I, and the gap $s$ is located at its vertexes to connect with the DSL of the transition.

The geometry of the microstrip-to-DSL transition is given in Fig. 3, and a balun reported in [11] is also introduced here. It can provide balanced currents to the crossed dipoles because of its symmetrical structures. The transition consists of three metallic layers and two dielectric layers with $\varepsilon_r = 2.2$ and 0.5 mm thickness, and it is mounted vertically on the ground plane. Since the resonance of the transition will influence the CP performances, 22 metallic via holes with a 0.6 mm diameter are employed on the transition to avoid the negative effects on the AR.

The optimized parameters are given as follows (in mm, $\lambda_0$ is the free-space wavelength at the center of the AR $\leq 3$ dB frequency band):

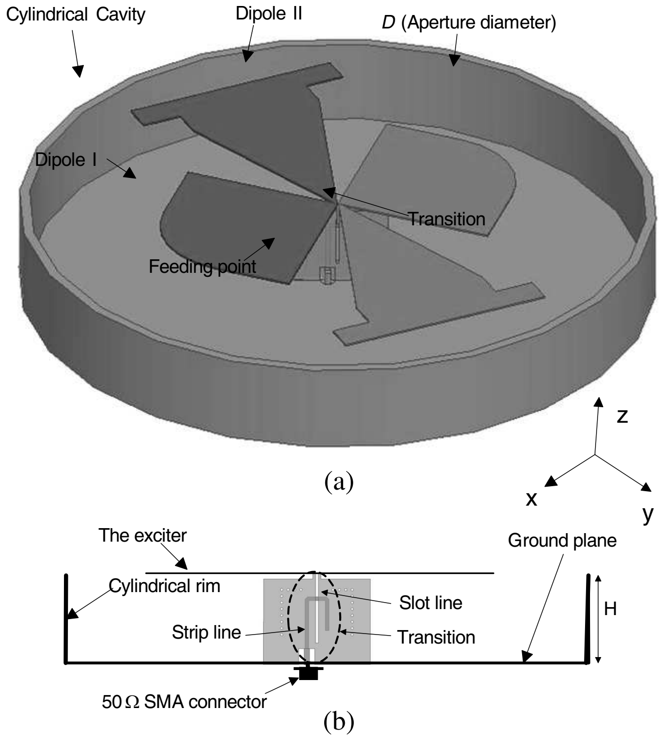



**Figure 1.** Geometry of the proposed CBA.

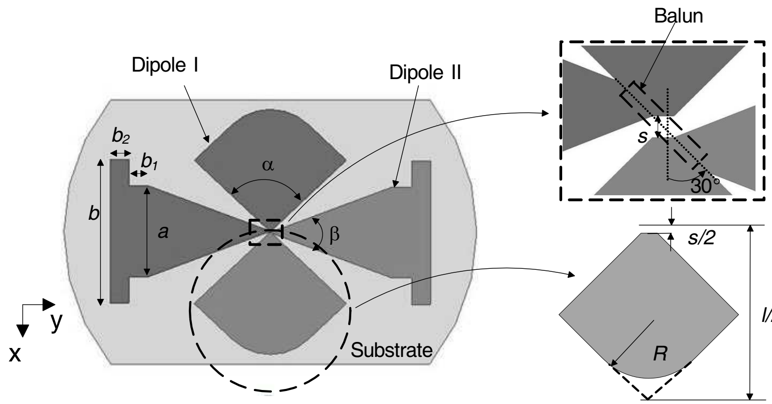



**Figure 2.** Geometry of the exciter.

$D = 122$ ($1.79\lambda_0$, aperture diameter), $H = 17$ ($0.25\lambda_0$, height of cylindrical cavity), $\alpha = 94°$, $\beta = 40.5°$, $l = 86.7$, $r = 17$, $a = 27.5$, $b_1 = 6$, $b_2 = 5.8$, $b = 43.5$, $s = 0.2$, $l_g = 12$ (length of the DSL), $g = 0.5$, $w_t = 20$ (width of the transition), $h_m = 12$ (height of the matching stripline), $l_m = 5.6$ (length of the matching stripline), and the other detailed dimensions of the transition are given in Fig. 3 in mm. The total electrical dimensions of the proposed antenna are $1.79\lambda_0$ in diameter and $0.25\lambda_0$ in height.

## 3. EXPERIMENTAL AND SIMULATED RESULTS

All simulations were performed by the commercial software HFSS$^{\text{TM}}$. An antenna prototype with the optimized dimensions was built, as shown in Fig. 4. The measured and simulated ARs, broadside

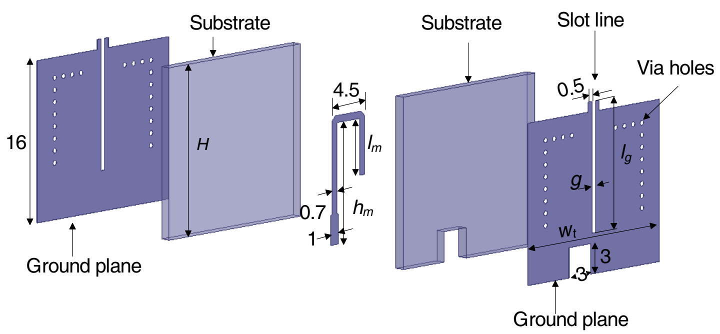



**Figure 3.** Geometry of the transition.

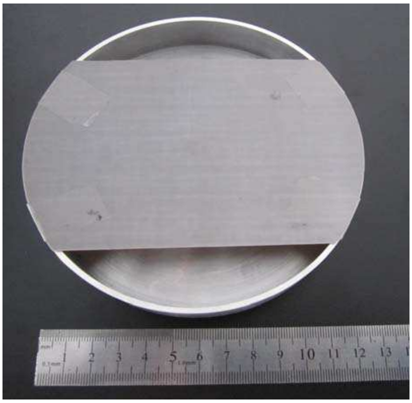


**Figure 4.** Photograph of the fabricated antenna prototype.

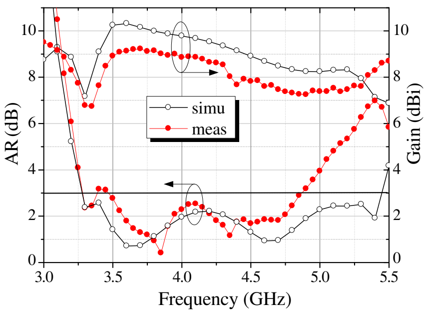



**Figure 5.** Measured and simulated ARs and broadside gains.

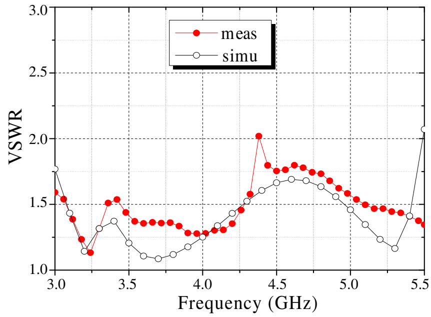



**Figure 6.** Measured and simulated VSWRs.

gains, and standing-wave ratios (SWRs) are shown in Figs. 5 and 6, respectively. The simulated 3-dB AR bandwidth is 50%, ranging from 3.25 to 5.45 GHz, but comparatively the measured one is only 33%, which is mainly attributed to the fabrication errors, especially the errors in connecting the precision balun to the crossed dipoles. The measured broadside gains are decreased by 1 dB compared with the simulated results, attributed to the loss of the coaxial cable connecting the antenna and the instrument which is not calibrated in the measurements besides the fabrication errors. The SWR are all below 2 in the whole 3-dB AR bandwidth.

Since the configuration of the antenna is rotationally symmetrical with respect to the balun, the radiation patterns on the plane of $\Phi = 30^\circ$ and its orthogonal plane ($\Phi = 120^\circ$) are presented. The simulated and measured radiation patterns on both planes are shown in Fig. 7, and measurements agree well with simulations along the main beams. As shown in the measured results, the side lobes are kept small when the antenna operates in lower frequency band but they become higher as frequency increases.

## 4. PARAMETRIC STUDY

To clearly show how each parameter controls the CP performance of the antenna, the parametric studies are performed in this section. When one parameter is studied, the others keep identical to their optimized values. In this study, the AR is emphasized because the return loss and broadside gain are almost immune to the parameters in the studied range.

The size of the cavity significantly dominates the antenna performances, as shown in Figs. 8(a) and (b). A smaller $D$ will improve

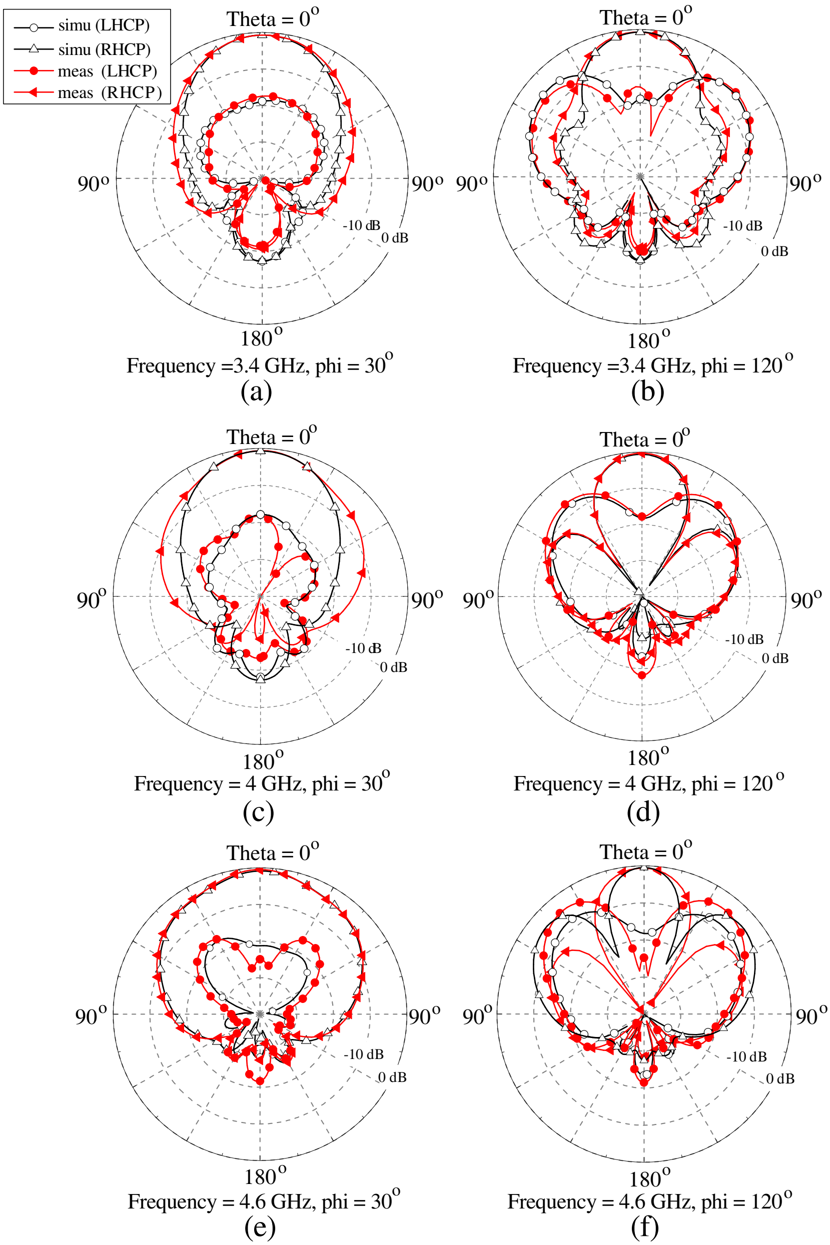
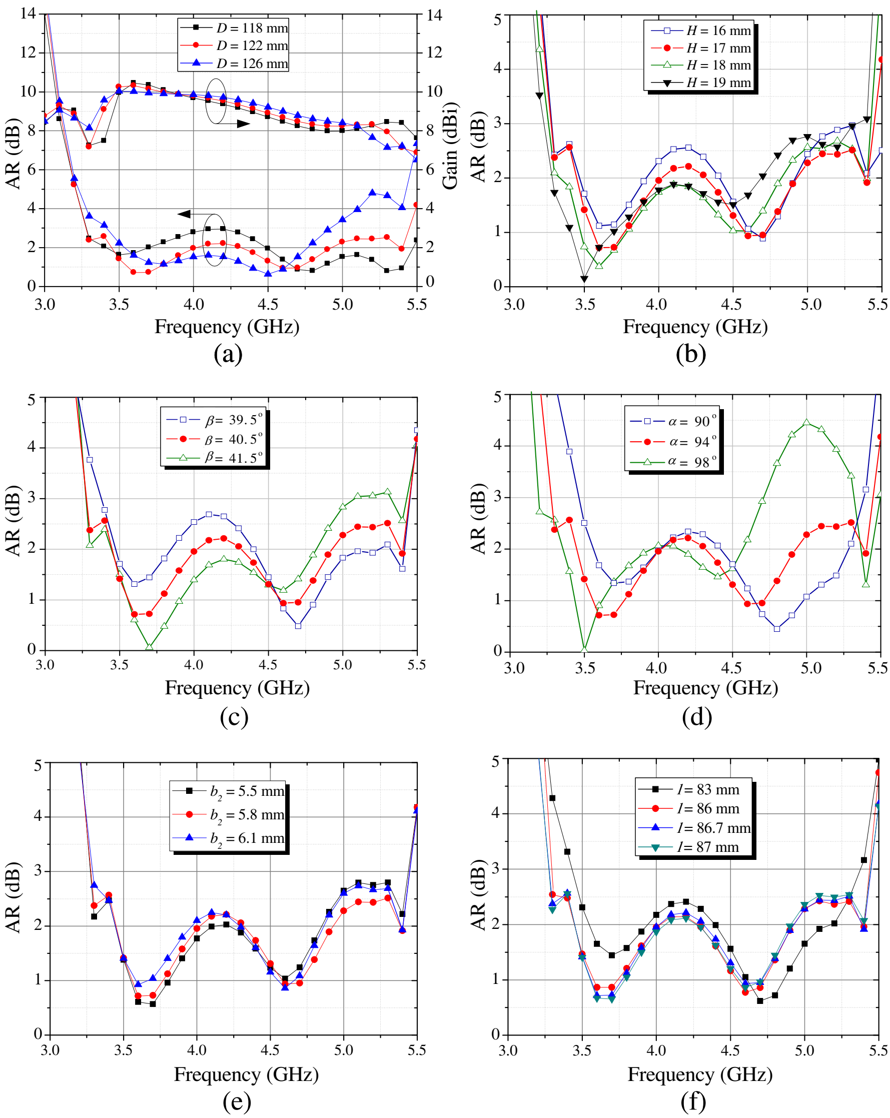



**Figure 7.** Measured and simulated radiation patterns.

the AR at high frequencies but worsen it at lower frequencies. In Fig. 8(a), changing the parameter $D$ causes small variations on the broadside gain only near the lower and upper edges of the operating frequency band. Actually, the other parameters also cause little fluctuation on the broadside gain, so no gain curves are given in the following figures.

Generally, the height of the cavity should be a quarter wavelength. Therefore, a suitable $H = 17\,\text{mm}$ corresponding to $0.25\lambda_0$, brings



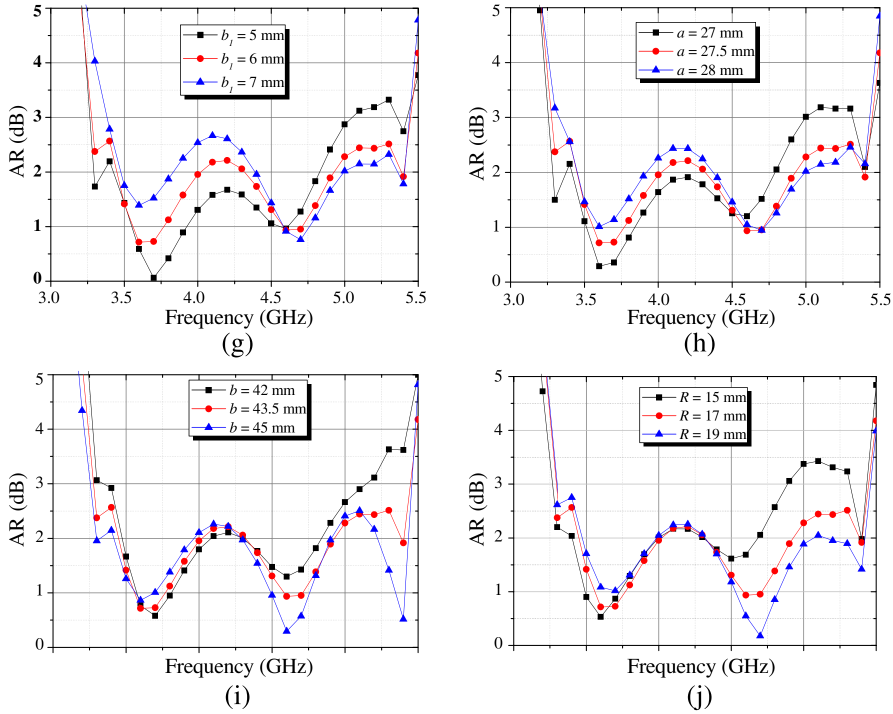



**Figure 8.** Influences of (a) $D$, (b) $h$, (c) $\alpha$, (d) $\beta$, (e) $l$, (f) $a$, (g) $b_1$, (h) $b_2$, (i) $b$, and (j) $R$ on AR.

the lowest AR at higher frequencies and an acceptable AR at lower frequencies.

There are two critical parameters of the exciter that determine the CP performance, i.e., $\alpha$ and $\beta$. As shown in Figs. 8(c) and (d) It can be observed that too large values of $\alpha$ and $\beta$ will produce a poor AR at high frequencies while smaller values will narrow the AR bandwidth.

As far as the exciter is concerned, the parameters $b_2$ and $l$ will cause very small influences on AR as $b_2$ and $l$ are varied from 5.5 to 6.1 mm and from 86 to 87 mm, respectively, as shown in Figs. 8(e) and (f). However, when $l$ is reduced to a small value of 83 mm, the AR bandwidth will be obviously decreased, indicating the antenna can endure the fabrication errors in a relatively large range. In Figs. 8(g)–(j), a smaller $a$ and $b_1$ produce a better AR at lower frequencies but a narrower AR bandwidth. However, as $a$ and $b_1$ go larger, the influences on AR are relatively small. Moreover, in the last two figures of Fig. 8, the CP performance becomes better as the parameters $b$ and $R$ increase in a notable range.

## 5. CONCLUSION

A novel CBCDA is investigated in the paper. By using the crossed dipoles as an exciter, broadband CP performances are achieved. From the simulated results, the antenna shows a 3-dB axial-ratio bandwidth of 50%, a broadside gain of 7–10 dBi and symmetrical radiation patterns. Parametric studies are performed for further understanding the operating principles and reference to practical designs.

## ACKNOWLEDGMENT

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