Circularly Polarized Crossed Dipole With Magnetoelectric Dipole for Wideband and Broadbeam Applications

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***Abstract*—A single-feed circularly polarized (CP) crossed dipole loaded with a magnetoelectric (ME) dipole is presented to enhance the bandwidth and beamwidth in this paper. The double-sided orthogonal strip-shaped dipoles are fed by a pair of vacant-quarter printed rings to realize CP radiation. A ME dipole is introduced to generate another resonance so that the CP bandwidth is significantly broadened. The antenna is backed with a corrugated cavity to obtain unidirectional radiation with high front-to-back ratio and a wide 3-dB axial ratio (AR) beamwidth. Simulated results show that the proposed antenna with an overall size of $0.58\lambda_0 \times 0.58\lambda_0 \times 0.15\lambda_0$ at 1.45GHz exhibits an impedance bandwidth of 72.1% for $|S_{11}| \leq -10$dB from 1.25-2.66GHz, a 3-dB AR bandwidth of 45.3% from 1.45-2.3GHz, an average boresight gain of 8.1dBic and a high radiation efficiency over 94% within passband. Moreover, the 3-dB AR beamwidth is greater than 162° from 1.85-2.25GHz.**

Keywords—Circularly polarized; broadbeam; wideband; crossed dipole; magnetoelectric dipole.

I. Introduction

In the past few years, as one of the most popular forms of circularly polarized (CP) antennas, crossed dipole antenna has been extensively investigated owing to its attractive characteristics such as simpler structure, lower cost, higher gain and lighter weight [1]-[3]. Therefore, various approaches to reach broad CP bandwidth have been constantly researched to meet the demands of several modern wireless communications [4]-[8]. Above all, loading is a relatively common technology. For example, four parasitic loop resonators were introduced to a printed strip-shaped crossed dipole to create one additional minimum axial ratio (AR) point and thus a broad AR bandwidth of 25.2% is realized [4]. Besides, design of kite-shaped crossed dipole added with two capacitive bent slots was reported in [5], giving a much wider AR bandwidth of 37%. Then, applying dipoles with wide open ends, such as rectangular patch dipoles (27%) [6], bowtie dipoles (43.5%) [7], is another effective method to enhance AR bandwidth. In addition, adopting feeding network can also greatly enlarge the CP bandwidth. For instance, structure of four straight strip dipoles connected with four rotating circular strip dipoles fed by an unequal power network was employed in [8], providing an AR bandwidth of 41.3%. Recently, magneto-electric (ME) dipoles for CP radiation have drew increasing attention due to its feature of nearly identical radiation patterns in both E-plane and H-plane [9] [10]. A modified CP ME dipole based on the single-fed cross-dipole attained the AR bandwidth over 40% [10]. However, there are little focus on techniques to broaden the 3-dB AR beamwidth, hence, most of the above-mentioned dipoles exhibited narrower CP radiation beamwidth.

In this paper, a novel single-feed CP crossed dipole antenna for wideband and broadbeam applications is proposed and investigated. By introducing a ME dipole, both the impendence and AR bandwidths can be substantially improved. Furthermore, a modified corrugated cavity is utilized to acquire unidirectional radiation with high front-to-back ratio and a broad 3-dB AR beamwidth. The rest of the paper is arranged as follows: the antenna geometry and operating principle are described in Section II. The simulated results are depicted in Section III. Section IV gives a conclusion.

II. Antenna Design

Fig. 1 shows the geometry of the proposed antenna, which consists of a strip-shaped crossed dipole, a ME dipole and a corrugated cavity. The ME dipole compromises four horizontal metallic plates incorporated with eight vertical plates connected with the ground. With reference to Fig. 1(b), two orthogonal strip-shaped dipoles excited by a 50-Ω coaxial cable are etched on both sides of a dielectric substrate with relative dielectric constant of 3.55 and loss tangent of 0.0027, while the horizontal metallic plates are implemented on the top side of the substrate. A pair of double-printed vacant-quarter rings are equipped to achieve impendence matching of the crossed horizontal metallic plates are implemented on the top side of the substrate. A pair of double-printed vacant-quarter rings are equipped to achieve impendence matching of the crossed dipole to the 50-Ω coaxial line and to radiate a CP wave. The whole structure is surrounded by a novel corrugated cavity to generate a unidirectional broad CP radiation beamwidth with high front-to-back ratio. The optimized parameters are depicted in Table I.

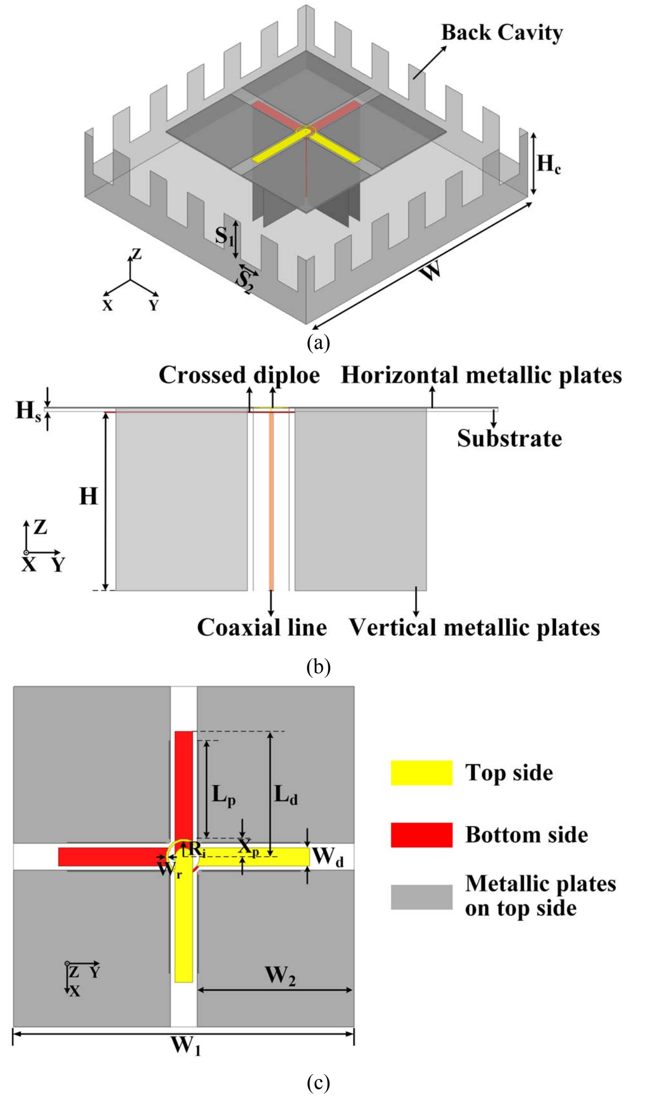

Fig. 1. Geometry of the proposed antenna. (a) 3-D view. (b) Side view without back cavity. (c) Top view of the radiator.

III. Analysis and Results

To better demonstrate the merits of the presented antenna, a traditional crossed dipole without ME dipole loading is chosen as the transitional structure, which is designed with the same physical area of the proposed antenna for the purpose of fare comparison. The simulated $|S_{11}|$ values and ARs in the boresight are plotted in Fig. 2(a), and the 3-dB AR beamwidths in both *xoz* and *yoz* planes are shown in Fig. 2(b). It can be found from Fig. 2(a) that the traditional dipole produces a CP wave at 2.11GHz (AR=1.44dB) with an impendence bandwidth of 55.1% for $|S_{11}|$ < -10 dB from 1.75-3.08GHz and a 3-dB AR bandwidth of 9.5% from 2.0-2.2GHz. Similar to the method of broadening CP bandwidth in [1], the introduced ME dipole generates another minimum AR point so that the combined two adjacent AR passbands can substantially enlarge the AR bandwidth. In addition, the impendence passband shifts downward influenced by the ME dipole. With reference to Fig. 2(a), for the presented design, the impedance bandwidth is 72.1% for $|S_{11}|$ < -10 dB from 1.25-2.66GHz and the 3-dB AR bandwidth is 45.3% from 1.45-2.3GHz with two minimum AR points at 1.56GHz (AR=0.66dB) and 2.11GHz (AR=0.60dB). The traditional crossed dipole produces the most symmetrical and broadest 3-dB AR beamwidth of 90° in both *xoz* and *yoz* planes at 2.15GHz, while the proposed antenna generates the most symmetrical and broadest 3-dB AR beamwidth of 237° at 2.15GHz in both planes. After the optimization with the HFSS, very wide CP radiation beamwidths in the principle planes of more than 162° can be achieved within the range of 1.85-2.25GHz.

The simulated gain at boresight and radiation efficiency are plotted in Fig. 3. It is observed that the boresight gain varies from 7.0 to 9.2 dBic and the radiation efficiency is over

TABLE I. ANTENNA DEMENTIONS

Parameter	Value (mm)	Parameter	Value (mm)
H_c	30	W_2	35
H_s	0.5	L_p	22
H	30	X_p	4
W	120	L_d	28
S_1	19	W_d	4
S_2	11	R_i	3.5
W_1	76	W_r	0.5

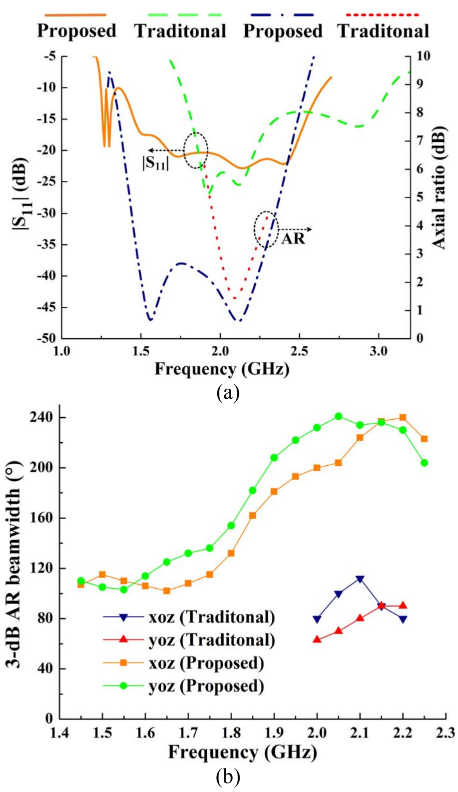

Fig. 2. Performance comparison between the proposed antenna and traditional crossed dipole. (a) $|S_{11}|$ and AR at boresight. (b) 3-dB AR.

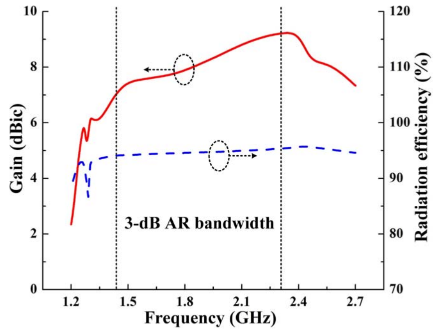

Fig. 3. Simulated boresight gain and radiation efficiency.

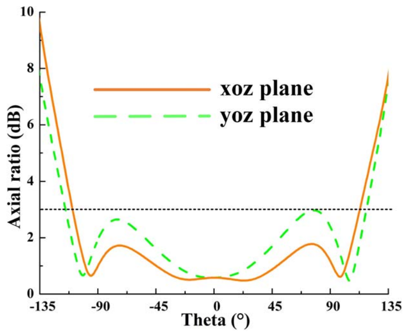

Fig. 4. Simulated ARs in *xoz* and *yoz* planes at 2.11GHz.

94% within the 3-dB AR bandwidth. In the *xoz* and *yoz* planes, the AR versus theta angle at 2.11GHz and the radiation

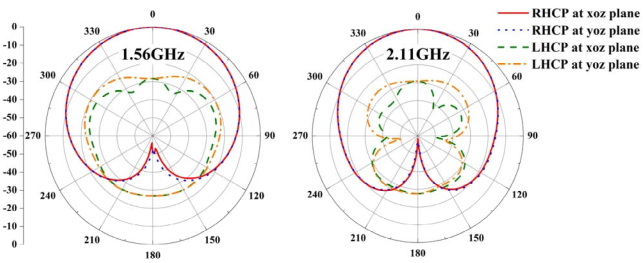

Fig. 5. Simulated radiation patterns in *xoz* and *yoz* planes.

patterns at 1.56 and 2.11GHz are separately pictured in Fig. 4 and Fig. 5. At 2.11GHz, the 3-dB AR beamwidth are 224° and 234° in the *xoz* and *yoz* planes, respectively. The proposed antenna radiates a right-hand CP (RHCP) wave with stable symmetrical unidirectional radiation patterns and high front-to-back ratio of 26.8 dB at 1.56 GHz and 27.6dB at 2.11GHz.

IV. CONLUSION

A single-feed corrugated cavity-backed crossed dipole with a ME dipole loading for wideband and broadbeam RHCP radiation is proposed in this paper. It has an impedance bandwidth of 72.1% for $|S_{11}| < -10$ dB from 1.25-2.66GHz, a 3-dB AR bandwidth of 45.3% from 1.45-2.3GHz, and a 3-dB AR beamwidth over 162° from 1.85-2.25GHz. In addition, the presented design exhibits stable symmetric unidirectional radiation pattern, high front-to-back ratio, an average broadside gain of 8.1 dBic with small variation of 1.1-dB and high radiation efficiency of more than 94%. All these outstanding characteristics make the proposed antenna a very good candidate for satellite communication systems, wireless local area networks, radio frequency identification, as well as many other kinds of modern wireless communication systems.

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