Single-Fed Dual-Band Circularly Polarized Patch Antenna With Wide 3-dB Axial Ratio Beamwidth for CNSS Applications

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***Abstract*—This paper presents a dual-band circularly polarized (CP) antenna with wide 3-dB axial ratio (AR) beamwidth for compass navigation satellite system (CNSS) applications. The antenna is designed to be a double-layer structure and fed through a single coaxial probe. Two patches stacked together with truncated corners and symmetry L-shaped stubs are used to achieve two operating frequency bands, i.e., B1 (1.561 GHz) and B2 (1.207 GHz), for CNSS. In particular, a circular ground plane with four curved slots is adopted to achieve a symmetrical radiation pattern and a wide 3-dB AR beamwidth. At 1.561 GHz, the peak gain of the proposed antenna is 6.4 dBi, and the 3-dB AR beamwidths of 214°and 200°in the *xz*- and *yz*-planes are obtained, respectively. At 1.207 GHz, the proposed antenna has a maximum gain of 6.0 dBi, and the 3-dB AR beamwidths of 221°and 202°in the *xz*- and *yz*-planes.**

***Index Terms*—Circular polarization, compass navigation satellite system (CNSS), curved slots, dual bands, wide 3-dB axial ratio beamwidth.**

I. Introduction

With the development of compass navigation satellite system (CNSS), antennas used for CNSS have received much attention. As one of the global navigation satellite systems (GNSS) in the world, the CNSS not only provides the navigation, positioning and speed measurement services, but also supports short message service (SMS) communications [1]. From the point of achieving wide range of signal coverage, the circularly polarized (CP) antenna with wide 3-dB axial ratio (AR) beamwidth is preferable. For instance, the CP antennas with a 3-dB AR beamwidth of larger than 120 ° in global positioning system (GPS) are usually required due to the fact that the wireless signals can be well received anywhere on the planet [2].

However, the 3-dB AR beamwidth of the conventional patch antenna is relatively narrow, and often unable to meet the requirements of practical applications. In order to widen the 3-dB AR beamwidth, several methods have been proposed. One way is to load parasitic elements, such as parasitic cylindrical monopoles [3] and parasitic square rings [4]. The other way of widening the 3-dB AR beamwidth is to use a three-dimensional ground plane, such as tapered-elliptical cavity [5], pyramidal ground planes [6], and folded conducting walls [7]. All these three-dimensional structures use the electromagnetic wave diffraction effects from the finite ground to change the beamwidth. Unfortunately, the three-dimensional ground planes will lead to complex structures and are manufactured difficultly. The antennas above are single frequency band. Two dual-band circularly polarization antennas with wide beamwidth are presented in [8], [9], however, they have low gains in one or two bands. A dual-band CP antenna with a cross asymmetrically dipole is developed in [10], whereas it has large dimension due to the cavity-backed reflector and relatively narrow the 3-dB AR beamwidth.

In this article, a dual-band CP antenna with wide 3-dB AR beamwidth for CNSS applications is proposed. A stacked structure is adopted to achieve dual-band CP radiation. By using a circular ground plane with four curved slots, the proposed antenna realizes the properties of symmetrical radiation pattern and achieves the wide 3-dB AR beamwidth with about 6 dBi gain at two operating frequency band. The design and simulation results of the proposed antenna are presented and discussed.

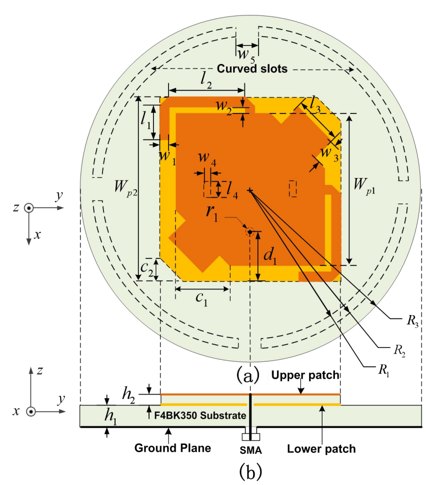

Fig. 1. Geometry of the proposed antenna on (a) top view, (b) side view.

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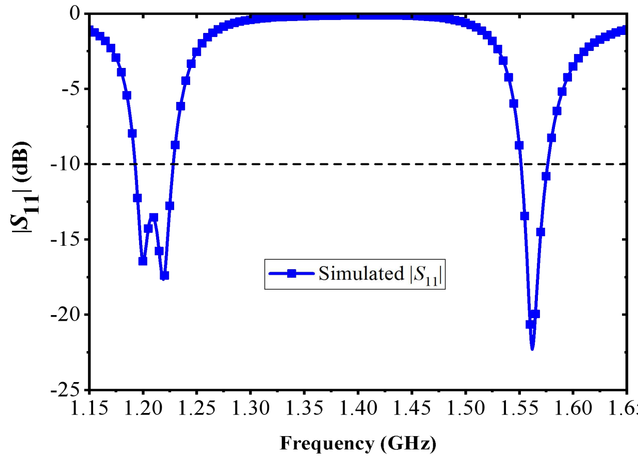

Fig. 2. Simulated $|S_{11}|$ of the proposed antenna.

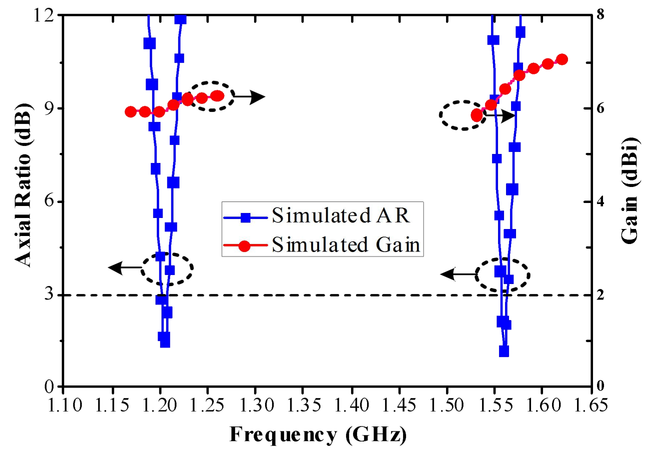

Fig. 3. Simulated AR and gain of the proposed antenna.

TABLE I

OPTIMIZED ANTENNA DIMENSIONS (UNIT: MM)

Parameter	Value	Parameter	Value	Parameter	Value
W_{p1}	52	w_2	2.4	r_1	1
W_{p2}	63.2	w_3	8.2	h_1	3
l_1	11.5	w_4	2.4	h_2	1.5
l_2	26.8	w_5	8	R_1	60
l_3	16.5	c_1	18.8	R_2	55
l_4	5.8	c_2	8.2	R_3	52.5
w_1	3.2	d_1	11.5	--	--

II. ANTENNA DESIGN

The configuration of the proposed antenna is shown in Fig. 1, and the optimized design parameters are given in Table I. The proposed antenna is assembled with two substrate layers, an upper patch and a lower one, and a slotted ground plane. Both substrate layers employ the F4BK350 with a relative permittivity of $\varepsilon_r = 3.5$, a loss tangent of $\tan\delta = 0.001$. The upper substrate is square with the dimensions of $70\ \text{mm} \times 70\ \text{mm}$ and the height of $h_2 = 1.5\ \text{mm}$. The lower substrate is circular with a radius of $R_1 = 60\ \text{mm}$ and the height of $h_1 = 3.0\ \text{mm}$. The upper patch is a driven radiation patch with two symmetrical L-shaped stubs and rectangular stubs which can widen the 3-dB AR beamwidth. In order to generate dual-band CP radiation, a lower patch is placed under the upper patch. The lower patch is a corner-truncated square patch with a via hole and two slits. By adjusting the dimensions of the truncated corners, a reliable CP can be achieved.

In this work, a circular ground plane with four curved slots is employed. Therefore, the 3-dB AR beamwidth is further broadened, realizing the properties of symmetrical radiation pattern. The proposed antenna is fed by a 50-Ω coaxial cable with an inner conductor radius of 0.5 mm. Moreover, the probe feed is directly connected to the upper patch via a hole in the lower patch. Meanwhile, the lower patch is excited through electromagnetic coupling. The dual-band CP antenna is compact through employing the simple feed mechanism.

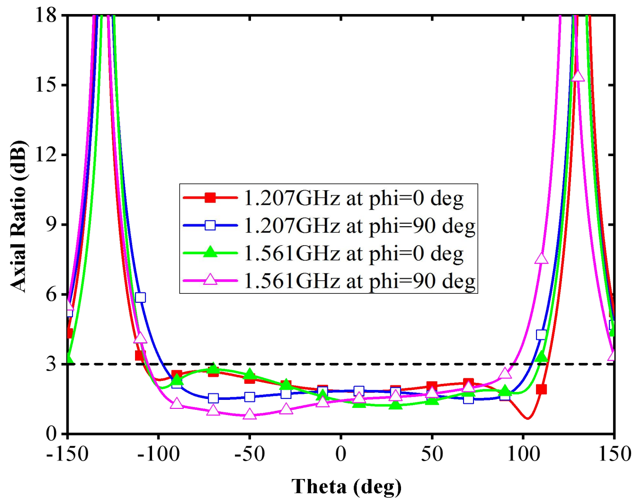

Fig. 4. Simulated 3-dB AR beamwidths of the proposed antenna.

III. SIMULATED RESULTS

To confirm the design, the performance of the antenna is computed with ANSYS HFSS *v*.14. The simulated $|S_{11}|$ of the proposed antenna is shown in Fig. 2. The simulated relative impedance bandwidth for $|S_{11}| < -10$ dB is about 3.0% ranging from 1.193 to 1.228 GHz and about 1.7% covering from 1.551 to 1.577 GHz, respectively. With reference to Fig. 3, the simulated results show that the 3-dB AR bandwidth is 8 MHz (1201 MHz–1209 MHz) at the lower band and 7 MHz (1.557 MHz–1564 MHz) at the upper band. The simulated peak gains in both bands are 6.0 dBi and 6.4 dBi, respectively.

Due to employ the circular ground plane with four curved slots, the wide 3-dB AR beamwidth is achieved. As shown in Fig. 4, at 1.561 GHz, the 3-dB AR beamwidth is 214° and 200° in the *xz*- and *yz*- planes, respectively. At 1.207 GHz, the 3-dB AR beamwidth is 221° and 202° in the *xz*- and *yz*-planes, respectively. It can be seen that the 3-dB AR beamwidth is greater than 180° in all planes, that is to say,

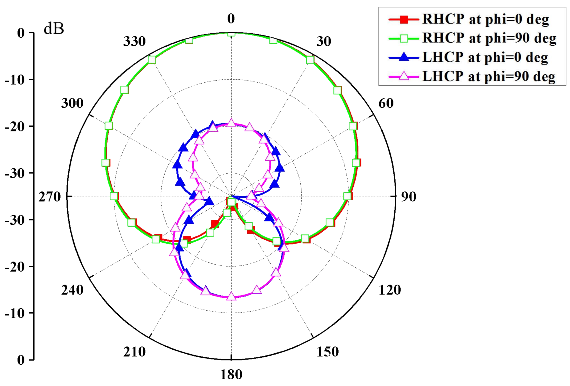

Fig. 5. Simulated RHCP and LHCP radiation patterns at 1.207 GHz.

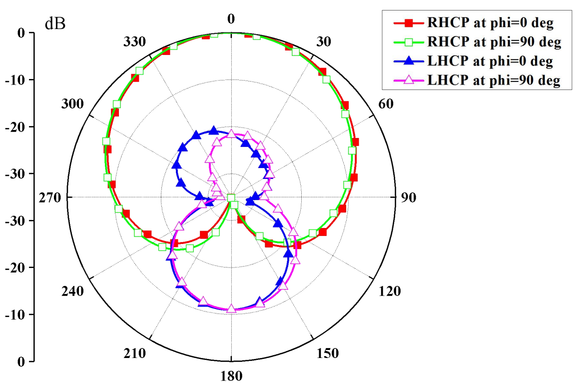

Fig. 6. Simulated RHCP and LHCP radiation patterns at 1.561 GHz.

the CP radiation is achieved in the space with $z > 0$.

The simulated normalized radiation patterns are shown in Figs. 5–6. It can be seen that the right-handed CP (RHCP) is achieved in both frequency bands. Meanwhile, the cross-polarization ratio is greater than 20 dB. Moreover, as shown in Fig. 5, at 1.207 GHz, the simulated half power beam width (HPBW) is 94° in the *xz*-plane and 92° in the *yz*-plane. At 1.561 GHz, the simulated HPBW is 90° in the *xz*-plane and 88 ° in the *yz*-plane as shown in Fig. 6.

The performances of different dual-band CP antennas are compared. As listed Table II, the proposed antenna realizes the greater 3-dB AR beamwidth and the gain are larger than 6 dBi in both bands.

IV. Conclusion And Future Work

In this article, a single-fed dual-band CP antenna with wide 3-dB AR beamwidth has been investigated for CNSS applications. In order to achieve dual bands, two patches are stacked on top of each other. The CP radiation can be achieved by adjusting the dimensions of the truncated corners and rectangular stubs. In addition, through introducing the ground plane with four curved slots, the CP radiation performance is achieved in the $z > 0$ entire space. Moreover, the gain of the proposed antenna is greater than 6 dBi in both operating bands.

TABLE II

Comparison Of The Proposed Antenna With Prior arts

Ref.	Operating Frequencies (GHz)	3-dB AR beamwidth		Gain (dBi)
		xz-plane (°)	*yz*-plane (°)	
[8]	1.575	210	205	0.91
	2.450	222	225	6.8
[9]	1.451	182	165	3.9
	2.029	184	175	3.9
[10]	1.227	132	140	6.3
	1.575	143	152	7.5
This work	1.207	221	202	6.0
	1.561	214	200	6.4

Based on these merit performances, the proposed antenna is suitable for CNSS applications. The future work for this study will include broadening the HPBW, fabricating, and measuring, *etc.*

Acknowledgment

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