A Low-Cost High-Isolation Low-Profile Broadband $\pm 45^\circ$ Dual-Polarized Antenna for Base Station Applications

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***Abstract*—In this article, a low-profile wideband dual-polarized antenna fed by electromagnetic coupling is proposed. The antenna is composed of a radiating patch at the top, parasitic strips around it, a coupling feed structure under the radiating patch, a balun, and a slotted reflector at the bottom. The operating frequency band of the antenna is 0.69∼0.96 GHz, and the overall size is small with low profile characteristics. It is 220 mm × 220 mm × 34.5 mm (about $0.608\lambda_0 \times 0.608\lambda_0 \times 0.096\lambda_0$), $|S_{11}|$ and $|S_{22}| \leq -10$ dB in the operating band, and the isolation between the two ports is lower than −41 dB. At the same time, it has a stable realization gain (7.86±0.35 dBi) and high total efficiency (90.87%±2.6%) in the whole frequency band and maintains excellent cross-polarization discrimination (XPD). Finally, the antenna's front-to-back ratio (FTBR) is higher than 22 dB, which has low backward radiation characteristics. The half-power beamwidth (HPBW) in the XOZ plane is (69.12°±5.93°), which has a wide half-power beamwidth in the horizontal plane, which meets the performance requirements of the base station antenna covering the sector junction.**

I. Introduction

In mobile communication systems, the performance of the base station antenna directly affects the signal quality and user experience during the communication process. In the case of increasingly integrated mobile communication systems, the base station antenna is required to have a wider signal bandwidth, more functions, and a smaller space size.

In recent years, many researchers have studied low-profile antennas. In [1], a low-profile dual-polarized dielectric resonator antenna was proposed. The antenna changes the electric-field distribution by slotting the dielectric resonator surface to improve the gain within the operating bandwidth. The antenna profile was as low as 0.09 λ_0. In [2], the author used an artificial magnetic conductor (AMC) as the reflector plate of the antenna to achieve low-profile characteristics. The antenna profile was 0.098 λ_0, but the bandwidth was limited by the operating bandwidth of the AMC. The relative bandwidths are only 7.9% (2.55∼2.76 GHz) and 13.7% (4.5∼5.16 GHz), which do not conform to the broadband operating characteristics. At the same time, the peak gain is small at 6.75 dBi. In [3], a low-profile antenna using an aperiodic AMC was proposed. By adjusting the AMC to the required performance and using it as a reflector, the entire antenna profile was as low as 0.053 λ_0. In [4] an embedded L-shaped probe was used to feed power to achieve high gain and broadband performance. In [5], a magnetic coupling method was proposed to simultaneously excite the parasitic patch to improve the impedance bandwidth and efficiency. In [6], the impedance bandwidth and efficiency bandwidth were expanded by electric-coupling excitation. At the same time, the antenna had an extremely low profile of approximately 0.006 λ_L(λ_L is the wavelength corresponding to the lowest frequency of the operating frequency band). In [7], the author improved the impedance matching of the antenna in the broadband using several trapezoidal strips and four pairs of rectangular strips and introduced metal pillars to stabilize the radiation pattern.

The proposed antenna operates in the same frequency band as the antenna in [8], but the profile is reduced by 17.1%(41.6 mm in [8]), and the reflector size is reduced by 24.1%(280 mm in [8]). In addition, while being more compact, the proposed antenna has higher isolation as well as overall efficiency.

II. Antenna Design

The geometry of the proposed antenna is shown in Fig 1, which is mainly composed of the following parts: the radiation patch printed on the dielectric substrate at the top and the parasitic strip around; the lower surface of the dielectric substrate is the coupling feed structure; the balun connecting the feeding structure and the reflector plate; and the bottommost reflector plate.

The material of radiation bodies such as radiation patch, parasitic strip, and reflection plate is aluminum plate with a thickness of 0.5 mm, and the material of coupling feed structure and balun structure is a layer of copper with a thickness of 0.035 mm printed on the medium substrate. The properties of the dielectric substrate used in the whole antenna are unified as follows: the relative dielectric constant is 4, the loss angle tangent is 0.005, and the single layer thickness is 0.762 mm.

The main radiator of the proposed antenna adopts the common form of four patches, which form a pair of dipoles placed orthogonally, and the dual polarization can be achieved by excitation of them respectively. Each patch is chamfered to

2025 International Conference on Microwave and Millimeter Wave Technology (ICMMT) | 979-8-3315-2573-6/25/$31.00 ©2025 IEEE | DOI: 10.1109/ICMMT65948.2025.11188989

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reduce mutual coupling, and an L-shaped gap is arranged in the center of the patch to prolong the current path. After that, four parasitic strips are placed at the center of the perimeter, which can be used to expand the impedance bandwidth. At the same time, when the main radiator is excited, the current induced on the parasitic strips helps to improve the XPD of the antenna.

The lower surface of the dielectric substrate is a coupling feed structure, which is composed of a cross structure at the center and a diamond structure connected with it. The lower surface can also be regarded as a pair of dipoles placed orthogonally, which together with the radiation patch on the upper surface form two resonant loops with two resonant frequencies. When the resonant frequencies of the two are adjusted close to each other, the frequency band can be broadened to form a bimodal resonant circuit.

The balun consists of a substrate, a microstrip line printed on the front, and a slot line printed on the back. To ensure that the balun performance is as consistent as possible, the front microstrip lines are misaligned up and down to enhance isolation.

To improve the forward radiation performance and gain of the antenna, a reflecting plate is added to the bottom of the antenna and a metal rim which is fabricated with periodic vertical slots is added around it. There is a circular slot at the bottom of the reflector plate. The dimensions of the proposed antenna are listed in Table I. The antenna was simulated and optimized using HFSS software.

TABLE I
THE OPTIMIZED PARAMETERS OF THE PROPOSED ANTENNA(UNIT: MM)

Parameter	p_l	p_{sl}	l_r	w_r
Value	220	176.1	115	2.5
Parameter	p_g	p_{gl}	p_a	p_b
Value	1.5	60	9	17
Parameter	f_l	f_{l2}	f_w	f_g
Value	26	58	4	1.5
Parameter	b_{l1}	b_{l3}	b_{l3}	b_{l4}
Value	29.06	4.52	9.5	20
Parameter	b_w	b_{sw}	b_{pw}	b_{cw}
Value	1.52	45	6.08	5
Parameter	b_h	h_w	w_r	r_s
Value	33.24	10	9	48
Parameter	r_g	h		
Value	1.6	34.54		

III. SIMULATION RESULTS

The simulation results of antenna scattering parameters and gain are shown in Fig. 2. It can be seen that the impedance bandwidth of the proposed antenna when port 1 (+45° polarization) and port 2 (−45° polarization) are excited includes 0.69∼0.96 GHz, and the $|S_{11}|$ and $|S_{22}|$ are less than 10 dB in the frequency band. At the same time, the isolation between

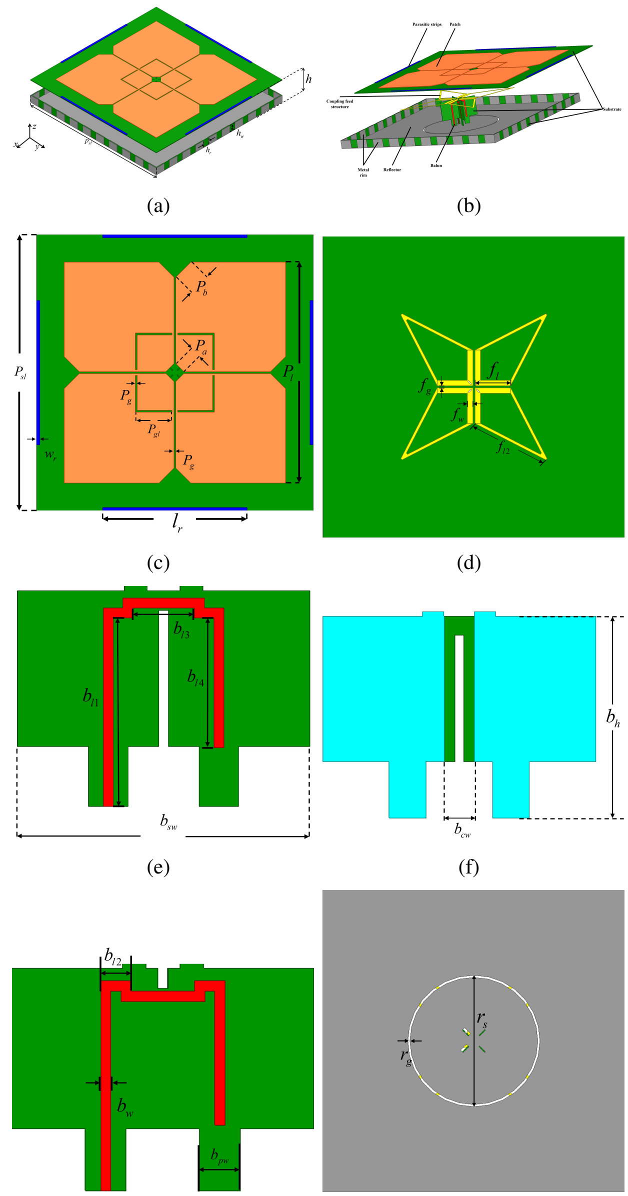


Fig. 1. Configuration of the antenna. (a) 3D view; (b) Radiation patch; (c) Coupling feed structure; (d) Front of balun 1; (e)Back of balun 1; (f) Front of balun 2; (g) Reflector bottom and ring slot.

the two ports is greater than 41 dB in the target frequency band, and the maximum isolation is 48 dB, which has excellent isolation performance. The antenna has a stable realized gain of 7.86±0.35 dBi in the operating frequency band, and the transceiver performance is excellent.

Fig. 3 shows the cross-polarization characteristics of 0.69 GHz, 0.78 GHz,0.87 GHz, and 0.96 GHz on the XOZ plane of the antenna when the +45° polarization excitation. It can be seen that the proposed antenna not only maintains a high XPD at 0° but also maintains an XPD above 20 dB at 60°, which has excellent cross-polarization discrimination. At the same time, the radiation pattern of the antenna remains stable

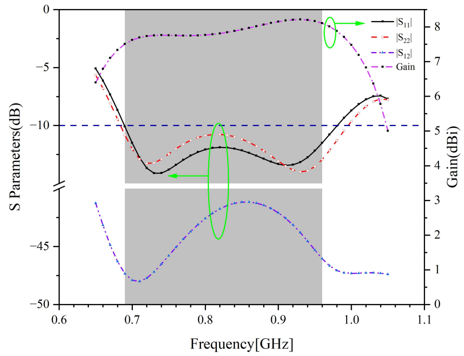
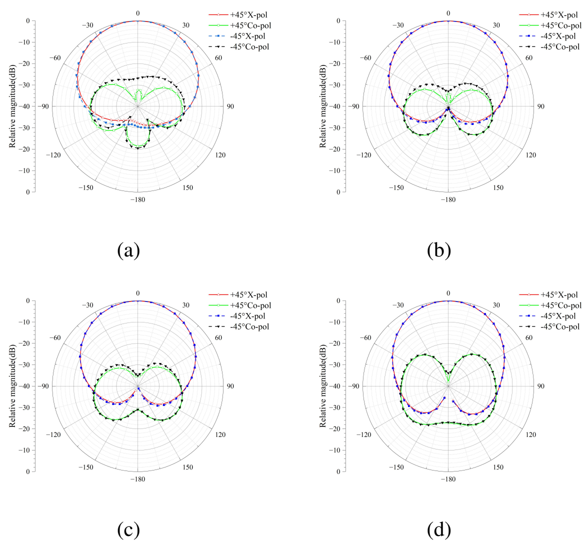


Fig. 2. S-parameters and gains of the proposed antenna.

in the whole frequency band, and is only slightly narrowed due to the change of radiation aperture caused by the change of frequency.



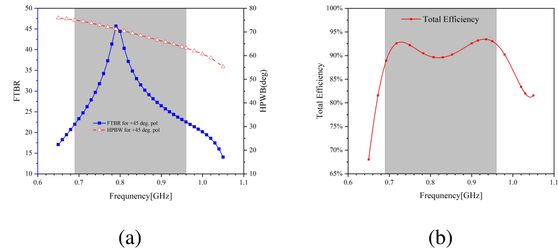
(a) (b) (c) (d)

Fig. 3. Simulated radiation patterns of the proposed antenna. (XOZ plane): (a) 0.69 GHz; (b) 0.78 GHz; (c) 0.87 GHz; (d) 0.96 GHz.

Fig. 4(a) shows the front-to-back ratio characteristics of the antenna and the horizontal half-power beamwidth. In the whole frequency band, the front-to-back ratio of the antenna is greater than 22 dB. Moreover, the horizontal half-power beamwidth is 69.12°±5.93°, which is relatively stable and wide. Finally, Fig. 4(b) shows the total efficiency of the antenna in the frequency band, with a minimum efficiency of 88% .

IV. Conclusion

In this paper, a low-profile wideband dual-polarized antenna for electromagnetic coupling feeding in the band 0.69∼0.96 GHz is proposed. By introducing coupling feed structures and diamond-shaped structures, we have effectively reduced the antenna profile while solving the impedance mismatch problem caused by the reduced profile. In addition, our addition of parasitic branches around the antenna significantly improves cross-polarization discrimination. Finally, a reflective plate is added to the bottom of the antenna, and to improve the front-to-back ratio, a circular gap is opened under the reflector plate, and a periodic slot is introduced on the metal edge, which effectively improves the front-to-back ratio of the antenna and reduces the backward radiation.The performance of the proposed antenna conforms to the requirements of the actual application scenario of the base station antenna



(a) (b)

Fig. 4. (a) Simulated half-power beamwidth and front-to-back ratio of the proposed antenna; (b) Simulated total efficiency of the proposed antenna.

Acknowledgement

This work is supported in part by the National Key Research and Development Program of China under Grant 2023YFE0107900, the National Natural Science Foundation of China (NSFC) under Grant 62071306, and the Shenzhen Science and Technology Program under Grants JSG-G20210802154203011, JCYJ20241202124219023, and JSG-G20210420091805014.

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