A Differential Broadband Dual-Polarized Base Station Antenna Element for 4G And 5G Applications

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***Abstract*—In this paper, a broadband differential feed $\pm 45^\circ$ dual-polarized base station antenna element is proposed for 4G and 5G mobile communications. The proposed antenna consists of two orthogonally placed dipoles, square patch and reflector, where each dipole adds six elliptical branches to broaden the bandwidth. Simulation results show that the proposed antenna element has the impedance bandwidth of 65% (1.84-3.6 GHz) within the operating frequency (S_{11} < -15 dB and S_{21} < -21 dB), and good radiation characteristics and high cross polarization ratio are also achieved.**

***Index Terms*—Base station antenna, broadband, differential, dual-polarized, 4G, 5G.**

I. INTRODUCTION

With the rapid development of communication technology, the fifth generation mobile communication (5G) is being commercialized since 2019, and the 5G frequency bands of various countries have been deployed, for example, 3.4-3.8 GHz used in Europe, 3.1-3.55 GHz and 3.7-4.2 GHz used in USA [1]. As for China, in order to speed up the 5G progress, the Chinese Ministry of Industry and Information Technology has issued the 5G license, and each operator has obtained different frequency bands — 3.4-3.5 GHz of China Telecom, 3.5-3.6 GHz of China Unicom, 2.515-2.675 GHz and 4.8-4.9 GHz of China Mobile, and 0.7 GHz of China Broadcasting Network. However, commercializing 5G will not ban the 4G network. Instead, 4G and 5G network will coexist for a long time . It is not a very good method to install a new frequency-band base station antenna on a used base station system, thus a broadband base station antennas will be utilized to cover 4G and 5G bands. In addition, base station antenna should have dual polarization characteristics to reduce the influence of multipath fading. In [2], although a broadband dual-polarized antenna is proposed, it can only operate at 1.67-2.72 GHz without covering the 5G bands. In [3] [4], although the antennas can operate at 3.18-5.19 GHz and 3.3-4.2 GHz respectively, they don't cover the 4G band. A broadband base station antenna was proposed in [5] , which operates at 2.05-3.64 GHz and covers 4G and 5G bands. However its S_{11} is less than -10 dB, which does not meet the application standard of the base station antenna.

This paper proposes a broadband base station antenna element for LTE and 5G applications covering the frequency bands of 1.84-3.6 GHz. This paper is organized as follows. Section II illustrates the structure of the proposed antenna. Section III analyzes the design process. Section IV presents the simulation results. Section V draws the conclusion.

TABLE I
DETAILED VALUES OF THE PROPOSED ANTENNA

Parameter	Value(mm)	Parameter	Value(mm)
L_1	46	L_2	10
L_3	2	L_4	12.2
L_5	8.9	L_f	12.9
L_d	65	L_g	135
R_f	12.5	H_d	0.95
H	36.5	X_{gap}	1.3
Y_{gap}	2		

II. CONFIGURATION

Fig. 1 shows the configuration of the proposed differential broadband antenna. The antenna consists of a square patch using differential feed, two pairs of orthogonally placed radiators with ±45° polarization, where each radiator is composed of two right-angle sides, circular arc and three elliptical branches. Two pairs of radiators (the area surrounded by dotted line) are printed on the bottom side of the dielectric substrate and the square patch is printed on the top side of the dielectric substrate, where the dielectric substrate holds the relative permittivity of $\varepsilon_r = 2.55$ and the thickness of 0.95 mm. The outer conductor of the fed coaxial cable is connected to the radiator, and the inner conductor is connected to the square patch through the dielectric substrate. The phase difference between the two ports is 180°. Four coaxial cables achieve differential feed in this way. All parameters of the antenna are

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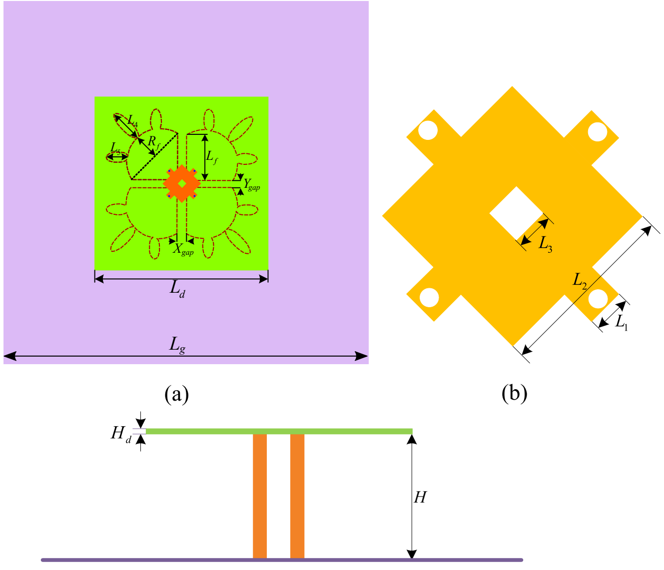


(a) (b) (c)

Fig. 1. The geometry of the proposed antenna: (a) Top view; (b) Feed patch; (c) Side view.

optimized and specific values of those parameters are listed in Table I.

III. DESIGN AND ANALYSIS

A. S parameters of Differential Dual-Polarized Antenna

For differential dual-polarized antenna elements, there are four independent ports, which are considered as dual-port networks with differential feeds, named as P_{d1} and P_{d2}. The differential reflection coefficients of differential ports P_{d1} and P_{d2} are defined as follow [6]. It is noted that all S_{11} in the article are S_{dd11}, and S_{21} are S_{dd21}.

$$S_{dd11} = \frac{1}{2}(S_{11} - S_{12} - S_{21} + S_{22}) \tag{1}$$

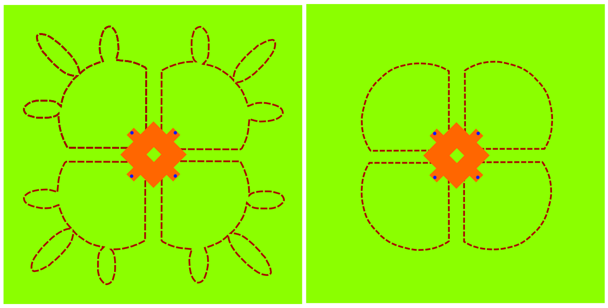
$$S_{dd22} = \frac{1}{2}(S_{33} - S_{34} - S_{43} + S_{44}) \tag{2}$$

$$S_{dd21} = \frac{1}{2}(S_{31} - S_{41} - S_{32} + S_{42}) \tag{3}$$

$$S_{dd12} = \frac{1}{2}(S_{13} - S_{14} - S_{23} + S_{24}) \tag{4}$$

B. Antenna Design

In order to analyze the effect of elliptical branches loaded at the edge of radiator on antenna performance, Ref1 antenna with loaded ellipse and Ref2 antenna without loaded ellipse are designed as shown in Fig. 2. The reflection coefficients of the two structures are shown in Fig. 3. As shown in Fig. 3, since Ref1 antenna with loaded ellipse generates two resonant points at 2 GHz and 3.2 GHz, the impedance bandwidth is effectively broadened to 65% within the operating band (S_{11} <-15 dB).



(a) (b)

Fig. 2. The structure of the antenna with loaded ellipse and without loaded ellipse: (a) Ref1; (b) Ref2.

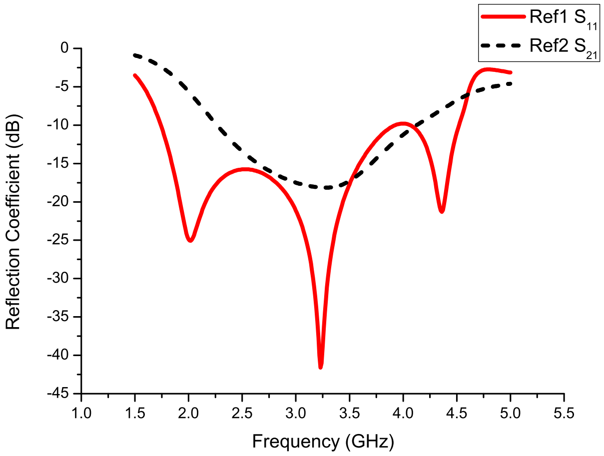


Fig. 3. Simulated reflection coefficients of the antenna Ref1 and Ref2.

C. Parameter Analysis

The influence of key parameter H on the antenna performance is analyzed as shown in Fig. 4. Due to the symmetry of the antenna structure, only the S parameters of one differential port are given. It can be seen that the parameter H has little influence on the isolation in the frequency range of 1.84-3.6 GHz, but H has a great influence on the return loss. When the H increases, the higher resonant frequency shift to the lower frequency and the curve of the return loss goes down gradually in frequency band. However, the bandwidth of S_{11} < -15 dB is obviously narrowed, resulting in insufficient bandwidth. Therefore, after considering the bandwidth and the height of the radiating element, H is selected as 36.5 mm.

IV. SIMULATION RESULTS

Under the optimized parameters, Fig. 5 shows the simulated S-parameter. It is observed that the antenna has broadband and high isolation, over the band of 1.84-3.6 GHz & 4.25-4.4 GHz, its S_{11}<-15 dB, and S_{21}<-21 dB. It is worth noticing that although another resonant frequency of 4.25-4.4 GHz appears in Fig. 5, its performance will not be discussed. The radiation pattern degrades in this frequency range from 4.25 GHz to 4.5 GHz due to the higher excited harmonic wave. Figure 6 shows that the H-plane simulated radiation patterns of the proposed

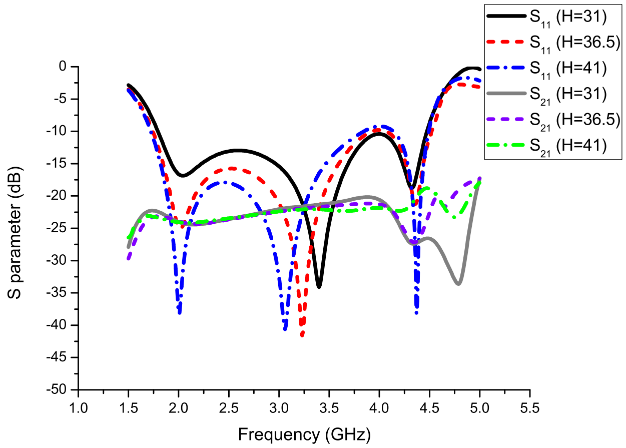


Fig. 4. Simulated S-parameters with different H.

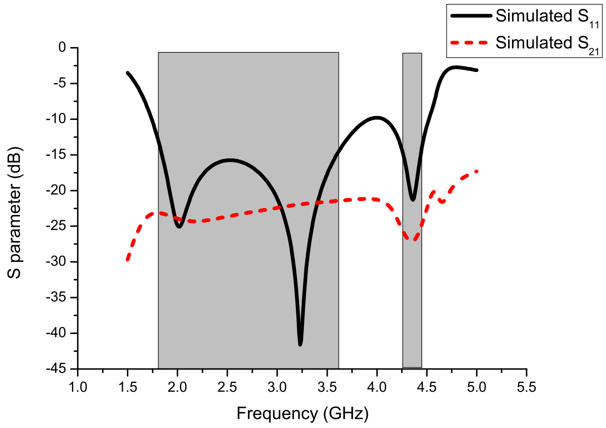
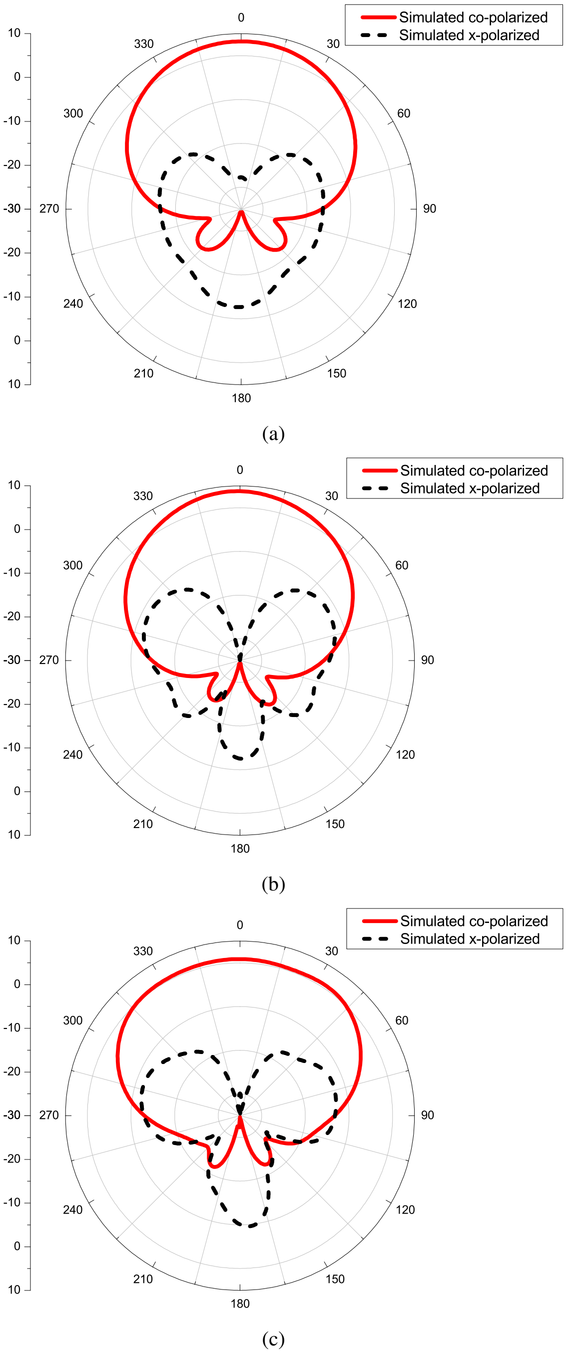


Fig. 5. The simulated S-parameters.

antenna at 1.84 GHz, 2.7 GHz, 3.3 GHz and the corresponding gains in above frequencies are 8.2 dBi, 8.7 dBi and 5.8 dBi respectively. The reason why the gain is lower at 3.3 GHz may be that the distance between the reflector and the radiator is too high to have enough reflect energy from the reflector. The front-to-back ratio of each frequency point is greater than 23 dB, and its axial cross-polarization is greater than 28 dB, benefiting from differential feed. Simulation results show the proposed antenna with broadband dual-polarized radiation performance is a good candidate in 4G frequency band and 5G frequency band.

V. CONCLUSION

A wide-band dual-polarized base antenna element is designed by using printed dipole with loaded elliptical branches. Simulation results show that the impedance bandwidth is as high as 65% (1.84-3.6 GHz) when S_{11} is less than -15 dB. The isolation in the frequency band is also below -21 dB, so the interference between different polarization ports is small. The gain in the 4G frequency band is about 8.4 dBi, and the gain in the 5G frequency band is about 6 dBi. Since the differential feed is used, the cross-polarization ratio is improved, and the



(a)

(b)

(c)

Fig. 6. Simulated gain radiation patterns in H-plane: (a) 1.84 GHz; (b) 2.7 GHz; (c) 3.3 GHz.

axial cross-polarization ratio is greater than 28 dB which is much larger than that of the general base station antenna element. Structurally, although the proposed antenna uses differential feed structure, the overall configuration is simple and easy to manufacture. It is implemented by printing the radiator and the feeding patch on two sides of the substrate.

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