A Tri-band Dual-Polarized Base Station Antenna for Sub-6 GHz 5G Communication Systems

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***Abstract*—A novel tri-band dual polarized antenna with frequency selective function is presented in this paper. This antenna is composed of two orthogonal square dipoles, two Y-shaped feeding structures, two parasitic loops and a reflector. The three 5G working bands are covered by the three resonant points generated by the dipoles and two parasitic loops, respectively. According to the simulated and measured results, the antenna can operate at the range of 2.52-2.68 GHz, 3.3-3.6 GHz and 4.82-5.0 GHz with voltage standing wave ratio (VSWR) <1.5 and port isolation >20 dB. The gains in 2.52-2.68 GHz, 3.2-3.6 GHz and 4.82-5.0GHz are 8.0 ± 0.2 dBi, 8.8 ± 0.1 dBi and 12.2 ± 0.3 dBi, and the corresponding half-power beamwidths (HPBWs) are about 67°, 68° and 38° respectively. The proposed antenna is a candidate of the sub-6GHz 5G base station antennas.**

***Index Terms*—Tri-band; frequency selective; dual-polarized; sub-6 GHz 5G base station antennas.**

I. Introduction

In the coming 5G era, more frequency bands are being used in wireless communication to provide more communication channels and faster communication speed. 5G frequency bands are mainly separated into sub-6 GHz bands and millimeter-wave bands. Because base station antennas with sub-6 GHz bands have larger coverage range and lower propagation loss compared with those with millimeter-wave bands, base station antennas with sub-6 GHz bands are more applicable for 5G outdoor coverage.

The sub-6 GHz bands are also divided into many separate communication bands. For example, in China, the 5G sub-6 GHz bands mainly include 2.515-2.675 GHz, 4.8-4.9 GHz (adopted by China Mobile) and 3.3-3.6 GHz (adopted by China Unicom and China Telecom). Therefore, designing antennas which cover multiple bands including 2.515 to 2.675 GHz, 4.8 to 4.9 GHz and 3.3 to 3.6 GHz has important theoretical and practical values.

To attain broadband or multi-band characteristics, different shapes of parasitic structures, slots and apertures are introduced into the antenna element to inspire multiple modes [1]- [2]. In [1], four metal lines that are used to connect the adjacent dipole arms are adopted to inspire multi-resonant points. Thus, the bandwidths of 46.7% can be attained. In [3] and [4], artificial magnetic conductor (AMC) is used to design multi-band antenna. [4] inserted frequency selective surface (FSS) between low frequency element and high frequency element to design multi-band antenna, however the problems of high cost and impedance matching degradation appear. In addition, combining different kinds of antenna elements operating in different bands has been proposed to achieve all-spectrum access characteristics in [5]. However, the more the antenna elements operating in different bands are, the more the complex electromagnetic environment is, which results in the deterioration of antennas' performance. To meet the trade-off, we design a tri-band 5G base station antenna which can cover three main sub-6 GHz 5G bands with VSWR <1.5 and port isolation >20 dB.

II. Antenna Design

The antenna construction is displayed in Fig.1, which is composed of two orthogonal square dipoles, two Y-shaped structures used to transmit energy, two parasitic loops and a planar reflector. The Y-shaped feeding structures and two square dipoles are printed on the top and bottom surface of the substrate 1 respectively, and the parasitic loop 1 and loop 2 are printed on the top face of the substrate 2 and substrate 3 respectively. The orthogonal square dipoles can achieve ± 45° polarization radiation. As shown in Fig. 1 (b), the central part of one of the Y-shaped feeding line is printed on the bottom face of the substrate 1 in order to prevent physical overlap. And this central part connects the part printed on the top face through two metal vias. The inner conductors of coaxial cables are connected to the Y-shaped lines directly, and the outer conductors are connected on one arm of the square dipole. All substrates are made of FR4 with permittivity of 4.4, loss tangent of 0.02 and thickness of 1mm. The performance of the antenna was simulated and optimized in Ansoft HFSS.

To explain its working principle, the simulation performance of the proposed antenna and the three reference antennas is compared and discussed. Fig. 2 shows the structures of the three reference antennas. Ant 1 only contains two orthogonal square dipoles without two parasitic loops. Ant 2 is the antenna which removes the loop 2 and retains the loop 1 based on the proposed antenna, and Ant 3 is the antenna which removes loop 1 and retains loop 2.

The simulated S_{11} results of the proposed antenna and the reference antennas are shown in Fig. 3, where Ant 1 only generates one resonant point, and the Ant 2 and Ant 3 with the addition of one parasitic loop produce two resonant points. The two resonant points generated by Ant 2 are at 2.75 GHz

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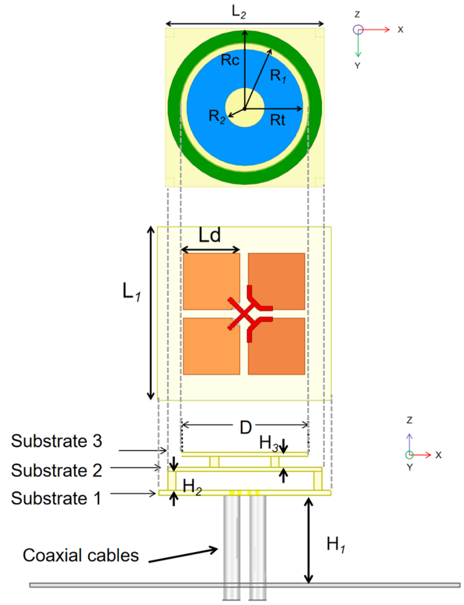
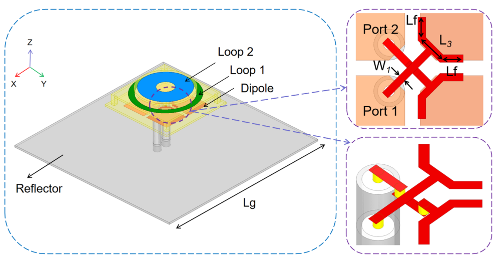


(a)



(b)

Fig. 1. Construction of the proposed antenna . (a) Top view and side view of the antenna. (b) 3D view of the antenna and feeding structures. (Detailed antenna parameters: L_1 = 40 mm, L_2 = 36 mm, L_3 = 4 mm, Ld = 13 mm, Lf = 3 mm, Lg = 100 mm, Rc = 17.5 mm, Rt = 13.2 mm, R_1 = 14.6 mm, R_2 = 4.5 mm, W_1 = 1 mm, H_1 = 20.4 mm, H_2 = 4.5 mm, H_3 = 2.5 mm, D = 29.4 mm.)

and 4.4 GHz, and The two resonant points generated by Ant 3 are at 3.3 GHz and 4.9 GHz. The proposed antenna with the addition of two parasitic loops can produce resonant points at three frequencies (2.6 GHz, 3.4 GHz and 4.9 GHz).

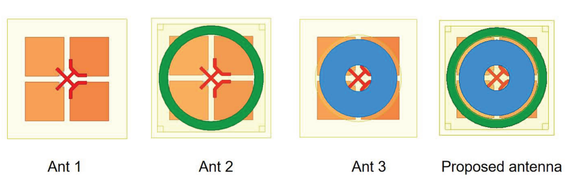


Fig. 2. Top view of the reference antennas and the proposed antenna .

The effects of the length of the square dipole Ld, the outer radius of loop 1 Rc and the outer radius of loop 2 Rt on the resonant point of the antenna are shown in Fig. 4, Fig. 5 and Fig. 6. With the increase of Ld, the frequency of the third resonant point moves to lower frequency, while the other two resonant points' positions basically unchange as shown in Fig. 4. According to Fig. 5 and Fig. 6 that the value of Rc and Rt control the positions of the first two resonant points respectively. Therefore, the resonant frequencies of the antenna can be adjusted independently.

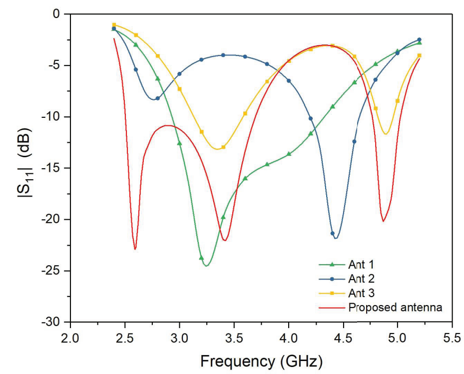


Fig. 3. Simulated $|S_{11}|$ of the reference antennas and the proposed antenna.

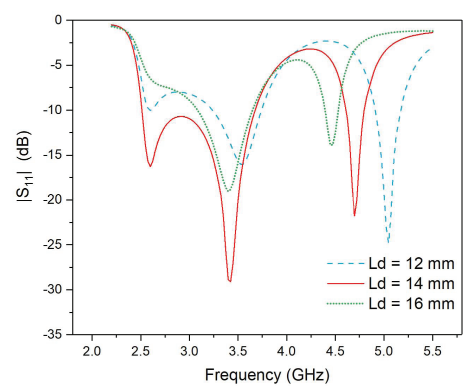


Fig. 4. Simulated $|S_{11}|$ corresponding to different Ld.

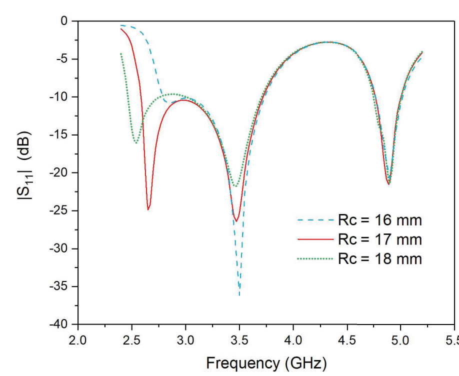


Fig. 5. Simulated $|S_{11}|$ corresponding to different Rc.

The three resonant points can be adjusted by the length of the dipoles and the radii of the two parasitic loops,

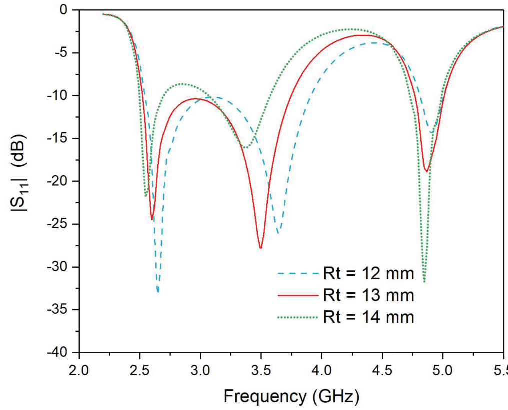


Fig. 6. Simulated $|S_{11}|$ corresponding to different *Rt*.

respectively. By using this design method similar to the prototype, we can also manufacture the other antenna to meet the requirements of other frequency coverage.

To validate our design, this tri-band antenna is manufactured and measured, and Fig.7 displays the simulated and measured S parameters. It has three operating bands of 2.52-2.68 GHz, 3.3-3.6 GHz, and 4.82-5.0 GHz with $|S_{11}|$ and $|S_{22}|$ less than -14 dB (VSWR<1.5). The port isolation is greater than 25 dB from 3.3 to 3.6 GHz, and greater than 20 dB from 2.52 to 2.68 GHz and 4.82 to 5.0 GHz.

The simulated and measured H-plane (YOZ plane) radiation patterns at 2.6 GHz, 3.3 GHz, 3.5 GHz and 5.0 GHz are given in Fig. 8. The cross-polarization discrimination (XPD) at boresight is greater than 20dB. As shown in Fig. 9, HPBWs are about 67°, 68° and 38° in three frequency bands, respectively, and the gains are 8.0 dBi, 8.8 dBi and 12.2 dBi, respectively.

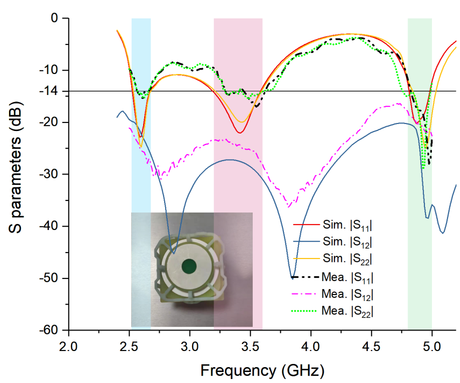


Fig. 7. Simulated and measured S parameters.

III. Conclusion

This article presents a novel promising method of design a dual-polarization tri-band base station antenna for 5G communication systems. By adjusting the length of the square dipoles arm and the radius of the two parasitic loops, the frequency of three resonant points of the proposed antenna can be adjusted

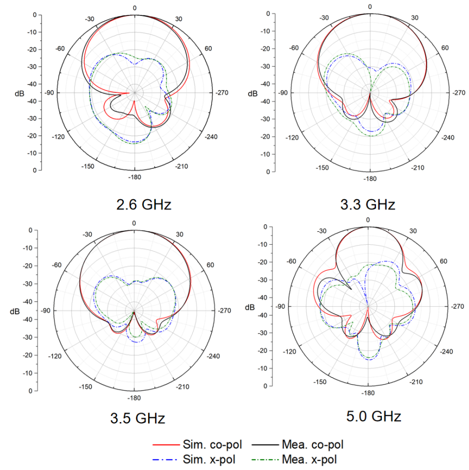


Fig. 8. Simulated and measured radiation patterns (at H plane).

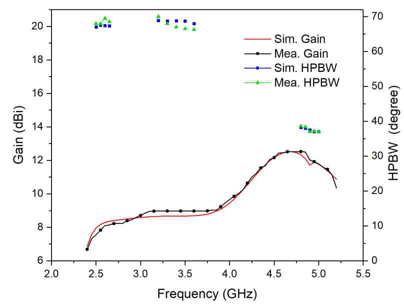


Fig. 9. Simulated and measured gain and HPBW.

so as to implement the coverage of three sub-6 GHz 5G bands (2.52-2.68 GHz, 3.3-3.6 GHz, 4.82-5.0 GHz). This proposed antenna operating in three sub-6 GHz 5G bands has VSWR less than 1.5, port isolation greater than 20 dB and XPD greater than 20dB. In the 2.52-2.68 GHz and 3.3-3.6 GHz bands, the HPBW and the gain are 67 ± 2° and 8.5 ± 0.5 dBi, respectively. From 4.82 to 5.0 GHz, the HPBW is only about 38°, which increases the gain to about 12.2 dBi.

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