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A Dual-Band Dual-Polarized Dielectric Resonator Antenna for 5G Base Station Application

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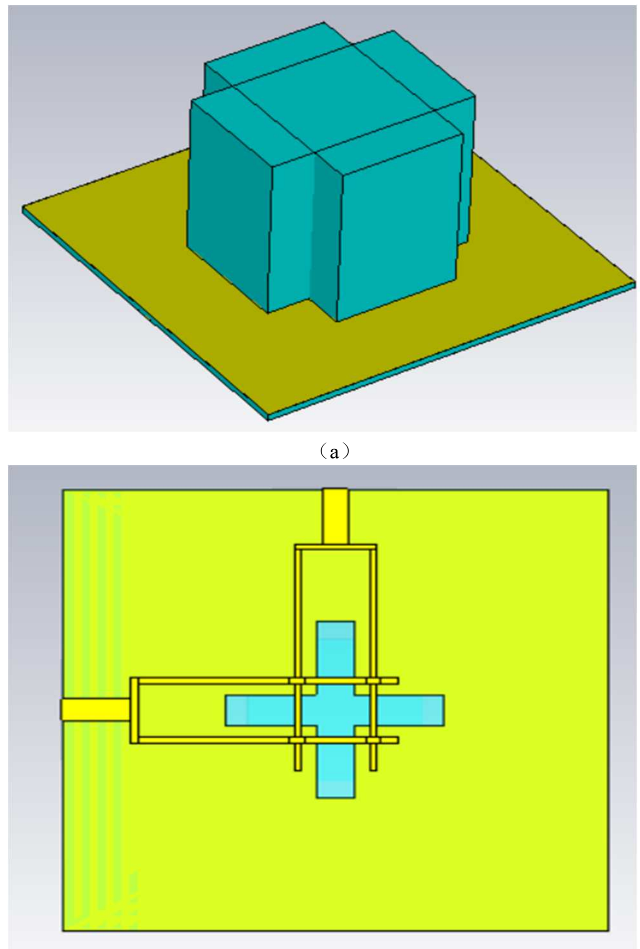
***Abstract*-A new base station antenna design of dielectric resonator (DR) antenna (DRA) is proposed for fifth generation base station application. The antenna is composed of a cross-shaped DR fed by U-shape microstrip power divider. The overall size of the cross-shape DR is only $0.24 \times 0.24 \times 0.21\lambda$ (λ is the the lowest frequency in the air region). By introducing two groups of modes, dual-band characteristic is realized and it will not interfere with other non-operating frequency bands. In order to explain the dual-band operation mechanism, we analyzed the E-field and H-field distribution of the proposed antenna. From simulation, the proposed base station antenna of dielectric resonator offers two band with the respective bandwidth of 11.4% (3.3-3.7) and 6.2% (4.7-5.0) for VSWR < 2 and exhibits extremely low cross-polarization characteristics and stable unidirectional radiation patterns in the operating frequency. These attractive features make the antenna an ideal candidate with further improvement for 5G base station applications.**

***Index Terms* — Base station antenna, dielectric resonator antenna, dual-band antenna, dual-polarized antenna.**

I. INTRODUCTION

Since the first generation of wireless communication in the 1970s, wireless communication systems have been rapidly updated and iterated in just a few decades. With the rapid development of fifth generation (5G) communication technology, there will be many new opportunities and challenges. The band of 3.3–3.6 GHz and 4.8–5 GHz is declared as the sub-6G band in China 1]. Different from the previous mobile communication system, the 5G mobile communication system will adopt independent networking. Therefore, it is practical to design a base station antenna that is only used for 5G communication systems and will not interfere with other frequency bands.

At present, base station antennas are mainly divided into die-cast antennas, stamped antennas and printed antennas in terms of their implementation forms. From the working principle of antennas, they can be mainly divided into dipole antennas, electromagnetic dipoles and patch antennas. The design of antennas applied to Sub-6GHz 5G base stations is similar to that of traditional 2/3/4G base station antennas. In recent years, some works on dual-polarized base station antennas for 5G applications [2][3][4]– [5] have been carried out. Reference [2] proposed a differentially fed 5G base station patch antenna, covering two sub-6GHz 5G frequency bands of 3.3-3.6GHz and 4.8-5GHz. In order to achieve suppression of non-operating frequency bands, it introduces radiation nulls on both sides to realize filtering characteristic. That is to say, it is complicated to design a dual-band/multi-band antenna. However, it is rare to see anyone taking advantage of the miniaturization and mode controllability of the dielectric resonator to explore its application in 5G base stations.



(a) (b)

Fig. 1. Configuration of the proposed dual-band DRA. (a) 3-D view. (b) feeding structure from the bottom view.

Therefore, this article proposed a dual-band dual-polarized dielectric resonator antenna for 5G base station application. The proposed antenna respectively achieves dual-band with the fractional bandwidth of 11.4% (3.3-3.7) and 6.2% (4.7-5.0), which covers the whole sub-6 GHz band and satisfy the requirement of multi-frequency coexistence in the base station systems. The dual-band response is realized by utilizing TE_{111} and TE_{113} and dual-polarized performance are achieved by corresponding orthogonal modes.

II. ANTENNA DESIGN AND WORKING THEORY

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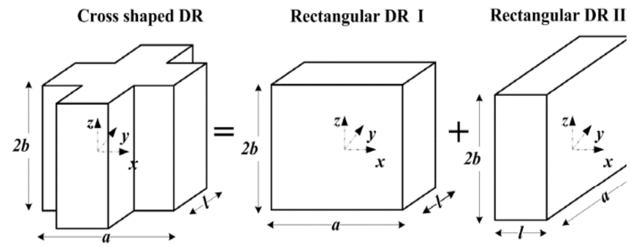
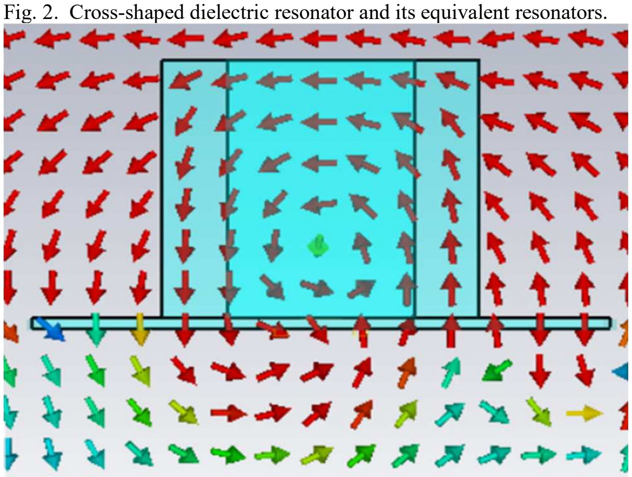
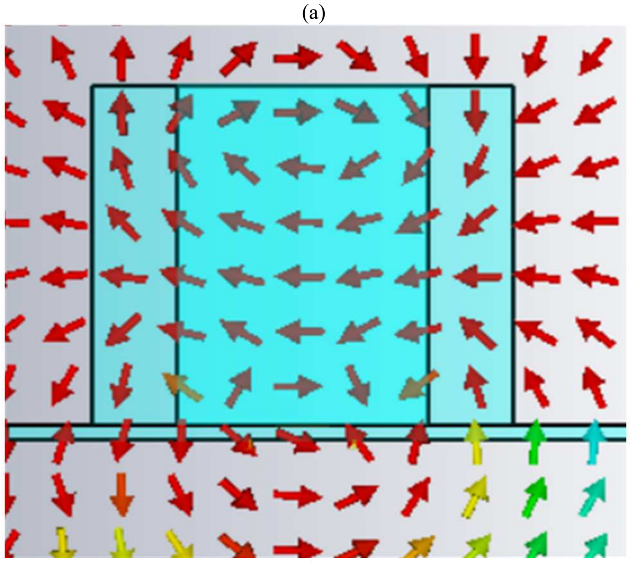


Fig. 2. Cross-shaped dielectric resonator and its equivalent resonators.



(a)



(b)

Fig. 3. Two modes of Rectangular DR Ⅰ. (a) TE111 mode. (b) TE113 mode.

A. Antenna Design

Fig. 1 shows the configuration of the dual-band dual-polarized dielectric resonator antenna. As shown in Fig.1(a) and (b), the proposed dual-band dual-polarized dielectric resonator antenna is comprised by a cross-shaped dielectric resonator, which is fed by microstrip slot coupling. Given a reasonable explanation of the working theory of the resonant antenna, we can consider the cross-shaped dielectric resonator as two identical equivalent rectangular dielectric resonators, which is shown in Fig.2. The dielectric constant of this cross-shaped

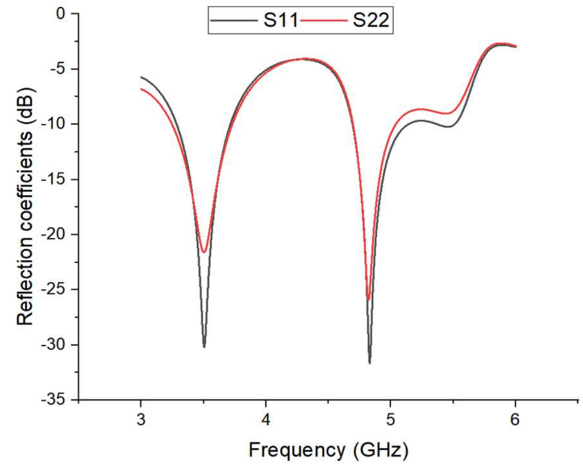


Fig. 4. The reflection coefficients of the proposed dual-band DRA.

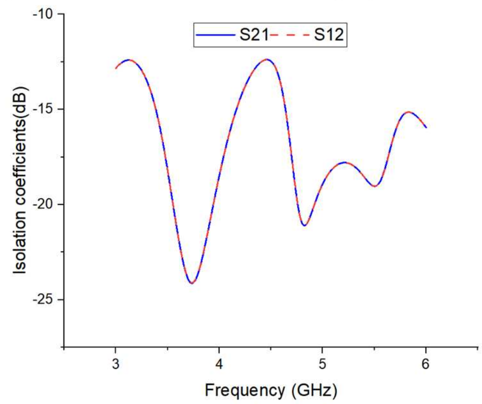


Fig. 5. The isolation coefficients of the proposed dual-band DRA.

dielectric resonator is 10, which is place on a high frequency dielectric plate with a dielectric constant of 2.94.

B. Working Theory

As shown in Fig.2, the cross-shaped dielectric resonator can be considered as two rectangle dielectric resonator, whose size is $a \times l \times 2b$. According to reference [6], we can figure out the size of the dual-band rectangle dielectric resonator antenna of response frequencies of the TE_{111} and TE_{113} mode. Fig.3 shows the distribution of E-field and H-field on two resonance frequencies of 3.5 and 4.8 GHz.

III. SIMULATION RESULTS

When the proposed dielectric resonator antenna is excited, there will be two resonance point. The first resonance point is due to TE_{111} mode, which works on 3.5 GHz and contributes to low-band from 3.3 to 3.7 GHz. And the second resonance point is due to TE_{113} mode, which operates on 4.8 GHz and contributes a high-band from 4.7 to 5.0 GHz.

Fig. 4 shows the extent of impedance match of two ports and indicates a good performance of the proposed DRA during wanted frequency. The reflection coefficients demonstrates that the fraction bandwidth of dual-band of 11.4% (from 3.3 to 3.7 GHz) and 6.2% (from 4.7 to 5.0 GHz) are achieved by the proposed DRA, which covers the whole sub-6G band.

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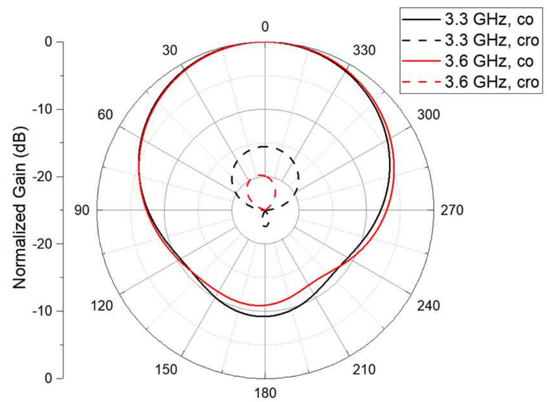
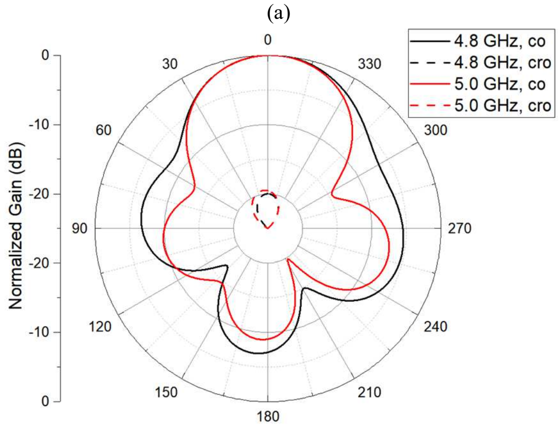


(a)



(b)

Fig. 6. Simulated normalized radiation patterns of dual-band DRA. (a) Working frequency on LB. (b) Working frequency on HB.

Fig. 5 shows the simulation detail of isolation coefficient between two ports, from which the proposed DRA achieves respectively more than 14dB and 19dB in the wanted 10-dB impedance bandwidth range.

Fig. 6 shows the radiation patterns of the proposed dielectric resonator antenna. We can see that stable unidirectional radiation patterns are obtained over the LB and HB operating bandwidth. In addition, the antenna exhibits extremely low cross-polarization characteristics in the operating frequency. That is to say, DR Ⅰ will not excite the mode of TE_{111} and TE_{113} when the DR Ⅱ excite TE_{111} and TE_{113} mode.

IV. CONCLUSION

A dual-band dual-polarized DRA for 5G base station application and its working theory are presented in the paper. From simulation, the details of E-field of working mode, impedance match of two ports, isolation between two ports and radiation pattern in dual-band range are all presented to demonstrate the rationality and attractive features. By introducing two modes of TE_{111} and TE_{113}, the DRA designed in sub-6G band respectively embrace the band range of 11.4% (from 3.3 to 3.7 GHz) and 6.2% (from 4.7 to 5.0 GHz). The isolation coefficient are respectively more than 14 dB and 19 dB in the wanted 10-dB impedance bandwidth range. Apart from above mentioned, not only stable radiation patterns but also low cross-polarization are obtained for the independence of TE_{111} and TE_{113}. All mentioned attractive features help to satisfy the requirement of multi-frequency coexistence in the base station systems.

ACKNOWLEDGMENT

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