

Low-Profile Dual-Band Dual-Circularly-Polarized Transmitarray

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Abstract—In this work, a low-profile, shared-aperture, dual-circularly-polarized (dual-CP) transmitarray (TA) is proposed for satellite communication systems. A multifunctional metasurface is proposed to provide four independent rotation angles to achieve independent dynamic regulation of four CP transmission phases: $\varphi(t_{RR})$, $\varphi(t_{LR})$, $\varphi(t_{LL})$, and $\varphi(t_{RL})$. Thus, four CP high-gain beams with different directions are obtained, and the corresponding simulated realized gains were 19.21, 19.44, 23.20, and 23.03 dBi, respectively. The designed TA has great potential for application in high-throughput satellite communication systems.

Keywords—Multifunctional metasurface, circular polarized, shared-aperture, transmitarray (TA), dual-band.

I. INTRODUCTION

On the one hand, compared with traditional linearly polarized antennas [1][2], circularly polarized (CP) antennas [3][4] demonstrate superior spectral efficiency and better resistance to multipath interference. On the other hand, K -band and Ka -band are influential bands in satellite communications. Therefore, RAs/TAs with dual-band dual-CP features are highly desirable for applications, such as high-throughput satellite (HTS) communications, due to their simultaneous polarization and frequency discrimination capability. However, for the RAs, the feeding source is usually at the focal point, which results in a large profile and feed blockage. Most of the currently reported dual-band, dual-CP antennas [5][6][7] can only produce a single CP beam in one frequency band and do not achieve polarization multiplexing. Therefore, it is necessary to study the dual-band, dual-CP TA for the satellite communication systems.

In this paper, a low-profile dual-band dual-CP TA is designed. A multifunctional metasurface is proposed to provide four independent rotation angles to achieve independent dynamic regulation of four CP transmission phases: $\varphi(t_{RR})$, $\varphi(t_{LR})$, $\varphi(t_{LL})$, and $\varphi(t_{RL})$. Eventually, four independent high-gain CP beams distributed in two frequency bands with full CP coverage are realized by exploiting a single functional aperture. The characteristics of double circular polarization and simple structure in two operating bands make it promising to apply in high-throughput satellite communication systems.

II. UNIT CELL DESIGN

The schematic of the ultralow-profile shared-aperture circular polarized FTA is illustrated in Fig. 1. As shown in Fig. 2, a CP receiver and LP transmitter structure is used to design the multifunctional metasurface unit. The length of metasurface unit is equal to 5.6 mm.

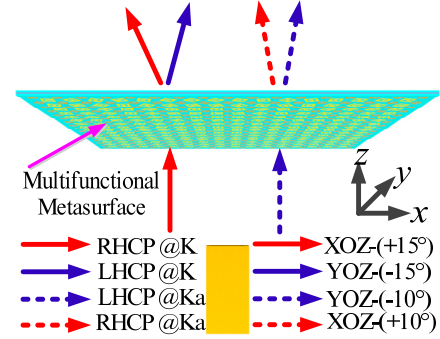


Fig. 1. Schematic of the dual-band dual-CP TA.

III. ANTENNA PERFORMANCE

Fig. 3 depicts the topological structure of the proposed multifunctional metasurface unit. The transmission spectra of the proposed multifunctional metasurface is simulated and characterized using commercial time-domain software CST Microwave Studio. In the K band, the co-polarization transmission coefficient and cross-polarization transmission coefficient of the RHCP wave are approximately equal, about -3.3 dB. In the Ka band, the co-polarization transmission coefficient and cross-polarization transmission coefficient of the LHCP wave are approximately equal, about -3.6 dB.

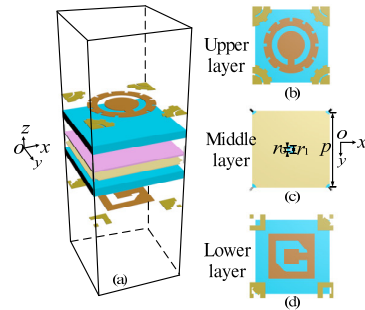


Fig. 2. (a) The structure of the multifunctional metasurface unit cell. (b) The Top Upper layer. (c) Middle layer view. (d) Bottom layer.

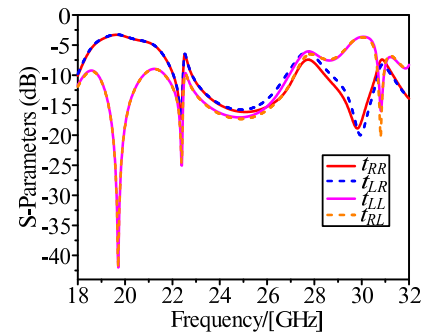


Fig. 3. The S-parameters of the multifunctional metasurface unit.

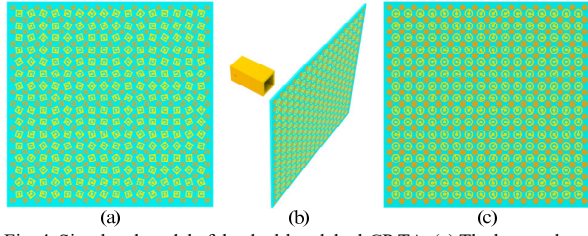


Fig. 4. Simulated model of the dual-band dual-CP TA. (a) The bottom layer of the TA. (b) The overview of the TA. (c) The top layer of the TA.

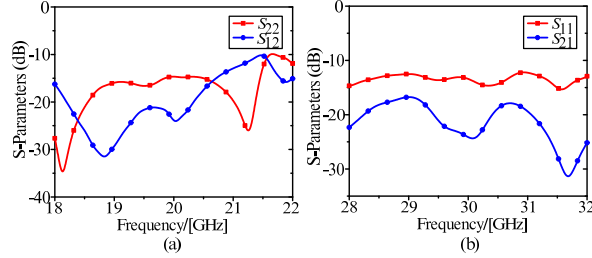


Fig. 5. Simulated S-parameters (a) RHCP feed at the low frequency. (b) LHCP feed at the high frequency.

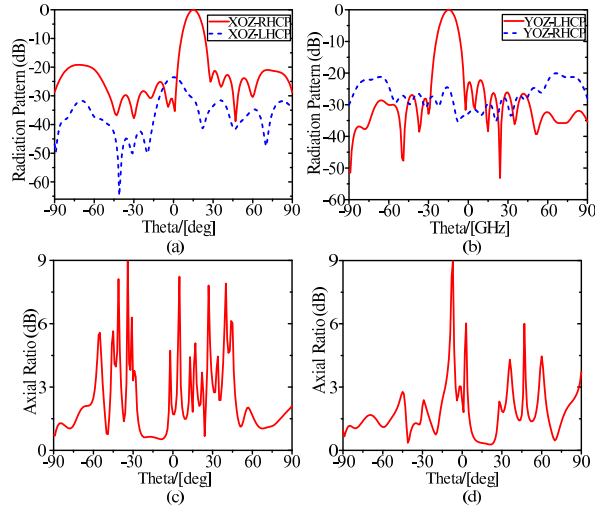


Fig. 6. Simulated radiation and axial ratio patterns at 19.8 GHz. (a) xoz -plane. (b) yo z -plane. (c) yo z -plane. (d) xoz -plane.

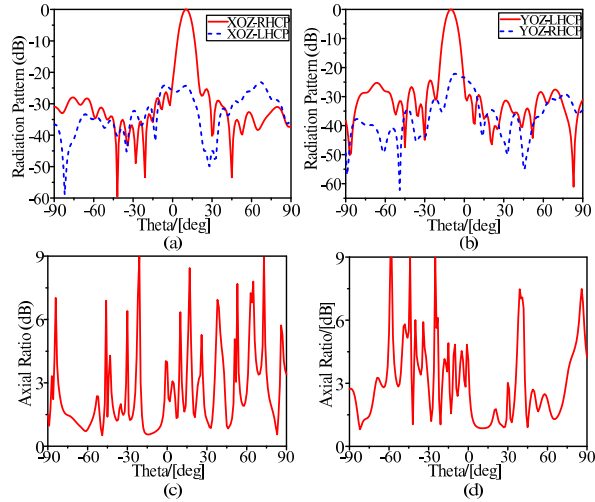


Fig. 7. Simulated radiation and axial ratio patterns at 29.8 GHz. (a) xoz -plane. (b) yo z -plane. (c) yo z -plane. (d) xoz -plane.

After composing the array and optimizing the focal length and aperture size, the whole structure of the

proposed TA is shown in Fig. 4. The TA is 95.2 mm * 95.2 mm, which consists of 17*17 HF units and 16*16 LF unit. The focal length of the TA is 35 mm. From Fig. 5, it can be seen that the proposed antenna exhibits good impedance matching characteristics in both low-frequency 18-22 GHz and high-frequency 28-32 GHz band ranges. As shown in Fig. 6, two high-gain beams with high polarization purity, consisting of RHCP/LHCP beams directed at $(15^\circ, 0^\circ)$ and $(-15^\circ, 90^\circ)$, are generated at 19.8 GHz. As shown in Fig. 7, two high-gain beams with high polarization purity, consisting of RHCP/LHCP beams directed at $(10^\circ, 0^\circ)$ and $(-10^\circ, 90^\circ)$, are generated at 29.8 GHz. Simulated peak gains of 19.21 and 19.44 dBic for LHCP and RHCP beams are obtained at 19.8 GHz, indicating aperture efficiencies of 16.8% and 17.7%. Simulated peak gains of 23.20 and 23.03 dBic for LHCP and RHCP beams are obtained at 29.8 GHz, indicating aperture efficiencies of 18.6% and 17.9%.

I. CONCLUSION

A dual-band, dual-CP TA based on a multifunctional metasurface is designed. With the help of a multifunctional metasurface, independent control of four degrees of freedom can be achieved, and ultimately, independent control of beams for low- and high-frequency LHCP waves and RHCP waves can be realized. The designed TA has great potential for application in high-throughput satellite communication systems.

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