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A Broadband Dual-Polarized Tightly Coupled Transmitarray Antenna

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***Abstract*—A broadband dual-polarized transmitarray antenna (TA) is proposed in this paper. By integrating tightly coupled dipole with coplanar strip line, a continuous and stable transmission phase response is obtained within the bandwidth of 5-10 GHz. The proposed unit cell consists of two linear-polarization dipole elements, which are constructed through egg-crate configuration. Through adjusting the length of coplanar strip line connected to the dual-polarized dipole individually, the transmission phase for each polarization can be tuned independently. A 15 × 15 square aperture array is designed and simulated, simulation results demonstrate that the designed TA antenna features dual-polarization operation capability, a stable radiation pattern and low cross-polarization across a 2:1 bandwidth.**

***Index Terms*—Broadband antenna, dual-polarized antenna, tightly coupled antenna, transmitarray antenna.**

I. Introduction

Transmitarray antenna (TA) has attracted increasing attention in the growing field of wireless communications. TA combines the benefits of both lens antennas and phased array antennas, offering many favorable features, such as high-gain, lightweight, ease of fabrication, and no feed blockage effect which provides it a distinct advantage over the reflectarray antenna. To date, most of the reported TAs' performance are often constrained by limited bandwidth and single polarization. In [1], a combination of tightly coupled dipoles and phase delay lines were used to design a TA, the measured maximum gain was 20.6 dBi with a aperture efficiency of 46%. However, the TA can only work in single polarization, limiting its application in wireless communication scenarios. In [2], a broadband transmitarray with dual polarization was achieved by sharing coupled patches. Nevertheless, the electrical connection of two perpendicular dielectric substrates is required, which undoubtedly increases the processing complexity. Similarly, phase modulation over a wide bandwidth is achieved by combining planar dipoles and strip lines, however the wide angle impedance matching (WAIM) layer loaded at the top of its unit cells makes it rather complex [3].

In this paper, a broadband, dual-polarized TA operating in the 5-10 GHz band is presented, which uses dual-polarized tightly coupled dipoles as the unit cell and incorporates coplanar strip line as the transmission line to achieve phase shift. Based on the proposed unit cell, a 15 × 15 TA is designed, and the full-wave simulation results demonstrate that stable radiation pattern and a maximum gain of 21.1 dBi are obtained.

II. Unit Cell Design and Results

In this section, a broadband dual-polarized TA unit cell is proposed. As shown in Fig. 1, the proposed unit cell employs a receive-ground-transmit configuration, which consists of two independent linear-polarization elements that are combined together through egg-crate configuration. The sized of the unit cell is 13mm × 13mm, which is about 0.22 λ_0 × 0.22 λ_0, where λ_0 is the wavelength in free space at the lowest operating frequency. The receiving dipole and transmitting dipole are connected through the coplanar strip line (CPS line), and the phase of the unit cell is regulated by controlling the length of the CPS line. The dielectric substrates used in the simulation are all Rogers RO4003 with a thickness of 0.5mm. Placing the meandered portion of the CPS line between the two ground planes prevents it from affecting the transmission characteristics. The full-wave simulation of the proposed RTA unit cell is performed in HFSS with periodic boundary conditions and Floquet ports loaded.

Transmission responses of the proposed TA unit cell under normal incidence are given in Fig. 2. It can be observed that the proposed unit cell achieves a high transmission magnitude and a fairly linear phase response within the bandwidth of 5-10 GHz . There is a slight variation in transmission magnitude between the different polarization elements, likely due to the different dipole geometries. Nonetheless, the insertion loss of both polarizations is less than 2 dB in the operating band. The reason for such a continuous and smooth phase curve is the use of a true-time-delay technique, which makes the phase response of the unit cell independent of frequency [4], [5]. As demonstrated in Fig. 3, When the length of the delay line of the y-polarization is changed, the phase of the x-polarization is not affected, and vice versa. This characteristic is essential for the design of dual-polarized units, demonstrating good orthogonal polarization isolation. Thus, the proposed unit cell can be used to realize a broadband as well as dual-polarized transmitarray antenna.

III. TA Design and Simulation

To further verify the performance of the proposed TA element, a 15 × 15 square aperture array is designed as

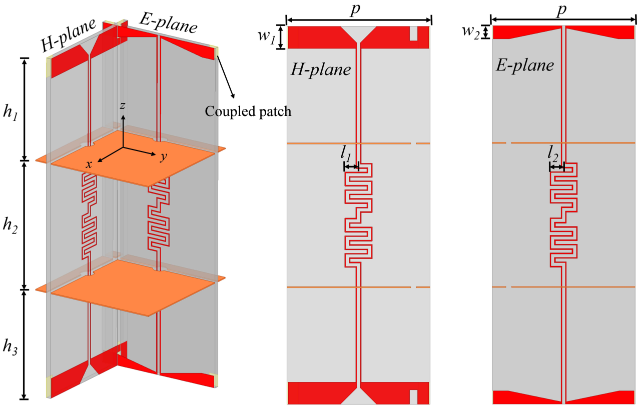

Fig. 1. Geometry of the proposed TA element. Dimensions (unit: mm) are: p = 13, h_1 = 10.7, h_2 = 13, h_1 = 10.7.

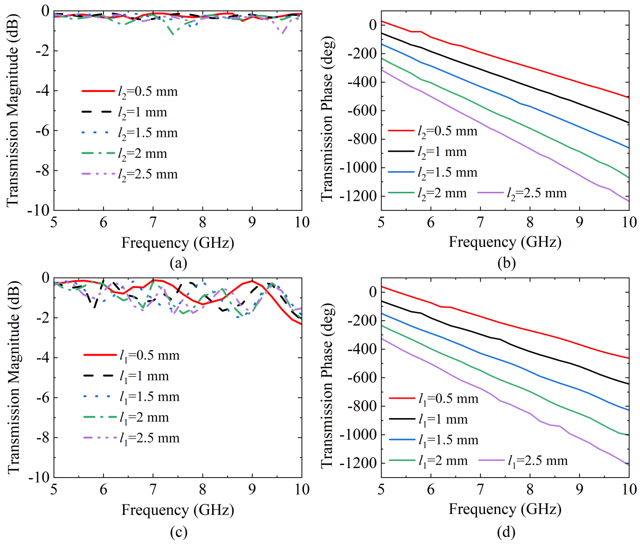

Fig. 2. (a) Transmission magnitudes of the y-polarized element with different l_2. (b) Transmission phases of the y-polarized element with different l_2. (c) Transmission magnitudes of the x-polarized element with different l_1. (d) Transmission phases of the x-polarized element with different l_1.

demonstrated in Fig. 4. The feed horn antenna used in the simulation has nearly the same radiation characteristics in both main planes. The simulated normalized radiation patterns of the proposed transmitarray in the two principal planes at different frequencies are demonstrated in Fig. 5 and 6.

It can be seen from Fig. 5 and Fig. 6 that well-defined pencil beams in both planes are obtained throughout the operating band and the main beam is oriented at broadside direction as originally designed. The simulated sidelobe levels are all below -10 dB across the operating band, and the simulated cross-polarization levels in both main planes are all below -20 dB.

The simulated gain and the aperture efficiency of the proposed TA are shown in Fig. 7. For y-polarization, the simulated maximum gain is 22.3 dBi at 9 GHz and the maximum

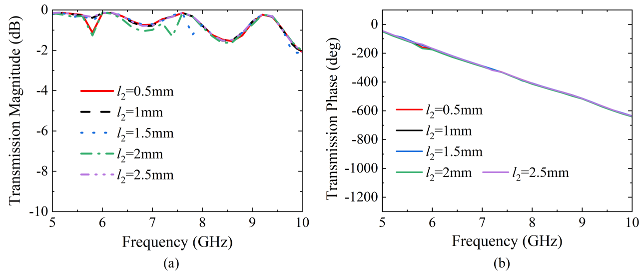

Fig. 3. (a) Transmission magnitudes of the x-polarized element with different l_2. (b) Transmission phases of the x-polarized element with different l_2. (l_1=1 mm)

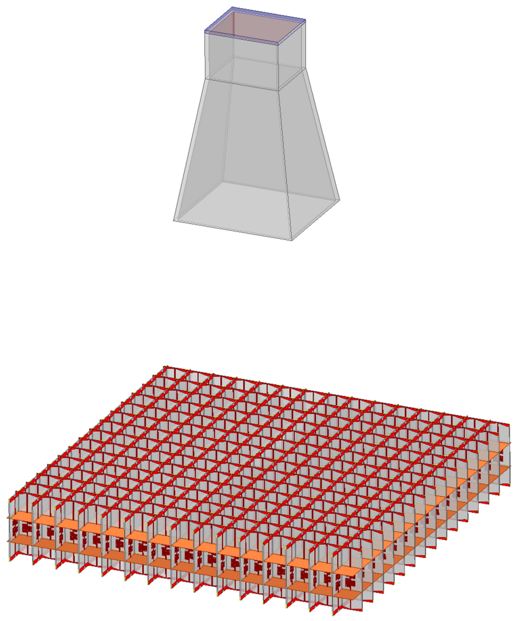

Fig. 4. The structure of the designed 15 × 15 TA.

aperture efficiency is 40.8% at 8 GHz. For x-polarization, the simulated maximum gain is 21.1 dBi at 10 GHz and the maximum aperture efficiency is 30.6% at 8 GHz. In general, the proposed TA has demonstrated a satisfactory performance in terms of broadband operation.

IV. Conclusion

In this paper, based on the tightly coupling effect, a broadband dual-polarized TA unit cell with high transmission magnitude and continuous wide-range phase response is proposed. A TA with 225 elements is designed and simulated. Simulation results demonstrate that the designed TA obtains a stable radiation pattern and low cross-polarization in a wide frequency band from 5 to 10 GHz for dual-polarization operation. Due to the broadband and dual-polarized characteristics, the proposed TA is appealing for various wireless applications.

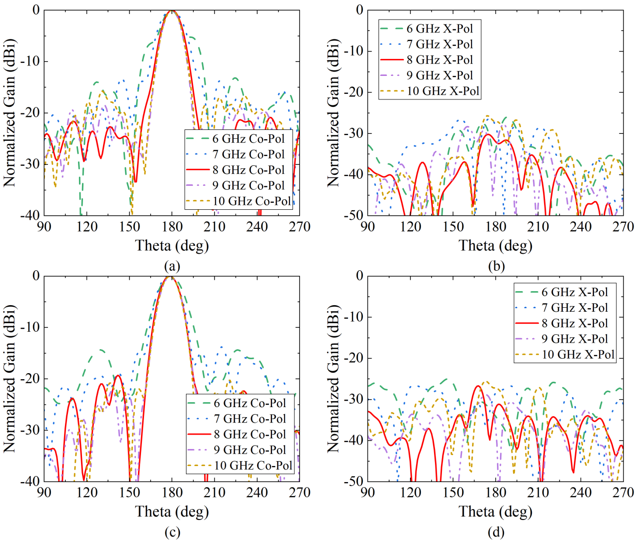

Fig. 5. Simulated normalized *y*-polarized radiation patterns of the proposed TA at various frequencies. (a) *xz*-plane co-pol. (b) *xz*-plane cross-pol. (c) *yz*-plane co-pol. (d) *yz*-plane cross-pol.

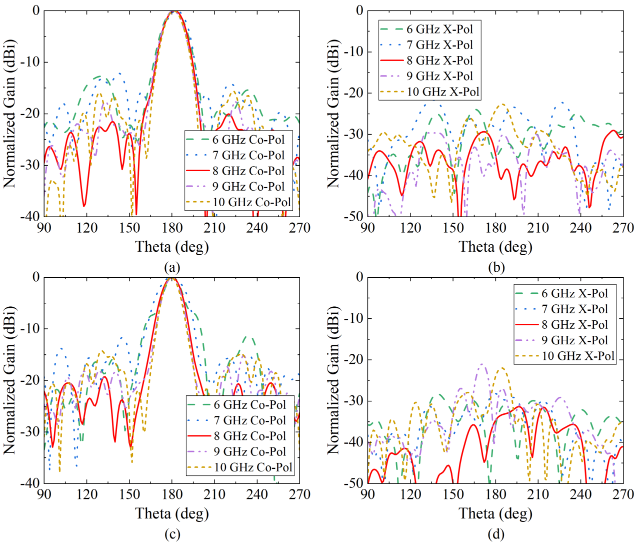

Fig. 6. Simulated normalized *x*-polarized radiation patterns of the proposed TA at various frequencies. (a) *xz*-plane co-pol. (b) *xz*-plane cross-pol. (c) *yz*-plane co-pol. (d) *yz*-plane cross-pol.

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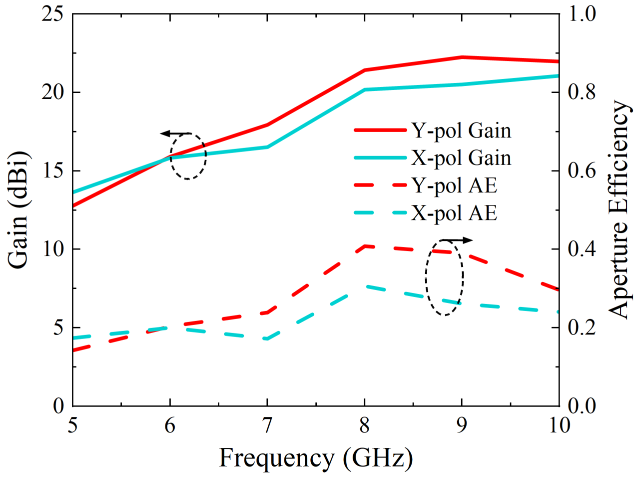

Fig. 7. Simulated gain and aperture efficiency of the proposed TA in the broadside direction.

References

[1] Y. -M. Cai et al., "A Novel Ultrawideband Transmitarray Design Using Tightly Coupled Dipole Elements," *IEEE Transactions on Antennas and Propagation*, vol. 67, no. 1, pp. 242-250, Jan. 2019.

[2] Y. Zhao and P. Li, "A Tightly Coupled Ultrawideband Dual-Polarization Transmitarray," 2023 IEEE Conference on Antenna Measurements and Applications (CAMA), Genoa, Italy, 2023, pp. 500-502.

[3] L. Xiao, S. -W. Qu and S. Yang, "Wideband Planar Tightly Coupled Dipole Transmitarray," 2019 13th European Conference on Antennas and Propagation (EuCAP), Krakow, Poland, 2019, pp. 1-4.

[4] W. Li, S. Gao, L. Zhang, Q. Luo and Y. Cai, "An Ultra-Wide-Band Tightly Coupled Dipole Reflectarray Antenna," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 2, pp. 533-540, Feb. 2018.

[5] W. Li, H. Tu, Y. He, L. Zhang, S. -W. Wong and S. Gao, "A Novel Wideband Tightly Coupled Dual-Polarized Reflectarray Antenna," *IEEE Transactions on Antennas and Propagation*, vol. 71, no. 6, pp. 5422-5427, June 2023.