# Array-Fed Dual-Band Transmitarray Antenna with Wide Frequency Ratio

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***Abstract* – This paper presents a novel aperture coupled patch array-fed dual-band transmitarray antenna with frequency ratio of 1.7 (10 GHz and 17 GHz). First, by introducing square loop slot and cross dipole slot, the element demonstrates over 75% phase coverage. Then, two aperture coupled patch array antennas are designed to illuminate the aperture, providing advantages of being low-profile and lightweight. Full-wave simulations show that realized gain of 22.3 dBi and 23.3 dBi, and 1-dB gain bandwidth of 3% and 5.3% are achieved in 10 GHz band and 17 GHz band, respectively.**

***Keywords* — Aperture coupled patch array, Dual-band, Periodic structure, Transmitarray.**

## I. Introduction

Transmitarray antennas (TAs), as an alternative to phased array antennas and lens antennas, have attract great attention in recent years. Consisting of a spacing feed and a flat transmissive aperture, the TAs provide advantages of easy-to-fabricate and versatile radiation performance. Among the plenty of the functionalities offering by TAs, dual-band operation is of vital importance in applications such as satellite communications. Several dual-band TAs have been reported [1-2]. They usually suffer from complicated element design and sophisticated optimization process.

In this paper, a novel aperture coupled patch array (ACPA)-fed dual-band TA is presented with reduced design complexity. The element demonstrates over 75% transmission phase coverage. Besides, ACPA antennas are designed to illuminate the aperture to further provide advantages of being low-profile and lightweight.

## II. Transmitarray Design

### A. Unit Cell Design

The 3-D perspective view of the proposed unit cell is shown in Fig. 1, where the yellow parts and transparent parts are metal and substrates ($\varepsilon_r = 3.3$, $\tan\delta = 0.001$, $T_{sub} = 0.6$ mm), respectively. The periodicity of the element is $P = 15$ mm. It consists of three identical layers printed with two kinds of slot (square loop and cross dipole) separating with the same air gap of $T_{air} = 4$ mm. The square loop, which is responsible for the transmission control of high frequency band (17GHz band), is with the size of $a = 4.6{\sim}5.8$ mm and $b = 1$ mm. The cross dipole, which controls the transmission in low frequency band (10GHz band), has dimensions of $L = 4.25{\sim}5.75$ mm and $w = 1.5$ mm.

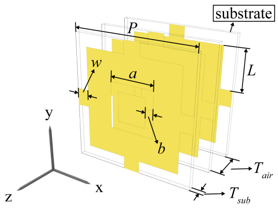

Fig. 1 3-D perspective view of the element.

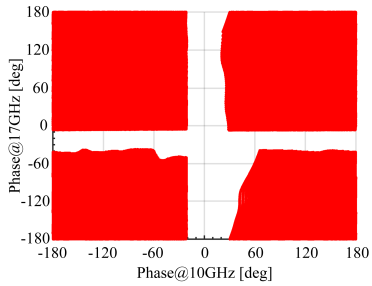

Fig. 2 Transmission phase coverage of the element.

The transmission responses of the element are obtained by using periodic boundary condition. Fig. 2 depicts the transmission phase coverage of both frequency bands with the condition of transmission amplitude (both bands) $\geq -4$ dB, demonstrating over 75% coverage.

### B. Feed Design

Two aperture coupled patch array (ACPA) antennas operating at 10 GHz and 17 GHz are designed to efficiently illuminate the TA aperture with the advantages of being low-profile and light-weight. The inset of Fig. 3 shows the perspective view of the ACPA antenna. The geometric parameters of the ACPA antennas are listed in Table I.

Fig. 3 presents the simulated normalized radiation patterns of the two ACPA antennas. Both of the antennas achieve realized gain of 14 dBi and 3-dB beamwidth of 31°.

### C. System Design

The TA system is shown in Fig. 4. The TA aperture is circular with radius of $R = 114$ mm. The ACPA antennas normally illuminate the TA aperture with spacing of $H = 200$ mm. Since the element cannot provide full-coverage of transmission phase, phase matching optimization [3] is performed for both bands to minimize the overall phase error. The inset of Fig. 4 shows the final element layout on the TA aperture.

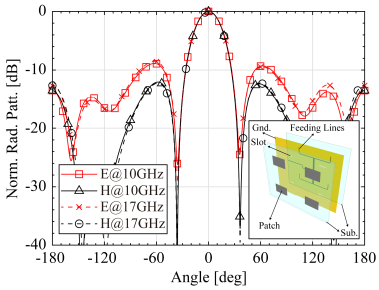


Fig. 3 ACPA performances. Inset: ACPA schematic.

TABLE I
ACPA Parameters (Unit: mm)

| | 10GHz | 17GHz |
|---|---|---|
| Patch Size | 10.2×6.6 | 6.0×3.75 |
| Slot Size | 4.5×0.3 | 2.9×0.18 |
| Top Substrate Thickness | 1.2 | 0.8 |
| Bottom Substrate Thickness | 0.2 | 0.2 |
| Feed Line Width | 0.45 | 0.45 |

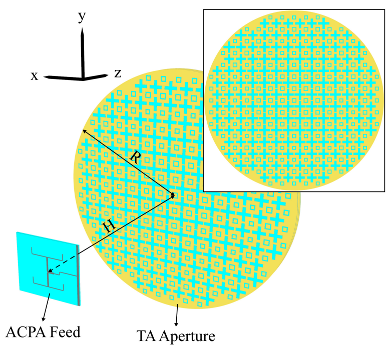


Fig. 4 System configuration. Inset: element layout.

## III. Simulation Results

The antenna system is modeled and verified by using full-wave simulation. The normalized radiation patterns for both Co-/Cr-Pol in E-/H-plane at 10 GHz and 17 GHz are given in Fig. 5. The radiation patterns show high consistency in main beam region for both 10 GHz and 17 GHz. The 3-dB beamwidths are 10.3° and 6.2° for 10GHz and 17GHz, respectively.

The realized gain responses are presented in Fig. 6. Realized gains of 22.3 dBi and 23.3 dBi and 1-dB fractional realized gain bandwidth of 3% (9.8-10.1 GHz) and 5.3% (16.4-17.3 GHz) are achieved in 10 GHz band and 17 GHz band, respectively. The narrow bandwidth of the TA is mainly attributed to the narrow bandwidth of the ACPA feeds.

## IV. Conclusion And Future Work

A novel aperture coupled patch array-fed dual-band transmitarray antenna with frequency ratio of 1.7 was presented in this paper. By integrating square loop slot and

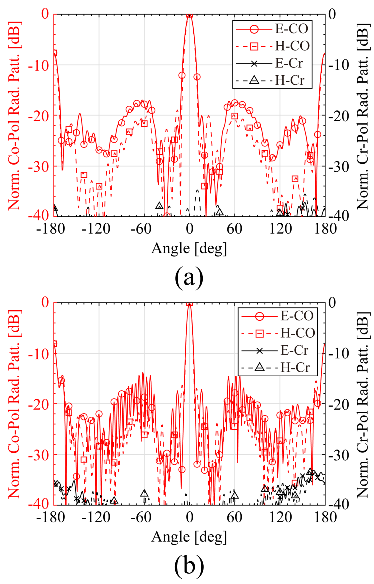


Fig. 5 Radiation patterns at (a) 10 GHz; (b) 17 GHz.

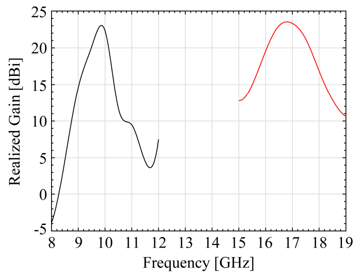


Fig. 6 Realized gain responses.

cross dipole slot, the element demonstrated over 75% phase coverage with the condition of transmission amplitude ≥ −4 dB. The current ongoing research is to further optimize the behavior in 17 GHz band and integrate the ACPA feeds for the two bands.

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## References

[1] S. A. Matos, E. B. Lima, J. S. Silva, J. R. Costa, C. A. Fernandes, N. J. G. Fonseca, and J. R. Mosig, "High Gain Dual-Band Beam-Steering Transmit Array for Satcom Terminals at Ka-Band," *IEEE Trans. Antennas Propag.*, vol. 65, no. 7, pp. 3528-3539, Jul. 2017.

[2] K. Pham, R. Sauleau, E. Fourn, F. Diaby, A. Clemente, and L. Dussopt, "Dual-Band Dual-Polarized Transmitarrays at Ka-Band," *Proc. 11th Eur. Conf. Antennas Propag. (EUCAP)*, pp. 59-62, Mar. 2017.

[3] A. H. Abdelrahman, P. Nayeri, A. Z. Elsherbeni, and F. Yang, "Bandwidth Improvement Methods of Transmitarray Antennas," *IEEE Trans. Antennas Propag.*, vol. 63, no. 7, pp. 2946-2954, Jul. 2015.