Single-Band and Dual-Band Dual-Polarized Filtering Antenna Arrays Based on High-Order Mode Resonators

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***Abstract*—This reports aims to summarize the latest progress of awardee's Ph. D. project in part supported by the 2020 IEEE MTT-S Graduate Fellowship Program. This project focuses on the characteristics and performances of high-order modes in a single cavity resonator, and their applications to a series of filtering antenna arrays (FAAs). It is found that each unit of the cavity slot arrays in the proposed high-order mode resonator is in-phase with the same amplitude, which helps to enhance the antenna gain and reduce the side-lobe level. The higher-order response can be achieved by cascading more high-order mode resonators with required external quality factor (Q_e) and coupling coefficient (K). For proof-of-concept, a single-band 3rd-order 4×5 filtering cavity slot array using a TM_{450} mode resonator and a dual-band dual-polarized 3rd-order 4×3 filtering cavity slot array, using TM_{430} and TM_{340} mode resonators, are fabricated and tested.**

***Index Terms*—Filtering antenna array, cavity resonator, dual-band, dual-polarized, high-order modes.**

I. Introduction

ANTENNA arrays with the properties of high gain, wide bandwidth, and low side-lobe level are in high demand in today's wireless communication systems. Conventionally, an antenna array consists of a feeding network and radiation elements. Source signals go through the feed lines and power dividing network before arriving at the radiation elements. When the number of radiation elements is large, the required feeding network will be complicated and challenging to achieve. Besides, a bulky feeding network often causes high insertion loss and brings design complexity. To tackle this challenge, the elimination of a feeding network by using high-order modes has attracted much attention.

In our previous studies [1], the fundamental modes of the multimode cavity resonators were investigated in designing filters, multiplexers, and functional microwave circuits [2]. Compared with high-order modes, the fundamental mode is a better candidate in designing compact microwave components. However, when designing an antenna array using the fundamental mode cavity resonators, the feeding and power dividing network are essential. A high-order mode resonator is more suitable for cavity slot array design because the radiation elements of a single high-order mode cavity resonator can produce in-phase outputs with the same amplitude. Therefore, the power splitting network is not required [3].

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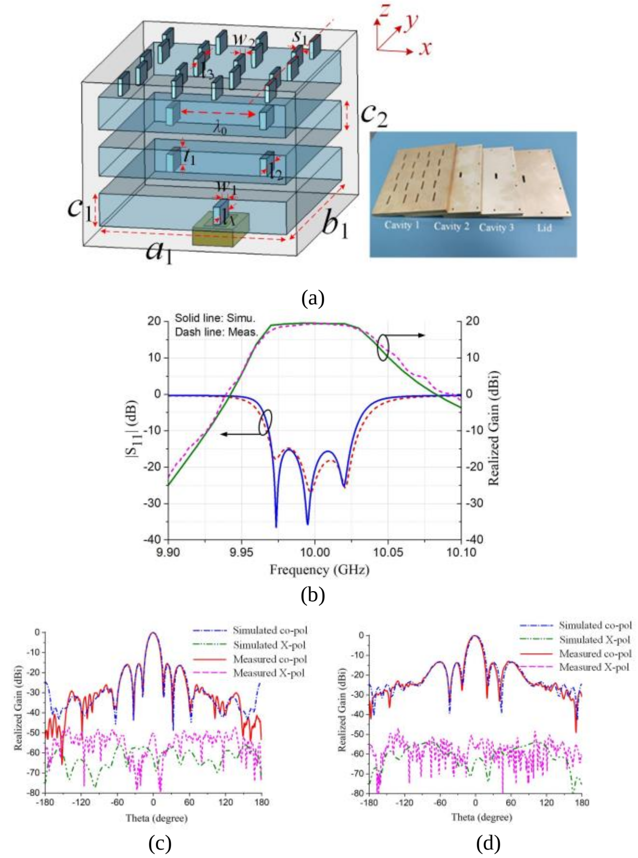

Fig. 1. 3rd-order filtering antenna array using TM_{450} mode with: (a) Geometry with photograph of manufactured prototype, (b) Measured S-parameter and realized gain, (c) E-plane and (d) H-plane radiation patterns at 10 GHz.

II. 3RD-Order Filtering Antenna Array using TM_{450} Mode

The geometrical configuration of a 3rd-order filtering antenna array is shown in Fig. 1(a). It is based on a TM_{450} mode cavity resonator with 4 × 5 radiating units. The electromagnetic (EM) waves are coupled from WR-90 to three consecutive TM_{450} mode resonators and radiate at the end of the slot arrays. For the

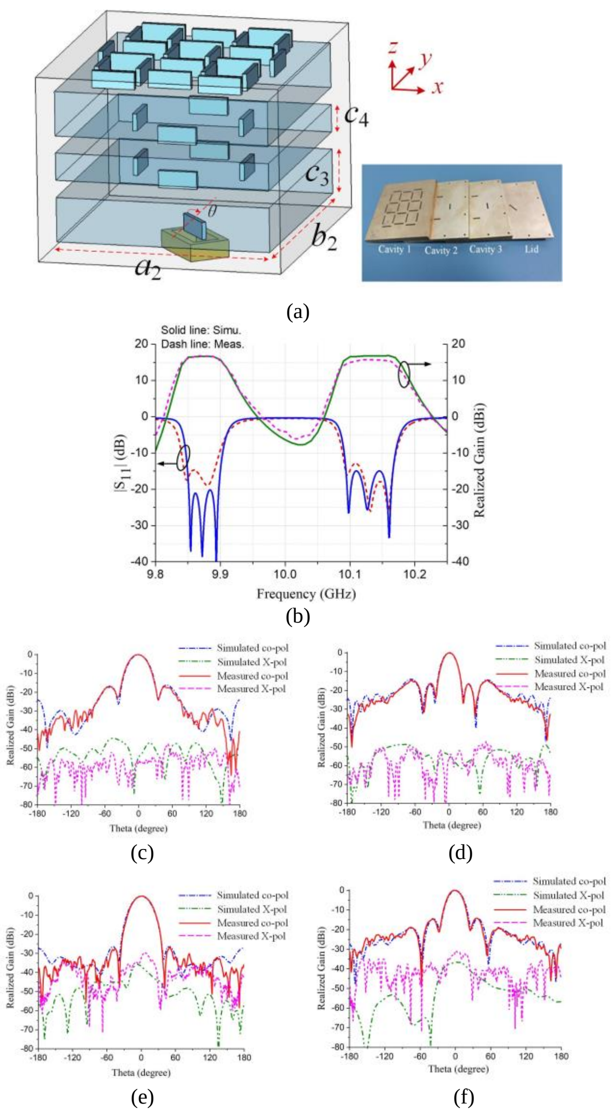

Fig. 2. 3rd-order dual-band dual-polarized filtering antenna array with: (a) Geometry with photograph of manufactured prototype, (b) Simulated and measured S-parameter results and realized gain, (c) E-plane and (d) H-plane pattern results at 9.87 GHz frequency. (e) E-plane and (f) H-plane pattern results at 10.13 GHz frequency

specified resonant frequency of 10 GHz, the length a_1 and width b_1 of the TM_{450} mode cavity resonator are 84 mm and 105 mm, respectively.

The measured S_{11} and realized gain of the prototype are shown in Fig. 1(b), along with the corresponding simulation results. It has three reflection poles with a return loss level of 15 dB, indicating a 3rd-order filtering response. The prototype resonates at 10 GHz, and the 10-dB bandwidth ranges from 9.97 GHz to 10.03 GHz. The measured average gain within the passband can achieve 19.5 dBi, and the achieved radiation efficiency is 90% within the band. As shown in Figs. 1(c) and (d), the side-lobe suppressions are -15.6 dB and -13.3 dB at E-plane and H-plane, respectively, while the cross-polarization level are -53.4 dB and -56.3 dB at E-plane and H-plane, respectively.

III. 3RD-ORDER DUAL-BAND DUAL-POLARIZED FILTERING ANTENNA ARRAY USING TM_{430} AND TM_{340} MODES

Fig. 2(a) presents the geometrical configuration of the proposed 3rd-order array prototype. It comprises three dual-mode cavity resonators, each of them is shared by TM_{430} and TM_{340} modes. The WR-90 waveguide is rotated with an angle of θ to excite these two modes.

The measured S_{11} and realized gains of the prototype are shown in Fig. 2(b), along with the corresponding simulation. It has three reflection poles with a return loss level of 15 dB in each channel of dual-band prototype, indicating a 3rd-order filtering response. The prototype resonates at 9.87 GHz, 10.13 GHz, and the 10-dB bandwidth ranges from 9.84 GHz to 9.9 GHz, and 10.09 GHz to 10.17 GHz, respectively. The measured average gain in the first and second channels can achieve 16.7 dBi and 15.8 dBi, respectively. The achieved radiation efficiency is 90% in the lower band and 85% in the upper band. As shown in Figs. 2(c) and (d), the side-lobe suppressions in the first channel are -14.1 dB and -16.4 dB at both E-plane and H-plane, respectively, while the cross-polarization levels are -53.6 dB and -48.4 dB at E-plane and H-plane, respectively. The measured 3 dB beamwidth is 29 degrees at E-plane and 20 degrees at H-plane. As shown in Figs. 2(e) and (f), the side-lobe suppressions in the second channel are -14.4 dB and -26.7 dB at both E-plane and H-plane, respectively, while the cross-polarization levels are -36.9 dB and -36.6 dB at E-plane and H-plane, respectively.

IV. FELLOWSHIP IMPACT AND CAREER PLAN

It is my great honor to receive the recognition of 2020 IEEE MTT-S Graduate Fellowship Awards. This fellowship directly impacted the publications [2] and [3], and other latest research results of my Ph. D. project are also underway. Moreover, it encourages me to further explore the unknown area in the field of waveguide multiple-mode resonators. It truly helps me to complete my doctoral research studies.

After completing my Ph.D., I plan to pursue an academic career through post-doctoral appointment or tenure in a teaching and research university. I really enjoy my current research and hope that more interesting and influential work would be done and presented.

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