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Design of Multistate Cavity Diplexer Based on Triple-Mode Resonators

Yu-Ming Li, Hong-Ji Li, Sai-Wai Wong*, Yejun He
State Key Laboratory of Radio Frequency Heterogeneous Integration
Sino-British Antennas and Propagation Joint Laboratory, Ministry of Science and Technology of China
Guangdong Engineering Research Center of Base Station Antennas and Propagation
Shenzhen Key Laboratory of Antennas and Propagation
College of Electronics and Information Engineering, Shenzhen University, 518060, China
Email:2200432051@email.szu.edu.cn, 2020124002@email.szu.edu.cn, wongsaiwai@ieee.org, heyejun@126.com

***Abstract*— This paper presents a design methodology for a multistate diplexer based on three-mode cavity resonators. The proposed multistate diplexer offers various operational states, making it suitable for environments requiring multiple channels. The three fundamental modes of a rectangular cavity can be utilized to create three distinct frequency channels, allowing a single triple-mode resonator(TMR) to function as a three-state diplexer. By connecting multiple TMRs, a multistate diplexer with a increased number of states can be realized. The design methods for three-state, four-state, and five-state diplexers are demonstrated in this paper, showcasing the versatility and scalability of the proposed approach.**

***Keywords*— Diplexer, multistate diplexer, rectangular cavity, slot coupling, triple-mode resonator**

I. Introduction

Diplexers play a vital role in wireless communication systems by serving as a frequency allocation network that separates signals into two distinct frequency components. As communication technology advances, there is a growing demand for diplexers with enhanced transmission performance and reduced size. More and more diplexers with improved transmission performance and reduced size are being proposed[1], [2], [3], [4], [5], [6]. However, when dealing with multiple channels, the use of multiple diplexers often leads to an increase in circuit size and complexity. Multistate diplexers, characterized by their high level of integration, can operate in various states, thereby eliminating the necessity for multiple diplexers.

In[7], a three-state diplexer(TSD) based on a planar structure is proposed. This diplexer utilizes three modes of planar elliptical resonators to establish three distinct filtering channels, resulting in the formation of a TSD. Subsequently, [8] enhances the number of states in a multistate diplexer on uniform- and stepped stub-loaded dual-mode resonators using microstrip line technology. Both of the these multistate diplexers are characterized by a planar structure, leading to limitations such as lower power capacity and higher insertion loss.

[9] has introduced a TSD based on a waveguide cavity, where the three fundamental modes of a rectangular cavity are utilized to construct and control three frequency channels. Notably, the TSD using a waveguide cavity exhibits a larger power capacity and higher quality factor, making it suitable for environments that require high-performance transmission. However, it is limited to only three states, which may impose constraints on practical applications. To address this limitation, this paper presents a design method for a multistate diplexer based on a waveguide cavity, which allows for an increase in the number of states, significantly enhancing the scalability and applicability of the multistate diplexer for diverse communication needs.

II. Analysis And Design

In a rectangular cavity, three fundamental modes, namely TE_{011}, TE_{101}, and TM_{110}, can be harnessed to create three distinct frequency filtering channels. The method of constructing a Three-Mode Resonator (TMR) for a TSD is illustrated in Fig. 1(a). By choosing different ports as the common port of the diplexer, and selecting different frequency channels as the two channels of the diplexer, three different operational states can be achieved.

The excitation of the three fundamental modes of the rectangular cavity is achieved through the rotation and movement of coupling slots [2]. The structure of a TSD composed of a single TMR is shown in Fig. 1(b). In this configuration, all three coupling slots are rotated but not moved, so only two modes will be excited at each port, allowing for the realization of three different states. Taking state 1 as an example, port 1 is selected as the common port, and the coupling slots on the xoy plane are rotated. This rotation induces the excitation of both horizontal and vertical electric fields, denoted as $\vec{E_x}$ and $\vec{E_y}$, respectively. This means that modes TE_{011} and TE_{101} can be excited by port 1. Electromagnetic waves can be transmitted through these two different modes from port 1 to ports 2 and 3, thereby constituting one state of the diplexer. Similarly, for

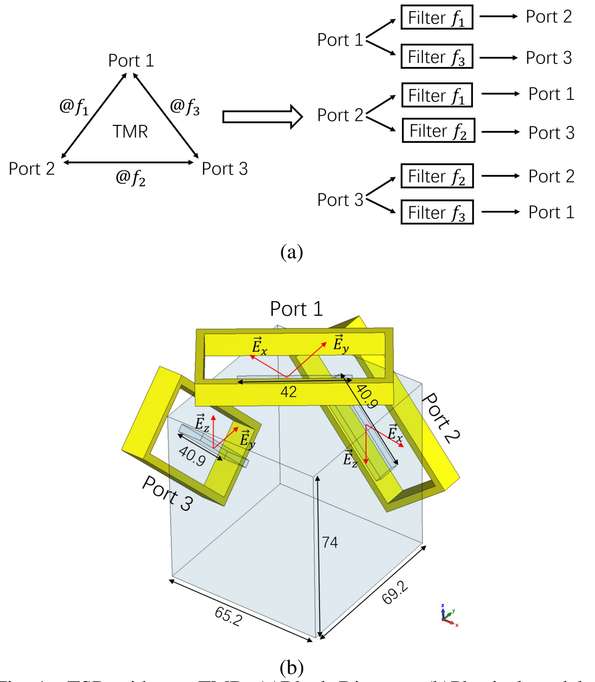


Fig. 1. TSD with one TMR. (a)Block Diagram. (b)Physical model.

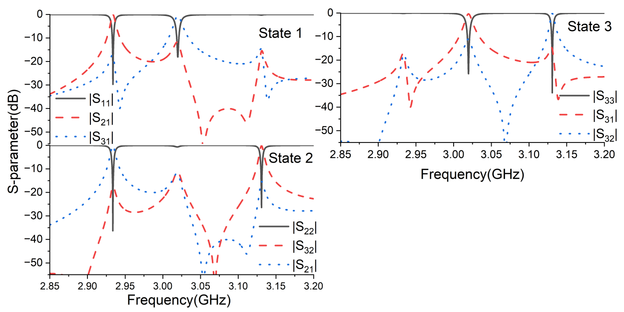


Fig. 2. Simulated results of the TSD consisting of a single TMR.

other states, two different modes will be excited at each port to form distinct channels, constituting the various operational states of the diplexer. The S-parameters of the TSD consisting of a single TMR are shown in Fig. 2.

To achieve a greater number of states, the introduction of more TMRs is considered. Fig. 3(a) illustrates the schematic diagram of a four-state diplexer composed of two TMRs. The structure of a four-state diplexer is shown in Fig. 3(b). Notably, the dimensions of the two rectangular cavities are not identical, and the frequencies of their three fundamental modes also differ. The three fundamental mode frequencies of the first TMR are denoted as f_1, f_2 and f_3, while those of the second TMR are designed as f_4, f_2 and f_3. The mode frequencies of the rectangular cavity can be easily controlled by adjusting its dimensions.

Due to the identical frequencies of two modes in the two TMRs, electromagnetic waves of these two modes can propagate in both cavities. This implies that we can connect these two TMRs to form a four-state diplexer. As previously

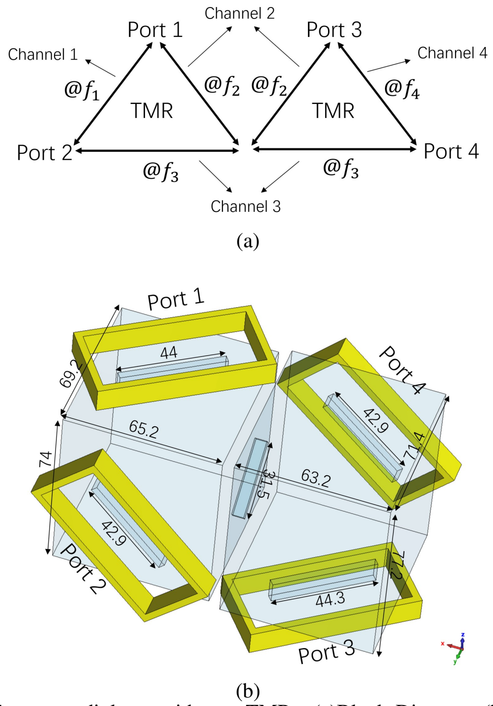


Fig. 3. Four-state diplexer with two TMRs. (a)Block Diagram. (b)Physical model.

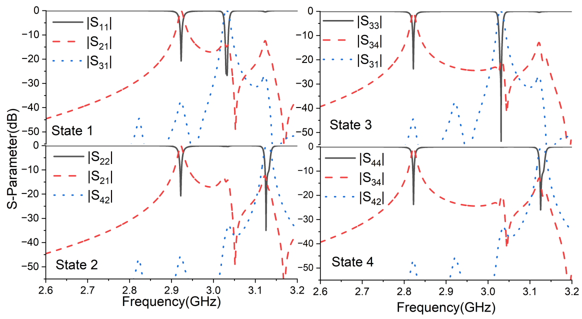
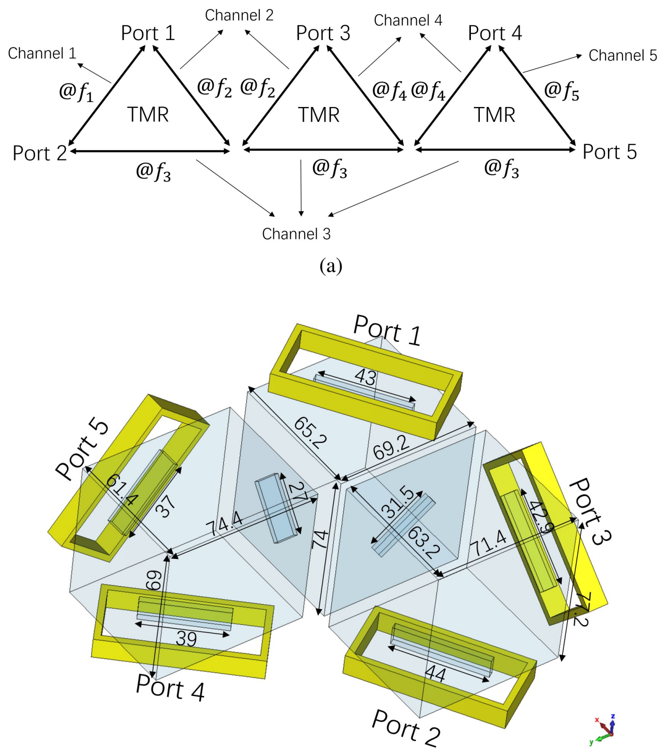


Fig. 4. Simulated results of the four-state diplexer consisting of two TMRs.

mentioned, two modes will be excited at each port. For these two TMRs, we select the ports with mode frequencies f_2 and f_3, respectively, as intermediaries, connecting the two cavities. This arrangement ensures that energy of the same frequency and mode can be transmitted through this port. Consequently, four passbands are constructed, with frequencies: f_1, f_2, f_3, and f_4. The S-parameters of the four-state diplexer composed of two TMRs are shown in the Fig. 4. Taking state 1 as an example, we choose port 1 as the common port of the diplexer, channels 2 and 3 together constitute the two channels of the diplexer, with ports 2 and 3 serving as the two output ports of the diplexer. Selecting different ports as the common port of the diplexer enables different operational states.

Applying the same method, it is possible to further increase the number of states in the diplexer. Fig. 5(a) illustrates the schematic diagram of a five-state diplexer composed of three TMRs. The structure of a five-state diplexer is shown in Fig. 5(b).By designing the dimensions of the



(a)

(b)

Fig. 5. Five-state diplexer with three TMRs cavity. (a)Block Diagram. (b)Physical model.

cavities and adjusting the mode frequencies of the three cavities, three TMRs can generate five channels with different frequencies. By selecting different ports as the common port of the diplexer, a total of five different operational states can be achieved. The S-parameters for the different states of the five-state diplexer are shown in the Fig. 6.

In fact, the expansion of the states in the diplexer can be continued by further increasing the number of TMRs. The dimensions of each rectangular cavity should be carefully calculated to meet the requirements of the corresponding mode frequencies. Additionally, each TMR should be connected to other TMRs through appropriate ports, ensuring that the electromagnetic waves of the corresponding modes can effectively propagate between the ports.

III. Conclusion

This paper introduces a design method for a multistate diplexer based on three-mode cavity resonators. Building upon the foundation of a single TMR constituting a TSD, by increasing the number of TMRs and connecting them appropriately, a multistate diplexer with more operational states can be realized. The method significantly enhances the scalability of the multistate diplexer, making it well-suited for application in more complex scenarios and diverse communication requirements. By increasing the order of the diplexer, its transmission performance can be further enhanced.

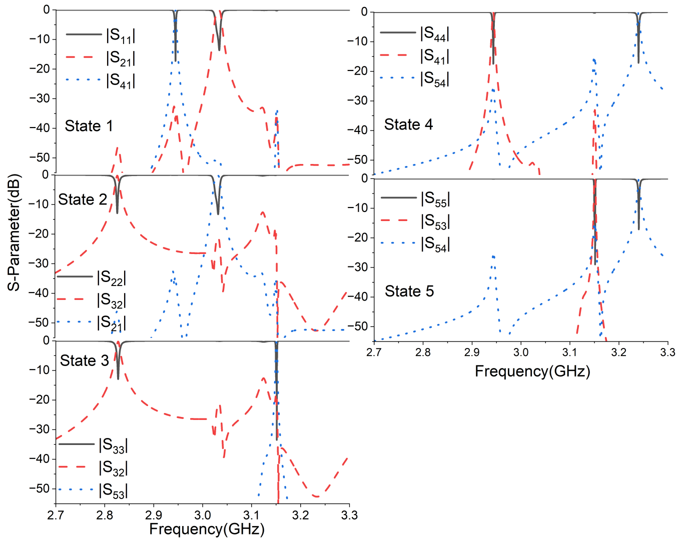


Fig. 6. Simulated results of the five-state diplexer consisting of three TMRs.

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