New Concept of Multi-State Diplexers Implemented on Planar and Cavity Circuits

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***Abstract*—This paper presents our recently proposed multi-state diplexers (MSDs) implemented on different structures. The proposed MSDs have inherent property of multiple frequency channels, two of which can be used for duplexing mechanism by exciting one port as the input in each state. The MSDs have an attractive application in frequency hopping communication systems with miniaturization in their overall sizes. Then, three approaches to design the MSDs using different structures (planar triple-mode resonator, triple-mode cavity resonator and uniform/stepped impedance stub-loaded resonators) are presented. All the MSDs are finally fabricated and measured, the measurement are in good agreement with the simulation.**

I. INTODUCTION

Diplexer is an essential component for modern wireless communication systems due to its inherent nature of frequency division applied in the multiple channels. As highly demanded, the design and synthesis of a diplexer has been widely studied. There are several approaches to design various diplexers, including planar structures and cavity structures [1-14]. The traditional approach of designing diplexers is employing two filters to cover two channels working at different frequencies, which enlarges the overall size. This inspires the research for the diplexers miniaturization [8-14], including the common resonator technologies [8], [9], compact resonator structures [10], [11], and multimode technologies [12]–[14]. However, all the aforementioned methods take the efforts on the miniaturization of a single diplexer, which has incremental benefits on the typical duplexed systems. Naturally, it will require multiple diplexers for multiple-channel systems, resulting in complicated system architecture, massive circuit layouts and high system cost. Therefore, it turns out to be an interesting and effective way of achieving the multifunctional diplexer with compact size into a single circuit structure.

Multi-state diplexer (MSD) is a kind of highly integrated multifunctional diplexer, such as three-state diplexer (TSD), as shown in Fig.1, combined with single-pole-three-throw switch circuits, a TSD is applied to achieve three-port network frequency-hopping circuit with circuit miniaturization. There are three frequency states for frequency-hopping system to be switched freely.

In this paper, the proposed MSD is realized on three different structures, including planar triple-mode resonator, triple-mode cavity resonator and uniform/stepped impedance stub-load resonator. All the three structures can achieve a TSD, in addition, the third method can achieve more than three states, then a four-state diplexer (FSD) is presented. The four MSDs are finally fabricated and measured.

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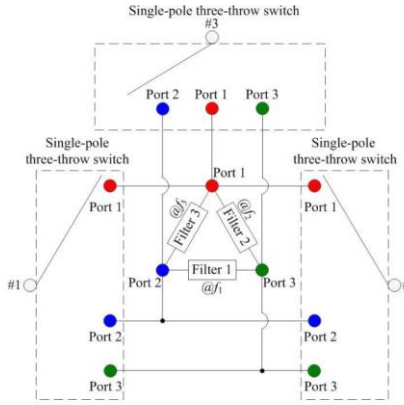


Fig. 1. Schematic of the proposed TSD circuit topology used for frequency-hopping communication.

II. DESIGN OF PROPOSED MSDS

A. TSD on Planar Tri-mode Resonator [15]

Figure 2 presents the top view of the elliptical-shaped triple-mode resonator used to implement the function of TSD. The three ports are located in particular position to excite the proposed three resonant modes, TM_{11+}, TM_{11-} and TM_{21}. The electric field distributions are provided in Fig. 3, which indicates that each port can excite two resonant modes of the three and serves as the isolated port for one state. For example, as shown in Fig. 3 (a), the filed is strong in port 1 and port 3, while very weak in port 2, obviously, it has a channel connecting port 1 and 3, and the port 2 is the isolated port. The frequencies of the three modes can be modified by varying the parameters r_1, r_2 and a.

The simulation and measurement are provided in Fig. 4. The insertion loss chart shows that one passband occurs between each two ports, while the return loss shows that each port have impedance matching in two frequencies, thus, the proposed configuration has essential mechanism of working at three states, which can be summarized as follows:

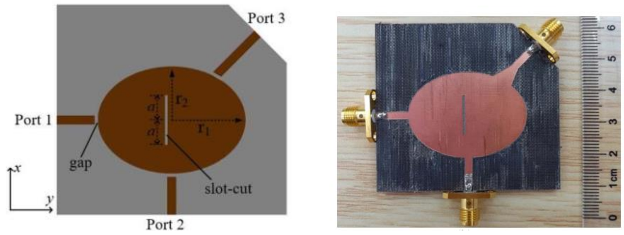
State 1: When the port 1 is the common port of the diplexer, the two filtering channels are the $|S_{21}|$ and $|S_{31}|$;

State 2: When the port 2 is the common port of the diplexer, the two filtering channels are the $|S_{21}|$ and $|S_{32}|$;

State 3: When port 3 is the common port of the diplexer, the two filtering channels are $|S_{31}|$ and $|S_{32}|$.

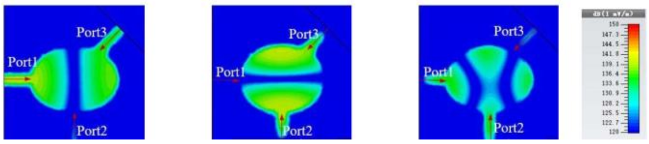
B. TSD on Tri-mode Cavity Resonators [16]

The former TSD works at three states and owns compact size, but suffers from high power loss, poor isolation and not applicable to the high-order design. In this section, a high-order TSD using tri-mode resonators (TMR) is



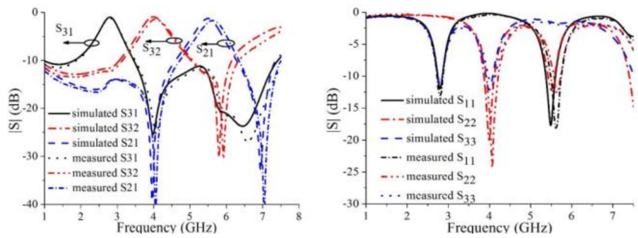
(a) (b)

Fig. 2 (a) Circuit layout and (b) photograph of proposed TSD.



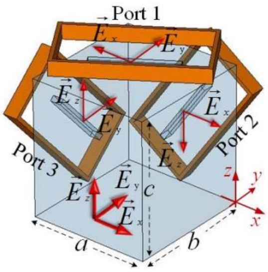
(a) (b) (c)

Fig. 3. Resonant modes of the proposed elliptical triple-mode resonator: (a) TM11+. (b) TM11-. (c) TM21.

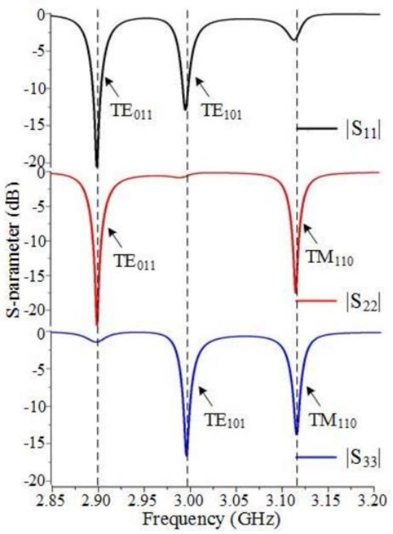


(a) (b)

Fig. 4 Comparison of simultion and measurement: (a) Insertion loss and (b) Return loss.

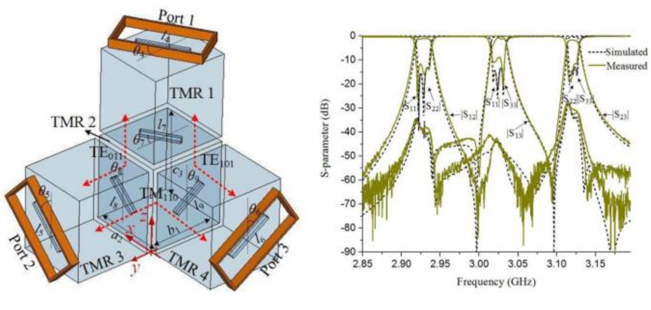


(a)



(b)

Fig. 5. First-order TMR TSD with (a) 3-D physical model and (b) simulated S-parameter curves.



(a) (b)

Fig.6 (a) Physical model of the four-cavity third-order TSD, (b) Simulated and measured results.

proposed. The basic configuration is given in Fig. 5 (a), according to the previous work shown in [13], the excitation of the three fundamental modes, namely, TE_{011}, TE_{101}, and TM_{110}, in a single TMR cavity can be implemented by a rotated and shifted coupling slot. For the design of TSD, all the three ports are rotationally engineered on the surface center of the cavity without any offsetting so that only two of the three modes (E_x, E_y and E_z) are excited when feeding each port, as shown in Fig. 5 (a). From the simulated S-parameters given in Fig. 5 (b), and compared to Fig. 4 (b), the proposed configuration can work at three states.

Then, a miniaturized third-order TSD structure with four TMRs is presented in Fig. 6 (a). It consists of four identical TMRs and three coupling slots among them. Three ports are adopted to feed this structure. Herein, TMR 2 is a common-shared cavity for all the three fundamental modes in every single state. From the simulated and measured results shown in Fig. 6 (b), three frequency channels are located at 2.92, 3.02, and 3.12 GHz with measured insertion loss of 0.7, 0.9, and 1.4 dB, respectively. There are two resonant modes of 2.92 and 3.02 GHz at port 1 denoted in $|S_{11}|$ while $|S_{22}|$ resonates at 2.92 and 3.12 GHz, $|S_{33}|$ resonates at 3.02 and 3.12 GHz, respectively. High isolation among three channels can be implemented under 27 dB from 2.85 to 3.2 GHz as depicted in Fig. 6 (b).

C. MSD on Microstrip-line SLR Structure [17]

The above two multiple-state diplexers are limited to work at three states. In this section, a TSD and a FSD using uniform/stepped-impedance stub loaded resonators (SLR) are firstly presented. The configurations are given in Fig. 7 (a) and (b), respectively. Each filter is composed of a two-mode SLR working at different frequencies, and each port couples to two filters of the three or four filters, thus, there are two resonant frequencies occurs at each ports denoted in $|S_{nn}|$, as shown in Fig. 7 (c) and (d), corresponding to Fig. 7 (a) and (b), respectively. According to previous analysis, the two configuration can serve as the TSD and FSD. All the isolation are better than 20 dB.

Based on the above-described design examples, i.e., TSD and FSD, a generalized m^{th}-order n-state diplexer can be formed as depicted in Fig. 8. It consists of n ports and n filters. Each filter is composed of m resonators with the resonant frequencies at those desired passbands. Without considering harmonics effect, this configuration can be extended to achieve an arbitrary-state diplexer with arbitrary-order filters in condition of sufficient circuit size. As shown in Fig. 8, with the increase of n and m, θ decreases and R increases. Where θ and R represent the angular radian between adjacent ports and the radius of position circle ($\theta=2\pi/n$).

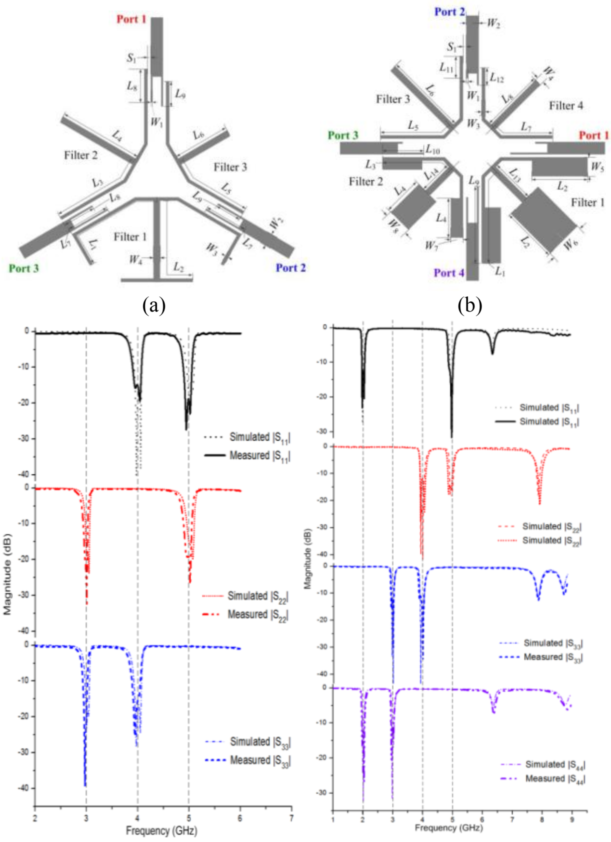


Fig. 7 Proposed MSD on microstrip-line structure: Configuration of (a) TSD and (b) FSD. Simulated and measured results of (c) TSD and (d) FSD.

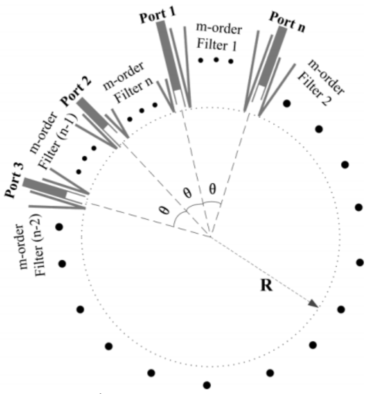


Fig. 8 Configuration of m^{th}-order n-state diplexer.

III. Conclusion

A new concept of multi-state diplexer (MSD) is proposed. The MSD is a kind of highly integrated multifunctional diplexer, which can be applied to frequency-hopping system. Then, the MSDs are analyzed and achieved using three different structures, namely, planar multi-mode resonator, cavity multi-mode resonator and microstrip SLR. Three TSDs and one FSD are presented and finally fabricated. Furthermore, the third structure can be applied to design m^{th}-order n-state diplexer. The proposed MSD have obvious advantage over the size-reduction compared to the traditional application of the diplexers in multi-channel and frequency-hopping systems.

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