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PAPER

Compact dual-mode loop resonators for microwave triplexer applications

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In this paper, we study meandered topologies of a dual-mode loop resonator for microwave multiplexer applications. Compact channel filter structures that characterize controllable transmission zeros locating simultaneously at the lower stopband or upper stopband are, for the first time, investigated for such a kind of resonators and based on this, a microstrip triplexer is proposed. The studied triplexer uses one of the filter structures to realize the middle channel, and the rest structure to realize the upper and lower channels. The center frequencies of the three channels are 1.8 GHz, 2.0 GHz and 2.2 GHz, and the 3-dB fractional bandwidths are 3.6%, 3.6% and 4.1%, respectively. The developed triplexer features high channel-isolations of over 40 dB as a result of the controllable transmission zeros of the channel filters.

Keywords: Dual-mode resonator, loop resonator, microstrip resonator, microstrip triplexer

1. Introduction

It is known the microwave multiplexers can be classified as frequency-division multiplexer (FDM) and time-division multiplexer (TDM). To date, both types have found wide applications in today`s wireless systems. The FDM is a filter-based circuit that separates the receiving and transmitting channels using different operation frequencies, thus can receive and transmit signals simultaneously. The FDMs became studied tracing back to the early 1960`s [1,2].

The microwave triplexer (three-channel multiplexer) is important to channel separation in microwave front-end systems used in various applications such as communication, radar and other transceiver systems. The waveguide-based hybrid-coupled multiplexer characterizes low insertion loss and good channel selection [1,3]. For compact realizations, the manifold-coupled schemes with dual-mode channel filters [4] and with bandstop like elements [5] as well as without dealing with the manifold peaks [6] can achieve the purpose with enhanced electric performances, while the circular-coupled multiplexer has the advantage of modular integration and easy realizations [7].

In [8], a triplexer composed of three pairs of bandpass filters based on stepped hairpin resonators and a star-junction was studied and confirmed. In [9], authors proposed a triplexer consisting of 3 sections of microstrip transmission line and resistor models operating at 0.915 GHz, 1.8 GHz and 2.45 GHz. Based on cross-coupled structure, the reported triplexer in [10] has the central frequencies and relative bandwidths of 1.37 GHz with 4%, 1.52 GHz with 5%, and 1.7 GHz with 5%. In [11], a microwave triplexer based on multiple higher-order open stubs with center frequencies on 1.85 GHz, 2.1 GHz, and 2.45 GHz is developed. For microwave frequency-division triplexers, high selectivity, sharp roll-off, good isolation as well as compact size are generally important to meet the stringent system requirements in modern communication systems.

This paper reports our recent research on dual-mode loop resonator with an in-line feedings for application to the microstrip multiplexers. The dual-mode ring resonator with compact structure and simple structure can control the transmission zero (TZ) flexibly by tuning the feeding stubs of the filter in this study. In particular, the TZs locating simultaneously at the lower stopband or upper stopband are investigated, for the first time, for such a kind of resonators. Base on the introduced resonators, we develop a microstrip triplexer with center frequencies of the three channels on 1.8 GHz, 2.0 GHz and 2.2 GHz. The 3-dB fractional bandwidths are 3.6%, 3.6% and 4.1%. The studied dual-mode loop resonator-based triplexer achieves the channel isolations of over 40 dB due to the controllable TZs of the channel filters. Both measured and simulated performances are presented with good consistency.

2. Meandered loop resonator for compactness

By meandering a full-wavelength loop resonator, two compact structures are developed in this study, as shown in Figs. 1(a) and (b). It is realized on a microwave substrate with a thickness of 0.8 mm and a relative permittivity of 9.6.

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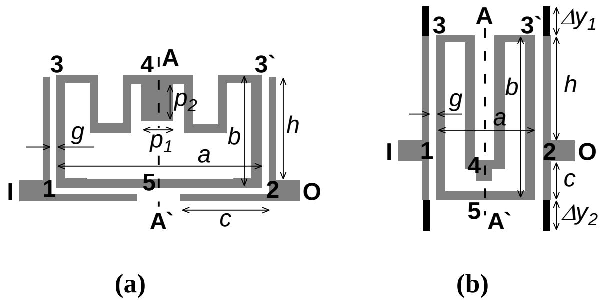


Fig. 1. Compact microstrip dual-mode loop resonator filters. (a) Circuit type I. (b) Circuit type II, where the dark segments marked as Δy_1 and Δy_2 are optional.

For the circuit type I, shown in Fig. 2 indicates that there are two TZs clearly located near the passband, thus greatly improving the response transition between the passband and stopband. Consequently, the response roll off is enhanced and so is the filter selectivity. The zero-shifting response in this case can be referred to [12] and thus, it is not detailed here.

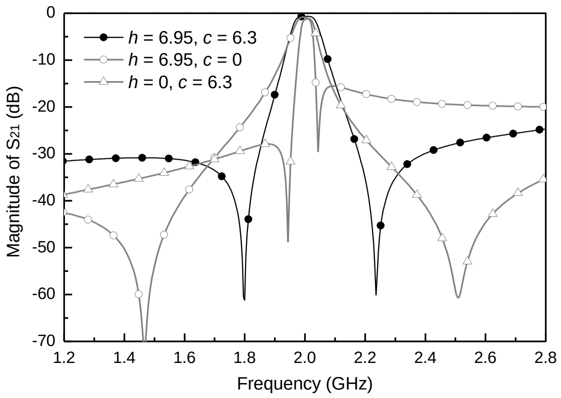


Fig. 2. Simulated responses of different coupling region for circuit type I.

To potentially develop microwave triplexers with enhanced channel isolations, here we focus on study the circuit type II as described in Fig. 1(b). It is found from Fig. 3 that without the stub extension, i.e., $\Delta y_1 = \Delta y_2 = 0$, the filter exhibits no TZs at the studied frequency band. However, when the optional stubs are involved, zeros located at either lower or upper stopbands are observed. As can be seen, when the upper feeding stubs (Δy_1) are extended, there are two zeros with both located at the lower stopband; the longer the extension is, the lower the zeros would be. On the contrary, an extension of the lower feeding stubs (Δy_2) also generates two TZs that are placed at the upper stopband. Correspondingly, a longer extension pushes the zeros to the higher frequencies. This suggests that one can optimally choose the parameters of the coupled sections to locate a pair of TZs to the desired frequencies. This is important in developing the microwave triplexers with performance improvement in this study.

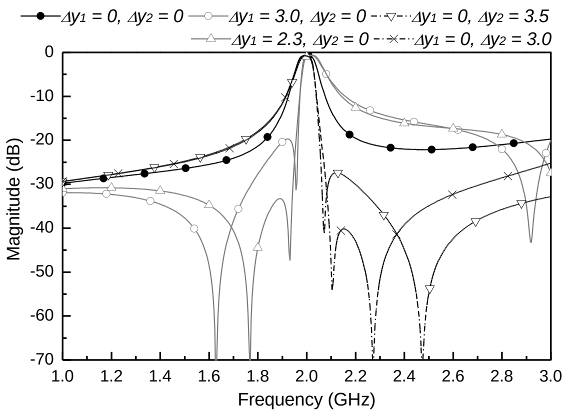


Fig. 3. Zero shifting capabilities of the studied circuit type II, where physical parameters referred to Fig. 3(b) are (units: mm): $a = 5.6$, $b = 15$, $h = 8.8$, $c = 5.4$, $g = 0.15$, $w = 0.5$ and 0.45 for the resonator and feeding stub.

3. Developing microstrip triplexer by using the studied resonator filters

Based on the above investigations, it is found that the combinations of circuit types I and II can be utilized to develop a microwave triplexer with high performance. Hence, such a triplexer is further designed and examined to confirm the study. The developed triplexer uses the circuit type II to realize the lower and upper channels, and employs circuit type I to realize the middle channel.

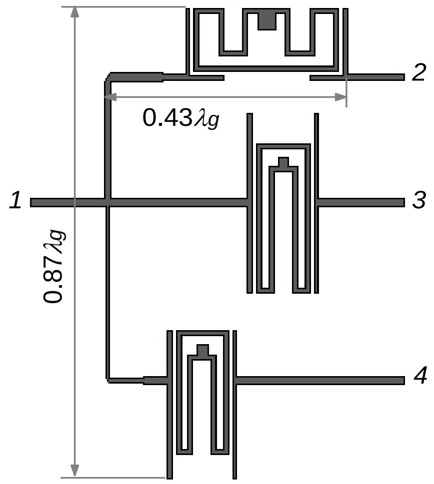
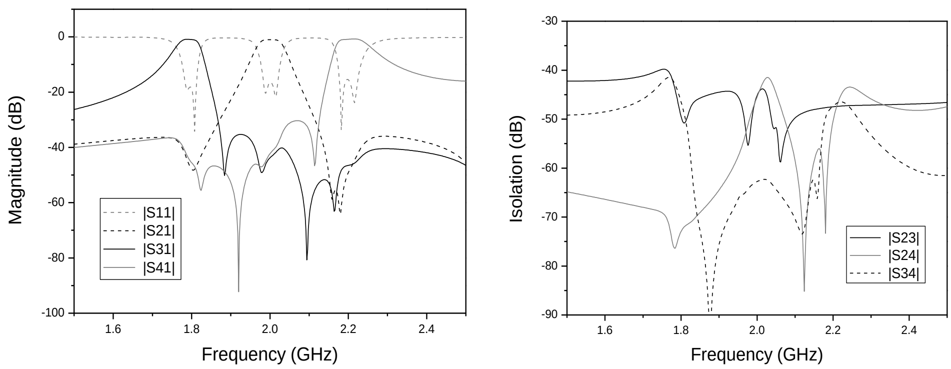


Fig. 4. Layout of the developed microwave triplexer using the proposed resonator filters.

The center frequencies of the triplexer are designed at 1.8 GHz, 2.0 GHz and 2.2 GHz with its 3-dB fractional bandwidths of 3.6%, 3.6% and 4.1%, respectively. Illustrated in Fig. 4 is the developed triplexer topology. The utilized microwave substrate is the same mentioned above. It can be seen that this triplexer totally uses three resonators with commonly matching networks. Also, it has a simple topology and compact size.

Figure 5(a) shows the simulated insertion and return losses. The isolations among output ports are described in Fig. 5(b). As can be seen, isolations over 40 dB are achieved; this is due to we place the two transmission zeros of Circuit type II simultaneously located at the frequencies of lower or higher channels, and make the ones of structure Circuit type I to be located at the center frequencies of adjacent two channels.



(a) **(b)**

Fig. 5. Simulated results of the studied triplexer. (a) Insertion and return losses. (b) Isolations.

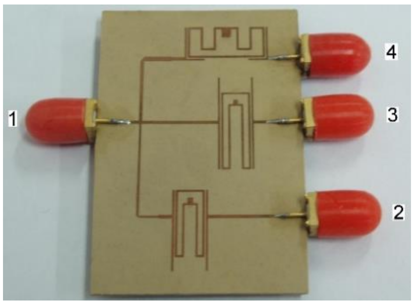
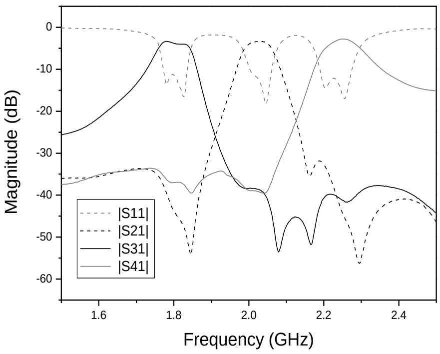
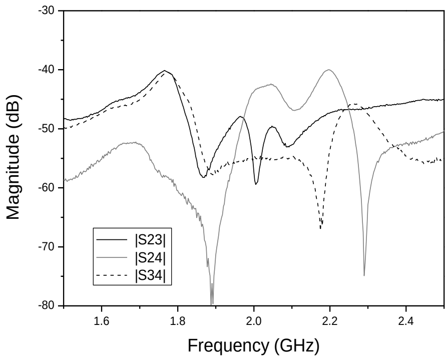


Fig. 6. Photograph of the fabricated triplexer circuit.



(a)



(b)

Fig. 7. Measured performances of the fabricated three-channel multiplexer. (a) Insertion and return losses. (b) Isolations.

Figure 6 is a photograph of the fabricated circuit. The developed triplexer occupies an area of $0.43\lambda_g$ by $0.87\lambda_g$ including the matching networks (where λ_g is the guided wavelength at 2.0 GHz). The measured performances, given in Fig. 7, indicate that good agreements between simulations and experiments have been obtained, as compared with Figs. 5 and 7. Measurements show that the fabricated triplexer has the insertion losses of 3.3 dB, 3.35 dB and 2.8 dB with return losses all better than 11 dB at the lower, middle and upper channels, respectively. Notice that the insertion losses include the loss of SMA connectors and the slightly higher losses are mainly attributed to the conductor and dielectric losses together with the loss of non-ideal coaxial/microstrip-line transitions. On the other hand, the measured isolations among output ports, depicted in Fig. 7(b), indicate that high isolations (over 40 dB) are achieved. The enhanced isolation performance would be attractive in modern communication systems.

4. Conclusion

A microstrip loop resonator-based filter with simple circuit layout, compact size and controllable response zeros has been studied for developing the microwave triplexers in this paper. The introduced topology is interesting to be found in application to the microwave multiplexers with high channel selectivity, sharp roll-off and high isolation. By meandering the loop resonator, two compact filter topologies are developed from the loop resonator, and further, microwave triplexer with high isolation is developed by effectively utilizing the controllable zero shifting properties, where the zeros located simultaneously at the lower or upper stopband are investigated for the first time in this study. Experimental results have confirmed the predicated performances and good consistency between them has been observed, thus validating the analyses. It is believed that the studied triplexer topology could be attractive for potential application to modern microwave systems.

5. Acknowledgment

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