Highly-Selective Dual-band Bandpass Filter with Extremely Wide Tuning Range for Passbands

Jian-Hui Guo[1], Sai-Wai Wong[2], Ze-Ming Xie[1], Long Zhang[2], Lei Zhu[3], and Yejun He[2]
[1] School of Electronic and Information Engineering, South China University of Technology, Guangzhou, China
[2] College of Electronics and Information Engineering, Shenzhen University, Shenzhen, China
[3] Department of Electrical and Computer Engineering, Faculty of Science and Technology, University of Macau, Macau, China
Email: 201720110622@mail.scut.edu.cn, wongsaiwai@ieee.org, eezmxie@scut.edu.cn, longzhang717@163.com, leizhu@umac, heyejun@126.com.

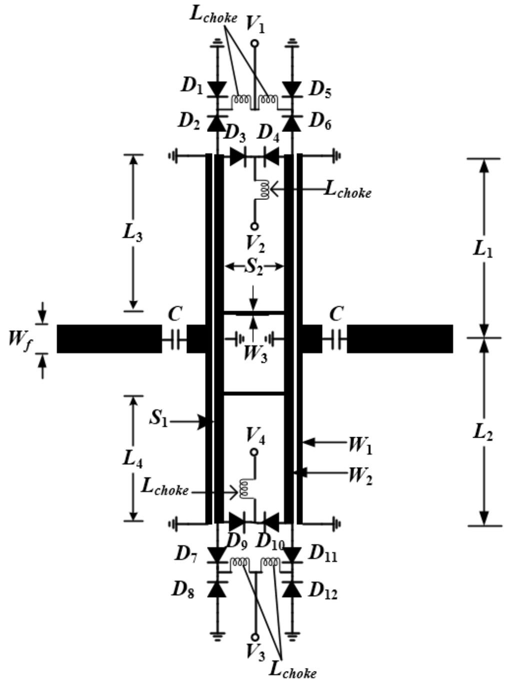
***Abstract*—In this paper, a second-order dual passband filter with an extremely wide tuning range of 0.7-1.5 GHz and three out-of-band transmission zeros is proposed. Good tunability is achieved by placing two varactors in back-to-back connection at each open-circuited end of this resonator. Two out-of-band transmission zeros are obtained through the combination of electric coupling and magnetic coupling. By properly adjusting the electric coupling, the upper and lower transmission zeros can be located at the desired frequencies to provide good selectivity. A middle common via simultaneously provide shorted point for upper and lower quarter-wavelength resonators, which reduces the size of the proposed filter. The tuning range of the lower passband is from 0.7 to 1.2 GHz (52.6%), whereas that of the upper passband ranges from 0.9 to 1.5 GHz (50.0%). At last, a good agreement is obtained between the simulated and measured results.**

***Index Terms*—dual passband filter, controllable transmission zeros, wide tunable range.**

I. Introduction

Microwave filter is an indispensable component in the front-end module of communication system. With the development of communication technology, more and more multi-band communication systems appear. In order to meet the demand of multi-serve communication system, multi-band bandpass filters emerge as the application [1], [2]. When multi-band bandpass filter has a tunability or reconfigurability, the application of multi-band bandpass filter will be greatly increased. Recently, some planar dual-band bandpass microwave filter has been proposed [3]-[6]. These filters provide the excellent performance in multi-band and tunability. However, there is room for improvement in the adjustable range and passband selectivity. Generally, high selectivity can be achieved by transmission zero. E.g., in [3], its first passband and second passband provide 19.5% and 18.2% adjustable range, respectively. In [4], its two passbands provide the tunable range of 36.4% and 32.7%, respectively. And both dual-band bandpass filters in [3] and [4] only have two transmission zeros. In addition, there is no controllable transmission zero in [3]-[5].

In this paper, a dual tunable bandpass filter with three transmission zeros is proposed. It uses quarter-wavelength resonator, and cascade two varactor diodes (SMV1413) at the end of quarter-wave resonator to control resonant frequency. It provides a 73% tuning range from 0.7 GHz to 1.5 GHz with dual-band. In addition, three transmission zeros are used to improve selectivity. Two transmission zeros are achieved by mix electric and magnetic coupling. One Transmission zero is achieved by signal interference of lower and upper path of the circuit. An effective method to control two transmission zeros is to change electric coupling in the mix electric and magnetic coupling.



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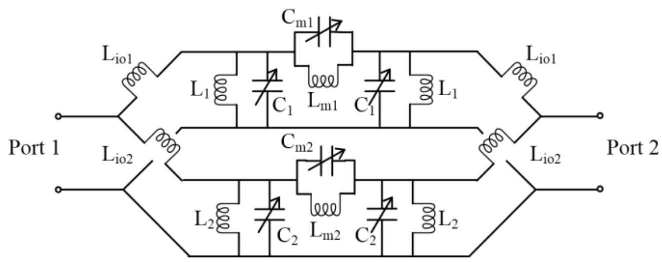

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Fig. 1. Proposed tunable dual-band bandpass filter. (a) Layout. (2) Equivalent circuit.

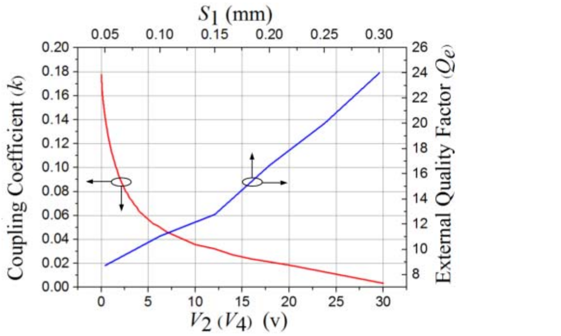
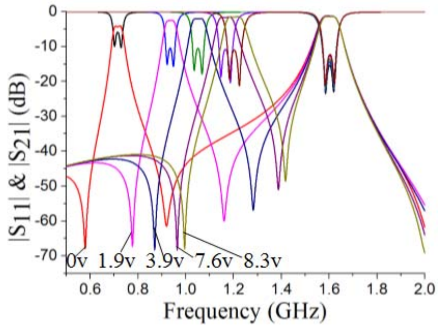


Fig. 2. Variation of k against changes in V_2 (or V_4) and variation of Q_e against changes in S_1.



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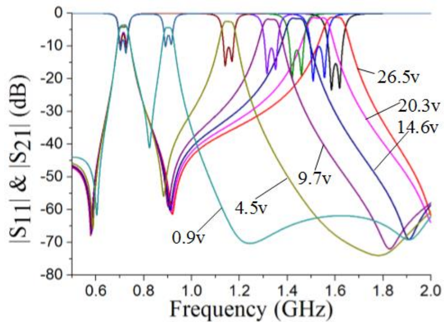

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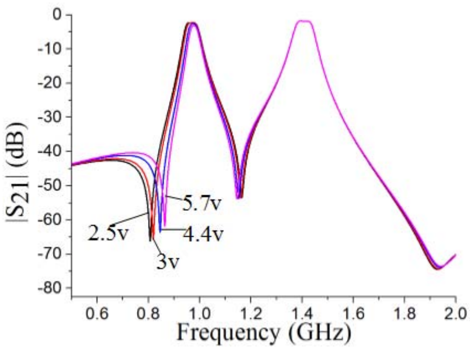
Fig. 3. Simulated frequency responses of the proposed tunable dual-band filter. (a) Lower passband with varied V_1. (b) Upper passband with varied V_3.

II. DESIGN FOR TUNABLE DUAL-BAND FILTER

Fig. 1 shows the configuration and equivalent circuit of the proposed tunable dual-band filter with three transmission zeros. It contains two sets of quarter-wavelength microstrip resonators responsible for the two passbands. The resonators are loaded with two diodes in back-to-back connection at each of their ends (D_1 and D_2, D_5 and D_6, D_7 and D_8, D_{11} and D_{12}). The bias voltages V_1 and V_3 to these diodes would change the resonant capacitances, and therefore tune the two passbands. An identical pair of diodes is connected across each set of the two near ends of the resonators (D_3 and D_4, D_9 and D_{10}). These diodes vary the capacitances between the resonators, and therefore control the electric coupling between them. The magnetic coupling is obtained by two connected conducting pins between adjacent resonators. To achieve good impedance matching and meet the required external quality factor (Q_e), a narrower microstrip line with both ends short to ground is



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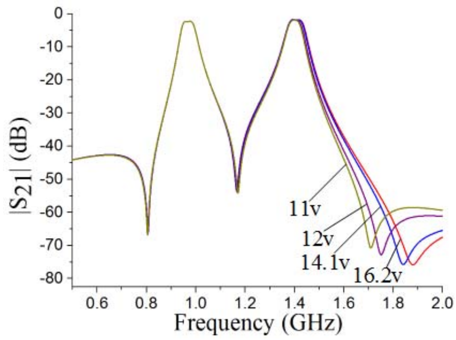

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Fig. 4. Simulated frequency responses to demonstrate the changes of the transmission zeros. (a) Lower passband with varied V_2. (b) Upper passband with varied V_4.

introduced next to each resonator to establish a parallel-line structure for input/output coupling. C_1 and C_2 represent the equivalent capacitors of the varactors-loaded resonators. C_{m1} and C_{m2} are the equivalent capacitors of the connected varactors between adjacent resonators, whereas L_{m1} and L_{m2} are the equivalent inductance of the connected conducting pins between adjacent resonators. Fig. 2 displays the variation of Q_e with respect to the spacing S_1 shown in Fig. 1, and the changes in the coupling coefficient k as the applied voltage V_2 (or V_4) varies. A desired Q_e can be obtained by selecting a proper value for S_1, and the two transmission zeros can be created and tuned by changing V_2 and V_4.

The proposed filter was fabricated on a 1.524-mm-thick Rogers RO4003C substrate with a dielectric constant of 3.38. The dimensions of its crucial design parameters were determined through the simulations and optimization provided by a commercial full-wave simulator, ADS. Their final values are given as follows: W_f = 2.2, S_1 = 0.2, S_2 = 5.4, W_1 = 0.2, W_2 = 0.3, W_3 = 0.25, L_1 = 13.95, L_2 =13.45, L_3 = 11.2, L_4 = 7.7, with all in mm. As can be seen from Fig. 3(a), the center frequency of the lower passband increases from 0.7 to 1.2 GHz as the value of V_1 rises. The same variation is applied to the upper passband versus V_3 with its center frequency changing from 0.9 to 1.5 GHz, as observed in Fig. 3(b). Fig. 4 demonstrates that the transmission zeros of the lower and upper passbands can move to higher frequencies independently by increasing the values of V_2 and V_4, respectively.

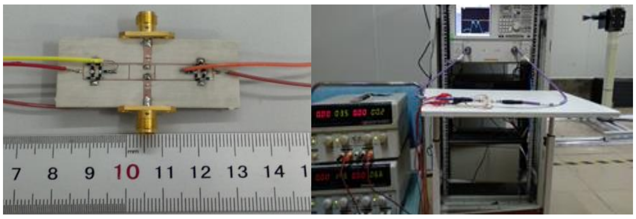
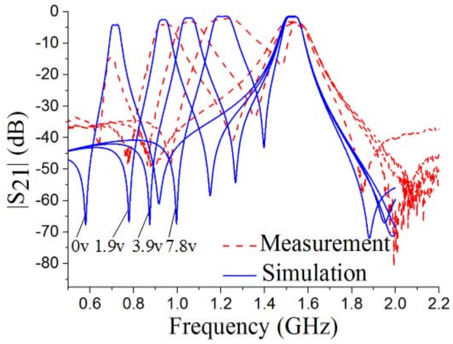


Fig. 5. Photographs of the fabricated filter and the measurement setup.



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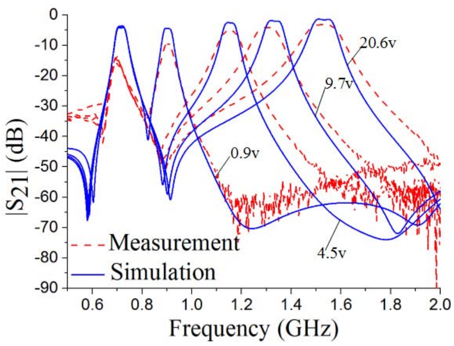

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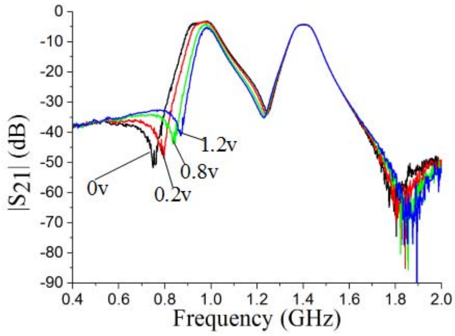
Fig. 6. Simulated and measured results of the proposed filter. (a) Lower passband with varied V_1. (b) Upper passband with varied V_3.

III. Simulated and Measured Results

The measurement setup and the fabricated unit of the proposed dual-band bandpass filter are shown in Fig. 5. The comparison between the simulated results and measured data of the proposed filter subjected to varied V_1 and V_3, respectively, is displayed in Fig.6. They are in good agreement. Fig. 7 shows that two transmission zeros of the proposed filter can be controlled by changing the values of V_2 and V_4. These results demonstrate the reconfigurable feature of the proposed filter on its passbands as well as its transmission zeros. However, in exchange for the insertion loss it suffers, which is mainly caused by the diodes employed in the design.

IV. Conclusion

In this paper, a second-order dual-band bandpass filter is proposed. This filter has a wide tuning range 0.7-1.5 GHz. The lower passband is changed from 0.7 GHz to 1.2 GHz (52.6%), and the upper passband is tuned from 0.9 GHz to 1.4 GHz (50.0%). Two transmission zeros are achieved by mixed electric and magnetic coupling. By changing the values of V2 and V4, the electric coupling between adjacent resonators is changed, which leads two transmission zeros located the lower and upper passband to be controlled.



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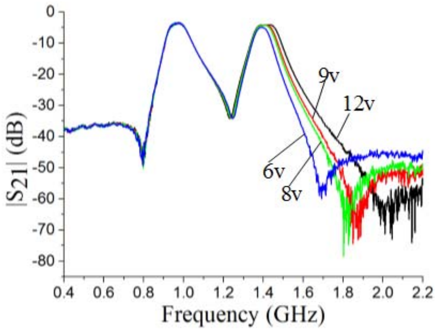

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Fig. 7. Measured results of the proposed filter. (a) Lower passband with varied V_2. (b) Upper passband with varied V_4.

Acknowledgment

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