

High-selectivity Dual-bandpass Filter Using Coupled Lines

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Abstract —In this paper, a microstrip dual-band bandpass filter is presented. The mechanism of the dual-band operation is shown as follows. Resonator modes are located to two passband by adjusting the even- and odd-mode impedance. Transmission zeros are then appear on both sides of two passband skirts and in the rejection bands by adjusting the coupling coefficient of the shorted quarter-wavelength microstrip line. Additional transmission zeros can be obtained to improve the passband selectivity. For demonstration, a dual-band bandpass filter working at 0.8 and 2.2 GHz is designed and fabricated. The theoretical analysis and measurement are presented. The good agreement verifies the proposed method.

I. INTRODUCTION

Microwave circuits are one of essential parts in modern communication system, and it requires compact size, low in-band insertion loss, and high out-of-band rejection skirts. Besides, Dual-band bandpass filter is one of the critical parts in the dual-band wireless communication system. Therefore, they have been extensively investigated and various design approaches have been proposed. There are several studies on dual-band BPFs with high selectivity [1–8]. A miniaturized and high-selectivity microstrip dual-passband filter using quadruple-mode stub-loaded resonator is presented in [1]. In the filter [2], which consists of two E-shaped resonators and two T-shaped feed lines has multi-transmission zeros in the stopband, which will also improve the selectivity of the passband. Similarly, a compact microstrip dual band bandpass filter[3] using short-circuited stub loaded half-wavelength resonator and stepped impedance resonator created multiple transmission zeros. Furthermore, the bandwidths of the filter can be regulated. The filter [4] using asymmetric stepped-impedance resonators is as well as a high selectivity dual-band bandpass filter. There are some articles [5-7] also introduce stepped-impedance resonators (SIRs) to design dual-band bandpass filters with good selectivity. One of the methods to achieve dual-band filter are proposed using the embedded spiral resonators [8, 9], which have good coupling for both passbands and additional transmission zeros to improve the passband selectivity. Moreover, a miniaturized dual-band bandpass filter [9] using the half-wavelength spiral-resonators and loaded open-stubs is presented. Meanwhile, the filter employs a strong enough passband enhancement around the dual-resonances.

In this paper, a dual-band BPF using an opened quarter-wavelength microstrip line cascading a shorted quarter-

wavelength microstrip line through two quarter-wavelength transmission lines is proposed. Nevertheless, we can fold two quarter-wavelength transmission lines to reduce the circuit size. The structure of the filter is shown in Fig. 1. Since the resonator is symmetrical, the odd-even-mode analysis is implemented. Moreover, when the coupled line is fabricated with the microstrip circuit, the unequal even and odd-mode phase velocities will decrease the filter's rejection level. To compensate the unequal even and odd-mode phase velocities using the interdigital capacitor is simultaneous proposed in the paper. Owing to the intrinsic characteristics of the resonator and additional transmission zeros be created on both sides of two passband skirts and in the rejection bands to improve the selectivity. Finally, a dual-band BPF at 0.8 GHz and 2.2 GHz are designed, the EM results of the BPFs are in good agreement with the full-wave simulation results.

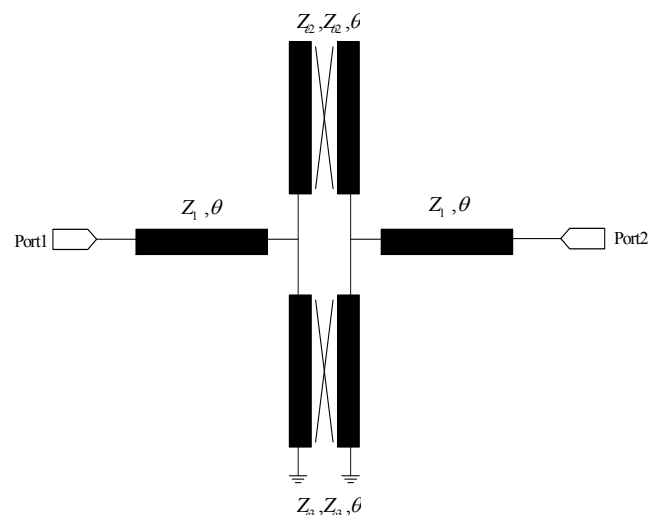


Fig. 1 The structure of the proposed dual-band bandpass filter.

II. DESIGN EQUATIONS

A. Even-Odd-Mode Analysis

Fig. 1 shows the proposed dual-band BPF with two quarter-wavelength transmission lines connected an opened quarter-wavelength microstrip line cascading a shorted quarter-wavelength microstrip line. Fig. 2(a) shows the structure of the proposed filter is symmetrical to the T-T' plane, so the odd-even-mode analysis is implemented. Fig. 2 shows the configuration of the proposed filter in 2(b) odd-mode equivalent circuit and 2(c) even-mode equivalent circuit.

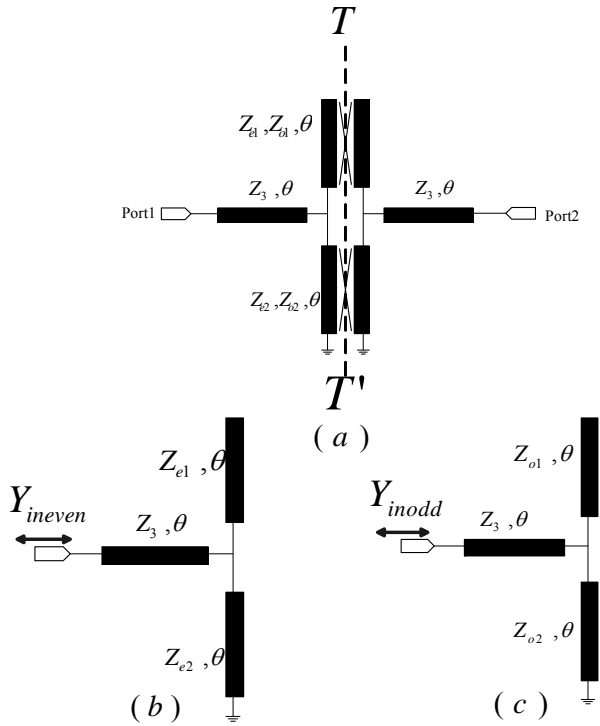


Fig.2 The structure of the proposed filter, (a) symmetrical to the T-T' plane, (b) odd-mode equivalent circuit and (c) even-mode equivalent circuit.

The input admittance Y_{ineven} of the even-mode resonator and Y_{inodd} of the odd-mode resonator can be derived as follows:

$$Y_{ineven} = j \frac{(Z_3(-Z_{e1} + Z_{e2}) \cot[\theta] + Z_{e1} Z_{e2} \tan[\theta])}{Z_3(Z_3(Z_{e1} - Z_{e2}) + Z_{e1} Z_{e2})} \quad (1)$$

$$Y_{inodd} = j \frac{Z_3(-Z_{o1} + Z_{o2}) \cot[\theta] + Z_{o1} Z_{o2} \tan[\theta]}{Z_3(Z_3(Z_{o1} - Z_{o2}) + Z_{o1} Z_{o2})} \quad (2)$$

According to (3)-(6), the transmission zeros $|S_{21}|=0$ and resonant frequencies of the proposed resonator $|S_{11}|=0$ can be mainly controlled by the impedance of the even-odd-mode. Fig. 3 shows the simulated $|S_{11}|$ and $|S_{21}|$ in dB of the proposed resonator. It can be noted that transmission zeros appear on both sides of two passband skirts to improve the passband selectivity.

$$\Gamma_e = \frac{Y_0 - Y_{ineven}}{Y_0 + Y_{ineven}} \quad (3)$$

$$\Gamma_o = \frac{Y_0 - Y_{inodd}}{Y_0 + Y_{inodd}} \quad (4)$$

$$|S_{11}| = \frac{\Gamma_e + \Gamma_o}{2} \quad (5)$$

$$|S_{21}| = \frac{\Gamma_e - \Gamma_o}{2} \quad (6)$$

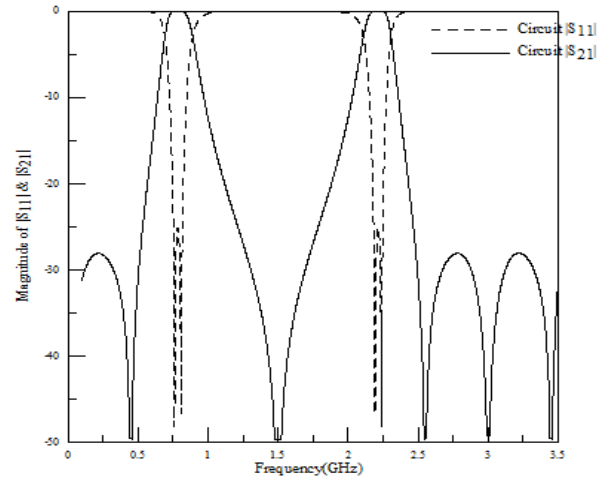


Fig. 3 showed (a) a structure of coupled line (b) comparison with and without the interdigital capacitor results

B. Phase Velocity Compensation

The coupled line is fabricated with the microstrip circuit, the unequal even and odd-mode phase velocities will decrease the filter's rejection of the out-band area. In this paper, a method for compensating the phase difference is shown. The method of using the interdigital capacitor between coupled lines for enhancing the coupling is well known, and it also can be as the phase velocity compensation. Fig. 4 shows the comparison of coupled line with and without the interdigital capacitor results. The structure was simulated using a full-wave EM simulator.

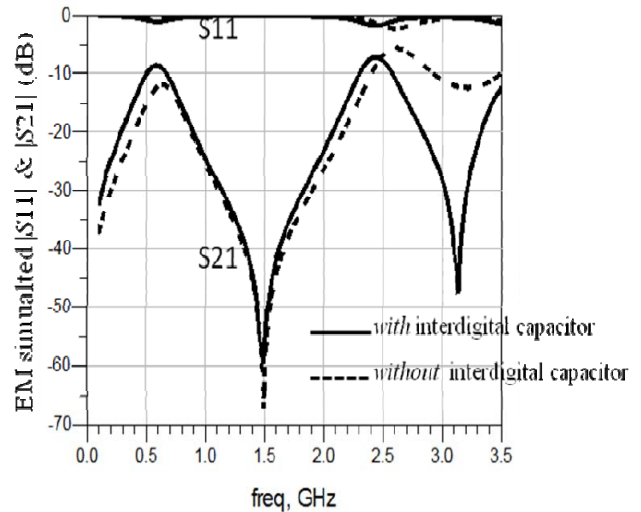


Fig. 4 Comparison of coupled line with and without the interdigital capacitor

III. SIMULATED AND MEASURED RESULTS

To provide verification on the above proposed structure, a prototype filter circuit is designed and optimized with dual passbands at 0.8 and 2.2 GHz in a full-wave electromagnetic simulator. The filter is fabricated on a substrate with

dielectric constant, loss tangent, dielectric thickness, and metal thickness are 3.38, 0.018, 1.524 mm, and 0.017 mm, respectively. Also, we can fold two quarter-wavelength transmission lines to reduce the circuit size. The dimension of the proposed filter is of 27.2mm \times 58.5mm. Fig. 5 shows the layout and photograph of the fabricated dual-band BPF with interdigital capacitor.

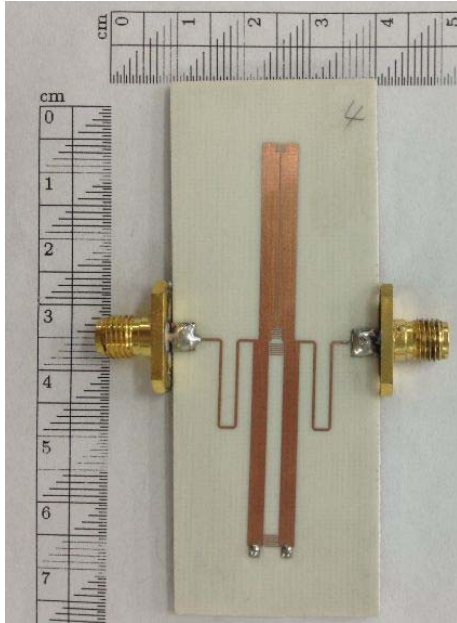


Fig. 5. Fabricated dual-band BPF with interdigital capacitor with Layout and photograph.

Here we compare measurement and theoretical prediction of the dual-band microstrip BPF in Fig. 6. We can note that a good agreement between the measurement and theoretical prediction. In the first passband, 0.75–0.84 GHz, the insertion loss is smaller than 0.74 dB while the return loss is greater than 15 dB. Similarly, within the second passband, 2.15–2.23 GHz the insertion loss is smaller than 1.6 dB while the return loss is greater than 16 dB. Otherwise, transmission zeros are located at 0.45, 1.5, 2.55, and 3 GHz.

IV. CONCLUSION

In this paper, a dual-band BPF using an opened quarter-wavelength microstrip line cascading a shorted quarter-wavelength microstrip line through two transmission lines is proposed. Due to the intrinsic characteristics of the resonator and additional transmission zeros be created on both sides of two passband skirts and in the rejection bands to improve the selectivity. Moreover, we use the interdigital capacitor to compensate the unequal even and odd-mode phase velocities from the coupled line. Finally, the good agreement between the measurement and theoretical prediction verify this proposed structure.

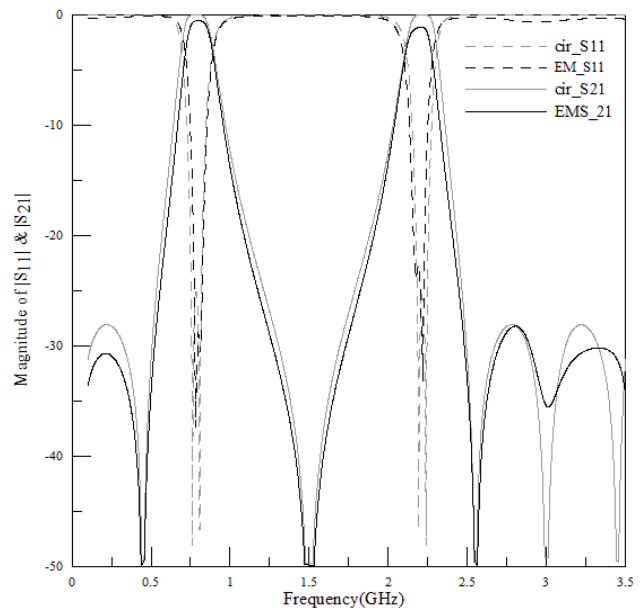


Fig. 6 compared measurement and theoretical prediction of the dual-band microstrip BPF

REFERENCES

- [1] Xiaowu Zhan, Zongxi Tang, Yunqiu Wu, Biao Zhang, "Miniaturized and High-selectivity Microstrip Dual-passband Filter Using Novel Quadruple-mode Stub-loaded Resonator," *Journal of Electromagnetic Waves and Applications*.
- [2] J. Wang, L. Ge, K. Wang and W. Wu, "Compact microstrip dual-mode dual-band bandpass filter with wide stopband," *ELECTRONICS LETTERS* 17th February 2011 Vol. 47 No. 4.
- [3] Mingqi Zhou, Xiaohong Tang, Member, IEEE, and Fei Xiao, "Compact Dual Band Transversal Bandpass Filter With Multiple Transmission Zeros and Controllable Bandwidths," *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*, VOL. 19, NO. 6, JUNE 2009.
- [4] X.Y. Zhang, J.-X. Chen, J. Shi and Q. Xue, "High-selectivity dual-band bandpass filter using asymmetric stepped-impedance resonators," *ELECTRONICS LETTERS* 1st January 2009 Vol. 45 No. 1.
- [5] Qing-Xin Chu, Member, IEEE, and Fu-Chang Chen, "A Compact Dual-Band Bandpass Filter Using Meandering Stepped Impedance Resonators," *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*, VOL. 18, NO. 5, MAY 2008.
- [6] Sheng Sun, Student Member, IEEE, and Lei Zhu, Senior Member, IEEE, "Compact Dual-Band Microstrip Bandpass Filter Without External Feeds," *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*, VOL. 15, NO. 10, OCTOBER 2005.
- [7] J. Wang, Y.-X. Guo, B.-Z. Wang, L.C. Ong and S. Xiao, "High-selectivity dual-band stepped-impedance bandpass filter," *ELECTRONICS LETTERS* 27th April 2006 Vol. 42 No. 9.
- [8] Xun Luo, Student Member, IEEE, Huizhen Qian, Student Member, IEEE, Jian-Guo Ma, Senior Member, IEEE, Kaixue Ma, Senior Member, IEEE, and Kiat Seng Yeo, "Compact Dual-Band Bandpass Filters Using Novel Embedded Spiral Resonator (ESR)," *IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS*, VOL. 20, NO. 8, AUGUST 2010.
- [9] Xun Luo, Sheng Sun, and Er-Ping Li, "Miniaturized Dual-Band Bandpass Filter Using 12 Spiral-Resonator and Loaded Open-Stub," 978-1-4673-1088-8/12/©2012 IEEE

