Compact Bandpass Filter Using Two Ring Resonators and Two Open Stubs

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Abstract—A compact bandpass filter (BPF) using two ring resonators and two open stubs is proposed, where fifth-order passband with twelve transmission zeros at the stopband is realized. For demonstration, a filter example with center frequency of 2.04 GHz and 3 dB fractional bandwidth of 18.6% is designed. Good performance including high selectivity in the passband and sharp stopband rejection for the filter has been realized.

I. INTRODUCTION

High-performance bandpass filters (BPFs) with low insertion loss in the passband and high stopband rejection are seriously desirable in the RF/microwave communication systems and concerned by many researchers or engineers [1]–[3]. The stopband rejections of the BPFs can be improved by generating multiple transmission zeros (TZs) [2]–[6]. In [2], a high-selectivity wideband BPF with seven transmission poles (TPs) and four TZs using two open coupled lines and several stubs is proposed, where two TZs can be introduced with the help of the two short stubs shunted to the input/output ports. In [4], the capacitive and inductive source-load coupling is employed to obtain multiple TZs to suppress the undesired harmonics. In [5], the concept of TZ resonator pair is proposed, where the locations of four TZs are exactly at the resonant frequency points of the two resonator pairs. Due to its structure limitation, the lower stopband does not suppress very well.

In this paper, a compact microstrip fifth-order BPF using two ring resonators and two open stubs is proposed. With the help of two extra open stubs loaded on the feedline of our previously reported BPF [6], four more TZs are introduced at the lower and upper stopbands, namely, the number of TZs is increased to 12. For demonstration, a filter example whose center frequency at 2.04 GHz is simulated to validate the design idea.

II. BPF DESIGN AND ANALYSIS

The proposed BPF using two ring resonators and two loaded open stubs is shown in Fig. 1(a), where two one-wavelength ring resonators coupled each other with $\lambda_g/4$ coupled length and sandwiched between the $3\lambda_g/4$ input and output feedlines. The filter structure also can be seen as three pairs of coupled lines and two half-wavelength open stubs.

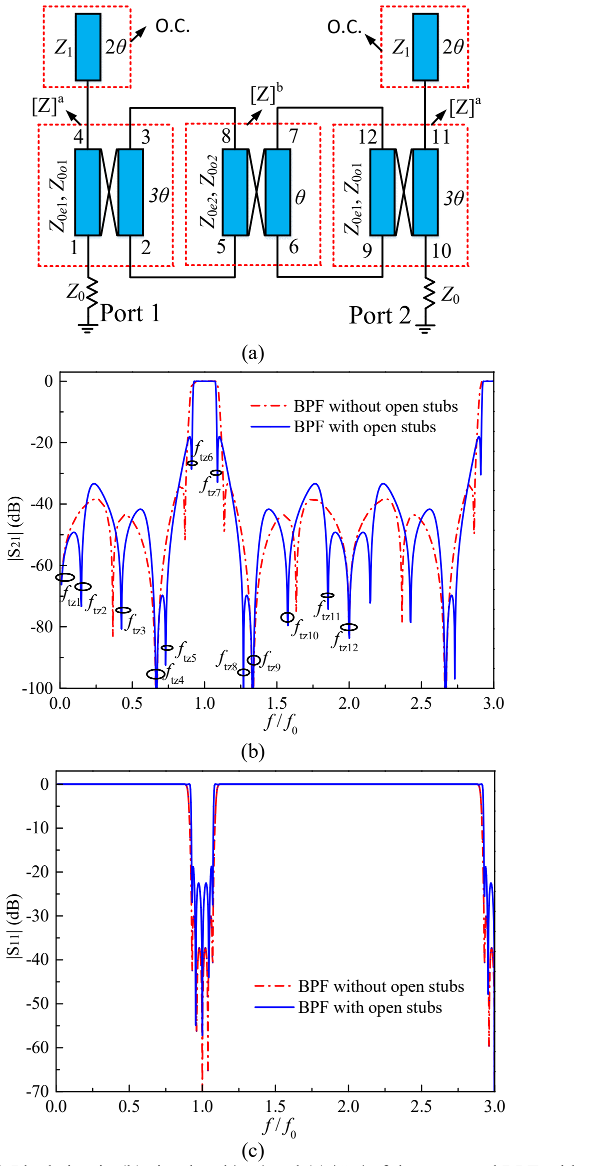

Fig. 1. (a) Ideal circuit, (b) simulated $|S_{21}|$ and (c) $|S_{11}|$ of the proposed BPF with θ=90 , Z_1=90 Ω, Z_{0e1}=158 Ω, Z_{0o1}=60 Ω, Z_{0e2}=109 Ω, Z_{0o2}=68 Ω (Z_{0o2}=65 Ω when BPF without open stubs).

Fig. 1(b) and (c) show the simulated S-parameter comparisons between the proposed BPF (i.e., BPF with open stubs) and the previous reported BPF in [6] (i.e., BPF without open stubs). As seen in Fig. 1(b), four more TZs (f_{tz2}, f_{tz5}, f_{tz8}, f_{tz11}) can be generated by adding the two open stubs, while the order of the passband remains fixed which can be seen in Fig. 1(c). For the previous generated eight TZs, four TZs f_{tz1}, f_{tz4}, f_{tz9} and f_{tz12} keep unchanged whose locations are expressed as Equations (1)-(4), and the locations of the other four TZs f_{tz3}, f_{tz6}, f_{tz7} and f_{tz10} are mainly relevant to the characteristic impedance of the open stubs Z_1, which can be seen in Fig. 2.

$$f_{tz1} = 0 \tag{1}$$

$$f_{tz4} = \frac{2}{3} f_0 \tag{2}$$

$$f_{tz9} = \frac{4}{3} f_0 \tag{3}$$

$$f_{tz12} = 2 f_0 \tag{4}$$

This circuit structure can be analyzed by using impedance matrix deduction. From Fig. 1(a), we can obtain that $V_2 = V_5$, $I_2 = -I_5$, $V_3 = V_8$, $I_3 = -I_8$, $V_6 = V_9$, $I_6 = -I_9$, $V_7 = V_{12}$, $I_7 = -I_{12}$, and $I_4 = I_{11} = -j\tan(2\theta)\cdot V_4/Z_1$. $[Z]^a$ and $[Z]^b$ denote the impedance matrice of the $3\lambda_g/4$ and $\lambda_g/4$ parallel-coupled lines, respectively. The overall impedance matrix $[Z]'$ and TZs of the filter can also be calculated similar to those in [6].

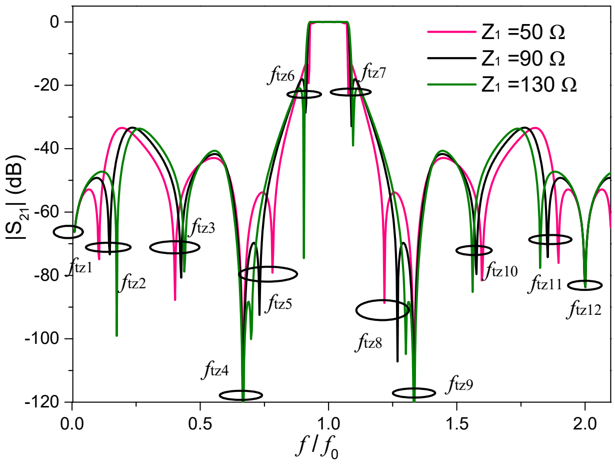

Fig. 2. Simulated $|S_{21}|$ versus Z_1, where θ=90 , Z_{0e1}=158 Ω, Z_{0o1}=60 Ω, Z_{0e2}=109 Ω, Z_{0o2}=68 Ω.

For demonstration, a filter example whose center frequency located at 2.04 GHz is designed on a substrate with dielectric constant of ε_r =2.65 and thickness of h=1 mm. Fig. 3(a) shows the layout of this filter, and its corresponding full-wave electromagnetic simulations can be seen in Fig. 3(b), where the 3-dB fractional bandwidth of this filter is about 18.6%. There are twelve finite TZs located at 0, 0.37, 0.88, 1.01, 1.38, 1.61, 1.83, 2.26, 2.75, 3.25, 3.75, and 4.04 GHz, respectively. The location of one TZ is moved from the upper stopband to lower stopband.

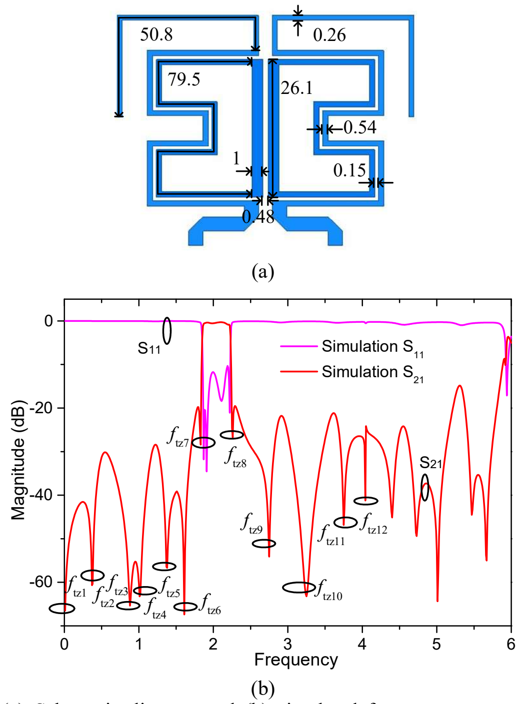

Fig. 3. (a) Schematic diagram and (b) simulated frequency response of the proposed BPF example.

III. Conclusion

A compact fifth-order BPF with twelve TZs has been proposed in this paper. It possesses the advantages of small size, high frequency selectivity, simple design method and easy fabrication on the printed circuit board.

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