Progress In Electromagnetics Research Letters, Vol. 21, 169–176, 2011

A STUB-LOADED TRIPLE-MODE SIR FOR NOVEL HIGH SELECTIVITY DUAL-WIDEBAND MICOSTRIP BPF DESIGN

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Abstract—In this letter, a novel high selectivity dual-wideband microstrip bandpass filter (BPF) is proposed using two stub-loaded triple-mode stepped-impedance resonators (SIR) which are the same type but with different sizes. The SIR is formed by attaching one T-type open stub at the center plane and two identical short-circuited stubs symmetrically to stepped-impedance open microstrip line. And it can generate one odd mode approximatively determined by the stepped-impedance microstrip line and two even modes flexibly controlled by the loaded stubs. Either of the SIRs in this filter can not only separately generate one passband but also control the passband performance. Due to the intrinsic characteristics of the SIR, four transmission zeros can be created to improve the selectivity. A dual-wideband filter with the fractional bandwidth 14.9% for the first band from 3.09 GHz to 3.58 GHz and 10.2% for the second band from 4.99 GHz to 5.53 GHz is designed and fabricated. The filter is evaluated by experiment and simulation with good agreement.

1. INTRODUCTION

Continuous advances in wireless communication require RF-integrated multiple-band transceivers to enable user access to various services. For instance, the global system for mobile communications (GSM) requires an RF transceiver for receiving and transmitting signals at both 900 and 1800 MHz. Similarly, wireless local area networks (WLANs) have standards such as IEEE 802.11b (2.4 GHz) and IEEE 802.11a (5.2 GHz). Therefore, the BPF, as a key component filtering unwanted

Received 17 January 2011, Accepted 9 March 2011, Scheduled 14 March 2011
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frequency in RF systems, is necessary to generating two transmission frequency bands. Thus, they have been extensively investigated, and various design approaches have been proposed. Among them, there are two typical methods. The first approach is to utilize SIRs [1–3], and the two resonant frequencies of which can be controlled by the impedance ratio and electrical length of two sections. However, the bandwidths of dual bands can hardly be individually met. The second one is to combine two sets of independent resonators with common input/output ports [4–8]. The dual-band BPFs that have features of compactness, good passband/out-of-band performances and operating band selectivity have been developed via two dual-mode resonators such as microstrip patches and square loops with perturbations [5–8]. Most of the aforementioned filters are basically appropriate for the design of narrow band (e.g., less than 10%), and only provide a very limited range of frequency ratio of the two passbands. However, a continuing challenge is designing dual-band filters with wide bandwidth, arbitrary frequency ratio and a compact size. In [9], a dual-wideband BPF is presented using short-circuited stepped-impedance resonators. Both dual-band performance and compact size are achieved by using dual-band SIRs instead of conventional single-band quarter-wavelength shorted stubs. But the selectivity needs to be improved.

In this letter, a stub-loaded triple-mode SIR is proposed to design a novel high selectivity dual-wideband microstrip BPF shown in Figure 1. Either of the SIRs can not only separately generate one passband but also control the passband performance. Due to the intrinsic characteristics of the SIR, four transmission zeros can be generated to improve the selectivity. One filter prototype with the fractional bandwidth 14.9% for the first band from 3.09 GHz to 3.58 GHz and 10.2% for the second band from 4.99 GHz to 5.53 GHz is designed, fabricated and measured, and the good agreement between the simulated and measured results demonstrates our proposed structure.

2. THE STUB-LOADED TRIPLE-MODE RESONATOR

The stub-loaded triple-mode resonator configured by adding one T-type open stub at the center plane and two identical short-circuited stubs symmetrically to the open microstrip line is illustrated in Figure 2(a). Since the resonator is symmetrical to the T-T' plane, the odd-even-mode method is implemented. Voltage and current vanishes in the impedance-stepped open stub, leading to the approximate transmission line circuit models represented in Figures 2(b) and (c).

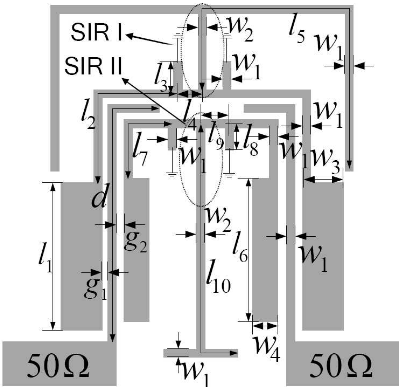


Figure 1. Schematic of the proposed dual-wideband BPF.

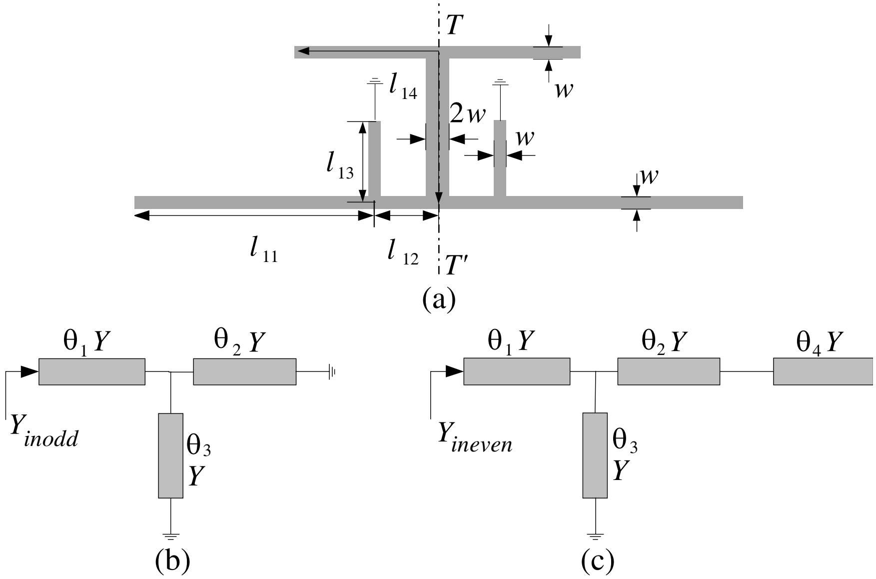


Figure 2. (a) Structure of the stub-loaded triple-mode resonator. (b) Odd-mode equivalent circuit. (c) Even-mode equivalent circuit.

θ_1, θ_2, θ_3 and θ_4 refer to the electrical lengths of the sections with lengths l_{11}, l_{12}, l_{13} and l_{14}, respectively. And Y refers to characteristic admittance of the width w. From the condition $Y_{inodd} = 0$ and $Y_{ineven} = 0$, the resonant frequencies of the odd excitation in

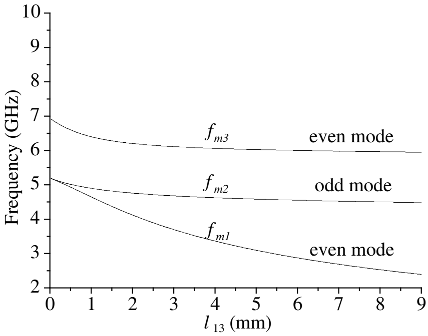


Figure 3. Resonant-mode frequencies with varied l_{13}.

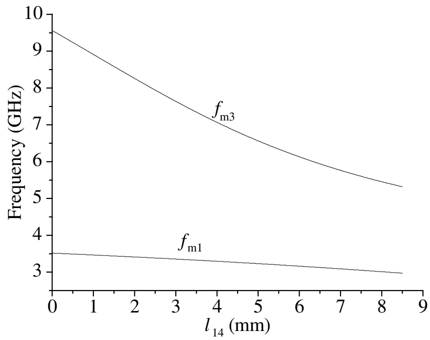


Figure 4. Even mode resonant frequencies with varied l_{14}.

Figure 2(b) and even excitation in Figure 2(c) can be extracted [10]:

$$\tan\theta_1 \tan\theta_2 \tan\theta_3 - \tan\theta - \tan\theta_3 = 0 \tag{1}$$

$$\tan\theta_1 \tan\theta_3 + \tan(\theta_2 + \theta_4) \tan\theta_3 - 1 = 0 \tag{2}$$

The identical short-circuited stubs can be applied to push one resonant mode to the desired passband [11]. According to the formulas (1) and (2), the specific effect of the length l_{13} is investigated and the resonant-mode frequencies with varied l_{13} are shown in Figure 3. The dimensions of the resonator herein are chosen as: $l_{11} = 10.95$ mm, $l_{12} = 1.95$ mm, $l_{14} = 6.15$ mm and $w = 0.3$ mm. It can be seen that there are one odd mode and two even modes in the range of 0.1–10 GHz. As the length l_{13} increases from 0.1 mm to 9 mm, the even mode resonant frequency f_{m1} moves towards the lower frequency, whereas the f_{m2} and f_{m3} merely have smaller change. Therefore, the short-circuited stubs can be mainly applied to adjust the resonant frequency f_{m1} and have less impact on the f_{m2}, f_{m3}. Under the other parameters keeping unchanged, the even mode resonant frequencies varied l_{14} are interpreted in Figure 4, where l_{13} is equal to 4.8 mm, for the reason that the T-type open stub at the center plane merely controls the even-mode resonant frequencies [10–12, 14]. As the length l_{14} increases from 0.1 mm to 8.5 mm, the even-mode resonant frequency f_{m3} shifts towards the lower frequency and the f_{m1} relatively remains stationary.

According to Figure 3 and Figure 4, the odd-mode resonant frequency f_{m2} can be allocated in the center frequency of the passband by reasonably choosing the lengths l_{11} and l_{12}. And the even-mode resonant frequencies f_{m1} and f_{m3} can be adjusted within the desired passband by simply varying the lengths l_{13} and l_{14}, respectively.

3. HIGH SELECTIVITY DUAL-WIDEBAND MICROSTRIP BPF

The stub-loaded triple-mode SIR in this letter is configured by adding one T-type open stub at the center plane and two identical short-circuited stubs symmetrically to the stepped-impedance open microstrip line instead of the open microstrip line, which can obtain compact size by the impedance ratio [12]. The dual-wideband microstrip BPF shown in Figure 1 is proposed using two stub-loaded triple-mode SIRs which are same type but different size.

We assume that f_{1ea}, f_{2oa} and f_{3ea} are the first (even mode), second (odd mode) and third (even mode) resonant frequencies of the SIR I with bigger size shown in Figure 1, respectively. And f_{1eb}, f_{2ob} and f_{3eb} are the first (even mode), second (odd mode) and third (even mode) ones of the SIR II. The signal is coupled to two resonators at the same time, providing two main paths for the signal between the source and load. No coupling between SIR I and SIR II [4] is introduced. Therefore, the frequencies f_{2oa} and f_{2ob} can be separately allocated in the center frequencies of the first and second passbands by reasonably choosing the parameters of the stepped-impedance open microstrip lines. Then first and third resonant frequencies of the SIR I and SIR II can be adjusted to the first and second passbands by simply varying the lengths of the loaded short-circuited stubs and T-type stepped impedance stubs, respectively.

As explained in [13] and [14], two transmission zeros can be obtained near the passband edge, due to the frequencies of the two even modes, which are higher and lower than that of the odd mode, respectively. As a result of the two even mode frequencies f_{1ea} and f_{1eb} lower than the two ones f_{3ea} and f_{3eb}, the T-type open stubs of the SIR I and SIR II are used to produce the transmission zeros T_{z2} and T_{z4} near the lower cut-off frequencies of the dual passbands, and the location of the transmission zeros T_{z1} and T_{z3} near the upper cut-off frequencies are mainly controlled by the short-circuited stubs. So the two SIRs may determine the locations of two transmission zeros near the passband controlled by themselves, respectively.

Table 1. Dimensions of two stub-loaded triple-mode SIRs (UNIT: mm).

stub-loaded triple-mode SIR I						stub-loaded triple-mode SIR II			
l_1	5.2 mm	l_4	0.85 mm	w_2	0.3 mm	l_6	5.0 mm	l_9	0.85 mm
l_2	5.9 mm	l_5	13.7 mm	w_3	1.5 mm	l_7	3.25 mm	l_{10}	9.3 mm
l_3	1.3 mm	w_1	0.3 mm			l_8	0.85 mm	w_4	0.9 mm

4. EXPERIMENTAL RESULTS

After simulation and optimization by HFSS, a high selectivity dual-wideband microstrip BPF with two stub-loaded triple-mode SIRs is fabricated on the RT/Duroid 5880 substrate and its photograph is shown in Figure 5. The fabricated dimensions of two stub-loaded triple-mode SIRs are listed in Table 1. Other geometrical parameters of the dual-wideband filter are $d = 9.8\,\mathrm{mm}$, $g_1 = 0.16\,\mathrm{mm}$ and $g_2 = 0.3\,\mathrm{mm}$. The filtering performance is measured by Agilent network analyzer N5230A. The measured $|S_{11}|$ in dB and $|S_{21}|$ in dB are shown in Figure 6 and illustrated good agreement with simulated results. In the dual passbands, the fractional bandwidths are about 14.9% for the first band from 3.09 GHz to 3.58 GHz and 10.2% for the second band from 4.99 GHz to 5.53 GHz, with measured minimum insertion

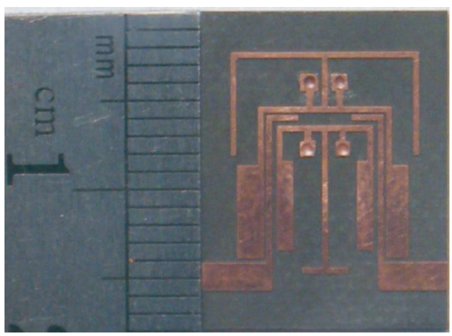
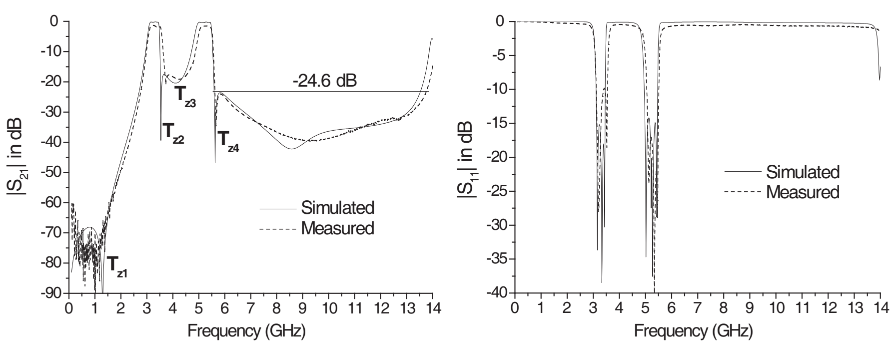


Figure 5. Photograph of the implemented dual-wideband BPF.



(a) (b)

Figure 6. Simulated and measured frequency responses of the dual-wideband BPF with high selectivity. (a) $|S_{21}|$ in dB and (b) $|S_{11}|$ in dB.

losses are −3 dB and the passband return loss better than −9.8 dB. Two transmission zeros T_{z1} and T_{z4} are located at 1.24 GHz and 5.51 GHz with an attenuation level of less than −48 dB, resulting in sharp lower skirt of first passband and upper skirt of second passband. Two additional transmission zeros T_{z2} and T_{z3} located at 3.46 GHz and 3.74 GHz are generated to improve the isolation between the dual passbands. The upper-stopband in experiment is extended up to 13.58 GHz with an insertion loss better than −24.6 dB.

5. CONCLUSION

In this letter, a novel high selectivity dual-wideband microstrip BPF with four transmissions zeros is proposed using two stub-loaded triple-mode stepped-impedance resonators (SIR) which are same type but different size. The SIR can generate one odd mode approximatively determined by the stepped-impedance microstrip line and two even modes flexibly controlled by the loaded stubs. Either of the SIRs can not only separately generate one passband but also control the passband performance. Finally, a dual-wideband filter with the fractional bandwidth 14.9% for the first band from 3.09 GHz to 3.58 GHz and 10.2% for the second band from 4.99 GHz to 5.53 GHz is simulated, fabricated and measured. The measured results agree well with the EM simulations.

ACKNOWLEDGMENT

This work was supported by the Funding of Jiangsu Innovation Program for Graduate Education (No. CX10109Z) and Funding for Outstanding Doctoral Dissertation in NUAA (No. BCXJ10-06).

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