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COMPACT DUAL-BAND BANDPASS FILTER USING FOLDED SIR WITH TWO STUBS FOR WLAN

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Abstract—A novel compact dual-band bandpass filter using tri-section stepped impedance resonators (SIRs) is presented for Wireless Local Area Network (WLAN). SIRs and one stub between parallel couple line are employed to realize two satisfactory passbands. Meanwhile, one transmission zero is generated between the two passbands to achieve a high out-of-band rejection. Simulated results show that two central frequencies are located at desired 2.4 and 5.2 GHz with 3 dB fractional bandwidths of 6.3% and 3.4% respectively. The measured results are in good agreement with the simulated ones.

1. INTRODUCTION

With the rapid development of wireless communication systems, there have been increasing demands for dual-band radio frequency (RF) devices. Dual-band bandpass filters are the essential components in the RF front ends of both receiver and transmitter. Compact size, low losses, high selectivity, low cost, and high performance bandpass filters are the goals for modern wireless communication applications. In response to this need, many methods used to realize the dual-band filter have been investigated. The traditional methods include: a wide-band bandpass filter and a bandstop filter cascaded [1] and two different filters set in parallel [2]. However, these solutions suffer from large overall sizes. Other methods contain utilizing SIRs to shift the spurious frequencies of the SIRs to create the second passband [3–12]. However, it is difficult to control the passbands individually by

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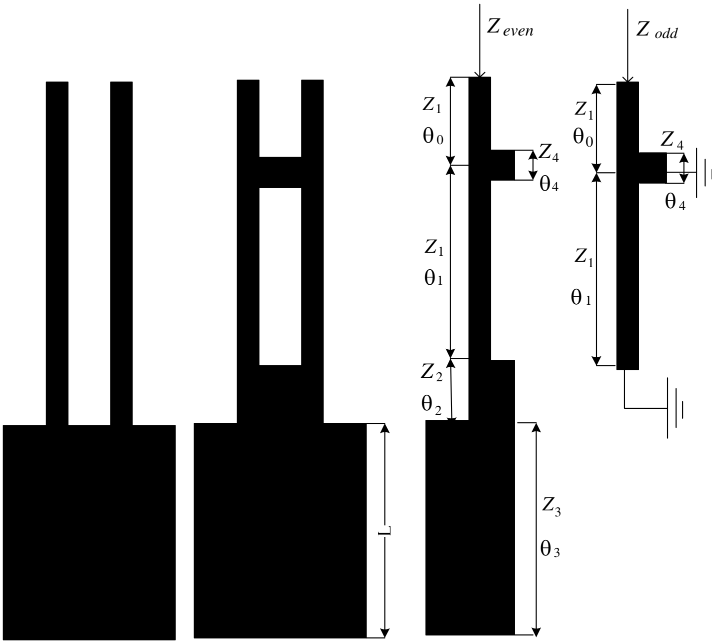
using SIR, since the dual passbands response is synthesized by the two resonator responses synchronously. In [13–17] although these filters have high selectivity and low losses, the design procedure is complex.

To solve these problems, in this paper we propose a novel compact structure of 2.4/5.2 GHz dual-band filters by cascading two folded SIRs for WLAN applications. The proposed filter is simple in structure and compact in size. In particular, one transmission zero can increase the isolation between two separate passbands, and can reduce image signals from the receiver link. Simulated and measured results are presented to prove the feasibility of this design method.

2. FILTER DESIGN

The traditional folded half-wavelength SIR is shown in Fig. 1(a) and the Proposed tri-section folded SIR is in Fig. 1(b). From Fig. 1(b) we can see a half wavelength folded SIR is a dual-mode resonator, which



(a) (b) (c)

Figure 1. (a) Traditional folded stepped impedance resonator. (b) Proposed tri-section folded stepped impedance resonator. (c) Structure of odd-even modes.

can motivate odd mode and even mode. Fig. 1(c) shows the structure of even-odd mode.

Ignoring the impact of step discontinuity and open-edge capacitance, when even mode motivates, the input admittance is given below:

$$Y_{even} = j\frac{\dfrac{\tan\theta_4}{Z_1Z_2}-\dfrac{\tan\theta_3+K_1\tan\theta_2+K_1K_2\tan\theta_1-K_2\tan\theta_1\tan\theta_2\tan\theta_3}{Z_1Z_2\left(-K_1+\tan\theta_2\tan\theta_3+\frac{\tan\theta_1(\tan\theta_3+K_1\tan\theta_2)}{K_2}\right)}+\dfrac{\tan\theta_0}{Z_1^2}}{\dfrac{1}{Z_1}-\left(\dfrac{\tan\theta_4}{Z_4}-\dfrac{\tan\theta_3+K_1\tan\theta_2+K_1K_2\tan\theta_1-K_2\tan\theta_1\tan\theta_2\tan\theta_3}{Z_2\left(-K_1+\tan\theta_2\tan\theta_3+\frac{\tan\theta_1(\tan\theta_3+K_1\tan\theta_2)}{K_2}\right)}\right)\tan\theta_0} \tag{1}$$

With three sections of the SIR assumed to have the same electric length (i.e., $\theta_1 = \theta_2 = \theta_3 = \theta$), then the parallel resonance conditions can be written:

$$\begin{aligned}&(K_3\tan\theta_4 + K_2\tan\theta_0)(K_2\tan\theta^3 + (1 + K_1 + K_2)\tan\theta^2\\&-K_1(1 + K_2)\tan\theta - K_1K_2) = 0\end{aligned} \tag{2}$$

where $K_1 = Z_3/Z_2$, $K_2 = Z_2/Z_1$ and $K_3 = Z_2/Z_4$ are the impedance ratio. From the formula, we can understand the even mode resonance condition of the SIR depends on θ_0, θ, θ_4 and the impedance ratio K_1, K_2, K_3.

When odd mode motivates, the expression of input admittance can be shown:

$$Y_{odd} = \frac{Z_1\tan\theta_1 + Z_4\tan\theta_4 - Z_4\tan\theta_0\tan\theta_1\tan\theta_4}{jZ_1Z_4\tan\theta_1\tan\theta_4 + jZ_1\tan\theta_0(Z_1\tan\theta_1 + Z_4\tan\theta_4)} \tag{3}$$

So the parallel resonance condition can be given:

$$K_3\tan\theta_1 + K_2\tan\theta_4(1 - \tan\theta_0\tan\theta_1) = 0 \tag{4}$$

From the formula, we know the odd mode resonance condition depend on θ_0, θ_1, θ_4 and the impedance ratio K_2 and K_3.

Figure 2 shows the mode distribution with different length L shown in Fig. 1(b). It can be seen that the odd mode resonant frequencies are scarcely affected by the length L and even mode resonant frequency can be shifted by changing the length L.

The structure of the proposed dual-band bandpass filter is shown in Fig. 3. It mainly consists of two symmetrically folded tri-section SIRs with one stub loaded between parallel couple line. From the above analysis the two center frequencies can be determined by the length L and the impedance ratio K_1, K_2 and K_3 conveniently. The stub is loaded between parallel couple line to improve the performance of passbands, which can be seen from Fig. 3 and Fig. 4. Without A stub the return loss is unsatisfactory at the two passbands. With A stub, the two center frequencies of filter do not change obviously and the performance of filter is improved.

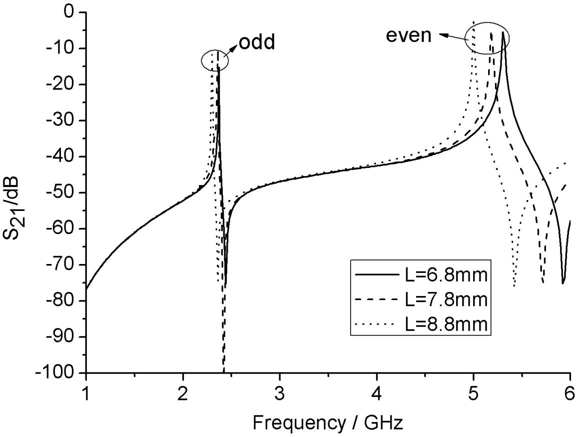


Figure 2. Odd-even modes of folded stepped impedance resonator.

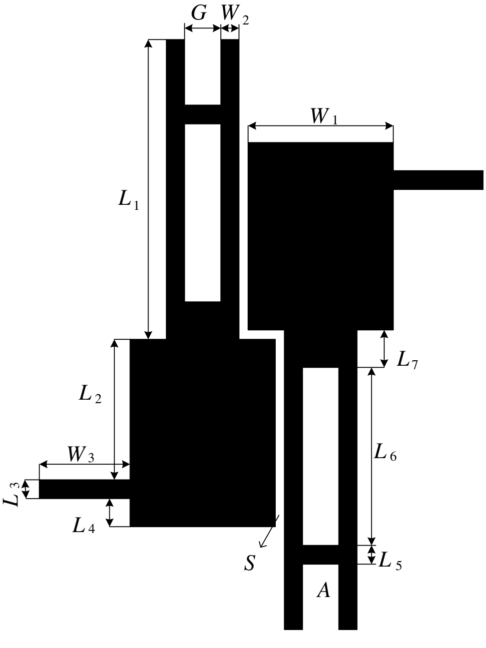


Figure 3. Structure of proposed microstrip filter.

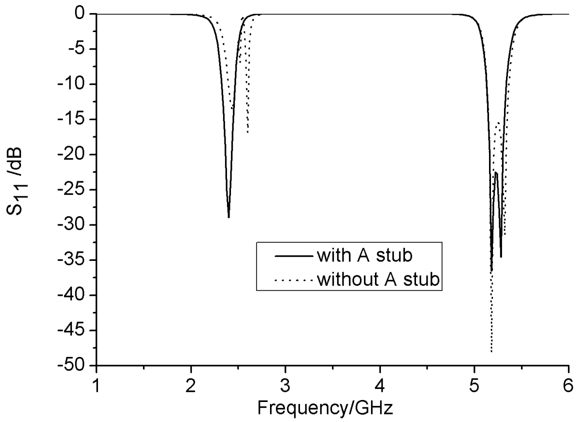


Figure 4. Comparison of with and without A stub.

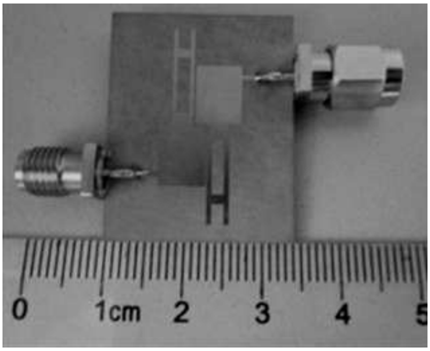


Figure 5. Photograph of fabricated filter.

3. SIMULATED AND MEASURED RESULTS

To verify the above-mentioned analysis, a novel filter is designed and simulated by an EM simulation software, Sonnet. According to the above analysis procedure, the dimensions of the filter are as follows: $W_1 = 6\,\text{mm}$, $W_2 = 0.6\,\text{mm}$, $W_3 = 6.7\,\text{mm}$, $L_1 = 12.8\,\text{mm}$, $L_2 = 6\,\text{mm}$, $L_3 = 0.6\,\text{mm}$, $L_4 = 1.2\,\text{mm}$, $L_5 = 1.2\,\text{mm}$, $L_6 = 7.2\,\text{mm}$, $L_7 = 1.8\,\text{mm}$, $G = 1.6\,\text{mm}$, $S = 0.2\,\text{mm}$. The thickness of the substrate is 0.8 mm, and corresponding relative dielectric constant is 10.2. The overall size of the filter is 24 mm × 30 mm. Fig. 5 shows the photograph of fabricated filter. The simulated and measured responses are compared

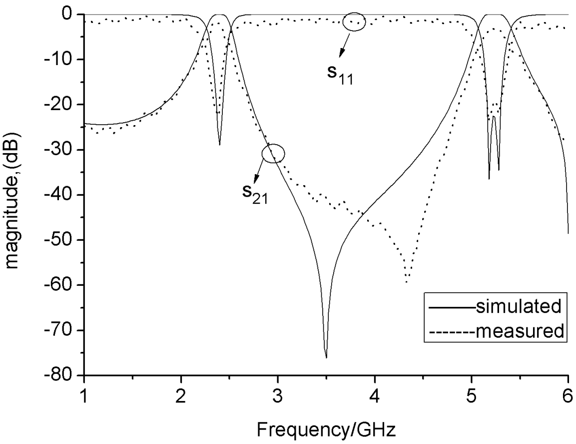


Figure 6. Comparison of simulated and measured frequency responses.

in Fig. 6. The S-parameters are measured by using an Agilent 8722ES vector network analyzer. From Fig. 6 simulated results show that the proposed filter yields two passbands at the centre resonant frequencies of 2.4 and 5.2 GHz, respectively. Additionally, there is one transmission zero located near the passband edges, resulting in sharp roll-off. In the lower passband, the filter has a return loss $>$ 15 dB and the insertion loss is $<$ 3 dB within 2.3–2.45 GHz. In the upper passband, the filter has a return loss $>$ 15 dB and the insertion loss is $<$ 3 dB within 5.14–5.32 GHz. The filter has bandwidth of 6.3% at 2.4 GHz and 3.4% at 5.2 GHz. The insertion loss is mainly attributed to the SMA connector, conductor and dielectric loss. The slight shift of the frequency might be due to the unexpected tolerance of fabrication. Comparison of measured and simulated results shows very good agreement.

4. CONCLUSION

A novel compact dual-band bandpass filter by cascading two folded tri-section SIRs is presented. Two passbands are centred at desired 2.4 and 5.2 GHz, with 3 dB fractional bandwidths of 6.3% and 3.4% respectively. One transmission zero is realized between the two passbands, resulting in high selectivity. Design curves are given for the filter design procedure. An experimental circuit is fabricated and measured to validate the design concept. Measured results show that the proposed filter is suitable for WLAN applications.

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