A Compact Dual-Band Bandpass Filter With Flexible Band Control and Simple Layout

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***Abstract*--A compact-size dual-band bandpass filter (BPF) with flexible band control and simple layout has been proposed in this paper. By employing the distributed coupling technique, each of the passbands can be independently designed based on the coupling coefficients and external quality factors. For a demonstration, a microstrip BPF operating at 0.7 GHz and 0.9 GHz with third-order Chebyshev bandpass response was designed and fabricated. Measured results are found in good agreement with the simulated ones.**

I. INTRODUCTION

In modern multi-service and multi-band communication systems, multiband bandpass filter (BPF) is an important and essential component in the RF/microwave front ends of both the receiver and transmitter. Recently, various design approaches have been reported to develop dual-band BPFs for multi-band communication systems [1]–[5]. However, due to the limited degrees of freedom in the design parameters, the design of dual-band BPFs is still challenging to the designers. Therefore, to overcome the aforementioned issue, a simple and efficient design method for dual-band BPFs is proposed in this work.

II. FILTER DESIGN

Fig. 1(a) shows the coupling structure of the proposed dual-band BPF, where each node represents a resonator. The solid and dashed lines between the nodes represent the coupling paths for lower and higher passbands, respectively. *S* and *L* denote the input and output ports, respectively. As can be seen, the proposed BPF with third-order Chebyshev bandpass response is constructed by six resonators (resonators $R1^{I}$, $R2^{I}$, $R3^{I}$, $R1^{II}$, $R2^{II}$, and $R3^{II}$). Note that, the resonators $R1^{I}$, $R2^{I}$, and $R3^{I}$ should be designed to resonance at the center frequency of the lower passband; whereas, the other resonators $R1^{II}$, $R2^{II}$, and $R3^{II}$ should be designed to resonance at the center frequency of the higher passband. Since the lower and higher passbands can be realized by the two independent coupling paths, the degrees of freedom in extracting the design parameters, i.e., coupling coefficients and external quality factors, are then increased. As compared to the traditional dual-band BPF in Fig. 1(b), the proposed one saves two complex three-pole matching networks, leading to a smaller circuit size.

For demonstration, a third-order Chebyshev dual-band BPF with a passband ripple of 0.04321 dB was designed and fabricated with microstrip technology. A Rogers RO4003 substrate with a thickness of 60 mil, permittivity of 3.38, and

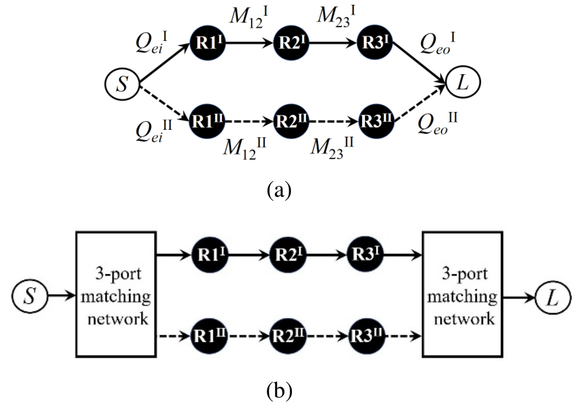

Fig. 1. Coupling structure. (a) Proposed and (b) traditional dual-band BPFs.

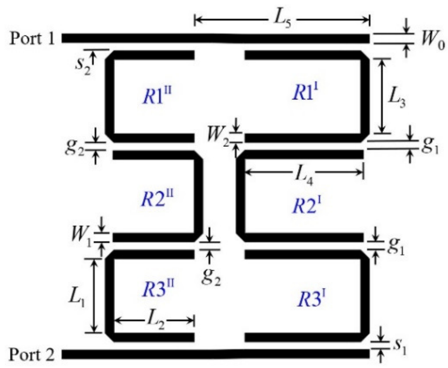

Fig. 2. Layout of the dual-band BPF.

loss tangent of 0.0027 is selected for the filter design. The design specification of the BPF is listed in Table I. Shown in Fig. 2 is the schematic layout of the dual-band BPF. Here, the half-wavelength uniform impedance resonators are used to build the BPF for compact size and simple structure. By employing the distributed coupling technique, the loading effect is very small, and thus the two passbands can be designed independently. It means that the passband control for the proposed dual-band BPF is very flexible.

To determine the physical dimensions of the BPF, the design procedure based on coupling coefficient and external quality factor is used [6]. When the fractional bandwidth (Δ) and frequency response are given, the required coupling coefficients and external quality factors can then be calculated as

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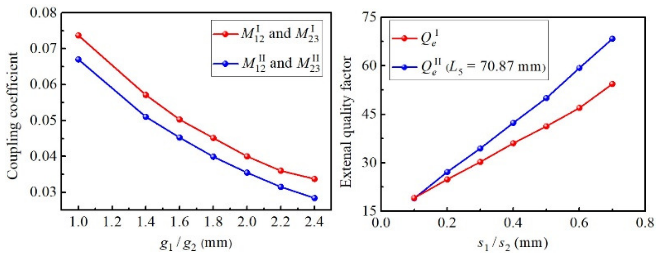
TABLE I
SPECIFICATION OF THE DUAL-BAND BPF

	Band I	Band II
Filter order	3	3
Center frequency (GHz)	0.7	0.9
Fractional bandwidth (%)	3.5	3



(a) (b)

Fig. 3. Design curves. (a) Coupling coefficient and (b) external quality factor.

$$M_{12}^{I} = M_{23}^{I} = \frac{\Delta_1}{\sqrt{g_1 g_2}} = 0.036 \quad (1)$$

$$M_{12}^{II} = M_{23}^{II} = \frac{\Delta_2}{\sqrt{g_1 g_2}} = 0.031 \quad (2)$$

$$Q_{ei}^{I} = Q_{eo}^{I} = \frac{g_0 g_1}{\Delta_1} = 26.8 \quad (3)$$

$$Q_{ei}^{II} = Q_{eo}^{II} = \frac{g_0 g_1}{\Delta_2} = 31.3 \quad (4)$$

where the g-values denote the lumped circuit element values of the low-pass prototype filter. As two synchronously tuned coupled resonators are in close proximity, the coupling coefficients can be evaluated from the two dominant resonant frequencies, i.e., f_{p1} and f_{p2}. The coupling coefficient can be obtained by

$$M_{ij} = \frac{f_{p2}^2 - f_{p1}^2}{f_{p2}^2 + f_{p1}^2} \quad (5)$$

where M_{ij} represents the coupling coefficient between resonators i and j. In addition, the external quality factor can be characterized by

$$Q_e = \frac{f_0}{\delta f_{3-dB}} \quad (6)$$

where f_0 and $\delta f_{3\text{-}dB}$ represent the resonant frequency and the 3-dB bandwidth of the I/O resonator. The design curves for coupling coefficients and external quality factors are plotted in Fig. 3(a) and (b), respectively. According to these design curves, the physical dimensions of the BPF can be easily determined.

Realizable physical dimensions of the dual-band BPF are as follows: L_1 = 30 mm, L_2 = 32.83 mm, L_3 = 30 mm, L_4 = 47.77 mm, L_5 = 70.87 mm, s_1 = 0.1 mm, s_2 = 0.15 mm, g_1 = 2.15 mm, g_2 = 2.27 mm, W_0 = 3.53 mm, and W_0 = W_1 = W_2 = 3.53 mm. The overall size of the dual-band BPF is 155 mm by 122.74 mm, i.e., about 0.59 λ_g by 0.47 λ_g, where λ_g is the guided wavelength at 0.7 GHz.

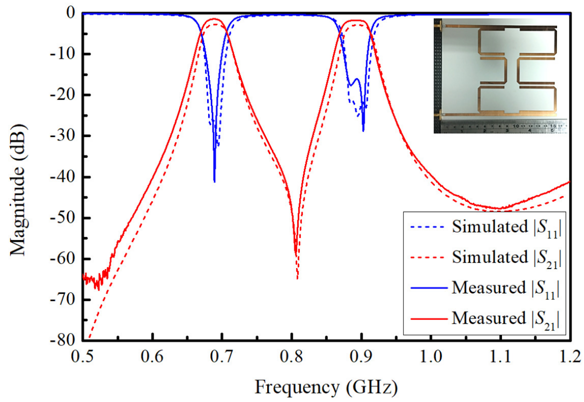


Fig. 4. Measured and EM simulated *S*-parameters of the dual-band BPF.

III. SIMULATION AND MEASUREMENT

The EM simulated and measured results of the dual-band BPF is shown in Fig. 4. Measurement was carried out using an Agilent N5230A network analyzer. It can be seen that good agreement is achieved between the simulation and measurement. The measured in-band return loss is better than 15 dB and the measured insertion losses at 0.7 GHz and 0.9 GHz are 1.41 dB and 1.77 dB, respectively. Note that the insertion loss is mainly attributed to the conductor loss.

IV. CONCLUSION

In this paper, a simple and effect design method for dual-band BPF has been proposed. The introduction of two independent coupling paths leads to more flexibility in the passband control. For demonstration, a dual-band BPF is designed and fabricated in microstrip technology. The results show that the proposed dual-band BPF has advantages of compact size, simple layout, and flexible band control. Thus, it can be believed that this BPF can be used in many applications, such as dual-band communications.

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