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DUAL-BAND BANDPASS FILTER WITH CONTROLLABLE CHARACTERISTICS USING STUB-LOADED RESONATORS

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Abstract—A compact microstrip-line dual-band bandpass filter with controllable characteristics is presented using a stub-loaded resonator. The resonator is formed by loading one open circuit terminated stub in shunt to a simple uniform impedance line. The passband frequencies of the dual-band filter can be conveniently controlled by tuning the lengths of stub-loaded resonators. The bandwidth of the first passband can be controlled by tuning the parameters of center stub-loaded resonator, and the bandwidth of the second passband is determined by the coupling between the sideward stub-loaded resonators. To illustrate the concept, a second-order dual-band filter is designed, fabricated and measured. Simulated and measured results are found in good agreement with each other.

1. INTRODUCTION

In modern wireless communication systems, the dual-band bandpass filter has become one of the most important circuit components [1], and many researches regarding them have been carried out. Lately, it is popular to design the dual-band filters using stub-loaded resonators and stepped impedance resonators [2–20], mainly because of their easily controlled resonant frequencies.

The dual-band filters were designed using stub-loaded resonators proposed in [2–4], the crossed resonators were presented to design the compact tri-band filters in [5]. However, the bandwidths of these

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multiband filters couldn't be controlled independently. The dual-band filters with controllable bandwidths were designed using the stub loaded resonators presented in [6, 7], but the bandwidths of two passbands were hardly controlled independently, as the second passband bandwidth was affected by two coupling paths.

In this paper, a second-order dual-band filter with independently controllable bandwidths is proposed. The filter utilizes three stub-loaded resonators (two sideward resonators and one center resonator) and the passband frequencies can be easily tuned. The center stub-loaded resonator works as a K-inverter between the sideward stub-loaded resonators. Two coupling routes are utilized. One route delivers only the signals at the lower passband frequency and the other route is able to transfer signals at the upper passband frequency. By properly tuning the coupling strength at each route, the desirable bandwidths of both passbands can be obtained. Based on the concept, a second-order dual-band filter is implemented. The design methodology and experimental results are presented.

2. DUAL-BAND BANDPASS FILTER DESIGN

As shown in Figure 1, the second-order bandpass filter that employs the open circuit terminated stub inverter is composed of two quarter-wavelength resonators. The resonators need not be shorted to ground, because the tapped open circuit terminated stub replaces the stub shorted to the ground [8]. The bandwidth of the filter can be changed by tuning the length of the open circuit terminated stub (L_1). Figure 1 also shows the simulated insertion loss responses under different L_1, and the bandwidth can be adjusted effectively by tuning L_1, meanwhile the port coupling should be changed to accommodate the bandwidth.

To obtain a dual-passband response, a stub-loaded resonator

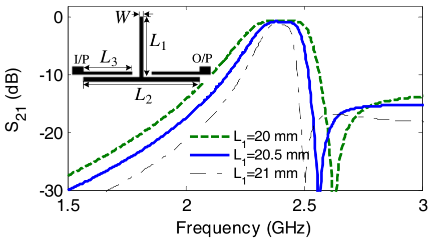

Figure 1. Simulated S_{21} responses of the bandpass filter using $\lambda/4$ resonators with open circuit terminated stub inverter under differentL_1. $L_2 = 41.8$, $L_3 = 13.7$, $W = 1$, all are in millimeter.

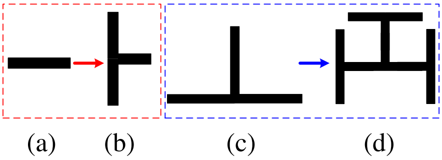

Figure 2. Resonator transformation.

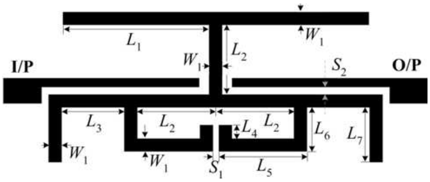

Figure 3. Layout of the proposed dual-band filter.

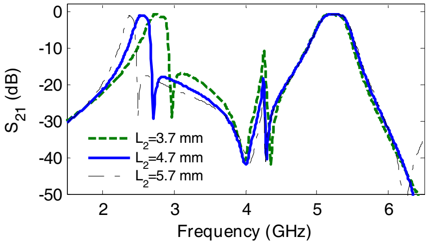

Figure 4. Simulated S_{21} responses of the dual-band bandpass filter under different L_2.

(Figure 2(b)) is introduced to replace the $\lambda/4$ resonator (Figure 2(a)). The stub is loaded at the center of the uniform impedance line. So the configuration in Figure 1 (or Figure 2(c)) can be transferred to the new structure shown in Figure 2(d).

The first two resonant frequencies of the stub-loaded resonators (f_1, f_2) can be designed to be the lower and upper passband frequencies of the dual-band filter. The resonator is symmetrical and thus odd- and even-mode analysis can be used to characterize it. Following the analysis in [2], it is found that f_2 is only determined by the uniform-impedance line and the stub only affects f_1.

Figure 3 shows the configuration of the dual-band bandpass filter. The filter utilizes three open circuit terminated stub-loaded resonators as illustrated in Figure 2(c). The center stub-loaded resonator works as a K-inverter between the two sideward stub-loaded resonators. The sideward stub-loaded resonators are meandered properly to obtain an additional coupling section.

The dual-band filter is to be designed on a substrate with dielectric constant $\varepsilon_r = 2.55$, loss tangent $\delta = 0.0029$, and thickness $h = 0.8\,\mathrm{mm}$. Let the designed frequencies be at 2.4 and 5.25 GHz. The starting dimensions of the dual-band filter can be obtained from the passband frequencies, the length of the uniform impedance line is determined by f_2, and the length of the stub (L_2) is determined by f_1, the optimized parameters of the filter are: $L_1 = 11.6$, $L_3 = 5$, $L_4 = 1$, $L_5 = 7.1$, $L_6 = 3.3$, $L_7 = 4.4$, $S_2 = 0.2$, $W_1 = 1$, all are in millimeter.

As shown in Figure 4, by changing the stub length L_2, the first passband frequency can be shifted within a wide range, whereas the second passband characteristics are fixed. As depicted in Figure 1, the required bandwidth of the first passband is mainly determined by the center stub-loaded resonator (L_1, L_2), and the bandwidth of the second passband is dominated by the coupling between the uniform-impedance line (S_1). To verify the above analysis, different coupling parameters are presented for demonstration. When S_1 varies from 0.1 mm to 0.5 mm (all the other parameters are fixed), the bandwidth of the second passband decreases obviously, while the characteristics of the first passband keep fixed, as shown in Figure 5.

According to the discussion, the design procedure of this kind of dual-band filter can be summarized as follows. Firstly, deduce the length of the uniform impedance resonator according to the second passband frequency (f_2). Secondly, deduce the length of the stub according to the first passband frequency (f_1). Thirdly, tune the coupling between the uniform impedance resonators (S_1) to satisfy the bandwidth of the second passband. Fourthly, tune the parameters of the center stub-loaded resonator to satisfy the bandwidth of the first passband. Based on this procedure, a compact dual-band filter of second-order is designed in the next section.

3. SIMULATION AND MEASUREMENT RESULTS

A dual-band filter with second-order Chebyshev frequency response and 0.1-dB ripple level is designed with the following specifications: the center frequencies of the two bands (f_1, f_2) are 2.4, 5.25 GHz. The fractional bandwidths are 0.015 and 0.04, respectively. The main physical parameters of the filter have been obtained in the previous Section. The coupling space between the uniform impedance lines should be determined firstly according to the bandwidth of the second passband. $S_1 = 0.2$ mm can be obtained quickly using full wave simulations. Then determine the parameters of the center stub-loaded resonator according to the bandwidth of the first passband. The optimized parameters of the dual-band filter are: $L_1 = 11.6$, $L_2 = 5.6$, $L_3 = 5$, $L_4 = 1$, $L_5 = 7.1$, $L_6 = 3.3$, $L_7 = 4.4$, $S_1 = S_2 = 0.2$, $W_1 = 1$, all are in millimeter.

The measured frequency responses of the proposed dual-band bandpass filter are characterized in HP N5230A vector network analyzer. The size of the filter is about 30 mm × 12 mm. Figure 6 shows the simulated and measured S-parameters. The measured

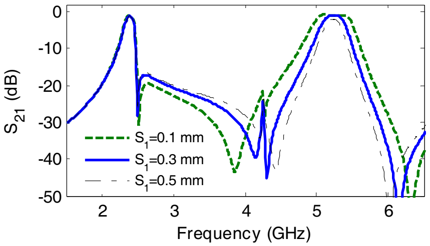

Figure 5. Simulated S_{21} responses of the dual-band bandpass filter under different S_1.

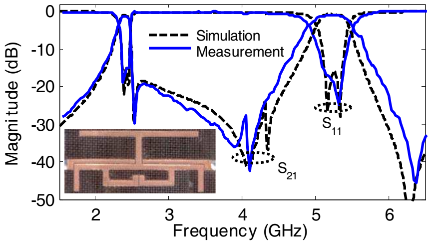

Figure 6. Simulated and measured S-parameters of the dual-band filter.

S-parameters agree well with those obtained from the simulation. As there are two coupling routes between the sideward stub-loaded resonator, transmission zeros in the stopbands can be obtained. The first transmission zero is mainly dominated by the magnetic coupling between the stub-loaded resonator, as shown in Figure 1, and the second transmission zero is mostly determined by the electric coupling between the stub-loaded resonator, as shown in Figure 5. The measured 0.1-dB bandwidths for the two passbands are found to be 2.37 to 2.415 GHz, 5.175 to 5.335 GHz, respectively. The minimum insertion losses measured for the two passbands in the same sequence are 1.18 and 1.03 dB. The two passbands are separated by a 20-dB stopband extended from 2.72 to 4.48 GHz.

4. CONCLUSION

In this paper, a simple microstrip-line dual-band bandpass filter with controllable characteristics is proposed, designed, and implemented based on the stub-loaded resonators. The passband frequencies of the proposed filter are flexibly controlled, and the bandwidth of the second passband can be tuned conveniently by adjusting the coupling between the uniform impedance lines while that of the first passband remains the same. The experimental results have shown that the proposed structure will be useful for dual-band bandpass filter applications of compact size and low loss.

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