A Compact Highly-Selective Planar Triple-band Bandpass Filter

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***Abstract*—This paper present a compact and highly-selective planar triple-band bandpass filter. This filter consists of two pairs of quarter-wavelength short-circuited resonators and a dual-mode resonator. And one pair of short-circuited resonators is embedded in the other pair. The two pairs of short-circuited resonators form the first and second passband, and the dual-mode resonator which used to form the third passband. Moreover, due to the existence of hybrid electromagnetic coupling and source-load coupling, there is a transmission zero on both sides of each passband of the filter. At last, this filter is manufactured and measured, and the mensuration results agree well with the simulation results.**

Keywords—triple-band; bandpass filter; compact; highly-selective.

I. INTRODUCTION

The development trends of modern communication system are large capacity and multi-band. In order to meet the need of multi-band communication system, multi-band bandpass filters are emerging. There are many common methods for designing multi-band bandpass filter: the cascade of band pass filters and band stop filter; the parallel of many different frequency bandpass filters; the use of multi-mode resonator. In [1], a triple-band band-pass filter which with six transmission zeros is designed by paralleling stepped-impedance resonators and dual-mode resonators. In [2], a triple-band band-pass filter is designed by paralleling some step impedance resonators. In [3], a triple-band band-pass filter is designed by utilizing multi modes of the multi-stub-loaded resonator. In [4], a triple-band bandpass filter is designed by using the degenerate mode of three pairs of ring resonator with stub loaded.

In this paper, a compact and highly-selective planar triple-band bandpass filter is proposed. It consists of two pairs of short circuit resonators with a quarter-wavelength and one dual-mode resonator. For better achieve the compact size of this filter, one pair of short-circuited resonators is embedded in the other. Moreover, due to the existence of hybrid electromagnetic coupling and source-load coupling, there is a transmission zero on both sides of each passband of the filter.

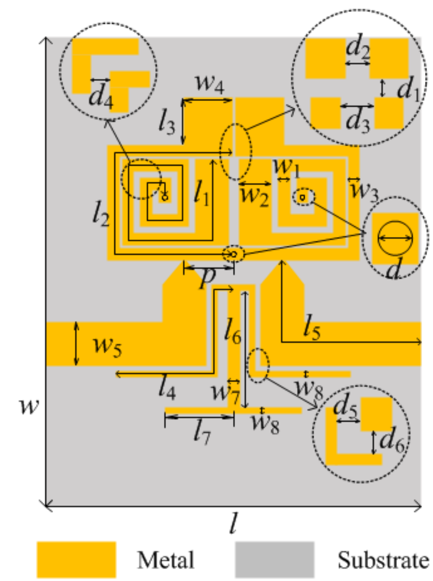


Fig. 1. Geometrical structure of the filter.

II. DESIGN FOR TRIPLE-BAND FILTER

The geometry and some key parameters of this proposed triple-band bandpass filter is show in Fig.1. It consists of two pairs of short-circuited resonators with a quarter wavelength and a dual-mode resonator. In this filter, the two pairs of short-circuited resonators which used to form the first passband and second passband, and the dual-mode resonator form the third passband. In order to better achieve the compact size of filter, a pair of spiral short-circuited resonators is embedded in another pair of short-circuited resonators. This filter is finally finished on a substrate which have a loss tangent of 0.0027, a dielectric constant of 3.38, and a thickness of 1.524 mm.

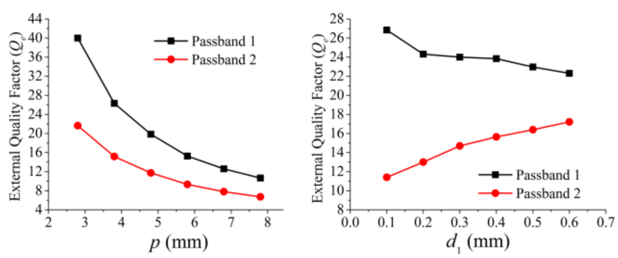
The design process of this triple-band bandpass filter is design a dual-band by short circuit resonator based on the theory of filter synthesis design firstly, and then parallel a dual-mode resonator to form the third passband. In this design, the center frequency of this filter with the first passband, the second passband and the third passband are 1GHz、1.76GHz and 3.10GHz respectively, and the corresponding fractional bandwidth are 5.6%、12.3% and 6.3% respectively. The design of the first and second passbands is based on the Butterworth lowpass filter, and the theoretical external quality factor Q_e and coupling coefficient K is calculated using (1) and (2).

$$Q_e = \frac{g_0 g_1}{\mathrm{FBW}} \tag{1}$$

$$k = \frac{\mathrm{FBW}}{\sqrt{g_1 g_2}} \tag{2}$$

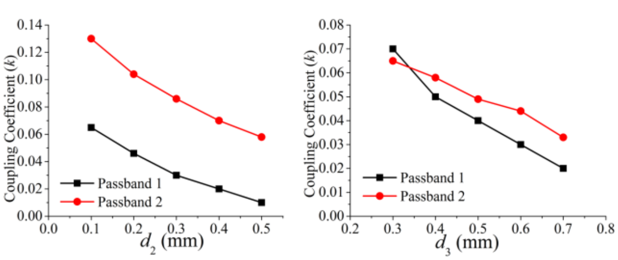
Where g_i (i =0, 1, 2) represents the component parameters in the Butterworth low-pass filter prototype; FBW represents the fractional bandwidth.

According to the method in [5], Q_e and k can be extracted. Fig. 2 and Fig. 3 clearly show the variation of extracted external quality factor and coupling coefficient with other variables. As shown in Fig. 2, the value of Q_e decreases as the value of the parameter p increases; the value of Q_e of the first passband decreases as the value of d_1 increases and the value of Q_e of the second passband increases as the value of d_1 increases. As can be clearly seen from Fig.3, the value of k decreases as the value of d_2 and d_3 increase. By combining the theoretical Q_e and k as well as the curves in Fig. 2 and Fig. 3, the initial values of relevant parameters can be obtained. After the obtained bandpass filter with dual-band, the third passband can be realized by paralleling a dual-mode resonator.



(a) (b)

Fig. 2. Extraction of Qe. (a) Extrated Q_e versus different p. (b) Extrated Q_e versus different d_1.



(a) (b)

Fig. 3. Extraction of coupling coefficient. (a) Extrated k versus different d_2. (b) Extrated k versus different d_3.

III. Simulated and Measured Results

According to the above theoretical data analysis, this proposed band-pass filter with triple-band is simulated and designed with the electromagnetic simulation software CST. The final parameters of optimization are as follows: l = 38.4, l_1 = 35.4, l_2 = 27.7, l_3 = 4, l_4 = 18.2, l_5 = 14.7, l_6 = 9.5, l_7 = 5.6, w = 30.6, w_1 = 1, w_2 = 2.7, w_3 = 1, w_4 = 4, w_5 = 3.6, w_7 = 1, w_8 = 0.5, p = 4, d_1 = 0.2, d_2 = 0.2, $d3$ = 0.8, d_4 = 0.5, d_5 = 0.2, d_6 = 0.4, d = 0.4 (unit： mm). Fig.4 clearly shows the final measured and simulated results. The center frequency of the first passband is 1 GHz, the measured insertion loss with a fractional bandwidth of 5.6% is 0.9 dB; the center frequency of the second passband is 1.76 GHz, the measured insertion loss with a fractional bandwidth of 12.3% is 0.8 dB; the center frequency of the third passband is 3.10 GHz, the measured insertion loss with a fractional bandwidth of 6.3% is 1.8 dB. Moreover, there is a transmission zero on both sides of each pass band of this filter.

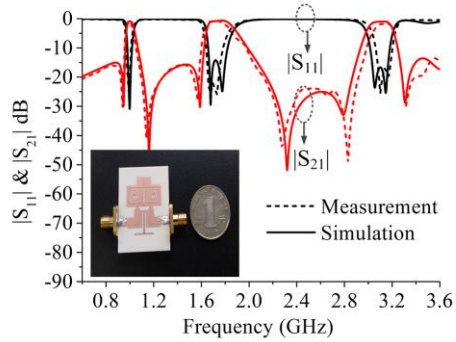


Fig. 4. Simulated and measured results.

IV. Conclusion

In this paper, a compact and highly-selective planar band bandpass filter with triple-band is proposed. The design process of this triple-band bandpass filter is design a dual-band bandpass filter by the theory of filter synthesis design firstly, and then parallel a dual-mode resonator to realize the third passband. At last, this filter is manufactured and measured, and the mensuration results agree well with the simulation results.

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