Progress In Electromagnetics Research Letters, Vol. 38, 17–23, 2013

COMPACT SQUARE DC-BLOCK BANDPASS FILTER WITH SLOTS

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Abstract—A compact square dc-block bandpass filter with slots is presented. The proposed dc-block bandpass filter using square shapes produces compact size and improved performance as compared to the conventional dc-block bandpass filter using cymbal shapes. Two filters with the same dimensions provide different center frequencies respectively. In other words, the center frequency of the square bandpass filter is lower than that of the cymbal bandpass filter. The center frequency and transmission zeros can also be controlled by the slots of the square shape in the proposed square bandpass filter. The proposed square bandpass filter has an insertion loss of better than 2 dB and a return loss better than 10 dB at center frequency of 7.2 GHz. The proposed square dc-block bandpass filter is optimized by electromagnetic simulator IE3D.

1. INTRODUCTION

Recently, microwave components begin to be widely used in wireless communication systems. The dc-block bandpass filter is an important component to block the unwanted microwave frequency causing severe damage and errors to the microwave and millimeter systems. Because the dc-block bandpass filter connects the other components of the wireless system, the size of the filter affects the overall size of the RF and microwave device. Due to the easy analysis and fabrication of the filter, several papers are given with the cymbal bandpass filters [1–11]. The dc-block cymbal bandpass filter is introduced in the paper [3]. For degenerate modes, T-slots and spur-lines on the input and the output feed lines are applied on the cymbal bandpass filter [6, 9]. The equivalent circuit of the cymbal resonator bandpass filters is presented in the paper [11].

Received 1 February 2013, Accepted 25 February 2013, Scheduled 27 February 2013

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In this paper, the square dc-block bandpass filter with slots is introduced with a simple design method. The square dc-block bandpass filter provides size reduction about 13% less than the conventional cymbal dc-block bandpass filter. The proposed bandpass filter also controls the transmission zeros for the wide stopband using slots on the square patches. The width of the slots shifts the center frequency and the length of the slots changes the locations of the transmission zeros in the proposed bandpass filter. The formulated design equations and parameters for the design of the proposed dc-block bandpass filter are given by a full-wave EM simulator (IE3D). The proposed compact square dc-block bandpass filter with slots provides low insertion loss, good return loss and compact size.

2. BANDPASS FILTER DESIGN EQUATIONS

Figure 1 shows the layout of conventional and proposed square bandpass filters [3]. The conventional bandpass filter has two cymbal

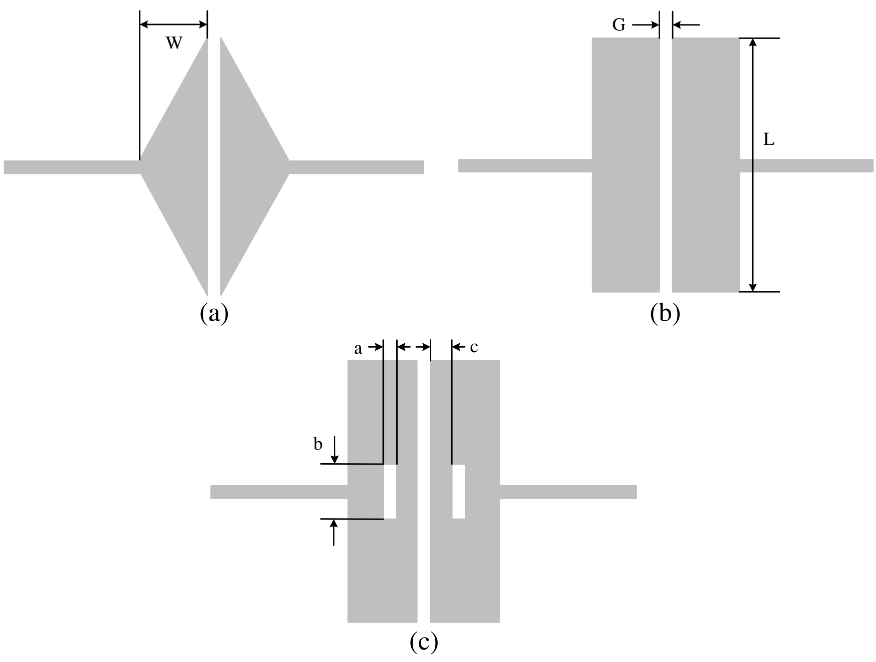


Figure 1. Layout of (a) conventional cymbal dc-block bandpass filter, (b) proposed square dc-block bandpass filter, (c) proposed square dc-block bandpass filter with slots.

shapes connected by cascaded coupling. The proposed bandpass filter has the same overall dimensions except that cymbal shape is changed to square shape. The two filters are designed on a RT/Duriod 6010.5 substrate. It has the dielectric constant of $\varepsilon_r = 10.5$ and thickness of 0.635 mm. The dimensions of the conventional cymbal bandpass filter are optimized to operate at the center frequency of 14.9 GHz using the electromagnetic simulator IE3D. The following design equations are determined by the expressed processes in the paper [3].

$$L \cong 1.29 f \frac{c}{\sqrt{\varepsilon_r}} \tag{1}$$

$$W \cong 5.01 \frac{c}{f\sqrt{\varepsilon_r}} \cong \frac{L}{6.5} \tag{2}$$

$$G \cong \frac{W}{6.2} \tag{3}$$

where ε_r is the dielectric constant, c the speed of light (3×10^8 m/s), and f the resonant frequency. The proposed square bandpass filter without slots is designed with the same dimension as the conventional cymbal bandpass filter. As shown in Figure 2, the two filters have different center frequencies even if they have the same layout. The center frequency of the conventional bandpass filter and proposed bandpass filter are observed at 14.9 GHz and 13 GHz, respectively. It is indicated that the overall size of the proposed square bandpass filter without slots is reduced by about 13% compared to the conventional cymbal bandpass filter.

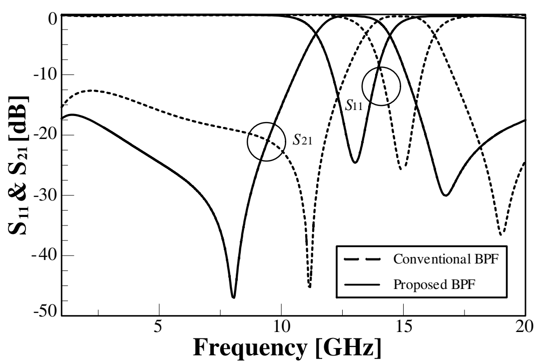


Figure 2. Comparison result of S_{11} between the conventional and square bandpass filter when $L = 8.06$ mm, $W = 1.24$ mm, $G = 0.2$ mm and feed lines (width = 0.56 mm for 50 Ω, length = 4.5 mm).

Consequently, the above equations of the proposed square bandpass filter without slots are changed to

$$L \cong 1.12 f \frac{c}{\sqrt{\varepsilon_r}} \tag{4}$$

$$W \cong 4.35 \frac{c}{f\sqrt{\varepsilon_r}} \cong \frac{L}{5.6} \tag{5}$$

$$G \cong \frac{W}{5.3} \tag{6}$$

In other words, the proposed square dc-block bandpass filter follows the steps from Equation (4) to Equation (6) to determine the dimension of the filter. At first, the length of the filter is determined by the desired frequency and used substrate. Next, the width of the proposed filter is set with the ratio between the length and width. Finally, the coupling gap in the proposed bandpass filter is created with the ratio between the width and the gap.

3. DC-BLOCK BANDPASS FILTER DESIGN WITH SLOTS

As shown in Figure 3, the proposed bandpass filter is designed with slots on the square patches. The slots on the square patches are used to control the center frequency and transmission zeros.

Figure 3 shows the results depending on the width and length of the slots in the proposed bandpass filter. As shown in Figure 3(a),

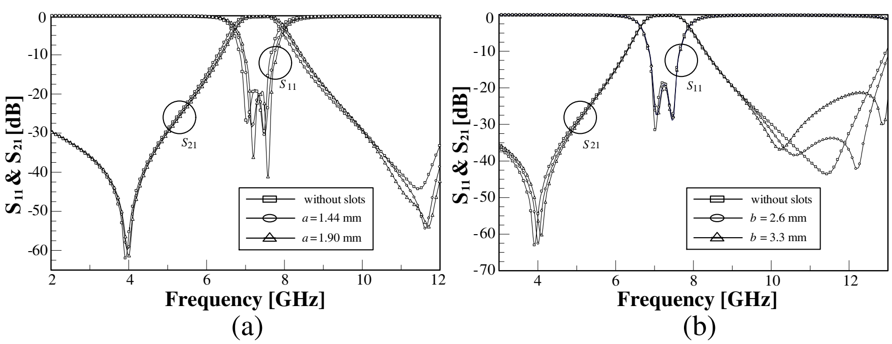
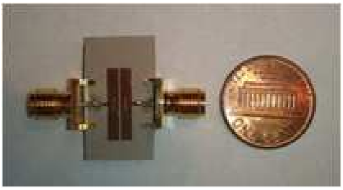
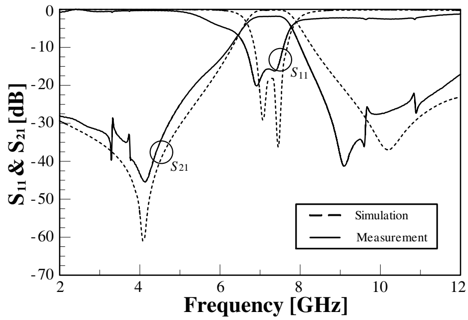


Figure 3. Simulated results for (a) different width with $a = 0.9$ mm, (b) different length with $b = 1.8$ mm when $W = 2.17$ mm, $L = 14.1$ mm, $G = 0.35$ mm and feed lines (width $= 0.56$ mm for $50\,\Omega$ length $= 4.5$ mm).



(a)



(b)

Figure 4. (a) Photograph of the proposed bandpass filter, (b) comparison results between simulation and measurement when $W = 2.17\,\text{mm}$, $L = 14.1\,\text{mm}$, $G = 0.35\,\text{mm}$, $a = 0.18\,\text{mm}$, $b = 2.64\,\text{mm}$, $c = 0.9\,\text{mm}$ and feed lines (width $= 0.56\,\text{mm}$ for $50\,\Omega$, length $= 4.5\,\text{mm}$).

the width of the slots in the proposed bandpass filter did not affect the center frequency considerably. As the width increases, the center frequency is moved slightly to the high frequency. As shown in Figure 3(b), the length of the slots in the proposed bandpass filter changes the transmission zero locations in lower and upper stopband. As the length of the slots increases, the transmission zero locations are moved near the passband. Specifically, one transmission zero in the upper stopband is divided into two transmission zeros causing the wide stopband of the proposed bandpass filter. However, the transmission loss of the proposed dc-block bandpass filter can be worse when the length of the slots increases.

Finally, the proposed dc-block bandpass filter with slots is designed at the center frequency of 7.2 GHz. Figure 4(a) is a photograph of the proposed bandpass filter. Figure 4(b) shows comparison results between simulation and measurement. The measurement results through HP Network Analyzer 8510C show that the proposed bandpass filter has a return loss with 10 dB from 6.6 to 7.6 GHz and a insertion loss with 2 dB from 6.9 GHz to 7.5 GHz at the center frequency 7.2 GHz. The lower and upper transmission zeros of the bandpass filter are provided at 4.1 GHz and 9 GHz. Consequently, the proposed square dc-block bandpass filter with slots provides a compact size, improved performances in return loss, insertion loss, and overall size than the conventional cymbal bandpass filter.

4. CONCLUSION

This paper presents a compact square dc-block bandpass filter with slots. The performance of the proposed dc-block bandpass filter with simple design method and easy fabrication is improved in insertion loss, return loss and overall size. The overall size of the proposed square dc-block bandpass filter is reduced by 13% as compared to the conventional cymbal dc-block bandpass filter. With the insertion of slots, the proposed square dc-block bandpass filter got a wide stopband in the upper stopband. Therefore, the proposed square dc-block bandpass filter with slots can be easily applied to RF/microwave system.

ACKNOWLEDGMENT

The authors would like to thank M. Li of Texas A&M University, College Station, Texas for his technical assistance.

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