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AN ULTRA-WIDEBAND BANDPASS FILTER WITH A NOTCH-BAND AND WIDE STOPBAND USING DUMBBELL STUBS

L. Chen, F. Wei, X.-W. Shi, and C.-J. Gao

National Key Laboratory of Science and Technology
on Antennas and Microwaves
Xidian University
Xi'an, Shaanxi 710071, China

Abstract—In this paper, an ultra-wideband (UWB) bandpass filter (BPF) with a notch-band at 5.8 GHz is presented. The proposed filter is constructed with multiple-mode resonator (MMR) using novel dumbbell stubs and one-arm-folded interdigital coupled lines in the input and output sides. The MMR consists of three pairs of shunt dumbbell stubs and a high impedance microstrip line. By adjusting the dimensions of the dumbbell stubs, the resonant modes of MMR are allocated in the UWB band. The arm-folded interdigital coupled lines are used to obtain a notch-band at 5.8 GHz. Finally, the proposed UWB BPF is fabricated. The simulated and measured results are in good agreement with each other.

1. INTRODUCTION

Since the US Federal Communications Commission (FCC) released ultra-wideband (UWB) spectrum (3.1–10.6 GHz) for unlicensed use in 2002 [1], researchers have paid great attention to the development of UWB bandpass filters (BPFs). Recently, different structures have been developed in the UWB BPFs design [2–14]: multiple-mode resonator (MMR), hybrid microstrip/coplanar-waveguide (CPW), three-line structure and so on. In [4], four filters were designed based on three-line structure. In [5, 6], two filters with a wide passband were designed with MMR and DGS respectively. In [7], a miniaturized filter was designed using folded MMR. But the filters mentioned above have relative narrow stopband and can't suppress the high-order harmonic.

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Corresponding author: L. Chen (chenli_xidian@163.com).

Meanwhile the existing wireless network such as WLAN at 5.8 GHz may interfere with the UWB application, thus it is necessary to develop the UWB BPF with a notch-band at specified frequency.

In this paper, an UWB bandpass filter based on multiple-mode resonator and one-arm-folded interdigital coupled line is proposed. Three dumbbell-shape stubs are in shunt to the high impedance microstrip line so as to form a wide stopband [15]; one arm of the interdigital coupled lines is folded at both sides so as to obtain a notch-band in the specified frequency [16]. The characteristics of this proposed BPF include: 1) a wide passband; 2) good insertion loss in the passband; 3) a notch-band at 5.8 GHz with high insertion loss; 4) a wide and deep upper stopband; 5) steep roll off skirts. Finally, the BPF is fabricated and measured.

2. ANALYSIS AND DESIGN OF THE UWB BPF

The schematic of the proposed filter is depicted in Fig. 1. The filter is simulated using Ansoft HFSS 11.0 software with RT/Duorid 5880 substrate of a relative dielectric constant 2.2 and a thickness 1.02 mm.

Figure 2 shows the geometry and equivalent transmission line model of the conventional MMR. Y_{in} is the input admittance; it can be easily derived as following [3]:

$$Y_{in} = jY_2 \frac{2(R\tan\theta_1 + \tan\theta_2)(R - \tan\theta_1\tan\theta_2)}{R(1-\tan^2\theta_1)(1-\tan^2\theta_2) - 2(1+R^2)\tan\theta_1\tan\theta_2} \quad (1)$$

where $R = Z_2/Z_1$ is the impedance ratio of high- and low-impedance lines. At the resonance frequencies, the input admittance Y_{in} is 0, it is

$$(R\tan\theta_1 + \tan\theta_2)(R - \tan\theta_1\tan\theta_2) = 0 \quad (2)$$

In the analysis for the case of $\theta_1 = \theta_2 = \theta$, the first three resonant modes f_{m1} f_{m2} f_{m3} are allocated in the UWB passband. But the first

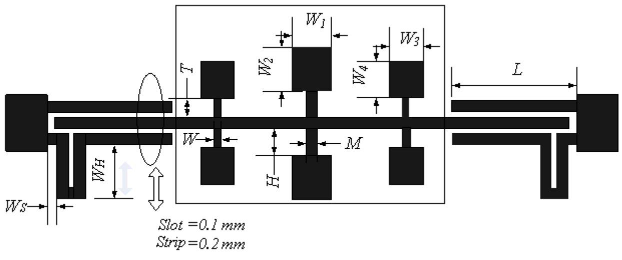


Figure 1. Schematic of the proposed UWB BPF.

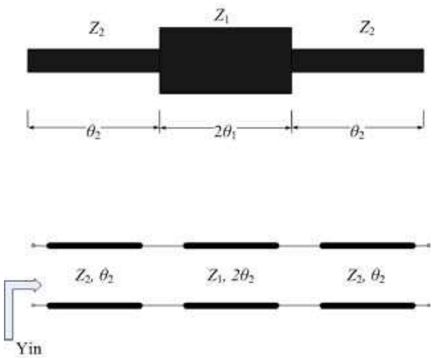


Figure 2. Geometry and the equivalent model of the initial MMR.

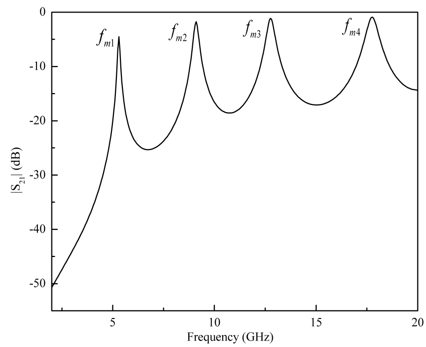


Figure 3. $|S_{21}|$ of the initial MMR.

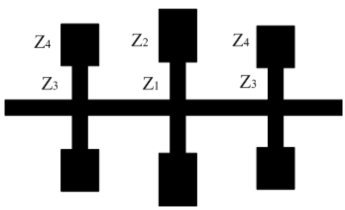


Figure 4. Geometry of the proposed MMR.

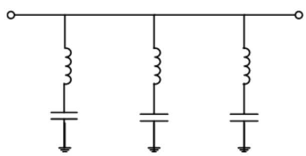


Figure 5. Equivalent circuit model of the proposed MMR.

spurious mode f_{m4} is near the passband so the stopband is narrow as shown in Fig. 3 [3].

In this paper, the proposed MMR consists of a high impedance line and three symmetrical dumbbell stubs as shown in Fig. 4. And the equivalent circuit model is depicted in Fig. 5. By adjusting the dimensions of MMR, the resonant modes $f'_{m1} f'_{m2} f'_{m3} f'_{m4}$ are allocated in the UWB passband. Moreover, spurious harmonics are suppressed in the upper-stopband to realize a wide and deep upper-stopband. As shown in Fig. 6, the proposed MMR has a better upper-stopband performance than the conventional MMR obviously. Using the method discussed in [10], $W = 0.3$ mm, $T = 0.6$ mm, $M = 0.3$ mm, $H = 0.6$ mm, $W_1 = 1.5$ mm, $W_2 = 2.0$ mm, $W_3 = 1.2$ mm, $W_4 = 1.8$ mm and $L = 8.0$ mm are chosen to form a wide passband from 2.8 to 11.2 GHz with a wide and deep stopband. With all the above variables fixed, W_S and W_H are varied to observe the notch-band characteristics.

The equivalent circuit of the folded arm is shown in Fig. 7. By

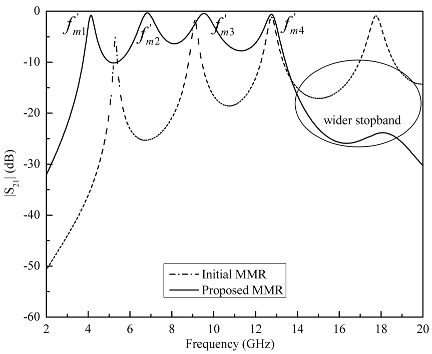


Figure 6. $|S_{21}|$ comparison of initial and proposed MMR.

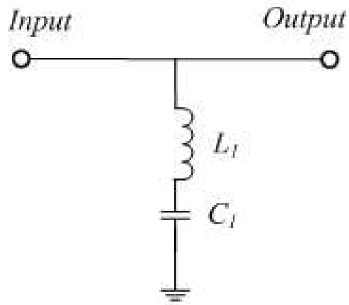
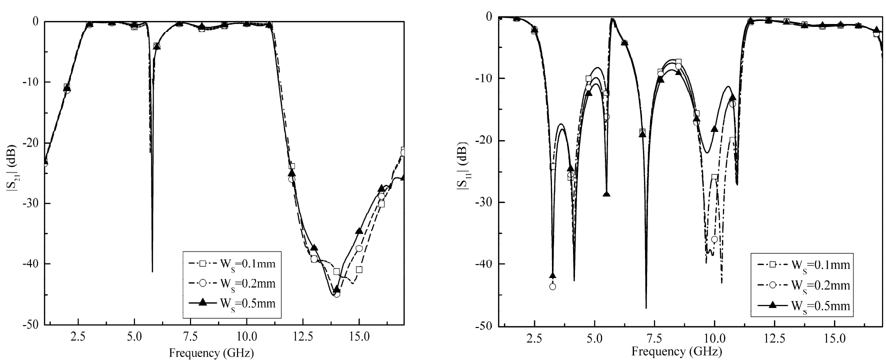


Figure 7. Equivalent circuit of the folded arm.



(a) (b)

Figure 8. (a) $|S_{21}|$ response with varied W_S. (b) $|S_{11}|$ response with varied W_S.

utilizing this folded structure, the notch band is achieved. While W_H is fixed as 3.3 mm, W_S varies from 0.1 mm, 0.2 mm to 0.5 mm. The frequency response is depicted in Figs. 8(a) and (b). It is clear that insertion losses with different W_S are almost the same, but return losses differentiate. To minimize the insertion loss in the passband, $W_S = 0.5$ mm is best in optimization design of such a notch-band filter. The length of the folded arm in interdigital coupled lines, W_H, determines the position of the notch-band. Fixing W_S as 0.5 mm, W_H varies from 3.0 mm, 3.4 mm to 3.8 mm respectively. From the regularity of the insertion loss in Fig. 9, it is found that as W_H increases, the center frequency of notch-band moves towards to lower frequency. When $W_H = 3.4$ mm, a notch-band at 5.8 GHz is just implemented.

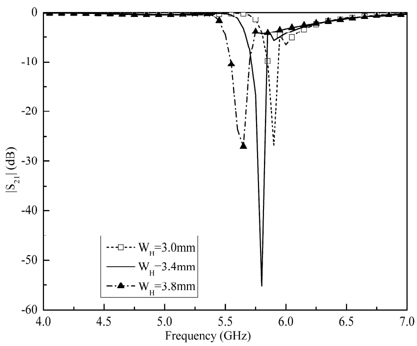


Figure 9. $|S_{21}|$ response with varied W_H.

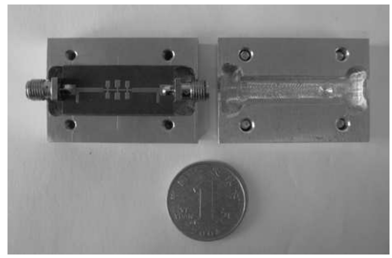


Figure 10. Photograph of the proposed BPF.

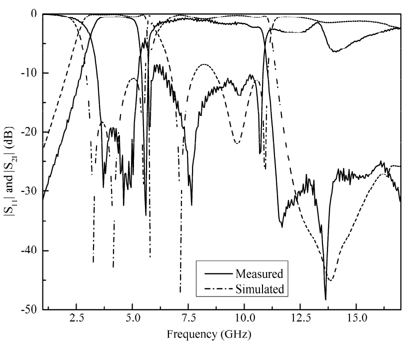


Figure 11. Simulated and measured frequency response.

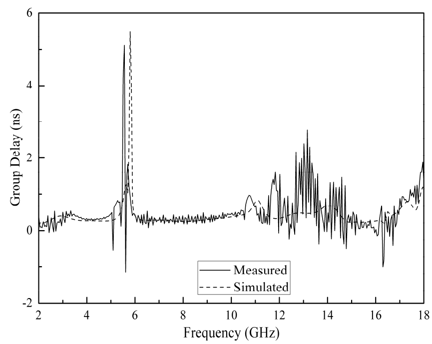


Figure 12. Simulated and measured group delay.

According to the above discussion, $W_H = 3.4\,\text{mm}$ and $W_S = 0.5\,\text{mm}$ are chosen as the final dimensions. An UWB BPF with a notch-band at 5.8 GHz is realized.

3. EXPERIMENT AND RESULTS

To verify the predicted performance, the proposed BPF is fabricated and measured. The photograph is depicted in Fig. 10. The filter is measured using an Agilent vector network analyzer N5230A. Fig. 11 shows the comparison between the measurement and the EM simulation. The measured and simulated results are found to be in good agreement with each other, except for a little frequency offset. The measurement shows that the proposed BPF has a 3 dB fractional bandwidth of 109% from 3.2 to 10.6 GHz against the counterpart frequency of 2.8 to 11.2 GHz in simulation. And the insertion loss is better than −1.6 dB in the passband. In the upper-stopband from 13.0 to 18.0 GHz, the insertion loss is lower than −25.0 dB. The measured rejection loss is about −30 dB at the center frequency (5.8 GHz) of the notch-band. The notch-band can be changed with the lengths of the asymmetric dumbbell stubs. The measured group delay is shown in Fig. 12, where good performance can be observed. Some minor discrepancies between measured and simulated results may be caused by the limited precision of fabrication, connectors and measurement.

4. CONCLUSION

In this paper, a novel MMR-based UWB BPF with a notch-band at 5.8 GHz is presented and fabricated. After the measurement verification, the BPF has a wide passband from 3.2 GHz to 10.6 GHz. Also, the proposed MMR is utilized to obtain a wide upper-stopband with an insertion loss lower than −25.0 dB from 13.0–18.0 GHz after experimental verification. By folding an arm in interdigital coupled lines symmetrically, the notch-band at 5.8 GHz is implemented. Furthermore, the roll off skirts of both insertion loss and return loss is quite steep. As a result, this filter is particularly suitable for the application of UWB system in the future.

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