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Compact dual-band bandpass filter with ultra wide stopband using open-loop resonator loaded by T-shape and open stubs

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Abstract: We present the design of a compact dual-band bandpass filter using open-loop resonator, which connected together with mixed coupling, loaded by T- shape stub and open stubs. Open stubs are loaded to achieve high performance and the tapped line feed structure is used in input-output port. By adjusting the tapping position, stubs length and the impedance ratio of T- shape stub, the filter performance can be controlled. The T shape stubs are used to suppress the harmonics above the second band. The insertion losses are 0.2 dB and 0.9 dB at 2.7 and 5 GHz respectively. Above the second pass band minimum attenuation is −20 dB from 5.3 to 20 GHz, so it can be used for ultra wide stopband applications. The measurement results have shown a good agreement with the simulation.

Keywords: dual band, mixed coupling, Open stub, ultra wide stopband

Classification: Microwave and millimeter wave devices, circuits, and systems

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1 Introduction

Recently dual-band filter application in modern wireless communication is developed such as: wireless code-division multiple-access (WCDMA), wireless local area network (WLAN), and global system mobile communication (GSM). The characteristics of compact size, low insertion loss, good return loss, wide fractional bandwidth and good skirt attenuation rate are needed for microwave dual band filter. In [1] the dual-band filter with the elliptic function response using net-type resonators is proposed that it has good selectivity. In addition, the developed filter provides wide stopband suppression. But this filter has problem of large implementation area and large insertion losses. In [2] the stepped impedance-comb resonator is proposed to realize dual band filter with a transmission zero between two pass bands that it has large insertion losses. In [3] dual band filter has been proposed using two parallel open and short-circuited stubs in parallel and series. This filter has good selectivity in first and second pass band but in this approach the insertion losses and the implementation area are large. In some case of dual-band bandpass filter design for exciting the resonator, dual-band impedance transformer for impedance matching is needed but Using tapped line structure lead to increment of circuit area [4]. [5] used short-circuited and open-circuited stubs to achieve dual-band resonator. In this filter using stepped impedance asymmetric coupled line lead to achieve coupling that it improved the filter performance, but adjusting impedance ratio while structure is asymmetric is difficult. In [6] and [7] open-loop resonators are implemented to realize dual-band filter. In [6] magnetic and electric coupling structures are needed to achieve the good dual-band band pass filter performance at the stop bands below the first pass band and between two pass band. In this filter above the second pass band the stopband performance is undesired and between two pass bands harmonics exist, also filter size is large. In [8] the elliptic function filter is designed with transmission zero, so sharp cutoff is achieved

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but two harmonics between two pass band are exist that they have undesired attenuation in the stop band between two pass bands, also above the second pass band the harmonics are not attenuated much, and this filter is limited to narrow band application. However, the insertion loss, high rejection in stopband and the circuit size remained as a challenge. In this paper, the open loop resonators loaded by T-shape and open stubs are used to realize the compact dual-band band pass filter with ultra wide stopband.

2 Design and study of the proposed filter structure

The open loop resonator that loaded by shunt open stub is shown in Fig. 1 The input admittance of the resonator from the open end (shown by $\theta 1$) is:

$$Yin = j * Y \frac{tan\theta_1 + tan\theta_2 + tan\theta_3 + tan\theta_4 + tan\theta_5 + tan\theta_6 + tan\theta_7}{1 - tan\theta_1 tan\theta_2 + tan\theta_3 + tan\theta_4 + tan\theta_5 + tan\theta_6 + tan\theta_7} \quad (1)$$

Where $Y_S = Y_R = Y$ and Y_R and Y_S are the characteristic admittances of the resonator and the stub, respectively. The resonance condition can be obtained when:

$$tan\theta_1 + tan\theta_2 + tan\theta_3 + tan\theta_4 + tan\theta_5 + tan\theta_6 + tan\theta_7 = 0 \quad (2)$$

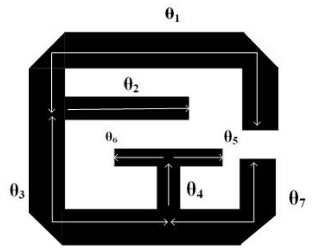

Fig. 1. Open loop resonator that loaded by T-shpe and open stub

So the resonance frequency can be controlled by adjusting the stub length. We can use two similar open loop resonators to achieve dual band bandpass response. The structure of the proposed resonator is shown in Fig. 2 (a) It consist of two similar open loop resonators with mix coupling. While dual-band resonators are needed to achieve dual-band band pass response, dual-band coupling structures or inverters between resonators are required to establish the bandwidth for each band [3]. So for designing dual band bandpass filter the resonators can be connected together using electric coupling, magnetic coupling and mixed coupling [7]. In many coupled resonator structures, both electric and magnetic couplings exist. In our filter design the mixed coupling are used to create two different pass bands. The tapped line feed structure is added to connect input and output ports. By tuning the tap line position, the filter performance can be improved. Two T-shape stepped impedance resonators and open stubs are added to improve the filter performance. The frequency response of this filter is shown in Fig. 2 (b).

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The effect of changing L4 is shown in 2 (c). As shown in Fig. 2 (c) the center frequencies are shifted to right by smaller length of L4, that is proved in equation 2.

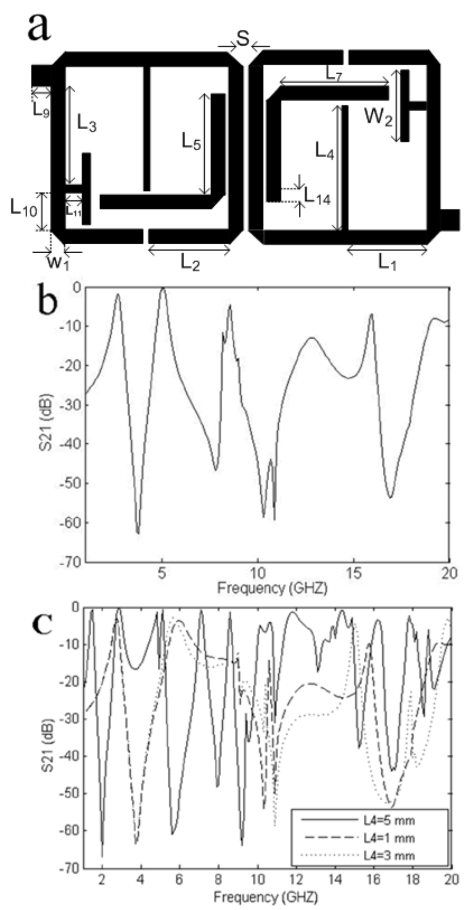

Fig. 2. (a) Two open loop resonators with mixed coupling and S=0.4 mm (b) frequency response (c) The frequency response for different L4

In order to achieve the improved dual-band bandpass response, we use four open loop resonators that loaded by T-shape stepped impedance and open stubs L4, L7 as shown in Fig. 3 (a). The measured and simulated frequency response of Fig. 3 (a) is presented in Fig. 3 (b). By using of the stepped impedance T-shape resonators 5 and 6 the harmonics above the second band can be attenuated and this dual band filter can be used for ultra wideband applications. The filter structure is symmetric expect T-shape 4 that its size is difference from another T-shapes. By adjusting the length L4 the center frequency at the second band can be shifted, that is presented for three different size of length L4 in Fig. 3 (c). Although for smaller length L4 the stop band between two pass bands is wide and center frequency at second pass band can be shifted to right and regulated at desired frequency, while L4 is small the harmonics above the second pass band are increased that it is a main problem for using filter at ultra wideband application. When L4 is increased the selectivity is improved above the second pass band. By

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adjusting the impedance ratios of stepped impedance T-shapes resonators, open stubs, lengths and widths the resonance frequencies are controlled and the filter performance can be improved. The insertion losses at the second and first bands are increased when S2 is increased that is shown as Fig. 3 (d). When S2=1 mm the insertion loss is highest and when S2=0.5 mm the insertion loss is lowest. When the proposed filter is symmetric the insertion losses will be better but the harmonics above second band are greater than the asymmetric shape as it is shown in Fig. 3 (e). The photograph of fabricated filter is shown in Fig. 3 (f).

3 Simulation and measurement

Fig. 3 (b) presents the measured and simulated frequency response of the proposed dual-band band pass filter. The dual-band bandpass filter is fabricated on a RT Duroid 5880 substrate having dielectric constant = 2.22 and 15 mil-thickness and loss tangent 0.0009. The proposed filter is simulated by using the full wave EM simulator. The size parameters of this filter are: L1= 4.4 mm, L2=4.3 mm, L3=5.6 mm, L4=7 mm, L5=5.3 mm, L6=2 mm, L7=6 mm, L8=2 mm. L9=1 mm, L10=4.3 mm, L11=0.4 mm, L12=0.5 mm, L13=1 mm, L14=0.2 mm, L15=0.5 mm, w1=0.8 mm, w2=4 mm, w3=4 mm, w4=0.5 mm, w5=0.3 mm, S1=0.2 mm, S2=0.3 mm, S3=0.2 mm and g=0.5 mm. This filter has cut off frequencies at 2.57 GHz and 2.85 GHz in the first pass band and 4.79 GHz and 5.23 GHz in the second pass band. Below the first pass band minimum attenuation is −54 dB from dc to 2 GHz. Between two pass bands minimum attenuation is −50 dB from 3.2 to 4.4 GHz. The minimum attenuation above the second pass band from 5.3 to 20 GHz is −20 dB. So this filter can be used for ultra wideband applications. The insertion losses at 2.71 and 5.05 GHz are 0.2 and 0.9 dB respectively and the insertion losses at the first and second bands better than 0.2 and 1.9 dB respectively. The filter size is 45.5 mm∗10.9 mm. In comparison of the previous works the filter size is smaller and insertion loss is better. The size is smaller than 62%, 60.8% and 73% in comparison with previous works [1], [8] and [10] respectively. The insertion losse in the first band is smaller than 92%, 96% and 81%, 89%, 90% in comparison with previous works [1], [5], [8], [9] and [10] respectively. The insertion losse in the second band is smaller than 63%, 83% and 10%, 52%, 61% in comparison with previous works [1], [5], [8], [9] and [10] respectively. BWRs in the first and second bands are 10%, 8.78% respectively.

4 Conclusion

A compact dual-band bandpass filter with low insertion loss is designed and fabricated using open-loop resonator that it loaded by T-shape stepped impedance and open stubs for ultra wideband application. The insertion losses at center frequencies at the first and second bands are 0.2 dB and 0.9 dB respectively. By adjusting the space between coupled lines, the insertion losses at both second and first pass bands can be improved. The

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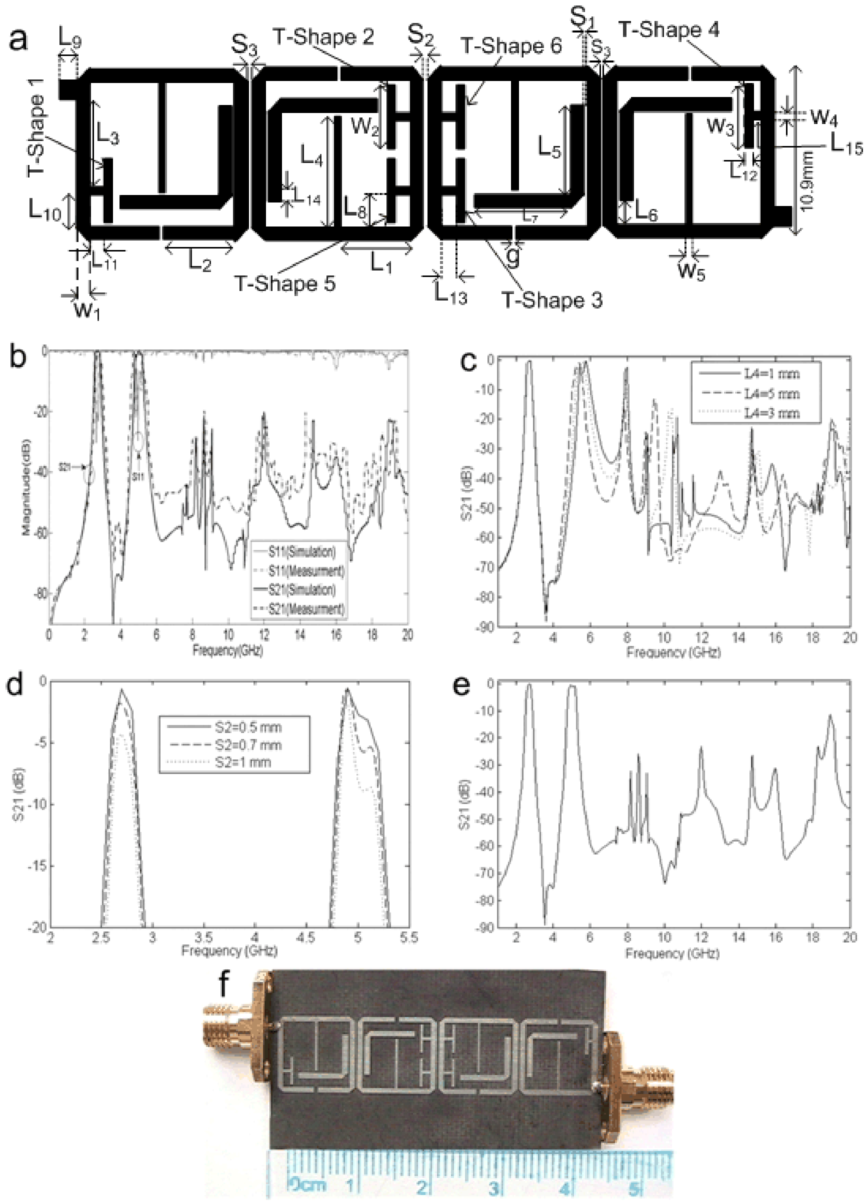

Fig. 3. (a) The configuration of the designed filter with six T-shape resonators for ultra wide band application (b) The measured and simulated frequency response (c) The simulated frequency response for difference L4 (d) The simulated narrowband frequency response for difference S2 (e) The simulated frequency response for L15=1 mm. (f) The photograph of fabricated

harmonics are removed above the second band end to 20 GHz.

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