

Microstrip Lowpass Filter with Very Sharp Transition Band and Wide Stopband

Mohsen Hayati and Akram Sheikhi

A novel lowpass filter with a very sharp transition band and wide stopband is proposed. The proposed filter is based on T-shaped patches which are etched in symmetrical structures and folded open stub. To obtain a wide stopband, we have used stub loaded semi-circle stepped-impedance structures. By designing the resonator with high inductance and capacitance, a very sharp transition band is achieved. The proposed filter has a 3-dB cutoff frequency at 2.37 GHz and a 40-dB rejection at 2.44 GHz. The stopband with an attenuation level better than -13.2 dB is up from 2.4 GHz to 16 GHz, and consequently we have reached the high and wide rejection in stopband with compact size. Good agreements between the simulated and the measured results are presented.

Keywords: Microstrip lowpass filter; open stub, transition band, wide stopband.

I. Introduction

A microwave lowpass filter (LPF) is required to suppress spurious signals and unwanted high-frequency harmonics in various communication systems. Planar filters are frequently used because of their easy fabrication and integration with the other microwave circuits, so planar LPFs with good performance have been studied in recent years. An LPF with a wide stopband and transition band equal to 0.4 GHz is proposed in [1], but the obtained response is not sharp enough. By using the open complementary split ring resonators (OCSRRs) [2], it is found that an LPF with sharp transition band in the stopband as well as compact size can be obtained; but it has a narrow stopband. Also, to reach the wide stopband, several OCSRRs have been used, which has resulted in the

increase of the insertion loss and the size of filter. The compact microstrip LPF with a sharp transition band of 0.14 GHz and a wide stopband is proposed in [3]. The elliptic-function LPF using a slit-loaded tapered compact microstrip resonator cell [4] has a sharp cutoff frequency, while the size is relatively large. In [5]-[8], the defected ground structure shows the bandstop and sharp response characteristics, but this structure, owing to etching in the ground plane, cannot be applied to metal surfaces and cannot give robust mechanical endurance against strain. The LPF, by using stepped-impedance hairpin resonators [9], [10], has finite attenuation pole close to the cutoff frequency. Due to low capacitance of coupled line, the finite attenuation pole is not located near the passband. Hence, the cutoff frequency is gradual. In [11], to reach the sharp response, interdigital capacitors have been used, but it does not have wide stopband. The elliptic-function LPFs by using elementary rectangular structures in [12] provide a wide passband with a sharp response but with narrow stopband.

II. Resonator and Its Specifications

As can be seen from Fig. 1, this resonator consists of T-shaped microstrip patches and folded open stubs. To obtain a good slow-wave factor (SWF), we have created high inductance and capacitance in the structure of the resonator. The T-shaped microstrip patches are utilized to create equivalent inductance l . The capacitance c is due to open stub and coupling gap between the resonator structures. Assuming the structure is loss-less, its phase velocity can given by

$$V_p = 1/\sqrt{lc}. \quad (1)$$

Also, the dimension of the filter is proportional to the guided wavelength at the cutoff frequency. On the other hand, λ_g is proportional to phase velocity V_p , so by reducing V_p , we get

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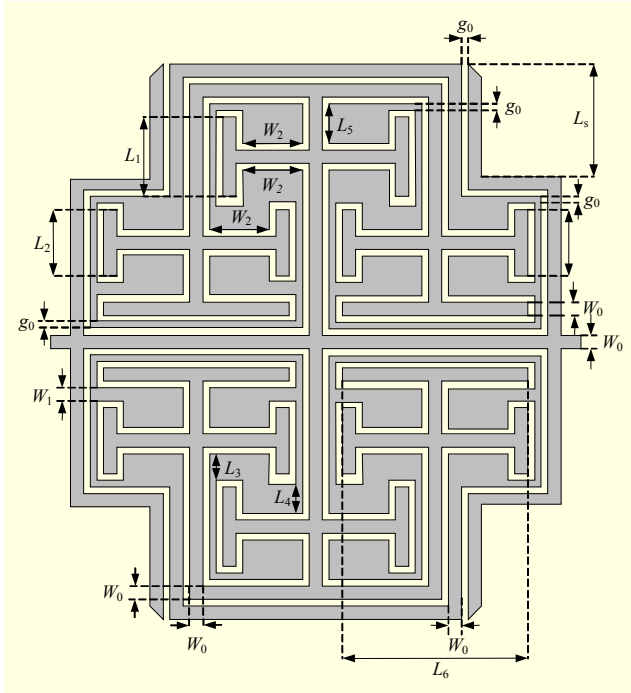


Fig. 1. Typical topology of proposed resonator.

slow-wave propagation. We can overtake low V_p by increasing the equivalent inductance and capacitance in the resonator. The SWF is given by

$$SWF = \frac{\lambda_0 \Delta\theta}{360L} + \sqrt{\epsilon_{\text{eff}}} \quad (2)$$

with

$$\epsilon_{\text{eff}} = \frac{1 + \epsilon_r}{2} + \frac{1 - \epsilon_r}{2} \left(1 + 12 \frac{h}{w}\right)^{-0.5}, \quad (3)$$

where L is a physical length of microstrip line, λ_0 is the guided wavelength, $\Delta\theta$ is the phase difference (in terms of degree) between the conventional microstrip and the proposed resonator, and ϵ_{eff} is the effective microstrip permittivity.

Therefore, high SWF causes the size of the resonator to be compact. In other words, the resonator will have high l and c , resulting in having attenuation poles close to cutoff frequency which leads to obtaining sharp response.

Figure 2(a) shows the SWF of the proposed resonator versus frequency. It can be seen from the result that the uniform 50- Ω microstrip line has SWF equal to 1.37 in the passband region, where the SWF of the proposed resonators increases and reaches 10.23 in the region close to 3-dB cutoff frequency. So, we have a 285.7% increase in SWF up to 2 GHz and a 733.57% increase in SWF around cutoff frequency in comparison with the conventional microstrip line.

In fact, the increment in the number of the T-shaped microstrip patches and folded open stubs in the resonator result in complexity of the filter structure, whereas these increments

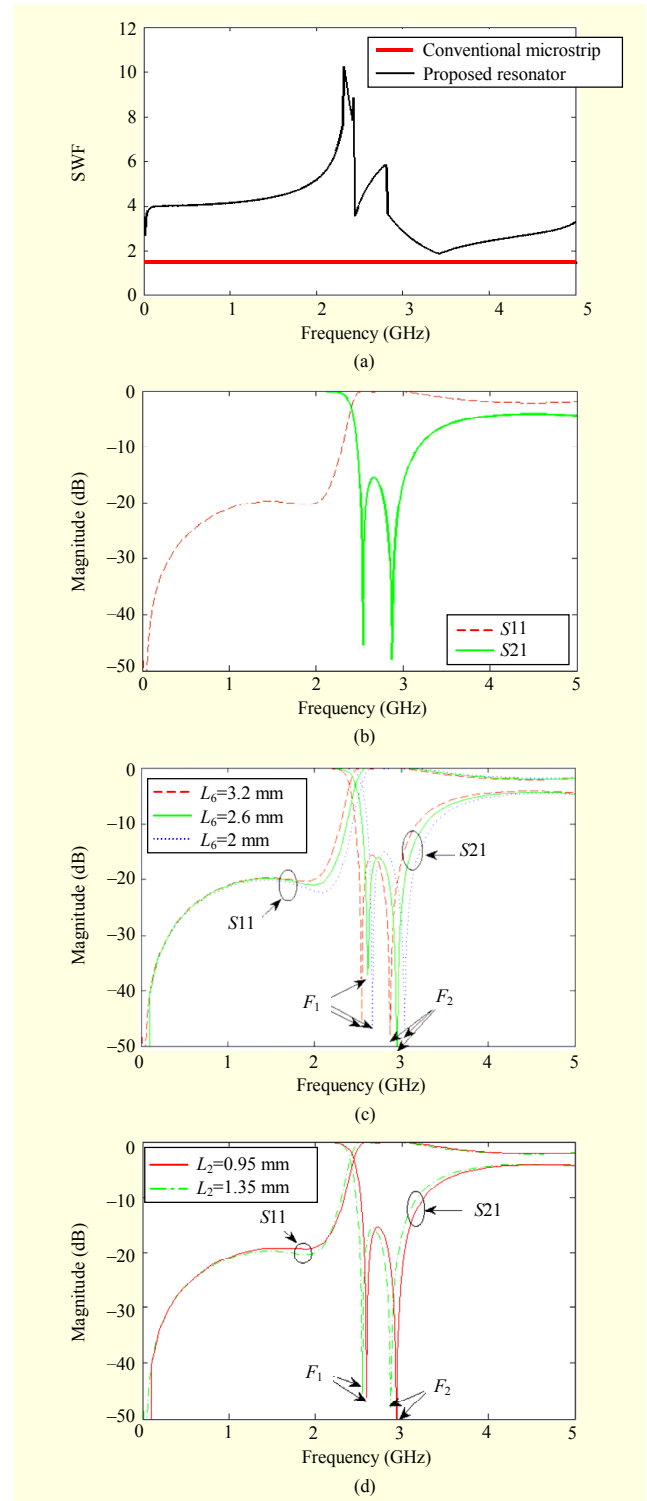


Fig. 2. Proposed resonator's (a) SWF, (b) frequency response, and S-parameter simulations as function of (c) L_6 and (d) L_2 .

steep the transitions from passband to stopband.

Figure 2(b) illustrates the frequency response of the resonator. From the results, it has been found that the insertion loss from DC to 1.9 GHz is close to 0 dB, and the return loss in passband

is better than -20 dB, which indicates that we have good power handling in the passband region. The initial disadvantage of the designed resonator is a narrow stopband.

The simulated S -parameters of the proposed resonator as the functions of L_6 and L_2 are shown in Figs. 2(c) and 2(d), respectively. In Fig. 2(c), when L_6 decreases from 3.2 mm to 2 mm with step equal to 0.6 mm, the location of cutoff frequency and transmission zeros in F_1 and F_2 will approach to upper frequency. Also, in Fig. 2(d), by decreasing L_2 with step equal to 0.4 mm due to the decrement of the equivalent inductance, the location of cutoff frequency and transmission zeros will move away from the lower frequency. Therefore, the location of cutoff frequency can be easily adjusted by changing the length of the L_2 and L_6 in the proposed resonator.

III. LPF Design: Measured and Simulated Results

Based on the proposed resonator structures, an LPF has been designed. The very sharp transition band is achieved by implementing the two resonators. To achieve the low insertion loss and the good return loss in filter, we have altered the L_8 to 0.9 mm in the third cell. Figure 3(a) shows the frequency response of the stub loaded with semi-circle stepped-impedance structure. This structure exhibits a wide stopband with one attenuation pole in the stopband. On the other hand, the addition of the proposed structures to the filter provides the extra finite transmission zeros inside the stopband, so we obtain wide stopband. We can control the level of the suppression in the LPF with variation of parameters, such as D_1 , D_2 , L_9 , L_{10} , L_{11} , and L_{12} , related to a stub loaded semi-circle stepped-impedance structure. For simplicity, the variation of D_2 parameter on the filter performance is shown in Fig. 3(b).

Figures 4(a) and 4(b) show the configuration of the proposed LPF and photograph of the fabricated LPF, respectively. The substrate is RT/Duroid 5880 with thickness of 0.7874 mm, dielectric constant of 2.2, and loss tangent equal to 0.0009. The dimensions of all the parameters determined are as follows: $L_1=1.4$ mm, $L_2=1.35$ mm, $L_3=0.3$ mm, $L_4=0.35$ mm, $g_0=0.1$ mm, $W_0=0.2$ mm, $W_1=0.15$ mm, $W_2=1.1$ mm, $L_5=0.7$ mm, $L_6=3.2$ mm, $L_7=0.35$ mm, $L_8=0.9$ mm, $L_9=2.45$ mm, $L_{10}=0.7$ mm, $L_{11}=2.6$ mm, $L_{12}=8.8$ mm, $L_s=1.65$ mm, $D_1=2.15$ mm, and $D_2=3.2$ mm. Finally, the designed LPF is simulated with an EM-simulator ADS and measured with an Agilent Network Analyzer N5230A. Figure 5(a) shows the comparison of the simulated and the measured results which are in good agreement. By observing the results, we can see that the proposed LPF has a 3-dB cutoff frequency at 2.37 GHz. The insertion loss is less than 0.164 dB in the passband from DC to 1.45 GHz. The return loss in all passband is less than -14.5 dB. The stopband with -13.2 dB attenuation level is up to 16 GHz and reaches

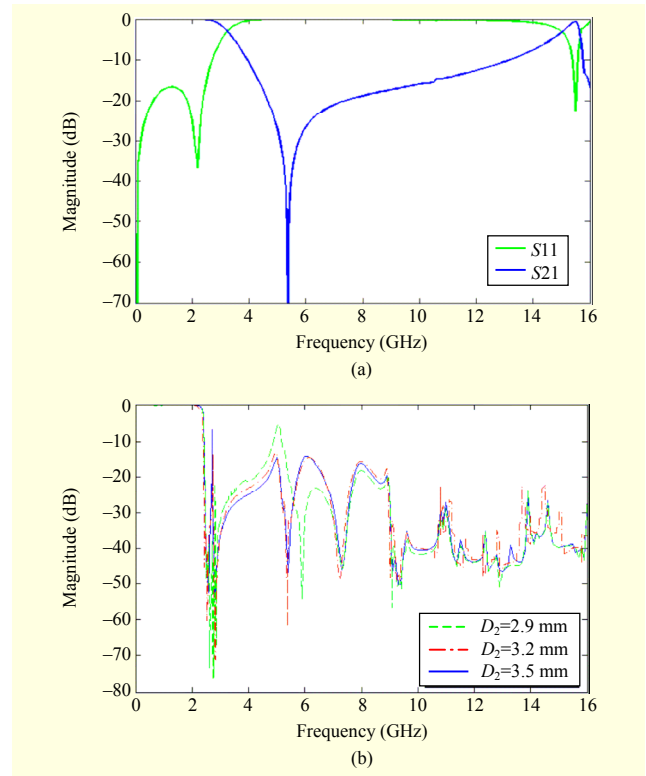


Fig. 3. (a) Frequency response of stub loaded with semi-circle stepped-impedance and (b) simulation S_{21} of proposed LPF as a function of D_2 .

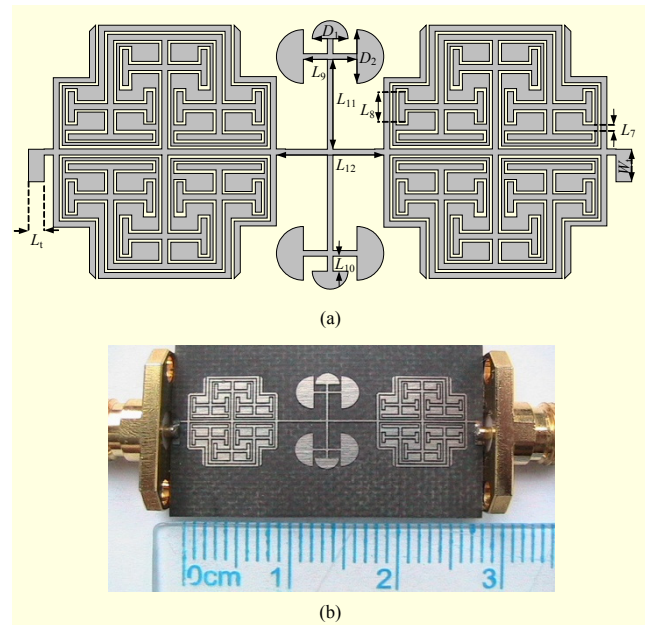


Fig. 4. (a) Geometry of proposed LPF and (b) photograph of fabricated LPF.

the stop bandwidth of 148%. The maximum attenuation rate is 528.57 dB/GHz. The designed filter has two transmission zeros at 2.45 GHz and 2.54 GHz with attenuation levels of

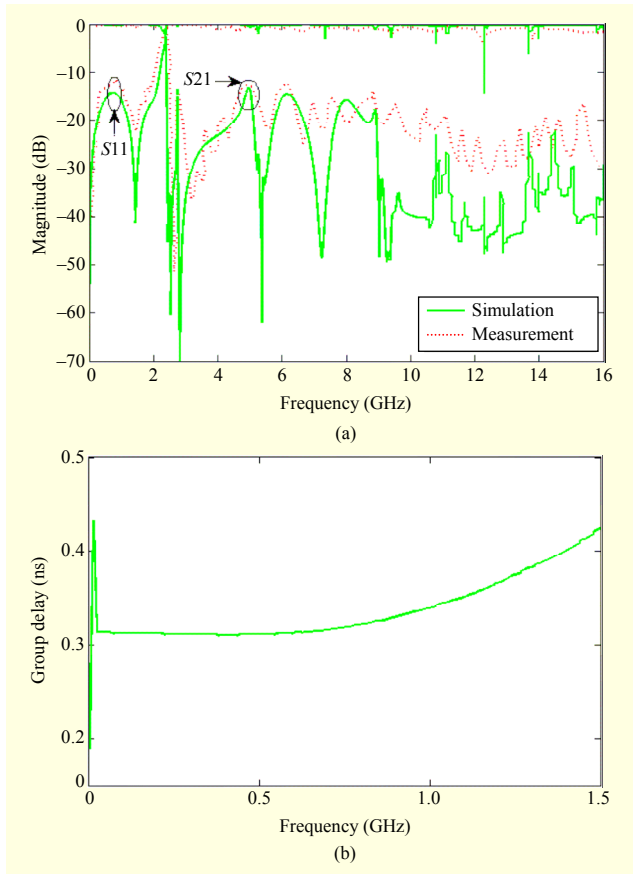


Fig. 5. (a) Simulated and measured S-parameters of designed lowpass filter and (b) group delay of proposed LPF.

–45.26 dB and –60.55 dB, respectively. Consequently, the obtained LPF has sharp skirt characteristics.

The purpose of connecting the two open microstrip stub lines with the width of 2.4 mm and length of 0.7 mm at both sides of the LPF is to match the impedance at input and output ports to 50 Ω . In addition, the flat group delay in Fig. 5(b) is achieved in the passband region with the maximum variation of 0.44 ns. By including the input and output matching impedance, the size of the proposed LPF is about 28 mm \times 9.4 mm. The designed filter shows good bandstop characteristics with sharp roll-off. This filter can be used where sharp roll-off and wide stopband is needed.

IV. Conclusion

In this letter, a compact microstrip LPF based on novel microstrip resonator with semi-circle stepped-impedance structures, which shows good SWF characteristics, is presented. The proposed filter shows good characteristics in the passband and the stopband. The insertion loss is less than 0.164 dB, and return loss is better than –14.5 dB. The transition band is only 0.07 GHz (from 2.37 GHz to 2.44 GHz). The stop bandwidth

is 148%. The designed LPF in comparison with LPFs in [1]–[3] has 82.5%, 42%, and 50% decrements in transition band, respectively. This filter has been simulated, fabricated, and measured, and good agreement between them has been obtained. The results indicate that the LPF has many desirable features, such as compact size, low insertion loss, very sharp transition bands, and wide stopbands. These are all good characteristics applicable in modern communication systems.

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