A Compact Low-Pass Filter with Simple Structure and Sharp Roll-Off

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Abstract – **In this paper a compact low pass filter (LPF) with desirable figure of merit (FOM) and sharp roll-off is designed. The cut-off frequency of the designed filter is 3 GHz. The designed filter has a sharp transition-band of 0.88 GHz, from 3 to 3.88 GHz with corresponding attenuation levels of -3 and -60 dB, respectively. Also, the proposed filter has wide ultra stop-band from 3.8 GHz to 10 GHz with 20 dB suppression level. The dimensions of the proposed LPF is 0.13λg × 0.058λg, which shows excellent size reduction.**

Keywords-component; low pass filter ; microstrip line; size reduction; wide stop-band

I. INTRODUCTION

Recently, microstrip filters are widely used in wireless circuits and systems [1-5]. Among the microstrip filters, compact LPFs with high performance are more attractive [1]. Several methods have been presented to achieve desirable mentioned parameters in LPFs. For instance, defected ground structure (DGS) and electromagnetic bandgap (EBG) techniques are used in [6-12] to design the LPF. However, these methods need backside etching and complex fabrication procedures.

Designing of the LPF is mainly performed by designing of the resonators. So far, several resonators have been presented for designing of the LPFS. For instance, triangular [1], rectangular [1] curved [2], T-shaped [11], π-shaped [13] resonators, stepped impedances [14] and open stubs [15] have been widely used to design different types of LPFs.

Despite of providing stop-band, resonators can also decrease the circuit size. For instance, curved T-shaped and π-shaped resonators can decrease the overall size of the filter [2, 11]. Usually a suppressor cell is inserted in the LPF structure to provide wide stop-band. Resonators can produce transmission zeros

(TZs) at desired frequencies. In [1] triangular and rectangular resonators are used to create an LPF with sharp roll-off and wide stop-band. Twelve T-shaped structures are used in [11] to design an aperiodic LPF at 700 MHz. This twelve section structures can provide twelve TZs which lead to a wide stop-band. This aperiodic LPF is finally used to design a harmonic suppressed power divider. A common application of LPFs is to use them in harmonic suppressed power dividers [16-18].

Compact LPFs with sharp response and wide harmonics suppression can be widely used in amplifiers design [19-20] and satellite communication systems [21].

In this design, open stubs, tapered and triangular resonators are applied to create a small LPF with good parameters.
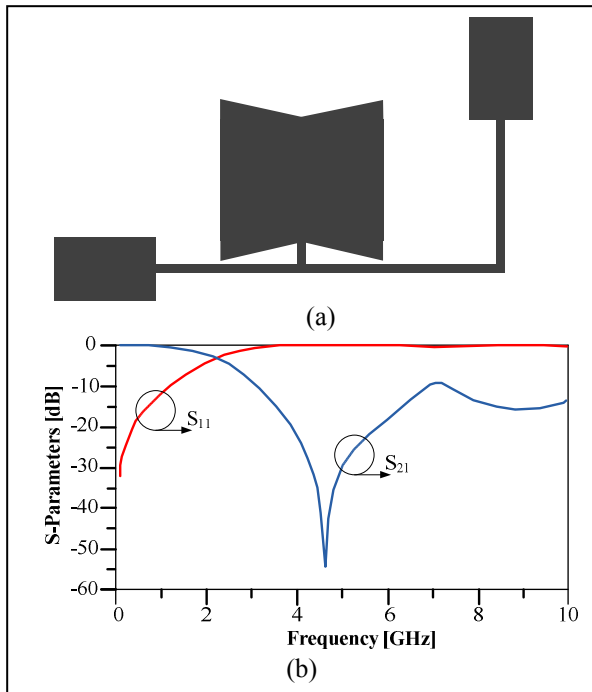
II. DESIGN OF THE LPF

To design the desired LPF at first a main resonator should be designed. A double trapezoidal cells are applied as the main resonator for the proposed circuit. The layout structure of this main resonator is depicted in Fig. 1 (a), while the scattering parameters of the main resonator are illustrated in Fig. 1(b).

All of the simulated results of the proposed LPF are obtained by electromagnetic simulator advanced design system (ADS) software.

The scattering parameters describe the electrical behavior of a linear device, which can be defined by a matrix. For a two port filter scattering parameters can be written in a 2×2 matrix. The $S_{21} = S_{12}$ parameters show the insertion loss of the filter, while the $S_{11}=S_{22}$ parameters show the return loss of the filter.
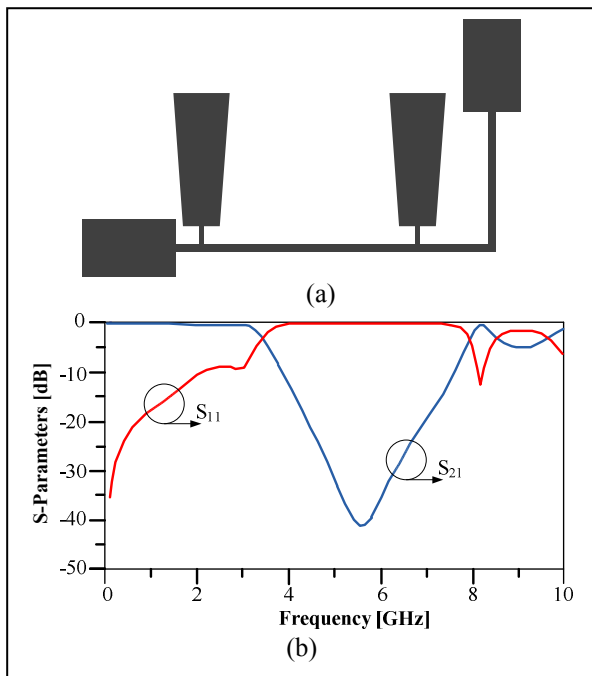
According to Fig. 1(b), the designed main resonator provides a TZ near 4.6 GHz and also provides a suppression band near 3 GHz up to 10 GHz.

Figure 1.   The (a) layout and (b) simulated S-parameters of the main resonator.
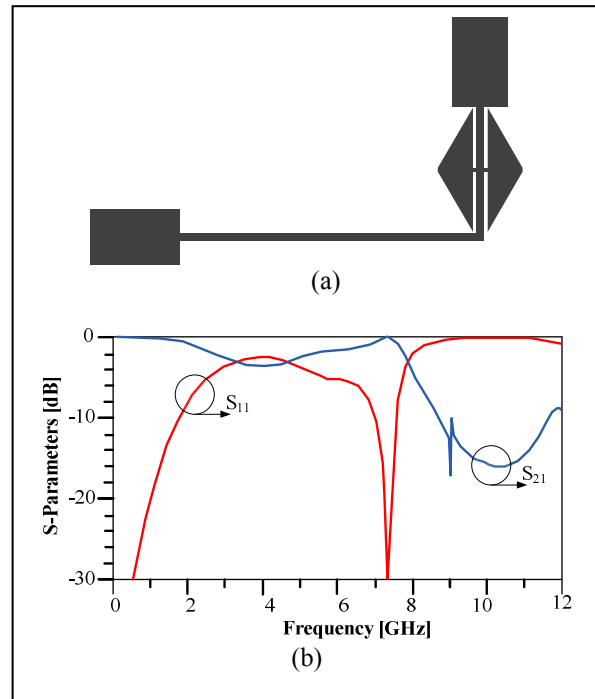

(a)

(b)

Frequency of the obtained TZ can be tuned by changing the dimensions of the double trapezoidal resonator. The main high impedance line between input and output port is folded to provide more size reduction.

Figure 2.   The (a) layout and (b) simulated frequency response of suppressing cell.

(a)

(b)

To provide a wide stop-band a suppressing cell should be added. A suppressing cell is presented as shown in Fig. 2. This suppressing cell is composed of two trapezoidal shaped open stubs. The proposed suppressing cell provides a TZ near 5.5 GHz and also provides a suppression band near 4 GHz up to 7 GHz.

Figure 3.   The (a) layout and (b) simulated S-parameters of the second suppressing cell.
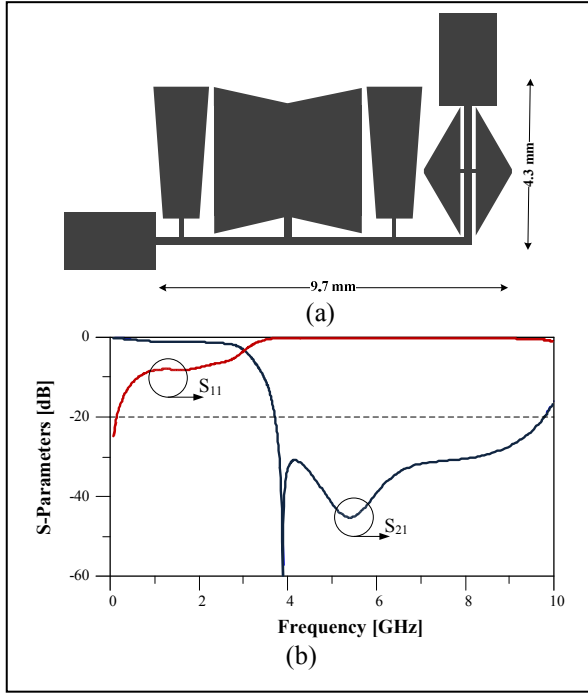

(a)

(b)

The obtained TZ by using the suppressor can widen the suppressing band of the filter.

Another suppressing cell is proposed to provide stop-band at higher frequencies. A double triangular resonator is applied to propose the second suppressing cell. The layout and S-parameters of the second suppressing cell is shown in Fig. 3. As seen, the proposed second suppressing cell provides two TZs near 4 GHz and 10 GHz. Also, it provides a suppression band near 8.5 GHz up to 12 GHz. The TZs obtained by the main resonator, first suppressing cell and second suppressing cell can provide a wide suppressing band for the proposed filter.

III.   RESULTS OF THE DESIGNED LPF

By combining of the designed resonators and suppressors, the structure of the proposed LPF will be obtained. The layout of the presented LPF is illustrated in Fig. 4(a). The presented LPF dimensions are 9.7 mm × 4.3 mm, which is corresponding to the normalized circuit size (NCS) of 0.13 λg × 0.058 λg. The obtained dimensions show that a small size is obtained for the proposed filter. The S-parameters of the designed filter is shown in Fig. 4(b). The cut-off frequency of 3 GHz is obtained for the designed LPF. Also, sharp transition band of 0.88 GHz is achieved, from 3 to 3.88 GHz with attenuations levels of -3 dB and -60 dB, respectively. This obtained transition band results in a roll of rate equal to 65 dB/GHz. Moreover, a wide suppressing band about 6 GHz is achieved from 3.8 GHz up to 9.8 GHz, so, the proposed filter can highly attenuate the unwanted signals at out of the operating band frequency. Finally, the achieved figure of merit (FOM) of about 17240 is calculated for the proposed LPF, which shows a desirable FOM for the proposed filter.

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Figure 4. The (a) layout and (b) simulated frequency response of the proposed LPF.

The performance comparison between of the designed filter and some similar LPFs is listed in the Table I. The results shows that the designed LPF roll of rate is very sharp (ζ =65). Also, wide stop-band with more than 20dB attenuation level in stop-band (SF=20) is achieved. Moreover, the designed LPF has very compact size, which is smallest size in this comparsion table.

TABLE I.   PERFORMANCE COMPARISON

Refs.	ζ	RSB	SF	NCS	AF	FOM
[22]	5.3	1.66	1.6	$0.12\lambda g \times 0.063\lambda g$	1	1159.3
[23]	24	1.65	1.5	$0.111\lambda g \times 0.091\lambda g$	1	5929
[24]	18	1.51	1.7	$0.12\lambda g \times 0.071\lambda g$	1	5664
[25]	36	1.32	1.5	$0.079\lambda g \times 0.079\lambda g$	1	11543
[26]	92	1.36	3	$0.351\lambda g \times 0.106\lambda g$	1	10106
[27]	44	1.63	1	$0.101\lambda g \times 0.15\lambda g$	1	4723
This work	65	1.07	2	$0.13\lambda g \times 0.058\lambda g$	1	17240

The figure of merit (FOM) parameter, which shows the efficiency of the LPF is calculated based on eq. (1) as follows:

$$FOM = (\zeta \times RSB \times SF)/(NCS \times AF) \qquad (1)$$

The proposed filter has the highest FOM value in this table, which shows the superiority of this device.

IV. CONCLUSION

A compact LPF was designed in this paper. The designed LPF showed good performances, such as sharp roll off and compact size. A wide suppressing band is obtained for the designed filter, so the filter can highly attenuate the unwanted signals at out of the operating band frequency. The achieved figure of merit (FOM) about 17240 is calculated for the proposed LPF, which shows a desirable FOM for the proposed filter. With the obtained parameters the designed filter could be used in modern communications.

V. ACKNOWLEDGMENT

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