Simple Configuration Low-pass Filter with Very Wide Stop Band

Behrooz Fath Ganji [1], Mahya Samadbeik [2], Abbas Ramezani [1], and Abdolmajid Mousavi [1]

[1] Department of Electrical Engineering
University of Lorestan, Kamalvand, Khorramabad, Lorestan, Iran
Ganji.behrooz@yahoo.com, Ramezani.ab@lu.ac.ir, mousavi.m@lu.ac.ir

[2] Department of Electrical and Engineering
West Tehran Islamic Azad University, Tehran, Iran
Samadbeik.m@gmail.com

Abstract ─ In this paper, a compact microstrip low-pass filter with elliptic-function response is presented. A half-ring along with two half-elliptic patch resonators is cascaded to design a compact low-pass filter with very wide stop band and high selectivity in a small circuit area. This filter has the stop band from 3.3 up to 27.57 GHz with attenuation level better than -20 dB. The proposed filter has low insertion loss in the pass band and stop band, high return loss (RL), and very wide rejection in the stop band, along with compact size and simple configuration .The filter is designed, fabricated and measured. Simulation and measurement results are presented and compared to previous researches. The results of simulations and measurements are in agreement.

Index Terms ─ Low-pass filter, microstrip components, semi-elliptic resonator, semi-ring resonator, stop band range.

I. INTRODUCTION

In new days microwave communication systems, microstrip low-pass filter (LFP) has a vital importance improving the performance of such systems. Compact size low-pass filters with high rejection and low insertion loss are important in developing the modern microwave communication systems.

Recently, studies on low-pass filter have been reported with different configurations in microwave applications. To achieve sharp response, we use multiple cells; these increments enlarge the size of the circuit and insertion loss in the pass band region of the proposed filter in [1]. In [2], the traditional low-pass filters produce slow roll-off and narrow stop band. In [3], a microstrip low-pass filter with a small size and mostly wide stop band using cell resonator has been introduced. The main disadvantage of this filter is the low rejection and the existence of harmonic in the stop band. The presented low-pass filter in [4] which uses the half-elliptic patch resonator, in spite of having an appropriate sharp roll-off and mostly wide stop bandwidth has a large size of the circuit and an unsuitable return loss. The low-pass filter in [5] which has been designed by the means of the hairpin resonator contains a harmonic and improper level suppression in the stop band having a high insertion loss. Also, in this filter, the defected ground structure cannot be etched on the metal surfaces. Compact quasi-elliptic microstrip LPF in [6] does not have sharp response, and has inadequate attenuation level in the stop band. The presented LPF in [7] which has been designed by the aid of half-circular and half-elliptic patch resonator is proposed to achieve wide stop band and sharp response. Despite the above mentioned advantages, the return loss in the pass band and the size of the filter is not suitable. The presented filter by the use of tub in hairpin resonator with radial stubs in [8], despite its small size, contains a low return loss in the pass band, and stop bandwidth with -20 dB suppression level is unsatisfactory. In [9], there is not sharp response and low insertion loss. In [10], measured result show that the design filter has a better than -10 dB stop band rejection but the new filters design with -20 dB attenuation level. The results in [11] are acceptable but quantity of cut-off frequency is about 4.24 GHz that is high value for design filter.

In this work, we have attempted to improve the major filter parameters by decreasing the filter size, simple configuration, decreasing the insertion loss, increasing the return loss and rising the stop bandwidth with a high rejection. The mentioned filter has been designed and manufactured using a semi-ring resonator and two semi-elliptic resonators with different size. The stop bandwidth is from 3.3 GHz to 27.57 GHz with under -20 dB suppression level. This filter was manufactured after designing and the experimental results have been measured. Measured and simulated S-parameters are in agreement.

II. DESIGN OF PROPOSED FILTER

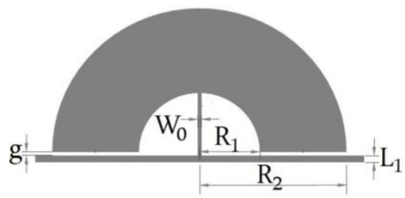
The designed filter is shown in Fig. 1 (a) and designed

Submitted On: March 1, 2015
Accepted On: December 13, 2015

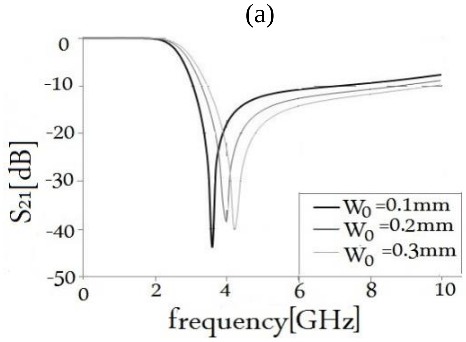
filter's dimensions are as follows: $R_1 = 1.75$ mm, $R_2 = 4.25$ mm, $L_1 = 0.2$ mm, $W_0 = g = 0.1$ mm. Figures 1 (b) and 1 (c) illustrate the simulation results of S_{21} of the designed resonator against W_0 and R_1.

Figure 1 (b) shows that by changing the value of W_0, the location of cut-off frequency and transmission pole can be controlled, with increasing of W_0 from 0.1 to 0.3 mm with steps of 0.1 mm, transmission zero in 3.6 GHz will approach the upper frequency. The effect of R_1 on the frequency response of resonator is shown in Fig. 1 (c).

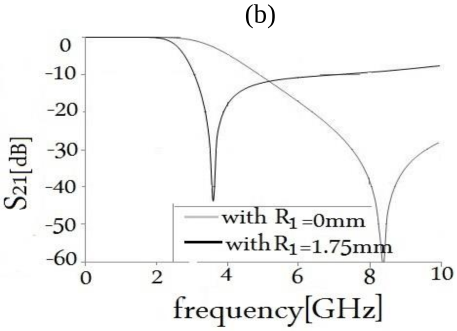
It can be observed that the cut-off frequency is affected by the R_1. In fact, the existence of R_1 is the basis of the designed resonator. The performance of the resonator is affected by the narrow line located along with the radius of the semi-ring patch. The narrow line is used to create equivalent inductance. Compared to the microstrip resonator in [4] & [7] the proposed resonator is more compact in size.



(a)



(b)



(c)

Fig. 1. (a) Schematic diagram of the designed filter, (b) simulation results for S_{21} with variation of W_0, and (c) simulation results for S_{21} with variation of R_1.

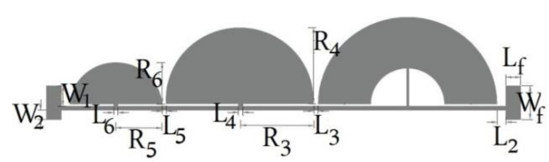
Compact size, simple configuration, high return loss and low insertion loss in the pass band are the advantages of the designed resonator. The designed semi-ring resonator has a low stop bandwidth which reaches to high rejection level and ultra wide stop band with the addition of two semi-elliptic resonators with different size in series.

III. SIMULATION AND MEASUREMENT

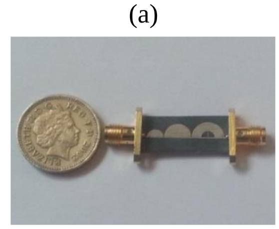
Figures 2 (a) and 2 (b) show the designed filter and fabricated filter respectively. Two other patches dimensions are as follows: $R_3 = 3.49$ mm, $R_4 = 3.73$ mm, $R_5 = 2.19$ mm, $R_6 = 2.03$ mm, $W_1 = 1$ mm, $W_2 = 0.45$ mm, $W_f = 1.65$ mm, $L_f = 0.7$ mm, $L_2 = 0.4$ mm, $L_3 = L_4 = 0.2$ mm, $L_5 = L_6 = 0.2$ mm. Simulated and measured results of designed filter are illustrated in Fig. 2 (c).

In order to impedance match, a pair of open microstrip stubs are fabricated at both sides of the LPF, so that the 50 Ω impedance at the input and output ports of the designed filter achieved, with the width $W_f = 1.65$ mm and length $L_f = 0.7$ mm.

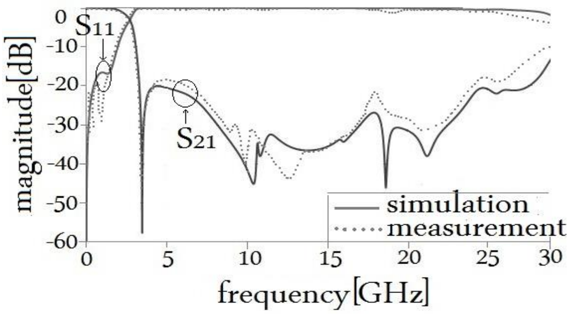
For fabricating of the deigned filter, a substrate with a relative dielectric constant $\varepsilon_r = 2.2$, thickness $h = 0.508$ mm, and loss tangent $\tan\delta = 0.0009$ is used. ADS used to simulate the results of designed filter. Agilent network analyzer N5230A is used to measure the S-parameters. Figure 2 (c) illustrating the simulated and measured results of the designed filter. It can be seen from figures that the designed filter has -3 dB cut-off frequency equal to 2.71 GHz, insertion loss less than approximate 0.3 dB in the pass band from DC to 1.81 GHz, by return loss about 16.55 dB and suppression level more than -20 dB from 3.3 GHz to 27.57 GHz that shows we achieve a ultra wide stop band and a proper suppression harmonic in the designed filter. The transition band is 0.59 GHz, from 2.71 to 3.3 GHz with -3 dB and -20 dB, respectively, which shows that the designed filter reaches a proper performance. The designed filter has a transmission zero at 3.48 GHz with attenuation level of -57.66 dB. Compared to the LPF in [7], our designed low-pass filter has 56% size reduction (considering input and output ports), along with 58% increase in stop bandwidth with -20 dB suppression level, 43% improved in return loss and also the configuration of the proposed filter is simpler than those of in [7]. The designed filter size is 21.11×4.55 mm^2.



(a)



(b)



(c)

Fig. 2. (a) Schematic of the designed filter, (b) photograph of fabricated filter, and (c) simulation and measuring results.

Table 1 shows the performance comparison between the proposed filter and other reported LPFs. In Table 1, ζ RSB, NCS, SF, AF, FOM and RL correspond to the roll-off rate, stop band bandwidth, normalized circuit size, suppression factor, architecture factor, figure of merit and respectively [11]. The roll-off rate is given by:

$$\zeta = \frac{\alpha_{\max} - \alpha_{\min}}{f_s - f_c}, \tag{1}$$

where $\alpha_{\max}$ is the 20 dB and $\alpha_{\min}$ is the 3 dB. F_c and f_s are the -3 dB cut-off frequency and -20 dB stop band frequency. The relative stop band bandwidth (RSB) is defined as:

$$\mathrm{RSB} = \frac{\text{stop band bandwidth}}{\text{stop band centre frequency}}. \tag{2}$$

The suppression factor (SF) shows the stop band suppression level divided by 10:

$$\mathrm{SF} = \frac{\text{rejection level}}{10}. \tag{3}$$

The normalized circuit size (NCS) is defined as:

$$\mathrm{NCS} = \frac{\text{physical size (length} \times width)}{\lambda^2 g}, \tag{4}$$

where λ_g is the guided wavelength at -3 dB cut-off frequency. The architecture factor (AF) is the complexity factor of the circuit, which is defined as 1 when the design is 2D and as 2 when the design is 3D. Finally, the figure of merit (FOM) is the overall index of the proposed filter, which is defined as:

$$\mathrm{FOM} = \frac{\mathrm{RSB} \times \zeta \times SF}{\mathrm{AF} \times NCS}. \tag{5}$$

Table 1: Performance comparisons between published works and proposed filter

Ref.	Fc (GHz)	ζ	RSB	NCS	SF	FOM	RL (dB)
7	3.12	30.35	1.35	0.059	2	1388.9	11.5
8	1.67	21.21	1.42	0.010	1	3011.82	12
9	2	14	1.35	0.0093	1	2032.25	11
10	2	43.9	1.636	0.0151	1	4788	13
This Work	2.71	28.81	1.57	0.0174	2	5199	16

This filter can be used in applications in which a wide stop band is necessary. Experimental and simulated results are in agreement.

IV. CONCLUSION

In this new designed filter, we have used a half-ring resonator and two half-elliptic resonators in series. This LPF is designed and fabricated in a way that is in a good consistent with the simulation results and the experimental sample. In the designed filter, parameters such as size, stop bandwidth, configuration, return loss and insertion loss have been improved. Return loss in the pass band is about 16.55 and stop bandwidth with -20 dB suppression level is satisfactory. Experimental and simulated results are in agreement. The compact size and ultra wide stop band of the proposed filter make it a good choice for microwave communication systems.

REFERENCES

[1] D. M. Pozar, "Microwave filters," *Microwave Engineering*, 4th ed., D. M. Pozar, pp. 550-582, New York, Wiley, 1998.

[2] J. S. Hong and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*, New York: Wiley, 2001.

[3] K. Deng, Q. Xue, and W. Che, "Improved compact microstrip, resonance cell low-pass filter with wide stop band characteristics," *Electron. Lett.*, vol. 43, no. 8, pp. 463-464, 2007.

[4] J.-L. Li, S.-W. Qu, and Q. Xue, "Compact microstrip low-pass filter with sharp roll-off and wide stopband," *Electron. Lett.*, vol. 45, no. 2, pp. 110-111, 2009.

[5] F. Wei, L. Chen, X.-W. Shi, Q.-L. Huang, and X.-H. Wang, "Compact low-pass filter with wide stopband using coupled-line hairpin unit," *Electron. Lett.*, vol. 46, no. 1, pp. 88-90, 2010.

[6] J. Wang, L. J. Xu, S. Zhao, Y. X. Guo, and W. Wu, "Compact quasi-elliptic microstrip low-pass filter with wide stop band," *Electron. Lett.*, vol. 46, pp. 1384-1385, 2010.

[7] M. Hayati, A. Sheikh, and A. Lotfi, "Compact low-pass filter with wide stop band using modified semi-elliptic and semi-circular microstrip patch resonator," *Electron. Lett.*, vol. 46, pp. 1507-1509, 2010.

[8] X. B. Wei, P. Wang, M. Q. Lin, and Y. Shi, "Compact wide-stop bandlow-pass filter using stepped impedance hairpin resonator with radial stubs," *Electron. Lett.*, vol. 47, iss. 15, pp. 862-863, 2011.

[9] M. H. Yang, J. Xu, Q. Zhao, L. Peng, and G. P. Li, "Compact broad-stop bandlow-pass filters using sirs-loaded circular hairpin resonators," *Pier 102*, pp. 95-106, 2010.

[10] F. Wei, L. Chen, and X.-W. Shi, "Compact low-pass filter based on coupled-line hairpin unit,"

Electron. Lett., vol. 48, 2012.

[11] M. Hayati, S. Naderi, and F. Jafari, "Compact microstrip low-pass filter with sharp roll-off using radial resonator," *Electron. Lett.*, vol. 50, no. 10, pp. 761-762, 2014.