# Compact Band-Stop Filter for X-Band Transceiver in Radar Applications

**Mohammad Pourbagher [1], Nasser Ojaroudi [2], Changiz Ghobadi [1], and Javad Nourinia [1]**

[1] Depertment of Electrical Engineering
Urmia University, Urmia, Iran
armanpurbaqer@yahoo.com, ch.ghobadi@urmia.ac.ir, j.nourinia@urmia.ac.ir

[2] Young Researchers and Elite Club
Ardabil Branch, Islamic Azad University, Ardabil, Iran
n.ojaroudi@yahoo.com

***Abstract*** **─** In this paper, we introduce a compact microstrip band-stop filter (BSF) at X-band communication and this shall be used in local oscillator chain for X-band transceiver due to its simple structure, compact size, and excellent performance. Presented microstrip filter consists of a transmission line with a square ring stub and four arrow-shaped strips protruded inside the ring, and a ground plane. Operation frequencies of the filter can be easily controlled by changing four protruded arrow-shaped strips in the square-ring stub. The proposed band-stop filter has wide bandwidth from 8 to 12 GHz for X-band communication that can be used in radar applications. Experimental results show good agreement between simulation results and measurements that excellent stop-band performance could be obtained through the proposed band-stop filter. The proposed microstrip filter is fabricated on a Rogers RT/Duroid 5880 substrate with a relative dielectric constant of 2.2 and has a very small size of 10×15 mm$^2$.

***Index Terms*** **─** Band-stop filter, radar application, X-band communications.

## I. INTRODUCTION

RF/microwave filter is one of the indispensable components in wireless communication systems. As the complexity of the communication systems increases, the demand for RF components operating in multiple bands becomes critically important. There have been numerous publications in the area of the filter technology. The development of microwave filter technology from an application perspective is given in detail in [1]. In modern communications, one of the important parameters is isolation between channels in a given bandwidth. Filters with different configurations are essential components in communication systems and these are generally used as signal rejection for unwanted signals and simultaneously allow the wanted signals in required bands [2].

Conventionally the microwave band-stop filter (BSF) is implemented either by all shunt stubs or by series connected high-low stepped-impedance microstrip line sections. However, generally these are not easily available in microwave band due to the high impedance microstrip line and the spurious pass-bands. Lately, to generate the frequency band-stop function, several modified planar microstrip filters have been reported [3-5]. In [3] and [4], different shapes of ground structures (i.e., slotted ground) are used to obtain the desired band-stop characteristics at X-band frequency range. In [5], band-stop function is achieved by using modified self-complementary structure. The desired resonant frequencies are obtained by adjusting the number of L-shaped teeth.

This paper work deals with design and development of a micro strip filter for X-band applications. In this structure, the resonant behaviors of the square-ring stub are used here introduces transmission zeroes to the filter response and consequently improves its stop-band performance. The reason for the choice of the protruded arrow-shaped strips is that they provide

*Submitted On: January 22, 2014*
*Accepted On: November 14, 2014*

an almost constant tight coupling, which is important to generate a good frequency response. The designed filter has a small dimension of 10×15×0.635 mm$^3$.

## II. MICROSTRIP FILTER DESIGN

The proposed microstrip filter configuration is shown in Fig. 1. Petal-shaped stub connected with the input and output ports at the top layer as revealed in Fig. 1. This added circuit behaves as a low pass filter, which improves the high stop band characteristics of the entire filter without the need to add more sections.

In general, the cut-off frequency of the microwave band-stop filter can be adjusted by setting proper values of the arrow-shaped structures of the filter stub [3]. To realize the desired capacitive and inductive values of the filter elements by the stub of the high/low impedance transmission lines, the characteristic impedance and effective dielectric constant of these transmission lines have to be determined. This band-stop filter was designed on a Rogers RT/Duroid 5880 substrate with 0.635 mm in thickness and with a relative dielectric constant of 2.2.

Theoretically, the loaded Q can be found using the 3 dB bandwidth of the insertion loss which is given by $Q_L = \omega_0 / \Delta\omega$. The arrow-shaped resonators were protruded on a 50 Ω microstrip-line 0.9 mm wide ($L_f$). There is an obvious band gap at the resonant frequency of 9 GHz. In addition, the arrow-shaped resonators provide a higher insertion loss and a narrow bandwidth. Basically, in order to obtain a deeper rejection and a wider band stop of the open-stub filter, more arrow-shaped should be employed. However, it would also increase the insertion loss [9]. On the other hand, two arrow-shaped filters are suitable only for moderate rejection bandwidth applications. The four types of resonator filters were designed with the center frequency of 10 GHz. The wave length, L= ($\lambda_g$/4) in microstrip filter is given by:

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} = \frac{c}{f_{bs}\sqrt{\varepsilon_{eff}}}, \tag{1}$$

where L is the length of the arrow-shaped strips; C is the light speed (3×10$^8$ m/s), $f_{bs}$ the band stop and (i. e., the desired rejected frequency) frequency, and $\varepsilon_{eff}$ the substrate effective permittivity [5]. The electrical length can be calculated from equation (2):

$$\phi = \beta . l = \frac{2\pi}{\lambda_g} . l, \tag{2}$$

where $\phi$ is the phase, $\beta$. the phase constant, and $l$ the equivalent electrical length of the spurline.

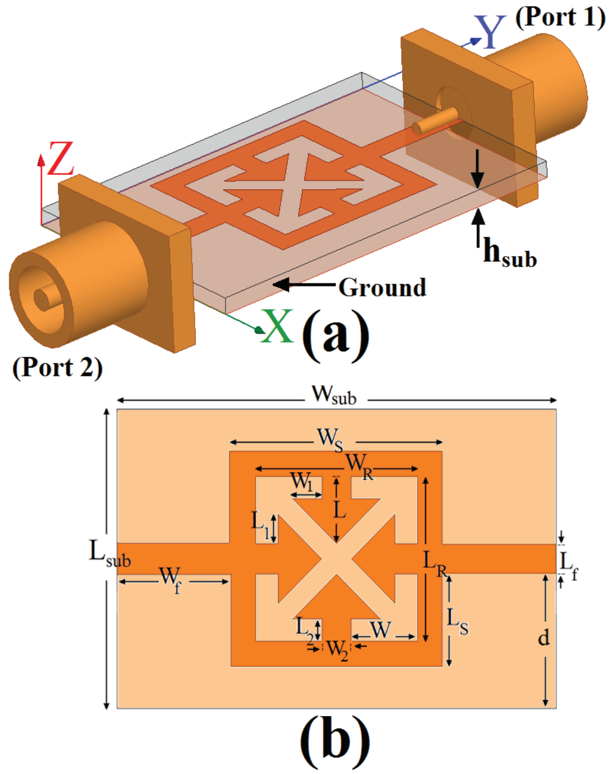


Fig. 1. Geometry of proposed microstrip band-stop filter: (a) side view, and (b) top view.

Final values of the presented band-stop filter design parameters are specified in Table 1.

Table 1: Final parameter values of the filter

| $W_{Sub}$ | $L_{Sub}$ | $h_{Sub}$ | $W_S$ |
|---|---|---|---|
| 15 mm | 10 mm | 0.635 mm | 7.2 mm |
| $L_S$ | $W_f$ | $L_f$ | $W_R$ |
| 3.15 mm | 3.9 mm | 0.9 mm | 5.5 mm |
| $L_R$ | $W$ | $L$ | $W_1$ |
| 5.5 mm | 2.3 mm | 2.25 mm | 1.05 mm |
| $L_1$ | $W_2$ | $L_2$ | $d$ |
| 1.05 mm | 0.9 mm | 0.75 mm | 4.55 mm |

## III. RESULTS AND DISCUSSIONS

The microstrip band-stop filter was designed on both substrate sides by opening apertures in the ground metallization under the high-impedance transmission line. Replacing of the square-ring stub with four protruded arrow-shaped strips introduces transmission zeroes. For the input/output connections 50-Ohm microstrip lines are used.

The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [6].

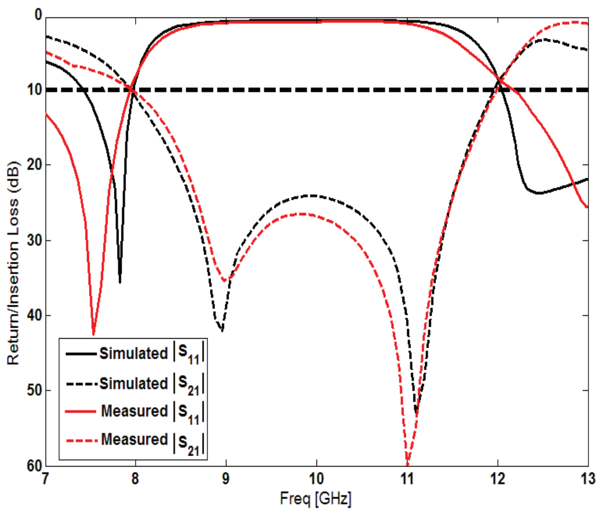


Fig. 2. Measured and simulated return/insertion loss characteristics for the proposed band-stop filter.

Figure 2 shows the simulated and measured insertion and return loss of the filter. As shown in Fig. 2, a flat insertion and return losses are introduced to the filter response at about 8.22 to 11.82 GHz. Consequently, a wide stop-band was achieved.

There exists a discrepancy between measured data and the simulated results. Additionally, the proposed band-stop filter also has characteristics of wider and deeper stop-band than those of conventional band-stop filters [7-8]. This discrepancy is mostly due to a number of parameters such as the fabricated filter dimensions as well as the thickness and dielectric constant of the substrate on which the filter is fabricated, the wide range of simulation frequencies and also the effect of SMA. In order to confirm the accurate return loss/insertion characteristics for the designed filter, it is recommended that the manufacturing and measurement process needs to be performed carefully, besides, SMA soldering accuracy and RT/Duroid substrate quality needs to be taken into consideration.

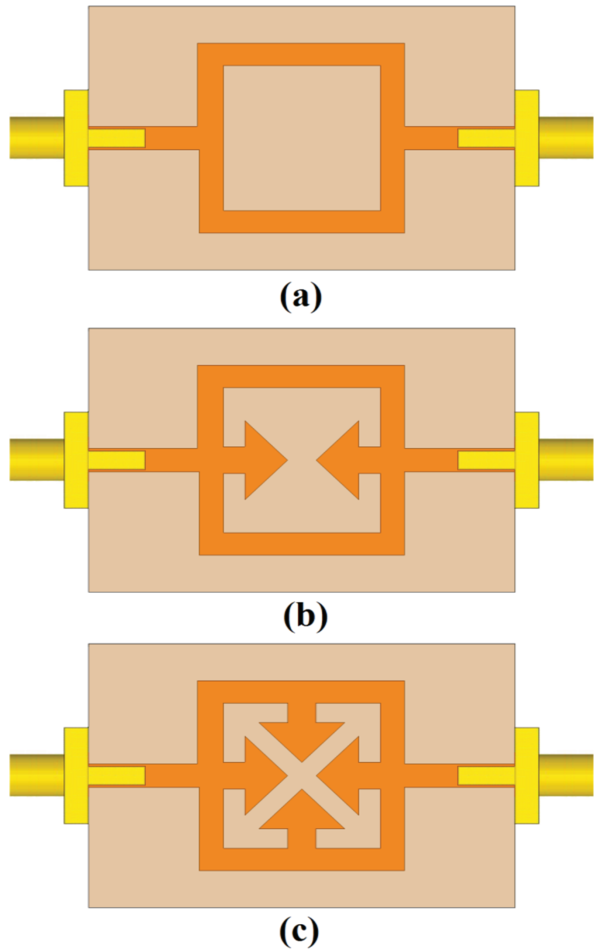


Fig. 3. (a) Ordinary microstrip filter with a circular-disk stub, (b) microstrip filter with a pair of C-shaped strips as a stub, and (c) the proposed microstrip filter structure.

The configuration of the various structures used for simulation studies were shown in Fig. 3. S-parameter characteristics for the microstrip filter with a square-ring stub (Fig. 3 (a)), the filter with a pair of arrow-shaped strips protruded inside the square-ring (Fig. 3 (b)), and the proposed filter structure (Fig. 3 (c)) are compared in Fig. 4. As illustrated in Fig. 4, by using pairs of protruded arrow-shaped strips inside the square-ring stub, two transmission zeroes at the lower and upper frequencies can be achieved, which provide an UWB frequency range. Good impedance matching for insertion/return loss ($S_{11}/S_{21}$) characteristics is generated [9-10].

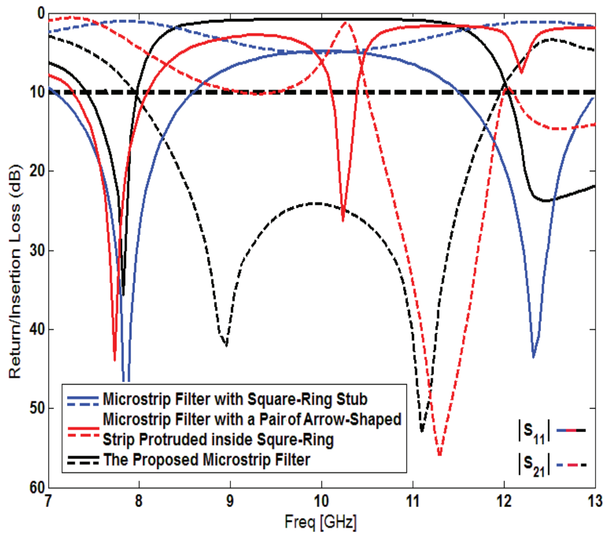


Fig. 4. Simulated return/insertion loss characteristics for various structures shown in Fig. 3.

From the simulated results in Fig. 4, the rejection bandwidth of four arrow-shaped strips is very wide compared to that of two arrow-shaped strips. Also, the rejection level of final configuration is very deep compared to that of two arrow strips.

With the compact circuit size of protruded strips, it is very suitable to apply pairs of arrow strips as a compact band stop filter. Both types of strips can be modeled as one parallel LCR resonator. The resonant frequencies are modeled by one LC resonator, and the radiation effect and transmission loss are considered as a resistor (R). Based on the transmission line theory and the spectral domain approach [1], the circuit elements can be extracted using the follow equations:

$$R = 2Z_0\left(\frac{1}{S_{21}} - 1\right), \qquad (3)$$

$$C = \frac{\sqrt{0.5(R+2Z_0)^2 - 4Z_0^2}}{2.83\pi Z_0 R\Delta f}, \qquad (4)$$

$$L = \frac{1}{4(\pi f_0)^2 C}, \qquad (5)$$

where $Z_0$ is the 50 Ω characteristic impedance of the microstrip line, $f_0$ is the resonant frequency, $S_{21}$ is the transmission coefficient at $f_0$, and $\Delta f$ is -3 dB bandwidth of $S_{21}$.

From the simulated results in Fig. 4, the extracted circuit elements are the following. For two arrow-shaped strips are: L= 0.867 nH, C=1.852 pF, and R=17.05 $k\Omega$. For the proposed structure with pairs of arrow-shaped strips are: L= 4.021 nH, C= 0.601 pF, and R= 71.33 $k\Omega$.

The proposed filter with final design, as shown in Fig. 5, was fabricated and tested that has a good insertion and return losses are introduced to the filter response from 8 to 12 GHz.

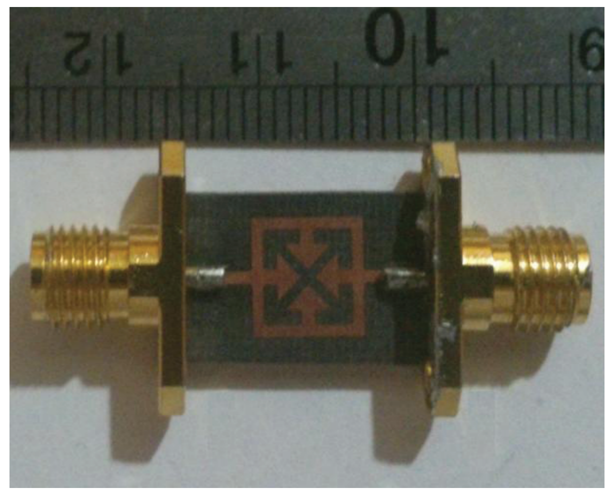

Fig. 5. Photograph of the realized printed band stop filter.

Figure 6 shows the current distribution of the proposed filter at the transmission zeroes. It can be seen that using the protruded arrow-shaped strips inside square-ring stub have effect on the overall performance of the filter. As shown in Fig. 6 (a), at 9 GHz (first zero transmission resonance) the current flows are more dominant around the arrow-shaped strips which are used at top/bottom sides of the square-ring stub and first zero transmission resonance of insertion loss response is affected from them. Figure 6 (b) clearly shows at the second zero transmission resonance in 11 GHz, the pair of arrow-shaped strips embedded at right/left sides acts as a half-wave resonant structure [7].

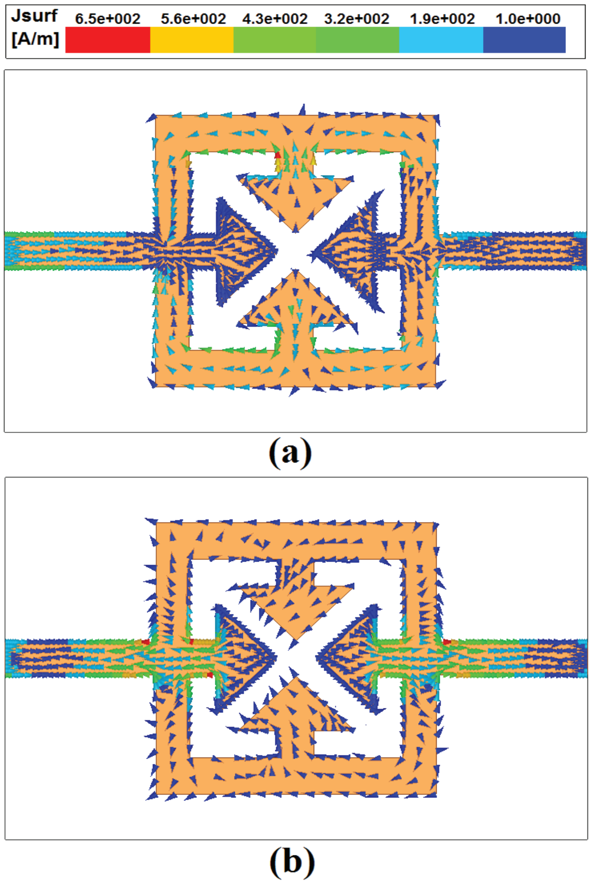


Fig. 6. Simulated surface current distributions for the proposed microstrip filter on the microstrip transmission line at: (a) 9 GHz, and (b) 11 GHz.

## IV. CONCLUSION

In this paper, a novel design of band-stop microstrip filter that covers all frequency range of X-band has been presented. Configuration of the presented filter consists of a transmission line with a square-ring stub, two pairs of arrow-shaped strips protruded inside square-ring stub and a ground plane. Operation frequencies of the filter can be easily controlled by changing the size of arrow-shaped strips. Controlling the transmission zeroes at the creating stop band, can be used to increase or decrease the stop-band generated by conventional filter. The measured results have shown that the fabricated filter has a band-stop that extends from 8.02 to 12.05 GHz. An excellent agreement between measured and simulated was obtained. Therefore, the proposed filters are promising for use in radar wireless technologies for X-band communications.

## ACKNOWLEDGMENT

The authors are thankful to MWT Company staff for their help (www.microwave-technology.com).

## REFERENCES

[1] J. A. Kong, *Electromagnetic Wave Theory*, EMW Publishing, Cambridge, 2000.

[2] X.-H. Wang, B.-Z. Wang, H. Zhang, and K. J. Chen, "A tunable band-stop resonator based on a compact slotted ground structure," *IEEE Trans. Microwave Theory Tech.*, vol. 55, pp. 1912-1918, 2007.

[3] D. S. La, Y. H. Lu, S. Y. Sun, N. Liu, and J. L. Zhang, "A novel compact band stop filter using defected microstrip structure," *Microw. Opt. Technol. Lett.*, vol. 53, pp. 433-435, 2011.

[4] W. D. Yan and R. R. Mansour, "Compact tunable band stop filter integrated with large deflected actuators," *IEEE MTT-S International Microwave Symposium*, Honolulu, HI, pp. 1611-1614, 2007.

[5] R. Habibi, Ch. Ghobadi, M. Ojaroudi, and N. Ojaroudi, "Very compact broad band-stop filter using periodic L-shaped stubs based on self-complementary structure for X-band application," *Electronic Letters*, vol. 48, 2012.

[6] *Ansoft High Frequency Structure Simulator (HFSS)*, ver. 13, Ansoft Corporation, Pittsburgh, PA, 2010.

[7] N. Ojaroudi, M. Ojaroudi, and Sh. Amiri, "Compact UWB microstrip antenna with satellite down-link frequency rejection in X-band communications by etching an E-shaped step-impedance resonator slot," *Microw. Opt. Technol. Lett.*, 55: 922-926, 2013.

[8] N. Ojaroudi, M. Ojaroudi, and R. Habibi, "Design and implementation of very compact band-stop filter with petal-shaped stub for radar applications," *Microw. Opt. Technol. Lett.*, vol. 55, pp. 1130-1132, 2013.

[9] N. Ojaroudi, "Novel design of low-profile microstrip band-stop filter (BSF) with koch fractal RSLRs," *22nd Telecommunications Forum, TELFOR 2014*, Belgrade, Serbia, November 25-27, 2014.

[10] N. Ojaroudi, H. Ojaroudi, and Y. Ojaroudi, "Very low profile ultra-wideband microstrip band-stop filter," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 709-711, 2014.