# Compact Band-Stop X-Band Filter Using Triple Meander-Line-Ring Defected Ground Structures

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***Abstract*** **─** This paper work deals with design and development of compact microstrip band-stop filter (BSF) for radar applications. The microstrip filter configuration consists of a transmission line and a modified ground plane with three meander-line ring defected ground structures (DGS). The proposed microstrip filter fabricated on a *Rogers* RT/Duroid 5880 substrate with a relative dielectric constant of 2.2 and has a very small size of 10×15×0.635 mm$^3$. The proposed BSF has a flat impedance bandwidth of 8-12 GHz with an insertion loss which is larger than 35 dB and a return loss which is less than 0.5 dB at the center of the band-stop frequency range. The operating frequencies of the filter can be easily controlled by changing the dimensions of the meander-line rings without changing the area taken up by the structures. The introduced filter has an excellent out-of-band performance. A good agreement between measured and simulated results was obtained. The proposed filters are promising for use in wireless technologies for radar communications due to their simple structure, compact size, and excellent performance.

***Index Terms*** **─** Band-stop filter, meander-line structure, radar system, X-band application.

## I. INTRODUCTION

In modern communications, one of the important parameter 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 [1]. In recent times, the design of filters has become an active research area as filtering is important when used in close proximity to other circuit components, like power amplifiers in the transmitter part and low noise amplifiers in receiver part, for various RF applications [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. To remove these disadvantages, defected ground structures for microstrip lines have been presented in recent years. They have been presented in a number of different shapes for filter applications [3]-[4]. The DGS applied to a microstrip line causes a resonant character of the structure transmission with a resonant frequency controllable by changing the shape and size of the slot. This technique is suitable for periodic structures and for both band-stop and band-pass filters, e.g., [5-7].

In this paper, a novel design of microstrip band-stop filter for X-band application is proposed. The reason for the choice of meander-line-ring DGSs is that these structures provide an almost constant tight coupling with three transmission zeroes at the lower, middle and upper frequencies of X-band frequency range which are important to generate a good frequency response. The designed filter has small dimensions of 10×15×0.635 mm$^3$.

## II. MICROSTRIP FILTER DESIGN

The proposed microstrip filter configuration is shown in Fig. 1. 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. For the input/output connections 50-Ohm microstrip lines are used. The microstrip band-stop filter was designed on both substrate sides by opening aperture in the ground metallization under the low-impedance transmission line. Final values of the presented band-

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stop filter design parameters are specified in Table 1.

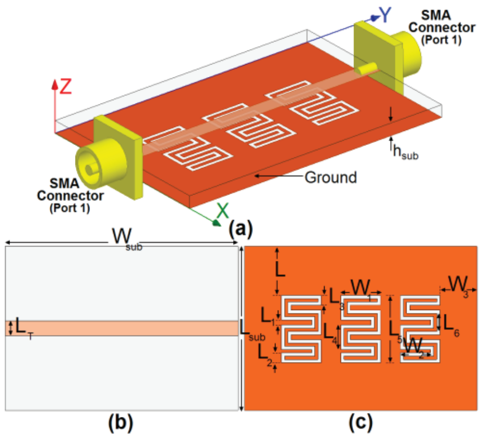


Fig. 1. Geometry of proposed microstrip band-stop filter: (a) side view, (b) top layer, and (c) bottom layer.

Table 1: The final dimensions of the filter

| Parameter | Value (mm) |
|---|---|
| $W_{sub}$ | 15 |
| $L_{sub}$ | 10 |
| $h_{sub}$ | 0.635 |
| $W$ | 1.25 |
| $L$ | 3 |
| $W_1$ | 2.5 |
| $L_1$ | 3.55 |
| $W_2$ | 1.9 |
| $L_2$ | 0.6 |
| $W_3$ | 2.5 |
| $L_3$ | 0.6 |
| $L_4$ | 1.5 |
| $L_5$ | 4.1 |
| $L_6$ | 1.1 |
| $L_T$ | 0.9 |

## III. RESULTS AND DISCUSSIONS

The proposed microstrip band-stop with various design parameters was constructed, and the experimental results of the S-parameter characteristics are presented and discussed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [7].

The configuration of the various structures used for simulation studies were shown in Fig. 2. S-parameter characteristics for the microstrip filter with an ordinary transmission line (Fig. 2 (a)), the filter with a single meander-line-ring slot (Fig. 2 (b)), and the proposed filter (Fig. 2 (c)) structures are compared in Fig. 3. As illustrated in Fig. 3, by these modified structures in the ground plane, three transmission zeroes at the lower, middle and upper frequencies can be achieved, which provide X-band frequency range. Good impedance matching for insertion/return loss ($S_{11}/S_{21}$) characteristics is generated [3-5].

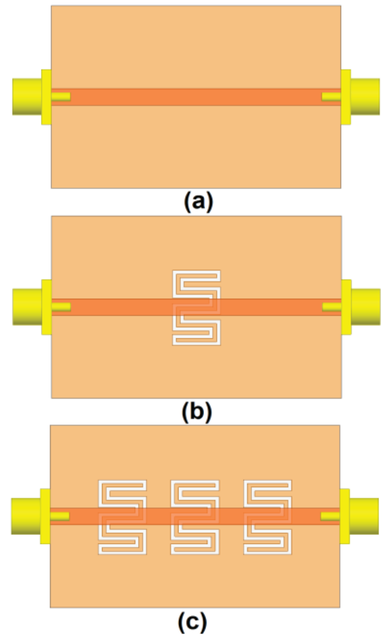


Fig. 2. (a) Basic structure (ordinary microstrip filter), (b) microstrip filter with a meander-line-ring DGS, and (c) the proposed microstrip filter structure.

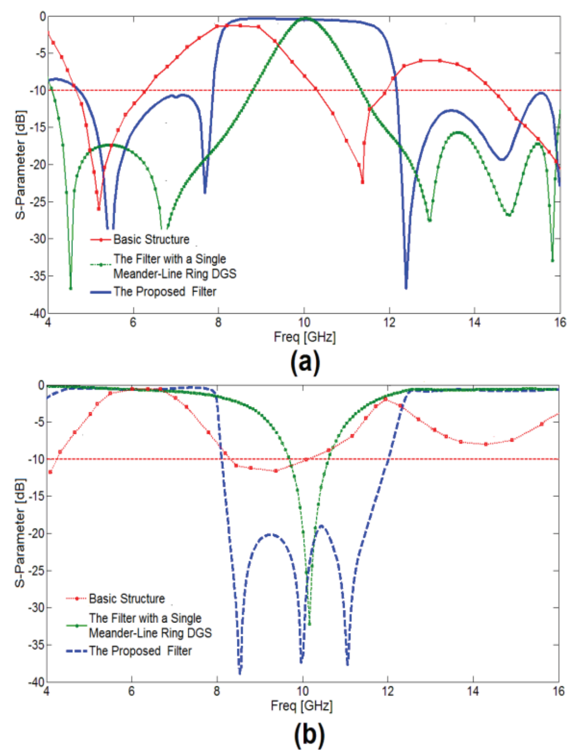


Fig. 3. Simulated S-parameters for various structures shown in Fig. 2.

Figure 4 shows the current distribution of the proposed filter at the transmission zeroes. It can be seen that using the modified meander-line ring slots as a defected ground structures have effect on the overall performance of the filter. As shown in Fig. 4 (a), at the second transmission zero resonance, the current flows are more dominant around the middle structure. The first and third zero transmission resonances at the insertion loss response of the filter (8.5 and 11 GHz) are affected from corners meander-line strutures. Figure 4 (b) and 4 (c) clearly show at the first and third zero transmission resonances, the meander-line rings at the corners side of ground plane act as half-wave resonant structures [8].

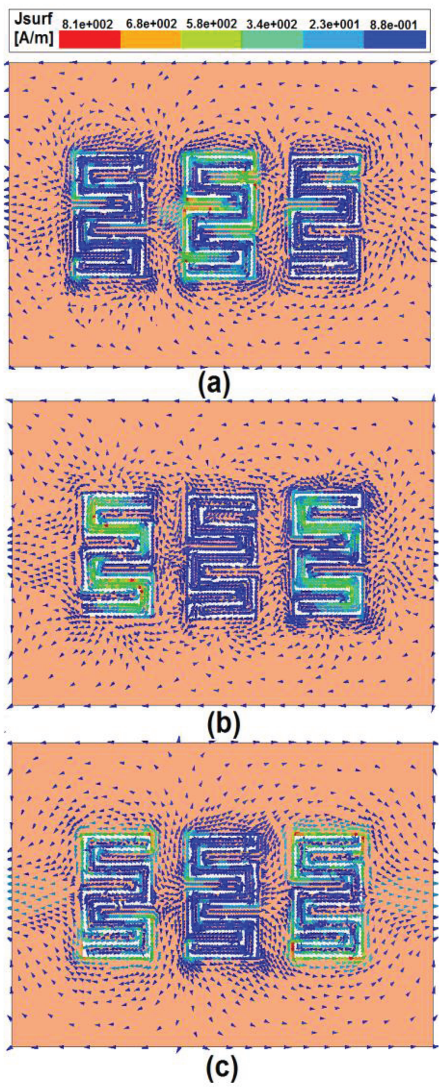


Fig. 4. Simulated surface current distributions for the proposed microstrip filter in the ground plane at: (a) 10 GHz, (b) 8.5 GHz, and (c) 11 GHz.

After checking all dimensions and final adjustments, the proposed filter with final design as shown in Fig. 5 was fabricated. After milling and drilling and plating processes, the filter is completed by adding the test port SMA connectors for measurements. The proposed filter performance is measured by using HP 8720ES network analyzer. The network analyzer is first calibrated for the operating frequency range. Measurement set-up of the proposed filter is shown in Fig. 6. The microstrip filter has good S-parameters ($S_{11}/S_{21}$) which are introduced to the filter response from 8 to 12 GHz.

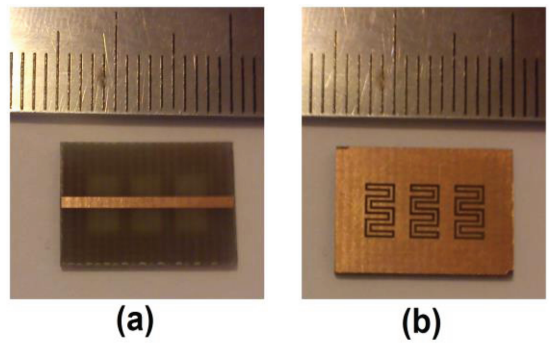


Fig. 5. Photograph of the realized printed band stop filter: (a) top view, and (b) bottom view.

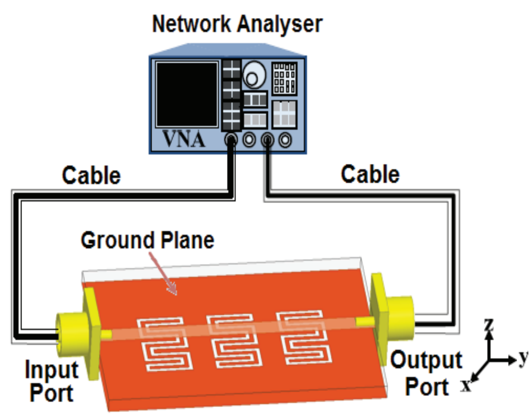


Fig. 6. The measurement setup of the proposed filter performance, using Network Analyzer.

Figure 7 shows the simulated and measured insertion and return losses of the filter. As shown in the figure, by using the proposed DGSs, we have a constant and flat impedance bandwidth at the X-band frequency range. The proposed band-stop filter has a constant and flat impedance bandwidth around of 8-12 GHz X-band with an insertion loss which is larger than 35 dB and a return loss which is less than 0.5 dB at the center of the band-stop frequency range [9].

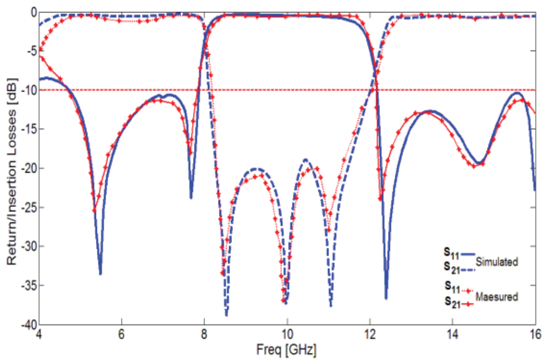


Fig. 7. Measured and simulated S-parameters for the proposed filter.

In order to investigate DGSs further, parametric analysis of $W_1$ and L is studied in Figs. 8 and 9, respectively. Figure 8 shows the effect of various dimension of $W_1$ on return loss ($S_{11}$). As observed in Fig. 8, with the increase of $W_1$, the three transmission zeroes shift to the lower frequency band. As illustrated, when the exterior widths of the meander-line DGSs ($W_1$) increase from 2 mm to 3 mm, the lower stop-band frequency is increases from 7.5 GHz to 11 GHz and also the upper stop-band frequency increases from 10.8 GHz to 13.7 GHz.

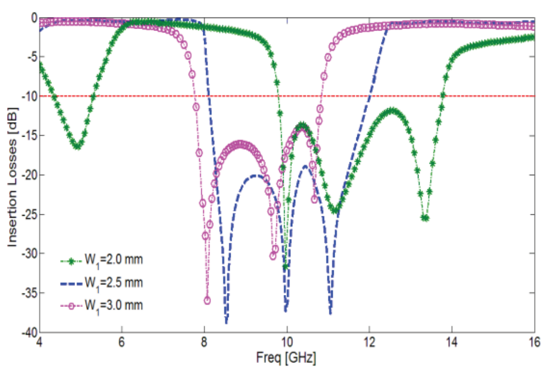


Fig. 8. Simulated insertion loss ($S_{21}$) characteristics of the filter for different values of $W_1$.

It is obvious that the variation of $W_1$ can change the physical length of DGSs significantly. Additionally, the zero separation approximately remains unchanged. From these results, we can conclude that the stop-band operation is controllable by changing the size of the employed meander-line DGSs.

The distance of embedded DGSs from corners of ground plane is set to L. By tuning its length, the characteristics impedance of proposed filter can be changed. Figure 9 shows the return loss characteristics of the filter with different values of L. The parametric study showing the relationship between the length of L and the corresponding characteristics impedance. As illustrated in Fig. 9, by properly tuning the dimensions and spacing of L, the proposed BSF has a flat impedance bandwidth of 8-12 GHz with a return loss which is less than 0.5 dB at the center of the band-stop frequency range. As seen, the proposed filter with L=3 mm, has a good out-of-band property in compared with different values of L.

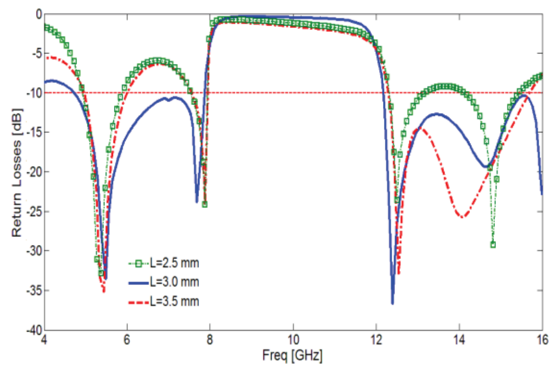


Fig. 9. Simulated return loss characteristics of the filter with different values of L.

## IV. CONCLUSION

In this paper, a novel design of band-stop microstrip filter that covers frequency bandwidth of 8-12 GHz has been presented. Configuration of the presented filter consists of a transmission line and a ground plane with triple meander-line rings as a DGS. The measured results have shown that the fabricated filter has a band-stop characteristic that extends from 8 to 12 GHz. The proposed filter configuration is simple, low-profile and can be integrated into any radar system.

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