Compact Broad Band-Stop Filter with Circular Fractal-Shaped Stubs for X-Band Radar Applications

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Abstract ─ In this letter, we use the fractal structures to design a novel compact band-stop filter with prominent cut-off sharpness and wide stop-band for X-band applications. By cutting five U-shaped slots on the ground plane and by inserting five Fractal- Shaped stubs in the microstrip transmission line, the proposed structure is created hence a constant and flat impedance bandwidth at the X-band can be produced. The operating frequencies of the filter can be easily controlled by changing the protruded fractal-shaped stubs dimensions, without changing the area taken by the structure. The experimental results show good agreement with simulation results and demonstrate that excellent stop-band performance could be obtained through the proposed band stop filter.

Index Terms ─ Band-stop filter, circular fractal-shaped stubs, defected ground plane, X-band applications.

I. INTRODUCTION

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 [1-2]. This technique is suitable for periodic structures, and for both band-stop and band-pass filters, e.g., [3]-[4]. The Defected Ground Structure (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 paper introduces a DGS with U-shaped slots. The resonant behavior of the DGS used here introduces transmission zeroes to the filter response and consequently improves its stop-band performance. The proposed structure is designed based on the fractal structures. By using this priodical structure, we have a constant and flat impedance bandwidth at the X-band frequency range. The designed filter has a small dimension of 10×15×0.635 mm^3.

II. BAND-STOP FILTER DESIGN AND CONFIGURATION

The proposed quasi-elliptic band-stop filter configuration with apertures under the high-impedance transmission lines is shown in Fig. 1. In general, the cut-off frequency of the microwave band-stop filter can be adjusted by setting proper values of the lumped elements of the filter [5]. In addition, to realize the desired capacitive and inductive values of the filter elements by the stubs of the high/low impedance transmission lines, the characteristic impedance and effective dielectric constant of these transmission lines have to be determined. The band-stop filter in Fig. 1 was designed and fabricated on a Rogers RT/Duroid 5880 substrate with 0.635 mm in thickness and with a relative dielectric constant of 2.2. Defected Ground Structure (DGS) evolved from Photonic Band Gap (PBG) is realized by etching defected pattern and slot in the ground plane. The etched defect in ground plane disturbs the shield current distribution in the ground plane. This disturbance can increase the effective capacitance and inductance of a transmission line respectively. Thus, an LC equivalent circuit can represent the proposed unit DGS circuit [1-2]. The proposed DGS slot is shown in Fig. 1 (b). The slot is etched in the ground metallization under the microstrip line. This slot has a major advantage in providing tighter capacitive coupling to the line in comparison to known microstrip DGS. Moreover, the resonant frequency of the structure can be controlled by changing the distance between the U-shaped slots. The resonant frequency of the slot can be modified by changing the overall slot size, which shifts the cut-off frequency of the filter down. To shift the frequency up instead of frequency back, it is necessary to reduce the inductance of the narrow strip-line that is located over the slot. This can easily be done by increasing the width of the strip [6]. The final values of presented band-stop filter design parameters are specified in Table 1.

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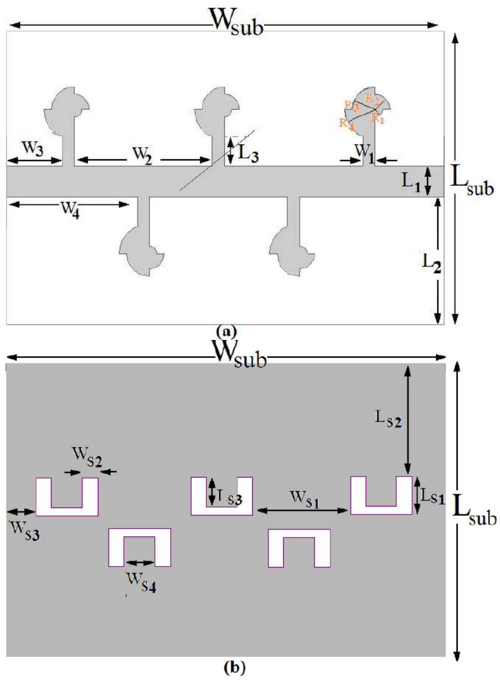


Fig. 1. Geometry of proposed microstrip filter: (a) top view and (b) bottom view.

Table 1: Optimal dimensions of proposed filter

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
W_1	0.4	L_2	4.5	W_{S1}	3
W_2	4.6	R_1	0.25	W_{S2}	0.5
W_3	2.3	R_2	0.5	W_{S3}	1.5
W_4	4.8	R_3	0.75	W_{S4}	1
L_1	1	R_4	1	L_{S1}	1.25
L_{S2}	3.5				

III. RESULTS AND DISCUSSIONS

The microstrip band-stop filter, as shown in Fig. 1, was designed on both substrate sides by opening apertures in the ground metallization under the high-impedance transmission line. Replacing some of the apertures by the proposed U-shaped structure introduces transmission zeroes. The number of transmission zeroes is equal to the number of apertures pairs according to centre in this case this number is three [6]. 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) [7], [8]. To minimize physical size of the proposed low-pass filter and increase its bandwidth, five U-shaped slots on the ground plane and five fractal-shaped stubs in the microstrip transmission line inserted to alter the input impedance characteristics. Figure 2 shows the return/ insertion loss characteristics of the various filter used for simulation studies. From the result in Fig. 2 (a), it is observed that when five U-shaped slots on the ground plane and five fractal-shaped stubs in the microstrip transmission line are used, the return loss of the proposed filter is increased amount of transmission zeros in the insertion loss. As shown in Fig. 2 (b), the five U-shaped slots on the ground plane and five fractal-shaped stubs in the microstrip transmission line also influence the bandwidth of the insertion loss. The proposed transmission line structure can be used to extend the lower edge frequency and the upper edge frequency of the insertion loss bandwidth.

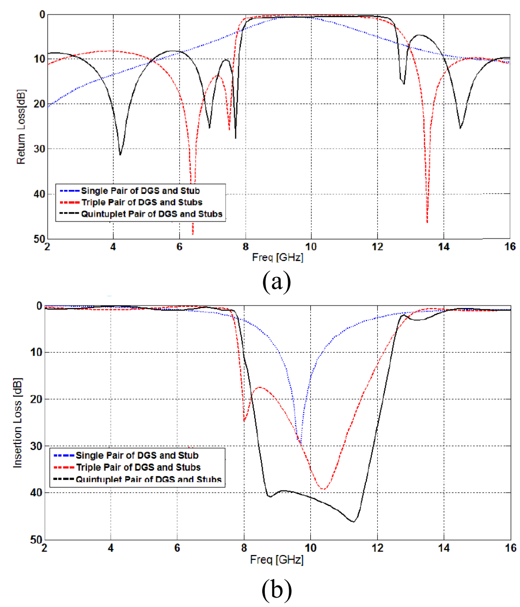
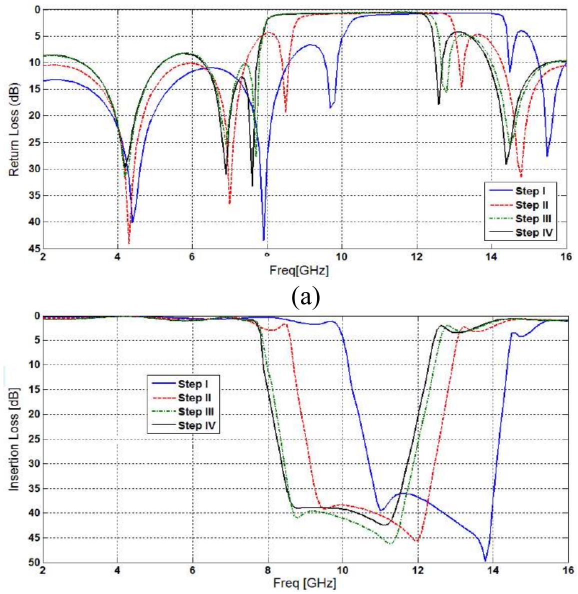


Fig. 2. Simulated return/insertion loss characteristics for the various filter structures: (a) return loss and (b) insertion loss.

To minimize physical size of the proposed band-stop filter and increase its bandwidth, four steps of semi-circular fractal-shaped open stubs are introduced into the microstrip transmission line to alter the input impedance characteristics.

Return/insertion loss characteristics for the structure of the various filter used for simulation studies are compared in Figs. 3 (a) and (b). From the result in Fig. 3 (a), it is observed that when four steps of semi-circular fractal-shaped open stubs are used, the return loss of the proposed filter is changed at lower frequencies. As shown in Fig. 3 (b), the semi-circular fractal-shaped open stubs also influence the bandwidth of the insertion loss.

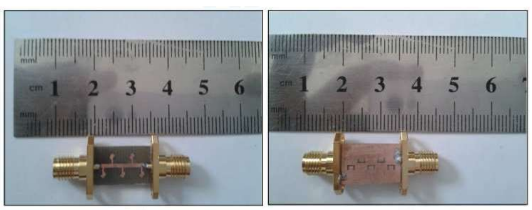
The proposed transmission line structure can be used to extend the lower edge frequency and the upper edge frequency of the insertion loss bandwidth. The proposed filter with optimal design, as shown in Fig. 4, was fabricated and tested in the Antenna Measurement Laboratory at Urmia University. Figure 5 shows the simulated and measured insertion and return loss of the filter.



(a)

(b)

Fig. 3. Simulated return/insertion loss characteristics for the various steps of Koch-Snowflake fractal structures: (a) return loss and (b) insertion loss.



(a) **(b)**

Fig. 4. Photograph of the realized printed band stop filter: (a) top view and (b) bottom view.

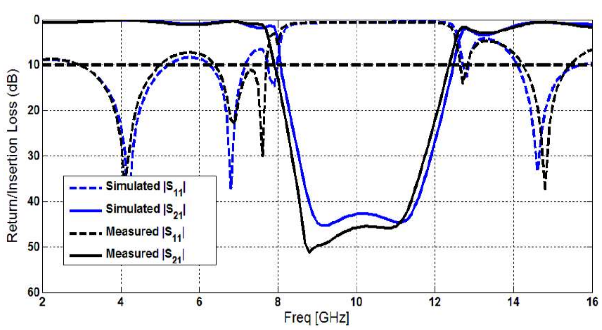


Fig. 5. Measured and simulated return/insertion loss for the proposed band stop filter.

As shown in Fig. 5, a flat insertion and return losses are introduced to the filter response at about 8.02 to 12.07 GHz. Consequently a wide stop-band was achieved. Additionally, the proposed DGS band-stop filter also has characteristics of wider and deeper stop-band than those of conventional band-stop filters [9], [10]. As shown in Fig. 5, there exists a discrepancy between measured data and the simulated results. 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 [10], [11]. In order to confirm the accurate return loss characteristics for the designed antenna, it is recommended that the manufacturing and measurement process need to be performed carefully, besides, SMA soldering accuracy and RT/Duroid substrate quality needs to be taken into consideration.

IV. CONCLUSION

In this paper, a novel band-stop microstrip filter by using a modified defected ground structure is presented for satisfying X-band applications. By cutting five U-shaped slots on the ground plane and by inserting five fractal-shaped stubs in the microstrip transmission line, the proposed structure is created; hence, a constant and flat impedance bandwidth at the X-band can be produced. The desired resonant frequencies are obtained by adjusting the number of U-shaped slots on the ground plane. Also, in order to enhance the impedance bandwidth characteristic five fractal-shaped stubs are inserted in the microstrip transmission line. Prototypes of the proposed filter have been constructed and studied experimentally. The measured results showed good agreement with the numerical prediction and good flat insertion and return losses characteristics.

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