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A Novel Design of Compact Microstrip Low-Pass Filter with Large Band-Stop Characteristic

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Abstract

In this paper, a compact microstrip low-pass filter (LPF) for radar applications is proposed. The microstrip filter configuration consists of a transmission line with a pair of S-shaped stub with radial stub loaded resonators (RSLRs), and a ground plane with triple array modified stairwell defected ground structures (DGSs). Operation frequencies of the filter can be easily controlled by changing the sizes of RSLR structures. The DGS slots evolved from photonic band gap (PBG) is embedded to achieve a good impedance matching and the required filter's characteristics. The proposed LPF has a flat rejected-band characteristic around of 3-15 GHz with an insertion loss which is larger than 27dB and a return loss less than 0.5dB at the centre of the band-stop frequency range. An excellent agreement between measured and simulated was obtained. 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 $10\times15\times0.635$ mm^3. The proposed filter configuration is simple, easy to fabricate and can be integrated into any radar system.

Keywords: DGS, low-pass filter, radar application, RSLR.

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. 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 [1].

Conventionally the microwave filter 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 [2]-[3]. 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 low-pass filters, e.g., [4]-[5].

This paper work deals with design and development of a microstrip low-pass filter for radar system applications. In this structure, the resonant behaviors of the RSLRs are used here introduces transmission zeroes to the filter response and consequently improves its band-stop performance. Also, the reason for the choice of stairwell DGS is that can provide an almost constant tight coupling, which is important to generate a good frequency response. The designed filter has a small dimension of $10 \times 15 \mathrm{mm}^2$.

II. FILTER DESIGN

The proposed microstrip filter configuration is shown in Figure 1.

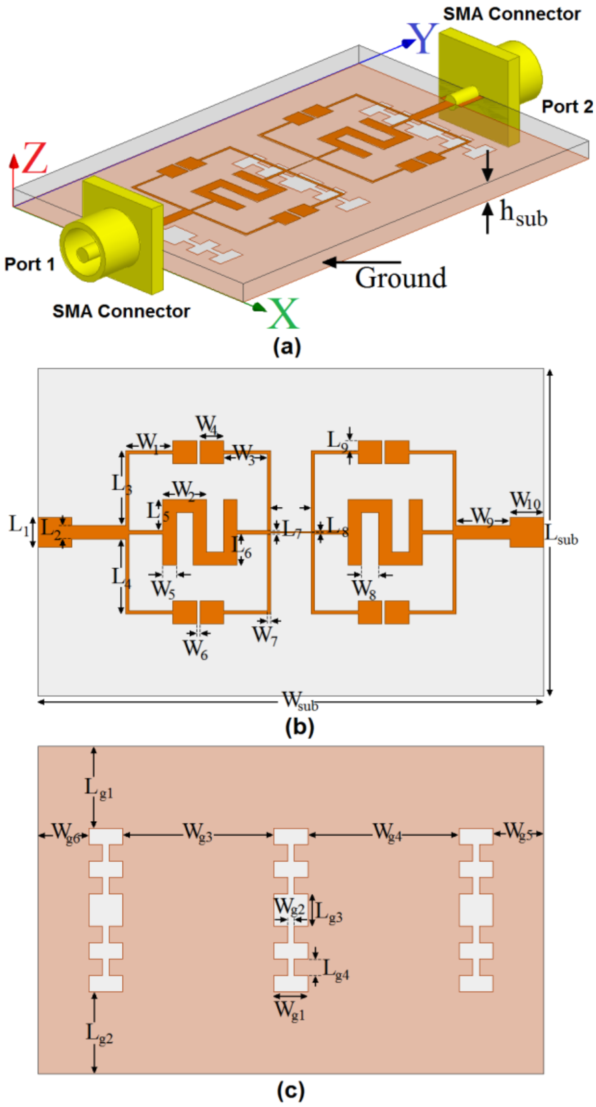

Fig. 1 Geometry of proposed filter (a) side view, (b) top layer, (c) bottom layer.

This 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 LPF was designed on both substrate sides by opening aperture in the ground metallization under the low-impedance transmission line. Replacing of the pair of the pair of S-shaped stub with RSLR structures introduces transmission zeroes. Final values of the presented band-stop filter design parameters are specified in Table. 1.

Table. 1. Final dimensions of the filter.

Parameter	W_{sub}	L_{sub}	h_{sub}	W_1
(mm)	15	10	0.635	1.4
Parameter	L_3	W_4	L_4	W_5
(mm)	2.3	0.7	2.3	0.4
Parameter	L_7	W_8	L_8	W_9
(mm)	0.1	0.5	0.04	1.6
Parameter	W_{g2}	L_{g2}	W_{g3}	L_{g3}
(mm)	0.2	2.5	4.5	1
Parameter	L_1	W_2	L_2	W_3
(mm)	0.9	1.3	0.4	1.4
Parameter	L_5	W_6	L_6	W_7
(mm)	0.95	0.1	0.95	0.1
Parameter	L_9	W_{10}	W_{g1}	L_{g1}
(mm)	0.3	1	1	2.5
Parameter	W_{g4}	L_{g4}	W_{g5}	W_{g6}
(mm)	4.5	0.5	1.5	1.5

III. RESULTS AND DISCUSSIONS

The proposed microstrip filter 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) [6]. The HFSS is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modelling, and automation in an easy to learn environment where solutions to 3D EM problems are quickly and accurate obtained. Ansoft HFSS employs the Finite Element Method (FEM), adaptive meshing, and brilliant graphics to give unparalleled performance and insight to all of 3D EM problems. Ansoft HFSS can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields [12].

The proposed filter with final design was fabricated and tested that has a good S-parameters (S_{11}/S_{21}) are introduced to the filter response from 3 to 15 GHz. Figure 2 shows the simulated and measured insertion and return loss of the filter. As shown in Figure 2, a flat insertion and return losses are introduced to the filter response. Consequently a very wide band-stop characteristic was achieved. The measured insertion and return losses (S_{21} and S_{11}) are found to be less than 27 dB and better than 0.5dB, respectively, over the entire stop-band for the filter. The filter shows two new transmission zeros at the lower and upper edges of the desired stop-band which increase the proposed filter performance.

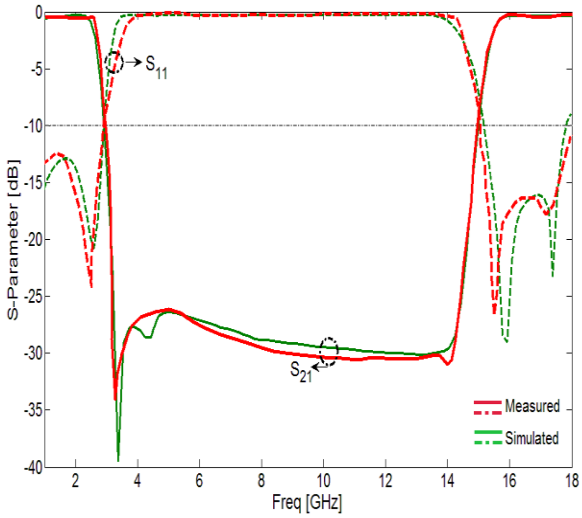

Fig. 2. Measured and simulated S_{11}/S_{21} characteristics for the proposed filter.

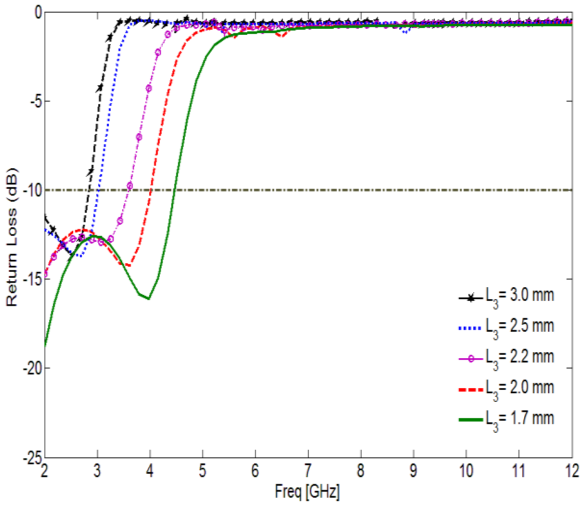

Fig. 4 Simulated insertion loss characteristics for the proposed LPF with and without DGSs.

Fig. 3 shows the simulated return loss characteristics for different values of L_S. It is seen we can control return loss bandwidth by changing the size of L_S. By using this structure with optimum size of L_S=3 mm, a good return loss bandwidth at the lower-edge frequency can be achieved.

Figure 4 shows the effects of DGS with different numbers on the insertion loss matching. It is found that by inserting the three vertical stairwell DGS of suitable dimensions at the ground plane good impedance matching for insertion loss characteristics in comparison to the same filter without DGS can be achieved. As illustrated in Fig. 3, the microstrip filter with slotted ground plane has a wider insertion loss bandwidth.

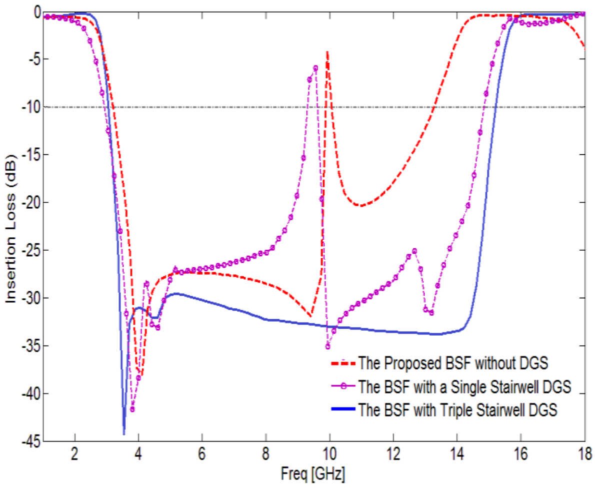

Fig. 4 Simulated insertion loss characteristics for the proposed LPF with and without DGSs.

IV. CONCLUSION

In this paper, a novel design of low-pass microstrip filter has been presented. The proposed microstrip LPF structure consists of a transmission line with a pair of S-shaped stub RSLRs, and DGS. The proposed filters are promising for use in wireless technologies for radar communications due to their compact size, and excellent performance.

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