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Microstrip Low Pass Filter using Defective Ground Structures

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Abstract: - Low pass filter forms the primary and vital component of a transceiver system. Three different methods to design compact microstrip low pass filter are discussed in this paper. All three prototypes contain defective ground structure (DGS) in the ground plane. Type I filter structure is designed with three fingered interdigital slot the ground plane. Type II low pass filter design contains circular DGS pattern, while type III low pass filter consist of many fingered interdigital slots on ground plane. Interdigital slot consists of metal fingers, which enhances the performance of the filter. The resonant frequency can easily be changed by tuning the length of the metal fingers. Based on the comparative study, it is found that the insertion loss is minimum for type III filter design i.e. 0.1dB. The return loss is found to be 26dB, 35.8dB and 21dB for type I, type II and type III low pass filter respectively.

Keywords: Low pass filter, Defective ground structure, Interdigital slots, Insertion loss, Return loss

I. INTRODUCTION

Microwave low pass filters are most important components in transceiver circuits, to suppress harmonics and spurious signals. An ideal low pass filter is one with minimum insertion loss and high return loss. By providing transmission at frequency within the passband and attenuation in the stopband, a filter can be used to control the frequency response at a certain point in microwave/RF system. Modern wireless communication system demand filter with miniature size, ultra-wide stopband, minimum insertion loss and enhanced selectivity. Compact size low pass filter is one of the major components in many communication systems. Conventional low pass filters provide gradual frequency response and hence require more number of sections to achieve required performance. This is not desirable, as the size and insertion loss of the filter increases. Realization of microwave low pass filter using DGS have drawn great attention due to its advantages like higher power handling capability and enhanced performance. DGS is realized by etching slots on the bottom layer which is the ground metal layer. Different size and shapes of DGS can be used. These slots provide better capacitive coupling. The equivalent circuit for a DGS is a parallel-tuned circuit in series with the transmission line to which it is coupled as shown in figure1.

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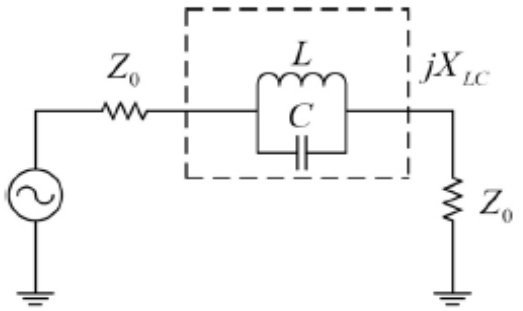

Figure 1: DGS Equivalent Circuit

To achieve size reduction with optimum performance, different methods are available to design low pass filter. A low pass filter using stepped impedance for a cut-off frequency of 2.2 GHz is discussed in [1]. Conventional stepped impedance has stopband rejection level degradation due to frequency distributed behaviour of finite section lines. Improving the stopband rejection requires more sections, which increases the size of the circuit. Low pass filter with triangular headed DGS (Defected Ground Structure) with a cut-off frequency of 2.5 GHz is proposed in [2]. Another low pass filter design using dumbbell shape DGS is discussed in [3-5]. The rejection levels in the stopband of these filters were not satisfactory. A split ring defected ground structure based low pass filter is reported in [6] with a 3 dB cut-off frequency at 2.6 GHz. Two methods of designing low pass filter are reported in [8] for a cut-off frequency of 3 GHz, one with rectangular DGS in ground plane and other using SGP (Series of Grounded Patches), but both models suffer from limitations in fabrication technique. A low insertion loss, low pass filter using rectangular coaxial line is discussed in [9] in which cascading many sections can lead to larger size of the circuit. A low pass filter based on SRR is reported in [10] that works for a cut-off frequency of 6 GHz, but has comparatively poorer insertion loss. Low pass filters discussed in [11-12] utilizes CSRR to attain higher quality factor, but have narrow stopband. Both SRR and CSRR require the presence of an effective medium with negative permittivity over the stop-band. A low pass filter with three finger interdigital DGS slot is reported in [13], which has a 3 dB cut-off at 3.1 GHz.

In this paper compact low pass filter designs with low insertion loss, using different DGS is discussed. It was found that different size and arrangement of DGS have different effect on the filter performance.

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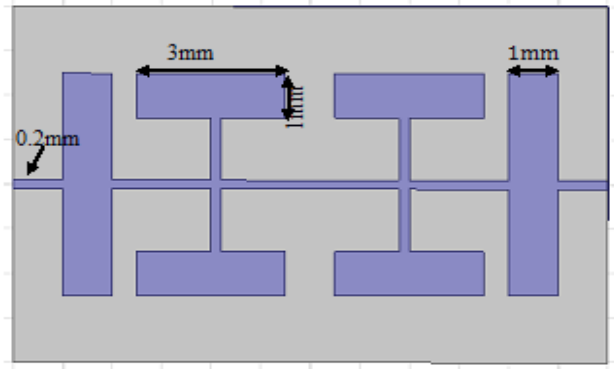
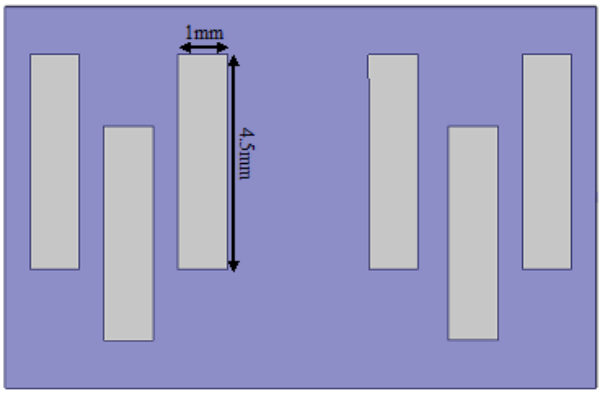
II. LOW PASS FILTER DESIGN

Type-I

The layout of proposed type I low pass filter top plane and bottom plane is shown in figure 2(a) and 2(b). The top plane consists of two I-shaped geometry between 2 rectangular patches. The substrate used is FR4_epoxy with a relative dielectric constant of 4.4 with a thickness of 0.6mm. The dimensions of the filter are 12mm×8mm×0.6mm.



(a) Top plane

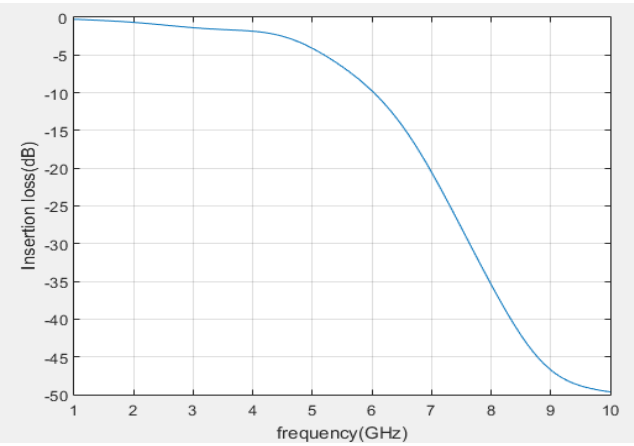


(b) Bottom plane

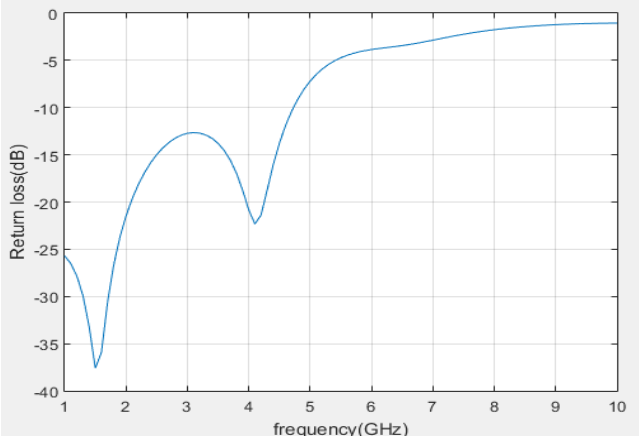
Figure 2: Layout of the type I low pass filter

The bottom plane contains defective ground structure with 3 fingered interdigital slots on the ground layer. The metal finger has dimension 4.5mm× 1mm. The frequency response of the filter can be varied by varying the length of these slots and inductance can be varied by varying the width of the metal finger.

The simulated results are shown in figure 3(a) and 3(b). It is evident that the insertion loss of the filter is 0.3B, with a 3 dB cut-off at 4.9 GHz. The return loss is found to be 26 dB.



(a) Insertion loss



(b) Return loss

Figure 3: Simulated S-parameters of type I low pass filter

Type-II

The bottom plane of proposed type II low pass filter shown in figure 4(a). The top plane is same as shown in figure 2(a).Circular DGS patterns with two different radiuses are used at the ground metal plane. The radius of bigger circle and smaller circle are 2mm and 1 mm respectively.

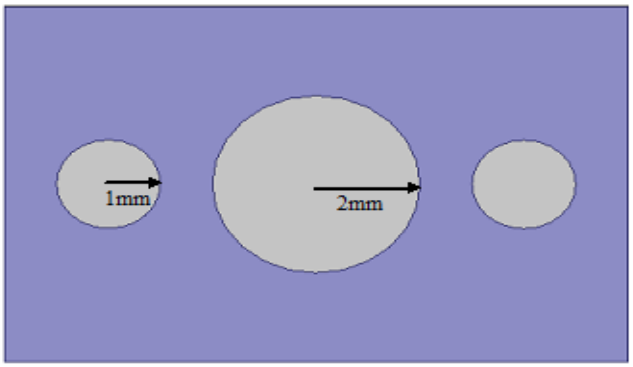
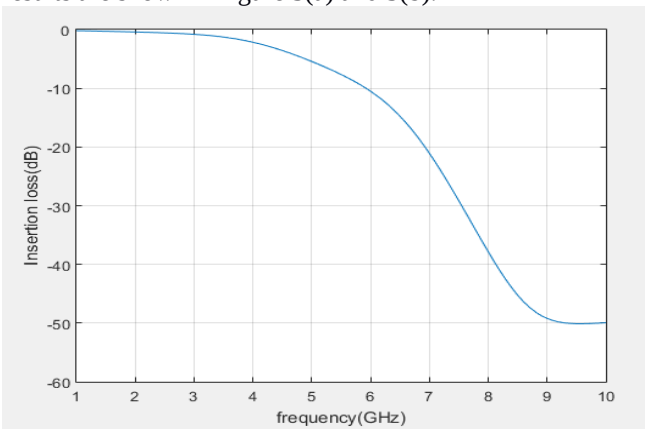


Figure 4: Layout of bottom plane of type II low pass filter

It is found that the return loss has enhanced to 35.8 dB and the insertion loss enhanced to be 0.2 dB in the passband. The 3 dB cut-off is found to be at 4.4 GHz. The simulated results are shown in figure 5(a) and 5(b).



(a) Insertion loss

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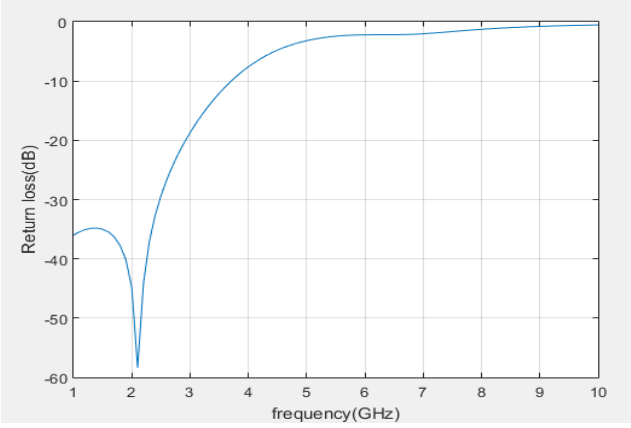


(b) Return loss

Figure 4: Simulated S- parameters of type II low pass filter

Type-III

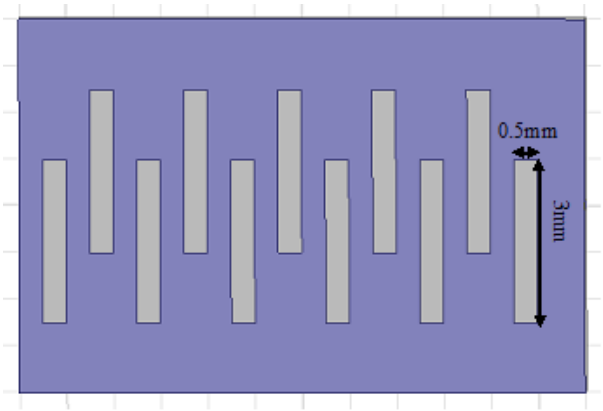
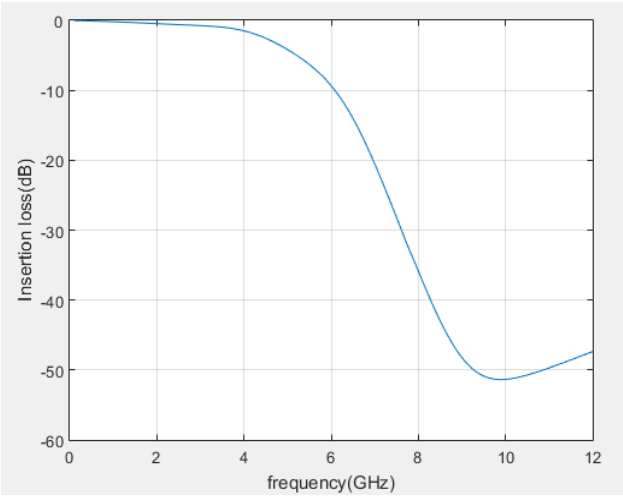
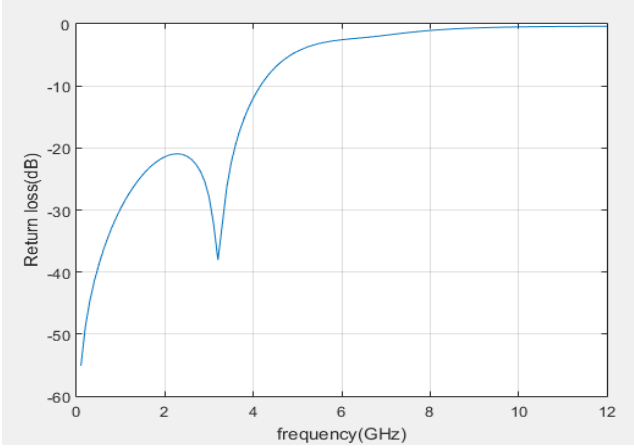


Figure 5: Layout of bottom plane of type III low pass filter

Figure 5 shows the ground plane of the low pass filter with interdigital slots on the ground plane. The top plane is same as shown in figure 2(a). Interdigital slots consist of metal fingers of dimension 3mm×0.5mm. Many fingered interdigital slots on the ground plane modify the shield current distribution of the ground plane. The return loss is found to be 21 dB and the insertion loss enhanced to 0.1 dB. Also sharper roll-off is obtained with the use of interdigital metal fingers. The 3db cut-off is at 4.6 GHz. The simulated results are shown in figure 6(a) and 6(b)



(a) Insertion loss



(b) Return loss

Figure 6: Simulated S- Parameter for type III low pass filter

III. CONCLUSION AND FUTURE WORK

Three different methods to design a compact low pass filter are discussed in this paper. Type I filter is designed using three fingered interdigital defect on the ground plane. Type II filter makes use of circular DGS pattern on the ground plane. Type III low pass filter is designed many fingered interdigital slot on the ground plane. The results are compared and it was found that the insertion loss performance enhanced for type III low pass filter .Though effort was to enhance the filter performance with the use of DGS slots in the ground plane, there are still more scope for novel designs. DGS with other size and arrangements can be etched on the ground plane that can enhance the performance of the low pass filter. The proposed filter can be used for long-distance radio telecommunication, radar and satellite communication applications.

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