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Compact Low Pass Filter Designs Using SIR, Circular DGS and Interdigital Slots

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***Abstract*— Highly Compact low pass filters designed for cut-off frequency of 6.3 GHz using stepped impedance resonators (SIRs) and Defective Ground Structures (DGS) is discussed in this paper. Three different filter structures are presented. The first structure has no defects on the ground plane. The second one with metal fingered interdigital slots on ground plane and the third one with circular DGS on the ground plane. The passband insertion loss is found to be minimum, i.e. 0.1dB. The effect of different DGS structures is carefully studied. It is found that return loss enhancement is achieved using different DGS structures. The return loss achieved for interdigital slot DGS is 20.8dB and for circular DGS is 23.2dB, while the one without any DGS on ground layer has a return loss of 19.5dB.**

***Index Terms*— Low pass filter, Defective ground structure, Interdigital slots, Insertion loss, Return loss.**

I. Introduction

Compact size low pass filter is one of the major components in many communication systems. In order to achieve the desired spectrum and suppress harmonics or spurious signals a low pass filter must be included at the transmitting and receiving end of the system. 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 [14]. 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. Stepped impedance low pass filter uses cascade structure of high and low impedance transmission lines. High impedance lines act as series inductors and low impedance lines act as shunt capacitors [7].

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 a low pass filter prototype is discussed with three different designs. One without any DGS on the ground plane and others with two different DGS structures on the ground plane. Interdigital slots and circular DGS are used respectively as defects on the ground plane. The effects of the above are carefully studied and analyzed. It is found that the return loss of the filter improved after the use of DGS and a compact size low pass filter is achieved. Simulation studies are conducted using Ansoft HFSS.

II. LOW PASS FILTER DESIGN

Type I low pass filter

The layout of proposed type1 low pass filter top plane and bottom plane is shown in figure 1(a) and 1(b). In this design the ground plane does not contain any defects. The top plane has 2 C-shaped section (1 & 2) facing each other. Between the C-shaped sections a rectangular patch is placed. 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 10mm×6mm×0.6mm.

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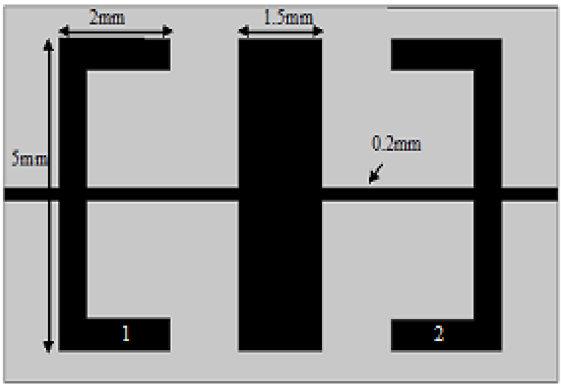

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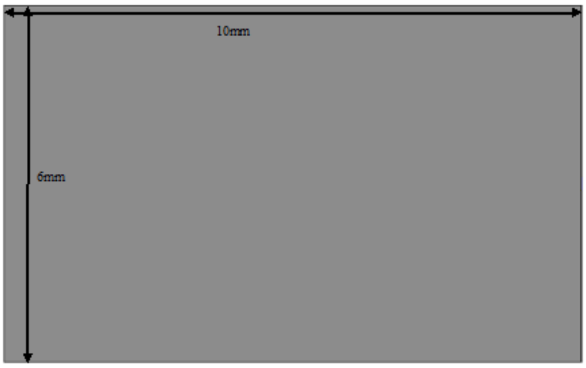

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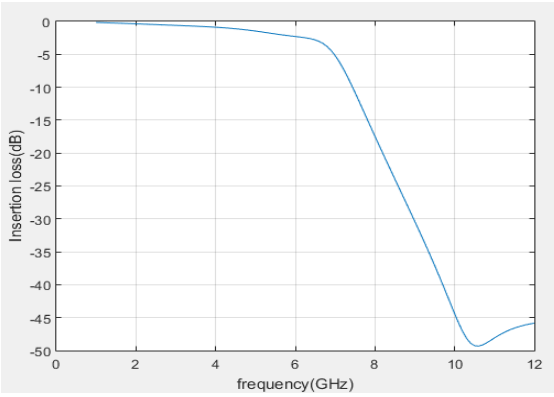
Figure 1: Layout of proposed type I low pass filter (a). Top plane (b) Bottom plane

The simulated results are shown in figure 2(a) and 2(b). It is evident that the insertion loss of the filter is 0.1dB, with a 3 dB cut-off at 6.3 GHz. The return loss is found to be 19.5 dB



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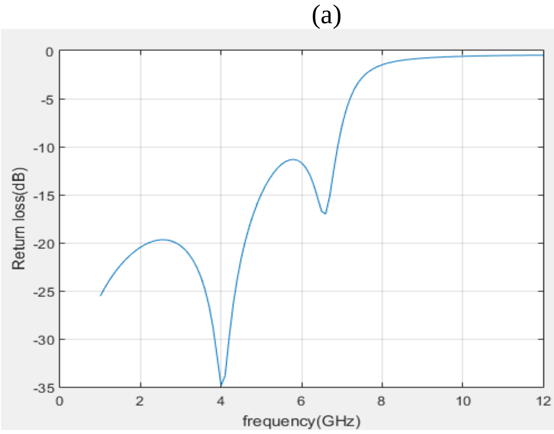


(b)

Figure 2: Simulated S parameters (a) Insertion loss (b) Return loss

Type II low pass filter

Figure 3(a) 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 1(a). Interdigital slots consist of metal fingers of dimension 2mm×0.5mm. 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.

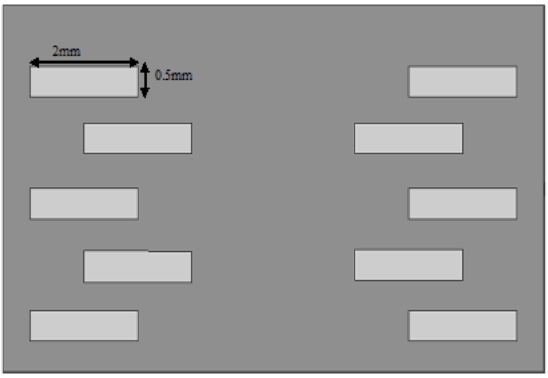
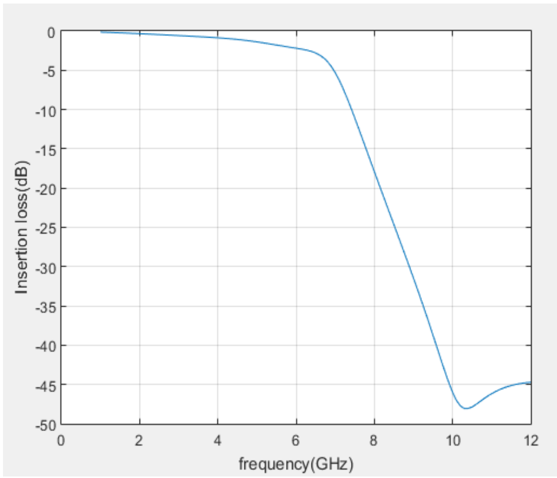


Figure 3(a): Layout of bottom plane of proposed type II low pass filter

Five fingered interdigital slots are used on both ends of the plane which modifies the shield current distribution of the ground plane. The return loss has enhanced with the use of the DGS structure and is found to be 20.8dB without any degradation in the insertion loss. Also sharper roll-off is obtained with the use of interdigital metal fingers.

The simulated results are shown in figure 4(a) and 4(b). It is evident that the insertion loss of the filter is 0.1dB, with a 3 dB cut-off at 6.3 GHz.



(a)

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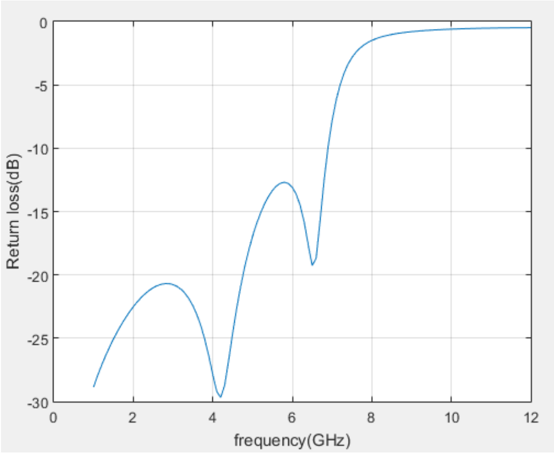
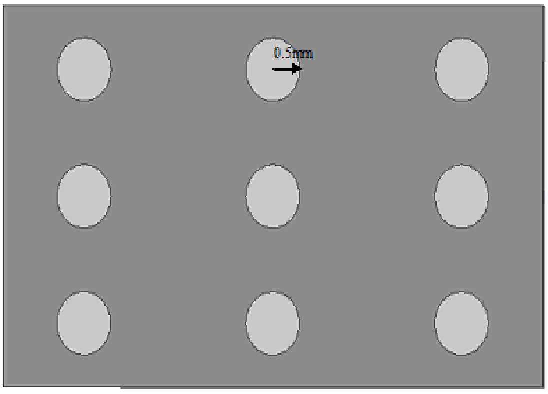


(b)

Figure 4: Simulated S parameters (a) Insertion loss (b) Return loss

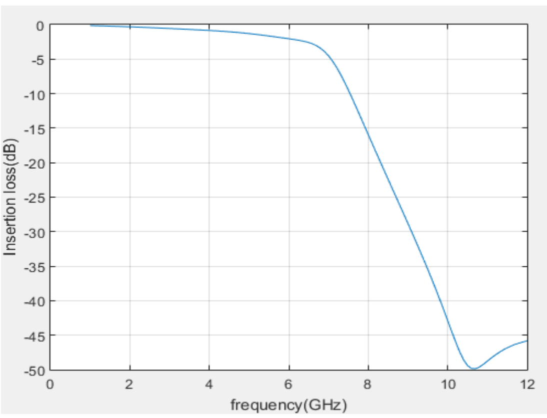
Type III low pass filter

The bottom plane of proposed type III low pass filter shown in figure 5(a). The top plane is same as shown in figure 1(a).Circular DGS patterns are used at the ground metal plane. The radius of the DGS used is 0.5mm. Nine such circular DGS are etched on the ground plane. Top plane is same as that of the type I low pass filter. It is found that the return loss has enhanced to 23.2dB and the insertion loss found to be 0.1dB in the passband. The simulated results are shown in figure 6(a) and 6(b).

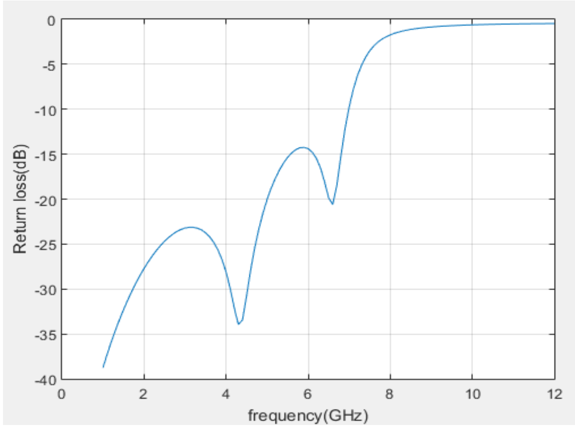


(a)

Figure 5(a): Layout of bottom plane of proposed type III low pass filter with circular DGS



(a)



(b)

Figure 6: Simulated S- parameters (a) Insertion loss (b) Return loss

III. CONCLUSION AND FUTURE WORK

Three different designs for low pass filter designed at 6.3 GHz are discussed in this paper. Type I filter is designed using stepped impedance resonators without any slots on the ground plane. Type II filter makes use of stepped impedance resonators with interdigital slots on the ground plane. Type III low pass filter is designed with stepped impedance resonators and circular DGS slot on the ground plane. The results are compared and it was found that performance of the low pass filter improved with the use of DGS on ground plane. Though effort was to enhance the filter performance with the use of DGS slots, there are still more to cover. DGS with other size and arrangements can be etched on the ground plane that can enhance the performance of the low pass filter and also filter can be designed on other substrates which can improve the characteristic like tunability. The proposed filter can be used for long-distance radio telecommunication, radar and satellite communication applications.

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