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RESEARCH ARTICLE

Study of Ultra Wide Stopband Filter (16.1GHz) Using DGS

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Abstract

In this paper a study of ultra wide stop band filter using DGS is presented. The LPF is comprised of Stepped Impedance Filter (SIF) with studies carried with different structures like (a) back to back C shaped DGS and (b) face to face C shaped DGS. This proposed design gives a wide stopband LPF. The substrate material is RT/Duroid5880 with dielectric constant 2.2 with the thickness of 0.502mm. The proposed LPF provides wide stopband from 2GHz to 18.1GHz the insertion loss is maintained at above -3dB and return loss is greater than 25dB for face to face C shaped DGS. The proposed design is simulated in Ansoft HFSS software and tested using VNA.

INTRODUCTION

In communication system the design of microwave filter has widely used for their high performance, compact size and low cost. Lowpass filter has been used to suppress harmonics and spurious signals (Kim, I. S *et.al,* 2005). Most of the filters are designed using Stepped Impedance Filter. The SIF is widely used for the microwave application. SIF comprises of ground plane, substrate and the stripline. In SIF stripline acts as an inductor and capacitor. Based on the impedance value inductor and capacitor are assigned. The High impedance act as an inductor and Low pass filter acts as a capacitor. The high and low impedance are cascaded in the microstrip SIF (Li, L. *et. al,* 2008).

The characteristic impedance Zo is 50Ω which is used as feedline for the SIF. Electromagnetic band gap (EBG), photonic band gap (PBG), DGS and Defective microstrip structure (DMS) these are several techniques to obtain the ultra-wide stopband. EBG is most widely used for microwave application. However EBG has the disadvantage in finding the equivalent circuits. DGS, which has etched defect in the ground plane has an easy implementation of the equivalent circuit. Comparing to other techniques DGS is simple, easy and low cost which gives a broader bandwidth (He, Q. *et al*, 2009).

The etched defect made in the metallic ground plane is defined as Defective Ground Structure, which is constructed by having periodic or non-periodic etched defects in the ground plane of the microstrip line. This defect made in the ground plane disturbs the shield current distribution. This disturbance changes the characteristic of microstrip line by modifying the inductance and capacitance value. Thin slot in the ground plane is etched beneath the inductor of the stripline.

The inductor value gets increased due to the slot in the ground plane. The slot can be of different shape. Based on the shapes the losses will change, the curve in the slot gives a smooth wave transaction. The size, shape and orientation influence the performance of the design. The cutoff frequency is based on the area of the slot head and attenuation is based on the width of the etched slot. The response of the DGS is totally based on the slot width, length, head area, slot with certain head shapes. Even DGS structure can give a compact size for the filter.

A microstrip elliptic-function LPF using a microstripline section in parallel with an interdigital capacitor was proposed in (Tu, W.-H *et al*, 2006). To achieve wider stopband, stepped-impedance resonators (SIRs) are usually employed or loaded with the circuit designs. In (Wang, L. *et al,* 2010), the compact LPF with ultra-wide stopband is designed with SIRs and open-circuited stubs. A circular hairpin resonator integrated with SIR was proposed in (Yang, M., J. Xu *et al,* 2010). By the loaded SIRs, transmission zeros can be easily introduced and controlled to suppress the spurious responses. Defected ground structure (DGS) is also widely used in LPF design recently (Weng, L. H *et al* , 2008 and Cheng H *et al*, *2006*).

In Cheng H *et al*, *2006*), the LPF with cross-shape DGS shows -20 dB suppression from 4.25 GHz to 15.9 GHz. In (Al Sharkawy, M. H. *Et al*, 2011) the multilayer LPF is designed based on the arrow-shaped DGS with centered etched ellipses. The LPF in (Wei, F., L., *et al*, 2010) is realized by using a cascading microstrip coupled-line hairpin unit, semi-circle DGS and semi-circle stepped-impedance shunt stub. In (Lim, J.S *et al*., 2005), the proposed LPF featuring sharp cut of response, 100 dB/GHz, consists of the stepped-impedance hairpin resonator, an improved split-ring resonator defected ground structure and elliptical DGSs. In (Balalem, A. *et al*, 2007), two quasi-elliptic LPFs with interdigital DGS are proposed. In [Yang, J. *et al*, 2008], a novel elliptic-function LPF consisting of a dumb-bell-shaped DGS, a spiral-shaped DGS and a broadened Microstrip line is presented. The LPF with Hilbert curve ring DGS achieves high out-band suppression of more than 33 dB (Chen J., *et al*, 2007). Furthermore, the compact LPF is demonstrated by employing meandered slotted and novel grounded plane resonator to obtain wide rejection bandwidth and high attenuation rate (Wang Wang, C. -J *et al*, 2011 Ahn *et al*, D. 2001),

The design of lowpass filter involves two steps. The first step is to select an appropriate lowpass prototype. The next main step is to find the appropriate microstrip realization that approximates the lumped element filter [5]. We designed a stepped impedance type LPF with 5 the order. In this the high impedance and low impedance are cascaded and 50Ω impedance is used as a feedline in both the ends.

2. Design of Low Pass Filter:

The SIF micro stripline is built on the RT/Duroid 5880 substrate with the thickness of 0.508mm and relative dielectric constant of 2.2 and a loss tangent of 0.0012. Copper acts as a ground layer beneath the substrate. Here the 50Ω standard characteristics impedance is made as a feedline for the design of LPF. The low impedance line has a wide width when compared to high impedance line. The wide space between the stripline act as a capacitor and less space act as an inductor as shown in the below Fig. 1. The SIF design formulas are from (Hong, J.-S. *et al* 2001, Pozar, 2012]

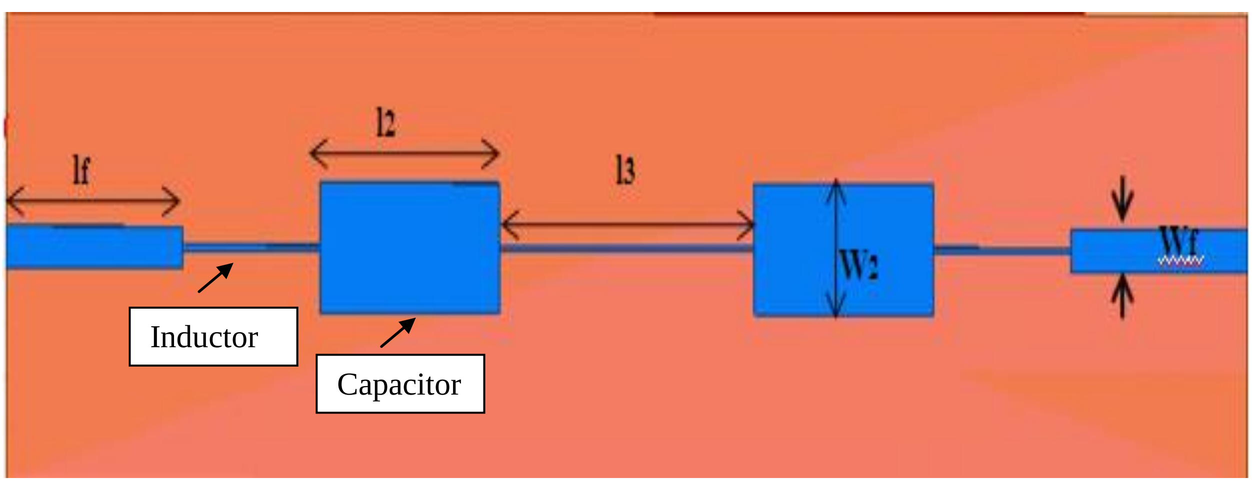


Figure 1. SILPF designed in HFSS

The dimensions are W_f= 1.6mm, W_1= 0.2mm, W_2= 5mm, and length are l_1 = 7.8mm, l_2 = 10.14mm, l_3 = 14.5mm, l_f = 10mm. The length (l) and width (w) for the stripline are calculated [4]. The design is simulated using the HFSS software. The designed SILPF has a cut off frequency of 2GHz and extend upto 7.5GHz. The simulated result is shown in the below Fig 2

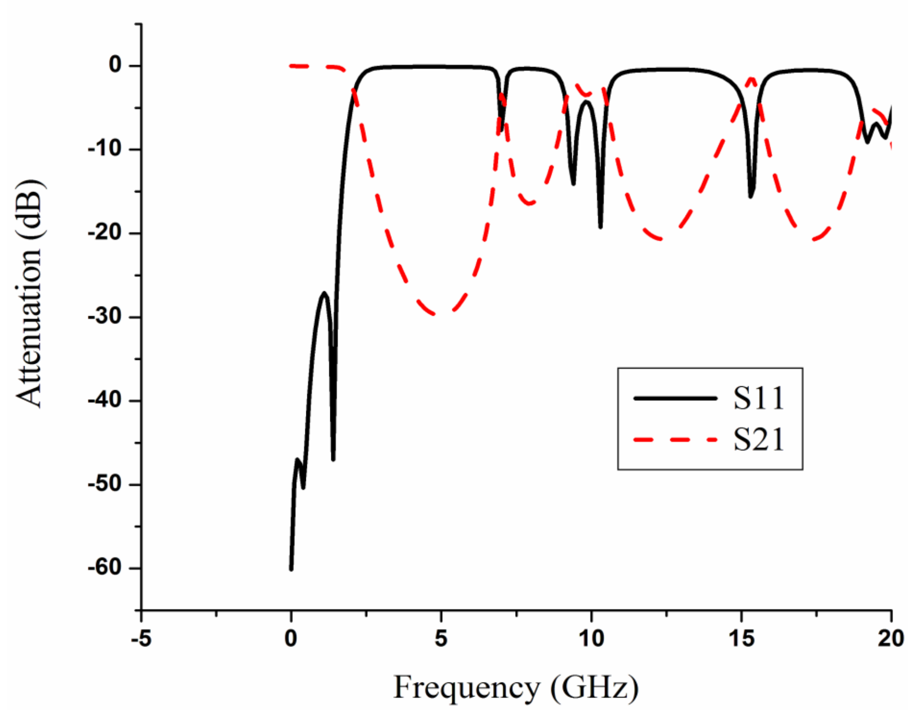


Figure 2. Simulated graph for SILPF

The above Fig. 2 gives result for simple stepped impedance Low pass filter (SILPF). The result shows 5.5GHz wide stopband. Hence, an attempt is made in the next section to enhance the bandwidth.

3. Optimized Ultra Wide Stop Band (face to face C- Shaped DGS)

The defect made in the metallic ground plane is Defective ground structure. In this proposed design a face to face C-shaped DGS is used to improve the stopband of the LPF. To get the wide stopband the C-shaped DGS is place beneath the inductor of the SILPF as shown in the below Fig. 3.

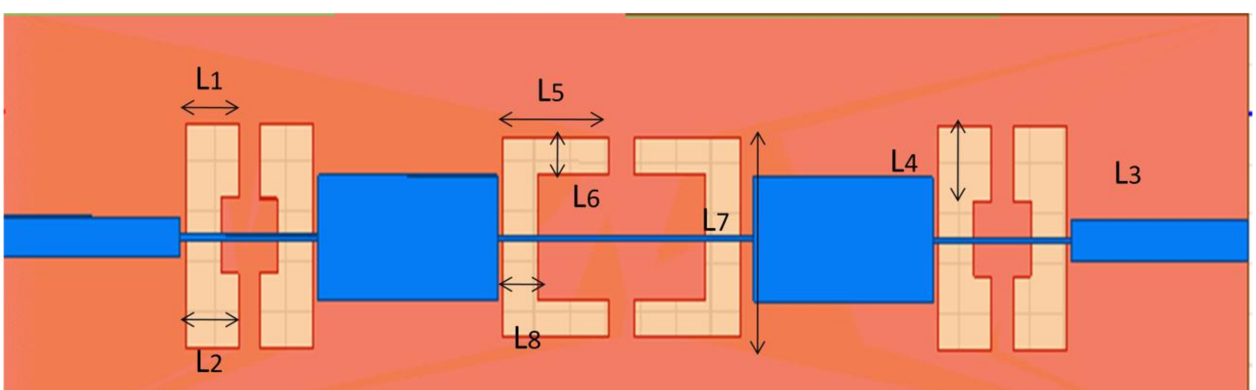


Figure 3. SILPF with face to face C shaped DGS

In this design the double C-shaped DGS is used. The double C- shaped slots are placed face to face beneath the inductor. Three pairs of C-shaped DGS are placed. The dimensions are optimized to get a wide stopband as shown in the below Table 1. The double face to face C-shaped filters with different shape will act as an LC parallel tank circuit with different resonant frequencies. Hence this results in a wide stop band.

Table 1: Optimization of face to face C-shaped DGS

First C(mm)				Middle C(mm)				Last C(mm)				Start frequency (GHz)	stop frequency (GHz)
L_1 (mm)	L_2 (mm)	L_3 (mm)	L_4 (mm)	L_5 (mm)	L_6 (mm)	L_7 (mm)	L_8 (mm)	L_1 (mm)	L_3 (mm)	L_2 (mm)	L_4 (mm)		
3	3	9	2	1.5	6	9	2	3	3	9	2	2	18.1
3	2.5	9	2	1.5	6	8	2	3	2.5	9	2	2	17.6
3	2.5	9	1.5	1.5	6	8	2	3	2.5	9	1.5	2	16.8
3	3	9	2	1.5	6	8	1.5	3	3	9	2	2	17.3

The C- shaped DGS is modified to obtain wide stopband low pass filter. Some of the optimized C-shaped values are given in the Table 1. The wider stop band reading is taken in to consideration and the same is used in HFSS software and the result is obtained for 2GHz- 18.1 GHz as shown in Fig 4. The same design is fabricated as in Fig 5(a), (b) and the results are obtained.

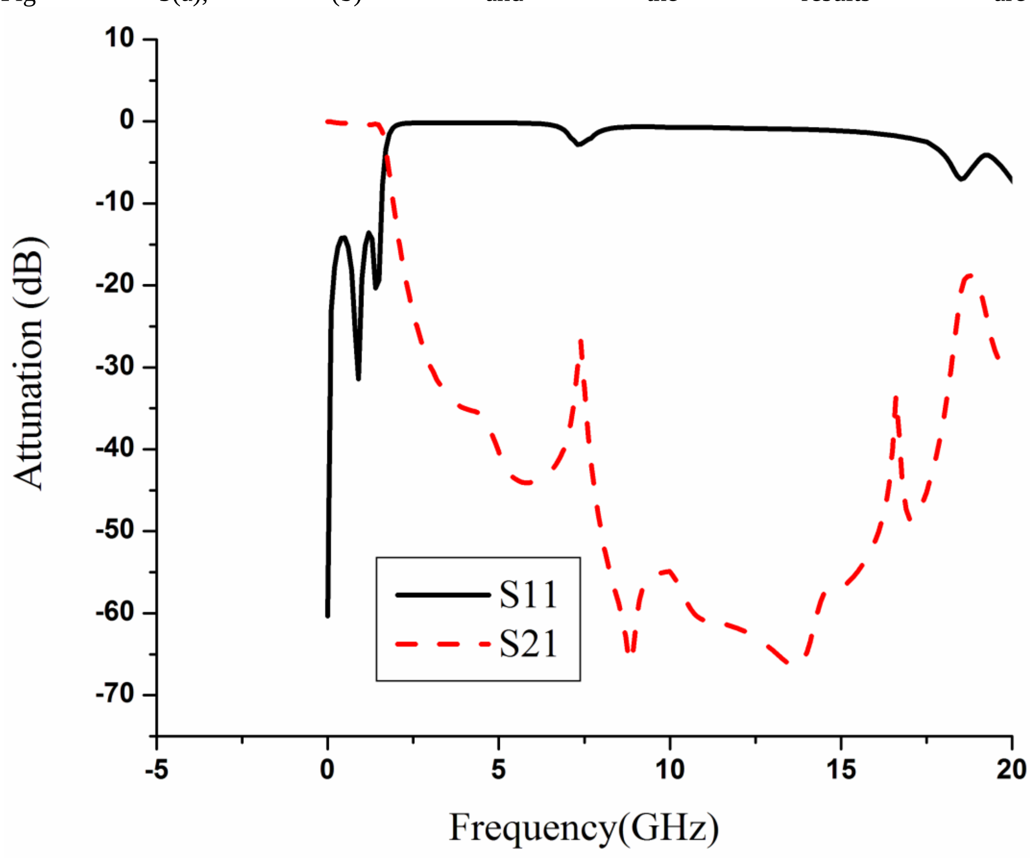
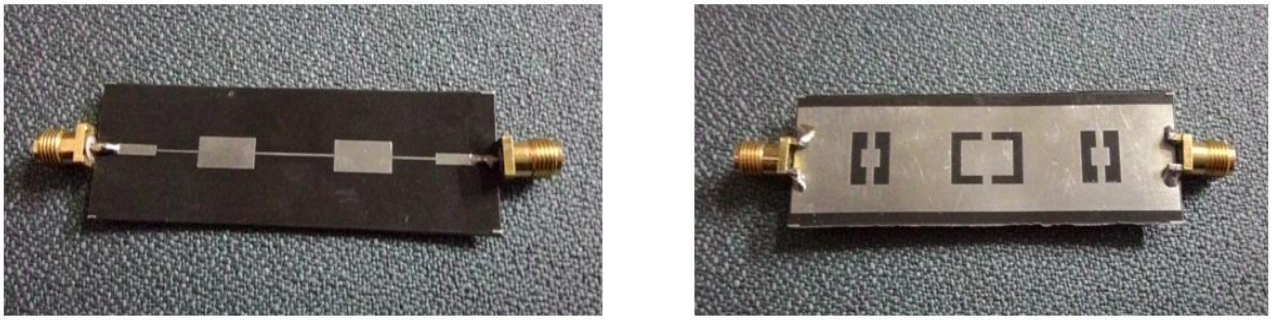


Figure 4. Simulated graph for SILPF with face to face C shaped DGS

The simulated result shows a cut off frequency at 2GHz and the stop band extends to 18.1 GHz. The insertion loss is maintained at 0dB and return loss is greater than 25dB. This result is simulated in Ansoft HFSS software.



a b

Figure 5 Fabricated SILPF with face to face C shaped DGS
(a) Front view (b) Back view

The proposed design is fabricated in RT/Duroid 5880 and the fabricated design is shown in the below Fig. 5(a),(b). The results are measured using Network Analyser (Agilent N9918A) and are shown in Fig. 6.

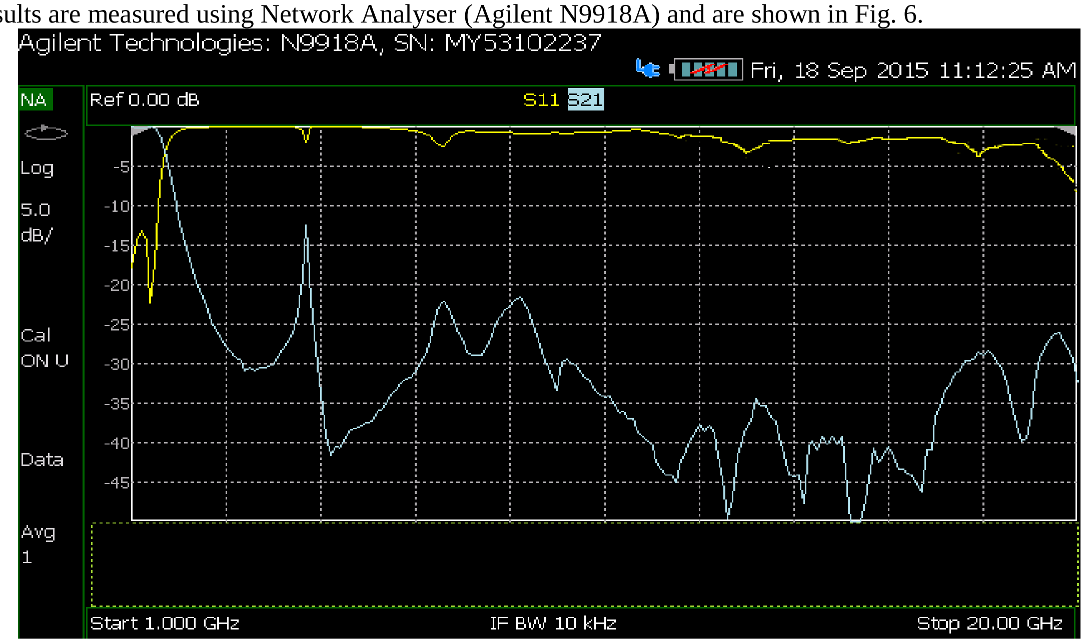


Figure 6: Measured Return and Insertion loss of SILPF with face to face to C shaped DGS

The simulated and measured results are in good agreement. There is only slight variation in the upper frequency around 18 GHz. The S_{11} is slightly gone below 3 dB because of the real time fabrication issues like soldiering, and bending (thin substrate) of the filter while connected to VNA.

4. **Optimized SILPF with Back To Back C Shaped DGS**

The defect made in the metallic ground plane is Defective ground structure. In this proposed design a back to back C-shaped DGS is used to improve the stopband of the LPF. To get the wide stopband the C-shaped DGS is placed beneath the inductor of the SILPF as shown in the below Fig. 4

From Table 2. The optimized back to back C shaped DGS gives a moderate bandwidth of 6.3 GHz which is very lesser than face to face C shaped DGS. Hence, face to face C shaped DGS is preferred over back to back C shaped DGS due to current in the closed area of the face to face C shaped DGS.

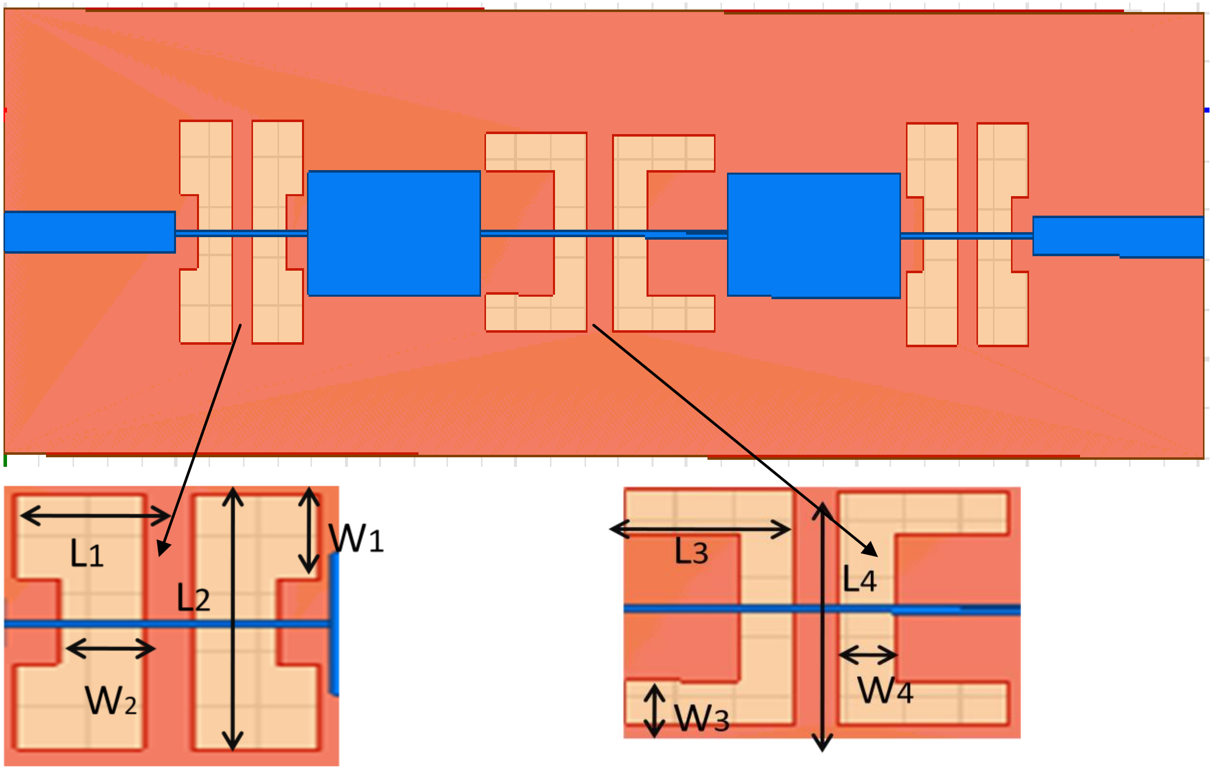


Figure 3. SILPF with back to back C shaped DGS

Table 2: Optimization of back to back C-shaped DGS

First (

L1	W1	L2	2	3	3	4	4	L1	1		W2		stop frequency (GHz)
3	3	9	2	6	1.5	8	2	3	3	9	2	1.6	7.9
3	2	9	1.5	6	1.5	10	1.5	3	2	9	1.5	1.6	7.2
3	2	8	1.5	6	1.5	8	1.5	3	2	8	1.5	1.6	6.8
3	2	9	1.5	6	1	8	1.5	3	2	9	1.5	1.6	6.8

*length and width are in mm

CONCLUSION

The study of ultra wide stop band filter using DGS is presented. The LPF is comprised of Stepped Impedance Filter (SIF) with studies carried with different structures like (a) back to back C shaped DGS and (b) face to face C shaped DGS. This proposed design gives a wide stopband LPF. From the study face to face C shaped DGS gives more bandwidth when compared to back to back C shaped DGS because of additional resonance due to current in the closed area of the face to face C shaped DGS. The response of the proposed design gives a cut-off from 2GHz and the stop band extend still 18.1 GHz. The bandwidth of the wide stop band is nearly 16GHz. The simulated result shows a good consistency with both the insertion loss and return loss. The measured result of the proposed filter is in good agreement with the simulated results. The SILPF configured with the face to face C shaped DGS can be applied to wideband microwave integrated circuits

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