Design and Fabrication of Hairpin Bandpass Filter with Square Shaped Defected Ground Structure

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***Abstract*— In this paper, the design and simulation of microstrip hairpin bandpass filter with square shaped defected ground structure is described. The method used to design the filter was very efficient and requires less effort. The filter was designed and then simulated on HFSS tool and the results were verified by the fabrication and testing process. The fabrication was performed on the material GaAs The proposed bandpass filter with a square shaped defected ground structure has good performance. The proposed hairpin bandpass filter showed the return loss of -14.69dB at 4.2 GHz, -14.97 dB at 4.8 GHz, and -19.15 dB at 5.6 GHz, -17.13dB at 6.5GHz, -13.7dB at 7.3 GHz. The insertion losses with square shaped defect were 0.8dB/0.3dB/0.16dB/0.8dB/1.4dB. 3dB and the bandwidth of proposed bandpass filter is 700 MHz/ 150 MHz/ 200 MHz /100 MHz/and 85 MHz at the center frequencies of 4.2 GHz/4.8 GHz/ 5.6 GHz/ 6.5GHz/ 7.3 GHz. In this work, the area has been reduced by 33%.**

***Index Terms*— Bandpass Filter; Hairpin Filter.**

I. INTRODUCTION

In the modern communication system, the increasing demands of wireless devices applications have led to further development in the field of microwave solid state devices. The microwave filters and radio frequency are widely used in satellite communications. The radar system and modern warfare also work on the application of microwave. Many other communication techniques such as mobile, TV broadcasting and radio broadcasting are also based on the applications of microwave systems.

For every different communication media, different frequencies are used and different bands are allocated for each of the applications. Nowadays, Radiofrequency (RF) engineering is a growing field of interest due to its advancement in voice, data, and video communication [1]. Bandpass filter is a device that has the quality to select the signals within a specific range, while rejecting the signals which are outside of that particular range. The bandpass filter plays an important role for the selection of the preferred signals in the radio frequency front end devices [2]. Nowadays, the defected ground structure (DGS) has become one of the well-known methods and an area of interest in microwave circuit [3]. DGS also has been used for bandpass filter (BPF) response. Several researches [4-6,10] have been put forward for defected ground structure. M.A. Othman, et.al.[7] designed a compact hairpin filter along with dumbbell shaped DGS. The return loss was improved from -20to -41dB. K.Vidhya and T. Jayanthy[8] used the defected ground structure for Microstrip Hairpin Bandpass Filter. The Authors used a five pole microstrip hairpin BPF by applying the dumbbell shaped DGS to suppress the second and the third order harmonics. Open stubs were also used with the dumbbell shaped defects for the efficient suppression of third order harmonics. The return loss was improved from-26dB to -32 dB. The conventional hairpin filter has insertion loss of 1 dB and using DGS hairpin filter has insertion loss of 2dB.

The size of the filter of a normal microstrip coupled line band pass filter is large because it uses the normal λ/2 resonators. Hairpin filter is the most popular and widely used configuration in microstrip bandpass filters due to their compact design. They are conceptually obtained by folding the arms of normal parallel coupled λ/2 resonators into U shape to reduce the size of filter. However, when folding the resonators, it is necessary to take into account the reduction of the coupled-line lengths, which reduces the coupling between the resonators.

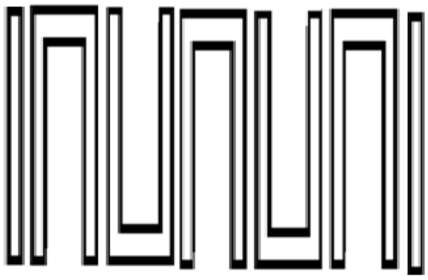

Figure 1: Hairpin bandpass filter

To design the hairpin filter, the central frequency is 6.1 GHz. The low pass prototype parameter are $g_o=g_6=1$, $g_1=g_5=1.1468$, $g_2=g_4=1.3712$ and $g_3=1.9750$, having obtained the low pass parameters, the design parameters can be calculated using equation (1) and (2)

$$Qe_1=g_0g_1/FBW \quad (1)$$

$$Qen=g_ng_n+1/FBW \quad (2)$$

where, Qe_1 and Qen are external quality factor of resonator at input and output.

$$Mi,i+1=FBW/\sqrt{gigi+1} \quad (3)$$

Where i= 1to n-1 are the coupling coefficient between adjacent resonator.

The input and output quality factor is $Qe_1= 7.456$, $Qe_5=7.45$ and the coupling coefficient $M_{12}=M_{45}=0.1250$, $M_{23}=M_{34} = 0.0934$.

II. DESIGN METHODOLOGY

In this work, five pole hairpin bandpass filter were designed and two square shaped defects were created in the ground plane of the hairpin bandpass filter. The filter was designed on the substrate Gallium Arsenide (GaAs), having relative permittivity of 12.9. Table 1 and Table 2 show the dimensions of the designed hairpin bandpass filter with the square shaped defect respectively. The top view and bottom view of the designed filter are shown in Figure 2 and Figure 3 respectively.

Table1
Parameters for hairpin filter

Parameter	Value
Internal gap of hairpin(L_1)	1mm
Length of hairpin(L_2)	4.1mm
Length of feed line(L_3)	1.55mm
Width of feed line(L_4)	0.12mm
Width of hairpin(L_5)	0.2mm
Height of copper	0.01mm
Gap width	0.06mm
Length of substrate	7mm
Width of substrate	10.79mm

Table 2
Parameters used in designing square shaped defect

Parameter	Value
a_1	2.6mm
a_2	2.6mm
b_1	2.6mm
b_2	2.6mm
c_1	4.4mm

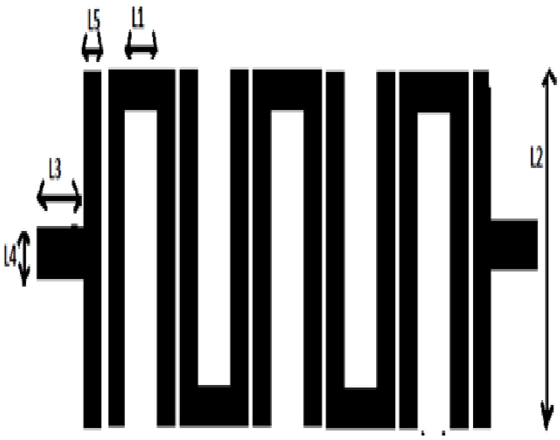

Figure 2: Top view of hairpin bandpass filter

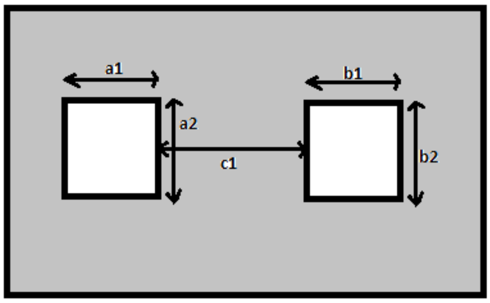

Figure 3: Bottom view of hairpin bandpass filter

III. RESULT ANALYSIS

This designed hairpin bandpass filter shows improved bandwidth and good return loss. The proposed hairpin bandpass filter shows the return loss of -14.69dB at 4.2 GHz, -14.97 dB at 4.8 GHz, and -19.15 dB at 5.6 GHz, -17.13dB at 6.5GHz, -13.7dB at 7.3 GHz. The insertion losses with square shaped defect are 0.8dB /0.3dB/0.16dB/0.8dB/1.4dB. 3dB bandwidth of proposed bandpass filter is 700 MHz/ 150 MHz/ 200 MHz, 100 MHz/and 85 MHz at center frequencies of 4.2 GHz/4.8 GHz/ 5.6 GHz/ 6.5GHz / 7.3 GHz. Area of the bandpass filter in previous work [9] is 75.53mm^2. Figure 4 shows, S_{11} and S_{21} plot of the hairpin bandpass filter with square shaped DGS. The area of hairpin bandpass filter in proposed work is 50.57mm^2. Thus, the area is reduced by 33%.

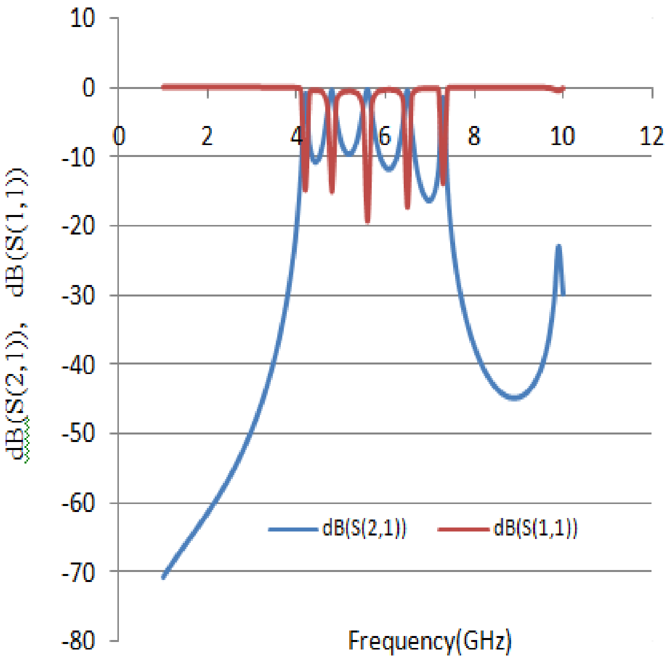

Figure 4: S_{11} and S_{21} plot with square shaped DGS

IV. FABRICATION AND MEASUREMENTS

The microstrip hairpin bandpass filter with Square shaped defected ground structure was also fabricated. The fabricated structure of the bandpass filter is shown in Fig.5 and Fig.6, filter is fabricated on GaAs substrate having dielectric constant 12.9 (ε_r) and the thickness of the substrate is 0.3mm. The fabrication of this filter was easy and at a low cost. Figure 7 indicates the S_{11} S_{21} plot of measured results. Figure 8 shows S_{11} plot of simulated and measured.

Figure 5: Top view of fabricated filter

Figure 6: Bottom view of fabricated filter

Table 3
Comparison between measured and simulated results

Parameters	Simulated	Measured
S11	-14.69dB/ -14.97dB/ -19.15dB/ -17.13dB/ -13.7dB	-14.85dB/ -25.23dB/ -16.04dB/ -10.65dB/ -6dB
S21	0.8dB/ 0.3dB/ 0.16dB/ 0.8dB/ 1.4dB	0.95dB/ 0.29dB/ 0.22dB/ 0.36dB/ 6.19dB
Center frequencies	4.2GHz, 4.8GHz, 5.6GHz, 6.5GHz, 7.3GHz	4.3GHz, 4.79GHz, 5.6GHz, 6.5GHz, 7.29GHz

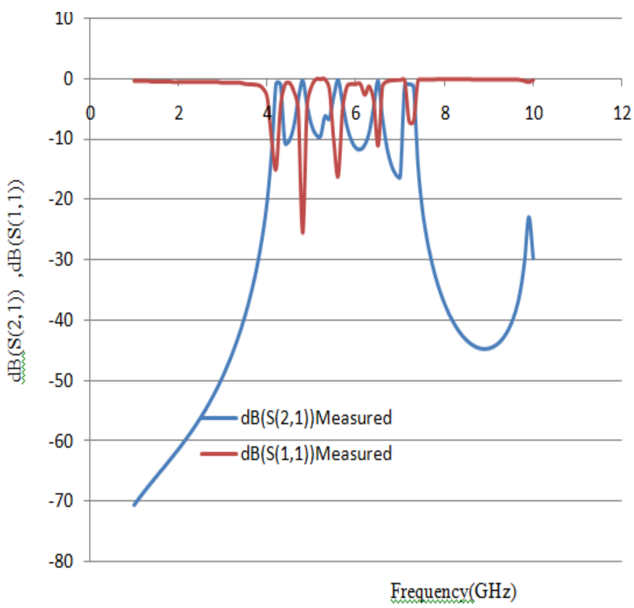

Figure 7: S11, S21 plot of measured result

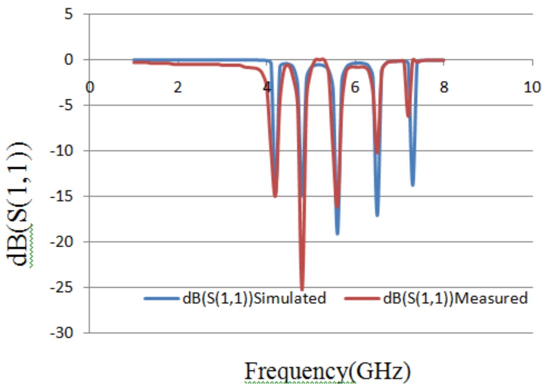

Figure 8: S11plot of simulated & measured

V. CONCLUSION

In this work, hairpin band pass filter with Square shaped defected ground structure is simulated and fabricated. Measured and simulated results are in good agreement. This hairpin bandpass filter showed improved bandwidth and good return loss. This filter can be used for surface ship radar, weather radar, optical communication, cordless phones, some Wi-fi devices and for satellite applications. Area of the bandpass filter in previous work[9] is 75.53mm^2, while area of the hairpin bandpass filter with square shaped defected ground structure is 50.57mm^2; hence the area is reduced by 33%.

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