Design and Analysis of Microstrip Bandstop Filter based on Defected Ground Structure

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***Abstract*—This Paper presents a planar Microstrip Bandstop filter with the use of defected ground structure. The bandstop filter has been designed with the use of step impedance microstrip line on the top of substrate and two convention rectangular defects in a ground plane (Using DGS technique). It produces stopband from the frequency range of 3.3GHZ to 4.8GHZ with the stop band attenuation more than 30dB. It provides relative 3dB bandwidth response of 1.5GHZ.The tuning of frequency has been carried out with the change in dimension of defected ground plane. A simulation has been performed on ANASOFT High frequency structure simulator (HFSS) and an equivalent LC circuit of the design has been verified with ANASOFT designer 8.0 Software**

Keywords-component; Attenuation, Bandstop filter, Defected ground structure (DGS), Microstrip line, Slow wave effect

I. INTRODUCTION

Bandstop filter is an essential component in microwave and wireless communication for the use of harmonic suppression, mutual coupling reduction and for the suppression of spurious and leakage transmission. So it is essential that the filter provides high performance, compact size and low cost with high attenuation in the stop band.

There are several techniques those have been adopted to design a filter to fulfill this requirement like substrate integrated waveguide (SIW), photonic band gap (PGB), low temperature co-fire ceramic technology (LTCT), low temperature co-fire ferrite (LTCF), ground plane aperture (GPA), defected ground structure (DGS) etc.

Selection of topology for the designing of filter depends upon several factors such as response need like Butterworth, Chebyshev, and elliptical type of response, requirement of bandwidth, size and power handling capacity. Microstrip line with defected ground structure provides good pass band and stop band response having higher bandwidth and due to slow wave effect it further reduce the size of a structure [1]. The complete pattern of the structure is deposited on a single substrate with conductive ground in the bottom plane so fabrication cost is also reduced [2].

This paper represents design of microstrip bandstop filter with the use of defected ground structure. We tried out two structures for the proposed design of the filter. In first structure on the top of the substrate Step impedance type of line is used with a conventional rectangular defect in ground plane. In second structure we gradually changed the characteristic impedance of the strip line with the same defect in the ground plane for the improvement of response. The structures have been simulated in HFSS simulator and Scattering parameters have been observed.

II. THEORY

A. *Microstrip line*

The general structure of Microstrip line consist dielectric substrate, a conductive strip is on the top of the substrate and the bottom of the substrate is conducting ground plane.

A microstrip line does not support true TEM wave, at a non zero frequency both the E field and H field have a longitudinal component. The longitude component is kept small so the dominant mode is referred as a quasi transverse electric and magnetic wave [2-3]. The characteristic impedance equation of Microstrip line is [2-3]

$$Z0 = \left(\frac{87}{\sqrt{\varepsilon r+1.41}}\right)\ln\left[\frac{5.98\text{h}}{0.8\text{ w}+\text{t}}\right] \qquad (1)$$

Where εr is the dielectric constant of the substrate material, h is the distance between the microstrip line and the ground, w is the width of microstrip line and t is the thickness of strip line.

Fabrication cost of microstrip line is substantially lower than Stripline, co-axial and waveguide structure because all geometries are fabricated on single substrate [3]. Due to the planar structure of Microstrip line both the active and passive elements can be easily attached to the Microstrip.

B. *Defected ground Structure*

Defected ground structure came into the picture due to the limitation offered by the photonic band gap [PGB] design. Limitation offered by PGB structure is that it increases the circuit size which causes feed line loss [4-5] and also creates difficulties in modeling [1].

Defected ground structure means that a defect has been created on the ground plane. This will disturb the shield current distribution of the structure. Due to this disturbance the characteristics of a transmission line such as induction and capacitance have changed [1]. Different types of defected ground structure are proposed in various literatures like dumbbell shape, spiral head, arrow head slot, H shape slot, a square open loop with a slot in middle section, open loop dumbbell; inter digital DGS, u-shaped DGS [1, 6-9].

By changing the dimensions of DGS unit it is possible to change the characteristics of transmission line such as inductance and capacitance. By doing this it is possible to change the value of cut-off frequency and a resonant frequency. Value of inductance and capacitance can be calculated from the equation as shown below [5, 10].

$$L = \frac{1}{4\pi\, fo^2\, C} \qquad (2)$$

$$C = \frac{fc}{2\, Zo}\,\frac{1}{2\pi\,(fo^2 - fc^2)} \qquad (3)$$

Where L is the inductance, C is the capacitance, fo is the resonant frequency and fc is the cutoff frequency.

The advantages of defected ground structure over other methods are that it provides more transition sharpness, it improves pass band and stop band characteristics, suppress higher harmonics, it posses broader stop band response [1]. Another advantage of DGS is that it produces a slow wave effect and because of that it further reduces the size of structure [1].

III. DESIGN

The geometric structure of the Bandstop filter with its top and bottom view is shown in figure 1 and figure 2 respectively. Step impedance type of microstrip line is used as top of the structure as shown in figure1. Two rectangular types of defect have been created in ground plane similar as shown in figure 5. Microstrip line is fed with 50 ohm impedance line. We chose Duroid (tm) as a substrate material having a dielectric permittivity of 2.2, dielectric loss tangent 0.0009 with a height of 0.507mm.

Relative dimensions of filter are as follows: A1=5.8, A2=8, A4=6, A5=8, A6=4, B1=4.6, B2=3.8, B3=7.2, B4=1.5, B5=3.8(all are in millimeters).Simulation has been performed on Anasoft HFSS simulator.

An equivalent LC circuit for the proposed design is shown in figure 3, here L1, L2, L3, C1 and C2 are the inductance and capacitance generated due to the step impedance line, C3, C4, C5, C6 are the corresponding capacitances between top and the bottom plane of the structure.Lx1, Cx1, Lx2, Cx2 are the inductance and capacitance produced due to the DGS. A simulate transmission coefficient (S21) for LC circuit is shown in figure4.

The complete geometry of the filter that we have been implemented in HFSS is shown in figure 5.

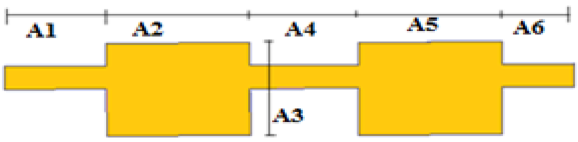

Fig.1. Top view of proposed filter

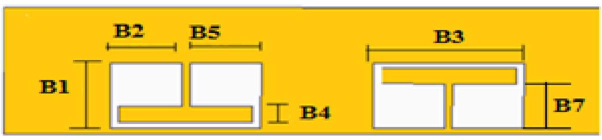

Fig.2. Bottom view of the structure

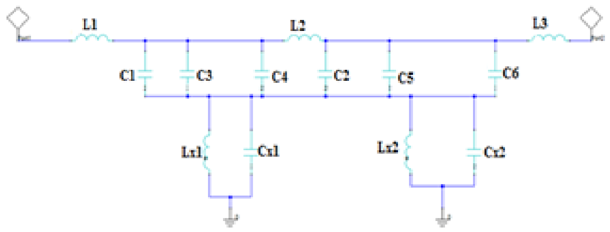

Fig.3. Equivalent LC circuit of the proposed circuit

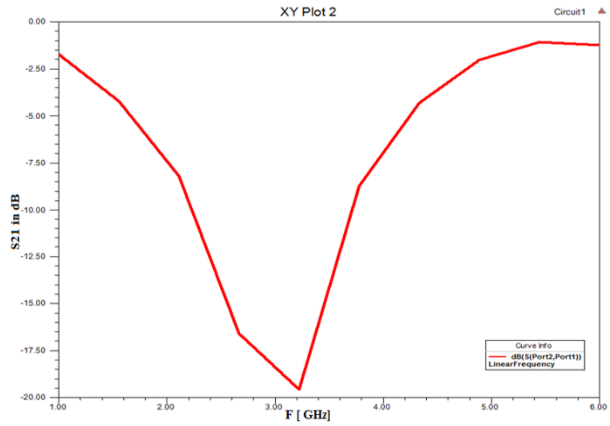

Fig.4. Simulate S21 parameter of LC circuit

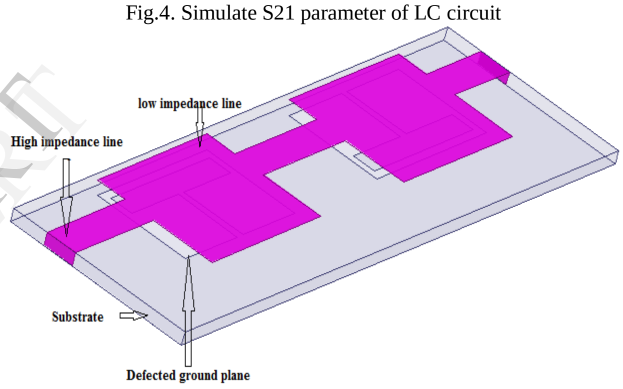

Fig.5. Complete 3D geometry of the propose filter

IV. SIMULATION RESULT

The proposed structures have been simulated by using ANSOFT HFSS (High frequency structure simulator). Figure 6 demonstrates the simulated scattering parameters of the proposed design. As shown in figure proposed design produce stop band from the frequency ranges 3.3GHZ to the 4.8GHZ with relatively 3 dB bandwidth of 1.5 GHz. It provides attenuation more than 25 dB within a stopband; also it exhibits good pass band selectivity.

Tuning in frequency can be achieved by changing the relative dimension of Microstrip line and the DGS unit. It is possible to increase the values of inductance by increase the etch area of DGS [1], and this increased inductance value gives lower cutoff frequency. Similarly capacitance value can change by changing the dimension of area between rectangular slots. Fig 7 shows the graph of S21 (Transmission parameter) for the different dimension of DGS.

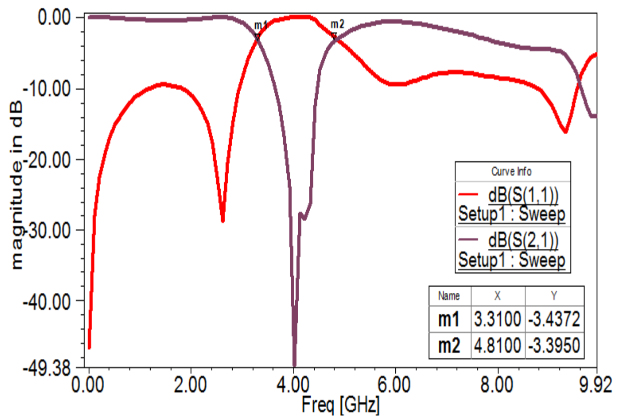

Fig.6.Simulated S parameter of the proposed filter

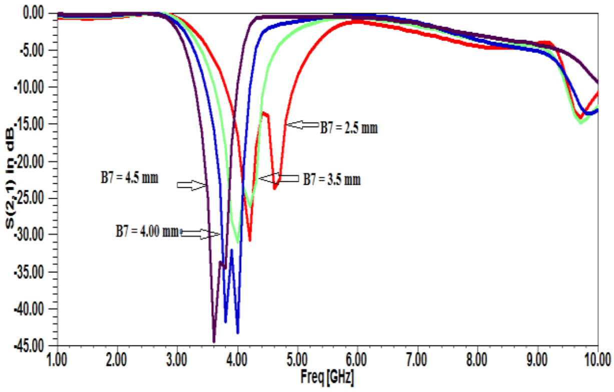

Fig.7. By changing the dimension of DGS unit tuning of resonant frequency carried out

Table 1 shown below give the information of Fig 7. It shows the relative change in cutoff frequency and bandwidth of stop band by changing the dimension of DGS unit.

TABLE I. TUNING OF FREQUENCY BY CHANGING THE DIMENSION OF DGS UNIT

B7	A2	A6	First 3dB cutoff freq FC1	Second 3dB cutoff freq FC2	Relative 3 dB bandwidth
3.1	6	6	3.30 GHz	4.80GHz	1.5GHz
2.5	6	6	3.30 GHz	5.30GHz	2.0 GHz
4.0	6	6	3.20 GHz	4.30 GHz	1.10 GHz
4.5	6	6	3.10 GHz	4.10GHz	1.0 GHz

To improve the selectivity of the filter and for sharper cut off we have modified the structure as shown in figure 8. It indicates in the top plane the spike change (low impedance) of impedance line we have gradually changed the impedance of line and the bottom plane of the structure is same as previous one.

A simulated scattering parameter of this structure is shown in fig 9. It provides same stop band as the previous one for the frequency range from 3.30 GHz to the 4.80 GHz with the attenuation more than 30 dB. As from the figure it produces two transmission poles at the frequency of 3.80 GHz and 4.20 GHz which provides sharper cutoff. It provides good Selectivity from DC to 3.8 GHz and from 4.80GHz to 10GHz.

VSWR curve for the modified structure is shown in figure10. Current distribution in the filter is shown in figure 11.

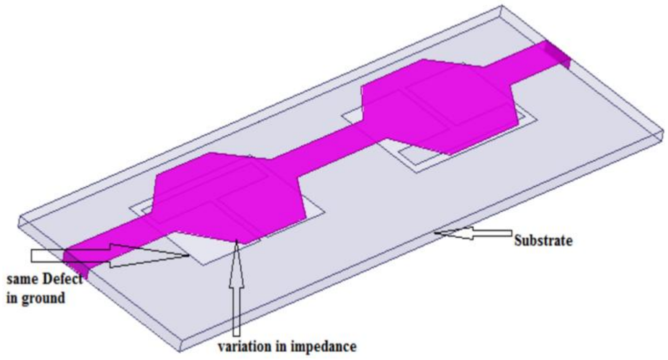

Fig. 8: Modified Structure

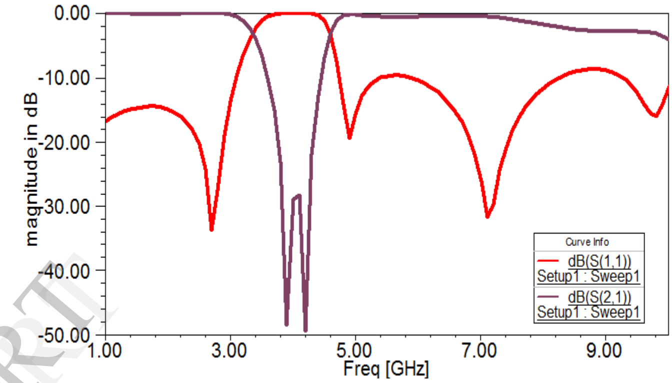

Fig.9: Simulate S parameter for modified structure

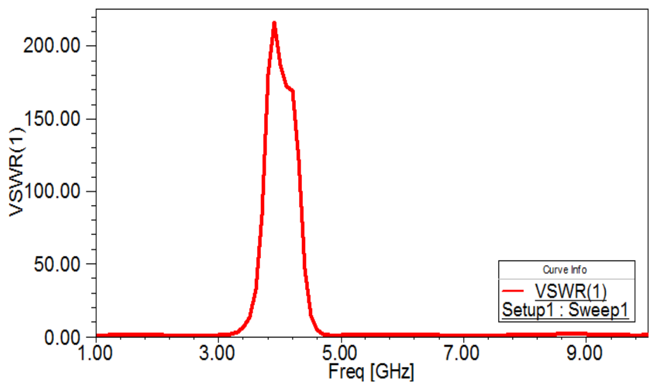

Fig.10. VSWR Curve for proposed filter

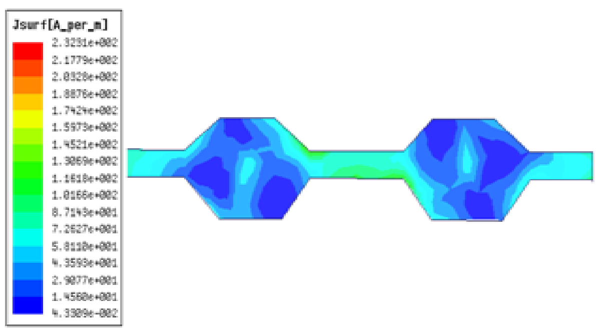

Fig.11. Current distribution in structure

V. CONCLUSION

In this paper we present the microstrip bandstop filter with the use of defected ground plane. We developed bandstop filter with the use of lowpass step impedance microstrip line and rectangular type defect in ground plane as shown in fig 5. For the improvement in the response we try out another structure by small change in top plane as shown in fig 8. We observed the simulated parameter of the filter and also tuning of frequency has been carried by changing the dimension of DGS unit. The design bandstop filter exhibits high selectivity and good stopband performance and also it consumes less area. The proposed design can be use for the suppression of the WI-MAX (3.5 GHz) and can be used for the suppression of higher order harmonics.

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