# Analysis of High Pass Filter Using DGS

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**ABSTRACT-** The performance of a High Pass Filter (HPF) with and without Defected Ground Structure (DGS) was analyzed. The defected ground structure is circular etched shapes in ground plane. Comparison of the response of filter with and without DGS was done separately. Parameters of the proposed configuration were calculated at the centre frequency of 1.5 GHz and with dielectric constant of 4.4, loss tangent of 0.02 and substrate height of 1.6mm. Results were simulated using computer simulation technology software (CST). The undesired sidebands and fluctuations of response were reduced by using defected ground structure (DGS).

**General Terms-** Microwave Filter, High Pass Filter

**Keywords -** High Pass Filter (HPF), Defected Ground Structure (DGS), Computer Simulation Technology Software (CST).

## 1. INTRODUCTION

A microwave filter is a two-port network used to control the frequency response at certain point in a microwave system by providing transmission at frequencies within the passband of the filter and attenuation in the stopband of the filter. Depending on the requirements and specifications, RF/microwave filters may be designed as lumped element or distributed element circuits; they may be realized in various transmission line structures, such as waveguide, coaxial line, and microstrip.

For designing high performance and compact filters, a defected ground structure has been widely used. A Defect on ground can change the propagation properties of a transmission line by changing the current distribution and applied field between the ground plane and upper surface. There are various different structures for implementing DGS [2]. By using these different DGS structures filters, power divider, power amplifier etc was implemented [1], [9]. PBG (photonic bandgap) and EBG (electromagnetic bandgap) structure are also a type of DGS, which is created by etching different periodic shapes in the ground plane. However, it so difficult to use PBG structure for the design of the microwave or millimetre wave components due to the difficulties of the modulating and radiation from the periodic etched defects.

So many etched shapes for the microstrip could be used as a unit DGS. An LC unit circuit can represent the unit DGS circuit.

They provide inductive and capacitive elements connected in series [11]. Which remove undesired output response fluctuations; move the high pass filer frequency limit to a higher value and the selectivity of a particular band is also improved in the case of BPF [5]. DGS has property of rejecting electromagnetic wave in certain frequency and direction, and most important function of these structures is the filtering of frequency bands, and harmonics of the filter in microwave circuit. In this proposed work an arbitrary shape of DGS is used to improve the parameters of the filters like return loss, transmission coefficient etc. And also the dimension of these different shapes varies to find efficient response. A lot of different shapes of DGS were tested and the more efficient one is introduces in this work.

## 2. IMPLEMENTATION OF 4TH ORDER HIGH PASS FILTER

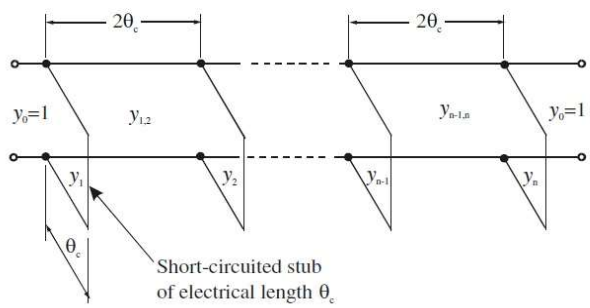



Figure 1: Optimum distributed high pass filter [12]

The proposed high pass filter (HPF) consists of shunt short circuited stubs of electrical length lc at some specified frequency fc (usually the cut off frequency of HPF). These elements were separated by unit elements (UE) of length 2lc shown in the figure 1 [12]. In theory this type of filter has very wide band response for small lc but this requires a high value of impedance in the short circuited stub (SC-Stub).

To design high pass filter let us consider the cut off frequency fc in GHz and 0.1dB Ripple in passband up to 5GHz. As in figure, the electrical length lc can be determined by equation (1) [12]:

$$\left(\frac{\pi}{\theta_c} - 1\right) f_c = 5 \quad (1)$$

With the help of $l_c$ and order of high pass filter, element values of optimum distributed high pass filter with 0.1dB ripple was obtained. For given terminating impedance $Z_0$ the associated impedance values can be determined by equation (2) and (3) [12]

$$Z_i = Z_0/Y_i \quad (2)$$

$$Z_{i,i+1} = Z_0/Y_{i,i+1} \quad (3)$$

For i=1, 2….4

Synthesis of *W/h* [12]

$$\frac{W}{h} = \frac{8\,e^{A}}{e^{2A}-2} \quad (4)$$

With

$$A = \frac{Z_c}{60}\left[\frac{\varepsilon_r+1}{2}\right]^{0.5} + \frac{\varepsilon_r+1}{\varepsilon_r+1}\left[0.23 + \frac{0.11}{\varepsilon_r}\right] \quad (5)$$

Where

Zc = Impedance (in Ohm) and $\varepsilon_r$ (dielectric constant) = 4.4, W= width, h = height of dielectric which is taken as 1.6mm.

Effective dielectric constant of dielectric material given by equation (6) and (7) [12]

For W/h>1

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\,\frac{h}{w}\right)^{-0.5} \quad (6)$$

For W/h>1

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\left(1+12\,\frac{h}{w}\right)^{-0.5} + 0.04\left(1-\frac{w}{h}\right)^{2}\right] \quad (7)$$

Whereas guided wavelength is given by equation (8)

$$\lambda_g = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}} \quad (8)$$

$\varepsilon_{re}$ = Effective dielectric constant , f= Cut off frequency

Lengths of the elements (l) were determined by equation (9) [12]

$$l_c = \beta * l \quad (9)$$

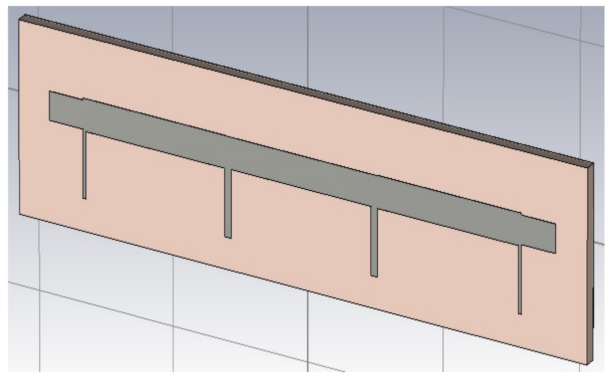
Where β is the phase constant.

The dimensions of length and width of the elements was calculated using the microstrip design equation 1-7 for a resonant frequency fc = 1.5GHz. The dimensions of the element values for the 4th order of high pass filter at a cut off frequency fc 1.5GHz is shown in the table 1.

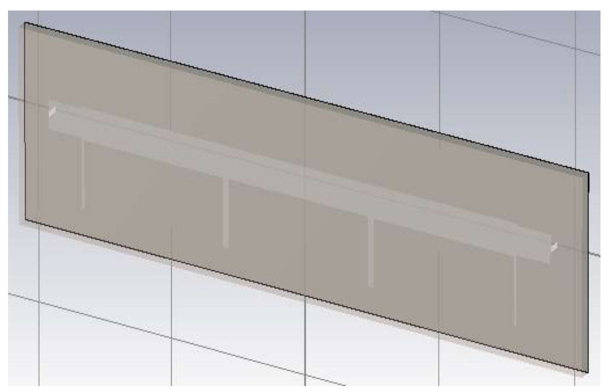
**Table 1:** Element values of the proposed configuration

| Element | Admittance Values (mho) | Impedance value(ohm) | Length of element (mm) | Width of element (mm) |
|---|---|---|---|---|
| Unit Element | $Y_{12}=Y_{34}$ =1.046 | $Z_{12}=Z_{34}$ =47.76 | $l_{12}=l_{34}$ =20.70 | $W_{12}=W_{34}$ =3.37 |
| | $Y_{23}$=1.027 | $Z_{23}$=48.65 | $l_{23}$=20.70 | $W_{23}$=3.29 |
| Short circuit Stub | $Y_1=Y_4$ =0.415 | $Z_1=Z_4$ =120.25 | $l_1=l_4$ =10.29 | $W_1=W_4$ =0.41 |
| | $Y_2=Y_3$ | $Z_2=Z_3$=90.48 | $l_2=l_3$ =10.33 | $W_2=W_3$ =0.95 |

The structure of proposed design for 4th order high pass filter is shown in figure 2. HPF is printed on the FR4 lossy substrate of dielectric constant 4.3 at a dimension of length 84mm and width 20mm.



(a) Front View



(b) Back View

Figure 2: Structure of Proposed 4th order HPF

## 3. SIMULATION RESULTS

The proposed structure of 4th order high pass filter was simulated using the CST Microwave Software. The simulated return loss of the proposed HPF is shown in the figure 3.

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With the use of SMA Connector of 50Ω at both the ports of filter, the response of the filter is symmetric at both the ports.

$$S_{11} = S_{22}, S_{12} = S_{21}$$

The graph shown in figure 3 shows the cut off frequency is at 1.5GHz means that the signals were passing after this frequency. Also before 1.5 GHz the signal shows attenuation of - 63dB means perfect stop band. Return loss after 1.5GHz is below -10 dB which shows perfect impedance matching after that frequency.

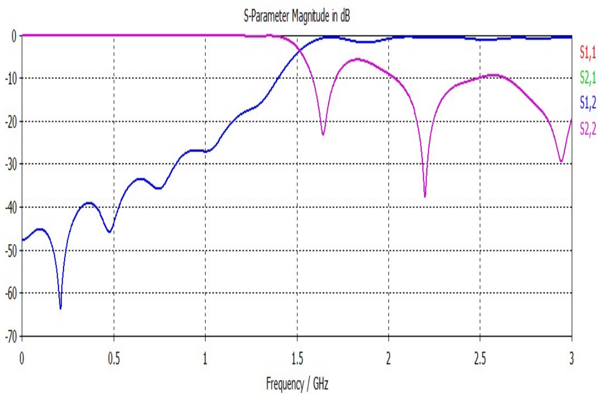


Figure 3: Simulated results of proposed HPF

Another layout which is made by using DGS which means etched the circle shape on ground plane with the remaining dimensions of proposed HPF are constant is shown in figure 4.

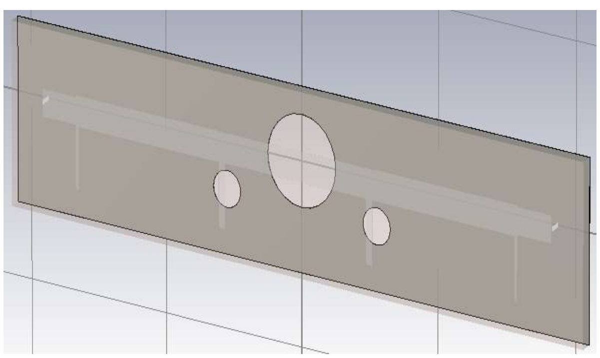

Figure 4: Back View of Proposed 4th order HPF using DGS

The response of this proposed configuration which means HPF after applying DGS is shown in figure 5. The radius of an etched circular ground structure is 5mm at the unit element which is placed at the exact middle portion of the proposed design and the radius of an etched circular ground structure is 2mm at the short circuit stubs which is nearer with the bigger circular structure of the ground plane.

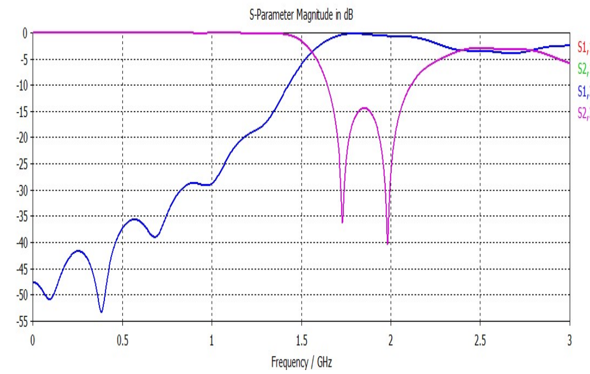


Figure 5: Simulated results of proposed HPF using DGS

From the figure 5, it is clearly seen that the cut off frequency is same which shows that the signal above 1.5 GHz were passed with negligible attenuation and response of the filter was achieved up to a 45dB strength of the signal and the signals which is below the 1.5 GHz is attenuation by up to -55 dB. By comparing both the results of figure 3 and figure 5 which means the response of the proposed 4th order HPF without and with DGS, it has been found that sidebands is reduced and also shifted towards the cut off frequency to achieve the ideal characteristics of the HPF. So for the application where we require increasing in side band of same order of filter, the use of DGS is advantageous.

## 4. CONCLUSION

A configuration of printed microstrip high pass filter with and without using the DGS of circular shapes was proposed and analyzed at the centre frequency $f_c$=1.5GHz with the dielectric constant of 4.3 and at the height of 1.6mm. It has been found that results of HPF using DGS are better than the results of HPF where DGS is not applied. And the sidebands fluctuation was reduced and shifter towards the cut off frequency. So for the application where shifting of cut off, reduced level of fluctuation of response and reduction in passband are needed, then use of DGS for designing the filter should be proposed.

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