Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 11, November -2017

# Performance analysis of Low Pass Filter and Band Stop Filter with DGS

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**Abstract-** *The Low Pass Filter(LPF) with elliptical shape and Band Stop Filter (BSF) with a defected ground structure (DGS) was studied and simulated. It does not use coupled line and resonator. The response of low pass filter (LPF) and band stop filter (BSF) with using defected ground structure (DGS) were calculated. Using computer simulation technology software (CST) the result was simulated which can be fabricate and results can be tested on spectrum analyzer. As the effect of DGS the undesired sidebands and fluctuations of response was reduced with improvement in bandwidth in case of band stop filter (BSF).*

***Keywords-*** *Low Pass Filter (LPF), Band Stop Filter (BSF), SMA* ***(submarine version-A)*** *Connector,* ***Defected Ground Structure (DGS)****, Computer Simulation* ***Technology*** *Software (CST).*

## 1. INTRODUCTION

In recent year the Defected ground structure for microstrip line was most common topic for research. They gives a lot of different structure for the implementation of DGS [1].Different structures like LPF [2], BSF [3], power divider [4], power amplifier etc was implemented by using it. In addition to PBG (photonic bandgap) and EBG (electromagnetic bandgap) structure, DGS was created by removing the dielectric in different shapes in ground plane. As the effect of it increase in inductance and capacitance values of microstrip line was achieved, so undesired output response fluctuations will be eliminated and in output a sharp stopband obtain in case of LPF [5] and increased bandwidth in case of BSF [6]. The property of DGS is that it rejects electromagnetic wave in certain frequency and direction, and another most important function of these structures is that it filter different frequency bands, harmonics in microwave circuit.

1. IMPLEMENTATION OF 7$^{TH}$ ORDER ELLIPTIC FUNCTION LOW PASS FILTER

In case of stepped impedance LPF and L-C ladder type LPF with open circuited stub having frequencies of infinite attenuation at f = infinite. To find sharper cutoff for a given number of reactive elements it is required to use filter structure giving infinite attenuation at finite frequencies. To achieve authors use elliptic function LPF shown in figure 1(a) [7]. It is having two series-resonant branches connected in shunt that short out transmission at their resonant frequencies and gives two finite-frequency attenuation poles. At f = infinite these two branches having no effect and, inductances $L_1$, $L_3$ and $L_5$ block transmission by infinite series reactance, whereas the capacitance $C_6$ shorts out transmission by having infinite shunt susceptance.

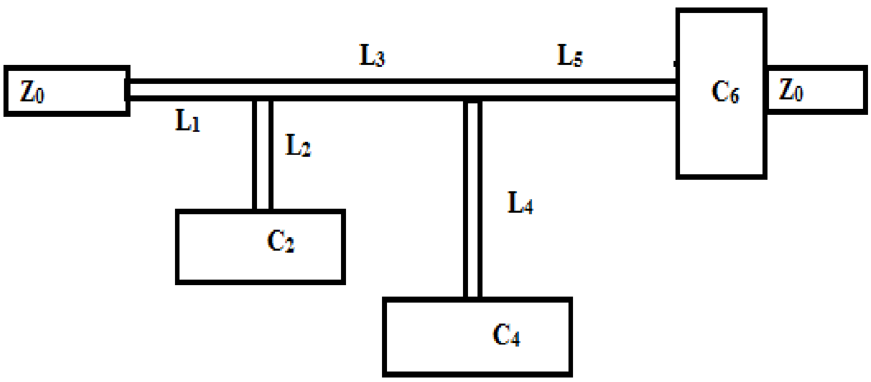


Figure1 (a) an elliptic-function, lumped element LPF [7]

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LPF was design at the cut off frequency of $f_c$=1.5 GHz. Electromagnetic equation [7] used for the design of LPF is

Synthesis of *W/h*

$$\frac{W}{h} = \frac{8\,e^{A}}{e^{2A}-2} \qquad (1)$$

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

Where Zc=Zo = 50Ω and $\varepsilon_r$ (dielectric constent) = 4.4, W= width, h= height of dielectric which is taken as 1.6mm.

Effective dielectric constant of dielectric material

For $W/h \leq 1$:

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

For W/h>1

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\,\frac{h}{w}\right)^{-0.5} + 0.04\left(1 - \frac{w}{h}\right)^2\right] \quad (3)$$

Guided Wavelength

$$\lambda_g = \frac{300}{f(\text{GHz})\sqrt{\varepsilon_{re}}} \quad (4)$$

$\varepsilon_{re}$ = Effective dielectric constant , f= 1.5 GHz

Values of inductor and capacitor are given by

$$C_i = \frac{1}{2\,\pi\,Z_0\,f_c}\,g'_i\,,\ L_i = \frac{1}{2\,\pi\,f_c}\,Z_0 g_i \quad (5)$$

For i = 1, 2, 3, ..... , 6.

Calculation of length of inductor and capacitor is done using formula

$$l_{Li} = \frac{\lambda_{gL}\,(f_c)}{2\pi}\,\sin^{-1}\left(2\,\pi\,f_c\,\frac{L_i}{Z_{oc}}\right) \quad (6)$$

$$l_{Ci} = \frac{\lambda_{gc}\,(f_c)}{2\,\pi}\sin^{-1}(2\pi\,Z_{0C}\,C_i) \quad (7)$$

Parameter values considered for elliptic function low pass prototype filter- source resistance $g_0$=$g_7$=1.0, cutoff frequency $\Omega_c$=1(rad/s), pass band ripple $L_{Ar}$=0.1dB, stop band cutoff frequency $\Omega_s$=1.25(rad/s), minimum stop band attenuation $L_{As}$=39.97 dB, $g_1$=0.7422, $g_2$=1.1189, $g'_2$ =0.3313, $g_3$= 1.2276, $g_4$= 0.9746, $g'_4$= 0.6260, $g_5$=1.1413, $g'_6$=1.0273.

Where $g_i$ represent inductance of the inductor (for i=1 to 5) and $g'_i$ represent capacitance of the capacitor (for i=2, 4, 6).

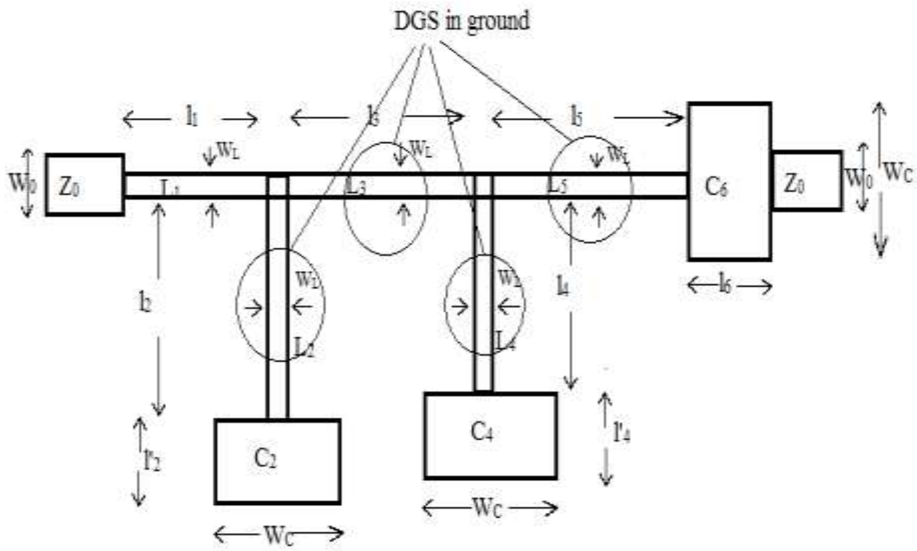


Figure1 (b) Designed microstrip elliptic function LPF Layout

Table1. Design parameters for 7th order microstrip elliptic function low pass filter

| **S. NO.** | **impeda-nces (ohm) value** | **Inductor(nH) and capacitor(pF) value** | **Length and width of inductor and capacitor (mm)** |
|---|---|---|---|
| 1 | $Z_{0L}$=93, $Z_{0c}$=24, | $L_1$=3.95, $L_2$=5.93, $L_3$=6.51, $L_4$=5.17, $L_5$=6.05,$C_2$ =0.703 $C_4$=1.32, $C_6$=2.18 | $l_1$ =7.48, $l_2$=11.74, $l_3$=13.98, $l_4$=10.05, $l_5$=12.02, $l'_2$=2.66, $l'_4$=5.03, $l_6$=8.57, $w_L$=0.862,$w_C$=9.27 |
| 2 | $Z_0$=50 | | $w_0$=3.058 |

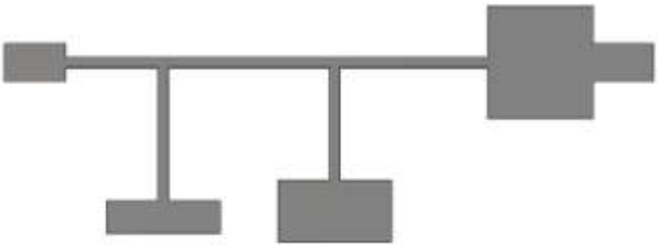

Figure1 (c) Simulated microstrip elliptic function LPF Layout

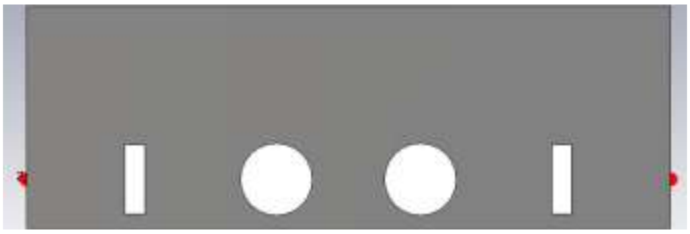

Figure1 (d) Defected Ground Structure(DGS) of microstrip elliptic function LPF Layout

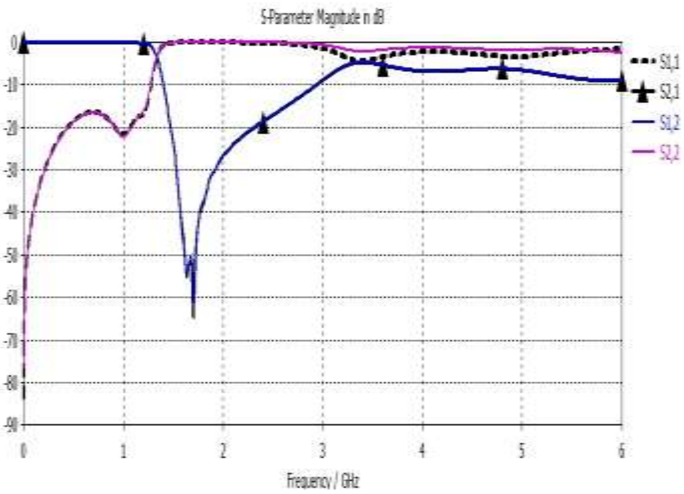


Figure1 (e) Simulated microstrip elliptic function LPF Result

2. IMPLEMENTATION OF 5TH ORDER BAND STOP FILTER

Figure 2(a) [7] shows a transmission line network of a bandstop filter with open circuited stubs. Where the shunt quarter-wavelength, open circuited stubs are separated by unit elements (connecting line). These unit element are quarter wavelength long at the mid stop band frequency. Filtering characteristics of the filter entirely depends on design of characteristic impedances $Z_i$ for the open circuited stubs, and characteristic impedance $Z_{i,i+1}$ (where i= 1, 2, 3, --, n where n is the order of the filter) for unit elements. It also has two terminating impedances $Z_A$ and $Z_B$. This type of BSF is more suitable for realization of wide band BSP.

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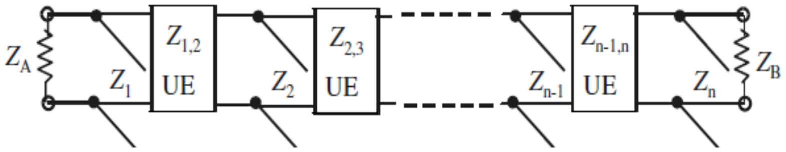


Figure 2 (a) Band stop filter with open-circuited stub (UE-Unit Element) [7]

BSF was designed with centre frequency of $f_0$=1.5GHz. Electromagnetic equations [7] used for the design of BSF are

Fractional bandwidth (FBW) of BSF is given by equation (8)

$$FBW = \frac{f_2 - f_1}{f_0} \ with \ f_0 = \frac{f_1 + f_2}{2} \qquad (8)$$

Where $f_0$=1.5GHz, $f_1$=1.0GHz, $f_2$=2 GHz

Calculation of impedance is given by following equations (9)

$$Z_1 = Z_A\left(2 + \frac{1}{\alpha\, g_0 g_1}\right)$$

$$Z_{1,2} = Z_A\left(\frac{1 + 2\alpha g_0 g_1}{1 + \alpha\, g_0 g_1}\right)$$

$$Z_2 = Z_A\left(\frac{1}{1 + \alpha\, g_0 g_1} + \frac{g_0}{\alpha g_2 (1 + \alpha g_1 g_0)^2}\right)$$

$$Z_{2,3} = \frac{Z_A}{g_0}\left(\alpha g_2 + \frac{g_0}{\alpha g_o g_1}\right)$$

$$Z_3 = \frac{Z_A}{\alpha\, g_0 g_3}$$

$$Z_{3,4} = \frac{Z_A}{g_0}\left(\alpha g_4 + \frac{g_6}{1 + \alpha g_6 g_5}\right)$$

$$Z_4 = \frac{Z_A}{g_0}\left(\frac{1}{1 + \alpha g_6 g_5} + \frac{g_6}{\alpha g_4\,(1 + g_6 g_5\,)^2}\right)$$

$$Z_B = \frac{Z_A}{g_0 g_5}$$

$$Z_{4,5} = \frac{Z_A g_6}{g_0}\left(\frac{1 + 2\alpha\, g_5 g_6}{1 + \alpha g_5 g_6}\right)$$

$$Z_5 = \frac{Z_A g_6}{g_0}\left(2 + \frac{1}{\alpha g_5 g_6}\right) \qquad (9)$$

Where $Z_A$=$Z_B$=$Z_0$=50 ohm, and α (an arbitrary constant) given by

$$\alpha = \cot\left|\frac{\pi}{2}(1 - \frac{FBW}{2})\right| \qquad (10)$$

Equation (1) to (4) is used for the calculation of width of the impedance and guided wavelength.

Length of the impedances will be given by

$$l = \frac{\text{guided wavelength } (\lambda g0)}{4} \qquad (11)$$

Element values for the design of BSF are- $g_0$=$g_6$=1, $g_1$=1.1468, $g_2$=1.3712, $g_3$=1.9750, $g_4$=1.3712, $g_5$=1.1468.

Where $g_j$ for j = 1 to 5 represent either the inductance of the inductor or capacitance of the capacitor, α= 0.58(obtain from equation (11)), Fractional bandwidth (FBW) =0.67 (obtain from equation (9)).

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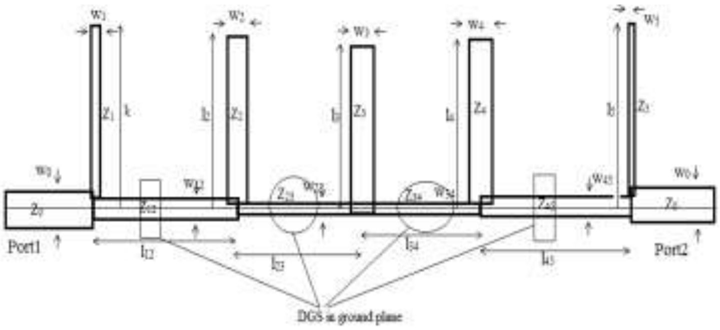


Figure 2 (b) Layout of the wide band BSF with DGS

Table 2 Microstrip design parameters for 5th order Band Stop Filter

| S. NO. | Values of impedances (ohm) | value of length (mm) | Value of width (mm) |
|---|---|---|---|
| 1. | $Z_1$=181.12 $Z_2$=53.52, $Z_3$=45.52 $Z_4$=53.52, $Z_5$=181.12, $Z_0$=50 | $l_1$=31.258, $l_2$=28.745, $l_3$=27.149, $l_4$=28.745, $l_5$=31.258 | $w_1$=0.0915, $w_2$=3.101, $w_3$=4.1015, $w_4$=3.101, $w_5$=0.0915, $w_0$=3.05 |
| 2. | $Z_{12}$=70, $Z_{23}$=123, $Z_{34}$=123, $Z_{45}$=70 | $l_{12}$=28.0425, $l_{23}$=29.0617, $l_{34}$=29.0617, $l_{45}$=28.0425. | $w_{12}$=1.656, $w_{23}$=0.47, $w_{34}$=0.47, $w_{45}$=1.656 |

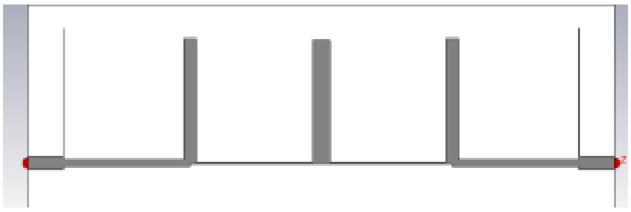

Figure 2 (b) Simulated wide band BSF Layout

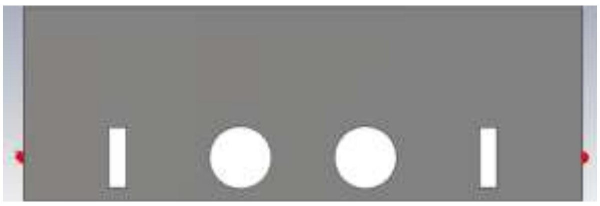

Figure 2 (c) Defected Ground Structure (DGS) of wide band BSF Layout

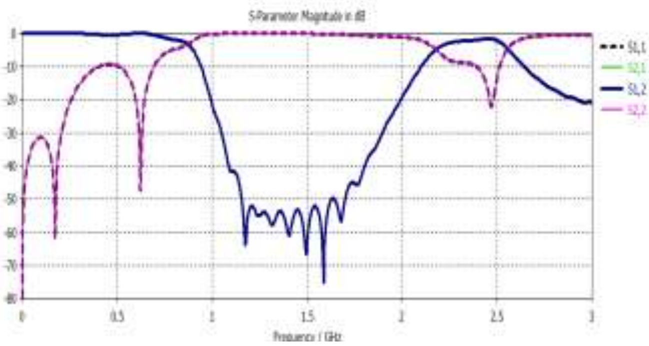

Figure 2 (d) Simulated wide band BSF Result

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## CONCLUTION

Centre frequency $f_c$=1.5GHz (same for LPF and BSF), and stopband frequencies of $f_1$=1.0GHz, $f_2$=2.0 GHz (for BSF) was used to design. At these frequency the design were implemented and analyzed. The simulated value found very good. A sharp rate of cutoff with reduce label of sideband fluctuation of the response achieved in case of LPF, increased bandwidth 10-20% as compare to filter implemented without using DGS is also achieved in case of BSF. Now it is concluded that the application where very sharp rate of cutoff and reduced label of fluctuation of response is needed than use of DGS for designing filter is good.

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