Analysis of Stepped Impedance Microstrip Line Filter for S Band Application

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Abstract: — In this paper different order lowpass filter has been analyzed using Stepped Impedance method. For N=3 and N=6 the response has been compared. Microstrip line is one of the most popular type of planar transmission lines and is easily miniaturized and integrated with both passive and active microwave devices This paper fulfills the demand of newer microwave and millimeter-wave systems to meet the various issues such as cost, performance and size in the field of telecommunication. This paper presents a low insertion loss and the low-cost design S-lowpass filter(LPF) with the use of microstrip layout having the center frequency at 2.5GHz with the permittivity of value 4.4 and the height/thickness of the substrate is 1.5mm. The use of microstrip provides the advantages of simplicity and ease of fabrication. The design and simulation are performed by using the 3D full wave electromagnetic simulator IE3D.

Keywords: Low Pass Filter, Microstrip, Stepped Impedance Configuration

I. INTRODUCTION

In order to get advantages of larger bandwidth and smaller device size as compare to wireless links microwave communication systems are expanding rapidly towards high frequency such as S-band. Such type of filters is realized with microstrip lines. Microwave filter are two-port network, reciprocal, passive, linear device which attenuate heavily the unwanted signal frequencies while permitting transmission of wanted frequencies. The type of construction of this filter is a reflective filter which is consists of capacitive and inductive elements producing ideally zero reflection loss in the pass band region and very high attenuation in the stop band region. The practical filters have small non-zero attenuation in the pass band a small signal output in the attenuation or stop band due to the presence of resistive losses in reactive elements of propagating medium. The proposed Microstrip Stepped-Impedance low pass filter is designed for 2.5 GHz[1][2]. The designed filters have been characterized using the commercially available software IE3D, in microstrip configuration the height of the circuit is much less than the other two dimensions, and there is no variation of the field along the height, therefore this type of circuits is also called planar circuits. In present work, the third and fifth order stepped impedance LC ladder low pass filter has been designed in microstrip configuration with the help of IE3D software and physically implemented on top of the FR/4 substrate using conventional fabrication process[3].

II. FITER DESIGN PROCEDURE

The design of low pass filters involves two main steps. The first step is to select an appropriate low pass prototype. The choice of the type of response, including the number of reactive elements (order of the filter) and pass band ripple will depend on the required specifications[9]. The element values of the low pass prototype filters, which are usually normalized to make a cutoff frequency Ω_c=1.0 GHz and a source impedance g_0=1, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for micro strip filters. After obtaining a suitable lumped element filter, the second step is to find an appropriate micro strip realization that approximates the lumped element filter[3][4].

Fig 1, Basic Structure

The design procedure for conventional microstrip Butterworth low pass filter of order n = 3 (3-pole low pass filter) are as follows: -

1) Filter design specifications:

Cut-off frequency, f_c = 2.2 GHz
Substrate height, h = 1.5 mm
Dielectric constant, ε_r = 4.4
Loss tangent, tanδ=.001
Lowest Line impedance Z_{OC} = 25 Ω
Characteristic impedance Z_O = 50 Ω
Highest Line impedance Z_{OL} = 120 Ω

First determine the value of the prototype elements to realize the specifications. Also, we have taken the[5][6]

$$L_i = \frac{\Omega_c}{\omega_c}\frac{Z_0}{g_0} g_i$$

$$C_i = \frac{\Omega_c}{\omega_c}\frac{g_0}{Z_0} g_i$$

The physical impedances of the high and low impedance lines are given below-

$$l_L = \frac{\lambda_{gL}}{2\pi}\sin^{-1}\left(\frac{\omega_c L_i}{Z_{oL}}\right)$$

$$l_C = \frac{\lambda_{gC}}{2\pi}\sin^{-1}(\omega_c C_i Z_{oc})$$

The formula used in order to calculate the width of the capacitor and inductor is given by

For $\frac{w}{h} < 2$

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$\frac{w}{h} = \frac{8\exp(A)}{\exp(2A)-2}$

Where,

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

And

$Z_c = \frac{\eta}{2\pi}\sqrt{\varepsilon_{re}}\ln\left(\frac{8h}{w} + 0.25\frac{w}{h}\right)$;

Where η= 120π ohms is the wave impedance in free space

The effective dielectric constant can be found by the following formula [1]

ε_{re}=

$\left(\frac{\varepsilon_r+1}{2}\right)+\left(\frac{\varepsilon_r-1}{2}\right)\left[\left(1+\frac{12h}{w}\right)^{-0.5} + (0.04)\left(1-\frac{w}{h}\right)^2\right]$

The effective wavelength can be also found as [1],

$\lambda_{ge} = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}}$ mm

Similarly, all other values of lengths and widths of transmission lines are calculated.

Table-1 shows the dimension of the Stepped Impedance Low Pass Filter for order third and Table-2 shows the dimension for order sixth. Figure 2 and Figure 3 shows the layout of filter from above Tables

S.No.	$Z_i = Z_L$ or Z_H (Ω)	W_i (mm)	L_i (mm)
1	120	0.4	4.8
2	25	9.2	9
3	120	0.4	4.8
4	50	1.1	3.1

Table 1: Dimensions of the Stepped Impedance Low Pass Filter (For N=3)

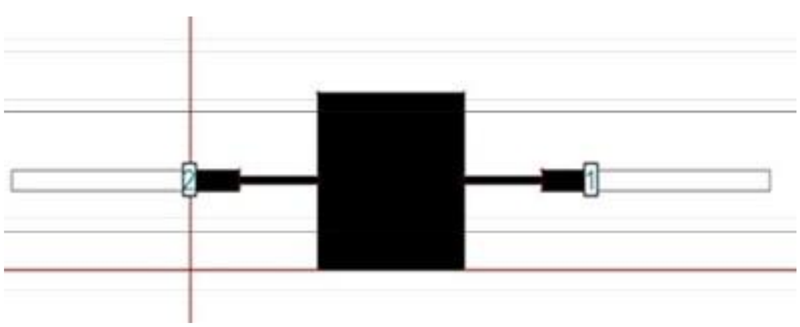

Fig.2, Layout of a 3-pole stepped impedance microstrip lowpass filter ona asubstrate with =4.4, h=1.5mm at 2.5GHz frequency

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S.No.	$Z_i = Z_L == Z_C(\Omega)$	W_i (mm)	L_i (mm)
1	25	9.780	4.350
2	120	0.553	6.523
3	25	9.780	9.3
4	120	0.553	9.43
5	25	9.783	8.510
6	120	0.553	4
7	50	2.47	4.3

Table 2: Dimensions of the Stepped Impedance Low Pass Filter (For N=6)

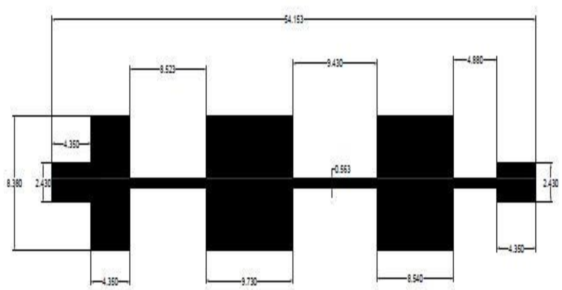

Fig.3, Layout of a 6-pole stepped impedance microstrip lowpass filter ona asubstrate with =4.4, h=1.5mm at 2.5GHz frequency

III. SIMULATED RESULT

The simulated filter structure and response is shown in fig. 4 and fig. 5. The response of the filter for N=3 is shown in fig. 4. In the response graph gain (dB) is plotted on the Y-axis and frequency (GHz) on the X-axis. The simulated LPF achieved a 3dB bandwidth of about 24%. From the graph shown in fig. 4, it is clear that the simulated cut-off frequency is found to be 2.5GHz for stepped-impedance low pass filter and from figure 4. Hence stepped- impedance low pass filter is capable of passing the frequency less than 2.5GHz & reject the frequency after 2.5GHz for the thickness of the substrate 1.5 mm and relative dielectric constant 4.4. For the simulation purpose we have used 3D full wave electromagnetic simulator IE3D[7][8].

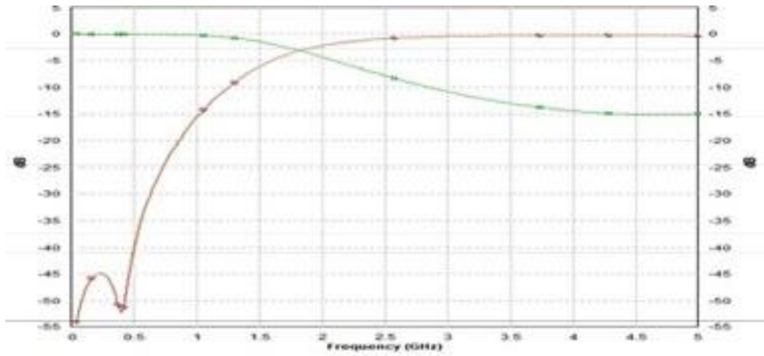

Figure 4. Full-Wave EM Simulated Performance of the Stepped Impedance Low Pass Filter for third order

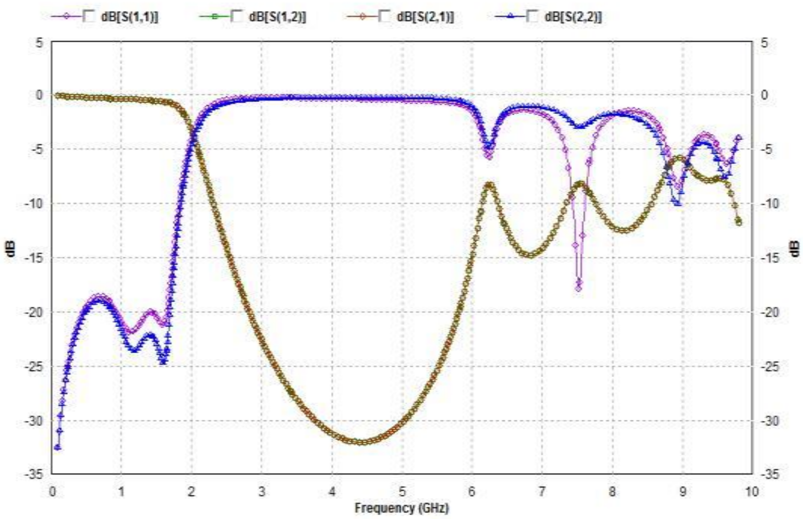

Figure 5. Full-Wave EM Simulated Performance of the Stepped Impedance Low Pass Filter for sixth order

IV. RESULT & CONCLUSION

In this paper low pass filter based on stepped impedance method is presented. Third order and fifth order Stepped impedance Low Pass Filter is synthesised. As per expectations, as the order increases the good return loss and insertion loss obtained, thus increase order value shows good result as comparison to the lower order result. This filter is widely used today in -radar, satellite and terrestrial communications, and electronic counter measure applications, both militarily and commercially

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V. APPLICATION

Microstrip line is an electrical transmission line which is very useful in conveying microwave frequency signal. Microstrip lines are useful in the analysis of superconducting microwave structures. Recently they are being used increasingly in VLSI circuit design and also in computer package design. It is of compact size therefore very suitable for realization and integration in wireless system.

VI. REFERENCES

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