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Implementation of Stepped Impedance Low Pass Microstrip Line Filter for Wireless Communication

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Abstract: 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. In this paper different order stepped impedance low pass microstrip line filter have been designed using IE3D software at 5GHz frequency and implemented on FR/4 substrate using conventional fabrication process. Design and analysis of the stepped impedance microstrip low pass filter has been described using moments method commercial software tool.

Keywords : Low Pass Filter, Microstrip, Stepped Impedance Configuration.

I. INTRODUCTION

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 5 GHz. 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 are 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.

II. FITER DESIGN PROCEDURE

The two basic steps to design the stepped impedance low pass filter are to select an appropriate low pass prototype and then

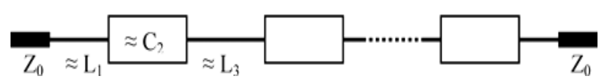

Figure 1. Basic Structure

find an appropriate microstrip realization that approximates the lumped element filter. For proposed design work, chebyshev approximation is assumed which exhibits the equal ripple pass-band and maximally flat stop-band. The general structure and LC ladder type stepped impedance low pass microstrip line filter is displayed in figure 1 .

Third and fifth order low pass filter have been designed in microstrip configuration with the following specification.

Dielectric constant ε_r = 3.7
Loss tangent, tanδ = 0.001
Pass band ripple = 0.1dB
Cut off frequency f_c = 5 GHz
Substrate thickness,h =1.6 mm
Lowest Line impedance $Z_{OC} = 25\ \Omega$
Characteristic impedance $Z_O = 50\ \Omega$
Highest Line impedance $Z_{OL} = 120\ \Omega$

First determine the value of the prototype elements to realize the specifications. Also we have taken the

$$L_i = \left(\frac{Z_0}{g_0}\right) \cdot \left(\frac{\Omega_c}{2\pi f_c}\right) g_i \qquad (1)$$

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$$C_i = \left(\frac{g_0}{Z_0}\right)\left(\frac{\Omega_c}{2\pi f_c}\right) g_i \quad (2)$$

$$l_L = \frac{\lambda_{gL}}{2\pi}\sin^{-1}\left(\frac{\omega_c L}{Z_{0L}}\right) \quad (3)$$

$$l_C = \frac{\lambda_{gC}}{2\pi}\sin^{-1}(\omega_c\, C\, Z_{0C}) \quad (4)$$

To calculate the width of capacitor and inductor we use the following formula

For inductor

$$\left(\frac{W}{h}\right) = \frac{8\,e^A}{e^{2A}-2} \quad (5)$$

Where, $A = \frac{Z_{0L}}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right)$

For capacitor

$$\left(\frac{W}{h}\right) = \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\varepsilon_r-1}{2\varepsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right] \quad (6)$$

Where, $B = \frac{377\pi}{2\, Z_{0C}\sqrt{\varepsilon_r}}$

Effective dielectric constant can be found by

$$(\varepsilon_{eff}) = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\frac{h}{W}}}\right] \quad (7)$$

Effective wavelength also found by

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{eff}}} \quad (8)$$

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 fifth. Figure 2 and Figure 3 shows the layout of filter from above Tables.

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

Sr. No.	$Z_i=Z_L=Z_C(\Omega)$	W_i(mm)	l_i(mm)
1	120	0.5	2.6
2	25	9.63	3.2
3	120	0.5	2.6
4	50	3.47	4

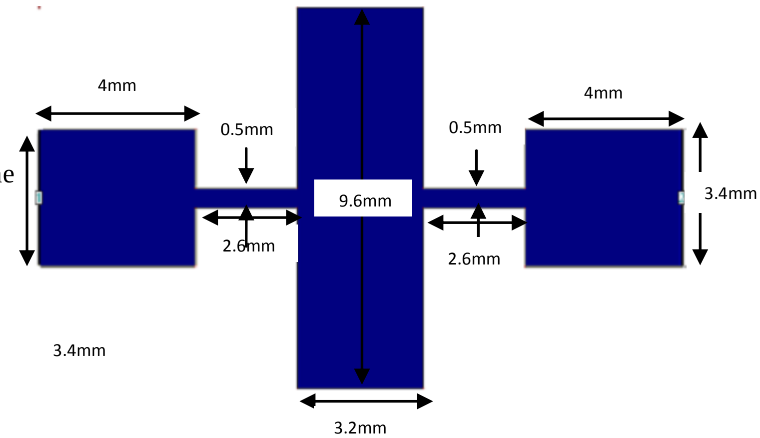

Figure 2. Layout of Third order low pass filter using IE3D

Table 2: Dimensions of the Stepped Impedance Low Pass Filter (For N=5)

Sr. No.	$Z_i=Z_L=Z_C(\Omega)$	W_i(mm)	l_i(mm)
1	120	0.5	2.9
2	25	9.66	4.075
3	120	0.5	5.76
4	25	9.66	4.075
5	120	0.5	2.9
6	50	3.4	4

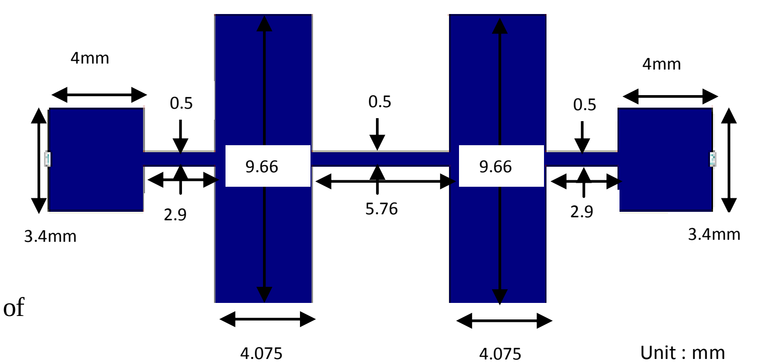

Figure 3. Layout of Fifth order low pass filter using IE3D

III. SIMULATED RESULT

The simulated filter as shown in Figure 2 and 3, predicts the geometry and response of low pass filters for n=3 and n=5.The graph is plotted by taking gain (dB) on the Y-axis and frequency in GHz on the X-axis. From the graph it is clear that the cut-off frequency is found to be 5GHz for stepped-impedance low pass filter. Hence stepped-impedance low pass filter is capable of passing the frequency less than 5GHz & reject the frequency after 5GHz for the thickness of the substrate 1.6 mm and relative dielectric constant 3.7. For the simulation purpose we have used method of moment based full-wave EM solver IE3D.

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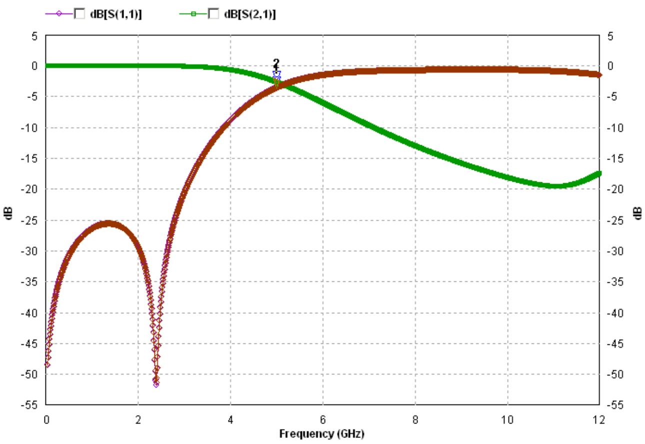

Figure 4. Full-Wave EM Simulated Performance of the Stepped Impedance Low Pass Filter for third order

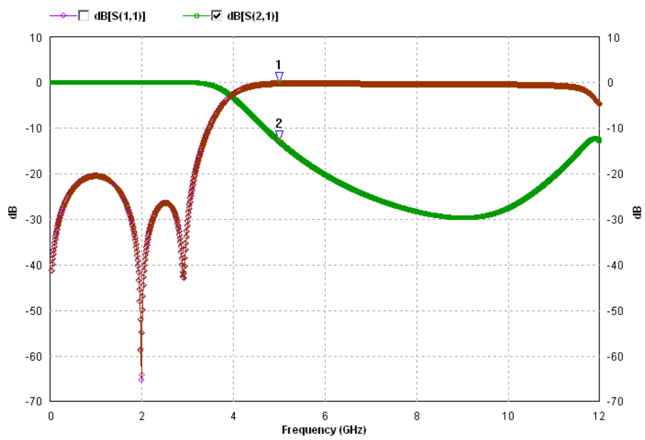

Figure 5. Full-Wave EM Simulated Performance of the Stepped Impedance Low Pass Filter for fifth order

IV. RESULT & CONCLUSION

In this paper study of low pass filter based on stepped impedance topology is presented. Third order and fifth order Stepped impedance Low Pass Filter is design and synthesis. 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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