Design and Synthesis of Stepped Impedance Microstrip Line Low Pass Filter

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ABSTRACT

There is an increasing demand for microwave system in modern communication system due to low cost, compact size and high accuracy. In this paper, design and synthesis of the seventh order stepped-impedance microstrip line low pass filter has been describe by method of moments, where FR4 material is used with dielectric constant 3.7 at 5GHz frequency. The analytic result obtained through IE3D software and thoroughly discussed.

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

I. INTRODUCTION

Microstrip line is the most popular type of transmission line because it can easily miniaturized and integrated with both active and passive microwave devices and also provide many advantages like low cost, compact size, light weight and low insertion loss. Conventional filter structures like equal ripple and Butterworth low pass filters are requirement of special fabrication methods. Conventional low frequency techniques for fabrication does not fit at these frequencies due to the very high losses associated. The design and synthesis are performed using 3D full wave method of moment based electromagnetic simulator IE3D.

In present work, the seventh 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. FILTER DESIGN

The design of low pass filters involves two main steps. The first one is to select an appropriate low pass prototype and then find an appropriate microstrip realization that approximates the lumped element filter. The choice of the type of response, including pass band ripple and the number of reactive elements will depend on the required specifications. The element values of the low pass prototype filters, which are usually normalized to make a source impedance g_0=1 and a cutoff frequency Ω_c= 1.0, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. 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.

Figure 1. Basic Structure

The cascade structure of alternating high and low impedance transmission line are act as an semi-lumped elements. The high impedance lines are act as series-inductor where low impedance transmission line are act as an shunt-capacitor. The steps to design the stepped impedance microstrip low pass filter is displayed in figure 2.

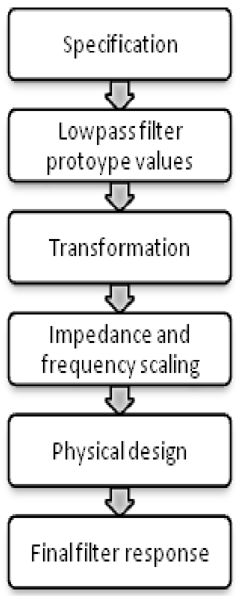

Figure 2. Flow diagram to design the filter

III. DESIGN PROCEDURE

Seventh order low pass filter have been designed in microstrip configuration with the following specification.

Cut off frequency f_c = 5 GHz
Dielectric constant ε_r = 3.7
Substrate thickness =1.6 mm
Loss tangent, tanδ = 0.001
Passband ripple = 0.1dB
Characteristic impedance Z_o = 50 Ω
Highest Line impedance Z_{oL} = 120 Ω
Lowest Line impedance Z_{oC} = 25 Ω
Pass band ripple = 0.1dB
Normalized frequency Ω_c = 1

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

$$L_i = \left(\frac{Z_o}{g_o}\right) \cdot \left(\frac{\Omega_c}{2\pi f_c}\right) g_i \quad (1)$$

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

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

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

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

For inductor

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

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

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, $B = \frac{377\pi}{2 Z_{OC}\sqrt{\varepsilon_r}}$

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: Dimensions of the Stepped Impedance Low Pass Filter (For N=7)

Sr. No.	$Z_i=Z_L=Z_C(\Omega)$	W_i (mm)	l_i (mm)
1	120	0.5	3.06
2	25	9.63	4.27
3	120	0.5	6.33
4	25	9.63	4.88
5	120	0.5	6.33
6	25	9.63	4.27
7	120	0.5	3.06
8	50	3.47	4

In order to verify the validity of above expression in millimeter wave regime, a simulation study was performed using IE3D. To get exact response, an optimization was performed using software. The Chebyshev response that exhibits the equal ripple pass band and maximally flat stop band have been selected. The filters were designed using the conventional procedure given in [1] & [2]. The designed filters are shown in figure 3.

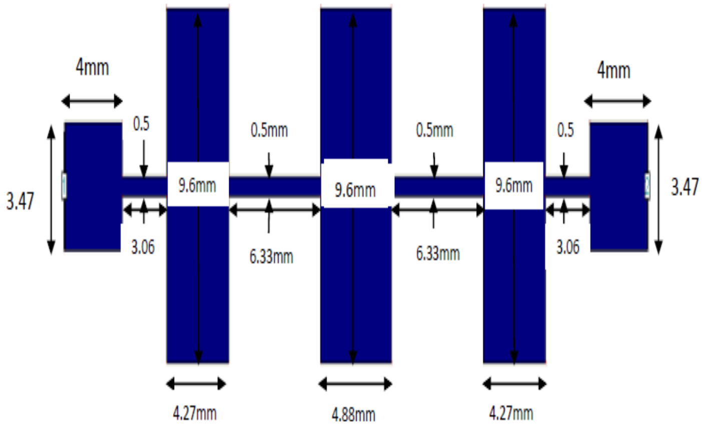

Figure 3. Seventh order low pass filter

IV. SIMULATED RESULT

The proposed filter is composed of seventh order stepped impedance LPF. The feed line is designed 50 ohm all geometric dimensions are shown in Table-1 and figure 4 shows simulated results of the proposed microstrip low pass filter. For the simulation purpose we have used method of moment based full-wave EM solver IE3D.

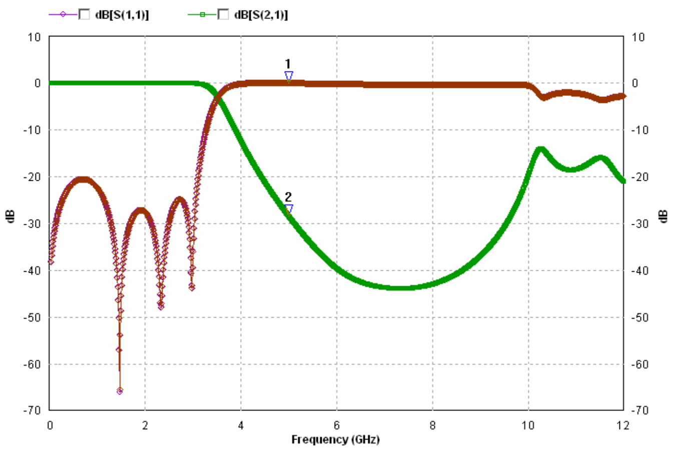

Figure 4. Full-Wave EM Simulated Performance of the Stepped Impedance Low Pass Filter.

V. RESULT & CONCLUSION

In this paper study of low pass filter based on stepped impedance topology is presented. Seventh order Stepped impedance Low Pass Filter is design and synthesis. As per the expectation, for higher order filters sharp cut-off has been found, the value of return loss is -67.01 dB and insertion loss is -43.9 dB, thus increases order value shows the good result as comparison with lower order. In future same design can be modified using fractal technology to get miniaturized dimensions.

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