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Design and analysis of Stepped impedence lowpass filter using microstrip line

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Abstract— **In this paper a lowpass filter has been designed. The filter has designed by using the method known as stepped impedance. 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 1.27mm for the order n=6. 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 **– Lowpass filter, IE3D, Dielectric constant, microstrip filter, Impedance configuration**.

I .INTRODUCTION

In today's fast growing world, microwave communication systems are expanding rapidly to higher frequency such as S-band since it is quiet advantageous as compared to conventional wireless links in respect of size and the bandwidth. Hence microstrip technology play important role in manu RF or microwave applications. A lowpass filter is defined as a filter that can pass low frequency signals and attenuates/cuts the amplitude of signals with frequencies higher than the cut-off frequency. It can be used as hiss filter for audio purpose, as digital filter for4 smoothing data, acoustic barrier ans as an anti-aliasing filter for conditioning signals.

The actual amount of attenuation for each frequency varies depending on specific filter design. It is sometimes called as high-cut filter or treble cut filter in audio applications. A lowpass filter is the opposite of the high pass filter. A banpass fiis a combination of the lowpass and a highpass filter. The filters are one of the primaand necessary components of a microwave systems. We prefer microstrip line as it is advantageous because of various parameters, such as low cost, compact size, light weight, planar structure and easy integration eith other components on a single circuit board. Conventional structures of filters such as equal ripple and butterworth lowpass filters are some requirements of special fabrication methods. Thus microstrip technology is used for simplicity and ease of fabrication . yhe design and simulation are performed u3D full wave electromagnetic simulator IE3D. this filter is widely used today in radarsatellite and terrestrial communication applications.

II. DESIGN AND ANALYSIS OF MICROSTRIP FILTER

In order to design low pass filter basically two steps to be followed- In the first step, an appropriate low pass prorotyoe is selected. The choice of the type of the response, including pass band ripple and the number of reactive elements will depend on the specifications that are required. 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, then transform to the L-C elements for the desired source impedance usually 50ohms for microstrip filters[1] is to find an appropriate microstrip realisation approximates the lumped element filter. The element values of the low pass prototype with chebyshev response at passband ripple factor L_{Ar}=0.1 db, characterize impedance source/load Z_0=50ohms, are taken from normalized values g_i, i.e., $g_1, g_{2,} g_{3,........} g_n$. The filter is assumed to be fabricated on a substrate of dielectric constant ε_r and of thickness(or height) h mm for angular(normalized) cutoff frequency Ω_c, using the element transformation[2].

The filter designing steps are mentioned below-

1) Determine the number of sections from specification characteristics for microstrip parameters:-

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Filter Specification-

Relative Dielectric constant, ε_r=4.4

Height of substrate h=1.27mm

Cutoff frequency, f_c=2.5 GHz

The loss tangent tanδ=0.02

The filter impedance, Z_0=50Ω

The highest line impedance $Z_H = Z_{OL}$ =100Ω

The lowest line impedance $Z_L = Z_{OC}$ =25Ω

Normalized cut off frequency, Ω_c=1 rad/sec

2)We have chosen the element values for the desired lowpass filter from table 3.2[1] for n=6. The values of the prototype elements to realize the specifications is given by the formula written below-

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

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

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

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

3)The formula used in order to calculate the width of the capacitor and inductor is given by[1],

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

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

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.

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

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

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

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

TABLE-I

Dimensions for a stepped impedance lowpass filter(For n=6).

Dimesions	Values		
Microstrip line width(in mm)	W_c= 8.38	W_o= 2.43	W_L= 0.563
Characteristic impedance(in ohms)	Z_{OC}= 22	Z_O= 50	Z_{OL}=100
Effective Dielectric constant	$(\varepsilon_{re})_C$= 5.843	$(\varepsilon_{re})_O$= 3.387	$(\varepsilon_{re})_L$= 3.042

III. SIMULATION RESULT

The layout of a 6-pole , stepped impedance microstrip lowpass filter on substrate with ε_r=4.4, h=1.2mm at 2.5GHz frequency, has been shown below,

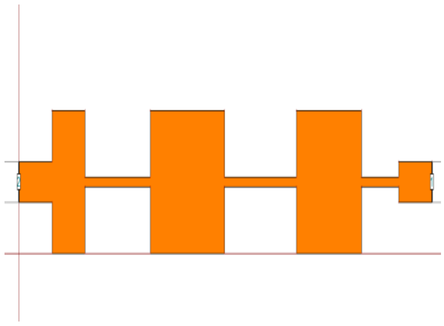

Fig.1: Layout of a 6-pole stepped impedance microstrip lowpass filter ona asubstrate with ε_r=4.4, h=1.2mm at 2.5GHz frequency.

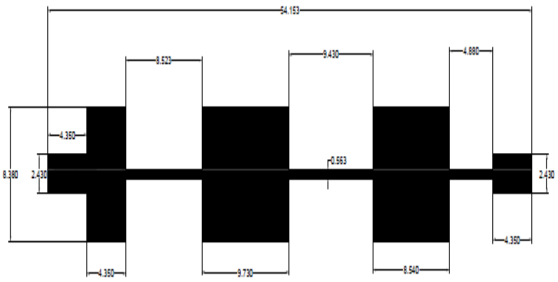

Fig.2, Layout of a 6-pole stepped impedance microstrip lowpass filter ona asubstrate with ε_r=4.4, h=1.2mm at 2.5GHz frequency with dimension.

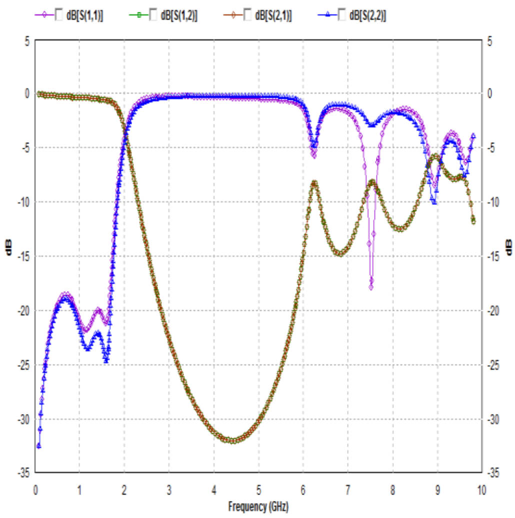

Fig.3, Full-wave EM Simulated Performance of the stepped impedance lowpass filter n=6 at 2.5GHz.

IV. RESULTS AND DISCUSSION

The simulated filter structure and response is shown in fig. 1 and fig. 3. The fabricated and measured response is shown in fig. 3. 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 3, it is clear that the measured value is 2.210580GHz at-8.0288dB.Hence the low pass filter is capable of passing the frequency less than 2.2105880 GHz & rejects the frequency after 2.2105880GHz. So this filter can be used for S-band applications i.e. above 2GHz.The response of the low pass filter with alternating sections of high and low impedance line is also plotted in fig5 by developing program code in Matlab which shows the value of insertion loss(S21) of -4dB at cutoff frequency 2.5GHz.

V. APPLICATIONS

Microstrip lines circuits find extensively applications in radar systems, microwave communication links, satellite communication systems, wireless and mobile communication systems, medical equipment etc.

VI.CONCLUSION

A stepped impedance low pass microstrip filter has been simulated, designed, fabricated and tested by measurement with a vector network analyzer. The cutoff frequency achieved is lower than the design specification value(2.5GHz).

VII. ACKNOWLEDGEMENT

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