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Stepped Impedance Low Pass Microstrip Line Filter

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Abstract: Micro strip filters plays various roles in wireless and mobile communication systems to meet the emerging telecommunication challenges with respect to size, performance and cost. In this filter with changing every high or low impedance characteristics such as length or width desired characteristics can be obtained. In this paper different order stepped impedance micro strip line filter have been designed using Hyper lynx 3D EM software at 5GHz. In present work, various even pole (2, 4, 6 and 8) and odd pole (3, 5, 7 and 9) are designed and compared in micro-strip configuration.

Keywords: Low Pass Filter, Ladder Filter, Micro strip Line, Stepped impedance Configuration.

I. INTRODUCTION

Micro strip is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave frequency signal [1]. The disadvantage of micro strip compared with waveguide is generally lower power handling capacity and higher losses.

A low pass filter is a L-C ladder network that allow low frequency signals and attenuates signal with frequencies higher than the cut-off frequency. A relatively easy way to implement low-pass filter in micro strip line is to use alternating section of very high and low impedance lines cascaded to form a ladder, such filters are usually referred to as stepped impedance. The actual amount of attenuation depends on filter design [6].

The designed filter have been characterised using the commercially available software Hyper Lynx 3D EM, in micro strip in configuration the height of the circuit is much less than the other two dimension, therefore this type of circuits are also called planar circuits. In present work, various even (2, 4, 6, 8) and odd (3, 5, 7, 9) pole filters are designed and compared, in micro strip configuration.

II. FILTER DESIGN PROCEDURE

The design of a low pass filter involves two main steps the first one is to select an appropriate low pass prototype. The choice of the type of response, including pass band ripple and the number of reactive elements will depend on the required specifications.

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 micro strip line filter is displayed in figure 1.

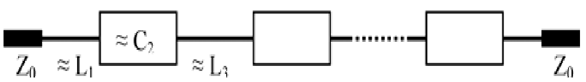

Figure 1: Basic Structure [1]

The design equations for this filter are [2]:-

- $L_i = (Z_0/g_o)(\Omega_c/2\pi f_c)g_i$ .... (1)
- $C_i = (g_o/Z_o)(\Omega_c/2\pi f_c)g_i$ .... (2)
- $l_L = \lambda_{gL}/2\pi \, Sin^{-1}(\omega_c L_i/Z_{OL})$ .... (3)
- $l_C = \lambda_{gC}/2\pi \, Sin^{-1}(\omega_c L_i/Z_{OC})$ .... (4)

To calculate the width of capacitor and inductor we use following formula [2]

For Inductor

- $(W/h) = (ge^{A}/e^{2A} - 2)$ .... (5)

Where, $A = (Z_{OL}/60)((\varepsilon_r + 1)/2)^{1/2} + (\varepsilon_r - 1)/(\varepsilon_r + 1)\{0.23 + 0.11/\varepsilon_r\}$

For Capacitor

- $(W/h) = 2/\pi\,[B - 1 - \ln(2B - 1) + (\varepsilon_r - 1)/2\varepsilon_r\{\ln(B - 1) + 0.39 - 0.61/\varepsilon_r\}$

Where $B = 377\pi/2Z_{OC}(\varepsilon_r)^{1/2}$

Effective dielectric constant can be found by [2]

- $(\varepsilon_{eff}) = (\varepsilon_r + 1)/2 + ((\varepsilon_r - 1)/2[1/\{1+12(h/W)\}^{1/2}]$

Effective wavelength also found by [2]

- $\lambda = c/f(\varepsilon_{eff})^{1/2}$

Similarly all the other values of lengths and widths are calculated.

III. DESIGN MODEL

The even pole filters i.e. Second, Fourth, Sixth and eighth and odd pole filters i.e. Third, Fifth, Seventh and Ninth order low pass filter have been designed in micro strip configuration with following specification.

- Dielectric constant, εr = 4.2
- Loss Tangent, $\tan\delta$ = 0.001
- Substrate Thickness, h = 1.6 mm
- Characteristics Impedance, Zo = 50 Ω
- Highest impedance = 120 Ω
- Lowest impedance = 25 Ω
- Cut Off frequency, f_c = 5 GHz
- Normalised frequency, Ω_c = 1

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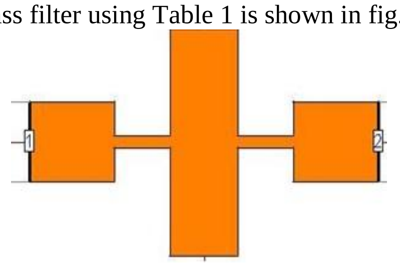
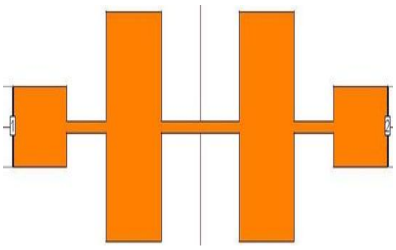
Table 1: Dimensions for Odd pole filter

Pole \ Section		1	2	3	4	5	6	7	8	9	10
3	W_i(mm)	0.5	9.6	0.5	3.4	-	-	-	-	-	-
	L_i(mm)	2.6	3.2	2.6	4	-	-	-	-	-	-
5	W_i(mm)	0.5	9.6	0.5	9.6	0.5	3.4	-	-	-	-
	L_i(mm)	2.9	4.075	5.76	4.075	2.9	4	-	-	-	-
7	W_i(mm)	0.5	9.6	0.5	9.6	0.5	9.6	0.5	3.4	-	-
	L_i(mm)	2.6	3.2	2.6	3.2	2.6	3.2	2.6	4		
9	W_i(mm)	0.5	9.6	0.5	9.6	0.5	9.6	0.5	9.6	0.5	3.4
	L_i(mm)	2.6	3.2	2.6	3.2	2.6	3.2	2.6	3.2	2.6	4

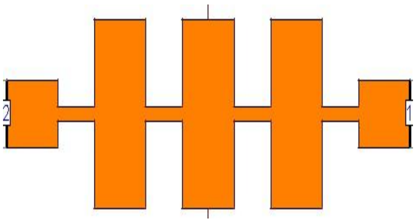
The geometry of odd pole stepped impedance micro strip line low pass filter using Table 1 is shown in fig. 2



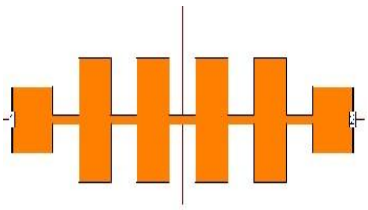
(A)



(B)



(C)

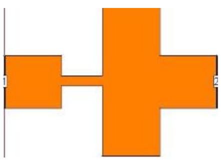


(D)

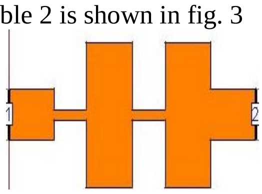
Fig. 2: Layout of, (A) 3 Pole (B) 5 Pole (C) 7 Pole (D) 9 Pole, Stepped impedance Micro-strip line Low Pass filter using Hyper Lynx 3D EM

Table 2: Dimensions for Even Pole low pass Filter

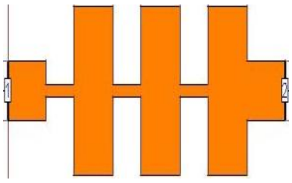
The geometry of odd pole stepped impedance micro strip line low pass filter using Table 2 is shown in fig. 3



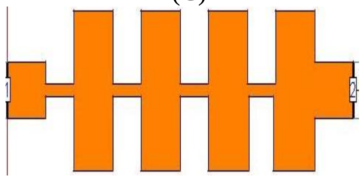
(A)



(B)



(C)



(D)

Fig. 3: Layout of, (A) 2 Pole (B) 4 Pole (C) 6 Pole (D) 8 Pole, Stepped impedance Micro strip line Low pass filter using Hyper Lynx 3DEM

IV. SIMULATED RESULTS

The simulated results of the filters as shown in figure 3 and 4 is shown by figure 4, 5, 6, 7, 8, 9,10, and 11 it predicts the geometry and response of low pass filter for even orders (n= 2, 4, 6, 8) and odd orders (n= 3, 5, 7, 9). The graph is plotted between gain (in dB) versus frequency (in GHz). Gain is taken on Y-axis and frequency on X-axis. From the curve it is clear that the cut-off frequency is found to be 5 GHz for stepped impedance low pass filter. Hence stepped impedance low pass filter is capable of passing the frequencies below 5 GHz and rejects frequency above cut-off for thickness of substrate 1.6 mm and dielectric constant 4.2. For simulation Hyper Lynx 3D EM software tool has been used [4]. Frequency Vs Gain curve for odd pole filter as shown in fig. 2

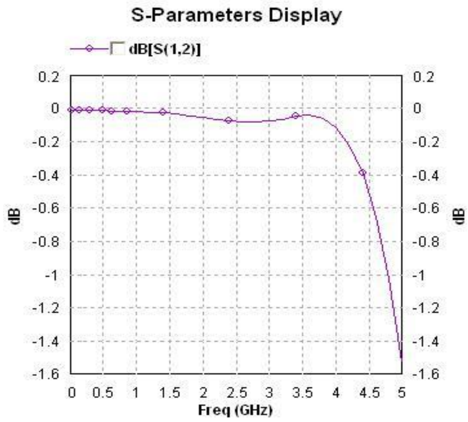


Fig. 4: Plot for 3 pole low pass filter

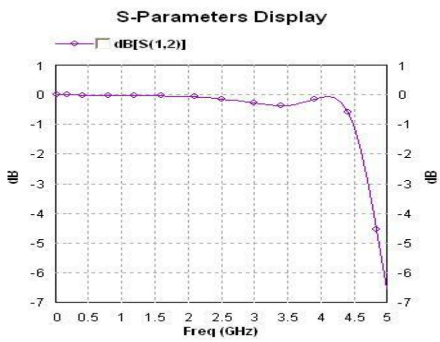


Fig 5: Plot for 5 pole low pass filter

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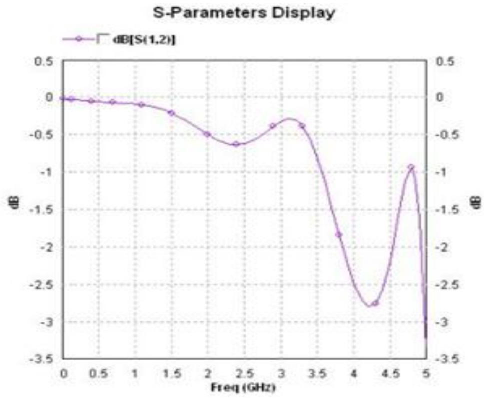

Fig. 6: Plot for 7 pole low pass filter

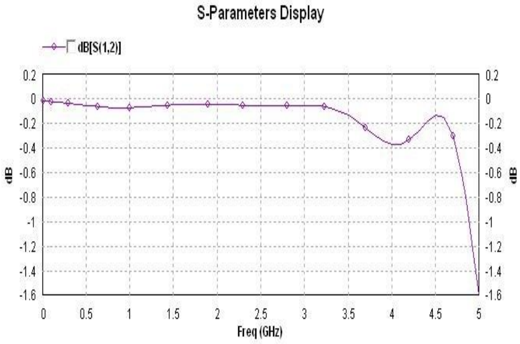

Fig. 7: Plot for 9 Pole low pass filter

Frequency Vs Gain curve for even pole filter as shown in fig.3

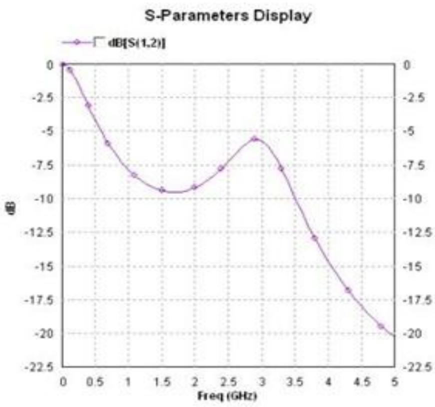

Fig. 8: Plot for 2 Pole low pass filter

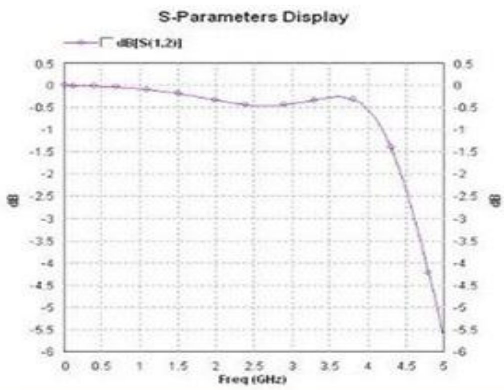

Fig. 9: Plot for 4 pole filter

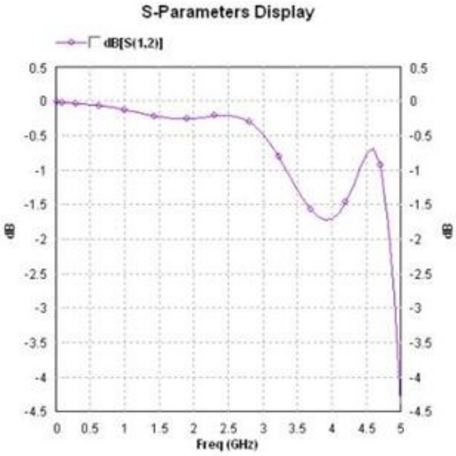

Fig. 10: Plot for 6 pole low pass filter

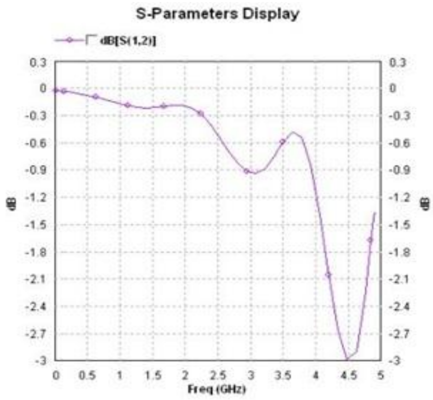

Fig.11: Plot for 8 pole low pass filter

The table 3 shows the values of the VSWR and return loss for Even order of filters:

Table 3: Different parameters for Even order filter

Pole	VSWR (in dB)	Return Loss (in dB)	Ref. Coff. (in dB)
2	24.1425	-0.7204	0.9204
4	4.83129	-3.648	0.6570
6	4.26923	-4.15244	0.61998
8	1.00789	-48.1143	0.003929

The table 4 shows the values of the VSWR and return loss for Even order of filters:

Table 4: Different parameters for Odd order filter

Pole	VSWR (in dB)	Return Loss (in dB)	Ref. Coff. (in dB)
3	5.36982	-3.2735	0.6860
5	2.69224	-6.776559	0.458323
7	1.52904	-13.58934	0.209186
9	1.002849	-56.93956513	-0.0014224

V. CONCLUSION

In this paper study of micro strip line stepped impedance low pass filter using Hyper Lynx 3D EM is presented. The even order filters i.e. second, fourth, sixth, eighth and the odd pole filters i.e. third, fifth, seventh and ninth are designed and simulated. From the simulated results above it can be concluded that as the order of the filter increases a sharper cut-off is obtained. From the table 3 and table 4 it can be concluded that the VSWR decreases and a good return loss is obtained with increase in order of filter.

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