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Design and Analysis of Hairpin Micro-Strip Line Band Pass Filter

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Abstract: This paper proposes analysis and stimulation of hairpin line microstrip band pass filter with the assistance of Hyper Lynx 3D EM software. Chebyshev low pass prototype with a pass band ripple of 0.1 db is chosen. The filter provides narrow bandwidth, high selectivity and compact size. The filter is designed to operate at centre frequency of 2 GHz; this frequency is used for wireless applications as most of them are below 3 GHz. In this paper various order of filters (3, 5,7) are designed and compared.

Keywords: Band pass Filter, Micro strip, Hairpin line, Chebyshev, Low pass Prototype.

I. INTRODUCTION

Micro strip is a type of electrical transmission line that consists of conducting strip separated from ground plane by a dielectric layer. Main advantage of micro strip band pass filter is that it is lighter, compact and less expensive than waveguide but the major disadvantages of micro strip when compared with waveguide are generally low power handling capacity and higher losses.

A band pass filter is one that passes frequencies within a certain range and attenuates frequencies outside that range. For most of the wireless applications high quality and compact sized RF/microwave filters at low cost are required. This purpose can be fulfilled by the use of planar filters. Among planar filters hairpin line filters are of much use as they are available in much reduced size as compared to parallel couple line structure. These hairpin line filters may conceptually be obtained by folding the resonators of parallel-coupled half-wavelength resonator filters. Their size can further be reduced by folding the two arms of U-shaped micro strip resonator i.e. double-fold hair pin line structure.

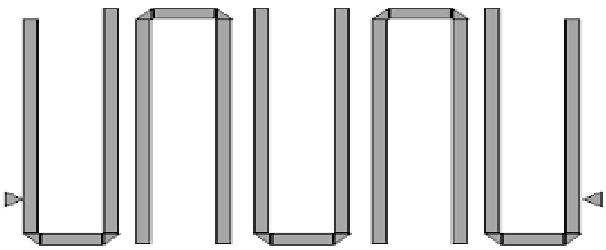

Fig.1 : Tapped line Hairpin filter

The filter is designed using the commercially available software Hyper Lynx 3DEM, in micro strip configuration called planar circuits. In present work, various odd (3, 5, 7) pole hairpin filters are designed and compared, in micro strip configuration.

II. FILTER DESIGN PROCEDURE

The design of a band 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. The general structure of band pass micro strip line filter is displayed in figure 1.

The design equations for this filters are [5]:-

$J_{01}/Y_0 = (\pi FBW/2g_0g_1)^{1/2}$ ....(1)

For j = 1 to n-1,

$J_{j,j+1}/Y_0 = (\pi FBW/2)(1/(g_jg_{j+1})^{1/2})$ ....(2)

$J_{n,n+}1/Y_0 = ((\pi/2)FBW/g_ng_{n+1})$ ....(3)

Where,

$g_{0,}g_{1,\ldots\ldots}g_n$ = elements of a ladder-type, Low pass prototype having Ω_c =1(Normalized cutoff)

FBW = fractional bandwidth of band pass filter.

J_j ,J_{j+1} = Characteristics admittances of J-inverters.

Y_0 = Characteristics impedance of lines

With the use of odd J-inverters odd modes impedances of coupled line micro strip line can be calculated as

$(Z_0)_{j,j+1} = (1/Y)[1- (J_{j,j+1}/Y_0) + (J_{j,j+1}/Y_0)^2$ ......(4)

III. DESIGN MODEL

A micro strip hairpin band pass filter is designed to have fractional bandwidth of 20% or FBW=0.2 at mid frequency of 2 GHz. Chebyshev low pass prototype with pass band ripple of 0.1 db is chosen. The low pass prototype parameter given for a normalized low pass cutoff frequency Ω_c=1 are g_0=g_6=1.0, g_1=g_5=1.1468, g_2=g_4=1.3712 and g_3=1.9750.Having obtained the low pass parameters, the band pass design parameters can be calculated by [2]

$Q_{e1} = g_0g_1/FBW$ ....(5)

$Q_{en} = g_ng_{n+1}/FBW$ ....(6)

For j=1 to n-1,

$M_{i,i+1} = FBW /(g_ig_{i+1})^{1/2}$ ....(7)

Where Q_1 and Q_{en} are external quality factors of the resonators at the input and output, and $M_{i,j+1}$ are coupling coefficients between the adjacent resonators.

Following specifications for the designing of various order of filters (3, 5, 7) are as follows: [2]

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- Dielectric constant, εr = 6.15
- Loss Tangent, $\tan\delta$ = 0.01
- Thickness =1.27mm
- Cut Off frequency, f_c = 2 GHz
- Normalised frequency, Ω_c = 1

By using the above parameters and specifications, the fifth order hairpin line microstrip bandpass filter can be designed as

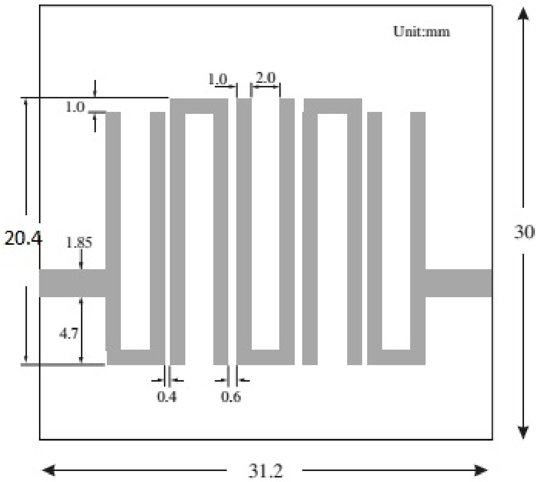
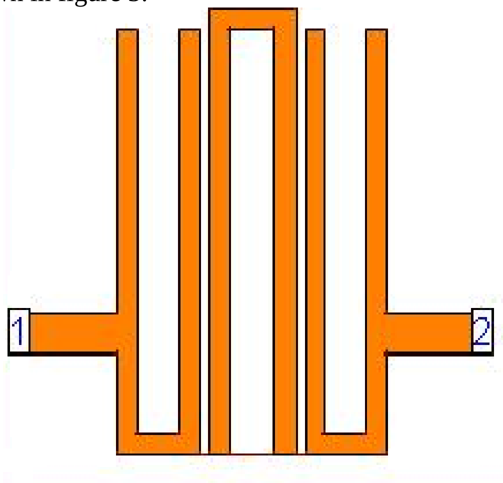
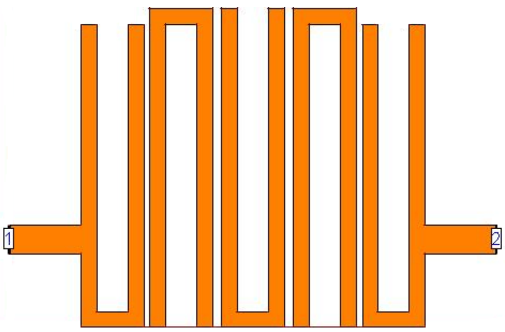


Fig. 2: 5 pole microstrip hair pin band pass filter[2]

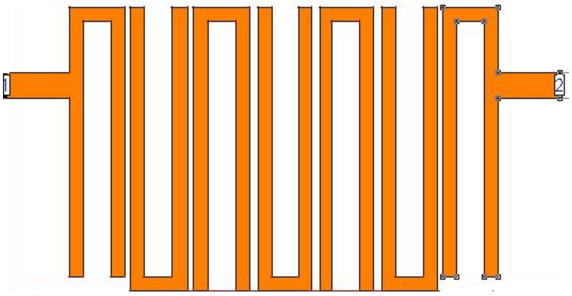
Similarly, by using the above mentioned specifications and the equations given above the dimensions of three pole and seven pole filter can be found out. The geometry of the 3 pole, 5 pole and 7 pole hairpin band pass filter is shown in figure 3.



(A)



(B)



(C)

Fig. 3: Layout of, (A) 3 Pole (B) 5 Pole (C) 7 Pole B, hair pin micro-strip line band pass filter using Hyper Lynx 3DEM

IV. SIMULATED RESULTS

The simulated results of the filters as shown in figure3, is shown in figure 4, 5, 6, it predicts the geometry and response of band pass filter for different odd orders (n= 3, 5, 7). 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 pass band of the filters is 1.5 GHz – 2.3 Ghz. Hence the Hairpin bandpass filter is capable of passing the frequencies between range 1.5 Ghz and 2.3 GHz and rejects all other frequencies for thickness of substrate 1.27 mm and dielectric constant 6.15. For simulation Hyper Lynx 3DEM software tool has been used [4].

Frequency Vs Gain plot for three pole filter as shown in fig. 4

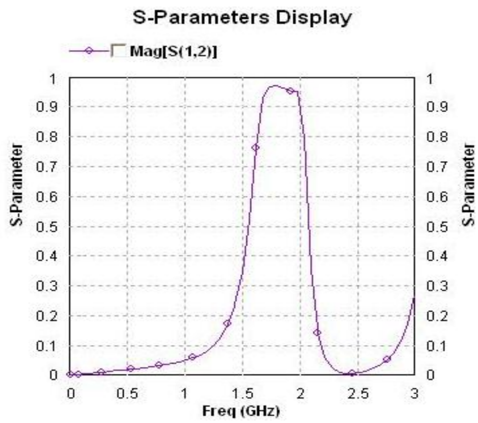


Fig. 4: Plot for 3 pole bandpass filter

Frequency Vs Gain plot for 5 pole hairpin filter is shown in figure 5.

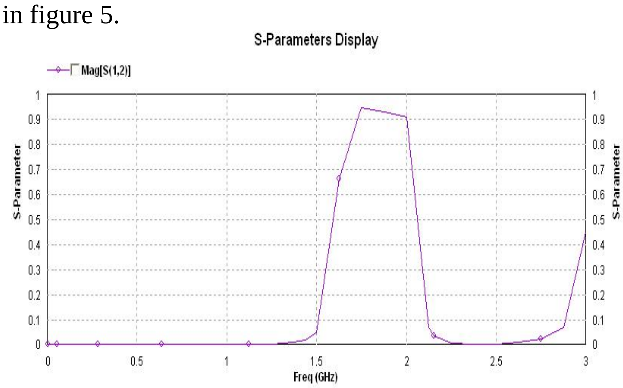


Fig 5: Plot for 5 pole band pass filter

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Frequency Vs magnitude for 7 pole hair pin filter is shown in figure 6.

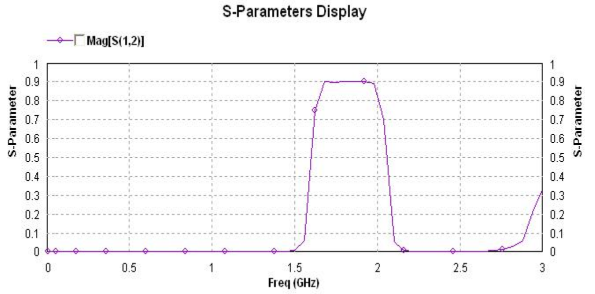

Fig. 6: Plot for 7 pole bandpass filter

From the different plots shown above it is observed that increasing the pole of the hairpin filter we obtain sharper characteristics at the cut-off points. Also, the pass band ripples decreases with increase in poles. But it is observed that with increase in poles the gain in the pass band region decreases slightly. The magnitude of the gain for 3 pole is 0.98562, for 5 pole it is 0.95214, and for 7 pole it is 0.9.

V. CONCLUSION

In this paper study of micro strip line hair pin band pass filter using Hyper Lynx 3DEM is presented. Different order filters i.e. third, fifth and seventh designed and simulated. From the simulated results above it can be concluded that as the order of the filter increases, sharper characteristics at cut-off is obtained. From the simulated results, it is clear that pass band ripples decrease with increase in order, with a slight decrease in gain of the filter.

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