Design and simulation of hairpin band pass filter for different substrate

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***Abstract*— In this paper we presented analysis and simulation of microwave hairpin filter. This hairpin filter is designed to operate at frequency of 2.4 GHz with a bandwidth of 42% and return loss of -22.5dB and second hairpin band pass filter is designed to operate at center frequency of 3 GHz with a bandwidth of 46% and return loss of -35 dB. This frequency is presenting for microwave S-band. The (2-4GHz) band is used by various radar, surface radar, and some communications satellites**

***Index Terms*— Microwave Hairpin filter, S-Band, Communication.**

I. INTRODUCTION

Band pass filters are essential part of any signal processing and communication systems, also the part of superhetrodyne receivers which are currently employed in many RF/Microwave communication systems. At Higher Frequencies the discrete components are replaced by transmission lines, microstrip are for low power applications used which provide cheaper and smaller solution of Band Pass Filter. This Paper describes the design of the microwave 'S band'Bandpass filter by using microstrip technology. There are various possible techniques used to create microstrip filters fifth order chebyshev hairpin filter is designed.

II. BASIC THEORY

Out of various bandpass microstrip filters, Hairpin filter is most commonly used filter. The concept of designing hairpin filter is same as that of parallel coupled half wavelength resonator filters. The advantage of hairpin filter over end coupled and parallel coupled microstrip is it takes low space. In this filter space is saved by folding the resonator which is half wavelength long. Also the designing of this filter is simple then the other microwave filters.

Figure 2.1: tapped line input 5-pole Hairpin Filter

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The mutual coupling coefficient between two resonators Mi, i+1, and quality factor at the input and output *Qe1* and *Qen* are the design parameters for the hairpin filter. The Coupling coefficient and Quality Factor can be calculated as

$$Qe1 = \frac{g_0 g_1}{FBW} \quad \text{(2a)}$$

$$Qen = \frac{g_n\, g_{n+1}}{FBW} \quad \text{(2b)}$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i\, g_{i+1}}} \quad \text{(2c)}$$

For i=1 to n-1

III. DESIGN METHODOLOGY

A microstrip hairpin bandpass filter is designed to have a fractional bandwidth 20% or *FBW* = 0.2 at a midband frequency f_0 = 2.8 GHz .A three pole (*n*=3) Chebyshev lowpass prototype with a passband ripple of 0.5 dB is chosen. The lowpass prototype parameters, lowpass cutoff frequency is calculated by following Table.

0.5 dB Ripple

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
1	0.6986	1.0000									
2	1.4029	0.7071	1.9841								
3	1.5963	1.0967	1.5963	1.0000							
4	1.6703	1.1926	2.3661	0.8419	1.9841						
5	1.7058	1.2296	2.5408	1.2296	1.7058	1.0000					
6	1.7254	1.2479	2.6064	1.3137	2.4758	0.8696	1.9841				
7	1.7372	1.2583	2.6381	1.3444	2.6381	1.2583	1.7372	1.0000			
8	1.7451	1.2647	2.6564	1.3590	2.6964	1.3389	2.5093	0.8796	1.9841		
9	1.7504	1.2690	2.6678	1.3673	2.7239	1.3673	2.6678	1.2690	1.7504	1.0000	
10	1.7543	1.2721	2.6754	1.3725	2.7392	1.3806	2.7231	1.3485	2.5239	0.8842	1.9841

The next step of the filter design is to find the dimensions of coupled microstrip lines that exhibit the desired even- and odd mode impedances. First calculate microstrip shape ratios (w/d) s. Then it can relate coupled line ratios to single line ratios.

For a single microstrip line,

$$Z_{ose} = \frac{(Z_{oe})_{j,j+1}}{2}$$
$$Z_{oso} = \frac{(Z_{oo})_{j,j+1}}{2} \qquad \textbf{(3.1)}$$

Use single line equations to find (w/h)se and (w/h)so from Zose and Zoso. With the given ε_r =4.2, find that for Zo=50, w/h is approximately 1.95. Therefore, *W/h≤ 2* has been chosen for this case.

$$For \frac{W}{h} \le 2$$
$$\frac{W}{h} = \frac{8\exp(A)}{\exp(2A)-2} \qquad \textbf{(3.2)}$$

With
$$A = \frac{Z_c}{60}\left\{\frac{\varepsilon_r+1}{2}\right\}^{0.5} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left\{0.23+\frac{0.11}{\varepsilon_r}\right\} \qquad \textbf{(3.4)}$$

We can use following design curves to calculate the separation between to microstrips and distance of the tapped input.

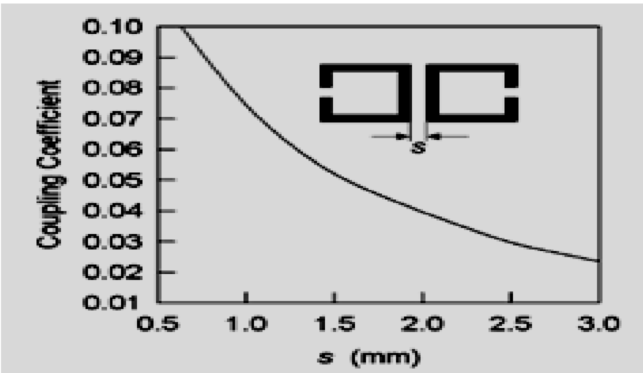

Figure.3.1: Design curve between separation and coupling coefficient [9]

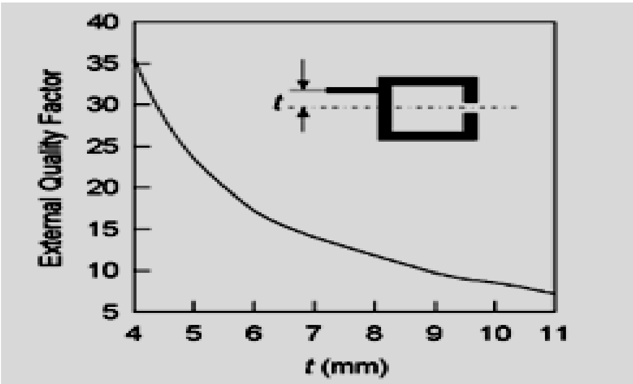

Figure.3.2: Design curve between tapped input and external quality factor [9]

Using the design curves for coupled microstrip lines given in the figure 3.1 and 3.2 the width and spacing for each section are found.

The layout of the proposed filter design with all the determined dimensions is illustrated in Figure 3.3. The size of filter is 18.4 X 30 mm which is very compact.

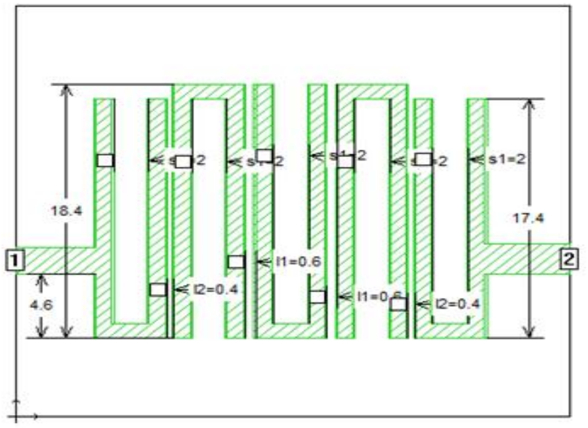

Figure.3.3: Dimensions of proposed compact hairpin band pass filter

IV. RESULTS AND ANALYSES

The response of proposed filter for rogers theta is in fig. 4.1 as shown in fig. proposed filter gave a center frequency of 2.4 GHz. The response of proposed filter for rogers RT5870 is in figure 4.4 as shown in figure proposed filter gave a center frequency of 3 GHz. Comparision of both filters are presented in Table I.Spurious modes which do appear due to in-homogeneities of the microstrip [7, 8] are not shown here.

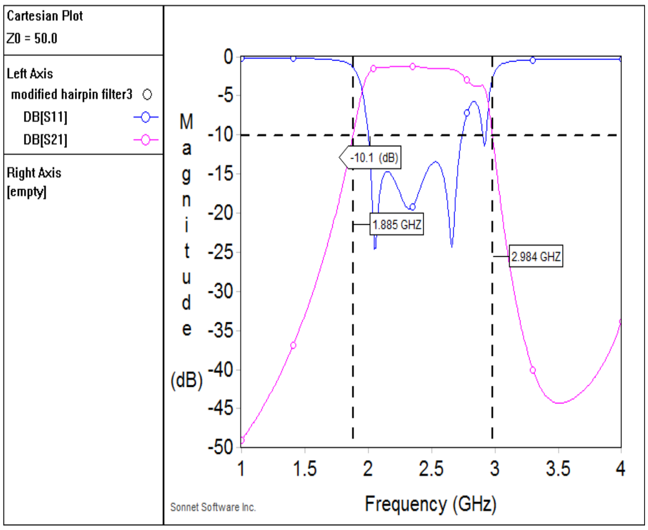

Figure.4.1: S11(blue line) and S12 (pink line) parameters of the proposed hairpin filter

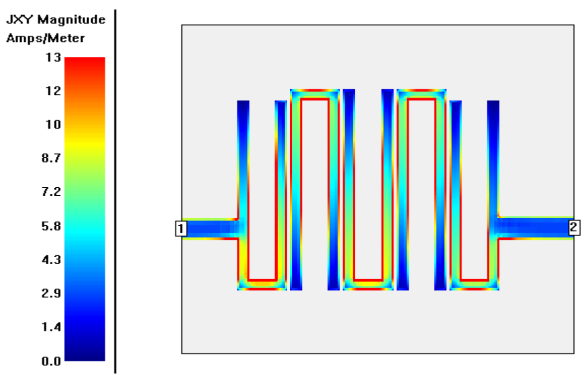

Figure.4.3: Current density of the proposed hairpin filter at 2.8 Ghz.

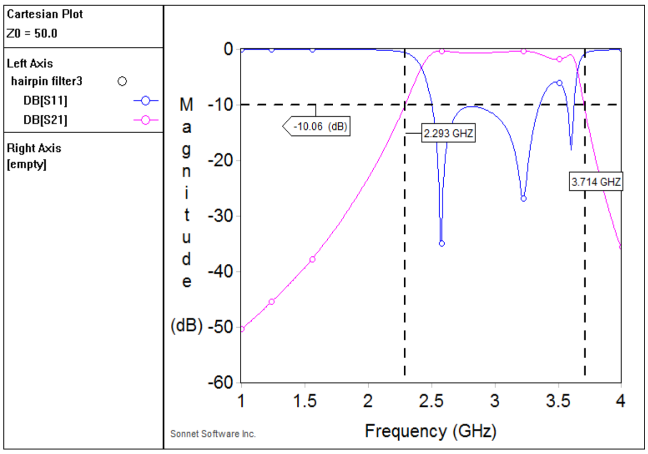

TABLE I

Parameters	**Proposed filter**	
Return loss	-24.5	-35
bandwidth	42%	46%
Size(mm)	18.4X30	18.4X30
subtrate	Rogers theta(4.01)	Rogers RT5870(2.33)
Center frequency(Ghz)	2.4	3

V. CONCLUSION

The layout of the final hairpin band pass filter designed with all the determined dimensions is illustrated. The filter is compact with substrate size of 18.4 by 30 mm. The input and output resonators are slightly shortened to compensate for the effect of the tapping line and the adjacent coupled resonator. The simulation of the filter is shown in figure 4.1, 4.2 and 4.4.

VI. FUTURE WORK

Physical development and measurement of RF filters design for more accurate design. Use of additional software such as CST simulations to compare the results with sonnet to accurately determine the final design.

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