Design and Simulation of Tapped Input Compact Hairpin Band Pass Filter

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Abstract—In this paper design and simulation of a tapped input microwave hairpin filter has been presented. The filter is designed for center frequency of 2.8 GHz. The proposed filter has a bandwidth of 390 MHz. It is found that the filter is giving return loss of -25dB. The 2.8 GHz frequency is covered by microwave S-band which have applications in surveillance radar, surface radar, and satellite communication. The proposed filter is suitable for radar applications due to its compactness. The filter is of 12 X 20mm size and works in a single band mode. The design steps are given to determine the filter dimensions.

Index Terms— Microstrip line, bandpass filter, Hairpin filter, S-band application, Microwave filter, Distributed system

1. Introduction

Band pass filters are necessary part of any Communication and signal processing system. It is also an essential part of superhetrodyne receivers which are presently used in many radio frequency communication applications. The discrete components are exchanged by transmission lines at microwave frequencies [1]. The microstrip finds its role in low power applications. The proposed Paper describes the designing of a microwave band pass filter using microstrips. There are many techniques by which a microstrip filter can be designed. In this paper a fifth order chebyshev hairpin bandpass filter is designed.

2. Design Methodology

Hairpin filter are one of the most commonly used filter in many microwave applications. The concept of hairpin filter designing is based on parallel coupled half wavelength resonator filters [2]. The major advantage of hairpin filter is its low space employment compared to parallel coupled and end coupled microstrip filters. In hairpin structure, the half wavelength long resonators are folded in U-shape hence the overall space is saved. This design is simpler than other microwave filters.

The mutual coupling coefficient is Mi, i+1, between two resonators and Qei and Qeo are the quality [1]factor at the input and output respectively. These are the design parameters for the hairpin filter and can be determined as

$$Q_{ei} = \frac{g_0 g_1}{FBW} \quad (1)$$

$$Q_{en} = \frac{g_n g_{n+1}}{FBW} \quad (2)$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}} \quad (3)$$

The proposed filter is designed for a fractional bandwidth equals to 20% or FBW = 0.2 at a center frequency f_0 = 2.8 GHz. For this filter a three pole Chebyshev lowpass prototype is chosen. The passband ripple of 0.5 dB is selected. For a given normalized lowpass cutoff frequency, the low pass prototype parameters are determined using table 1.

In the next step of the filter design, dimensions of coupled microstrip lines are determined. These lines show the desired odd and even mode impedances. In the first step microstrip shape ratios (w/d) is determined. The shape ratio relates the coupled line ratios to the single line ratios.

Figure 1: tapped line input 5-pole Hairpin Filter

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Table 1: Low pass filter prototype parameters

N	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}
0.5 dB Ripple											
1	0.698	1.00									
2	1.402	0.707	1.984								
3	1.596	1.096	1.596	1.000							
4	1.670	1.192	2.366	0.841	1.984						
5	1.705	1.229	2.540	1.229	1.705	1.000					
6	1.725	1.247	2.606	1.313	2.475	0.869	1.984				
7	1.737	1.258	2.638	1.344	2.638	1.258	1.737	1.000			
8	1.745	1.264	2.656	1.359	2.696	1.338	2.509	0.879	1.984		
9	1.750	1.269	2.667	1.367	2.723	1.367	2.667	1.269	1.750	1.000	
10	1.754	1.272	2.675	1.372	2.739	1.380	2.723	1.348	2.523	0.884	1.984

For a single microstrip line,

$$Z_{ose} = \frac{(Z_{oe})_{j.j+1}}{2} \quad (4)$$

$$Z_{oso} = \frac{(Z_{oo})_{j.j+1}}{2} \quad (5)$$

The single line equations are used to determine $(w/h)_{se}$ and $(w/h)_{so}$ from Z_{ose} and Z_{oso}. Since $\epsilon_r = 4.2$ is taken, it is found that w/h is approximately 1.95 for Z_o=50. Therefore, W/h≤ 2 equation has been chosen for this case.

For $\frac{W}{h} \le 2A$

$$\frac{W}{h} = \frac{8\exp(A)}{\exp(2A)-2} \quad (6)$$

where

$$A = \frac{Z_o}{60}\left\{\frac{\epsilon_r+1}{2}\right\}^{0.5} + \frac{\epsilon_r-1}{\epsilon_r+1}\left\{0.23 + \frac{0.11}{\epsilon_r}\right\} \quad (7)$$

The design curves given in figure 2 can be used for coupled microstrip lines to determine the width and spacing for each section. The design curve in figure 3 can be used to determine the separation between microstrips and distance of the tapped input.

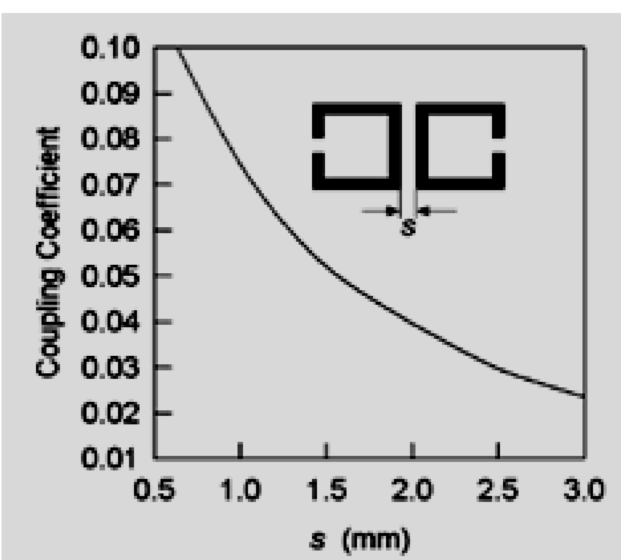

Figure.2: Design curve between separation and coupling coefficient [9]

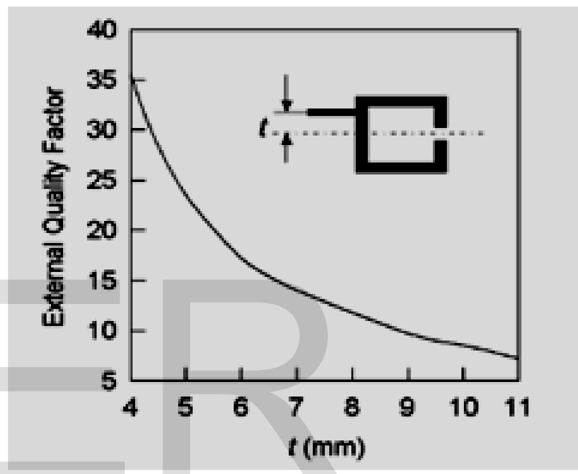

Figure.3: Design curve between tapped input and external quality factor [9]

3. Proposed Filter Design

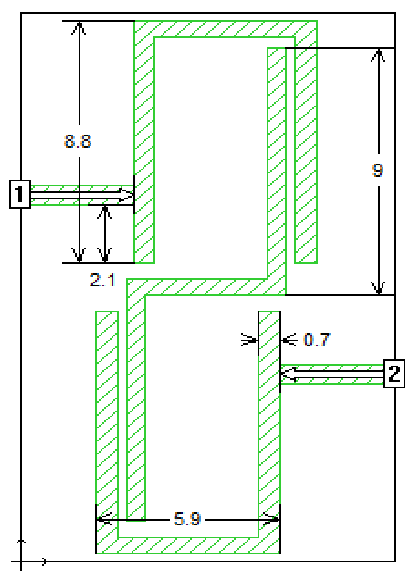

Figure.4: Dimensions of proposed compact hairpin band pass filter

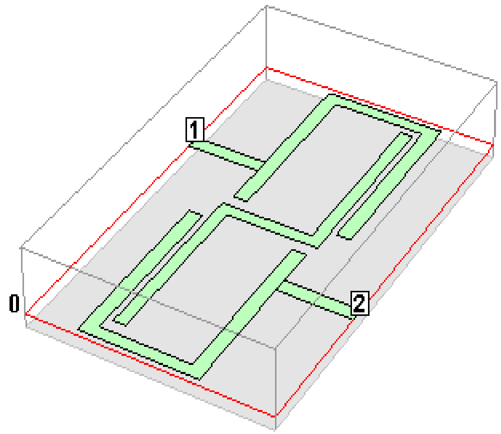

Figure.5: 3- Dimensional view of proposed compact hairpin band pass filter

The layout of the proposed hairpin bandpass filter is illustrated in Figure 4 and Figure 5. The dimensions of the proposed filter are determine using equations and design curves presented in previous section. The size of filter is 12 X 20 mm which is compact than the conventional hairpin filter.

4. Results and Analysis

The performance of the proposed filter is illustrated in Figure 6, Figure 7 and Figure 8. The return loss and gain of the filter is shown in figure 6. It shows the proposed filter is giving a center frequency of 2.8 GHz. The approximate bandwidth of the filter is 390 MHz, which is suitable for many radar applications. Spurious modes may be appeared in the structure due to in-homogeneities [7,8] but these are not shown here.

Figure 7 shows the smith chart of the parameter S_{11} of the filter and Figure 8 shows the current distribution of the filter at center frequency.

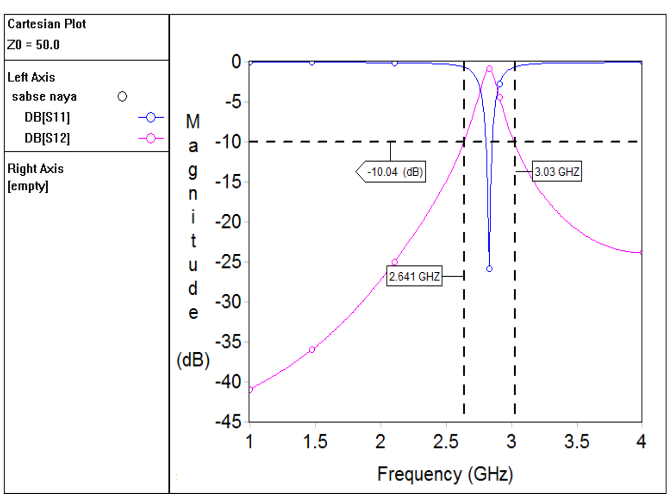

Figure.6: S_{11} and S_{12} parameters of the proposed hairpin filter

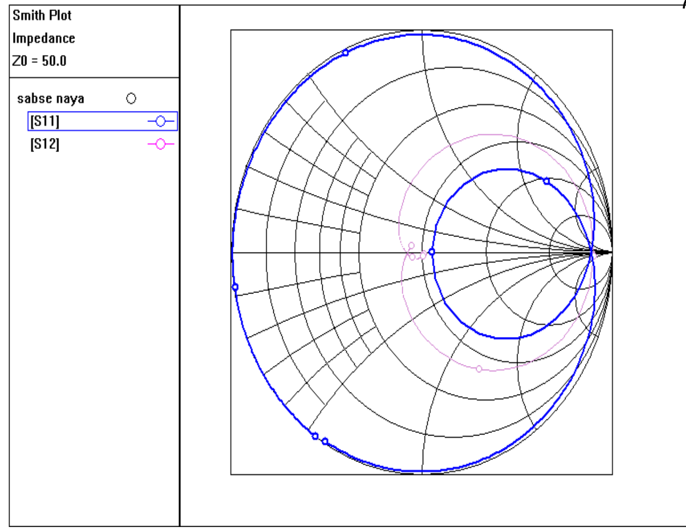

Figure.7: smith chart of parameter s_{11} of the proposed hairpin filter

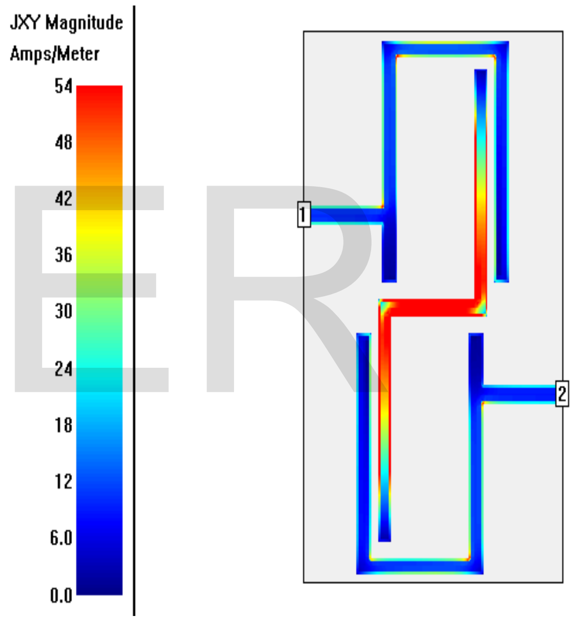

Figure.8: Current density of the proposed hairpin filter at 2.8 Ghz.

5. Conclusion

The compact hairpin filter is designed and simulated. The layout of the final filter design with all the determined dimensions is illustrated. The filter is quite compact with a substrate size of 12 by 20 mm. The input and output resonators are slightly shortened to compensate for the effect of the tapping line and the adjacent coupled resonator. The proposed filter is a single band BPF which works in microwave S-band and mainly used for radar applications operating in the 2700–2900 MHz range.

REFERENCES

[1] Matthaei, L. Young, and E. M. T. Jones, Microwave Filters, Impedance-Matching Networks, and Coupling Structures. Boston, MA: Artech House, 1980.

[2] D. M. Pozar, "Microwave Engineering", Second Edition, Wiley and Sons, 1998.

[3] R. Rhea, HF Filter Design and Computer Simulation. Atlanta, GA: Noble Publishing, 1994.

[4] T. Edwards, Foundations for Microstrip Circuit Design, 2nd edition, England: John Wiley & Sons Ltd.,1981.

[5] N. Toledo, "Practical Techniques for designing Microstrip tapped hairpin resonator filters on FR4 laminates" 2nd National ECE Conference, Manila, Philippines, November 2001.

[6] Eagleware Corporation, " TLine Program," Genesys version 8.1, Norcross, GA, May 2002.

[7] T. Yamaguchi, T. Fujii, T. Kawai, and I. Ohta, "Parallel-coupled microstrip filters with periodic oating conductors on coupled-edges for spurious suppression," IEEE MTT-S International Microwave Symposium Digest, 2008.

[8] K. Singh, "Design and analysis of novel microstrip filter at l-band," in Agilent EESoF 2005 India User Group Meeting, 2005.

[9] Jia-Shen Hong "Microstrip filters for RF/microwave applications" second edition Wiley publication.