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Design and Analysis of Microstrip Hairpin Bandpass Filter for ISM Band

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ABSTRACT: In this paper, the design of 2.4 GHz Hairpin band pass filter with 0.5dB ripple factor and 25% bandwidth has been elaborated. The coupled line bandpass filter has been simulated using Ansys HFSS simulation software on a FR4 substrate with εr = 4.4 and thickness of 1.6mm.The filter provides the wider bandwidth and the compact size of the 37mm × 23.5 mm The development of band pass filter includes calculation, simulation, testing and measurement of the filter parameters process has been presented.

KEYWORDS: Band pass Filter, Micro strip, Hairpin line, Anysys Design, substrate

I.INTRODUCTION

A Filter is a two-port network which is used as a frequency selective component, in communication systems. In communication systems we required the desired frequency band for particular application from the electromagnetic spectrum.An antenna at receiver section can receive a wideband of frequencies, few of which them may be not desired and need to be filtered first before processing the signal. Filters have been used in conjunction with antennas to achieve the desired task.Filters play important roles in many RF/microwave applications. They are used to separate or combine different frequencies. Emerging applications such as wireless communications continue to challenge RF/Microwave filters with ever more stringent requirements-higher performance, smaller size, lighter weight, and lower cost.Oftenly, many practical considerations and limitations determine the actual filter construction. For low selectivity, wideband applications, strip lines and Microstrip line are ideal. Parallel coupled structure with very tight coupling gives higher bandwidth. The resonators sections are placed side by- side for more compactness includes structures like Combline, Interdigital, and Hairpin etc. The hairpin configuration is most preferred in MIC or MMIC filter design process as it doesn't required ground when ceramic substrate is chosen. Higher dielectric constant material can be used to decrease the size of the filter. For Hairpin filter high dielectric constant of 80 and 90 is basically used for wide band applications[1].Hairpin line filter basically is a folded version of a half wave parallel coupled–line filter. The parallel coupled bandpass design is most preferably used, because available full EM simulator softwares provide faster optimization of dissimilar propagation velocities, short end coupling element, and bend etc.

The Hairpin line filter are larger in size as compared to combline and interdigital filters. The reason is that, the interarm spacing, should be kept large. It becomes impractical to fold the resonator, as the frequency increases, the length-to- width ratio becomes smaller for a given substrate thickness. The various methods mentioned above for hairpin design are thoroughly discussed in [4] to [8]. Cristal and Frankel's design method [4] takes these condition into account, but assumes negligible phase shift over the line joining the arms of a filter. The comparison of several types of hairpin filter is given by [2].With keeping aim in reducing the size of hairpin filter than the parallel coupled line filter, the Ansoft Designer(HFSS) is used in driven terminal solution type to test and measured the desired results for the frequency of 2.4GHz.

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II.FILTER PARAMETER DESIGN EQUATIONS

There are two types of hairpin structures mainly, the Tapped line input and the coupled line Input. We have chosen the first one. Having obtained the lowpass parameters, as per the specifications, the bandpass design parameters can be calculated by [2]

$$Qe1 = \frac{g0g1}{FBW} \quad \ldots(1)$$

$$Qen = \frac{gngn+1}{FBW} \quad \ldots(2)$$

$$Mi.i + 1 = \frac{FBW}{\sqrt{gigi+1}} \; i = 1 \text{ to } n\text{-}1 \quad \ldots(3)$$

Where Q_{e1} and $Q_{en}$are the external quality factors of the resonators at the input and output, and $Mi,i+1$ are the coupling coefficients between the adjacent resonators.

We then carry out full-wave EM simulations to extract the external Q and coupling coefficient M against the physical dimensions. Now the length of the resonator can be calculated which is given by "L_{len}" can be calculated using equation [4] through [6]. The optimized value of "L_{len}" obtained is 18mm.The tapped line is chosen to have characteristic impedance that matches to a terminating impedance$Z0$ = 50 ohms.

The design equation proposed for estimating the tapping point *tap "H" at input and output is given* as

$$Htap = \frac{2L}{\pi}\sin^{-1}\left(\sqrt{\frac{\pi}{2}} \times \sqrt{\left(\frac{Z0}{ZrQe}\right)}\right) \quad \ldots(4)$$

*Where Zr*is the characteristic impedance of the hairpin line

,Z_0 is the terminating impedance.

The dimension of the length of the resonator of hairpin filter if given by "L"

$$L_{1,2,3} = {}^{\lambda_g}/_4 \quad \ldots (5)$$

Where

$$\lambda_g = \frac{\lambda_0}{4Fr\sqrt{\varepsilon_{reff}}} \quad \ldots (6)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} \quad \ldots (7)$$

III. DESIGN METHODOLOGY

A microstrip hairpin bandpass filter is designed to have a fractional bandwidth of 25% or FBW = 0.25 at a midband frequency $f0$ = 2.4 GHz. For Second order Chebyshevlowpass prototype with a passband ripple of 0.5 dB is chosen. The lowpass prototype parameters, given for a normalized lowpass cutoff frequency are $g1$= 1.4029,g2= 0.7071,g3= 1.9841.

The design equations of the parallel coupled line filter consequently may be used to find the physical dimensions realization on EM simulations. We use a substrate FR4 with a relative dielectric constant of 4.4mm and a thickness of 1.6 mm for microstrip realization**.**

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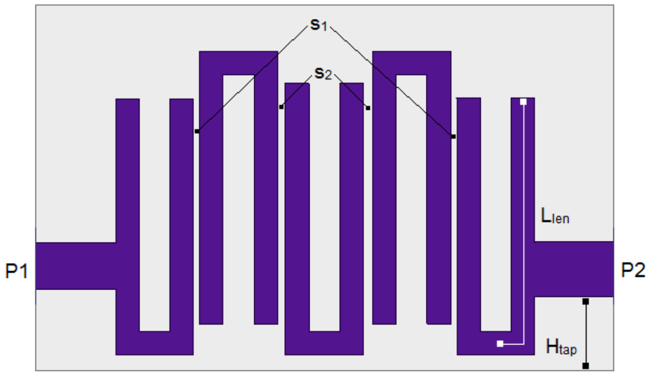

Fig.1: Geometry of Hairpin Bandpass Filter

The physical structure of prototype for the given specification are as shown in fig.1.The length of the tap pin point input is to be found on EM simulation for the condition of the impedance matching at 50 ohm. The width of the resonator can be calculated theoretically by

To calculate the width at for w/h>2 the filter we have

$$W/h = 2/\pi\left\{(B-1) - \ln(2B-1)\frac{\varepsilon r-1}{2\varepsilon r}\left[ln(B-1) + 0.39 - \left(\frac{0.61}{\varepsilon r}\right)\right]\right\} \quad \ldots\ldots\ldots(8)$$

With $B= 60\pi^2/Z_c\sqrt{\varepsilon_r}$

IV. RESULT AND DISCUSSION

The figure 2 shows the simulated result of the Transmission Bandwidth and the Reflection Bandwidth obtained.

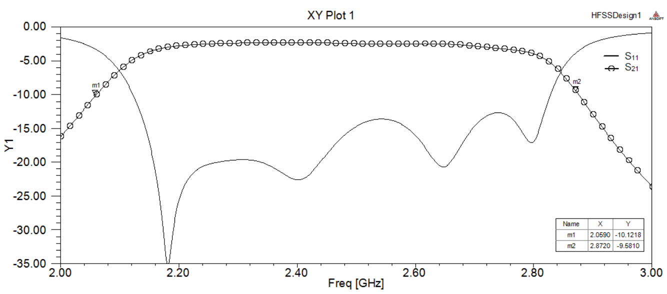

Fig.2 Simulated Reflection (S_{11}) and Transmission (S_{21}) Return Loss Of the Hairpin Bandpass Filter.

The hairpin filter offers reflection and transmission bandwidths of 760 MHz and 815 MHz over the frequency ranges 2 – 2.8 GHz and 2.12 – 2.83 GHz respectively.; implying wideband operation. The parameters such as gap between the coupled lines highly influences the bandwidth of the filter which can be optimized using parametric study.

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VI.CONCLUSION

The Hairpin filter is simulated. The filter is quite compact with a substrate size of by 37 ×23.5 mm^2.The transmission bandwidth is 760 MHz and Reflection bandwidth is 815 MHz Therefore it can be used for wideband filter applications. The input and output resonators are slightly shortened to compensate for the effect of the tapping line and the adjacent coupled resonator.

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