# A Novel Hair Pin Line Band Pass Filter design for WIMAX applications

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*Abstract:* **Band pass Filters plays important role in Microwave applications. A compact microstrip Hairpin line filter design is presented in this paper for a centre frequency of 2.4GHz. Hair pin line band pass filters are compact structures obtained by folding the resonator of parallel-coupled half wave length resonator. The use of microstrip line in microwave systems is often preferred because of advantages with respect to size, weight, costs, and usually reproducibility. A five pole microstrip Hair pin line filter is designed with 500 MHz bandwidth at the centre frequency of 2.4 GHz used for unlicensed WIMAX applications. This passive filter was simulated in Agilent's ADS software. The filter shows low insertion loss of less than 1 dB and return loss of >25dB at the proposed centre frequency.**

*Keywords:* **Wireless communication, WiMAX, Band pass filter, Hair pin Line Filter, parallel-coupled microstrip, coupling factor.**

## 1. INTRODUCTION

Micro strip Band pass filters plays important role in all communication systems. Microstrip is a popular type of planar high frequency due to ease of fabrication and its ability to integrate with the other devices. The basic structure of Microstrip line consists of a conductive strip separated from ground plane by dielectric. RT Duroid is one of the microstrip laminates used as dielectric substrate that are suitable in designing hairpin band-pass filter. For microwave circuits parallel-coupled-line and hairpin filters are widely used. The basic microstrip Band pass Filter will allow certain range of frequencies and attenuate certain range of Frequencies. These filter topologies can be realized by using Chebyshev filter response.

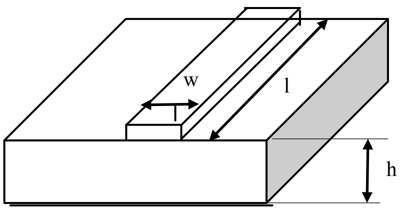


Fig.1 Structure of Microstrip line

The microstrip circuits has their own advantages compare to other microwave transmission like waveguide, coaxial cable, strip line as Filter realized with wide bandwidth, compact size, easy to fabricate, good reliability and reproducibility. A compact hair pin line filter is proposed in this paper. The filter is designed, simulated in ADS (Agilent‘s Advanced Design systems) with the centre frequency of 2.4GHz. Microstrip filter based on printed circuit board (PCB) offers the advantages as easy and cheap in mass production with different Dielectric constants.

## 2. WIMAX TECHNOLOGY

The new applications offer certain features in telecommunication services, which in turn offer three important items to the customers.

- The first is the coverage, meaning each customer must be supported with a minimal signal level of electromagnetic waves.
- The second is capacity that means the customer must have sufficient data rate for uploading and downloading of data.
- The last is the quality of services (QoS) which guarantee the quality of the transmission of data from the transmitter to the receiver with no error. WiMAX is the suitable technology to satisfy above all.

WiMAX (Worldwide interoperability microwave Access) is an air interface telecommunications technology for combined fixed, portable and mobile broadband wireless access, and is based on the IEEE 802:16d 2004 (Fixed WiMAX) and IEEE 802:16e 2005 (Mobile WiMAX) standards .The development of Wi-Fi was triggered by the FCCs decision in 1985 to allow unlicensed spread spectrum systems in the *915 MHz, the 2.4 GHz and 5.8 GHz* bands allocated for industrial, scientific and medical (ISM) applications.

In realization of such a system like WiMAX we need a complete new transmitter and receiver. A Band pass filter is an important component must be found in the transmitter or receiver.

Filter networks are essentials building elements in many areas of RF/ microwave engineering. Such network are used to selects, rejects and combine signals at different frequencies Band pass filter is a passive component which is able to select signals inside a specific bandwidth at a certain center frequency and reject signals in another frequency region. The Microstrip based on BPF printed circuit board (PCB) offers the advantages easy and cheap in mass production for different Dielectric constants.

## 3. HAIR PIN LINE FILTER

The hairpin filter is one of the most popular microwave frequency filters because of it is compact size and does not require grounding.

 

*3.1. Basics of Hair Pin Line Filter*

The hairpin filter configuration is derived from the edge-coupled filter by folding back the ends of the resonators into a **"U"** shape. (Ref.fig.2.) each resonator of the hairpin filter is 180 degrees so that the length from the center to either end of the resonator is 90 degrees. From 90 degrees, 0 degrees are "slid" out of the coupled section into the uncoupled segment of the resonator (fold of the resonator). This reduces the coupled line lengths and, in effect reduces the coupling between resonators.

The tapping distance will determine Q-factor and the spacing between mutual coupling. As the frequency is increased, the aspect ratio of each resonator becomes squarer and saves space.

Many people have presented numerous design techniques for the realization of band pass filters such as parallel coupled line, comb line and split ring resonators. The disadvantage of parallel coupled line filter is that it suffers from spurious response which degrades the pass band and stop band performance of the filter. The advantage of hairpin filter over edge coupled and parallel coupled microstrip realizations, is the optimal space utilization. This space utilization is achieved by folding of the half wavelength long resonators. Fig. 1 shows the structure of basic hair pin resonator. Also the absence of any via to ground plane or any lumped element makes the design simpler and fabrication of the Filter made easy.

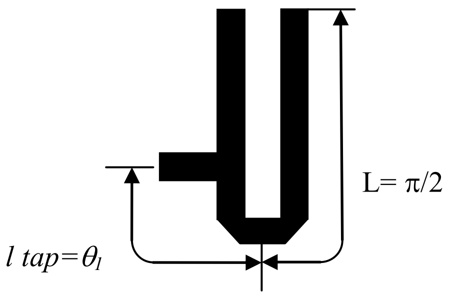


Fig.2 Structure of Tapped Hair pin Resonator

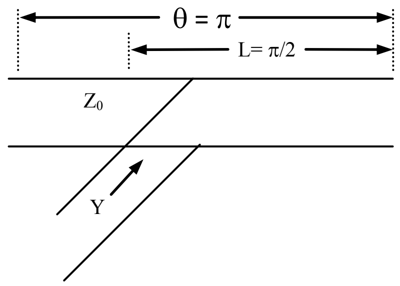


Fig.3 Equivalent of Tapped Hair pin Resonator

The tapped Hairpin resonator schematic structure is shown in Fig.2 and the equivalent circuit is shown in Fig.3. With reference to hairpin resonator (Fig.3) the input impedance at the tap point (Y) is

$$Y = G + jB = \frac{\pi Yo}{2\sin^2\theta_1}\left(\frac{1}{Q_s} + j2\,\frac{f-fo}{fo}\right) \text{ - (1)}$$

Provided that $\frac{f-fo}{fo} \ll 1.0$

Hairpin-line band pass filters are compact structures. They may conceptually be obtained by folding the resonators of parallel-coupled, half-wavelength resonator filters, which were discussed in the previous section, into a U shape. This type of U shape resonator is the so-called hairpin resonator. Consequently, the same design equations for the parallel-coupled, half-wavelength resonator filters may be used.

However, for folding the resonators, it is necessary to accentuate reduction of the coupled line lengths to reduce the coupling between resonators. So if two arms, if each hairpin resonators are closely spaced they will act as a pair of coupled line, which could affect coupling as well. An experimental hairpin filter with this type has been demonstrated by Hong and Lancaster (2001) where, the design equation proposed for estimating the tapping point T is:

$$T = \frac{2L}{\pi} \times \arcsin\left(\frac{\pi}{2} \times \left(\frac{z_o}{Q_e z_r}\right)\right)^{0.5} \quad (2)$$

Where

T = The tap point height

L = λ/8 long

Zr = The characteristic impedance of the hairpin line

$Z_o$ = The terminating impedance

$Q_e$ = The external quality factor

So, if we can find the best size for the filter and T, we can find the best Return loss and insertion loss.

*3.2. Design calculations for Hair pin line Filter*

The design parameters of Coupling coefficient and Quality Factor can be calculated as

$$Q_{e1} = (g_0\, g_1) / FBW \text{ - - - - - (3)}$$

$$Q_{en} = (g_n\, g_{n+1}) / FBW \text{- - - - (4)}$$

where $Q_{e1}$ and $Q_{en}$ are external quality factor of resonator at input and output.

$$M_{i,j} = FBW / \sqrt{g_i\, g_{i+1}} \text{ - - - - (5)}$$

For i= 1 to n-1 are the coupling coefficient between adjacent resonator.

FBW is the Fractional bandwidth

$$FBW = (\omega_{upper} - \omega_{lower}) / (\omega_o) \text{ - - - - (6)}$$

It is necessary to take into account the reduction of coupled line lengths, which reduce the coupling between the resonators. The arms of each hairpin resonator function as a pair of coupled lines when closely spaced.

 

### *3.3. Design Specifications of Hair pin line Filter*

A commercial substrate of RT Duroid made by Rogers with relative dielectric constant of 2.5 with thickness of 60mil and the loss tangent of 0.0015 is selected. The EM simulation was done using Agilent EESOF Advanced Design System (ADS).

In this paper a Micro strip Hair pin filter is design to have a fractional band width of 20.83% for mid band frequency of Fo =2.4 GHz . A five pole (n=5) Chebyshev low pass prototype with pass band ripple of 0.1 dB is chosen. The filter design specifications are as follows. (Refer Table1).The Rogers Corporation made RT Duroid with dielectric constant of 2.5 is used to fabricate the PCB.

TABLE 1. BPF DESIGN SPECIFICATIONS

| | |
|---|---|
| Centre Frequency | 2.40 GHz |
| Lower cutoff frequency | 2.15 GHz |
| Higher cutoff frequency | 2.65 GHz |
| Band width | ±500 MHz |
| Order of the filter | 5th |

### *3.4. Hair pin line Filter Design*

The first step to designing the filter is to determine the specifications of the desired Hairpin line BPF. Refer specifications for the proposed 5th order filter in Table 1.

The second step is the filter element values for Chebyshev response to be selected. The low pass prototype parameters were calculated for pass band ripple of 0.1 dB, shown in Table 2. The characteristic impedance of the microstrip resonator (*Zo*) has a pronounced effect on Quality factor (*Q*) and thus on the FBW (fractional Bandwidth) of the filter. Each element in the filter represents the corresponding g-values which are normalized with respect to the characteristic impedance of the microstrip resonator (*Zo*).

The next step is to calculate the even and odd impedances of the characteristic line. The corresponding width and length values are calculated in Agilent' ADS software design and simulate for the required frequency.

TABLE 2. CHEBYSHEV FILTER PROTOTYPES (5TH ORDER)

| $g_0$ & $g_6$ | $g_1$ & $g_5$ | $g_2$ & $g_4$ | $g_3$ |
|---|---|---|---|
| 1 | 1.1468 | 1.3712 | 1.9750 |

## 4. SIMULATED RESULTS

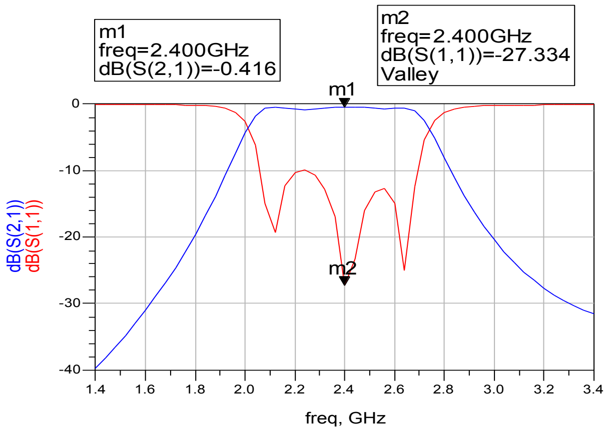


Fig.4 Simulated results (Reflection & Transmission coefficients) of BPF

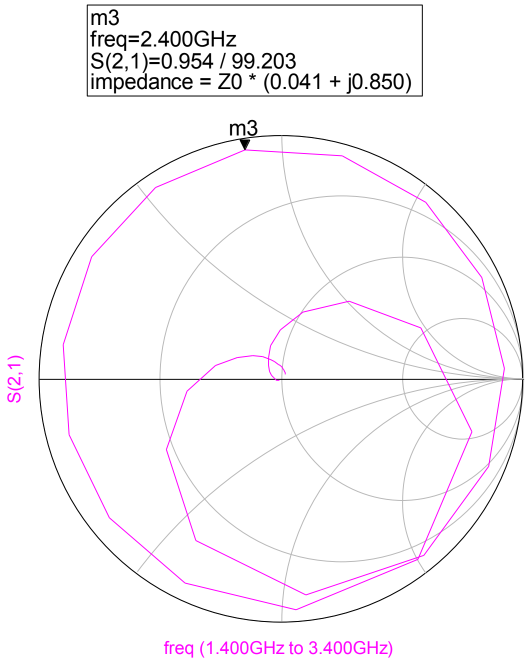


Fig.5 Simulated results (Reflection coefficient) of BPF in Smith chart

The Transmission and Reflection characteristics of the Hair pin Band pass filter at 2.4 GHz shown in fig.4. We got flat band width of desired 500MHz band width and good input return loss. This result ensures that the band pass characteristics are indeed valid for proposed bandwidth spectrum.

Fig.5 shows the Reflection coefficient of the Hair pin Band pass filter in Smith chart.

Fig.6 shows the Layout of the proposed 5th order Hair pin Band pass filter.

 

## 5. HAIR PIN LINE FILTER LAYOUT

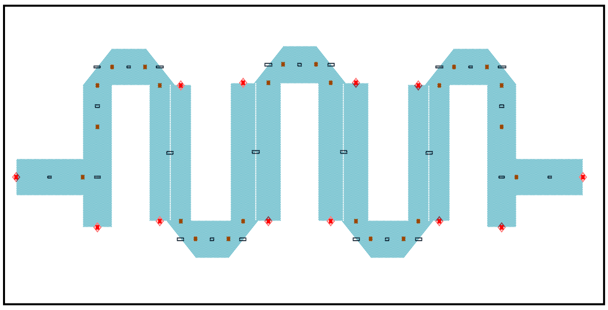

Fig.6. Layout for the 5th order Hair pin line BPF

## 6. CONCLUSION

This paper has presented the detailed design, analysis and simulation of fifth order Chebyshev Hairpin band-pass filter. The design procedure including Hair pin line structure and fundamentals also discussed. The objective to design, fabricate and measure the characteristics of a microstrip hairpin band-pass filter is achieved. . Insertion loss (IL) in pass band is less than 1 dB and Return loss (RL) is greater than 25dB with good out of band rejection. The filter can be useful for WiMAX unlicensed applications and other modem wireless communication system applications which operate within this frequency range.

## 7. REFERENCES


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