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Design of Band Pass Filters using Meander Line Structure for WIMAX Applications

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Abstract: A band Pass filter is a device or electronic circuitry that allows just certain frequencies to pass through while rejecting or recognising unwanted frequencies. This paper presents the design and implementation of a compact wide band-pass filter and dual-band pass filter using meander split ring open resonator and meander line structure. The most common application of band pass filters is in Radio Frequency (RF) and WiMAX applications. The micro-strip technology is adopted in all simulation and fabrication. The substrate used in the fabrication is a FR4 with dielectric constant 4.5 and thickness 1.5mm. The filter response has two transmission zeros located below and above the pass band to improve the filter selectivity due to asymmetrical locations of feeding lines. The study also suggests structural, material, and characteristic enhancement to achieve high gain, high return loss, and low insertion loss with a low ripple factor. The proposed filter has been designed, simulated, fabricated, and measured where both the measured and simulated results are in good agreement.

Keywords: Band pass filter, Meander line, WiMAX, Radio frequency.

Nomenclature–Computer Simulation Technology (CST)

I. INTRODUCTION

The passive Band Pass Filter (BPF) is an essential component in a mobile communications system and commonly used in receivers and transmitters [5]. Important design characteristics of BPFs include their response, frequency selectivity, transmission zero, and cost [5]. A popular low-cost BPF design is a micro-strip line for dual-band operation. In fact, dual-band BPFs are widely used for reception and transmission in mobile communications systems [5]. In general, a dual-band BPF composed of a BPF and a band-stop filter (BSF) connected to series and shunt components. However, the overall BPF size is large. Alternatively, a stepped impedance resonator (SIR) can be adopted in a dual-band BPF, which can then be adjusted to reject spurious bands. Nevertheless, Stepped Impedance Resonator (SIR) based dual-band BPFs are large which increases the insertion and return losses [5]. To miniaturize a device, a high-dielectric (ε_r) substrate can be used. In this article, a dual-band BPF is proposed using an SIR with a meander line. The meander line is integrated with a symmetric shape[5]. The most common application of band pass filters is in Radio Frequency (RF) applications with frequency ranges of 3 KHz to 300 GHz. Cell phones (GSM 900/1800), GPS (1.17645 GHz-1.57542 GHz), wireless Local Area Network (2.45GHz), Bluetooth (2.45GHz), ZigBee(868MHz-2.4GHz), TV, Radio Frequency Identification (RFID), and many other applications use RF. Wireless receivers and transmitters of RFID tags and readers are examples of band pass filter applications. The advances of telecommunication technology arising hand in hand with the market demands and governmental regulations push the invention and development of new applications in wireless communication[16].

These new applications offer certain features in telecommunication services that 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, and 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[16]. WiMAX (Worldwide interoperability Microwave Access) which is believed as a key application for solving many actual problems today is an example[16].

In realization of such a system like WiMAX we need a complete new transmitter and receiver. In designing the band pass filter, we are faced the questions, what is the maximal loss inside the pass region, and the minimal attenuation in the reject/stop regions, and how the filter characteristics must look like in transition regions.

In the process to fulfil these requirements there are several strategies taken in realization of the filters, for example, the choice of waveguide technology for the filter is preferred in respect to the minimal transmission loss (insertion loss). This strategy is still in satellite applications[16]. The effort to fabricate waveguide filters prevents its

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application in huge amounts. As alternative, micro-strip filter based on printed circuit board (PCB) offers the advantages easy and cheap in mass production with the disadvantages higher insertion losses and wider transition region. In this work we would like to give a way to conceive and design band pass filter for the WiMAX application at the frequency 2.2 GHz with micro-strip structures as opposed to which designed filter for wireless local area network 5.75 GHz, and which used the composite resonators and stepped impedance resonators for filter realization [16].

Defected Ground Structures (DGS) is etched periodic or non-periodic configuration that produces defect in ground plane. This defect causes the change in the characteristics of the transmission lines such as line capacitance and inductance. This gives rise to effective capacitance and inductance[17]. Complementary split ring resonators (CSRR) are meta-materials that can be inserted horizontally between the patch and the ground. CSRR consists of multiple concentric rings etched from a conducting disk and can offer a negative permittivity [18]. These structures can be made to resonate at lower frequencies by increasing its effective inductance and capacitance.

Based on the above study, this work proposed

- To design band pass filter with Stepped Impedance Resonator (SIR) meander line structure to improve the selectivity
- Defected Ground Structure design for II nd order Butterworth wide band pass to obtain a maximal flat pass band

II. SYMMETRIC DUAL-BAND PASS FILTER:

Design method and analysis:

The Figure1 depicts the dual band pass filter design using the SIR (Stepped Impedance Resonator) meander line with symmetric structure. The SIR structure is expressed as open stubs with low and high impedances. The meander shaped structure is designed and coupled with stepped impedance resonator. Here two sets of open loops are used to form the meander structure, in order to achieve a good response in the band pass filter. The substrate used here is FR-4(lossy). The dielectric constant of the substrate is 4.4. The thickness of the substrate is 0.8mm. The overall substrate size for the design is (30 x 51.5) mm^2. The plane of the substrate is first divided into two equal halves. The first half consists of a meander coupled with Stepped Impedance Resonator (SIR). The SIR acts as a feed for port1. The second half consists of the mirror image of the same as shown. These two structures are connected through another meander structure. This design is a series connected and cascaded. The bottom layer consists of the ground plane. The thickness of the ground plane is **'T'.** The above described structure is simulated using CST Studio Suite software which is shown in Figure 1. The Figure 2 shows the front view of the proposed design.

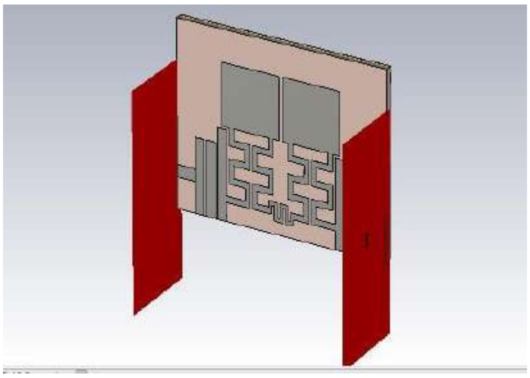

Figure 1: Dual band pass filter designed using CST

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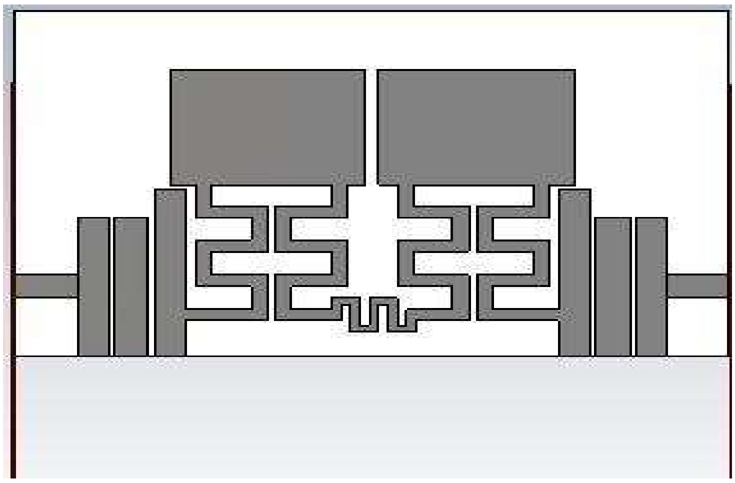

Figure 2: Front view of the filter design

Design parameters:

The Figure 3 and Table 1 explain about the design parameters used for Dual Band Pass filter.

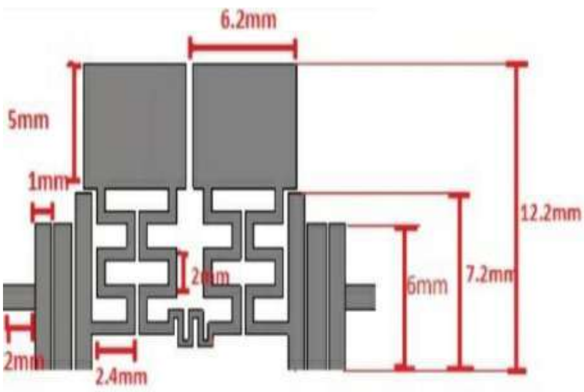

Figure 3: Design Parameters of the Dual Band Pass filter

Table 1: Physical dimension of the filter substrate

Parameters	Values(mm)
L	23
W	15
h	0.8
T	0.01

Where L is the Length in mm, W is the width in mm, H is the height, T is the thickness of strip lines in mm.

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III. WIDE-BAND PASS FILTER

Design method and analysis:

This micro strip band pass filter (BPF) is made up of two open-loop resonators that are arranged next to each other. Both open loop resonators are shaped in a way that makes them compact. The advantages of using open loop meandering resonators are its small size, low loss, high selectivity, and light weight, making them ideal for low-power wireless communication systems. At a design frequency, each meandering resonator's overall length is a half wavelength. A very small gap s separates the two resonators. The parameter s is crucial in establishing the proposed filter's bandwidth. Once the filter is adjusted, the s will be fixed. The open ends of resonators are oriented face to face to obtain the electric coupling type, which has a significant impact if one wishes to control bandwidth with greater flexibility .The widths of the strip conductors of the main resonators are the same, optimised with an impedance characteristic of about Z=90ohm, and 50ohm tapped-feed lines are attached directly to the resonators where the two distances from the open ends to locations of feed lines are different, acting as short circuits when the distance between the feed line and the open end becomes a quarter wavelength. For small microstrip transmission lines, this process produces two transmission zeros before and after the pass band.

W/h<1

$$W=\frac{v_0}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$\varepsilon_{eff}=\frac{1+\varepsilon r}{2}+\frac{1-\varepsilon r}{2}\left\{\frac{1}{\sqrt{12\frac{h}{W}+1}}+0.04\left(1-\frac{W}{h}\right)^2\right\} \qquad (2)$$

$$Z_{narrow}=\frac{\eta}{\pi\sqrt{\varepsilon eff}}\ln\left(0.25\frac{W}{h}+8\frac{h}{W}\right) \qquad (3)$$

$$\lambda_g=\frac{300}{fc(GHz)\sqrt{\varepsilon eff}}\ \text{mm} \qquad (4)$$

$$l=\frac{\lambda g}{2} \qquad (5)$$

Where ε_{eff} = Effective permittivity, Z_{narrow} = Characteristic Impedance, λg = guided wavelength , ε_r= Relative permittivity, fc = center frequency.

The external quality factor and the coupling coefficient are the two most essential parameters that determine a filter's overall performance. These factors can be controlled in one way or another by all of the filter's dimensions. The parameter g, for example, can control both the external quality factor and the coupling coefficient by representing the distance between the locations of the feeding position from the centre. The smaller g, the closer the tapped feed line is to the resonator's virtual ground (i.e., the voltage at the centre open end resonator is zero), the higher the external quality factor or the weaker the coupling. The transmission zeros positioned below and above the filters pass band are also caused by asymmetric placements of tapped feed lines at the open ends of the loop resonators.

Equivalent circuit of wide band pass filter

Figure 4 depicts the proposed BPF's equivalent circuit diagram. A single open loop resonator is represented by each resonant tank (R, L2, and C2). Because we have two microstrip open loop resonators, the circuit model uses two resonant tanks. The capacitance influence of the electrical coupling between the two resonators is represented by the capacitor C1 between the resonant tanks. The inductors (L1, L2) represent the inductance effects of the feeding lines as well as the feed line-to-resonator junction.

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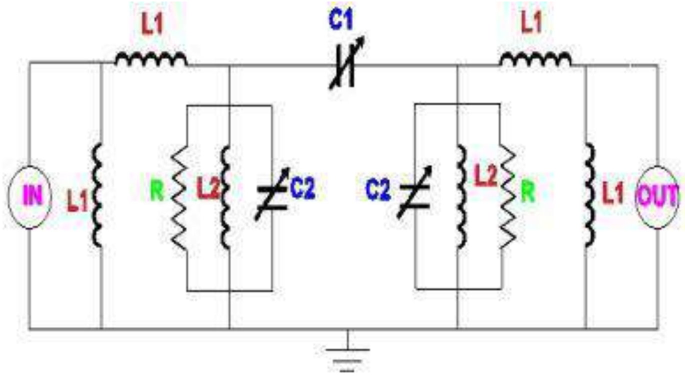

Figure 4: Equivalent circuit of proposed wide band pass filter design

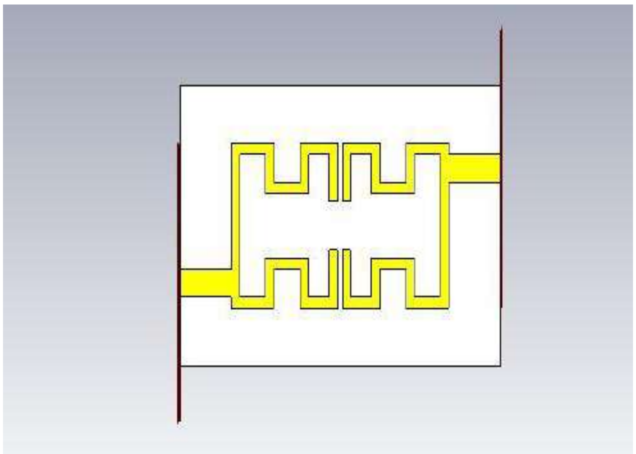

Figure 5:Front view of proposed filter

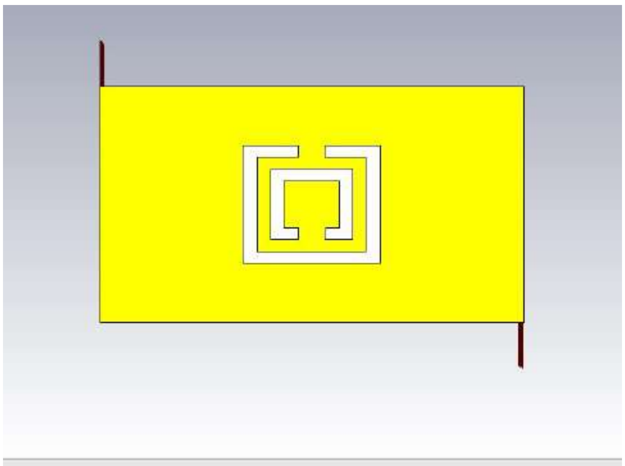

Figure 6: Back view of proposed filter

Design parameters of Wide Band Pass Filter

The whole size of the proposed filter is (31×20 mm^2). It is designed and built on a FR4 substrate having a thickness (h) of 1.5mm, a relative dielectric constant r of 4.6, and a tangent loss of 0.01. The thickness of conductor t laid over the substrate is 0.035mm. All other physical dimensions related to the filter design are introduced in Table 2&3.

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Table 2: Physical Dimensions of the filter

Parameter	Value(mm)
L1	8.98
L2	4.1
L3	3.36
L4	2.8
L5	2.5
L6	5
S	0.5
G	4.02
W1	2

Where L1 is Outside Loop length in mm, L2 inside Loop length in mm, G open loop gap in mm andw1 is width of the outer loop in mm

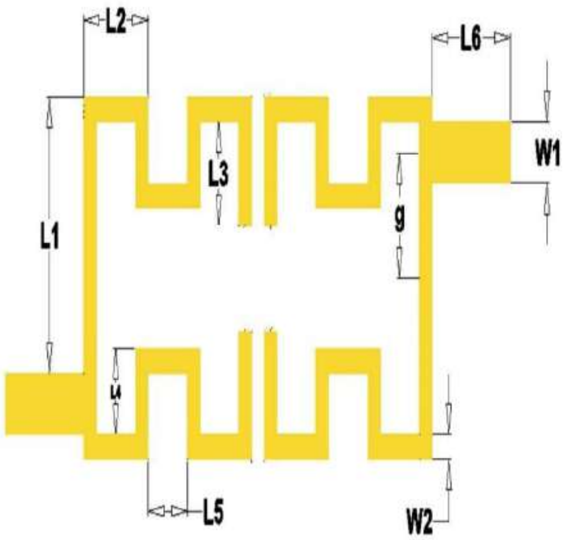

Figure 7: Design Dimensions of front view

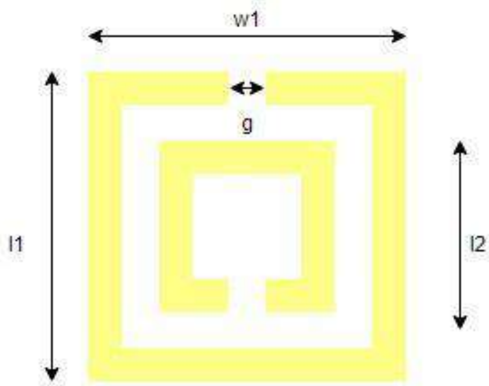

Figure 8: Design Dimensions of CSRR

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Table 3: Physical Dimension of the back view (CSRR Structure) of filter

Parameter	Value(mm)
L1	5
L2	3
G	1
w1	5

L is the length of the filter in mm, S is the length of space between two meander line structures in mm, G is the distance between the locations of feeding position from the centre of plane in mm, and W1 represents width of the feed lines.

IV. SIMULATION RESULTS

A. Simulation Result of dual band pass filter

The figure 9 illustrates the simulation result of the dual band pass filter. The dual frequencies are at 3.4GHz and 3.7GHz. The insertion loss and return loss obtained for this structure is found to be -3.72 dB and -21.95dB respectively. The symmetric stepped impedance resonator with meander line structure is used to control the spurious response and insertion loss of filters by changing the impedance/admittance ratio of the stepped impedances and also produces high selectivity, wide stop band characteristics.

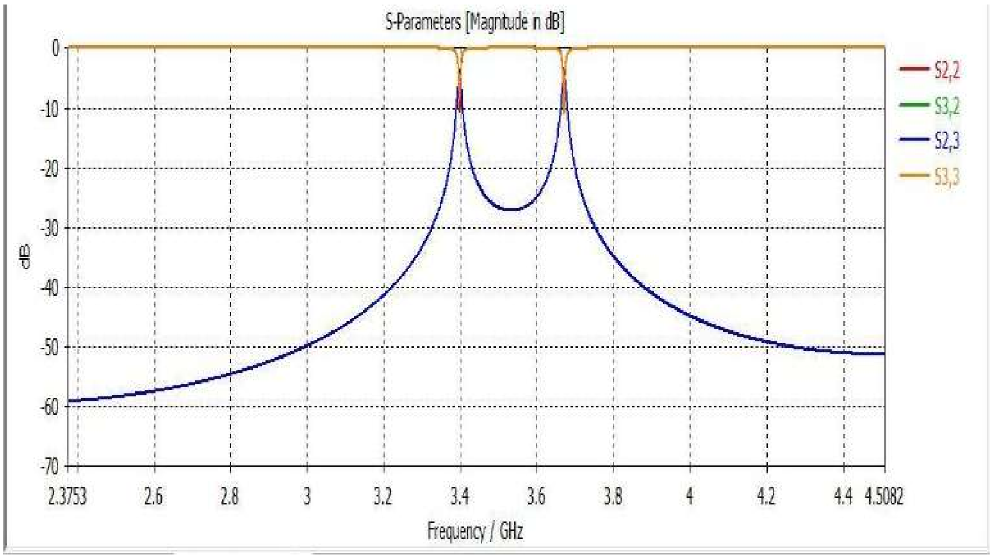

Figure 9: Simulation result of dual band pass filter

B. Simulation Result of wide band pass filter

The band pass filter has a bandwidth of 300MHz and a centre frequency of 2.2GHz.The pass band's insertion loss (S21) is -2.4dB, whereas the return loss (S11) is -14dB. Throughout the whole response, the filter exhibits an out-of-pass band rejection of more than 17dB. The results show that at 1.85GHz and 2.72GHz, there are two transmission zeroes, one on each side of the pass band, which helps to increase out-of-band rejection and filter selectivity. The two transmission zeroes can be formed by the positions of both tapped feed lines, as previously stated. So far, all of the outcomes have been stagnant.

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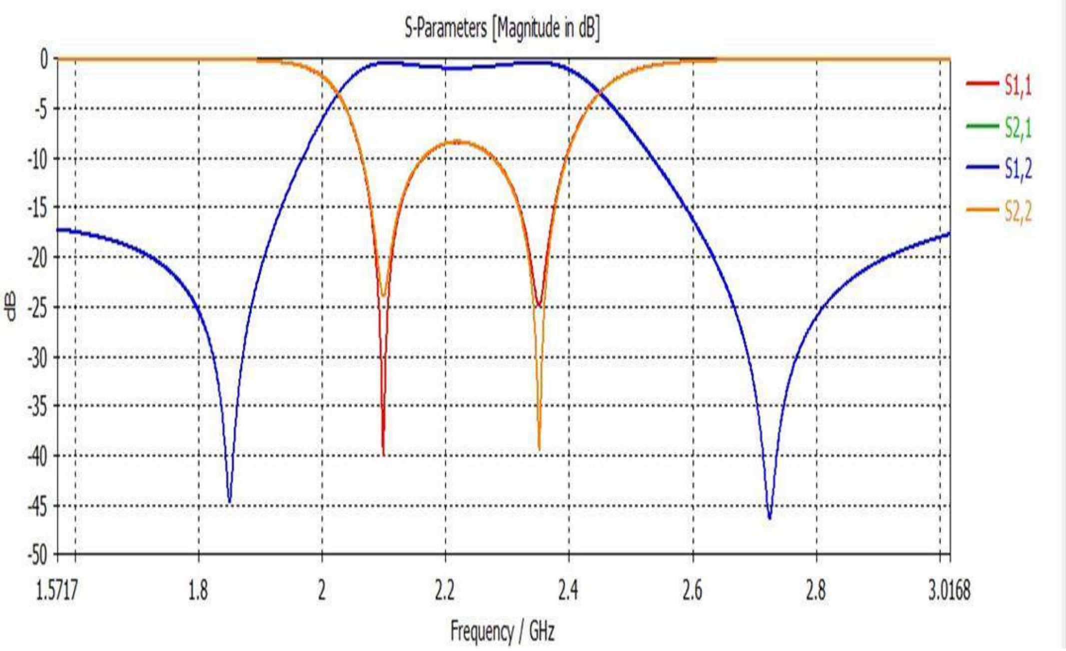

Figure 10: Simulation result of wide band pass filter

Table 4: Proposed filter parameter

S.NO	MEASURED PARAMETERS	DUAL BAND PASS	WIDE BAND PASS
1	INSERTION LOSS	-3.72dB	-2.4dB
2	RETURN LOSS	-21.95dB	-14dB
3	CENTER FREQUENCY	3.4 GHz, 3.7GHz	2.2GHz

The CSRR creates a sharp rejection stop band and has a negative effective permittivity at resonance. Finally, if we employ a bunch of filters mentioned in the previous part that work at different frequencies, the design with dynamic functions gives a substantial reduction in size. The figure 10 represents the simulated outcome of the wide band pass filter design using meander line structure and the measured parameters are tabulated in Table 4.

V. CONCLUSION

At last, we have designed and simulated two compact band pass filters applicable in WiMAX technologies with perks of low insertion and return losses. This work proposed a dual BPF with SIR has high degree of resonant frequency. The proposed dual band pass filter achieves Insertion Loss of -3.72 dB, Return loss of -21.95 dB, Dual pass band frequency 3.4GHz and 3.7GHz. The wide band pass filter achieve Insertion Loss of -2.4 dB, Return loss of -14 dB, Pass band frequency 2.2 GHz and a bandwidth of 300MHz. Thus the proposed filter is designed with low loss, flat passband in wide band pass filter and high selectivity in dual band pass filter. Eventually this filter can be utilized for WiMax applications. For Future scope this work can be extend this work by upgrading it to reconfigurable filter.

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