# A Hairpin Bandpass Filter for 5GHz Unlicensed WiMAX

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*Abstract*— **This paper presents an improved design of Chebyshev three poles microstrip hairpin bandpass filter for unlicensed WiMAX applications. The filter is designed to operate within the 10% operating bandwidth with center frequency of 5.78 GHz. The specified passband insertion loss must not exceed 3dB while the passband return loss to be at least 10dB. The filter was designed using Genesys software and implemented on Roger 5870 substrate. The simulated results using Genesys were then compared with the previous work done by [1] to evaluate the overall performance. Based on the experimental analysis, it was observed that the results from Genesys show good results compared to [1].**

***Keywords- Hairpin bandpass filter, Unlicensed WiMAX***

## I. INTRODUCTION

Bandpass filter was investigated and exploited extensively as a key circuit-block in modern communication systems. As technologies advances, more stringent requirements for filters are required. In order to fulfill these requirements, microwave bandpass filter with a compact size, high quality in performance and low cost is required. In many applications, especially including satellite and mobile communications, keeping filter structures to a minimum size and weight is very important [2].

One of the most popular microstrip filter configurations used in the lower microwave frequencies is the hairpin resonator filter. In term of manufacturing, it is considered easy to manufacture a hairpin filter because it has open-circuited ends that require no grounding [3]. A hairpin filter is one of a modified structure that comes from parallel coupled lines [4]. The main idea is to obtain a better couple affect by folding the resonators from parallel-coupled transmission line, half wavelength resonator was modified and adjusted into a "U" shape and was recognized as hairpin. The structure is widely utilized in designing a microwave resonator due to the ability of providing a flexible coupling variation and producing a compact size in a package of simple design procedures [5].

WiMAX, the acronym that stands for Worldwide Interoperability for Microwave Access, is a certification mark for products that pass conformity and interoperability tests for the IEEE 802.16 standards and is officially known as wireless metropolitan area network (WMAN).

The spectra covered by WiMAX are available and allocated in various licensed and unlicensed bands. The licensed bands are those that are currently “owned” by carriers that have paid for the use of the bands. Unlicensed bands are freely available for any experimental or enterprise application.

The unlicensed national information infrastructure (U-NII) 5GHz band covers the spectrum 5725-5850 MHz with 125 MHz bandwidth. This is an industrial scientific and medical (UNII/ISM) band. Most WiMAX activities are in the upper U-NII/ISM band because there are fewer competing services and less interference there [6].

Previous work done by [1] proposed hairpin bandpass filter using CST as simulation tool. However, the results showed that the bandwidth is 4.49%. Based on the improved design, the percentage of the bandwidth is reduced to 3.26%. On the other hand, results obtained from Genesys able to reduce the size of the filter and also improved the responses of return loss and insertion loss.

## II. METHODOLOGY

The first step in designing a filter is to determine the design specifications of the filter such as type of response, the operating frequency range, passband ripple, and the order of the filter, *n* required. Table 1 shows the specifications of a band-pass filter design.

TABLE 1: BANDPASS FILTER DESIGN SPECIFICATIONS

| | |
|---|---|
| Centre frequency, | 5.78 GHz |
| Upper cut-off frequency | 5.85 GHz |
| Lower cut-off frequency | 5.725 GHz |
| Bandwidth | 0.125 GHz |
| Pass-band ripple | 0.1 dB |
| Filter order, *n* | $3^{rd}$ order |

Based on the design specification, $3^{rd}$ order filter was chosen as the design of the proposed hairpin structure. In [7], order of the filters can be determined as explained.

By using (1) and (2), value of components can be calculated. Where $g_n$ was indicated the number of elements, while n was an integer numbers 1, 2, 3, 4…, $n$+1[8].

$$g_1 = \frac{2}{\gamma} sin\left(\frac{\pi}{2n}\right) \tag{1}$$

$$g_i = \frac{1}{g_{i+1}} \frac{\left(4\sin\left[\frac{(2i-1)\pi}{2n}\right]\sin\left[\frac{(2i-3)\pi}{2n}\right]\right)}{\gamma^2 + \sin^2\left[\frac{(i-1)\pi}{n}\right]} \tag{2}$$

The lowpass prototype elements value for 3rd order filter was represented as shown in Table 2.

TABLE 2: LOW-PASS PROTOTYPE ELEMENTS VALUES

| Order | $g_0$ | $g_1$ | $g_2$ | $g_3$ | $g_4$ |
|---|---|---|---|---|---|
| 3rd | 1 | 0.6291 | 0.9702 | 0.6291 | 1 |

The values obtained were then converted to bandpass filter prototype at the specific cut-off frequency.

The circuit was designed on Roger 5870 substrate with dielectric constant of 2.33, loss tangent of 0.0012 and substrate height of 0.508 mm. Table 3 indicates the detail properties of the substrate.

TABLE 3: ROGERS DUROID 5870'S PROPERTIES

| | |
|---|---|
| Dielectric Constant | 2.33 |
| Loss Tangent | 0.0012 |
| Resistivity | 1 |
| Metal Thickness | 0.035 mm |
| Metal Roughness | 2.4e-3 mm |
| Substrate Height | 0.508 mm |

## III. RESULT AND DISCUSSION

Nowadays, there are many tools were used to help create effective circuits and systems. This filter is designed using Genesys and being optimized using Electronic Design Automation (EDA). Layout data from Genesys were then transferred directly from Genesys into the Autocad 2007.The resulting layout and the dimension of the filter were shown in Figure 1. Based on the dimension, this filter is more compact in size than [1].

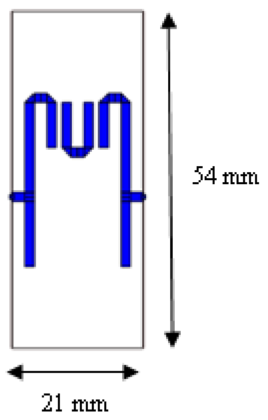


Figure 1: Layout

The specification was set up to obtain a minimum 10 dB return loss and the insertion loss must not exceed 3 dB. Based on the simulated results, it is observed that the response of the filter is better in term of the return loss and also the insertion loss.

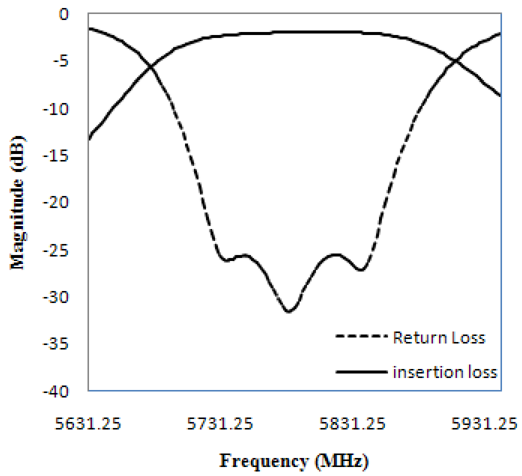


Figure 2: Responses of filter of three elements using Genesys

The comparison between simulated and measured results was shown in Table 4. There were slightly different between the measured and simulated values.

TABLE 4: COMPARISON BETWEEN DESIGN, SIMULATED AND MEASURED RESULT USING GENESYS

| Parameter | Design specifications | Simulated results | Measured results |
|---|---|---|---|
| Centre frequency, (GHz) | 5.78 | 5.78 | 5.775 |
| Upper cut-off frequency, (GHz) | 5.850 | 5.909 | 5.925 |
| Lower cut-off frequency, (GHz) | 5.725 | 5.678 | 5.738 |
| Insertion loss, (dB) | Not exceed 3 | 1.978 | 3.275 |
| Return loss, (dB) | More than 10 | 25.645 | 22.693 |

The measured passband response is slightly narrower than Genesys. Passband flatness is very close to that modeled by Genesys. Return loss response is less symmetrical across the passband than the Genesys simulation, but it remains at 20 dB or better.

TABLE 5: COMPARISON BETWEEN SIMULATED RESULT USING GENESYS AND CST [1]

| Parameter | Design specifications | Genesys | CST [1] |
|---|---|---|---|
| Centre frequency, (GHz) | 5.78 | 5.78 | 5.6397 |
| Bandwidth, (GHz) | 0.125 | 0.231 | 0.7353 |
| Insertion loss, (dB) | Not exceed 3 | 1.978 | 0 |
| Return loss, (dB) | More than 10 | 25.645 | 45.91 |

During the design process, it is observed that the simulated values using Genesys is slightly difference compared using CST [1] as showed in Table 5. The response for insertion loss is a bit lower. In term of return loss, it only able to swing up to 25.645 dB compared using CST [1]. This is due to this software use an algorithm which adjusts the width and spacing of a shortened coupling section cascaded with two adjacent lines to match the characteristics of the original quarter-wave section [9]. However, the bandwidth and centre frequency were better compared using CST [1].

TABLE 6: COMPARISON BETWEEN MEASURED RESULT USING GENESYS AND CST [1]

| Parameter | Design specifications | Genesys | CST [1] |
|---|---|---|---|
| Centre frequency, (GHz) | 5.78 | 5.775 | 5.6575 |
| Bandwidth, (GHz) | 0.125 | 0.187 | 0.252 |
| Insertion loss, (dB) | Not exceed 3 | 3.275 | 4.432 |
| Return loss, (dB) | More than 10 | 22.693 | 23.908 |

Table 6 indicates comparison between measured results using Genesys and CST [1]. Based on the results, the bandwidth shows an improvement compared to simulated results. The measurement for return loss is 22.693 dB, meeting the specification requirement. However, the insertion loss is -3.275 dB which exceed the specification requirement by 0.275 dB. The discrepancy between the measured and simulated value may be explained by the difference in the dielectric constant of the substrate, variations in the film thickness, over-etching of the pattern, or some simulation error [10].

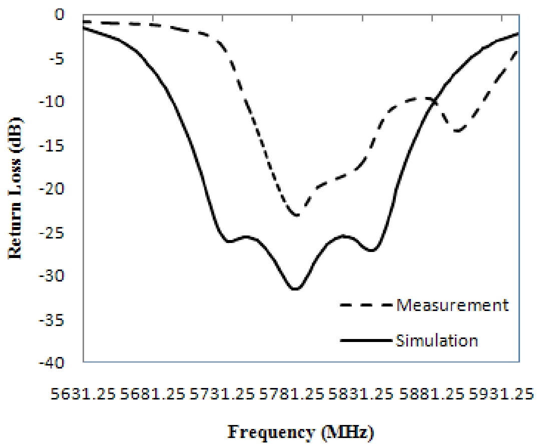


Figure 3: Comparison of return loss using Genesys

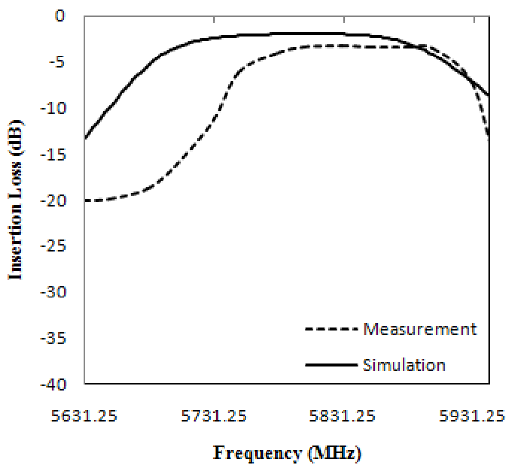


Figure 4: Comparison of insertion loss using Genesys

The responses of insertion loss and return loss for both simulated and measured results using Genesys as simulation tool are illustrated in Fig.3 and Fig. 4.

## IV. CONCLUSION

A detail design procedures and development of hairpin band-pass filter for 5GHz Unlicensed WiMAX applications were presented in this paper. The objective was achieved as the filter has been successfully designed at the desired specifications. This filter also can be used for other modern wireless communications which operate within this frequency range.

## V. RECOMMENDATIONS

For future research and work, it's recommended that several improvements or alternatives to be taken for better results. For example, the filter can be designed using different tools such as *CST* or *ADS.* Besides that, by using different type of microstrip with different substrate properties also can affect the results. It is also recommended that the bandwidth of the designed filter to be widen as it surely affected the response of the filter.

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