Compact Microstrip Bandpass Filter

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Abstract
In microwave communication systems, the bandpass filter is an essential component, which is usually used in both transmitter and receiver. Parallel-coupled microstrip bandpass filter is one of the most popular filters in communication systems. However, this arrangement of parallel-coupled microstrip bandpass filter gives disadvantage in terms of size where the arrangement of this topology results in an electrically large in size of the filter. Therefore, this research focuses on designing a compact microstrip bandpass filter by using Sonnet Lite software at centre frequency of 3.2GHz with the bandwidth of 400MHz. Besides, the design of the compact microstrip bandpass filter has achieved the objective when it successfully reduced the overall size to about 70% as compared to the size of conventional filter, which is parallel-coupled microstrip bandpass filter. Both filters give the same performance based on their frequency responses. The design also has successfully fabricated and measured by using network analyzer software to verify the simulated results obtained earlier. Although there is slightly mismatch between the simulated and measured frequency response due to some fabrication errors and variation of material properties, the design of filter is not affected since the results obtained from the designing process by using Sonnet Lite software are still valid and can be used in future improvement of the design.

1.0 Introduction

Research Overview

Filters play important roles in many RF/microwave applications. They are used to separate or combine different frequencies. The electromagnetic spectrum is limited and has to be shared; filters are used to select or confine the RF/microwave signals within assigned spectral limits. Emerging applications such as wireless communications continue to challenge RF/microwave filters with ever more stringent requirement which are higher performance, smaller size, lighter weight, and lower cost. Depending on the requirements and specifications, RF/microwave filters may be designed as lumped element or distributed element circuits; they may be realized in various transmission line structures, such as waveguide, coaxial line, and microstrip.

A filter is an AC circuit that separates some frequencies from others within mixed-frequency signals [1]. A common need for filter circuits is in high-performance stereo systems, where certain ranges of audio frequencies need to be amplified or suppressed for best sound quality and power efficiency.

The design of filters' circuit may be very simple, consisting of a single capacitor or inductor whose addition to given network leads to improved performance. They may also be fairly sophisticated, consisting of many resistors, capacitors, inductors and op amps in order to obtain the precise response curve required for a given application. Filters are used in modern

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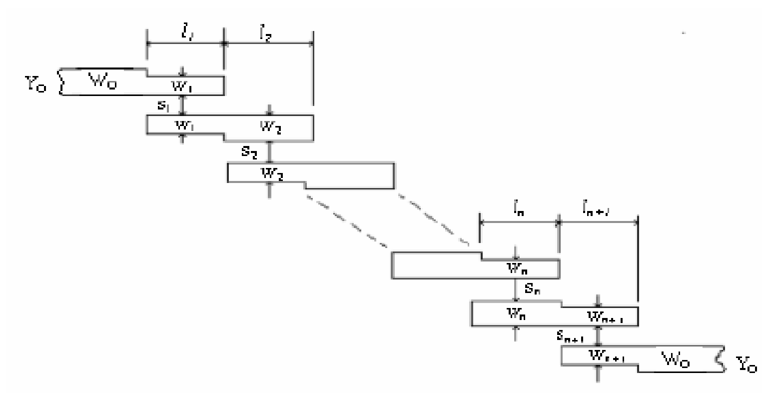
electronics to obtain dc voltages in power supplies, eliminate noise in communication channels, separate radio and television channels from the multiplexed signal provided by antennas and boost the bass signal in a car stereo as for example.

A low-pass filter passes frequencies below a cutoff frequency, while significantly damping frequencies above the cutoff. A high-pass filter, on the other hand, does just the opposite. The chief figure of merit of a filter is the sharpness of the cutoff, or the steepness of the curve in the vicinity of the corner frequency.

Combining a low-pass and a high-pass filter can lead to a band pass filter. In this type of filter, the region between the two corner frequencies is referred to as the passband; the region outside the passband is referred to as the stopband. By swapping the cutoff frequencies of the two filters, a band stop filter can be created, which allows both high and low frequencies to pass but attenuates any signal with a frequency between the two corner frequencies.

Parallel-coupled microstrip bandpass filter is one of the most popular bandpass filter and can be applied in many application of microwave communication systems. General layout of this bandpass filter is shown in figure 1.



$Y_0=1/Z_0$

Figure 1.1: General structure of parallel-coupled microstrip bandpass filter [1]

This paper will concentrate on the design of a compact size microstrip bandpass filter. This filter will be developed and then will be compared with existing structures. Two existing filters were designed which are the conventional parallel coupled microstrip bandpass filter, and the other one is the existing compact microstrip bandpass filter with multispurious suppression. The selected frequency used for the design is based on the current applications in communication systems. The design process is done by using the Sonnet Lite software and then followed by the fabrication of the designed filter. The analysis of the designed filter will be presented and discussed briefly in further sections.

Problem Statement

In microwave communication systems, the bandpass filter is an essential component, which is usually used in both transmitter and receiver. Parallel-coupled microstrip bandpass filter is one of the most popular filters in communication systems due to its advantages of ease in manufacture, ease of synthesis method, low cost and high practicality.

The parallel-coupled microstrip bandpass filter structure is of open circuited coupled microstrip lines. The components are positioned so that adjacent resonators are parallel to each other along half of their length. This parallel arrangement gives relatively large coupling for a given spacing between resonators, and making this filter structure particularly convenient for constructing filters having a wider bandwidth as compared to other type of bandpass filter.

However, this arrangement of parallel-coupled microstrip bandpass filter gives disadvantage in terms of size. The arrangement of this topology results in an electrically large in size of the filter. Thus, this problem of size limit the application for this type of filter in certain communication systems and it became less favourable as compared to other filters.

A compact, low insertion loss and wide rejection band bandpass filter has come to be one of the recent trend in global system for mobile communication (GSM), wireless code-division multiple-access (WCDMA), and wireless local area network (WLANs).

It is clear that there is a need to design a compact filter to fulfil the recent need in microwave communication system. Microstrip line is a good candidate for filter design due to its advantages of low cost, compact size, light weight, planar structure and easy integration with other components in single board. Thus, a compact microstrip bandpass filter is proposed to be designed.

Objectives

The objectives of this research are:

i. To design a compact microstrip bandpass filter for a selected frequency using Sonnet Lite software
ii. To analyze the performance of the designed filter in terms of its S parameters, physical size of the filter and bandwidth.
iii. To compare the designed compact microstrip bandpass filter with the conventional bandpass filter.
iv. To fabricate and measure the frequency response of the designed filter for the frequency used

2.0 Literature review

At the starting point of searching the types of filter to be designed, some method has been used to find the information that suite the requirement in designing the compact microstrip bandpass filter. To help in more understanding and exposing to various types of filter design, the articles found in the IEEE website and some other websites are really useful.

The article “Compact Microstrip bandpass Filter with Multispurious Suppression” written by H.W. Wu, S. K. Liu, M. H. Weng and C. H Hung (2010)[3]. This article presented a compact microstrip bandpass filter with multispurious suppressiom. The filter consists of two coupled half-wavelength stepped impedance resonators (SIRs) and tapped input/output (I/O) lines. n average rejection level better than 25dB.

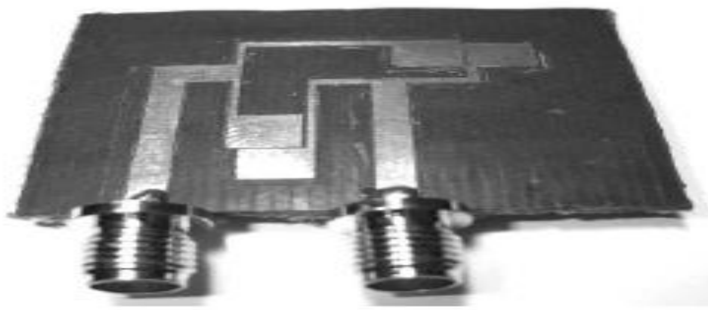


Figure 3.1: Fabricated filter [3]

Figure 3.1 shows the fabricated filter. The filter consists of two bended half-wavelength SIRs and tapped I/O lines. Size of the filter by adopting bended SIRs can be easily miniaturized. In addition, the arrangement of the tapped I/O lines can be further miniaturized the circuit size.

In the other article, entitled “Compact Third-Order Microstrip Bandpass Filter Using Hybrid Resonators” written by F. Xiao and M.Norgren (2011) [4]. In this paper, a novel microwave bandpass filter structure is proposed

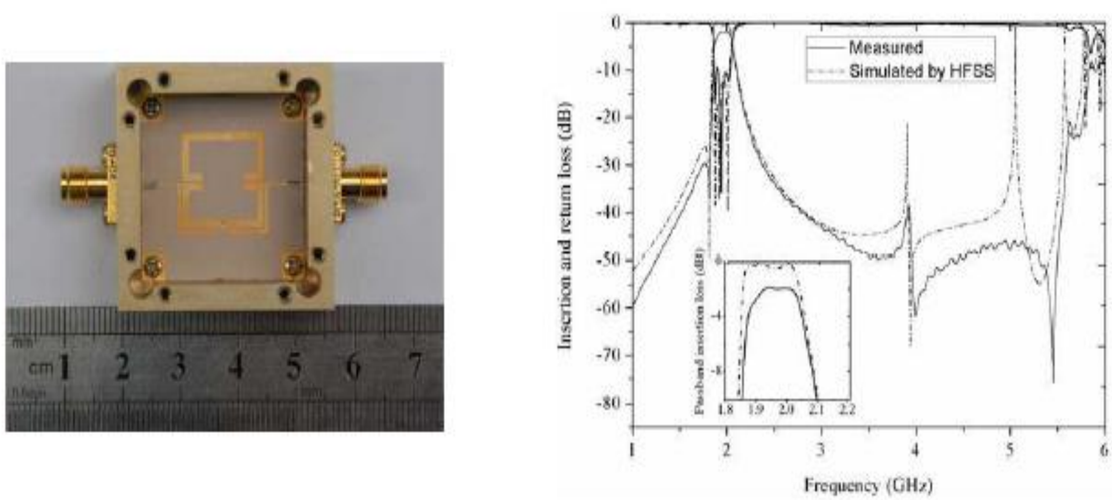


Figure 3.2: Fabricated filter and the simulated and measured frequency response of the filter [4]

3.0 Methodology

Flowchart of Design Procedures

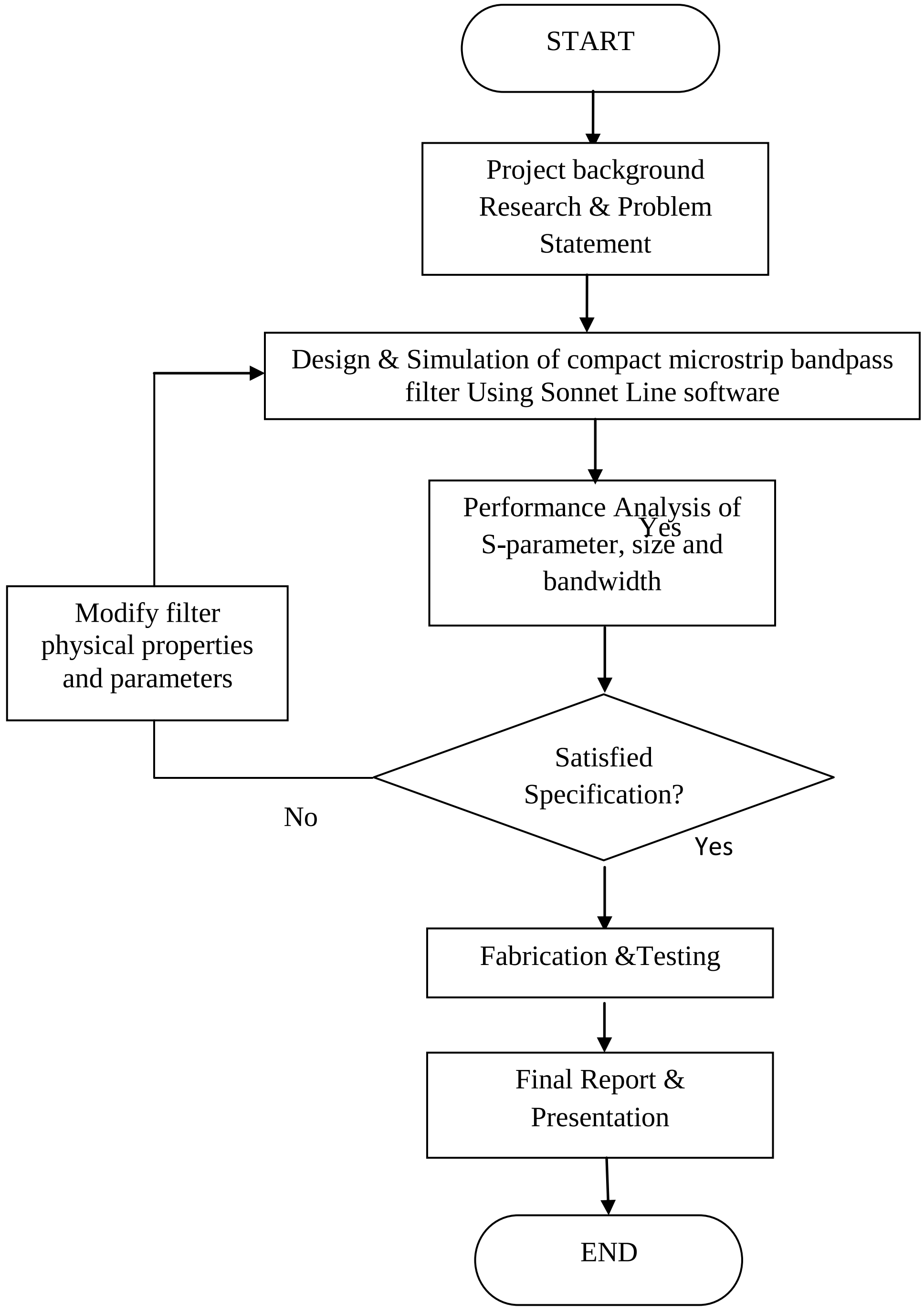


Figure 3.1: Flowchart of the design procedure

4.0 Data analysis and results

Results and Analysis

The design of a compact microstrip bandpass filter that consist of two bended half-wavelength SIRs has been done by using Sonnet Lite and has been simulated to see the response. The results of the design are as the following:

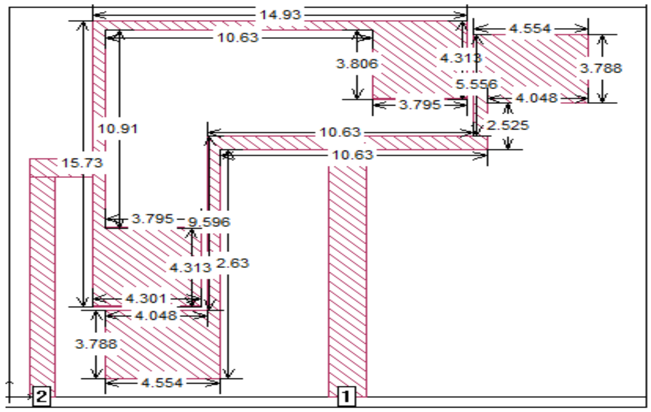


Figure 4.1: Design of compact microstrip bandpass filter in Sonnet Lite

Based on the design shown in figure 5.4, the details of dimensions of the filter are as follows:

W1 = 4.544mm, W2= 0.75mm, W3= 4.313mm, W4= 0.506mm
L1= 3.788mm, L2= 2.525mm, L3= 10.63mm, L4= 12.63mm, L5= 14.93mm, L6= 10.91mm, L7= 4.313mmS1= S4 = 0.25mm, S2= 2.02mm

The design is then analyzed to obtain the response of the filter. The response of the designed compact microstrip bandpass filter is shown in figure 5.3.

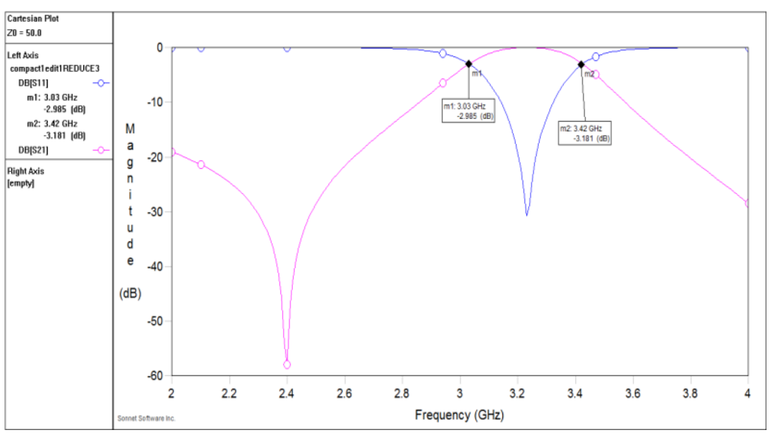
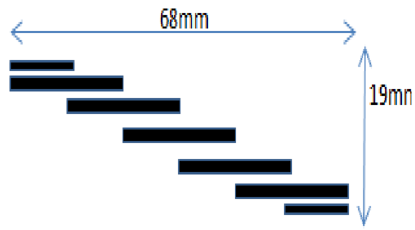
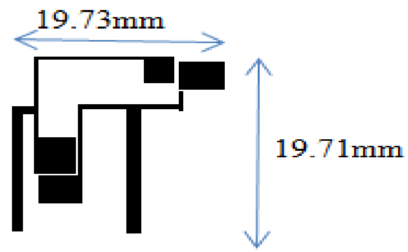
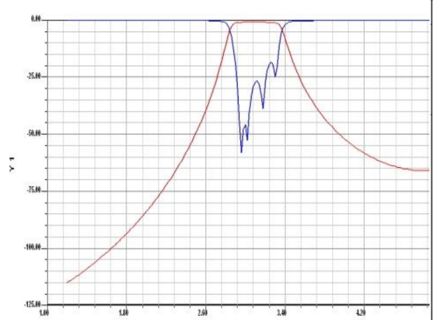
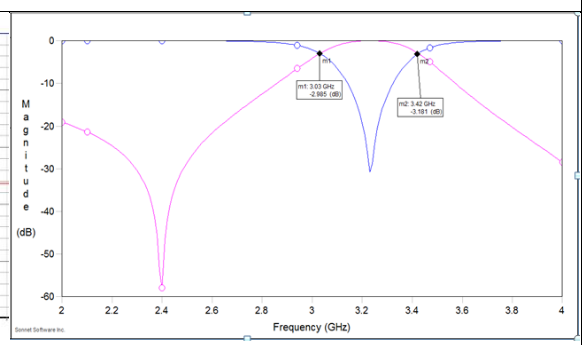
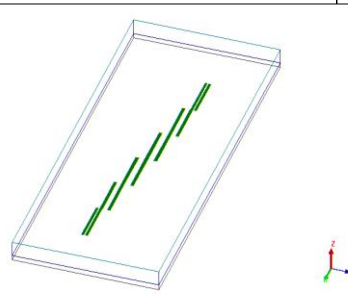
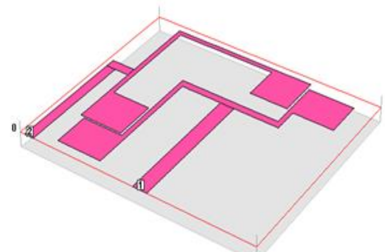


Figure 4.2: The filter frequency response

Figure 5.5 shows the response of the simulated filter which consist of the insertion loss, S21 and return loss, S11. The best tuning can be verified by analyzing response at -3dB. The centre frequency and the bandwidth of this filter can be measured as the following:

Center Frequency, $f_o = (f_H + f_L) / 2 = (3.4GHz + 3GHz) / 2 = 3.2GHz$
Bandwidth, $BW = f_H - f_L = 3.4GHz - 3GHz = 400MHz$

<table>
<tr><th>Specification</th><th>Conventional Filter</th><th>Compact Filter</th></tr>
<tr><td>Design layout</td><td>
</td><td>
</td></tr>
<tr><td>Overall Physical Size</td><td>68 mm x 19mm = 1292mm²</td><td>19.73mm x 19.71mm = 388.88mm²</td></tr>
<tr><td>Response</td><td></td><td>
</td></tr>
<tr><td>Bandwidth</td><td>400MHz</td><td>400MHz</td></tr>
<tr><td>3D View</td><td></td><td></td></tr>
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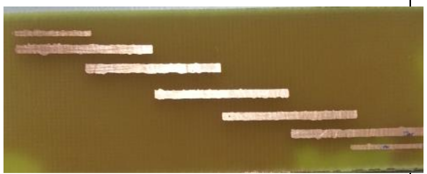
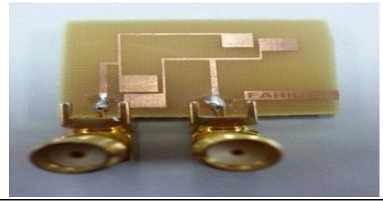
Fabricated design		

So, this filter is designed for the applications in communication engineering for centre frequency of 3.2GHz and providing a good bandwidth available which is 400MHz from 3GHz to 3.4GHz.

As observed in the same figure, the insertion loss (S21) is 0dB at the centre frequency of 3.2GHz. This implies that the filter allow maximum transmission within the passband. The return loss (S11) within the passband is very low which is about -30dB. This implies that the reflection within the passband is very low or minimum.

Comparison between the Compact Filter and Conventional Filter

The summary of the comparison between the conventional filter and the compact filter is presented in the following table:

Fabrication of the Design

In order to provide verification on the simulated frequency response, the designed compact microstrip bandpass filter is fabricated on FR-4 substrate with relative dielectric constant εr = 4.4 and thickness h = 1.27mm. The fabrication process has been discussed earlier in Chapter 4. The photograph of the fabricated filter is shown in figure 5.12.

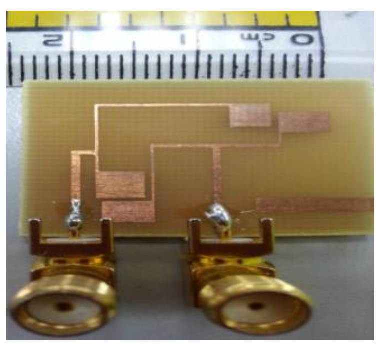


Figure 4.3: Fabricated structure of the compact microstrip bandpass filter

The fabricated compact microstrip bandpass filter size is based on the one that has been designed in Sonnet lite software. The performance of the filter is then measured by using network analyzer. Due to some constraints of distance and equipment limitation, the fabricated filter is measured by using network analyzer software, which is Windfreak Synth Network Analyzer. The measurement process by using the software is shown in figure 5.13. The frequency response of the filter will be observed when both, input and output ports are connected by using BNC connector which is connected to the computer via USB port.

Measurement Results

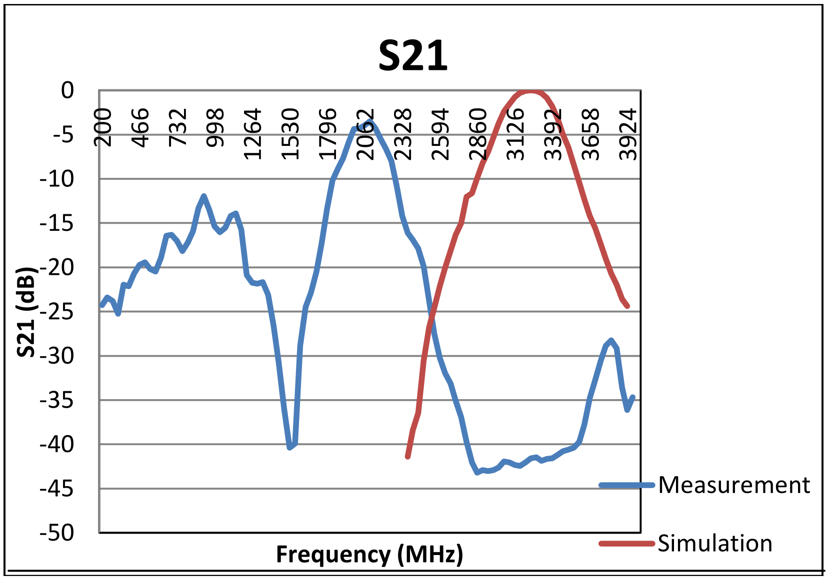


Figure 4.4: Measured and simulated frequency response of the fabricated filter

Figure 5.15 shows the comparison between the simulated and measured frequency response of insertion loss (S21) of the filter. The blue line represents the measured response and the red line represents the simulated response. As can be observed, the centre frequency is shifted to 2.1GHz, instead of 3.2GHz. This slightly mismatch between the simulated and measured results might be due to some fabrication errors or the variation of material properties. Nevertheless, the design of the filter is not affected since the results obtained from the designing process by using Sonnet Lite software are still valid and can be used in future improvement of the design. This is somehow should not be concluded that the design is unsuccessful because the only problem is caused by the fabrication and material issues. The result can be taken as the reference to the actual result which needs to perform the center frequency at 3.2GHz.

5.0 Conclusions

Filters play important roles in many RF/microwave applications. Emerging applications such as wireless communications continue to challenge microwave filters with ever more stringent requirements which are higher performance, smaller size, lighter weight, and lower cost.

In this project, a compact microstrip bandpass filter is successfully designed by using Sonnet lite software at centre frequency of 3.2GHz with the bandwidth of 400MHz. The performance of the filter is observed based on its S-parameters which are return loss (S11) and the insertion loss (S21).
Besides, the design of the compact microstrip bandpass filter has achieved the objective when it successfully reduced the overall size to about 70% as compared to the size of conventional filter, which is parallel-coupled microstrip bandpass filter. Both filters give the same performance based on their frequency responses.

The design also has successfully fabricated and tested by using network analyzer software to verify the simulated results obtained earlier. Although there is slightly mismatch between the simulated and measured frequency response due to some fabrication errors and variation of material properties, the design of filter is not affected since the results obtained from the designing process by using Sonnet Lite software are still valid and can be used in future improvement of the design.

References

Allan,W.S. (1995) *Understanding Microwaves*, 1st ed. Pearson Prentice Hall Publications

Hong,J.S. & Lancaster,M.J (2001) *Microstrip Filters for RF/Microwave Applications*, New York: Wiley Interscience Publication

Wu,H. W., Liu,S.K., Weng,M.H & Hung, C.H.(2010). Compact Microstrip bandpass Filter With Multispurious Suppression. *Progress In Electromagnetics Research Letters(v107),* pp. 21-30.

Xiao, F., Norgren,M.& He,S.(2011) Compact Third-Order Microstrip Bandpass Filter Using Hybrid Resonators. *Progress In Electromagnetics Research Letters (v.19)*, pp 93-106.

Alaydrus, M. (2010). Designing Microstrip Bandpass Filter at 3.2GHz. *Progress In Electromagnetics Research Letters(PIER)* pp. 273-280

Alhauri, A.R.H (2013). Compact Microstrip bandpass Filter using Coupled Spiral Resonator at 2.3GHz. *Master's thesis, UPM*

Borhani, S.J.& Honarvar,M.A. (2013). A Novel Compact Size UWB Bandpass Filter With Sharp Rejection Skirt And Wide Upper-Stopband Based On Multiple-Mode Resonator. *Progress In Electromagnetics Research C (v.43)*, pp. 175-185.

Chen,C.F. Huang, T.Y & Wu, R.B.(2012). Design of Microstrip Bandpass Filter with Multiorder Spurious-Mode Suppression. *IEEE Transactions On Microwave Theory and Techniques(v.53)* No. 12.

Chen, H. & Zhang,Y.X. (2011). A Novel and Compact UWB Bandpass Filter Using Microstrip Fork-Form Resonators. *Progress In Electromagnetics Research Letters(PIER)* pp. 273-280

Chen,C.Y. & Lin, C.C.(2011). The Design and fabrication of a Highly Compact Microstrip Dual-Band Bandpass Filter. *Progress In Electromagnetics Research Letters(v.112*) pp. 299-307.

Huang,J.Q. & Chu, Q.X. (2013) Compact UWB Bandpass Filter Utilizing Modified Composite Right/Left-Handed Structure With Cross Coupling. *Progress In Electromagnetics Research,(v.107)* pp. 179-186.

Maharjan,R.K., Shreshta,B. & Kim,N.Y. (2012). Compact Microstrip Square Open-loop Bandpass Filter using Open Stub. *Electronic Letters (v.48)* No.6.

Maleki,S.J., Sadi,S. & Najafi,K.S. (2012). A Novel Passive Dual-band Bandpass Microwave Filter Using Microstrip Loop Resonators. *Progress in Electromagnetic Research Symposium Proceedings.* No.1407.

Nosrati,M. & Mirzaee,M.(2011). Realization of a Highly Miniaturized Bandpass Filter Using Quasi-Multimode Resonator for Wideband Application. *Progress In Electromagnetics Research Letters (v.14)* pp. 1-9.

Sayantika,B., Poddar,D. Saurabh, S. & Das,S.(2013). Design of Microstrip Parallel-Coupled Bandpass Filter for Global Posotioning System. *Journal of Engineering, Computers & Appplied Sciences (JEC&AS) (v.2),* No.5.