A Design of 2.4 Giga Hertz to 5 Giga Hertz Microstrip Bandstop Filter

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A design of a microstrip bandstop filter (BSF) is presented in this paper. The filter is designed to give a bandwidth of 70 percent, centered at 3.7 GHz with lower and upper cut-off frequency of 2.4 GHz and 5 GHz respectively. The filter is required to have an insertion loss of at least 60 dB with passband ripple of 0.1 dB. The design involves a Tschebychev third order bandstop filter whose input to output is matched to 50 Ω impedance.

The bandstop filter was realized to an open-circuited transmission lines and spaced by unit elements (UE)s which a quarter-wave long at mid-stop-band frequency. The proposed bandstop filter was simulated by using Genesys CAD package and fabricated on a microstrip that have relative permittivity of 2.33, and substrate and copper thickness of 0.5 mm and 0.0356 mm respectively. The filter is then measured using a Scalar Network Analyzer and lastly a data analysis is done to compare both result from simulation and measurement.

Keywords
Bandstop filter, microstrip, Wiltron 562 Scalar Network Analyzer.

1.0 INTRODUCTION

Filters have always been known to be one of the main key building blocks in modern communication system. The most obvious application of filter, of course, used as a frequency selective device in many radio frequency (RF) and microwave applications [1] – [2]. A bandstop filter for example, plays a major role of filtering out the unwanted signals and passing through the desired signal. Moreover, bandstop circuit devices that are employed to suppress the harmonics are very important in power amplifier and mixer applications. Filters can be realized using lumped or distributed circuit elements. However, with the advent of advanced materials and new fabrication techniques, microstrip filter is becoming more attractive because of their low-cost, low-weight and ease of implementation.

Filters design beyond 500 MHz are difficult to realize with discrete components because the wavelength becomes comparable with the physical filter element dimensions, resulting in various losses severely degrading the circuit performance [3]. Thus the lumped element must be converted into distributed element for physical realization. In this work, a Richard's transformation has been used to provide distributed elements where the same behavior of the lumped elements can be achieved.

However, the presence of the series short-circuited stub in a circuit makes them impossible to realize. By applying the Kuroda's identities, the series short-circuited stub can be eliminated [4]. Figure 1 shows the four Kuroda's transformation.

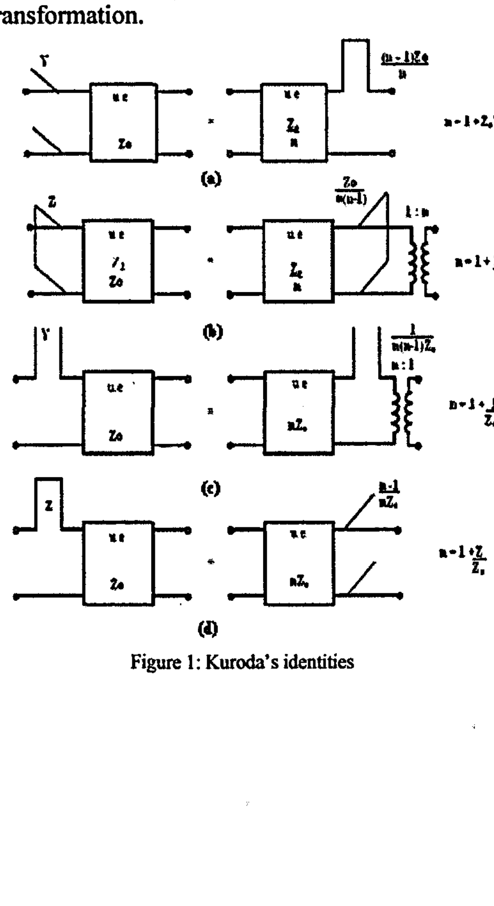

Figure 1: Kuroda's identities

2.0 METHODOLOGY

The design starts by choosing a third order low pass Tschebychev prototype to meet the design criteria. From [5], the low-pass prototype parameters are g_o=g_4= 1, g_1=g_3= 1.0315, g_2= 1.1474 and ω_1'= 1. The prototype inductance and capacitance are replaced by equivalent quarter-wave long transmission line at frequency ω_o where the line impedances and admittance are multiplied by the bandwidth factor. Note that a series inductor in the low pass prototype becomes a short-circuited series stub and shunt capacitor in the prototype becomes an open-circuited shunt stub.

$$\text{Bandwidth factor, } bf = \cot\left(\frac{\pi}{2}\frac{\omega_1}{\omega_o}\right) \quad (1)$$

$$= \cot\left(\frac{\pi}{2}\frac{2.4}{3.7}\right)$$

$$= 0.6157$$

$$Z_1 = Z_3$$
$$Z_1 = bf.g_1$$
$$= 0.6137(1.0315)$$
$$= 0.6351\ \Omega$$

$$Y_2 = bf.g_2$$
$$= 0.6137(1.1474)$$
$$= 0.7064\Omega^{-1}$$
$$Z_2 = 1.4156\ \Omega$$

Since the series stub is not suitable due to difficulties to construct into TEM-mode microwave structure, the series stub is converted to shunt open-circuited stub by applying Kuroda's identity. Two additional unit elements (UE) of impedance Z_{UE1} =Z_{UE2} = Z_A=Z_B =1 have been introduced to allow the use of Kuroda's identity. Z_{UE1} and Z_{UE2} are added to the source and load port respectively. They have no effect on the filter performance since they are match to the source and load impedance. Figure 2 shows how the UE arranged.

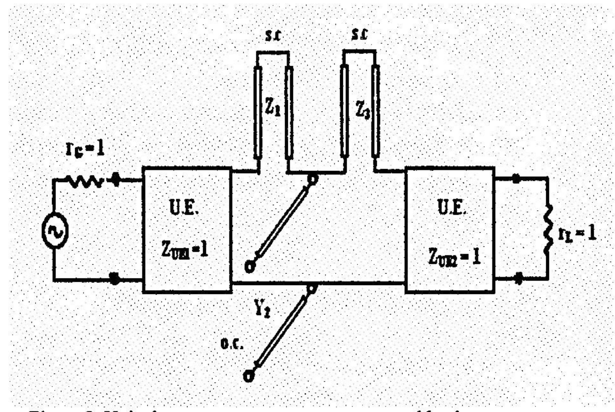

Figure 2: Unit elements arrangement at source and load port.

By applying the two circuits of identity (a) in Table 3.2,

$$Y_1' = Y_3' = \frac{Z_1}{Z_{UE1}(Z_{UE2} + Z_1)}$$

$$= \frac{0.6351}{1(1 + 0.6351)}$$

$$Z_1' = 2.574\,\Omega$$

$$Z_{UE1}' = Z_{UE1} + Z_1$$
$$= 1.6351\ \ \Omega$$

The next step is to de-normalize and to compute the physical dimensions before it can be implemented in Genesys for further analysis. In the transformation lumped to distributed elements, the value of K_{eff}, and width are automatically calculated by the Line Calc in *EESof Libra*. The length of each elements is computed to be l=λ/4. Therefore the length of distributed elements were given by,

$$l = \frac{\lambda_o}{4\sqrt{K_{eff}}} \quad (4.4)$$

Table 1 and Figure 3 show the dimensions of first design.

Table 1: Physical dimensions of first filter design.

	$Z_G=Z_L$	$Z_1=Z_3$	$Z_{UE1}=Z_{UE2}$	Z_2
Line impedance(Ω)	50	128.73	81.75	70.76
Width (mm)	1.44	0.202	0.507	0.88
Length (mm)	14.88	15.31	14.92	14.72

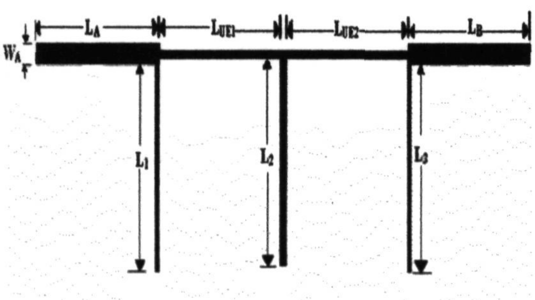

Figure3:dimension of the proposed filter.

The performance of the filter is investigated through the insertion and return losses response. The final circuit design is fabricated and is measured by using the Scalar Network Analyzer. The simulation and measured response are then compared.

3.0 RESULT AND DISCUSSION

3.1 Simulation Results

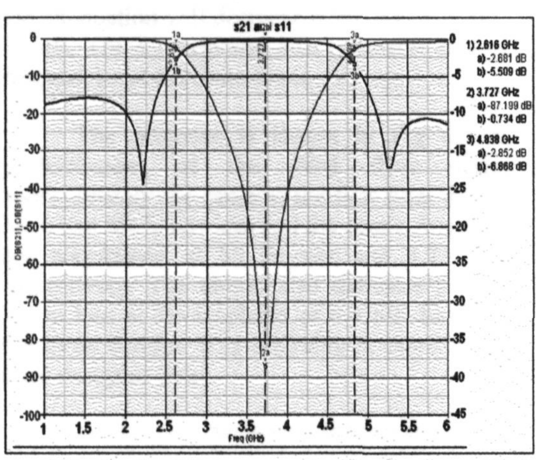

Fig 4: Simulated insertion loss and return lost of first filter design.

Figure 4 shows the insertion, S_{21} and return, S_{11} losses response of the first design. The S_{21} graph shows the center frequency of 3.73 GHz is achieved as desired but the bandwidth is decreased by 10 percent from the desired of 70 percent. The return loss in the stopband is approximately 0.583 dB. The S_{21} graph also shows the highest insertion loss of -94 dB occurs at center frequency.

To analyze and further improve of the filter response, optimization has to be done. Furthermore, the Z_1 width of 0.202 mm is also too small and not suitable for fabrication. Another design must be carried out in order to get a suitable width. The optimization need to be done carefully since the circuit is symmetrical. For this reason, a more practical form for finding optimum performance is to tune or tweak the circuit elements. Several investigations were carried out due to changing the width and length of the circuit elements.

Changing the width Z_1 and Z_3 alone will shift the center frequency and the f_L and f_H worsen. Otherwise, by tuning all the widths give a better result of f_L, f_H and return loss but the center frequency is still remain shifted. Table 2 and Figure 5 show the filter new dimensions and its responses respectively. Table 2 shows the new width of second design.

Table 2: Physical dimensions of second filter design.

	$Z_1=Z_3$	Z_2	$Z_{UE1}=Z_{UE2}$	$Z_G=Z_L$
Width (mm)	0.382	0.5	0.766	1.44
Length (mm)	15.31	14.72	14.92	14.88

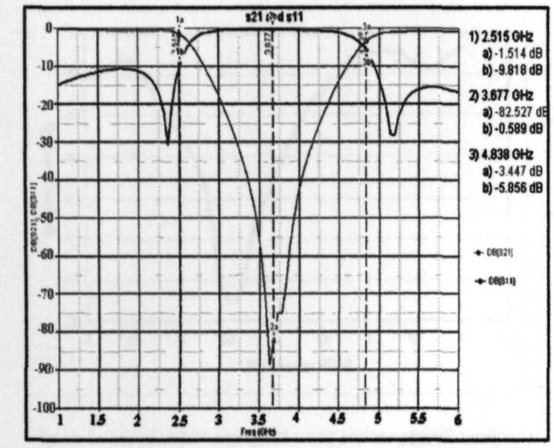

Fig 5: Simulated insertion loss and return lost of second filter design.

From the graph of Figure 5 above, a better 3 dB stopband bandwidth of 63% is achieved when the f_L is 2.515 GHz but the center frequency is slightly shifted to 3.677 GHz. The circuit also indicates a better return loss of -0.589 dB.

The third filter design is achieved by changing the length from the second filter. Generally, tuning of even a very small length of any of the stubs ($Z_1 = Z_2$ or Z_3) give a tremendous affect to the center frequency and the insertion loss except for the ($Z_{UE1}=Z_{UE2}$) transmission lines. The f_H, f_L and return loss is maintained as before but the center frequency tends to shift when varying the stub length. It also offers a large stop-width at higher insertion loss level but the attenuation will decrease from -83 dB up to -30 dB. The S_{21} response also resonants at three frequencies at the same time.

The response is shown in Fig 6. The performances of the third filter design approximately the same as the first filter design. Note that the bandwidth and the center frequency are maintained at 60 percent and 3.73 GHz respectively. The circuit also indicates a better return loss at the stopband of 0.4 dB. Based on the three designs, it is desirable to fabricate the third designed filter.

Table 3: Physical dimensions of third filter design

	$Z_1=Z_3$	Z_2	$Z_{UE1}=Z_{UE2}$	$Z_G=Z_L$
Width,(mm)	0.382	0.77	0.5	1.44
Length (mm)	14.827	14.903	14.661	14.88

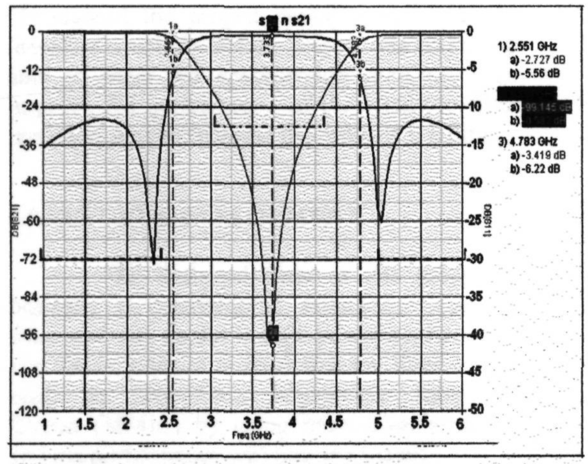

Fig 6: Simulated insertion loss and return lost of third filter design.

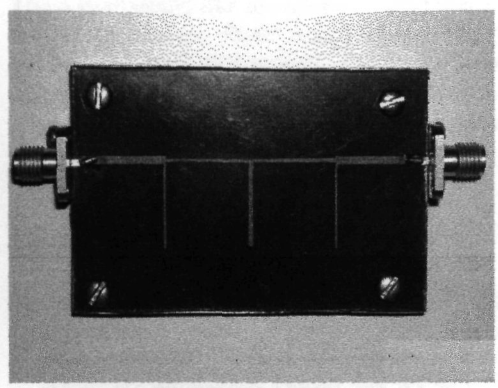

Figure 7: the realization of the microstrip bandstop filter.

3.2 Measurement Results

To confirm the idea of the designed filter, an all-stubs bandstop filter of the second design was fabricated as shown in Figure 6. A *Wiltron* 562 Scalar Network Analyzer is used to perform the measurements. Figure 8 and Figure 9 show the measured of insertion loss and return loss result. Surprisingly the bandwidth of the fabricated filter increased by 4 percent then the simulation one but the frequency is slightly shifted to 3.56 GHz. Furthermore, the graphs from measurement are not smooth as desirable in the simulation results. This may be due to the effect of the connecter and losses arising from the fabrication error.

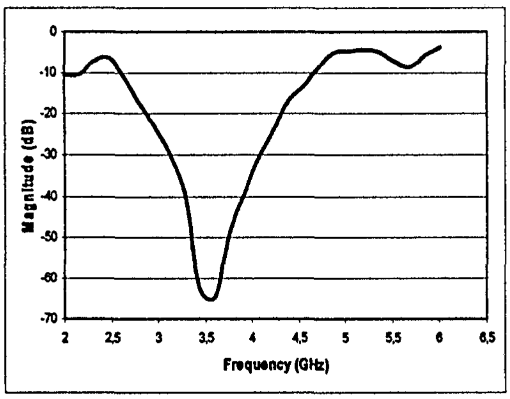

Figure 8: Insertion loss measured using scalar network analyzer

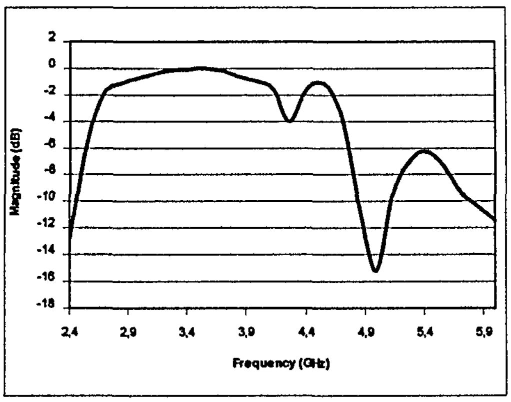

Figure 9: Return loss measured using scalar network analyzer

Based on the data shown in Table 3, the measured is better since the bandwidth is wider 4 percent than the simulation. At the same time, 0.2 dB of return loss is good than the simulation one. The insertion loss is no longer goes to infinity at center frequency, but constant at some value. This is inevitably because of the dissipation loss in practical.

Table 3: Comparison of simulated and measured results.

	Simulated	Measured
Bandwidth (%)	60	64
Insertion loss 9dB)	-96	-64
Return Loss (dB)	0.4	0.2
Center frequency	3.70	3.56

4.0 CONCLUSION

The measured performance shows a good agreement with the simulated results. The slight difference between the simulated and measured result may be due to error in designing, fabrication and measurement process. Throughout the project deployment, we could therefore conclude that the project was still being able to meet the specification required. To improve the performance of the bandstop filter response, we can increase the order of the filter.

5.0 FUTURE DEVELOPMENT

The designed filter in this project is basically a conventional microstrip bandstop filter and very useful in high-power applications. For future work, it is hope that the filter can be built on Monolithic Microwave Integrated Circuit (MMIC) by using multi-layer structure and the performance will become better.

6.0 ACKNOWLEDGEMENT

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7.0 REFERENCES

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