Design of a Modified L-Shaped Bandstop Filter for UWB Applications

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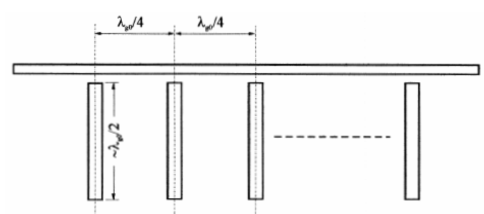
***Abstract* - Performance of UWB system may be degraded since the interference may be exist due to the presence of signals from other existing wireless communication systems. Currently, the major interference are in-band signal from 802.11a WLAN system which occupies the 5-6 GHz spectrum and signals from 802.11b/g WLAN system covering 2.4-2.48 frequency band. This paper presents the design of a modified L-shaped resonator bandstop filter for UWB applications. The applicability of the proposed design method is demonstrated by a conventional 2.45 GHz L-shaped bandstop filter with -60 dB attenuation, which was extended to include a modified L-shaped resonator's design and result discussion. Methods of increasing bandwidth such as changing L-resonator width and cascading of filters are presented. The filters have been simulated using ADS design software and implemented on FR4 substrate.**

Keywords – L-resonator, bandstop filters, microstrip resonator, Ultra Wideband (UWB)

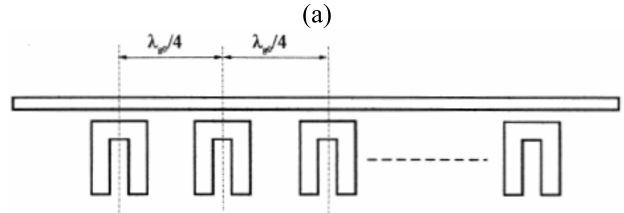
I. INTRODUCTION

Federal Communications Commission (FCC) released the 3.1-10.6GHz spectrum with an indoor emission limit of -41 dBm/MHz for Ultra wideband communication (UWB) in 2002. Ultra Wideband (UWB) technology has attracted a lot of interest in the research community and in industry. It offers the potential for high data rates, low-power transmissions, low cost, excellent range resolution (geolocation) capabilities, and robustness to multipath fading. One of the main research focus was to capitalize on the low transmission power of UWB pulses in communications, thereby catalyzing UWB transceiver research. The simpler transceiver circuitry required in this system, compared to more complicated structures in narrowband transceivers, have also been seen as another promising, as small-sized devices can be manufactured at a lower price. [1]

One of the transceiver components that have received much research attention due to this is the filter. Various researchers have carried out investigations on different aspects of filters, which includes the bandpass UWB filters [2, 3], filters with tunability and switchability features [4-6], and transmission zeroing at passband [7]. Much attention have also been paid to notching out signal reception in the ISM spectrum range of 5-6 GHz [2, 8, 9]. These works have focused on implementing the notch filters using various means such as parasitic patches, coupled line structures, defected ground structures (DGS), split ring resonators (SRR), photonic band gap (PBG) and etc. Less have been done in notching out the WLAN 802.11 b/g spectrum range for application in UWB. This work is an effort to design and examine an L-resonator bandstop filter which was designed to have attenuation of at least -60 dB between 2.4 GHz and 2.5 GHz. L-resonator bandstop filter presented in this paper used an EM-simulation method to obtain the reactance slope parameters required for designing the filter. Section II presents the basic design procedure for an L-resonator bandstop filter. Section III presents the results of L-resonator bandstop filter with 2.45 GHz center frequency, and discuss about the findings. Section IV investigates the methods for obtaining larger bandwidth by parametric study and cascading of multi-staged filters.



(a)



(b)

Figure 1: Common bandstop configuration [10]

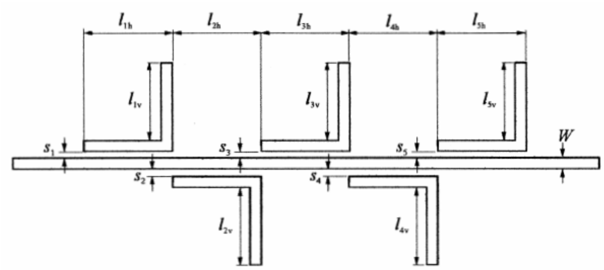


Figure 2: L-resonator bandstop filter

II. NARROWBAND *L*-RESONATOR BANDSTOP FILTER DESIGN

Two common configurations of narrow-bandstop filter are shown in Figure 1 [10]. The *L*-resonator bandstop filter introduced in this work is as shown in Figure 2, which is a combination structure of these 2 configurations. The filters designed were then implemented on a FR4 substrate, with a dielectric constant of 5.4, loss tangent of 0.035 and substrate height of 1.6 mm.

Based on the design specifications, the order of filter can be determined from [10]. Through this method, a bandstop UWB filter of the 7th order filter was required. From the order of the filter, the low-pass prototype element values were obtained using equations (3), (4) and (5), where $g_0 = 1.0$. Element values computed are shown in Table 1.

$$g_1 = \frac{2}{\gamma}\sin\left(\frac{\pi}{2n}\right) \tag{3}$$

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

For i = 2,3,…,n

$$g_{n+1} = \begin{cases} 1.0 & \textit{for n odd} \\ \coth^2\left(\frac{\beta}{4}\right) & \textit{for n even} \end{cases} \tag{5}$$

where

$$\beta = \ln\left[\coth\left(\frac{ripple}{17.37}\right)\right]$$

$$\gamma = \sinh\left(\frac{\beta}{2n}\right)$$

TABLE 1 LOW-PASS ELEMENT VALUES

Low-Pass Elements	Values
g_0 and g_8	1.0
g_1 and g_7	1.1812
g_2 and g_6	1.4228
g_3 and g_5	2.0967
g_4	1.5734

Once the low-pass prototype element values have been obtained, the reactance slope parameters were computed using (6). The reactance slope parameters computed are shown in Table 2.

$$\frac{x_1}{Z_0} = \left(\frac{Z_u}{Z_0}\right)^2 \frac{g_0}{g_1\Delta} \qquad \text{for } i = 1 \text{ to } n \tag{6}$$

where

$$\left(\frac{Z_u}{Z_0}\right)^2 = \frac{1}{g_0 g_{n+1}}$$

TABLE 2 REACTANCE SLOPE PARAMETERS

Reactance Slope Parameters	Values
x_1 / Z_0 and x_7 / Z_0	20.65
x_2 / Z_0 and x_6 / Z_0	17.14
x_3 / Z_0 and x_5 / Z_0	11.63
x_4 / Z_0	15.5

As seen from Figure 2, each *L*-shaped resonator was designed to be half wavelength, while L_k and L_v was each quarter wavelength. The guided wavelength were calculated using (7), resulting in L_k and L_v to be both 15 mm in length. For simplicity, width of the main line and *L*-resonators were assumed to be 2.6 mm based on a 50 Ω line dimension.

$$\lambda_g = \frac{300}{f(GHz)\sqrt{\varepsilon_{re}}} \tag{7}$$

A circuit as shown in Figure 4 was simulated using ADS software to obtain the reactance slope parameters. Space of the coupled line (*CLin1*) was varied to obtain a set of measured reactance slope parameter values, using the simulated S_{21}(dB) magnitude plot from the circuit setup and (8). Figure 5 shows the resulting simulated S_{21}(dB) magnitude plot. The spaces associated with the calculated reactance slope parameters shown in Table 2 were obtained by using a graph plotted based on the measured reactance slope parameters obtained.

$$\left(\frac{x}{Z_0}\right)=\frac{f_0}{2\Delta f_{3dB}} \tag{8}$$

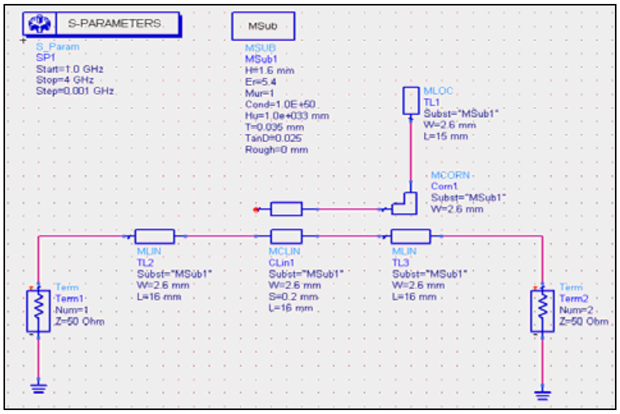


Figure 4: Setup for reactance slope parameters

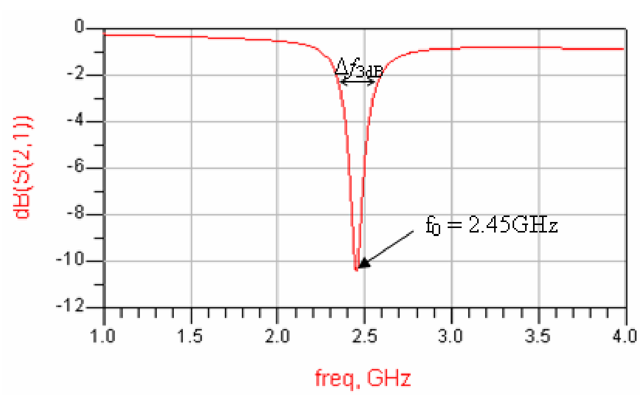


Figure 5: Simulated S_{21} magnitude plot

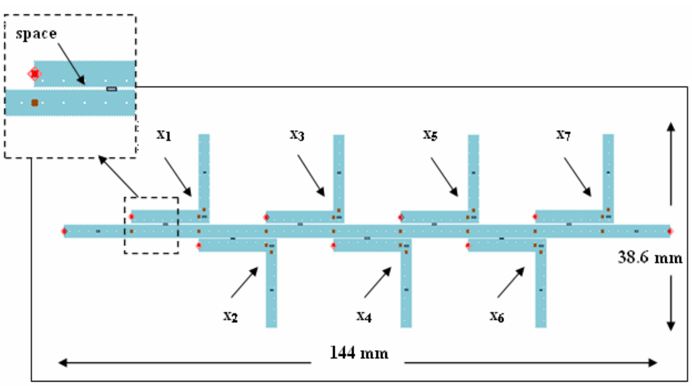


Figure 6: Layout of modified L-resonator bandstop filter

TABLE 3 SIMULATED REACTANCE SLOPE PARAMETERS

Space (mm)	f_o (GHz)	Δf_{3dB} (GHz)	x/Z_o
0.1	2.45	0.161	7.64
0.25	2.45	0.092	13.37
0.35	2.45	0.057	21.4
0.5	2.45	0.045	26.75

III. RESULT AND DISCUSSION

Figure 6 shows the layout dimension of the L-resonator bandstop filter designed using ADS. Seven elements were included as part of the filter structure, and were swept using different spacing. These spaces were associated with the reactance slope parameters, and were obtained based on the method discussed in Section II. The result is shown in Table 3, and was plotted against space in Figure 7. Based on this figure, the spaces associated with the calculated reactance slope parameters in Table 2 were obtained and tabulated in Table 4. Figure 8 shows the fabricated L-resonator bandstop filter structure.

Based on the Figure 9, the center frequency of simulation definitely success at 2.45 GHz but the measurement result was slightly increased to 2.57 GHz. This variation was caused by various fabrication imperfections such as dimensional inaccuracies and port to line transition losses.

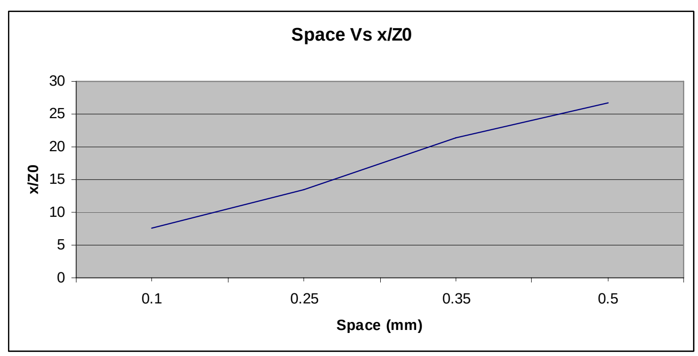


Figure 7: Reactance slope parameters versus space

TABLE 4 SPACES FOR REACTANCE SLOPE PARAMETERS

Reactance slope parameters	Values	Spaces (mm)
x_1 / Z_0 and x_7 / Z_0	20.65	0.33
x_2 / Z_0 and x_6 / Z_0	17.14	0.25
x_3 / Z_0 and x_5 / Z_0	11.63	0.18
x_4 / Z_0	15.5	0.27

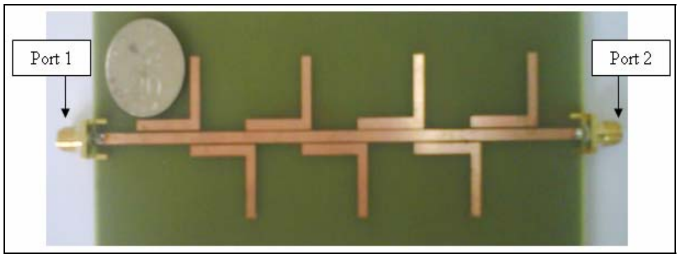


Figure 8: Fabricated modified L-resonator bandstop filter

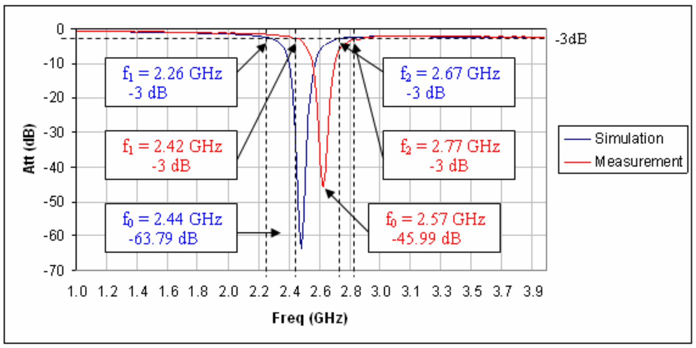


Figure 9: Result of simulation and measurement

IV. MODIFIED *L*-RESONATOR BANDSTOP FILTER DESIGN

In order to obtain a larger bandwidth the width of *L*-resonator was reduced. Figure 10 and Table 5 shows the comparison between *L*-resonator width of 1.8mm, 2.2mm, 2.6mm, 3.0mm and 3.4mm. In order to increase the notch bandwidth, two 7th-order filters were cascaded together, as shown in Figure 11 and the simulated result in Figure 12.

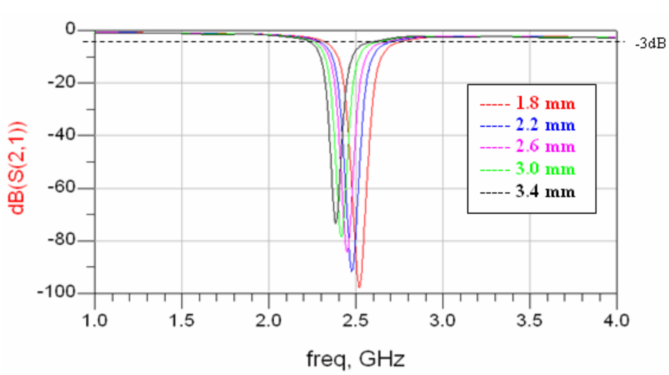


Figure 10: Comparison of bandwidth between differently spaced filters

TABLE 5 COMPARISON WIDTH OF L-RESONATOR

Width (mm)	f_1 (GHz)	f_2 (GHz)	f_0 (GHz)	Δf_{3dB} (GHz)
1.8	2.26	2.87	2.51	0.61
2.2	2.24	2.82	2.48	0.58
2.6	2.22	2.78	2.45	0.56
3.0	2.2	2.74	2.41	0.54
3.4	2.17	2.7	2.38	0.53

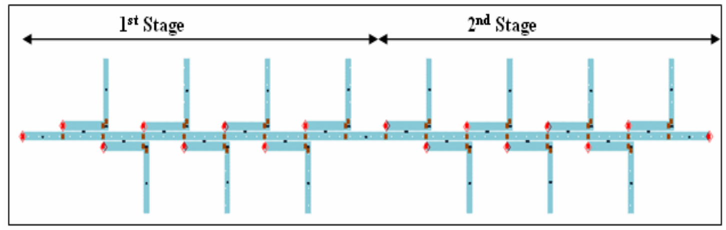


Figure 11: Layout of cascaded filter

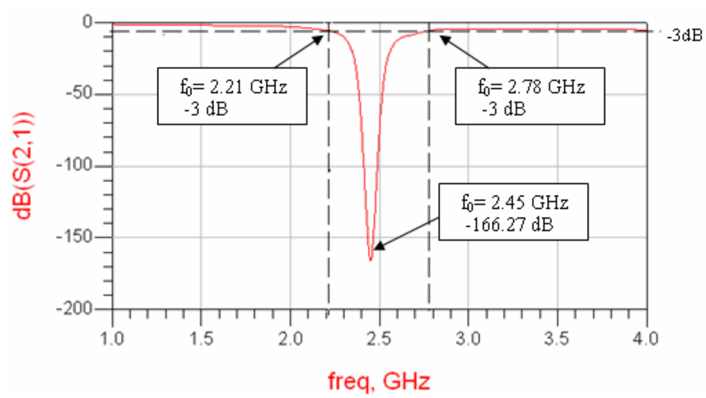


Figure 12: Simulation of cascaded filter

The first and second stage filters were designed to have the same specifications with a cutoff frequency of 2.45 GHz and 3dB-bandwidth of 0.57 GHz. As the impedances were matched, cascading the filters produced a near to zero center frequency to shift. The notch bandwidth was successfully increased by cascading of filters but it was still insufficient to meet the design specification.

Two 7th-order L-resonator filters having different stopband frequency as a Figure 13 were cascaded. The simulation result of the cascaded structure is showed in Figure 14.

TABLE 6 BANDSTOP PERFORMANCE COMPARISON

	f_1 (GHz)	f_2 (GHz)	f_0 (GHz)	Δf_{3dB} (GHz)
1st stage	2.22	2.77	2.45	0.55
2nd stage	2.26	2.82	2.50	0.56
Cascaded	2.14	2.85	2.47	0.71

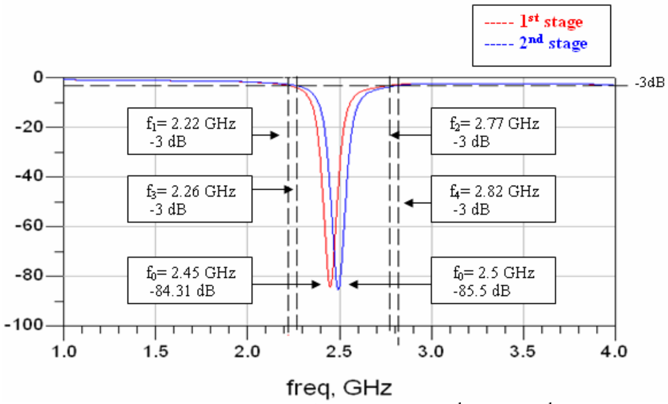


Figure 13: Simulation of 1st stage and 2nd stage 7th Order L-Resonator Filter

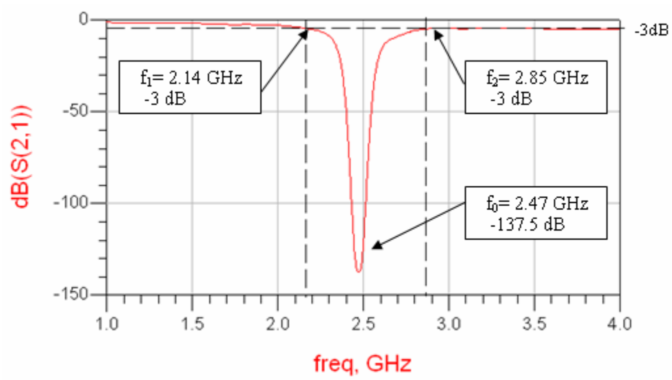


Figure 14: Simulation result of cascaded structure

Table 6 shows the design parameters (cutoff frequencies, center frequency and 3dB-bandwidth) of each stage. The bandwidth for the 1st stage and 2nd stage was designed to be 0.55 GHz and 0.56 GHz. The resulting cascaded structure produced an increased bandwidth of 0.71 GHz.

TABLE 7 COMPARISON METHODS

Method	Effects on bandwidth	Effects on S_{21} center frequency
Increasing width (every 0.4 mm)	5.0 %	5.0 %
Cascading	6.3 %	5.0 %

Based on Table 7, methods of changing width and cascading different filter structures have produced the same effects on S_{21} center frequency which was about 5 %. However, the cascading method has been proven to be more effective in increasing the bandwidth, up to 6.3 %. On the other hand, the width varying method has produced an improvement of up to 5 %. However, one important point to note is that the width varying method have emerged as a more practical method as it can be easily implemented on an electromagnetic simulator and therefore saves cost.

IV. CONCLUSION

A new, modified L-shaped resonator bandstop filter that was implemented for UWB applications is presented. Two methods to tune its bandwidth and center frequency of the filter have been identified, which are the width varying method and the cascading method. A bandwidth improvement of up to 6% has been verified using the cascading method, through simulation and measurement carried out in this work.

V. REFERENCES

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