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A Simple UWB Band Pass Filter Design based on Signal Interference Approach

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ABSTRACT
This paper reports an Ultra wideband pass filter with a center frequency of 3.96 GHz and 3 dB bandwidth of 1584 MHz. The filter design is based on transversal signal interference principle implemented by means of transmission lines.The features of this filter include low insertion loss, sharp rejection along with simple design approach. Also, comparison of simulation and measured filter parameters shows a good correlation. The measured insertion loss and return loss in the Ultra-Wideband (UWB) band are found to be 0.8 dB and 12 dB respectively. Further, the filter provides a high roll-off rate of 160 dB/ GHz.

General Terms
Filter, RF.

Keywords
Ultra-Wideband, band pass filter, transmission line techniques, Advance Design System, MB-OFDM, RF filters.

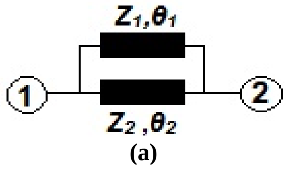
1. INTRODUCTION
The UWB technology provides a wide operating frequency range of 7500 MHz (3.1-10.6 GHz) and allow power requirement of -41.5 dBm [1]. Multi-band Orthogonal Frequency Division Multiplexing (MB-OFDM) is an approach to realize UWB, which splits the entire bandwidth into fourteen sub-bands with bandwidth of 528 MHz each to realize a short-range, high speed wireless communication system. These fourteen bands are grouped into four groups among which group A has the bandwidth of 1584 MHz at 3.96 GHz centre frequency. The microstrip band pass filter described in this paper is designed to meet these specifications. Furthermore, Wireless LAN (WLAN) frequency bands are also present on both the sides of UWB band i.e., 2.45 GHz and 5.2 GHz. Since UWB is a low power technology, these filters need to provide low insertion loss to make them viable and sharp rejection to avoid interference from those WLAN signals. In general terms, the required characteristics may be obtained by increasing the filter order. However, alternate schemes by means of cross coupling between the resonators and the use of shunt-open stubs on the input and output feed lines, are also reported. In the recent past, a number of designs have been developed for UWB filters [2-8]. However most of them do not provide sharp rejection characteristics along with low insertion loss. Signal Interference technique provides better option for designing wideband filter with sharp rejection characteristics [9-11]. Band stop filter design has been widely reported with transmission line based circuit configuration. Alternately, with lower transmission line impedances this technique can also be used to design band pass filters [11]. The filter design adopted in this paper is based on transversal signal interference technique with two basic transmission line sections cascaded to provide better performance. Based on the above approach, an ultra-wide band pass filter with center frequency 3.96 GHz, 40% fractional bandwidth is developed and its characteristics are obtained by simulating the design in ADS software.

2. FILTER DESIGN
It is preferable for UWB filters to have rejection level of 30 dB or better, but this may not be realizable with just one single section. However, it may be achieved by adding shunt-open stubs towards both the input and output feed lines or cascading one or more basic sections or both. To make the case for underlying principle of the filter design, a basic transmission line section and a cascaded multi section with open stubs are shown in Figure 1a & Figure 1b respectively. As indicated in Figure 1a, Z_1 & Z_2 are the characteristic impedances and θ_1 & θ_2 are the electrical lengths of the two transmission lines connected in parallel fashion.

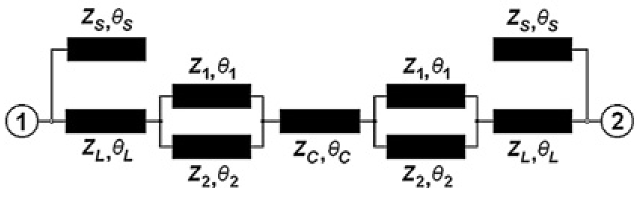
The input signals is divided into two components at one of ends of the transmission line section and are made to interfere at the other end, however with different phase and magnitudes so as to induce a destructive interference at the edges of passband, which is essentially the concept of signal interference technique [11]. This technique provides low insertion loss, sharp rejection and wideband band pass characteristics. To determine the electrical length (θ_i) of basic transmission line sections, if θ_1, θ_2 are taken as θ_{10} and θ_{20} at f_0, then at any arbitrary frequency f

$$\theta_i = f\left(\frac{\theta_{io}}{f_o}\right);\, i = 1,2 \qquad (1)$$

For the basic filter section, the proposed electrical lengths are θ_{10} = 90° and θ_{20} = 270° and the corresponding impedances Z_1 & Z_2 values are 30Ω and 90Ω respectively.



(a)



(b)

Figure 1: Configuration of (a) Basic filter section, (b) Cascaded sections [11]

The choice of low impedance values also lead to decreased pass band insertion loss, increased selectivity, increased bandwidth and also provides for ease of fabrication. Also, the 3 dB fractional bandwidth of the filter depends on the chosen Z_1 & Z_2 values. Based on the transmission-line model, the ABCD matrix of the basic filter configuration can be derived as given in [11].

A two section filter with shunt-open stubs is used in this work. The value of Z_1 & θ_1, Z_2 & θ_2 are fixed as 30Ω & 90°, 95Ω & 270° respectively, for the design. For improving the stop band rejection level, two or more basic sections are cascaded along with open stubs connected at the feeding ends. If the electrical length between the two basic configurations θ_c is taken as 90° at f_0, the filter response maintains its symmetry. Due to cascading, the number of passband pole increases, leading to improved selectivity. The solutions of Z_c for a two-stage cascaded structure of Figure 1b, are obtained for $Z_1 = 33\Omega$ and $Z_L = Z_O = 50\ \Omega$. Similar to the single-stage filter, rejection magnitude increases with decreasing Z_s. The operating frequency, the substrate information, characteristic impedances and the corresponding electrical lengths are provided as input to ADS tool, which provide the required length & width of the transmission line segment. The entire filter design follows the procedure reported by Mandal et al [11]. The layout of the designed filter is shown in Figure 2.

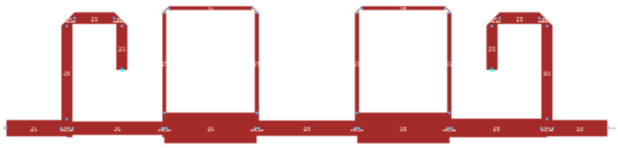
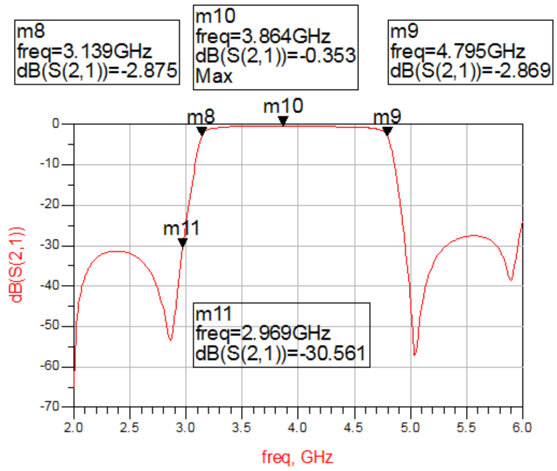


Figure 2: Layout of the Filter structure with cascaded sections

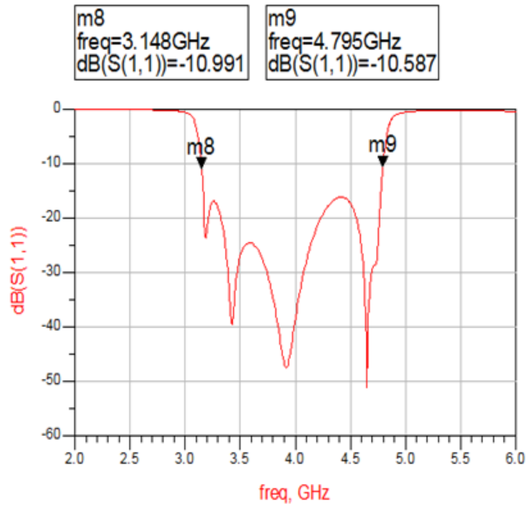
The filter is designed with RO 4730 substrate with ε_r=3 and a thickness of 0.831 mm. In this filter structure shunt stubs are folded in order to reduce the area required for fabrication.

3. RESULTS AND DISCUSSION

The *S*-parameter characteristics of the filter are obtained by simulating the design using ADS. The S_{21} & S_{11} characteristics are shown in Figure 3a and 3b respectively. As shown in the Figure 3a, the insertion loss varies from 0.4 dB to 0.8 dB within the passband and return loss better than 15 dB are observed. The rejection characteristics in upper band and lower band are close to 30 dB as seen in Figure 3a. Furthermore, the photograph of the fabricated filter based on the design in ADS is depicted in Figure 4.



(a)



(b)

Figure 3: (a) S_{21} response (b) S_{11} response

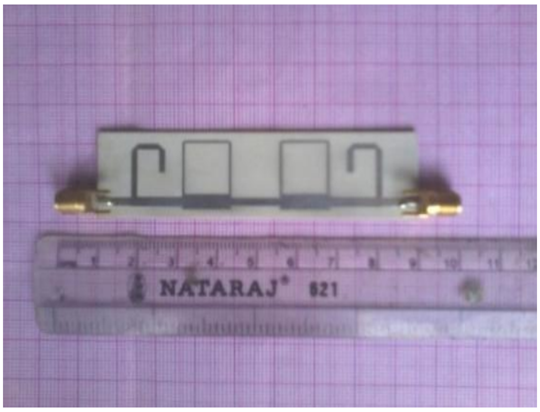


Figure 4: Photograph of the fabricated filter

Measurement of the *S*-parameters of the fabricated filter is carried out using Network Analyzer (ZVH-8), and a comparison of the measured results with that of simulation is shown in Figure 5. It is noticed that the simulation results agree well with those obtained from the measurement. The experimental insertion losses are 0.8 dB, while the return losses are 12 dB. Also, Figure 6 shows the transmission (S_{21}) characteristics, which also indicates sharp roll off characteristics at the desired frequencies and is an excellent match with the simulation results. The 3 dB bandwidth obtained is greater than 1.656 GHz against the design intentions of 1.584 GHz.

$$Roll\ of\ rate = |\alpha_{max} - \alpha_{min}| / |f_s - f_c| \qquad (2)$$

where α_{max} is the 30 dB attenuation point and α_{min} is 3 dB attenuation point; f_s is the 30 dB stopband frequency and f_c is the 3 dB cutoff frequency. For this filter design, a roll off rate of 160 dB/GHz is obtained.

Further, the measured impedance is plotted in Figure 7, where the values are close to 50Ω on both the edges of the pass band frequencies. Variation in group delay is shown in Figure 8, which predicts a maximum variation of 5 ns in the pass band.

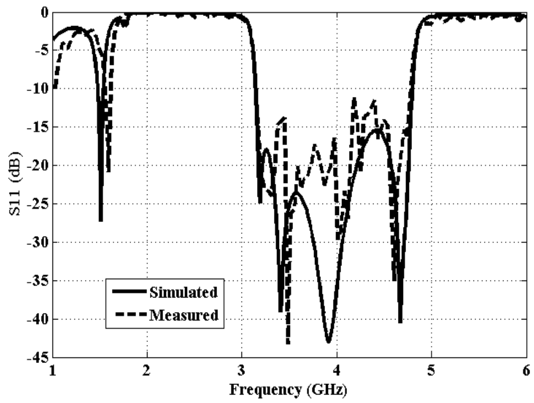


Figure 5: Measured Return Loss (S_{11})

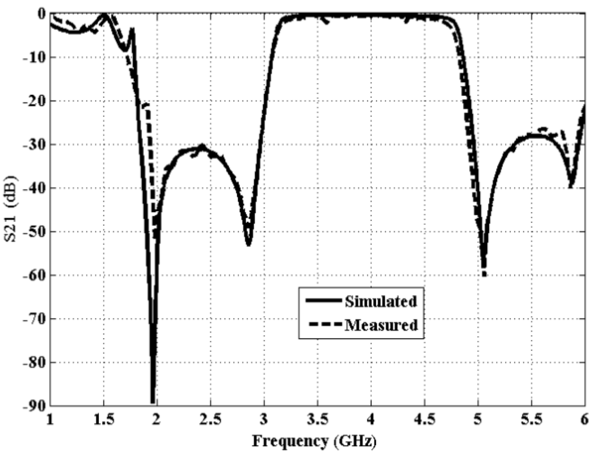


Figure 6: Measured transmission (S_{21}) characteristics

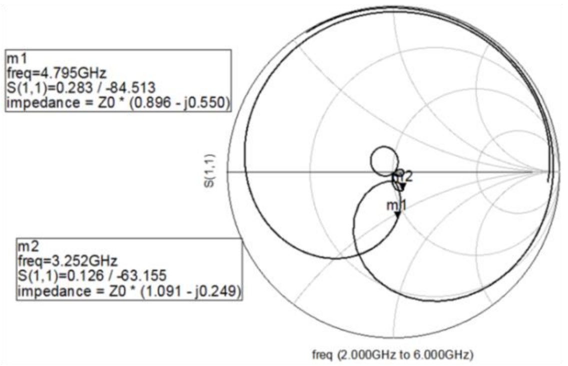


Figure 7: Impedance characteristics

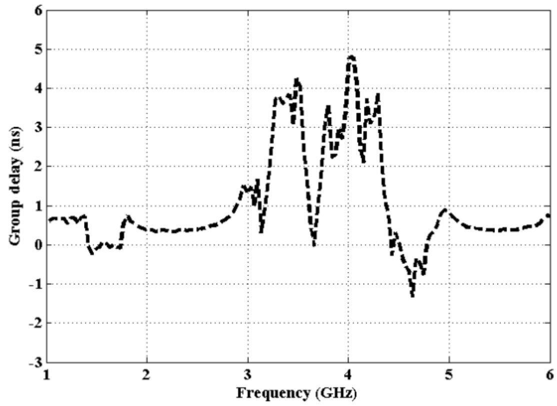


Figure 8: Group delay

4. CONCLUSION

An UWB band pass filter configuration using two transmission-line section and two shunt-open stubs is designed and simulated. The main features of the filter are low pass band insertion loss and sharp rejection characteristics. Simple lossless transmission-line model has been used and the filter structures are easy to realize. The simulated results and measurement predict 40% fractional bandwidth at a centre frequency of 3.96 GHz. The maximum insertion loss and return loss are found as 0.8dB and of 12dB respectively. Further, the roll-off rate of the proposed filter is obtained as 160 dB/GHz. This work could be further expanded by means of introducing meandering in the transmission line sections and in the shunt stubs, which would entitle a reduction in the overall size of the filter.

5. ACKNOWLEDGEMENT

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