Ultra-Wideband Bandpass Filter using Short Circuited Stubs

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Abstract

This paper presents a microstrip ultra-wideband (UWB) bandpass filter using short circuited stubs. The proposed filter is designed using combination of step impedance lowpass filter (LPF) and the optimum distributed highpass filter (HPF). The UWB filter is deployed on FR4 Epoxy dielectric substrate with thickness of 0.8mm and the filter occupies 26.4mm × 16mm die of area. This filter is operating in the whole UWB passband of 3.1 GHz to 10.6 GHz. The designed filter has been optimized using CST microwave studio software. The fabricated filter was tested and compared the result. The simulated and measured results shows the close agreement.

Index Terms *—Bandpass, microstrip, optimum distributed HPF, step impedance LPF, ultra-wide band (UWB).*

1.INTRODUCTION

ULTRA-WIDEBAND (UWB) filters have attracted much research interest and various design methods have been reported. Because of its high-data rate capability, the UWB wireless technology with unlicensed frequency limits from 3.1 GHz to 10.6 GHz [1]. Industries has attracted various devices such as antenna, RF amplifier, and power combiner/splitter that support the technology have been investigated including a number of UWB filters which have been realized using some techniques such as microstrip and uniplanar circuits [2]-[7]. Various methods and structures are being used to develop these UWB filters [8]-[12].

Lumped element filter design is generally unpopular due to the difficulty of its use at microwave frequencies along with the limitations of lumped-element values. Hence, microstrip filters being a popular choice. Bandpass filters (BPF) are key devices in communication systems. For ultra wideband (UWB) applications, the BPF is required to have low insertion loss over the band 3.1 GHz to 10.6 GHz, and a flat group delay performance within that band. In the design of ultra-wideband (UWB) bandpass filter, the topology constructed from the step impedance lowpass filter (LPF) and the optimum distributed highpass filter (HPF) is employed [13].

By taking inspiration from [14][15] and focusing in the bandwidth improvement, the aim of this paper is to develop a UWB filter working in the bandwidth of 3.1 GHz to 10.6 GHz. The filter is designed by combining and cascading the step impedance lowpass filter (LPF) and the optimum distributed highpass filter (HPF), which gives a good solution for a wideband performance. The design was properly calculated and design simulation was carried out using CST software to verify the performance.

2.THEORY ANALYSIS AND DESIGN

A. Step impedance low-pass filter

A relatively easy way to implement low-pass filters in microstrip or stripline is to use alternating sections of very high and very low characteristic impedance. Such filters are referred to as step impedance and are popular because they are easier to design and take less space.

The step impedance low-pass filter is designed by using chebyshev polynomial with ripple value of 0.05dB. To determine the impedance values of the step impedance LPF the tabulated element values given in [14] for low-pass filters are used. After doing some calculations and parametrical studies to have optimum design, the number of reactive element is odd number in order to have a symmetrical filter. The width of lines section for series inductor and shunt capacitor elements is 0.75mm and 3.2mm. These widths correspond with the high impedance value (Z_{high}) of 72Ω for series inductor elements and with the low impedance value (Z_{low}) of 30Ω for shunt capacitor elements. The lumped elements of LPF are converted into distributed elements and their microwave integrated circuit (MIC) layout is shown in Fig. 1(a). The LPF MIC layout is simulated on CST microwave studio and simulated S-parameters are shown in Fig. 1(b).

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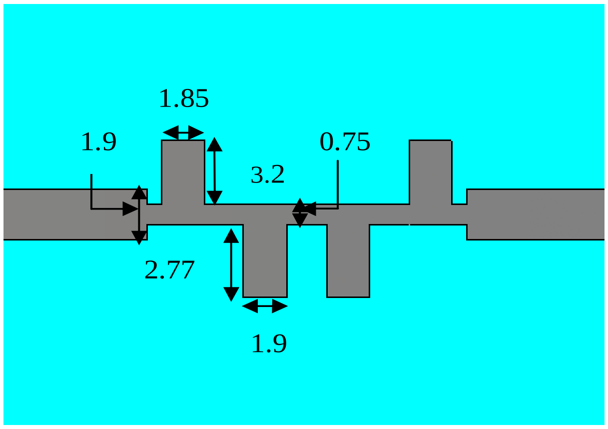

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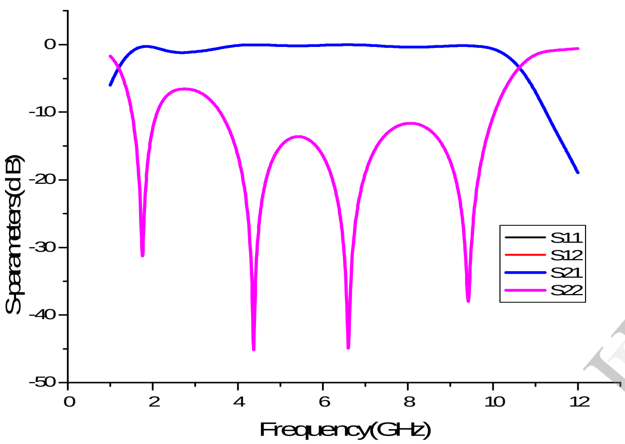

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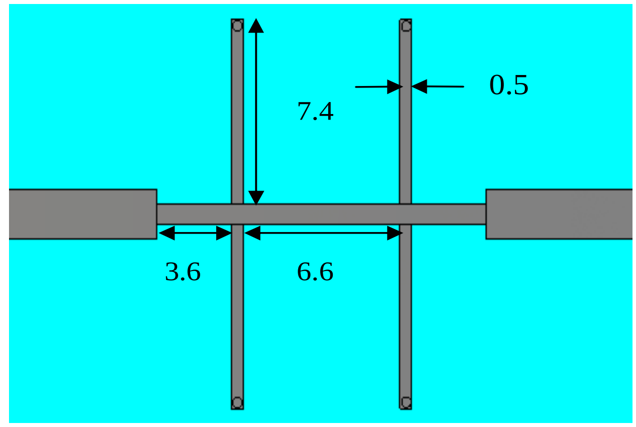
Fig.1 (a) MIC layout of step impedance LPF (All dimension in mm), (b) Simulated S-parameters of step impedance LPF.



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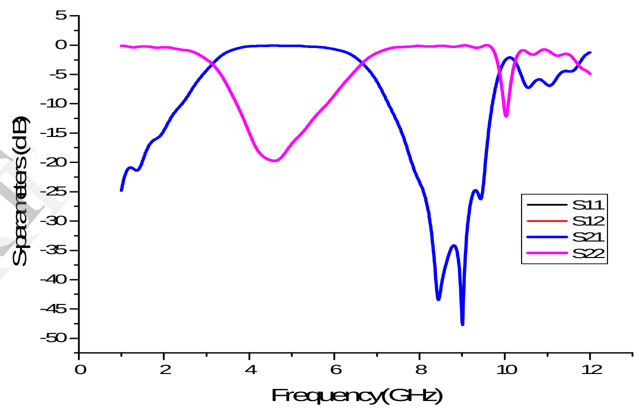

(b)

Fig.2 (a) MIC layout of optimum distributed HPF(All dimension in mm), (b) Simulated S-parameters of optimum distributed HPF.

B. Optimum distributed high-pass filter

Optimum distributed high pass filter consists of shunt short-circuited stubs of equal length alternating with transmission lines. To obtain bandpass response from the LPF above, optimum distributed HPF is used which consists of 4 stubs. The width of each stub has characteristic impedance of 85Ω. The 4 short-circuited stubs are terminated by drawing cylindrical vias from top transmission lines down to the ground plane. Which serves as optimum distributed HPF. Its microwave integrated circuit (MIC) layout is shown in Fig. 2(a) and simulated S-parameters are shown in Fig. 2(b). It is a vertical symmetry structure and the 4 stubs have the same length 7.4mm and width of 0.5mm.

3. SIMULATION RESULTS

The final microwave integrated circuit (MIC) layout of the complete design is shown in Fig. 3(a). The optimum distributed HPF is embedded in step impedance LPF with nine reactive elements. This serves as BPF. This BPF is designed to have working bandwidth of 3.1-10.6 GHz.

The proposed ultra-wideband bandpass filter is deployed on substrate with a relative dielectric constant of 4.1 with thickness of 0.8mm and the filter occupies 26.4mm × 16mm die of area. The filter use microstrip line feed impedance of 50Ω with the width of each port 1.9mm. The simulated insertion loss and return loss are shown in Fig. 3(b) and this

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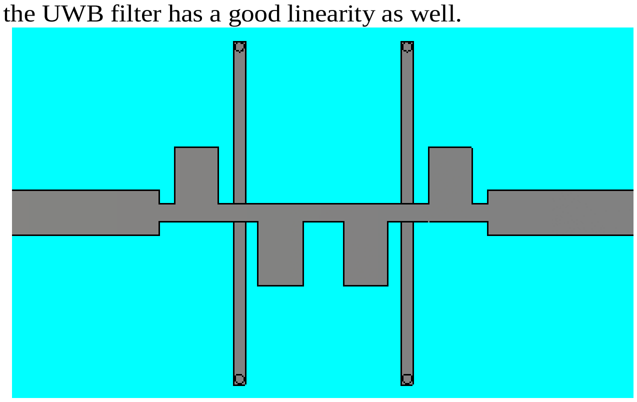
UWB bandpass filter shows 3dB bandwidth of 7.5 GHz (3.1-10.6GHz). The simulated group delay in Fig. 3(c) varies between 0.4 ns and 0.5 ns in the passband. This means that the UWB filter has a good linearity as well.



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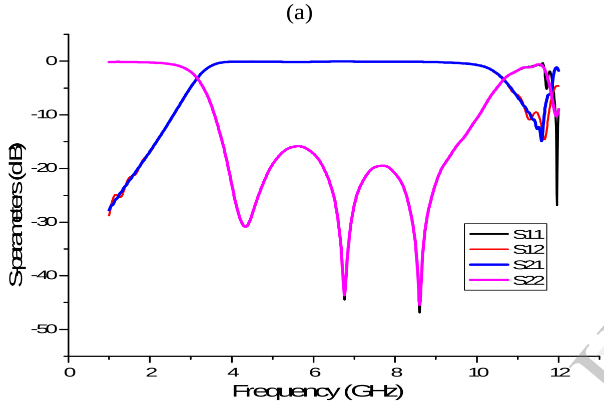

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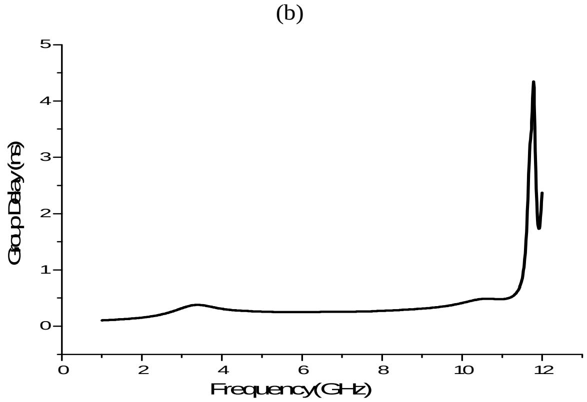


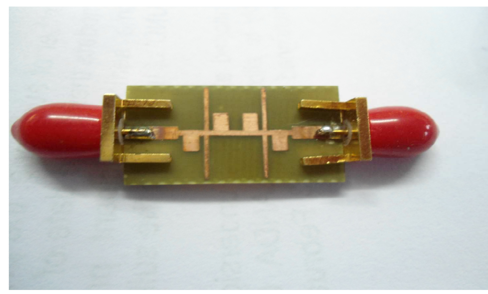
(c)

Fig.3 (a) MIC layout of proposed UWB filter (All dimension in mm),
(b) Simulated S-parameters of proposed UWB filter,
(c) Simulated group delay of proposed UWB filter.

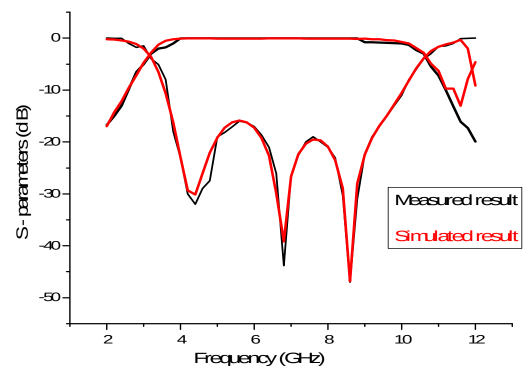
4. FABRICATED STRUCTURE AND RESULTS

The proposed UWB filter is realized on FR4 substrate. For designing of this structure FR4 substrate of thickness 0.8 mm with Dielectric constant of 4.1 is used. For the measurement of UWB filter the vector network analyzer (VNA) is used. The fabricated UWB bandpass filter is shown in Fig. 4(a). The measured and simulated insertion loss and return loss are shown in Fig. 4(b).

From the Fig. 4(b), it is clear that the fabricated structure of the proposed filter gives the approximately similar result to the simulated result of this filter. The measured 3dB bandwidth is from 3.1GHz-10.6 GHz.



(a)



(b)

Fig.4 (a) Fabricated structure of proposed UWB filter,
(b) Simulated and Measured result of proposed filter.

5.CONCLUSION

In this paper, the design of ultra-wideband BPF using short circuited stubs has been described and their simulated results are compared with measured results. It has 3dB bandwidth of 7.5 GHz and the variation of group delay is less than 0.5 ns within the band. The design method is that the optimum distributed HPF is embedded in step impedance LPF with 9 reactive elements. With the lowpass and bandpass filter designed separately, the method is more convenient and easily implemented. This compact size filter is useful in UWB systems.

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