Uwb Bpf using Quad Section Stepped Impedance Resonator

Thomas George and Lethakumari B

Abstract : Ultra wide band (UWB) frequency range is from 3.1 to 10.6 GHz with a bandwidth of 7.5 GHz. UWB bandpass filter(BPF) is an essential component of any UWB communication system. Design of UWB BPF with extremely high bandwidth is a challenge task. In this paper a simple method is developed for the design of UWB BPF. A quad section stepped impedance resonator (QSSIR) is used as the basic element of the filter. QSSIR has four impedance sections connected in cascade. Ultra wide bandwidth is realized by appropriately selecting impedance ratio and electrical length ratio of the SIR. Two transmission zeros are introduced in the insertion loss response by folding the QSSIR. Designed filter has bandwidth extending from 3.73 to 9.93 GHz with a fractional band width (FBW) of 91% and center frequency 6.83 GHz. There are five transmission poles in the obtained frequency response. Simulation is performed using ANSOFT HFSS. Designed filter was fabricated using FR4 substrate. Test results are found to be in good agreement with simulations. Proposed filter has a simple planar structure. Fabrication is easy. It can be used in UWB systems as band pass filter.

Keywords: Fractional bandwidth (FBW), Multiple mode resonator (MMR), Quad-section SIR (QSSIR), Stepped impedance resonator (SIR), Uniform impedance resonator (UIR), Ultra wideband (UWB).

I. INTRODUCTION

Ultra wideband frequency band is from 3.1 To 10.6 GHz [1]. U.S Federal Communication Commission (FCC) in 2002 legalized the use of UWB for license free applications. UWB provides high data rate in the range 110 Mb/s with very low power. Some of the applications of UWB band are position location, tracking, through wall imaging, medical imaging, wireless sensors, low power RFID tags and high speed wireless USB. Important advantages of this system are wide bandwidth, low power requirement and large throughput. According to FCC, the indoor and hand held operations of UWB must be strictly restricted in the range of 3.1 to 10.6 GHz. For implementing this frequency limit, bandpass filter is an essential building block in all UWB systems. Such an UWB BPF must have a fractional bandwidth of 109.5% with a center frequency of 6.85 GHz. A large number of diverse methods are available for UWB bandpass filter design in the literature. A filter using a multi mode resonator which is a stepped impedance resonator, coupled to the input output through parallel lines is capable of producing UWB response in the range 3.1-10.6 GHz [2]. A very simple method of UWB filter design is based on parallel coupled lines [3]. Coupling between lines is to be made tight for wideband response [4]. Tight coupling can be obtained by reducing the spacing between lines. Minimum realizable coupled space is dependent on the fabrication process. Sophisticated techniques are required for very narrow line spacing. High pass and low pass filters using liquid polymer technology are cascaded for achieving UWB response in [5]. A hybrid UWB filter is proposed in [6] using a CPW non-uniform resonator. In [7] a compact UWB BPF design is reported by connecting a short ended coupled line coupler and a transmission line in parallel.This paper proposes a very simple design approach for UWB BPF design. Proposed filter uses a single quad section SIR. QSSIR is folded and is connected to 50Ω input output feed lines. SIR operating as multiple mode resonator (MMR) helps to keep the structure compact. SIR folding leads to further reduction of the filter size. Folding also results in two signal travelling paths from input to output. This multipath introduces two transmission zeros, one each at the two edges of UWB passband. In order to obtain a wideband response, a number of higher order resonances of the SIR are located within the passband. It is to be noted that, the designed filter has a very simple structure.

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II. STEPPED IMPEDANCE RESONATOR

Makimoto and Yamashita in 1980 [8] first proposed SIR which is a logical extension of uniform impedance resonator (UIR). It is a multi mode resonator consisting of two composite transmission lines in cascade [9]. Simple two section SIR has two impedance sections Z_1 and Z_2 with electrical lengths θ_1, θ_2 connected together. Main advantages of SIR are compact size and independently tunable resonant frequencies. In addition to the above mentioned features, BPFs based on SIRs usually have high selectivity and low insertion loss. Hence SIRs are widely used for BPF design. Structure of a simple SIR is shown in Fig.1.

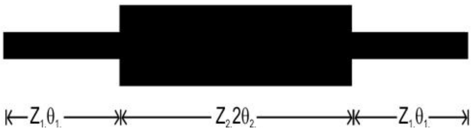

Fig.1. Simple SIR

The two important parameters which characterizes the SIR are the impedance ratio k defined as k = $\frac{Z_1}{Z_2}$ and the electrical length ratio α = $\frac{\theta_1}{\theta_1+\theta_2}$. The input admittance of SIR is given by,

$$Y_{in} = j\,\frac{Z_2\tan\theta_1\tan\theta_2 - Z_1}{Z_1(Z_1\tan\theta_1 + Z_2\tan\theta_2)} \quad (1)$$

From (1) it is clear that the resonant behavior of the SIR can be greatly controlled by varying the parameters k and α [8]. Fig.2 shows the structure of a quad section SIR (QSSIR) which is constituted by four impedance sections of Z_1, Z_2, Z_3 and Z_4 with electrical lengths θ_1, θ_2, θ_3 and θ_4. Asymmetric form of the above QSSIR is shown in Fig.3 and when folded it will appear as in Fig.4.

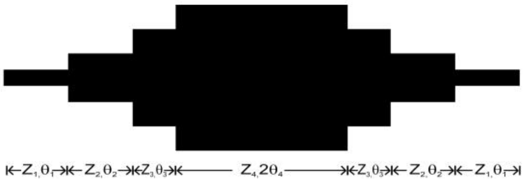

Fig.2. QSSIR

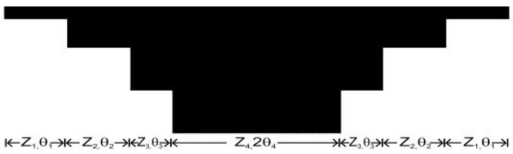

Fig 3. Asymmetric QSSIR

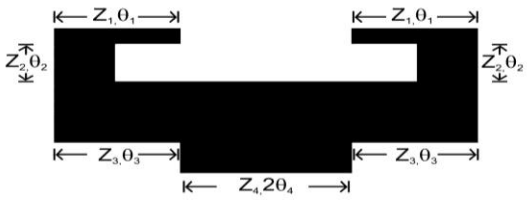

Fig 4. Folded QSSIR

III. PROPOSED UWB BPF

Structure of the proposed UWB BPF filter, which consists of a single QSSIR is given in Fig.5. Initially the SIR is appropriately tuned to get a flat S21 response. Then the tuned SIR is folded and two transmission zeros appear at both sides of the frequency response. This limits the passband into ultra wide band, 3.1 GHz to 10.6 GHz (7.5 GHz). Transmission zeros are formed due to signal multipath from input to output. Optimization of the designed structure is done using HFSS. Input output feed lines with 50Ω impedance are connected to the folded SIR.

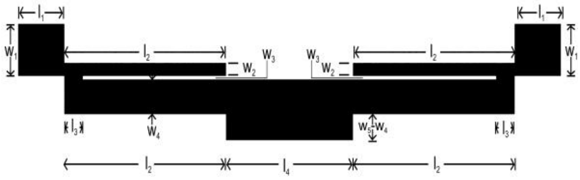

Fig.5. UWB BPF using QSSIR

The QSSIR used is having four impedance levels. Different parameters of the QSSIR are Z1 = 97.73 Ω, Z2 = 70.83 Ω, Z3 = 63.57 Ω, Z4 = 46.27 Ω, θ1 = 171.06º, θ2 = 2.50º, θ3 = 176.42º, θ4 = 70.86º, k1 = 1.38, k2 = 1.11 and k3 = 1.37. Dimensions of the filter are, l1 = 4mm, l2 = 14mm, l3 = 1.6mm , l4 = 11mm, w1 = 3mm, w2 = 0.75mm, w3 = 0.2mm, w4 = 2mm, w5 = 3.5mm. Passband of the filter is derived from five resonant frequencies from 3rd onwards. Resonant frequency locations are listed in Table 1.

Table 1. Resonant frequency locations

Transmission Pole locations in GHz	
Below the passband	1.55 2.6
In the pass Band	4 4.89 6.76 8.57 9.75
Above the Passband	10.23 10.63

IV. RESULTS AND DISCUSSIONS

The proposed filter was simulated using Ansoft HFSS 3D full-wave electromagnetic field simulation software version 13.0 based on finite element method (FEM). Filter was fabricated using conventional FR4 PCB board with dielectric constant $\varepsilon_r = 4.4$, dielectric loss tangent tan δ = 0.02 and with a thickness of h = 1.6 mm. Input and output ports are connected to SMA connectors for measurement. Photograph of the fabricated filter with SMA connectors is shown in Fig.6. Ground plane area of the filter is only 47 mm x 11 mm = 517 mm^2. Fabricated filter was tested using KESIGHT E5063A (100 KHz – 18 GHz) Series Network Analyzer.

Fig.6. Photographs of fabricated filter

Responses of the simulated and fabricated filters are shown in Fig.7. Simulated band pass response is from 3.73 to 9.93 GHz (6.20 GHz) and measured 4 to 9 GHz (5 GHz). Comparison of various parameters of simulated and fabricated filters are given in Table 2. Some of the reasons for deviations in the measured results are tolerances in the fabrication process, SMA connectors, radiation loss and soldering.

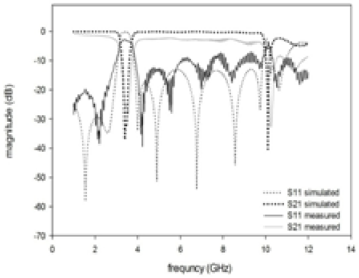

Fig.7. Filter response

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Insertion loss is found to be increasing with frequency increase. It is mainly attributed to variation of material characteristics with frequency.

Table 2. Comparison of parameters of the filter

Parameter	Simulated	Measured
Lower cut off frequency	3.73 GHz	4.00 GHz
Upper cut off Frequency	9.93 GHz	9.00 GHz
Center frequency	6.83 GHz	6.50 GHz
Bandwidth	6.20 GHz	5.00 GHz
Location of first transmission zero and insertion loss	3.40 GHz 37 dB	3.56 GHz 28 dB
Location of second transmission zero and insertion loss	10.11 GHz 41 dB	10.25 GHz 32.8 dB
Maximum in band insertion loss	0.64 dB	3.93 dB
Minimum in band return Loss	-13 dB	-7.90 dB
Fractional band width	91%	77%

V. CONCLUSION

A simple UWB BPF is designed using a single folded quad section SIR. Ultra wide band response is achieved by tuning the two SIR parameters, impedance ratio and electrical length ratio. Folding of the QSSIR leads to multipath and two transmission zeros are generated, which limits the response into ultra wide bandwidth. Experimental verification is done by fabricating and testing the filter. Test results are found to be in good agreement with simulations. Designed filter has the advantages of simple structure, low cost, small size, good skirt selectivity, low insertion loss and wide passband. Since no via holes and defected ground structures are used, fabrication of the filter is easy. This filter can be used as bandpass filter in UWB communication systems.

REFERENCES

1. United States Federal Communication Commission (FCC, www.fcc.gov) , Revision of Part 15, the Commission's Rules Regarding to Ultra Wide Band Transmission System, First Note and Order Federal Communication Commission, ET-Docket 98-153, 2002.
2. L. Zhu, S. Sun and W. Menzel, "Ultra-Wideband (UWB) Bandpass Filters using Multiple-Mode Resonator", IEEE Microwave & Wireless Component Letters, Vol. 15, No. 11, 2005, pp. 796–798.
3. R. Xiao, G. Yang , Y. Wang and W. Wu, "Compact and High Selectivity Dual Band Dual Mode Microstrip BPF with 5 Transmission Zeroes", IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies, Oct 2017, pp.300-302
4. D. –M. Pozar, "Microwave Engineering", 2nd ed., New York: Wiley 1998
5. Z. Hao and J. Hong, "UWB Bandpass Filter using Cascaded Miniature High Pass Low Pass Filters with Multilayer Liquid Crystal Polymer Technology", IEEE Transactions on Microwave Theory and Techniques, Vol.58, no.4, April 2010, pp.941-948
6. H. Wang, L. Zhu and W. Menzel, "Ultra-wideband bandpass filter with hybrid microstrip/CPW structure", IEEE Microwave and Wireless Component Letters, Vol. 15, No. 12, 2005, pp. 844–846.
7. A. Miguel, E. Bronchalo and G. T. Penalva, "Compact UWB Bandpass Filter Based on Signal Interference Technique", IEEE Microwave and Wireless Components Letters, Vol.19, No.11, Nov.2009,pp.692-694.
8. M. Makimoto and S. Yamashita, "Microwave Resonators and Filters for Wireless Communication Theory, Design and Application", Springer, Japan,2000, Ch.2.
9. F. Sakai, M. Makimoto and K. Wada, "Multimode Stepped Impedance Resonators and Their Applications in Chipless RFID Tags", European Microwave conference, 2016.

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