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A Compact UWB BPF with a Notch Band using Rectangular Resonator Sandwiched between Interdigital Structure

Yatindra Gaurav[1], R.K. Chauhan[2]
Departement of Electronics and Communication Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

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ABSTRACT

This paper presents a compact design of an ultra wide band bandpass filters with a notch band using interdigital structure. The aim of the design is to reduce the size of filter, reduce the complexity of the design, and improve the performance of filter response. The proposed filter comprises of a rectangular resonator sandwiched between Interdigital structures, with rectangular slot as defected microstrip structure at the input and output ports. This design has been used for the first time to achieve the above aim. The advantage with this design is that, it does not use any via or defected ground structure. The insertion loss of proposed filter, in passband between 3.1 GHz to 10.8 GHz, is less than 0.7dB, and for the notched band it is 21.5 dB centred at 7.9 GHz. The proposed filter is fabricated, tested and compared with simulated results. The proposed design was small in size with less complexity, and shows performance better than the other designs available in the literatures at this dimension.

Corresponding Author:

R. K. Chauhan,
Departement of Electronics and Communication Engineering,
Madan Mohan Malaviya University of Technology,
Gorakhpur, Uttar Prdesh, India.
Email: rkchauhan27@gmail.com

1. INTRODUCTION

Ultra-Wideband (UWB) devices and systems have attracted the attention since the Federal Communications Commission has released the unlicensed use of the frequency spectrum 3.1 - 10.6 GHz for UWB applications in 2002 [1]. High performance and compact size are the two important issues that has been an active area of research in the last decade [2], [3], [4], [5], [6] and [7]. For high performances algorithm methods and modified ground plane method is being used recently for various ultra wide band application [8] and [9]. The investigation on UWB bandpass filter, which is one of the main components of UWB communication systems, has been a subject of interest. Several UWB Filters has been proposed and implemented recently [10], [11], [12] and [13]. Earlier the focus was on the passband requirement, but later on research shifted towards the addition of notch within the passband.

To realize a notch band in UWB BPF, several techniques has been proposed in the last few years. In one of the work, a coplanar waveguide (CPW) technique is used to obtain a notch band [14]. A ring resonator with two stepped impedance stubs as well as multiple slotline resonators has been used to create a notch band in UWB BPF [15] and [16]. A compact UWB BPF has been realized recently for better notch band characteristics using dual stub loaded resonator and folded T-shaped stepped impedance resonator [17] and [18]. However, all the above designs shows good response to return loss and insertion loss but have a drawback of larger area and complexity in design that leads to increase in number of fabrication steps. For reducing the size of UWB BPF with a notch band, defected ground structures were used in the design by several researchers [19]. Such structure shows improved filter performance, but the drawback is that its complexity increases and fabrication becomes difficult. Recently, a UWB BPF using a ring resonator with interdigital-coupled feed-line planar structure is being proposed to overcome some of the above deficiencies [20].

Here in this paper, a compact UWB BPF structure is proposed whose area is less and capable of realizing notch band centred at 7.9 GHz to eliminate interference from satellite communication system with the help of rectangular resonator sandwiched between two interdigital structure. Also, the effect of rectangular slot, used to connect the interdigital structures to the respective input and output ports, on filter performance has been analyzed. The filter is fabricated on FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm, and its size is of 0.569 λg × 0.083 λg, where λg is the guided wavelength of 50 ohm microstrip line at 6.85 GHz. The proposed filter is designed using ADS software and fabricated and tested at Central Instrument Facility Centre, IIT-BHU, India.

2. ANALYSIS AND DESIGN OF THE PROPOSED UWB BPF

The structure of proposed filter consists of a rectangular resonator with open stub finger lines sandwiched between two interdigital structures, see Figure 1. Interdigital structure in the filter is a combination of coupled finger lines, which can be represented as an equivalent circuit which consists of inductor and capacitor, see Figure 2(a) and (b). The length of finger generates effect of inductance L, and capacitor C is generated by gap between the fingers. Capacitor CP1 and CP2 are generated due to dielectric material of the filter. From the equivalent circuit and frequency response of interdigital structure, it is clear that the behaviour of Interdigital structure is like a band pass filter with its harmonics.

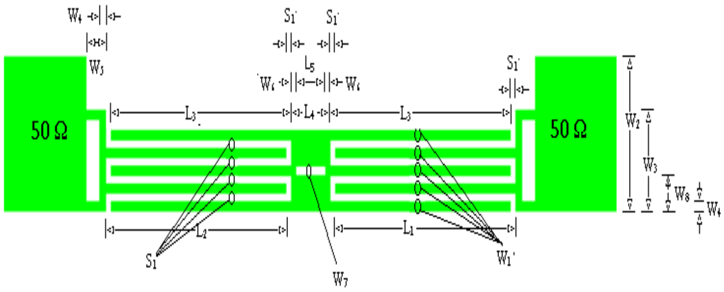


Figure 1. Configuration of the proposed UWB BPF with rectangular slot at input/output port

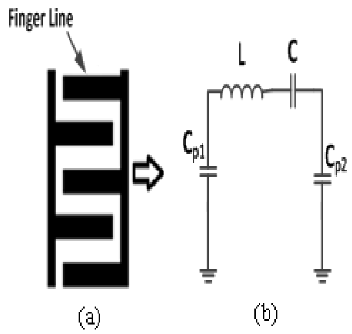


Figure 2. Interdigital Structure (a) Layout (b) Equivalent circuit

The first higher cut off frequency of the Interdigital structure is used as a notch of the filter at 7.9GHz and second higher cutoff frequency of Interdigital is used to create higher cut off frequency of the proposed filter. The frequency response of this structure can be varied by varying the length of interdigital coupled lines L1 and L2, see Figure 3(a). On increasing the length of L1, keeping L2 constant, the notch band of structure shifts towards lower frequency, with the slight decrease in the value of higher cut off frequency. The effect on lower cut off frequency is negligible, see Figure 3(b). When the L2 length is increased, keeping the L1 constant, then higher cut off frequency reduces, without affecting notch band and lower cut off frequency, see Figure 3(c).

But the attenuation at 7.9GHz is not satisfactory; therefore some modification in the design is needed to improve it. On using a resonator of rectangular shape with open stub finger lines of length L3, the attenuation at 7.9GHz was found to improve. To improve the stop band rejection for frequencies above higher cut off frequency, a resonator is sandwiched between two Interdigital structures. Although this combination is showing a band pass nature with a notch in its pass band, but the lower and higher cut off frequencies are not satisfying the UWB frequency range. The notch band as well as higher cut off frequency can be controlled by the length L1 and L2 as described above. To vary higher and lower cut off frequency, without affecting the notch band frequency, the use of variation in L1 and L2 is quite difficult. To make it easier, a rectangular slot as defected microstrip structure is introduced to connect the interdigital structures to the respective input and output ports as shown in Figure 1.

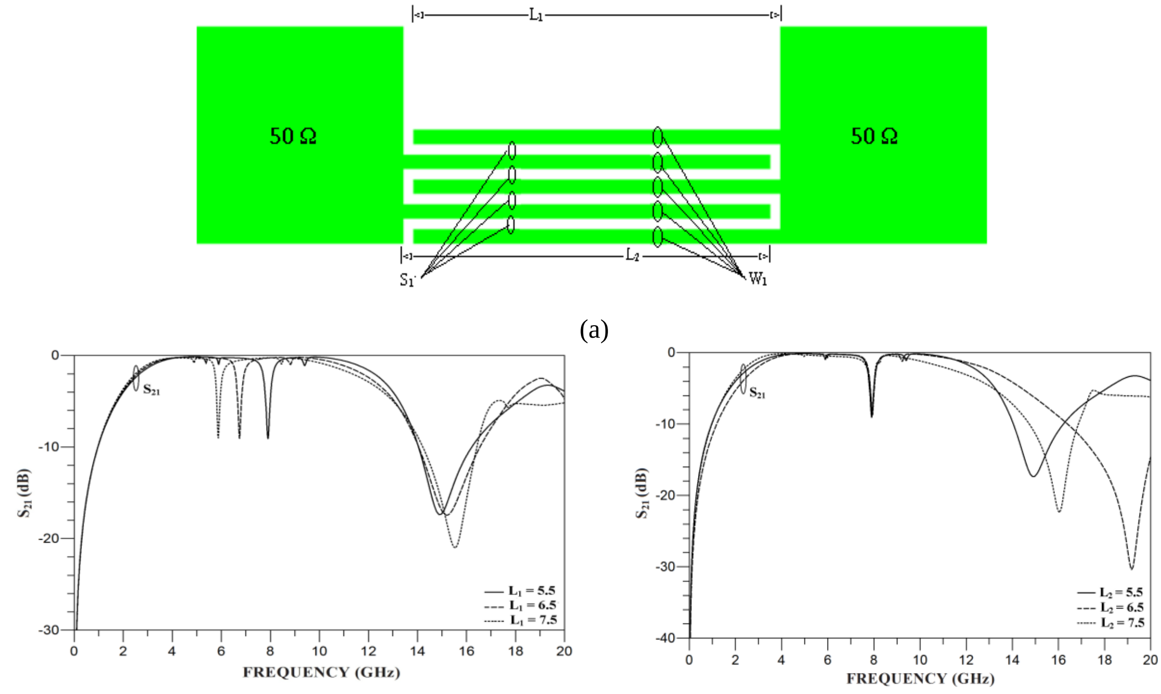


Figure 3 (a) Layout of the coupling structure. (b) L2 is kept constant and L1 is varied. (c) L1 is kept constant and L2 is varied

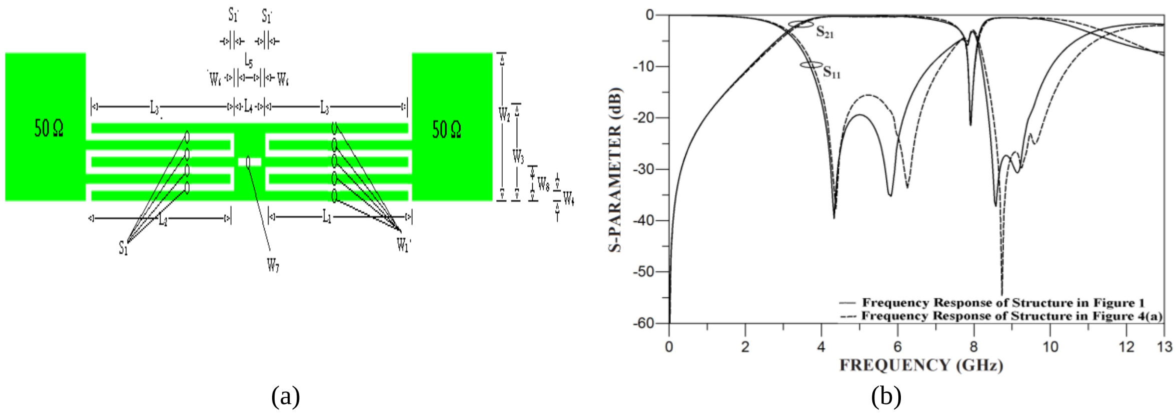
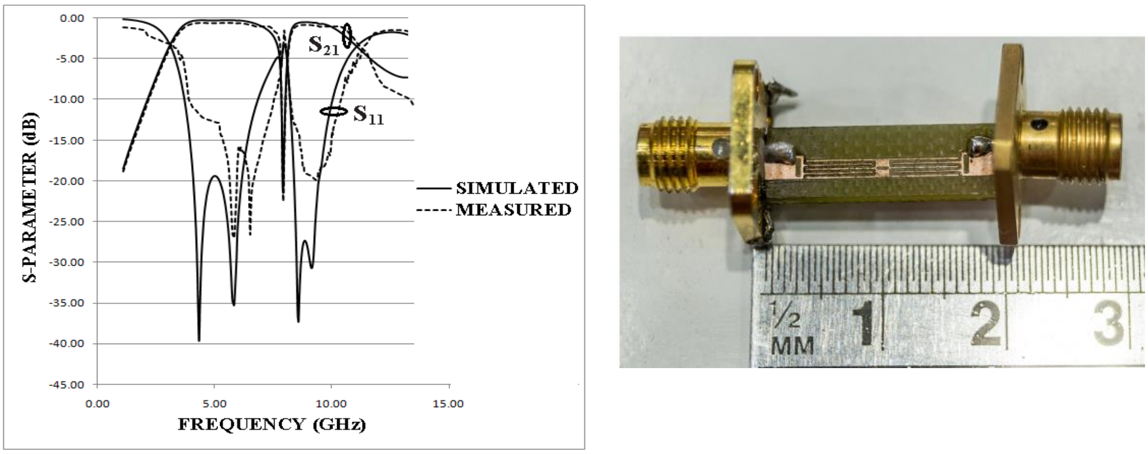


Figure 4 (a) Proposed filter without rectangular slot at input/output port. (b) S-parameter of Proposed filter with and without rectangular slot

To see the impact of rectangular slot on the performance of proposed design, the structure without rectangular slot, shown in Figure 4(a), is simulated and compared, see Figure 4(b). It was observed that the rectangular slot does not affect notch frequency of the filter, but on varying its length and width, the higher and lower cut off frequencies can also be changed. It also shows that there is a slight decrease in the value of lower cut off frequency by 0.15GHz and the higher cut off frequency decreases by 0.35GHz. Improvement is also seen in the insertion loss and return loss of the filter. Therefore, it can be inferred that the introduction of rectangular slot (a) improves the matching between ports and filter, that finally improves the S-parameters of the proposed filter, and (b) finger length reduces to achieve the same response of the filter. By optimizing the dimensions of fingers, rectangular slots, and resonator's dimension, the pass band range of the filter is achieved between 3.1GHz and 10.8GHz with a notch at 7.9GHz.

3. FABRICATION AND MEASUREMENT

The proposed filter is fabricated with dimensions as follows: L1=L2=L3= 5.5 mm, L4= 1.2 mm, L5= 0.9 mm, W1= 0.2 mm, W2= 3.05 mm, W3= 2 mm, W4= 0.2 mm, W5= 0.6 mm, W6= 0.15 mm, W7= 0.17 mm, W8 = 0.715 mm, S1 = 0.15 mm. The lower and higher cut off frequencies of the UWB bandpass filter in the simulated results were 3.1 GHz and 10.8 GHz whereas, these frequencies when measured, shows 3.3 GHz and 11.1 GHz respectively. The notch band centred at 7.9 GHz having 10-dB rejection fractional bandwidth is 2.1 %. The insertion loss in simulated result within the passband is less than 0.7dB and the return loss is more than 19.37 dB. The measured results shows insertion loss less than 1 dB and return loss greater than 15.9 dB, see Figure 5(a). The size of the filter is 0.569 λg × 0.083 λg, see Figure 5(b).



(a) (b)

Figure 5 (a) Comparison between simulated & measured. (b) Photograph of the fabricated filter

Proposed filter is fabricated on a FR-4 substrate with a relative dielectric constant of 4.4 and a thickness of 1.6 mm. Table 1 describes the comparative study of the performance of proposed design with that of already existing design mentioned [14], [15], [16], [17], [18], [19] and [20].

Table 1. Comparison between proposed design and previous design

Ref. No.	Relative Dielectric Constnt/Thickness of Dielectric (mm)	Insertion Loss (dB)	Return Loss (dB)	3-dB Fractional Bandwidth (%)	Size ((λg×λg)	Notch Capability
14	2.2/0.508	0.9	11.6	113.5	0.3 × 0.17	Yes
15	6.15/0.635	1.33	8	102.8	1.05 × 0.51	Yes
16	2.2/0.127	1.1	10	125	0.27 × 0.22	Yes
17	3.38/0.81	0.94	12	123	0.94 × 0.14	Yes
18	2.55/0.8	1.5	10	122	0.75 × 0.48	No
19	2.65/1.0	<2	>20	118	1.012 × 0.539	Yes
20	3.5/0.508	1	13	118	0.58 × 0.12	Yes
This Work	4.4/1.6	0.7	.19.37	111	0.569 × 0.083	Yes

4. CONCLUSION

In this paper a planar, compact UWB BPF using a rectangular resonator sandwiched between two interdigital structures is designed, implemented and measured. A good agreement between simulated and measured result is found. The proposed filter shows smaller size and better performance than the previously reported filters, as reported in Table-1. The size of the filter is only 0.57 $\lambda g \times 0.083\ \lambda g$ with 3dB fractional bandwidth of 111% in pass band and good attenuation in notch and band stop frequency range. The notch band at centre frequency 7.9 GHz with 10dB rejection fractional bandwidth of about 2.1% has been achieved. This design therefore avoids interference with satellite communication. In the design of proposed filter a rectangular slot as a defected microstrip structure is used at input/output ports to improve impedance matching and frequency response of the filter. The use of this slot is a new concept, and it avoids the use of via or defected ground structure which makes the fabrication of filter easier and cost effective.

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BIOGRAPHIES OF AUTHORS

Yatindra Gaurav received a Bachelor of Technology degree in Electronics and Communication Engineering from Uttar Pradesh Technical University of Uttar Pradesh, India in 2006 and received his Master of Technology in Electronics Design and Technology from Uttar Pradesh Technical University of Uttar Pradesh, India in 2010. He now holds a research scholars chair at the Madan Mohan Malaviya University of Technology, Gorakhpur, Uttar Pradesh, India. His main research interests is Microwave Bandpass Filter using Resonators.

Dr. Rajeev Kumar Chauhan received the Ph.D degree in Electronics Engineering from IIT-BHU, Varanasi in 2002 and ME from MNNIT – Allahabad in 1993 and B.Tech from G.B.P.U.A.T –Pantnagar in 1989. He has joined erstwhile Madan Mohan Malaviya Engineering College, Gorakhpur in 1993 as a Lecturer, as an assistant professor from 2002 and Associate Professor since 2006. The college has been reconstituted as Madan Mohan Malaviya University of Technology by U.P. State Government in 2013. He also worked as Professor in Department of ECE, Faculty of Technology, Addis Ababa University, Ethiopia between 2003 to 2005. He is author of more than 100 research papers published in Journals and Conferences. His current research interests include emerging nanoscale devices and issues in in VLSI as well as circuits and systems. He is also involved in exploring the microstrip based antenna and metamaterials based filter design. He has just completed one AICTE sponsored Research Project on "Design and Development of SRAMs".