Miniaturized UWB BPF using Stub Loaded Pseudo-Interdigital Structure

Yatindra Gaurav[1], R. K. Chauhan

Abstract – **This paper presents a compact and planar design of an ultra wideband bandpass filters using stub loaded pseudo-interdigital structure. The design is aimed to reduce the size of filter and improve its passband performance with better selectivity. Traditional interdigital structure is modified to reduce the ripples in the pass band for good insertion and return losses. Stubs are then loaded on the proposed pseudo interdigital structure to control the selectivity and cut-off frequency of the filter. The insertion loss of proposed filter in passband between 2.8 GHz to 10.9 GHz is less than 1 dB, and the return loss is more than 16 dB with centre frequency at 6.85 GHz. The proposed filter is fabricated, tested and compared with previously reported results. The structure is much smaller in size and shows better performance when compared to other reported structures.**

Keywords – **Interdigital structure, Ultra wideband, Bandpass filter, Stub, Selectivity.**

I. INTRODUCTION

Ultra-Wideband (UWB) technology based filters and devices are being developed continuously in the field of communication system for unlicensed use of the frequency spectrum 3.1 - 10.6 GHz from last decade. High performance and compact size of the devices are the two basic research areas in the ultra wideband devices and systems. UWB bandpass filters with different design methods, structures and architectures have been proposed and implemented in previously reported researches [1-3].

Several design techniques are being adopted in the last few years to obtain small size and compact design with good passband characteristics of filter. One of the design techniques uses multiple-stub loaded to a resonator [4-5] to have a passband in UWB BPF. A passband in UWB BPF has also been achieved by the use of three-feed-line coupled resonator (TLCR) [6] and dual stub loaded resonator [7]. To realize a passband in UWB BPF, short-circuited stubs in a cross-coupling structure were used [8]. Recently to achieve the miniaturization the interdigital structure was modified but it lacks behind with good passband characteristics and selectivity of filter [9]. A continuous effort is therefore going on to achieve good passband characteristics with selectivity considering miniaturization as main constraint.

In this work, a planar and compact UWB BPF structure of small size, using new pseudo-interdigital structure with stub is proposed for the first time to achieve good passband characteristics. The filter is fabricated on FR_4 epoxy substrate with a dielectric constant of 4.4, tangent delta value of 0.013 and thickness of 1.6 mm. The electromagnetic simulation and designing of proposed filter is done on Keysight Technologies Advanced Design System (ADS) using method of moments (MOM) approach and is fabricated and tested at Central Instrument Facility Centre, IIT-BHU, India.

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II. ANALYSIS AND DESIGN OF PROPOSED UWB BPF

The proposed UWB BPF structure consists of pseudo-interdigital structure loaded with stubs and rectangular slot, Fig. 1. This pseudo-interdigital structure also has combination of coupled finger lines.

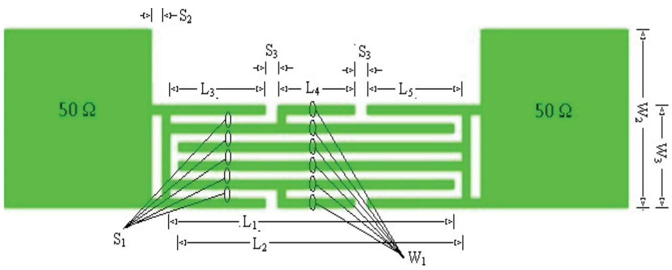

Fig. 1. Configuration of the proposed filter

The study of interdigital structure for successful design of BPF has been done before proposing new psedo-interdigital structure. The effect of inductance and capacitance in the interdigital structure is generated by the length of fingers and the space between them respectively. The capacitors, C_{P1} and C_{P2} generated due to dielectric material of the filter, are shown in the equivalent circuit, Figs. 2 and 3. 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. But due to couplings between different capacitors and inductors some ripples are generated in the pass band of the frequency response. To remove these ripples, coupling of finger lines were modified as shown in Fig. 4. Fig. 5 shows the comparison of frequency response of BPF designed using interdigital and pseudo-interdigital structure.

The length of fingers in the proposed structure controls the higher cut off frequency of the filter. On increasing its length L_1 by keeping L_2 constant, the inductive effect of structures increases and because of this, the higher cut off frequency of filter decreases, as shown in Fig. 6. The same effect was seen when length L_2 was varied, by keeping L_1 constant, as shown in Fig. 7.

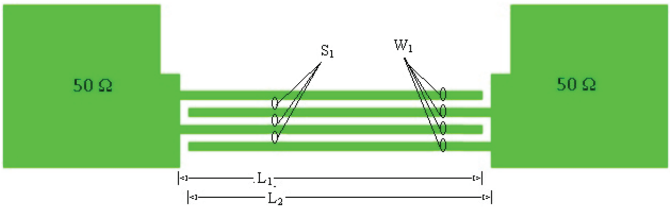

Fig. 2. Interdigital structure

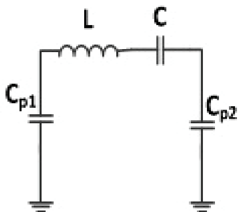

Fig. 3. Equivalent circuit of interdigital structure

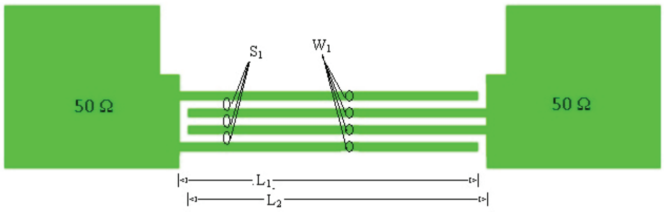

Fig. 4. Pseudo-interdigital structure

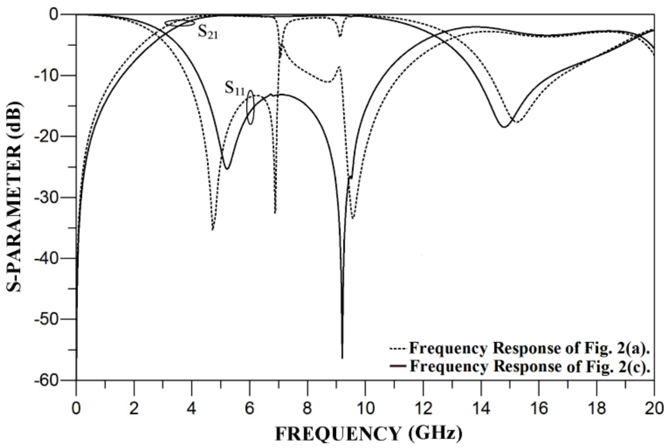

Fig. 5. S-Parameter of interdigital structure and pseudo-interdigital structure

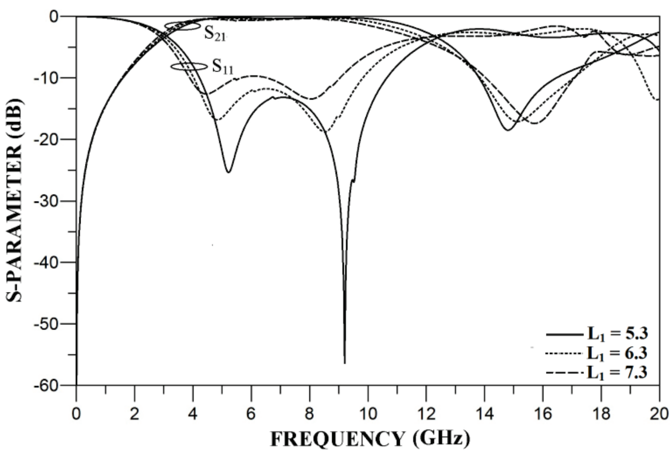

Fig. 6. S-Parameter of pseudo-interdigital structure when L_2 is kept constant and L_1 is varied

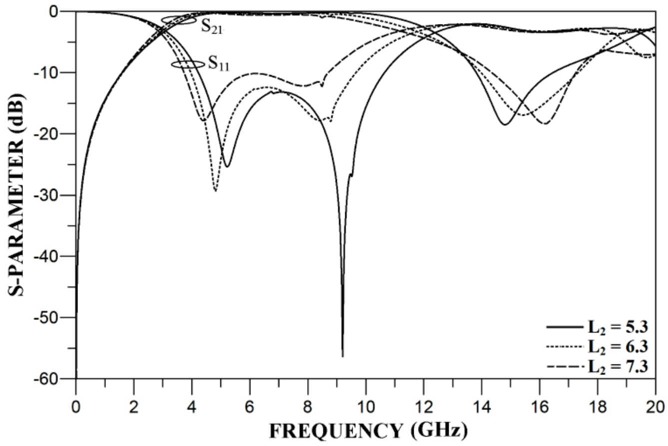

Fig. 7. S-Parameter of pseudo-interdigital structure when L_1 is kept constant and L_2 is varied

To control the selectivity and cutoff frequencies, transmission zeros are created near the cut off frequencies of filter by loading stubs on pseudo Interdigital structure of length L_3 and L_5, as shown in Figs. 8 and 9. Figure clearly shows that the selectivity of filter improves on introducing L_3 and L_5 and a higher and lower cut-off frequency reduces by 1.1 GHz and 0.25 GHz respectively.

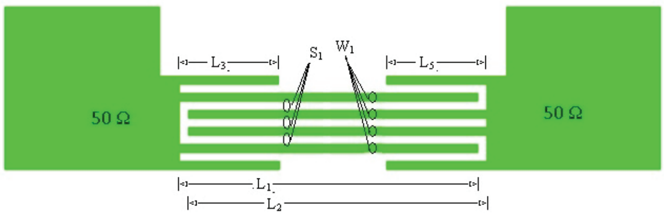

Fig. 8. Pseudo-interdigital structure with L_3 and L_5 length stub

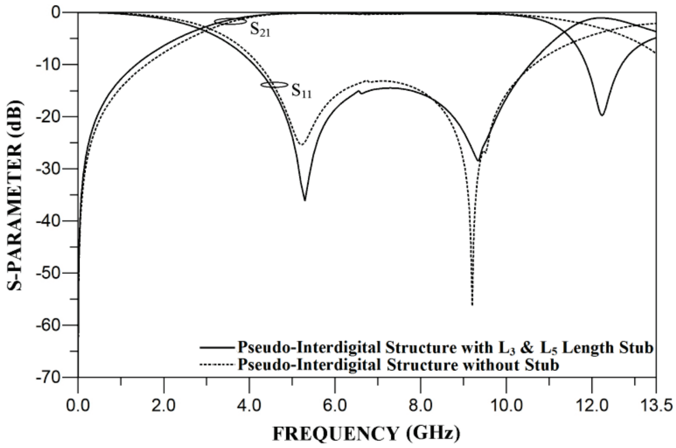

Fig. 9. S-Parameter of pseudo-interdigital structure with and without L_3 & L_5 length stub

For further improvement in S-parameter performance of passband, a rectangular slot is introduced at the interface of pseudo-interdigital structure at its input/output ports, see Fig. 10. A reduction in an upper cut-off frequency is seen by value of 0.25 GHz while the lower cut-off frequency remains almost same, Fig. 11. An additional stub L_4 is loaded to improve the return loss and cut-off frequencies, Fig. 1. The impact of stub length L_4 reduces the higher cut-off frequency by value of 0.15 GHz while the return loss is improved by value of 1.7 dB. The lower cut-off frequency and insertion loss remains almost same, Fig. 12. The presence of L_4 between L_3 and L_5 in the structure of proposed filter creates capacitive effect which include electric coupling between input and output ports and also improves impedance matching. The displacement current flowing through gaps between stub length L_3, L_4 and L_5 creates a magnetic coupling. Also, the rectangular slot and stub length L_4 together shows some improvement in selectivity, insertion loss and return loss which makes the proposed structure result different from the result of the structure for pseudo-interdigital filter used in enhancing the performance of monopole antenna for UWB application [9]. By optimizing the dimensions of fingers, rectangular slots and stubs, the pass band range of the filter is achieved between 2.8 GHz and 10.9 GHz, with 118% 3dB FBW. The optimized dimensions of the design are as follows: $L_1 = L_2 = 5.3$, $L_3 = 1.78$, $L_4 = 1.44$, $L_5 = 1.78$, $W_1 = 0.15$, $W_2 = 2.87$, $W_3 = 1.65$, $S_1 = 0.15$, $S_2 = 0.2$, $S_3 = 0.225$ (all dimensions are in millimetre).

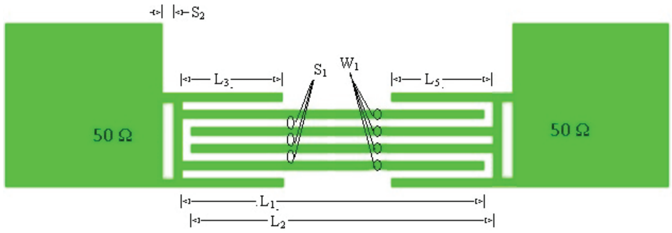

Fig. 10. Pseudo-interdigital structure with rectangular slot, L_3 and L_5 length stub

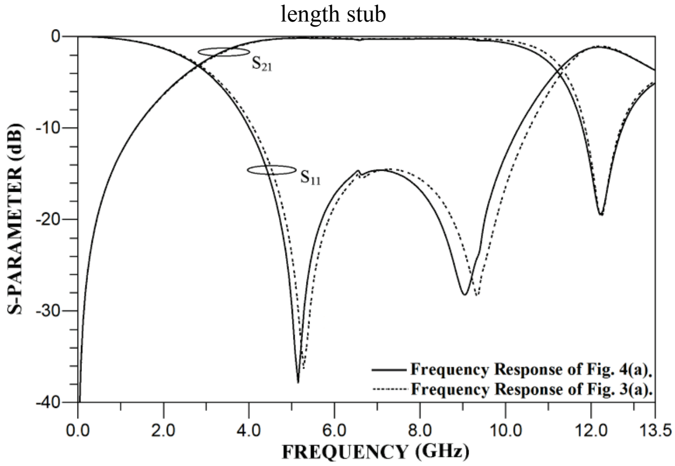

Fig. 11. S-parameters of pseudo-interdigital structures shown in Figs. 10 and 8

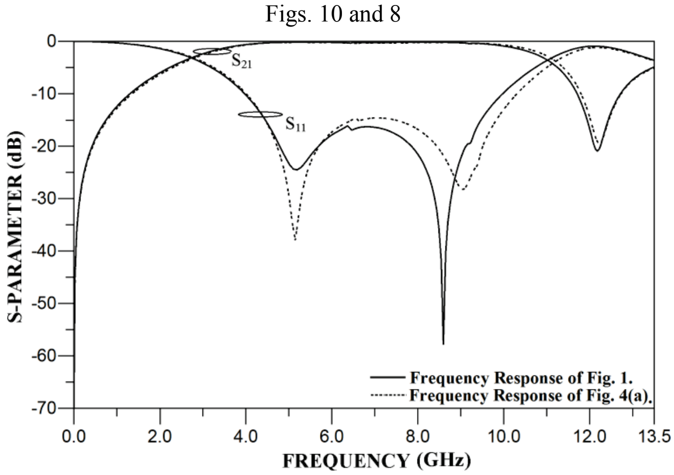

Fig. 12. S-parameters of pseudo-interdigital structures shown in Figs. 1 and 10

III. Fabrication and Measurement

The proposed filter is fabricated on FR4 substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm, shown in Fig. 13. The size of the filter is $0.265\ \lambda_g \times 0.071\ \lambda_g$ (where λ_g is the guided wavelength of 50 Ohm microstrip line at 6.85 GHz). The measured lower and higher cutoff frequency is found to be 3.1 GHz and 11.4 GHz whereas simulated is 2.8 GHz and 10.9 GHz. The measured Insertion and return loss is found to be less than 2 dB and more than 16 dB whereas simulated is less than 1 dB and more than 16 dB within passband. Comparing the size of pseudo-interdigital structure with other reported results, as shown in Table-1, it was found to be smallest of them. The simulated and measured frequency response of BPF is shown in Fig. 14. Table 1 describes the comparative study of the performance of proposed design with that of already existing design mentioned [4-8]. Three samples of the proposed filter was fabricated and measured on Vector Network Analyzer (VNA) the variation in result was seen negligible so only result of one sample is shown. The tolerance in fabrication is approximately 0.5 mm which is much less than $\lambda_g/4$ at 6.85 GHz. Simulated and measured result are seen in good agreement with some losses in measured results. The losses in measured result represent dielectric loss and SMA connector loss etc.

TABLE 1
Comparison of Proposed Design with Other Reported Designs

S.No	ε_r/h (mm)	IL (dB)	RL (dB)	3-dB FBW (%)	Size
4	2.55/0.8	≤1.4	>11.1	117	$0.747\ \lambda_g \times 0.542\ \lambda_g$
5	2.55/0.8	≤0.2	>10	117	$0.753\ \lambda_g \times 0.457\ \lambda_g$
6	2.65/0.8	<1	>13	117	$0.3399\ \lambda_g \times 0.1088\ \lambda_g$
7	2.55/0.8	<1.5	>10	122	$00.75\ \lambda_g \times 00.48\ \lambda_g$
8	2.45/0.8	<3	>12.5	108	$0.6251\ \lambda_g \times 0.4606\ \lambda_g$
This work	**4.4/1.6**	**< 1**	**>16**	**118**	**$0.265\ \lambda_g \times 0.071\ \lambda_g$**

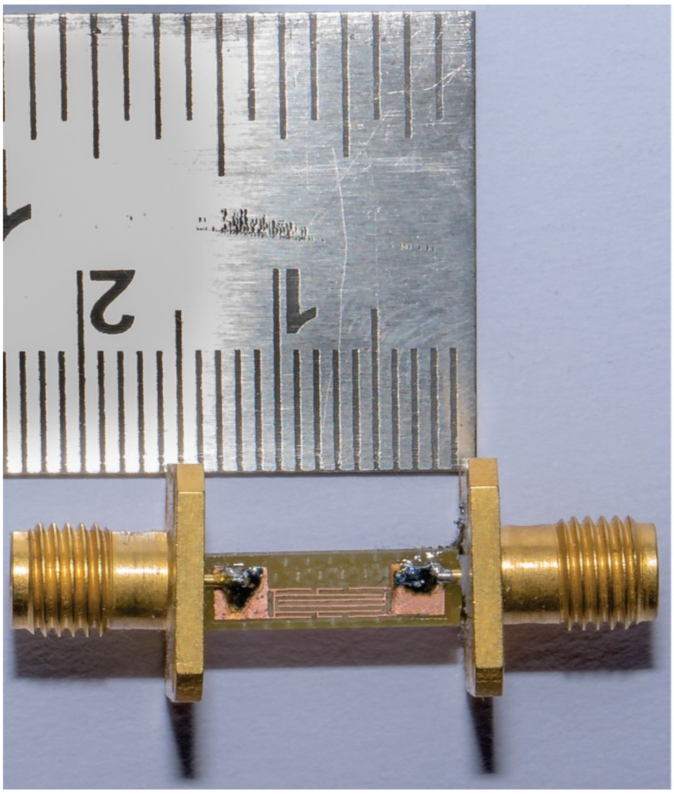

Fig. 13. Photograph of fabricated proposed filter

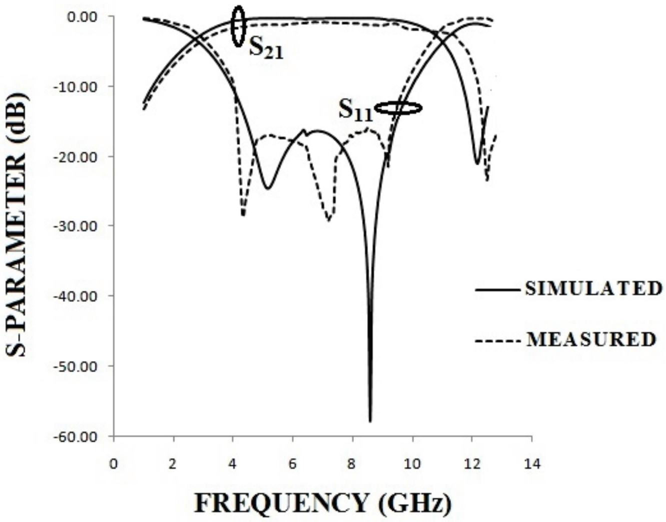

Fig. 14. S-parameter of simulated and measured proposed filter

IV. CONCLUSION

In this paper a new pseudo-interdigital structure is proposed and used to design an UWB bandpass filter. Stubs are loaded on the structure to improve the insertion loss, return loss, selectivity and cut off frequencies of the filter maintaining good passband characteristics with miniaturization. A good agreement between simulated and measured result is found. Insertion and return loss of the filter is good. The proposed designed filter has smaller size and better performance at this scale than the previously reported filters, as shown in Table 1. The filter has small size of 0.265 $\boldsymbol{\lambda}_g \times 0.071\ \boldsymbol{\lambda}_g$ with 3dB fractional bandwidth of 118%. The proposed filter does not use any via or defected ground structure, thus making fabrication easier and cost effective.

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