Design of UWB BPF using diamond shape microstrip resonator nestled between inter digital structure.

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***Abstract*—An UWB BPF utilizing a diamond-shaped resonator is described in the paper. It encompasses an innovative design approach and simulation results for an UWB BPF. The filter design integrates diamond-shaped resonators between the interdigital structures. Filter operates efficiently across a broad frequency range from 3.2 GHz to 11.25 GHz. This filter exhibits an impressive fractional bandwidth of 105.9%. The filter configuration is physically realized on an FR4 epoxy substrate with a thickness of 1.16 mm and a relative permittivity of 4.4. These compelling findings are rigorously supported by simulated results obtained using Keysight Advanced Design System (ADS). The filter is physically implemented and tested and is found to be in good similarity with the simulated result.**

Keywords— Ultra-wideband (UWB) Band pass filter (BPF), pass band filter, diamond-shape resonator, inter-digital structure, bandwidth

I. INTRODUCTION

In recent dynamic landscape of wireless communication systems, there is an unmistakable surge in demand for ultra-wideband band pass filters [5-9]. Since Federal Communication Commission (FCC) has approved the unlicensed frequency range from 3.1 to 10.6 Gigahertz. of UWB [17], this frequency range has played an valuable role in enabling transmission and reception of wide array, ensuring seamless communication across a diverse spectrum of frequency bands [10,11]. As technology continues its relentless march forward, the need for highly efficient pass band filters becomes increasingly critical, particularly in applications like broadband communication, radar systems, and wireless transceivers [12] since this frequency range has a wide range of scientific and short-range communication applications. This includes wireless communication widely [13-16], radar precise sensing and signal transmission with great efficiency. Radar and monitoring UWB technology offers a wide range of applications across industries, enabling high-speed communication, precise sensing, and accurate positioning in various environments and scenarios.

In the search for innovative approach, engineers had devised an ingenious idea for designing the filter. By employing a diamond-shaped resonator nestled between inter digital structures and utilizing an advanced RF and microwave simulation software like Keysight Advanced Design System, they have empowered themselves to craft high-performance ultra-wideband band pass filters with precision and speed. This can be achieved by designing a filter with two square shaped boxes between which some rectangular fingers are coupled and a diamond shaped resonator is sandwiched between these shape resonators as mentioned in the paper. Through careful optimization of the diamond-shaped resonator's dimensions and characteristics, this design aims to broaden the filter's pass band while ensuring exceptional performance in terms of pass band flatness, insertion loss, and return loss [17-22].

This paper takes an in-depth dive into the comprehensive design methodology and simulation techniques utilize to craft an ultra wide band band pass filter that can fulfill the requirements of communication systems and devices to present era. The paper delve into the complexities of the design process, simulation results, and comparative analysis shedding light on the distinct advantages of the proposed filter over traditional designs. This innovative approach to ultra wideband band pass filtering holds great promise for revolutionizing signal processing in high-frequency applications.

II. ANALYSIS AND DESIGN OF UWB BPF

A. Interdigital Structure

A crucial role is being played by the inter-digital structure in achieving the desired filter response and performance characteristics in the ultra-wideband band pass filter with a diamond-shaped resonator. In this specific filter design, it's shown that the diamond-shaped resonator is embedded between inter-digital coupled feed line structures. This placement indicates that the inter-digital structures are likely to be used for coupling energy into and out of the diamond-shaped resonator. Physical structure of the inter-digital coupled element being utilized of a series of alternating conductive fingers or meanders on a dielectric substrate, see Fig. 1. The spacing between the alternative conductive fingers of inductance L demonstrates effect of Capacitance C. These conductive elements are interleaved in a way that provides the desired coupling or impedance transformation. The two dielectric capacitance, C_1 and C_2, are used to adjust the resonant frequencies of the interdigital filter. This arrangement serves to achieve specific electrical properties, such as coupling and impedance transformation, which are important in microwave and RF circuit designs. A close study of the graph shown in Fig. 3 explains that the interdigital structure behaves like a band pass filter.

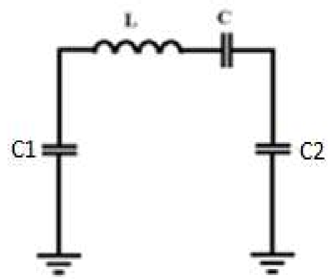

Fig. 1. Interdigital Equivalent Circuit

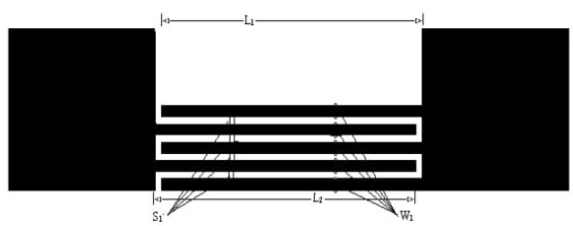

Fig. 2. Interdigital Structure

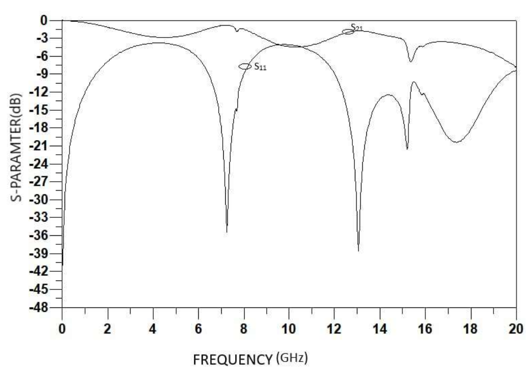

Fig. 3. S-parameter characteristic of Fig. 2

B. Designing of filter

The interdigital structure with rectangular slot and without a resonator is shown below in Fig. 4. A rectangular slot at the port is used to increase the capacitive or inductive effect at the point which will definitely improve the insertion loss and return loss in overall passband and stop band. After simulating the structure, the graph shown in Fig 5 is obtained. We observe some good changes in the insertion and return losses. A narrowband is obtained due to the rectangular slot and a proper pass band is obtained centred at 7.6 GHz and others are the harmonics of the high frequencies in characteristics performance.

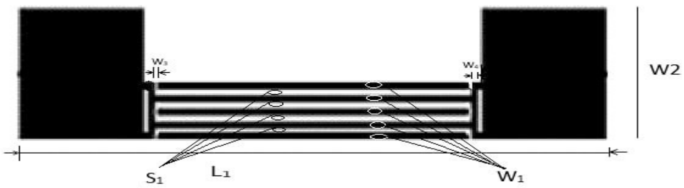

Fig. 4. Structure of filter without diamond shape resonator

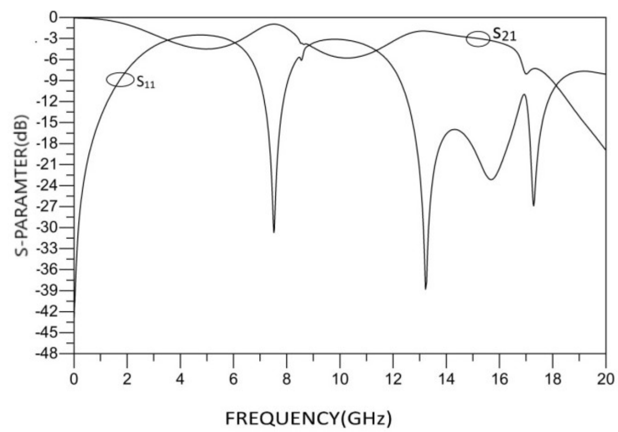

Fig. 5. Graph of structure of proposed filter without resonator

C. Fabrication of filter

To have the desired frequency response of the filter a diamond-shaped resonator is embedded at the mid-section of interdigital structures, as a result an improvement is seen in the pass band performing WB BPF S-parameter performance characteristics. The specification of S-parameter characteristics are as follows:- lower cut off frequency- 3.2GHz, higher cut off frequency- 11.25GHz, minimum insertion loss-0.61dB and maximum return loss- 48dB and minimum return loss value as 11dB during the pass band, see Fig.7. The design and dimensions given in Fig. 6 are explained as follows: The length L_1=10, L_2=4.7, L_3= 4.7 and L_4= 0.6. The slot width S_1 is 0.15. The coupling line widths: W_1=0.15, W_2 = 3.1, W_3 = 1.35, W_4 = 0.67, W_5=0.33, W_6=0.15, W_7=0.37 and W_8=0.3 and minimum return loss 11dB during the pass band (All the above dimensions are in millimeter).

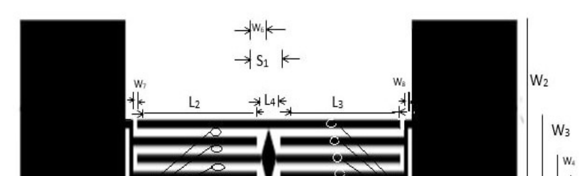

Fig. 6. Proposed filter

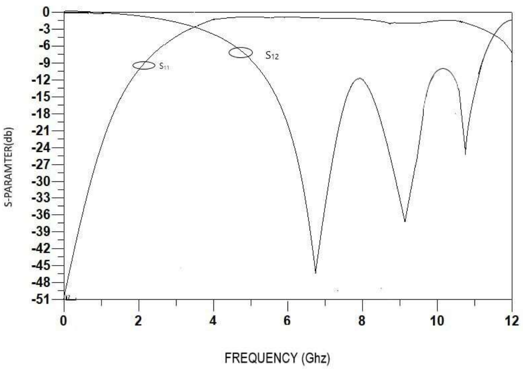

Fig. 7. S-Parameter proposed Filter performance

D. Fabrication and Measurement

The proposed ultra wide-band band pass filter is fabricated on a double sided copper coated printed circuit board, already explained in abstract. The filter size is 0.51 λ_g 0.071 λ_g. (λ_g= guided wavelength). The measured cut off frequencies of ultra-wideband band pass filter is 3.85 Gigahertz as lower and 11.25 Gigahertz as higher while the simulated is 3.25 GHz and 11.25 GHz respectively. Similarly, simulated insertion loss is figured out to be <0.61 dB and max return loss is >48 dB whereas the measured maximum return loss turns out to be 51 dB and minimum insertion loss is 0.5 dB.

$$\lambda_{g}= \frac{c}{f\sqrt{\varepsilon_{eff}}}$$

On comparing size structure of the proposed filter with the previously designs are shown in Table 1. As result proposed filter size is found to be small to others. Comparitive table also demonstrates the s-parameter characteristics of filter with that of already existing design mentioned in references[17-21].

TABLE I. COMPARISON OF PROPOSED FILTER WITH OTHER PREVIOUSLY REPORTED DESIGNS

Ref. No.	$^{\epsilon_r}/_{h}$ *(mm)*	*IL (dB)*	*RL (dB)*	*3db FBW (%)*	*Size*
17.	4.4/1.6	<1	>16	118	0.265 λg ×0.071 λg
18.	2.55/0.8	1.5	10	122	0.51 λg ×0.33 λg
19.	2.2/0.78	1	17	112.2	0.263 λg ×0.0365 λg
This work	4.4/1.16	<0.61	>48	105.9	0.531 λg ×0.071 λg

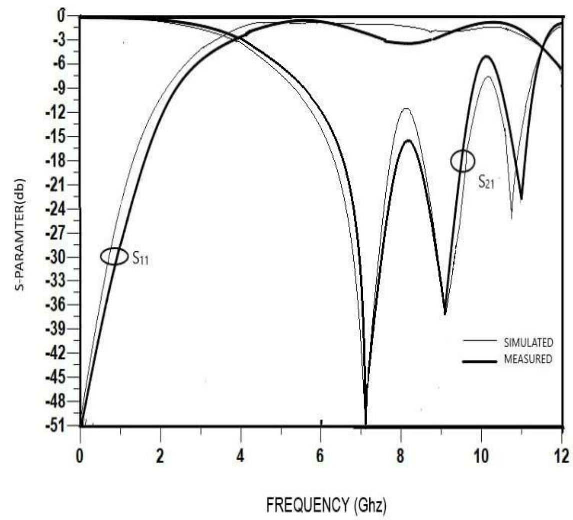

Fig. 8. S-parameter of simulated and measured proposed filter

Fig. 9. Photograph of fabricated proposed filter

CONCLUSION

The paper states the micro-strip ultra wideband band pass filter featuring a diamond-shaped resonator sandwiched between interdigital structures, designed and implemented using Keysight Advanced Design System. This innovative approach offers precise control over frequency response, making it a valuable tool for achieving desired performance characteristics in the ever-evolving world of wireless communications and RF applications. The design is compact and planar. Overall, smaller in size as compared in Table 1. Also, proposed filter gives ease of fabrication as no via or defected ground structure is used as of small size filter is easily applicable to different devices and systems in microwave Engineering & Technology.

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