An Ultra-Wideband Bandpass Filter using planar Interdigital structure with E stub for RF system

Ayush Verma
Electronics Engineering
Institute Of Engieering and Rural Technology
Prayagraj, India

Chandranshu Gupta
Electronics Engineering
Institute Of Engieering and Rural Technology
Prayagraj, India

Geetansh Gupta
Electronics Engineering
Institute Of Engieering and Rural Technology
Prayagraj, India

Dr. Yatindra Gaurav
Electronics Engineering (HOD)
Institute Of Engieering and Rural Technology
Prayagraj, India

Dr. C.P. Singh
Electronics Engineering (Faculty)
Institite of Engineering and Rural Technology
Prayagraj, India

Abstract— **This study aims to design and model a planar interdigital bandpass filter optimized for high-frequency applications. The proposed filter contains E Stub in the middle of the filter. Operating effectively across the frequency span of 3.6 GHz to 11.2 GHz. The UWB bandpass filter demonstrates an impressive fractional bandwidth of 102%. This design efficiently allows the desired frequency bands to pass while suppressing unwanted signals, making it highly suitable for wireless communication systems The filter is based on a microstrip configuration comprising multiple resonator fingers arranged in an interdigital pattern. The presented filter design was implemented using Rogers RO 4003 as substrate of 1.16 mm thickness with relative permittivity as 3.55. These compelling findings were substantiated through simulations conducted using Keysight Advanced Design System (ADS).**

Keywords:* *Ultra-Wideband, Planer Interdigital Structure, Bandpass Filter, Attenuation, Fractional Bandwidth.

I. INTRODUCTION

With the growing demand for high-speed and reliable wireless communication, modern systems have evolved to offer enhanced data transmission with minimal interference. Among these advancements, Ultra-Wideband (UWB) stands out by exploiting a wide frequency range to deliver fast and efficient data transfer over short distances. UWB has become integral to a variety of applications, including wireless personal area networks, sensor networks, and radar systems [1].

The rapid advancement of wireless systems, alongside developments in communication technologies, has paved the way for more efficient transmission systems capable of supporting high data rates while minimizing interference.

The 3.1 GHz to 10.6 GHz frequency range has been allocated by the Federal Communications Commission (FCC) for use in Ultra-Wideband (UWB) systems. This wide frequency range enables UWB technology to transmit short-duration, low-power pulses with minimal interference, supporting high-speed data transmission. To make efficient use of the UWB spectrum, the development of key components—particularly UWB bandpass filters (BPFs)—is essential. These filters play a vital role in eliminating unwanted signals and noise, ensuring that only the desired frequency range is transmitted or received [2]. Creating compact filters with narrow notch bands and efficient transmission characteristics presents ongoing challenges in RF design.

Approaches like coplanar waveguide structures, resonators with stub loading, and transversal signal interaction mechanisms have been widely studied to address these design goals [3, 4].

In recent filter design strategies, interdigital structures have been recognized for their ability to deliver strong frequency discrimination and sharply defined notches within the UWB passband. This has been accomplished without incorporating complex design features like DGS, thereby simplifying fabrication [5]. Their small footprint and compatibility with UWB circuits make them a preferred choice for system-level integration [6]. The paper proposes a design for an Ultra-Wideband (UWB) bandpass microstrip filter that utilizes a semi-arc resonator structure along with pseudo-interdigital configurations. This design focuses on achieving a significant fractional bandwidth and a precisely placed attenuation notch while ensuring compactness and integration simplicity. The performance of the filter was confirmed via simulations using Keysight Advanced Design System (ADS) [7]. The next sections will provide a thorough examination of the proposed design approach, simulation outcomes, discussion, concluding remarks, and suggestions for future exploration in UWB communication technologies [4].

II. THE FILTER DESIGN

A. Planer interdigital structure

This layout introduces an innovative planer interdigital arrangement to allow a specific frequency range while suppressing unwanted signals, the design specifically employs a hairpin or coupled-line filter—commonly used in RF and microwave circuits. The filter is constructed using microstrip technology, which involves arranging conductive traces on a dielectric substrate. The inductance and capacitance in an interdigital structure are determined by the length of the fingers and the spacing between them, respectively.

Fig.1 Planer Structure

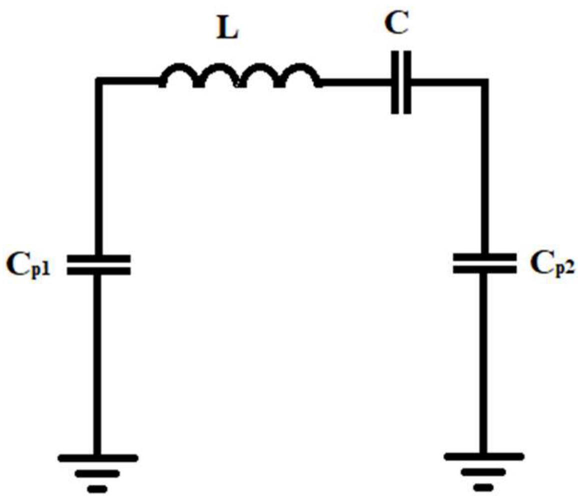

Fig.2 Equivalent circuit model of the interdigital-based structure

Associated parameters are L1= 2.3, L2= 5.5, L3= 2, W1=0.15 (dimensions are in millimeters).

B. Filter design using E-Stubs

The proposed ultra-wideband (UWB) Bandpass Filter (BPF) design introduces an innovative approach as the operating within the 4.3 GHz to 11.1 GHz frequency range stipulated by UWB communication standards. In this structure the E-stub are placed in the middle of the structure which gives better control over how sharply the filter transitions from passband to stopband. By applying these stubs, the filter performance improves. As bandwidth control, improves return loss suppression of unwanted harmonics, more compact structure.

From a signal processing perspective, the E-shaped stub improves filter efficacy by optimizing signal alignment (impedance matching), extending the passband, and providing steeper roll-off characteristics. These improvements directly translate to better signal clarity and noise rejection in practical applications.

The dimensions of the critical filter components, including the geometry of the resonator and the finger length and width of the interdigital structures, are meticulously tailored to achieve the desired frequency response, and coupling efficiency.

Fig.2 Proposed UWB BPF

TABLE-1

1	L1	2.3
2	L2	5.5
3	L3	2
4	L4	2.15
5	L5	3
6	L6	1.5
7	L7	2.1
8	L8	0.8
9	W1	0.15
10	W2	0.1
11	W3	0.9

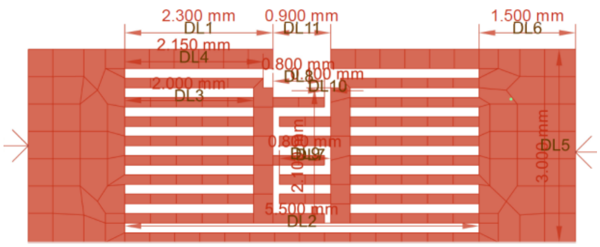

Fig.3 Dimensions of Filter

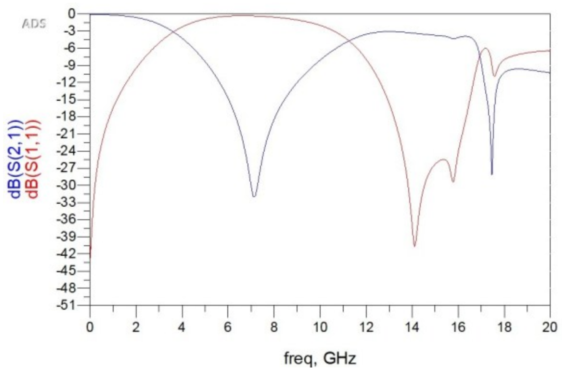

Fig. 4 S-parameter Characteristics performance of the proposed structure

The S-parameter simulation graph shows two main curves: S(2,1) in blue and S(1,1) in red. The curve S(2,1) represents the insertion loss, or how much signal passes from input to output. The red curve, S(1,1), shows return loss, which indicates how well the filter is matched at the input. A sharp dip in S(1,1) near 3.6 GHz shows good matching and minimal signal reflection. The simulation confirms that the filter works effectively around 3.64 GHz, with good signal transmission and low reflection. This makes it suitable for wireless communication applications in this frequency range.

CONCLUSION

This work presents the evolution of an Interdigital Bandpass Filter from a standard layout to an advanced design using an E-stub. The original structure successfully achieves signal transmission near 3.64 GHz, but the modified design with the E-STUB shows clearer resonance, stronger signal control, and reduced signal reflection. These improvements confirm the E-stub's usefulness in enhancing filter efficiency, making it a suitable choice for modern communication systems.

By comparing both versions of the filter, it is clear that the E-stub insertion significantly boosts the filter's performance. The standard design already supports signal flow near 3.64 GHz, but lacks in minimizing return loss. The updated design not only preserves the desired frequency but also improves matching and out-of-band suppression. This proves the value of using an E-shaped stub in filter design to meet high-performance RF specifications.

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