Design Of UWB Band Pass filter with Hexagonal Shaped EBG Structure and WLAN notch using Metamaterial Structure

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***Abstract*—This paper present the designing and stimulation of a bandpass filter operates under the ultra wide band(UWB) range. The filter design involves two interdigital coupled lines at the terminal and hexanol shaped EBG structure at the center of filter along with WLAN notch using spiral resonator as metamaterial structure. The hexagonal shaped EBG structure provide better return loss characteristics and provide a wide band rejection outside the passband. The bandwidth of the designed filter is 11GHz (2.225-11.25GHz).**

Keywords—EBG, UWB, Spiral Resonators, Metamaterial, Notch.

I. INTRODUCTION

Ultra Wide Band has emerged as interesting area for the researchers and scholars after the release of its unlicensed use of Ultra wide band (3.1-10.6 GHz) by federal communication commission (FCC). Due to its large bandwidth and high data rate, it is used in personal area network (PAN), transmission of HDTV stream from a set-top box, radar and imaging system. It minimizes the interference by spreading the power over large bandwidth and helps in solving error control coding technique [1], [2]. In earlier days, filter was used to design using lumped elements. But at microwave frequencies it is difficult to realize with lumped elements and hence distributive element came into use. Several types of UWB Band pass filter have been proposed in literature so far. Some designed methods include: parallel coupled microstrip line, MMR [3] - [7], combination of high pass filter and low pass filter, short circuited stubs with Defected ground structures [8]. Most of these UWB BPFs have good performance and are suitable for implementation. UWB bandpass filter design using Interdigital hairpin resonators [9] inhabits poor return loss as well as its large size is not suitable for practical implementation. So, a method of filter design using Interdigital coupled line with vary shape of EBG in this paper, hexagonal shaped electromagnetic band gap structures is proposed in this paper. EBG structures are periodic or non-periodic structures that prevent the propagation of electromagnetic wave in a specified band of frequency for all incident angles and all polarization states [10]. EBG structures act as multimode resonators for tuning frequency range and to improve return loss characteristics of filters. EBG can be of rectangular, square, E-shaped etc. In this paper a UWB filter using Interdigital coupled line resonators and hexagonal shaped EBG structures has been designed and implemented. To avoid its interference with the WLAN spectrum a notch using spiral resonator as metamaterial structure is implant. The proposed filter consists of two similar Interdigital coupled lines at the left and right section with three hexagonal shaped electromagnetic band gap structures (EBG) at the center of filter and notch at the center of input feed

Split Ring Resonator (SRR) is the most popular metamaterial structure which is being used in numerous microwave and antenna application. There are different approaches towards the arrangement and shape of such structure but scope of this paper is limited to Spirals. Spirals are the classic resonators known for their inductive property. Such structure been experimented and proven to exhibit metamaterial property. The fabrication of such structure is also easy due to their small size at electrical resonance. Their small size is also handy when introducing it into microwave devices.

In this paper, rectangular spiral structure been implemented in the input feed lines of 3mm length either side of the structure. The structure is design on FR4 substrate with relative permittivity of 4.4, thickness of 1.6mm, width of 3mm and characteristic impedance of 50 Ω. The size of the structure is 30.2 mm x 3mm.

II. DESIGN AND STIMULATION

The proposed UWB Band pass filter is realized on FR4 Substrate with dielectric constant '$\in_r$' of 4.4 and thickness 'h' of 1.6mm. Design of BPF using Interdigital coupled line and hexagonal shaped EBG structures are simulated and studied. To validate the design equations, the filter structures were simulated using Ansoft HFSS13.0.

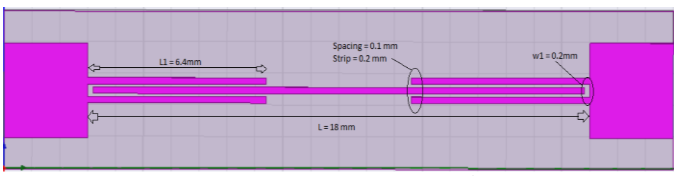

Figure 1. Interdigital Coupled Line Configuration

A. *Interdigital Coupled Line*

Two Interdigital coupled lines connected with a high impedance line are realized on a FR4 substrate with '$\in_r$' =4.4 and thickness 'h'=1.6mm as shown in Fig.1. The width of strip and slot are kept 0.2mm and 0.1mm respectively. As coupling length, "l" = 6.4mm a desired UWB passband can be found in Fig. 2. But the return loss characteristic of designed filter is very poor and there is no wide rejection after upper cutoff frequency. So this can be improved by using hexagonal shaped electromagnetic band gap structures (EBG) at the centre of filter. There is interference with the WLAN frequency i.e. 5.6GHz which can be achieve using rectangular spiral resonator.

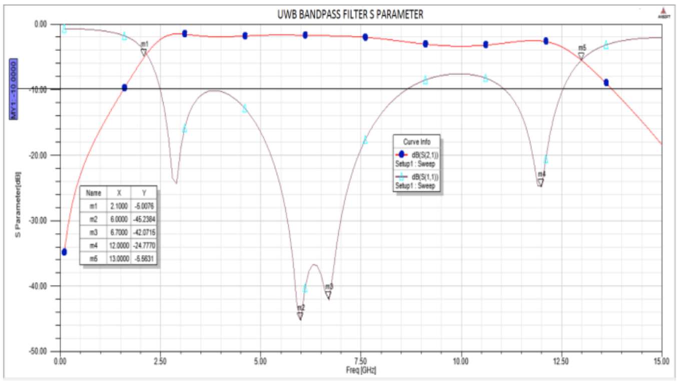

Figure 2. S Parameter of the Interdigital Coupled Line

B. *Single Spiral Resonator*

Rectangular shaped spiral resonator is used to provide a notch of 5.6GHz this is due to the notch property of metamaterial in microwave devices. No fabrication limit on the structure. Spiral Resonator is embedded in input feed lines of fixed length of 9.2mm out of which 3.2mm is used for spiral and 3mm both side. Spiral comprise of 9 arms of width 0.2 mm and spacing of 0.2mm as shown in Figure 3.

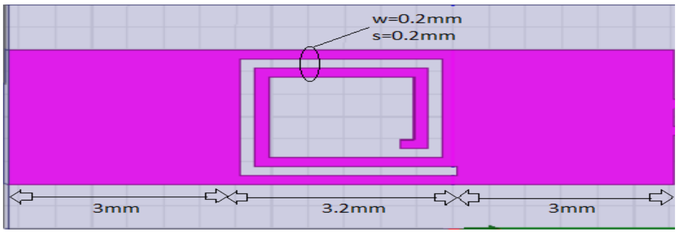

Figure 3. Spiral Resonator of 5.6GHz

Length of the spiral is sum of all the 9 arms that is 20mm. Width of spiral resonator is 3 mm equal to the width of 50 Ω Microstrip transmission line. The S parameter of structure is shown in Figure 4 shows a notch with center frequency of 5.6GH. The 3dB bandwidth of notch is 420MHz. The frequency of rejection is from 5.35 to 5.77GHz.

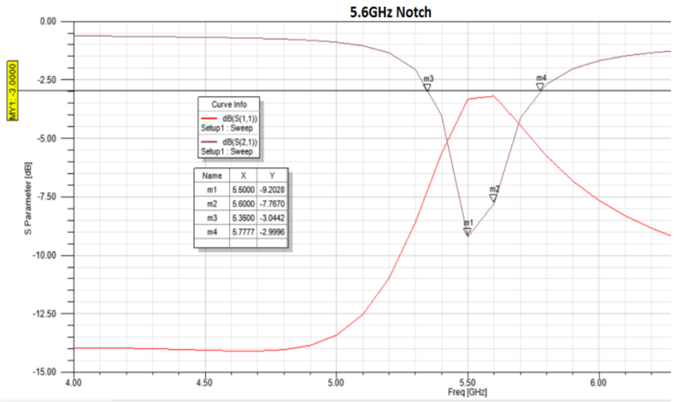

Figure 4. S parameter of Spiral Resonator

C. *Hexagonal EBG Structure*

Hexagonal shaped EBG structures is placed at the center of filter. Structure is realized on a FR4 substrate with '$\in_r$'=10.2 and thickness 'h'=1.6mm as shown in Figure 5. The proposed design consists of hexagonal shaped stubs. Hexagonal shaped is similar to circle but with 6 segments instead of 0. Total height of the link is 0.8mm and total length is 5.2mm. The first center stub is of radius "r2=0.45mm" and two smaller symmetrically hexagonal shaped stubs of radius "r1=0.4mm" at either side of the middle stub. The spacing between the three stubs is kept constant 0.6mm. Fig. 6 shows the low pass behavior of the simulated structure which rejects higher band above 11.25GHz.

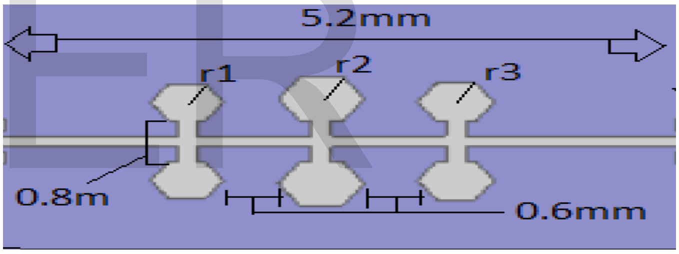

Figure 5. Hexagonal Shaped EBG Structure

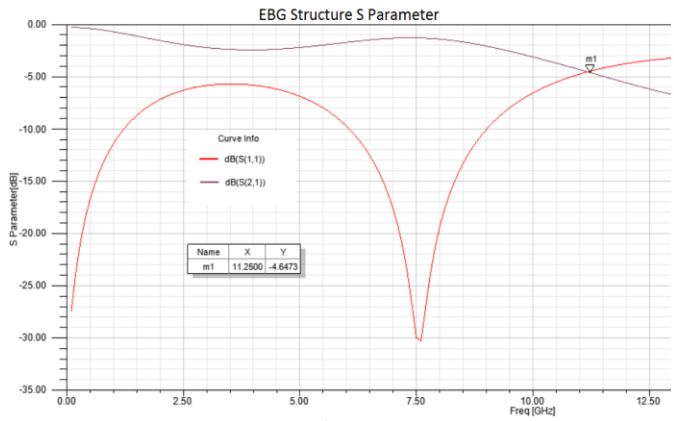

Figure 6. S Parameter of Hexagonal EBG Structure

D. Proposed UWB Band pass filter

Interdigital coupled lines, hexagonal shaped EBG structures and Spiral Resonator in the section (A, B and C) were combined to obtain band pass filter with WLAN Notch as shown in Fig.7.

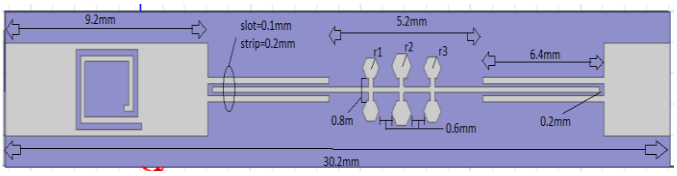

Figure 7. Final UWB Band pass filter structure

To study the effect of EBG dimensions on resonance mode, hexagonal shaped EBG of radius "r1" and "r3" is varied with keeping other parameters fixed and center EBG resonator of radius "r2" of 0.45mm.

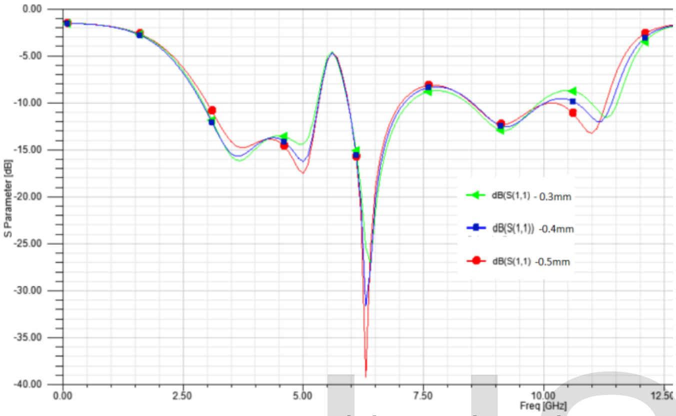

Figure 8. Variation in S11 with change in radius r1 and r3

It can be inferred from Fig. 8 that as the radius "r1" increases the resonant frequencies increases with more better return loss at certain frequency. Therefore, by adjusting the radius "r1, r2", the width "g=0.2mm" and distance between the EBG structures 'a=0.6mm', the resonant frequencies are aligned in the desired UWB pass band at places to improve the return loss. The optimized dimensions of proposed bandpass filter are L=5.2mm, r1=0.4mm, r2=0.45mm and g=0.2mm as labeled in Figure 7.

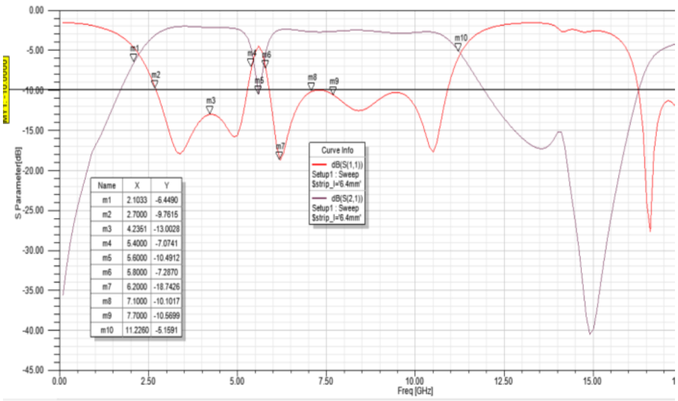

Figure 9. Frequency Response of UWB Band pass Filter

Figure 9 shows the simulated frequency characteristic of the proposed UWB Bandpass filter. It can be inferred from figure that by introducing EBG structures, the filter act as an UWB bandpass filter with good return loss and provides maximum rejection after upper cutoff frequency as compared to Figure 2. The lower and upper cut-off frequency of the BPF are 2.25 GHz and 11.25 GHz. The bandwidth is 11 GHz which covers the entire UWB range.

III. CONCLUSION

In this paper, a UWB Band pass filter is proposed using hexagonal shaped EBG structure which is having WLAN notch also. The size of the proposed filter is 30.2x5x1.6mm^3. The filter has better return loss, low insertion loss and wide band rejection after upper cutoff frequency. Hexagonal shaped EBG is used to suppress the harmonic and to improve response characteristic of filter. The bandwidth of proposed filter is 11 GHz (2.25-11.25 GHz) which covers the entire UWB range.

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