Development of Band Reject Filter to Mitigate the effect of WLAN in UWB Receivers

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***Abstract*— This paper is about a dual band single notch filter to eliminate the effect of WLAN in UWB range. A novel square resonator with interdigital coupling at both sides plays a key role in this filter design. Design and EM Simulation of the dual band notch filter's characteristics are discussed in this paper. The proposed dual band notch filter produces excellent bandwidth from 2 GHz to 5 GHz and from 5.5 GHz to 8 GHz. The filter rejects the band of frequency from 5 GHz to 5.5 GHz which is very narrow band in which the filter eliminates the effect of WLAN (IEEE 802.11a). Also the out band performance of the proposed dual band filter meets the requirement of FCC's mask. The simulation analysis of the proposed filter is performed by electromagnetic solver. The return loss, insertion loss, group delay and phase of the filter are simulated and their performances are analyzed. The overall dimension of the filter is achieved to be 39mm×3.2mm×1.6mm on accounting the above features. The fractional bandwidth of the notch filter is calculated from the bandwidth and the center frequency and it is obtained about 115%. The S parameter results of the filter such as return loss (S_{11}) in stop band is about -24 dB and insertion loss (S_{21}) is about -28 dB is obtained.**

***Keywords*— Ultra wideband filter, square resonator, insertion loss, return loss, group delay analysis.**

I. INTRODUCTION

The growth of Wireless radio communication technology in the engineering field over few years is emerging drastically. It is believed that wireless communication technology will continue to grow in the near future since the necessity of wireless communication receivers are increasing day by day because of rapidly developing wireless systems. The major development in wireless communication is mobile radio communication system which has wide range of applications like data, video, ranging in mobile phones. The ultimate goal of wireless communication system is to provide the best services in the limited power and within the allocated spectrum. Nowadays mobile users are tremendously increasing in large number, whereas there is a tough challenge in managing crowding of spectrum and coexistence of wireless devices whose operating frequency is close to one another will become a major issue. The mobile service providers are facing lot of challenges in allocating bandwidth and best data rate to all the users from limited availability of resources. In this regard, an innovative and efficient technology is needed that can able to satisfy all the requirements of service providers and consumes as well. Ultra wideband is one such technology which can able to meet out all the expectations of mobile service providers and it can coexists with licensed and unlicensed narrowband very well [1].

As per Federal Communication Commission (FCC) in USA declaration, the frequency band range starts from 3.1 (GHz) till 10.6 (GHz) is assumed to be license free band. This wide band is mainly suitable for high speed indoor data communication applications and this wide range band is termed to be Ultra wideband. The Ultra wideband technology has created excellent opportunities and increasing research interests towards wireless industries. More researches has been recorded in the literature towards exploring various segment of the UWB system.

UWB system has certain special features namely, it operates in low-power which is near to -41dBm, requires minimum cost to design the communication system and can able to achieve positioning. These features can give way for plenty of applications such as logistics, security applications, medical applications, high speed data applications and military/navigation applications [3]. UWB system also have following some unusual characters, it occupies a bandwidth very much greater than 500 MHz or a fractional bandwidth of larger than 20%. According to Shannon's capacity theorem, this large bandwidth provides a very high data handling capacity. Thus, high processing gain can be achieved that allows large number of users can access the system with equal best services.

In this rapidly developing wireless system, the challenging deal is to design the various system elements that should be compatible and match the UWB system's requirements. However, the emerging UWB technologies will face interference due to spectral crowding and coexistence of various wireless devices and that would be a major issue. Co-existence of WLAN services in the UWB range will affect the performance of UWB receivers. So the WLAN is considered to be the major interference that should be mitigated. In this aspects, design of bandpass and notch filters received lot of attention among many researchers since they are the unavoidable segment of UWB receivers [4, 5]. In this regard, many researchers have been working towards the development of miniaturized and cost effective filters which are the essential block of any receiver system and crack the attraction of end users as well.

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The proposed Dual band single notch filter is designed with a simple compact axially rotated square shaped resonator and the notch is introduced by open stubs connected from the feed lines. The filter is unique in its structural design and this simple design is achieved with limited number of design parameters when compared to the existing filter designs in the literature. The organized flow of the paper is given by: Section II details the operation of axially rotated square shaped resonator design model. In Section III, the proposed Dual band Single notch filter design using axially rotated square resonator is described. Simulation results and analysis are discussed in Section IV. Section V deals with paper conclusion and future enhancement.

II. SQUARE RESONATOR DESIGN MODEL

The square resonator principle is similar to logic of transmission line confined in a closed loop. The logical circuit diagram of the resonator consists of the feed lines for input signal, coupling lines for strong matching, and the resonator structure to produce sustained oscillation [6]. Figure 1 shows a type of square shaped resonator circuit arrangement. Transmitting power is fed into and receiving power out of the resonator with the support of feed lines and coupling gaps. The resonant frequencies of the square resonator remains unaffected only when the feed lines and gap between the resonator is large.

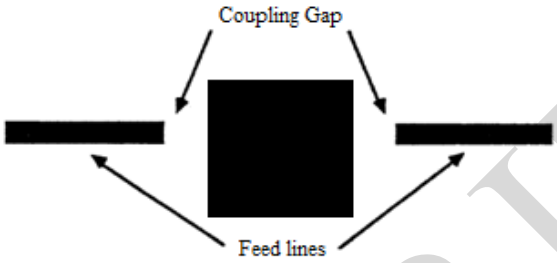


Fig. 1. Microstrip Square resonator

In the literatures, this fashion of coupling is denoted as loose or weak coupling. This types of weak coupling exhibits negligibly small capacitance in between the coupling gap. The coupling becomes strong which in turn increase capacitances between the gap only when the gap between the feed lines and the resonator is small. This effects may results in the deviation of resonant frequencies from the intrinsic resonant frequencies of the square resonator. In order to specifically design the square resonator, the capacitances of the coupling gaps should be taken into account. When the average value of the sides of the square resonator is same as that of the integral multiple of a guided wavelength, resonance will takes place. This may be mathematically represented in Eqn. (1) and (1a) as

$$2\pi r = n\lambda_g \quad (1)$$

$$f_0 = \frac{nc}{2\pi r\sqrt{\varepsilon_{reff}}} \quad (1a)$$

Where, λ_g guided wavelength, 'r' mean side of the square, 'n' mode value, f_0 resonant frequency, 'c' light speed in free space, ϵ_{reff} effective dielectric constant. This mathematical representation is applicable for the case of loose coupling because coupling gap effects are not considered. The resonant frequencies for various modes can also be manipulated from the above mentioned expression because λ_g is dependent on frequency [7-9]. In the starting mode, the field will be maximum at the position of coupling gap and the there is no field takes place at normal from the coupling gap locations.

III. DUAL BAND NOTCH FILTER USING SQUARE RESONATOR

The geometric design topology of the proposed Dual band single notch filter can be viewed in Figure 2. The dual band single notch filter considered in this work is mainly comprised of a simple compact axially rotated square resonator structure with loaded open stub. The filter is designed by assuming the substrate material (FR4) with 1.6mm dielectric height and a relative permittivity of 4.4, so that it is compatible with all the elements of communication system.

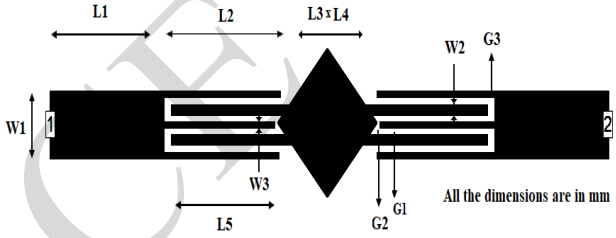


Fig. 2. Design topology of the Band Elimination Filter.



Fig. 3. Cross section of microstrip substrate.

The cross section of such microstrip substrate used for the design of filter is shown in Figure 3. The square resonator based UWB band pass filter is a simple circuit and easy to build whose optimal geometric values are listed in Table I. The logical structure of the axially rotated square resonator will allow only the waves that have an integral multiple of the guided wavelength which is equal to the mean or average side. There are many more complicated circuits with complex topology are available in the literature [10]. However, this proposed simple filter topology produces better results on par with those complex structures.

The axially rotated square resonator circuits can also implemented over transmission lines and waveguides. The selection of feed lines, coupling mode and type of resonator are depending upon the applications and operating frequency ranges [11,12].

A simple compact Dual band single notch filter using axially rotated square resonator is proposed in this paper. The signal is feed through feed lines whose width is designed in

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such a way to match the impedance of 50 ohms. Both the input and output ports are connected to these feed lines. The inter connected multiple finger like coupling line arrangement is defined as inter digital which is associated with square shaped MMR (Multi Mode Resonator) in order to provide wide operating bandwidth and enhance out-of band performance [13,14].

TABLE I. OPTIMAL GEOMETRIC VALUES OF THE PROPOSED BAND NOTCH FILTER

Filter elements	Descriptions	All Dimensions are in mm
L	Length of the substrate	39
W	Width of the substrate	20
H	Thickness of the substrate	1.6
L1	length of the feed line	8
W1	Width of the feed line	3.2
L2	Length of Inter digital coupling line	8.3
W2	Width of Inter digital coupling line	0.5
L3	Side of the Square	6
L4	Side of the Square	6
L5	Length of the middle Inter digital coupling line	8.2
W3	Width of the middle Inter digital coupling line	0.3
G1	Gap between Inter digital coupling line	0.3
G2	Gap between coupling line and resonator	0.45
G3	Gap between feed line stub and coupling line	0.35

The inter-digital coupling line structure and MMR are united and produce the sustained oscillation for the wide range of frequencies (3.1-10.6) GHz. This range of frequency is exactly matching the operating frequency of the UWB system. Hence it is best candidate for UWB band pass filter. The dimensions and the design specifications of the filter are mentioned in the design. The filter design is simulated using an EM simulation tool HFSS.

IV. SIMULATION RESULTS AND ANALYSIS

This section deals with the discussion on the result analysis of the proposed single notch filter. To analyze the characteristics over wide pass band range of the filter, the effects of adjusting the various filter parameters with respect to the various elements are investigated in this work. This filter is analyzed for various parameters like strip width, length and thickness by assuming variable values for one parameter and maintaining constant with respect to other parameters.

The simulated Scattering parameters (S_{11} and S_{21}) like insertion loss and return loss, phase, group delay and Q factor of the proposed notch filter using square shaped resonator are observed in Figure 4. The response clearly infers that the proposed filter possess excellent insertion loss value close to -2 dB and the extreme low profile of return loss of -27 dB obtained. The proposed dual band notch filter produces excellent bandwidth from 2 GHz to 5 GHz and from 5.5 GHz to 8 GHz. The filter rejects the band of frequency from 5 GHz to 5.5 GHz which is very narrow band in which the filter eliminates the effect of WLAN (IEEE 802.11a). These values are obtained by assuming -10 dB bandwidth line. The fractional bandwidth is manipulated from the response using bandwidth and resonant frequency ratio which is approximately 115%.

The phase variation response simulation of the filter with respect to S_{21} parameter values are clearly denoted in Figure 5. It is evident from the response that the proposed filter is having excellent in phase character in the pass band region.

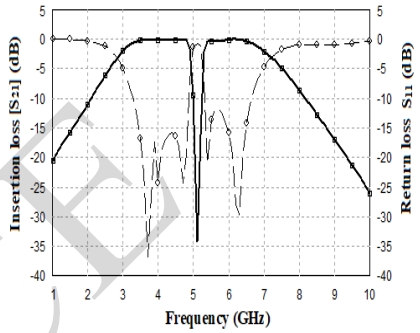


Fig. 4. Simulated S_{11} and S_{21} values of the proposed Notch Filter.

The significant and most important quality of a filter is that the filter's phase should be linear over the frequency range of the pass band, where the phase response with respect to return loss of the filter is a linear function of frequency. Linear phase of the filter should have minimum group delay over the desired band. The phase of the concerned filter is appreciably linear so the best suited for UWB services with WLAN notch throughout the pass band.

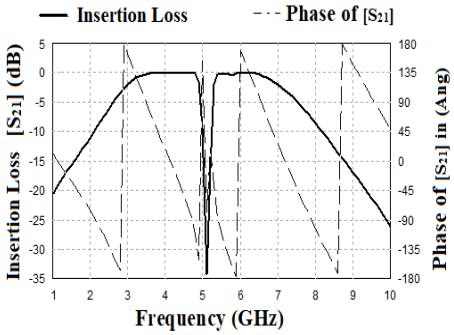


Fig. 5. Simulated Phase of S_{21} of the proposed Dual band Notch filter.

Figure 6 depicts the group delay simulation performance of the notch filter. The response implies that the proposed WLAN notch filter is having well excellent linear signal

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transfer. It is also observed that the group delay value lies below 3 ns in the UWB's pass band region.

Table II listed the essential and required filter performance parameters like insertion loss, return loss, fractional bandwidth, pass band frequency, group delay, phase and physical size of the proposed notch pass filter.

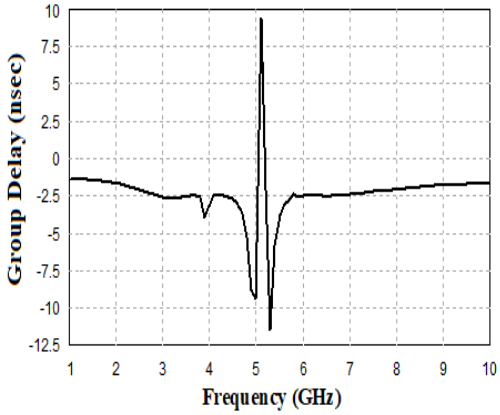


Fig. 6. Group delay response of the proposed Dual band Notch filter.

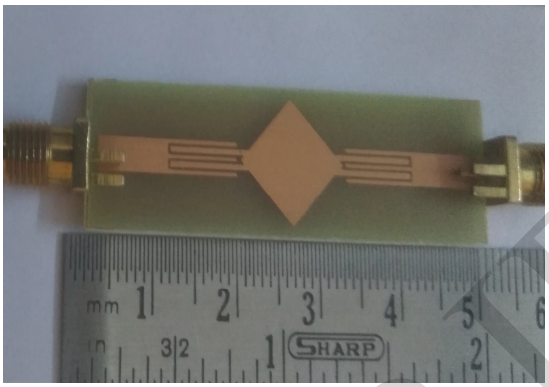


Fig. 7.Prototype model of the Notch filter.

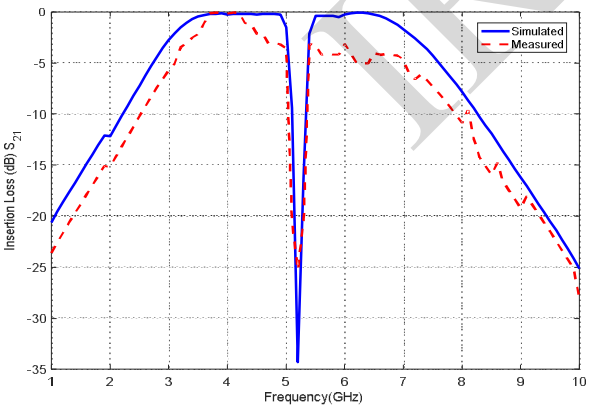


Fig. 8. Simulated and measured S_{21} of the proposed Dual band filter.

The prototype of band stop filter is shown in Figure 7. Using Hewlett Packard Network analyser (HP8757D), the insertion loss and return loss of the fabricated filter is measured and shown in Figure 8 & 9 respectively. A small discrepancy between them may be explained as an effect from fabrication tolerance and/or having not done the calibration of the SMA connectors.

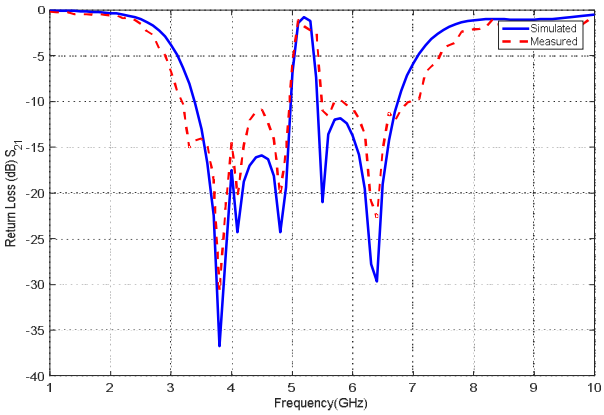


Fig. 9. Simulated and measured S_{11} of the proposed Dual band filter.

TABLE II. VALUES OBSERVED FROM THE SIMULATION

Parameters	Proposed Dual Band Filter	Fabricated Dual band Filter
Insertion Loss $\|S_{11}\|$ in dB	-37 dB	-30 dB
Return Loss $\|S_{21}\|$ in dB	-2 dB	-1 dB
Pass Band	2 GHz to 5 GHz and from 5.3 GHz to 8 GHz.	2.5 GHz to 5 GHz and from 5.3 GHz to 7.8 GHz.
Stop Band	5 GHz to 5.3 GHz	5 GHz to 5.3 GHz
Bandwidth	Band I: 3 GHz , Band 2: 2.7 GHz	Band I: 2.5 GHz , Band 2: 2.5 GHz
Phase at Pass Band	Linear	Linear
Group Delay	< 3 nsec	< 3 nsec
Size	39mm×3.2mm×1.6mm	39mm×3.2mm×1.6mm

V. CONCLUSION

A novel, simple and compact topology of Axially rotated square resonator based dual band single notch filter is detailed in this work. The notch filter is realized by inter-digital conductors. The square shaped resonator produces wide pass band in the range of 2.2 (GHz) to 10 (GHz) which is UWB. However the coexistence of WLAN will mitigate the performance of UWB receiver. The size of the square shaped resonator and inter digital coupling line designs can have flexibility to vary easily based on the wide band requirements. On the other side, size of the open loaded stubs are responsible for the elimination of certain bands in the pass band. The simulation design and performance behavior of the notch filter is explicitly discussed. The filter considered in this work demonstrates smooth and uniform wide bandwidth ranges from 2 GHz to 5 GHz and from 5.5 GHz to 8 GHz. The filter also rejects the band of frequency from 5 GHz to 5.5 GHz

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which is very narrow band in which the filter eliminates the effect of WLAN (IEEE 802.11a) with the size of 39mm×3.2mm×1.6mm. This circuit will also have excellent out of band performance in terms of roll on and roll off. On accounting all the discussed structural and performance characteristics, the fractional bandwidth is calculated about 115% with return loss and insertion loss of about -27 dB and -2 dB respectively. Thus the S parameter, phase and group delay and wide operating band behavior of notch filter conveys better performance, so it is optimally fit for wide band wireless radio system applications.

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