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Diamond Shape Patch Antenna with Triangular Integrated Band Notch Filter for Ultra Wide Band Applications

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Abstract— ***In the rapid development of the user and the wireless technology, an increasing number of requirements for wide bandwidth and high data rate devices. In order to achieve such a high speed broadband applications, the US Federal Communications Commission (FCC) announced a ultra-wideband (UWB), with a 7.5 GHz bandwidth from 3.1 GHz to 10.6 GHz. The shortcoming of such a wide band is the interference between the license free ISM 5.7 GHz band existing in public wireless LAN applications and UWB (3.1 to 10.6 GHz). This can be overcome by using a band rejection filter cascaded with UWB antenna, but will result in bulky apparatus.***

The antenna design consist of a new Diamond shaped UWB microstrip patch antenna having a triangular notch filter integrated with the ground element so that the antenna is compact enough to fit in any radio device as most of the component of wireless technology are implanted on a single chip these days. The proposed ultra-wideband antenna will be designed and simulated using easily available FR-4 substrate on CST Microwave Studio. The results are investigated for UWB i.e. from 3.1 GHz to 10.6 GHz with adequate radiation characteristics such as bandwidth, gain, minimum return loss; proper impedance matching without any supplementary equipment and will be able to filter the WLAN frequency band. The proposed antenna structure can be used in applications which required high data rates such as WPAN, defence etc.

Keywords— CST, FCC, Microstrip Patch Antenna, Notch Filter, UWB.

I. INTRODUCTION

A flagship benefit of wireless lifestyle has led to huge demand for advanced wireless communications. Rapid growth in wireless communications market demands new efforts radio system that provides high data rates such as for video applications. However, this trend is the coexistence of available resources such as spectrum, power, and wireless devices limits. Therefore, innovative technology and equipment can coexist in a crowded band operation, to overcome the problem of limited bandwidth.

In February 14, 2002, the Federal Communications Commission (FCC) revised its dominant unlicensed wireless devices, including 15 of UWB devices operating rules. The Federal Communications Commission has also allocated 7.5 GHz bandwidth from 3.1 GHz to 10.6 GHz to UWB applications [1], by far the largest unauthorized use of the FCC spectrum allocation once granted. Ultra-wideband (UWB) wireless transmission technology, which occupies an extremely wide bandwidth exceeds the minimum or center frequency of 500 MHz at least 20% [1], is a revolutionary method for short-range, high-bandwidth wireless communication. Different from traditional narrowband radio systems a UWB transmission signal is obtained by modulating the sinusoidal amplitude, frequency or phase, through the transmission of information at a specific moment in very short pulses of radio energy form thus occupy a very large bandwidth, making time modulation. Due to the non-continuous of short pulses UWB radio propagation as compared with conventional narrowband wireless systems, the power consumption is extremely low. In addition, the short pulse generation revocation multipath fading. Because of these attractive features, UWB technology is widely used in many applications, such as indoor positioning, radar, medical imaging and target sensor data collection.

The challenge faced during the implementation of UWB antenna design is to develop a suitable or optimal antenna. The first important requirement UWB antenna design is extremely wide impedance bandwidth i.e. covering the frequency band of 3.1 GHz to 10.6 GHz. Next, the radio communication chamber required the radiation pattern with omnidirectional characteristics in order to facilitate communication between the transmitter and receiver. Last but not least, because UWB technology is mainly used for indoor and / or table equipment, ultra-wideband antenna size must be small enough so that they can be easily incorporated into a variety of wireless devices.

In recent years, a variety of UWB antennas with high data rate have been reported [6] - [12]. However, there are still some challenges in designing of such UWB antenna. A few of the challenges in designing of UWB antennas are discussed in [1]-[3]. Patch antenna has come out as a possible solution to overcome the challenges faced in designing of such kind of antenna. However, the patch antenna has a limited bandwidth, but it can be overcome by changing the patch size.

One of the limitations of ultra wideband applications is the coexistence of IEEE 802.11 WLAN frequency band. Thus a band reject filter is required to eliminate the cross talk in between UWB and ISM 5.7 GHz band.

The focus of this research work is to design a unique diamond shaped ultra wideband patch antenna with integrated band notch filter to eliminate WLAN frequency bands with sufficient radiation characteristics desired for high data rates applications.

The paper is organized as follows. Section II and III discusses the novel design of the proposed findings and results respectively. Section IV discusses the conclusion and future scope.

II. ANTENNA DESIGN

The design of the ultra wideband antenna having a modified diamond shaped patch element consists of triangular notch filter embedded in ground element as shown in figure 1. The antenna is feed with a 50 Ω line feed and is designed on FR4 (lossy) substrate which is 1.574 mm thick and having dielectric constant $\in r$ = 4.3. The dimensions of the optimized antenna structure are given in Table 1.

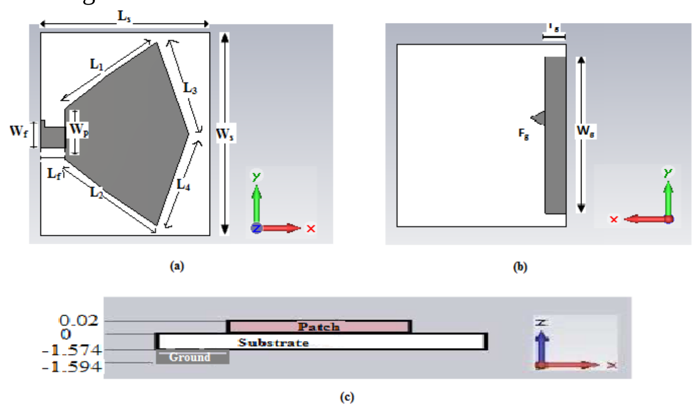

Figure1 (a), 1(b), 1(c): Front, back and bottom view of antenna design

Table 1: Parameter description of antenna design

Parameter	Description	Dimensions(mm)
W_p	width of patch	5.8
L_1, L_2	positive slope lengths of patch	22
L_3, L_4	negative slope lengths of patch	18
L_f	length of feed	4.3
W_f	width of feed	5.6
L_s	length of substrate	34.2
W_s	width of substrate	42
l_g	length of ground	4.2
W_g	width of ground	36
F_g	area of triangular ground filter	4.5

III. RESULT AND DISCUSSION

One of the objectives of the proposed work is to design a antenna for UWB operations i.e. from 3.1 to 10.6 GHz band. The antenna is designed first to resonate at 3.1 GHz and ultra wide band characteristics are achieved using a diamond shaped patch slab. As by varying the geometrical aspect of radiating patch which further culminates in deviation of current and hence the resonating frequency and other required characteristics. Band reject filter is introduced to avoid interference from ISM 5.7 GHz frequency band with the use triangular filter element embedded in ground slab in such a position that they provide segregation from license free WLAN band as shown in fig 1.

The proposed design is simulated for return loss, impedance band-width, resonance frequency, surface current, radiation pattern and gain. The return loss, radiation patterns, surface currents and smith chart is shown in Fig. 2, 3, 4 and 5 respectively.

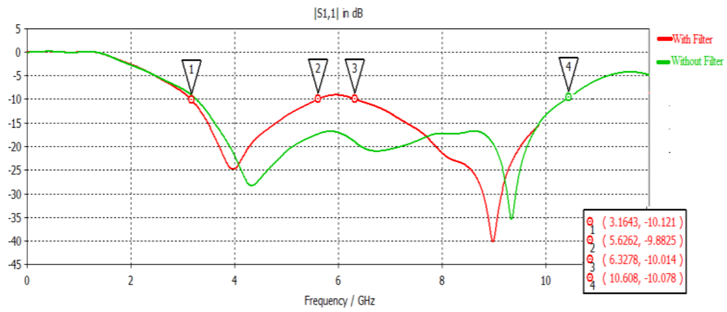

Figure 2: Return loss with and without band notch filter

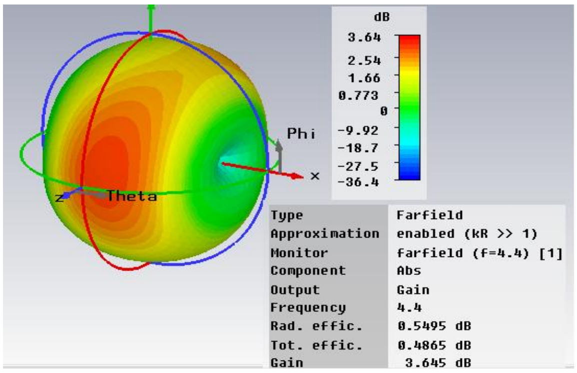

Figure 3: Radiation pattern and gain at 4.4 GHz

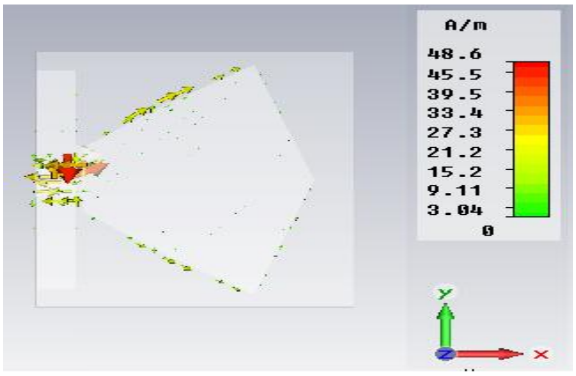

Figure 4: Surface current at 4.4 GHz

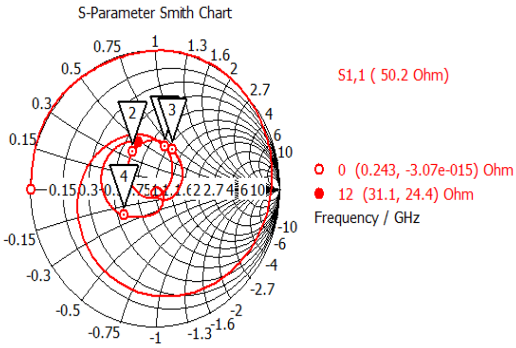

Figure 5: Smith Chart for designed antenna

Design diamond shaped antenna covers the impedance bandwidth of 7.45 GHz i.e. from 3.1643 GHz to 10.608 GHz with a return loss of -35 dB without triangular filters. In addition to this antenna design with integrated triangular band eliminate filter occupy two bands, first band of 2.47 GHz from 3.1643 GHz to 5.6262 GHz and second band of 4.28 GHz from 6.3278 GHz to 10.608 GHz. Thus UWB operation is achieved without the triangular filter element and with embedded triangular filter the WLAN licensed free band is eliminated as illustrated in fig 2.

In 4.4 GHz resonance frequency band i.e. band 1 a gain of 3.645 dB is achieved as shown in the radiation pattern in fig 3. Surface current and smith chart are shown fig 4, 5 which illustrate the information regarding current flowing through diamond shaped patch and input impedance of antenna respectively. The rest of the cases are simulated similarly and are summarized in Table 2.

Table 2: Summarized result for all cases

Filter	**Band**	**Frequency Range (GHz)**	**Band Width (GHz)**	**Band Width Percentage (%)**	**Gain (dB)**	**Input Impedance (Ω)**
Without Filter	UWB	3.1643-10.608	7.45	108.5	4.974	50.02
With Filter	Band 1	3.1643-5.6262	2.47	56.2	3.645	50.02
	Band 2	6.3278-10.608	4.28	50.5	6.643	

IV. CONCLUSIONS

A novel Diamond shaped Ultra Wide Band patch antenna with integrated triangular band reject filter had been introduced. The designed antenna is capable of operating in UWB frequency band i.e. from 3.1 to 10.6 GHz with a return loss of -35 dB without triangular filter and the bandwidth percentage obtained is 108.48 %. On the other hand the antenna design with integrated triangular band notch filter covers two bands, one from 3.1 GHz to 5.6 GHz and second from 6.3 GHz to 10.6 GHz. Hence, provides isolation from WLAN licensed free band with sufficient radiation characteristics, gain, band width and minimum return loss. The paper depicts the concept of UWB operations with the help line feed method. The design can be used for high data rates applications like WPAN, defence etc to solve the problem of interference of UWB with WLAN license free band on a single chip. The design is compact enough (32.4 × 39 × 1.62 mm) to fit in any wireless device and offer an input impedance of 50.02Ω (≈50Ω), thus does not requires any extra impedance matching device.

Future work includes comparison of measured and simulated result. Also, the design can be optimized to operate in any desirable frequency band according to the type of application.

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