Survey on Design of UWB Antenna with Notching Techniques

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Abstract— Ultra wide band is one of the most promising technology for high speed, short-range wireless communication since release by federal communications commission (FCC) of a bandwidth of 7.5GHz (from 3.1GHz to 10.6GHz). The other hand, the 5-6GHz band is associate with the wireless LAN (WLAN) and 3.3-3.8GHz is operating frequency band for WiMAX. Therefore, an unwanted inference is observed in this frequency range. In this paper a panoptic review has been done over a wide range of UWB micro-strip antennas which all are having the band notching property over the WLAN and WiMAX band to effectively avoid this interference. All the band-notching techniques in literatures have been categorized in different methods including the tuning stub and the shaped slot. Some papers have been studied in each category. At last of this article, a comparison has been done among these methods and relative papers.

Key words: Ultra Wideband, Band Notched, Micro-Strip Antenna, Shaped Slot, Tuning Stub

I. INTRODUCTION

UWB technology is one of the most attractive wireless communication technology which operates a wide range of frequency band (3.1-10.6GHz) resonates 10dB bandwidth [1]. Recently, this technology has been employed in a wide range of applications such as radar, telemetry, navigation, biomedical system, mobile satellite communications, the direct broadcast system, GPS, and remote sensing. For these systems designing an appropriate antenna is a most important challenging task. Stable omnidirectional radiation patterns, gain flatness, and linear phase variation are also required to fulfil the requirements for UWB application [3].

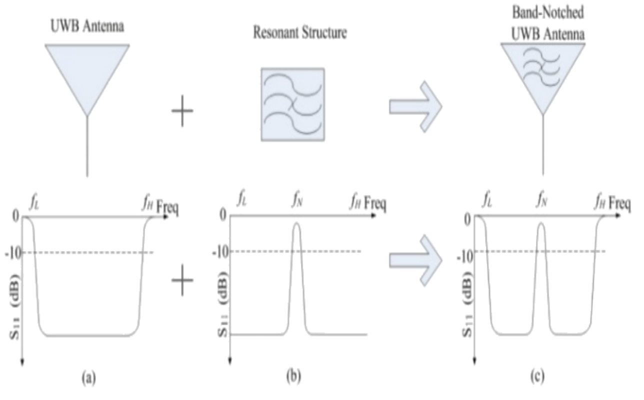

Fig. 1: Basic design of band-notched UWB antenna [11]

Studies for development of suitable or optimal antennas have increased and various design have been introduced and implemented to enhance this effect. Many techniques like U-shaped slot are etched in radiating patch [2], tapered shaped slot and rectangular tuning stub [3], square slot patch with a vertical coupling strip [4], dual and multiband U-slot patch antenna[5], and other techniques [6]-[8] are described to obtain wideband and small size micro-strip antennas.

The UWB communication system has allowed very low power emission level, thus it could be easily interfered by nearby communication system such as WiMAX communication system operating at 3.5GHz(3.4-3.7HGz), WLAN system such as IEEE 802.11/a operating at 5.2GHz (5.15-5.35GHz, 5.725-5.875GHz) and X-band downlink communication frequency operating at 7.5GHz (7.1-7.76GHz) [9]. To avoid the interference, band-stop filter can have used, but the use of band-stop filters increases the cost and complexity of the system. A better way to avoid interference is using UWB antenna with band-notch characteristic. In planar slot antennas, the slot width and feed structure affect the impedance bandwidth of the antenna. The wider slot gives more bandwidth and the optimum feed structure gives good impedance matching [10]. Figure 1. Shows basic design for a band notched UWB antenna. Figure 1(a) has a frequency band rang of f_L to f_H which resonates -10dB frequency. In Figure 1(b) a band stop resonates structure is shown with bandwidth ranging from f_L to f_H but a resonant frequency is also there to suppress the unwanted signal passing through it. Combing the UWB antenna and resonant structure a band-notched UWB antenna is formed as shown in figure 1(c) which suppress the interference between UWB antenna and other communication systems which are using the same frequency band at f_N. [12].

In this paper, a review and comparison have be done to study different UWB antenna techniques and also to described notching techniques for unwanted frequencies in UWB range. Two methods tuning stub and shaped slot are proposed here for notching.

II. TECHNIQUES OF BAND NOTCHING

A. *Shaped Slot*

By using different shaped slot, different slot antennas with wide-band or ultra wideband performance can be achieved. In Figure 2 different shaped slots are shown like tapered, circular, hexagonal, semicircular arc and elliptical which give different bandwidths.

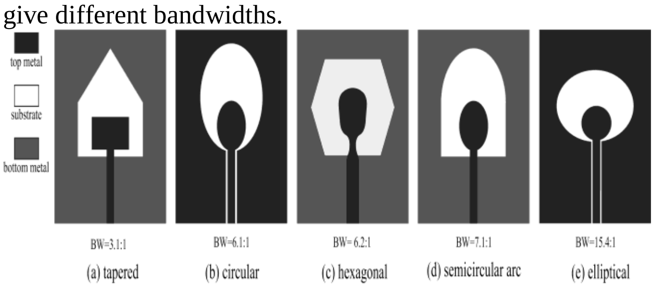

Fig. 2: Different shaped-slots (a) Tapered, (b) Circular, (c) Hexagonal, (d) Semicircular arc,(e) Elliptical

In [2] microstrip patch antenna is introduced with band notch characteristics, to create such band notch for the rejection of interference at the WLAN band (5.1GHz to 5.8GHz), a rectangular patch antenna is implemented with U-shaped slot is etched in the radiating patch and FR4 substrate with dielectric constant of 4.4 and substrate thickness of 1.6 mm with loss tangent of 0.02. The result of this antenna has a wide bandwidth ranging from 3.95 GHz to 9.69 GHz.

In [3] proposed antenna comprises a tapered-shape slot and rectangular tuning stub. This antenna gives the stable radiation patterns over an operating bandwidth of 3-11.2 GHz (115.5%) for VSWR ≤ 2 that covers the entire UWB and gives the maximum gain of 5.4 dBi. The dimension of this antenna is 22mm×24 mm which is significantly smaller than other UWB antennas. In this antenna FR4 substrate of thickness 1.6mm with relative permittivity 4.6 and loss tangent 0.02. Better impedance bandwidth and radiation characteristics can be achieved by selecting proper slot shape and tuning stub. Full-wave electromagnetic simulator IE3D software used to calculate the impedance characteristics of proposed antenna. The average peak gain of 3.6 dBi is found.

In [5] Dual and Multiband U-slot patch antenna is introduced. U-slot is mainly used for bandwidth enhancement rather than producing band notch. In this article L-probe feeding techniques is used in wideband patch antenna. Properly use of L-probe feeding technique, impedance bandwidth can yield 40% [18]. When U-shape slot is cut into patch, dual-band notch is introduced and then with 2 U-slot, 2 notches are introduced and triple-band antenna is presented. Zeland IE3D software is used to get the result and impedance bandwidth are given into TABLE I.

In [9] a compact UWB planar monopole antenna with the triple notch band is proposed. Two round shape slot is etched in radiating patch to achieve notch characteristics at WiMAX band and WLAN band. A pair of rotated V-shape slot are also etched on the ground plane to achieve notch band at X-band downlink satellite communication (7.1-7.76GHz). Operating impedance bandwidth of proposed antenna ranges from 2.9 to 10.9GHz. The size of antenna is very small of 27×25 mm^2.

It is observed by author that as the slot shift downward to upward or near to away from the micro-strip line, both the magnitude and bandwidth decreases keeping center frequency almost constant and it is concluded that length variation has a dominant effect for changing the center frequency of the notch and changing of bandwidth of the notch band in dominant manner, position of the slot is responsible. Proposed antenna has a nice omnidirectional radiation pattern in H-plane and bi-directional pattern in E-plane.

In [12] U-shaped slot etched onto ground plane to create a band notch at 3.6GHz frequency for WiMAX application and C-shaped slot of copper strip inserted into substrate to filter out 5.2GHz frequency and it gives the WLAN application. Size of this UWB antenna is 40×40 mm^2 and Rogers substrate material is used with dielectric constant of 2.5 of thickness 0.77 mm. Dual notch is used, by etching U-shaped slot into ground plane band rejection in lower frequency is found and C-shaped copper strip on substrate has been inserted to produce another rejection from UWB antenna. For making the input impedance singular, the design concept of the notch function is to adjust the total length of C-shaped slot to be approximately half-wavelength at the desired notched frequency. The notch frequency given the dimensions of the band-notched feature can proposed as [13]-[15],

$$F_{notch} = \frac{c}{2L\sqrt{\varepsilon eff}} \qquad (1)$$

Where, L is the total length of c-shaped copper strip, C is the speed of light, ε_{eff} is effective dielectric constant. The proposed antenna gives the gain of 5dB without notch and gives min gain with notch.

In [13] proposed compact planar UWB antenna with 3.4/5.5 GHz dual band notched characteristics, two nested C-shaped slot is used in the patch for band rejection of WLAN and WiMAX. A compact UWB antenna area of 26 by 30 is first proposed. Single band-notched characteristic from 5 to 6 GHz can be easily obtained By etching a C-shaped slot in the radiating element and By etching two nested C-shaped slots in the radiating patch, dual band-notched characteristics is obtained. Antenna yields an impedance bandwidth of 3.1–10.6 GHz with VSWR < 2. FR4 epoxy substrate is used with the thickness of 1.6 mm and ε_r of 4.4, loss tangent of 0.02. The gain of antenna is find out between 2 to 5 dBi.

In [17] proposed antenna consist of a microstrip line and a wide rectangular slot with a reverse L-shaped slot and a microstrip fed line. The reverse L-shaped slot operates the high frequency mode and the wide rectangular slot operates the low frequency mode. This antenna resonates the 10 dB bandwidth from 2.17 to 6.25 GHz. Two antenna is proposed in this article, first antenna is a broadband antenna with frequency band from 2.17 to 6.25 for WLAN and WiMAX and then second antenna had two notch band for rejecting two unwanted bands.

Length of strip controls the high rejection band. The longer length of strip, the lower of high rejection frequency band. Proposed both antenna is equal of 30×40 mm^2, FR4 substrate is used with the thickness of 1.6mm and ε_r of 4.4. Bandwidth proposed by this antenna covers the standard IEEE 802.11b/g (2.4-2.485GHz) and IEEE 802.11a (5.15-5.35GHz, 5.725-5.875GHz) for WLAN applications and 2.5 GHz (2.5-2.69), 3.5 GHz (3.3-3.8 GHz) and 5GHz (5.25-5.85 GHz) for WiMAX application.

In [18] proposed antenna is variation of circular monopole antenna. Spiral shaped λ/4 open stub in the microstrip fed line, frequency band notched for WiMAX is created. By etching a pair of symmetrical L-shaped slots and a pair of symmetrical step slots in the rectangular ground plane of antenna, a frequency band notch for WLAN is created. The dimension of antenna is 24mm×34mm×1.6mm. Omnidirectional characteristics and radiation bandwidth can be improved if the ground plane length is approximately the same size as that of the radiating structure width [19]. Proposed antenna provides gain varies between 2dB and 5dB over the 2.75–10.6GHz frequency range except in the 3.27–4.26GHz and 5.01–5.99GHz notched frequency bands.

In the last few years, various UWB antennas with band-notch characteristics have been presented. The most general method is to etch slots of different shapes either on radiating patch or in the ground or in microstrip, adding circuit stub, using metamaterial resonator [20-23]. Using these techniques, many antennas have been reported to achieve single notch band [24-28], dual band notch [29-34] and triple notch band [35-38] in UWB region.

B. Tuning Stub

The resonant frequency and bandwidth are controlled by the size of the tuning stub, rectangular slot and antenna. There are different kind of tuning stubs are used shown in Figure 3.

In [10] a compact coplanar waveguide (CPW) fed Ultra Wideband (UWB) slot antenna is presented. Antenna consists of a rectangular slot with cross like structure tuning stub. In this article observed that increasing the length of the arm the return loss is slightly increase in the lower and upper resonant frequency and vice versa for deceasing the length. The effect of width variation of the cross is that return loss is reduced and slight shift in the resonant frequency when the width of the cross stub is increased. The dimension of the proposed antenna is 19mm (length) × 20mm (width) × 1.6mm (thickness) fabricated on FR4 substrate. A better impedance bandwidth is found from 4.8 to 12.8 GHz with return loss of -10 dB (VSWR≤ 2).

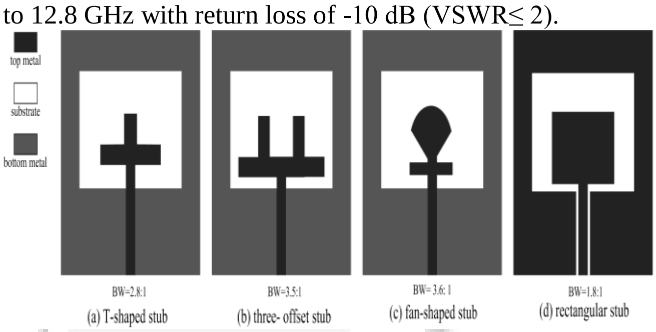

Fig. 3: Tuning stubs of different shapes (a) T-shaped stub, (b) Three offset stub, (c) Fan-shaped stub, (d) Rectangular stub

In [39] Printed wide-slot antennas fed by a microstrip line with a fork-like tuning stub for bandwidth enhancement are proposed. Enhanced coupling between the microstrip feed line and the printed wide slot by the fork-like tuning stub gives the bandwidth enhancement. When dimensions of the fork-like tuning stub vary, the coupling changes and the input impedance curve can have different resonant loops on the Smith chart in this article. A 1:1.5 VSWR bandwidth of 1GHz is achieved at operating frequencies around 2 GHz and it also obtained a 2 dB gain bandwidth of at least 0.5 GHz and satisfactory radiation pattern is observed.

III. Performance Comparison

In this section, a comparative report is given between different UWB antennas which all are having band notching behavior. In TABLE II, the operating and rejection frequencies of the antennas are presented and techniques which are used is also mentioned. In TABLE III and IV substrate name with their size, height and dielectric constant is presented. And in TABLE V the different antenna gain are reported.

Antenna	Simulation/GHz
Fed by L-probe	5.26-7.25(31.8%)
Single U-slot	4.97-5.22(4.9%) 5.94-7.26(20%)
two U-slot	4.95-5.20(4.9%) 5.74-6.00(4.4%) 6.41-7.24(12.2%)

Table 1: Simulated Impedance Bandwidth [5]

Reference no.	Operating Frequency (GHz)	Rejecting Frequency (GHz)	Rejecting Technique
2	3.95-9.69	5.1-5.8	Shaped Slot
9	2.9-10.9	3.4-3.7 5.15-5.35, 5.725-5.875 7.1-7.76	Shaped Slot
12	3.1-10.6	3.6-5.2	Shaped Slot
13	3.1-10.6	3.3-3.8 5-6	Shaped Slot
17	2.17-6.25	2.96-3.17 4.13-4.95	Shaped Slot
18	2.75-10.6	3.27-4.26 5.01-5.99	Shaped Slot

Table 2: Comparison of the operating frequency and rejecting frequency with different techniques

Reference Number	Size[mm]
2	36×34
3	22×24
9	27×25
12	40×40
13	26×30
17	30×40
18	24×34×1.6

Table 3: Comparison of size of different UWB antenna

Reference Number	Substrate	ε_r and thickness
2	FR4	4.4 and 1.6
3	FR4	4.6 and 1.6
9	FR4	4.4 and 0.8
12	Rogers	2.5 and 0.77
13	FR4	4.4 and 1.6
17	FR4	4.4 and 1.6
18	FR4 epoxy	4.4

Table 4: Comparison of different substrate and parameters used between different band notching UWB antennas

Reference Number	Average Pass Band Gain [dBi]
3	5.4
4	3.02to 3.92
12	>5
18	2 to 5
40	2

Table 5: Comparison of the gain

IV. Conclusions

A comprehensive report has been made over the recent UWB antennas with the band notching characteristics. All the methods, which were used in given literatures, to notch the unwanted frequencies are arranged in tuning stub and the shaped slot. Every section has been evaluated and studied of relevant papers. Finally comprehensive comparisons has been done among the operating frequencies, rejecting frequency, rejection techniques used, gain, used substrates and their thickness and relative permittivity and dimensions.

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