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Compact UWB Bandnotch Antenna for UWB Applications

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Abstract---In this paper, a compact UWB band notch antenna is proposed. Band notching is achieved by inserting a slot in the radiating patch. The antenna is analyzed for single band notch. The proposed antenna is operating in the frequency range of 3.4 to 10.6 GHz while its performance is not good in the WLAN band (5/6 GHz). The VSWR plot also shows that antenna has one stop band (5/6 GHz). The proposed antenna is simulated using Ansoft HFSS while its results is verified using CST Microwave studio suite. This miniature size has best matching in the UWB band because of low VSWR and advantageous radiation pattern. The ripples present in higher frequencies of the previous designed antenna has been removed by increasing the length of the ground plane. Moreover the antenna has a very compact size of (18×23 mm^2) and could be easily fabricated into portable UWB devices.

Keywords ----Radiating patch, VSWR, Ripples, UWB (ultra-wide band), WLAN (wireless local area network), UWB band notch antenna.

1. Introduction

The most popular and promising technology for future short range and high speed communication is Ultra wide band (UWB). The frequency band from 3.1 to 10.6 GHz has been allocated by the Federal Communications Commission (FCC), for UWB communication applications [1].

Two subsets of UWB exist within the technology. The first one termed as direct sequence UWB (DS-UWB) and the second one is orthogonal frequency division multiple access UWB (OFDM-UWB). DS-UWB ranges from 3.1–4.85 GHz and 6.2– 9.7 GHz while OFDM-UWB ranges from 3.432 – 4.488 GHZ and 6.6– 10.296 GHz. A notch band is required at 5.7 GHz for both frequency bands. Also attenuation at 10.6 GHz is needed for both frequency bands. It turns out that since the lower band is more popular in the implementation of both DS-UWB and OFDM-UWB, the mid-range stop-band is currently likely to be more useful [10].

The advantages of UWB communication are that they offer more resistance to multipath phenomenon, high data rate short range wireless communication, low complexity and low emission power [2]. The problem that encounters is that the IEEE 802.11a WLAN system operates in 5.15 to 5.825 GHz band which causes potential interference with the UWB communication. This interference can be mitigated by using a good filtering techniques. But the filtering techniques is much expensive and increases the system complexity. So by designing antenna having band notch characteristics is the most simple and economical solution [3]. There are various techniques to design band notch antennas such as etching L-shaped, E-shaped, C-shaped, arc shaped and U-shaped slots on the radiating patch [4-8]. Also there is another technique which uses parasitic strips in the printed monopole [9].

Here in this paper, We designed the UWB antenna using the work of [3]. The objective of our paper is to achieve a band notching characteristics in the designed antenna without using FR-4 substrate as it seems impractical for microstrip antennas having bandnotch more than 4 GHz. Also selecting the acceptable length of the ground plane so that no ripples may be present at higher frequencies. To achieve the desired notch band, we used a new technique of etching a slot with certain angles on the radiating patch. The optimized parameters of the slot resonator is mentioned in the table 2. The position and effect of the slot is analyzed from the surface current distributions at different frequencies. The parameters of the slots is optimized by simulations. The simulated VSWR plot shows that designed antenna operates only from 3.4 to 10.6 GHz while rejecting WLAN band in 5/6 GHz. The antenna is nearly Omni-directional and a peak gain of 4.575 dBi. The gain is suppressed in the WLAN band which is clear from the simulated gain curve. The designed antenna geometry is very simple and a very compact size which make it good to use in a portable devices.

2. Related Work:

In [3], the author designed UWB antenna having bandnotch characteristics. Also different UWB bandnotch antennas are designed by different authors such as etching L-shaped, E-shaped, C-shaped, arc shaped and U-shaped slots on the radiating patch [4-8]. These authors constructed antenna on FR-4 substrate. It seems good, however simulating and implementing antenna for more than 3 or 4 GHz frequency with FR-4 substrate isn't practical which mainly because very high loss tangent of FR-4, especially in notch frequencies and microstrip antennas design. It can be used in planar monopole antenna, but can't be used in planar monopole antenna that has the band notch more than 4 GHz.

By observing radiation pattern of different designed antennas it will be clear that some nulls are present at higher frequencies. This is because that maximum designers select very small length of the ground plane which create ripples at higher frequencies. In some designs these nulls are due to higher order harmonics.

3. ANTENNA GEOMETRY

The geometry of the proposed antenna is shown in the Fig 1 while its parameters are listed in the table 1. The antenna is constructed on Rogers R04003 substrate with thickness (h) of 1.5mm, relative permittivity of 3.55 and $\tan\delta = 0.0027$. The antenna is fed by a 50 Ω microstrip feedline.

The dimensions of the design is listed in table and shown in the Fig 1 and 2:

Table 1: optimized parameters of the UWB antenna with band notch characteristics.

W_{sub}	L_{sub}	W_f	L_{gnd}	L_1	L_2	L_3	L_4	h	W_1
18mm	23mm	2.8mm	7.2mm	7.4mm	11.5mm	5.3mm	7.28mm	1.5mm	4mm

Table 2: optimized parameters of the slot.

Ls	Le	α°	β°	We
10mm	4.75mm	65°	115°	0.45mm

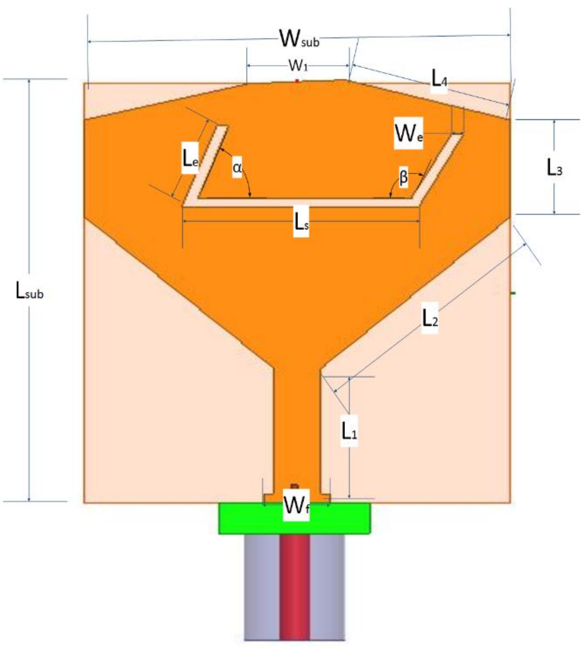

Figure 1: Front view of Designed Antenna

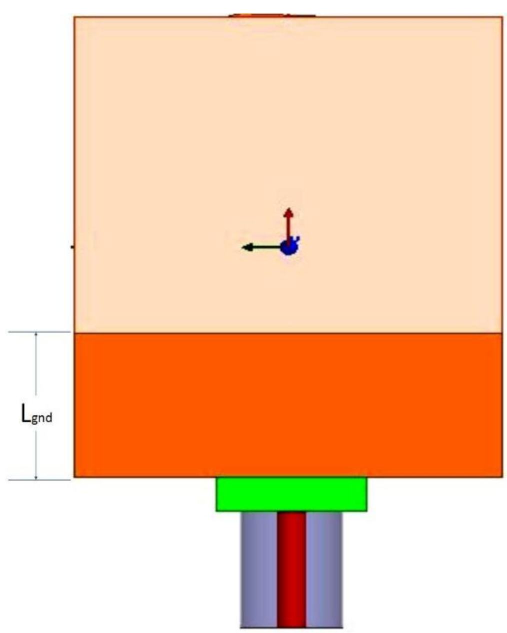

Figure 2: Back view

We inserted a slot resonator in the radiating patch of the above UWB antenna to achieve band notching. The dimensions of the slot is listed in the table 2 and shown in Fig 2. The antenna designed operate from 3.4 to 10.6 GHz while band notching characteristics at 5/6 GHz. So we have made one stop band for filtering of the WLAN signal.

4. RESULTS AND DISCUSSIONS

3.1. UWB antenna without slot-- First the antenna has been designed without slot in the radiating patch. The S_{11} plot shows that the antenna covers the entire UWB band and is matched to the transmission line from 3.4 to 10.7 GHz. The S_{11} plot without slot is shown in Fig 3. It is obvious from the plot that antenna have potential interference with the WLAN signal as it is operating in the WLAN band. The VSWR curve shows that antenna has no mismatch in UWB band as VSWR < 2 in the entire band and a maximum VSWR of 1.82 at 6 GHz. The VSWR plot without slot is shown in Fig 4.

3.2. UWB antenna with slot-- By inserting slot in the radiating patch, the antenna operate in the entire UWB band while rejecting WLAN signal. The geometry of slot is shown in the Fig 1. Now there is no more potential interference of the UWB and WLAN signals. The length of the notch band is calculated from the equation (1) below:

$$f_{notch}=\frac{C}{2\times \mathbf{L}\sqrt{\frac{\varepsilon r+1}{2}}} \qquad (1)$$

Where, L is the length of the slot resonator, ϵ_r is the relative permittivity and C is the speed of light. The length of the slot resonator is calculated from (1) while its position is analyzed from surface current distribution as shown in Fig 5. The width of the slot is optimized by simulating at different slot width as shown in Fig 3 and 4. After simulating at different slot widths we select the width of the slot as We =0.45mm. It is cleared from the S_{11} plot and VSWR plot that the antenna has a good performance in the UWB band while notch at the WLAN band (5/6 GHz).

So, by introducing the slot of length and width discussed above in the radiating patch, the VSWR in 5/6 GHz WLAN band is greater than 2, which shows that the antenna performance is not good in this band. The antenna has been simulated using HFSS and CST microwave studio suite and the simulation results are shown in Figures.

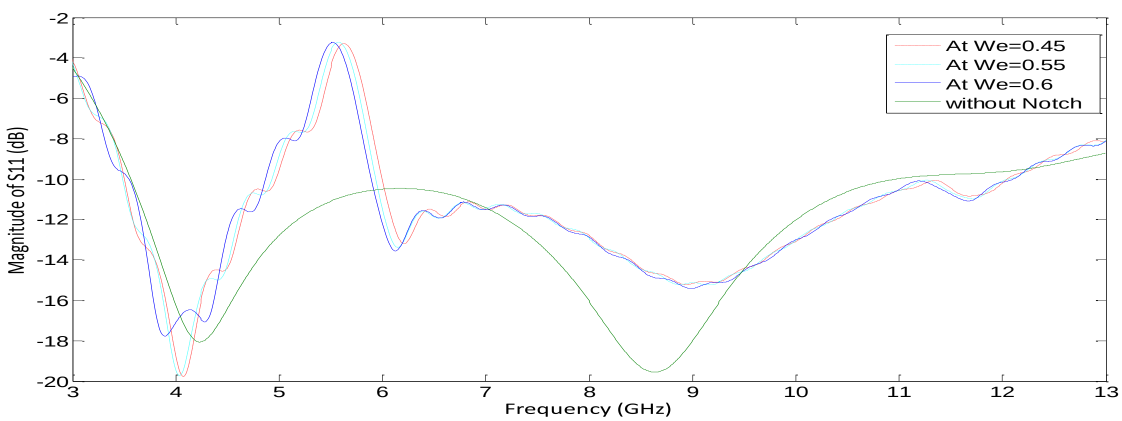

Fig 3 S11 vs. Frequency plots with and without Notch

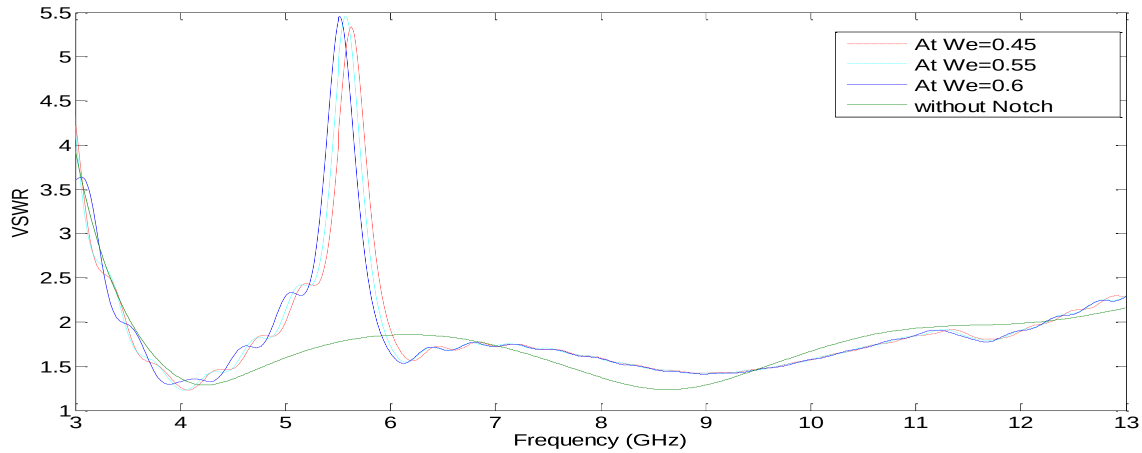

Fig 4 VSWR vs. Frequency plots with and without Notch

Surface current distribution-- Fig 5 shows the simulated current distributions on the surface of the proposed antenna at 5.5, 7.1, 8.2 and 10.1GHz. At 7.1, 8.2, and 10.1 GHz, the maximum current flows along the microstrip feed line, while low current densities around the slot. On the other hand, the surface current distribution on the antenna at 5.5 GHz is totally concentrated around the slot. So a maximum electromagnetic energy has been stored around the slot and no current flows along the microstrip feedline.

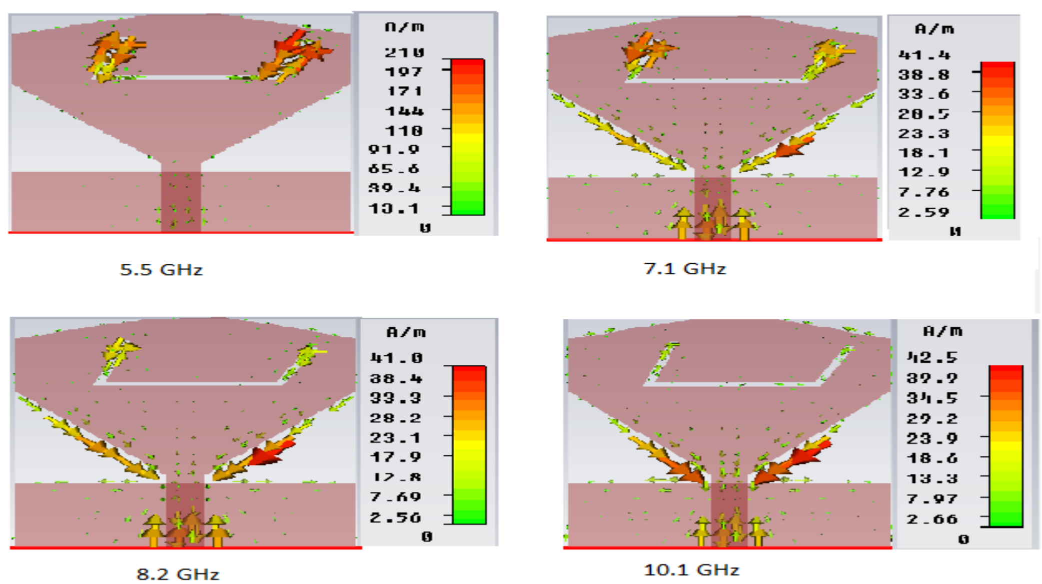

Fig 5 Simulated current distributions on the surface of the proposed antenna at different frequencies

Far field radiation pattern-- The simulated Far field of the proposed antenna at different frequencies are shown in the Fig 6. These results shows that antenna is nearly omnidirectional which make it a good candidate for UWB portable devices. These results also reveals that antenna has consistent radiation pattern throughout the band. The radiation pattern at higher frequencies are also shown in Fig 6 which shows that no ripples are present at higher frequencies. This is because that we have selected an acceptable length of the ground plane.

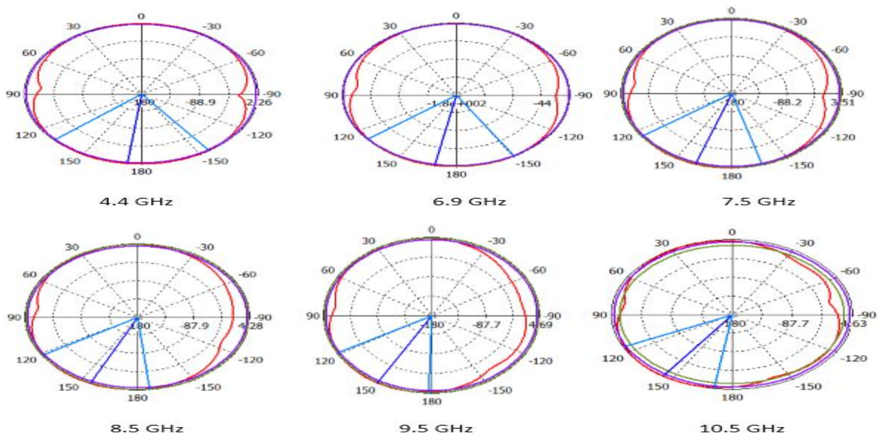

Fig 6 Radiation patterns for antenna with notches

Antenna Gain plot without notch-- The antenna gain is evaluated without notch in the radiating patch. The gain plot shows that antenna has a maximum gain of 4.5 dBi while an average gain of almost 4.3 dBi. The gain increases considerably as we move towards higher frequencies.

Antenna Gain plot with notch-- The gain plot with Notch shows that antenna gain is suppressed well in the WLAN band. The gain plot also shows that antenna performance is not good at WLAN band. The minimum gain is -1.7 dBi at 5.6 GHz which is at WLAN band. The negative gains (in dBi) indicates the destructive interference of surface currents at those frequencies leading to band-notch creation. The sharp decrease in the antenna gain is observed while moving from 5 GHz to 5.8 GHz. After this the gain increases considerably as shown in Figure 7. The maximum gain occur at 8.5 GHz which is 4.5 dBi. So the gain is also enhanced along with band notching.

Comparison of Gain with and without Notch

The Antenna gain is compared with and without notch as shown in the Fig 7. The plot clearly shows the Notch frequency band.

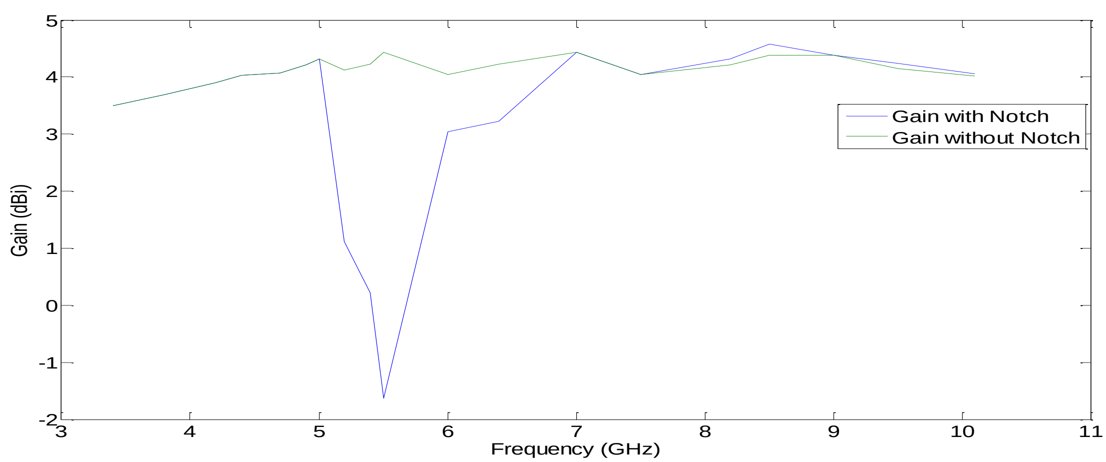

Fig 7 Antenna Gain plot with and without Notch

5. CONCLUSIONS

A compact wide band radiating patch UWB bandnotch antenna has been proposed. The potential interference between the UWB system and WLAN band has been minimized by introducing slot in the radiating patch, which rejecting the WLAN frequency band. Notching has been observed at the WLAN band which make this antenna much useful for UWB applications. This antenna work in the entire UWB band. The antenna results has been analyzed showing high average gain and nearly Omni-directional radiation pattern. The nulls at higher frequencies has been removed. The antenna provides best matching and low VSWR in the frequency band from 3 to 10.6 GHz with a band-notching effect at the frequency band from 5/6 GHz. The antenna has a very compact size of 23×18 mm^2 which make them to use it in the portable UWB devices without causing potential interference.

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