Antenna Design with Band Notched Characteristic for UWB Applications

Hashmatullah Ahmadzai¹, Saeid Karamzadeh²

Abstract - In this paper, a small, low cost and light weight monopole antenna is presented with notched characteristic for Ultra Wideband application. The patch of the antenna consists of sides that are cut a half circle and a rectangle. A narrow rectangular slot has been made to notch the undesired frequency band. The ground plane of the proposed antenna has a rectangular cut which is useful for Impendence matching. The antenna is fed with 50 Ω micro-strip feedline. It has been printed on FR4 substrate which has the relative permittivity of $\varepsilon_r$ =4.4 and the thickness of 1mm. The total size of the antenna is (26 ×20×1) mm³. The proposed antenna is working at a larger frequency band from 2.9 GHz to 10.8 GHz and has notch band characteristic at 5 GHz to 5.9 GHz. C band notch can be achieved with a band width from 4GHz to 8GHz by increasing the slot size. Some of the simulation results and the characteristics of the proposed antenna are explained in this paper.

Keywords - Monopole antenna, ultra wideband, notch band, rectangle slotted

1. Introduction

The Ultra wide band technology got more attention from the time when the Federal Communication Commission (FCC) approved that the band Width 3.1GHz - 10.6GHz said to be Ultra Wideband UWB [1]. In the recent years, a significant development was achieved in Ultra Wideband technology and it has been widely used in some radars, wireless communication systems, medical and military applications. The main part of the Ultra wideband technology is the antenna; the printed monopole antenna is a better choice for Ultra wideband applications due to its simple structure, wide frequency range, omni-directional properties and low cost.

There are many different shapes and structures of monopole antennas and ultra-wide band was achieved [2-5], however the main problem in UWB antennas is that there are some standard narrow bands allocated in FCC frequency range such as Wireless Local Area Network (WLAN) which has the band Width of 5.1 GHz-5.8 GHz according to IEEE802.11a or C Band which has band width of 4GHz to 8GHz that may cause potential interference. For avoiding interference, filters can be used with Ultra Wideband antenna but it means more complexity and extra cost [6] so another option to avoid or minimize the interference is using Rejection techniques. There are commonly two main techniques used in antenna design to notch band of frequencies [7]. The first technique is very simple. In this technique, undesired band of frequencies can be notched or filtered by cutting different shapes of slots in radiator or ground plan or both [8-9] whereas in the second technique, notch band frequencies can be obtained by using different shapes of parasitic elements which are electromagnetically coupled with radiating patch and placed near the ground plane [10-11].

In this paper, we have discussed compact size, low profile, simple structure and omni-directional properties of the Ultra-Wide band antennas that have a band width from 2.9 GHz to 10.8 GHz which covers FCC’s Ultra-wide band frequency range. This antenna has avoided the frequency range from 5 GHz to 5.9 GHz which is WLAN frequency range according to IEEE802.11a by simple narrow rectangle slot. or C band 4GHz to 8 GHz can be notched by making
the slot wider. The Ansoft’s (HFSS) software was used for designing the structure and analyzing the properties of the proposed antenna [12]. This paper was arranged as follows:

In Section II, the geometry of proposed antenna was explained; in Section III, C band notched antenna was explained; in Section IV, various results were shown and discussed and in Section V, we sum up with a brief conclusion.

2. Antenna Design

Figure 1 shows the design of the proposed antenna. The antenna is fabricated on FR4 substrate, the relative permittivity of FR4 substrate is $\varepsilon_r = 4.4$ with loss tangent of $\delta = 0.02$. The overall size of the proposed antenna is $20 \times 26 \times 1$ mm$^3$, which shows the width $W_s$ of antenna is 20 mm, the length $L_s$ of antenna is 26 mm and the thickness $h$ of substrate is 1 mm. The radiating patch which is one of the important parts of the antenna, consists of sides cut a half circle with radius $R$ and a rectangle with Width $W_2 \times$ Length $L_2$. The ground plane has the length $L_g$ and width $W_s$. Rectangular cut was made for good impedance matching and for getting wide range of frequency band; that is why the rectangle cut in ground plane produces capacitive load which minimizes or cancels out the inductive nature of radiating patch to produce almost resistive input impedance [13]. The radiating patch is fed with 50Ω micro-strip feed line with width $W_f$.

![Figure 1](image1.png)

Figure 1. (a) Shows the front view of proposed antenna, (b) Shows the back view of proposed antenna

All the parameters which are shown in Figure 1 are listed in Table 1 and each of the parameters is measured in millimeters (mm).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values (mm)</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$W_s$</td>
<td>20</td>
<td>$W_2$</td>
<td>5</td>
</tr>
<tr>
<td>$L_s$</td>
<td>26</td>
<td>$L_2$</td>
<td>5</td>
</tr>
<tr>
<td>$h$</td>
<td>1</td>
<td>$W_f$</td>
<td>2</td>
</tr>
<tr>
<td>$R$</td>
<td>14</td>
<td>$L_f$</td>
<td>7</td>
</tr>
<tr>
<td>$L_g$</td>
<td>10</td>
<td>$L_d$</td>
<td>10</td>
</tr>
<tr>
<td>$L_d$</td>
<td>8.6</td>
<td>$W_3$</td>
<td>6</td>
</tr>
<tr>
<td>$W_1$</td>
<td>17.5</td>
<td>$L_3$</td>
<td>4</td>
</tr>
<tr>
<td>$L_1$</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Note: In order to notch the C Band, just increase the size of slot, change the value of $L_1$ from 0.4mm to 4.5mm and $W_1$ from 17.5mm to 19mm and change the position of slot $L_d$ from 8.6mm to 3.4mm.

In Figure 2, all the phases were shown to get the proposed antenna. Simple antenna was shown in first phase (I) without any changes in its patch and ground plan. In the second phase (II), a rectangular cut was made in ground plane and no changes were made in radiating patch whereas in the third phase (III) we only added a rectangle shape to the radiating patch and Ultra wideband has been achieved in this phase. In the fourth phase (IV), a narrow rectangle slot was cut in radiating patch which helps us to notch undesired frequency band.

![Figure 2](image_url)

**Figure 2.** (I) Sample antenna, (II) Rectangle Cut in ground plan, (III) adding Rectangle to radiating Patch, (IV) Slot in Patch

The return losses or the S11 of all the phases (I to IV) were shown in Figure 3. The figure shows the variation that has occurred in each phase, and in phase (III) we have achieved the Ultra wideband and in phase (IV) an undesired frequency band was notched.
Antenna Design with Band Notched Characteristic for UWB Applications

Figure 3. The variation that has occurred in S11 due to the changes made in the design antenna from (I),(II),(III) and (IV)

In Table 2, we compared our design with some other designs which are in References. We have compared the designs in terms of dimensions, gain, notched band, and bandwidth.

Table 2. Comparison of some Reference designs with proposed antenna in terms of Dimensions, Gain, Frequency Range and Notched Band

<table>
<thead>
<tr>
<th>Reference No</th>
<th>dimensions (mm$^3$)</th>
<th>Frequency Range (GHz)</th>
<th>Gain</th>
<th>Notched band (GHz)</th>
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<tbody>
<tr>
<td>[8]</td>
<td>26×35×1.6</td>
<td>2.8 ~ 11.4</td>
<td>6.7 dB</td>
<td>5.1 - 5.825</td>
</tr>
<tr>
<td>[14]</td>
<td>30×40×1.6</td>
<td>2.3 - 11.4</td>
<td>5.5 dB</td>
<td>4.9 – 6</td>
</tr>
<tr>
<td>[15]</td>
<td>26×32×1.6</td>
<td>2.8 – 11</td>
<td>2.7 dB</td>
<td>3.3 - 3.6</td>
</tr>
<tr>
<td>[16]</td>
<td>35×35×1.6</td>
<td>2.21 – 12.83</td>
<td>6.7dB</td>
<td>3.3 - 3.8, 5.15 - 5.8 &amp; 7.9 - 8.4</td>
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<tr>
<td>[17]</td>
<td>48×48×0.8</td>
<td>2.5 – 12</td>
<td>6.7dB</td>
<td>5.1-6</td>
</tr>
<tr>
<td>[18]</td>
<td>50×45×0.787</td>
<td>2.7 - 10.9</td>
<td>4dB</td>
<td>5.1-5.9</td>
</tr>
<tr>
<td>[19]</td>
<td>32×38×1.6</td>
<td>2.8 - 14.9</td>
<td>6.5 dB</td>
<td>3.1-4.8 &amp; 9.6-11.2</td>
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<td>The proposed antenna</td>
<td>20×26×1</td>
<td>2.9-10.8</td>
<td>4.7 dB</td>
<td>5 - 5.9</td>
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3. C Band Notched Antenna

According to IEEE, C band has a bandwidth ranging from 4GHz to 8GHz, which is also allocated in FCC’s Ultra wideband range and may cause potential interference. Therefore, rejection techniques that we have discussed can be used for avoiding the interference. In this paper, we have designed a C band notched antenna by making some changes in the slot of our proposed antenna. We have changed the width $W_1$ of the slot which was 17.5mm to 19mm, the length
The variation that has occurred in S11 due to the changes made in the design antenna from (I), (II), (III) and (IV).

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The proposed antenna 20×26×1 was designed to work from 2.9GHz to 10.8GHz with the notch band at 4GHz to 8GHz.

L1 of the slot which was 0.4mm to 4.5mm and we have also changed the position of the slot Ld from 8.6mm to 3.4mm. Figure 4 shows the design of C band notched Antenna.

Figure 4. C Band Notched Antenna Design

The return loss or the S11 of the antenna is shown in Figure 5. The figure shows that the antenna is working from 2.9GHz to 10.7GHz with the notch band at 4GHz to 8GHz.

Figure 5. The Return loss S11 of C Band Notched antenna
4. Results and Discussions

The simulated results have been measured and analyzed in the Ansoft’s High Frequency Structure Simulator (HFSS) software [12]. The proposed antenna has a bandwidth of 7.9GHz and it is working in the frequency range of 2.9GHz to 10.8GHz that covers the frequency range of Ultra-Wide band. The proposed antenna is notching the WLAN Band.

S11 or Return loss is one of the important parameters of the antenna, which is also called the reflection coefficient. It shows how much power is reflected from the antenna. The S11 of proposed antenna is shown in Figure 6 which shows that the antenna is working from 2.9GHz to 10.8GHz with the notched band at 5GHz to 5.9GHz. Figure 7, shows that by changing the size of the slot, the performance of the notched band also changes. As we can see in Figure 7 (a), by keeping the Width of the slot W1=17.5 and changing the Length L1 of the slot, the performance of a notched band does not vary that much whereas in Figure 7 (b), some variation is observed in the performance of the notched band by keeping the Length of the slot L1=0.4 and by changing the Width W1 of the slot and at W1 =17.5mm notch band can be observed to rise from 5GHz to 5.9GHz.

![Figure 6. S11 of the Proposed Antenna](image)

![Figure 7. (a) shows the return Losses of the proposed antenna with different Length L1 slot that is 0.2,0.3,0.4 and 0.5 with W1=17.5 and Ld=8.6 where all units are given in mm. While (b) shows the return losses of the proposed antenna with different Width W1 of slot that is 16.5,17.5,18.5 and 19.5 with L1 =0.4 and Ld=8.6 where all units are given in mm.](image)

Figure 8 shows the simulated surface current distribution and compares at notched frequency 5.4GHz, the comparison was done on the basis of the slot. In Figure 8 (a), it is shown that the maximum current distribution is around the edges of the rectangular part of the patch when we have no slot in the antenna whereas in Figure 8 (b) we can see that maximum current distribution is around the slot.

Figure 9 shows The Voltage Standing Wave Ratio (VSWR); VSWR describes the power reflected from the antenna. The value of VSWR should be less than 2 (VSWR<2). In Figure 9, we can see that the value of VSWR is less than 2 in the frequency range from 2.9GHz to 10.8GHz while in the notched frequency band from 5GHz to 5.9GHz, the value of VSWR is greater than 2 (VSWR>2).

In Figure 10, the radiation pattern of the proposed antenna was measured and compared at notched frequency of 5.4GHz when there was no slot and when there is a slot. The gain of the proposed antenna is shown in Figure 11, which is another good measurement to describe the performance of the antenna. The gain of proposed antenna is sharply decreases at 5.41 GHz then it increases back and almost reach es to 4.7 dB.
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Antenna Design with Band Notched Characteristic for UWB Applications

Figure 9. The VSWR of the proposed antenna

Figure 10. The Radiation pattern of Proposed antenna at notched frequency 5.4GHz (a) without a slot and (b) with a slot

Figure 11. The Peak Realized Gain of Proposed antenna
5. Conclusion

A new microstrip-fed monopole Ultra Wideband antenna was discussed in this paper. The proposed antenna has a frequency band width range from 2.9GHz to 10.8GHz and band rejected characteristic at 5GHz to 5.9GHz. The band reject characteristic can be obtained by cutting a rectangular slot in its radiating patch. The rectangular cut in the ground plane is made for obtaining good impedance matching. The above mentioned results and discussions show that the proposed antenna is an appropriate choice for Ultra wideband applications.

References