A CPW-Fed Printed Monopole Ultra-Wideband Antenna with E-Shaped Notched Band Slot

A coplanar waveguide (CPW) fed printed monopole ultra-wideband antenna with E-shaped notched band slot is presented. This antenna is fed by a 50 Ω CPW line and it is fabricated on the FR-4 substrate with a thickness of 1.5 mm and relative dielectric constant of 4.4. Two modifications are introduced on this antenna to improve its operating bandwidth. The first one is to remove a 90° angles from the two upper corners of the ground plane by blending them in a radius of 10 mm. The second modification is to chamfer the feed edges at the patch. All simulations in this work were carried out by using CST Microwave Studio™ package. Compared with the recently proposed antennas, the proposed antenna has wide bandwidth with acceptable returned losses, compact in size and easy design, easy controllable band-notch characteristics and good gain characteristics over the entire desired bandwidth.

Keywords: Ultra wideband, Coplanar waveguide, Band-notch, UWB antenna

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1. Introduction

Ultra wideband (UWB) technology has become one of most promising technologies in wireless communications since the federal communications commission (FCC) has released the 3.1-10.6 GHz frequency band in 2002 for UWB technology and applications [1]. Many different types of antenna are being considered for UWB applications. Among these antenna configurations, circular monopole features simple structure, easy fabrication, wide frequency bandwidth and satisfactory radiation patterns [2,3].

However the designated band overlaps with the HIPERLAN/2 bands (5.15-5.35 GHz, 5.470-5.725GHz) and the IEEE 802.11.a bands (5.15-5.35GHz, 5.725-5.825) which can interfere with the UWB communication systems. Therefore, the UWB antenna with a band notched characteristics is required to reduce the interference. Researchers in some literatures produce band rejection characteristics by cutting a slot on the antenna, or adding a tuning metal stub within the antenna structure [4,5]. The antenna notched band is simile to the virtual-open or virtual-short circuit and is capable of not only preventing energy from transmitting to free space, but of also avoiding receiving the unwanted signal from free space [6,7].

In this paper a new design for printed CPW fed elliptical monopole antenna with notched slot were presented. The notched frequency band is adjustable by varying the length and location of the slot. This antenna can cover UWB frequency range (3.1-20 GHz) and rejects the limited (5.15-5.825 GHz) band. To understand the behavior of the antenna model and to obtain the optimum parameters, the simulation was performed with CST Microwave Studio™ package based on transient time solver method.

2. Antenna Design

The proposed geometry of the antenna is presented in Fig. (1) and the parameters are summarized in Table (1). This antenna is consist of elliptical patch fed by a 50Ω CPW line with rectangular ground plane and has a dimension of 22.2×26.5 mm² that is fabricated on the FR-4 substrate with a thickness of 1.5 mm and relative dielectric constant of 4.4. The proposed antenna is located in x-y plane and the normal direction is parallel to z-axis.

<table>
<thead>
<tr>
<th>Table (1) Antenna parameters, mm</th>
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<tbody>
<tr>
<td>l₁</td>
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<tr>
<td>l₂</td>
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<tr>
<td>l₃</td>
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<td>g</td>
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<td>h</td>
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</table>

It has been shown in literature that the -10 dB operating bandwidth of UWB antenna can be enhanced significantly by using tapered microstrip or CPW feeding line, arc shaped patch and tapered ground plane [8-11]. Accordingly, two modifications are introduced on the
proposed antenna to improve its operating bandwidth. The first one is to remove a 90° angles from the two upper corners of the ground plane by blending them in a radius of 10mm. The second modification is to chamfer the feed edges at the patch with 15° angle and distance equal to 4.1mm.

![Configuration of proposed antenna: (a) Top view (b) Proposed cutting slot](image)

As depicted in Fig. (1), a thin E-shaped slot is etched in the interior of the radiating element. The presence of the slot produces an additional resonance mode in the structure, called slot mode, which is responsible for the degradation of the input impedance of the antenna at certain frequencies, i.e., within the notched frequency band [12]. Resonance of the slot occurs, when the length of its external perimeter is approximately half wavelength of the notched band center frequency and given by:

$$\frac{\lambda}{2_{\text{Notched}}} = 2(S_1 + S_2 + S_5)$$  \hspace{1cm} (1)

The notched center frequency can be adjusted by tuning the length of the U shape slot and the notched depth can be slightly adjusted by optimizing the length $S_6$ of the middle slot.

3. Antenna Simulation Results

In this section analysis of the proposed antenna are obtained by using CST Microwave Studio TM package. Figure (2) shows the simulated return loss $S_{11}$ for the proposed antenna. As shown in Fig. (2), the effect of modifications is clearly illustrated. It can be noticed that chamfering the edge of the feeder near the patch has more effect than blending the upper edges of the ground plane. Both modifications have a considerable effect on the performance of the return loss of the antenna.

The proposed antenna satisfies the -10dB return loss (VSWR<2) requirements from 3GHz-20GHz. The proposed antenna can cover the frequency band 3.1 to 10.6 released by FCC for UWB system for VSWR<2 and rejected band from 5-6 GHz.

![Fig. (2) Return loss of the proposed antenna](image)

Figure (3) shows the simulated VSWR performance of the proposed antenna. The simulated bandwidth of the antenna ranges from 3.1 to more than 11GHz for VSWR less than 2. It is also observed that the sharp frequency band-stop characteristic is obtained much closed to the desired frequency of 5.5GHz when an E-shaped slot with the optimized dimensions given in Table (1) is inserted into the antenna structure.

![Fig. (3) Simulated VSWR for the proposed antenna with E-slot](image)

Figure (4) shows the current distributions at 4, 5.5, 6.5, and 10.5 GHz. At notched band center frequency 5.5 GHz, it reveals that, current distribution concentrate over the area of the slot.
more and stronger than any other area. It seems that, exciting the slot mode in the radiating structure, play a role in a band notched filter [9,12,13].

Fig. (4) Current distribution at 4 GHz, 5.5 GHz, 6.5 GHz and 10.5 GHz

Figure (5) shows the simulated radiation patterns for the proposed antenna at 3.5GHz, 6.5GHz, 8.5GHz and 10.5GHz frequencies. The proposed antenna has an acceptable Omni-directional pattern required to receive signal from all directions.

Fig. (5) Polar plot of far-field antenna pattern at selected frequencies
The antenna gain is varying from about 2.84dBi to 5.68dBi across the entire bandwidth. Figure (6) shows the 3D plot of the field pattern of the proposed antenna at selected frequencies and the gain value at each of the selected frequencies.

![Field pattern plots](image)

Table (2) presents a comparison between the performance of some recently UWB antennas that cover the UWB band from 3.1-10.6 GHz and the proposed antenna. The proposed antenna shows wide impedance bandwidth, compact size, narrow selective notched band and good gain features.

<table>
<thead>
<tr>
<th>Antenna</th>
<th>Simulated Bandwidth (GHz)</th>
<th>Simulated Notch Bandwidth (GHz)</th>
<th>Notch Slot Type</th>
<th>Antenna Size (mm²)</th>
<th>Gain (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This work</td>
<td>3-20</td>
<td>5-6</td>
<td>E-Shaped</td>
<td>22.2x26.5</td>
<td>2.84-5.68</td>
</tr>
<tr>
<td>[7]</td>
<td>2-12</td>
<td>5.24-6.46</td>
<td>Resonator</td>
<td>35x30</td>
<td>Not defined</td>
</tr>
<tr>
<td>[13]</td>
<td>3-23</td>
<td>5-6</td>
<td>C-Shaped</td>
<td>28x30</td>
<td>0.2-3.9</td>
</tr>
<tr>
<td>[14]</td>
<td>2-12</td>
<td>4-6.5</td>
<td>E-Shaped</td>
<td>35x35</td>
<td>Not defined</td>
</tr>
</tbody>
</table>

4. Conclusion

In this paper, a novel CPW-fed printed UWB antenna with band rejection E-shaped slot is proposed. The proposed antenna design begins from simple printed elliptical monopole fed by 50 Ω CPW with rectangular ground plane. Two modifications are proposed to enhance the -10 dB UWB characteristics. It can be noticed that chamfering the edge of the feeder near the patch has more effect on impedance matching than blending the upper edges of the ground plane. Both modifications have a considerable effect on the performance of the return loss of the antenna. The notched frequency band covers the WLAN frequency range for interference reduction between UWB and WLAN system. By adjusting the dimension of the slot, it can obtain the desired band-notched characteristics.

References


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