Chapter 5:

Y-SHAPED ULTRA WIDE-BAND ANTENNA
5.1 Introduction

UWB is a short range unlicensed wireless communication system which has a potential to offer high capacity with low power compared with the contemporary wireless systems for short range applications. After the release of UWB for unlicensed application by the Federal Communications Commission (FCC), it receives much lower frequency than the resonant frequency of the conventional printed antenna with the same patch area. Attention of researchers was drawn to UWB due to its inherent properties of low power consumption, high data rate and simple configuration [1]. Under the rapid developments of UWB systems, a lot of attention is being given to designing the UWB antennas. The design of antennas for UWB applications must satisfy the following requirements. They should have ultra wide impedance bandwidth, omni-directional radiation pattern, constant gain high radiation efficiency, constant group delay, low profile and easy manufacturing [2]. Interestingly the planar slot antennas with CPW feed posses the features mentioned above with simple structure, less radiation loss, less dispersion and easy integration of monolithic microwave integrated circuits (MMIC) [3]. Hence, the CPW fed planar slot antennas [4-10] are identified as the most promising antenna design for wide-band wireless applications. In planar slot antennas, the slot width and feed structure affect the impedance bandwidth of the antenna. The wider slot of patch gives more bandwidth, and the optimum feed structure gives good impedance matching [11-15]. The CPW feed line with various possible patch shapes are available such as `T', cross, fork like, volcano and square are used to give wideband width [16-24]. The proposed antenna in this work is designed with a compact Y slot. The antennas can be tuned with inductive shorting pins or capacitive screws, but tuning is prohibitive when the number of elements in an array is large. Our aim is to reduce the size of the antenna as well as increase the operating bandwidth. While comparing the same type of antennas existing in the literature [25-30], the proposed antenna has 58% fractional bandwidth which is higher than the reference antenna [20] is more than sufficient for any UWB applications. The radiation pattern obtained from the simulation is almost stable across the matching bandwidth an average gain of 3dBi. The simulation software used for this analysis is IE3D [33]. The work is organized as follows: Section 2: brings out the geometry of the antenna. In Section 3, simulation results and analysis are discussed. Section 4: concludes the work [31-32].

5.2 Summary of Proposed Antenna Design

Design and analysis of two compact coplanar waveguide (CPW) fed Ultra Wideband (UWB) slot antenna is presented in this work. The antenna consists of a Y- shaped slot. The CPW feed is designed for 50Ω impedance. The characteristics of the designed structure are investigated by using MoM based electromagnetic solver, IE3D. An extensive analysis of the proposed antenna is presented in this chapter. The simulation of the proposed antenna [31-32] was fabricated with FR4 substrate. A better impedance bandwidth is obtained in proposed antenna from 2.85 GHz to 5 GHz that constitutes a fractional bandwidth of 58% with return loss of about -10 dB is greater than the impedance bandwidth which is obtained in reference antenna [20] from 7.70 GHz to 11 GHz that constitutes a fractional bandwidth of 38% with
return loss of about -10 dB. Also the proposed antenna have a return loss of about -27.75 at 8.51 GHz and obtained a impedance bandwidth from 9.9 GHz to 11.5 GHz that constitutes a fractional bandwidth of 14.73% with return loss of about -10 dB. The simple configuration and low profile nature of the proposed antenna leads to easy fabrication that may be built for any wireless UWB device applications.

- **5.3 Antenna Structure**

The structure of the proposed antenna is shown in Fig.5.1. The parameters \(W_1\) and \(L_1\) are the width and length of the ‘Y-Shaped’ slot, \(W_2\), \(W_3\), \(L_2\) and \(L_3\) are the widths and lengths of the rectangular slot. \(d\) = 0.375 mm is the distance between the patch and feed line. \(W\) and \(L\) are the width and length of the whole antenna respectively. In this work, a dielectric substrate (FR4) with thickness of 1.6 mm and a relative permittivity of 4.4 as substrate. The CPW feed is designed for 50 Ω characteristic impedance with fixed 2 mm feed line width and 0.375mm ground gap. The structure of the reference antenna [20] is shown in Fig.5.2. The parameters \(W_1\) and \(L_1\) are the width and length of the ‘Y-Shaped’ slot, \(W_2\), \(W_3\), \(L_2\) and \(L_3\) are the widths and lengths of the rectangular stub. \(d\) is the distance between the patch and feed line along with dielectric substrate thickness of 5 mm and a relative permittivity of 1.05 is chosen as substrate. \(W\) and \(L\) are the width and length of the whole antenna respectively. The CPW feed is designed for 50Ω characteristic impedance with fixed 2 mm feed line width and 0.375mm ground gap. The designs of the antennas are same, only difference between the reference antenna & proposed antenna is its dielectric constant and substrate height.

![Fig 5.1: Structure of Proposed Antenna](image-url)
The proposed antenna produces wide bandwidth with omni-directional radiation pattern. The wide bandwidth and impedance matching with reduced size of the antenna is achieved due to resultant of different surface magnetic currents.

5.4 Simulated Results and Analysis

In this section, various parametric analyses for the proposed UWB antennas are carried out and presented. The proposed work is designed on the modification of reference antenna [20] which is shown Fig. 5.1. The analysis and optimization were performed for the best impedance bandwidth. Extensive parametric study was made by IE3D software. The best results of the antenna are shown in Table 5.1. The simulated return loss of the proposed antenna is shown in Fig. 5.3; whereas the return loss of reference antenna is shown in Fig. 5.4; which clearly indicates that the impedance bandwidth of the reference antenna is 3.30 GHz (7.70 GHz-11GHz) for a return loss ($S_{11}$) of -10dB and the impedance bandwidth of the proposed antenna is 2.15 GHz (2.85 GHz-5GHz) for a return loss ($S_{11}$) of -10 dB. The ultra wide band is due to the coupling between the Y-Shaped slot and the rectangular slot. The resonant frequency and band-width are controlled by the size of the Y-Shaped slot antenna and rectangular stub in the ground plane. Proper geometrical selection of the antenna parameters results in the variation of field distribution, which in turn affects the characteristics of the proposed antenna.

For proposed antenna, band-width of 58% was much higher than the reference antenna whose band-width is 38%.

In the proposed antenna, we also get another -10dB band-width in the range of 9.9 GHz-11.5 GHz and get a resonant frequency in 8.51 GHz of about -27.75 dB with a Band-Width of 326 MHz.
All the parameter values are summarized in the following Table 5.1:

**Table 5.1:**

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>L</th>
<th>W</th>
<th>L₁</th>
<th>W₁</th>
<th>L₂</th>
<th>W₂</th>
<th>L₃</th>
<th>W₃</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>VALUES (mm)</td>
<td>40.5</td>
<td>44.75</td>
<td>22.5</td>
<td>30</td>
<td>14.9</td>
<td>21</td>
<td>15</td>
<td>21</td>
<td>0.375</td>
</tr>
</tbody>
</table>

Fig 5.3: Return Loss of Proposed Antenna

Fig 5.4: Return Loss of reference antenna [20]
All the simulated results are summarized in the following Table 5.2.

**Table 5.2: Simulated results for Reference Antenna & Proposed Antenna**

<table>
<thead>
<tr>
<th>Antenna Structure</th>
<th>Resonant Frequency</th>
<th>Return Loss (dB)</th>
<th>10 dB Band Width (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Starting Freq.</td>
<td>Ending Freq.</td>
<td>Centre Freq.</td>
</tr>
<tr>
<td>Reference</td>
<td>7.70</td>
<td>11</td>
<td>8.79</td>
</tr>
<tr>
<td>Proposed</td>
<td>2.85</td>
<td>5</td>
<td>3.71</td>
</tr>
<tr>
<td></td>
<td>8.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.9</td>
<td>11.5</td>
<td>10.86</td>
</tr>
</tbody>
</table>

5.5 *Simulated 2-D Radiation Pattern*

The simulated E-plane & H-plane radiation patterns (2-D) for reference antenna of all the resonant frequencies are shown in Figure 5.5 to Figure 5.10. Also the simulated E-plane & H-plane radiation patterns (2-D) for proposed antenna of all resonant frequencies are shown in Figure 5.11 to Figure 5.22.

![Simulated E-field pattern radiation pattern at 7.7 GHz for Reference Antenna](image1)

![Simulated H-field pattern radiation pattern at 7.7 GHz for Reference Antenna](image2)
Fig 5.7: Simulated E-field pattern radiation pattern at 11 GHz for Reference Antenna

Fig 5.8: Simulated H-field pattern radiation pattern at 11 GHz for Reference Antenna

Fig 5.9: Simulated E-field pattern radiation pattern at 8.79 (Center Freq) for Reference Antenna

Fig 5.10: Simulated H-field pattern radiation pattern at 8.79 (Center Freq) for Reference Antenna
Fig 5.11: Simulated E-field pattern radiation pattern at 2.85 GHz for Proposed Antenna

Fig 5.12: Simulated H-field pattern radiation pattern at 2.85 GHz for Proposed Antenna

Fig 5.13: Simulated E-field pattern radiation pattern at 5 GHz for Proposed Antenna

Fig 5.14: Simulated H-field pattern radiation pattern at 5 GHz for Proposed Antenna
Fig 5.15: Simulated E-field pattern radiation pattern at 3.71 (Center Freq) for Proposed Antenna

Fig 5.16: Simulated H-field pattern radiation pattern at 3.71 (Center Freq) for Proposed Antenna

Fig 5.17: Simulated E-field pattern radiation pattern at 8.51 GHz for Proposed Antenna

Fig 5.18: Simulated H-field pattern radiation pattern at 8.51 GHz for Proposed Antenna
Fig 5.19: Simulated E-field pattern radiation pattern at 9.9 GHz for Proposed Antenna

Fig 5.20: Simulated H-field pattern radiation pattern at 9.9 GHz for Proposed Antenna

Fig 5.21: Simulated E-field pattern radiation pattern at 11.5 GHz for Proposed Antenna

Fig 5.22: Simulated H-field pattern radiation pattern at 11.5 GHz for Proposed Antenna
5.6 SIMULATED 3-D RADIATION PATTERN

The simulated E-plane & H-plane radiation patterns (3-D) for reference antenna of all the resonant frequencies are shown in Figure 5.23 to Figure 5.28. Also the simulated E-plane & H-plane radiation patterns (3-D) for proposed antenna of all resonant frequencies are shown in Figure 5.29 to Figure 5.40.
Fig 5.27: Simulated 3-D E-field radiation pattern at 8.79 (Center Freq) for Reference Antenna

Fig 5.28: Simulated 3-D H-field radiation pattern at 8.79 (Center Freq) for Reference Antenna

Fig 5.29: Simulated 3-D E-field radiation pattern at 2.85 GHz for Proposed Antenna

Fig 5.30: Simulated 3-D H-field radiation pattern at 2.85 GHz for Proposed Antenna
Fig 5.31: Simulated 3-D E-field radiation pattern at 5 GHz for Proposed Antenna

Fig 5.32: Simulated 3-D H-field radiation pattern at 5 GHz for Proposed Antenna

Fig 5.33: Simulated 3-D E-field radiation pattern at 3.71 GHz (Center Freq) for Proposed Antenna

Fig 5.34: Simulated 3-D H-field radiation pattern at 3.71 GHz (Center Freq) for Proposed Antenna
Fig 5.35: Simulated 3-D E-field radiation pattern at 8.51 GHz for Proposed Antenna

Fig 5.36: Simulated 3-D H-field radiation pattern at 8.51 GHz for Proposed Antenna

Fig 5.37: Simulated 3-D E-field radiation pattern at 9.9 GHz for Proposed Antenna

Fig 5.38: Simulated 3-D H-field radiation pattern at 9.9 GHz for Proposed Antenna
5.7 **Simulated VSWR (Voltage Standing Wave Ratio) Pattern & Current Distribution Pattern**

The simulated E plane VSWR pattern for reference antenna is shown in Figure 5.41. Figure 5.42 shows simulated E plane VSWR pattern for proposed antenna. For reference antenna [20], the VSWR values for all the resonant frequencies are between 1.93 to 1.83. Also the VSWR value for center frequency (8.79 GHz) is 1.16. For the proposed antenna, the VSWR values for all the lower resonant frequencies are 1.94. Also the VSWR value for center frequency (3.71 GHz) is 1.63. Again the VSWR values for all the higher resonant frequencies are 1.92. Also the VSWR value for center frequency (10.86 GHz) is 1.40. For the proposed antenna, the VSWR value for the resonant frequency (8.51 GHz) is 1.08. All these values are within 2:1 VSWR range.

Also total current distribution pattern for the proposed antenna is shown in Figure 5.43.
**5.8 Conclusion**

This work describes the detailed analysis and implementation of a CPW fed UWB slot antenna. With the above structural features the overall dimension of the proposed antenna comes around 40.5 mm (length) x 44.75 mm (width) x 1.6mm (thickness). However, the observed 58% fractional bandwidth of the proposed antenna is more than sufficient for any UWB applications. The time domain analysis of the antenna is also performed to ensure the suitability of the proposed antenna for the UWB environment. Thus, the proposed antenna is simple, easy to fabricate and can be integrated into any UWB systems.
5.9 References


[32] Samiran Chatterjee, Santosh Kumar Chowdhury, Partha Pratim Sarkar and Debasree Chanda (Sarkar), “Comparison Between Two CPW-FED UWB Antennas Based on Dielectric Constant of Substrate”, *INTERNATIONAL JOURNAL OF ELECTRONICS & COMMUNICATION TECHNOLOGY (IJECT)- VOL IV, ISSUE I, VER. 1, JAN-MARCH 2013*

[33] Zeland Software Inc. IE3D: MoM-Based EM Simulator. Web: http://www.zeland.com/