A Coplanar Waveguide Fed Hexagon Slotted Hexagonal Patch Antenna for Ultra Wideband Applications

Riboy Cheriyan
Research Scholar, Department of Electronics & Communication, SAINTGITS College of Engineering, Kottayam, Kerala, India.
E-mail: riboycheriyan@gmail.com

Dr. K P Zacharia
Professor, Department of Electronics & Communication, SAINTGITS College of Engineering, Kottayam, Kerala, India.
E-mail: zacharia.kp@saintgits.org

Abstract
A Coplanar Waveguide Fed ultra wide band (UWB) slotted Hexagonal patch antenna which finds application in wireless communication is presented here. It was designed to operate in the UWB range (3.1GHz to 10.6GHz). The antenna presented here is designed on FR4 substrate with loss tangent δ=0.0025 and dielectric constant 4.4. The dimension of the proposed antenna is 34 X 29 X 1.6 mm. The fundamental parameters of the antenna such as return loss, VSWR and 2D radiation patterns were measured and found to meet standards specified for such antennas. The antenna was designed and simulated using Ansoft HFSS13.

Keywords: Ultra wide band, micro strip, hexagon slot, return loss, VSWR.

Introduction
In 2002 Federal Communication Commission (FCC) allotted the frequency range 3.1 – 10.6 GHz for commercial ultra wideband applications [1]. This technology specifies short pulses with constant phase throughout the whole frequency band to convey the information without distortion of pulse in wireless communications. It has gained wide attention both in academics and industry [2]. The major advantages of UWB systems are lower power consumption and high data transmission rate. Hence, in wireless design field UWB antenna design has gained wide attention. Due to ease of integration with RF front ends the most commonly used antenna among recently proposed antennas for wireless applications are planar slot antennas [3]-[4]. More over planar slot antennas are easy to design and has small size and wide bandwidth. Narrow impedance bandwidth is a major disadvantage of conventional microstrip patch antenna in spite of its small size and less weight. The techniques proposed to improve the bandwidth and impedance of Micro strip antenna is to use E-shaped patch [5], defected ground plane structure (DGS) [6] etc. However, bandwidth achieved by this technique is not up to the desired level. Ultra-wide bandwidth is achieved by using coplanar wave guide feed (CPW) with different types of radiating patches as elliptical [7], crescent patch [8] etc.. The return loss of the proposed antenna is to be maintained below -10dB throughout the entire wireless band. Also the antenna is to be miniaturized so that it could easily be integrated into modern communication systems [9] – [13][16][17]. Flatness of the gain, linearity of phase and group delay are also needed for an ultra wide band antenna not to distort the ultra narrow waveform of electromagnetic pulse of the order of nanoseconds. The impulse response in time domain is also a significant factor for the performance of antenna in UWB applications. With minimal dispersion effect UWB signals must be transmitted by the antenna [14]. The antenna gain is a function of frequency. The pattern of radiation should be such that the antenna will receive signals from all directions. In this article, antenna characteristics such as return loss, VSWR, gain and radiation pattern are discussed. A coplanar waveguide fed hexagon antenna with hexagonal slot is presented in this paper for UWB applications. The proposed antenna has good radiation pattern and improved impedance matching over the UWB. In this paper, the variations in return loss, VSWR and bandwidth due to change in various geometrical parameters of the antenna are probed by parametric study and are presented. Also E-plane and H-plane radiation patterns of the antenna are simulated and presented.

Antenna Geometry and Design

![Figure 1: Geometry of proposed antenna](image-url)
Fig. 1 shows the geometry of the proposed antenna. The substrate used for fabricating the antenna is FR4 epoxy with loss tangent $\tan \delta = 0.0025$, dielectric constant $\varepsilon_r = 4.4$ and thickness of 1.6mm. The size of the antenna is 34 X 29 mm. Coplanar wave guide (CPW) is used to feed the antenna. The gap (g) between the center conductor and ground plane is 0.4mm.

**Figure 2:** Radiation setup of the antenna

The feed has a characteristic impedance of 50Ω and is designed with feed line width of 3.6mm and length of 10mm. The patch and feed structure are fabricated on the same plane so that only one metallic layer is present in the design. Hence, it can be easily fabricated and has low cost. The effects of various geometrical parameters are analyzed in order to provide design parameters for the antenna. The antenna has novel tuning stub in Hexagonal slot to achieve the ultra wide band property of the antenna. The size of the ground is same as that of the substrate size and its inner profile is a hexagonal cut. The antenna is optimized with Ansoft HFSS 13. Fig.2 shows the radiation set up of the antenna for simulation.

The total width ‘W’ and Length ‘L’ [15] of the planar antenna are given by Equations (1) and (2)

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\varepsilon_r+1}}$$  \hspace{1cm} (1)

where ‘$f_r$’ is the resonant frequency and ‘c’ = 3 x $10^8$ m/s

$$L = \frac{c}{2f_r \sqrt{\varepsilon_{reff}}} \cdot 2\Delta L$$  \hspace{1cm} (2)

where $\varepsilon_{reff} = \frac{\varepsilon_r}{2\varepsilon_r+1} \cdot \frac{\varepsilon_r+1}{2\sqrt{(1+12h/w)}}$  \hspace{1cm} (3)

$$\Delta L = h \cdot 0.412 \cdot \frac{(\varepsilon_{reff}+0.3)[W/h+0.264]^2}{(\varepsilon_{reff}-0.268)[W/h+0.8]}$$  \hspace{1cm} (4)

$$L_{eff} = L + 2\Delta L$$  \hspace{1cm} (5)

Width and height of CPW wave ports are given by

$$W_{port} \geq 3 \times (2g + w)$$  \hspace{1cm} (6)

where ‘g’ is the distance between the inner conductor and the ground.

$$L_{port} \geq 4 \times h$$  \hspace{1cm} (7)

Where ‘h’ is the height of the antenna.

Equations (1) and (2) are used to find the theoretical values of W and L for the highest resonant frequency $f = 10$ GHz and dielectric constant $\varepsilon_r = 4.4$. The optimized values of W and L are obtained using HFSS.

**Simulation Results and Discussions**

The proposed antenna was designed and simulated using Ansoft HFSS 13.0 to estimate the performance. The analysis of the antenna was done by varying one of the physical parameters keeping others constant. The estimated return loss and VSWR of the proposed antenna is shown in Fig.3 and Fig.4.

**Figure 3:** Return loss - proposed antenna.

**Figure 4:** VSWR - proposed antenna.

From Fig.3, it is seen that the proposed CPW fed hexagon patched UWB antenna radiates between the entire UWB frequency band of 3.1 GHz to 10.6 GHz and it achieves a peak return loss of -37.18 dB. From Fig. 4 it is seen that the estimated voltage standing wave ratio (VSWR) is less.
than 2 for the entire frequency range of 3.1 to 10.6 GHz. It is seen that VSWR is around 1 for the entire band which satisfies good VSWR bandwidth.

**Parametric Analysis**

In this session, the effects of different geometric parameters on return loss and bandwidth of the proposed antenna was examined and presented. The parametric analysis helps to blueprint UWB antenna with larger bandwidth. The analysis was carried out by changing one parameter at a time, keeping all other parameters constant.

![Figure 5: Return loss when Wh = 8mm](image1)

![Figure 6: VSWR at Wh = 8mm](image2)

![Figure 7: Return Loss at Wh = 7mm](image3)

The parameter considered for optimizing the design are the bottom length of the hexagonal patch Wh and the length of the feed line Lf. The variation of resonance characteristics of the proposed antenna with bottom length Ws is shown in Fig. 5 to Fig. 8. The Wh is varied from 7mm to 9mm by keeping length of the feed Lf at 10mm.

![Figure 8: VSWR at Wh = 7mm](image4)

By comparing Fig.3 and Fig.4 with Fig.5 to Fig.8 it was found that the return loss has increased from -37.18 dB to -30.83 dB and the values of VSWR remained at values less than 1.5. Next the effect of feed length Lf with the performance of the antenna was considered. This parameter is optimized such that there is proper coupling between feed lines and the patch. The variation of resonance characteristics of the proposed antenna with feed line length Lf is shown in Fig. 9 to Fig.11. The Lf is varied from 9mm to 11mm by keeping bottom length of the patch Ws at 9mm.

![Figure 9: Return loss at Lf = 9mm](image5)

![Figure 10: VSWR at Lf = 9mm](image6)
When length of feed line $L_f$ was decreased to 9mm keeping $W_s$ constant at 9 mm, it is seen that the return loss is increased from $-37.18 \text{ dB}$ to $-34.19 \text{ dB}$. When $L_f$ was changed to 11mm, the return loss shows an increase in value from $-34.19 \text{ dB}$ to $-31.97 \text{ dB}$. The variation in return loss of the antenna due to change in patch height $W_s$ and feed length $L_f$ are tabulated in Table 1. The VSWR remains less than 1.6 in all the cases considered.

### Table: 1

<table>
<thead>
<tr>
<th>Bottom length of Patch ($W_s$) (mm)</th>
<th>Feedline length ($L_f$) (mm)</th>
<th>Return Loss ($S_{11} &lt; -10 \text{ dB}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9mm</td>
<td>10mm</td>
<td>-37.18</td>
</tr>
<tr>
<td>8mm</td>
<td>10mm</td>
<td>-32.16</td>
</tr>
<tr>
<td>7mm</td>
<td>10mm</td>
<td>-30.83</td>
</tr>
<tr>
<td>9mm</td>
<td>9mm</td>
<td>-34.19</td>
</tr>
<tr>
<td>11mm</td>
<td>9mm</td>
<td>-31.97</td>
</tr>
</tbody>
</table>

The simulated E plane and H plane patterns of the proposed antenna at 10GHz are shown in Fig.13 and Fig. 14. The beam width seems to be broad and it can cover wide direction of communication.

### Conclusion

In this paper, a CPW fed hexagonal shaped patch antenna with hexagonal slot cut is proposed for UWB application. The size of the proposed antenna is 34 X 29 X 1.6mm. The examined results prove that the antenna satisfies the -10 dB return loss specified by FCC from 3.1 to 10.6 GHz. Various geometric parameters of the antenna is optimized to attain an optimal design. The small size, low manufacturing cost and sufficient bandwidth make this antenna suitable for Ultra wide band applications.

### References
