Design and Development of a Small Compact Ultra Wideband Antenna

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Abstract. In this paper the design of a novel and compact U slot UWB printed monopole microstrip antenna of size 19.2 x 28.8 mm\textsuperscript{2} has been presented for wireless applications. The planar, small and thin UWB antenna design consists of a U slot radiator fed by a single 50$\Omega$ microstrip line with truncated ground plane is excited by a coaxial SMA connector. The simulations are done using the Ansoft High Frequency Structure Simulator (HFSS) software tool. The simulated results of impedance bandwidth are well supported by measurement. The measured group delay and radiation pattern results are also presented and performance of the antenna is analyzed/discussed.

1. Introduction
In the last decade, Ultra-wideband (UWB) has come up as a revolutionary and contemporary wireless technology which has generated a great deal of interest for use in the industry and academia. The rapid progress of UWB as a high data rate wireless communication technology has mainly been spurred on by the release of a bandwidth of 7.5 GHz (3.1 GHz - 10.66 GHz) for UWB applications by the Federal Communications Commission (FCC) \cite{1,2}.

As is the case in any conventional wireless communication systems, an antenna also plays a very fundamental role in UWB systems. On the other hand the challenges faced in designing a UWB antenna are many more. A good candidate for UWB applications are printed monopole antennas due to their compactness, light weight and simple structure \cite{1,3,4,5,6,7}.

The design of a tapered U slot printed monopole microstrip antenna is reported in ultra wideband for wireless applications in this paper. First the planar PCB antenna design is introduced. Also the various design considerations and dimensions are summarized. Finally the simulated and measured results have been compared and in the process a novel antenna is realized and fabricated.

2. UWB Antenna Design
The planar, very small, thin UWB antenna is etched on a 19.2mm x 28.8mm FR4 substrate having a relative permittivity of 4.4 and a substrate height of 1.6mm. The geometry of the proposed antenna is shown in figure 1 and the photograph of the fabricated antenna is shown in figure 2. The U slot radiating patch and transmission line are connected by tapered edges to obtain better impedance matching. A partial ground plane having the length of 9.2mm is used on the other side of the substrate.

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It consists of a slot of dimensions 2.8mm x 1.2mm just behind the transmission line to improve the bandwidth.

![Figure 1. Geometry for the proposed antenna.](image1)

Figure 1. Geometry for the proposed antenna.

![Figure 2. Fabricated UWB Antenna.](image2)

Figure 2. Fabricated UWB Antenna.

The resonant length of a microstrip patch can be obtained by using simple relations of the effective relative dielectric constant as a function of the substrate parameters and the operating frequency as follows [8]

\[
\begin{align*}
\epsilon_{\text{reff}} &= \frac{\epsilon_{\text{reff}} + 1}{2} + \frac{\epsilon_{\text{reff}} - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-1} \\
W &= \frac{c}{2f} \sqrt{\frac{2}{\epsilon_{\text{eff}} + 1}} \\
L_{\text{eff}} &= \frac{c}{2f} \sqrt{\epsilon_{\text{reff}}} \\
\Delta L &= 0.5h \\
L &= L_{\text{eff}} - 2\Delta L
\end{align*}
\]

where c is the speed of light in free space, L and W are the length and the width of the resonant patch antenna respectively. By simulating different patches with substrate parameters, it is possible to obtain the appropriate values as the patch does not have a ground plane on the other side of the substrate as shown in figure 1. The center frequency used in the simulations is 6 GHz. For this operating frequency and substrate parameters which are discussed before, the dimensions of the patch are calculated to be W = 15.21mm and L = 11.98mm. These dimensions represent the starting point for the present design of the UWB antenna as shown in figure 1. The parameters of the proposed antenna are given in Table I.

| Serial No. | Symbols | Size(mm) |
|------------|---------|----------|
| 1          | L       | 28.8     |
| 2          | W       | 12.8     |
| 3          | L_1     | 18.16    |
| 4          | L_2     | 1.04     |
| 5          | L_3     | 1.2      |
| 6          | L_4     | 0.4      |
| 7          | L_5     | 9.2      |
| 8          | L_6     | 19.2     |
| 9          | W_1     | 5.2      |
| 10         | W_2     | 8.2      |
| 11         | W_3     | 2.8      |
Some modifications are introduced on this patch to improve its operating bandwidth. The first one is to taper the patch near the feeding microstrip line. Due to the tapering effect of that part connected to the microstrip line, the dimensions of the patch are modified through simulations to be matched with the line such that the length $L$ of the patch is changed to be 12.8 mm and the width $W$ is changed to be 19.2 mm as mentioned in table 1. Using these dimensions with tapering length $L_{\text{taper}} = 6.4$ mm are adequate to introduce an UWB patch antenna that operates in the frequency range from 4.1 to 14.0 GHz as is shown by the simulated result in the following section.

3. Results and Discussion
Figure 3 shows the variations of the measured and simulated results of impedance bandwidth (VSWR < 2) for the proposed UWB antenna. The measurements were done using vector network analyzer (VNA, PNA N5230A, Agilent Technologies). The results show that the proposed fabricated antenna achieves an impedance bandwidth (VSWR < 2) from 3.4 – 14 GHz. Some differences in the simulated and measured return loss curves ($S_{11}$ plots) are seen. The main reason is that measurement is done in a non-controlled environment.

![Figure 3. Simulated and measured return loss and VSWR curves.](image)

Figure 4 shows the simulated radiation patterns of the proposed antenna at 4.5, 6.5, 8.5 and 10.5 GHz. The far field radiation patterns measured using C-band (4-8 GHz) and X-band (8-12.4 GHz) Microwave benches at 6.5, 8.5 and 10.5 GHz are plotted in Figure 5.

![Figure 4. Simulated Radiation patterns at 4.5, 6.5, 8.5 & 10.5 GHz.](image)

It is clearly seen that the radiation patterns of E-plane are monopole like and H-plane radiation patterns show almost omni-directional characteristics, especially at lower frequencies. However the radiation patterns start to change in higher frequencies and UWB antenna becomes directive. At high frequencies (i.e. from 7 GHz onwards) because of spurious radiation side lobes appear as seen in figure 4.

![Figure 5. Measured Radiation patterns at 6.5, 8.5 & 10.5 GHz.](image)
The simulated antenna gain varies from 4.4dB to 6dB over the operating UWB frequency range as shown in figure 6. Another important parameter in UWB antenna design is the group delay. From the measured results the antenna group delay is approximately constant and within the frequency band of interest as shown in figure 7.

4. Conclusion
A new small UWB antenna has been designed, simulated, measured and fabricated. The simulation results obtained by Ansoft HFSS software show good agreement with the measured results. Group delay which is more meaningful parameter to show good time domain characteristic in UWB antenna is investigated and the variations obtained are also good and within the acceptable limit. To miniaturize UWB antenna, tapering and truncated ground planes are used. It is seen from the measured result that very large bandwidth is obtained for the proposed antenna which can be used in UWB communication systems.

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