A Compact Microstrip Antenna for Ultra Wideband Applications

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Abstract

In this study, a simple and compact ultra-wideband (UWB) patch antenna with rectangular slot is presented. The fabricated antenna consists of a rectangular patch tapered from a microstrip feeding structure and a truncated ground plane. The proposed antenna is etched onto a FR4 printed circuit board (PCB) with an overall size of 28 mm × 29 mm × 1.6 mm. Simulated and experimental results are compared and are shown to be in good agreement. Experimental results indicate that the antenna achieved an UWB impedance bandwidth ($S_{11} < -10$ dB) ranges from 3.8 to 12 GHz. The small antenna exhibits a good voltage standing wave ratio (VSWR) performance and its $E$– and $H$–plane radiation patterns are stable over the UWB frequency range. The simulated result shows that the designed antenna can achieve a gain between 1.5 and 4.5 dBi against frequency. Besides, the group delay is less than 0.4 ns over the operating frequency band. These characteristics make the designed antenna suitable for various UWB applications.

Keywords: Ultra Wideband Antenna, Microstrip Antenna, Partial Ground Plane, Group Delay.

1. Introduction

The Federal Communications Commission (FCC) approval of the frequency band in the range of 3.1 to 10.6 GHz in 2002 [1], has motivated both academic and industrial communities to develop compact antennas for UWB radio applications. It is anticipated that UWB technology enable high-speed data transmission rate with low power consumption. Low cost UWB antennas are desirable for various
applications such as wireless communications, medical imaging, radar and indoor positioning [2]. The merits of printed antenna such as light weight, small size and low profile make them an attractive candidate for UWB antenna development [3].

A conventional microstrip antenna exhibits the inherent drawback of narrow impedance bandwidth. Numerous techniques have been investigated and reported to enhance the printed antenna impedance bandwidth. This includes employing slot at the patch antenna such as the square-ring slot [4] and U-shaped slot [5]. Other methods to increase the operation bandwidth of antennas include meandered ground plane [6], electromagnetically coupled stacked patch [7], patch antenna with integrated bandpass filter [8], gap-coupled feed [9] and optimally designed impedance matching network [10, 11].

In the present paper, a simple and compact microstrip-fed patch antenna for UWB application is proposed. The 

\[-10 \text{ dB return loss bandwidth of the antenna covers } 3.8 \text{ to } 12 \text{ GHz which satisfies the UWB system requirement.}

The outline of this paper is as follow. Section 2 describes the geometry of the proposed antenna. Simulation and experimental results are presented in Section 3 and the conclusions are summarized in Section 4.

2. Antenna Geometry

Figure 1 shows the geometry of the proposed antenna. The antenna is located in the $x$–$y$ plane and the normal direction is $z$–axis. It consists of symmetrical single-beveled planar patch with rectangular shaped slot and partial ground plane. A small rectangular patch is located on top of the radiating element. It is observed that similar to many planar antennas, this antenna is fed by a microstrip feed line with a characteristic impedance of $50 \ \Omega$. The antenna design is etched onto a piece of FR4 substrate with dielectric constant of 3.38 and thickness of 1.6 mm. On the other side of the dielectric substrate, a ground plane with the width $W$ and length $L_g$ is printed below the microstrip feed line. The antenna parameters are as shown in Table 1.

3. Results and Discussions

Based on the numerical results discussed in Section 2, the antenna prototype is fabricated as shown in Figure 2. The antenna is studied both numerically and experimentally.
Table 1: Parameters of the antenna.

<table>
<thead>
<tr>
<th>Basic Configuration</th>
<th>Variable</th>
<th>Dimension (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate</td>
<td>W</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>29</td>
</tr>
<tr>
<td>Patch Antenna</td>
<td>l_p</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>l_f</td>
<td>11.5</td>
</tr>
<tr>
<td></td>
<td>w_f</td>
<td>3.5</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>w_p</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>w_s</td>
<td>10.4</td>
</tr>
<tr>
<td></td>
<td>s</td>
<td>1</td>
</tr>
<tr>
<td>Ground Plane</td>
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<td>3.5</td>
</tr>
<tr>
<td></td>
<td>L_g</td>
<td>10.4</td>
</tr>
</tbody>
</table>

3.1. Input Performances

The simulation is carried out using CST Microwave Studio software and the input performance of the antenna is measured using a Rhode and Schwarz ZVL vector network analyzer (VNA). The simulated and measured return loss curves of the proposed antenna are plotted and compared with each other in Figure 3. The designed antenna has the impedance bandwidth for return loss below –10 dB from 3.8 to 12 GHz. This result agrees very well with the calculated ones.

Figure 2: Fabricated antenna.

Figure 3: Simulated and measured return loss.
It is observed that the return loss curve has several resonance frequencies close to 6.6, 8.8 and 11.8 GHz. The little difference between the curves is probably due to intrinsic properties of FR4 substrate. According to [12], if a slot is etched on the active zone of the patch antenna it is possible to obtain a wider impedance bandwidth. Based on Figure 3, it is observed that the application of rectangular-shaped slot on the proposed antenna has introduced a resonant frequency at 6.6 GHz. By employing the slot structure, capacitive reactance has been introduced on the patch antenna which helps cancel out the inductive reactance of the feed component [13].

Bandwidth extension can also be achieved by truncating the patch antenna diagonally at the lower edge. This technique has an effect on the antenna geometry which leads to a discontinuity in the microstrip line [14]. Owing to this approach, a second resonance frequency is introduced at 8.8 GHz. The capacitive coupling between the patch antenna and the ground plane is tuned to achieve a wider impedance bandwidth. The vertical notch is introduced on the partial ground plane to satisfy the 10 dB return loss requirement between the frequency region of 3.8 GHz and 12 GHz.

Figure 4 shows the antenna’s input impedance over the bandwidth between 3 and 14 GHz. The graph shows input impedance fluctuating across the entire bandwidth from 3 to 14 GHz. The real part of impedance varies between 40 Ω and about 100 Ω, whereas the imaginary part varies between –20 Ω and about 50 Ω. Figure 5 shows the voltage standing wave ratio (VSWR) characteristic of the antenna. This figure shows that the VSWR of the antenna remains less than 2 over a bandwidth range of 3 to 14 GHz. The result indicates that the VSWR complies with the UWB characteristic and the same frequency region also displays the return loss curve less than –10 dB, as seen in Figure 2.

3.2. Radiation Patterns and Gain

For the proposed antenna, two principle planes are selected to present the radiation pattern. These are referred to as the $x$–$y$ plane (E–plane) and the $y$–$z$ plane (H–plane). Figure 6 shows the plots of the normalized simulated radiation patterns in the $E$–plane and $H$–plane at several frequencies. In the $E$–plane, the value of azimuth angle $\varphi$ of 0°, 45° and 90° while for the $H$–plane the value of elevation angle $\theta$ of 0°, 45° and 90° are taken into consideration.

Figure 4: Simulated real and imaginary input impedance.
Figure 5: Simulated VSWR of the proposed antenna.

It is observed that, the proposed antenna exhibits an omnidirectional pattern in the $H$–plane and a quasi omnidirectional pattern in the $E$–plane. Figure 7 shows variation of the antenna gain versus frequency. The graph shows that the gain steadily increases with frequency and reaches a peak of around 4.5 dBi at 9 GHz, and thereafter the gain drastically decreases.

Figure 6: Simulated $E$ – plane and $H$ – plane radiation patterns for the proposed antenna at (a) 3 GHz, (b) 6 GHz, and (c) 9 GHz.
3.3. Group Delay

Group delay is another important criterion to determine the performance of UWB antenna. The antenna should be able to transmit the electrical pulse with minimal distortion. The calculated group delay of the proposed antenna is portrayed in Figure 8. The variation is less than 0.4 ns over the frequency band from 3 to 14 GHz. It shows that the antenna has low-impulse distortion and is suitable for UWB applications.
4. Conclusions
A compact UWB microstrip antenna is proposed and a prototype is fabricated. The operating bandwidth of the antenna at a minimum workable return loss of 10 dB achieved was 3.8 GHz to 12 GHz. The measurement result shows a good agreement with the simulated one. The antenna exhibited a stable radiation patterns and a maximum gain varies from 1.5 to 4.5 dBi over most of the UWB frequency range. Due to its very wide bandwidth, the antenna can be considered as a potential candidate for cost effective UWB applications.

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References