Microstrip Line-Fed-Slotted UWB Antenna With Truncated Ground Plane

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Abstract

In this paper, the concept of strip lined truncated ground plane with Inset Fed slotted Microstrip Patch Antenna is used. And a slot of $0.85 \times 0.07 \text{ cm}^2$ is cut within the radiating patch at a distance of $0.12 \text{ cm}$ from the end of the patch, on either sides, due to which return loss decreases below $-50 \text{ dB}$ at $10.5 \text{ GHz}$. The developed antenna operates at an UWB frequency of $9.25 \text{ GHz} - 14.2 \text{ GHz}$ with a bandwidth of $4950 \text{ MHz}$ or $47.14\%$ at the center frequency of $10.5 \text{ GHz}$ and has a VSWR of less than $2$ over the entire operating band. A maximum gain of $5.2 \text{ dB}$ is obtained with almost a complete Omni-directional radiation pattern and does not require additional impedance matching circuitry. The results show that the reference antenna (without slot) has a return loss of $-34 \text{ dB}$ and the proposed antenna (with slots on either sides of patch) has a return loss of $-50 \text{ dB}$ at $10.5 \text{ GHz}$. The design and simulation of the antenna structure is carried out in HFSS ver 13.

Keywords: Inset feed, truncated ground plane, Slotted patch and UWB Antenna.

1. Introduction

Modern wireless communication technology demands compact and wideband antennas. Microstrip antennas can be classified into two basic types by structure, namely microstrip patch antenna and microstrip slot antenna. The slot antennas can be fed by microstrip line, slot line and CPW.

In this work we present the design and optimization of a microstrip inset fed patch antenna with reduced ground plane by including slots in the patch which is a modification in the design of previously available antenna design technique[1], to obtain low return loss and high gain conserving broad bandwidth, and proper impedance matching with reduced ground plane effects without the need for impedance matching circuitry as in [2]. It has been found that by choosing suitable combinations of feeding structure and slot shape, an optimum impedance bandwidth can be obtained, which includes use of thick substrate, cutting a resonant slot inside the patch, use of a low dielectric substrate. For enhancing the bandwidth, various slot shapes, that is, square [3], triangle [4] and circular/ellipse [5], have been utilised with a suitable feeding stub. Various stub shapes, that is, forklake, triangular, bow-tie, arc shape and L-shape [6], are used. For some cases, rotation of the wide slot is used for larger bandwidth [7]. Ultra-wideband (UWB) is also known as ultraband. UWB is a technology for transmitting information spread over a large bandwidth (>500 MHz). Ultra wideband was formerly known as "pulse radio", but the FCC (Federal Communication Commission ) and the ITU-R( International Telecommunication Union Radio communication) Sector currently defined UWB in terms of a transmission from an antenna for which the emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the center frequency and has a fractional bandwidth (FBW) greater than 0.25 [8].

2. Antenna Configuration

Fig. 1 shows the geometry and dimensions of the reference Strip Lined Truncated Ground Plane on Inset Fed Slotted Microstrip UWB Antenna[1].

![Figure 1: Geometry of the reference UWB antenna.](image-url)
The antenna dimensions length \( L \), width \( W \) are calculated using the patch antenna design equations [9] given below:

\[
W = \frac{c}{2f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}
\]

\[
\Delta L = 0.412h \left( \frac{(\varepsilon_{reff} + 0.3)(W/\varepsilon_r + 0.264)}{(\varepsilon_{reff} - 0.268)(W/\varepsilon_r + 0.8)} \right) \tag{2}
\]

\[
L = L_{eff} - 2\Delta L \tag{3}
\]

\[
L_{eff} = \frac{c}{2f_r \sqrt{\varepsilon_{reff}}} \tag{4}
\]

\[
\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-3/2} \tag{5}
\]

Where,

\( \varepsilon_{reff} \) --- Effective dielectric constant

\( L_{eff} \) --- Effective Length

\( \Delta L \) --- Length Extension

The ground plane dimensions are calculated as:

\[
W_g = 6h + W \tag{6}
\]

\[
L_g = 6h + L \tag{7}
\]

Where, \( W_g \) and \( L_g \) are the length and width of ground plane respectively.

Fig. 2 and table 1 gives the geometry and dimensions of the proposed antenna structure respectively.

The proposed antenna is fabricated on commercially available FR4 dielectric substrate with a permittivity of 4.4 and a thickness of 62mil and a slot of of 0.85 x 0.07 cm\(^2\) is cut within the radiating patch at a distance of 0.12cm from the end of the patch on either sides.

### Table 1: Dimensions of proposed antenna structure

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>DIMENSIONS (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground plane</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truncated Ground plane</td>
</tr>
<tr>
<td></td>
<td>L=2.19, W=0.61</td>
</tr>
<tr>
<td></td>
<td>Patch (at center)</td>
</tr>
<tr>
<td></td>
<td>L=1.0, W=0.5</td>
</tr>
<tr>
<td></td>
<td>On top metal</td>
</tr>
<tr>
<td></td>
<td>Patch with line feed and a slot in the radiating patch</td>
</tr>
<tr>
<td></td>
<td>(i) Patch</td>
</tr>
<tr>
<td></td>
<td>(ii) Feed</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(iii) Slot</td>
</tr>
<tr>
<td></td>
<td>On either sides</td>
</tr>
<tr>
<td></td>
<td>Substrate</td>
</tr>
<tr>
<td></td>
<td>FR4, ( \varepsilon_r =4.4, h=1.6 ) mil</td>
</tr>
</tbody>
</table>

![Figure 2: Geometry of the proposed UWB antenna](image)

3. **Calculations**

(i) **Percent bandwidth**

\[
\% \text{Bandwidth} = \frac{(f_H - f_L)}{f_C}
\]

\( f_L =9.25 \) GHz, \( f_H =14.2 \) GHz, \( f_C=10.5 \) GHz.

\[
\% \text{Bandwidth} = \frac{(14.2-9.25)}{10.5} = 47.14 \% \text{ w.r.t center frequency 10.5 GHz.}
\]
(ii) Fractional Bandwidth

\[ FBW = 2\left(\frac{(f_H - f_L)}{(f_H + f_L)}\right) \]

\[ FBW = 2\left(\frac{(14.2 - 9.25)}{(14.2 + 9.25)}\right) \]

= 0.422

Where,

F_L ---- Lower cut off frequency
f_H ---- Upper cut off frequency
f_C ---- Center frequency

4. Simulation results

4.1 Reference Antenna

Structure

Return loss

4.2 Proposed Antenna

Structure

Return Loss
Table 2: Comparison of Reference and Proposed Antenna Configurations

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>REFERENCE ANTENNA</th>
<th>PROPOSED ANTENNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain (dB)</td>
<td>4.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Resonating Frequencies (GHz)</td>
<td>10.5 and 13.0</td>
<td></td>
</tr>
<tr>
<td>Return loss (dB) at</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.25 GHz</td>
<td>-32</td>
<td>-51</td>
</tr>
<tr>
<td>14.2 GHz</td>
<td>-22</td>
<td>-40</td>
</tr>
</tbody>
</table>

5. Conclusion

By cutting a slot of of 0.85 x 0.07 cm² within the radiating patch at a distance of 0.12cm from the end of the patch, on either sides return loss increases in negative. The proposed antenna exhibits stable far-field radiation characteristics in the entire operating bandwidth with high gain and low cross polarization. The bandwidth of the proposed antenna can be further increased using any of the techniques described above.

6. References


