A High Miniaturized Antenna for Wi-Max and Small Wireless Technologies

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Abstract

This letter presents a single feed novel miniaturized patch antenna for WiMax applications and small wireless technologies. Antenna is fabricated on FR4 substrate with 1.6mm thickness and copper sheet of 0.035mm. The miniaturization of 82% is achieved by etching a Fork shape slot in ground plane as response is observed at 3.4GHz. Simulated and measured results shows acceptable gain of 3.4 to 3.6dB and efficiency ranging to 82% with 260MHz bandwidth. The proposed antenna is simulated in Computer Simulation Technology 2015. The measurement results demonstrate that the proposed antenna provides acceptable radiation performances with directional radiation patterns at desired frequency.

Keywords: Miniaturization, Microstrip Patch Antenna (MPA), directivity, gain, bandwidth, Slots, Computer Simulation Technology (CST).

I. Introduction

The permanent demand for low-cost compact antennas that can be integrated into the electronic and radio-frequency components has made patch antennas an attractive alternative in modern wireless communication systems. For over two decades communication technologies have trended towards miniaturization. Patch antennas offer unique characteristics due to their lighter structure and ease of fabrication in RF and microwave circuits. Patch antenna size can be reduced by number of techniques. In [III] using combination of Defected Microstrip structure and spur line combo technique, size reduction of
30% is achieved with low bandwidth of 14 to 26MHz and gain of 1.5dBi. In [V] using U shape slots in Ground plane and fractal patch miniaturization of 52% is achieved for WiMax and GPRS technologies.

In [VI] using slots strategically on various positions in ground plane and radiating patch up to 78% of miniaturization is achieved. In [IV] using simple C shape defected ground structures resulted in 52% of miniaturization with extremely low gain near to zero and 2.1dB in case of 28% miniaturization. In [X] by cutting two mirror L shape slots size reduction of 41% is achieved with dual band response for WLAN applications however with very low measured efficiencies of 32 and 18% and gain of 0.4 to -1.6dB respectively. Size reduction has also been seen using Metamaterials structures.

In [XII] 69% antenna size is decreased with tri band response. In [VII] using combination of meta material and modified Split ring Resonators resulted in peak gain of above 3 dB with additional wide band response of 3.83 to 6.3GHz and 90% efficiency however miniaturization is only 8.9%. With thin and compact slots on ground plane followed by central T slot resulted in reducing size of an antenna up to 33% in [VIII]. Using artificial Magnetic Conductors in [XI] a high gain of 6 dB is seen but miniaturization is only 35%. By loading metallic Vias on Patch 60% of size reduction has been resulted with combination of U mounted slots [XIII]. In [XI] using an arch projection technique size has been decreased up to 37%. In [I] with use of split ring resonators 40% of miniaturization is seen in 1x4 Linear array and in [IX] size reduction with loaded split ring resonators is only 21%. The slots mounted on edges or center of patch or ground plane are directly related to the performance parameters and define their characteristics like gain, bandwidth, impedance losses even efficiencies. This paper focuses solely on miniaturization of patch antenna using slot technique. A novel shape of fork slotted ground plane patch antenna. Using slots on ground plane fundamental resonant frequency has been shifted downwards to significant level. This paper is organize as follow.

Section 1 covers introduction. Section 2 covers antenna design parameters which is further divided into two sections. First fundamental antenna is designed and analyzed. In second section, miniaturized shape is constructed using fork shape slots and all its design details are covered. Section 3 covers simulation measured results and in last section Conclusion is covered.

II. Design
a) Antenna

The antenna is designed and fabricated on commercially available FR4 with dielectric constant of 4.4 and loss tangent of 0.02 and height having 1.6mm. FR4 is selected due its availability and unique weather and temperature handling capabilities.
At fundamental frequency of 8GHz patch antenna is designed and is fed by 50 Ω transmission line. The length and width of the patch are derived by equations mentioned in [XIV] [XV].

\[ W = \frac{C}{2f_0 \sqrt{\frac{\epsilon + 1}{2}}} \]  

(1)

\[ L = L(\text{eff}) - 2\Delta L \]  

(2)

Where

\[ L(\text{eff}) = \frac{C}{2f_0 \sqrt{\epsilon(\text{reff})}} \]  

(3)

And

\[ \epsilon(\text{reff}) = \frac{\epsilon + 1}{2} + \frac{\epsilon - 1}{4} \left(1 + \frac{12h}{W}\right)^{-1/2} \]  

(4)

The antenna design parameters are covered in Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patch Length</td>
<td>15.5</td>
<td>mm</td>
</tr>
<tr>
<td>Patch Width</td>
<td>12.3</td>
<td>mm</td>
</tr>
<tr>
<td>Substrate Height</td>
<td>1.6</td>
<td>mm</td>
</tr>
<tr>
<td>Patch Height</td>
<td>0.035</td>
<td>mm</td>
</tr>
</tbody>
</table>

Table 1. Antenna Design Parameters

Figure 1. Front View of Proposed Antenna
A microstrip rectangular patch antenna is designed to operate around 8 GHz. The antenna is designed on commercially available FR4 due to advantages like cost and availability. The permittivity of the substrate is 4.1 and has a thickness of 1.6 mm. The antenna is 15.5 mm x 12.3 mm. The antenna is fed by 50 Ω transmission line.

b) Ground Plane

The ground plane has dimensions of 31 mm x 31 mm. The ground plane is formed firstly by introducing giant square shape slot nearly diminishing the ground plane. The length and width of the slot are named $S_1$, $S_2$ having values of 25 mm respectively. This is followed up by adding three rectangle geometries making up shape to look like a fork form. The length of these rectangular geometries is labeled as $S_3$ having value of 12 mm and space between them has been named $S_4$ 3 mm. The right most and left most corners of fork shape slot are named as $S_6$ and have width with values of 3.5 mm. The width of the central 2 slots is labeled as $S_5$ with width having 4 mm.

III. Results and Discussions

The proposed antenna is simulated using full-wave electromagnetic software CST, which includes the effects of substrate, metal thickness and all losses. From simulation, it was observed that the antenna fundamental resonance shifted downwards from 8 GHz to 3:41 GHz. The comparison between the conventional microstrip patch antenna and the proposed model is illustrated in the Table II.
Table 2. Comparison between the conventional antennas and the proposed model.

<table>
<thead>
<tr>
<th>Geometric Parameters</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional MPA at 3.41GHz</td>
<td>27.2</td>
<td>41.3</td>
</tr>
<tr>
<td>Proposed Antenna</td>
<td>12.5</td>
<td>14.3</td>
</tr>
</tbody>
</table>

a) Performance Parameters

Fig. 3 shows the return loss of the proposed antenna in dBs for a range of frequencies. The 1-Dimensional E-plane and H plane radiation patterns for 3.2 GHz are shown in the Figure 3. The radiation characteristics are observed on resonant frequency. The main lobe of magnitude of 3.46 dB shows significant performance with 3dB angular width of 147 degree. The YZ plane or H plane response radiation pattern shows the main lobe of our design with slight tilt of 178 Degrees and 3dB angular width of 87.1 degree. The 3D max gain is shown in figure 5 which shows peak gain of 3.62 dB. To summarize, the radiation pattern in yz plane is bidirectional or in +z and -z direction with maximum gain of 3.5 dBi. And for xz plane resemble more like dipole-like form. Overall the radiation characteristics of proposed antenna design is well performed and shows well established gain for patch antenna design.

Figure 3. Reflection Co-efficient of Proposed Antenna
Figure 3. Radiation Patterns of antenna (a) E-Plane (b) H-Plane

Figure 3. 3D Gain Radiation Patterns of antenna
The key performance parameters attained through the simulation are listed in Table III.

Table 3.Performance Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonance Frequency</td>
<td>3.4GHz</td>
</tr>
<tr>
<td>Return Loss</td>
<td>-26.5dB</td>
</tr>
<tr>
<td>Impedance Bandwidth</td>
<td>2.3%</td>
</tr>
<tr>
<td>Directivity</td>
<td>3.46dBi</td>
</tr>
<tr>
<td>Gain</td>
<td>3.62dB</td>
</tr>
<tr>
<td>VSWR</td>
<td>1.19</td>
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<tr>
<td>Bandwidth</td>
<td>260MHz</td>
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</tbody>
</table>

b) Miniaturization

Slots play an important role in size reduction of antenna. By using slots on various positions, current path is altered and change or shifting of resonance takes place. In our proposed design, a fork shape is etched on ground plane through various stages. By comparing traditional antenna design dimensions, our proposed forked shape etched design has shown size reduction of 82% with satisfactory performance parameters and radiation patterns.

The size reduction comparison of published research work and proposed research work is shown in Table IV.

Table 3.Published Literature Comparison

<table>
<thead>
<tr>
<th>Reference</th>
<th>Miniaturization (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VII</td>
<td>8.9</td>
</tr>
<tr>
<td>VIII</td>
<td>33</td>
</tr>
<tr>
<td>IX</td>
<td>35</td>
</tr>
<tr>
<td>X</td>
<td>60</td>
</tr>
<tr>
<td>XI</td>
<td>37</td>
</tr>
<tr>
<td>XII</td>
<td>40</td>
</tr>
<tr>
<td>XIII</td>
<td>21</td>
</tr>
<tr>
<td>Proposed Work</td>
<td>82</td>
</tr>
</tbody>
</table>

IV. Conclusion

A high miniaturized patch antenna is presented in this study. The antenna is proposed with a novel Fork slotted ground plane. Through introduction of slots, size reduction of 82% is achieved. The design is compared with previous published results and performance parameters have shown satisfactory results with minimum mismatch losses and higher efficiency. The proposed antenna can be used for Wi-MAX and small sized wireless technologies and applications.

V. Competing Interest

The authors declare that they have no competing interests.
References


