Design of A Compact Multiband Microstrip Antenna for WiMAX, WLAN and X-Band Applications

Akansha Suthar¹ and Navneet Agrawal²

¹MPUAT
²Maharana Pratap Univ Agr

May 9, 2023

Abstract

In this research work, a compact triple-band antenna for WiMAX, WLAN and X-band applications is presented. The proposed antenna has compact size of 18x21.3mm². The miniaturization of 52.10% is achieved compared with the conventional antenna. For achieving compactness and multiple frequency operation a square patch is loaded with inverted U-shaped slots and partial ground is used and can resonates at 3.26 GHz, 5.95 GHz and 8.83 GHz with a return loss of -29.15 dB, -43.40 dB, -41.14 dB respectively with highest gain of 2.69 dB. The proposed multiband structure yields good impedance matching, acceptable gain, and wide bandwidth.

Design of A Compact Multiband Microstrip Antenna for WiMAX, WLAN and X-Band Applications

A. Suthar and N. Agrawal

In this research work, a compact triple-band antenna for WiMAX, WLAN and X-band applications is presented. The proposed antenna has compact size of 18x21.3mm². The miniaturization of 52.10% is achieved compared with the conventional antenna. For achieving compactness and multiple frequency operation a square patch is loaded with inverted U-shaped slots and partial ground is used and can resonates at 3.26 GHz, 5.95 GHz and 8.83 GHz with a return loss of -29.15 dB, -43.40 dB, -41.14 dB respectively with highest gain of 2.69 dB and wide bandwidth. The proposed multiband structure yields good impedance matching, acceptable gain, and wide bandwidth.

Introduction: With the advancement of wireless technology, modern portable gadgets serve a wide range of applications. As a result, numerous antennas are required in a single device, but it increases the size and complexity of the system. Therefore, multiband antennas are appropriate choice due to its ability to function in multiple frequency bands, it integrates several communication standards in a single system. The number of antennas in a wireless communication system can be decreased by using multiband antenna. Therefore, it plays crucial role in device miniaturization.

There are numerous techniques in the literature that are devoted to designing for compact multiband antenna. In [1] multiband antenna is designed using periodic slots on radiator and defected ground structure on an FR4 dielectric substrate. The antenna operates in four frequency bands of 3.271 GHz, 4.92 GHz, 6.35 GHz and 11.04 GHz for WiMAX, Wi-fi, space and fixed satellite applications. The overall size of antenna is $32\times32\text{mm}^2$. In [2] an antenna with rectangular slot in radiating patch to achieve triple band operation. The antenna resonates at 2.4 GHz, 5.5 GHz and 7.5 GHz frequency bands and can be used for Wi-Fi, WiMAX and X-band applications. The size of antenna is $53\times53\text{mm}^2$ which is major constraint in portable devices. The triple band antenna for GPS/WLAN/WiMAX applications proposed in [3] has a size of $29\times27\text{mm}^2$. Two identical metamaterial unit cells have been embedded in the ground plane in order to achieve multiband. In [4] a copper cladding Arlon Cu Clad substrate material (loss tangent $\delta =0.0009$) with overall
size of 60×30 mm$^2$ is used to print the antenna. To make this antenna tripe band a bow-tie slot is used. [5] presented the triple band antenna for WLAN and X-band applications with the size of 18×34.5 mm$^2$. To achieve multiband behaviour, two arc-shaped strips, two inverted L-shaped stubs, and partial ground are used. For reduction in size researchers presented the concept of slots both in radiating element and ground to miniaturization and multiband operation. A kite shaped slot is inserted in the radiating patch to attain miniaturization. A miniaturization of 50% is achieved in the radiating patch area by inserting this slot [6,7]. Various designs studied in literature having drawback of large size and a trade of between the size and performance of antenna.

So, in this research work we proposed a compact multiband antenna. For miniaturization and multiple frequency bands Inverted U-shaped slots in radiating patch and partial ground is used. Partial ground is used to enhance the overall performance of the antenna. Compared with the conventional antenna 52.01% miniaturization is achieved. The proposed antenna resonates at 3.26 GHz (WiMAX), 5.95 GHz (WLAN) and 8.83 GHz (X-band) with wide bandwidth.

Antenna design: Figure 1 shows the design of an inverted-U slot microstrip antenna with partial ground. The proposed structure is designed to achieve the tri-band operation for WiMAX, WLAN and X-band applications with improved performance and reduced size. Partial ground is used for enhancing the performance of an antenna. The antenna is printed on a FR-4 substrate of thickness 1.6mm with permittivity $\varepsilon_r$ of 4.4 and dielectric loss tangent of 0.02. CST microwave studio software is used for simulate design. The total dimension (Ws × Ls) of antenna is 18 × 21.3mm$^2$. The radiating patch is fed with 50 Ω microstrip transmission line.
Initially, a conventional microstrip patch antenna is designed for initial resonant frequency \( f_r \) of 5.8 GHz. By using the following standard transmission line equations \[9\] antenna dimensions are determined.

Width of the radiating patch:

\[
W_p = \frac{c}{2f_r\sqrt{(\varepsilon_r + 1)/2}}
\]

Here, \( c = 3 \times 10^8 \text{m/sec} \), \( f_r = 5.8 \text{ GHz} \), and \( \varepsilon_r = 4.4 \).

Effective dielectric constant \( \varepsilon_{eff} \):

\[
\varepsilon_{eff} = \frac{\varepsilon_r + 1}{\varepsilon + \varepsilon_r - 1}
\]

English2+\( \varepsilon \)-1

\[
\varepsilon_n = \sqrt{\frac{\varepsilon_r + 1}{\varepsilon_r}}[1 + 12 \frac{h}{\lambda} ]^{0.5}
\]

The effective length \( L_{eff} \):

\[
L_{eff} = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}}
\]

Extension length \( l \):

\[
l = 0.412 \frac{(\varepsilon_{eff} + 0.3)(W_p + 0.264)}{(\varepsilon_{eff} - 0.258)(W_p + 0.8)} h
\]
Length of radiating patch $L_p$:

$$L_p = L_{eff} - 2l$$

here $h=1.6\text{mm}$ is the thickness of the substrate.

To determine the length and width of the ground plane:

$$L_g = 6h + L_p$$

$$W_g = 6h + W_p$$

**Table 1.** Dimensions of the proposed antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mm)</th>
<th>Parameter</th>
<th>Value (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W_s$</td>
<td>18</td>
<td>$t_1$</td>
<td>0.5</td>
</tr>
<tr>
<td>$L_s$</td>
<td>21.3</td>
<td>$w_2$</td>
<td>6</td>
</tr>
<tr>
<td>$W_p$</td>
<td>15</td>
<td>$l_2$</td>
<td>4</td>
</tr>
<tr>
<td>$L_p$</td>
<td>15</td>
<td>$t_2$</td>
<td>2</td>
</tr>
<tr>
<td>$W_f$</td>
<td>2.8</td>
<td>$w_3$</td>
<td>4</td>
</tr>
<tr>
<td>$L_f$</td>
<td>5</td>
<td>$l_3$</td>
<td>3</td>
</tr>
<tr>
<td>$W_g$</td>
<td>18</td>
<td>$t_3$</td>
<td>0.5</td>
</tr>
<tr>
<td>$L_g$</td>
<td>3</td>
<td>$a$</td>
<td>2</td>
</tr>
<tr>
<td>$w_1$</td>
<td>13</td>
<td>$b$</td>
<td>1</td>
</tr>
<tr>
<td>$l_1$</td>
<td>11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the step 1, the square shape radiating patch with partial ground is designed as shown in figure 1 (a) and covers the wide frequency range of 3.99 GHz-7.12 GHz with the return loss of -27.50 dB. Also the partial ground enhance the performance of whole system. Then by cut the rectangular slots on edge of radiating patch the return loss of an antenna is increase by -64.75 dB and resonant frequency is shifted from 5.9 GHz to 4.9 GHz. This antenna only resonates at singel frequency band so for achieving additional resonance in the antenna two inverted-U slots are incorporated as shown in figure 2 (b). by adding a slot in radiating patch the current path length will be increase thus antenna shifts to lower band frequency and multiband operation is also achieved. So, the antenna can resonate at three frequency bands 3.25 GHz, 5.63 GHz and 8.78 GHz with good return loss values. Then in final step two more inverted-U shaped slots are inserted at the bottom. These slots improves the impedance response at all the three bands.
Thus, the proposed antenna resonates at three frequencies 3.26 GHz, 5.95 GHz and 8.83 GHz with good performance parameters.

![S11 parameter comparison of different steps of proposed antenna](image1)

**Fig. 3 S11 parameter comparison of different steps of proposed antenna**

**Results and discussion:** The antenna is designed and simulated using CST studio suite 2021. Figure 4 shows the resultant simulated S-parameter. The proposed tri-band antenna resonates at 3.26 GHz, 5.95 GHz and 8.83 GHz with return loss of -29.15 dB, -43.40 dB, -41.14 dB respectively.

![S11 parameter of the proposed antenna](image2)

**Fig. 4 S11 parameter of the proposed antenna.**

It has been found that the proposed antenna with full ground plane gives the frequency bands with return loss of >-10dB which are unacceptable values for the antenna to work efficiently. But by using partial ground antenna resonates at desired tri-band and also improves its overall performance.
Figure 6. displays the resultant simulated VSWR. VSWR is a measurement of mismatch between an antenna and the feed line connecting to it. And to avoid mismatch, VSWR value should be $<$2. The VSWR of the proposed antenna are 1.07, 1.01 and 1.01 at resonant frequency bands.

Figure 7. shows the surface current distribution of the proposed antenna at different frequencies. Figure 7(a) shows the surface current distribution for 3.26 GHz and it can be observed that large amount of surface current is shown at the both left and right arms of the first U-shaped slot. Figure 7(b) illustrates the current distribution for 5.95 GHz, as per observation the current flows towards the patch. Similarly, in figure 7(c) it can be observed that large amount of surface is spread over the edge of the U-shaped slots. It is evident that the surface current is more apparent close the all four U-shaped slots. This effect demonstrate that the designed antenna operates in multiband.
**Fig. 7** surface current distribution of the proposed antenna at
a 3.26 GHz  
b 5.95 GHz  
c 8.83 GHz

Figure 8. shows the simulated gain of the proposed antenna which are 1.41 dB, 2.69 dB and 2.0 dB for resonating frequency of 3.26 GHz, 5.95 GHz and 8.83 GHz respectively.

**Fig. 8** Gain of the proposed antenna

Figure 9. shows the simulated 2D radiation pattern in the both E and H planes for all three resonating frequencies.
Fig. 9 Simulated radiation pattern of the proposed antenna in E and H plane

a 3.26 GHz
b 5.95 GHz
c 8.83 GHz

Table 2. Comparative analysis of the proposed antenna with previously reported antenna

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Size (mm²)</th>
<th>Operating frequencies (GHz)</th>
<th>Return loss (dB)</th>
<th>Gain (dB)</th>
<th>Bandwidth (MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>53×53</td>
<td>2.4, 5.5, 7.5</td>
<td>-27.12, -28.88, -28.97</td>
<td>1.24, 3.57, 3.28</td>
<td>70, 220, 250</td>
</tr>
<tr>
<td>4</td>
<td>60×30</td>
<td>3.1, 7.5, 10.1</td>
<td>-18, -18, -28</td>
<td>0.49, 6.9, 3.96</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>18×34.5</td>
<td>2.45, 5.5, 7.5</td>
<td>-40, -25, -15</td>
<td>1.5, 2.8, 3.4</td>
<td>290, 1270, 850</td>
</tr>
<tr>
<td>8</td>
<td>24.8×30</td>
<td>3.6, 5.6, 7.4</td>
<td>-35, -35, -35</td>
<td>1.14, 1.13, 0.8</td>
<td></td>
</tr>
</tbody>
</table>
Table 2. gives the comparative analysis of the proposed antenna with previously designed multiband antenna. This comparison is done in terms of operating frequencies, size, reflection coefficient, gain and bandwidth. We can conclude from this comparison that proposed antenna is compact in size and also archives less return loss and wide bandwidth compared to the other multiband antenna. Therefore, the proposed antenna can be employed efficiently in WLAN, WiMAX and X-band applications.

**Conclusion:** A compact triple band antenna loaded with inverted U-shaped slots with partial ground for WLAN, WiMAX and X-band application is presented in this paper. The proposed antenna resonates at three operating frequencies of 3.26 GHz, 5.95 GHz and 8.83 GHz with wide bandwidth and significant gain. Highest gain of 2.69 dB is achieved. The advantages of designed antenna is its compact size, less return loss, wide bandwidth and significant gain. A miniaturization of 52.10% is achieved compared to the conventional antenna. In Table 2, the performance of the proposed antenna is compared with some previous work on multiband antenna in terms of the size, reflection coefficient, gain and bandwidth. Also, the proposed simulated antenna is fabricated on FR4 substrate and compare the fabricated antenna results with the simulated results.

**References:**


The final simulated antenna design is fabricated to verify the performance. The antenna is printed on a FR-4 substrate of thickness 1.6mm with permittivity $\varepsilon_r$ of 4.4 and dielectric loss tangent of 0.02. A 50 SMA connector is used to excite the antenna. Figure 10 represents the fabricated prototype of the proposed antenna.


Fig. 10 Proposed fabricated antenna