A Miniatured WLAN/Wi-MAX Chip Antenna for Mobile Phone Applications

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Abstract—A compact WLAN/Wi-MAX chip antenna for mobile phone applications is presented in this paper. Two chip antenna designs are proposed. One is for WLAN (2.4~2.48, 5.15~5.35, 5.725~5.85 GHz) and Wi-MAX (3.4~3.7 GHz). Its dimensions are 3 mm × 9 mm × 1.6 mm. The other is for WLAN (2.4~2.48, 5.15~5.35, 5.725~5.85 GHz)/Wi-MAX (2.5~2.7 GHz). The dimensions are 3 mm × 11 mm × 1.6 mm. The antenna configuration of the two designs comprises two resonant branches. Not only the fundamental mode but also the second order resonance are utilized. Furthermore, the meander line structure is used to create two adjacent resonant frequencies to achieve a tri-band operation. Measurements of the return loss and antenna patterns were performed. The measured result shows good agreement with simulated ones. The main advantage of the proposed chip antenna is that it doesn’t require a guard region from other circuit components and is therefore attractive to mobile devices.

1. INTRODUCTION
The wireless communication market is growing up quickly. So does consumers’ demand for multi-functional handsets. Nowadays, mobile phones not only provide voice calls but also need to offer connectivity to the Internet. Among various protocols, wireless local area network (WLAN) and worldwide interoperability for micro-wave access (Wi-MAX) are current and potential future candidates for this application. At the same time, compact mobile devices are popular in the market and therefore produce demands for miniaturized antennas. By using meandered metal strip structure, it can offer WLAN connectivity in a compact footprint. In [2], the radiator of the monopole is loaded with a cylindrical ceramic dielectric piece to achieve a dual-band operation. In [3], the miniaturized surface-mount chip antenna contains two radiating structures with a feeding pin and a shorting pin. The antenna yields a superior performance in size reduction and is cost effective. For Wi-MAX, the most common licensed bands are 2.5~2.7 GHz and 3.4~3.7 GHz. This paper proposes two chip antenna designs One can cover WLAN and Wi-MAX at 3.4~3.7 GHz, while the other can operate at WLAN and Wi-MAX at 2.5~2.7 GHz. The proposed antenna does not require additional matching circuit and guard region so that the sizes on PCB are 9 × 3 mm² and 11 × 3 mm², respectively. A low cost FR4 substrate of 45 mm by 100 mm is served as the platform to mount the chip antenna. Both simulations and measurement results are provided to validate the antenna performance.

2. ANTENNA CONFIGURATION
The proposed miniaturized WLAN (2.4~2.48, 5.15~5.35, 5.725~5.85 GHz)/Wi-MAX (3.4~3.7 GHz) chip antenna is illustrated in Figs. 1(a) and (b) The substrate is FR4 with a dielectric constant of ε_r = 4.4 and its thickness is 0.8 mm The dimensions are 3 mm × 9 mm × 1.6 mm. The detailed antenna configuration and antenna dimensions are show in Fig 2. The other chip antenna design is tuned to WLAN (2.4~2.48, 5.15~5.35, 5.725~5.85 GHz)/Wi-MAX (2.5~2.7 GHz) operation. As shown in Figs. 3(a) and (b), its dimensions are 3 mm × 11 mm × 1.6 mm. Fig. 4 provides detailed geometric parameters of this antenna design.

3. ANALYSIS OF SIMULATION AND MEASUREMENT RESULTS
Figure 5(a) shows simulated and measured reflection coefficient spectra of the first chip antenna design. The two curves agree well and the resonant bands are located within WLAN (2.4~2.48, 5.15~5.35, 5.725~5.85 GHz) and Wi-MAX (3.4~3.7 GHz) bands. The input impedance is shown in Fig. 6. As the simulated results in Figs. 7 and 8 indicate the resonance is largely invariant to the changes in neither test board length nor width. The chip antenna comprises two resonant branches and takes advantage of its second order resonance to achieve a tri-band response. According to the current distributions in Fig. 9, the second order resonance and the coupled meander line section
Figure 1: Proposed WLAN/Wi-MAX (3.4 ∼ 3.7 GHz) chip antenna. (a) Top layer. (b) Bottom layer.

Figure 2: Detailed dimensions of the proposed WLAN/Wi-MAX (3.4∼3.7 GHz) chip antenna.

Figure 3: Proposed WLAN/Wi-MAX (2.5 ∼ 2.7 GHz) chip antenna. (a) Top layer. (b) Bottom layer.

Figure 4: Detailed dimensions of the proposed WLAN/Wi-MAX (2.5 ∼ 2.7 GHz) chip antenna.

Figure 5: Reflection coefficient spectra of WLAN/Wi-MAX (3.4 ∼ 3.7 GHz) chip antenna.

Figure 6: Input impedance spectra of WLAN/Wi-MAX (3.4 ∼ 3.7 GHz) chip antenna.
result in a wide resonant band around 5.7 GHz. The branch at circumference offers WLAN operation and the meander line in the middle works for Wi-MAX at the 3.4 to 3.7 GHz band.

Figure 10(a) shows simulated and measured reflection coefficient spectra of the second chip antenna design. The two curves largely agree with desired resonant bands, which are WLAN and Wi-MAX at 2.5~2.7 GHz band. Fig. 11 shows the input impedance. The resonance is also invariant to the changes in test board length and width as shown in Figs. 12 and 13. The current distributions shown in Fig. 14 indicate a broad resonant band is available from 2.4 to 2.7 GHz. The coupled meander line sections excite a second order resonance at 5.2 GHz.
Figure 12: Simulated reflection coefficient spectra of various test board lengths ($L$).

Figure 13: Simulated reflection coefficient spectra of various test board widths ($W$).

Figure 14: Current distributions of WLAN/Wi-MAX (2.5 ∼ 2.7 GHz) chip antenna at 2.45, 2.55, and 5.2 GHz.

Figure 15: Spherical near-field chamber used for radiation pattern measurement.

Figure 16: Fabricated prototype WLAN/Wi-MAX antenna.

Table 1: Performance summary of miniaturized chip antennas.

<table>
<thead>
<tr>
<th>Dimension (mm$^2$)</th>
<th>9(L)x2(W)x1.6(H)</th>
<th>11(L)x3(W)x1.6(H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>WLAN/Wi-MAX</td>
<td>WLAN/Wi-MAX</td>
</tr>
<tr>
<td>Center frequency (GHz)</td>
<td>2.46</td>
<td>2.48</td>
</tr>
<tr>
<td>Peak Gain (dBi)</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>42</td>
<td>47</td>
</tr>
<tr>
<td>VSWR</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>Return loss (dB)</td>
<td>-10</td>
<td>-7.5</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
<td>Linear</td>
</tr>
<tr>
<td>Pattern</td>
<td>Omni-directional</td>
<td>Omni-directional</td>
</tr>
<tr>
<td>Impedance ($\Omega$)</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>
In order to evaluate the radiation patterns, the chip antennas were put in a spherical near-field anechoic chamber as shown in Fig. 15. The fabricated prototype antenna is shown in Fig. 16, Figs. 17 and 18 provide the $xz$-plane radiation patterns at various bands, which are in general omnidirectional. Table 1 summarizes the antenna performance features.

![Figure 17: Measured radiation patterns of the WLAN/Wi-MAX (2.5 $\sim$ 2.7 GHz) chip antenna.](image1)

![Figure 18: Measured radiation patterns of the WLAN/Wi-MAX (34 $\sim$ 3.7 GHz) chip antenna.](image2)

4. CONCLUSIONS
The chip antennas proposed in this work come with low profile, light weight, small form factor features. Their omni-directional radiation patterns are quite suitable for mobile communications. Furthermore, their impedance matching performance is invariant to variations in test board sizes. There is no need for a guard region on the circuit board and therefore is particularly attractive for portable devices.

REFERENCES