MIMO Antenna for the 2.4/5.8GHz Dual WiFi System of the Mobile Phone

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Abstract. The MIMO antennas to be operated in dual WiFi bands (2.4GHz/5.8GHz) were designed and embodied as the hybrid one that incorporated the monopole antenna and IFA. The grounding structure that could enhance an isolation of MIMO antennas was presented. The antennas were implemented on the FR4 board. The characteristics of the antennas demonstrated the VSWR below 3:1 and ECC less than 0.1 over design bands. In the efficiency and average gain, the antennas also revealed excellent characteristics with corresponding measurements of 63.92–72.36% and -1.94–1.40dBi (2.4GHz) and 39.49–58.39% and -4.03–2.34dBi (5.8GHz).

Keywords: ECC, MIMO antenna, Hybrid, ECC, Mobile phone

1 Introduction

For the embodiment of the MIMO, more than two antennas should be embedded in each mobile phone and, for the embodiment of MIMO system, the ECC (Envelope Correlation Coefficient) and isolation between antennas are important. However, the installation of multiple antennas could generate couplings included by electromagnetic mutual interference between antennas and, thereby, the securing of proper isolation between these antennas becomes difficult. Therefore, securing higher level of isolation between such antennas is essential together with the keeping of predetermined performance of each antenna to be realized through the minimization of respective quality defects. Recently, the method of decoupling network[1][2], the application of the method of diversity (capacitance current feed, the use of different current modes)[3][4], the method of the expansion of the ground on which multiple antennas are grounded[5], and the method using the meta structure[8] etc. are used for the design of MIMO antennas.

In this paper, the MIMO antenna for the dual WiFi bands is designed as a hybrid antenna enabling the simultaneous operations of the monopole one and IFA (Inverted F Antenna).[6] And the structure that could control the electric field to be included to the ground plane will be designed to improve the isolation (S21). The HFSS of Ansoft will be employed for the design. The antennas and the non-contact ground structure for measurement will be embodied on the FR4 board. Overall characteristics of the antennas are measured through network analyzer and in the anechoic chamber.
2 Antenna design and measurements

As shown in Figure 1, the proposed antennas were designed as symmetrical hybrid antennas on top of the PCB to enable the simultaneous operations of the monopole and IFA for the operation of MIMO. Figure 1 shows an overview of the proposed antennas. The FR4 PCB (relative permittivity 4.4) in dimensions of 60(w) x 107(L) x 1mm(T) that is identical to those used for current mobile phones was used. The space (15mm) on top of the board is a space the built-in antennas will be embedded. The built-in antennas are placed symmetrically on top the board for the operation of MIMO for which the two ports placed on both ends from the center of PCB are prepared for the current feed to antennas through the CPWG (Co-Planer Wave Guide) line. The MIMO antennas are configured to have each entire length of λ/4 where λ denotes the wavelength of signals being received. The dimensions of the non-contact grounding structure inserted into the center of the front side antenna are 4mm(W) x 12.3mm(L) and, those of the non-contact grounding structure inserted into the center of the backside antenna are 10mm(W) x 15.8mm(L). And it also is shown the detail of the non-contact grounding structure. The structure was designed to be a coupling structure (gap=0.3mm) other than the type to be joined to the backside ground for the convenient attachment.

Fig. 1. Geometry of the dual band WiFi MIMO antenna

Figure 2 represents the field strength distributing over each antenna at WiFi bands of 2.4GHz and 5.8GHz, this illustrates the improvement in isolation. The field strength above represents how much the field is induced to the antenna 2 from the antenna 1 to which the signals are released. If the two antennas are distant from each other, the phenomenon like this would be less probable or otherwise, the closer gap between two antennas will be resulted in significant mutual coupling of the two antennas.
The non-contact grounding structure was thus inserted in between to compensate this phenomenon. Thereby the coupling between two antennas was reduced and the electric field that was supposed to be induced from antenna 2 to antenna 1 is now induced to the grounding structure by leaving almost no field to be induced to antenna 2. This, accordingly, demonstrates the improved isolation in WiFi bands of 2.4GHz and 5.8GHz.

Figure 3 shows the picture of antennas made based on the design of simulation. To achieve the result to be approximating to the result obtained from the simulation. Figure 4 shows the comparison between actual measurements and results of the simulation of isolation and reflection coefficient of antennas. The Agilent network analyzer was used to obtain actual measurements that exhibited roughly close correspondence to the results of the simulation despite some errors attributable to the fabrication of the analyzer. The results of the reflection coefficient obtained from both the simulation and measurements in the WiFi band of 2.4GHz were -16.4dB and -14.8dB (18.9dB and 22.1dB; at 5.8GHz) whereas those of the isolation obtained from the simulation and measurement were -27dB and -25.3dB (43.2dB and 42.7dB; at 5.8GHz), respectively. The differences in compared values were estimated that they could be attributable to the application of SMA connectors and the tolerance in the
permittivity of the board. The characteristics of port 2 were almost close to those of the port1, thus the explanations thereof are abridged.

![Fig. 4. Return losses and isolations of the antenna. (a) return loss (b) isolation.](image)

The important element for the data communication is ECC. The ECC is an indicator showing the influence of the RF signal channels reaching MIMO antennas. The range of this coefficient spans from 0 to 1 and is determined by the formula employing the data of S11, S22, S12, and S21. When the value of ECC is less than 0.5, the antennas will get the diversity gain and the convergence of the value to 0 implies the perfect MIMO performance. The ECC performance of studied antenna was below 0.1 at each WiFi band of 2.4GHz and 5.8GHz.

### Table 1. Efficiency and the average gain of the antenna

<table>
<thead>
<tr>
<th>Freq.[GHz]</th>
<th>Port 1</th>
<th>Port 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Eff.[%]</td>
<td>Avg.[dBi]</td>
</tr>
<tr>
<td>2.300</td>
<td>70.19</td>
<td>-1.54</td>
</tr>
<tr>
<td>2.350</td>
<td>68.17</td>
<td>-1.66</td>
</tr>
<tr>
<td>2.400</td>
<td>69.92</td>
<td>-1.55</td>
</tr>
<tr>
<td>2.450</td>
<td>72.36</td>
<td>-1.40</td>
</tr>
<tr>
<td>5.750</td>
<td>47.53</td>
<td>-3.23</td>
</tr>
<tr>
<td>5.800</td>
<td>58.39</td>
<td>-2.34</td>
</tr>
<tr>
<td>5.850</td>
<td>48.73</td>
<td>-3.12</td>
</tr>
<tr>
<td>5.900</td>
<td>51.45</td>
<td>-2.89</td>
</tr>
</tbody>
</table>

The measurements of the efficiency of antennas and average gain are summarized in Table 1. In the band of 2.4GHz including the WiFi band, the measurements of average efficiency at port1 and port2 were 68.912% and 67.976%; and in the band of 5.8GHz, they were 49.118% and 49.83%. With regard to the average gain that is important for the mobile communication antennas, the measurements at port1 and
port2 were -1.618dBi and -1.686dBi (2.4GHz); and -3.122 dBi and -3.072 dBi (5.8GHz), respectively.

3 Conclusion

In this study, a MIMO antennas in dual WiFi bands (2.4GHz/5.8GHz) for the mobile phone was studied. The antennas were designed and embodied as the hybrid one that incorporated the monopole antenna and IFA, and were implemented on the FR4 board. Measurements of the MIMO antennas demonstrated the VSWR below 3:1 and ECC less than 0.1 over design bands. The efficiency and average gain of the antennas were 63.92~72.36% and -1.94~1.40dBi for 2.4GHz band and 39.49~58.39% and -4.03~2.34dBi for 5.8GHz band.

Acknowledgement. This research was supported by Basic Science Research Program Through the national Research Foundation of Korea (NRF) funded by the Ministry of Education (2015023260).

References