Research Article

New Configuration of Handset MIMO Antenna for LTE 700 Band Applications

Byeonggi Mun,¹ Frances J. Harackiewicz,² Byeongkwan Kim,¹ Hyunho Wi,¹
Jonghyun Lee,¹ Myun-Joo Park,¹ Changwon Jung,³ and Byungje Lee¹

¹ Department of Wireless Communications Engineering, Kwangju University, 447-1 Wolgye-Dong, Nowon-Gu, Seoul 139-701, Republic of Korea

² Department of Electrical and Computer Engineering, Southern Illinois University Carbondale, Carbondale, IL 62901, USA

³ Graduate School of NID Fusion Technology, Seoul National University of Technology, 172 Gongneung-2 Dong, Nowon-Gu, Seoul 139-743, Republic of Korea

Correspondence should be addressed to Byungje Lee; bj.lee@kw.ac.kr

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A compact handset multiple-input multiple-output (MIMO) antenna for long-term evolution (LTE) 700 band (746~787 MHz) applications is proposed. The proposed antenna consists of two symmetrical PIFAs. Without the usage of any additional coupling elements between closely mounted antennas, a high isolation (>15 dB) and a low enveloped correlation coefficient ($ECC < 0.35$) are achieved by the optimum location and arrangement of MIMO antenna elements.

1. Introduction

The long term evolution (LTE) standard has attracted attention as the fourth generation of mobile communications technology to provide better mobile broadband and multimedia services. Multiple-input multiple-output (MIMO) operation of the LTE system has become a prerequisite to enhance data reliability, channel capacity, and network coverage in multipath environments using multiple antennas without additional power [1]. Since more than two neighboring antennas should be designed within the very limited spaces available in the mobile handsets, achieving high isolation and a low enveloped correlation coefficient (ECC) between closely spaced antennas is very important. A number of studies has been conducted on improving isolation by cutting slots or slits in the ground plane [2, 3] and using the ground wall among radiators and a T-shaped short strip [4]. Suspended neutralization line or neutralizing structures have been used for the enhancement of isolation as well [5–9]. However, applying these techniques to LTE MIMO antennas at 700 MHz has become a serious technical challenge, because the ground plane requires modification, and there is no sufficient space to

embed additional elements between closely packed antennas. In this paper, we present a promising design of a handset antenna comprising a main antenna for the GSM850/900 (824~960 MHz) and DCS/PCS (1.71~1.99 GHz) bands and an auxiliary antenna covering the LTE 700 (746~787 MHz) band to perform the MIMO operation. High isolation can be achieved by collinearly arranging the E -field directions of LTE MIMO antennas in the near-field region, because a collinearly arranged antenna has a lower mutual impedance than that of a broadside arranged antenna [10]. Moreover, low ECC is achieved by the pattern diversity technique, with LTE MIMO antennas symmetrically located on the top sides of the ground plane.

2. LTE MIMO Antenna Simulation

Figure 1 shows the proposed compact LTE MIMO antenna. The overall dimensions of the proposed antenna are $5 \times 35 \times 6 \text{ mm}^3$, and the size of the ground plane is $60 \times 110 \times 1 \text{ mm}^3$. As shown in Figure 1(a), the proposed PIFA structure antennas are printed on FR4 substrate ($\epsilon_r = 4.4$) and

FIGURE 3: E -field distribution in the near-field region; (a) case 1, (b) case 2, (c) case 3, and (d) case 4.

arrangement of the E -field directions [10]. This proposed method is verified by four cases of antenna arrangements—case 1: perpendicular, case 2: broadside, and cases 3 and 4: collinear—as shown in Figure 2. These are divided into the perpendicular, broadside, and collinear arrangements by the E -field distribution as shown in Figure 3. Figure 4 shows that the perpendicular (case 1) and collinear arrangements (cases 3 and 4) give higher isolation (magnitude of S_{21} in dB) than that of the broadside arrangement (case 2). However, the collinearly arranged MIMO antenna in case 3 only gives the lowest ECC (<0.19), which is less than the recommended value [11] of 0.5, as shown in Table 1. This is due to the MIMO antenna in case 3 achieving better pattern diversity in the far-field region than the MIMO antenna in case 1, where the two antennas are physically perpendicular to each other. The ECC shown in Table 1 is obtained by using the far-field radiation patterns [12], as shown in (1), where the incident wave is assumed as a uniform environment ($P(\theta, \phi) = 1$):

$$\text{ECC}(\rho_e) = \frac{\left| \int_0^{2\pi} \int_0^\pi E_1^*(\theta, \phi) \cdot E_2(\theta, \phi) \cdot P(\theta, \phi) \sin(\theta) d\theta d\phi \right|^2}{\left[\left(\int_0^{2\pi} \int_0^\pi E_1^*(\theta, \phi) \cdot E_1(\theta, \phi) \cdot P(\theta, \phi) \sin(\theta) d\theta d\phi \right) \cdot \left(\int_0^{2\pi} \int_0^\pi E_2^*(\theta, \phi) \cdot E_2(\theta, \phi) \cdot P(\theta, \phi) \sin(\theta) d\theta d\phi \right) \right]}, \quad (1)$$

where $E_{1,2}(\theta, \phi)$ is the electric field pattern of antennas 1 and 2, respectively, and $P(\theta, \phi)$ is the incident field angular density function.

3. Main/MIMO Antenna Design and Measurement

Based on the simulation results to find the optimum location and arrangement of the LTE 700 band MIMO antenna, the main antenna covering the GSM850/900 bands (824~960 MHz) and DCS/PCS bands (1.71~1.99 GHz) and the MIMO antenna (case 3 in Figure 2(c)) covering the LTE 700 band (746~787 MHz) are designed and measured. Figure 5 shows the structure of the proposed main antenna and MIMO antenna. The compact main antenna mounted on a ground plane $60 \times 110 \times 1 \text{ mm}^3$ in size consists of the PIFA structure with a capacitively coupled feed [13]. Its overall dimensions are $60 \times 5 \times 6 \text{ mm}^3$, and it is printed on a multilayer consisting of FR4 (thickness = 1 mm) and foam (thickness = 5 mm) substrates. Each LTE MIMO antenna ($5 \times 35 \times 6 \text{ mm}^3$) is located on top sides of the ground plane with collinearly arranged E -fields in the near-field region.

Figure 6 shows the measured S-parameters of the proposed antenna. The proposed antenna ($\text{VSWR} < 3$) covers the LTE 700 band (746~787 MHz), GSM850/900 bands (824~960 MHz), and DCS/PCS bands (1.71~1.99 GHz). Although the main antenna and MIMO antennas are embedded in a

FIGURE 4: Simulated S-parameters; (a) S_{11} and (b) S_{21} .

FIGURE 5: Geometry of the proposed antenna; (a) overall view, (b) detailed view of main antenna, and (c) fabricated antenna.

TABLE I: Simulated results for each case.

Contents	Ant. type			
	Case 1	Case 2	Case 3	Case 4
Resonant frequency (f_r)	0.765 GHz	0.791 GHz	0.766 GHz	0.754 GHz
Isolation	11.8 dB	6.7 dB	15.7 dB	10.3 dB
ECC (at f_r)	0.52	0.78	0.19	0.81
Arrangement (gap)	Perpendicular (20 mm)	Broadside (10 mm)	Collinear (50 mm)	Collinear (10 mm)

FIGURE 6: Measured S-parameters.

FIGURE 8: Measured radiation patterns at 766 MHz (zx-plane).

FIGURE 7: Measured average gain and ECC.

narrow area, they operate almost independently. The measured isolation between the two MIMO antennas is higher than 15 dB, and this is generally acceptable for practical MIMO antenna applications in industry. Figure 7 shows the measured average gain and ECC. The proposed antenna has an average gain of more than -4.3 dBi in the LTE band and

more than -3 dBi in the GSM850/900 and DCS/PCS bands. Moreover, the proposed LTE MIMO antenna shows a lower ECC (<0.35). Figure 8 shows the measured radiation patterns of two MIMO antennas in the LTE700 band (766 MHz). They have been measured with one antenna excited and the other terminated to a load with 50Ω . The polarizations of the two antennas are orthogonal to each other. Since each MIMO antenna element (PIFA) has both the vertical E -field component (due to current on the radiating element) and the horizontal E -field component (due to current on the ground plane), the direction of the composite E -field can be diagonal. In addition to this, since the horizontal E -field component of each MIMO antenna element is in opposite direction, the polarizations of the two antennas are diagonally orthogonal to each other, as shown in Figure 8. Therefore, these orthogonal radiation patterns and high isolation (>15 dB) result in a lower ECC (<0.35) which is less than the recommended value of 0.5 [11].

4. Conclusion

A compact ($5 \times 35 \times 6$ mm³) handset MIMO antenna for LTE 700 band applications has been proposed and constructed with two symmetrical PIFAs. Closely packed MIMO antennas were designed, without any additional coupling structures to obtain good isolation. The proposed antenna achieves high isolation (>15 dB) and low ECC (<0.35) by

collinearly arranging the E -fields of two antennas in the near-field region and obtaining diagonally orthogonal radiation patterns.

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