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Research Article

A High Isolation MIMO Antenna without Decoupling Structure for LTE 700 MHz

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This paper presents a long-term evolution (LTE) 700 MHz band multiple-input-multiple-output (MIMO) antenna, and high isolation between the two symmetrical antenna elements is obtained without introducing extra decoupling structure. Each antenna element is a combination antenna of PIFA and a meander monopole antenna. The end of the PIFA and the meander monopole antenna are, respectively, overlapped with the 50 Ω microstrip feed line, the two overlapping areas produce additional capacitance which can be considered decoupling structures to enhance the isolation for the MIMO antenna, as well as the impedance matching of the antenna elements. The MIMO antenna is etched on FR4 PCB board with dimensions of $71 \times 40 \times 1.6\ mm^3$; the edge-to-edge separation of the two antenna elements is only nearly 0.037 λ at 700 MHz. Both simulation and measurement results are used to confirm the MIMO antenna performance; the operating bandwidth is 698–750 MHz with $|S_{11}| \le -6$ dB and $|S_{21}| \le -23$ dB.

1. Introduction

With the development of wireless communication, mobile terminals require much higher data-rate transmission than the past. As a key technology of wireless communication, long-term evolution (LTE) standard allows employing multiple-input-multiple-output (MIMO) technique, which has been considered one of the most promising technologies to provide increased channel capacity and enhanced spectrum efficiency, without the need for additional transmit power. But it is a challenge to design MIMO antenna in slim mobile terminal applications, especially for lower band LTE 700 MHz.

Many works have been carried out to reduce mutual coupling between MIMO antenna elements. In [1], an idea was to use field cancellation to enhance isolation by creating an additional coupling path between antenna elements. A tree-like decoupling structure was used to achieve high isolation, as mentioned in [2]. A T-shaped ground plane was placed between two orthogonal linear monopole antennas [3]. According to research in [4], an LC-based branch-line hybrid coupler had been integrated with the antenna to decouple the ports. Utilizing EBG structures is an effective method to reduce the mutual coupling between antenna elements [5–7]. Two bent slits had been etched into the ground plane to improve isolation at lower frequency and widen impedance bandwidth at higher frequency [8]. Defected ground structure (DGS) has also been proved to provide a significant effect to improve isolation by changing the ground current flowing [9]. A suspended neutralization strip was used in [10] to deliver one antenna element signal to the other antenna element in order to cancel out the existing mutual coupling.

As mentioned above, there are several methods that have been reported to improve the isolation between antenna elements, but decoupling structure is expensive and occupies a large area, especially for lower band. That is disadvantageous to portable devices because of their small volumes and low costs.

In order to study the decoupling of LTE MIMO antenna at lower frequencies, MIMO antenna for LTE 700 MHz with small size of $71 \times 40 \times 1.6\ mm^3$ is presented in this paper.

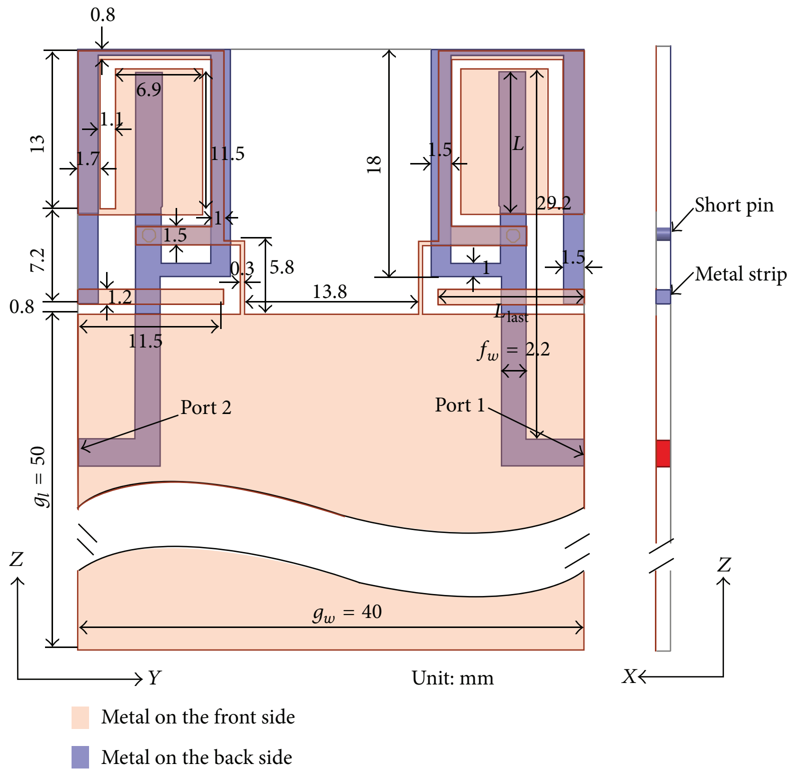


FIGURE 1: Structure of the proposed MIMO antenna.

The proposed antenna has a high isolation without extra decoupling structure and performs over the lowest LTE band. It is found that the design can achieve more than 23 dB isolation over the LTE 700 band and even better than 35 dB over frequency range of 690–725 MHz. Details of our antenna design and experiment results are presented and discussed.

2. Antenna Design

2.1. Configuration of the Proposed Antenna. Figure 1 shows the geometry of the proposed LTE MIMO antenna, which is etched on FR4 PCB board with length $L_{sub} = g_l + 0.8\,\text{mm} + 7.2\,\text{mm} + 13\,\text{mm} = 71\,\text{mm}$, width $g_w = 40\,\text{mm}$, height $h = 1.6\,\text{mm}$, relative permittivity $\varepsilon_r = 4.4$, and loss tangent $\tan\sigma = 0.02$. The MIMO antenna consists of two symmetric antenna elements; each element includes a mender monopole antenna and PIFA. The mender monopole antennas are printed on both sides of the substrate and connected by the metal strips which are located at the flank of PCB board. The ground plane is located on the front side of the PCB board, and the PIFAs are grounded by the short pins. Each 50 Ω microstrip feed line has a protruded part; it has an overlapping area with the end of its corresponding PIFA. Moreover, the strip of each monopole printed on the front side of the PCB board also has an overlapping part with its corresponding 50 Ω microstrip feed line.

2.2. Study of LTE MIMO Antenna. As mentioned above, the LTE MIMO antenna element is composed of a mender monopole antenna and a PIF antenna. Monopole antennas are used in mobile devices popularly for their inherent advantages. Here, we designed a mender monopole antenna firstly and adjust its length to $L_{monopole} = 11.5 + 20.2 + 12 + 18 + 7.5 + 3 = 72.2\,\text{mm}$, a little shorter than quarter-wavelength at 800 MHz. A parasitical capacitance is produced by the overlapping area between the feed line and end of monopole antenna, which can help the antenna excite a resonant mode at about 800 MHz as shown in Figure 2.

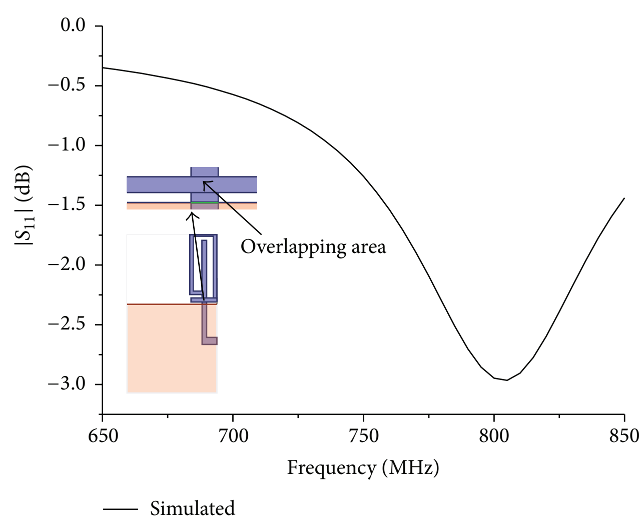
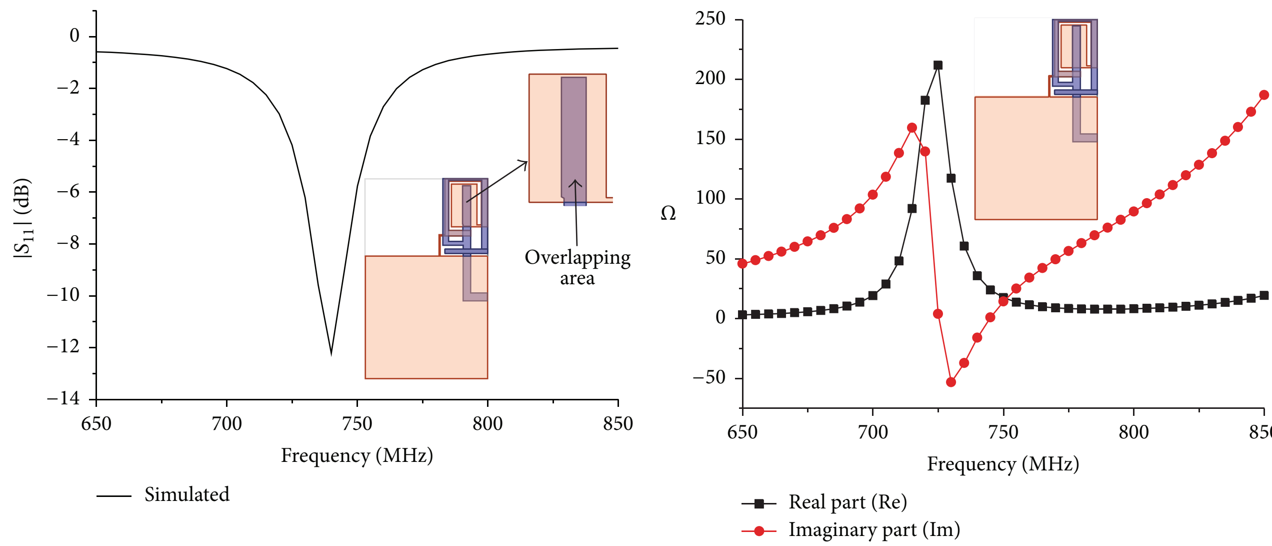


FIGURE 2: $|S_{11}|$ curve of the monopole antenna.



(a) (b)

Figure 3: Antenna performance of the monopole antenna with improved ground plane: (a) $|S_{11}|$ curve. (b) Input impedance.

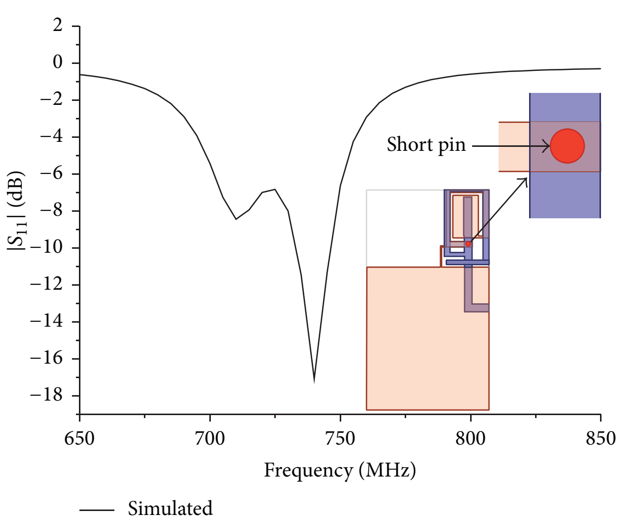


Figure 4: $|S_{11}|$ curve of MIMO antenna element.

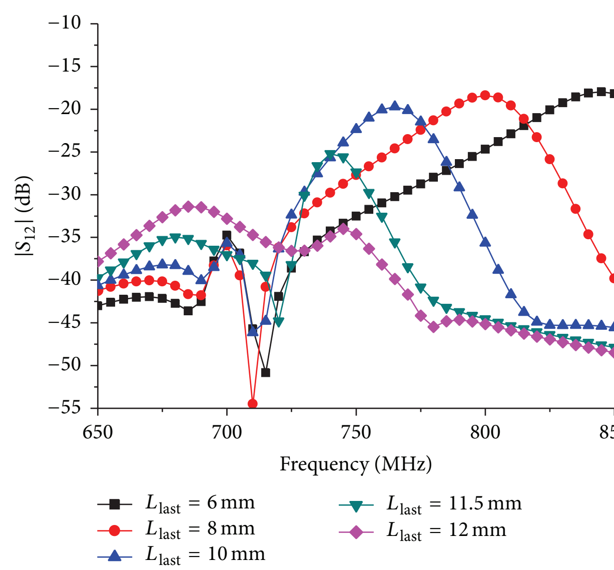


Figure 5: $|S_{12}|$ curve of MIMO antenna with different L_{last}.

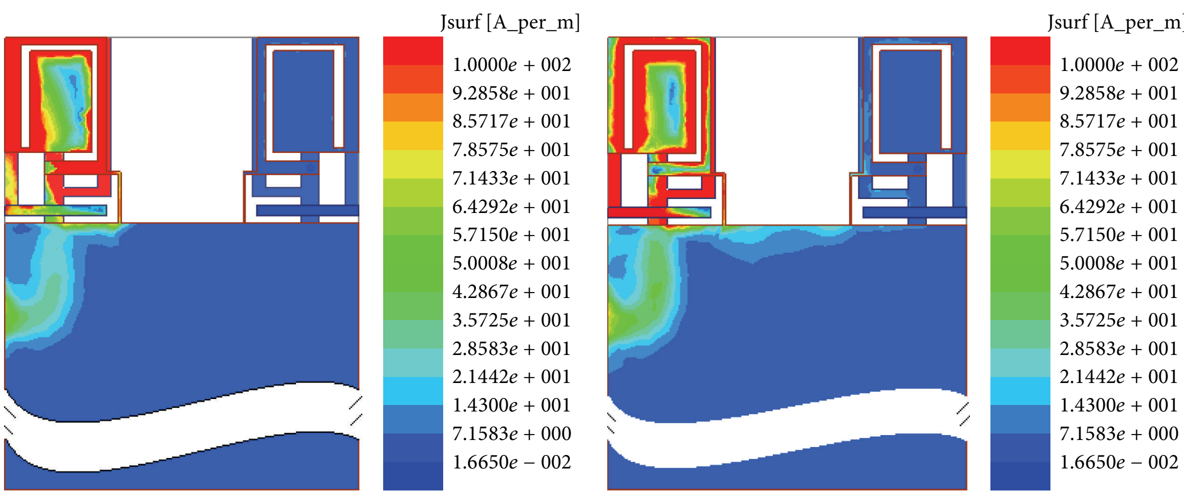
But the impendence matching is bad and that needs to be improved in the further work. A ground branch is used to lower this resonant frequency and improve the impedance matching of the monopole antenna. The results are shown in Figures 3(a) and 3(b), the resonant frequency shift was to 740 MHz from 800 MHz, with $|S_{11}| \leq -6$ dB, and an operation band from 730–750 MHz is obtained.

To cover the whole bandwidth of LTE 700 MHz, a PIF antenna is produced by adding a short pin, and another resonance mode is introduced at about 710 MHz. The production of this resonant mode is benefited from the overlapping area between the ground branch and the feed line, which can introduce additional capacitance for the inductive PIF antenna. Thus, an operating bandwidth covering 700–750 MHz is obtained. Figure 4 shows the simulated $|S_{11}|$ and the antenna structure, which can be considered a combined antenna of a monopole antenna and a PIF antenna, and it is chosen as antenna element for the MIMO antenna shown in Figure 1.

As we know, isolation is an important parameter of MIMO antenna. Performance of PIF antenna is stable, so the isolation for the frequencies at about 700 MHz is good enough without need to introduce additional decoupling structure. Figure 5 shows the simulated $|S_{12}|$ of the MIMO antenna with varying L_{last}, which is the length of the last segment of the monopole antenna, as shown in Figure 1. We can find from Figure 5 that the effect of varying L_{last} is slight for the frequencies around 700 MHz, because this resonance

(a) (b)

Figure 6: Prototype photograph of the proposed antenna: (a) top layer; (b) bottom layer.



(a) (b)

Figure 7: Simulated surface current distributions at (a) 700 MHz and (b) 750 MHz.

mode is produced by PIFAs, and a high isolation is obtained for equilibrium PIFA structure. But $|S_{12}|$ for the frequencies around 750 MHz is changed gravely with the variation of L_{last}. When L_{last} is chosen to 11.5 mm, the value of $|S_{12}|$ is −25 dB at 750 MHz, which is benefited from the overlapping areas between the last segment of the monopole antennas and their corresponding 50 Ω microstrip feed lines. Due to the existence of the overlapping areas, strong coupling is induced between the monopole antennas and their corresponding 50 Ω microstrip feed lines, and the monopole antennas can be considered loop antennas by the mutual coupling. Loop antenna is more stable than monopole antenna, and ground currents induced by the equilibrium loop antenna are small, so high isolation for the frequencies around 750 MHz is obtained.

3. Results and Discussions

The MIMO antenna is designed and simulated using High Frequency Structure Simulator V13.0 and is fabricated and measured too. The photographs of the proposed MIMO antenna are shown in Figure 6.

With one port excited and the other terminated with 50 Ω impedance, the simulated surface current distributions of the proposed MIMO antenna are shown in Figure 7. At 700 MHz, the currents mainly distribute on the PIFA but mainly distribute on the monopole antenna at 750 MHz. That further explains that the resonant modes at 700 MHz and 750 MHz are produced by the PIFA and the meander monopole antenna, respectively. Observing from Figure 7, we also can know why the coupling between two elements is more serious

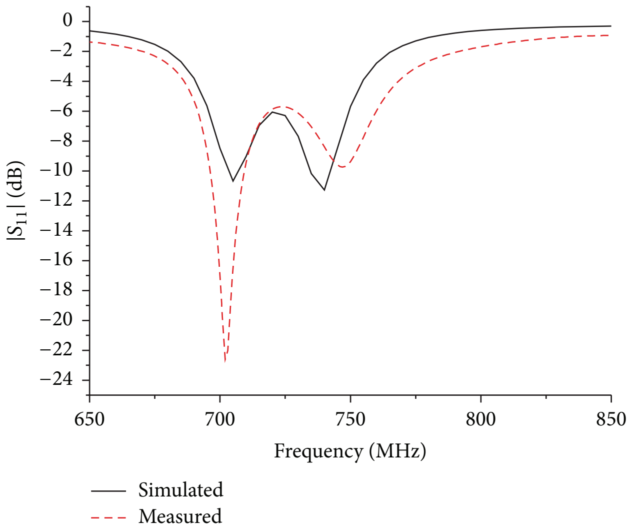


Figure 8: Simulated and measured $|S_{11}|$ of the proposed antenna.

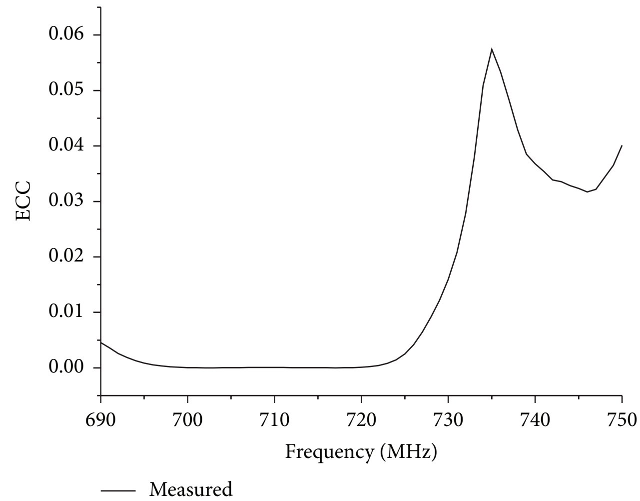


Figure 10: Measured ECC of the proposed antenna.

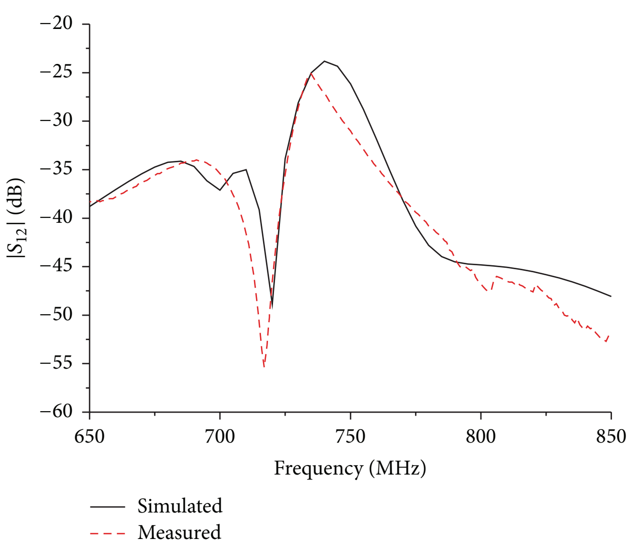


Figure 9: Simulated and measured $|S_{12}|$ of the proposed antenna.

at the higher frequency. As shown in Figure 7(b), there are more currents distributing on the ground plane, and that is because of the good stability of PIFA.

The measured and simulated $|S_{11}|$ of the proposed antenna can be seen in Figure 8. There are two resonant modes at about 700 MHz and 750 MHz, and they are produced by the PIFA and meander monopole, respectively. These two resonant modes are interrelated and interact with each other, so a good operation band is achieved. With $|S_{11}| \leq -6$ dB, the operating band is from 698 to 750 MHz, and LTE 12 and LTE 17 bands are covered.

Figure 9 shows the measured and simulated $|S_{12}|$ of the proposed LTE MIMO antenna. The deviation of measured and simulated results is due to the ground currents, which has strong effect on the mutual coupling between the two antenna elements and are susceptible to the test instruments. Without any decoupling structure, we can see that the simulated result shows that the isolation between two ports is better than 23 dB.

Figure 10 shows the measured envelope correlation coefficient results; the calculated correlation is obtained from the radiation efficiency and S-parameters [11]:

$$\text{ECC} = \frac{\left|S_{11}^{*}S_{12} + S_{21}^{*}S_{22}\right|^{2}}{\left(1-\left(\left|S_{11}\right|^{2}+\left|S_{21}\right|^{2}\right)\right)\left(1-\left(\left|S_{22}\right|^{2}+\left|S_{12}\right|^{2}\right)\right)\eta_{\text{rad}i}\eta_{\text{rad}j}}. \quad (1)$$

The values are less than 0.06 over the operating bandwidth, and that means the MIMO antenna has a good diversity performance.

When measuring 2D patterns of the proposed MIMO antenna, port 1 is excited and port 2 is terminated to a load with 50 Ω impedance. The simulated and measured results are shown in Figure 11. Because the two antenna elements are symmetric, the radiation patterns of the other antenna element are not shown.

4. Conclusions

In this paper, LTE 700 MHz MIMO antenna without decoupling structure has been presented. The MIMO antenna has a small size and a good performance. With edge-to-edge separation of the two antenna elements nearly 0.037λ at 700 MHz, and without decoupling structure, high isolation is obtained. Both simulation and measurement results had shown that isolation of the proposed antenna is better than 23 dB, and the impedance bandwidth is 698–750 MHz with $|S_{11}| \leq -6$ dB.

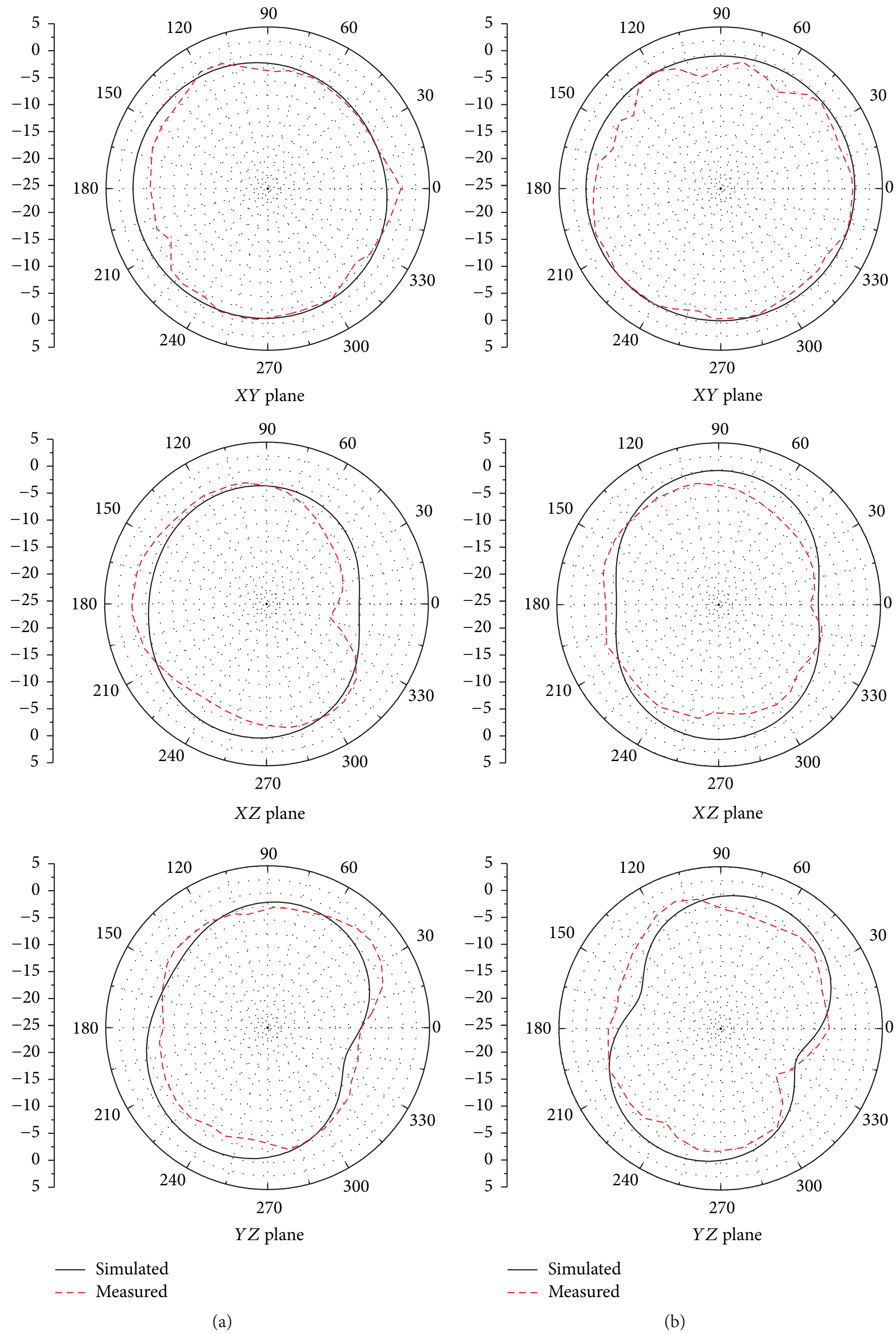


FIGURE 11: Simulated and measured 2D patterns of the proposed antenna. (a) 700 MHz; (b) 750 MHz.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

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References

[1] A. C. K. Mak, C. R. Rowell, and R. D. Murch, "Isolation enhancement between two closely packed antennas," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 11, pp. 3411–3419, 2008.

[2] S. Zhang, Z. Ying, J. Xiong, and S. He, "Ultrawideband MIMO/diversity antennas with a tree-like structure to enhance wideband isolation," *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1279–1282, 2009.

[3] T.-Y. Wu, S.-T. Fang, and K.-L. Wong, "Printed diversity monopole antenna for WLAN operation," *Electronics Letters*, vol. 38, no. 25, pp. 1625–1626, 2002.

[4] R. A. Bhatti, S. Yi, and S.-O. Park, "Compact antenna array with port decoupling for LTE-standardized mobile phones," *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1430–1433, 2009.

[5] D. Sievenpiper, L. Zhang, R. F. Jimenez Broas, N. G. Alexöpolous, and E. Yablonovitch, "High-impedance electromagnetic surfaces with a forbidden frequency band," *IEEE Transactions on Microwave Theory and Techniques*, vol. 47, no. 11, pp. 2059–2074, 1999.

[6] F. Yang and Y. Rahmat-Samii, "Microstrip antennas integrated with electromagnetic band-gap (EBG) structures: a low mutual coupling design for array applications," *IEEE Transactions on Antennas and Propagation*, vol. 51, no. 10, pp. 2936–2946, 2003.

[7] L. Li, B. Li, H.-X. Liu, and C.-H. Liang, "Locally resonant cavity cell model for electromagnetic band gap structures," *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 1, pp. 90–100, 2006.

[8] J.-F. Li, Q.-X. Chu, and T.-G. Huang, "A compact wideband MIMO antenna with two novel bent slits," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 2, pp. 482–489, 2012.

[9] D. Ahn, J.-S. Park, C.-S. Kim, J. Kim, Y. Qian, and T. Itoh, "A design of the low-pass filter using the novel microstrip defected ground structure," *IEEE Transactions on Microwave Theory and Techniques*, vol. 49, no. 1, pp. 86–93, 2001.

[10] A. Diallo, C. Luxey, P. Le Thuc, R. Staraj, and G. Kossiavas, "Study and reduction of the mutual coupling between two mobile phone PIFAs operating in the DCS1800 and UMTS bands," *IEEE Transactions on Antennas and Propagation*, vol. 54, no. 11, pp. 3063–3074, 2006.

[11] P. Hallbjörner, "The significance of radiation efficiencies when using S-parameters to calculate the received signal correlation from two antennas," *IEEE Antennas and Wireless Propagation Letters*, vol. 4, no. 1, pp. 97–99, 2005.