Box-folded four-element MIMO antenna system for LTE handsets

Lingsheng Yang✉ and Tao Li

A multiple-input–multiple-output (MIMO) antenna system for mobile handsets is presented. The proposed MIMO system consists of four identical box-folded planar inverted-F antenna. A broad operating band (1.84–2.69 GHz) with overall MIMO system dimensions of $136 \times 68.8 \times 6$ mm^3 and an element size of only $10 \times 10 \times 5$ mm^3 can be achieved. Lower than −14.2 dB isolation between any two of the elements has been obtained at the whole operating band. The correlation coefficient, radiation pattern and antenna gain are also studied.

Introduction: The multiple-input–multiple-output (MIMO) antenna is a key technology for fourth-generation (4G) wireless systems. According to [1], an increase in the number of transmitter antennas and receiver antennas can improve communication quality and increase the channel capacity without extra radiation power and spectrum bandwidth. However, because of the limited size of the mobile terminals and the increased number of other components, the multiple antennas should be small in structure and easy to fabricate. Moreover, the whole system should cover a wide bandwidth (at least 40 MHz) to support the wider bandwidths specified in the 4G and 5G standards [2]. When antennas are placed close to each other, high correlation between antenna elements will occur. Obtaining a high-isolation MIMO antenna with limited space becomes a challenging task. Many researches have been reported recently. A T-shaped parasitic element connected to the ground plane between the two antenna elements was used in [3] to fulfil a higher than 13 dB isolation over the working frequency range. In [4], two inverted L-branches combined with an etched slot on the ground plane were proposed. Higher than 15 dB isolation was obtained; however, a longer than 40 mm slot on the ground plane is necessary. However, for practical applications, maintaining the integrity of the ground is preferred and the use of carefully designed isolation structures between the radiators is complicated to design and is space consuming.

In this Letter, a wideband four-element MIMO antenna system is proposed. Its measured −10 dB bandwidth is 850 MHz (1.84–2.69 GHz). In the whole operational band, and the isolation among either elements is lower than −14.2 dB. The total dimensions of the antenna element are only $10 \times 10 \times 5$ mm^3. The antenna system can cover the GSM1900, UMTS, LTE2300 and LTE2500 for mobile terminals. The correlation coefficient, antenna gain and other parameters show it is competitive for these applications.

Antenna design: Fig. 1 shows the geometry of the proposed MIMO antenna system. The system consists of four symmetric box-folded planar inverted-F antenna (PIFA). The PIFA is folded on an FR4 box to lower the antenna *Q* as mentioned in [5], thereby enhancing the antenna bandwidth. By modifying the antenna topology, as shown in Fig. 2, electrical length approximately equal to one quarter wavelength at the centre of the GSM1900 (1.9 GHz), LTE2300 (2.35 GHz) and LTE2500 (2.58 GHz) frequency bands can be achieved; moreover, we can find the current is constrained around the element and low conductive coupling occurs. The antenna radiation characteristics are used to further improve the isolation between antenna elements. The strongest radiation of antenna element should avoid orientation towards other elements or at least not oriented to the nearest element. When the direction of the elements 1 and 2 (Fig. 3*a*) is rotated 90° anticlockwise, as shown in Fig. 3*b*, the isolation between elements 1 and 4 can be improved from <−14.2 to <−16.9 dB. However, because of the change of radiation direction and the distance between elements 1 and 2 is the smallest among the four elements, the isolation deteriorated from <−15.3 to <−11.8 dB. If rotation degrees are 180 and 270, not all antenna elements will maintain the wide bandwidth. Therefore, we use the arrangement as shown in Fig. 3*a* in this Letter. The size of the box is $10 \times 10 \times 5$ mm^3. The system is built on the front of a double-sided 1 mm-thick FR4 substrate with dimensions 136×68.8 mm^2 which models a realistic mobile handset size. On the back of the substrate, there is a whole piece of copper layer with four 10×10 mm^2 cut on the four corners functioning as the ground. The relative permittivity of the substrate is 4.4 and the loss tangent is 0.02.

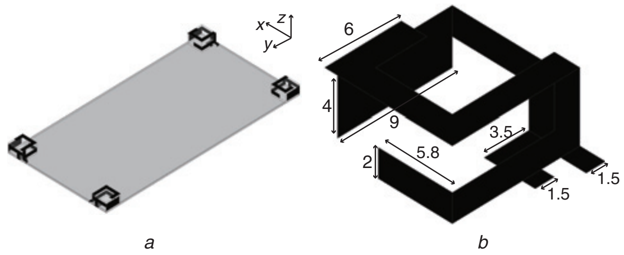

Fig. 1 *Geometry of four-element MIMO antenna*

a Overall view
b Detailed dimensions

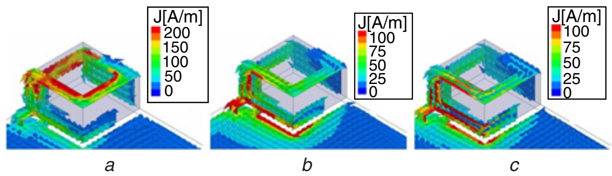

Fig. 2 *Surface current path on antenna element at three different working frequencies*

a 1.9 GHz
b 2.35 GHz
c 2.58 GHz

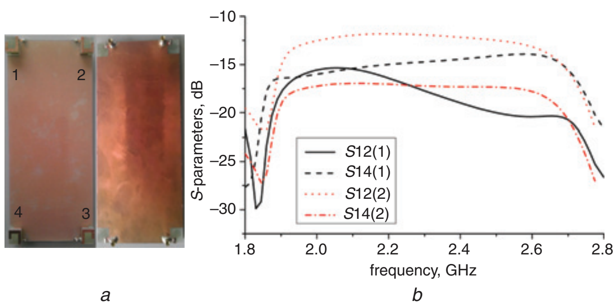

Fig. 3 *Photograph of fabricated antenna, and comparison of isolation between elements 1–2 and elements 1–4 when direction changes 90°*

a Fabricated antenna
b Comparison of isolation

The proposed antenna system was fabricated and measured, as shown in Fig. 4*a*; good agreement is realised, and for the sake of clarity, we only put the results of one antenna here. The measured isolation between antennas is lower than −14.2 dB at the whole operating band (Fig. 4*b*). The simulated results are obtained by ANSOFT high-frequency structure simulator ver.15, whereas the measured results are achieved using an Agilent 85058E vector network analyser.

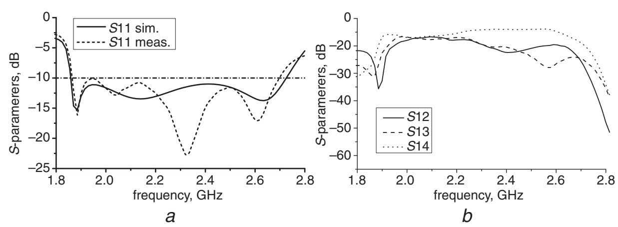

Fig. 4 *Reflection coefficients of MIMO antenna system, and measured isolation between MIMO antenna elements*

a Reflection coefficients
b Measured isolation

The correlation coefficient can be calculated using the equation mentioned in [6]. As plotted in Fig. 5, the value is far smaller than 0.3 which has been set as an acceptable value for 4G wireless systems. The measured peak gains against frequency are also presented in Fig. 5. The gain varies from 1.24 to 4.1 dBi.

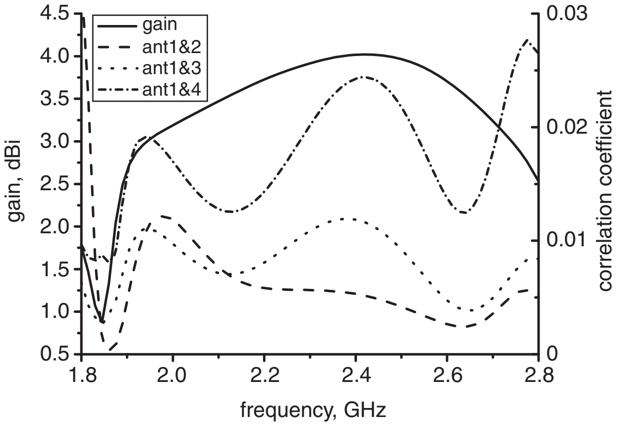

Fig. 5 *Correlation coefficient |ρ| and gain curves for proposed MIMO antenna system*

Fig. 6 shows the radiation pattern of the MIMO antenna system at three frequencies of 1.9, 2.35 and 2.58 GHz. The radiation patterns are similar to each other at these three measuring frequency points.

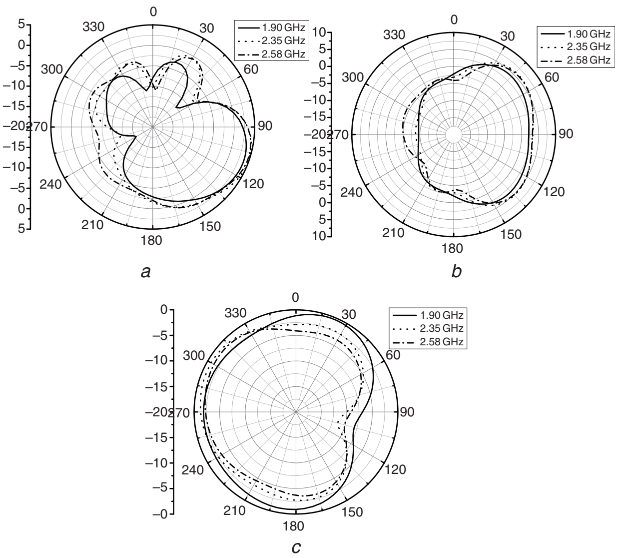

Fig. 6 *Radiation patterns of proposed antenna*

a xy-plane
b yz-plane
c xz-plane

Conclusion: In this Letter, a novel compact four-element MIMO antenna system is proposed. Using the box-folded PIFA as the antenna element and arranging the radiation directions between the antenna elements, high isolation through a wide operating band is realised. The results of *S*-parameters, correlation coefficients, gain and radiation pattern are presented. The proposed antenna system is a potential candidate for mobile handsets for LTE, GSM and UMTS applications.

Acknowledgments: This work was supported by the Priority Academic Program Development of Jiangsu Higher Education Institutions.

23 October 2014
doi: 10.1049/el.2014.3757
One or more of the Figures in this Letter are available in colour online.

Lingsheng Yang and Tao Li (*Jiangsu Key Laboratory of Meteorological Observation and Information Processing, Nanjing University of Information Science and Technology, Nanjing 210044, People's Republic of China*)

✉ E-mail: ylsinchina@163.com

References

1 Song, L., and Shen, J.: 'Evolved cellular network planning and optimization for UMTS and LTE' (CRC Press, London, 2011)
2 Sharawi, M.S.: 'Printed multi-band MIMO antenna systems and their performance metrics', *IEEE Antennas Propag. Mag.*, 2013, **55**, (5), pp. 219–232
3 Toktas, A., and Akdagli, A.: 'Wideband MIMO antenna with enhanced isolation for LTE, WiMAX and WLAN mobile handsets', *Electron. Lett.*, 2014, **50**, (10), pp. 723–724
4 Sultan, S., Imran, S., Nosherwan, S., Xiaodong, C., and Parini, C.G.: 'Design and performance study of a dual-element multiband printed monopole antenna array for MIMO terminals', *IEEE Antennas Wirel. Propag. Lett.*, 2014, **13**, pp. 329–332
5 Geyi, W., Rao, Q., Ali, S., and Wang, D.: 'Handset antenna design: practice and theory', *Prog. Electromagn. Res.*, 2010, **80**, pp. 123–160
6 Blanch, S., Romeu, J., and Corbella, I.: 'Exact representation of antenna system diversity performance from input parameter description', *Electron. Lett.*, 2003, **39**, (9), pp. 705–707