Dual-port planar MIMO antenna with ultra-high isolation and orthogonal radiation patterns

Han Wang, Zhijun Zhang and Zhenghe Feng

A dual-port planar MIMO antenna designed for 2.4 GHz WLAN applications is presented. It consist of two X-shaped arms etched on a square-shaped substrate, which forms a self-decoupled structure that can generate two orthogonal modes with ultra-high isolation. In measurement, the −10 dB bandwidth covers from 2.39 to 2.51 GHz, and better than 43 dB isolation is achieved between the two ports. Meanwhile, the patterns are orthogonal, and the envelope correlation coefficient is only 0.0052. The antenna it is fabricated on FR-4 substrate, and the size is only 33 × 33 × 3.2 mm, which is very much suited to space-limited MIMO applications that require ultra-high isolation, good pattern diversity and low fabrication cost.

Introduction: Multiple-input and multiple-output (MIMO), as a wireless technology that can provide significant performance improvement over the traditional single-input and single-output system, has attracted growing interest since being introduced in the 1990s. It utilises multiple antennas at both the transmitting ends and receiving ends to separate independent wireless channels in a rich multipath environment, and uses them to transmit multiple data streams simultaneously to yield a linear increase in channel capacity. Thus, low correlation between these channels is the prerequisite to achieving the desired performance, and high isolation between radiation elements is demanded for MIMO antenna designs.

In the existing literature, many techniques have been proposed to improve the isolation in MIMO antenna designs, which include the modified ground structure [1], meta-material [2], the neutralisation line [3] and parasitic elements [4]. However, these methods need additional space for the added structures and their decoupling effects are limited. Moreover, some of these added structures are also resonant at the working frequency, which will cause some loss of efficiency. Thus, decoupling methods that utilise high isolation between different modes [5, 6] or elements' orientation [7] have received increasing attention. However, these designs have disadvantages in that their matching and radiation characteristics are different between ports. In addition, some of these methods [6] need a three-dimensional structure, which is not easy to fabricate in real applications.

In this Letter, a planar dual-port MIMO antenna is proposed and fabricated, which is designed for 2.4 GHz WLAN applications. Different from traditional decoupling techniques, this proposed MIMO antenna has a self-decoupled structure, which can generate two orthogonal modes with ultra-high isolation (above 50 dB in simulation). Moreover, the geometry of this proposed antenna is rotationally symmetric. Thus, an identical matching characteristic and orthogonal radiation patterns with ultra-low correlation are achieved in its two ports. Moreover, its structure is planar and is fabricated on the low cost FR-4 substrate, and the size is only $0.26\,\lambda \times 0.26\,\lambda \times 0.02\,\lambda$. Consequently, it is very much suited to size- and cost-limited MIMO applications that require superior characteristics including high isolation and good pattern diversity.

Antenna design: The geometry of the proposed antenna is shown in Fig. 1. It is fabricated on a square-shaped FR-4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.02$), the size being 33 (0.26λ) × 33 (0.26λ) × 3.2 mm (0.02λ). On the top and bottom layer of the substrate, two X-shaped arms are placed along the diagonal directions, and are connected together with shorting vias at the corners of the substrate. The feeding ports are located at the centre of the X-shaped arms, and are orthogonally oriented to form a rotationally symmetric structure.

When resonating, the current distribution of the proposed antenna is as shown in Fig. 2. This Figure is obtained when feeding port 1, and the arrow in grey colour shows the direction of the current on the X-shaped arms. On the top layer of the substrate, the current flows across the feeding port (port 1), and changes direction at the shorting vias. This generates the current nulls at those positions, and the current on the bottom layer flows in the same direction as the one on the top. Since the two feeding ports are orthogonally oriented, the current on the bottom just bypasses port 2 rather than flowing across it. Consequently, it is self-decoupled, and high isolation (more than 50 dB in simulation) is achieved between ports 1 and 2. Moreover, considering that the direction of current is the same on both layers (Y-axis when feeding port 1), a doughnut-type pattern is generated (see Fig. 5). Owing to its rotationally symmetric geometry, similar phenomenon can be observed when feeding port 2. In this condition, the direction of the current is along the X-axis on both layers, which will generate a doughnut-type pattern orthogonal to the one when feeding port 1.

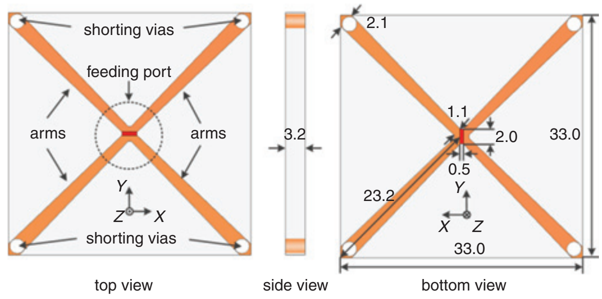

Fig. 1 *Geometry and dimensions (in millimetres) of proposed MIMO antenna*

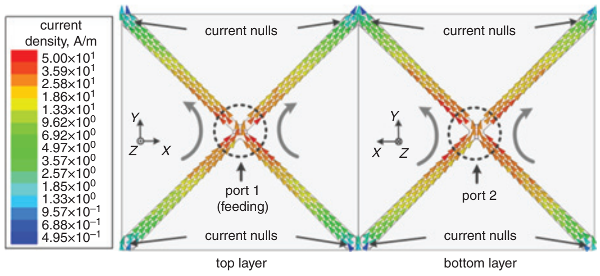

Fig. 2 *Current distribution when feeding port 1*

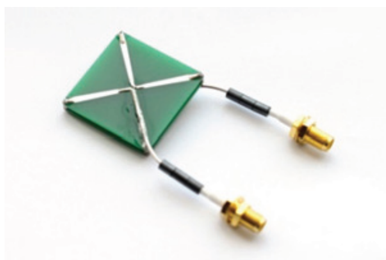

Fig. 3 *Photograh of fabricated prototype*

Prototype and measurement: To verify the performance of the proposed MIMO antenna, a prototype was built and fabricated, the photograph is shown in Fig. 3. Two semi-rigid coaxial cables were connected to perform the measurements, and its S-parameters, radiation patterns, gain and efficiency are investigated in this Letter. Considering that the structure is rotationally symmetric, the results for port 1 are as follows.

The S-parameters were measured with an Agilent© vector network analyser E5071B. Fig. 4 shows the measurement results compared with the simulation ones. The −10 dB matching bandwidth ($S_{11} <$ −10 dB) covers from 2.35 to 2.51 GHz with more than 50 dB isolation ($S_{12} < -50$ dB) in simulation, and shifts around 45 MHz towards the higher frequency with more than 43 dB isolation ($S_{12} < -43$ dB) in measurement. The difference between the measured and simulated results in S_{11} could be caused by variation in the dielectric constant of the substrate, and the deterioration in isolation (S_{12}) may be due to the existence of the coaxial cables-based feeding structure.

The radiation patterns were measured in an ETS-Lindgren anechoic chamber AMS8500, and the normalised patterns at the central resonant frequency are plotted in Fig. 5. It can be observed that the measured results fit the simulation well, and orthogonal radiation patterns are achieved when feeding different ports. The simulated cross-polarisation component is not visible in these Figures due to its low level, and the measured cross-polarisation component is comparatively higher due to the existence of the feeding structure.

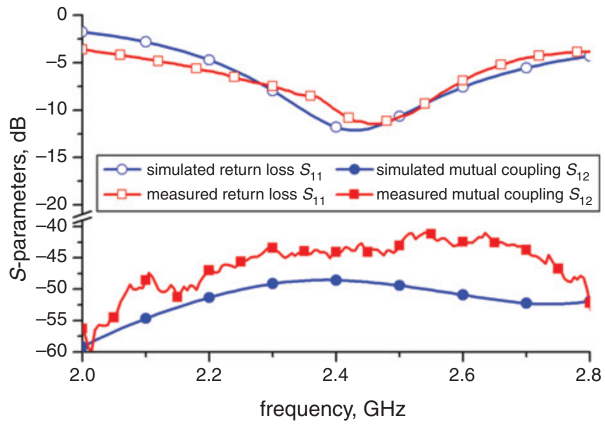

Fig. 4 *Measured and simulated S-parameters of proposed MIMO antenna*

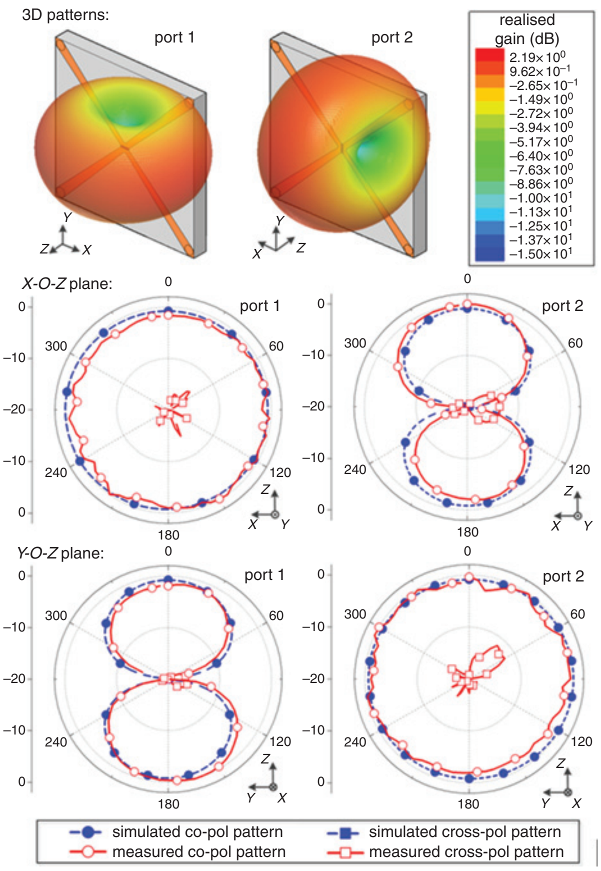

Fig. 5 *Measured and simulated radiation patterns of proposed MIMO antenna at 2.45 GHz*

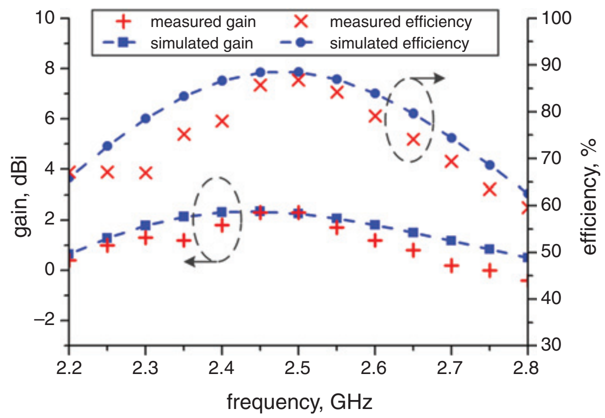

Fig. 6 *Measured and simulated gain and efficiency of proposed MIMO antenna*

The gain and efficiency were also measured in the AMS8500, and the results are shown in Fig. 6. Around 2.2 dBi gain is achieved, and the efficiency is above 75% at the working band.

MIMO performance: For MIMO antennas, the envelope correlation coefficient (ECC) between different ports is the most important parameter to evaluate MIMO performance. It is calculated with far-field results [8], and the lower ECC level means higher pattern diversity in general. Since the isolation between these two ports is high and their radiation patterns are orthogonal, the ECC level is close to zero in simulation. In measurement, the ECC level is 0.0052 at the central resonant frequency, which indicates that good pattern diversity is achieved with the proposed design.

Conclusion: In this Letter, a dual-port planar MIMO antenna designed for 2.4 GHz WLAN applications is proposed, whose bandwidth covers from 2.39 to 2.51 GHz with more than 43 dB isolation in measurement. Owing to its rotationally symmetric geometry, the resonant characteristics are nearly identical in its two ports, and their radiation patterns are orthogonal with a very low ECC level. Moreover, this antenna is fabricated on the FR-4 substrate, the size being only $0.26\lambda \times 0.26\lambda \times 0.02\lambda$. Consequently, it is ready to be implemented in a MIMO system with superior characteristics including compact size, ultra-high isolation, good pattern diversity and low fabrication cost.

Acknowledgment: This work was supported by the National Science and Technology Major Project of the Ministry of Science and Technology of China 2013ZX03003008-002.

21 August 2014
doi: 10.1049/el.2014.2998
One or more of the Figures in this Letter are available in colour online.

Han Wang, Zhijun Zhang and Zhenghe Feng (*State Key Laboratory of Microwave and Communications, Tsinghua National Laboratory for Information Science and Technology, Tsinghua University, Beijing 100084, People's Republic of China*)

E-mail: zjzh@mail.tsinghua.edu.cn

References

1 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
2 Ketzaki, D.A., and Yioultsis, T.V.: 'Metamaterial-based design of planar compact MIMO monopoles', *IEEE Trans. Antennas Propag.*, 2013, **61**, (5), pp. 2758–2766
3 Chen, S.C., Wang, Y.S., and Chung, S.J.: 'A decoupling technique for increasing the port isolation between two strongly coupled antennas', *IEEE Trans. Antennas Propag.*, 2008, **56**, (12), pp. 3650–3658
4 Minz, L., and Garg, R.: 'Reduction of mutual coupling between closely spaced PIFAs', *Electron. Lett.*, 2010, **46**, (6), pp. 392–394
5 Li, W.W., Zhang, B., Zhou, J.H., and You, B.Q.: 'High isolation dual-port MIMO antenna', *Electron. Lett.*, 2013, **49**, (15), pp. 919–921
6 Xiong, J., Zhao, M.Y., Li, H., Ying, Z.N., and Wang, B.Z.: 'Collocated electric and magnetic dipoles with extremely low correlation as a reference antenna for polarization diversity MIMO applications', *IEEE Antennas Wirel. Propag. Lett.*, 2012, **11**, pp. 423–426
7 Zhang, S., Zetterberg, P., and He, S.: 'Printed MIMO antenna system of four closely-spaced elements with large bandwidth and high isolation', *Electron. Lett.*, 2010, **46**, (15), pp. 1052–1053
8 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