# Wideband tri-port MIMO antenna with compact size and directional radiation pattern

Han Wang, Longsheng Liu, Zhijun Zhang and Zhenghe Feng

A wideband tri-port multiple-input-multiple-output (MIMO) antenna designed for worldwide interoperability for microwave access (WiMAX) and wireless local area network (WLAN) applications is presented. The proposed antenna is composed of three printed dipoles with an integrated balun, the size of which is only $0.08\lambda^2$. By introducing ground stubs between adjacent elements, impedance matching is improved and mutual coupling is reduced. A bandwidth of 51.6% (2.30–3.90 GHz) with $S_{11} < -10$ dB and $S_{12}$, $S_{13} < -10$ dB is achieved, which can cover the whole three WiMAX bands and the 2.4 GHz WLAN band. Moreover, directional radiation patterns are achieved in these bands, and the average gain reaches 3.5 dB with up to 21.4 dB front-to-back ratio. The envelope correlation coefficient is below 0.038, which can provide good pattern diversity for a MIMO system.

*Introduction:* Multiple-input-multiple-output (MIMO), as a wireless technology that can increase the channel capacity effectively, has become an essential technique in most wireless standards such as wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) [1]. Since the channel capacity is directly related to the number of spatial streams, the 3T × 3R up to 8T × 8R MIMO system has gradually been deployed to achieve higher bit rates than a classic 2T × 2R one. This presents new challenges for MIMO antenna designs since the bandwidth and the mutual coupling deteriorate when integrating more elements in one antenna. It is particularly serious for the antenna designs in portable devices at the receiving end, since the elements are closely spaced and the size is limited.

In the existing literature, most MIMO antenna designs for multi-elements ($N > 2$) MIMO systems are of narrowband [2, 3], which is not suitable for WiMAX/WLAN application, which requires wideband coverage from 2.30 to 3.80 GHz. For wideband designs [4, 5], the size is comparatively large, which does not suit the portable devices at the receiving end.

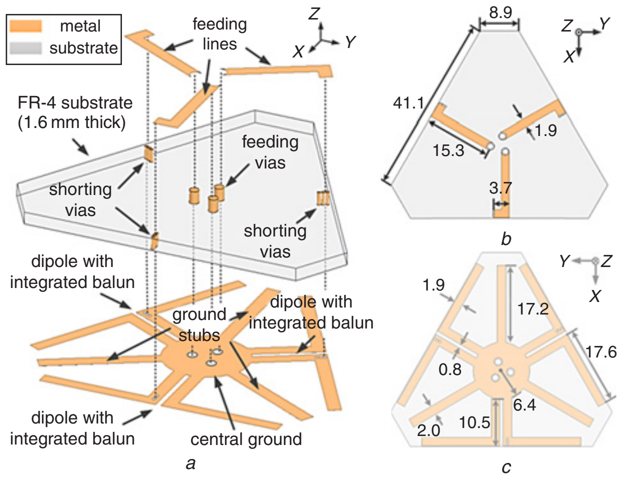


**Fig. 1** *Geometry and dimensions (in millimetres) of proposed antenna*
*a* Structure view
*b* Top view
*c* Bottom view

In this Letter, a wideband tri-port MIMO antenna designed for WiMAX and WLAN applications is proposed, whose bandwidth covers the whole three WiMAX bands (2.30–2.36, 2.50–2.90 and 3.30–3.80 GHz) and the 2.4 GHz WLAN band (2.40–2.48 GHz). Printed dipoles with an integrated balun are adopted as the radiation elements, and the size of this tri-port antenna is only $0.08\lambda^2$. To reduce the mutual coupling between these closely spaced elements, ground stubs are introduced and the coupling level is below –10 dB in the operating bands. Meanwhile, these stubs improve the impedance matching at lower frequency, with which the bandwidth reaches 51.6% (2.30–3.90 GHz). Moreover, directional radiation patterns with a low envelope correlation coefficient (ECC) are achieved, which provide good pattern diversity for a MIMO system. This design is very much suited to wideband 3T × 3R MIMO systems, especially for those that have limited space for the antenna system.

*Antenna design:* The geometry of the proposed MIMO antenna is shown in Fig. 1. It is fabricated on a triangle-shaped FR-4-based printed circuit board with truncated corners, whose dimensions are shown in Figs. 1*b* and *c*. On the bottom side of the substrate, three printed dipoles are placed rotationally symmetrically around a round-shaped central ground with an interval of 120°, and are fed with the feeding lines located on the top side of the substrate. Since both arms of these dipole elements are connected to the central ground with a $\lambda/4$ length strip conductor, an integrated balun is formed, with which the current on the arms is balanced. Meanwhile, the length of the feeding line is also close to $\lambda/4$, thus it acts like an impedance transformer, and a broadband matching is achieved by tuning the width and length of this feeding line.

Since the space between elements is quite small, three ground stubs are introduced between the adjacent elements to reduce strong coupling. Meanwhile, these three stubs extend the size of the ground, thus improving the impedance matching at lower frequencies. As a result, the −10 dB matching band covers from 2.30 to 3.90 GHz, and the mutual coupling is below − 10 dB throughout this band. Moreover, these metal stubs also act like reflectors, and three-directional radiation patterns are achieved with 120° intervals in the azimuth (*X*–*O*–*Y*) plane. They are characterised with 3.5 dB average gain and up to 21.4 dB front-to-back ratio, which can provide very good pattern diversity for a multi-elements MIMO system.

**Fig. 2** *Fabricated prototype*

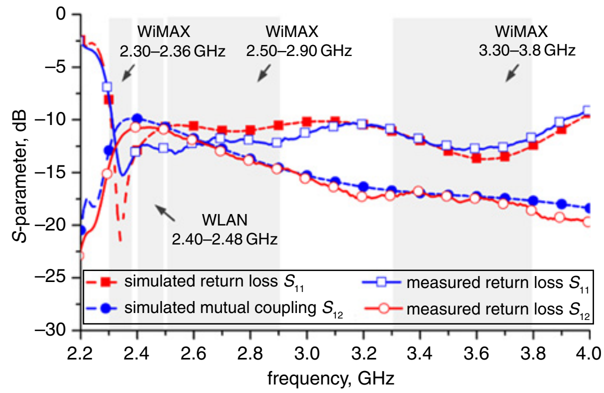


**Fig. 3** *Measured and simulated S-parameters*

*Prototype and measured results:* To verify the performance of the proposed antenna, a prototype was built and measured. Fig. 2 shows its photo image, in which three semi-rigid coaxial cables are connected to perform the measurements. Considering that the radiation elements are rotationally symmetrical and the measured results are similar for all three ports, the results of port 1 are provided as follows.

The *S*-parameters of the prototype were measured with an Agilent© vector network analyser E5071B and the results are shown in Fig. 3. It can be observed that good impedance matching and high isolation are achieved in both the measured and simulation results. The return loss ($S_{11}$) and mutual coupling level ($S_{12}$) are below –10 dB from 2.30 to 3.90 GHz, which covers the whole three WiMAX bands and the 2.4 GHz WLAN band.

The radiation patterns were measured in the ETS anechoic chamber AMS8500, and the normalised patterns for 2.35, 2.45, 2.70 and

3.55 GHz are provided in Fig. 4. These results reflect the radiation characteristics of the proposed MIMO antenna in the central frequency of the three WiMAX bands and the 2.4 GHz WLAN band, and the measured results match the simulation ones well. Directional radiation patterns can be observed at all frequencies, and a more than 10.1 dB front-to-back ratio is achieved throughout the band.

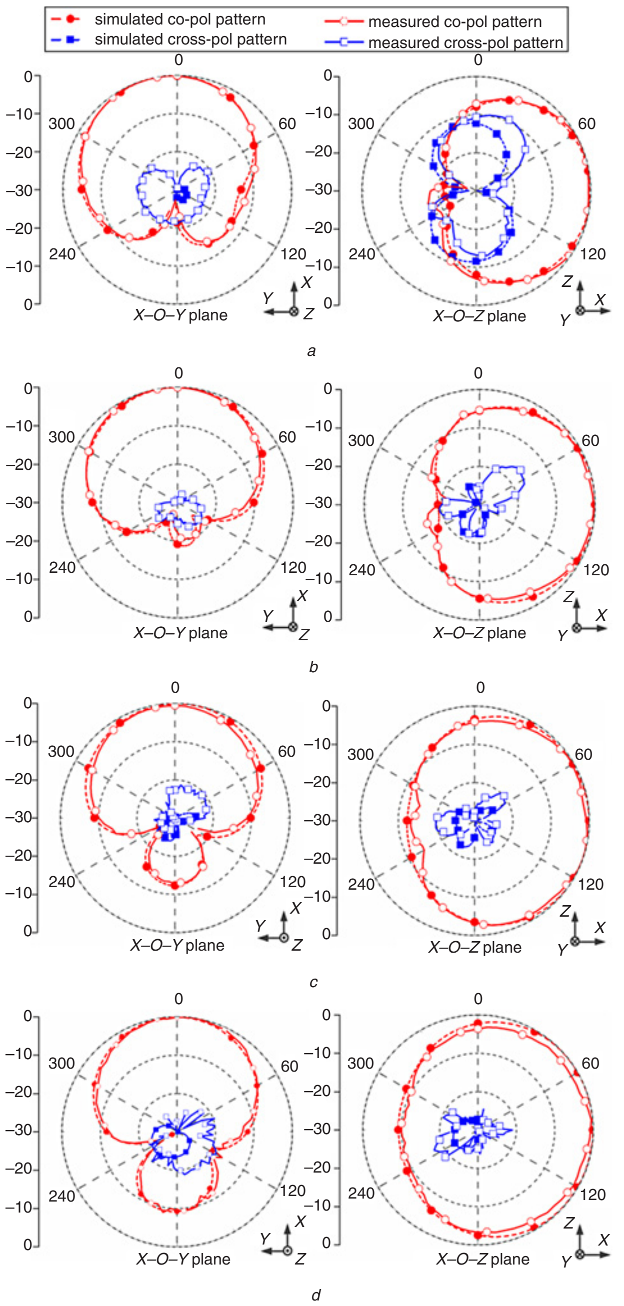


**Fig. 4** *Measured and simulated radiation patterns at different frequencies*

*a* 2.35 GHz
*b* 2.45 GHz
*c* 2.70 GHz
*d* 3.55 GHz

The gain was also measured in the ETS anechoic chamber, and the results are provided in Fig. 5. It can be observed that the gain is very stable throughout the band, and the measured result is in good agreement with the simulation one. The peak gain reaches 3.9 dB in the measurement and the average gain is 3.5 dB.

*MIMO performance:* To evaluate the MIMO performance of the proposed antenna, the ECC was calculated [6] and is shown in Fig. 5. This value reflects the pattern diversity characteristics of a MIMO antenna, and a lower ECC level means higher diversity in general. Since the radiation patterns of the proposed antenna are directional and are spaced at intervals of 120° between adjacent ports, the ECC level is well controlled, as expected. It is below 0.038 throughout the band, which means good pattern diversity is achieved with the proposed antenna.

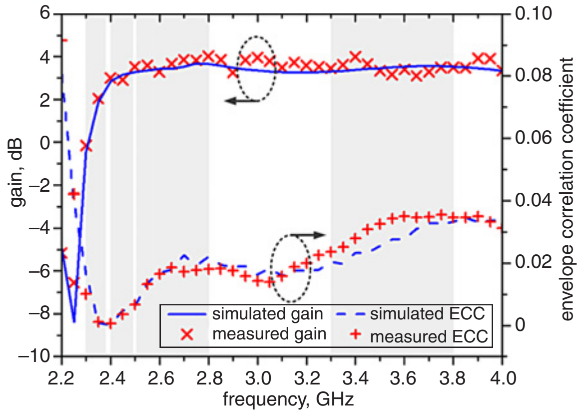


**Fig. 5** *Measured and simulated gain and ECC*

*Conclusion:* In this Letter, a wideband tri-port MIMO antenna is proposed and fabricated, which is designed for WiMAX and WLAN applications. The size of this antenna is only $0.08\lambda^2$, which can be easily integrated into portable devices at receiving ends. Dipoles with an integrated balun are adopted as radiation elements, and three ground stubs are introduced to lower the mutual coupling. Meanwhile, these stubs extend the ground size, thus improving the impedance matching at lower frequencies. The simulated and measured results verify that the bandwidth of the proposed antenna reaches 51.6% (2.30–3.90 GHz) and the mutual coupling level is below −10 dB, which is capable of covering the whole three WiMAX bands and the 2.4 GHz WLAN band. Moreover, directional radiation patterns with an up to 21.4 dB front-to-back ratio and 3.5 dB average gain are achieved, and the ECC level is 0.038 at maximum. Consequently, this design is suited to be implemented in a 3T × 3R MIMO system with superior characteristics such as compact size, wideband, low mutual coupling and good pattern diversity.

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**References**

1 Li, Q.H., Lin, X.T., Zhang, J.Z., and Roh, W.: 'Advancement of MIMO technology in WiMAX: from IEEE 802.16d/e/j to 802.16 m', *IEEE Commun. Mag.*, 2009, **47**, (6), pp. 100–107
2 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
3 Luo, Y., Chu, Q.X., Li, J.F., and Wu, Y.T.: 'Planar H-shaped directive antenna and its application in compact MIMO antenna', *IEEE Trans. Antennas Propag.*, 2013, **61**, (9), pp. 4810–4814
4 Costa, J.R., Lima, E.B., Medeiros, C.R., and Fernandes, C.A.: 'Evaluation of a new wideband slot array for MIMO performance enhancement in indoor WLANs', *IEEE Trans. Antennas Propag.*, 2011, **59**, (4), pp. 1200–1206
5 Nguyen, K.K., Huynh, N.B.P., Quang, N.H., and Chien, D.N.: 'A compact printed 4 × 4 MIMO-UWB antenna with WLAN band rejection'. IEEE Antennas and Propagation Society Int. Symp., Orlando, FL, USA, July 2013, pp. 2245–2246
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