Dual-polarised monopole-slot co-located MIMO antenna for small-volume terminals

Y. Li, Z. Zhang, J. Zheng and Z. Feng

A dual-polarised monopole-slot co-located MIMO antenna is proposed for 2.4 GHz wireless local area network (WLAN) applications. The antenna consists of a monopole with its ground folded and a compact coplanar waveguide feed, providing the vertical and horizontal polarisations. The antenna is designed for a volume-limiting MIMO system due to its compact dimensions of $50 \times 16 \times 16$ mm^3 ($0.4\lambda_0 \times 0.128\lambda_0 \times 0.128\lambda_0$) and high isolation better than -24 dB. The performance of the proposed antenna has also been measured, including the S-parameters, the radiation patterns and the gain, which agree well with the simulation results.

Introduction: For modern wireless communication technology, the multi-input multi-output (MIMO) system is a promising solution to provide high channel capacity. Multiple antennas are utilised at both sides of the transmitter and receiver to provide multi-channel transmission. However, at least half of the wavelength must be required for isolation between two adjacent elements, making the overall system very large. In a volume-limiting system, it is difficult to mount such a spatially extended antenna array.

To save space between two elements, the dual-polarised antenna has been widely studied and adopted in the MIMO system. The dual-polarised antenna with high isolation is able to take the place of two antennas with single polarisation. The feasibility of dual-polarised antennas in the MIMO system has been validated for indoor and outdoor scenarios [1–3]. In recent papers [3–8], different patterns of dual-polarised antennas have been proposed, such as the patch [4, 5], slot [6, 7] and loop [8]. As discussed in [3], the dimensions and isolation are two key issues of dual-polarised MIMO systems. Low mutual coupling between modes can be achieved by adopting a high-isolated feeding structure as in [4–8]. However, the overall dimensions are dictated by the pattern of the radiating element. The required resonating length of the patch [4, 5] or slot [6, 7] is half of the wavelength for each polarisation. The dimensions can be decreased by using a loop antenna [8], the circumference of which is a wavelength. However, the mutual coupling increases with reducing volume. It is a challenge to reduce the antenna dimensions while maintaining port isolation.

In this Letter, a 3D design of a dual-polarised MIMO antenna system is proposed to achieve even smaller dimensions. Dual polarisations are provided by a monopole-slot co-located antenna at the operating frequency of 2.4 GHz for WLAN applications. The proposed antenna consists of a ground-folded monopole with a compact CPW feed with the overall dimensions of $50 \times 16 \times 16$ mm^3 ($0.4\lambda_0 \times 0.128\lambda_0 \times 0.128\lambda_0$, λ_0 is the wavelength in free space). The vertical polarisation is provided by the monopole and the horizontal polarisation is provided by the slot of the CPW, with the port isolation lower than -24 dB. The reflection coefficient, radiation patterns and gain are also measured. Because of the compact volume, the proposed antenna is suitable for volume-limited portable access points, where the antennas of [3–8] are unable to mount.

Antenna design and configuration: The geometry of the proposed antenna is shown in Fig. 1. As shown in Fig. 1*a*, the antenna is made of FR4 substrate ($\varepsilon_r = 4.4$, $\tan\delta = 0.01$), with thickness of 1 mm. A monopole and the CPW feed are printed on the front side. The CPW is connected to a 50 Ω microstrip line on the back side through a via, as shown in Fig. 1*c*. A shorting bridge is soldered on the front side. Another 50 Ω microstrip line on the back side positions across the CPW. By folding the ground along the folded trace, a centre-hollow cuboid antenna was built and is illustrated in the 3D view of Fig. 1*b*. As a result, the ground and the monopole are on the outer side and the microstrip lines are in the inner side. The overall dimensions are $50 \times 16 \times 16$ mm^3, much more compact than the dimensions in the reference papers. When fed through port 1, the antenna operates at the vertical polarisation mode. The CPW feed structure is also designed to 50 Ω by tuning the parameters of W_3 and S. When the antenna is fed through port 2, the energy is coupled from the microstrip line to feed the slot of the CPW. Horizontal polarisation is excited in the slot. By tuning the position of the shorting bridge L_6 and the parameters of W_2, L_3 and L_4, good impedance matching is achieved. The lengths of the monopole and the CPW are approximately a quarter of a wavelength on the substrate. The key parameters are optimised by using the Ansoft High Frequency Structure Simulator (HFSS) software. The detailed optimised values of each parameter are listed in Table 1.

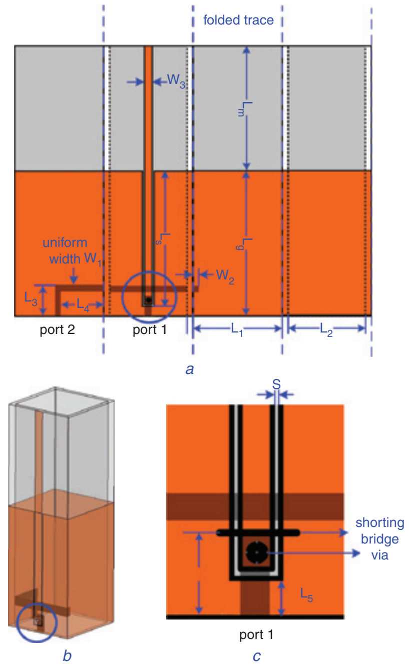

Fig. 1 *Geometry of proposed antenna*

a Planar view
b 3D view
c Detailed view of shorting bridge

Table 1: Detailed dimensions of proposed antenna

Parameter	L_1	L_2	L_3	L_4	L_5	L_6	L_s
Value (mm)	16	14	6.5	6.05	1.5	3	25.5
Parameter	L_m	L_g	S	W_1	W_2	W_3	
Value (mm)	23	27	0.2	1.9	1	1.9	

The isolation between the vertical mode and the horizontal mode is the key issue in the dual-polarised antenna design. The currents on both sides of the slot are in the same direction for the vertical mode and in the opposite direction for the horizontal mode. The amplitudes of the current on the slot sides are almost the same. Therefore, good orthogonality can be achieved between the two modes.

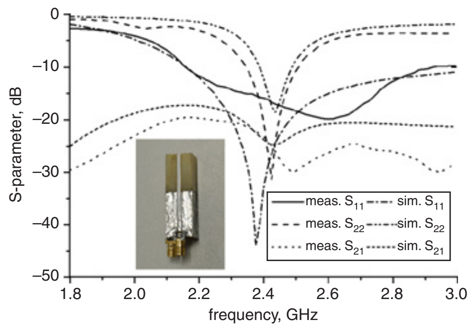

Fig. 2 *Simulated and measured S-parameters of proposed antenna*

Experimental results: A prototype of the proposed dual-polarised antenna was built and measured. The simulated and measured S-parameters, including the reflection coefficient and isolation, are shown in Fig. 2. The measured −10 dB impedance bandwidths are 2.16–2.92 GHz and 2.35–2.51 GHz for vertical and horizontal modes, respectively, both covering the desired WLAN band of 2.4–2.48 GHz. In this band, the port isolation is better than −24 dB.

The measured radiation patterns at 2.44 GHz for both polarisations are shown in Fig. 3, compared with the simulated results. For the vertical polarisation, a nearly omnidirectional pattern is shown in the azimuth plane. Owing to asymmetrical structure of the monopole and the ground, a tilt pattern is shown in the elevated plane. For the horizontal polarisation, the electric field propagates along the folded ground to the back side, and a nearly bidirectional pattern is shown in the azimuth plane. The measured gains are better than 2.2 and 0.8 dBi for the vertical and horizontal polarisations separately. The efficiency of the horizontal mode is a bit lower owing to the cavity effect of the folded ground.

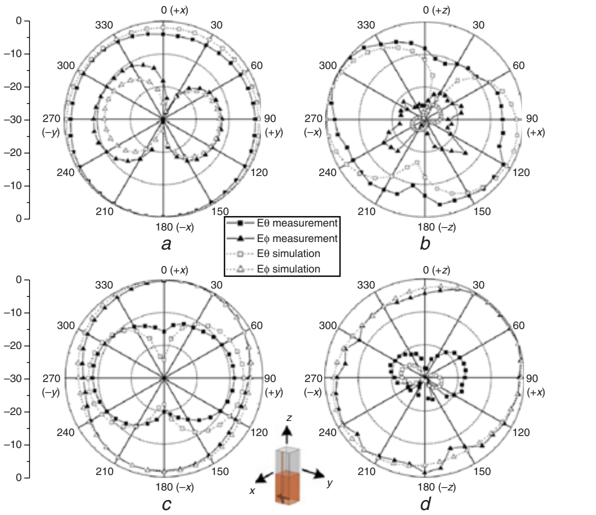

Fig. 3 *Simulated and measured radiation patterns of proposed antenna at 2.44 GHz*

a x-y plane fed through port 1
b x-z plane fed through port 1
c x-y plane fed through port 2
d x-z plane fed through port 2

Conclusion: A dual-polarised monopole-slot co-located MIMO antenna is proposed for volume-limited portable terminals. The vertical polarisation is radiated by the monopole with a folded ground fed by a CPW. The horizontal polarisation is radiated by the slot of the CPW. The overall dimensions of the proposed antenna are $50 \times 16 \times 16\ \text{mm}^3$, much more compact than the reference design. The isolation is lower than −24 dB in the 2.4 GHz WLAN band. Because of the advantages of compact dimensions and good isolation, the proposed MIMO antenna has potential application for volume-limited portable systems.

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One or more of the Figures in this Letter are available in colour online.

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