Compact planar MIMO antenna array with polarisation diversity on single layer

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A novel compact and planar MIMO antenna array with polarisation diversity is proposed on a single layer. The proposed array is composed of two orthogonal polarised elements which act as electric and magnetic loop antennas. A high isolation of 20 dB between the two antennas is achieved at 2.3 GHz. The overall size of the array is 38 × 28 mm (i.e. 0.291 × 0.214 λ_0). The calculated envelope correlation coefficient is 0.00035.

Introduction: In multiple-input-multiple-output (MIMO) communication systems, a promising technology, it is important to increase channel capacity [1]. When compact MIMO antennas are realised with high isolation, the envelope correlation can be reduced. Many studies have sought to enhance channel capacity and reduce the mutual coupling between the antenna elements [2–4]. In [2], a resonant radiator built by the adjacent edges of two planar inverted-F antennas (PIFAs) suppresses the direct coupling, so that high isolation can be obtained. The distance between the two PIFAs is 3 mm (0.024 λ_0). Other compact MIMO antennas are presented in [3, 4] using polarisation diversity. A configuration consisting of three orthogonal dipoles decreases the mutual coupling and increases the channel capacity in [3]. However, it is difficult to use MIMO antennas in portable systems, since they do not have a planar structure. In [4], a compact MIMO antenna structure with a square ring provides high isolation of 25 dB and relatively low height of 3.164 mm compared with that in [3].

In this Letter, a novel compact MIMO antenna array is proposed by utilising the polarisation diversity to enhance capacity gain. The proposed array is composed of two orthogonal polarised elements which act as electric and magnetic loop antennas. The electric loop antenna is realised using a printed square loop wire, while the magnetic loop antenna is realised using the miniaturised zeroth-order resonant antenna proposed in [5]. The antennas consist of a planar single layer structure (i.e. thickness of 1.6 mm) and the magnetic loop antenna is placed inside the electric loop antenna. Although the antenna elements are closely aligned (i.e. the minimum distance between the two elements is 1 mm) on the same plane, both a high isolation of 20 dB and low envelop correlation of 0.00035 are achieved thanks to their orthogonal current distributions.

Antenna designs: The proposed MIMO antenna array consists of the electric and magnetic loop antennas. A one-wavelength square loop wire antenna is employed to design the electric loop antenna [6]. Each side of the square loop has length of a quarter-wavelength ($\lambda_0/4$) and its width is 0.0002 λ_0. A miniaturised zeroth-order resonant antenna which is very compact to be inside the electric loop antenna on a single layer is introduced as the magnetic loop antenna. Its design principle is studied in [5]. Fig. 1 explains the orthogonal current distributions of the two antenna elements. The electric current distributions (J_S) of the electric loop antenna are formed to be sinusoidal, so that a horizontal polarised electric field is produced. When the magnetic current distributions (M_S) of the magnetic loop antenna are constant around the patches of the magnetic loop antenna, the magnetic loop current can be effectively generated. The magnetic loop is of duality with an ideal electrical dipole, so that vertical polarisation is achieved. By properly combining the two orthogonal polarised antennas, compact MIMO antennas can be designed. Because the magnetic loop antenna can be greatly miniaturised using spiral slots on the ground plane, it is arranged inside the electric loop antenna. The geometry of the two closely aligned antennas is illustrated in Fig. 2. The overall dimensions of the magnetic loop antenna are determined by the ground plane area, which is $L_{GND} \times W_{GND}$ (34.57 × 15.3 mm). The electric loop antenna's overall size is $L_{Loop} \times W_{Loop}$ (38 × 28 mm), where the square loop is properly modified to produce a rectangular configuration due to the ground plane. To eliminate the coupling between the two radiators, the non-radiating edges of the electric loop antenna are placed far from the ground plane, while the distance between the radiating elements of the electric loop antenna and the ground plane is closely aligned. In addition, the size of the ground plane is controlled by taking into consideration the radiating performances of the magnetic loop antenna. Consequently, the total size of the proposed MIMO antenna array is reduced by adjusting the size of the ground plane. Moreover, the excitation positions are determined by considering the antenna isolation as well as the radiation efficiency.

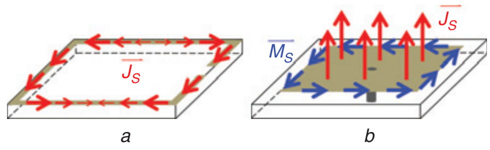

Fig. 1 *Surface current vectors of each element*

a Electric loop antenna
b Magnetic loop antenna
→ J_S, → M_S

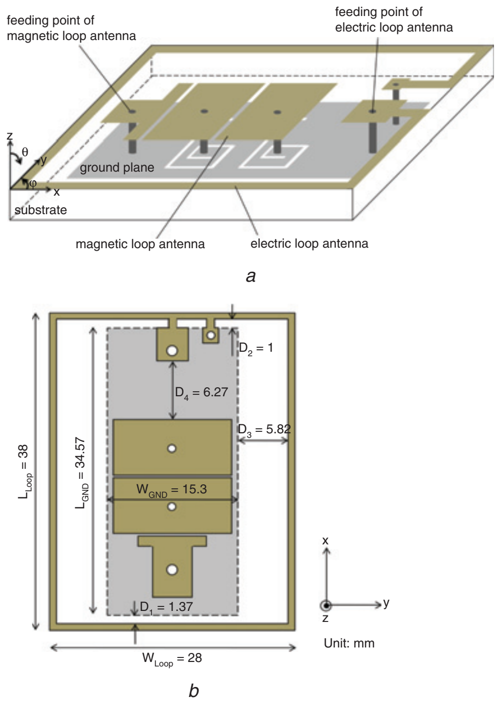

Fig. 2 *Geometry of proposed MIMO antennas*

a 3D view
b Perspective view
signal conductor, ground conductor

Fig. 3 *Photograph of proposed MIMO antennas (top and bottom view)*

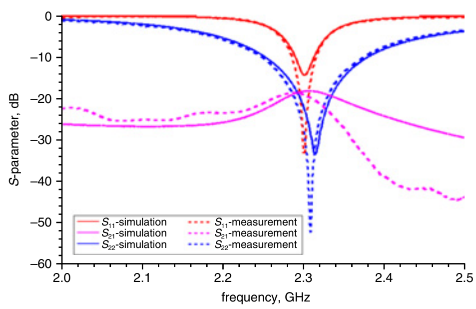

Fig. 4 *Simulated and measured S-parameters (port 1: magnetic loop antenna, port 2: electric loop antenna)*

Numerical and experimental results: The proposed MIMO antennas' performances were investigated by means of the commercial simulator Ansoft HFSS (High Frequency Structural Simulator). Fig. 3 shows a picture of the fabricated prototype. The minimum distance D_2 between the proposed MIMO antenna elements is only 1 mm (i.e. 0.0076 λ_0 at 2.3 GHz). Fig. 4 illustrates that the measured return losses of the magnetic and electric loop antennas are 51 and 33 dB, respectively, at 2.3 GHz.

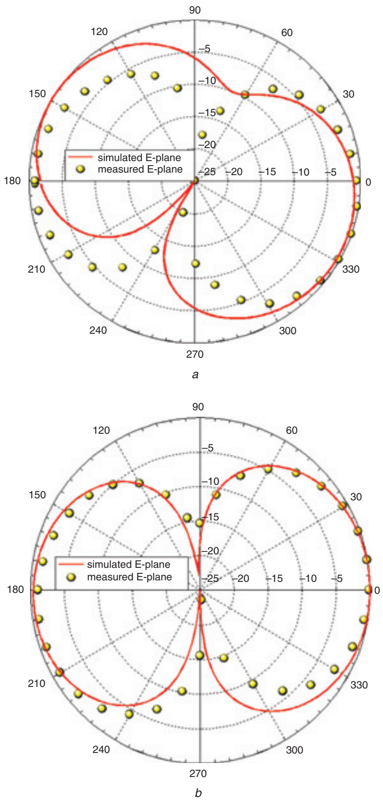

Fig. 5 *Simulated and measured radiation patterns*

a Magnetic loop antenna (*x-z* plane)
b Electric loop antenna (*x-y* plane)

By using the polarisation diversity, a high isolation of 20 dB is experimentally obtained at 2.3 GHz. The envelope correlation coefficient [7] is given by

$$\rho_e = \frac{|S_{11}^* S_{21} + S_{12}^* S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)}$$

At 2.3 GHz, the envelope correlation coefficient is calculated to be 0.00053 from the measured S-parameters. Since this value is very small, it is verified that the proposed antennas are appropriate for MIMO communication applications.

Fig. 5 compares measured radiation patterns with simulated results in the E-plane. The *x-z* plane represents the E-plane of the magnetic loop antenna while the *x-y* plane corresponds to the E-plane of the electric loop antenna. The measured peak gains of the electric and magnetic loop antennas are about 1.36 and 0.48 dBi, respectively, at 2.3 GHz.

Conclusion: A novel compact MIMO antenna array with polarisation diversity is proposed. Its structure is composed of electric and magnetic loop antennas. By placing the greatly miniaturised magnetic loop antenna inside the electric loop antenna, two orthogonal polarised antennas are realised on a single layer. Its overall dimensions are 38 × 28 × 1.6 mm (i.e. 0.291 × 0.214 × 0.012 λ_0). The mechanism is explained by the orthogonal current sources of the two elements. Based on experimental results and calculations, a high isolation of 20 dB and low envelope correlation of 0.00053 are obtained.

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

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