Wideband unidirectional circularly polarised slot array with integrated feeding network

Xiaolei Jiang, Zhijun Zhang, Yue Li and Zhenghe Feng

A wideband planar unidirectional circularly polarised slot array is proposed. The slot array has a truly planar structure where the feeding network is integrated with the radiating elements on the same substrate, which makes it low cost and easy to fabricate. The measured result shows that the proposed array obtains an impedance bandwidth of 33.8% and an axial ratio bandwidth of 24.5%. The proposed array has a good unidirectional pattern and can be used in base station applications.

Introduction: Circularly polarised (CP) antennas are widely used due to the agile orientation angle between receivers and transmitters. CP antennas with a wideband axis ratio bandwidth have been desirable in recent years as they can be utilised for two or more communication systems. When used in base station applications, antennas with unidirectional patterns and sufficient gain are required. Different types of wideband CP antennas have been reported, such as those using stacked patches [1], L-probe patches [2], crossed dipoles [3] and dual-rhombic loops [4]. However, all these antennas need a separated printed circuit board (PCB) for their feeding network and some of them are not of a planar structure, which would increase the cost of production.

The slot antenna is a good candidate for a planar design and its inherent ground can be used to deploy a feeding network. However, most slot arrays are bidirectional [5, 6] and via holes are still needed for the coplanar waveguide-slot design [5]. A reflector can be used for a unidirectional pattern [7], but stacked structures are applied to improve the axial ratio (AR) and gain performance. In this Letter, we propose a wideband CP-slot array based on the designs in [8]. The feeding network and radiating elements are designed on a single substrate and no additional stacked structures are needed to obtain a wideband characteristic. A metal plate is used to generate the unidirectional pattern without degenerating the wideband characteristic.

Antenna design: The design of the slot array is shown in Fig. 1. It is constructed on a single substrate (FR4-epoxy) with a permittivity of 4.4 and a loss tangent of 0.02. The proposed array is composed of four (2 × 2) ring slots. All these slots are etched on the ground plane (bottom layer) and a sequentially rotated feeding network (top layer) is applied to excite the antenna. With such a structure, the whole array needs only one piece of PCB where the radiating elements and the feeding network are integrated together. A metal plate, with a distance h below the substrate, is used as a reflector to generate the unidirectional pattern. The distance h is about $0.25\lambda_0$, where λ_0 refers to the wavelength of the CP centre frequency.

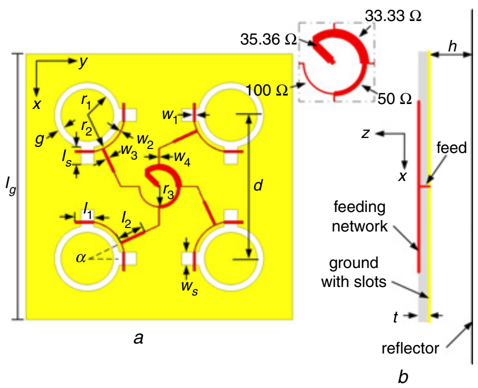

Fig. 1 *Geometry of proposed antenna*

Parameters are: $r_1 = 16$, $r_2 = 22.25$, $r_3 = 12$, $g = 4$, $w_1 = 1.5$, $w_2 = 0.44$, $w_3 = 1.64$, $w_4 = 0.44$, $l_s = 10$, $w_s = 8$, $l_1 = 11.5$, $l_2 = 16$, $d = 87.5$, $t = 1$, $h = 30$, $l_g = 162.5$, all in mm, $\alpha = 25°$
a Top view
b Side view

The ring-slot element antenna that has two perpendicular branch slots is derived from our previous work [8]. The two branch slots could couple two perpendicular electrical fields in the ring slot. When these two branches are excited by the T-junction with well-designed unequal arms, a phase difference of 90° can be introduced between two coupling electrical fields, thus leading to the CP radiation of the element antenna. Take the top right element for example, two coupling fields in the ring slot are along the –x- and y-directions. The phase of the –x-direction leads 90° so that a left-hand CP (LHCP) radiation is generated at the z-direction. The wideband characteristic, as described in [8], could be obtained by appropriately chosen l_s and w_s. To form a 2 × 2 array, four elements are arranged in a rotational symmetric structure and the spacing d between the two adjacent elements is about $0.7\lambda_0$. Since the current on the sequentially rotated feeding network flows clockwise, the array can also radiate in a LHCP pattern, corresponding to the element antenna.

Results: The high-frequency structure simulator (HFSS v.14) was first used to model the proposed and a prototype with the parameters listed in Fig. 1 was fabricated and measured. Fig. 2 shows the simulated and measured $S11$ of the proposed CP-slot array antenna. It can be seen that the simulated and measured bandwidths for $S11 \leq -10$ dB are about 35.5 and 33.8%, respectively. The simulated and measured AR and gain are shown in Fig. 3. Both the simulated and measured results have reasonable agreement. The measured AR bandwidth covers from 2.1 to 2.8 GHz (~24.5%) and the maximum gain of the proposed array is about 13 dB. Radiation patterns of the array at the centre frequency of 2.45 GHz are presented in Fig. 4. Unidirectional radiation with the LHCP pattern is clearly observed and the front-to-back (FB) ratio is higher than 20 dB.

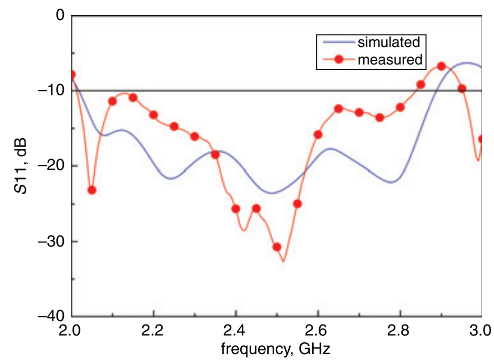

Fig. 2 *Simulated and measured S11 of proposed array*

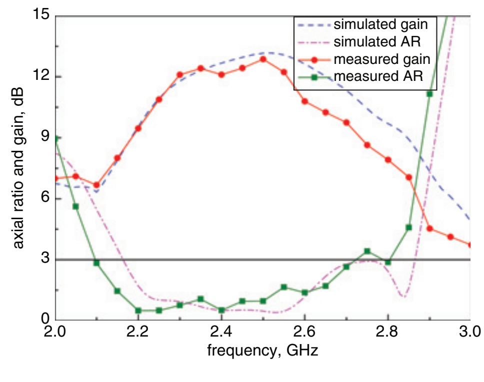

Fig. 3 *Simulated and measured AR and gain of proposed array*

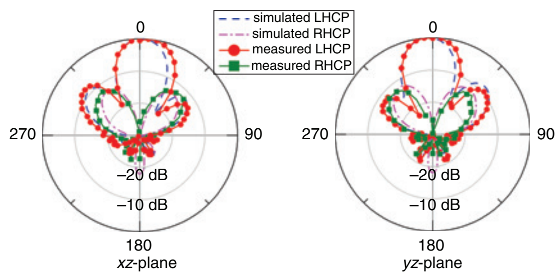

Fig. 4 *Simulated and measured radiation patterns at centre frequency of 2.45 GHz*

Conclusion: A 2 × 2 ring-slot CP array antenna is proposed in this Letter. From the measured results, the proposed array obtains an impedance bandwidth of 33.5% and an AR bandwidth of 24.5%. A peak gain of 13 dB and a FB ratio of more than 20 dB makes it suitable for base station applications. Moreover, the proposed array is printed on a single PCB so that it could have low production cost.

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

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