Circularly polarised array antenna with cascade feed network for broadband application in C-band

S. Karamzadeh, V. Rafii, M. Kartal, O.N. Ucan and Bal S. Virdee

A new configuration of a circularly polarised square slot antenna (CPSSA) array operating in C-band is presented. The array consists of 2 × 2 CPSSA elements and is fed by a novel feeding network consisting of the circuit stripline couplers and delay lines. The proposed feeding technique is applied to the 2 × 2 antenna array to increase the axial ratio (AR) bandwidth. The measured impedance bandwidth for a voltage standing wave ratio (VSWR) <2 is around 78.5% (3.4–7.8 GHz), the 3 dB AR bandwidth is about 35.7% (4.6–6.6 GHz) and the antenna has an average 14.2 dBic gain over the 3 dB AR bandwidth. The measured results corroborate well with the simulated results.

Introduction: In recent years, antenna arrays have been widely used in radar and microwave communications because of their high gain, good directivity and extensive coverage area. For the patch antennas, the CP waves are generated by exciting two or more orthogonal linearly polarised modes in equal amplitude, but in phase quadrature. There are different techniques that can excite two orthogonal modes for square slot antennas. Loading the square slot antenna by appropriate perturbation structures such as two inverted-L grounded strips around two opposite corners of the slot [1], a T-shaped grounded metallic strip that is perpendicular to the axial direction of the coplanar waveguide (CPW) feed line [2] and extending across the square slot, a slot line-loaded inductively coupled conducting strip [3] are some of these techniques. Moreover, various techniques have been investigated to improve the axial ratio (AR) and impedance performance of circularly polarised microstrip antennas [4–9]. In this Letter, the design of a circularly polarised square slot antenna array (CPSSAA) which has a feed network comprising a 180° ring hybrid coupler linked to two branch-line hybrid couplers for generating broadband circular polarisation performance is proposed. The presented array employs a pair of branch-line couplers to feed CPSSA elements, which improves the performance of the array considerably. Details of the proposed 2 × 2 sequentially rotated planar CPSSA array configuration are given, and simulation and experimental results are discussed in the following Sections.

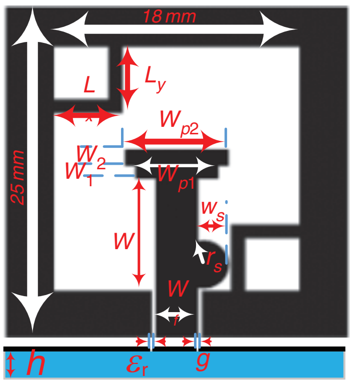

Fig. 1 *Geometry of proposed CPW-fed CPSSA*

$W_f = 3$, $W = 8.5$, $W_{p1} = 6$, $W_{p2} = 7.6$, $g = 0.3$, $W_1 = 1$, $W_2 = 1.2$, $L_x = L_y = 5$, $W_s = 2.5$, $r_s = 2$ (all parameters in millimetres)

Antenna elements: The configuration of the proposed antenna element is shown in Fig. 1. The antenna element is printed on an inexpensive FR4-epoxy laminate which has a thickness h of 0.8 mm with a manufacturer specified dielectric constant ε_r of 4.4 and loss tangent tan δ of 0.024. To generate CP radiation, two inverted-L metallic strips are inserted around two opposite diagonal corners of the square slot. Each of the 1 mm-width metallic strips has a length of L_x and L_y, respectively, in the directions perpendicular and parallel to the CPW. The simulation results show that the impedance bandwidth and AR of the proposed CPSSA element is 111% (3.1–10.9 GHz) for a voltage standing wave ratio (VSWR) <2, and 40.7% (4.5–6.8 GHz)–21.9% (7.3–9.1 GHz) for an AR <3 dB. The proposed CPSSA element has a compact size of 25 × 25 mm^2 operating at a frequency of 6.4 GHz. The design principles of the proposed CPSS antenna are summarised in detail in [4].

Feed network and CPSSAA configuration: A 2 × 2 planar array antenna (Fig. 2) has been established using the proposed CPSSA element. In Fig. 3, the configuration of the proposed feed network is shown. The basic principle of operation can be explained as follows. The feed network utilises a 180° ring hybrid coupler to achieve a 3 dB power split, equal in magnitude, but 180° out of phase. Two supplementary branch-line hybrid couplers then divide the signal energy into two paths and give the signal to each of the output branches with the same amplitude, but phase-shifted by 90°, wherein the relative phases at four feed points are 0°, 90°, 180° and 270°. The feeding network is fed with an surface mounted assembly panel connector located at the backside of the board. The total size of the 2 × 2 elements array is 112 × 97 × 0.8 mm^3. The proposed antenna is simulated by the commercial Ansoft™ high-frequency structure simulator software. The spacing between the two elements is 35 mm ($0.7\lambda_0$) in two dimensions.

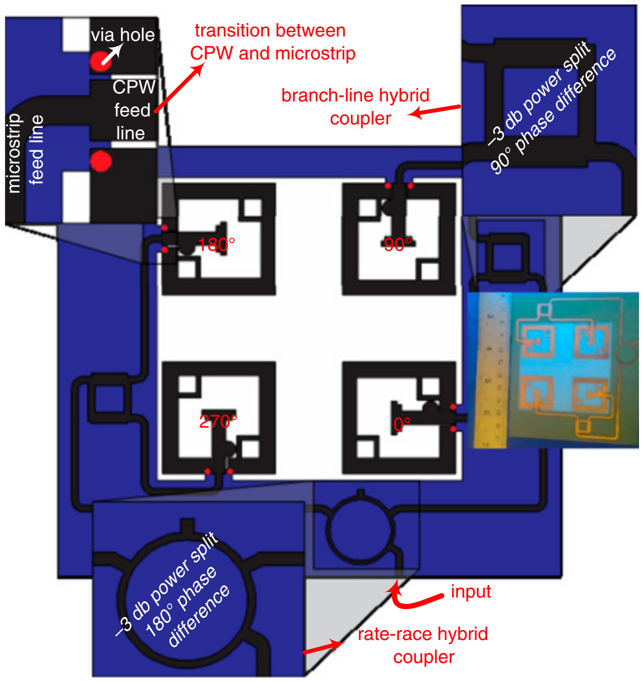

Fig. 2 *Configuration of feed network and CPSSAA*

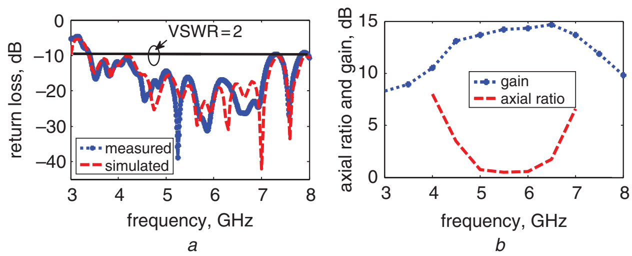

Fig. 3 *Comparison between measured and simulated return losses of proposed CPSSAA, and measured gain and AR*

a Comparison between measured and simulated return losses of proposed CPSSAA
b Measured gain and AR

Results and discussion: Measurements of the fabricated array were carried out and compared with the simulations. Since the antenna was manufactured by handwork, there were slight differences between the measured and simulated results. In Fig. 3a, a comparison between the measured and simulated return losses of the proposed CPSSAA is presented. The antenna array delivers a measured impedance bandwidth of 78.5% from 3.4 to 7.8 GHz for a VSWR <2 and the simulated impedance bandwidth of the CPSSAA is from 3.4 to 8 GHz, and the measured 3 dB AR bandwidth is 35.7% from 4.6 to 6.6 GHz. As shown in Fig. 3b, the minimum value of the AR is achieved to be 0.57 dB at 5.5 GHz. The minimum value of the measured gain is

8.3 dBic and the maximum value of gain is 14.8 dBic at 6.5 GHz and the average gain of the antenna array in the whole of the bandwidth frequency is 11.8 dBic. The measured radiation patterns of the antenna array at the three frequencies in the principal plane are shown in Fig. 4: the measured patterns at the three frequencies (4.6, 5.5 and 6.6 GHz at the beginning, minimum and end of the 3 dB AR bandwidth) are shown. As shown, the side lobe levels of the antenna array in Figs. 4*a–c* are lower than −10, −14 and −9 dB and the angular widths are 39°, 30° and 34°, respectively.

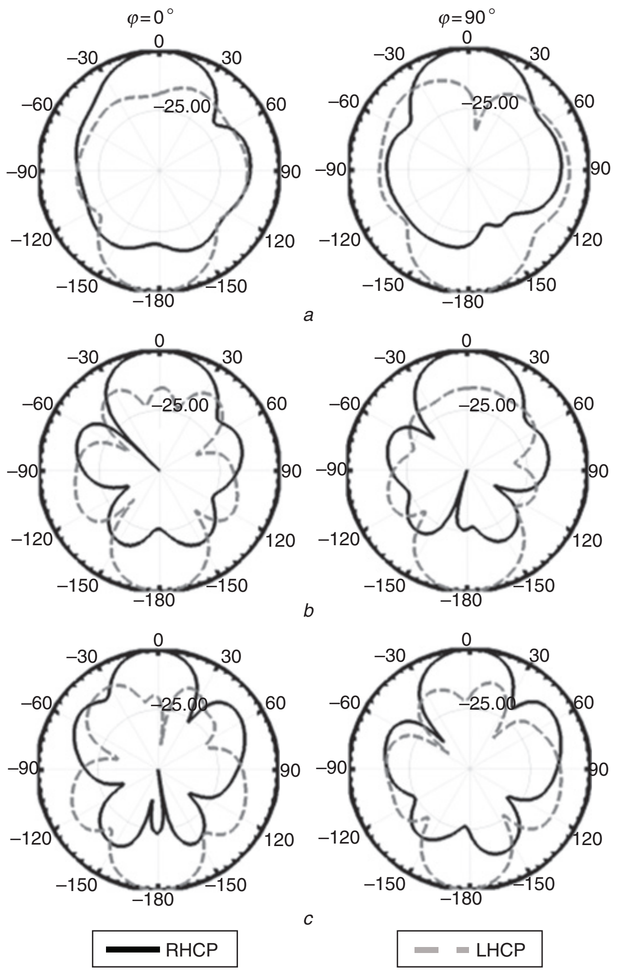

Fig. 4 *Array measurements with normalised RHCP and LHCP at 4.6, 5.5 and 6.6 GHz*

a 4.6 GHz
b 5.5 GHz
c 6.6 GHz

Conclusion: In this Letter, a design of a CPSSA array using a two-section cascaded coupler feeding system for generating broadband circular polarisation performance has been presented. The feeding network of the array is composed of a 180° ring hybrid coupler connected to the two branch-line couplers generating circular polarisation. The proposed antenna array architecture presents a number of well-behaved attributes including the flexibility of the mixed type of feeding, low parasitic radiation from the feeding network, high polarisation purity (35.7% (4.6–6.6 GHz) 3 dB AR bandwidth) and a very high gain (14.8 dBic).

1 June 2014
doi: 10.1049/el.2014.1147
One or more of the Figures in this Letter are available in colour online.

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