Antenna polarisation adjustment for microstrip patch antennas using parasitic elements

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A novel and simple approach to adjust the polarisation properties of a microstrip patch antenna in the entire axial ratio (AR) range is proposed. The proposed antenna consists of a radiating patch and a parasitic strip separated into two parts, and the separated strip is placed at the outer perimeter of the patch for capacitive coupling. This structure enables the antenna to induce opposite-direction currents on the strip, which allows flexible polarisation adjustment by moving the separated positions of the strip. For evaluation, two antennas with linear and circular polarisations are fabricated, and their performance is measured in a full anechoic chamber. The results prove that the proposed approach is suitable for flexible AR adjustment without a significant degradation of the matching characteristics and the design complexity.

Introduction: In wireless communications systems, antennas are used to transmit and receive radio waves with particular polarisations: vertical or horizontal polarisation is usually adopted in ground communications, while circular polarisation is often applied to satellite signal reception [1]. To provide such a wide range of polarisations, a microstrip patch antenna has been a suitable candidate in various practical applications because its polarisation axis can be rotated by changing the feed position. In addition, circular polarisation is easily achieved by applying asymmetric antenna structures with corner truncation [2] and slot insertion [3–5]; however, previous studies are limited to obtaining a specific polarisation without an in-depth concern for the entire axial ratio (AR) range, including linear, right-hand-side circular (RHC), left-hand-side circular (LHC) and even elliptical polarisations.

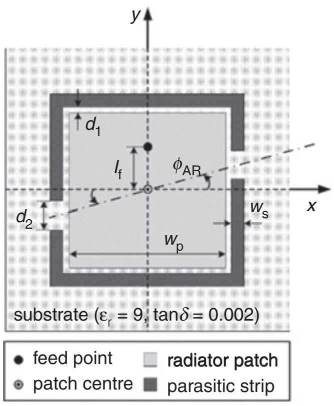


Fig. 1 *Geometry of proposed microstrip patch antenna; polarisation adjusted using parameter ϕ_{AR}*

In this Letter, we propose a novel and simple approach to adjust the polarisation properties of a microstrip patch antenna for flexible AR control. The proposed antenna consists of a radiating patch and a parasitic strip that is separated into two parts having the same length. The strip is placed at the outer perimeter of the radiating patch to induce an opposite-direction current by capacitive coupling, and the coupling strength is adjusted by the distance between the strip and the radiating patch. This structure enables the antenna to achieve a flexible capability of polarisation adjustment in the entire AR range because the current distribution of the patch can be controlled by varying the separated positions of the strip. To verify the suitability of the proposed approach, two antennas with different polarisations were fabricated, and their radiation gains, patterns and ARs were measured in a full anechoic chamber. The results confirm that the entire AR range can be achieved by the proposed approach without a significant increase in design complexity.

Proposed approach: Fig. 1 shows the geometry of the proposed microstrip patch antenna, which consists of a square patch having an edge length of w_p and two strips with a width of w_s. The patch is connected to a 50 Ω coaxial cable at the y-axis to feed the antenna, and the feed point is determined by the parameter l_f. The strips are separated by a spacing of d_2 and placed at a distance of d_1 along the outer perimeter of the patch, so that opposite-direction currents can be induced on the strips by capacitive coupling. These currents are then controlled to change the AR by an angular parameter ϕ_{AR}, as illustrated in Fig. 2. The proposed antenna has the advantage that the varying ϕ_{AR} barely shifts the resonance frequency and affects only the antenna polarisation within the entire AR range from AR = −1 (LHC) to AR = 1 (RHC), which includes linear and various elliptical polarisations.

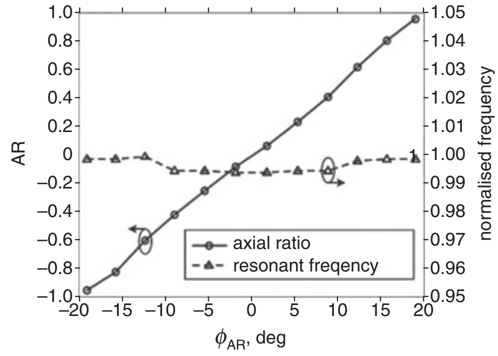


Fig. 2 *Effects of parameter ϕ_{AR} on AR and resonant frequency*

Fig. 3 shows variations of the RHC gain in the bore-sight direction and the reflection coefficient according to ϕ_{AR}. The RHC gain is increased from −18.3 to 4.8 dBic, and the reflection coefficients are less than −16.2 dB, which implies that varying ϕ_{AR} affects only the AR without degradation of the matching characteristics of the antenna.

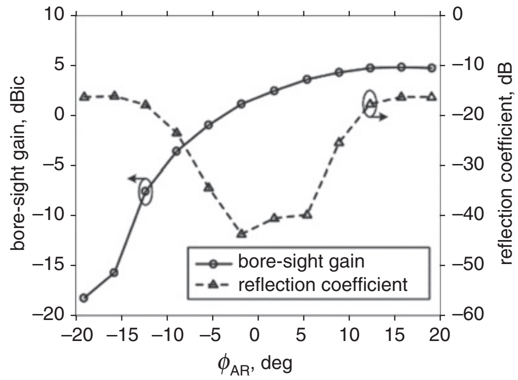
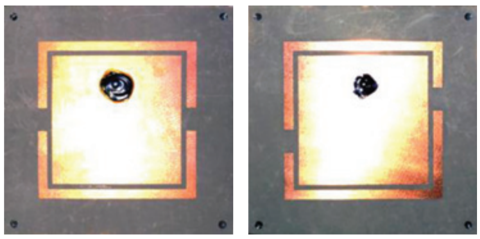


Fig. 3 *Effects of parameter ϕ_{AR} on bore-sight gain and reflection coefficient*



a *b*

Fig. 4 *Photographs of fabricated antennas*

a Linearly polarised antenna with $\phi_{AR} = 0°$
b Circularly polarised antenna with $\phi_{AR} = 15.7°$

Fabrication and measurement: To evaluate its feasibility, the proposed antenna was applied for a global positioning system operating in the L-band. Two sample antennas were chosen among the existing antennas in the AR range shown in Fig. 2 and were fabricated on a ceramic substrate from Taconic (50 × 50 mm, $\varepsilon_r = 9$, tan$\delta = 0.002$). Figs. 4*a* and *b* present the chosen sample antennas with linear and RHC polarisations, which are denoted as *Ant.* 1 and *Ant.* 2, respectively. Their design parameters are $w_p = 27.8$ mm, $w_s = 2$ mm, $l_f = 7.5$ mm, $d_1 = 1.1$ mm and $d_2 = 5$ mm, with a substrate height of 7.85 mm. The separated positions of *Ant.* 1 are symmetrically placed at $\phi_{AR} = 0°$, while those of *Ant.* 2 are slightly rotated by $\phi_{AR} = 17.5°$.

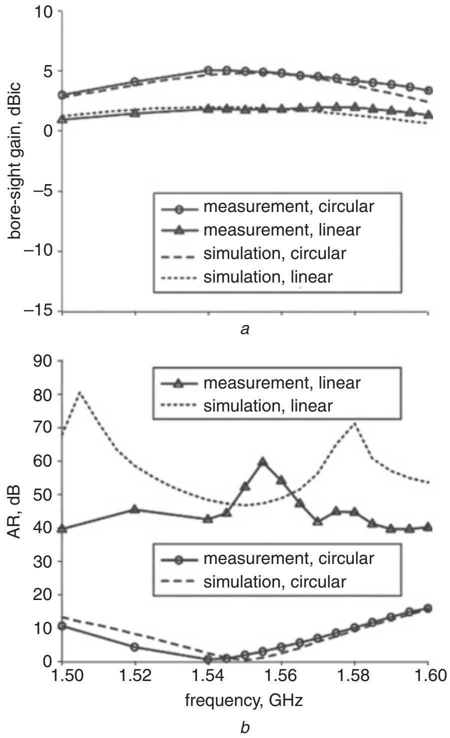


Fig. 5 *Performance comparison of fabricated antennas*

a Bore-sight gain
b AR

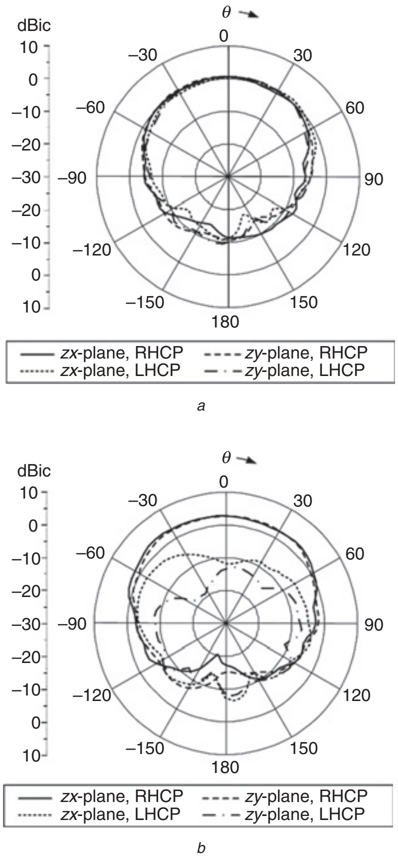


Fig. 6 *Radiation patterns of fabricated antennas*

a Linearly polarised antenna
b Circularly polarised antenna

The fabricated antennas were mounted on a circular ground plate with a diameter of 10 cm to measure the radiation characteristics, such as bore-sight gain, AR and radiation patterns in a full anechoic chamber.

Fig. 5*a* shows that the RHC gain of *Ant.* 1 is 1.7 dBic and that of *Ant.* 2 is 4.9 dBic at 1.55 GHz, which means that the gain is increased by about 3 dB because of the polarisation change. The polarisation change can also be verified in Fig. 5*b*, which shows the ARs of *Ant.* 1 and *Ant.* 2. *Ant.* 2 has an AR value of 0.6 dB at 1.54 GHz with a 3 dB AR bandwidth of 28 MHz from 1.527 to 1.555 GHz, while the AR of *Ant.* 1 is greater than 40 dB.

Fig. 6 presents measured the radiation patterns of *Ant.* 1 and *Ant.* 2 at 1.55 GHz. *Ant.* 1 exhibits half-power beamwidths of 131° and 138°, and those of *Ant.* 2 are 144° and 132° in the *zx*- and *zy*-planes, respectively. Owing to their different polarisation properties, the cross-polarisation level of *Ant.* 2 is increased by 15.3 dB at $\theta = 0°$, compared with *Ant.* 1. These results demonstrate that flexible adjustment for the entire AR range can be achieved by applying the proposed approach without a loss of radiation efficiency.

Conclusion: We have proposed a novel and simple approach for flexible polarisation adjustment in the entire AR range. We placed the parasitic strip at the outer perimeter of the radiating patch for capacitive coupling and adjusted the separated positions of the strip to change the antenna polarisation in the entire AR range. We then fabricated two sample antennas with different ARs to evaluate the feasibility of the proposed approach through measurement. The results confirmed that the AR could be varied from 40 dB to 0.6 dB and vice-versa without significant degradation of reflection coefficients and radiation efficiency.

Acknowledgment: This research was supported by the Civil Military Technology Cooperation (CMTC).

Submitted: *17 February 2015* E-first: *23 June 2015*
doi: 10.1049/el.2015.0611
One or more of the Figures in this Letter are available in colour online.

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