# Omnidirectional circularly-polarised microstrip patch antenna

A. Narbudowicz, X.L. Bao and M.J. Ammann

An omnidirectional circularly-polarised patch antenna is proposed. The antenna radiates right-handed circular-polarisation with an average axial ratio of 2.3 dB over a full 360°. A shallow diagonal CPW inset-feed was used to achieve good matching to the back-to-back coupled patches, providing a measured $S_{11} < -15$ dB at the centre frequency. The measured cross-polar performance is better than 13 dB and the realised gain variation is ~3 dB in the plane normal to the substrate.

*Introduction:* Omnidirectional circularly-polarised (CP) antennas have been a subject of interest for many years now, owing to the requirement for greater penetration and coverage in wireless communications and satellite systems. Early implementations of omnidirectional circular-polarisation were made by wrapping an array of three or more microstrip patch radiators around a small cylinder [1] or by using a linearly polarised antenna surrounded by a complex polariser [2]. Subsequently, two planar omnidirectional circular-polarisation antennas were reported. The first employed the zeroth-order resonance of an epsilon negative transmission line [3]. It generated an omnidirectional circular-polarisation pattern in the plane of the substrate with an average axial ratio (AR) of 2 dB and gain of 0.4 dBic. In the second case two back-to-back coupled truncated-corner patches were fed by an orthogonal coplanar waveguide (CPW) [4] and realised omnidirectional circular-polarisation with an AR below ~4 dB in the plane normal to the substrate. The radiation pattern however, exhibited more than 6 dB variation and there is no reported gain data.

In this Letter an omnidirectional CP low-profile antenna is proposed, employing two back-to-back patches augmented by a novel bonding strip and a diagonal CPW inset-feed. The use of the diagonal feed and bonding strip provides a more robust CP antenna owing to improved phase stability of the feed arrangement. An omnidirectional circular-polarisation pattern is realised in the $\phi = 0°$ plane with good AR and the variation in radiated power is ~3 dB. The plane of omnidirectionality is orthogonal to that presented in [3], thus the two designs are suitable for different terminal device applications in which the orientation cannot be predetermined.

*Antenna design:* The antenna consists of two layers of Taconic RF-35 substrate ($\varepsilon_r = 3.47$, $\delta_{loss} = 0.0018$ and height $h = 1.5$ mm) and three layers of metallisation: the two outer layers forming the patches, the middle layer forming the ground plane with CPW feed. The patches are connected by a copper conducting strip as shown in Fig. 1. The antenna is fed using a SMA connector, soldered to a 50Ω microstrip line (3.6 mm wide) on a single layer substrate, which after 6 mm transforms to a 50Ω CPW (conductor 5 mm and slot 0.6 mm wide) with substrate on both sides. The ground planes of both transmission lines are connected by four vias of diameter 1.2 mm, two on each side with 2 mm spacing. The microstrip-to-CPW transition allows the use of the SMA connector for measurement purposes.

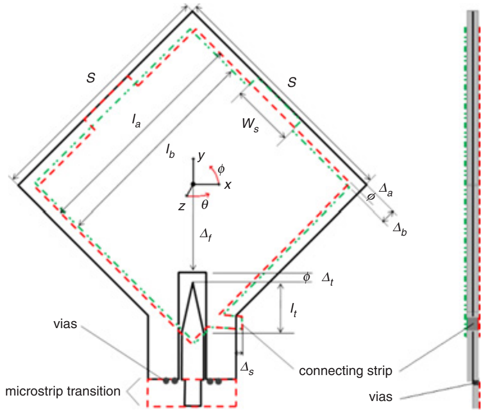


**Fig. 1** *Antenna geometry with parameters*

Dash (red) – bottom layer, dash-dot-dash (green) – top layer, solid – middle layer (ground plane and CPW feed)

The structure was modelled using CST MWS. The parameters of the optimised antenna are as follows (mm): $l_a = 51.2$, $l_b = 49.6$, $W_s = 14$, $S = 55.8$, $\Delta_a = 2.3$, $\Delta_b = 3.1$, $\Delta_f = 19.5$, $\Delta_t = 2$, $l_t = 12$, $\Delta_s = 1$. The strip connecting both patches is 3 mm wide and located 5 mm from the corner. In general the best performance is achieved when the strip is located close to the feed point, however the exact position is subject to optimisation and depends on other antenna parameters.

*Impedance match:* The patches are fed by proximity coupling to a CPW. Unlike [4], the right-handed circular-polarisation (RHCP) is achieved by employing an almost-square patch fed along its diagonal. The use of the CPW feed requires a slot to be cut in the ground plane and its location along the diagonal could perturb the current distribution on the ground plane. To address this, the feed is shallowly inserted under the patch, by 23% of the diagonal length (see Fig. 1). As the input resistance of a patch antenna increases as the feed point moves towards the edge, two independent techniques were used to provide a satisfactory match. First, the end of the CPW metallisation was tapered into a triangular shape. This acts as a tapered impedance transformer and ensures good coupling with the patch. Secondly, the ground plane size (as well as substrate) was reduced to decrease the input impedance [5]. The latter has also contributed to the omnidirectional CP radiation pattern, as well as reducing the antenna footprint.

*Results:* Fig. 2 shows the measured and simulated $S_{11}$ to be in agreement for the proposed antenna. The $S_{11}$ is better than −15 dB for the circular-polarisation frequency of 1.596 GHz. The measured $S_{11} <$ −10 dB from 1.579 to 1.613 GHz corresponding to a 2.1% fractional impedance bandwidth. RHCP is achieved (AR < ~4 dB) in the band 1.593–1.601 GHz, providing an omnidirectional circular-polarisation bandwidth of 7 MHz (0.4 %). The measured and simulated AR at 1.596 GHz is shown in Fig. 3. It can be seen that for all directions the AR is better than ~4 dB, and generally with only small peaks above the 3.5 dB level. The measured average AR is 2.3 dB. The measured peak gain is 1.1 dBic, with a variation of ~3 dB in the $\phi = 0°$ plane, which is a significant improvement over [3] and [4]. The total efficiency is 86%. The cross-polar isolation is better than 13 dB, as shown in Fig. 4.

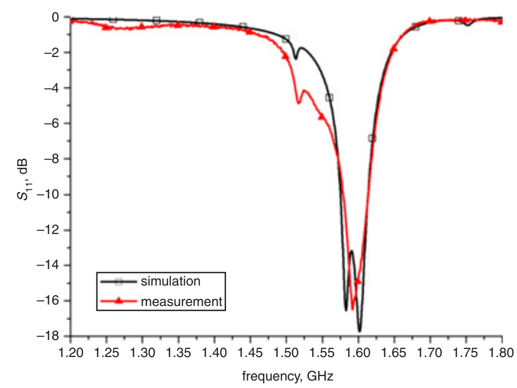


**Fig. 2** *Measured and simulated $S_{11}$*

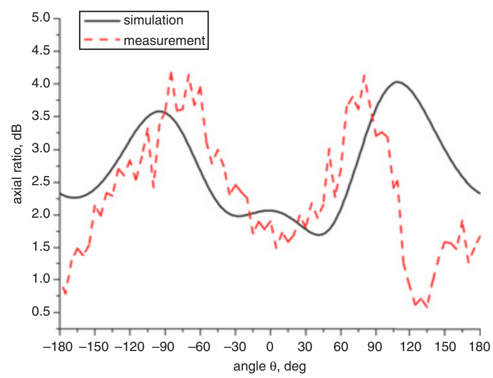


**Fig. 3** *Measured axial ratio in $\phi = 0°$ plane*

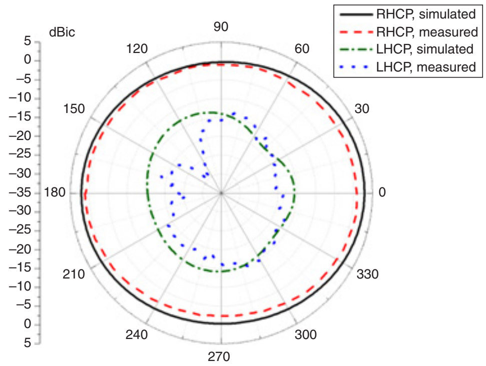


**Fig. 4** *Measured co- and cross-polar gains for $\phi = 0°$ plane*

*Conclusion:* An omnidirectional CP antenna comprising nearly-square coupled patches was shown to yield an AR below ~4 dB in the $\phi = 0°$ plane. A new technique to control the current distribution by bonding the back-to-back patches and the use of a diagonal CPW shallow inset feed was demonstrated to provide good matching and axial ratio. The small ground plane contributes to the omnidirectional pattern, decreases the input impedance and reduces the antenna's footprint.

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

A. Narbudowicz, X.L. Bao and M.J. Ammann (*Antenna and High Frequency Research Centre, School of Electronic and Communications Engineering, Dublin Institute of Technology, Kevin Street, Dublin 8, Ireland*)

E-mail: max.ammann@dit.ie

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