Dual circular polarisation microstrip array antenna for WLAN/WiMAX applications

C.-H. Weng, H.-W. Liu, C.-H. Ku and C.-F. Yang

A planar 2 × 2 microstrip array antenna with dual circular polarisation (CP) is presented. This array can be reconfigured and operated with either the right-handed (RH) or left-handed (LH) CP by controlling the input state of the branch-line coupler. A prototype has been fabricated with a 0.4 mm-thick FR4 top layer for radiating elements and a 0.8 mm-thick FR4 bottom layer for a feeding network, where a 5 mm air spacing is inserted between them. Wide operating frequency ranges for RHCP and LHCP states can be achieved at about 1.55 GHz and 1.54 GHz, respectively. Good radiation properties across the operating band are also obtained so that the proposed array antenna is suitable for WLAN and WiMAX applications.

Introduction: In recent years, microstrip antennas have been widely and rapidly developed in various modern wireless communication systems. Compared with ordinary linear polarisation (LP) arrays can mitigate the effects caused by the multipath owing to their polarisation diversity. However, lower radiation performance will be expected as these CP arrays radiate with narrow operating bandwidth and half-power beamwidth. To address this problem, many designs for CP arrays have been reported in [1–5] to achieve better performance. By properly adding a ring structure with two paths of 90° difference, the single feed microstrip CP array was achieved to reduce array size [1]. Research investigating how to widen the operating bandwidth [2–4] and half-power beamwidth [5] suitable for CP applications has also been carried out.

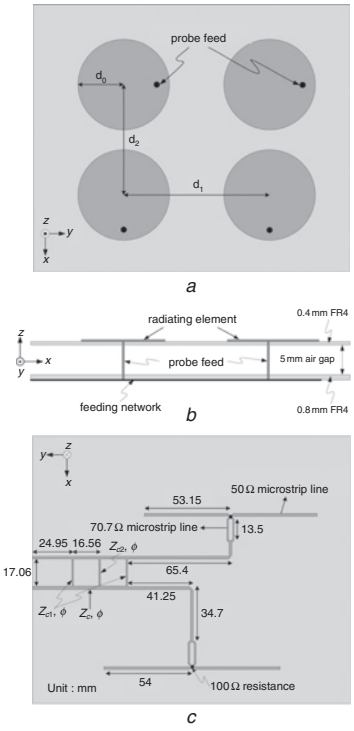

Fig. 1 *Geometry of proposed dual CP microstrip array antenna*

a Top view
b Cross-sectional view
c Bottom view

In this Letter, we propose a single feed 2 × 2 microstrip array antenna that can provide a reconfigurable property to realise dual CP for WLAN/WiMAX operations. A feeding network, consisting of a 90° branch-line coupler and two Wilkinson power dividers, is used in this work to make good impedance matching and axial-ratio across the operating band for both right-handed (RH) and left-handed (LH) CP operations. Hence the CP state of the proposed array can be switched flexibly. Details of the array design are presented and analysed, and a prototype of the proposed array has been constructed and experimentally studied.

Antenna design: Fig. 1 indicates the whole geometry with detailed design parameters of the proposed reconfigurable microstrip array antenna, which has a proper size of 200 (L) × 150 (W) mm. This array was fabricated with a 0.4 mm-thick FR4 top layer for 2 × 2 radiating elements and a 0.8 mm-thick FR4 bottom layer for a feeding network, where a 5 mm air spacing was designed to be inserted between them. Also note that the FR4 substrate has dielectric constant $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.02$. For the radiator structure, d_1 and d_2 are about 106 and 72 mm, which are respectively equal to the horizontal length along the y-axis and vertical length along the x-axis, among the 2 × 2 radiating elements, as shown in Fig. 1*a*. Moreover, in such a structure, each element of the array has been designed with a radius of $d_0 = 30$ mm. Thus, the linear radiation directions for those array elements can be determined by the x- and y-axes for the lower and upper elements, respectively.

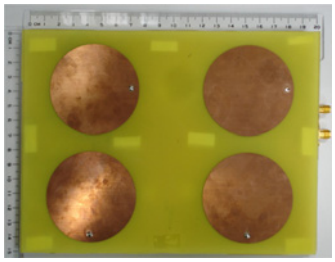

Fig. 2 *Photograph of implemented prototype for proposed array*

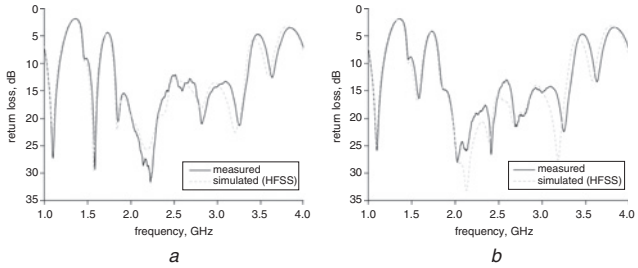

Fig. 3 *Simulated and measured return losses of proposed array*

a RHCP with port 1 feeding and port 2 matching
b LHCP with port 2 feeding and port 1 matching

To further attain the CP operation for the array, the feeding network shown in Fig. 1*b* was developed with a wideband 90° branch-line coupler and two 3 dB Wilkinson power dividers, which was capable of providing not only good impedance matching over the operating band but also equal input power for each element. The design parameters optimised for the array are indicated in Figs. 1*b* and *c*, where the electrical characteristics with respect to the branch-line coupler are $Z_c = 47\ \Omega$, $Z_{c1} = 105\ \Omega$, $Z_{c2} = 66.8\ \Omega$, and $\varphi = 90°$. Hence the RHCP and LHCP states can be flexibly created and controlled by exciting ports 1 and 2, respectively.

Results and discussion: As shown in Fig. 2, a fabricated prototype for the proposed array antenna was constructed and implemented. The measured results were performed by using a vector network analyser (Agilent PNA 8362B). Fig. 3 shows the simulated and measured return losses against frequency for the array, where fairly good agreements between them have been achieved. As shown, the measured impedance bandwidths with 10 dB return loss for ports 1 and 2 excitations are about 1.81–3.36 GHz and 1.82–3.36 GHz, corresponding to 60 and 59.5%, respectively. In such a wideband design, the undesirable effects such as frequency shifting caused by the array to be integrated within various transceiver modules can be well reduced. Hence the proposed design achieves not only the WLAN band of 2.4–2.483 GHz, but also the authorised WiMAX band of 2.5–2.69 GHz.

Fig. 4 shows the measured far-field radiation patterns in the xz-plane for frequencies of 2.45 and 2.6 GHz, respectively. Fairly good RHCP and LHCP patterns, generated by feeding the ports 1 and 2, can be attained with appreciable gain, whose 3 dB beamwidths are also about 29 and 28°, respectively. To evaluate the CP performance, a simulated axial-ratio against frequency for the array was performed using HFSS, as shown in Fig. 5. Referring to 3 dB axial-ratio, the operating frequency ranges for RHCP and LHCP have been determined to be about 2.37–

2.89 GHz and 2.51–2.99 GHz, respectively. We can also observe that the LHCP state has a higher frequency range than the RHCP one. Better CP performance in the lower frequency band for the LHCP state can be obtained by retuning the structure of the branch-line coupler. Fig. 6 shows the measured radiation efficiency against frequency of the proposed array. As seen, the array efficiency varies from 35 to 51% for the WLAN system at 2.4–2.483 GHz. Results given in the WiMAX band of about 2.5–2.69 GHz indicate that the efficiency is from 46 to 69% in our design. These medium efficiencies are mainly due to the dielectric loss of the feeding network, which may be improved significantly by using a low loss substrate.

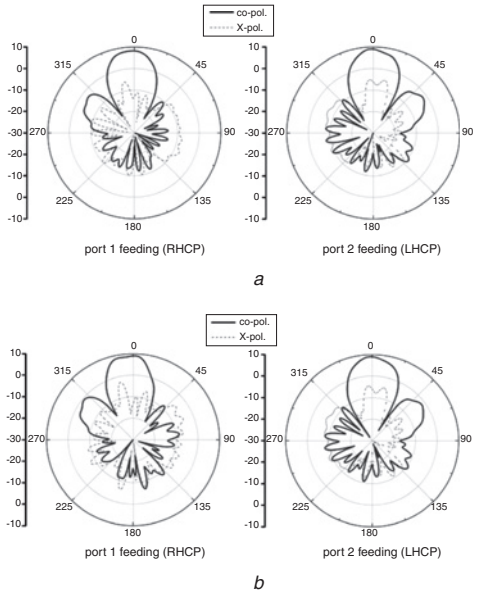

Fig. 4 *Measured radiation patterns of proposed array*

a 2.45 GHz
b 2.6 GHz

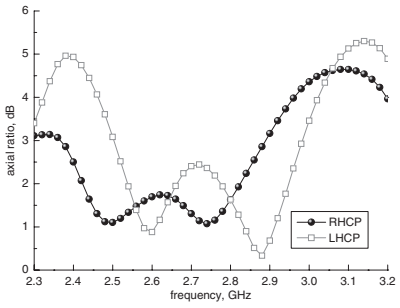

Fig. 5 *Simulated axial-ratio of proposed array*

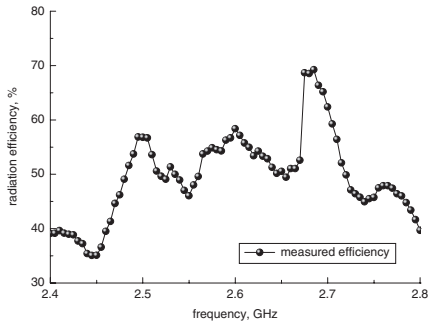

Fig. 6 *Measured efficiency of proposed array*

Conclusions: A novel microstrip array antenna with dual circular polarisation has been presented and investigated in this Letter. Compared to other designs, this array is rather simple, and also achieves a wider operating frequency band for both RHCP and LHCP operation. By controlling the input state of the branch-line coupler, polarisation diversity of the array may be achieved flexibly. Simulated and experimental results also show that the array has good radiation properties in terms of the patterns and axial-ratio. For these reasons, the proposed array antenna is well suited to applications in WiMAX and WLAN systems.

9 March 2010
doi: 10.1049/el.2010.0636
One or more of the Figures in this Letter are available in colour online.

C.-H. Weng, H.-W. Liu and C.-F. Yang (*Department of Electrical Engineering, National Taiwan University of Science and Technology, 43, Keelung Road, Sec. 4, Taipei, Taiwan*)

E-mail: M9707601@mail.ntust.edu.tw

C.-H. Ku (*Department of Electrical Engineering, Ming Chi University of Technology, 84, Gungjuan Road, Taishan, Taipei, Taiwan*)

References

1 Ramirez, R.R., Flaviis, F.D., and Alexopoulos, N.G.: 'Single-feed circular polarised microstrip ring antenna and arrays', *IEEE Trans. Antennas Propag.*, 2000, **48**, (7), pp. 1040–1047
2 Guo, Y.-X., Khoo, K.-W., and Ong, L.-C.: 'Wideband circularly polarised patch antenna using broadband baluns', *IEEE Trans. Antennas Propag.*, 2008, **56**, (2), pp. 319–326
3 Guo, Y.-H., Bian, L., and Shi, X.Q.: 'Broadband circularly polarised annular-ring microstrip antenna', *IEEE Trans. Antennas Propag.*, 2009, **57**, (8), pp. 2474–2477
4 Xue, Q., and Qu, S.-W.: 'Compact loaded slot ring antenna for circularly polarised radiation', *Electron. Lett.*, 2009, **45**, (17), pp. 866–867
5 Mak, K.M., and Luk, K.M.: 'A circularly polarised antenna with wide axial ratio beamwidth', *IEEE Trans. Antennas Propag.*, 2009, **57**, (10), pp. 3309–3312