Dual-band dual sense microstrip antenna with improved characteristics

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The development of a dual polarised microstrip antenna for S- and C-band with improved characteristics is presented. It is dual linearly polarised at S-band and dual circularly polarised at C-band. Two orthogonal feeds have been conceived for proximity coupling at S-band. The other two composite feeds are aperture coupled at C-band. These generate left-hand and right-hand circular polarisations exclusively. The antenna reveals 3.5% or more impedance bandwidth at the S-band ports with an isolation better than 22 dB (the best isolation is ≈31.5 dB at the band-centre). It yields >21.2% impedance bandwidth and about 10.2% axial-ratio bandwidth at each of the C-band ports, both being improved compared to the earlier reports. Achieved isolation between the C-band ports is better than 18.5 dB (≈23.5 dB at the centre of the working band).

Introduction: Bandwidth and isolation are the two major concerns in a multi-band and multi-polarised antenna design. Several dual-band microstrip antenna configurations were proposed [1–6]. These were aimed to achieve several features and improvements, such as dual-band single linear polarisation (LP) [1, 2], dual-band dual LP [3–5], and recently, a miniaturised dual-band single LP [6]. None of these designs addresses dual circular polarisation at any of the bands. Dual circularly polarised (CP) microstrip antenna with a broad axial ratio (AR) bandwidth is a requirement in some communication system. CP can be generated using a single composite feed or dual feeds [7, 8]. Single composite feed has the advantage of not requiring an external 90° hybrid coupler. However, wider AR bandwidth with high inter-port isolation without power divider (which requires more space) is the design challenge.

In this Letter, we report the development of a microstrip antenna which operates at S- and C-band. The antenna is dual feed dual LP at S-band and dual feed dual CP at C-band. Each of the two composite feeds at C-band causes left hand circular polarisation (LHCP) or right hand circular polarisation (RHCP) radiation exclusively. The design is validated experimentally using a prototype. The antenna yields matching bandwidths of ≥3.5% at S-band with an isolation better than 22 dB. It also exhibits ≥20.9% impedance bandwidth and ≈10.2% AR-bandwidth at each of the C-band ports, both being improved compared to the earlier reported results.

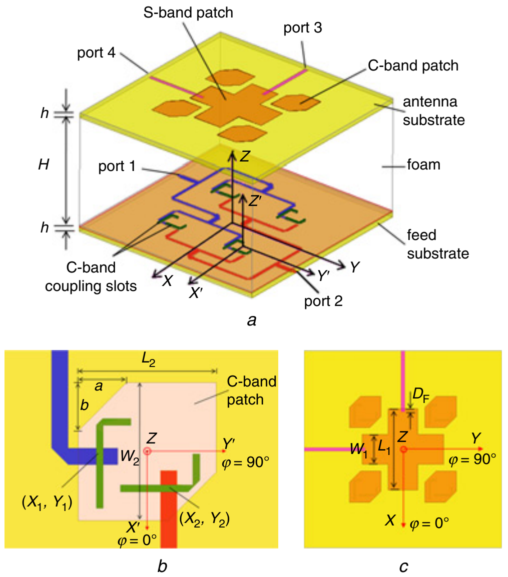

Fig. 1 *Configuration of the proposed antenna*

a Overall antenna
b Enlarged top view of the C-band patch, coupling slots and feed lines
c Top view of S-band proximity coupled cross-shaped with feed lines

Antenna configuration: The antenna configuration is shown in Fig. 1. It consists of two substrate layers (thickness = h) separated by a low loss dielectric foam (thickness = H). The top layer of the upper substrate bears the cross-shaped S-band patch surrounded by four chamfered corner square patches for C-band. The S-band element is proximity coupled to the two orthogonal feed lines on the back side of the upper substrate. This produces dual orthogonal LP. Aperture coupled technology has been employed for the C-band. The top surface of the lower substrate serves as the ground plane for the complete antenna. Two off-centred mutually orthogonal L-shaped coupling-slots are conceived for each of the C-band patches. Its bottom layer contains two composite feeds for C-band. One of these causes LHCP, while the other excites RHCP. 31 mil thick RT Duroid 5880 has been considered as the substrates. A specific foam ($\varepsilon_{rf} = 1.08$, $\tan\delta = 0.001$) has been used as the spacer. The slots and the patch parameters are optimised through successive simulations using the commercial solver HFSS. The optimised dimensions are $L_1 = 52$ mm, $W_1 = 19$ mm, $L_2 = W_2 = 20$ mm, $a = b = 7$ mm, $h = 0.7874$ mm, $H = 4.3$ mm, and ground plane = 126 mm × 126 mm.

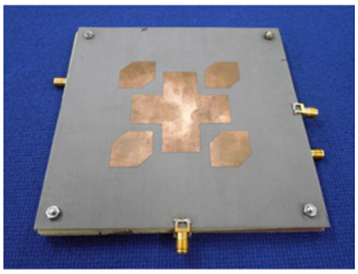

Fig. 2 *Fabricated and assembled overall microstrip antenna*

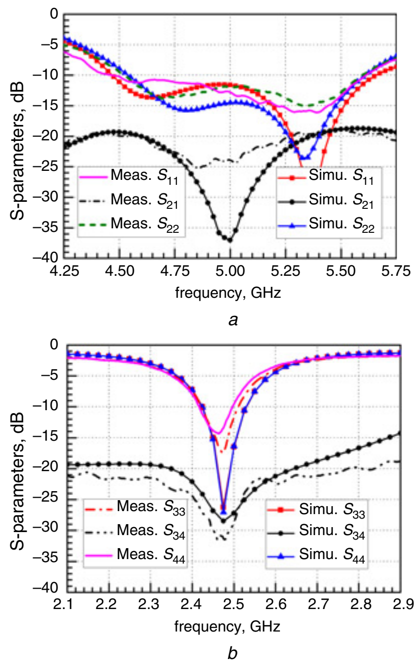

Fig. 3 *Measured and simulated S-parameters of the overall antenna*

a C-band
b S-band

Prototype and results: A photograph of the fabricated prototype is shown in Figs. 2 and 3 compares the measured and simulated *S*-parameters of the overall antenna. A close agreement between the measured and simulated *S*-parameters at C-band is documented in Fig. 3*a* as evidence. Measured matching bandwidths (S_{11}, $S_{22} \leq -10$ dB) are 22.8% (4.465–5.615 GHz) at port-1 and 21.2% (4.52–5.595 GHz) at port-2. Achieved isolation is better than 18.5 dB over the entire operating band and is ≈23.5 dB at the band-centre (5 GHz). Fig. 3*b* also demonstrates that the measured *S*-parameters at S-band have a similar nature to the simulated results. The achieved impedance bandwidths are 3.9% (2.422 – 2.517 GHz) at port-3 and 3.5% (2.42–2.5 GHz) at port-4. The measured isolation is better than 22 dB over the working band and the best isolation is ≈31.5 dB at the centre frequency (2.47 GHz).

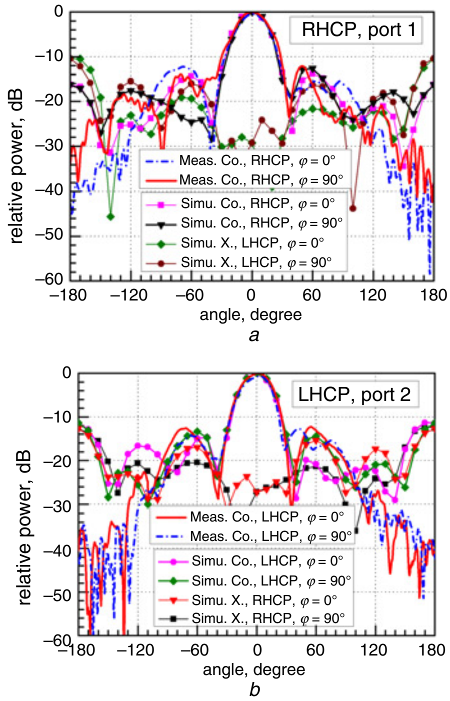

Fig. 4 *Measured and simulated radiation patterns at C-band (f = 5 GHz)*

a Port-1, RHCP
b Port-2, LHCP

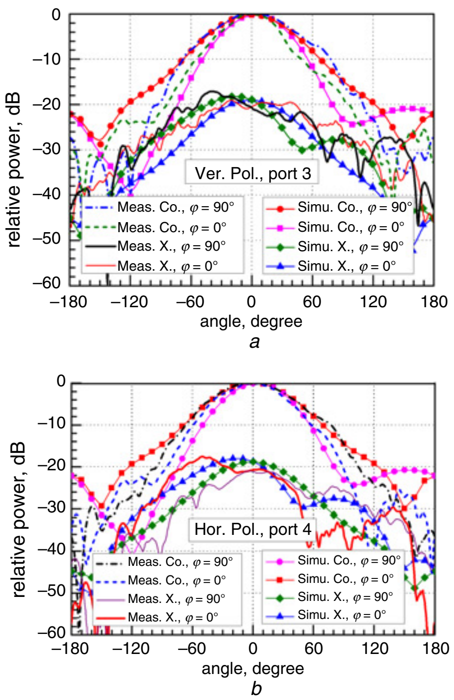

Fig. 5 *Measured and simulated radiation patterns at S-band*

a Port-1, vertical polarisation
b Port-2, horizontal polarisation

Considerable conformity of the measured patterns at port-1 (RHCP) with simulation is portrayed in Fig. 4*a*. The measured half-power beamwidths are 30.1° at $\varphi = 0°$ cut and 31.2° at $\varphi = 90°$ cut. The side lobe levels (SLLs) are about 12.2 dB lower than the main beam peak, and the asymmetry between the side-lobes is lower than 1 dB. The gain of the antenna is 12.7 dBi. Fig. 4*b* depicts the measured and simulated patterns at port-2 (LHCP, $f = 5$ GHz). The realised 3 dB beamwidth are 31.5° at $\varphi = 0°$ cut and 30.3° at $\varphi = 90°$ cut. SLL and lobe asymmetry are similar to port-1. Gain, as high as 12.9 dBi is realised. For pattern measurement, the antenna (ground plane = 126 mm × 126 mm) was mounted on a positioner with a metallic base diameter of 2 feet, causing the higher value of measured front-to-back (FB) ratios than simulation.

The measured S-band patterns are also identical to the simulated patterns. Fig. 5*a* compares the measured and simulated patterns at port-3 (vertical polarisation, $f = 2.47$ GHz). The 3 dB beamwidths are 50.5° at $\varphi = 0°$ cut and 80.5° at $\varphi = 90°$ cut. It yields a gain of about 6.5 dBi and an FB ratio of about 27 dB. The patterns at port-4 (horizontal polarisation, $f = 2.47$ GHz) are examined in Fig. 5*b*. This depicts half power beamwidths of 82° at $\varphi = 0°$ cut and 62° at $\varphi = 90°$ cut. The realised gain value is 6.3 dBi and FB ratio is about 32 dB. The boresight cross-polarisation discrimination is about 20.2 dB.

Conclusion: This work demonstrates a dual-band (S and C) polarised microstrip antenna with improved features and performances. The simulation and the measurement conformity validates the design. The realised impedance- and AR-bandwidths are higher than earlier reported works. This approach may be extended to other microstrip geometries for dual-band dual polarised communication.

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

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References

1 He, S., and Xie, J.: 'Analysis and design of a novel dual-band array antenna with a low profile for 2400/5800-MHz WLAN systems', *Trans. Antennas Propag.*, 2010, **58**, (2), pp. 391–396
2 Naishadham, K., Li, R.L., Yang, L., *et al.*: 'A shared-aperture dual-band planar array with self-similar printed folded dipoles', *Trans. Antennas Propag.*, 2013, **61**, (2), pp. 606–613
3 Pozar, D.M., and Targonski, S.D.: 'A shared-aperture dual-band dual-polarised microstrip array', *Trans. Antennas Propag.*, 2001, **49**, (2), pp. 150–157
4 Vetharatnam, G., Kuan, C.B., and Teik, C.H.: 'Combined feed network for a shared-aperture dual-band dual-polarised array', *Antennas Wirel. Propag. Lett.*, 2005, **4**, pp. 297–299
5 Kong, L.-B., Zhong, S.-S., and Sun, Z.: 'Broadband microstrip element design of a DBDP shared-aperture SAR array', *Microw. Opt. Technol. Lett.*, 2012, **54**, (1), pp. 133–136
6 Chakrabarti, S.: 'A compact dual frequency microstrip antenna', *Int. J. RF Microw. Comp. Aided Eng.*, 2018, **28**, (6), pp. 1–10
7 Karmakar, N.C., and Bialkowski, M.E.: 'Circularly polarised aperture-coupled circular microstrip patch antennas for L-band applications', *Trans. Antennas Propag.*, 1999, **47**, (5), pp. 933–940
8 Pozar, D.M, and Duffy, S.M.: 'A dual-band circularly polarised aperture-coupled stacked microstrip antenna for global positioning satellite', *Trans. Antennas Propag.*, 1997, **45**, (11), pp. 1618–1625