X-band circular ring-slot antenna embedded in single-layered SIW for circular polarisation

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A circularly-polarised antenna which has a novel feeding structure like a substrate integrated waveguide, a cavity-backed resonator and a conventional ring-slot antenna is proposed for right-handed circular polarisation (RHCP) in a single-layered fabrication. The CP generation and broadband impedance matching characteristics are accomplished by using a simple shorting via between the top patch and bottom ground plane and inserting inductive via arrays at the input port, respectively. A broadband impedance bandwidth of 18.74% and a RHCP axial ratio of 2.3% have been obtained under the condition of less than VSWR 2:1 and axial ratio −3 dB, respectively.

Introduction: Substrate integrated waveguide (SIW) technology of low-loss transmission characteristic has recently become widespread in the design of many passive and active devices at microwave and millimetre-wave. An advantage is that it can be easily integrated with planar circuits by replacing the conventional microstrip and strip line. Basically, there are various techniques using feeding network and different shapes of radiating elements for cross-polarisation (CP) generation in a ring-slot antenna. For example, a stabilised CP has been generated by introducing a hybrid coupler with the same magnitudes and 90° phase differences at two ports [1]. However, as expected, the feeding network is not so simple. As other methods to generate CP, such as the L-shaped microstrip (series microstrip) feeding structure and a shorted section between the annular slot and ground plane, have been introduced [2, 3], a result has been undesirable radiation owing to the feeding network and reduced radiation efficiency caused by back radiation in the opposite side of the main direction. In this Letter, to overcome problems such as feeding loss, undesirable radiation, and reduced efficiency, a novel SIW-based and cavity-backed ring-slot antenna unified with a SIW feeding network having low-loss and broadband impedance matching characteristics is proposed for right-handed circular polarisation (RHCP) generation.

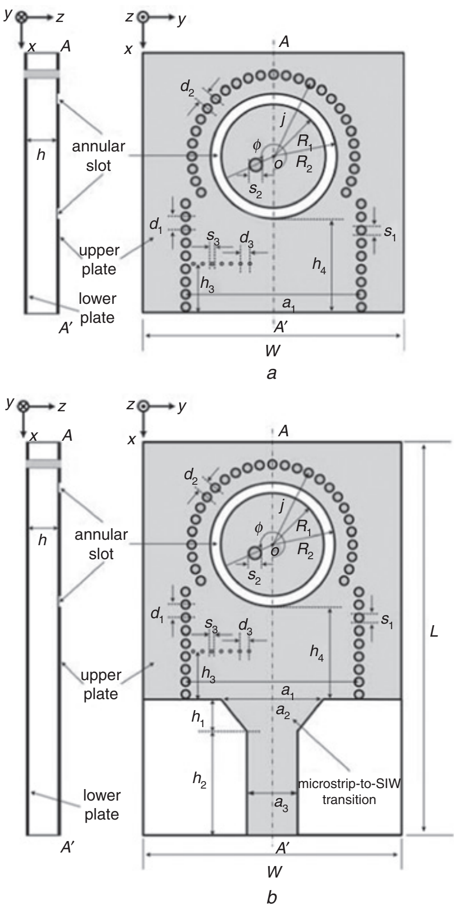

Fig. 1 *Proposed antenna configuration*

a Without transition
b With transition for measurement

Antenna configuration: We considered the proposed cavity-backed circular ring-slot antenna using SIW technology as shown in Fig. 1. The proposed antenna is mainly composed of three parts: a SIW-based cavity-backed resonator and a ring-slot antenna; horizontal via arrays and a SIW-based rectangular waveguide for a broadband input impedance matching and feeding network, respectively, and microstrip-to-SIW transition for measurement. The total occupied area is 25 (W) × 38 (L) mm^2 in Fig. 1*b* with RT/Duroid 5880 substrate which has thickness (h) 1.57 mm, relative permittivity 2.2, and loss tangent 0.0009. The optimised parameter values for generating RHCP are listed in Table 1.

Table 1: Design parameter values of proposed antenna

Parameter	a_1	a_2	a_3	d_1	d_2	d_3	h	h_1	h_2	h_3
Value (mm)	16.8	10	4.9	1	1.2	0.9	1.57	3.2	10	4.43
Parameter	h_4	j	L	R_1	R_2	s_1	s_2	s_3	W	ϕ
Value (mm and deg)	9	7.8	38	5	6	0.8	1.1	0.3	25	296.5°

The width (a_1) of the feeding waveguide has been determined from the centre frequency, 10 GHz in the X-band and the cutoff frequency 6.3 GHz of the fundamental TE_{10} mode. In particular, it can be assumed [4] that the leakage from the side walls of the feeding waveguide working as perfect electric walls is small enough to be neglected.

Experimental results: A measured return loss of the proposed antenna is shown in Fig. 2, which shows good agreement between data and the simulated result using commercially available software (CST MWS). There is also a photograph of the fabricated antenna. It can be evaluated from Fig. 2 that the input impedance bandwidths are 12.86% from 9.46 to 10.76 GHz and 18.74% from 9.38 to 11.32 GHz for simulation and measured results, respectively. From Fig. 3, which shows the gain and axial ratio (AR), it is seen that the proposed antenna has 5.75 dBic as maximum gain within 8.875 to 10.875 GHz, a very stable 3 dB gain bandwidth of 1.4 GHz, and axial ratio bandwidth of 2.3% from 10.3 to 10.54 GHz for less than −3 dB. The measured radiation patterns in two orthogonal cutting planes shown in Fig. 4 imply that the proposed antenna satisfies the RHCP generation with a lower cross-polarisation at the boresight direction.

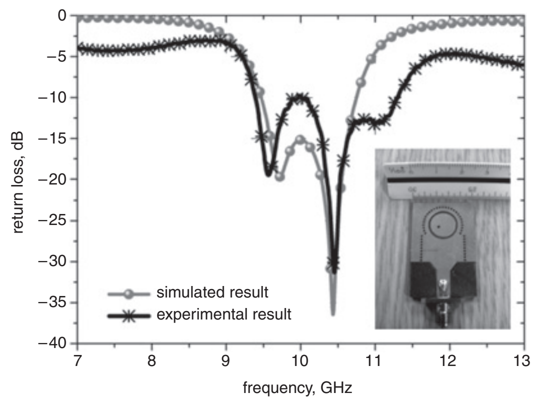

Fig. 2 *Simulated and experimental return loss characteristics with photograph of fabricated antenna*

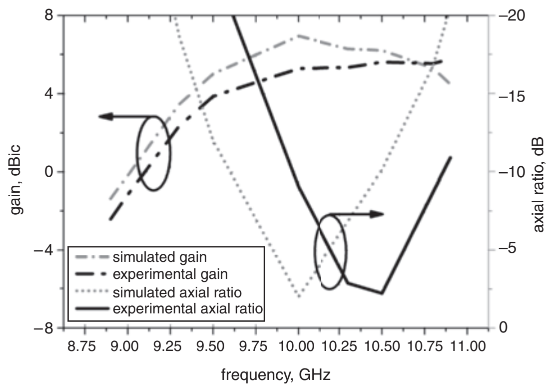

Fig. 3 *Gain and axial ratio characteristics against frequency*

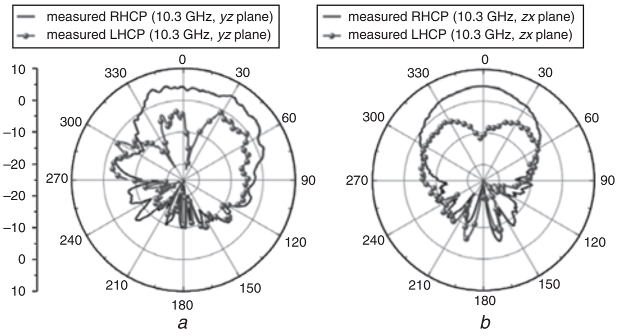

Fig. 4 *Co- and cross-polarised radiated patterns at 10.3 GHz*

a yz plane
b zx plane

Conclusion: A novel single-layered SIW-fed ring-slot antenna embedded in a cavity-backed resonator is proposed, that has a unified impedance matching network inside the SIW feeding structure. In addition, the RHCP characteristic has been easily accomplished by employing a guiding-wave-type feeding structure and inserting a single via between the upper and lower plates. It is expected that the proposed structure can be applied to the phased array antenna for high-speed data communication in satellite systems.

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References

1 Qing, X.M., and Chia, Y.W.: 'Circularly polarised circular ring slot antenna fed by stripline hybrid coupler', *Electron. Lett.*, 1999, **35**, (25), pp. 2154–2155

2 Row, J.-S., Sim, C.Y.T., and Lin, K.-W.: 'Broadband printed ring-slot array with circular polarisation', *Electron. Lett.*, 2005, **41**, (3), pp. 110–112

3 Chen, W.-S., Huang, C.-C., and Wong, K.-L.: 'Microstrip-line-fed printed shorted ring-slot antennas for circular polarization', *Microw. Opt. Technol. Lett.*, 2001, **31**, (2), pp. 137–140

4 Xu, F., and Wu, K.: 'Guided-wave and leakage characteristic of substrate integrated waveguide', *IEEE Trans. Microw. Theory Tech.*, 2005, **53**, (1), pp. 66–73