Progress In Electromagnetics Research Letters, Vol. 35, 29–35, 2012

A CIRCULARLY POLARIZED ELLIPTICAL-RING SLOT ANTENNA USING AN L-SHAPED COUPLING STRIP

M.-Z. Wang* **and F.-S. Zhang**

National Laboratory of Antennas and Microwave Technology, Xidian University, Xi'an, Shaanxi 710071, China

Abstract—A circularly polarized (CP) elliptical-ring slot antenna is proposed. A tapered slot is excited by an L-shaped coupling strip. A good impedance match is obtained, and an excellent CP characteristic is achieved. The antenna has been investigated numerically, and prototype of the presented antenna is fabricated and tested. The measured results show that the antenna has a bandwidth of 37.5% (3.9 GHz–5.7 GHz) for return loss less than −10 dB and 34.7% (3.8 GHz–5.4 GHz) for average axial ratio (AR) less than 3 dB. The proposed antenna provides good CP performance.

1. INTRODUCTION

Because the circularly polarized (CP) antennas allow flexible orientation of the transmitter and receiver, they are commonly used in radar, wireless communication and navigational systems. Two near-degenerated orthogonal resonant modes of equal amplitude and 90° phase difference (PD) need to be excited to generate the CP operation [1, 2].

Circularly polarized broadband antenna is required due to the need to handle large volumes of information. Broadband characteristics are met in both input impedance matching and radiation characteristics, such as the axial ratio (AR) and gain. Printed wide-slot antennas have the well known merits of large impedance bandwidth, low profile and a single metallic layer [3]. It is also expected that a broadband CP design of antenna using printed ring slot can be obtained [4, 5]. An attractive method to generate the CP radiation from the slot antenna is using an L-shaped coupling feed line [6, 7]. The open stub of the L-shaped feed line can be regarded

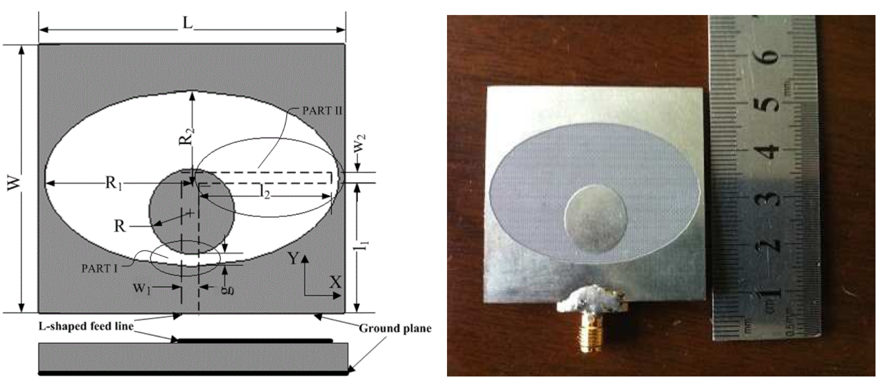
Received 13 June 2012, Accepted 5 September 2012, Scheduled 18 September 2012
* Corresponding author: Mao-Ze Wang (wangmaoze@163.com).

as a capacitive loading of the coupling strip. By tuning the length of the open stub, two orthogonal resonant modes can be excited with the same amplitude and 90° phase difference, and good impedance matching can be obtained. An annular-ring slot antenna excited by an L-shaped coupling strip is loaded with a resistor whose 3 dB axial-ratio bandwidth is 2.6% [7]. Another annular-ring slot antenna excited by a shorted L-shaped coupling strip has 3 dB axial-ratio bandwidth of 1.5% [8]. A printed squarer-ring slot antenna with an L-shaped series feed structure has 3 dB axial-ratio bandwidth of 6% [9].

In this article, we deal with a circularly polarized (CP) elliptical-ring slot antenna fed by an L-shaped feed line with a single geometry. The elliptical-ring slot can achieve broadband characteristics by making use of multi-modes of the tapered structure, and the tapered slot is excited by an L-shaped coupling strip. The proposed antenna can achieve wider bandwidth of impedance and axial ratio without a complicated series feed structure or resistor loading. The simulated and numerical results show that a relatively wider impedance bandwidth ($S_{11} \leq -10$ dB) of 37.5% and the measured axial ratio bandwidth (AR $\leq$ 3 dB) of 34.7% are achieved. The proposed antenna provides good CP performance.

2. ANTENNA CONFIGURATION AND ANALYSES

The configuration of the proposed antenna is shown in Figure 1. It is constructed on a substrate with a relative permittivity $\varepsilon_r = 2.55$ and



(a) (b)

Figure 1. (a) Geometry of the proposed slot-ring antenna; (b) photograph of the manufactured antenna.

thickness $h = 1.5\,\mathrm{mm}$. The size of the substrate is $L \times W$. The antenna consists of ground plane and an L-shaped strip on the other side of the substrate. To obtain broadband radiation pattern, a tapered slot ring is cut in the ground plane of the substrate. The tapered slot ring can be recognized as a parasitic circular patch placed in an elliptical slot. The x and y axes of the elliptical slot are denoted with R_1 and R_2. R is the radius of the circular patch. The offset distance from the edge of the circular patch to the margin of the elliptical slot is g. To achieve the CP radiation characteristic, an L-shaped strip coupling to the elliptical-ring slot is employed to answer the requirement of excitation of two orthogonal resonant modes with the same amplitude and 90° phase difference. The L-shaped strip has a characteristic impedance of $50\,\Omega$ with width of w_1 and length of l_1. By adjusting lengths l_1 and l_2 of the open stub of the L-shaped strip, good axial ratio and impedance matching performance can be obtained.

To strengthen our understanding of the working principles and design rules, we thoroughly studied the parameters of the proposed antenna. Figure 2 shows return loss and axial ratio versus frequency with different length l_1 variation: 20 mm, 22 mm, 24 mm and 25 mm. It is apparent that the center frequency of the return loss shifts down toward the lower frequency, and the bandwidth of axial ratio becomes narrower as the length of l_1 increases, because the value of the coupling between the L-shaped strip and the elliptical-ring slot at PART II in Figure 1(a) is mismatched or unbalanced compared to that at PART I. The effects of different lengths l_2, 15.5 mm, 17.5 mm, 19.5 mm and 21.5 mm, are studied. It can be seen that as the length l_2 increases, return loss reaches about $-30\,\mathrm{dB}$, and the bandwidth of axial ratio becomes wider.

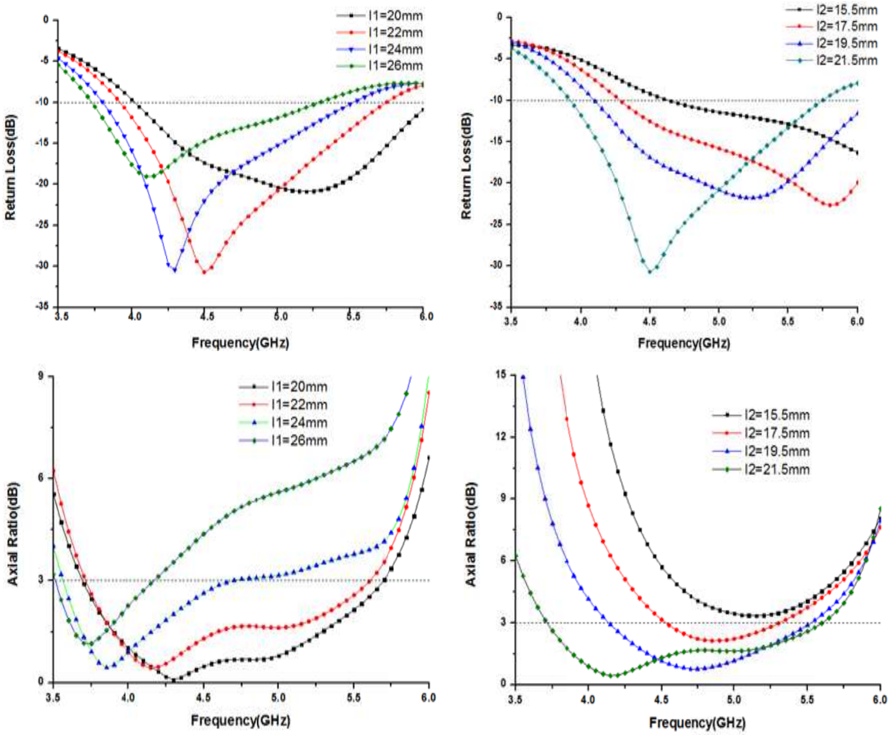
Simulation design for the CP antenna including a SMA feed connector model was carried out using HFSS, a commercially available software. The final optimal dimensions of the proposed antenna listed in Table 1 were determined by simulation adjustment.

3. RESULTS AND DISCUSSIONS

A prototype of the proposed antenna with the above optimal dimensions is fabricated and measured by a Wiltron-37269A network

Table 1. The optimal dimensions of the proposed antenna.

L	W	l_1	w_1	l_2	w_2	R	R_1	R_2	g
50	44	22	2.5	21.5	1	7	24	14.4	2



(a) (b)

Figure 2. Comparison of the simulated return loss and axial ratio in terms of the different length (a) l_1 and (b) l_2.

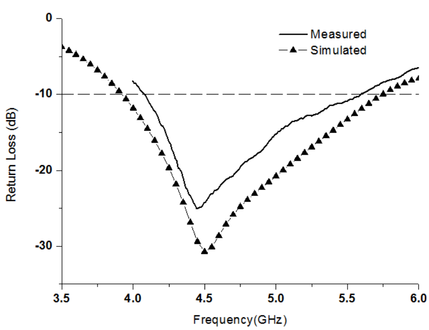


Figure 3. Return loss versus frequency of the proposed antenna.

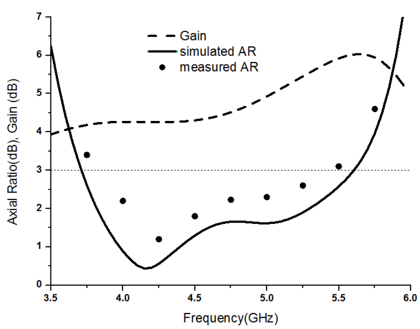


Figure 4. Axial ratio and gain versus frequency in the direction of boresight.

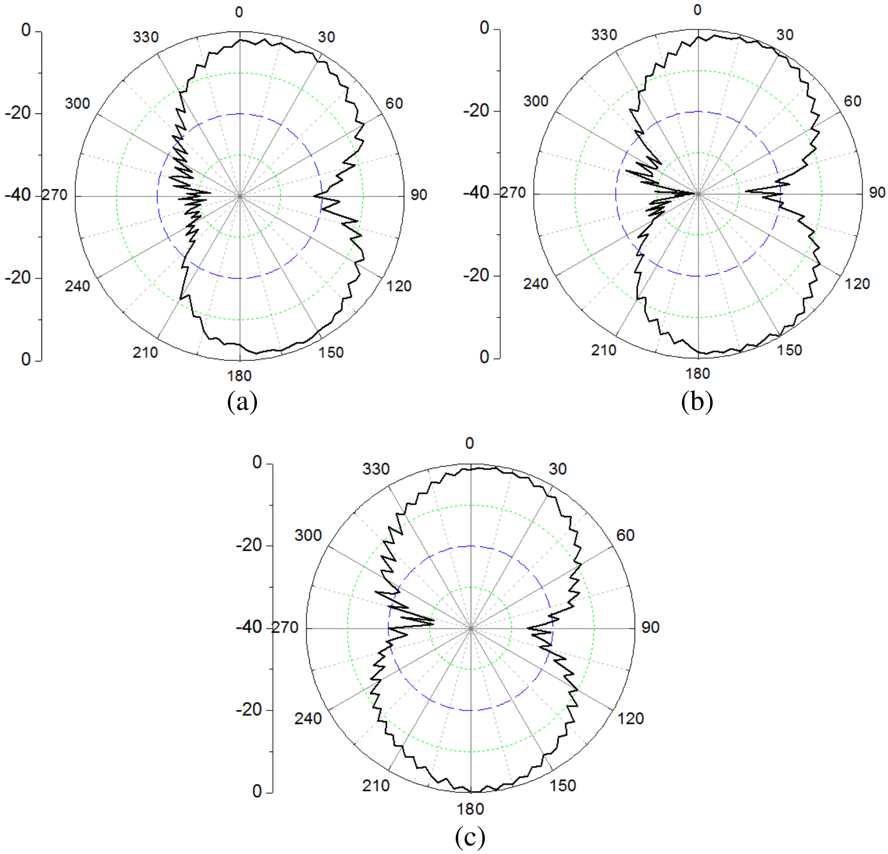
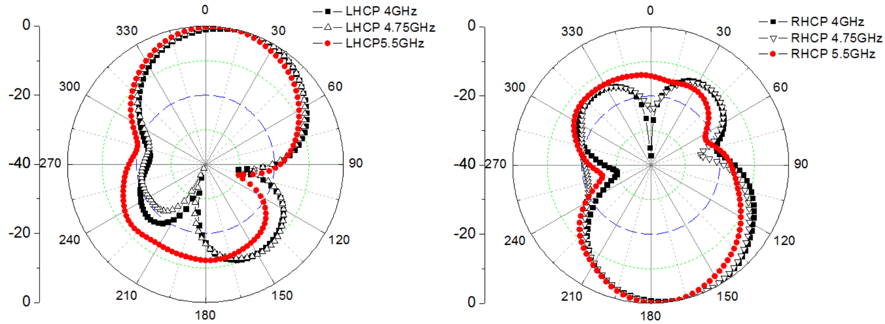


Figure 5. Spinning-horn measured radiation patterns for the proposed CP antenna in the XOZ plane: (a) 4 GHz; (b) 4.75 GHz and 5.5 GHz.

analyzer. Figure 3 shows simulated and measured return loss versus frequency of the proposed antenna, which presents the impedance bandwidth ($S_{11} \leqslant -10$ dB) of the developed antenna with a bandwidth of 37.5% (3.9 GHz–5.7 GHz) in simulation and 33.3% (4 GHz–5.6 GHz) in measurement. It can be seen that there is a little discrepancy between the simulated and measured results because of the manual processing error and the effect of experimental instruments. Figure 4 shows the axial ratio and gain characteristics. The measured axial ratio bandwidth (AR $\leqslant$ 3 dB) of 34.7% (3.8 GHz–5.4 GHz) is obtained, and the gain reaches 6 dB with variation less than 2.1 dB in the direction of boresight.

The antenna shown in Figure 1 generates left hand circularly polarized (LHCP) radiation in the $+Z$ direction and right hand



(a) (b)

Figure 6. The simulated radiation patterns for (a) LHCP and (b) RHCP at 4 GHz; 4.75 GHz and 5.5 GHz.

circularly polarized (RHCP) radiation in the $-Z$ direction. When the L-shaped strip is mirrored to the other side, right hand circularly polarized (RHCP) radiation will be achieved in the same direction. Figure 5 plots the normalized XOZ plane spinning-horn radiation patterns at 4 GHz, 4.75 GHz, and 5.4 GHz, respectively. The simulated LHCP and RHCP radiation patterns at 4 GHz, 4.75 GHz, and 5.4 GHz are shown in Figures 6(a) and (b), respectively. The difference between the two sides of the radiation patterns around the symmetrical axis of the antenna is due to the effect of the induced surface currents on the L-shaped feed line.

4. CONCLUSION

A circularly polarized elliptical-ring slot antenna using an L-shaped coupling strip is proposed. The elliptical-ring slot can achieve broadband characteristics by making use of multi-modes of the tapered structure. The tapered slot is excited by L-shaped coupling strip which introduces two orthogonal modes with a 90° phased difference for CP operations. The proposed antenna shows a relatively wider impedance bandwidth ($S_{11} \leqslant -10$ dB) of 37.5% and axial ratio bandwidth of 34.7% (AR $\leqslant$ 3 dB) compared to the antennas with series feed structure and resistor loading. The proposed antenna with a simple structure and good CP performance is fabricated easily and suitable for the modern wireless communication system.

REFERENCES

1. Jou, C. F., J.-W. Wu, and C.-J. Wang, "Novel broadband monopole antennas with dual-band circular polarization," *IEEE Trans. on Antennas and Propag.*, Vol. 57, 1027–1034, Apr. 2009.
2. Huang, C.-Y., J.-Y. Wu, and K.-L. Wong, "Cross-slot-coupled microstrip antenna and dielectric resonator antenna for circular polarization," *IEEE Trans. on Antennas and Propag.*, Vol. 47, 605–609, Apr. 1999.
3. Batchelor, J. C. and R. J. Langley, "Microstrip annular ring slot antennas for mobile applications," *Electronics Letters*, Vol. 32, 1635–1636, Aug. 1996.
4. Wong, K.-L., C.-C. Huang, and W.-S. Chen, "Printed ring slot antenna for circular polarization," *IEEE Trans. on Antennas and Propag.*, Vol. 50, 75–77, Jan. 2002.
5. Chang, T.-N., "A CPW-fed annular slot-antenna with an L-shaped strip," *Microwave Opt. Technol. Lett.*, Vol. 53, 2821–2827, Dec. 2011.
6. Hsieh, T. H. and J. S. Row, "Design of dual-frequency circularly-polarized slot antennas with switchable frequency," *Microwave Opt. Technol. Lett.*, Vol. 52, 2023–2029, Jun. 2010.
7. Wang, C.-C., T.-Y. Lee, and J.-S. Row, "A simple design for circularly polarized ring-slot antennas," *Microwave Opt. Technol. Lett.*, Vol. 53, 2262–2265, Oct. 2011.
8. Liu, W.-L., M.-Y. Chen, and T.-R. Chen, "A design for circularly polarized ring slot antennas backed by thin grounded substrate," *Microwave Opt. Technol. Lett.*, Vol. 54, 1549–1775, Jul. 2012.
9. Row, J.-S., "The design of a squarer-ring slot antenna for circular polarization," *IEEE Trans. on Antennas and Propag.*, Vol. 5, 1967–1972, Jun. 2005.