*Progress In Electromagnetics Research Letters, Vol. 28, 83–90, 2012*

# A NOVEL COMPACT PRINTED ANTENNA WITH CIRCULARLY POLARIZED CHARACTERISTIC

**W.-M. Li*, Y.-C. Jiao, and J. Huang**

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

**Abstract**—A new design of a circularly polarized single-layer antenna which has a compact structure of $10\,\text{mm} \times 20\,\text{mm} \times 1\,\text{mm}$ is presented. The proposed antenna only consists of a feedline and a rectangular ground plane both printed on the same metallic layer. To compact the antenna size and overcome the high impedance problem, the circular polarization (CP) operation can be attained by locating the feedline at the left of the ground plane. Parameters such as substrate length and patch length are investigated and design results from parametric simulations are presented.

## 1. INTRODUCTION

In order to reduce the loss caused by the misalignment between the signal and the receiving antenna and allow more flexible orientation of the transmitter and receiver antennas, the circularly polarized microstrip antennas [1] with small size, light weight and low profile win more and more applications in wireless communications. However, some traditional proximity coupled CP microstrip antennas [2] have more complex geometry, larger size or higher loss at the feeding network compared to the newly reported antennas. It is well known that, the small size is an important requirement for portable communication equipment, and high data-rate capability in a communication standard has to be supported by antennas which have large operating bandwidth. In view of these perspectives, the need for broadband CP antennas is inevitable. To meet these requirements of wireless data transformation communication systems, such as wireless local area network (WLAN) band, research into broadband circularly polarized antennas with compact structures has covered many aspects

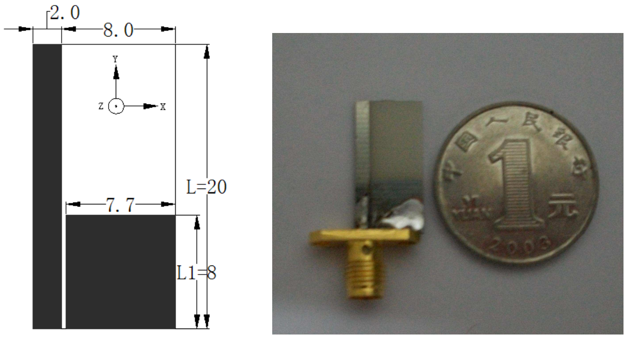
*Received 20 October 2011, Accepted 30 November 2011, Scheduled 6 December 2011*
* Corresponding author: Wei-Mei Li (li_weimei@163.com).

and several designs of circular polarization (CP) have been reported [3–5]. Different techniques have been proposed in previous reports [6–11] for reducing antenna size and increasing bandwidth. In these designs, compact CP operation is achieved by using high dielectric constant material [6], square or annular rings patch [7, 8], stacking several levels [9], modification of the feeding network [8, 9] and surface etching [10], but putting slots or slits causes reduction in the antenna bandwidth. The methods of corrugated configuration and spur-like strip have been reported to reduce the antenna size in [10, 11] respectively, and many related compact antennas fed by a coplanar waveguide (CPW) line with broad-band property [12, 13] and circularly polarized radiation have also been reported, but the size of these antennas is still not small enough and their structures are too complex, and the bandwidths of some do not met the requirements for broadband of the circularly polarized antenna.

This paper presents a novel compact printed antenna with circular polarization and a small structure of 20 mm × 10 mm × 1 mm. The achieved fractional 3-dB axial ratio (AR) bandwidth is up to 14.5%, covering 5.725 to 5.825 GHz (specified by IEEE 802.11a) bands for wireless communication, and it can be easily integrated with other RF front-end circuits in a conventional printed circuit board (PCB). The simulated antenna structure has also been fabricated using PCB, both the simulated and measured results are provided to validate the CP performance of the proposed antenna in the following sections.

## 2. ANTENNA DESCRIPTION

The configuration of the proposed printed antenna with broad-band circular polarization is presented in Figure 1. The conductor is printed on an inexpensive FR-4 substrate of $h = 1$ mm, relative permittivity $\varepsilon_r = 4.4$ and dielectric loss tangent of 0.02. The proposed antenna only consists of a ground plane and a feedline. The width of the feedline and the gap between the feed line and the ground plane are 2 mm and 0.3 mm, respectively. The feed dimensions are fine designed to obtain 50 Ω impendence. To find optimized parameters of the proposed antenna structure, numerical work was carried out using a commercially available software package HFSS and included a SMA feed connector model. The feed line together with the ground plane is applied to generate a resonator for exciting two orthogonal modes with equal amplitude and 90° phase difference at a given frequency to create the circular polarization. The load position of the feed line at the left of the ground plane can cause meandering of the surface current paths [3], which lead to lower the resonant frequency of the antenna,




(a) (b)

**Figure 1.** Geometry and dimensions of the proposed circularly polarized antenna: (a) design schematic figure; (b) photograph of the manufactured antenna.

corresponding to a reduced antenna size compared to a conventional circularly polarized CPW-fed antenna for a given operating frequency.

To illustrate the CP mechanism, the simulated surface current distributions are plotted in Figure 2 at phase $= 0°$, $90°$, $180°$, and $270°$. When phase $= 0°$, the dominant surface currents lines are along the $+X$ direction. For the $90°$ phase, the dominant surface currents are changed along the $-Y$ direction, while currents in the feedline is phase opposed to adjacent the ground plane edge currents. At phase $= 180°$, the principal currents flows along the $-X$ direction while the principal currents flow in the $+Y$ direction for phase $= 270°$. As can be seen from Figure 2 that the surface current distributions in $180°$ and $270°$ are equal in magnitude and opposite in phase of $0°$ and $90°$, respectively. It also can be observed from Figure 2 that the direction of the surface current in the ground plane varied with similar fashion as the principle surface current which rotates in the clockwise (CW) direction. As a result, the antenna is able to radiate the left-hand circular polarization (LHCP) in the $+Z$ direction. By varying the surface current distributions as a function of frequency within the circularly polarized bandwidth, the proposed design is able to generate LHCP radiation at the boresight ($+Z$) and RHCP radiation at the backside ($-Z$) direction in a similar fashion.

Furthermore, through experimental and theoretical analysis, we find that the lengths of the substrate ($L$) and the ground plane ($L_1$) have a sensitive effect on the axial ratio (AR) and voltage standing wave ratio (VSWR). As can be seen from Figure 3 that the 3-dB AR bandwidth increases with the increase of the length $L$ of the

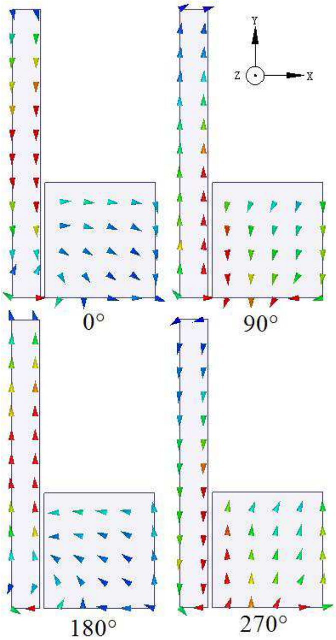



**Figure 2.** Simulated surface current distributions for orthogonal phases.

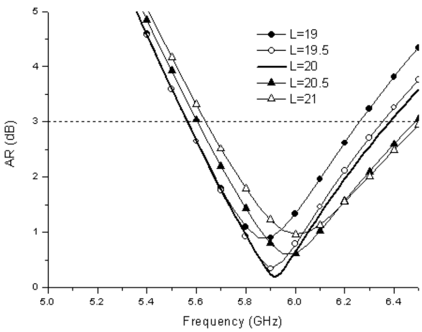



**Figure 3.** Simulated AR of the proposed antenna with different $L$ values.

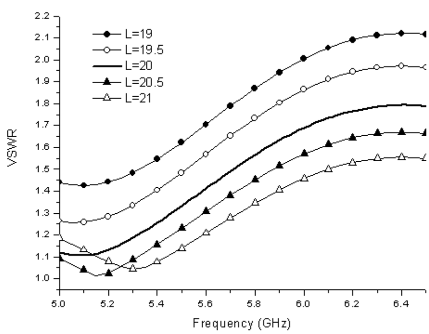



**Figure 4.** Simulated VSWR of the proposed antenna with different $L$ values.

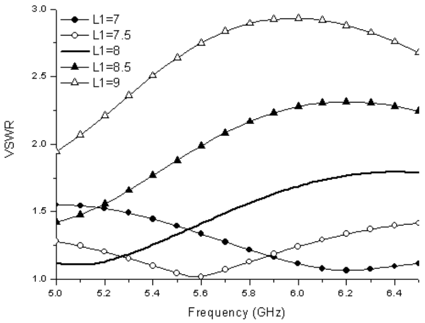



**Figure 5.** Simulated VSWR of the proposed antenna with different $L_1$ values.

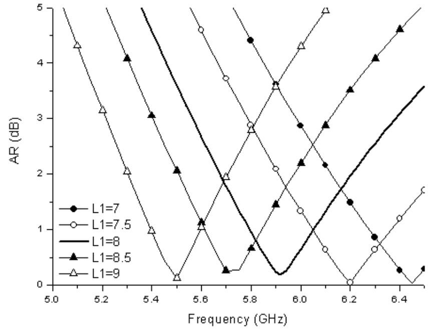



**Figure 6.** Simulated AR of the proposed antenna with different $L_1$ values.

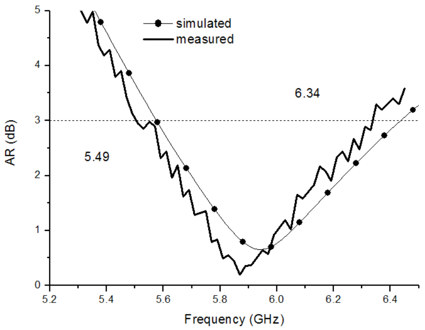



**Figure 7.** Measured and simulated AR for the proposed antenna.

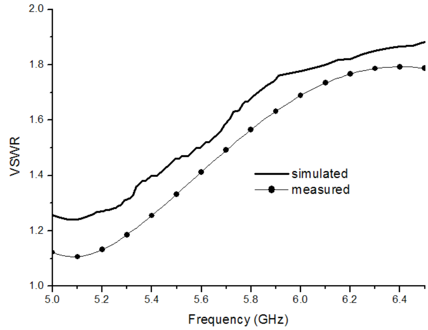
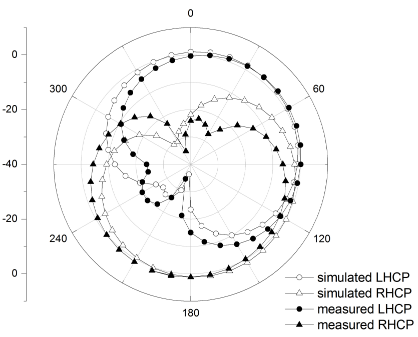
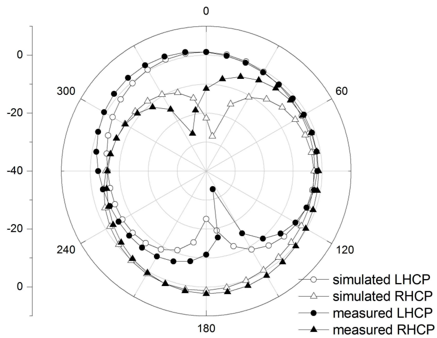



**Figure 8.** Measured and simulated VSWR for the proposed antenna.

feedline, whereas the minimum value of the center frequency occurred at $L = 20$ mm. Figure 4 shows that the impedance matching becomes better in a regular rule as $L$ increases when all other parameters are fixed. Considering the AR, a value of 20 mm is optimum from Figure 3 and Figure 4. Figure 5 illustrates the sensitivity of the impedance to variation in the ground plane length $L_1$. In addition to impedance matching, the ground plane also affects the CP mode frequency. Figure 6 shows that the CP center frequency shifts downwards as $L_1$ increases from 7 mm to 9 mm. These parametric studies have helped to facilitate the design of a compact wideband circularly polarized antenna.




(a)




(b)

**Figure 9.** Radiation pattern of the proposed antenna (in dB): (a) $XZ$-plane, (b) $YZ$-plane.

## 3. ANTENNA PERFORMANCES

The proposed antenna is measured by a Wiltron-37269A network analyzer to evaluate its performance. In this section, simulated and measured VSWR, axial ratio and radiation patterns are presented. Figure 7 presents the simulated and measured variations of the axial ratio as a function of frequency at broadside direction. From the figure, the measured axial ratio attains a minimum value at resonance frequency of 5.83 GHz, and the measured 3-dB AR bandwidth is of 0.85 GHz from 5.49 to 6.34 GHz (14.5% at 5.83 GHz) with slight shift toward lower frequency compared to the simulated one. The measured variation of the VSWR for the compact antenna as a function of frequency is shown in Figure 8. It can be seen this antenna presents impedance bandwidth more than 1.5 GHz or more than 25% with respect to the central frequency. Due to the limitations of applied simulation software, the difference between the simulated and the measured environments, fabrication tolerances of the antenna and the measuring errors, there is a slight deviation in simulated and measured values.

The simulated and measured normalized LHCP and RHCP radiation patterns in the $XZ$-plane and $YZ$-plane for frequency of 5.83 GHz are shown in Figures 9(a) and (b), respectively. The cross-polarizations can keep more than 15 dB lower than the co-polarizations in each plane. The patterns are mainly LHCP for $Z > 0$ and RHCP for $Z < 0$. Experimental results show the proposed antenna has good CP characteristics for both RHCP and LHCP.

## 4. CONCLUSION

A novel compact antenna has been proposed for CP operations just using the feedline and the ground plane. The designed antenna was measured to present 3-dB AR bandwidth of 0.85 GHz from 5.49 to 6.34 GHz approximately 14.5% with respect to the center frequency at 5.83 GHz, along with an even larger impedance bandwidth of more than1.5 GHz corresponding to a fractional bandwidth of more than 25% with respect to center frequency. The proposed design offers advantages in structure, size, weight, fabrication and performances, which make the proposed antenna suitable for integration into RF circuitry and a good candidate in commutation systems.

## REFERENCES

1. Lai, C.-H., T.-Y. Han, and T.-R. Chen, "Circularly-polarized reconfigurable microstrip antenna," *Journal of Electromagnetic Waves and Applications*, Vol. 23, No. 2–3, 195–201, 2009.
2. James, J. R. and J. R. James, *Handbook of Microstrip Antennas*, Peter Peregrinus Ltd., London, UK, 1989.
3. Li, J.-F., B.-H. Sun, H.-J. Zhou, and Q.-Z. Liu, "Miniaturized circularly-polarized antenna using tapered meander-line structure," *Progress In Electromagnetics Research*, Vol. 78, 321–328, 2008.
4. Yu, A., F. Yang, and A. Z. Elsherbeni, "A dual-band circularly polarized ring antenna based on composite right and left handed metamaterials," *Progress In Electromagnetics Research*, Vol. 78, 73–81, 2008.
5. Heidari, A. A., M. Heyrani, and M. Nakhkash, "A dual-band circularly polarized stub loaded microstrip patch antenna for GPS applications," *Progress In Electromagnetics Research*, Vol. 92, 195–208, 2009.
6. Lo, T. K., H. Chun-On, Y. Hwang, E. K. W. Lam, and B. Lee, "Miniature aperture-coupled microstrip antenna of very high permittivity," *Elect. Lett.*, Vol. 33, No. 1, 9–10, Jan. 2, 1997.
7. Guo, Y.-X., L. Bian, and X. Q. Shi, " Broadband circularly polarized annular-ring microstrip antenna," *IEEE Trans. Antennas Propag.*, Vol. 57, No. 8, 2474–2477, Aug. 2009.
8. Tong, K.-F. and J. Huang, "New proximity coupled feeding method for reconfigurable circularly polarized microstrip ring antennas," *IEEE Trans. Antennas Propag.*, Vol. 56, No. 7, 1860–1866, Aug. 2008.

9. Sun, X., Z. Zhang, and Z. Feng, "Dual-band circularly polarized stacked annular-ring patch antenna for GPS application," *IEEE Antennas Wireless Propag Lett.*, Vol. 10, 49–52, 2011.
10. Chen, C. H., E. K. N. Yung, and B. J. Hu, "Miniaturized CPW-fed circularly polarized corrugated slot antenna with meander line loaded," *Elect. Lett.*, Vol. 43, No. 25, 1404–1405, Dec. 6, 2007.
11. Sze, J.-Y. and Y.-H. Ou, "Compact CPW-fed square aperture CP antenna for GPS and Inmarsat applications," *Microw. Opt. Technol. Lett.*, Vol. 49, No. 2, 427–430, Feb. 2007.
12. Felegari, N., J. Nourinia, C. Ghobadi, and J. Pourahmadazar, "Broadband CPW-fed circularly polarized square slot antenna with three inverted-L-shape grounded strips," *IEEE Antennas Wireless Propag. Lett.*, Vol. 10, 274–277, 2011.
13. Sze, J.-Y., C.-I. G. Hsu, Z.-W. Chen, and C.-C. Chang, "Broadband CPW-Fed circularly polarized square slot antenna with lightening-shaped feedline and inverted-L grounded strips," *IEEE Trans. Antennas Propag.*, Vol. 58, No. 3, 973–977, Mar. 2010.