Wideband Circularly Polarized Antenna Based on Ring Traveling Wave

Weiwen Li, Guang Yang, Qiuhao Li

December 2022

1 Introduction

Circularly polarized (CP) planar antennas of low profile and compact structure allow more flexible orientation of the transmitter and receivers. Two orthogonal equal-amplitude linear polarization field components of the phase quadrature introduced by perturbing the rectangular or circular patch element can be synthesized to radiate circularly polarized waves [1]. However, this single-fed antenna is difficult to achieve a wide operating band. In fact, multiple feed methods are usually used to efficiently generate a circularly polarized wave. In this regard, it is necessary to utilize power-dividing and phase-shifting components to form a quadrature feeding network [2]–[4].

Circularly polarized waves can also be radiated by loop patch antennas using two working mechanisms. One is to synthesize two orthogonal resonance modes of the loop, which is consistent with the circular polarization realization of a rectangular microstrip antenna[5], [6]. Here, this is called the synthesized circular polarization of the loop antenna. The other is to directly excite the ring traveling wave current on the loop antenna to achieve circular polarization, which is called traveling-wave circular polarization of the loop antenna. Normally, the single fed loop antenna radiates linearly polarized waves. However, it is demonstrated that a uniform traveling-wave current can be obtained on a circular loop of one wavelength perimeter by loading a lumped reactance at a position of 45 degree from the feed point [7]. In this case, the specific reactance value can be derived by using an equivalent circuit [8], [9]. These traveling-wave rings are usually placed above the ground plane, which also facilitates the selection of lumped components on the ring. Traditionally, the allowable 3-dB axial ratio (AR) bandwidth is typically less than 10% for the single-fed cases [10].

In our opinion, since the ring current on a conductor loop is an inductive mode, the effective ring traveling-wave distribution can be achieved by introducing capacitive component into the ring structure and combining the design of feed structure to compensate for the inductive component. Based on this idea, with the help of characteristic mode analysis, a patch ring structure is adjusted and a coupled feed network is applied to realize the circularly polarized radiation of printed annular ring antenna. Operating in 2.4-GHz band, the

proposed antenna can achieve an impedance bandwidth of 2.20–2.85 GHz (relative bandwidth of 26%), and a 3-dB axial ratio bandwidth of 2.23–2.48 GHz (relative bandwidth of 10.6%). Structural parameter analysis shows that it has large structural tolerances.

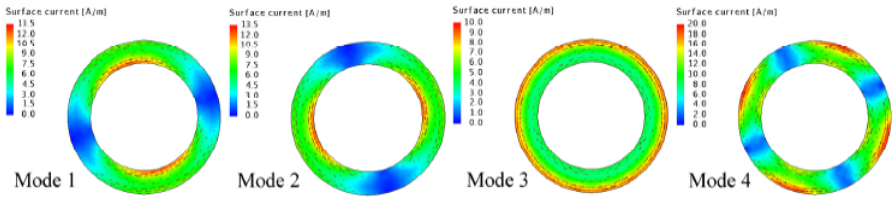

Figure 1: Characteristic current distributions

2 Conclusion

For an annular conductor patch, a ring traveling wave current can be realized by cutting a wide slot in the ring structure and by capacitive coupling feeding, and thus the circularly polarized radiation is generated. Utilizing such an annular patch structure, a compact broadband antenna with a relative impedance bandwidth of 26% and a relative axial ratio bandwidth of 10.6% has been achieved, which can be applied to small indoor base station systems. Meanwhile, this antenna can maintain circular polarization characteristics over a wide range of spatial angles, and also shows good structural tolerance capabilities. Although it begins with the characteristic mode analysis of the loop patch structure, in essence, the ring traveling wave is implemented through double reactance loading.

References

[1] K. P. Yang and K. L. Wong, "Dual-band circularly-polarized square microstrip antenna," *IEEE Trans. Antennas Propag.*, vol. 49, no. 3, pp.377–382, Mar. 2001.

[2] J. S. Row, "Design of aperture-coupled annular-ring microstrip antennas for circular polarization," *IEEE Trans. Antennas Propag.*, vol. 53, no. 5, pp. 1779–1784, May 2005.

[3] Z. Wang, S. Fang, S. Fu, and S. Lu, "Dual-band probe-fed stacked patch antenna for GNSS applications," *IEEE Antennas Wireless Propag. Lett.*, vol. 8, pp. 100–103, 2009.

[4] Y. Zhou, S. Koulouridis, G. Kiziltas, and J. L. Volakis, "A novel 1.5" quadruple antenna for tri-band GPS applications," *IEEE Antennas Wireless Propag. Lett.*, vol. 5, pp. 224–227, 2006.

[5] H. M. Chen and K. L. Wong, "On the circular polarization operation of annular-ring microstrip antennas," *IEEE Trans. Antennas Propag.*, vol.47, no. 8, pp. 1289–1292, Aug. 1999.

[6] J. S. Row, "Design of square-ring microstrip antenna for circular polarization," *Electron. Lett.*, vol. 40, no. 2, pp. 93–95, Jan.2004.

[7] S. Okubo and S. Tokumaru, "Reactively loaded loop antennas with reflectors for circular polarization," *Trans. IECE Jpn.*, vol. J65-B, no. 8, pp.1044–1051, Aug. 1982.

[8] R. L. Li, N. Bushyager, J. Laskar, and M. M. Tentzeris, "Circular loop antennas reactively loaded for a uniform traveling-wave current distribution," *in Proc. IEEE Antennas Propag. Soc. Int. Symp.*, vol. 3B, Jul. 2005, pp. 455–458.

[9] R. Li, N. A. Bushyager, J. Laskar, and M. M. Tentzeris, "Determination of reactance loading for circularly polarized circular loop antennas with a uniform traveling-wave current distribution," *IEEE Antennas Wireless Propag. Lett.*, vol. 53, no. 12, pp. 3920–3929, Dec. 2005.

[10] Y. X. Guo, L. Bian, and X. Q. Shi, "Broadband circularly polarized annular-ring microstrip antenna," *IEEE Trans. Antennas Propag.*, vol.57, no. 8, pp. 2474–2477, Aug. 2009.