Wideband probe-fed circularly polarised circular loop antenna

R.L. Li, J. Laskar and M.M. Tentzeris

A wideband probe-fed circularly polarised circular loop antenna is presented. The wideband performance is achieved by introducing a parasitic loop inside the original loop that is driven by a feed probe. It is found that the 2 dB axial ratio bandwidth can be increased from 6% for a single circular loop to 16% by the introduction of a parasitic loop.

Introduction: In recent years, circularly polarised (CP) planar antennas have received much attention for wireless applications because they not only are able to reduce the multipath effects [1] but also allow more flexible orientation of the transmitter and receiver antennas [2]. The simplest feeding structure for circular polarisation is a single probe feed since it does not require a quadrature hybrid or a balun circuit. However, a probe-fed CP antenna usually has a narrow bandwidth. For example, the 2 dB axial ratio (AR) bandwidth for a probe-fed circular loop antenna is less than 6% [3–5]. For wireless communication applications, such as the PCS band (1.77–1.99 GHz) and the WLAN in 5 GHz UNII band (5.15–5.85 GHz), the bandwidth requirement is more than 10%.

In this Letter, we enhance the bandwidth of a probe-fed circular loop antenna by introducing a parasitic loop inside the original loop that is directly driven by a feed probe. The parasitic loop is electromagnetically coupled to the driven loop, helping improve the bandwidth of the loop antenna.

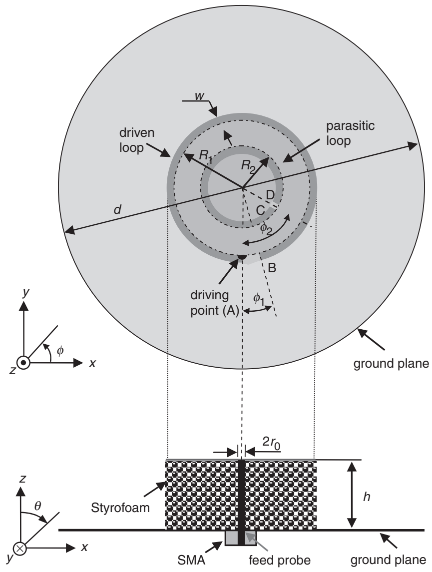

Fig. 1 *Geometry of wideband probe-fed circularly polarised circular loop antenna*

Antenna configuration: The geometry of a probe-fed CP circular loop antenna is shown in Fig. 1. The antenna consists of two concentric circular wire loops: an outer loop and an inner loop, which are backed by a ground plane at a height h for unidirectional radiation. The outer loop is directly driven by a feed probe that is connected to the inner conductor of an SMA connector (its outer conductor is soldered to the ground plane). To radiate a CP wave, there is a small gap (the gap width is defined by an angle ϕ_1) on the outer loop. The inner loop (also with a small gap) serves as a parasitic element which is electromagnetically coupled to the outer loop. By adjusting the loop radii (R_1 for the outer loop and R_2 for the inner loop), the gap width ϕ_1, the gap position (ϕ_2), and the height h, a wideband performance for circular polarisation can be achieved. We fabricated a wideband CP loop antenna for operating in the 5 GHz UNII band. The outer and inner loops were printed on a thin dielectric substrate (substrate thickness = 0.127 mm) with a low dielectric constant (RT/Duroid 5880, $\varepsilon_r = 2.2$). The printed circular loops were mounted above a circular copper plate (diameter $d = 60$ mm) with the support of a piece of Styrofoam ($\varepsilon_r \cong 1.03$). The feed probe was formed by the extension of the inner conductor (radius $r_0 = 0.62$ mm) of a PE4000 SMA connector. The strip width of the printed loops was chosen to be $w = 4r_0$.

The antenna was initially designed using a method-of-moment based software, *NEC 1.1*, and optimised by a full-wave (transmission-line matrix method based) design tool, *Microstripes 6.5*. By simulation, the optimised geometrical parameters for the wideband CP loop antenna were found to be $R_1 = 11$ mm, $R_2 = 7$ mm, $\phi_1 = 15°$, $\phi_2 = 60°$ (the gap width on the inner loop was 0.6 mm), and $h = 11$ mm.

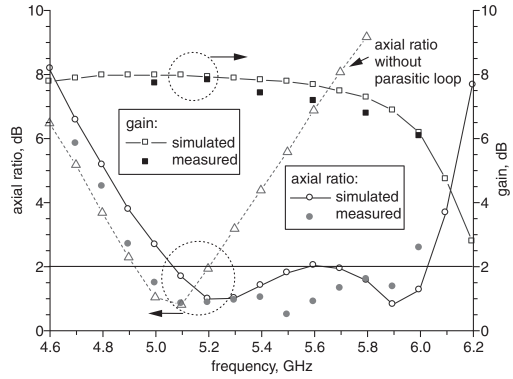

Fig. 2 *Simulated and measured results for axial ratio and gain of wideband probe-fed circular loop antenna*

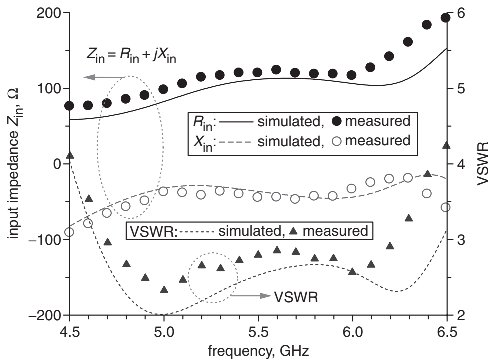

Fig. 3 *Frequency characteristics of input impedance of wideband probe-fed circular loop antenna*

Results: Fig. 2 shows the simulated and measured results for the on-axis (in the z direction) axial ratio and gain of the wideband probe-fed CP loop antenna. It is found that the bandwidth for AR ≤ 2 dB of the wideband probe-fed loop antenna is about 16%, which can cover the entire 5 GHz UNII band. For comparison, the axial ratio simulated for the probe-fed loop antenna without the parasitic loop is also plotted in Fig. 2, which shows a 2 dB AR bandwidth of less than 6%. Obviously the parasitic loop plays an important role for the bandwidth enhancement. The reason for this phenomenon is that the driven loop can only create one minimum AR point while the parasitic loop produces an additional minimum AR point. An appropriate combination of the two minimum AR points results in a significant enhancement for the CP bandwidth. The gain of the antenna is around 6–8 dBi. The decreased gain with increasing frequency is due to a slight shift of the direction of maximum radiation from the z-axis. The frequency response of input impedance of the antenna is presented in Fig. 3. It can be seen that over the AR ≤ 2 dB bandwidth the input impedance is close to 100–150 Ω, which can easily match to a 100 Ω (VSWR < 1.5) or a 75 Ω (VSWR < 2) system. For a 50 Ω system, the voltage standing-wave ratio (VSWR) is found to be less than 3. Fig. 4 shows the radiation patterns in the principle planes ($\phi = 0°$ and $\phi = 90°$ planes) at 5.2 and 5.8 GHz. Good agreement is observed between the simulated and measured results. The radiation pattern becomes asymmetrical with the z-axis because of a non-uniform current distribution along the circular loops. The current distribution calculated at 5.5 GHz is plotted in Fig. 5, which shows a smoothly decaying travelling-wave current both on the driven loop and on the parasitic loop. This contributes to the production of a desirable CP wave.

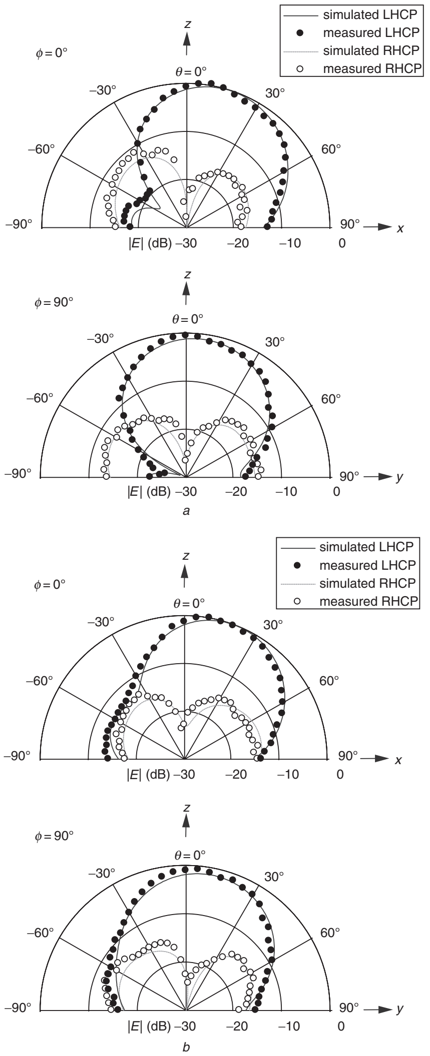

Fig. 4 *Radiation patterns of wideband probe-fed circular loop antenna*

a At 5.2 GHz
b At 5.8 GHz

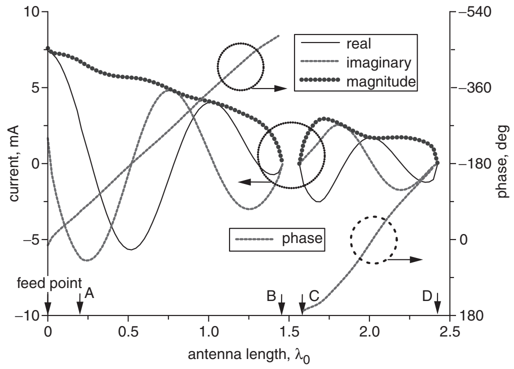

Fig. 5 *Current distribution of wideband probe-fed circular loop antenna at 5.5 GHz*

λ_0 = free-space wavelength at 5.5 GHz

Conclusion: A wideband probe-fed CP circular loop antenna has been developed in the 5 GHz UNII band. By introducing a parasitic loop, the AR bandwidth is significantly increased. This antenna has a 2 dB AR bandwidth of 16% with a gain of 6–8 dBi. It may find wide applications in wireless communications.

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References

1 Manabe, T., Miura, Y., and Ihara, T.: 'Effect of antenna directivity and polarization on indoor multipath propagation characteristics at 60 GHz', *IEEE J. Sel. Areas Commun.*, 1996, **14**, (3), pp. 441–448
2 Heikkinen, J., and Kivikoski, M.: 'Low-profile circularly polarized rectifying antenna for wireless power transmission at 5.8 GHz', *IEEE Microw. Compon. Lett.*, 2004, **14**, (4), pp. 162–164
3 Nakano, H., Yoshida, H., and Wu, Y.: 'C-figured loop antennas', *Electron. Lett.*, 1995, **31**, (9), pp. 693–694
4 Ojiro, Y., Hiraguri, T., and Hirasawa, K.: 'A monopole-fed circularly polarized loop antenna'. IEEE AP-S Int. Symp., 1998, pp. 810–813
5 Li, R.L., Fusco, V., and Nakano, H.: 'Circularly polarized open-loop antenna', *IEEE Trans. Antennas Propag.*, 2003, **51**, (9), pp. 2475–2477