A Circularly-Polarized Microstrip Monopole Antenna by Utilizing Dual-Loop Topology

#Yang Dai, Jin-Wei Wu, Chien-Jen Wang
Department of Electrical Engineering, National University of Tainan
33, Sec. 2, Shu-Lin St. ,Tainan 700, Taiwan , Email:cjwang@mail.nutn.edu.tw

Abstract

A broadband microstrip-fed monopole antenna with circular polarization (CP) is presented in this paper. The suggested asymmetrical feeding and dual-loop topology can generate the two orthogonal modes for circular polarization. Parametric studies for the enhancement of circular polarization and impedance bandwidth are shown. The measured impedance bandwidth is about 3.66 GHz from 0.98 to 4.64 GHz, which covers most of the commercial communication systems. The 3-dB axial ratio (AR) bandwidth is 12% at 1.5 GHz.

Keywords : Monopole antenna, circular polarization (CP), loop-like.

1. Introduction

Automotive systems incorporating satellite receivers, especially those known as the GPS receiver, provide the global positioning service to users. In order to reduce the effect of multi-path interference, which produces fading, it is preferable to operate in the circular polarization (CP) mode for the satellite-to-ground communication systems. However, due to strongly linear polarization, in general, the monopole antenna can not excite the circularly polarized wave [1]. As conclusion, it will be an important research topic for the monopole antenna to achieve the circular polarization. In the recent, several studies about the circularly polarized monopole antenna have been proposed [2-4]. By adding an inverted-L sleeve at the ground plane of the C-like monopole, a traveling wave is excited which results in the circular polarization [2]. Another design of exciting circular polarization is to utilize a ground plane embedded with an inverted-L slit, which is capable of generating a resonant mode for broadband impedance-bandwidth, and excites two orthogonal E vectors with equal amplitude and phase difference (PD) of 90° [3]. In [4], an asymmetric-feed structure is used to provide an orthogonal component distinct from its original linear polarization. In addition, by embedding a slit and a stub on the ground plane, this antenna could generate CP wave radiation and achieve a broad impedance bandwidth.

In this paper, an asymmetrically feeding monopole antenna to achieve a broad impedance bandwidth and wideband CP is proposed. By using a rectangular dual-loop topology and tuning the separation between the ground plane and the antenna, the monopole antenna possesses a circular polarization. The measured results show that this antenna excites a broad impedance bandwidth of 130.7 % at a centre frequency of 2.8 GHz and a wideband CP radiation wave of 12 % with respect to a centre frequency of 1.5 GHz.

2. Antenna Design

The geometry of the proposed microstrip-fed circularly-polarized monopole antenna is illustrated in Fig. 1. It comprises an asymmetrically dual-loop monopole antenna and an asymmetrically feeding structure. The antenna is fabricated on an FR4 substrate, which has a relative permittivity of 4.4, a thickness of 1.6 mm and a loss tangent of 0.02. The design parameters of the proposed antenna after the optimization process are listed in Table I. Feeding structures are typically classified into two categories, central feeding and asymmetric feeding, which can cause different surface current distributions on an antenna. Figure 2(a) shows the surface current distribution for the central-feeding rectangular-loop antenna, which can be divided into vertical and horizontal currents. The distribution of the horizontal current excites two components that are 180°

out of phase. Therefore, the radiation in the far field in the horizontal direction is very weak. Thus, it is very difficult for a conventional monopole antenna to excite CP. The asymmetric-feeding case, on the other hand, generates two orthogonal currents, which include the vertical and horizontal currents, as shown in Fig. 2(b). Their amplitudes and PD cannot reach CP conditions; hence, the asymmetric feeding method can only excite an elliptically polarized wave. It is the reason that the feeding structure of the monopole antenna in this paper is asymmetrical. In order to enhance the PD, the dual-loop topology is utilized so that the CP mode can be easily excited.

3. Results and Discussion

For the original case of d = 0 mm and loop's width = 4.5 mm, the loop-like monopole antenna has multi-band frequency response. When d increases from 0 mm to 9.5 mm, the impedance matching condition over the observed frequency band except 2.4 GHz and 4.8 GHz. The bandwidths at each band are improved. After tuning the metal-line widths of each side of the rectangular loop, the reflection coefficients around 2.2, 3.1 and 4.0 GHz are effectively reduced so that the loop monopole antenna becomes wideband. Due to the unchanged phase characteristics, the AR is slightly affected. With the dual-loop topology, there is no apparent variation in the impedance matching condition and circular polarization of the antenna. The exhibits the comparison of the simulated reflection coefficients and axial ratios of the dual-loop monopole antenna when changing the separation s between the antenna and ground plane. Hence, an improvement in the AR is achieved by increasing the separation. However, for the case of s = 5.5 mm, the impedance matching condition becomes poor. Hence, s is set by 3.5 mm.

It is noted that the variation of the impedance matching condition of the dual-loop monopole antenna is unapparent by changing the widths (W_3, W_4) of the two loops. In order to have good AR, it is the requirement that the width W_3 is larger than the width W_4. The reason may be attributed to the criterion of PD = 90 degree for two orthogonal electrical fields. For the case of W_2 = 12.5 mm, because of the unequal powers of the two orthogonal electrical fields, the AR bandwidth decreases. Figure 3 and 4 illustrate the comparison of the reflection coefficients, axial ratios and phase differences of the proposed CP monopole antenna. The antenna attains a measured matching bandwidth (S_{11} < -10 dB) of 130.7 % (0.98-4.64 GHz). Moreover, the antenna attains a measured AR bandwidth (AR < 3 dB at broadside direction) of 12 % (1.41-1.59 GHz). The phase difference over the operated band is about at 270 degree (as similar as 90 degree). Fig. 5 shows the measured radiation efficiency of the proposed dual-loop monopole antenna. The radiation efficiency from 2.4 to 2.6 GHz is larger than 80 %. Compared to the studies in [2-4], it is unnecessary for the proposed antenna to cut the antenna and ground plane. The measured radiation patterns of the antenna at 1.4 GHz, 1.8 GHz, 2.4 GHz, and 4.0 GHz are shown in Fig. 6. It is noted that the antenna has large cross-polarized power level due to the asymmetrical feeding structure.

4. Conclusion

A design of the circularly polarized monopole antenna has been successfully demonstrated. By using the loop topology and the asymmetrical feeding structure, the proposed antenna can not only provide impedance bandwidth, but the axial-ratio bandwidth achieved is also wider than 12 %, respectively. The proposed antenna can be utilized to wideband multi-polarized systems, especially to reduce the Faraday's effect and mitigate interference effect.

References

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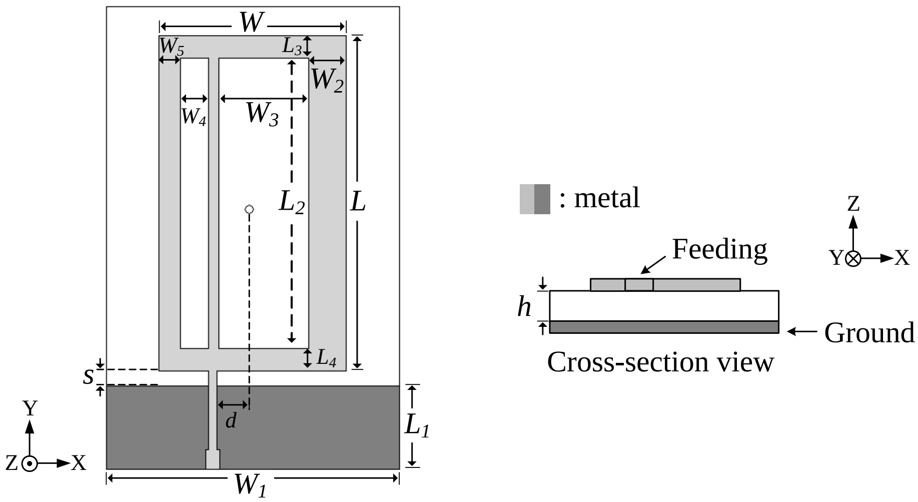
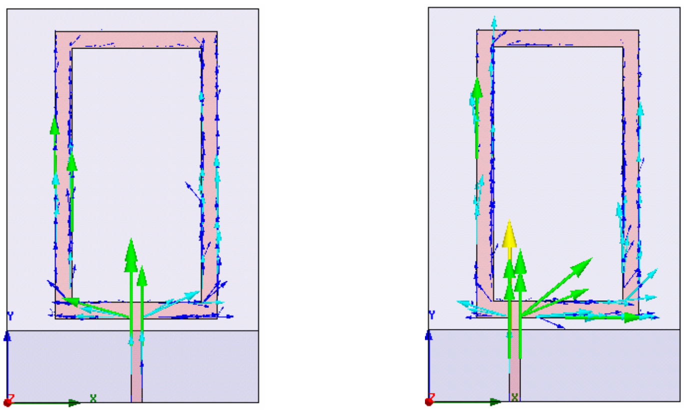


Figure 1 : Geometry of the proposed microstrip-fed circularly-polarized monopole antenna.

Table I : Design parameters of the proposed antenna after the optimization process.

Parameter	W	W_1	W_2	W_3	L	L_1	L_2	L_4	s	d	h
(mm)	45	70	9.5	21.45	80	20	69	5.5	3.5	8.45	1.6



(a) (b)

Figure 2 : Simulated surface current distribution of the loop-like monopole antenna: (a) central feeding; (b) asymmetrical feeding.

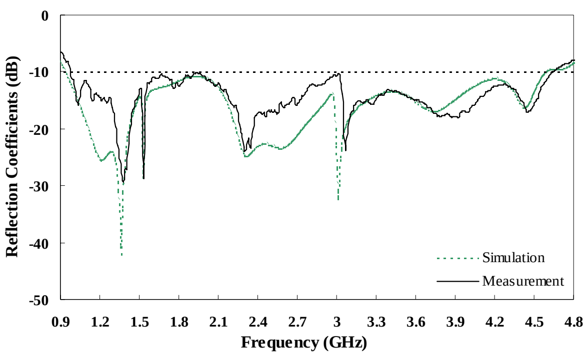


Figure 3 : Comparison of the reflection coefficients of the proposed CP monopole antenna.

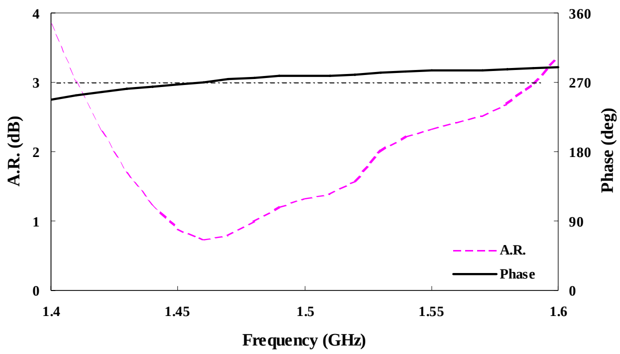


Figure 4 : Comparison of the axial ratios and phase differences of the proposed CP monopole antenna.

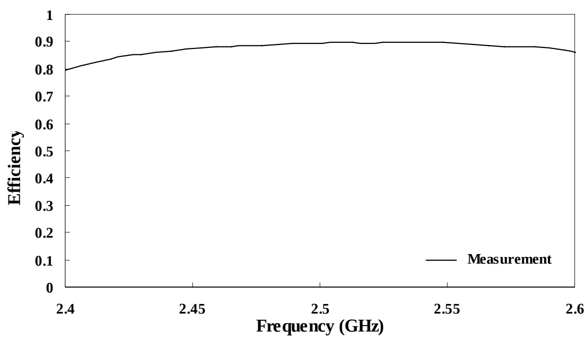


Figure 5 : Measured radiation efficiency of the proposed dual-loop monopole antenna.

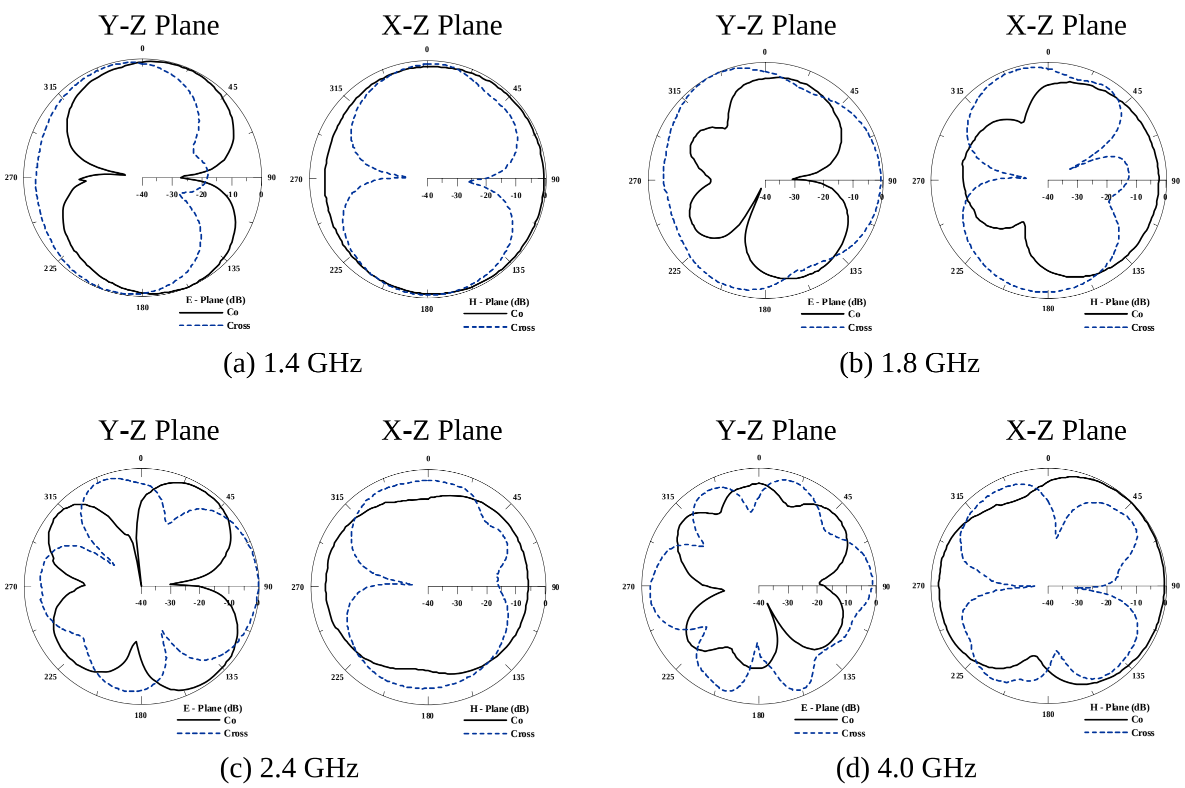


Figure 6 : Measured radiation patterns of the proposed dual-loop monopole antenna at 1.4 GHz, 1.8 GHz, 2.4 GHz, and 4.0 GHz.