A Dual-Band Circularly Polarized Planar Monopole Antenna for WLAN/Wi-Fi Applications

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***Abstract*—This letter presents a dual-band circularly polarized planar monopole antenna. The antenna consists of a radiator, a ground plane, and a microstrip line. The radiator is composed of a "C" shaped strip and an "L" shaped strip. The "C" shaped strip is mainly used for the higher band and the "L" shaped strip for the lower band. The overall dimension of the prototype is only $40mm \times 47mm \times 1.5mm$. The proposed antenna has been built and tested. Its measured -10dB impedance bandwidths are 380MHz (2.32-2.70GHz) in the lower band and 1240MHz (4.76-6GHz) in the higher band. Its measured 3dB axial-ratio (AR) bandwidths in the broadside direction are 180MHz (2.39-2.57GHz) in the lower band and 870MHz (5.13-6GHz) in the higher band. The overlapped impedance and AR bandwidths can fully cover all the 2.4/5.2/5.8 GHz WLAN bands and all the 2.4/5.5GHz Wi-Fi bands. The patterns have the characteristic of bidirectional radiation and the gains are stable in both bands.**

***Index Terms*—Monopole antenna, dual-band, circularly polarized.**

I. Introduction

WITH the rapid development of wireless communication technology, dual frequency bands at 2.45 and 5.5 GHz are popularly used in Wireless Local Area Network (WLAN) and Wireless Fidelity (Wi-Fi). Circularly polarized (CP) antennas can reduce polarization mismatch and multipath interference between the transmitter and receiver antennas. Therefore, CP antennas are more popular than linearly polarized (LP) antennas in practical WLAN/Wi-Fi applications. Antennas with dual-band and CP functions simultaneously are of great research importance and have a great prospect.

Planar monopole antennas are widely used in WLAN because of their compact dimension and multi-band operation capability. A planar monopole antenna in [1] operates in dual frequency bands and a planar monopole antenna in [2] can operate in triband. However, they are LP in the operating bands. On the other hand, there are some planar monopole antennas with the CP performance. A planar monopole antenna in [3] utilizes an unequal width ground plane to excite circular polarization. In [4], a vertical stub and a horizontal slit are used to make the planar monopole antenna obtain the CP performance. However, they are CP in only one frequency band. For the applications of two bands in WLAN, the demand for planar monopole antennas with the CP performance in dual-band is urgent. In [5], a planar monopole antenna has realized CP function in dual-band, which can cover 2.4/5.2GHz WLAN bands but cannot cover 5.8GHz WLAN band.

This letter presents a dual-band CP planar monopole antenna for WLAN/Wi-Fi applications. The antenna has a simple and compact structure with a total size of just $40mm \times 47mm \times 1.5mm$. The radiator is composed of two parts. A "C" shaped strip is mainly used to make the antenna obtain a good impedance match and CP performance in the upper band. An "L" shaped strip is mainly used for obtaining a good impedance match and CP performance in the lower band. The proposed antenna has a measured -10dB impedance bandwidth of 380MHz and a 3dB axial-ratio (AR) bandwidth of 180MHz in the lower band. The overlapped impedance and AR bandwidth can cover 2.4GHz WLAN/Wi-Fi band. In the upper band, it has a measured -10dB impedance bandwidth of 1240MHz and a 3dB AR bandwidth of 870MHz. The overlapped impedance and AR bandwidth can cover 5.2/5.8 GHz WLAN bands and 5.5GHz Wi-Fi band. Details of the antenna design and the simulated and measured results are presented and discussed in the following sections.

II. Antenna Design

Fig. 1 shows the geometrical configuration of the proposed antenna. It uses an inexpensive Teflon substrate with a thickness of 1.5mm and a relative permittivity of 2.65. The antenna is printed on the substrate and fed by a microstrip line. A radiator and a microstrip line are located above the substrate while a ground plane is located below the substrate.

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The “C” shaped strip on the left of the radiator is mainly used for producing resonance in the upper band and the length of the strip is approximately a quarter-wavelength at its operating frequency. The “L” shaped strip on the right of the radiator is mainly used for producing resonance in the lower band, which is approximately a quarter-wavelength. Geometric parameters of the antenna are listed in Table I. The antenna design and optimization are carried out by using the commercial software High Frequency Structure Simulator (HFSS).

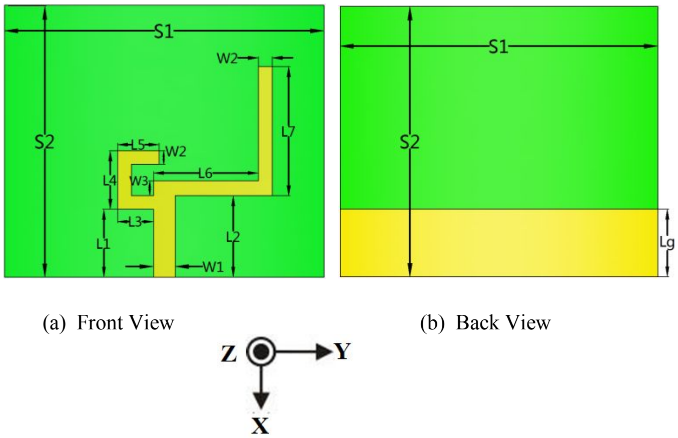

Fig. 1. Configuration of the proposed antenna.

TABLE I

GEOMETRICAL PARAMETERS OF THE PROPOSED ANTENNA

Parameter	S1	S2	W1	W2	W3	Lg	L1
Value(mm)	47	40	3.2	2	2.2	10	10
Parameter	L2	L3	L4	L5	L6	L7	
Value(mm)	12	5.25	8.6	6.1	15.45	19	

In order to explain the CP operation mechanism, how the surface current density distribution on the proposed antenna varies with time has been investigated. Fig. 2 presents the simulated surface current density distribution on the proposed antenna at the CP frequency of 2.45GHz at four different times. In this figure, the red arrow represents the direction of the predominant surface current. As shown in the figure, the current on the radiator contributes much to the antenna radiation, and the current on the ground plane also does some contribution to the antenna radiation, which should not be negligible. When *t*=0, the predominant surface current points to the right. When *t*=T/4, a downward directed predominant current is observed. It can be observed that the predominant current at *t*=T/2 (3T/4) is basically equal in magnitude and opposite in direction to that at *t*=0 (T/4). As the time marches on, the predominant current turns in the clockwise direction in the azimuth plane. Hence, left-hand CP (LHCP) waves in the broadside direction (+Z axis) can be excited.

Fig. 3 gives the simulated surface current density distribution on the proposed antenna at the CP frequency of 5.5GHz. As the time marches on, the predominant current turns in the anticlockwise direction in the azimuth plane. Hence, right-hand CP (RHCP) waves in the broadside direction can be excited.

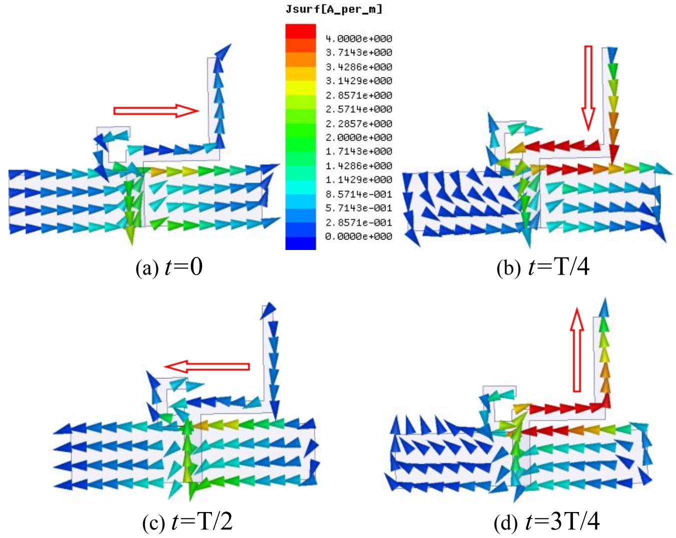

Fig. 2. Simulated surface current density distribution on the proposed antenna at 2.45 GHz.

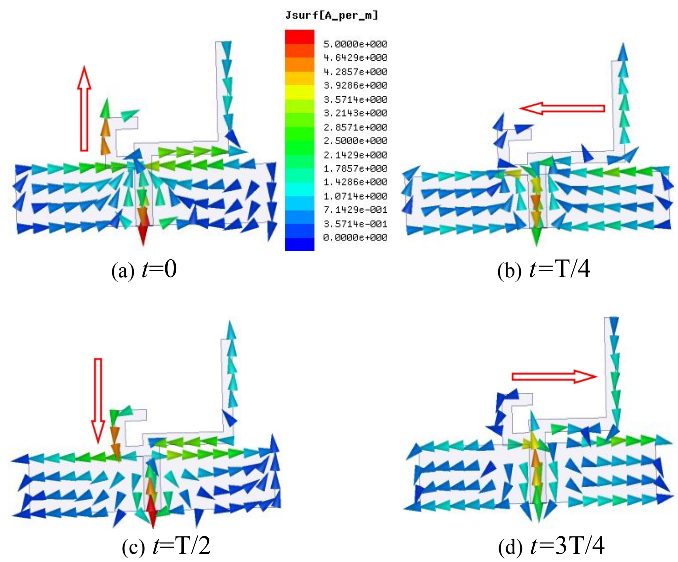

Fig. 3. Simulated surface current density distribution on the proposed antenna at 5.5 GHz.

Several parameters have important effect on the antenna electronic performance, which will be studied below. When one parameter is studied, the others are kept constant as listed in Table I.

The width of the ground plane, S1, may affect the impedance match and especially CP performance. Fig. 4 and Fig. 5 present the effect of the width S1. It is clearly seen from Fig. 4 that increasing S1 will make the -10dB impedance bandwidth narrower in the lower band and wider in the upper band. When S1 is increased, the AR performance will get better and the AR bandwidth will shift toward lower frequency in the lower band, and the effect of S1 on AR in the upper band is little. S1=47 mm is chosen for a good impedance match and CP performance.

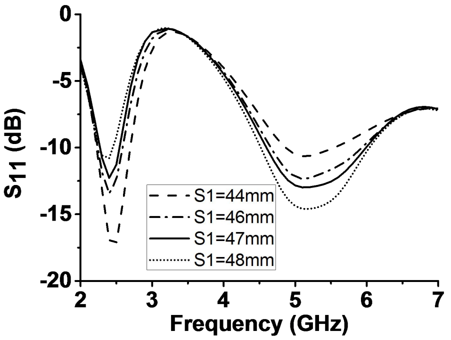

Fig. 4. The S_{11} of the proposed antenna with different S1.

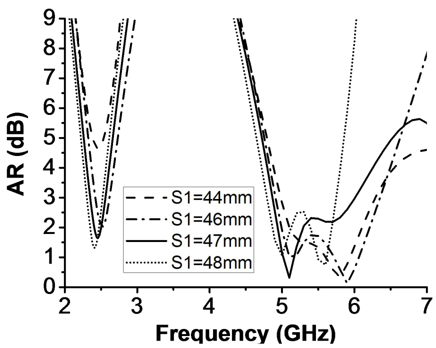

Fig. 5. The AR of the proposed antenna with different S1.

The effect of the length L1 is also analyzed as illustrated in Fig. 6 and Fig. 7. When L1 is increased, the impedance match performance gets worse in the upper band. Also the length L1 will affect the AR bandwidth. In the upper band, the AR bandwidth moves to higher frequency with the increasing of the length L1. For dual-band circular polarization operation, L1 is set to be 10 mm.

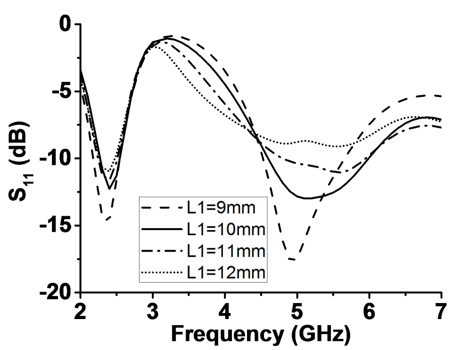

Fig. 6. The S_{11} of the proposed antenna with different L1.

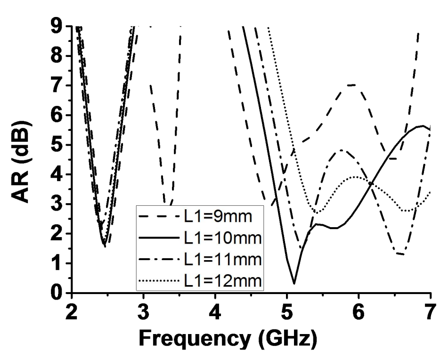

Fig. 7. The AR of the proposed antenna with different L1.

III. Simulated and Measured Results

The proposed antenna in Fig. 1 was fabricated and its reflection coefficients were measured using Agilent Vector Network Analyzer (E8361A). Fig. 8 shows the simulated and measured S_{11} of the proposed antenna. The simulated and measured AR in the broadside direction is shown in Fig. 9. Simulated and measured results agree well with each other. It has a measured -10dB impedance bandwidth of 380MHz (2.32-2.70GHz) and a 3dB AR bandwidth of 180MHz (2.39-2.57GHz) in the lower band. The overlapped impedance and AR bandwidth is from 2.39 to 2.57GHz, which can cover 2.4GHz (2.4-2.48GHz) WLAN/Wi-Fi band. In the upper band, it has a measured -10dB impedance bandwidth of 1240MHz (4.76-6GHz) and a 3dB AR bandwidth of 870MHz (5.13-6GHz). The overlapped impedance and AR bandwidth is from 5.13 to 6GHz, which can cover 5.2GHz (5.15-5.35GHz) /5.8GHz (5.725-5.825GHz) WLAN bands and 5.5GHz (5.15-5.85GHz) Wi-Fi band. The slight discrepancies between the simulated and measured results may be caused by inevitable fabrication error and deviation between the actual dielectric constant and the one used in the simulation. The performance of the proposed antenna is compared with other dual-band CP antennas in Table II. The 3dB AR bandwidths of the antennas in [5-6] cannot cover 5.8GHz WLAN band and cannot fully cover 5.5GHz Wi-Fi band. In [6], the 3dB AR bandwidths of the antenna cannot fully cover 2.4GHz WLAN band. The 3dB AR bandwidths of the antenna in [7] cannot cover WLAN/Wi-Fi bands. The proposed antenna achieves a considerable wide 3dB AR bandwidths when compared with other dual-band CP antennas in Table II. Both its -10dB impedance bandwidths and 3dB AR bandwidths fully cover all the 2.4/5.2/5.8 GHz WLAN bands and all the 2.4/5.5GHz Wi-Fi bands.

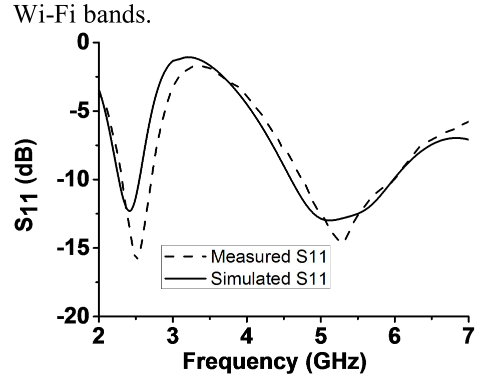

Fig. 8. Simulated and measured S_{11} of the proposed antenna.

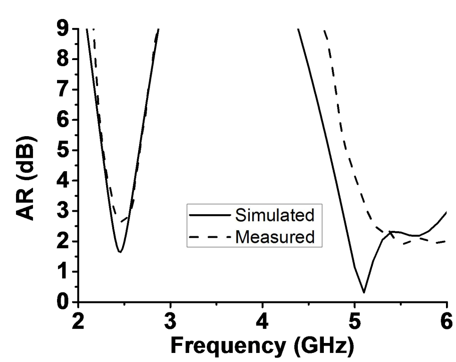

Fig. 9. Simulated and measured AR results of the proposed antenna.

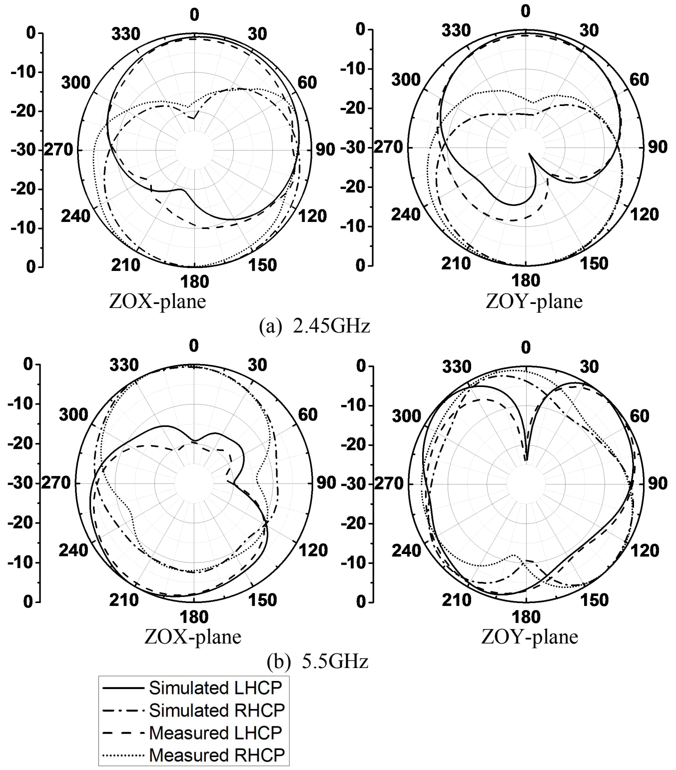

Fig. 10. The simulated and measured radiation patterns of the proposed antenna.

The radiation patterns were tested in an anechoic chamber. Fig. 10 presents the simulated and measured normalized far-field radiation patterns of the proposed antenna in ZOY plane and ZOX plane at 2.45GHz and 5.5GHz. It is clearly seen from the figure that the patterns have the characteristic of bidirectional radiation. At 2.45GHz, LHCP radiation power is much more than RHCP radiation power in the +Z axis direction, which verifies that the polarization sense is LHCP in the +Z axis direction. At 5.5GHz, RHCP radiation power is much more than LHCP radiation power in the +Z axis direction, which verifies that the polarization sense is RHCP in the +Z axis direction. In the -Z axis direction, the polarization sense is RHCP at 2.45GHz and LHCP at 5.5GHz.

Fig. 11 presents the peak gain of the proposed antenna. In the lower band, the antenna gain approximately varies from 2.01 to 2.48 dBi. The gain approximately varies from 2.55 to 3.09 dBi in the upper band. The gains are stable in the two operating bands.

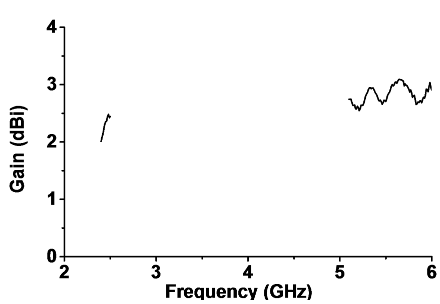

Fig. 11. Measured gain of the proposed antenna.

TABLE Ⅱ

PERFORMANCE COMPARISON FOR DUAL-BAND CP ANTENNAS

Antennas	-10dB impedance bandwidth	3dB AR bandwidth	Overall dimension
antenna in [5]	1.918-3.85GHz 5.137-5.476GHz	2.27-2.52GHz 5.11-5.47GHz	$40mm \times 45mm$
antenna in [6]	2.3-2.7GHz 4.8-6.8GHz	2.39-2.43GHz 5.06-5.70GHz	$42mm \times 30mm$
antenna in [7]	2.444-3.615GHz	2.49-2.67GHz 3.48-3.59GHz	$45mm \times 36mm$
proposed antenna	2.32-2.7GHz 4.76-6GHz	2.39-2.57GHz 5.13-6GHz	$40mm \times 47mm$

IV. Conclusion

A compact dual-band circularly polarized planar monopole antenna is presented in this letter. The “L” shaped strip on the radiator is mainly used for the lower band and the “C” shaped strip for the higher band. The proposed antenna has been fabricated and tested. Its measured -10dB impedance bandwidths are 380MHz in the lower band and 1240MHz in the higher band. Its measured 3dB AR bandwidths are 180MHz in the lower band and 870MHz in the higher band. The overlapped impedance and AR bandwidths are from 2.39 to 2.57GHz in the lower band and from 5.13 to 6GHz in the higher band, which can fully cover all the 2.4/5.2/5.8 GHz WLAN bands and all the 2.4/5.5GHz Wi-Fi bands. The proposed antenna has the advantages of low profile, compact dimension, simple structure, and stable gains. These good performances make it a very good candidate for practical WLAN/Wi-Fi applications.

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