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A DUAL-MODE APERATURE-COUPLED STACK ANTENNA FOR WLAN DUAL-BAND AND CIRCULAR POLARIZATION APPLICATIONS

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Abstract—A compact stack antenna consisting of square loop resonators, aperture couples, feed line and the perturbation for dual-band and circular polarization (CP) applications is proposed in this paper. This perturbation applies both dual-mode and orthogonal mode effects existing in the square loop resonator to present wide-band and CP characteristics simultaneously. The stack antenna presents the desired bands of 2.46 GHz with bandwidth (BW) = 160 MHz (6.58%) and 5.28 GHz with BW = 450 MHz (8.52%). The circular polarizations for dual-band are demonstrated with axial ratio (AR) spectrum and orthogonal modes. The proposed antenna is successfully simulated and measured with frequency responses, radiation patterns and current distributions.

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1. INTRODUCTION

With the rapid growth of wireless local area network (WLAN) systems, there is a concomitant demand for dual-band, low cost and small sized antennas for commercial applications [1–16]. The dual-band antenna is designed to operate in 2.4 GHz (2.4–2.48 GHz) and 5.0 GHz (5.15–5.35 GHz and 5.725–5.825 GHz in the United States and 5.15–5.35 and 5.47–5.725 GHz in Europe) frequency bands.

For implementations, the stacked antennas [1–9] and aperture-coupled stack antennas [10–19] were developed for broad-band, high gain and high efficiency applications. The individual characteristics of these antennas include dual-band [4, 6, 7], wideband [3–5, 11, 13, 16, 18], unidirectional patterns [15], high gain [1, 14], high efficiency [15], dual-polarized [3, 5] and circularly polarized (CP) [2, 10, 11, 17, 19]. The smallest size was $19.5 \times 16.0 \times 1.6\,\mathrm{mm}^3$ [3].

Dual-polarized and CP antennas are required to implement polarization diversity, in order to prevent degradation due to multi-path fading in the propagation environments. The four-layer stacked slot antenna composed of director, reflector, slot-plane and the L-shaped strip is provided for the CP antennas [11]. However, these stack structures will result in increasing the antenna height and fabrication cost. Furthermore, difficulty in manufacturing will also be encountered when mass production is required. On the other hand, the microstrip antennas can provide a circularly polarized radiation pattern using only a single feed in an asymmetrical patch. The elliptical microstrip antenna [19–21], diagonal fed nearly square patch, truncated-corners square patch and square patch with a diagonal slot [22], and asymmetrical C-shaped slot patch [23] were presented. Two resonant frequencies are presented for the orthogonal modes which together yield circular polarization. Therefore, an aperture-coupled stack antenna designed with dual-frequency and CP operation is an attractive topic for applications.

Based on the study of the square loop [2, 9, 17], CP characteristics [2, 10], dual-band responses [9, 17] and orthogonal modes [19–23], an alternative design of the aperture-coupled stack antenna with a perturbed square loop resonator for 2.46/5.28 GHz dual-band CP applications is presented in this paper. By the perturbation, this asymmetrical structure applies both dual-mode and orthogonal mode effects existing in the square loop resonator to present wide-band and CP characteristics simultaneously. The CP and wide band operation is achieved by exciting two TM modes on the same resonator, and the parasite loop enhances the characteristics. The AR spectrums and current distribution are applied to the demonstration. It is a simple structure

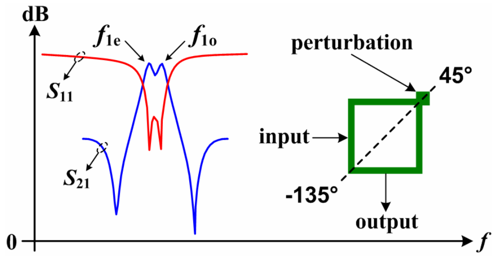

Figure 1. Characteristics of DMSLR.

and available microstrip antenna for WLAN dual-band and CP applications.

2. ANTENNA CONFIGURATION AND BASIS

2.1. Dual-mode and Orthogonal Mode

For a typical square loop resonator, when the mean circumference, $2(L_4 - L_5)$, of the loop is equal to an integral multiple of the guided wavelength, the resonances are established in Figure 1. Keeping input port in 0° and putting perturbations such as stub line in corner located 45° or 135° offset from input ports, the dual-mode square loop resonator (DMSLR) is established. The responses of DMSLR can be depicted in Figure 1. The even and odd modes exhibit the wide-bands in each resonance. In this paper, the first resonance is applied as the lower band, and the second resonance is used as the higher band for dual-band applications.

Figure 2 shows a square patch with single-point feed where CP is induced by a perturbation segment, in this case a pair of truncated corners [19–22]. Modes 1 (#1) and 2 (#), in the diagonal planes, are of equal amplitude and in phase quadrature at f_0. It is clear that off f_0, phase and amplitude errors will rapidly degrade the axial ratio [19, 21].

2.2. Proposed Antenna

In Figure 3(a), the proposed antenna is composed of DMSLR with a parasite loop (upper layer), substrate 1, the aperture coupling (middle), substrate 2 and the feed-line (lower layer). The parasite loop is applied to enhance the main loop. The 50 Ω microstrip feed-line is excited with a SMA feed. The FR4 substrate with thickness 1.6 mm and relative permittivity 4.4 is used. By tuning feed-line structure, more wideband performance can be achieved. The detailed dimensions in Figure 3(b) are $W \times L = 50 \times 50\,\mathrm{mm}^2$, $L_1 = 27.0\,\mathrm{mm}$, $w_1 = 3.0\,\mathrm{mm}$, $L_2 = 22.0\,\mathrm{mm}$, $L_3 = 10.0\,\mathrm{mm}$, $L_4 = 19.0\,\mathrm{mm}$, $L_5 = 16.0\,\mathrm{mm}$, $L_6 =$

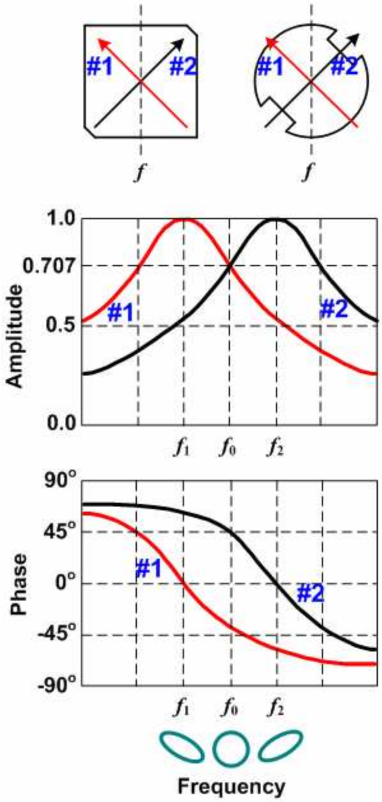

Figure 2. Orthogonal mode of single-point feed square patch.

15.0 mm, $L_7 = 13.0$ mm, $g_1 = 1.5$ mm, $g_2 = 1.0$ mm, $g_3 = 0.5$ mm, $w_{p1} = w_{p2} = 3.0$ mm.

3. SIMULATION AND MEASUREMENT

The S_{11} reflection coefficient spectrums and radiation patterns are simulated by using commercial software Ansoft HFSS [24]. The S_{11} spectrums of the proposed antenna with bands of 2.46 and 5.28 GHz are shown in Figure 4. It is evident that the simulated and measured results of frequency responses are in agreement. In measurement, while the reflection coefficient is smaller than -10 dB, the frequency responses cover two bands, from 2.42 to 2.58 GHz (bandwidth = 160 MHz) and from 5.08 to 5.53 GHz (bandwidth = 450 GHz). For applications, the frequency responses are covered in the operation bands of the IEEE802.11a/b/g bands.

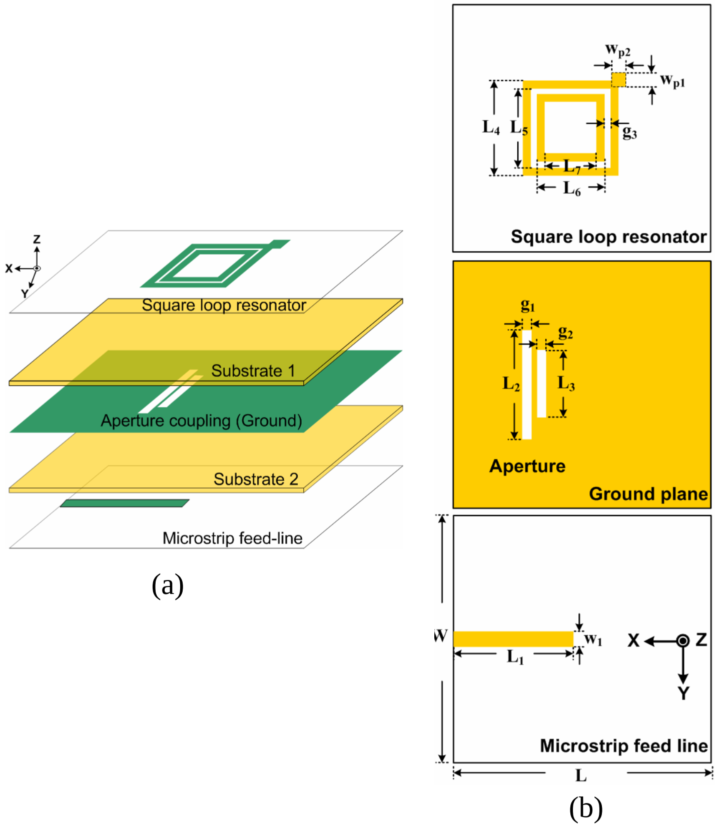

Figure 3. Configuration of proposed antenna. (a) Structure, (b) configuration with the dimensions.

In Figures 5(a) and 5(b), the square loop exhibits the vector current distributions. It is according to dual-mode (even and odd modes) resonances at the frequencies (2.45 and 2.53 GHz, 5.18 and 5.45 GHz) respectively. The two more coupled magnitudes (red) in the corners and less coupled magnitudes (blue) in the opposite corners are observed in Figure 5(a) for even mode (TM_{010}, left side), and for odd mode (TM_{110}, right side). Circular polarization wave can be generated by exciting two orthogonal modes in a patch. Theses two orthogonal modes are in 90-degree phase with the sign of the relative phase determining polarization hand. Thus, the even mode represents the first (#1) mode direction as the arrow, and the odd mode represents the second (#2) mode. The two orthogonal modes occur and left-hand CP presents.

In Figure 5(b), these current distributions with TM_{210} modes are

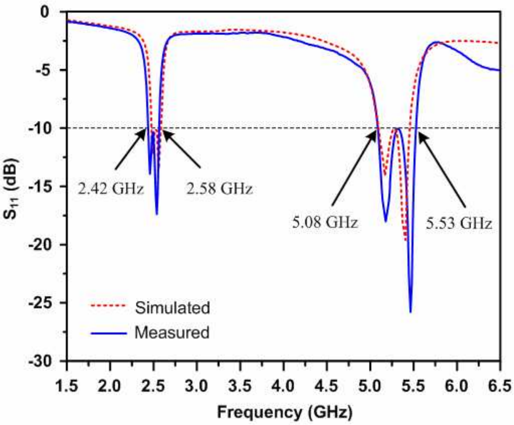

Figure 4. Results of return loss spectrum.

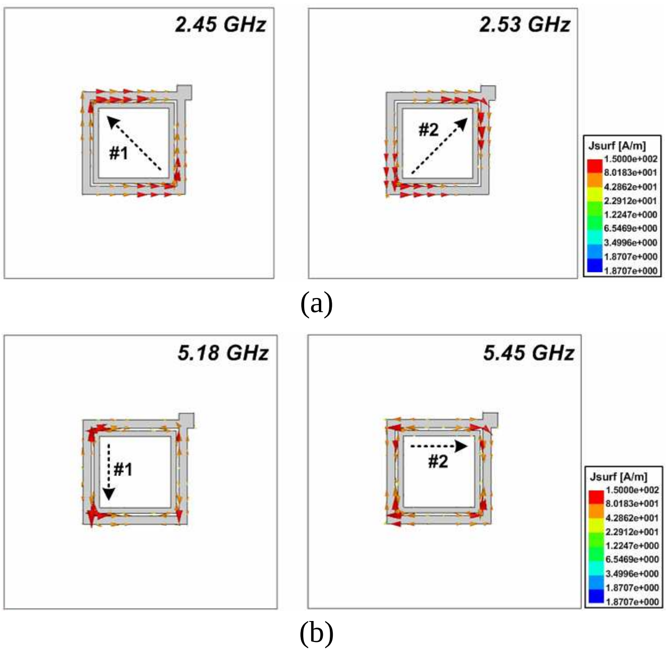

Figure 5. Vector current distributions. (a) 2.46 GHz, (b) 5.28 GHz.

located with four more coupled magnitudes (red) in the corners. The even mode represents the first (#1) mode direction as the arrow, and the odd mode represents the second (#2) mode. Similarly, the angle of orthogonal mode equates to 90°. This is also expressed with right-hand circular polarizations. These are confirmed from obtaining the

CP characteristics of the proposed antenna.

Since the two quasi-degenerate orthogonal modes of unequal amplitude and phase difference are excited, the purity of circular polarization will be relatively less. Thus, the circular polarization, related to direction, can be observed in Figures 6(a) and 6(b). For the AR spectrum, the minimum AR (0.21) for 2.46 GHz (−3 dB BW = 20 MHz) and the minimum AR (0.58) for 5.28 GHz (−3 dB BW = 130 MHz) are observed. Thus the proposed antenna can be applied to CP applications, which represents the availability and usefulness in contrast to the conventional dual-band antennas.

In field analyses, the radiation patterns were obtained by an automatic measurement system in an anechoic chamber. For the field coordinates, the under-tested antenna is located on the x-y plane

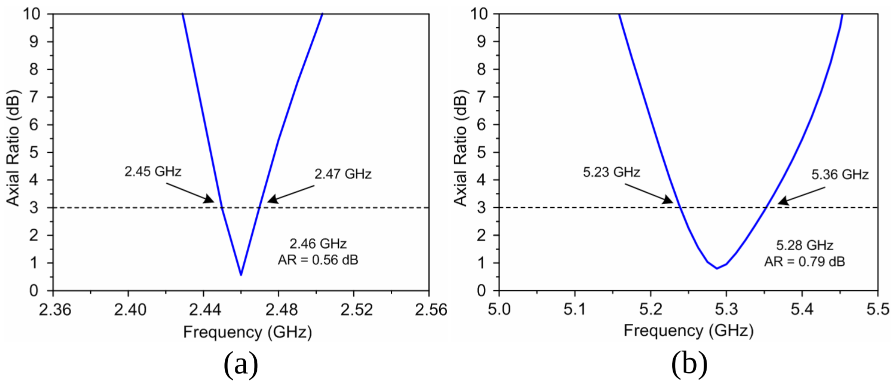

Figure 6. AR Spectrum. (a) 2.46 GHz, (b) 5.28 GHz.

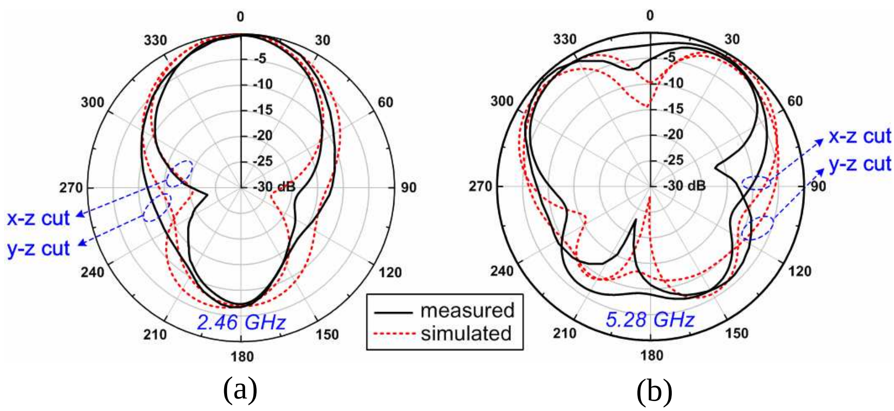

Figure 7. Radiation patterns.

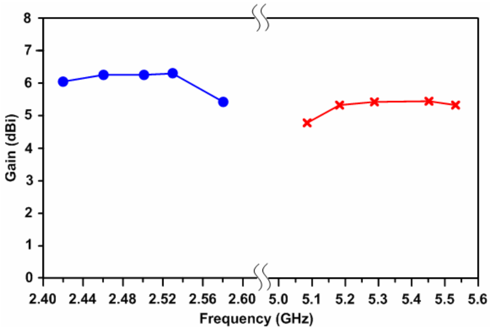

Figure 8. Antenna gain.

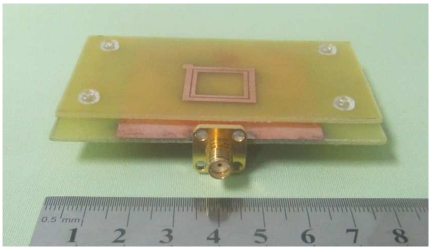

Figure 9. Photograph of proposed antenna.

shown in Figure 3(a), and the feeding line is located along the x-axis. The radiation patterns with resonant frequencies 2.46 GHz and 5.28 GHz are represented in Figure 7. The directional patterns are presented. Both simulation and measurement are in agreement. The antenna gains for dual-band are shown in Figure 8. The photograph of the proposed antenna is presented in Figure 9.

4. CONCLUSION

The aperture coupled stack antenna design of dual-band CP operation via a single-feed includes the use of a square loop resonator to excite dual-mode and orthogonal mode of the resonator simultaneously. Its operations simultaneously from 2.44 to 2.58 GHz (bandwidth = 160 MHz) and from 5.08 to 5.53 GHz (bandwidth = 450 GHz) for return loss < -10 dB. The circular polarization represents the availability and usefulness in contrast to the conventional stack antennas for dual-bands.

In field analysis, the directional patterns are obtained for 2.46 GHz and 5.28 GHz band respectively with peak power gains 6.2 dBi and 5.4 dBi. In applications, it can be applied to the WLAN IEEE802.11a/b/g systems.

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