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Single-Fed Dual-Band Dual-Polarized U-Slot Patch Antenna

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***Abstract* —A dual-band dual-polarized patch antenna is proposed for WiMax and WLAN systems. Impedance bandwidths of 7.5% and 9.6% can be achieved at 3.6 GHz and 5.2 GHz, respectively. The asymmetrical U-slot has been used to generate the orthogonal modes for circular polarization at 3.6 GHz with a 3dB axial ratio bandwidth of 0.7%, and the linear polarization is obtained by cutting a symmetrical U-slot on the patch. Higher gains at both CP and LP bands are obtained simultaneously. The peak gains in lower and higher bands are 8.5 dBic and 8.6 dBi, respectively. The simulated results of the antenna have been presented and discussed.**

***Index Terms* —Circular polarization, dual-polarized, dual-band, U-slot, patch antenna.**

I. INTRODUCTION

Compact, multiband, low-profile and low-cost antennas are widely used in personal communication devices along with the rapid development of the wireless communication systems. The worldwide interoperability for microwave access (WiMax) and the wireless local area network (WLAN) systems offer high-speed channel, multiple access and multimedia communication which are important to short-range communication. A large number of antennas have been proposed and reported in the literature to satisfy the need for multifunctional antennas to work at multiple frequency bands.

For the past decades, the microstrip, slot, and stacked patch antennas have been used to implement dual-band linear polarization performance [1]-[6]. A single-fed single-layer tri-band linear antenna is realized by cutting three symmetrical U-slots [7]. In [8], stacked patches are used to achieve a dual-band characteristic by adjusting the relative sizes of the upper and lower circular discs. Additionally, a multilayer multi-band CP U-slot patch antenna has been introduced in [9]. In order to obtain the left-hand CP (LHCP) and right-hand CP (RHCP) performances simultaneously for the WLAN (5.725~5.825GHz) and WiMax (3.3~3.8GHz) applications, two asymmetrical U-slots are cut at the lower and higher layers. Nevertheless, all of the above have only one kind of polarization (LP or CP) in different bands.

Recently, CP and LP performances at different bands are integrated into one antenna by employing dipole-like printed, multilayer and dielectric resonator structures [10]-[12]. A dual-band dual-polarized antenna is developed by using an arrow-shaped patch and a microstrip feed in two different substrates [10]. It can be seen that a size reduction of 70% compared with the conventional rectangular patch antenna is obtained. In [11], a CP and LP dual-band antenna is obtained due to the patch structure with a slab capacitor and two short pins. As a result, a wider bandwidth and a higher gain is accomplished. Compared with [10], it has a larger size. In order to realize a dual-band dual-polarized antenna, a new dielectric resonator double-fed antenna has been introduced in [12]. The wider 3 dB axial ratio and impedance bandwidths are achieved in CP and LP bands, respectively. However, the peak gains of the antenna are only 4.2 dBi and 0.5 dBi in two different bands. Meanwhile, the 3 dB axial ratio and impedance bandwidths are widen as a result of stacked patches, aperture coupling [10] and double-fed [12] structure. From the above literature, it can be observed that the higher gain, wider impedance bandwidth, different polarizations and the simple structure are difficult to realize at the same time for these multifunctional antennas.

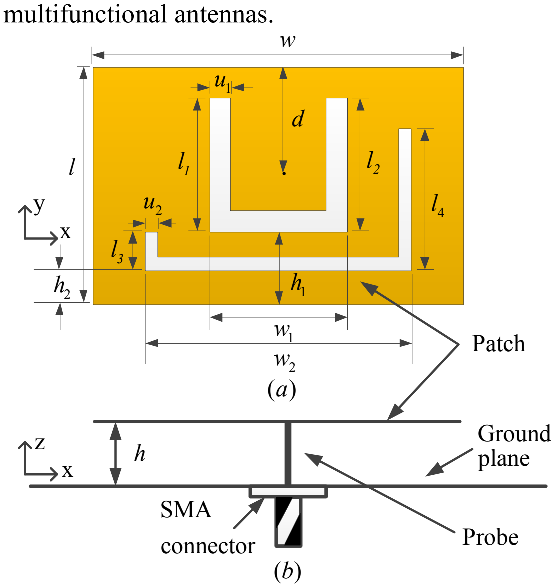

Fig. 1. Geometry of the dual-band dual-polarized patch antenna. (a) patch with two U-slots, (b) cross-sectional view.

In this paper, an approach of cutting two independent U-slots in a single patch is presented to obtain a CP and LP performance in WiMax and WLAN bands, respectively. In addition, the proposed antenna has smaller size and can obtain higher gains at both CP and LP bands simultaneously. Simulated peak gains in lower and upper bands are 8.5 dBic and 8.6 dBi, respectively. The impedance bandwidths of the lower and upper bands are 7.5% and 9.5% respectively. The 3 dB axial ratio bandwidth of the antenna is about 0.7% in the CP band.

II. ANTENNA DESIGN

The geometry of a dual-band dual-polarized U-slot patch antenna is shown in Fig. 1. The CP and LP performances are achieved by cutting asymmetrical and symmetrical U-slots in a single layer patch. Another 50×50 mm copper plate is used as a ground plane under the patch. The coaxial probe is directly connected to the patch. The inner and outer diameters of the SMA connector are 0.6 mm and 2.0 mm, respectively.

As shown in Fig. 2, two resonant frequencies are excited simultaneously by cutting a symmetric U-slot. Accordingly, a wide band linear polarized antenna can be designed. In order to generate the CP radiation pattern, an asymmetrical U-slot is employed to excite two orthogonal modes on the patch. By changing the lengths of the arms of the asymmetrical U-slot, same magnitude and 90º phase differences of the two modes can be achieved at the given frequency. In this paper, a LHCP antenna is designed by setting the right arm of the asymmetrical U-slot longer than the left one. The commercial electromagnetic software Ansoft HFSS was employed on the simulations and optimized design of this antenna. The final optimized parameters of the antenna are listed in Table I.

TABLE I
OPTIMIZED DIMENSIONS OF THE ANTENNA (mm)

Parameters	l_1	l_2	l_3	l_4	w_1	w_2	u_1
Values	19	19	2.6	21	13	24	2
Parameters	u_2	h_1	h_2	w	l	d	h
Values	1.2	5	0.5	33.2	26.6	18.1	5

III. PARAMETRIC STUDY AND RESULTS

Simulation have been carried out to demonstrate the performance of the dual-band dual-polarized antenna. The parametric studies for l_3 and w_n (n=1, 2) have been done to investigate the effect on the 3 dB axial ratio, impedance bandwidth and center frequency.

As shown in Fig. 2, the CP impedance bandwidth $|S_{11}|$< -10 dB of the antenna is about 7.5% from 3.49 to 3.74 GHz and the LP one of the antenna is about 9.6% from 4.92 to 5.42 GHz. Fig. 3 shows the simulated 3 dB axial ratio bandwidth which is about 0.7% from 3.59 to 3.61 GHz. Simulated center frequencies in WiMax and WLAN bands are 3.6 GHz and 5.2 GHz, respectively.

The simulated RHCP and LHCP radiation patterns at 3.6 GHz are shown in Fig. 4. It can be seen that more than 15 dB difference between the LHCP and RHCP radiation are obtained. The simulated linear polarization radiation patterns in the E-plane (Φ=90º) and H-plane (Φ=0º) at 5.2 GHz are plotted in Fig. 5. It can be seen that the cross-polarization level is below -11 dB for both E-plane and H-plane. The simulated peak gains in lower and upper bands are 8.5 dBic and 8.6 dBi.

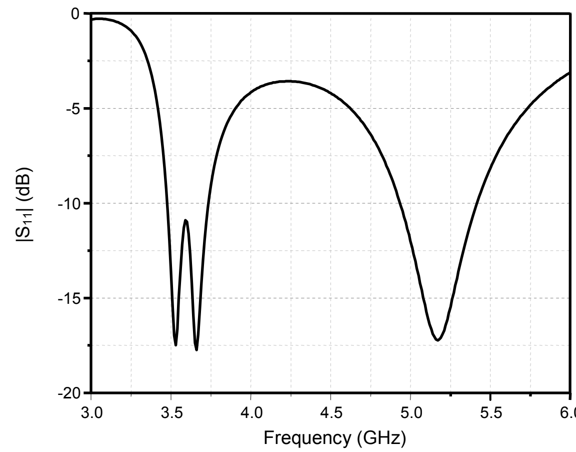

Fig. 2. Simulated reflection coefficient of the dual-band dual-polarized antenna.

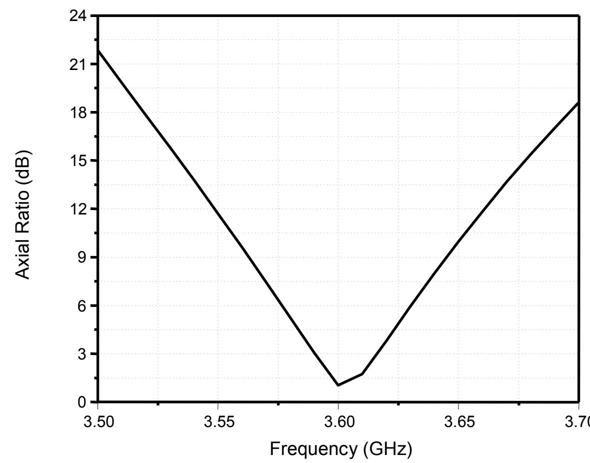

Fig. 3. Axial ratio of the dual-band dual-polarized U-slot antenna.

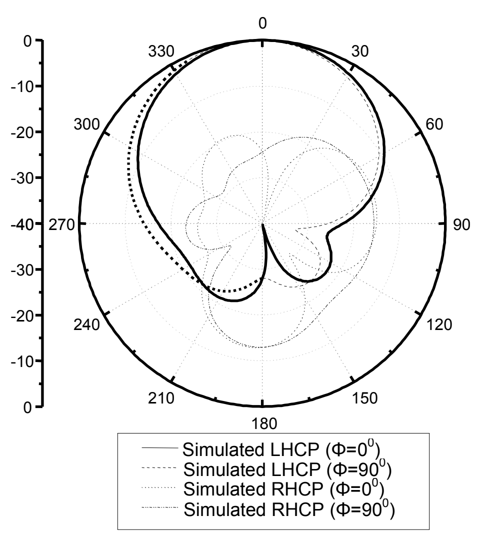

Fig. 4. Simulated normalized radiation pattern of the antenna at 3.6 GHz.

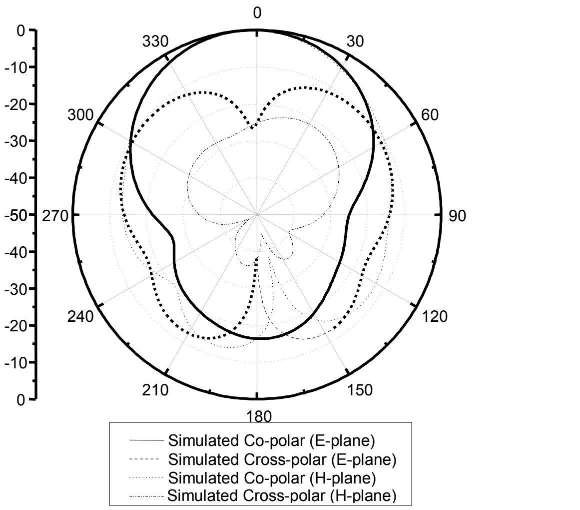

Fig. 5. Simulated normalized radiation pattern of the antenna at 5.2 GHz.

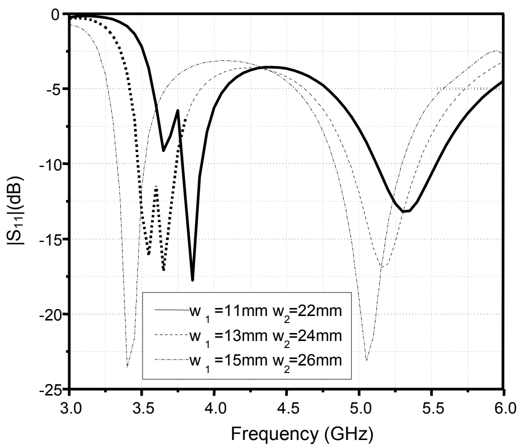

Fig.6. Simulated reflection coefficients for the different w_n (n=1, 2).

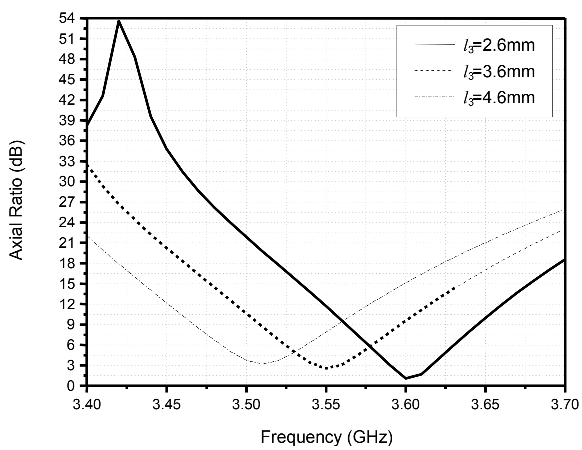

Fig. 7. Simulated axial ratio for the different l_3.

In Fig. 6, it can be observed that the center frequency and impedance bandwidth are affected by w_n (n=1, 2). The resonant frequencies are moved to the lower frequency band when the w_n (n=1, 2) is increased and vice versa. Moreover, along with the reducing of l_3, the 3 dB axial ratio bandwidth is increased as shown in Fig. 7. In addition, by adjusting the lengths of the w_n (n=1, 2) and l_3, the frequency bands of the $|S_{11}|$< -10 dB and 3 dB axial ratio are gradually overlapped.

IV. CONCLUSION

A dual-band dual-polarized antenna which is applied in WiMax and WLAN bands has been demonstrated. The CP and LP radiation patterns have been obtained by using asymmetrical and symmetrical U-slots. The antenna provides impedance bandwidths of 7.5% with respect to center frequency of 3.6 GHz for WiMAx and 9.4% with respect to the center frequency of 5.2 GHz for WLAN. The simulated peak gains are 8.5 dBic and 8.7 dBi, respectively.

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