A Dualband Circularly Polarized Rectangular Dielectric Resonator Antenna with L-shaped Slots on the Ground

Yuxiang Sun, **Kwok Wa Leung**, **and Wei Wei Li**
Department of Electronic Engineering and State Key Laboratory of Millimeter-Waves
City University of Hong Kong, Hong Kong SAR, China

Abstract— This paper presents a dualband circularly polarized (CP) rectangular dielectric resonator (DR) antenna (DRA). Its fundamental TE_{111} mode and higher-order TE_{113} mode are excited simultaneously to obtain two working bands. The dimensions of the dual-band DRA are calculated by solving simplified formulas of the dual-mode rectangular DRA. To generate circularly polarized fields, two asymmetric diagonal L-shaped slots are etched on the ground plane to excite two degenerate orthogonal modes in each band, giving a CP dualband antenna. For demonstration, a dual-band dual-sense CP antenna working in GPS L1 band (1.575 GHz) and 2.4 GHz WLAN band are designed using ANSYS HFSS. Its reflection coefficient, axial ratio (AR), antenna gain, and radiation pattern are studied. The antenna radiates right- and left-hand circularly polarized fields in the lower and upper bands, respectively.

1. INTRODUCTION

The dielectric resonator antenna (DRA) has been studied extensively over the last three decades [1–3]. Most DRA designs generate linearly-polarized (LP) fields, but a circularly-polarized (CP) system has advantages over the LP counterpart [4]. For example, a CP antenna is relatively more flexible in its orientation. Also, it is less sensitive to multi-path propagation effects and fading problems. Today, it has been a trend to have highly-integrated systems, therefore multiband antennas are generally more desirable than single-band antennas for they can reduce the system size and cut the cost.

In this paper, a dual-band slot-coupled CP rectangular DRA working in GPS L1 band and 2.4 GHz WLAN band is introduced. The CP fields are generated by fabricating two diagonal L-shaped slots onto the ground; one for the lower band CP and the other one for the higher band. The CP polarizations in the two bands are of opposite senses due to different orientations of the slots.

2. ANTENNA DESIGN

Figure 1 shows the configuration of the proposed dual-band CP rectangular DRA. The DRA, made of material with a dielectric constant of $\varepsilon_r = 10$, has a square cross section with a side length of a, and height of h. It is located at the center of a square substrate, with a thickness of $t = 1.57$ mm, and length of $L_g = 80$ mm. The dielectric constant of the substrate is $\varepsilon_{rs} = 2.33$ and therefore the width of the 50-Ω feedline is $w_f = 4.67$ mm. A rectangular coupling slot with a length of l_s and width of w_s is cut at the center of the ground plane to excite the DRA. Two L-shaped slots of different sizes are etched along the diagonal line of the ground plane, with offsets of d_{xi}, d_{yi} $(i = 1, 2)$. The total lengths of the two slots are $L_{x1} + L_{y1}$ and $L_{x2} + L_{y2}$, with the widths of w_{s1}, w_{s2}.

The proposed structure was simulated and optimized with ANSYS HFSS. To begin, the size of the DRA working in both GPS L1 band (1.575 GHz) and 2.4 GHz WLAN band was determined. By solving the equations in [5, 6] with $f_1 = 1.6$ GHz and $f_2 = 2.4$ GHz, the original dimensions of $a = 37.5$ mm and $h = 40.3$ mm were obtained. Next, the sizes of the L slots and DR were optimized with HFSS simulations to obtain a good CP antenna. The optimized parameters are obtained given by $L_g = 80$ mm, $t = 1.57$ mm, $a = 35.7$ mm, $h = 40.5$ mm, $w_f = 4.67$ mm, $l_s = 30$ mm, $w_s = 2.5$ mm, $d_{x1} = d_{y1} = 2.5$ mm, $d_{x1} = d_{y1} = 2$ mm, $L_{x1} = 16$ mm, $L_{y1} = 27.5$ mm, $L_{x2} = 16$ mm, $L_{y2} = 16$ mm, and $w_{s1} = w_{s2} = 2$ mm.

3. ANTENNA PERFORMANCE

Figure 2 shows the simulated reflection coefficient of the dualband CP rectangular DRA. With reference to the figure, wide impedance bands ($|S_{11}| < -10$ dB) are obtained at ~ 1.57 GHz and 2.4 GHz, with their fractional bandwidths given by 17.8% (1.385–1.655 GHz) and 10.3% (2.345–2.60 GHz), respectively.

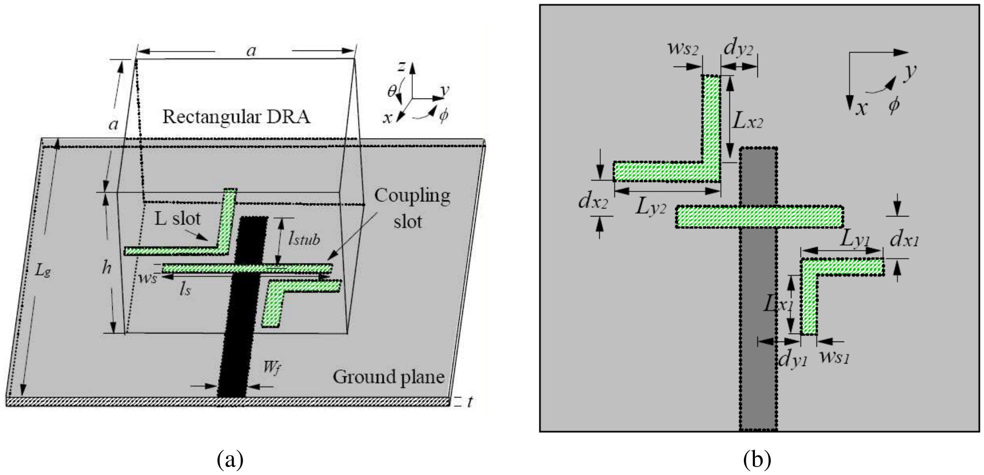
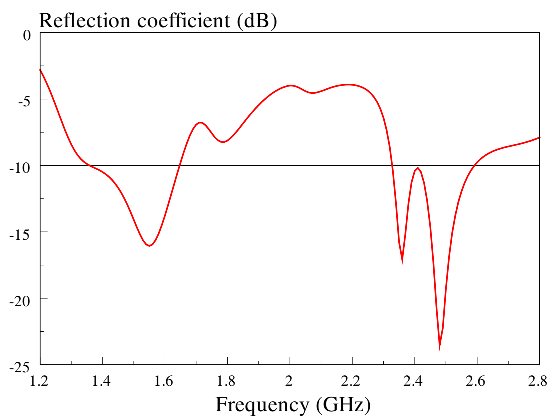


Figure 1: (a) Perspective view and (b) top view of the proposed dualband CP DRA.



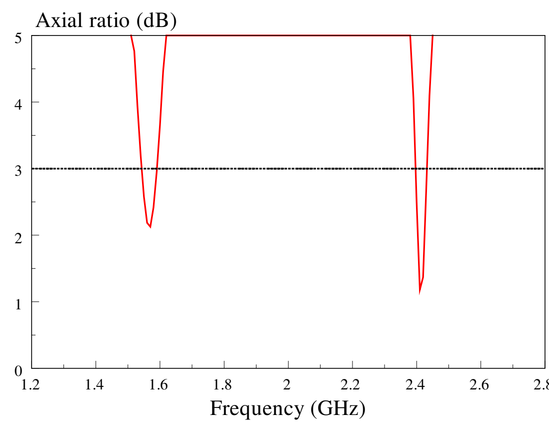


Figure 2: Simulated reflection coefficient of the proposed antenna.

Figure 3: Simulated axial ratio (AR) of the proposed antenna in boresight direction ($\theta = 0°$).

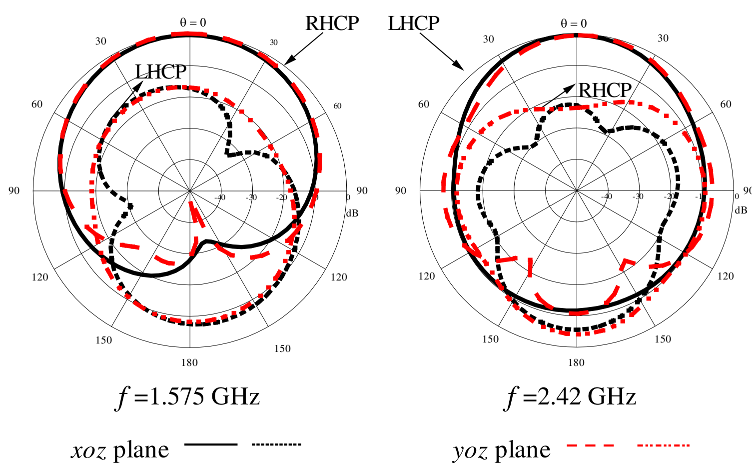


Figure 4: Simulated radiation patterns of the proposed antenna at 1.575 GHz and 2.42 GHz.

Figure 3 shows the simulated axial ratio (AR) of the proposed antenna. Two frequency bands can be observed. The 3-dB AR bandwidths of the lower and upper bands are 3.5% (1.54–1.595 GHz) and 1.65% (2.405–2.445 GHz), respectively.

Figure 4 shows the *xoz*- and *yoz*-plane simulated radiation patterns at 1.575 GHz and 2.42 GHz. As can be observed from the figure, broadside radiation patterns can be observed, as expected. At each frequency, the co-polarized fields are $\sim$ 20 dB stronger than their counterparts in the boresight direction ($\theta = 0°$). It is noted from the figure that the co-polarized fields are right-hand circular polarized (RHCP) and left-hand circular polarized (LHCP) for the lower and upper bands, respectively. This is because the sense of polarization is determined by the orientations of the diagonal L-shaped slots. It can also be observed from the antenna gain given in Figure 5. With reference to the figure, the simulated peak gains are 6.33 dBic (RHCP) and 7.36 dBic (LHCP), which are quite typical for DRAs.

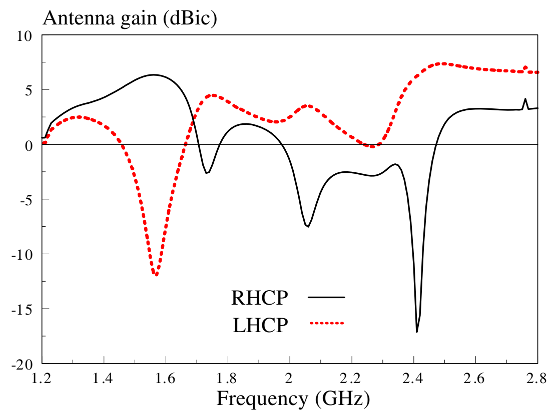


Figure 5: Simulated antenna gains of the proposed antenna in boresight direction ($\theta = 0°$).

4. CONCLUSION

In this paper, a dualband CP rectangular DRA has been studied for GPS L1 and 2.4 GHz WLAN applications. Simulated results have been obtained by using ANSYS HFSS. The proposed antenna can work in the two aforementioned bands. Broadside radiation patterns with different senses of polarization have been obtained in the lower and upper bands.

ACKNOWLEDGMENT

This work was supported by a NSFC/GRF Joint Research project (Project No. N_CityU134/13).

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