A Dual Band Dual Polarization Slot Patch Antenna

Jianling Chen, Junhong Wang

Department of Electronics and Information Engineering,
Beijing Jiaotong University,
Beijing, China
10111002@bjtu.edu.cn, wangjunh@bjtu.edu.cn

Kin-Fai Tong, Allann Al-Armaghany

Department of Electronic and Electrical Engineering,
University College London
Torrington Place, WC1E 7JE London, UK
k.tong@ucl.ac.uk, a.al-armaghany@ucl.ac.uk

Abstract—**A dual band and dual polarization slot patch antenna for Global Positioning System (GPS) and wireless LAN network with the corresponding polarizations is proposed. An L-shaped slot and a small stub are utilized to excite the desirable right-hand circular polarization (RHCP) for GPS. Meanwhile the linearly polarized electromagnetic wave for Wi-Fi communications at 2.4 GHz is contributed by an arc-shaped slot embedded circular patch. The multi-layered geometry and the capacitive feeding disk placed between the substrate layers enhance the operating bandwidths of the antenna. The achievable percentage bandwidths at the low and high bands are 6.4% and 7% respectively. The measured 3dB axial ratio (AR) bandwidth is 34 MHz, which covers the GPS L1 band.**

Keywords—L-shaped slot, arc-shaped slot, circular patch antenna; GPS; Wi-Fi; dual-polarization, capacitive feeding

I. INTRODUCTION

Nowadays, antennas for wireless communications have to be compact and able to operate at several frequency bands simultaneously. The frequency bands normally include GPS systems, wireless LAN, and the 60 GHz band for the soon coming 5G mobile communication systems [1-3]. Therefore, there is a demand for antennas that can operate in several frequency bands, in addition to the low profile, polarization alignment and low fabrication cost. A few multi-band antennas are reported for the GPS/WiMAX/WLAN systems [4-6], but polarization loss are expected for GPS reception. In [7-9], the single band circular polarization is excited by unsymmetrical U-slot or truncated corner U-slot patch antenna. In [10] a dual band and dual polarization antenna for GPS and Wi-Fi application is introduced. A 90° hybrid coupler chip is inserted to generate the two degenerative modes. Linear polarization in the Wi-Fi band is excited by the two symmetrical slots on the top radiator. Due to mounting process and extra DC biasing lines for the hybrid chip, the antenna fabrication is more complicated than a single feed antenna. The antenna performance is restricted.

In this paper, a single capacitive-fed patch antenna features a simple and compact structure is presented. This simple antenna can simultaneously support the GPS and Wi-Fi applications with the appropriate polarizations. For the GPS 1.575 GHz band, it is designed to be RHCP, while linear polarization is achieved in the Wi-Fi 2.4 GHz band.

II. ANTENNA CONFIGURATION AND DESIGN

Fig. 1 shows the top and side views of the proposed antenna geometry. The first layer is a single-side copper cladded Rogers Duriod 5880 substrate (thickness, t_1 = 1.575 mm, and

relative permittivity, ε_r= 2.2), the second layer is polystyrene foam (t_2 = 7 mm, ε_r = 1.06), and a copper ground plane is cladded on the bottom side of the second layer. On the top of the first layer, an arc-shaped slot (slot 1), an L-shape slot (slot 2), and a stub (stub 1) are inserted into a circular microstrip patch. On the top of the second layer, there is a circular feeding disc (diameter, D_2=6.4 mm) connected to the center pin of the SMA on the ground plane. The overall dimension of the antenna is $100\times100\times8.68$ mm^3. Slot 2 and the stub 1 are responsible to excite the orthogonal modes to generate the RHCP. Slot 1 radiating at 2.4 GHz are embedded in the circular patch. The multi-layered geometry and the capacitive feeding disk placed between the substrate layers enhance the operating bandwidths of the antenna. By adjusting the dimension of the L-shape slot and the stub, the CP operating frequency and AR can be optimized. The detailed dimensions of the antenna are tabulated in Table 1.
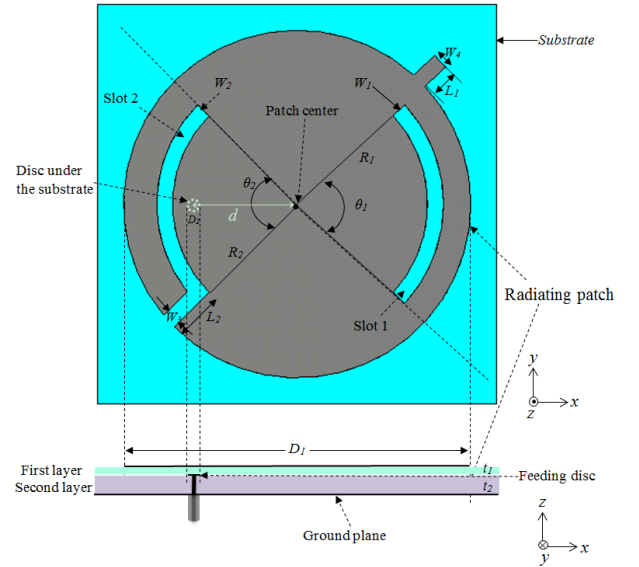

Fig. 1. Top and side view of the antenna model

TABLE I. DETAILED ANTENNA PARAMETERS (MM)

Diameter of the circular patch, D_1	87	Inner radius of slot 1, R_1	32.6	Inner radius of slot 2, R_2	31.2
Subtended angle of the slot 1, θ_1	85.32°	Subtended angle of the slot 2, θ_2	90°	Width of the slot 1, W_1	4.0
Width of the slot 2, W_2	4.0	W_3	4.0	Width of the stub W_4	4.0
Distance between the centers of the patch to feeding disc, d	26.0	Length of the stub L_1	6.5	L_2	12.3

III. RESULTS

The antenna parameters were optimized by using the commercial software package CST Microwave Studio in the simulation process. From Fig. 2, the two orthogonal modes for circular polarization can be observed in the low band around 1.575 GHz, while a single mode at 2.45 GHz appear in the high band. The impedance bandwidth ($|S_{11}| < $ -10 dB) is between 1.52 and 1.62 GHz, i.e. 6.4%, for GPS and between 2.36 to 2.55 GHz, i.e. 7%, for Wi-Fi systems.

Fig. 3 shows the simulated axial ratio bandwidth of the antenna at the GPS band. The 3 dB AR bandwidth is about 2.1% from 1.562 to 1.596 GHz.

Fig. 4 and 5 show the simulated radiation patterns of the antenna at 1.575 GHz and 2.45 GHz. The gains of the antenna at 1.575 GHz is about 6.5 dBi, while it is about 7.8 dBi at 2.45 GHz.

In our further study, the frequency bands of the antenna can be optimized independently and simultaneously. The designed antenna has been fabricated and the measured results will be presented in the conference.
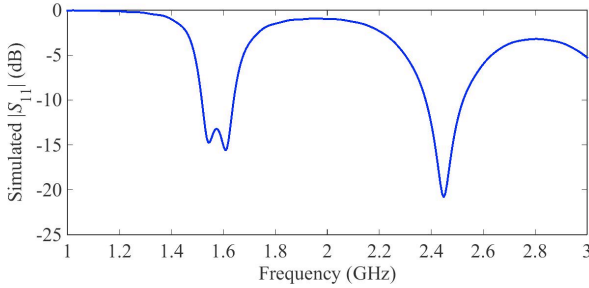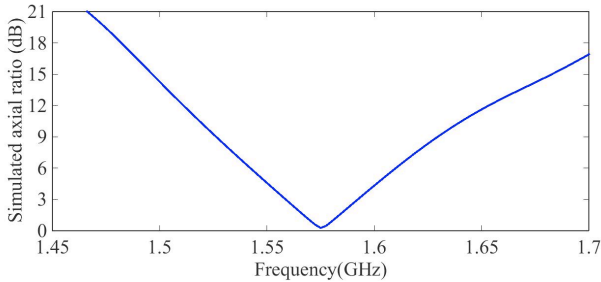

Fig. 2. S$_{11}$ of the proposed antenna

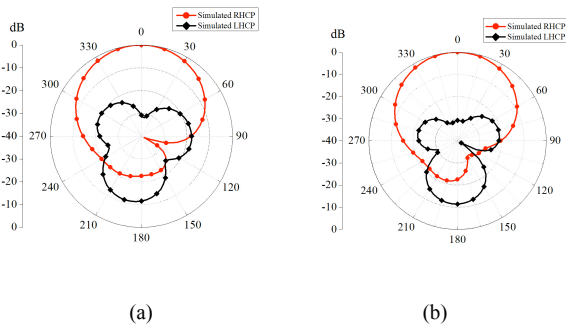Fig. 3. Axial ratio of the proposed antenna

(a)   (b)

Fig. 4. Normalized radiation pattern at 1.575 GHz in (a) *xz*-plane and (b) *yz*-plane

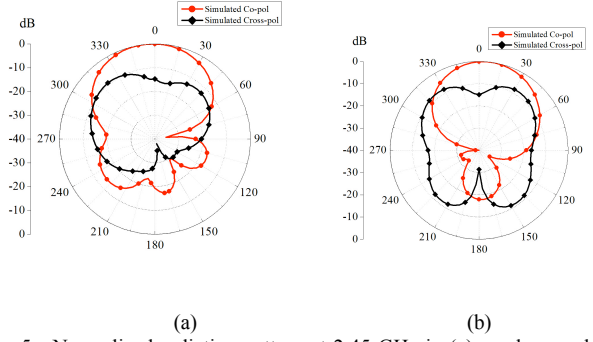(a)   (b)

Fig. 5. Normalized radiation pattern at 2.45 GHz in (a) *xz*-plane and (b) *yz*-plane

IV. CONCLUSIONS

In this paper, we presented a single capacitive-fed technique to achieve a dual band antenna with desirable polarization at the specific band. Both low and high frequency bandwidths of the antenna meet the requirements of GPS and Wi-Fi standards.

REFERENCES

[1] M.J. Ammann and Zhi Ning Chen, "Wideband monopole antennas for multi-band wireless systems", *IEEE Antennas and Propag. Mag.*, vol.45, no.2, pp.146-150, April. 2003.

[2] Y. Li and K. M. Luk,"Low-Cost High-Gain and Broadband Substrate-Integrated-Waveguide-Fed Patch Antenna Array for 60-GHz Band", *IEEE Trans. Antennas and Propag.*, vol.62, no.11, pp.5531-5538, Nov. 2014 .

[3] Y. Li and K. M. Luk, "60-GHz Substrate Integrated Waveguide Fed Cavity-Backed Aperture-Coupled Microstrip Patch Antenna Arrays", *IEEE Trans. Antennas and Propag.*, vol.63, no.3, pp.1075-1085, March 2015

[4] Y.F. Cao, S.W.Cheung and T.I. Yuk, "A Multiband Slot Antenna for GPS/WiMAX/WLAN Systems," *IEEE Trans. Antennas and Propag.*, vol.63, no.3, pp.952-958, March 2015.

[5] R. K. Raj, M. Joseph, B. Paul and P. Mohanan, "Compact planar multiband antenna for GPS, DCS, 2.4/5.8 GHz WLAN applications", *Electron. Lett.*, vol. 41, no. 6, pp. 290-291, 17 March 2005.

[6] R. Zhang, H. Kim and H. Kim, "Triple-band ground radiation antenna for GPS, WiFi 2.4 and 5 GHz band applications", *Electron. Lett.*, vol. 51, no. 25, pp. 2082-2084, 12 10 2015.

[7] W. Yang, J. Zhou, Z. Yu and L. Li, "Single-Fed Low Profile Broadband Circularly Polarized Stacked Patch Antenna," *IEEE Trans. Antennas and Propag.*, vol.62, no.10, pp.5406-5410, Oct. 2014.

[8] M. Chen and C.-C. Chen, "A Compact Dual-Band GPS Antenna Design," *IEEE Antennas Wireless Propag. Lett.*, vol. 12, pp. 245–248, 2013.

[9] K. F. Tong and T. P. Wong, "Circularly Polarized U-Slot Antenna," *IEEE Trans. Antennas and Propag.*, vol.55, no.8, pp.2382-2385, Aug. 2007.

[10] J. Chen, K. Tong, A. Al-Armaghany and J.Wang, "A Dual Band Dual Polarization Slot Patch Antenna for GPS and Wi-Fi Applications," *IEEE Antennas Wireless Propaga.Lett.*, vol. 15, no. , pp. 406-409, 2016.

[11] CST Microwave Studio user manual