A Dual-Band Circularly Polarized Stacked Microstrip Antenna with Single-fed for GPS Applications

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***Abstract*— A single probe feeding stacked microstrip antenna is presented to obtain dual-band circularly polarized (CP) characteristics using double layers of truncated square patches. The antenna operates at both the L1 and L2 frequencies of 1575 and 1227 MHz for the global positioning system (GPS). With the optimized design, the measured axial ratio (AR) bandwidths with the centre frequencies of L1 and L2 are both greater than 50MHz, while the impedance characteristics within AR bandwidth satisfy the requirement of VSWR less than 2. At L1 and L2 frequencies, the AR measured is 0.7 dB and 0.3 dB, respectively.**

I. INTRODUCTION

In recent years, Dual-band CP antennas are being more and more interested because of their convenient application to communication systems for handling two different communication protocols or systems such as satellite communication and Global positioning system (GPS) [1]. Among all of the dual-band CP antennas, microstrip antennas have obtained the most attention due to their advantages in cost, size, low profile, conformity to the supporting of structure and easy fabrication [2], [3]. Generally, CP characteristic of microstrip antenna may be derived by approaches of single fed and hybrid fed. A single-fed CP antenna provides simple structure, easy manufacture, and advantage in array with small size. However, it has the disadvantages of both narrow AR bandwidth and impedance bandwidth [4]. For a single fed microstrip antenna, applying of stacked structure is an effective approach for enhancing the bandwidth. In reference [5]-[7], stacked microstrip antennas using almost square patch has obtained 13%, 13.5%, and 14% 3 dB AR bandwidth of at C band, respectively. In reference [8], a stacked microstrip antenna using double layers of truncated square patches obtained a 3 dB AR bandwidth of 8%. However, the stacked microstrip antennas in reference [5]-[8] are all for single-band.

In this paper, a single-fed CP stacked microstrip antenna is presented using availably common dielectric laminates, which operates at both L1 and L2 frequency bands for GPS applications. Two truncated square patches are used for obtaining CP characteristics in the dual-band. The antenna is designed and optimized by HFSS.

II. ANTENNA GEOMETRY AND DESIGN

The geometry of the proposed antenna is shown in Fig. 1

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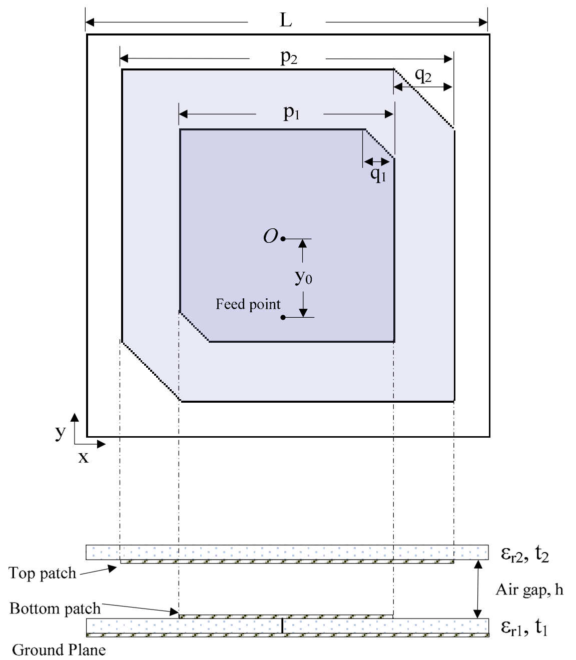


Fig. 1 Geometry of the proposed dual-band CP stacked microstrip antenna

The top patch (length p_2) is printed on substrate with thickness t_2 and dielectric constant ε_{r2}, and the bottom patch (length p_1) printed on substrate with thickness t_1 and dielectric constant ε_{r1}, while a air gap with thickness h separate the two layers of substrates. For well performance on VSWR and AR in stacked microstrip antenna, the bottom dielectric layer has to have a greater permittivity than the upper layer, thus making the parasitic patch loosely coupled [8], [9]. In this paper, we use Polyflon_NorCLAD (ε_{r2} = 2.55, tanδ = 0.0011) with t_2 = 1.5mm as the superstrate, and FR4_epoxy (ε_{r1}= 4.4, tanδ = 0.02) with t_1 = 1mm as the substrate. For the application of inexpensive substrates, the antenna costs lowly.

As we known, the side length of square patch affects the center frequency of the antenna, so the initial p_1, p_2 are determined by L1 and L2 using empirical formula on the cavity model of microstrip antenna [10]. In this paper, corner truncated approach is used with a pair of opposite corners (side length q_1, q_2) of square patch cut providing as a perturbation for obtaining two orthogonal near degenerate resonant modes of CP radiation [11]. To a single layer truncated square patch, with a fixed single feeding point and

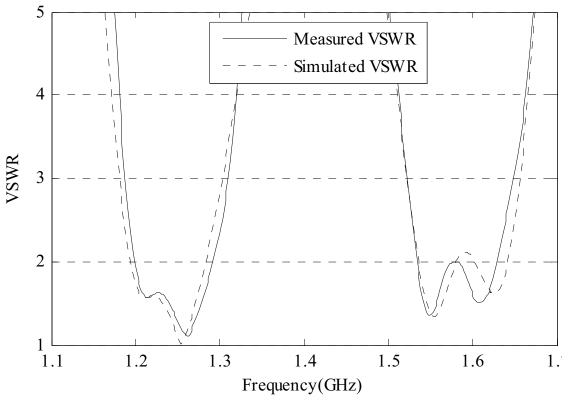


Fig. 2 Measured and simulated VSWR for the designed antenna.

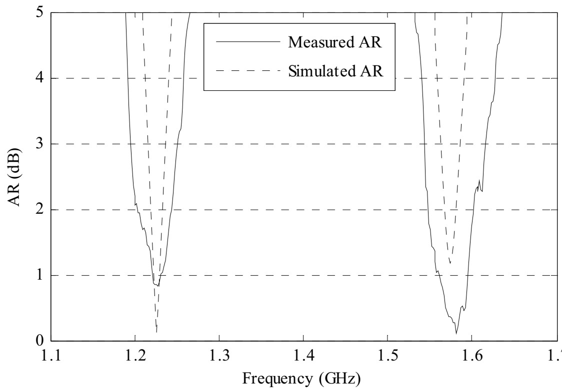


Fig. 3 Measured and simulated AR for the designed antenna.

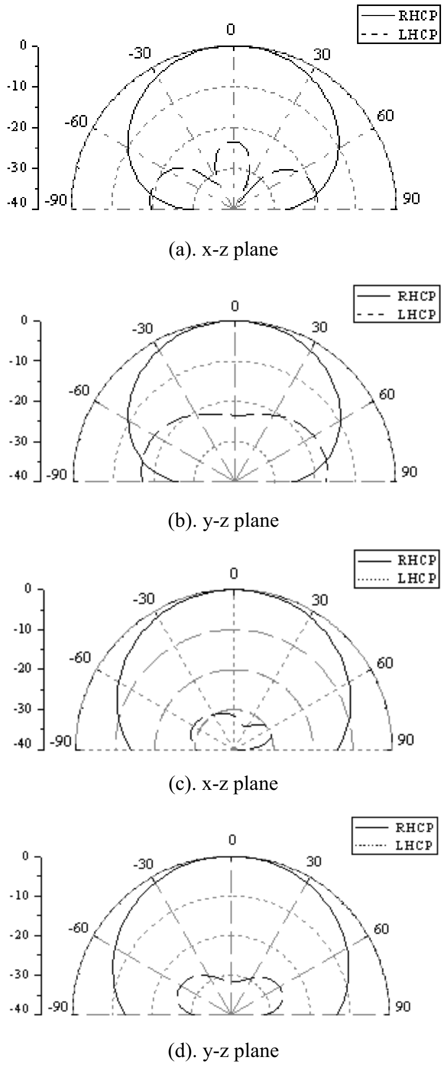
square patch side length, the perturbation determines the CP characteristic. In stacked patch antenna, h is the other freedom parameter affecting AR performance, which controls the coupling between patches for locating the resonant frequencies directly at L1 and L2. TABLE I gives the movement of dual resonant frequencies by adjusting h. If we define the frequency interval (Δf) of double resonant frequencies (lower frequency: f_1, higher frequency: f_2) as: $\Delta f = f_2 - f_1$, Δf decreases by the increasing of h.

In the antenna design, two layers of truncated square patches are utilized to obtain dual-band CP radiation. Both patch lengths p_1, p_2 and the perturbations q_1, q_2 are optimized

TABLE I
MOVEMENT OF THE RESONANT FREQUENCIES BY CHANGING AIR GAP THICKNESS

p_1=52.6mm, q_1=7.2mm, p_2=82.6mm, q_2=14.8mm, y_0=23mm

h	f_1	f_2	Δf
8mm	1221 MHz	1585 MHz	364 MHz
9mm	1227 MHz	1575 MHz	348 MHz
11mm	1245 MHz	1565 MHz	320 MHz
13mm	1255 MHz	1547 MHz	292 MHz



(a). x-z plane

(b). y-z plane

(c). x-z plane

(d). y-z plane

Fig. 4 The simulated radiation patterns for L1 and L2 frequencies. (a), (b) is the radiation pattern in x-z and y-z plane for L1 frequency, respectively. (c), (d) is the radiation pattern in x-z and y-z plane for L2 frequency, respectively.

in the design. And also, feeding point location (0, y_0) and air gap thickness h are optimized too.During the whole design process, locating the dual resonant frequencies at the direct frequency points meeting GPS application operating at 1227MHz and 1575MHz is the most difficult task.

III. EXPERIMENT RESULTS

The simulated and measured VSWR of the designed single-fed dual-band CP antenna are shown in Fig.2. The measured bandwidth of VSWR<2 is 10.64% (1184MHz to 1317MHz) for L2 band and 8.82% (1516.5MHz to 1656.5 MHz) for L1, while the simulated is 6.92% (1196.25MHz to 1282MHz) and 6.29% (1539.25MHz to1639 MHz), respectively. Comparing to the simulated result of impedance band, the measured shift left a little at L1 band and right a little at L2. For the CP microstrip antenna, the most attractive characteristic is AR.

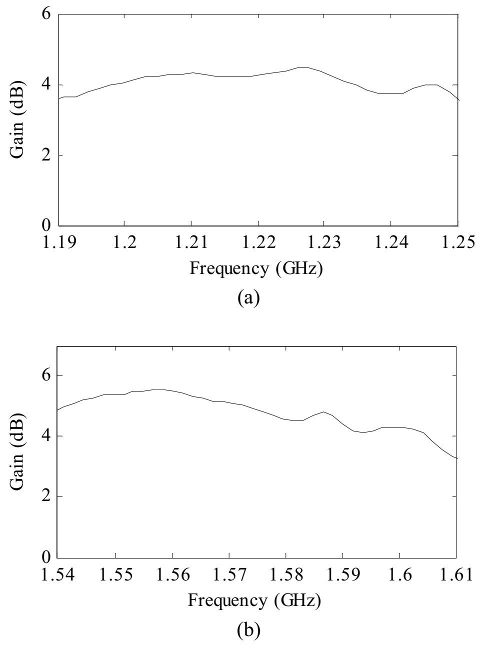


Fig. 5 Measured gains for the dual frequency band of AR< 3 dB. (a) is for L2 band, and (b) is for L1 band.

The simulated and measured AR are shown in Fig. 3. The measured 3 dB AR bandwidth is52.5MHz (4.3%,1196.25MHz to 1248.75MHz) for L2 frequency band and 71.75MHz (4.5%, 1544.5MHz to 1616.25MHz) for L1, while the simulated is 21MHz (1.72%, 1210.25MHz to 1231.25MHz) and 21MHz (1.33%, 1563.75MHz to 1584.75MHz), respectively. Both the 3 dB AR bandwidths near L1 and L2 frequencies are covered by the impedance bandwidths of VSWR less than 2. At the frequency points L1 and L2, the AR measured is 0.3 dB and 0.7 dB, respectively.

The simulated radiation patterns are shown in Fig. 4 (a), (b), (c) and (d), and good RHCP radiation characteristic with broadside radiation patterns can be seen from the patterns, while the 10 dB beamwidth at L1 and L2 is about 120°and 150°, respectively. The gain measured at 1227MHz and 1575MHz is about 4.4 dB and 4.9 dB, respectively. Fig. 5 shows the measured gain versus frequency over the 3dB AR bandwidth covering both L1 and L2 bands.

IV. Conclusion

A single-fed dual-band circularly polarized patch antenna is presented with double layers of truncated square patches for use in GPS requiring approximately 40MHz at 1227MHz and 1575MHz each. Measurement results of the fabricated antenna show that the obtained 3 dB AR bandwidths for L1 and L2 frequency bands are both greater than 50MHz. Because both the dielectric constants of FR4 and Polyflon_NorCLAD are relatively low, the patch sizes are large, which led to relatively narrow pattern beamwidths (10dB). Improvement could be obtained by using antenna substrates with higher dielectric constants in order to reduce the size of the patch antenna.

References

[1] Zhizhang Chen, Acep D. Ganjara, and Xiaomin Chen, "A Dual-L Antenna with a novel tuning technique for dual frequency applications," *IEEE Transactions on Antennas and Propagation,* vol. 50, pp. 402-403, March 2002.

[2] Shancheng Pan, and Kinlu Wong, "Dual-Frequency Triangular Microstrip Antenna with a Shorting Pin " *IEEE Transactions on Antennas and Propagation*, vol. 45, pp.1889-1891, 1997.

[3] Jaume Anguera, Carles Puents, and Carmen Borja, "Dual-fequency Broad-Band stacked Microstrip patch Antennas," *IEEE. Antenans Wireless Propag. Lett ,* vol. 2, pp. 36-39, 2003.

[4] Hyungrak Kim, Byoung Moo, and Young Joong Yoon, "A single-feeding circularly polarized microstrip antenna with the effect of hybrid feeding," *IEEE Antennas and Wireless Propagation Letters*, vol. 2, pp: 74-77, 2003.

[5] N. Herscovici, Z. Sipus, and D. Bonefaci, " Circularly polarized single-fed wideband microstrip patch, " *IEEE Transactions on Antennas and Propagation,* vol. 51, no. 6, pp. 1277-1280, 2003.

[6] Nasimuddin, Karu P. Esselle, and A. K. Verma, " Wideband circularly polarized stacked microstrip antennas, " *IEEE Antennas and wireless Propagation letters*, vol. 6, pp. 21- 24, 2007.

[7] Jianfeng Ye, Yufeng, Wang, and Weizheng Pang, " Optimized Desgin of Circularly Polarized Wideband Stacked Microstrip Antenna With Single-Fed" *2008 International Conference on Microwave and Millimeter Wave Technology (ICMMT 2008)*, *Nanjing* vol. 4, pp. 1651-1653, April 2008.

[8] Kwok Lun Chung, and Ananda Sanagavarapu Mohan, " A systematic design method to obtain broadband characteristics for single-fed electromagnetically coupled patch antennas for circular polarization" *IEEE Transactions on Antennas and Propagation*, vol. 51, pp 3239-3248, Dec, 2003.

[9] R. B. Waterhouse, "Stacked patches using high and low dielectric constant material combinations," *IEEE Transactions on Antennas and Propagation,* vol. 47, pp. 1767-1771, Dec. 1999.

[10] Lo. Y. T, Solomon D, and Richards. W. F, "Theory and experiment on microstrip antennas," *IEEE Transactions on Antennas and Propagation*, vol. 27, pp. 137–145, 1979.

[11] P. C. Sharma and K. C. Gupta, "Analysis and optimized design of single feed circularly polarized microstrip antenna," *IEEE Transactions on Antennas and Propagation*, vol. 31, pp. 949–955, 1983.