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 center 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 available 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. The top patch (length $p_2$) is printed on substrate with thickness $t_2$ and dielectric constant $\varepsilon_{2r}$, and the bottom patch (length $p_1$) printed on substrate with thickness $t_1$ and dielectric constant $\varepsilon_{1r}$, 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 ($\varepsilon_{2r} = 2.55, \tan\delta = 0.0011$) with $t_2 = 1.5$mm as the superstrate, and FR4 epoxy ($\varepsilon_{1r} = 4.4, \tan\delta = 0.02$) with $t_1 = 1$mm 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
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 \( L_1 \) and \( L_2 \). TABLE I gives the movement of dual resonant frequencies by adjusting \( h \). If we define the frequency interval (\( \Delta f \)) of double resonant frequencies (lower frequency: \( f_1 \), higher frequency: \( f_2 \)) as: \( \Delta f = f_2 - f_1 \), \( \Delta f \) 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 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 1227 MHz and 1575 MHz is the most difficult task.

### TABLE I

<table>
<thead>
<tr>
<th>( h )</th>
<th>( f_1 )</th>
<th>( f_2 )</th>
<th>( \Delta f )</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 mm</td>
<td>1221 MHz</td>
<td>1585 MHz</td>
<td>364 MHz</td>
</tr>
<tr>
<td>9 mm</td>
<td>1227 MHz</td>
<td>1575 MHz</td>
<td>348 MHz</td>
</tr>
<tr>
<td>11 mm</td>
<td>1245 MHz</td>
<td>1565 MHz</td>
<td>320 MHz</td>
</tr>
<tr>
<td>13 mm</td>
<td>1255 MHz</td>
<td>1547 MHz</td>
<td>292 MHz</td>
</tr>
</tbody>
</table>

In the 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% (1184 MHz to 1317 MHz) for \( L_2 \) band and 8.82% (1516.5 MHz to 1656.5 MHz) for \( L_1 \), while the simulated is 6.92% (1196.25 MHz to 1282 MHz) and 6.29% (1539.25 MHz to 1639 MHz), respectively. Comparing to the simulated result of impedance band, the measured shift left a little at \( L_1 \) band and right a little at \( L_2 \). For the CP microstrip antenna, the most attractive characteristic is AR.
The simulated and measured AR are shown in Fig. 3. The measured 3 dB AR bandwidth is 52.5 MHz (4.3%, 1196.25 MHz to 1248.75 MHz) for L2 frequency band and 71.75 MHz (4.5%, 1544.5 MHz to 1616.25 MHz) for L1, while the simulated is 21 MHz (1.72%, 1210.25 MHz to 1231.25 MHz) and 21 MHz (1.33%, 1563.75 MHz to 1584.75 MHz), 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 1227 MHz and 1575 MHz is about 4.4 dB and 4.9 dB, respectively. Fig. 5 shows the measured gain versus frequency over the 3 dB 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 40 MHz at 1227 MHz and 1575 MHz 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 50 MHz. 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 (10 dB). Improvement could be obtained by using antenna substrates with higher dielectric constants in order to reduce the size of the patch antenna.

REFERENCES