Compact Dual Circularly-Polarized Microstrip Antennas

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Abstract – This paper presents a compact dual-feed patch antenna capable of achieving dual-polarized radiation suitable for applications demanding frequency reuse or polarization diversity. Circular polarization is obtained by feeding the antenna with 90° phase shift between its two ports using Wilkinson power divider having λ/4 difference between its outputs. This proposed circularly polarized antenna is suitable for GPS applications.

Introduction

Microstrip patch antennas are widely used because of its low profile, light weight, simple construction, and conformity. Compact microstrip antennas have recently received much attention due to the increasing demand of small antennas for personal communications equipment. To reduce the antenna size at a fixed operating frequency, high-permittivity substrate is employed and embedding suitable slots in the radiating patch is also used [1]. This kind of slotted patch causes meandering of the patch surface current path in two orthogonal directions.

This paper presents a design of a compact dual-polarized square patch microstrip antenna. Antenna size reduction is employed through the use of a four bent embedded slots in the square patch. Effects of these bent slots length on both antenna gain and patch size are studied, while Wilkinson power divider as 90° phase shifter is presented. A high permittivity substrate is used to improve antenna size reduction. The simulations were performed using both Ansoft High Frequency Structure Simulator (HFSS) [2] and the FDTD software based on [3].

Compact Dual-Polarized Microstrip Antenna Structure and results

Figure 1 shows the geometry of the compact dual-polarized square patch microstrip antenna with four bent slots parallel to the patch’s central lines [1]. The four bent slots are of the same dimensions. The two arms of each bent slot have the same length and are perpendicular to each other. The two probe feeds for the two feeding ports are located along the x and y axes respectively, at a distance from the patch center for impedance matching. The feed arrangement excites 0° (x-directed) and 90° (y-directed) linearly polarized waves. An inexpensive FR4 substrate of thickness h=1.5 mm, relative permittivity of εr=4.35, and loss tangent of 0.02 is used, and the resonant frequency is adjusted at 1575.42 MHz.

Figure 2 shows the radiation pattern of the antenna indicating cross polarization level of less than -28 dB. Figure 3 shows the return loss S11 of one port “the two ports are identical” and the isolation S21 indicating good port decoupling.
Based on the above design concept, Table 1 confirms that by increasing the bent slots length, antenna patch size decreases due to meandering of the current path, on the expense of both antenna gain and impedance bandwidth.

### Table 1 – Performance of the compact dual-polarized microstrip antenna versus slot length.

<table>
<thead>
<tr>
<th>Slot Length (mm)</th>
<th>Patch Length (mm)</th>
<th>Feeding Position from origin (mm)</th>
<th>Compact Ratio (%)</th>
<th>Gain (dB)</th>
<th>Impedance Bandwidth (MHz)</th>
<th>Impedance Bandwidth Ratio (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>44.7</td>
<td>11.2</td>
<td>0</td>
<td>-0.26</td>
<td>38</td>
<td>2.41</td>
</tr>
<tr>
<td>4</td>
<td>44.2</td>
<td>10.6</td>
<td>1.12</td>
<td>-0.38</td>
<td>38</td>
<td>2.41</td>
</tr>
<tr>
<td>6</td>
<td>43.3</td>
<td>9.7</td>
<td>3.13</td>
<td>-0.58</td>
<td>36</td>
<td>2.29</td>
</tr>
<tr>
<td>8</td>
<td>41.8</td>
<td>9</td>
<td>6.49</td>
<td>-0.90</td>
<td>35</td>
<td>2.22</td>
</tr>
<tr>
<td>10</td>
<td>39.3</td>
<td>8.2</td>
<td>12.08</td>
<td>-1.53</td>
<td>29</td>
<td>1.84</td>
</tr>
<tr>
<td>12</td>
<td>35</td>
<td>7.5</td>
<td>21.7</td>
<td>-3.10</td>
<td>28</td>
<td>1.78</td>
</tr>
</tbody>
</table>

**Compact Circular-Polarized Microstrip Antenna**

In order to get circular polarization, the two orthogonal feeds of the square patch antenna discussed above are to be fed with 90° out of phase which allows exciting two orthogonal TM_{01} modes on the square patch [4]. Figure 4 shows the geometry of the compact circular polarized square patch microstrip antenna. It must be noticed that, to get circular polarization, the slot length and the width should be identical and symmetric with respect to orthogonal axes. Slight asymmetry can produce strong degradation of the polarization purity because the two principle axes modes can resonate at different frequencies [4].

A microstrip Wilkinson power divider having λ/4 difference in length between its outputs is integrated on the back side of the antenna ground plane using the same FR4 substrate of the patch antenna. Figure 5 shows the phase shift between the outputs feed points, and Figure 6 shows the scattering parameters of the feeding circuit.

Figure 7 depicts the left and right hand circular polarized far field patterns of the antenna. It is worth noting that a high degree of polarization purity is maintained also for low incidence angles and the sensitivity to nearby scattering structures is highly reduced because the two exciting quadrature TM_{01} modes are strongly decoupled [4], the antenna axial ratio is 0.35 dB.

**Compact Enhancement using High Permittivity Substrate**

For achieving more reduction in antenna patch size at a fixed operating frequency, the use of a high permittivity substrate is an effective method [1], and to improve antenna efficiency, a low loss material should be used [4]. A new design has been realized employing RT/Duroid 6010 LM substrate (ε_r = 10.8, tan δ = 0.0023, thickness = 1.9mm), achieving patch length of 26.6mm, a reduction of about 38.6% compared to the mentioned above FR4 substrate in expenses of impedance bandwidth reduction to 19 MHz.

With a size reduction at a fixed operating frequency, the impedance bandwidth of a microstrip antenna is usually decreased [1]. To enhance the impedance bandwidth, one can simply increase the antenna’s substrate thickness to compensate for the decreased electrical thickness of the substrate due to the lowered operating frequency [1]. A relatively larger substrate thickness of the same substrate (RT/Duroid 6010 LM of thickness = 2.5mm) is also used which increased the impedance bandwidth from 19 MHz to 26 MHz.
Conclusion

This paper presents compact operations for microstrip antennas. Size reduction is achieved by meandering current path through four bent slots embedded in the patch antenna and by increasing substrate’s permittivity. Compact dual-feed dual-polarized and circular-polarized microstrip square patch antennas are depicted. The effect of increasing the slot length on both antenna size and gain are studied.

References


Fig. 4 – Geometry of the compact Circular-polarized square patch microstrip antenna with bent slots in parallel with the patch’s central line and Wilkinson feeding network configuration, placed under the ground plane.

Fig. 5 – Phase shift between Wilkinson power divider outputs feed points.

Fig. 6 – Scattering parameters of Wilkinson power divider phase shifter in Fig. 4.

Fig. 7 – Radiation pattern of the circularly polarized antenna at 1575.42 MHz using HFSS Simulator [2], (a) RHCP and LHCP in x-z plane, (b) RHCP and LHCP in y-z plane.