Rectangular Microstrip Antenna for GPS receiver

MARIO REYES-AYALA, EDGAR ALEJANDRO ANDRADE-GONZALEZ, JOSE RAUL MIRANDA-TELLO
Department of Electronics
Metropolitan Autonomous University
Av. San Pablo 180, Azcapotzalco, ZIP Code 02200, Mexico City
MEXICO
mra@correo.azc.uam.mx

Abstract: - In this paper, a rectangular patch antenna for GPS receivers is analyzed and designed. The antenna model is presented, calculated and simulated. Radiation patterns and antenna matching are the most important simulation parameters.

Key-Words: - Microstrip antennas, GPS, GPS receivers, antenna matching, radiation pattern, antenna gain, antenna efficiency, SWR.

1 Introduction
The Global Positioning System (GPS) is the most extended positioning approach, because its features in comparison with the russian equivalent (GLONASS). The most important advantages of GPS are: 31 satellites in six Medium Earth Orbit (MEO), very strong encryption techniques and, high position accuracy. Many terrestrial and aeronautical transportation systems use GPS in order to obtain position and time information; where this information is usually used in combination with maps and databases.

GPS approach is based in a Mesh satellite network, then there are at least four visible satellites in any point on the Earth surface. In addition to this, the very stable atomic clocks employed in the GPS give its amazing time accuracy. It is clear, that the receiver requires an omni-directional antenna, with a moderate antenna gain, because GPS operation need four or more satellites, which could be in any direction.

Microstrip antennas can be used in GPS applications because they are compatible with microwave circuits, they have the electrical restrictions and they are easy to put in the body of the transportation system. Frequently, this kind of antennas are selected, because they do not modify the aerodynamic behavior of the ships [1] [2] [3] [4] [8].

2 Antenna model
Rectangular microstrip antennas can be modeled as an equivalent line transmission that is necessary to match with the terminal equipment. The antenna is normally matched with a microstrip line with the aim to optimize the power transference to the free space [4].

The antenna and its dimensions are illustrated in Fig. 1. The antenna has a single patch in the top layer and a ground plane in the bottom one. The length and width of the patch are calculated according to the operation frequency; and, the size of the ground plane determines the back lobe generation. In the top layer there is a microstrip line in order to minimize the power losses and the SWR [7] [8] [9].

Fig. 1 Rectangular microstrip antenna.
The dielectric constant of the substrate is very important, because the matching of the antenna and antenna efficiency can be changed if the relative permittivity is modified.

As a consequence of the fringing effect it is necessary to calculate the effective value of the dielectric constant. In equation (1) the effective relative dielectric constant is calculated as a function of the dimensions of the patch.

\[ \varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{1/2} \]  

(1)

Where \( h \) is the thickness of the substrate, m; \( W \) is the width of the patch, m; and \( \varepsilon_r \) is the relative dielectric constant of the substrate. All the models of patch antennas should have a substrate thickness very small in comparison with its width.

The electric field can be considered uniform into the substrate, but there is a fringing effect near the edges of the patch, especially in the slot. This effect is taken into account in the model, because the effective length of the patch is different than the physical antenna. The length correction is determined by equation (2).

\[ \Delta L = \frac{0.412}{h} \left( \sqrt{\frac{\varepsilon_{\text{eff}} + 0.3}{\varepsilon_r + 0.3}} \left( \frac{h}{W} + 0.264 \right) \right) \]  

(2)

In order to get an efficient radiator, it is necessary to achieve the best patch width. In the equation (3), the width of the patch is determined by the operating frequency.

\[ W = \frac{v_0}{2f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \]  

(3)

Where \( f_r \) is the operating frequency, Hz; and, \( v_0 \) is the light velocity constant, m/s.

The line transmission feeder is calculated in order to achieve impedance matching between the GPS receiver and the microstrip antenna; and in this case, it was designed for a 50Ω SMA standard connector. The model of the antenna is illustrated in Fig. 1, where the line transmission feeder, SMA connector and, coaxial cable are included.

Following the procedure mentioned in this section, the antenna has the appearance illustrated in Fig. 1.

The final dimensions of the rectangular microstrip antenna are shown in the table I.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Width of the ground plane</td>
<td>( W_g )</td>
<td>100 mm</td>
</tr>
<tr>
<td>2 Length of the ground plane</td>
<td>( L_g )</td>
<td>100 mm</td>
</tr>
<tr>
<td>3 Width of the patch</td>
<td>( W )</td>
<td>57.94 mm</td>
</tr>
<tr>
<td>4 Length of the patch</td>
<td>( L )</td>
<td>45.14 mm</td>
</tr>
<tr>
<td>5 Length of the feeder</td>
<td>( l )</td>
<td>23.28 mm</td>
</tr>
<tr>
<td>6 Width of the feeder</td>
<td>( w )</td>
<td>0.69 mm</td>
</tr>
</tbody>
</table>

### 3 Results

After computation, the model of the antenna is simulated using a finite element software.

The structure have two slots between patch and ground layer, one of them is connected to the microstrip line feeder and, the other one in the opposite side of the patch. The sizes of these slots are calculated for a particular carrier frequency equal to 1.5 GHz approximately.

![Fig. 2 3-D Antenna Pattern of the antenna.](image)
amplitude of the electromagnetic waves between the layers of the antenna.

![Fig. 3 S11 of the antenna.](image)

In Fig. 3 the S11 parameter of the antenna is shown, where the antenna is matched in the carrier frequency. Besides this, it is obvious that the quality factor allows us to eliminate many spurious and harmonic components.

4 Conclusion

In this paper, a rectangular microstrip antenna for GPS applications was carried out. The antenna was design using the equivalent line transmission model and it was simulated employing a finite element computational tool (CST).

The mechanical features of the structure are compatible with serial manufacturing process for mass production. The antenna gain and resonant frequency are very similar using that kind of fabrication processes, even if inexpensive machinery is employed for educational purposes, for instance.

The beamwidth of the antenna pattern are compatible with a large number of mobile communications systems. The antenna gain (6.07 dBi) is enough to provide the needed power for the link budget in many terrestrial and aeronautical applications.

The antenna can be improved using slots in the patch or other sort of defected structures. The antenna bandwidth increased and it is possible to narrow down the total area of the antenna [5] [6].

It is also feasible to tune the antenna in the carrier frequency by multiple simulations, where the width and length of the patch are slightly modified.

References:


