Design and Photo-Lithographic Fabrication of Microstrip Patch Antenna

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Abstract: Microstrip patch antennas are generally fabricated by photo-lithographic method. Photo-lithographic method produces highly accurate etched pattern for the microstrip patch. Fabrication accuracy is very critical as the microstrip patch antennas are narrow band resonant structures that usually operate in the microwave bands. Fabrication errors in the patch dimensions will shift its resonant frequency. Photo-lithographic method is a chemical etching process which removes the unwanted metal regions of the metallic layer. This paper describes the design, simulation and the step by step fabrication process for a rectangular microstrip patch antenna.

Keywords: Microstrip Patch Antenna, EMCoS Simulation, Photo-lithography, Fabrication, UV light

1. Introduction

Microstrip patch antennas (MSPAs) consist of a metallic patch printed on a grounded and electrically thin dielectric substrate. The radiating metallic patch can assume any shape but regular geometrical shapes are generally employed. Regular geometrical shapes simplify analysis and provide performance prediction. Rectangular and circular geometries are common. The rectangular patch has to be half wave length long at the resonant frequency [1]. Thick substrates with a low value of dielectric constant εr are generally used to enhance the fringing fields, which account for the radiation from microstrip patch antenna [2], [3].

This paper describes the designing and fabrication of a rectangular microstrip patch antenna. The microstrip patch antenna is designed and simulated using EMCoS Antenna VirtualLab™ electromagnetic simulation software, which is based on the Method of Moment (MOM) technique of solving electromagnetic problems [5]. The design steps are detailed below.

2. Rectangular Microstrip Patch Antenna Design

This section presents the design and simulation of rectangular microstrip patch antenna, for resonant frequency of 1950 MHz, using EMCoS Antenna VirtualLab™ electromagnetic simulation software.

2.1 Initial Design

The initial microstrip patch antenna design parameters, patch length L, patch width W, feed position (x_f, y_f) from the center of the patch, ground plane length L_g and ground plane width W_g, are estimated, using the Transmission Line model [7] and the Cavity model of microstrip patch antenna [8]. The design steps are detailed below.

The second step determines the effective dielectric constant of air-substrate-air multilayer medium,

\[ \varepsilon_e = \frac{\varepsilon_r + 1 + (\varepsilon_r - 1)(1 + 12\frac{h}{W})^{-1}}{2} \]  

where, \( h \) is the height or thickness of the substrate.

The third step calculates the electrical elongation of patch length,

\[ f_0 = \frac{c}{2(L + 2\Delta l)\sqrt{\varepsilon_e}} \]  

The resonant frequency \( f_0 \) of the TM_{10} mode is given by,
where, \( c \) is the speed of light in free space.

The fourth step obtains the physical length \( L \) of the patch resonating at frequency \( f_0 \),

\[
L = \frac{c}{2f_0 \sqrt{\varepsilon}}
\]

(5)

The fifth step determines the feed position, relative to the origin, located at the center of the patch,

\[
x_f = \frac{L}{\pi} \arcsin \left( \frac{50}{R_{\text{in}}} \left( x = \frac{L}{2} \right) \right)
\]

\[
y_f = 0
\]

(6)

The sixth step decides the ground plane length \( L_g \) and width \( W_g \), which should be at least

\[
L_g = 6h + L
\]

\[
W_g = 6h + W
\]

(7)

The design parameters estimated using the above six steps, for a rectangular microstrip patch antenna, resonant at 1950 MHz, which uses RO3003™ copper clad substrate from Rogers, USA, are shown in the Table 1. The table also shows RO3003™ copper clad substrate parameters [10]. The half wavelength rectangular microstrip patch antenna is illustrated in the Fig 1.

### Table 1: Initial Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value in mm</th>
<th>RO3003™</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td>43.942995</td>
<td></td>
</tr>
<tr>
<td>( W )</td>
<td>54.392829</td>
<td></td>
</tr>
<tr>
<td>( L_g )</td>
<td>53.086995</td>
<td>( \varepsilon_r ) 3</td>
</tr>
<tr>
<td>( W_g )</td>
<td>65</td>
<td>( \tan(\delta) ) 0.0013</td>
</tr>
<tr>
<td>( x_f )</td>
<td>8.247373</td>
<td>Colour White</td>
</tr>
<tr>
<td>( y_f )</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>1.30</td>
<td></td>
</tr>
</tbody>
</table>

### Figure 1: Rectangular Microstrip Patch Antenna on RO3003™

#### 2.2 Simulation and Final Design

The initial antenna design obtained using the Transmission Line model and the Cavity model, is simply a rough estimate. It needs further refinements, to achieve the design specifications. The initial design is refined using computer simulation. The electromagnetic simulation software EMCoS Antenna VirtualLab™ is used for simulation and corrections. The details of simulation of microstrip patch type antenna using EMCoS Antenna VirtualLab™ are given in [9].

The antenna model is improved by changing any one of antenna model parameters, the patch dimensions or ground dimensions or the feed location and the resulting model is simulated and obtained results are compared again with the antenna parameters required. The process of changing antenna model, simulating it and comparing results with the antenna parameters of the design specifications, is repeated until a good match between simulation results and the design specified antenna parameters is obtained.

The final microstrip patch antenna model dimensions and feed location, obtained using the technique of iteratively improving antenna model, described previously, is shown in the Table 2.

### Table 2: Final Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value in mm</th>
<th>RO3003™</th>
</tr>
</thead>
<tbody>
<tr>
<td>( L )</td>
<td>42.215513</td>
<td>( h ) 1.524 mm</td>
</tr>
<tr>
<td>( W )</td>
<td>54.392829</td>
<td>( \varepsilon_r ) 3</td>
</tr>
<tr>
<td>( L_g )</td>
<td>65</td>
<td>( \tan(\delta) ) 0.0012</td>
</tr>
<tr>
<td>( W_g )</td>
<td>65</td>
<td>Colour White</td>
</tr>
<tr>
<td>( x_f )</td>
<td>8.907163</td>
<td></td>
</tr>
<tr>
<td>( y_f )</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>1.30</td>
<td></td>
</tr>
</tbody>
</table>

The antenna characteristics for \( S_{11} \) and \( Z_{11} \) are presented in Fig 2 and Fig 3, respectively. The VSWR and Smith chart for the antenna design, are presented in Fig 4 and Fig 5 respectively.
The results for some important antenna parameters are given in the Table 3

Table 3: Rectangular Microstrip Patch Antenna Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_0$</td>
<td>1950</td>
<td>MHz</td>
</tr>
<tr>
<td>$S_{11}$ Minimum</td>
<td>-39.0398</td>
<td>dB</td>
</tr>
<tr>
<td>VSWR Bandwidth</td>
<td>32</td>
<td>MHz</td>
</tr>
<tr>
<td>$S_{11}$ Bandwidth</td>
<td>34</td>
<td>MHz</td>
</tr>
<tr>
<td>$Z_{11}$ at resonance</td>
<td>51.1144-j0.183245</td>
<td>Ohm</td>
</tr>
</tbody>
</table>

[1] Fabrication of Rectangular Microstrip Patch Antenna

This section describes the photo-lithographic fabrication of rectangular microstrip patch antenna designed and simulated in the earlier section. The dimensions of designed rectangular microstrip patch antenna are given in the Table 2.

The results for some important antenna parameters are given in the Table 3
3. Conclusions and Discussions

A half wavelength rectangular microstrip patch antenna, resonant at frequency $f_o = 1950$ MHz, is designed and simulated on RO3003™ copper clad substrate. The microstrip patch antenna dimensions obtained from the simulation are used to fabricate the antenna. The antenna is fabricated using photo-lithography technique. The photo-lithographic fabrication of microstrip patch antenna is described.

4. Acknowledgements

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References


Figure 6: Photo-lithographic Fabrication Initial Steps

Figure 7: Photo-lithographic Fabrication Final Steps

Figure 8: Rectangular Microstrip Patch Antenna

Figure 9: UV Exposure Unit