Performance Analysis Of A Rectangular Microstrip Patch Antenna With Different Ground Materials For Wireless Communications

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Abstract: Present days technology demands antenna that can operate at different wireless frequency bands and should have features like low cost, minimal weight, low profile that are capable of maintaining high performance over large frequency spectrum. The proposed antenna is designed with rectangular FR-4 (lossy) substrate with dielectric constant $\varepsilon_r = 4.4$ and the thickness $h=1.6$mm . A rectangular microstrip antenna with copper (annealed) ground is designed using CST software at 2.4GHz frequency. This frequency used in microwave applications like WLAN and WiMAX have been widely used in mobile devices such as hand held computers and smart phones. And compared performance parameters like Gain, Return loss, VSWR for different ground materials like platinum, Aluminum and copper (annealed).

Index Terms: Rectangular microstrip antenna, Dielectric constant of substrate, Ground materials, antenna parameters, CST software

1. INTRODUCTION

1.1 Microstrip Antenna

Microstrip antennas became very popular in the 1970’s for space-born applications. Today they are used for government and commercial applications. This antennas consist of a metallic patch on a dielectric substrate which is present above the ground plane as shown in fig.1.

![Fig 1 Structure of Microstrip Patch Antenna](image)

1.2 Radiation mechanism of microstrip antenna

Radiation mechanism of rectangular microstrip antenna shown in the figure 2. The field varies along the patch length which is about half a wavelength. Radiation may be ascribed mostly to the fringing fields at the open circuited edge of the patch.

![Fig 2 Rectangular microstrip patch antenna](image)

1.3 Applications of Microstrip Antenna

Microstrip antenna is the most popular types of printed antenna. These play a very significant role in today’s wireless communication systems, satellite communication, mobile communication as shown in table 1. with their frequency range.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Application</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GPS</td>
<td>1575MHz and 1227 MHz</td>
</tr>
<tr>
<td>2</td>
<td>GSM</td>
<td>890-915MHz and 935-960MHz</td>
</tr>
<tr>
<td>3</td>
<td>Cellular video</td>
<td>28 GHz</td>
</tr>
<tr>
<td>4</td>
<td>Wireless LAN WiFi</td>
<td>2.40-2.48 GHz and 5.4 GHz</td>
</tr>
<tr>
<td>5</td>
<td>Collision Avoidance RADAR</td>
<td>60 GHz, 77GHz and 94GHz</td>
</tr>
<tr>
<td>6</td>
<td>Wide Area Computer Networks</td>
<td>60GHz</td>
</tr>
<tr>
<td>7</td>
<td>Direct Broadcast Satellite</td>
<td>11.7-12.5 GHz</td>
</tr>
</tbody>
</table>

2. ANTENNA CHARACTERISTICS

2.1 Gain

Gain of an antenna is defined as “the ratio of the intensity, in given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically.
\[ G = \frac{\text{radiation intensity}}{\text{total input (accepted power)}} = \frac{4 \pi U(\theta, \phi)}{P_n} \]

\[ G = \frac{4 \pi U(\theta, \phi)}{P_n (\text{lossless isotropic source})} \]

2.2 Directivity

The mathematical expression for directivity is given by

\[ D = \frac{U}{U_o} = \frac{4 \pi U}{P_{rad}} \]

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity) expressed as

\[ D_{max} = D_o = \frac{U_{max}}{U_o} = \frac{4 \pi U_{max}}{P_{rad}} \]

For an isotropic source, it is obvious from above equations that the directivity is unity because \( U, U_{max} \) and \( U_o \) are all equal.

2.3 Return Loss

The return loss (RL) mathematical expression is given as

\[ RL = 10 \log_{10} \left( \frac{P_{in}}{P_{ref}} \right) \]

2.4 Efficiency

General expression of the radiation efficiency is given by

\[ \epsilon = \frac{P_{rad}}{P_{rec}} \]

2.5 Bandwidth

The bandwidth of the patch usable frequency

\[ BW = 100 \times \frac{F_H - F_L}{F_C} \]

2.6 VSWR

VSWR is defined by the following formula as

\[ \text{VSWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|} \]

3. EXPRESSION OF PARAMETERS

1. Calculation of the width

\[ W = \frac{C}{2 \pi f_o} \times \sqrt{\frac{2}{\varepsilon_r + 1}} \]

2. Calculation of the effective dielectric constant

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

3. Calculation of the effective length

\[ L_{eff} = \frac{C}{2 \pi f_r \sqrt{\varepsilon_{eff}}} \]

4. Calculation of length extension

\[ \frac{\Delta L}{h} = 0.412 \left( \frac{\varepsilon_{eff} + 0.3}{h} + 0.264 \right) \left( \frac{\varepsilon_{eff} - 0.258}{h} + 0.8 \right) \]

5. Calculation of actual length

\[ L = L_{eff} - 2 \times \Delta L \]

4. RESULT ANALYSIS OF PATCH ANTENNA WITH DIFFERENT GROUND MATERIALS:

4.1 Platinum as ground material:

![The patch antenna with platinum ground.](image)

![Return loss for platinum ground.](image)

The return loss obtained using FR-4 (lossy) as a substrate material is -35.481db at 2.4 GHz Frequency.
The VSWR obtained using Platinum as ground material is 1.241 at 2.4 GHz Frequency.

The gain obtained using Platinum as round material is 6.08 at 2.4 GHz Frequency.

The VSWR obtained using Aluminum as a ground material is 1.035 at 2.4 GHz Frequency.

The gain obtained using Aluminum as a ground material is 6.08 at 2.4 GHz Frequency.

The patch antenna with Copper (annealed) as ground material.

The patch antenna with Copper (annealed) as ground material.
The return loss obtained using Copper (annealed) as a ground material is -45.742 at 2.4 GHz Frequency.

**Fig 14** VSWR for copper (annealed) as ground material.

The VSWR obtained using Copper (annealed) as a ground material is 1.012 at 2.4 GHz

**Fig 15** Far Field for copper (annealed) as ground material.

The Far Field obtained using Copper (annealed) as a ground material is 6.07dB at 2.4 GHz Frequency.

**Table 2** for comparison of results with various grounds

<table>
<thead>
<tr>
<th>S.No</th>
<th>Parameters</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ground</td>
<td>platinum</td>
<td>Aluminum</td>
<td>Copper(annealed)</td>
</tr>
<tr>
<td>2</td>
<td>Substrate</td>
<td>FR-4 (lossy)</td>
<td>FR-4 (lossy)</td>
<td>FR-4 (lossy)</td>
</tr>
<tr>
<td>3</td>
<td>Patch</td>
<td>Copper (annealed)</td>
<td>Copper (annealed)</td>
<td>Copper (annealed)</td>
</tr>
<tr>
<td>4</td>
<td>Reflection coefficient (dB)</td>
<td>-35.481</td>
<td>-36.557</td>
<td>-45.742</td>
</tr>
<tr>
<td>5</td>
<td>Voltage Standing Wave Ratio(VSWR)</td>
<td>1.241</td>
<td>1.035</td>
<td>1.012</td>
</tr>
<tr>
<td>6</td>
<td>Bandwidth(Mhz)</td>
<td>53</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>7</td>
<td>Resonant Frequency(GHz)</td>
<td>2.418</td>
<td>2.42</td>
<td>2.42</td>
</tr>
<tr>
<td>8</td>
<td>Gain(dBi)</td>
<td>6.083</td>
<td>6.083</td>
<td>6.073</td>
</tr>
</tbody>
</table>

5. CONCLUSIONS

The rectangular microstrip antenna is designed and tested with three different ground materials namely Platinum, Aluminum, Copper (annealed) using CST Studio software. The return losses obtained for platinum and aluminum are nearly equal which is -35dB whereas for the microstrip antenna with copper (annealed) as ground has got significant and enhanced result i.e, return losses are -45.742dB at 2.4GHz. Also for this antenna a sufficient bandwidth is introduced via the microstrip feed line at the desired resonant frequency of 2.4GHz is achieved. As mentioned above the designed Microstrip Patch antenna is optimized such that it covers WLAN.

REFERENCES:
