Design of Single Band Rectangular Patch Antenna for Satellite Application and Analysis using different Optimizer

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ABSTRACT
A Microstrip patch antenna for Satellite application is proposed. The antenna has a high gain of 6.01dB at a frequency of 7GHz and return loss of -39.04dB. The Microstrip antenna has a planar geometry and consists of a ground, a substrate, a patch and a feed. The basic theory and design are analyzed, and simulation using IE3D software, is employed to optimize the antenna's properties. Results show that the proposed antenna has promising characteristics for Satellite application at 7 GHz frequency.

Keywords: Microstrip Antenna, single band,Gain,Return loss,Optimization,IE3D.

I. INTRODUCTION
Since the invention of the microstrip antenna[1-2] four decades ago, the demand for its application has been increasing rapidly, especially within the last two decades. However, these applications have been in demand mostly by the Department of Defense. Because of their extremely thin profile (0.01 to 0.05 wavelength), printed microstrip antennas have found heavy applications in military aircraft, missiles, rockets, and satellites. However, in developing L-band mobile satellite communications [3], because of the limited spacecraft solar-battery power and spacecraft antenna size, the mobile vehicle terminal requires a higher gain antenna (on the order of 10 dBi) to ensure an adequate system link margin. Recent developments in communication systems such as the global positioning systems (GPS), Wireless local network (WLAN), vehicular satellite communication and wireless communications often require antennas with compact size, low cost and capable of operating more than one band of frequencies. For these applications, new research motivations have evolved for design of dual band Microstrip antenna [4–5]. The second and very important work is done in this paper is to implement the single band Microstrip antenna using the interfacing between the IE3D and Fast EM Optimization. The design optimization of a single band rectangular patch antenna has been implemented combining an efficient evolutionary optimization method with a standard electromagnetic simulator (IE3D). The accuracy, robustness and ease of implementation of this method validate its potential application in patch antenna design. This method can also be effectively used in the design of various complex microwave and millimeter-wave circuits. In this paper, a combination of IE3D and Fast EM, Powel algorithms is used to design the antenna and simulation and optimization results are presented.

II. GEOMETRY OF MICROSTRIP PATCH ANTENNA
In this antenna, the substrate has a thickness h=0.787 mm and a dielectric constant $\varepsilon_r = 4.4$. The length and width of patch are L=13.0410 mm and W=9.9994 mm respectively. The inset Depth of the Patch ($y_o$) = 3 mm and Width of Microstrip line ($w_f$) = 2 mm figure 1 shown bellow. Edges along the width are called radiating edges and that along the length are called non radiating edges [6]. It can be fed by different methods like microstrip line feed, coaxial probe feed, aperture coupling, electromagnetic coupling and coplanar waveguide (CPW). In this work, microstrip line (50 ohm) feed has been used. Antenna is designed for a resonating frequency of 7 GHz and is analyzed using IE3D software.
III. SIMULATION STUDIES

For the designing of rectangular microstrip antenna, the following relationships are used to calculate the dimensions of rectangular microstrip patch antenna [7].

Calculation of the Width \((W)\): The width of the MSA is given by equation

\[
W = \left(\frac{c}{2f_r}\right) \sqrt{\frac{2}{\varepsilon_r+1}}
\]

Calculation of Effective dielectric constant \((\varepsilon_{\text{reff}})\): Equation that gives the effective dielectric constant is

\[
\varepsilon_{\text{reff}} = \frac{(\varepsilon_r+1)}{2} + \left[\frac{(\varepsilon_r-1)}{2}\right] \left[1 + 12 \left(\frac{h}{W}\right)\right]^{-1/2} \text{ for } W/h > 1.
\]

Calculation of the Effective length \((L_{\text{eff}})\): Equation that gives the effective length is:

\[
L_{\text{eff}} = \frac{c}{2f_r} \sqrt{\varepsilon_{\text{reff}}}
\]

Calculation of the length extension \((\Delta L)\): Equation that gives the length extension is:

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

Calculation of actual length of patch \((L)\): The actual length is obtained by the equation:

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

For calculating the actual length and width of the antenna we also use Microstrip Calculator available in the wave site http://www.emtalk.com/mpacalc.php.

IV. RESULTS AND DISCUSSION

The patch antenna was designed with operating frequencies of 7 GHz, with a dielectric constant \((\varepsilon_r)\) of 4.4 and thickness of 0.787mm. The patch was fed with a 50Ω inset-fed Microstrip-line (Fig. 1). This optimized antenna is simulated using IE3DTM (version 14.0). The simulated return loss curves are shown in Figure below. It shows a maximum return loss at 7 GHz is -39.04 dB with acceptable bandwidth at -10dB. The plots of radiation pattern in Polar form are shown in Figure also. We analysis the following parameter for our antenna

(a) Return loss: Theoretical result (IE3D)
   Return loss is -13.94 (6.86 GHz)

(b) Powel Optimizer (IE3D) results:
Return loss is -39.04 (7 GHz)

(c) Fast EM Optimizer (IE3D) results:

Input Impedance at 7 GHz is 49.5 $\Omega$

Input Impedance at 6.86 GHz is 60 $\Omega$

(b) Powel Optimizer (IE3D) results:

Gain of the patch is 5.6 dB at f=6.9GHz

Input Impedance at 7 GHz is 50 $\Omega$

(a) Gain vs. Frequency Plot : Theoretical result (IE3D)

Gain of the patch is 6.01 dB at f=7.02 GHz

(b) Powel Optimizer (IE3D) result:
V. COMPRESSION BETWEEN THE THEORETICAL, POWEL OPTIMIZATION AND FAST EM OPTIMIZATION RESULTS

We have investigated the result of our design for different optimizer available in IE3D and enlisted bellow.

<table>
<thead>
<tr>
<th>Antenna Parameter</th>
<th>Theoretical (IE3D)</th>
<th>Powel Optimizer (IE3D)</th>
<th>Fast EM Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length(L)</td>
<td>9.999mm</td>
<td>9.999mm</td>
<td>11.34mm</td>
</tr>
<tr>
<td>Width(W)</td>
<td>13.0410mm</td>
<td>13.0410mm</td>
<td>12.65mm</td>
</tr>
<tr>
<td>Inset Depth(yo)</td>
<td>3 mm</td>
<td>3.29</td>
<td>3.30</td>
</tr>
<tr>
<td>Return (dB)</td>
<td>-13.94</td>
<td>-39.04</td>
<td>-39.04</td>
</tr>
<tr>
<td>Impedance(Ω)</td>
<td>243</td>
<td>49.5</td>
<td>50</td>
</tr>
<tr>
<td>VSWR</td>
<td>3.123</td>
<td>1.01</td>
<td>1.01</td>
</tr>
</tbody>
</table>

(a) Radiation Pattern Plot: Theoretical result (IE3D)

(b) Powel Optimizer (IE3D) result

(c) Fast EM Optimizer (IE3D) result

Elevation Pattern for Φ=0 & Φ= 90 degrees at f=6.86 GHz

Elevation Pattern for Φ=0 & Φ= 90 degrees at f=7.02 GHz

V. CONCLUSION

In this paper microstrip line fed single frequency microstrip patch antenna has been designed for satellite communication and simulated using IE3D software. Our designed antenna also optimized using Powel & Fast EM optimizer and we done comparative studies among them. We found the best result for Fast EM Optimization technique.

REFERENCES