Performance Analysis of Rectangular Patch Antenna with Dielectric Constants

Karuna Kumari. K , P. V. Sridevi

Abstract: The developments in communication systems, patch antennas play a very significant role in today’s world of communication systems. The most commonly used microstrip patch antennas are Rectangular patch antennas.

The rectangular microstrip patch antenna parameters are analyzed for S-band frequency which is used for wireless communications (2.0-2.5GHz). In this design, performance parameters like V.S.W.R, Returnloss, are simulated and radiation patterns are observed.

Rectangular patch antenna is designed with uniform and non-uniform linear arrays. The uniform and non-uniform arrays are designed with Dolph-Tschebycheff.

Keywords : Rectangular micro strip patch antenna, uniform array and Dolph-Tschebycheff.

I. INTRODUCTION

Radiating element of rectangular patch antenna on one side of a dielectric substrate which has a ground plane on the other side of the antenna are shown in Fig. 1.

![Rectangular antenna](image1)

Fig.1. Rectangular antenna

The patch is made of conducting material such as copper or gold and can be found in various shapes. The radiating element & feed lines are fabricated using a process of photo etching which uses a photo resist and etchants to corrosively machine away selected areas on the dielectric substrate. Structure and side view of the rectangular microstrip patch antenna as shown in Fig. 2.

![Structure of Microstrip antenna](image2)

(a)Structure of Microstrip antenna

II. RECTANGULAR MICROSTRIP PATCH GEOMETRY

Rectangular microstrip antenna consists of a very thin such that \( t < \lambda_0 \) (where \( \lambda_0 \) is the free – space wavelength and \( t \) is the patch thickness) metallic strip is placed a small fraction of a wavelength, dielectric height \( h \),is usually \( 0.003\lambda_0 \leq h \leq 0.05\lambda_0 \) above a ground plane. The \( L \) is the length of the patch is usually \( 0.3333\lambda_0 < L < 0.5\lambda_0 \)

III. RECTANGULAR PATCH DESIGN EQUATIONS

A. The width of the microstrip patch antenna

\[
W =\frac{c}{2f_r}\sqrt{\varepsilon_r+1}\frac{\lambda_0}{2}
\]

\(c\) = The speed of light
\(W\) = Patch width
\(\varepsilon_r\) = Substrate dielectric constant
\(f_r\) = Resonant frequency
B. Effective dielectric constant $\varepsilon_{\text{reff}}$

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

C. The effective length $L_{\text{eff}}$

$$L_{\text{eff}} = L + 2\Delta L$$

Rectangular patch length

$$L_{\text{eff}} = L + 2\Delta L$$

D. The resonance frequency:

$$f_r = \frac{C}{2\sqrt{\varepsilon_{\text{reff}}}} \left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2}$$

E. The radiated power:

$$P_{\text{rad}} = \frac{|V_o|^2}{2\pi\eta_0} \left[\sin\left(\frac{k_0W}{2}\cos\theta\right)\right]^2 \sin^3 \theta d\theta$$

Rectangular patch antenna, the x-y plane ($\theta = 90^\circ$, $0^\circ \leq \phi \leq 90^\circ$ and $270^\circ \leq \phi \leq 360^\circ$) is the principal $E$-plane. The radiated fields

$$E_r = \frac{+jk_0Wv_r}{\pi r} \left[\sin\left(\frac{k_0h}{2}\cos\phi\right)\right] \cos\left(\frac{k_0L_e}{2}\sin\phi\right)$$

E-plane ($\theta = 90^\circ$, $0^\circ \leq \phi \leq 90^\circ$ and $270^\circ \leq \phi \leq 360^\circ$)

$$E_\theta = \frac{+jk_0Wv_\theta}{\pi r} \left[\sin\theta \left(\frac{k_0h}{2}\sin\theta\right) \sin\left(\frac{k_0W}{2}\cos\theta\right)\right]$$

H-plane ($\phi = 0^\circ$, $0^\circ \leq \phi \leq 180^\circ$)

F. Directivity of a single slot given as

$$D_0 = \left(\frac{2\pi W}{\lambda_0}\right)^2 \frac{1}{I_1}$$

$$I_1 = \int_0^{\pi} \left[\sin\left(\frac{k_0W}{2}\cos\theta\right)\right]^2 \sin^3 \theta d\theta$$

G. Reflection Coefficient $|\Gamma|$

Reflection coefficient given by

$$|\Gamma| = \frac{V_r^+}{V_0^-} = \left(\frac{Z_L - Z_0}{Z_L + Z_0}\right)$$

$V_r^+$ incident voltage

$V_0$ voltage of reflection

Where $|\Gamma|$ is the reflection coefficient

H. Voltage Standing Wave Ratio (VSWR)

$$\text{VSWR} = \frac{V_{\text{max}}}{V_{\text{min}}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

VSWR ranges from 1 to $\infty$.

I. Return Loss

$$RL = -20\log |\Gamma| dB$$

Where $|\Gamma|$ is the reflection coefficient

IV. RECTANGULAR MICROSTRIP PATCH ARRAY

This paper presenting two different arrays.

A. The Arrayfactor of an N-element linear array of isotropic sources is

$$AF = 1 + e^{jkd\cos\theta} + e^{jk2d\cos\theta} + \ldots + e^{jk(N-1)d\cos\theta}$$

$$= \sum_{m=0}^{N-1} e^{imkd\cos\theta} = \sum_{m=0}^{N-1} e^{j\Delta km\cos\theta}$$

For the rectangular array antenna, the principal $E$-plane in x-y is given by

$$E_{\text{rad}}(\phi) = E(\phi) \times AF$$

<p>| Dielectric | Dielectric |</p>
<table>
<thead>
<tr>
<th>Constant</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.8</td>
<td>2.23</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Length(mm)</th>
<th>Width(mm)</th>
<th>Efficiency</th>
<th>Gain</th>
<th>Directivity(DB)</th>
<th>Characteristic Impedance</th>
<th>E-PLANE</th>
<th>H-PLANE HPBW</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.96</td>
<td>26.89</td>
<td>0.9996</td>
<td>14.31</td>
<td>5.3006</td>
<td>71.9</td>
<td>180</td>
<td>86</td>
</tr>
<tr>
<td>41.84</td>
<td>49.12</td>
<td>0.9998</td>
<td>20.14</td>
<td>7.3406</td>
<td>92.3</td>
<td>94</td>
<td>78</td>
</tr>
</tbody>
</table>

B. Dolph-Tschebyscheff Array

For a broadside array ($\beta = 0$), $P = 2M$(even)

$$AF = \frac{\sin\left(\frac{k_0h\cos\phi}{2}\right)}{\sin\left(\frac{k_0h}{2}\cos\phi\right)} \times \frac{\sin\left(\frac{k_0L}{2}\cos\theta\right)}{\sin\left(\frac{k_0W}{2}\cos\theta\right)}$$

V. RESULTS AND CONCLUSIONS:

Rectangular microstrip patch antenna output parameters are designed using S-band frequency which is used for Wi-Fi applications. The sizing of the antenna are the width(W) ,Length (L) and the performance parameters of the antenna are shown in Table1, observed that with $\varepsilon_r=2.23$, the size of
the antenna \( L = 41.84 \text{mm}, \ W = 49.12 \text{mm} \) increased. Directivity of the antenna is very high = 7.35 dB. With the 9.8(Alumina), the size of the antenna \( L = 9.96 \text{mm}, \ W = 26.89 \text{mm} \) reduced, and the Directivity of the antenna is low = 5.33 dB.

![Fig. 4. Variation of Radiation in the rectangular microstrip patch with Theta.](image1)

![Fig. 5. Variation of Directivity in the rectangular microstrip patch with Theta.](image2)

![Fig. 6. Variation of Radiation Conductance with Directivity of rectangular patch](image3)

![Fig. 7. Plot of variation of Thickness of substrate with Resonant frequency of rectangular microstrip patch.](image4)

![Fig. 8. Plot of variation of Thickness of substrate with Effective length.](image5)

![Fig. 9. Plot of variation of Thickness of substrate with Physical width of the substrate for rectangular microstrip patch.](image6)

Performance parameters of rectangular patch antenna are VSWR and Returnloss, are simulated.

![Fig. 10. Variation of VSWR of rectangular microstrip patch with respect to frequency.](image7)

![Fig. 11. Variation of Return losses of rectangular microstrip patch at 2.5 GHz.](image8)
Performance Analysis of Rectangular Patch Antenna with dielectric constants

![Image of rectangular microstrip antenna with dielectric constant](http://example.com/antenna_image)

**Fig. 12.** 20 element rectangular microstrip linear array with Dielectric constant ($\varepsilon_r$) = 2.23.

![Image of rectangular microstrip antenna with dielectric constant](http://example.com/antenna_image)

**Fig. 13.** 20 element rectangular microstrip linear array with $\varepsilon_r$ = 9.8.

Table 2. Comparison between uniform & non uniform rectangular microstrip array antenna Side Lobe Level (SLL) with different values of substrate dielectric constant ($\varepsilon_r$) values.

<table>
<thead>
<tr>
<th>Dielectric constant ($\varepsilon_r$)</th>
<th>Uniform rectangular linear array</th>
<th>Non uniform rectangular linear array</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HPBW (Deg.)</td>
<td>PSLL (dB)</td>
</tr>
<tr>
<td>1</td>
<td>4.22</td>
<td>-13.36</td>
</tr>
<tr>
<td>2.23</td>
<td>4.42</td>
<td>-13.28</td>
</tr>
<tr>
<td>4.4</td>
<td>5.02</td>
<td>-13.20</td>
</tr>
<tr>
<td>9.8</td>
<td>5.30</td>
<td>-13.07</td>
</tr>
</tbody>
</table>

Table 2. shows the Comparison between uniform & non uniform rectangular microstrip array antenna Peak Sidelobe Level (SLL) with different values of substrate dielectric constant($\varepsilon_r$).

From all the simulated results from the table 2, the rectangular micro strip antenna with non uniform array, with lower values of $\varepsilon_r$ is preferred to get, reduced Peak Sidelobe Level, HPBW, FNBW, good voltage standing ratio and good Returnlosses, this designed rectangular array is good choice to used in Wi-Fi Modems.

REFERENCES


AUTHORS PROFILE

Dr. P.V. Sridevi honored with Ph.D from AUCE, Andhra University, Visakhapatnam, A.P, India in 1997. She published many research papers in different international/national journals and also conferences. Presently she is a professor in the Dept. of ECE, AUCE, Andhra University, Visakhapatnam, India. She guided 10 Ph.D theses in the fields of Antennas, Electron Magnetics, EMFEMC and Microwave, Radar Communications, VLSI. She is having 31 years of experience in teaching and 20 years in research.

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