Comparative Study of Micro-strip Patch Antennas

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Abstract: comparative performance study of rectangular, square and circular shape micro-strip patch antennas at 2.4 GHz band frequency is bestowed in this paper. To stimulate and differentiate the various parameters of different shapes of patch antenna, the Ansoft HFSS version 11.0 software is used. It is found that the rectangular patch antenna shows lower return loss than the return loss of circular and square patch antenna. Moreover, the rectangular patch antenna has least VSWR value of 1.22 better than that of the circular patch with VSWR 1.82 & square patch with VSWR 1.63.

INTRODUCTION

MODERN Wireless communication Systems need low profile, light-weight, high gain and simple structure antennas to guarantee reliability, mobility, and high efficiency. A patch antenna is very easy to construct using a conventional micro-strip fabrication technique. They are best suited for aerospace and mobile applications. Moreover, the micro-strip patch antennas can provide dual and circular polarizations, broad bandwidth, frequency agility, dual frequency operation, feed line flexibility, beam scanning omni-directional pattern.

The specification for the design purpose of the structure is as follows,

- Type of antenna : Micro-strip patch antenna
- Resonance frequency : 2.4GHz
- Feeding method: Micro-strip co-axial feed

II. DESIGN OF MICRO-STRIP PATCH ANTENNA

The most crucial step is choice of substrate of appropriate thickness, permittivity and loss tangent. The proposed antennas are designed using the substrate FR4 (permittivity ε = 4.4) which is widely used for patch antennas, 2.4GHz resonant frequency, 0.1588cm height.

i. Square patch antenna

Design:
1. Dimensional width (W) of the patch is

\[ W = \frac{c}{2fr} \sqrt{\frac{2}{\epsilon r + 1}} \]

\[ W = \frac{3 \times 10^8}{2 \times 2.4 \times 10^5 \times 4.4 + 1} \]

\[ W = 38.036mm = 3.80cm \]

2. The effective dielectric constant of the patch is

\[ \epsilon_{reff} = \epsilon \frac{r + 1}{2} + \frac{\epsilon - 1}{2} \left(1 + \frac{10h}{w}\right) \]

\[ \frac{4.4 + 1}{2} + \frac{4.4 - 1}{2} \left(1 + \frac{10 \times 1.588}{38.036}\right) = 4.72 \]

3. The effective length of the patch is

\[ L_{eff} = \frac{c}{2fr \sqrt{\epsilon_{reff}}} \]

\[ L_{eff} = \frac{3 \times 10^8}{2 \times 2.4 \times 10^5 \times \sqrt{4.72}} \]

\[ L_{eff} = 28.76mm = 2.87cm \]

4. The length extension of the patch is

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

\[ \Delta L = 0.412 \times 1.588 \left(\frac{38.036}{1.588} + 0.264\right) \]

\[ \Delta L = 0.72mm \]

5. Actual length of the patch(L) is

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

\[ L = 28.76 - 2 \times 0.7 \]

\[ L = 27.32mm = 2.73cm \]

Result of Square Patch Antenna:
Return loss of sq. Patch Antenna
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VSWR for Sq. Patch Antenna

Impedance of Sq. Patch Antenna

Radiation Pattern for Square Patch Antenna

ii. Circular patch antenna

\[
F = \frac{8.791 \times 10^8}{fr \sqrt{\pi r}}
\]

\[
\frac{8.791 \times 10^8}{2.4 \times 10^9 \times \sqrt{4.4}} = 0.175
\]

\[
a = \frac{F}{\sqrt{\left\{1 + \frac{2h}{\pi r F} \left[\left(\ln \frac{\pi F}{2h}\right) + 1.7726\right]\right\}^2}}
\]

\[
\left\{1 + \frac{2 \times 1.588}{\pi \times 4.4 \times 0.175} \left[\ln \left(\frac{\pi \times 0.175}{2 \times 1.588}\right) + 1.7726\right]\right\}^2
\]

1.72 cm

Result of Circular Patch Antenna:

Return Loss of Circular Patch Antenna

VSWR of Circular Patch Antenna

Impedance of Circular Patch Antenna

Radiation Pattern of Circular Patch Antenna

Design:
iii. Rectangular patch antenna

Design:

[1] The width of patch is

\[
W = \frac{V_0}{2\pi \sqrt{\varepsilon_{\text{eff}}}} \left( \frac{2}{\varepsilon_r + 1} \right)
\]

\[
W = \frac{3 \times 10^{11}}{2 \times 2.4 \times 10^9} \left( \frac{2}{4.4 + 1} \right)
\]

\[
W = 38.03\, \text{mm} = 3.80\, \text{cm}
\]

[2] Effective dielectric constant of the patch

\[
\varepsilon_{\text{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + 12 \left( \frac{1.588}{3.80} \right)^{-1} \right]
\]

\[
\varepsilon_{\text{eff}} = 4.08
\]

[3] The extended incremental length of the patch

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

\[
\Delta l = 0.412(0.1588) \left( \frac{4.08 + 0.3}{4.08 - 0.258} \right) \left( \frac{4.94 + 0.264}{4.94 + 0.1588 + 0.8} \right)
\]

\[
\Delta l = 0.0733\, \text{cm}
\]

[4] The actual length L of the patch is

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

\[
L \approx 3.09 - 2(0.0733)
\]

\[
L = 2.94\, \text{cm}
\]

Result of Rectangular Patch Antenna:

Return loss of Rectangular Patch Antenna

VSWR of Rectangular Patch Antenna

Impedance of Rectangular Patch Antenna

Radiation pattern of Rectangular Patch Antenna
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Result Table:

<table>
<thead>
<tr>
<th>Antennas</th>
<th>Return Loss</th>
<th>VSWR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectangular</td>
<td>-19.80</td>
<td>1.22</td>
</tr>
<tr>
<td>Square</td>
<td>-12.35</td>
<td>1.63</td>
</tr>
<tr>
<td>Circular</td>
<td>-10.69</td>
<td>1.82</td>
</tr>
</tbody>
</table>

CONCLUSION:
ISM band, 2.4GHz frequency and a co-axial feed is used for simulation using HFSS. The comparative study shows that return loss of rectangular patch antenna is the least. In order to improve return loss of patch antenna changes the position of co-axial feed. Ideally VSWR is unity. Low VSWR proves that antenna is well-matched. A value of 1.22 is the most least for rectangular patch antenna.

REFERENCES:
[3] Ka Ming Mak1, Hau Wah Lai1, (Senior Member, IEEE), Kwai Man Luk2, (Fellow, IEE), And Chi Hou Chan2, (Fellow, IEEE), “Circularly Polarized Patch Antenna For Future 5g Mobile Phones,” IEEE, December 18, 2014.