DESIGN OF RECTANGULAR PATCH ANTENNA ARRAY FOR WIRELESS COMMUNICATIONS

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ABSTRACT

In this paper, design of rectangular patch antenna arrays, suitable for wireless communication applications, are presented. This paper demonstrates rectangular micro strip patch antenna array, such as single element and four element rectangular patch antenna array. This paper presents a comparison between single element rectangular patch antenna with four element rectangular patch antenna array. In this paper coaxial probe feeding techniques is used. Coaxial probe feed is a contacting scheme, in which the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch while the outer conductor is connected to ground plane. The main advantage of this type of feeding scheme is that the feed can be placed at any desired location inside the patch in order to match with its input impedance. The micro strip patch antenna is designed and simulated using high frequency structural simulator software (HFSS) and it is designed to operate in S- band frequency range is 2 to 4 GHz. These antennas are designed using RogerRT/duroid5880(tm) dielectric substrate with respect to $\varepsilon_r$ values. In this analysis, we have compared the antenna parameters such as gain, impedance, reflection coefficient, VSWR and return loss. Application such as aircraft, satellite communication, medical purpose and wireless local area network.

Keywords: Rectangular patch antenna array, Substrate, HFSS, Antenna Parameters. Resonant frequency of patch antennas (2.25GHz).

1. INTRODUCTION

Micro strip patch antenna is very popular because of ease in fabrication, planar design, mechanical reliability and mass production. The advantages of micro strip antennas are that they are low-cost, conformable, lightweight and low profile, while both linear and circular polarization can be achieved. They are low profile, light weight antennas, most suitable for aerospace and mobile applications. The conducting patch can take any shape, but rectangular configuration is the most commonly used configurations.

Limitations for micro strip antenna suffer from a number of disadvantages as compared to conventional antennas. They are low bandwidth, low efficiency and low-gain antennas with low power handling capacity. In this paper, designs of rectangular patch antenna arrays are presented. Specifically, single element and four element micro strip patch antenna array shapes are designed. Moreover, these designs are simulated using HFSS (High Frequency Structure Simulation) software. Based on simulation results, comparison between single element and four element micro strip patch antenna array is achieved.

Indentations and Equations

The Mobile Communication Systems uses the frequency range from 2100-5600 MHz Hence the antenna designed must be able to operate in this frequency range. The resonant frequency selected for my design is 2.25 GHz. The dielectric material selected for our design is RT Duroid which has a dielectric constant of 2.2. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna. The height of the dielectric substrate is selected as 1.58 mm. The resonant frequency of micro-strip antenna and the size of the radiation patch can be similar to the following formulas.

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Calculation of the Width (W):

\[ W = \frac{c}{2\pi \sqrt{\frac{\varepsilon + 1}{2}}} \]

Where, \( c \) is the free space velocity of light.

Calculation of Effective dielectric constant (\( \varepsilon_{\text{eff}} \)):

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

Where

- \( \varepsilon_{\text{ref}} \) = Effective dielectric constant
- \( \varepsilon_r \) = Dielectric constant substrate
- \( H \) = Height of dielectric substrate
- \( W \) = width of the patch

Calculation of actual length of patch (L):

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

\( \Delta L \) is the extended length.

Calculation of the ground plane dimensions (\( L_g \) and \( W_g \)):

\[ L_g = 6h + L \]
\[ W_g = 6h + W \]

2. FIGURES AND TABLES

2.1 Rectangular Patch Antenna Design

A micro strip antenna element can be used alone or in combination with other like elements as part of an array. In either case, the designer should have a step-by-step element design procedure. Usually, the overall goal of a design is to achieve specific performance at a stipulated operating frequency. If a micro strip antenna configuration can achieve these overall goals, then the first decision is to select suitable antenna geometry. The antenna is designed for the resonance frequency of 2.25GHz. There are 1 rectangular micro strip patch antenna connected in parallel with coaxial probe feed in the form of array. Fig 1 shows the geometry of conventional rectangular micro strip antenna. The designed antenna mainly contains Substrate, Micro strip patch antenna, Ground Plane and Radiation Box. The coordinate axis is taken at the center of the patch or substrate.

![Fig. 1: Geometry of the proposed rectangular micro strip antenna in HFSS](image-url)
Rectangular Patch Antenna Design Simulation Results

2.1.1 D Gain Total
The following fig2 Shows the Total Gain of antenna array in 2D for Rogers RT/Duriod Material and the value is given by 6.8243dB for Phi=0°.

![Fig 2: 2D Gain Total for Rogers RT/duriod 5880](image)

2.1.2 VSWR in absolute
The following Fig. 3 shows the VSWR of an Antenna array for Rogers RT/duriod Material and the value of VSWR is given by 1.7678 abs.

![Fig. 3: VSWR in abs for Rogers /RT Duroid 5880](image)

2.1.3 VSWR in dB
The following Fig4 shows the VSWR of an Antenna array for Rogers RT/duriod Material and the value of VSWR is given by 0.2667 dB.

![Fig. 4: VSWR in db for Rogers /RT Duroid 5880](image)
2.1.4 Directivity

The following fig5 shows the directivity of the antenna array of RogersRT/duriod material is given by 9.884dB.

Fig. 5: Directivity for Rogers /RT Duroid 5880

2.1.5 Radiation Pattern

Fig. 6 shows the gain of Rogers RT/duriod substrate is 6.824dB.

Fig. 6: Radiation pattern for Rogers /RT Duroid 5880

2.1.6 Return loss

Fig. 7 shows the variation of return loss versus frequency. Plot Rogers RT/duriod resonates at 2.25GHz which achieves a return loss -36.6609dB.

Fig. 7: Return loss for Rogers /RT Duroid 5880
2.2 Four Element Rectangular Patch Antenna Array Design

The antenna is designed for the resonance frequency of 2.25GHz. There are 4 rectangular micro strip patch antennas connected in parallel with coaxial probe feed in the form of array. Fig 8 shows the geometry of conventional rectangular micro strip antenna. The designed antenna mainly contains Substrate, Micro strip patch antenna, Ground Plane and Radiation Box. The coordinate axis is taken at the center of the patch or substrate.

![Fig. 8: Geometry of the proposed four element rectangular micro strip antenna in HFSS](image)

### Four Element Rectangular Patch Antenna Array Design Simulation Results

#### 2.2.1 2D Gain Total

The following fig 9 shows the Total Gain of antenna array in 2D for Rogers RT/Duriod Material and the value is given by 9.9036dB for Phi=0°.

![Fig. 9: 2D Gain Total for Rogers RT/duriod 5880](image)

#### 2.2.2 VSWR in absolute

The following Fig. 10 shows the VSWR of an Antenna array for Rogers RT/duriod Material and the value of VSWR is given by 1.3283abs.

![Fig. 10: VSWR in abs for Rogers /RT Duroid 5880](image)
2.2.3 VSWR in dB
The following Fig. 11 shows the VSWR of an Antenna array for Rogers RT/duriod Material and the value of VSWR is given by 2.267 dB.

Fig. 11: VSWR in db for Rogers /RT Duroid 5880

2.2.4 Directivity
The following fig12 Shows the directivity of the antenna array of Rogers RT/duriod material is given by 9.884 dB.

Fig. 12: Directivity for Rogers /RT Duroid 5880

2.2.5 Radiation Pattern
Fig. 13 shows the gain of Rogers RT/duriod substrate is 9.79 dB.

Fig. 13: Radiation pattern for Rogers /RT Duroid 5880

2.2.6 Return loss
Fig. 14 shows the variation of return loss versus frequency. Plot Rogers RT/duriod resonates at 2.25 GHz which achieves a return loss -32.75 dB.
Fig. 14: Return loss for Rogers /RT Duroid 5880

Table 1: Comparison of single Patch antenna and 4 Element patch Antenna Array

<table>
<thead>
<tr>
<th>Antenna Parameters</th>
<th>Single element patch antenna (dB)</th>
<th>Four element patch Antenna array (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain</td>
<td>6.284</td>
<td>9.9036</td>
</tr>
<tr>
<td>VSWR</td>
<td>0.2267</td>
<td>2.2671</td>
</tr>
<tr>
<td>Return loss</td>
<td>-36.6609</td>
<td>-32.75</td>
</tr>
<tr>
<td>Directivity</td>
<td>6.92</td>
<td>9.884</td>
</tr>
</tbody>
</table>

**Antenna Design**

The fabrication of antenna is shown in fig proposed rectangular micro strip patch antenna dimension length L=93mm, width W=83mm. The antenna is designed for the resonance frequency of 2.25GHz. The dielectric material selected for our design is RT Duroid which has a dielectric constant of 2.2. The height of the dielectric substrate is selected as h=1.58mm. This antenna 50 Ω micro strip feed line are used.

Fig. 15: Patch Antenna test using Spectrum Analyzer

The fabrication of antenna is shown in fig proposed rectangular micro strip patch antenna array dimension length L=48mm, width W=43mm. The antenna is designed for the resonance frequency of 2.25GHz. The dielectric material selected for our design is RT Duroid which has a dielectric constant of 2.2. The height of the dielectric substrate is selected as h=1.58 mm. This antenna 50 Ω micro strip feed line are used.

Fig. 16: Antenna Array test using Spectrum Analyzer
3. CONCLUSION

Thus, a rectangular micro strip patch antenna array using Rogers RT Duroid has been designed, simulated, optimized and analyzed using HFSS (High Frequency Structure Simulator) software version 13. The results showing that the antenna can be operated at 2.25GHz frequency for Rogers RT Duroid substrate. This result is an improvement when compared to the original rectangular micro strip patch antenna and radiation pattern is also being improved to a large extent using patch antenna characteristics. This array especially used for linear polarization, all S-band application, military and other communication applications.

4. FUTURE SCOPE

1. The rectangular micro strip patch antenna array was successfully implemented. There are little advancement that can be made as per current requirements and further implementation is also possible by using different dielectric consents and different shapes.

2. The antenna design was completed by using probe feed method. This can be further improved by using other methods of feeding also.

3. With this improvement micro strip patch antennas can be used in various other applications. This will be very useful in other areas of communication like global position services. since micro strip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feed line flexibility, beam scanning Omni directional patterning.

4. The proposed design can be further developed in order to enable tracking system and other advanced application.

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REFERENCES


