Design of Rectangular Patch Antenna: Analysis with Different Feed Positions and Bandwidth Improvement

P.Bharghava, M.Pachiyaannan

Abstract—This letter describes that analysis of rectangular microstrip patch antenna with different feeding positions & bandwidth improvement. The design of the proposed antenna is performed with FR4-epoxy dielectric substrate material with variable thickness. It is observed that the position of feeding can be taken symmetrically by changing feeding locations. Different thickness of substrate (h=2, 3, 4, 5, 6 mm) have been taken to increase the bandwidth. The simulated results for height h=4mm have bandwidth=113MHz. The proposed rectangular microstrip antenna is at the operating frequency of 2.4GHz. The configurations proposed are simulated & analysed by Ansoft HFSS. The VSWR, gain pattern and return loss performance are used for the analysis of the configuration.

Keywords—Bandwidth, Dielectric Substrate, Rectangular patch, Return Loss

1. INTRODUCTION

A micro strip patch antenna does have the advantage of low price, less weight and less profile planner configuration. The disadvantage of rectangular micro strip patch antennas is low operating bandwidth [1-2]. The bandwidth can be improved in such a way that the increased substrate thickness or the reduced dielectric constant. The range of the dielectric constant is usually in (2.2≤εr≤12) [3-4]. The coaxial probe feed is used for the rectangular patch micro strip antenna operating at resonant frequency of 2.4GHz of TM0 mode. By choosing the proper feed position the antenna is matched [6].

The rectangular micro strip patch antenna is described using its width W, length L and thickness h. The substrate should be of narrow thickness (h≤λc/20), regularly 0.003*λc≤h≤0.05*λc) where λc is indicating wavelength of free space on the ground plane [7].

2. DESIGN OF RECTANGULAR PATCH ANTENNA

The care has to be taken in the selection of resonant frequency of the antenna. The range of frequencies from 2-3 GHz is utilized for the WIFI applications. The resonant frequency f0 2.4GHz is selected for this design. The FR-4 Epoxy is selected as substrate material for the design which contains a dielectric constant εr of 4.4

The dielectric substrate height (h) is chosen as 4 mm. The elements for the design are: f0= 2.4GHz, εr= 4.4 (FR4-Epoxy), loss tangent=0.02 and h=4mm.

The coaxial feeding is used for the antenna to get excitation. The advantage is no further impedance matching network is required in case of coaxial feeding. The radii of outer cylinder, inner cylinder are 1.6mm and 0.6mm. The radius of substrate is 0.6mm. The height of the cylinder used in the substrate is 4mm that is the heights of the substrate cylinder and substrate are same.

2.1 Calculation of width (W)

The calculation of width of patch at f0=2.4GHz with εr = 4.4 as

\[ W_p = \frac{c_0}{2f_0\sqrt{\varepsilon_r}} \]

W=38mm.

2.2 Determination of effective dielectric constant (εreff)

The calculation of εreff with εr = 4.4 and f0=2.4GHz can be calculated as

\[ \varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \sqrt{1+\frac{4}{\varepsilon_r}} \]

εreff= 3.7

2.3 The extension of length calculation (∆L)

The calculation of length extension with εreff=3.7, f0= 2.4GHz, W=38mm and h=4mm as

\[ \Delta L = 0.412h \left( \frac{(\varepsilon_{eff}+0.3)(w_{ef}+0.264)}{(\varepsilon_{eff}-0.258)(w_{ef}+0.813)} \right) \]

\[ \Delta L = 2.44mm \]

2.4 Determination of the effe length

The effe length can be determined with εreff = 3.7 and f0 = 2.4GHz

\[ L_{eff} = \frac{c_0}{2f_0\varepsilon_{eff}} \]

L_{eff} =32.5mm.

2.5 Determination of physical length of patch (L)

The physical length is calculated as

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

Lp =27.6 mm.

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2.6 Determination of ground plane’s dimensions (L_{ground} and W_{ground}) by equations as

For L_p = 27.6mm, W_p = 38mm and h = 6mm

L_{ground} = L_p + 6h
W_{ground} = W_p + 6h

L_{ground} = 63.60mm.
W_{ground} = 74.0mm.

By changing the height of substrate the bandwidth can be changed. The change of height of substrate h(mm) from 2mm to 6mm along with the changes of S_{11} and bandwidth are given in Table-2. At the height of substrate h=4mm, the S_{11} is equal to -30 and bandwidth is equal to 113MHz. This is acceptable one.

<table>
<thead>
<tr>
<th>S.NO.</th>
<th>h(mm)</th>
<th>W(mm)</th>
<th>L(mm)</th>
<th>S_{11}</th>
<th>BW(MHz)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>38</td>
<td>28.20</td>
<td>-31</td>
<td>68</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>38</td>
<td>27.75</td>
<td>-36</td>
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</tr>
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<td>4</td>
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<td>27.00</td>
<td>-30</td>
<td>113</td>
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<td>4</td>
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<td>38</td>
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<td>6</td>
<td>38</td>
<td>27.10</td>
<td>-14</td>
<td>86</td>
</tr>
</tbody>
</table>

3. RESULTS

Return loss is the parameter by which we can indicate the reflection of signal due to impedance mismatch. Return loss for proposed patch antenna which is in rectangular shape is about -30dB when height of the substrate is 4mm. In this case, the higher cut off frequency is 2.46GHz and the lower cut off frequency is 2.3463GHz as given in Figure-2. The higher and lower cutoff frequencies have to be taken at the value of -10dB of return loss. The bandwidth is given by difference of higher cutoff frequency and lower cutoff frequency. The resulted bandwidth is 113MHz.
As impedance is symmetrically distributed from centre of the patch towards the edges that is from 0 ohms to maximum resistance value, the feeding can be given on left side symmetrically. Even the feed point location is changed symmetrically the return loss and VSWR are not altered that can be seen in the figure-7 and figure 8. The geometry of micro strip antenna by taking feed point on left side symmetrically is shown in figure-9.

4. CONCLUSION

The bandwidth of rectangular micro strip patch antenna is improved by increasing and setting the height of substrate up to 4mm and the bandwidth is around 113MHz. By symmetrical distribution of impedance it was proved that giving feed point location on left and right sides from the middle point does not alter the execution of the patch antenna.

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REFERENCES