Design & Analysis of Microstrip Patch Antenna & Comparison between the Arrays

Deeksha Anand Naik  
PG Student  
Department of Electronics & Telecommunication Engineering  
Goa College of Engineering, Farmagudi - Goa

Priyanka Kiran Padiyar  
PG Student  
Department of Electronics & Telecommunication Engineering  
Goa College of Engineering, Farmagudi - Goa

Vishakha Namdev Virnodkar  
PG Student  
Department of Electronics & Telecommunication Engineering  
Goa College of Engineering, Farmagudi - Goa

Mr. Yeshudas Muttu  
Assistant Professor  
Department of Electronics & Telecommunication Engineering  
Goa College of Engineering, Farmagudi - Goa

Mohini Naik  
Assistant Professor  
Department of Electronics & Telecommunication Engineering  
Goa College of Engineering, Farmagudi - Goa

Abstract

This paper demonstrates low cost and high gain microstrip array antennas with suitable feeding technique and suitable dielectric substrate for applications in the Giga Hertz frequency range. The objective of this paper is to design a microstrip patch array antenna using IE3D software for improvement of antenna radiation parameters like gain, directivity etc. We have analyzed a single rectangular patch antenna along with the 2 x 1, 4 x 1, 8 x 1 array for parameters such as gain, directivity efficiency and bandwidth. Simulations will be performed on Zeland software.

Keywords: Array, Microstrip patch, λ/4 transformer

I. INTRODUCTION

In Telecommunication, a microstrip antenna (also known as a printed antenna) usually means an antenna fabricated using microstrip techniques on a printed circuit board[1]. Microstrip patch antenna consists of a radiating patch on one side of the dielectric substrate and has a ground plane on the other side[1]. The patch is generally made up of a conducting material such as copper or gold and can take any possible shape like rectangular, circular, triangular, elliptical or some other common shape. The radiating patch and the feed lines are usually phoetched on the dielectric substrate. For good antenna performance, a thick dielectric substrate having a low dielectric constant (<6) is desirable since it provides higher efficiency, larger bandwidth and better radiation[1]. However such a configuration leads to larger antenna size. In order to design a compact microstrip patch antenna, a substrate with a higher dielectric constant (<12) must be used, which results in lower efficiency and narrower bandwidth[1]. Hence a compromise must be reached between antenna dimensions and antenna performance[1]. Microstrip patch is a single layer design which contains mainly these four parts[1]. The first one is the microstrip patch which can take any geometrical shape such as rectangular, circular, square etc. However rectangular and circular are most widely used because they can be easily designed and fabricated. The second one is the ground plane which can be finite or infinite according to the model used for analysis. The third part is the substrate whose characteristics are given by the relative permittivity and height. The next part is the feed which can be provided by different techniques such as Microstrip line feed, Coaxial probe, Aperture coupling and Proximity coupling.

II. ANTENNA DESIGN

The three essential parameters for the design of a rectangular Microstrip Patch Antenna are:

- The frequency of operation (\(f_0\)) = 2.45GHz
- Dielectric constant of the substrate (\(\varepsilon_r\)) = 2.
- Height of the dielectric substrate (h) = 1.58

The design equations are as follows:

- The width of the microstrip patch antenna is given as:
\[ W = \frac{\frac{c}{2f_0}}{\sqrt{\frac{\left(\epsilon_r + 1\right)}{2}}} \]

Therefore we found the value of \( W \) to be 46.62

- The Effective dielectric constant is given as:

\[ \epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{W} \right]^{-1} \]

Where \( \epsilon_{\text{reff}} \) = Effective dielectric constant
\( \epsilon_r \) = Dielectric constant of substrate
\( h \) = Height of the dielectric substrate
\( W \) = Width of the patch.

Therefore \( \epsilon_{\text{reff}} = 2.3362 \)

- The effective length is given as:

\[ L_{\text{eff}} = \frac{\frac{c}{2f_0}}{\epsilon_{\text{reff}}} \]

Therefore, the effective length is, \( L_{\text{eff}} = 40.056 \)

- The length extension is given as:

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

Therefore, the length extension = 0.812

- The actual length is given as

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

Therefore \( L = 38.432 \)

A feed line is used to excite to radiate by direct or indirect contact. There are different methods of feeding and four most popular methods are microstrip line feed, coaxial probe, aperture coupling and proximity coupling.

A. Quarter Wavelength Transmission Line:

The microstrip antenna can also be matched to a transmission line of characteristic impedance \( Z_0 \) by using a quarter wavelength transmission line of characteristic impedance \( Z_1 \).

The goal is to match the input impedance \( Z_{\text{in}} \) to the transmission line \( (Z_0) \).

If the impedance of the antenna is \( Z_A \), then the input impedance viewed from the beginning of the quarter wavelength line becomes:

\[ Z_{\text{in}} = Z_0 = \frac{Z_1}{Z_A} \]

The wider the strip, the lower the characteristic impedance \( Z_0 \) is for that section of line.

III. Simulation Results

A. Single Patch

The Simulations were performed on IE3D software. The results are shown below. The single patch is shown in Fig. 1. The return loss and radiation pattern were obtained after the simulation. The return loss is shown in Fig. 1.b. As we can see, the return loss is -12.5dB. The Radiation Efficiency is found to be 87.7621%, Antenna Efficiency as 82.6251%. The gain is 6.17244 dBi and Directivity is 7.00132 dBi.

Fig. 1: Design of a single patch
Fig. 1: a. Return loss

Fig. 1: b. Radiation Pattern

**B. 2X1 array**

The 2x1 array is shown in Fig. 2. The return loss is shown in Fig. 2.b. As we can see, the return loss is -13dB. The Radiation Efficiency is found to be 87.0216%, Antenna Efficiency as 70.8246%. The gain is 9.19828 dBi and Directivity is 10.6964dBi. The gain and directivity in this case is slightly better than that for a single patch.
C. **4X1 Array**

The 4x1 array is shown in Fig. 3. The return loss is shown in Fig. 3.b. As we can see, the return loss is -14.2dB. The Radiation Efficiency is found to be 83.6588%, Antenna Efficiency as 63.912%. The gain is 10.9896dBi and Directivity is 12.9338dBi. The gain and directivity in this case is slightly better than that for a 2x1 array. A power combiner is used at the feed. The λ/4 transformer is used to match 50Ω with 100Ω line.

![Fig. 3.4: x 1array](image-url)

![Fig. 2: b. Radiation Pattern](image-url)
The 4x1 array is shown in Fig. 4. The return loss is shown in Fig. 4.b. As we can see, the return loss is -22.43dB. The Radiation Efficiency is found to be 87.1776%. Antenna Efficiency as 85.9143%. The gain is 14.7277 dBi and Directivity is 15.387dBi. The gain and directivity in this case is slightly better than that for a 2x1 array. A power combiner is used at the feed. The $\lambda/4$ transformer is used to match 50$\Omega$ with 100$\Omega$ line.
Fig. 3: a. Return Loss

Fig. 3: b. Radiation pattern

<table>
<thead>
<tr>
<th>Arrays</th>
<th>Radiation Efficiency (%)</th>
<th>Antenna Efficiency (%)</th>
<th>Gain(dBi)</th>
<th>Directivity(dBi)</th>
<th>Return Loss (dB)</th>
</tr>
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<tbody>
<tr>
<td>Single patch</td>
<td>87.7621</td>
<td>82.6251</td>
<td>6.17244</td>
<td>7.00132</td>
<td>-12.5</td>
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<td>70.8246</td>
<td>9.19828</td>
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<td>-13</td>
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<tr>
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<td>63.912</td>
<td>10.9896</td>
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<tr>
<td>8 x 1 Array</td>
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<td>85.9143</td>
<td>14.7277</td>
<td>15.387</td>
<td>-22.43</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

From the results above we can conclude that Radiation Efficiency and Antenna Efficiency approximately remain the same. As the number of elements increases, the gain, directivity and return loss increases. Therefore it can be concluded that the above parameters can be improved by making arrays of the single patch.

REFERENCES