Design and Analysis of Microstrip Antenna using Reduced Butler Matrix for 2.4GHz Frequency Band

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Abstract—In this paper the array of rectangular patch antenna is connected to the reduced size butler matrix network. Butler matrix network is used for beam switching. This design is realized on a low cost substrate FR4 with dielectric constant $\varepsilon_r =4.4$ and height of substrate is 1.6mm. Here antenna is operated at 2.4GHz frequency. The simulation result is obtained using HFSS.

Keywords- Butler Matrix, Beam forming Network (BFN), Micro- strip Antenna, VSWR, Return Losses

I. INTRODUCTION

In recent years, wireless technology has rapid growth in creating new and improved services at lower costs. In wireless communication it is very important to separate desired signal from unwanted signal. Thus to overcome this problem smart antenna system is developed. There are main two types of smart antenna systems. One is Switched beam system and another is Adaptive array system. Here smart antenna is form by using butler matrix network. In switched beam system manual switching of beam is possible but on other hand in adaptive array system we can use different type of algorithms for switching the beam.

In this paper the microstrip patch array is use as a radiating element and butler matrix is use for beam switching. Here 2x2 butler matrix network is use. There are number of advantages of using this network the advantages are low profile, easy fabrication and low cost. The diagram shows the reduced size butler matrix network it consist of hybrid coupler, phase shifter and crossover. There are number of advantages of using microstrip antenna as a radiating element. The main advantages of microstrip antenna is low profile, simple and inexpensive to manufacture using modern printed circuit technology, possible to have dual or triple frequency operations. The figure 1 below shows 2x2 butler matrix

![Butler Matrix](image)

Figure 1. Butler Matrix

II. DESIGN AND ANALYSIS

A. Rectangular Patch antenna(Microstrip Antenna)

To design microstrp antenna we must know the length and width of patch. The width and length of antenna is calculated by formula

$$W = \frac{c}{2f} \times \sqrt{\frac{2}{\varepsilon_r+1}} \quad ............. \ (1)$$
\[ \varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[ 1 + 12 \frac{h}{w} \right] (-0.5) \quad \ldots \quad (2) \]

\[ \Delta L = 0.412 \times h \left( \frac{\varepsilon_{reff} + 0.3}{h} + 0.264 \right) \quad \ldots \quad (3) \]

\[ \Delta L = 0.412 \times h \left( \frac{\varepsilon_{reff} - 0.258}{h} + 0.8 \right) \]

\[ L = \frac{\lambda}{2} - 2 \times \Delta L \quad \ldots \quad (4) \]

The figure 2 shows the antenna created in HFSS software. This antenna is designed for 2.4GHz range of frequency.

![Figure 2. Design of Patch Antenna at 2.4GHz](image)

Figure 2. Design of Patch Antenna at 2.4GHz

Figure no 3, 4, 5 shows the simulation result of designed antenna in HFSS software at 2.4GHz frequency. Here return loss and VSWR of antenna is minimum for 2.4GHz range of frequency.

Calculated value of patch antenna

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Width</td>
<td>38mm</td>
</tr>
<tr>
<td>Antenna Length</td>
<td>29mm</td>
</tr>
<tr>
<td>Substrate Height</td>
<td>1.6mm</td>
</tr>
</tbody>
</table>

VSWR- For the proper working of antenna the VSWR of antenna is less than 2db. Here for 2.43GHz to 2.47GHz range of frequency VSWR of antenna is less than 2db, so antenna can work properly for that band of frequency. This is shown in figure 5.

![Figure 3. Return Loss](image)

Figure 3. Return Loss

Return loss- For proper working of the antenna return loss must be less than -10db. Here for 2.47 to 2.43GHz range of frequency return loss is less than -10db.

![Figure 4. Radiation Pattern](image)

Figure 4. Radiation Pattern

![Figure 5. VSWR](image)

Figure 5. VSWR
B. Design of 4x4 Matrix Array

The butler matrix is a NxN network consisting of N input ports and N output ports. The NxN Butler matrix creates a set of n orthogonal beams in space by processing the signal from N antenna elements.

The components of Butler Matrix are
1. 90° Hybrid
2. Crossover
3. Phase Shifter

1. 90° Hybrid:

The design of hybrid can be calculated by following formulae.

\[
\lambda = \frac{c}{f} \quad \text{(5)}
\]

\[
\lambda/4 \quad \text{(6)}
\]

\[
\text{feed length} = \frac{\lambda}{4\sqrt{\varepsilon_r}} \quad \text{(7)}
\]

\[
\text{width of hybrid} = \frac{377}{\sqrt{\varepsilon_r}}(W+h) \quad \text{(8)}
\]

Where

\[Z_{50}\] is the impedance of 50ohm line

W is the required width

h is the height of substrate

Obtained results are as follows

a. \(\lambda/4 = 30\text{mm}\)

b. \(\text{feed length} = \frac{\lambda}{4\sqrt{\varepsilon_r}} = 15\text{mm}\)

c. Width of hybrid = 3mm

d. \(L = 4.8\text{ mm}\)
2. Crossover-
Crossover is used to transmit information from one hybrid coupler to another without loss of information. The formula for the design of crossover is similar to that of the crossover. It is used to avoid interference of electromagnetic signal when two electromagnetic signal travelling close from each other.

3. Phase shifter-
Phase shifter is used to provide phase shift to the signal. Here phase shifter is provided 45-degree phase shift. The length of phase shifter is given by formula
\[ \phi = \frac{2\pi}{\lambda} \times L \quad \ldots \ldots \quad (9) \]
\[ \lambda = \frac{\lambda_0}{(\varepsilon_{\text{eff}})^{0.5}} \quad \ldots \ldots \quad (10) \]

<table>
<thead>
<tr>
<th>Port No.</th>
<th>Antenna Element</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0°</td>
</tr>
<tr>
<td>3</td>
<td>x°</td>
</tr>
<tr>
<td>1</td>
<td>x°</td>
</tr>
<tr>
<td>4</td>
<td>2x°</td>
</tr>
</tbody>
</table>

Table 1: Phase Excitation at Output with respect to input

When we can combine all the component of butler matrix which is individually designed in HFSS software then we can get sharp switched beam these expected result are shown in figure9.

III CONCLUSION
This paper represents optimum design of 2x2 planer butler matrix for ISM band application. Here because of 2x2 butler network cost of implementation is reduced. The formulae for designing antenna are mentioned in paper. The results are simulated in HFSS. For larger area coverage design can be extended to 8x8 matrix.
REFERENCES


