Performance Evaluation of Back to Back E-Shape Microstrip Patch Antenna for MIMO Applications

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Abstract—A back to back E-shaped rectangular microstrip patch antenna for obtaining circular polarization with an axial ratio of 2.5 dB for Multiple Input Multiple Output (MIMO) applications is designed using IE3D software from Zeland. The microstrip patch antenna is constructed using a single layer RT/duriod (5880) substrate, having dielectric constant εr = 2.2 and loss tangent tan δ = 0.001. A 2x2 MIMO is developed using the proposed antenna for improved channel capacity having a bandwidth of 2.097 GHz and a return loss of -50 dB.

Keywords—MSA, Circular polarization, MIMO, Wi-MAX, WLAN.

I. INTRODUCTION

MIMO (Multiple Input Multiple Output) systems are capable of achieving higher data rates by using multiple antennas at both the transmitter and receiver instead of a single antenna at the respective locations without using additional bandwidth or an increase in the respective power [1]. Recent studies have shown that the multiple input multiple output (MIMO) system is a promising solution to meet the needs of the growing demands for higher data rates, higher channel capacity and a more spectrum efficient wireless communication system.

MIMO systems are very much suitable for the present and emerging communication systems like Wi-Fi, WLAN, and 4G. This has led to extensive work to design antennas that can optimize the MIMO system performance. The MIMO antennas mainly aim at minimizing the effect of mutual coupling that degrades the performance of the communication systems. Lesser the mutual coupling greater is the efficiency of the antenna. [2] The mutual coupling can be decreased by adjusting the distance between the antenna elements.

Microstrip patch antennas are an ideal choice for the development of such systems and have been well known for its advantages such as light weight, low fabrication cost, mechanically robust when mounted on rigid surfaces and capability of dual and triple operating frequencies. [3]

Various approaches have been taken to suit the need of wireless communication applications including modification of substrate parameters and the patch shape.

Traditional antenna designs yields circular polarization by either inserting perturbation elements at the boundary of a circular patch or by cutting diagonal slots along the patch. [4] Circular polarization has been observed typically in circular, square and triangular microstrip patches.

In this paper a rectangular patch having a total area 344 mm² cut into an E-shape joined back to back having reduced total radiating area 256.8 mm² design has been proposed with the sides of the patch being truncated. A 2X2 MIMO array antenna design for reduced mutual coupling and improved channel capacity is further proposed. Experimental geometry of the single element antenna and the two element MIMO array, the simulated results for the both yielding circular polarization, improved return loss and bandwidth are presented and discussed.

II. MATHEMATICAL ANALYSIS

To design a rectangular microstrip patch antenna following parameters such as dielectric constant (εr), resonant frequency (fr), and height of the substrate (h) should be considered for calculating the length and the width of the patch [5].

Width of patch (w).

\[ W = \frac{c}{2f_0 \sqrt{\varepsilon_r + \frac{1}{\varepsilon_r}}} \]  

(1.1)

Effective dielectric constant of antenna is

\[ \varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left( 1 + 12 \frac{h}{W} \right)^{-\frac{3}{2}} \]  

(1.2)

Effective dielectric length of antenna is

\[ L_{eff} = \frac{c}{2f_0 \sqrt{\varepsilon_{reff}}} \]  

(1.3)

The extended length (ΔL) of antenna is

\[ \Delta L = 0.421h \left( \frac{\varepsilon_{reff} + 0.3}{\varepsilon_{reff} - 0.258} \right) \frac{W}{h} + 0.264 \]  

(1.4)
III. ANTENNA DESIGN

The antenna design is shown in fig.1 proposed back to back rectangular microstrip patch antenna having dimension length (L) 17.2 mm, width (W) 20 mm, and thickness (h) 3.2 mm. The substrate of the patch is RT/duroid 5880 having dielectric constant = 2.2. [6] The back to back E-shape patch is truncated along the corners. The corners of the patch are truncated such that a square slot of 4x4 dimension with 45 degree rotation is obtained. The patch is provided with a co-axial feed.

\[ L = L_{\text{eff}} - 2\Delta L \]  
(1.5)

![Figure 1: Geometry of the proposed antenna](image1)

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>OPTIMIZED ANTENNA PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Parameter</td>
<td>Value</td>
</tr>
<tr>
<td>Dielectric constant</td>
<td>2.2</td>
</tr>
<tr>
<td>Thickness(h)</td>
<td>3.2 mm</td>
</tr>
<tr>
<td>Length(L)</td>
<td>17.2 mm</td>
</tr>
<tr>
<td>Width(W)</td>
<td>20 mm</td>
</tr>
<tr>
<td>Cut width d1</td>
<td>2 mm</td>
</tr>
<tr>
<td>Cut length d2</td>
<td>6 mm</td>
</tr>
<tr>
<td>Cut width W1</td>
<td>5.9 mm</td>
</tr>
<tr>
<td>Cut width Ws</td>
<td>6.2 mm</td>
</tr>
<tr>
<td>Cut length Ls</td>
<td>5 mm</td>
</tr>
</tbody>
</table>

Figure 2: Geometry of the proposed 2x2 MIMO antenna

The proposed antenna simulated using IE3D simulator resonates at a dual band of 7.5 GHz and 8.6 GHz. The antenna design shown in fig.2 is the proposed 2x2 MIMO system developed using the back to back E-shaped corner truncated microstrip patch antenna. The separation between the elements for the proposed design is taken to be 10 mm. The dimensions for the proposed design are taken to be the same as that of the single back to back E-shaped corner truncated microstrip patch antenna.

The proposed antenna simulated using IE3D software from Zeland yields circular polarization and improved return loss.

IV. RESULT AND DISCUSSION

The back to back E-shaped corner truncated microstrip antenna designed is operable at dual band of frequencies 7.5 GHz and 8.6 GHz. The simulations are done using IE3D simulator from Zeland.
A. Smith Chart

Figure 3: Smith chart

B. Return Loss Measurement

Return loss = -17 dB at 7.5 GHz
Return loss = -20 dB at 8.6 GHz

C. VSWR Measurement

Figure 5: VSWR v/s Frequency
VSWR = 1.3 at 7.5 GHz.
VSWR = 1.24 at 8.66 GHz

D. Axial Ratio

Figure 6: Axial ratio v/s Frequency
Axial ratio = 2.5 dBi at 5.575 GHz
E. Gain

Figure 7: Total gain v/s Frequency

Gain = 5.15 dBi at 5.4 GHz

F. Directivity

Figure 8: Total field Directivity v/s Frequency

Directivity = 8 dBi at 5.4 GHz

G. Radiation Pattern

The 2D elevation and azimuth angle pattern for the antenna are shown below in fig. 9 and fig. 10.
H. Antenna Efficiency and Radiation Efficiency

The antenna and radiation efficiency are shown below in fig. 11.

![Figure 11: Efficiency](image)

Antenna efficiency = 60%
Radiation efficiency=80%

The 2x2 MIMO antenna design is simulated using IE3D software from Zeland. The antenna yields circular polarization and a better return loss compared to that of the 1x1 back to back E-shaped microstrip patch antenna.

I. 2x2 MIMO antenna Smith chart

![Figure 12: 2x2 MIMO Antenna Smith Chart](image)

J. 2X2 MIMO Antenna Return Loss Measurement

![Figure 13: 2x2 MIMO Antenna Return Loss v/s Frequency](image)

Return loss = -50 dB at 7.8 GHz

K. 2X2 MIMO Antenna VSWR Measurement

![Figure 14: 2x2 MIMO Antenna VSWR v/s Frequency](image)

VSWR = 1.0 at 7.8 GHz.
VSWR = 1.2 at 8.66 GHz
L. 2X2 MIMO Antenna Axial Ratio

Axial ratio = 1.4 dBi at 5.575 GHz

M. 2X2 MIMO Antenna Gain

Gain = 7.5 dBi at 5.4 GHz

N. 2X2 MIMO Antenna Directivity

Directivity = 10 dBi at 7.5 GHz

O. 2x2 MIMO Radiation Pattern

The 2D elevation and azimuth angle pattern for the antenna are shown below in fig. 18 and fig. 19.
A 2x2 MIMO design technique yielding circular polarization and improved return loss and bandwidth was presented. The 1x1 and 2x2 MIMO system microstrip patch antenna is designed and the results are justified by simulating using IE3D simulator. The optimized antenna parameter results show that the 1x1 MIMO system antenna yields circular polarization having an axial ratio of 2.5 dB, VSWR 1.3, 1.24 at 7.5 GHz, 8.66 GHz respectively. Return loss of about -17 dB at 7.5 GHz and -20 dB at 8.66 GHz was observed. The 2x2 MIMO antenna design yields circular polarization having an axial ratio of 1.4 dB. An improved return loss as compared to that of the 1x1 back to back E-shape microstrip antenna of about -50 dB was obtained. The antenna has a bandwidth of 2.097 GHz. Antenna efficiency for the 2x2 MIMO system was observed to be 55% at 5.4 GHz while the radiation efficiency was observed to be 80% at 5.4 GHz.

REFERENCES


