Design of a Microstrip Patch MIMO Antenna with DGS for UWB Applications

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Abstract—A microstrip patch MIMO antenna with T-shaped stub and dumbbell-shaped DGS with two parallel rectangular slots in the ground plane is designed to operate at UWB (3.1-10.6 GHz.) range. The proposed MIMO antenna contains two antennas at the receiver side which are placed orthogonally to each other. Each antenna comprises of rectangular patch fed by a microstrip line. Defected Ground Structure (DGS) improves isolation between two antennas by making use of the ground plane. Results after simulation exhibits that the return loss is less than -10 dB and mutual coupling is less than -15 dB in the whole UWB range.

Keywords—MIMO, DGS, UWB, Return loss, Mutual Coupling.

I. INTRODUCTION

Systems with multiple antennas both at the transmitter and receiver, are commonly referred to as Multiple Input Multiple Output (MIMO) systems. In wireless communications there has been always growing demand for capacity, data rate, coverage and reliability [1]. MIMO achieves each one of them and improves the overall performance of wireless systems. MIMO antenna which is for small handheld mobile devices should be of compact size. Secondly, there should be low mutual coupling or high isolation between the various antennas [2]. These are two major considerations in implementation of MIMO antenna. The main advantage that UWB has over other current wireless technology (Wi-Fi, Bluetooth) is bandwidth. UWB has a total bandwidth of 7.5 GHz which is unique [3]. UWB is projected at having upwards of 6 devices working simultaneously at 480Mb/s within a range of 10m, which is unheard of in today’s wireless communications [4]. UWB has the potential to revolutionize the consumer electronics industry. Defected Ground Structure (DGS) improves isolation between two antennas by making use of ground plane itself to provide a filter effect [5]. This effect suppresses the surface waves, and thus it provides lower mutual coupling between the antennas. This can be done with a combination of capacitance and inductance effects by means of several slits etched in the middle of the printed circuit board [6]-[7]. DGS with a slitted pattern obstructs the passage of current from one side to the other side of the ground plane. Here ground plane of the antenna is intentionally modified to enhance performance.

II. DESIGN DETAILS

The MIMO antenna has a small size of 32mm×32mm and is shown in Figure 1. It is printed on a 0.8 mm thick FR4 substrate of 4.4 relative permittivity. The proposed MIMO antenna contains two rectangular patch MIMO antennas which are placed orthogonally to each other. A T-shaped stub is attached to the rectangular patch which increases the bandwidth. The narrow slot at an angle of 45 degrees is made on the ground plane to increase the isolation between two antennas. Defected Ground Structure (DGS) improves isolation between two antennas by making use of the ground plane. A dumbbell shaped DGS pattern along with two parallel rectangular slits is used to reduce mutual coupling, as it is simple and its design procedure is easy.
Table 1. Dimensions of the Proposed MIMO Antenna shown in Figure 1

<table>
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<tr>
<th>Parameters</th>
<th>W</th>
<th>L</th>
<th>W1</th>
<th>L1</th>
<th>L2</th>
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<td>8</td>
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<td>W4</td>
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<td>W8</td>
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<td>W9</td>
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<td>1.5</td>
<td>5</td>
<td>0.6</td>
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<tr>
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<td>L9</td>
<td>W10</td>
<td>W11</td>
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<tr>
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<td>1</td>
<td>4</td>
<td>1</td>
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</table>

III. SIMULATION AND MEASUREMENT RESULTS

The MIMO antenna is simulated using HFSS (High Frequency Structure Simulator) software, fabricated and tested with the help of VNA (Vector Network Analyzer). The return loss is less than -10dB in the whole UWB as shown in Figure 2.
The mutual coupling is less than -15 dB in the whole UWB as shown in Figure 3. Simulated radiation pattern in Figure 4 shows that there are two major lobes in the E-plane. Simulated radiation pattern in Figure 5 shows the direction of magnetic field in the H-plane. Figure 6 shows the VSWR (voltage standing wave ratio) of the antenna. VSWR at 3.1-10.6 GHz is in between 1.25 and 1.93. The gain observed is 3.42 dB at 3.75 GHz solution frequency as shown in Figure 7. Figure 8 shows the fabricated MIMO antenna from the top view and the bottom view.

![Figure 2 Return Loss of Simulated Antenna](image)

![Figure 3 Mutual Coupling of Simulated Antenna](image)

### Table 2. Comparison Table of the Proposed Design with some of the Reference Papers

<table>
<thead>
<tr>
<th>REFERENCE PAPERS</th>
<th>Size (mm)</th>
<th>Mutual Coupling (dB)</th>
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</thead>
<tbody>
<tr>
<td>Defected Ground Structure for Isolation Enhancement in a Printed MIMO Antenna System [10]</td>
<td>50 × 100</td>
<td>-9</td>
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<tr>
<td>A Compact Planar Printed MIMO Antenna Design [11]</td>
<td>27.5 × 30</td>
<td>-10</td>
</tr>
<tr>
<td>Mutual Coupling Reduction of Dual-band Printed Monopoles Using MNG</td>
<td>35 × 25</td>
<td>-14</td>
</tr>
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</table>
Metamaterial [12]

Proposed Design | 32 × 32 | -15

**Figure 4** 2-D Radiation Pattern t E-Plane (\( \phi = 0^\circ \))

**Figure 5** 2-D Radiation Pattern at H-Plane (\( \phi = 90^\circ \))

**Figure 6** VSWR Parameter of Simulated Antenna
Figure 7 Antenna Gain at 3.75 GHz

Figure 8(a) Top View of Fabricated Antenna

Figure 8(b) Bottom view of Fabricated Antenna

Figure 9 Designed MIMO antenna tested with the help of VNA (Return loss less than -10 dB)

Figure 10 Designed MIMO antenna tested with the help of VNA (Mutual Coupling less than -15 dB)
Figure 11 below shows that the simulated and measured results are in good agreement.

![Figure 11. Comparison of Simulated and Fabricated result](image)

IV. CONCLUSION

A Printed MIMO antenna with dumbbell-shaped DGS and two parallel rectangular slots in the ground plane is designed to operate at UWB range. The proposed MIMO antenna contains two antennas at the receiver side. As mutual coupling of less than -15 dB is enough for the UWB applications, the antenna is suitable for MIMO application across the whole UWB band.

REFERENCES