MIMO Systems with One Directional Antenna

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Abstract – The use of one directional antenna in MIMO systems utilizes the fact that faded propagation is not random in azimuth, but has local maxima. Thus it can improve the link performances (Throughput, Bit Error Rate and Signal to Noise), provided that the directional antenna can be rotated towards the optimal direction. Indoor tests with two antennas (one monopole and one microstrip) show typical capacity improvement of 50% to 80% in comparison to two omni directional antennas.

Index Terms – MIMO systems, Diversity, Non Line of Sight Links

I. INTRODUCTION

Most modern wireless communication systems are working in Non Line Of Sight environment which includes effects of reflections, diffractions, scattering and multi-path. The use of several independent transmissions through the channel enables not only to overcome the fading problem, but also to enlarge the spectral efficiency by multiple radio transceivers. The key feature for these improvements are diversified antennas at the transmit side and at the receive side.

Diversity / MIMO (Multi Input Multi Output) antennas should be spaced apart one from the other. Traditional analysis suggested that optimal spacing is between half wavelength to one wavelength, but updated empirical studies showed that spacing of quarter wavelength gives good results as well. Also, high quality results were gained with multi-polarity or mixed polarizations. The key factor in designing good antennas is therefore to diversify their locations and orientations.

It has also believed that MIMO systems show best performance with Omni-Directional antennas such as monopoles or Inverted-F elements [1]-[3]. This conception assumes that the multi-path fading is random. In this sense it is better not to limit the angular spread of radiation but to transmit and receive isotropically. However, in recent years there are evidences that local indoor interferences are not statistically "flat", i.e. the scattering is not pure isotropic. Hence, one or more directional antennas can improve the link performances (SNR, BER, capacity, diversity gain, range etc.) performance, assuming that their orientation can be dynamically optimized.

II. ANTENNA TYPES

Some findings show that using directive antennas with beamwidths in the range of 40°-80° and gains in the range of 5 -10 dBi can improve the capacity by factor of 2 and even more. The improvement in the link performance due to the directional antennas depends on the scattering environment and is sensitive to the location and the rotation of the antennas. The ability to move or rotate the antennas in small steps and adjust them automatically to any spread scattering situation is a must.

The use of directional antennas with such a control unit is most valuable for broadband services, either by conventional broadcasting or in mesh topology. Relevant antenna candidates are the microstrip patch (6-8 dBi), a small horn (8-12 dBi) or small arrays of monopoles and dipoles (6-10 dBi). In this work we have used two printed monopoles with Gain 0 to 1 dBi as shown in figure 1 versus a monopole and a microstrip with Gain 7 to 8 dBi, as shown in figure 2.

III. TEST LAYOUT

In this study we compare a MIMO system with two omni antennas to a MIMO system with one directional antenna and one omni antenna The experiment had been done in a two floor apartment with two access points (AP#1 and AP#2 Netgear WNR3500 2T2R 11n) and six test points. Average throughputs for USB dongle Linksys AE1000 2T 2R 11n with two omni antennas versus DirectBeam unit (patent pending based on Linksys AE1000 circuit with monopole and microstrip antennas) were measured by an FTP streamer. Figure 3 shows a proprietary WiFi manager that displays the different routers and access points and the best antenna direction for optimal link performances. The environment of the indoor link tests is described in figure 4.
Figure 1  Two omni antenna structure

Figure 2  One omni and one directional antenna

Figure 3  Test presentation by WiFi manager shows the best direction for optimal link performance (data rate and range).

AP#1- No 7 in the Direct Beam application is the testing AP.

AP#2 – No 8 in the Direct Beam application (used for Internet connection).

IV. TEST RESULTS

The downstream and the upstream data rates are shown in tables 1-2 and in figures 5-6. The throughput with one directional antenna was considerably more repeatable and stable than with two omni antennas and typical improvement of 50%-80% had been demonstrated. In addition, we have found out that at outdoor environments (almost Line of Sight) the data rates were improved by factor of 5 to 10.

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Distance</th>
<th>DirectBeam Downstream</th>
<th>USB AE1000 Downstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>25 feet</td>
<td>11.81 Mbps</td>
<td>8.34 Mbps</td>
</tr>
<tr>
<td>TP2</td>
<td>45 feet</td>
<td>2.92 Mbps</td>
<td>0.45 Mbps</td>
</tr>
<tr>
<td>TP3</td>
<td>43 feet</td>
<td>3.58 Mbps</td>
<td>0.34 Mbps</td>
</tr>
<tr>
<td>TP4</td>
<td>40 feet</td>
<td>1.93 Mbps</td>
<td>0.31 Mbps</td>
</tr>
<tr>
<td>TP5</td>
<td>48 feet</td>
<td>0.43 Mbps</td>
<td>0.42 Mbps</td>
</tr>
<tr>
<td>TP6</td>
<td>43 feet</td>
<td>0.25 Mbps</td>
<td>0.31 Mbps</td>
</tr>
</tbody>
</table>

Table 1  Downstream data rates for six Test Points

<table>
<thead>
<tr>
<th>Test Point</th>
<th>Distance</th>
<th>DirectBeam Upstream</th>
<th>USB AE1000 Upstream</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>25 feet</td>
<td>9.17 Mbps</td>
<td>5.56 Mbps</td>
</tr>
<tr>
<td>TP2</td>
<td>45 feet</td>
<td>3.11 Mbps</td>
<td>1.17 Mbps</td>
</tr>
<tr>
<td>TP3</td>
<td>43 feet</td>
<td>2.13 Mbps</td>
<td>1.26 Mbps</td>
</tr>
<tr>
<td>TP4</td>
<td>40 feet</td>
<td>3.23 Mbps</td>
<td>1.02 Mbps</td>
</tr>
<tr>
<td>TP5</td>
<td>48 feet</td>
<td>1.58 Mbps</td>
<td>0.21 Mbps</td>
</tr>
<tr>
<td>TP6</td>
<td>43 feet</td>
<td>0.42 Mbps</td>
<td>0.19 Mbps</td>
</tr>
</tbody>
</table>

Table 2  Upstream data rates for six Test Points
Figure 4  Test environment of two floor apartment.
V. CONCLUSION

The use of one directional antenna within a MIMO array, provided that the antenna can be rotated towards the optimal direction in the room, can improve the link performance in indoor areas by factor of 1.5 to 2. This concept, demonstrated here for computer networks at home, can be used for other wireless channels such as high speed multimedia, multi camera transmission and DTT as well.

REFERENCES


