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Evaluating the Antenna Performance of 802.11n Wireless Routers in an Indoor Environment

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Abstract

The antenna performance of three 2x2 802.11n wireless routers is assessed at 2.4GHz using a laptop as a reference client. The analysis combines in-situ measured 3D radiation patterns with state-of-the-art 3D ray-tracing for a number of different client locations and access-point/client orientations in a typical three-floor home.

A router employing two PIFAs achieves the highest average signal level on the top floors (3-10dB better); a router with two external dipoles on the same floor level (1-5dB better); and a router with two patches is in-between and results in the largest signal variations (5-15dB larger dynamic range).

Results also demonstrate the importance of measuring 3D radiation patterns of all the individual elements of a MIMO system in-situ and not just a single element in isolation.

Antenna Radiation Patterns

Fig. 1: Routers and laptop client antenna configurations and total power radiation patterns (measured at 2440 MHz in the anechoic chamber).

Propagation Environment

- Spatial and temporal multipath components modelled with a 3D indoor ray-tracer (analysis performed at 2.4GHz with 12dBm transmit power per radio chain).
- Typical three-floor home with AP location fixed on ground floor and ten client locations distributed around the property.
- AP rotated in azimuth over 360°; Client tilted in elevation between 0° and 40°; and rotated in azimuth over 360°.
- Received signal strength at the client computed at each location for each antenna-to-antenna link, AP rotation, and client tilt and rotation.

Results

Fig. 3: Received signal strength averaged over all antenna links and AP/client orientations at each location.

On the same floor level, router 3 results in the highest average signal level, whereas router 1 in the lowest (1-5dB difference).

Router 1 transmits the highest signal in average to almost all the top floors locations, where router 3 has the worst performance (3-10dB difference). The only exception is location 7, where dipoles perform better.

The average performance of router 2 is in almost all cases in-between the other two.

Routers 1 and 3 result in a dynamic range (i.e. difference between maximum and minimum) between 17dB and 32dB. This shows that even with routers with omnidirectional antennas, the performance is sensitive to the AP/client orientation.

The dynamic range of router 2 is 5-15dB higher than the other two, as it is more sensitive to orientation due to the directional radiation of the patches.

Conclusions

- The 3D radiation patterns allow a full insight into the behaviour of the antenna system that is not possible to deduce from single planes (e.g. x-y, x-z, y-z).
- The patterns of all the individual antennas of a MIMO system should be measured in-situ and not just a single element in isolation, as identical elements produce significantly different patterns and directivities.

Table 1: Radiation patterns statistics

<table>
<thead>
<tr>
<th>Element</th>
<th>Power in Polariation (%)</th>
<th>Maximum Directivity (dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vertical</td>
<td>Horizontal</td>
</tr>
<tr>
<td>PIFA 1</td>
<td>49</td>
<td>51</td>
</tr>
<tr>
<td>PIFA 2</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Patch 1</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Patch 2</td>
<td>14</td>
<td>76</td>
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<td>Dipole 1</td>
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<td>6</td>
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<tr>
<td>Dipole 2</td>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>Laptop Antenna 1</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>Laptop Antenna 2</td>
<td>63</td>
<td>35</td>
</tr>
</tbody>
</table>

Fig. 4: Dynamic range of received signal strength at each location.

- A router employing two PIFAs achieves the highest average signal level on the top floors (3-10dB better); a router with two external dipoles on the same floor level (1-5dB better); and a router with two patches is in-between and results in the largest signal variations (5-15dB larger dynamic range).
- Results demonstrated the importance of measuring 3D radiation patterns of all the individual elements of a MIMO system in-situ. Antennas must be designed for a communication system accounting for the effect that the application will have on their performance. It is important not just to measure a single element in isolation.
- Future work will combine the RF-level results with an 802.11n simulator to predict the impact of the antennas on the system-level performance, accounting for the various modulation and coding schemes and the different MIMO transmission techniques (e.g. spatial-multiplexing or eigen-beamforming) of the 802.11n standard.