
Peer reviewed version

Link to published version (if available):
10.1109/ICWMC.2010.63

Link to publication record in Explore Bristol Research
PDF-document

University of Bristol - Explore Bristol Research
General rights

This document is made available in accordance with publisher policies. Please cite only the published version using the reference above. Full terms of use are available: http://www.bristol.ac.uk/red/research-policy/pure/user-guides/ebr-terms/
Novel Antenna Configurations for Wireless Broadband Vehicular Communications

George Zaggoulos (University of Cyprus)
David Halls and Andrew Nix (University of Bristol)
Outline

- Introduction
- Propagation Environment and WiMAX Measurement Scenario
- Omni Vs Directional Antenna (real WiMAX performance)
- Dual Slant (+/- 45) vs. Horizontal/Vertical Polarization
- Conclusion
Introduction

- Investigate performance of omni vs. directional antennas in terms of
  1. RSSI
  2. Throughput

- Investigate the effects of antenna polarization configuration on
  1. RSSI
  2. Throughput
  3. Spatial Multiplexing usage
Propagation Environment and Drive tests

Drive test route:
A >> B >> C >> D >> E
and back to start via
D >> C >> F >> A

Red numbers: local path loss exponents

Return trip: 3.5 km
at vehicular speed of
30 to 70 kmph depending on the traffic
Mobile WiMAX System Parameters

- Mobile WiMAX BS at 3.5 GHz
- Bandwidth: 5 MHz
- Sub-carriers: 1024
- BS EIRP: 46.5 dBm
- Tx config: Dual Slant
- Maximum Ratio Combining (MRC)
- MIMO 2x2 system with adaptive Modulation and Coding (AMC) and adaptive MIMO switching (AMS) turned ON
WiMAX Antennas

Vehicular (external) Antennas connected to PCI WiMAX cards \((d=10\lambda)\)

- Omni. Antennas \((4\text{dBi})\)
- Directional Antennas \((60\text{ degrees}, 8\text{dBi})\)
- Sector Antenna \((90\text{ degrees }16.5\text{dBi})\)
- 2D Antenna Array \((\text{for beamforming})\)

Base Station Antennas \((\text{EIRP}=46.5\text{ dBm})\)
Omni vs. Directional Antennas

i) co-polar
60-degree vertically polarized directional antenna at 3.5GHz with large ground plane

ii) cross-polar

i) co-polar
omni-directional vertically polarized antenna at 3.5GHz with large ground plane

ii) cross-polar
RSSI with different Rx antennas

**Graph:**
- **Axes:**
  - Y-axis: RSSI (dBm)
  - X-axis: Distance (m)

**Legend:**
- Omni-directional 1
- Omni-directional 2
- Directional 1
- Directional 2

**Note:** Both pairs of Rx antennas are polarized at +/- 45 degrees from vertical.

**Text:**
RSSI versus distance with different Rx antennas (driving away from the BS)
RSSI with different Rx antennas

Both pairs of Rx antennas are polarized at +/- 45 degrees from vertical

RSSI versus distance with different Rx antennas (driving towards the BS)
Throughput with different antennas

- Throughput (kbps) vs Distance (m)
- RSSI (dBm) vs Distance (m)

Both pairs of Rx antennas are vertically polarized

Graphs showing throughput and RSSI for various antenna types and distances.
MIMO Capacity Equation

\[ C = \log_2 \left[ \det \left( I_{N_R} + \left( \frac{\rho}{N_T} \right) HH^* \right) \right] \]

- \( I_{N_R} \) is the \( N_R \times N_R \) identity matrix, \( N_T \) and \( N_R \) are the number of Tx and Rx antennas respectively.
- \( \rho \) is the mean SNR per received branch, \( H \) is the power normalised channel matrix.

- RSSI (or SNR) is not the only metric that determines the capacity of MIMO systems.
- MIMO systems also require low fading envelope correlations between the multiple antenna branches in order to fully exploit the capabilities of SM and STBC; This increases the determinant of the MIMO channel matrix, which enhances the theoretic capacity of the system.
- In the ideal situation, the channel experiences independent and identically distributed (iid) fading on the elements of \( H \).
Requirements for Capacity improvement in vehicular MIMO applications

- Balanced links (similar SNR on all branches)
- Low fading envelope correlations between multiple antenna branches
- Links with strong LoS require additional actions in order to achieve low fading envelope correlations (e.g. use of dual polarization) at the receiver
- Also incorporating the effect of the large ground plane (vehicle’s roof) which alters the radiation pattern of the antenna
Results with dual polarized antennas

![Graph showing throughput and RSSI over distance for different antenna configurations.](image)
Mean Throughput with different Antenna Configurations

- Directional (+/-45 Degrees)
- Directional (Vertical/Horizontal)
- Directional (Both Vertical)
- Omni-directional (+/- 45 Degrees)
- Omni-directional (Both Vertical)
Spatial-Multiplexing usage with different Rx antenna configurations on the vehicle

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization</td>
<td>+/- 45 Deg.</td>
<td>Vert./ Horiz.</td>
<td>Both Vertical</td>
<td>+/- 45 Deg.</td>
<td>Both Vertical</td>
</tr>
<tr>
<td>LoS</td>
<td>77.52</td>
<td>85.52</td>
<td>37.93</td>
<td>56.08</td>
<td>59.65</td>
</tr>
<tr>
<td>NLoS</td>
<td>57.95</td>
<td>67.55</td>
<td>41.4</td>
<td>33.25</td>
<td>30.05</td>
</tr>
</tbody>
</table>

Dually polarized directional antennas support the highest usage of Multiplexing while the pair of vertically polarized directional antennas gives the least among the five antenna configurations tested.
Conclusions

• Vehicular communications perform better with directional antennas aligned to the direction of motion.
• MIMO 2x2 requires balanced links and low fading envelope correlations to exploit the advantages of MIMO
Questions?

Thank you!

zaggoulos.george@ucy.ac.cy
david.halls.03@bristol.ac.uk
andy.nix@bristol.ac.uk