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MIMO Radio Propagation Channel Measurements in a Small Urban Macrocell at 4.5GHz

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Why model?

One of the general goals of MIMO propagation channel modeling:

MIMO performance exploitation for future cellular communication systems

Double-directional channel model

antenna independent

4.5 GHz

- part of the spectrum proposed for 4G mobile networks by Japan
- not many channel sounding has been done at this frequency
  - especially in considering certain parameters based on the polarimetric information
Why model?

Goal: show certain characteristics of selected propagation channels in terms of condensed parameters

- root-mean-square (rms) delay spread
- cross-polarization ratio (XPR)
- co-polarization ratio (CPR)
How did we measure the channel?

<table>
<thead>
<tr>
<th>Medav RUSK-Fujitsu MIMO Channel Sounder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
</tr>
<tr>
<td>Bandwidth</td>
</tr>
<tr>
<td>BS Antenna</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>MS Antenna</td>
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<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>Tx Signal</td>
</tr>
<tr>
<td>Tx Power</td>
</tr>
<tr>
<td>Maximum path delay</td>
</tr>
</tbody>
</table>
How did we measure the channel?

Medav RUSK-Fujitsu MIMO Channel Sounder

BS Antenna

MS Antenna

BS

MS
Where and how did we measure the channel?

**Measurement site**
Kamikodanaka, Nakahara-ku, Kawasaki City
- a mix of residential, commercial, & industrial zones

**Dynamic measurements**
- 20-meter lengths
- performed after midnight
Where and how did we measure the channel?

Small macrocell setup

BS height: \(\sim 85\) m
- highest location within the MS locations

MS height: \(\sim 1.8\) m
- nearest point: \(\sim 215\) m
- farthest point: \(\sim 430\) m
How and what were the parameters extracted?

Offline data processing

- obtain parameter estimates of the propagation channel
- multidimensional maximum-likelihood algorithm
  - based on the double-directional channel concept

Estimated parameters of each radio path

- direction of arrival (DoA); azimuth & elevation
- direction of departure (DoD); azimuth & elevation
- delay time
- complex amplitude of the polarimetric components
  \((\gamma_{VV}, \gamma_{VH}, \gamma_{HV}, \gamma_{VV})\)
Some Introductions
Why model?

Channel Sounding
Setup
MIMO Channel Sounder
Environment Setting
Parameter Estimation

Propagation
Channel Scenarios
Some Remarks
XPR
RMS Delay Spread
CPR

Summary

### Channel Scenario Descriptions

<table>
<thead>
<tr>
<th>Label</th>
<th>BS-MS distance (m)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>~400</td>
<td>better LOS among the other scenarios</td>
</tr>
<tr>
<td>J</td>
<td>~320</td>
<td>a building blocked most of the measurement —mostly NLOS-like scenario</td>
</tr>
<tr>
<td>N</td>
<td>~267</td>
<td>main obstructions: trees &amp; buildings, but they did not completely block the channel</td>
</tr>
<tr>
<td>S</td>
<td>~232</td>
<td>better LOS than scenarios J &amp; N</td>
</tr>
</tbody>
</table>
Some Remarks (1)

MS moved toward the BS

scenario C towards scenario S

Irregular measurement route

not like a Kyoto-street grid
Some Remarks (2)

Computation of condensed parameters

- relatively strong paths—until 20 dBm below the normalized strongest path (0 dBm)
- considered specular paths only & not the diffuse components
XPR - amount of polarization change of a signal from being V-polarized to being H-polarized, or vice versa

\[
XPR(s)^{BS}_V = 10\log_{10} \left( \frac{\sum_{l=1}^{L(s)} |\gamma_{VV,l}|^2}{\sum_{l=1}^{L(s)} |\gamma_{VH,l}|^2} \right) \text{ [dB]}
\]

\[
XPR(s)^{BS}_H = 10\log_{10} \left( \frac{\sum_{l=1}^{L(s)} |\gamma_{HH,l}|^2}{\sum_{l=1}^{L(s)} |\gamma_{HV,l}|^2} \right) \text{ [dB]}
\]

\[
XPR(s)^{MS}_V = 10\log_{10} \left( \frac{\sum_{l=1}^{L(s)} |\gamma_{VV,l}|^2}{\sum_{l=1}^{L(s)} |\gamma_{HV,l}|^2} \right) \text{ [dB]}
\]

\[
XPR(s)^{MS}_H = 10\log_{10} \left( \frac{\sum_{l=1}^{L(s)} |\gamma_{HH,l}|^2}{\sum_{l=1}^{L(s)} |\gamma_{HV,l}|^2} \right) \text{ [dB]}
\]
Most of the scenarios preferred V-polarized signals

Scenarios J & S

lower polarization change than in scenarios N & C
Scenario J

highest mean XPR; low variation

- interacting objects (IOs) of the building: mostly present throughout the measurement route
Scenario J

IOs of the building: mostly present throughout the measurement route
Scenario C

least mean XPR; highest variation

- LOS presence in most of the measurement route
- preserved the co-polarized components
Scenario C

least mean XPR; highest variation

- LOS presence in most of the measurement route
  - preserved the co-polarized components
- positions of the IOs near the MS
  - contributed to changing the polarization
  - many horizontally oriented IO positions
RMS Delay Spread

Scenario J was the most spread

Scenarios N & S were the less spread

- relative nearness of the MS to the BS
- weaker LOS in scenario N than in scenario S
RMS Delay Spread

Scenario N should have been more spread, but not in our case

- constructively rich scattering in scenario N
- scenario N had an obstructed line-of-sight-like (OLOS-like) setting
CPR

The dB value of the CPR (like in XPR) was used for the statistics, assuming the log-normal distribution

\[
\text{CPR}(s) = 10 \log_{10} \left( \frac{\sum_{l=1}^{L(s)} |\gamma_{VV,l}|^2}{\sum_{l=1}^{L(s)} |\gamma_{HH,l}|^2} \right) \text{ [dB]}
\]
Scenarios

- fewer vertically oriented IOs than that in scenario J
- difficult to decide which of the IOs were predominant
  - highest CPR standard deviation
CPR

Scenario N

difficult to decide which of the IOs were predominant
Conclusions

Polarization change

- LOS presence did not assure co-polarized components
- orientation of the IOs surrounding the BS or MS
- XPR higher in our NLOS scenario than in our LOS scenario

RMS delay spread

more spread in the NLOS scenario but lesser in the LOS scenario

Overall, the results follow the general channel behavior of macrocell scenarios

but, environment-specific circumstances make propositions about MIMO propagation channel characteristics difficult