Broadband Wireless Channel Measurements for High Speed Trains

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Motivation

- Achieving broadband communications at high speeds
  - LTE has been designed for up to 150Mbps and up to 500km/h, but realistic throughput is much lower (~20Mbps)

- LTE-Advanced increases throughput through
  - Higher order MIMO (8 antennas)
  - Carrier Aggregation (CA)

- However, fundamental problems remain
  - High Doppler causes inter-carrier interference (ICI)
  - High channel variation makes feedback difficult
  - Different propagation conditions at different carriers

- This work presents
  - High-speed (300km/h) channel measurement campaign
  - Combining MIMO and CA
  - Carried out in the French CORRIDOR project
Channel Sounding Campaign

- 3 LTE carriers
- 4 transmit antennas each
- Sounding signal
  - LTE-like (OFDM)
  - Pilots only

<table>
<thead>
<tr>
<th></th>
<th>5MHz</th>
<th>10MHz</th>
<th>20MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Rate (MSPS)</td>
<td>7.68</td>
<td>15.36</td>
<td>30.72</td>
</tr>
<tr>
<td>Symbol duration</td>
<td></td>
<td>66 μs</td>
<td></td>
</tr>
<tr>
<td>Prefix length</td>
<td></td>
<td>16 μs</td>
<td></td>
</tr>
<tr>
<td>Frame duration</td>
<td></td>
<td>10 ms (120 OFDM symbols)</td>
<td></td>
</tr>
<tr>
<td>OFDM size</td>
<td>512</td>
<td>1024</td>
<td>2048</td>
</tr>
<tr>
<td>Useful carriers</td>
<td>300</td>
<td>600</td>
<td>1200</td>
</tr>
</tbody>
</table>
Measurement Equipment

- TX and RX built upon Eurecom’s ExpressMIMO2 cards
  - Each card provides either 4 x 5MHz, 2 x 10 MHz, or 1 x 20MHz
  - Multiple cards can be synchronized

- TX uses additional power amplifiers
  - 40dBm for 800MHz channel
  - 36dBm for 2.6GHz channel
Antennas

- **Base station**
  - 2 HUBER+SUHNER (2.6GHz)
  - 2 Kathrein (800MHz)
  - All sectorized & dual polarized

- **Train**
  - Sencity Rail Antennas from HUBER+SUHNER
  - 2 double-directional antennas at 2.6GHz (only one direction used)
  - 3 omni-directional antennas at 800MHz
Scenarios

- **Train: IRIS 320 TGV**
  - SNCF INFRA

- **Rail line: LGV Atlantique**
  - Southwest of Paris

**Scenarios**

1. **Operator type:** eNB 1.5km away from rail line
2. **LTE-R type A:** eNB next to railway line, antennas point both sides
3. **LTE-R type B:** eNB next to railway line, antennas point in same direction
Data acquisition and Post processing

- Recording raw IQ data
  - Continuously for 5MHz channel
  - 1/2 seconds for (10+20MHz) channel

- Timing synchronization and tracking

- Channel Estimation

- Delay Doppler Power Spectrum Estimation
  - One estimate per second $\rightarrow$ 1Hz Doppler resolution
Path loss results

Path loss coefficient:
- 3.2 - 4.5

Mean
- 800MHz: 3.6
- 2.6GHz: 4
Delay Doppler Spectrum 800MHz Scenario 1
**Doppler Profile 800MHz Trial 1 Run 1**

- **Strong frequency offset**
  - Calibrated mostly in trial 2

- **Possible Model: (offset) Jakes + specular component**
  - Specular component corresponds well to geometry and speed of train
  - Hypothesis yet to be tested
Delay Doppler Spectrum 2.6GHz (Carrier 1) Scenario 2A
Second specular component when train is southwest of base station!
Model of scattering environment

- Strong local reflection from gantries along track
- Antenna main lobe pointing away from TX → LOS strongly attenuated
Conclusions and Future Work

- First measurement campaign on a high speed train combining MIMO and carrier aggregation
- Time-frequency analysis shows highly non-stationary behavior
- Antenna (port) selection very important to reduce Doppler effects
- Channel could be modeled as geometry based stochastic model
- Future work: spatial analysis (MIMO)
BACKUP
Motivation and Context

- **CORRIDOR project**
  - Cognitive Radio for Railway Through Dynamic and Opportunistic Spectrum Reuse
  - Nov 2011 - Apr 2015, funded by ANR
Huber&Suhner Sencity Rail Antenna 2.6GHz

Port 1

Port 2
Delay Doppler Spectrum 2.6GHz (Carrier 2) Scenario 2A