ISART 2018 Panel Session:

"Driving Forward": Advances in Propagation Modelling

Evelyn Dohme, University of New Mexico
Katsuyuki Haneda, Aalto University
David Matolak, University of South Carolina
Paul McKenna, NTIA/ITS
Kevin Sowerby, University of Auckland (Moderator)
ISART 2018 Panel Session: "Driving Forward": Advances in Propagation Modelling

Kevin W Sowerby
Department of Electrical & Computer Engineering
Cellular radio coverage

- 2600 MHz
- 2100 MHz
- 1800 MHz
- 900 MHz
- 800 MHz
<table>
<thead>
<tr>
<th></th>
<th>3G</th>
<th>LTE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data rate</strong></td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td><strong>Available bandwidth</strong></td>
<td>3840</td>
<td>1260</td>
</tr>
<tr>
<td><strong>Frequency band</strong></td>
<td>1800</td>
<td>1800</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>urban</td>
<td>urban</td>
</tr>
<tr>
<td><strong>Max Tx power</strong></td>
<td>23.0</td>
<td>23.0</td>
</tr>
<tr>
<td><strong>Tx antenna gain</strong></td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Body loss</strong></td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>EIRP</strong></td>
<td>23.0</td>
<td>23.0</td>
</tr>
<tr>
<td><strong>Noise figure</strong></td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Thermal noise</strong></td>
<td>-108.1</td>
<td>-113.0</td>
</tr>
<tr>
<td><strong>Rx noise</strong></td>
<td>-106.1</td>
<td>-111.0</td>
</tr>
<tr>
<td><strong>SINR</strong></td>
<td>-10.5</td>
<td>-7.2</td>
</tr>
<tr>
<td><strong>Rx sensitivity</strong></td>
<td>-116.7</td>
<td>-118.1</td>
</tr>
<tr>
<td><strong>Interference margin</strong></td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Cable loss</strong></td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>Rx antenna gain</strong></td>
<td>18.0</td>
<td>18.0</td>
</tr>
<tr>
<td><strong>Fast fading margin</strong></td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Soft handover gain</strong></td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td><strong>Coverage reliability</strong></td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td><strong>Shadowing plus penetration loss</strong></td>
<td>mean 22.3</td>
<td>22.3 dB</td>
</tr>
<tr>
<td></td>
<td>sigma 9.5</td>
<td>9.5 dB</td>
</tr>
<tr>
<td></td>
<td>margin 34.5</td>
<td>34.5 dB</td>
</tr>
<tr>
<td><strong>Max. allowable path loss</strong></td>
<td>117.4</td>
<td>120.7 dB</td>
</tr>
<tr>
<td><strong>Path loss model (COST 231 Hata)</strong></td>
<td>fixed 134.8</td>
<td>134.8 dB</td>
</tr>
<tr>
<td></td>
<td>distance 35.2</td>
<td>35.2 dB</td>
</tr>
<tr>
<td><strong>Max. allowable cell range</strong></td>
<td>0.32 km</td>
<td>0.40 km</td>
</tr>
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</table>
LTE 1800 MHz coverage

Actual LTE coverage from coastal site, using the UHF band (1800 MHz).
The Finite-Difference Time-Domain (FDTD) Method

- Numerical solution of Maxwell’s equations in the time domain
- Usually solved on regular cartesian lattice
- Spatial discretisation usually ~ wavelength/20
- Time step chosen to ensure stability – typically in ps
- Pulse excitation usually employed
- Simulation is run until transients die out
- Time harmonic response can be straightforwardly extracted
\[ E_z|_{\text{new}} = c_a E_z|_{\text{old}} + c_b (H_y^2|_{\text{old}} - H_y^1|_{\text{old}} + H_x^2|_{\text{old}} - H_x^1|_{\text{old}}) \]
FDTD simulated path loss at 1GHz on a horizontal slice for (a) ‘basic’ and (b) ‘detailed’ internal geometries
Streamline Visualisation

- Time-averaged Poynting vector

\[ \mathbf{S} = \frac{1}{2} \Re \left[ \mathbf{E} \times \mathbf{H}^* \right] \]

- Streamlines defined by

\[ \frac{d\vec{\rho}(a)}{da} = \mathbf{S}(\vec{\rho}(a)) \]

- Can be used to visualise energy flow
Streamlines of energy flow at 1GHz on a horizontal slice for (a) ‘basic’ and (b) ‘detailed’ internal geometries.
Our Propagation Modelling Paradigm

- Semi-deterministic approach

- ‘Exhaustive’ electromagnetic analysis of typical range of building environments

- Use results to derive simpler ‘mechanistic’ models which capture the key effects which dominate propagation
Radio spectrum is defined as electromagnetic energy of frequencies lower than 1000 GHz. It is regulated by the Government through the Radio Spectrum Management (RSM) team within the Ministry of Business, Innovation and Employment, on behalf of the people of New Zealand. The efficient use of the radio spectrum is vital to the safety of life, communications, broadcasting, and other services as well as to the functioning of a modern economy.

Frequency bands are allocated for various services in accordance with Government policy and international practice and technical standards. Persons wishing to utilise frequencies in accordance with these plans apply for a licence for which a usual fee is charged.

This chart shows in simplified form the significant primary and secondary radio spectrum usage in New Zealand. Many frequency bands are also utilised for other secondary purposes which may not be shown. Hence this chart must be regarded as indicative only and the Crown does not accept responsibility whether in contract, tort, equity, or otherwise for any action taken, or reliance placed on the information in this chart or for any error or omission from this chart. For specific details of current allocations, please refer to Table of Radio Spectrum Usage in New Zealand 2021.

VLF = Very Low Frequency
LF = Low Frequency
MF = Medium Frequency
HF = High Frequency
VHF = Very High Frequency
UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extremely High Frequency
Indoor Millimetre Wave Channel Measurements for 5G Wireless Systems

Dr Andrew Austin, Dr Michael Neve, and Ms Damla Guven
System design is going to be easier at mmWave:
- Steerable high-gain antennas to overcome increased pathloss
- Accordingly, mostly LOS propagation
- RXs don’t need to worry (much) about multipath: simple equalisers

High attenuation & beam-steering: indoor mmWave systems will be coverage limited, not interference limited
- Solution: put a mmWave access point in every office!

Need experimental measurements of the indoor channel:
- How much scatter do we observe?
- Impact of human shadowing?
- Impact of co-channel interference? (from systems in adjacent offices)
“Insertion loss” for various material samples measured at Q-band (33-50 GHz) using network analyser.

Drywall is practically invisible at mmWave bands.

Water content is important!
Impact of Water Content

- Comparison between a dry and “wet” sponge

Approx. 10 dB additional attenuation due to water
Directional horn antennas: azimuth/elevation and location varied

Frequency sweep over 1 GHz bandwidth for 0º – 360º
- Frequency average to account for multipath
Environment Investigated

- Indoor interior office: no exterior windows!
- Internal partitions: drywall/gib-board on timber frame

- Full of “academic clutter”: probably more books than a typical office
Reference case (all results scaled to this one)

- Max. power when Tx and Rx antennas aligned (as expected)
- Reflected paths >15 dB down from main beam
In-Office Deployment

Reduction in power when moving off boresight (15° 3-dB beamwidth)

- Similar to previous RX location: reflected paths >15 dB down from main beam
Reflection Paths Within an Office

Block possible reflection points with absorbers

Strong specular reflections can arise from metal door frames & glass

Specular reflections are sensitive to position of RX/TX: easily "disappear"
Interference from Adjacent Offices

- TX placed in adjacent office: LOS path between wooden studs

Approx. 12 dB attenuation through the wall

Potential for very significant levels of inter-office interference!
Interference from Adjacent Offices

- Position of wooden studs matters: can shadow the through-wall signal

LOS path blocked by a wooden stud: 10 dB power reduction compared to LOS between studs
Blocking the LOS Path

- 60 GHz signals are readily shadowed by the human body

Main beam attenuated by 20 dB

Desired signal is reaching user via reflected paths

Through-wall interference signal **3 dB stronger** than the reflections!
Strong scattering is possible from curved surfaces
Conclusions

- Strong specular reflections (single, double and triple bounce) can exist at 60 GHz: **but sensitive to location**

- “Soft” internal partitions (gib on timber frame): 12 dB attenuation
  - Comparable power levels to in-office specular reflections

- LOS path readily shadowed by the human body
  - Interference from adjacent offices can **dominate**
  - Difficult to improve desired signal levels via beam-steering

- **Potentially**: introduce “engineered scatter” and combine with beam-steering to eliminate shadow regions