Overview of the COST IC1004 white paper on 'Channel measurement and modelling for 5G networks in the frequency bands above 6 GHz

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Primary motivation

- Large available bandwidths in higher frequency bands
- Demand for high data rate services
- WRC15 identified a number of mm wave band between 24-86 GHz
- Need for channel measurements and models for channels in the higher frequency bands
## WRC15 frequency bands

<table>
<thead>
<tr>
<th>WRC15 Band (GHz)</th>
<th>Band Designation</th>
<th>Bandwidth (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.25-27.5</td>
<td>I</td>
<td>3.25</td>
</tr>
<tr>
<td>31.8-33.4</td>
<td>II</td>
<td>1.6</td>
</tr>
<tr>
<td>37-43.5</td>
<td>III</td>
<td>6.5</td>
</tr>
<tr>
<td>45.5-50.2</td>
<td>IV</td>
<td>4.7</td>
</tr>
<tr>
<td>50.4-52.6</td>
<td>V</td>
<td>2.4</td>
</tr>
<tr>
<td>66-76</td>
<td>VI</td>
<td>10</td>
</tr>
<tr>
<td>81-86</td>
<td>VII</td>
<td>5</td>
</tr>
</tbody>
</table>
Main topics

1. Use scenarios of the mm-wave band.
2. An overview of propagation characteristics based on available ITU-R recommendations and recent studies.
3. State of the art channel sounding techniques for mm-wave measurements for the different use scenarios.
4. Channel measurement and ray tracing results.
5. Propagation models.
7. Recommendations for further studies.
Use Scenarios: outdoor

Street canyon

Open square

Backhaul

Small cells~200 m
Use Scenarios: indoor

- Shopping mall
- Inside Train
- Aeroplane
ITU-R recommendations

ITU-R P676-10: Gaseous absorption
Model input parameters:
temperature, ambient pressure, and water vapour density.
Use can be made of
ITU-R P.836-5 water vapour density
ITU-R P1510 mean annual surface temperature

ITU-R P.840-6: Fog absorption
ITU-R P838-3: Rain absorption
ITU-R P 837-6: Rain rates
Rain attenuation model ITU-R P838-3

Rain: 10 dB/km at 25 mm/hr increasing to 30 dB/km at 100 mm/hr rainfall
Gaseous absorption

Gaseous: 0.3-0.5 dB/km for frequencies up to 38 GHz and 70-100 GHz maximum at 60 GHz of 15 dB/km
Fog absorption

as high as 5dB/km at 100 GHz for 1g/m³
ITU priority areas

To address

ITU-R P-1411-8 Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300MHz-100 GHz

ITU-R 1238-8 Propagation data and prediction methods for indoor radiocommunication systems and radio local area networks in the frequency range 300MHz-100 GHz
State of the art channel sounding techniques for mm-wave measurements

Equipment based channel sounding

Custom designed multi-band MIMO channel sounders

1. PRBS sounder: Illmenau
2. FMCW sounder: Durham
Channel measurement: environments

(a) Hall, office Illmenau
(b) Outdoor and indoor Durham

(a) Durham University
(b) Durham University
Channel measurement: results

Hall environment, Ilmenau

Impact of antenna aperture
Lens, open waveguide, Durham
Path loss model: ray tracing

\[
\text{PL[dB]} = \text{FSPL}(f, 1m)[\text{dB}] + 10n\log_{10}d + X
\]

LOS: 5, 18, 28, 38, 73 GHz

NLOS: 38 GHz
Path loss model: environment

\[ PL[dB] = \alpha + 10n\log_{10}d + X \]
Path loss model: measurement based
Example of PDP
Power versus angle
Estimation of path loss: possible approaches

Filter data for:
(a) Strongest received signal
(b) sum of received power from main lobe of antenna
(c) Sum of received power from all angles except main lobe
(d) Sum from all angles to synthesise omni-directional antenna
Power in the main beam
Maximum power

LOS Maximum power

Path loss dB

Distance m

- link VH
- VH n = 2.4092 y0 = 64.5681 sig = 1.6679
- link VV
- VV n = 1.5996 y0 = 50.7272 sig = 1.4719
- link HH
- HH n = 1.8966 y0 = 47.0128 sig = 1.5431
- link HV
- HV n = 2.2225 y0 = 70.1623 sig = 1.8686
Sum of power over main beam

Sum of LOS Angles

Path loss dB

Distance m

- link VH
- VH $n = 2.378$, $y_0 = 64.1946$, $\sigma = 1.5107$
- link VV
- VV $n = 1.6469$, $y_0 = 49.1776$, $\sigma = 1.4775$
- link HH
- HH $n = 1.9899$, $y_0 = 44.6071$, $\sigma = 1.6085$
- link HV
- HV $n = 2.1724$, $y_0 = 69.9414$, $\sigma = 1.8961$
Synthesised omni

![Graph showing path loss dB vs distance m for different links with equation parameters]

- Link VH: $n = 2.2945$, $y_0 = 62.6433$, $\sigma = 0.98126$
- Link VV: $n = 1.6536$, $y_0 = 48.5732$, $\sigma = 1.4473$
- Link III: $n = 1.9788$, $y_0 = 44.5266$, $\sigma = 1.5855$
- Link HV: $n = 1.8536$, $y_0 = 71.8798$, $\sigma = 1.133$
OLOS: all angles
Sum of power from all OLOS

Sum of OLOS Angles

Path loss dB

Distance m

- link VH
- VH n = 1.9458 y0 = 69.4793 sig = 0.6256
- link VV
- VV n = 1.7095 y0 = 57.3736 sig = 1.2814
- link HH
- HH n = 1.8035 y0 = 59.7891 sig = 1.3673
- link HIV
- HIV n = 1.412 y0 = 81.9617 sig = 0.8473
Standardisation:

1. SG3 and SG5 of the ITU with various correspondence groups: target end of March 2017 in preparation for WRC19

2. 3GPP

3. ETSI
Further studies

Dynamic simulations and channel measurements of moving transceivers and scatterers with variations of speed and motion direction.

Interference between fixed links. While it is presumed that directional antennas facilitate point to point link communication, the impact of Rayleigh and Mie scattering from rain and precipitation need to be addressed over multiple links.

\[ \pi \frac{D}{\lambda} \ll 1 \quad \text{Rayleigh scattering} \quad \pi \frac{D}{\lambda} > 1 \quad \text{Mie scattering} \]
Future activity for backhaul

Higher frequency band ~50-90 GHz

Multiple distributed links for interference study
Conclusions

Review of ITU Recommendations

State of the art channel sounders and measurements

Proposed path loss estimation

Review of channel models

Directions for future work