60-GHz Millimeter-Wave Pathloss Measurements in Boise Airport

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Contents

- 60 GHz channel measurement
  - Hardware setup and
  - Specifications

- Motivations
- Measurements procedure and environment
- Large-scale path loss models at 60 GHz
- Measurement results
- Conclusion and Future work
Motivations

- Why do we choose airport environment?
  - This is the very first work conducted in the airport environment.
  - Only few works are done at sub- GHz in the airport environment.
  - Many people are present, so to support this larger user base at the airports, we need to take advantage of mmWave frequency bands, e.g., the 60 GHz band.

- There are many different path loss parameters in indoor and outdoor scenarios. So we need to take more measurement on the channel measurement to characterize the channel in mmWave.
Hardware Setup for Channel Measurement (Tx Side)

M8190A AWG

E8267D PSG

N5152 A
Upconverter

57-66 GHz Horn Antenna

[1] https://www.keysight.com
Hardware Setup for Channel Measurement (Rx Side)

[1] https://www.keysight.com
## Hardware Specifications

### Table I: CHANNEL MEASUREMENTS HARDWARE SPECIFICATION AT 60 GHZ CAMPAIGN

<table>
<thead>
<tr>
<th>60 GHz campaign</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Carrier frequency</td>
<td>60 GHz</td>
</tr>
<tr>
<td>Modulation scheme</td>
<td>BPSK</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>1.3 GHz</td>
</tr>
<tr>
<td>Tx and Rx antenna gain</td>
<td>25 dB</td>
</tr>
<tr>
<td>Tx and Rx antenna 3dB beamwidth in E-plane</td>
<td>7.92°</td>
</tr>
<tr>
<td>Tx and Rx antenna 3dB beamwidth in H-plane</td>
<td>9.65°</td>
</tr>
<tr>
<td>Max. Tx power</td>
<td>-5 dBm</td>
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</tbody>
</table>
Measurement Environment

- The measurement campaigns were conducted at Boise Airport & Boise State University
  - Airport gate areas
  - Airport baggage claim areas
  - Hallway of Engineering building
  - Outdoor of the Engineering building

- Measurement procedure
  - The Tx is kept fixed, but the Rx is changed
  - Point-to-point links
  - For NLOS links, we used obstacles (poly-carbonate, steel, wood and cardboard)

Fig. 2: 60 GHz channel measurement conducted in airport gate (left) and hallway (right)
Large-scale Fading Model

Close-in reference path loss model

\[ PL(d) = PL(d_o) + 10 \, n \, \log_{10} \left( \frac{d}{d_o} \right) + \chi_\sigma \]  

\[ PL(d_o) = 20 \, \log_{10} \left( \frac{4\pi d_o}{\lambda} \right) \],  \text{here}  \, d_o = 1 \, \text{m,} \, \lambda \, \text{presents wavelength of the carrier frequency} 

\( n \) = path loss exponent  

\( \chi_\sigma \) = log-normal random variable with 0 mean and standard variation \( \sigma \)

Floating-Intercept path loss model

\[ PL(d) = \alpha + 10\beta \log_{10}(d) + \chi_\sigma \]  

\( \alpha \) = floating intercept in dB  

\( \beta \) = linear slope  

\( \chi_\sigma \) = log-normal random variable with 0 mean and standard variation \( \sigma \)

Two Approaches

- Least-square (FIM)
- Gradient-descent algorithm (GDM). We carried out this approach, because
  - One of the best optimization algorithm
  - Computationally faster
Path Loss Results

- The measurement campaign at the Boise Airport
- The path loss exponent and shadow factor are determined using three approaches: CIM, FIM (i.e. least-square) and GDM (i.e. gradient-descent)

Fig. 3: FIM, GDM and CIM along with the measurement data taken from the airport baggage (left) and gate (right) area at 60 GHz
Result and Analysis

- Measurement campaign at 60 GHz at Boise State University
- Two Indoor measurements
- One outdoor campaign measurement

Fig. 3: FIM, GDM and CIM along with the measurement data taken from the indoor of LOS link (left), outdoor of LOS link (middle) and indoor NLOS link (right) at 60 GHz
Recent Work (Path Loss Values at 60 GHz)

**Similarities**
- The free space line overshoots all the loss lines except the line of single-floor environment [2]
- The path loss values of the airport gate and baggage area are almost similar to that in the outdoor environment [1]
- The PLE of gated area scenario is close to the PLE of the single floor indoor scenario [2]

**Dissimilarities**
- The PLEs of hallway and airport baggage areas are slightly varied from the PLEs of free-space and indoor environment [2]

![Path Loss Power vs T-R Separation Distance](image)

Fig. 4: Linear plots of the path loss values from recent work at 60 GHz and 2.5 GHz in indoor (left) and outdoor (right)

Conclusion & Future Work

- Gradient-Descent approach is used, and comparable path loss parameters are found with the least-square approach.
- CIM overshoots all the data in LOS links, because this model mostly depends on the free-space path loss value at reference distance (1 m).
- CIM exhibits higher shadow factors (e.g. in few dB) than the widely used FI model.

- Multipath propagation effects can be examined in the airport environments.
- Wideband MIMO (Multiple-input Multiple-Output) channel measurements.
References


Thank You
## Result and Analysis

### Table I: PARAMETERS OF THE CLOSE-IN REFERENCE MODEL (CIM), FLOATING INTERCEPT MODEL (FIM) AND GRADIENT DESCENT FIT MODEL (GDM) FOR AIRPORT AND UNIVERSITY ENVIRONMENTS

<table>
<thead>
<tr>
<th>Environments</th>
<th>Scenarios</th>
<th>CIM</th>
<th>FIM</th>
<th>GDM</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>σ, dB</td>
<td>α, dB</td>
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<tr>
<td>Airport gate area</td>
<td>LOS</td>
<td>1.38</td>
<td>3.6</td>
<td>56</td>
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<tr>
<td>Airport baggage area</td>
<td>LOS</td>
<td>1.12</td>
<td>2.27</td>
<td>57</td>
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<tr>
<td>Indoor</td>
<td>LOS</td>
<td>1.05</td>
<td>2.75</td>
<td>53</td>
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<td>Outdoor</td>
<td>LOS</td>
<td>1.31</td>
<td>3.7</td>
<td>51.5</td>
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<tr>
<td>Indoor</td>
<td>NLOS</td>
<td>1.15</td>
<td>3.58</td>
<td>59.086</td>
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