BOISE STATE UNIVERSITY
COLLEGE OF ENGINEERING

60-GHz Millimeter-Wave Pathloss Measurements in Boise Airport

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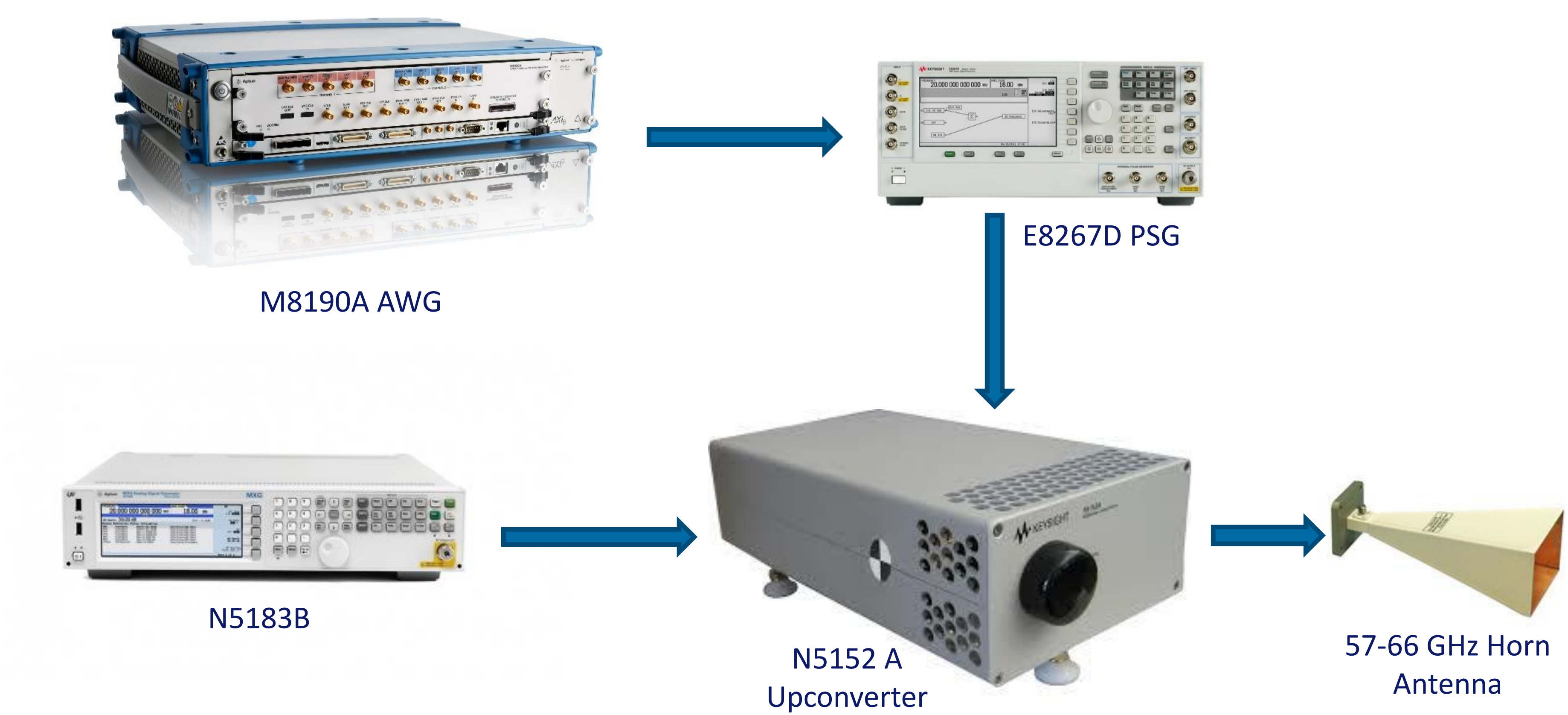
Motivations

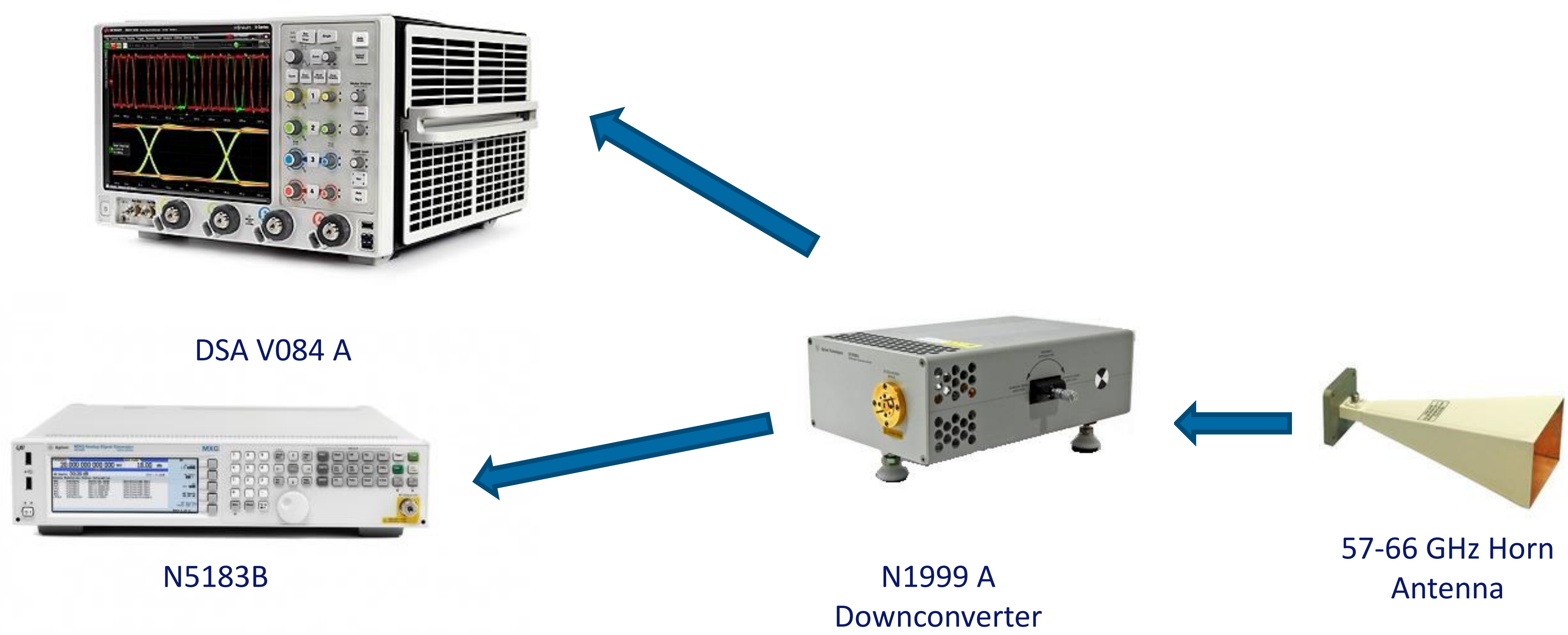
- Why do we choose airport environment ?
  - This is the very first work conducted in the airport environment.
  - Only few works are done at sub- GHz in the airport environment
  - Many people are present , so to support this larger user base at the airports, we need to take advantage of mmWave frequency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



[1] https://www.keysight.com

Hardware Setup for Channel Measurement (Rx Side)



[1] https://www.keysight.com

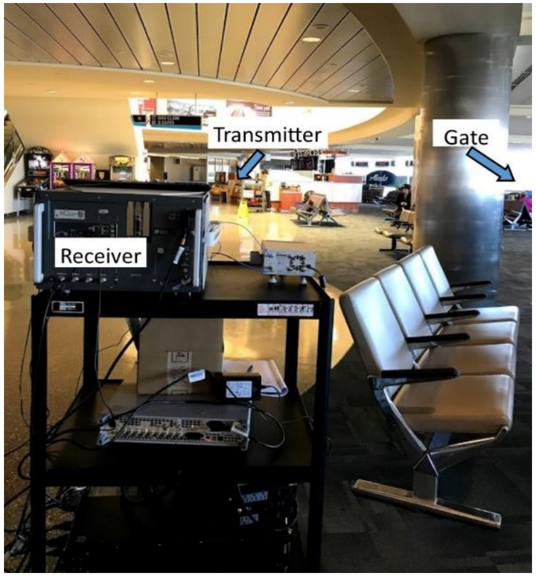
Hardware Specifications

Table I: CHANNEL MEASUREMENTS HARDWARE SPECIFICATION AT 60 GHZ CAMPAIGN

60 GHz campaign	
Carrier frequency	60 GHz
Modulation scheme	BPSK
Bandwidth	1.3 GHz
Tx and Rx antenna gain	25 dB
Tx and Rx antenna 3dB beamwidth in E-plane	7.92°
Tx and Rx antenna 3dB beamwidth in H-plane	9.65°
Max. Tx power	-5 dBm

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)



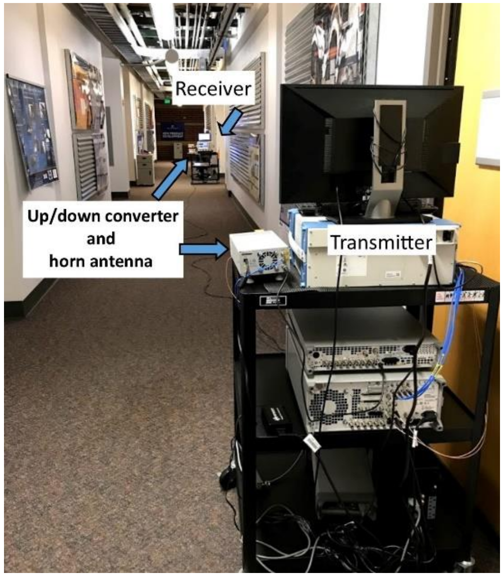


Fig. 2: 60 GHz channel measurement conducted in airport gate (left) and hallway (right)

Large-scale Fading Model

Close-in reference path loss model

$$PL(d) = PL(d_o) + 10\,n\,log_{10}\left(\frac{d}{d_o}\right) + \chi_\sigma \qquad 1$$

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

n = path loss exponent

χ_σ = log-normal random variable with 0 mean and standard variation σ

Floating- Intercept path loss model

$$PL(d) = \alpha + 10\beta log_{10}\,(d) + \chi_\sigma \qquad 2$$

α = floating intercept in dB

β = linear slope

χ_σ = log-normal random variable with 0 mean and standard variation σ

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)

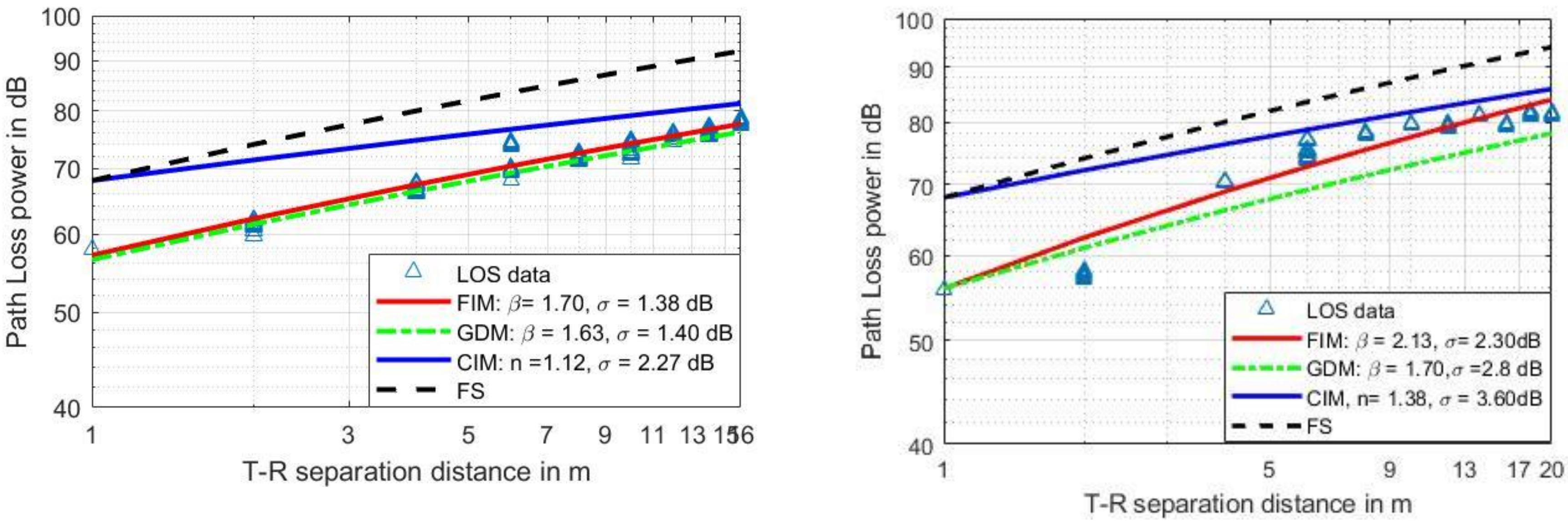


Fig. 3: FIM, GDM and CIM along with the measurement data taken from the airport baggage (left) and gate (right) area at 60 GHz

Result and Analysis

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

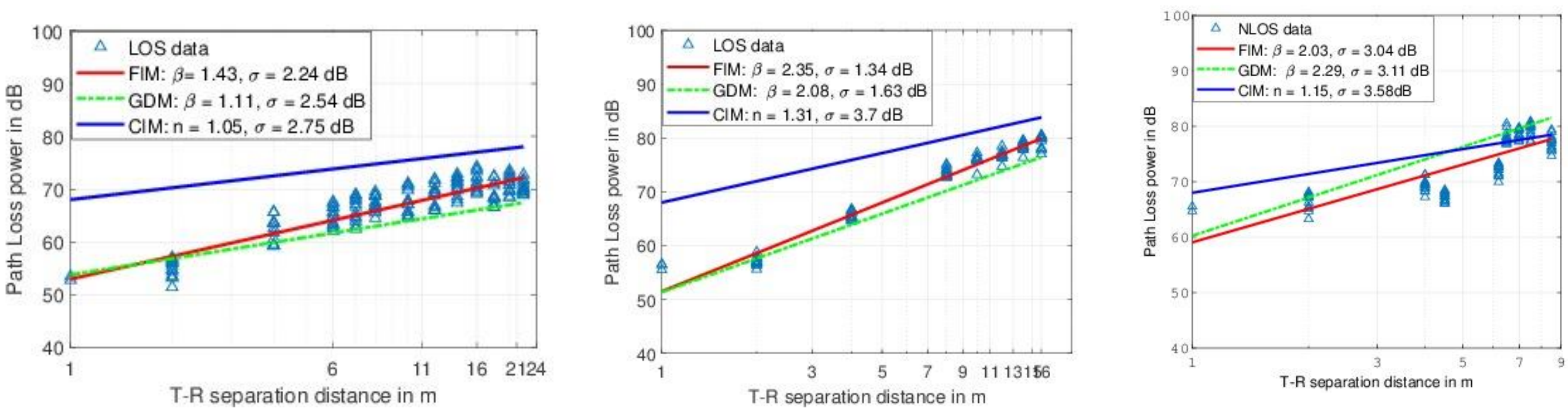


Fig. 3: FIM, GDM and CIM along with the measurement data taken from the indoor of LOS link (left), outdoor of LOS link (middle) and indoor NLOS link (right) at 60 GHz

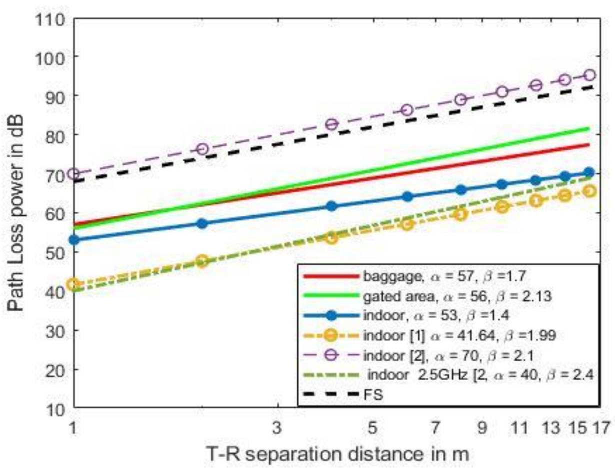
Recent Work (Path Loss Values at 60 GHz)

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]



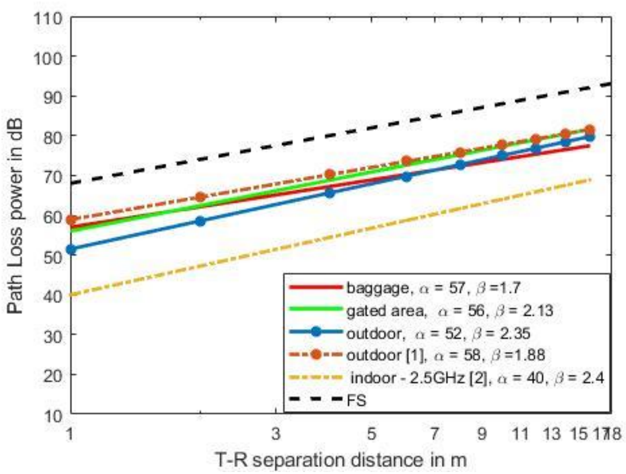


Fig. 4: Linear plots of the path loss values from recent work at 60 GHz and 2.5 GHz in indoor (left) and outdoor (right)

[1] A. I. Sulyman, A. Alwarafy, H. E. Seleem, K. Humadi, and A. Alsanie,"Path loss channel models for 5g cellular communications in riyadh city at 60 ghz," in IEEE Int. Conf on Comm., 2016, pp. 1–6.
[2] C. R. Anderson and T. S. Rappaport, "In-building wideband partition loss measurements at 2.5 and 60 ghz," IEEE Trans. Wireless Commun., vol. 3, no. 3, pp. 922–928, 2004.

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

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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

Directional Path Loss Models									
Environments	Scenarios	CIM		FIM			GDM		
		n	σ, dB	α, dB	β	σ,dB	α	β	σ,dB
Airport gate area	LOS	1.38	3.6	56	2.13	2.30	56	1.7	2.8
Airport baggage area	LOS	1.12	2.27	57	1.70	1.38	56.78	1.63	1.4
Indoor	LOS	1.05	2.75	53	1.43	2.24	53.78	1.11	2.54
Outdoor	LOS	1.31	3.7	51.5	2.35	1.34	51.37	2.08	1.63
Indoor	NLOS	1.15	3.58	59.086	2.03	3.04	60.25	2.29	3.11