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60-GHz Millimeter-Wave Pathloss Measurements in Boise Airport

Mahfuza Khatun†, Hani Mehrpouyan†, David Matolak‡

†Department of ECE, Boise State University ‡Department of Electrical Engineering, University of South Carolina email: mahfuzakhatun@u.boisestate.edu, hani.mehr@ieee.org, matolak@cec.sc.edu

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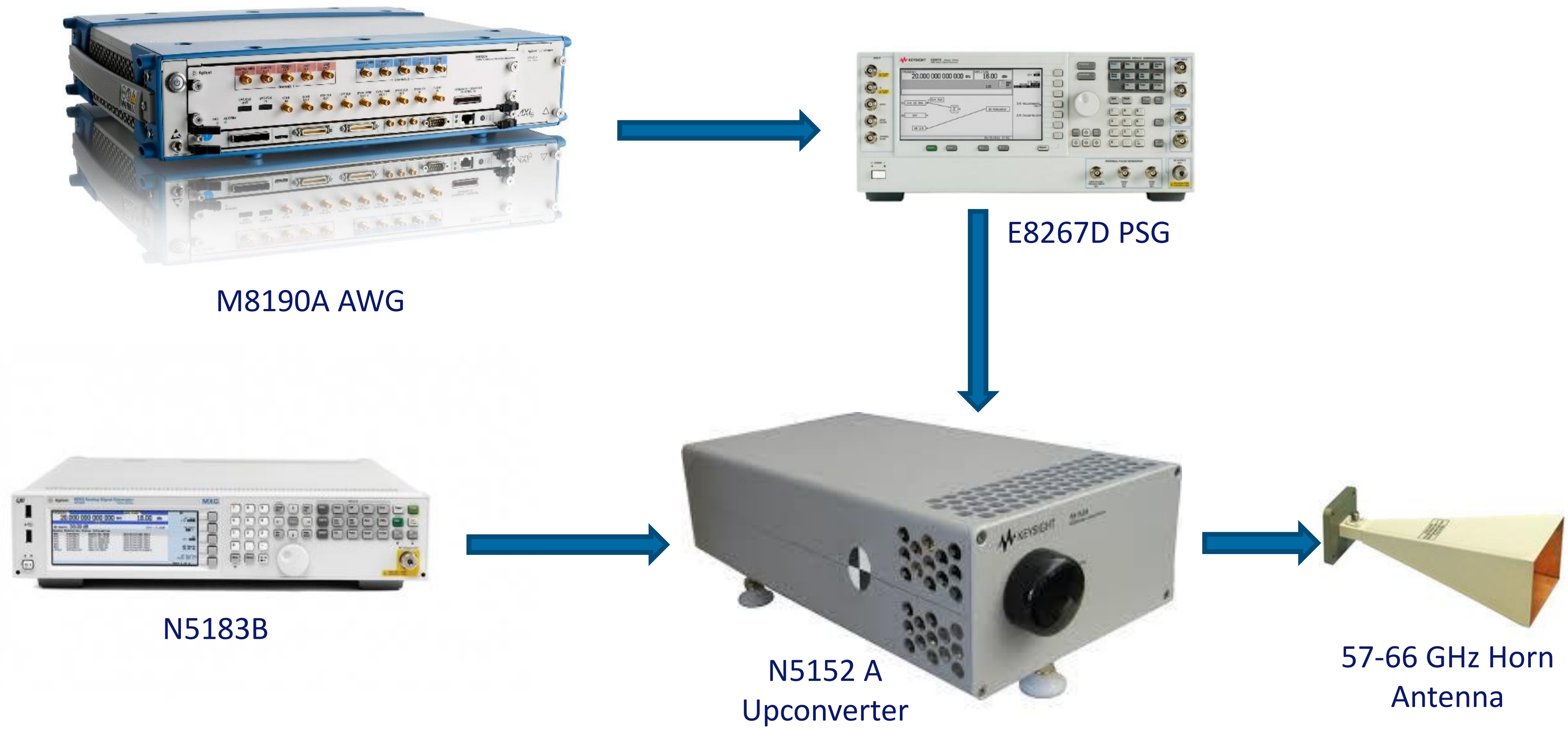
Hardware Setup for Channel Measurement (Tx Side)



Hardware Setup for Channel Measurement (Rx Side)

DSA V084 A

N5183B

N1999 A
Downconverter

57-66 GHz Horn
Antenna

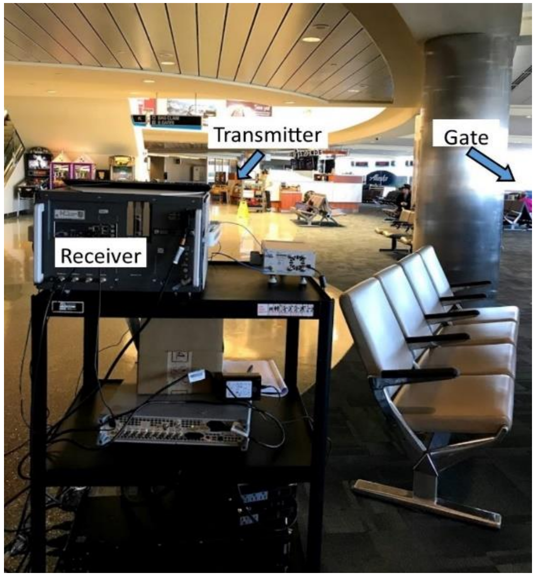
Hardware Specifications

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



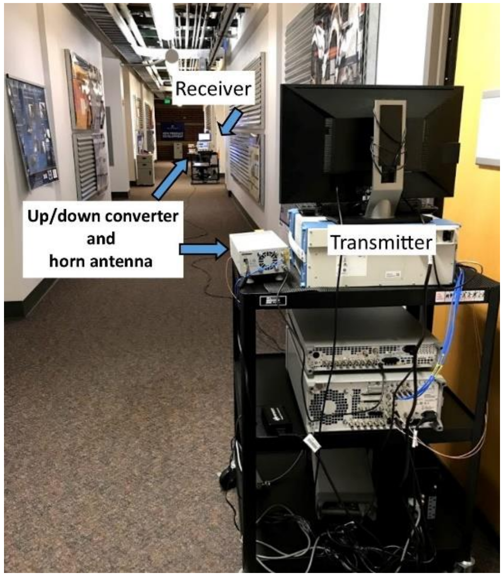


Fig. 2: 60 GHz channel measurement conducted in airport gate (left) and hallway (right)

Large-scale Fading Model

Close-in reference path loss model

$$PL(d) = PL(d_o) + 10\, n\, log_{10}\, (\frac{d}{d_o}) \;+\; \chi_\sigma$$

$PL(d_o)$ = free -space path loss in 1 m reference distance at 60 GHz
n = path loss exponent, how fast the path loss increases with the separation
χ_σ = log-normal random variable with 0 mean and standard variation σ

Floating- Intercept path loss model

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

$\alpha =$ floating intercept in dB
β = linear slope
χ_σ = log-normal random variable with 0 mean and standard variation σ

Two Approaches

- ❑ Gradient- descent fit (GDM)
- ❑ Least-square fit (FIM)

Path Loss Results

- The blue triangle represents the LOS measurement data
- The path loss exponent and shadow factor are determined using three models: CIM, FIM and GDM

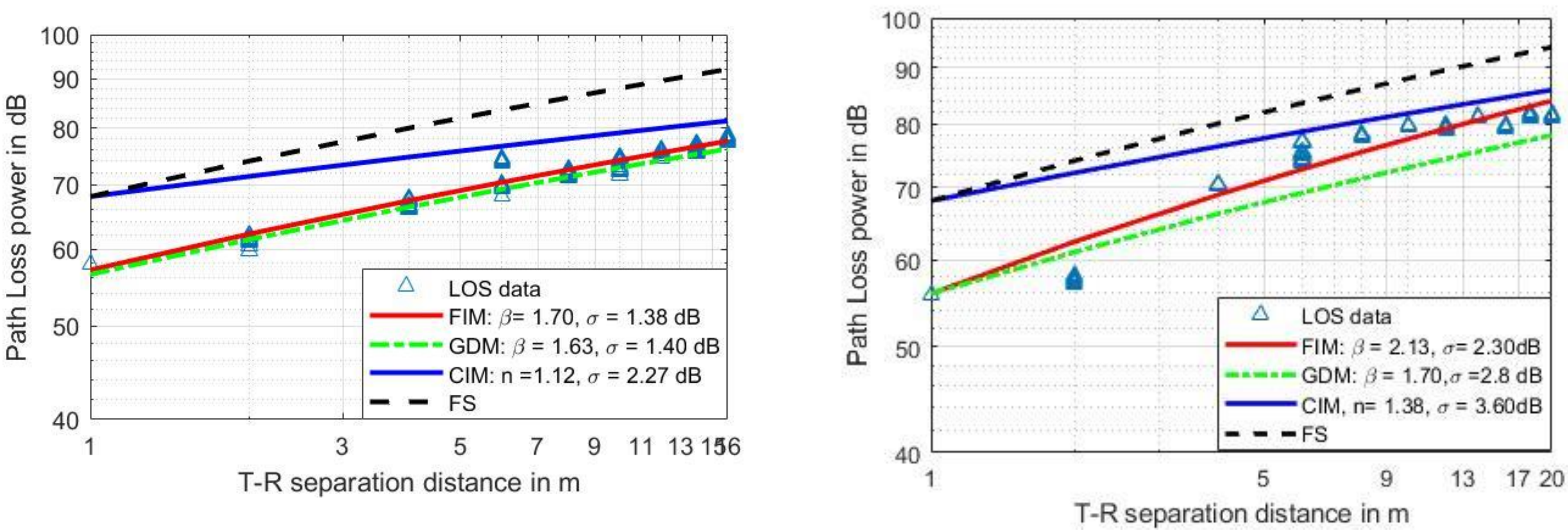


Fig. 3: FIM, GDM and CIM along with the measurement data taken from the airport baggage (left) and gate (right) area at 60 GHz

Result and Analysis

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

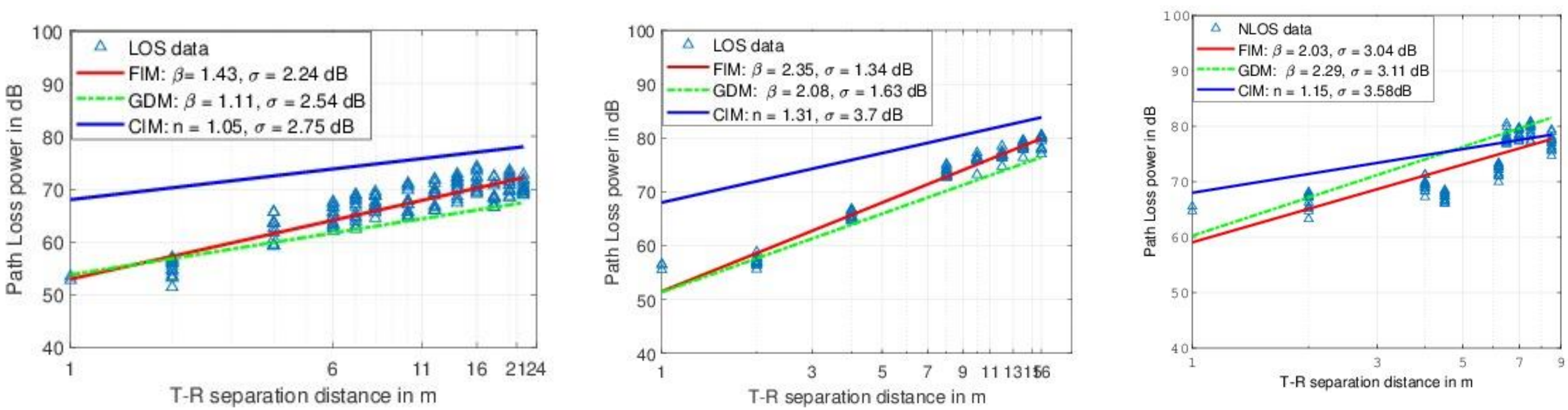


Fig. 3: FIM, GDM and CIM along with the measurement data taken from the indoor of LOS link (left), outdoor of LOS link (middle) and indoor NLOS link (right) at 60 GHz

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

Recent Work (Path Loss Values at 60 GHz)

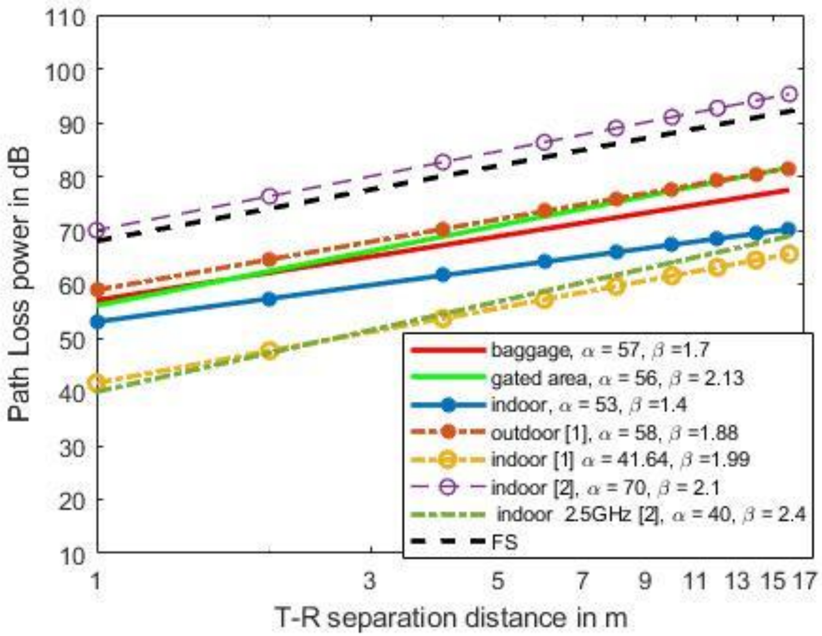


Fig. 4: Linear plots of the path loss values from recent work at 60 GHz and sub-6GHz

- Similarities
  - The free space line overshoots all the path loss lines excepting the line of indoor [2]
  - The path loss values of the airport gate and baggage area are almost similar to that in the outdoor [1]
  - The PLE of gated area scenario is close to Free-space (n=2) and indoor [2]
- Differences
  - A considerable loss is seen among the losses of indoor [2], indoor [1] and hallway (our work)
  - The PLEs of hallway and airport baggage areas are slightly varied from the PLEs of Free-space and indoor [2]

[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 regression fit is used, and comparable path loss parameters are found with the least-square fit line
- CIM overshoots all the data excepting the NLOS data, because this model mostly depends on the free- space path loss value at reference distance.

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

References

[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.

[3] S. Rangan, T. S. Rappaport, and E. Erkip, “Millimeter-wave cellular wireless networks: Potentials and challenges,” IEEE Proceed., vol. 102, no. 3, pp. 366– 385, 2014.

[4] T. S. Rappaport, R. W. Heath Jr, R. C. Daniels, and J. N. Murdock, Millimeter wave wireless communications. Pearson Education, 2014.

[5] X. Wu, C.-X. Wang, J. Sun, J. Huang, R. Feng, Y. Yang, and X. Ge, “60-ghz millimeter-wave channel measurements and modeling for indoor office environments,” IEEE Trans. Antennas Propag., vol. 65, no. 4, pp. 1912–1924, 2017.

[6] M. Khatun, H. Mehrpouyan, D. Matolak, and I. Guvenc, “Millimeter wave systems for airports and short-range aviation communications: A survey of the current channel models at mmwave frequencies,” IEEE Digital Av. Systems Conf., 2017.

[7] P. Nobles and F. Halsall, “Indoor propagation at 17 ghz and 60 ghzmeasurements and modelling,” IET National Conf. on Antennas and Propag., 1999.

[8] M. Kyro, K. Haneda, J. Simola, K. Nakai, K.-i. Takizawa, H. Hagiwara, and P. Vainikainen, “Measurement based path loss and delay spread modeling in hospital environments at 60 ghz,” IEEE Trans. Wireless Commun., vol. 10, no. 8, pp. 2423–2427, 2011.

[9] P. Pagani, I. Siaud, N. Malhouroux, and W. Li, “Adaptation of the france telecom 60 ghz channel model to the tg3c framework,” IEEE P802, vol. 15, 2006.

[10] 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.

[11] M.-W. Jung, J. Kim, and Y.-K. Yoon, “Measurements of path loss in mm-wave for indoor environments,” in IEEE Microw. Conf., 2009, pp. 1068–1071.

[12] G. R. MacCartney, M. K. Samimi, and T. S. Rappaport, “Omnidirectional path loss models in new york city at 28 ghz and 73 ghz,” in IEEE Int. Symposium. IEEE, 2014, pp. 227–231.

Thank You