Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: 154/300 GHz Dual-band Channel Measurement in a Large Conference Room
Date Submitted: May 2024
Source: Minghe Mao, Minseok Kim, Shigenobu Sasaki
Graduate School of Science and Technology, Niigata University, 8050 Ikarashi 2-no-cho, Nishi-ku, Niigata, Niigata, Japan
Voice:+81-25-262-7478, E-Mail: meika@eng.niigata-u.ac.jp, mskim@eng.niigata-u.ac.jp

Re: N/A

Abstract: In this document, an indoor dual-band channel measurement in a large conference room using an in-house developed 154 and 300 GHz channel sounder is presented. In the measurement, the wide-beam probe antennas were used at the transmitter side and the narrow-beam horn antennas were used at the receiver side to investigate the scattering processes. The multipath propagation characteristics were identified by using the angular and delay power spectra obtained from the measurement data. The results reveal that the indoor terahertz channel exhibits significant sparsity. Subsequently, the measured and modelled transmission loss are estimated with fit coefficients. Finally, r.m.s. delay spread is evaluated .

Purpose: Information document for IEEE 802.15 SC THz

154/300 GHz Dual-band Channel Measurement in a Large Conference Room

Minghe Mao, Minseok Kim, Shigenobu Sasaki
Niigata University, Japan

Motivation

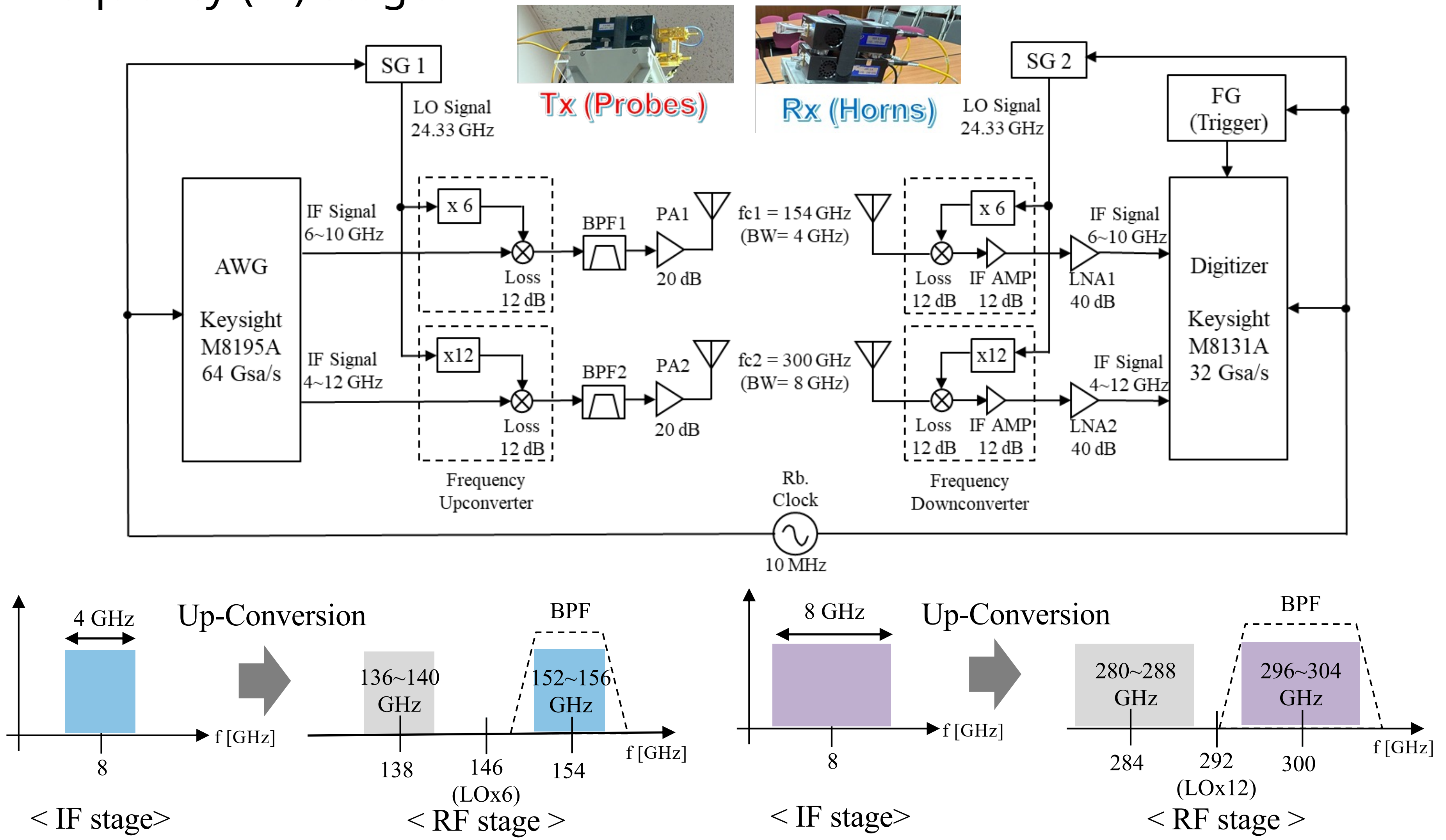
- Beyond 5G Communication requirements
  - Ubiquitous connection for a heterogenous network
  - Ultra-high data-rate: upwards of 100 Gbps
    - Tens of GHz worth bandwidth available in 0.1-10 THz
  - Ultra-reliable communication for life-critical applications
  - Low latency to support real-time application
- Our Effort
  - Channel measurement at 154/300 GHz in large conference room
  - Contribute measurement results
  - Path loss and model fitting
  - Large scale parameter estimation: r.m.s. delay spread

Outline

- 154/300-GHz Dual-Band Channel Sounder
- High resolution
    - Bandwidth: 4 and 8 GHz
    - Beamwidth: 9° at Rx, 55° at Tx
- Channel Measurement and Results
  - Large Conference Room
    - Measurement and post processing
    - Power Spectra visualization
    - Synthesized omni PL model
    - r.m.s delay spread parameters
- Summary and Future Works

Channel Sounder Architecture: Dual-Band

- Instruments-based super-heterodyne architecture and intermediate frequency (IF) stages

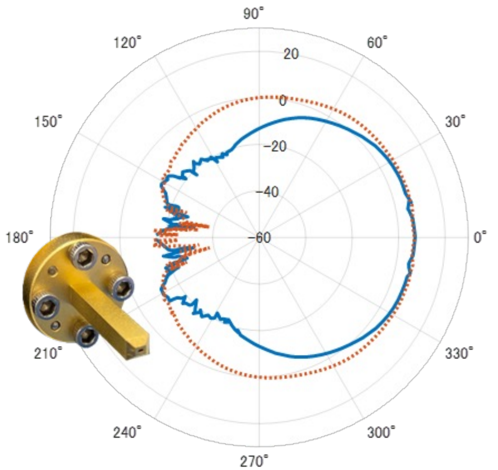


Channel sounder setup and parameters

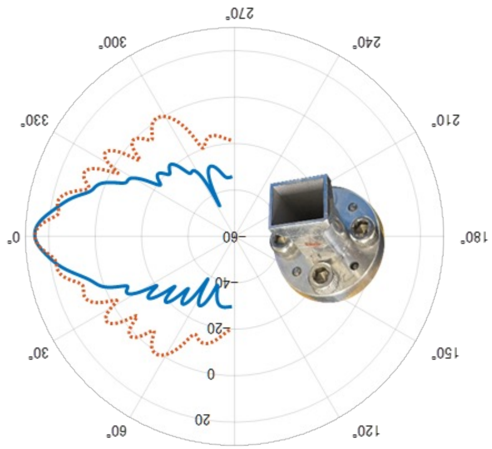
■ Channel sounder setup

Parameters	Description or Value	Parameters	Description or Value
Freq.	154/300 GHz	Delay span	160 ns
Signal BW	4/8 GHz	Dynamic range	60~80 dB
Sounding signal	NPM (N=640/1, 280)	Polarization	Vertical
Sampling rates	64 GSa/s (AWG), 32 GSa/s (Digitizer)	Tx height	2.6 m
Delay resolution	250/125 ps	Rx height	1.2 m

■ Angle sweep setup



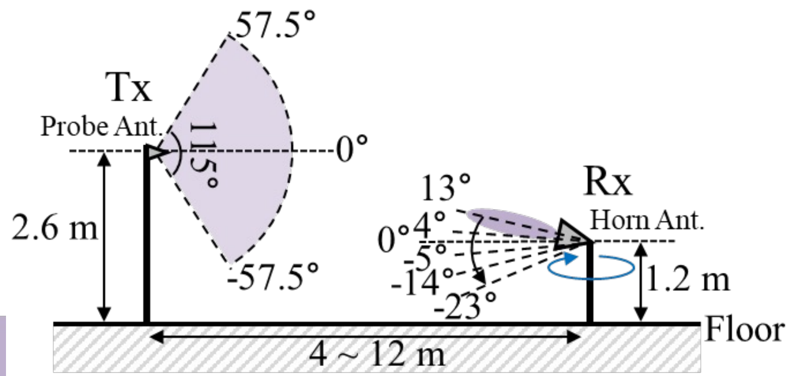
Gain: 6.5 dBi
HPBW: 55°@Az, 115°@El



Gain: 26 dBi
HPBW: 9°@Az, 8°@El

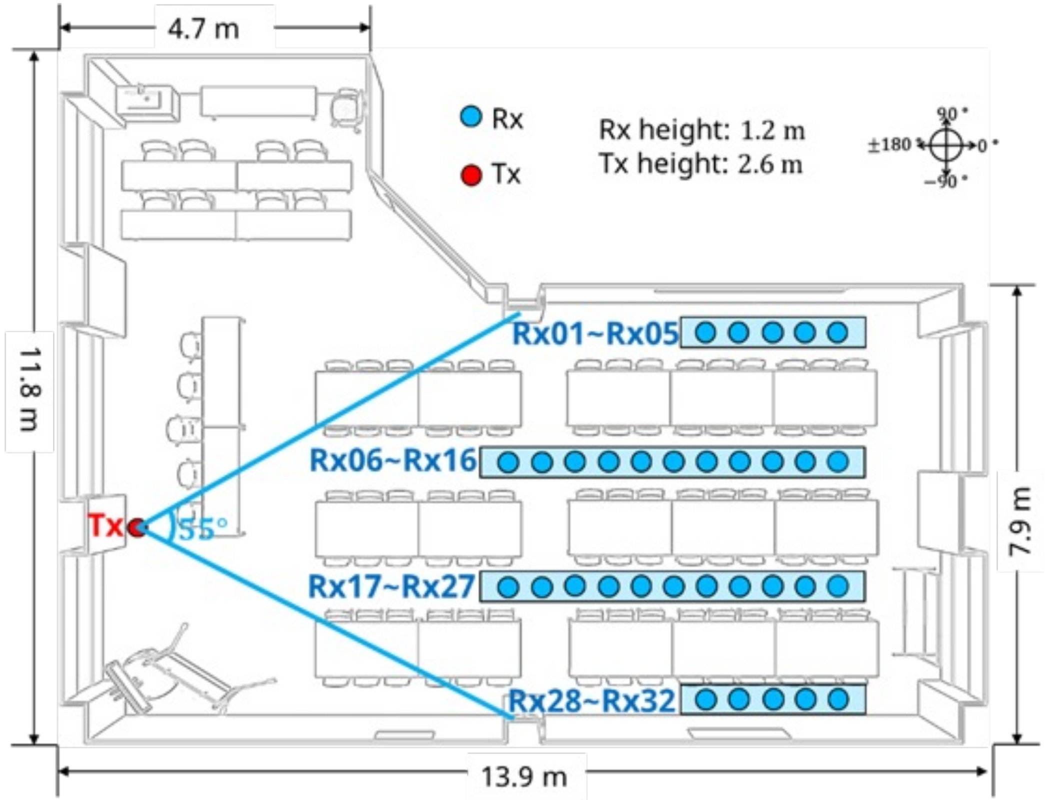
Angle sweep (Rx)

Azimuth [deg]	0:9:351 (40)
Elevation [deg]	13:-9:-23 (5)



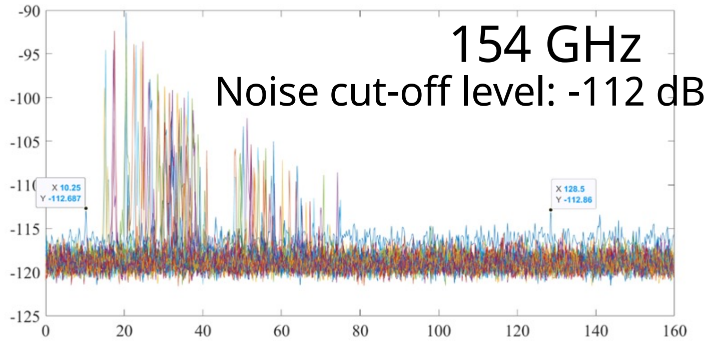
Measurement setup

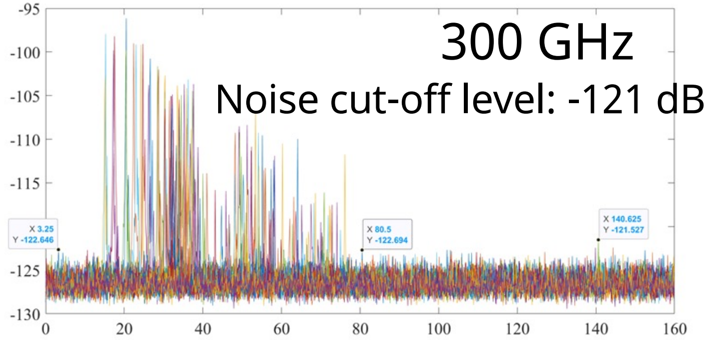
- Tx: fixed near the wall
- Rx: 32 positions (Rx-Tx separation is from 5 m to 12 m) in LoS scenario



Power Spectra

- Obtained Data
  - 3-D impulse response data : $h(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})$
- Angle Delay Power Spectrum
  - $P(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}}) = \left|h(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})\right|^2$
- Max-hold Power Delay Profile (PDP)
  - $\mathrm{PDP}(\check{\tau}) = \max_{n_{\theta_{\mathrm{R}}}, n_{\phi_{\mathrm{R}}}} P(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})$
- Noise reduction (noise threshold: P_{Nth})
  - $P'(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})[\mathrm{dB}] = 10\log_{10}\left(P(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}}) - P_{\mathrm{Nth}}\right)$
- Azimuth Delay Power Spectrum (ADPS)
  - Rx : $\mathrm{ADPS}_{\mathrm{R}}(\check{\tau}, \check{\phi}_{\mathrm{R}}) = \sum_{n_{\theta_{\mathrm{R}}}} P'(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})$
- Omnidirectional Power Delay Profile (Omni PDP)
  - $\mathrm{PDP}(\check{\tau}) = \sum_{n_{\theta_{\mathrm{R}}}, n_{\phi_{\mathrm{R}}}} P'(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})$

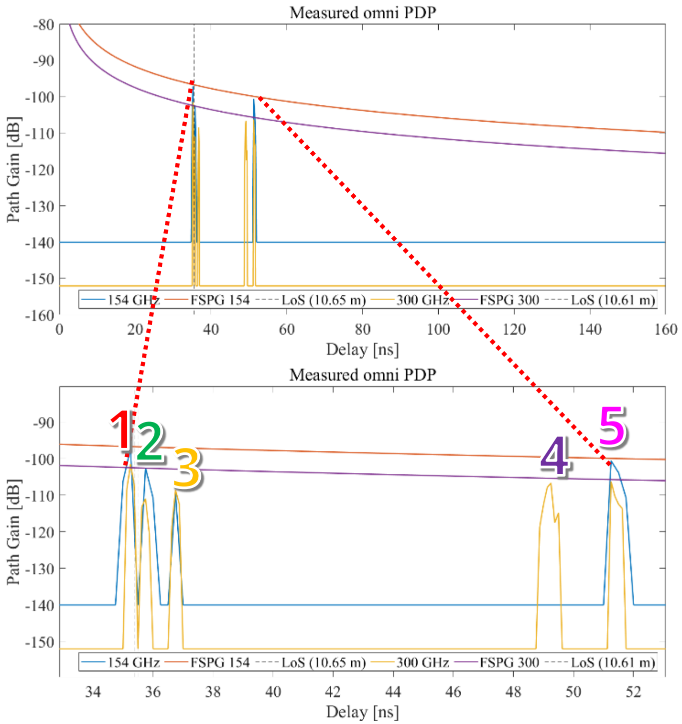




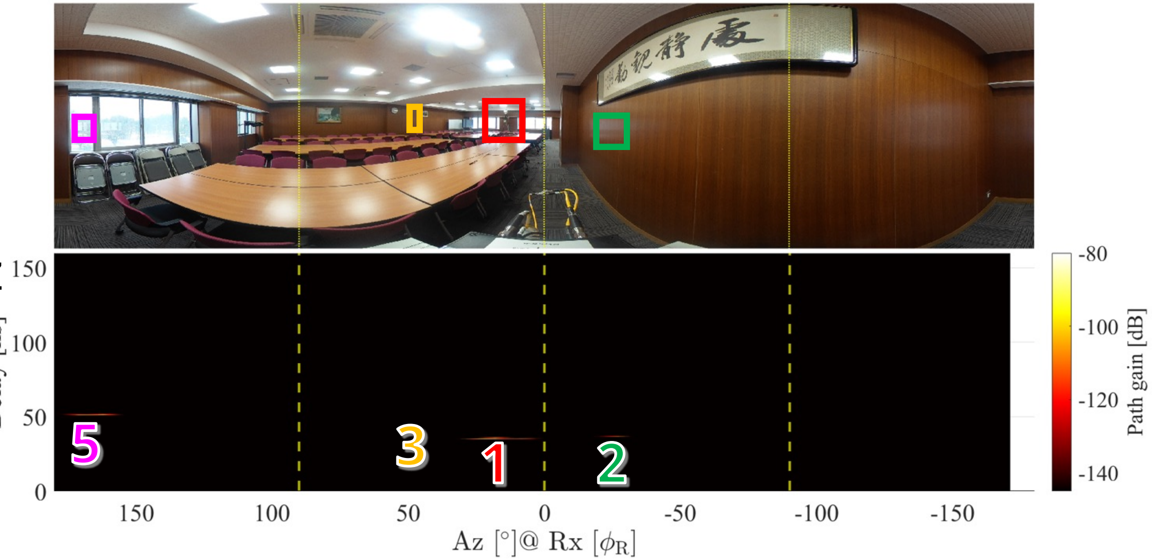
$\check{\tau}$	: delay bin
$\check{\theta}_{\mathrm{R}}$	: Elevation pointing angle of Arrival
$\check{\phi}_{\mathrm{R}}$	: Azimuth pointing angle of Arrival

PDP and ADPS

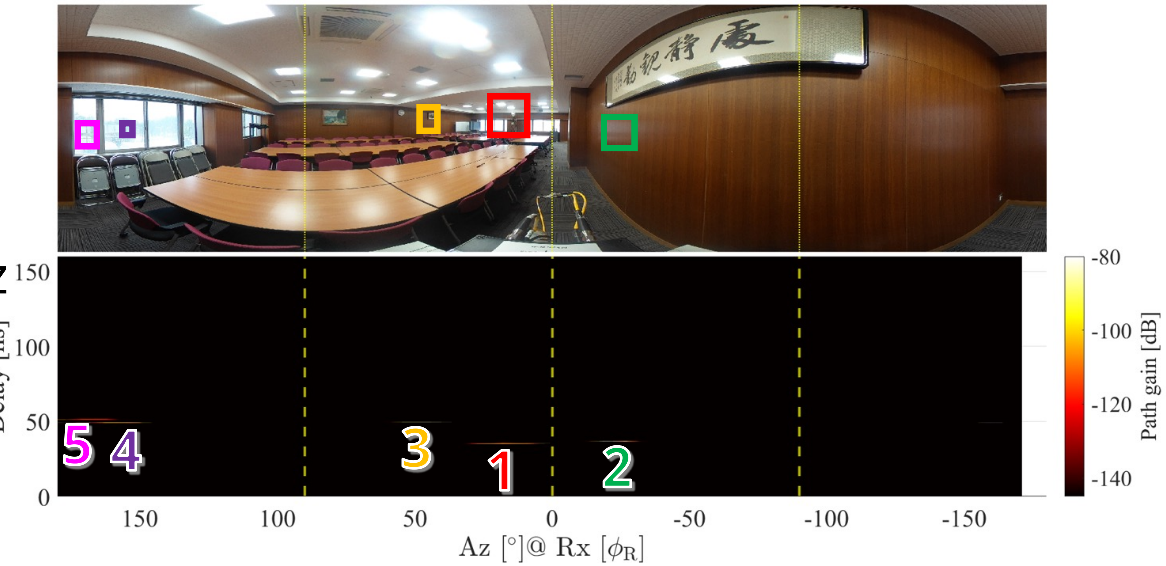
- The dominant reflectors
  - Window glass
  - Wooden wall



154 GHz



300 GHz



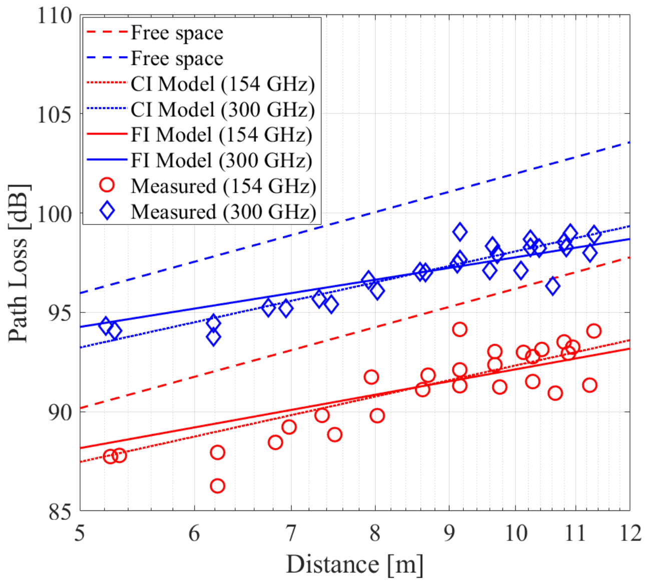
Omni path loss and site-general/specific models

- Omni path loss for 3-D data set
  - $\mathrm{PL_{omni}}\ [\mathrm{dB}] = -10\log_{10}\left(\sum_{n_{\theta_{\mathrm{R}}}, n_{\phi_{\mathrm{R}}}} P'(\check{\tau}, \check{\theta}_{\mathrm{R}}, \check{\phi}_{\mathrm{R}})\right)$
  - $P'(\cdot)$ is the noise-filtered power spectrum
- Path Loss Models:
  - Close-in free space (CI)
    - $L_{\mathrm{CI}}(d)\ [\mathrm{dB}] = 10n\log_{10}(d) + 20\log_{10}\left(\frac{4\pi f_{\mathrm{GHz}} \times 10^9}{c}\right)$
  - Floating-intercept (FI)
    - $L_{\mathrm{AB}}(d)\ [\mathrm{dB}] = 10\alpha\log_{10}(d) + \beta$
  - The median basic transmission loss: site-general model (ABG) [1]
    - $L_b(d, f) = 10\alpha\log_{10}(d) + \beta + 10\gamma\log_{10}(f) \quad [\mathrm{dB}]$
    - with an additive zero mean Gaussian random variable $N(0, \sigma)$ with a standard deviation σ.

[1] ITU-R, “Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 450 GHz,” ITU-R P.1238-12, Tech. Rep., Aug. 2023.

Path Loss Model Fitting (154/300 GHz)

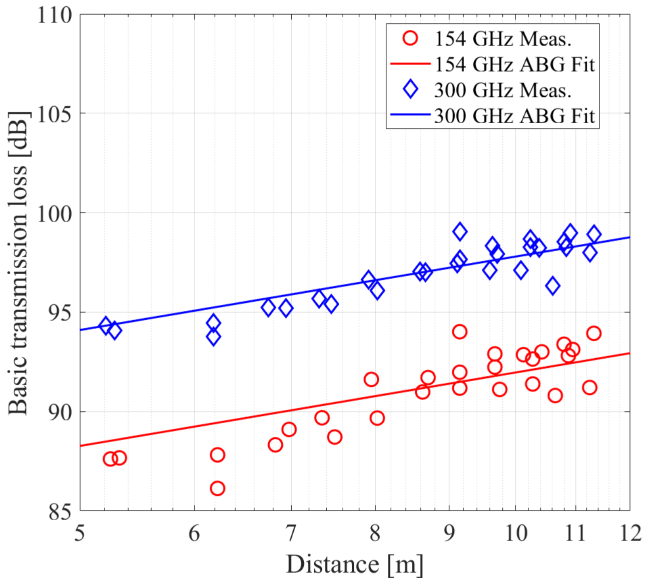
- CI, FI



parameters		154 GHz	300 GHz
CI	n	1.60	1.61
	σ	1.44	0.99
FI	α	1.32	1.16
	β	78.82	86.12
	σ	1.41	0.84

FI has a better fit for 154/300 GHz

- ABG



Freq. (GHz)	Distance range (m)	α	β	γ	σ
154, 300	5.0-12.0	1.23	35.65	2.01	1.15

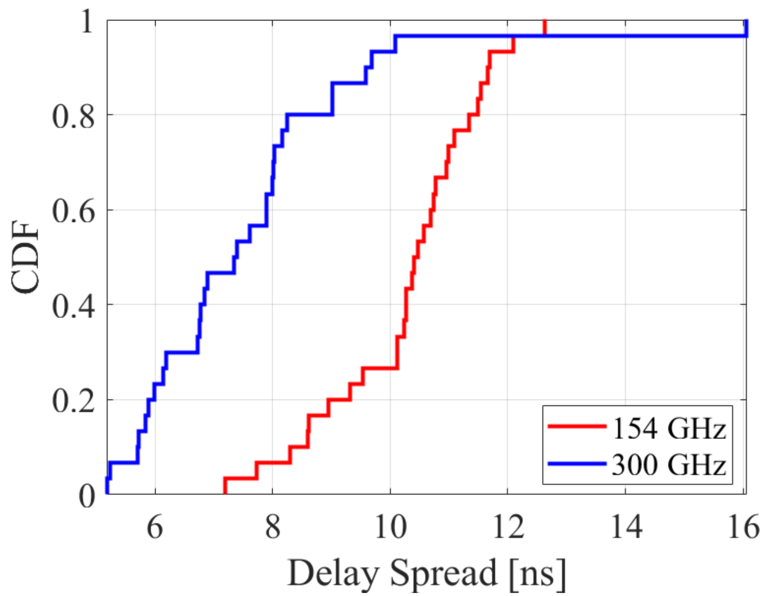
300 GHz is about two times of 154 GHz which results in the value of γ : 2.01

r.m.s. Delay Spread

■ Root Mean Square Delay Spread (r.m.s. DS) [#]

$$\mathrm{DS_{RMS}} = \sqrt{\frac{\sum_{n_\tau} \check{\tau}^2 \mathrm{PDP}(\check{\tau})}{\sum_{n_\tau} \mathrm{PDP}(\check{\tau})} - \left(\frac{\sum_{n_\tau} \check{\tau}\mathrm{PDP}(\check{\tau})}{\sum_{n_\tau} \mathrm{PDP}(\check{\tau})}\right)^2}$$

The 154 GHz band is estimated with larger delay spread compared with 300 GHz band



Measurement conditions				r.m.s delay spread (ns)		
Freq. (GHz)	Environment	Polarization	Time delay resolution (ns)	10%	50%	90%
154	Conference Room	VV	0.25	8.29	10.40	11.67
300			0.125	5.70	7.34	9.59

[#] ITU – R Recommendation P.1407.

Summary

- Sparse nature of the synthesized PDP eased the identification of specular phenomenon at both the bands in conference room.
- The influence of wooden wall surface and glass windows reflected waves is large.
- Comparing with 154 GHz, the 300 GHz band has more component power when the distance getting larger and is with smaller PLE and less shadowing.
- The 154 GHz band with a double duration of time delay resolution has larger delay spread compared with the 300 GHz band.
- Future works
  - Further extensive campaigns in more scenarios with more number of measurement points for LSP evaluation.
  - Double directional measurements will be conducted using horn-to-horn antennas.

Thank You

http://radio.eng.niigata-u.ac.jp/

mskim@eng.niigata-u.ac.jp

+81 – 025 – 262 – 7478

This work includes the research results conducted under the National Institute of Information and Communications Technology (NICT) Beyond 5G R&D Promotion Program (Grant No. 02701).