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Abstract: [This contribution describes LOS residential channel model based on TSV model.]

Purpose: [Contribution to mmW TG3c meeting.]

LOS residential channel-model based on TSV model

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Agenda

- Background
- Measurement procedure and results
- Extracted TSV model parameters

Background

- Channel model for LOS residential environment was released. However the parameter for only omni antenna is available

Purpose

- Re-analyzing LOS residential data (provided by NICT) based on TSV model, and extracting the parameters for all directional antennas

Measurement conditions (06/012)

Instrument	HP8510C VNA
Center frequency	62.5 GHz
Bandwidth	3 GHz
Time resolution	0.333 ns
Distance resolution	19.1 cm
# of frequency points	401
Frequency step	7.5MHz
Times of average	128 times

Time resolution and distance resolution were determined by bandwidth

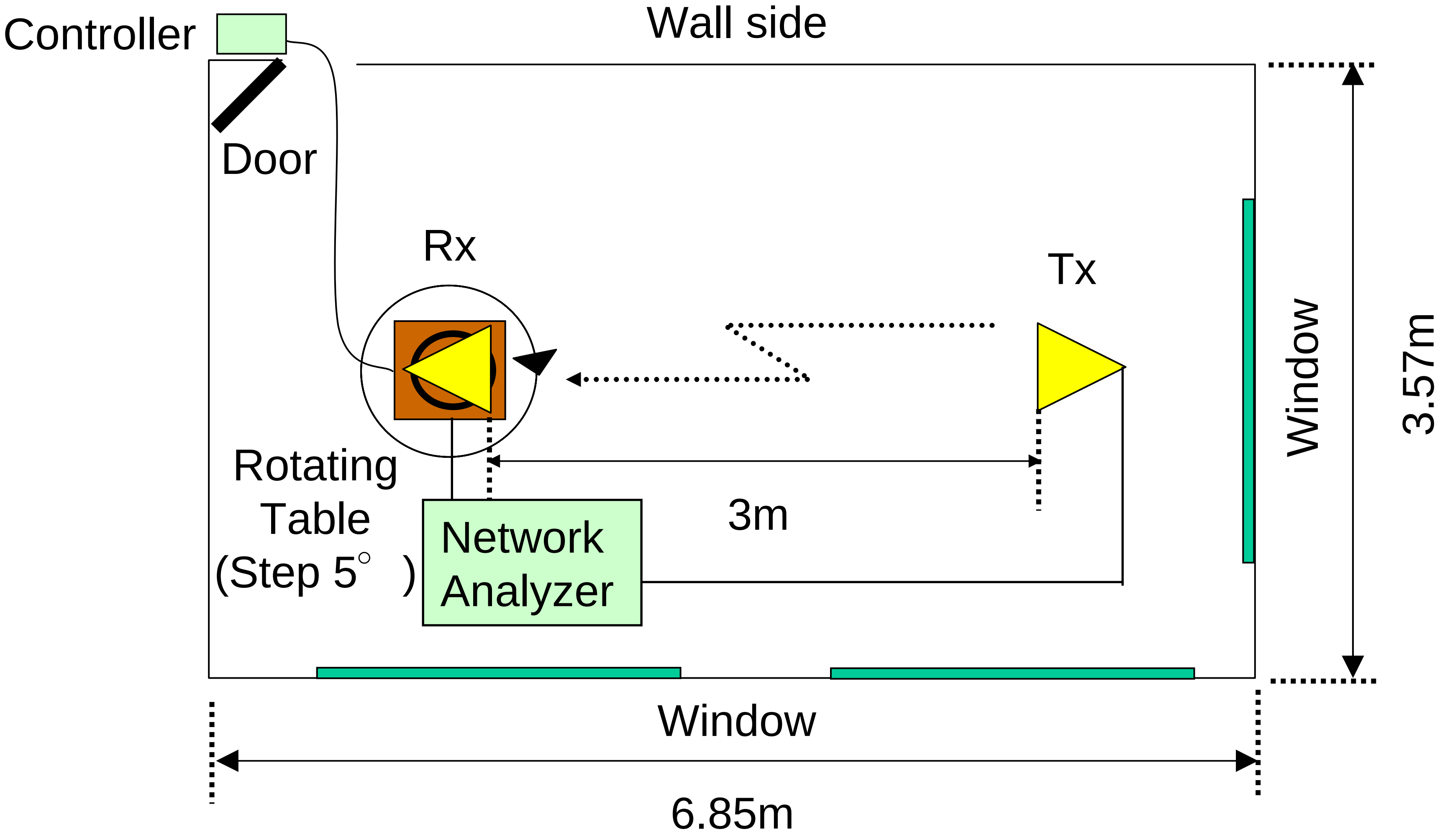
Measurement conditions (cont')

- Pyramidal horn antennas
- Omni directional antenna
- Calibration performed with 1m reference separation

Omni directional

Pyramidal horn

Measurement environment

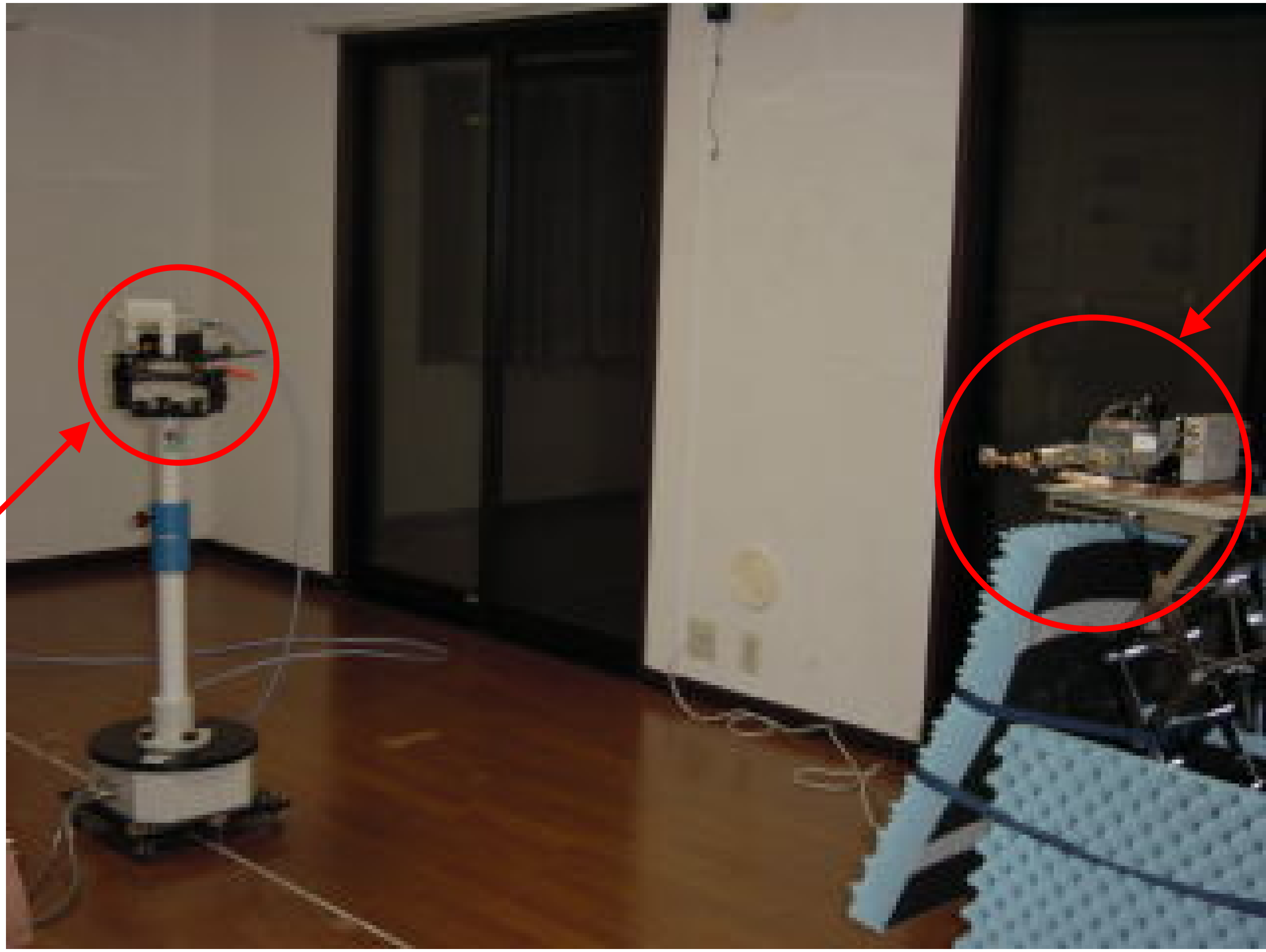


Floor plan of home environment

Measurement environment (cont’)

Tx side

Rx side



Antenna height : 1.1m

TSV model for LOS residential environment

- For LOS desktop environment (06/297)

TSV model = Statistical two-path component + S-V components

$$h(t) = \beta\,\delta(t) + \sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\alpha_{l,m}\,\delta(t - T_l - \tau_{l,m})\,\delta(\varphi - \Psi_l - \psi_{l,m})$$

$$\beta = \sqrt{PL}\left(\frac{\mu_D}{D}\right)^2\left|\sqrt{G_{t1}G_{r1}} + \sqrt{G_{t2}G_{r2}}\Gamma_0 \exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D}\right]\right|$$

Statistical factors in both two-path and S-V

PL: Path loss

- For LOS residential environment

Reflection coefficient: $\Gamma_0 \fallingdotseq 0$

Modified TSV model = Direct-path component + S-V components

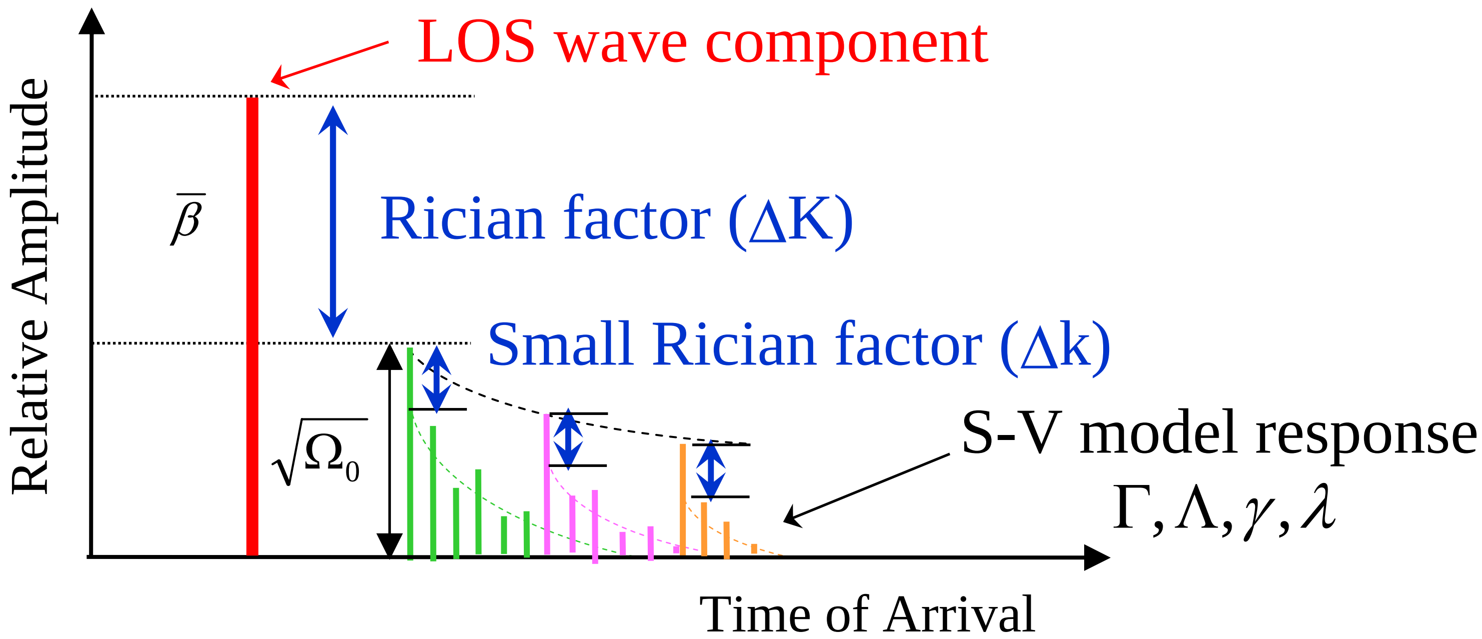
$$h(t) = \beta\,\delta(t) + \sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\alpha_{l,m}\,\delta(t - T_l - \tau_{l,m})\,\delta(\varphi - \Psi_l - \psi_{l,m})$$

$$\beta\big|_{\mu_D \ll D} = \sqrt{PL\,G_{t1}G_{r1}}$$

Statistical factors in only S-V

Refer to Appendix A for each parameter

Impulse response



By setting $\Gamma_0 = 0$, TSV model can generate impulse response for LOS residential channel without any modification

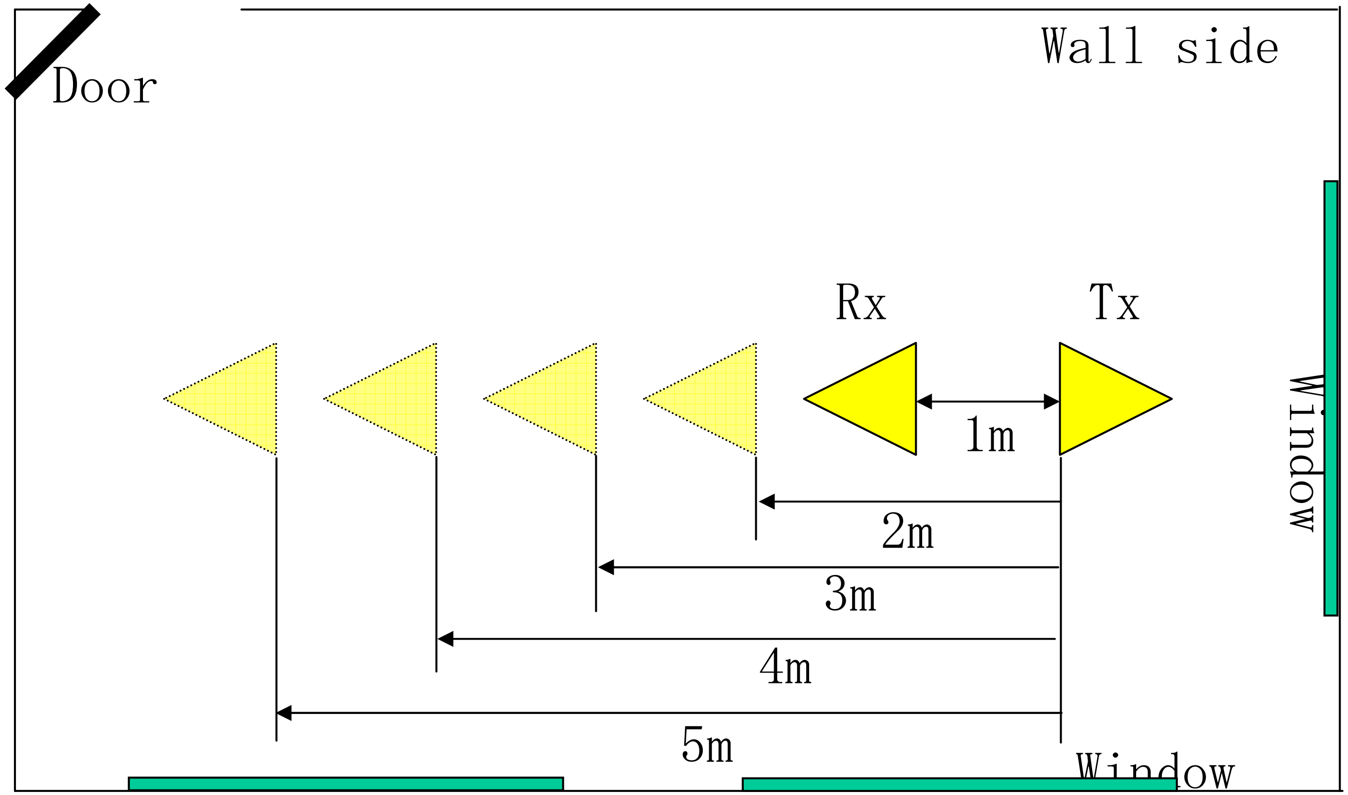
Extracted TSV model parameters

	TSV Model	Small Rician effect	S-V model oriented parameter							Number of cluster
Parameter	Ω_0(D)@3m [dB]	k (Δk)	Γ [ns]	1/Λ [ns]	γ [ns]	1/λ [ns]	σ_1 cluster	σ_2 ray	σ_ϕ [deg]	N
Tx:360 Rx:15	-88.7	4.34 (18.8 dB)	4.46	5.24	6.25	0.820	6.28	13.0	49.8	9
Tx:60 Rx:15	-108	4.00 (17.4 dB)	8.98	5.15	9.17	1.11	6.63	9.83	119	11
Tx:30 Rx:15	-111	2.73 (11.9 dB)	21.5	6.94	4.35	0.856	3.71	7.31	46.2	8
Tx:15 Rx:15	-110.7	1.06 (4.60 dB)	12.6	22.2	4.98	1.08	7.34	6.11	107	4

Channel model for LOS residential environment was reanalyzed

Refer to Appendix B for each parameter

Measurement of Path loss in LOS residential environment



- No rotational measurement, only path loss in LOS direct component was measured

Path loss of LOS component in residential environment

$$\text{Path loss}\,[\text{dB}] = PL_0 + 10n\log_{10}(\mu_D / D_0)$$

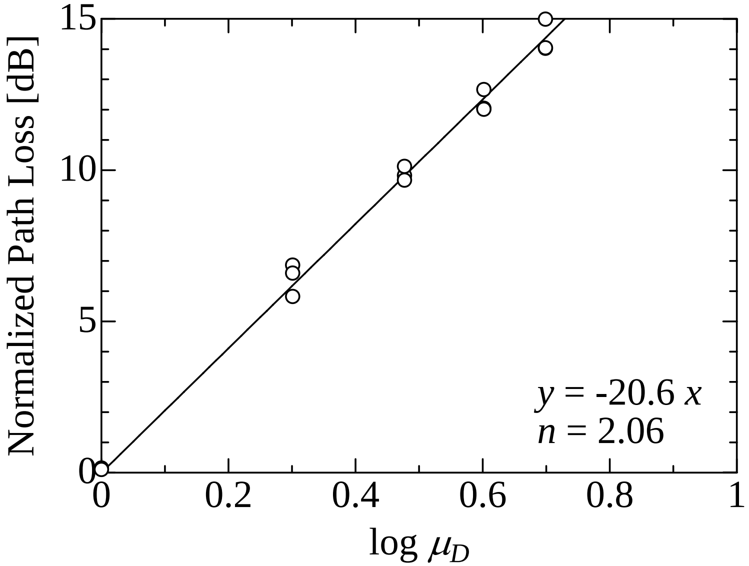


Fig. Path Loss result

- Path loss at D_0=1m distance

$$PL_0[\text{dB}] = 20\log_{10}\left(\frac{4\pi D_0}{\lambda}\right) \approx 68.4$$

$$\lambda \approx 4.8\text{mm}\;(f = 62.5\,\text{GHz})$$

- Path loss exponent

$$n = 2.06$$

- Path loss of LOS component follows free space loss

Summary of available LOS / NLOS channel models

	LOS	NLOS
Office	Available (NICT)	Available (NICTA)
Residential	Available (NICT)	N/A
Desktop	Available (NICT)	N/A
Library	Available (IMST/Intel)	N/A

These parts are now available based on TSV-model

Summary

- The parameters for LOS residential channel model was re-reanalyzed based on TSV-model
- Path loss for LOS residential environment was clarified
- Channel model and Path loss model for LOS residential environment is now available
- Channel models for LOS environments (residential, office, desktop) based on TSV model are now available

Appendix A: Definition of TSV model (modified)

CIR: $$h(t)=\beta\,\delta(t)+\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\alpha_{l,m}\,\delta(t-T_l-\tau_{l,m})\,\delta(\varphi-\Psi_l-\psi_{l,m})$$

(Complex impulse response)

$$\overline{\left|\alpha_{l,m}\right|^2}=\Omega_0 e^{-T_l/\Gamma}e^{-\tau_{l,m}/\gamma-k[1-\delta(m)]}\sqrt{G_r(0,\Psi_l+\psi_{l,m})},\ \angle\alpha_{l,m}\propto \text{Uniform}[0,2\pi)$$

PL: Path loss of the first impulse response
t: time[ns]
δ(•): Delta function
l = cluster number,
m = ray number in l-th cluster,
L = total number of clusters;
M_l = total number of rays in the l-th cluster;
T_l = arrival time of the first ray of the l-th cluster;
$\tau_{l,m}$ = delay of the m-th ray within the l-th cluster relative to the firs path arrival time, T_l;
Ω_0 = Average power of the first ray of the first cluster
$\Psi_l \propto$ Uniform[0,2π); arrival angle of the first ray within the l-th cluster
$\psi_{l,m}$ = arrival angle of the m-th ray within the l-th cluster relative to the first path arrival angle, Ψ_l

Two-path response

$$\beta=\sqrt{PL\left(\frac{\mu_D}{D}\right)^2}\left|\sqrt{G_{t1}G_{r1}}+\sqrt{G_{t2}G_{r2}}\Gamma_0\exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{D}\right]\right|$$

Path number of G_{ti} and G_{ri} (1 : direct, 2 : refrect)

Arrival rate: Poisson process

$$p(T_l \mid T_{l-1})=\Lambda\exp[-\Lambda(T_l-T_{l-1})],\quad l>0$$
$$p(\tau_l \mid \tau_{l,(m-1)})=\lambda\exp[-\lambda(\tau_l-\tau_{l,(m-1)})],\quad m>0$$

Two-path parameters (4)

$D \propto$ Uniform : Distance between Tx and Rx
$h_1 \propto$ Uniform : Height of Tx
$h_2 \propto$ Uniform : Height of Rx
$\mu_D \propto$ Average of distance between Tx and Rx
$|\Gamma_0|$: Reflection coefficient
$|\Gamma_0| \cong 1$: LOS Desktop environment (incident angle $\cong \pi/2$)
$|\Gamma_0| \cong 0$: Other LOS environment

S-V parameters (7)

Γ : *cluster* decay factor
$1/\Lambda$: *cluster* arrival rate
γ : *ray* decay factor
$1/\lambda$: *ray* arrival rate
σ_1 : *cluster* lognormal standard deviation
σ_2 : *ray* lognormal standard deviation
σ_ϕ : Angle spread of ray within cluster (Laplace distribution)

Antenna parameters (2)

$Gt(\theta,\phi)$: Antenna gain of Tx
$Gr(\theta,\iota)$: Antenna gain of Rx

Rician factor (2)

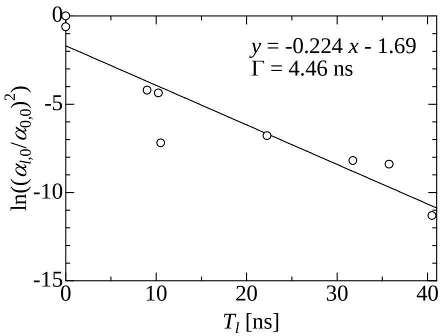
k : Small Rician effect in each cluster

$$K=\frac{\beta^2}{\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\left|\alpha_{l,m}^2\right|\delta(t-T_l-\tau_{l,m})\delta(\varphi-\Psi_l-\psi_{l,m})G_r(0,\Psi_l+\psi_{l,m})}$$

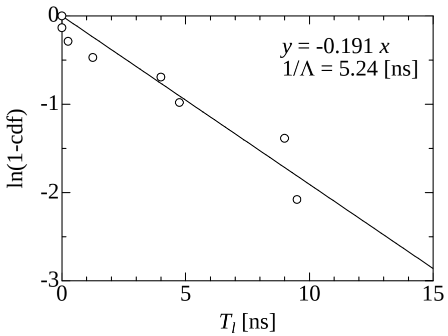
Appendix B: Results of data analysis

Antenna beamwidth

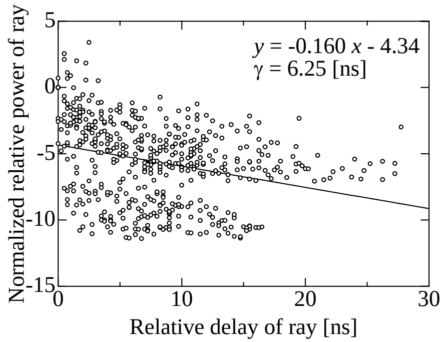
Tx: 360 deg, Rx: 15 deg



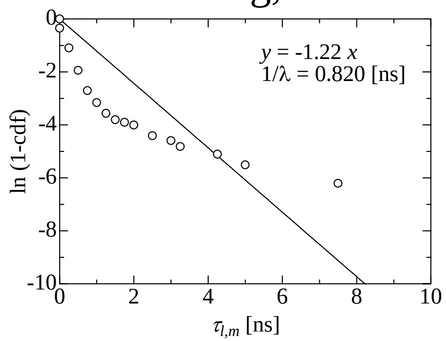
Cluster decay factor (Γ)



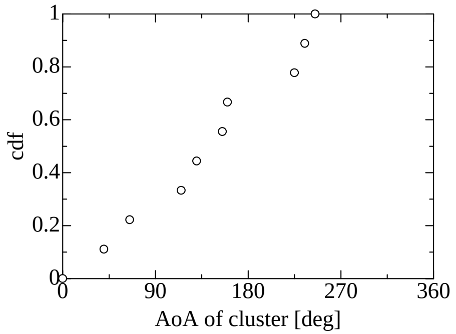
Cluster arrival rate ($1/\Lambda$)



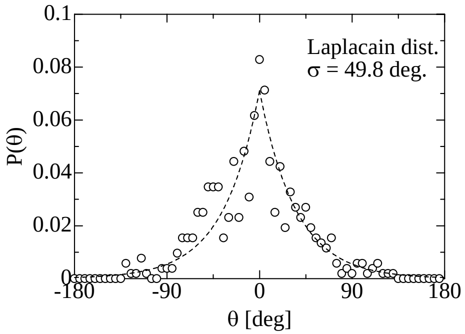
Ray decay factor (γ)



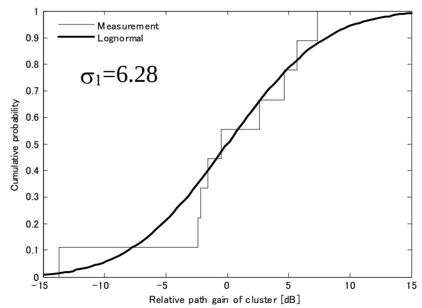
Ray arrival rate ($1/\lambda$)



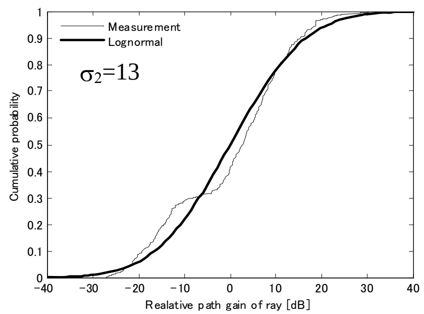
Angle of arrival in cluster ($\propto$Uniform)



Angle spread of ray (σ_ϕ)



Standard deviation of cluster (σ_1)



Standard deviation of ray (σ_2)