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

Purpose: [Contribution to mmW TG3c meeting.]

LOS office channel model based on TSV model

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Agenda

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

Background & Purpose

- Not available LOS office channel model in TG3c
- Measurement and analysis for LOS office channel are performed

Measurement conditions

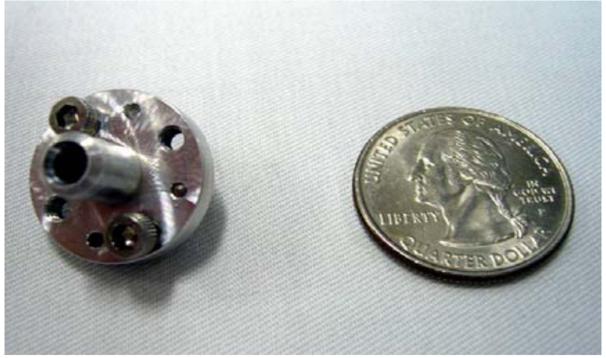
Instrument	HP8510C VNA
Center frequency	62.5 GHz
Bandwidth	3 GHz
Time resolution	0.333 ns
Distance resolution	19.1 cm
# of frequency points	801
Frequency step	3.75MHz
Times of average	128 times

Time resolution and distance resolution were determined by bandwidth

Measurement conditions (cont')

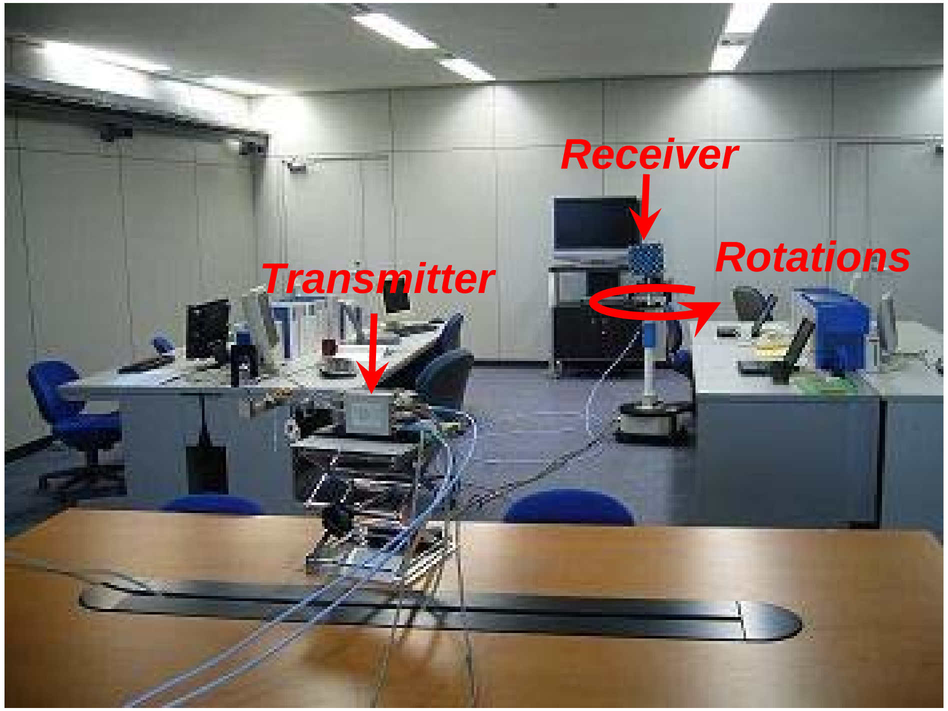
- **Antenna:** Conical horn antenna
- **Polarization:** Vertical
- **Beam-width:** Tx:30 and Rx 30, Tx:60 and Rx60

Conical horn antenna
Beam-width 30 deg



Conical horn antenna
Beam-width 60 deg

Measurement environment



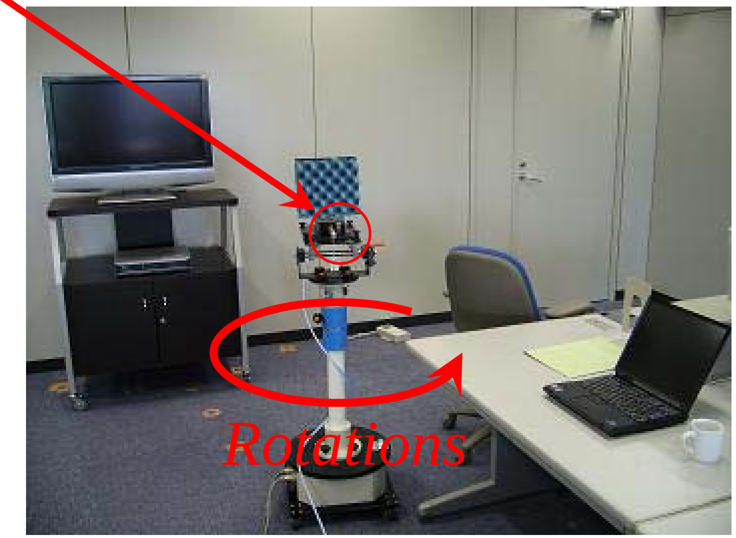
- Office room: 7.0 m × 11.9 m
- Ceiling height: 2.7 m
- Surrounding: Metallic wall, glass window
- Floor: Concrete plates covered with carpet
- Furniture: Metal desk, chair, computer, LCD TV, books

Receiver was rotated from 0 to 360 with 5 degree step

Measurement environment(cont')

Antenna

Tx side



Rx side

- Receiver was not put on the desk due to large rotator size
- Calibration was done at 1 m distance

TSV model for LOS office 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 office environment

Reflection coefficient: $\Gamma_0 \fallingdotseq 0$

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

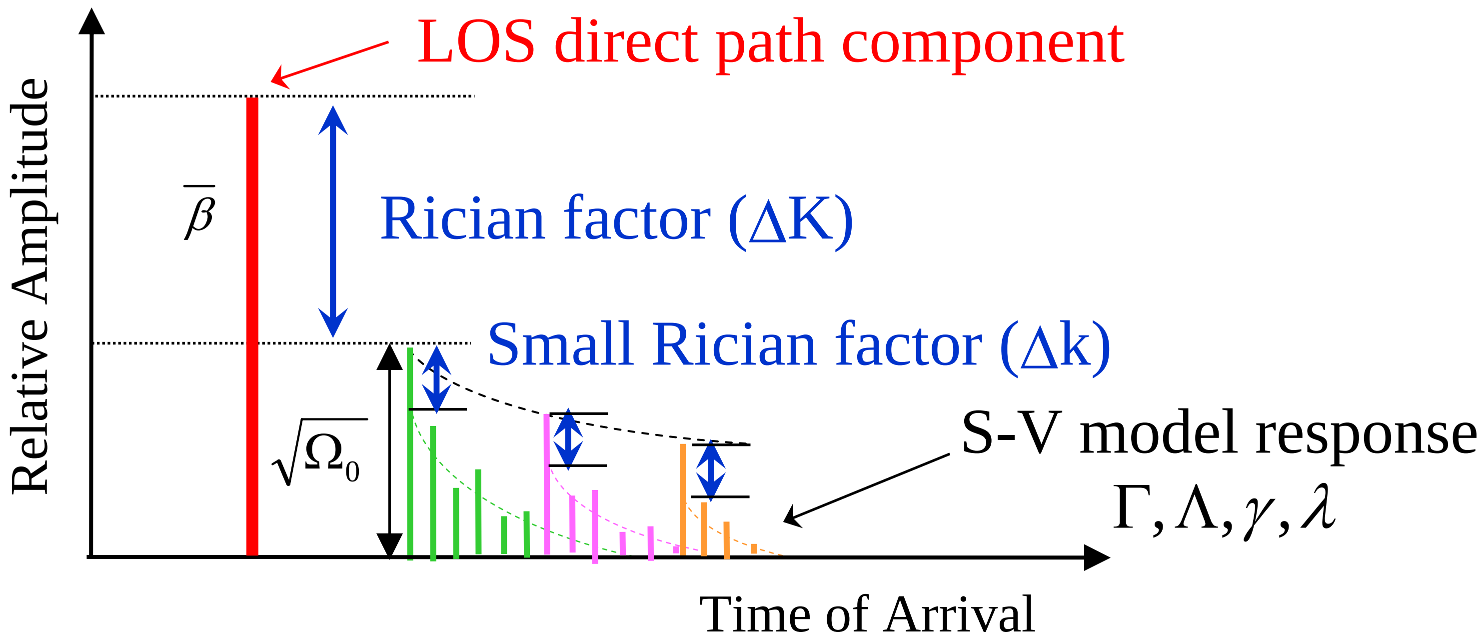
$$h(t)=\beta\,\delta(t)+\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\alpha_{l,m}\,\delta(t-T_l-\tau_{l,m})\,\delta(\varphi-\Psi_l-\psi_{l,m})$$

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

Statistical factors in only S-V

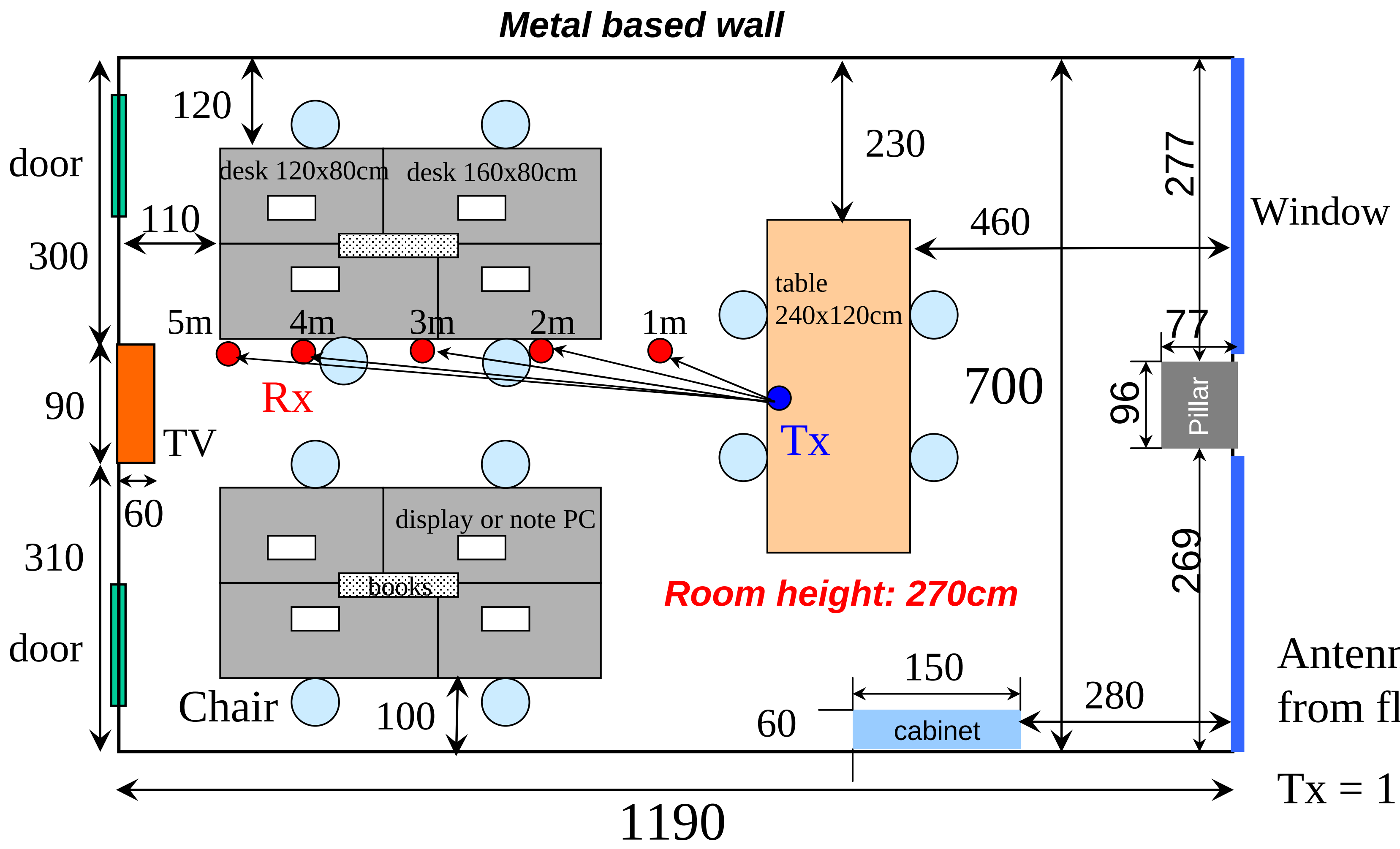
Refer to Appendix A for each parameter

Impulse response



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

AoA measurement environment

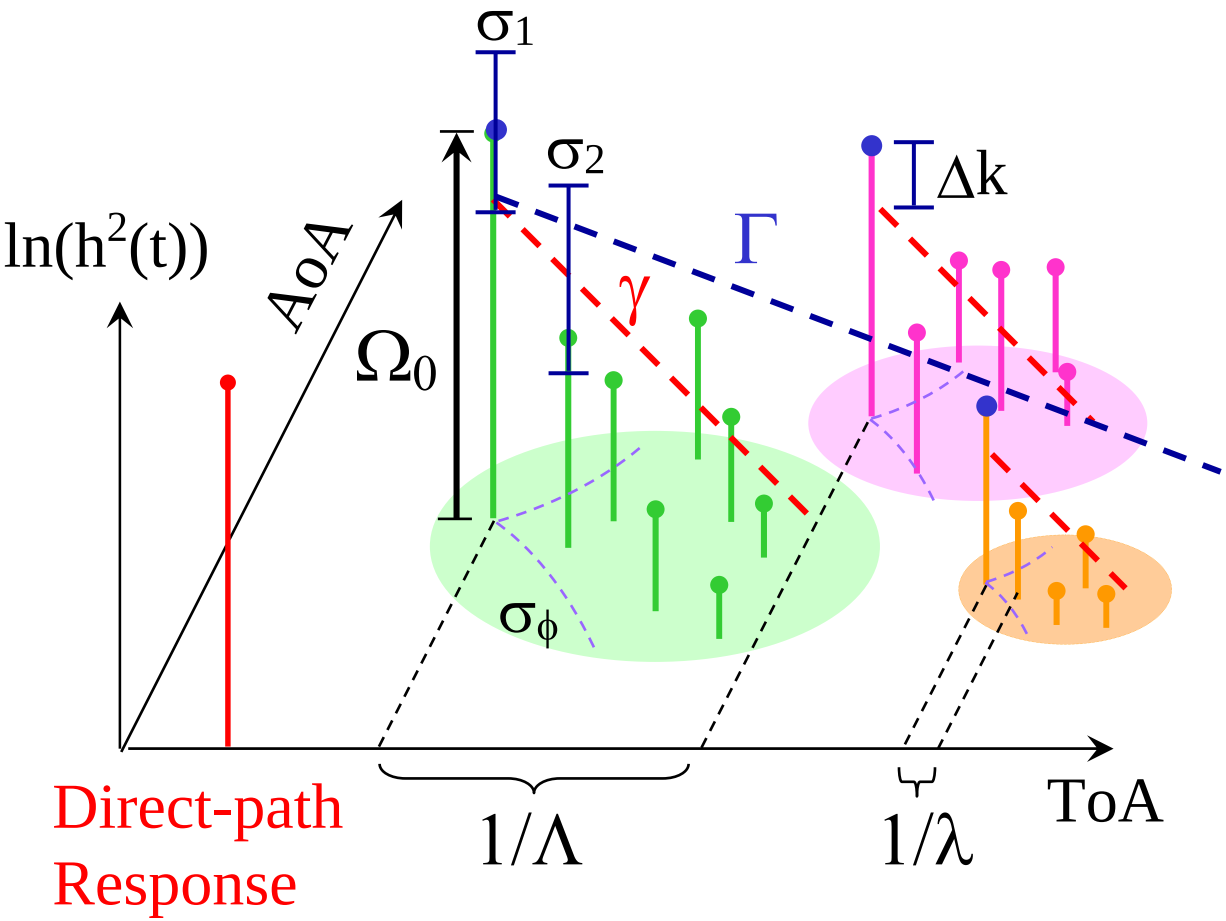


Antenna height from floor

Tx = 110 cm

Rx = 110 cm

TSV model parameters to be extracted



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)

Ω_0 : Average power of the first ray of the first cluster

Small Rican factor Δk and Ω_0 are necessary for TSV model

Extracted TSV model parameters

	TSV Model	Small Rician effect	S-V model oriented parameter							Number of cluster
Parameter	$\Omega_0(D)$ [dB]	k (Δk)	Γ [ns]	$1/\Lambda$ [ns]	γ [ns]	$1/\lambda$ [ns]	σ_1 cluster	σ_2 ray	σ_ϕ [deg]	N
Tx:30 Rx:30	-3.27 D -85.8	5.04 (21.9 dB)	49.8	24.6	45.2	1.03	6.60	11.3	102	6
Tx:60 Rx:60	-0.303 D -90.3	2.63 (11.4 dB)	38.8	37.6	64.9	3.41	8.04	7.95	66.4	5

Channel model for LOS office environment is now available

Refer to Appendix B and C for each parameter

Path loss model for LOS office environment

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

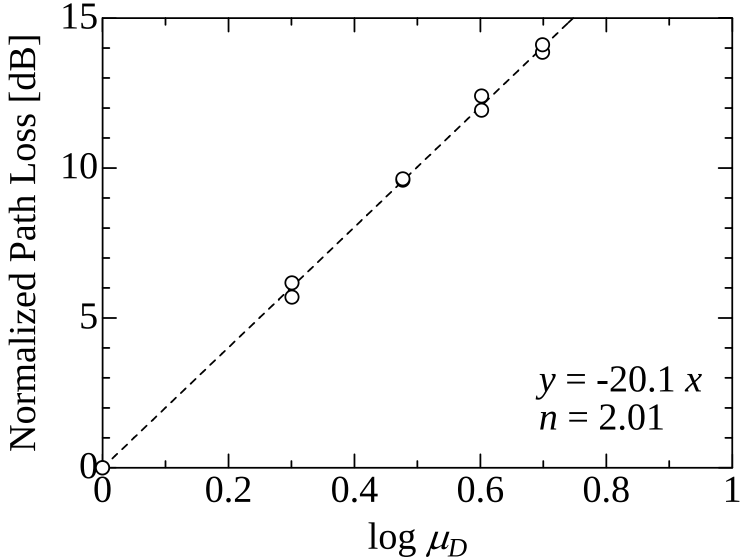


Fig. Path Loss result

- 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

$$n = 2.01$$

- Path loss of LOS component follows free space loss

Summary

- Channel model for LOS office environment is available
- Path loss model for LOS office environment was confirmed

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)

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

PL: Path loss of the first impulse response
t: time[ns]
$\delta(\cdot)$: 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

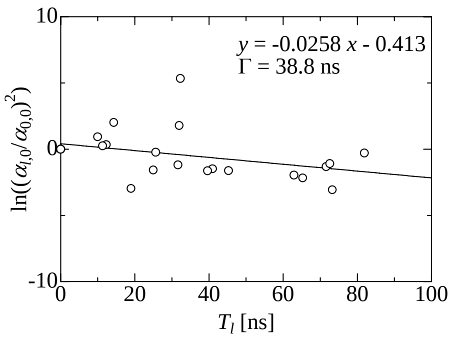
Rician factor (2)

k : Small Rician effect in each cluster

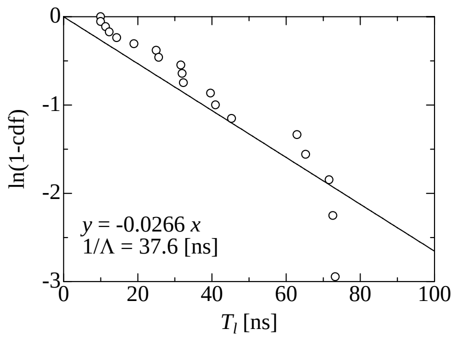
$$K=\frac{\beta^2}{\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}|\alpha_{l,m}^2|\,\delta(t-T_l-\tau_{l,m})\delta(\varphi-\Psi_l-\psi_{l,m})G_r(0,\Psi_l+\psi_{l,m})}$$

Appendix B: Results of data analysis

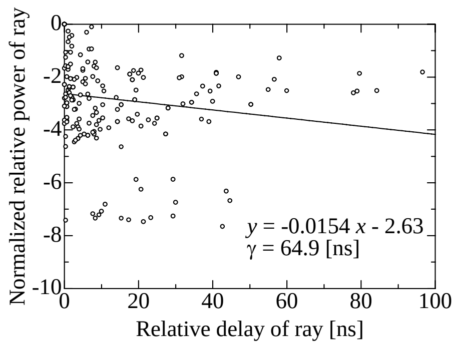
Antenna beamwidth
Tx: 60 deg, Rx: 60 deg



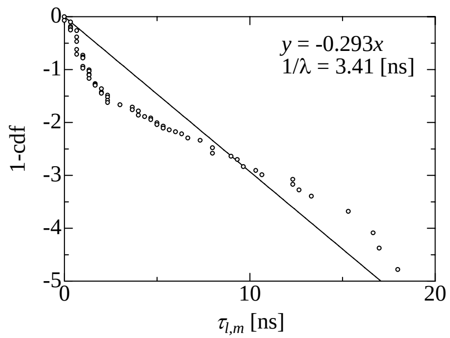
Cluster decay factor (Γ)



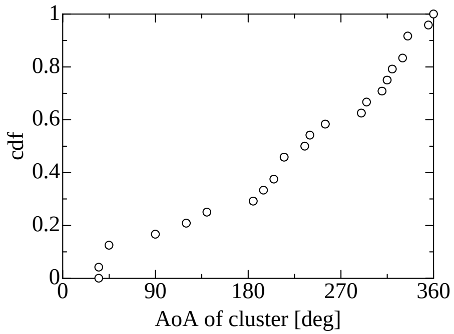
Cluster arrival rate (1/Λ)



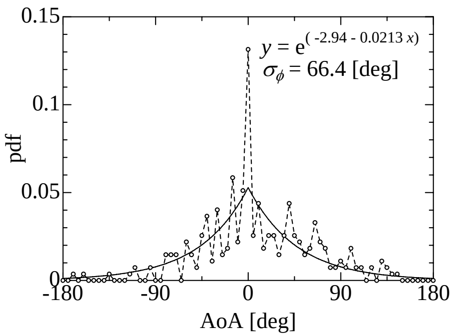
Ray decay factor (γ)



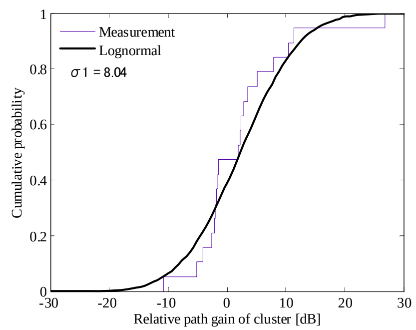
Ray arrival rate (1/λ)



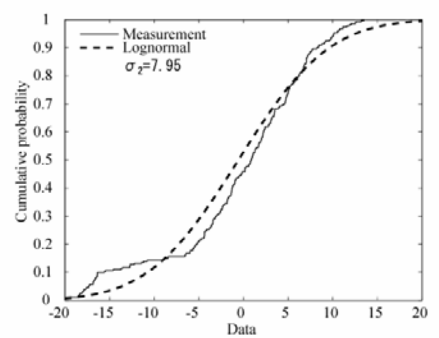
Angle of arrival in cluster (∝Uniform)



Angle spread of ray (σ_ϕ)

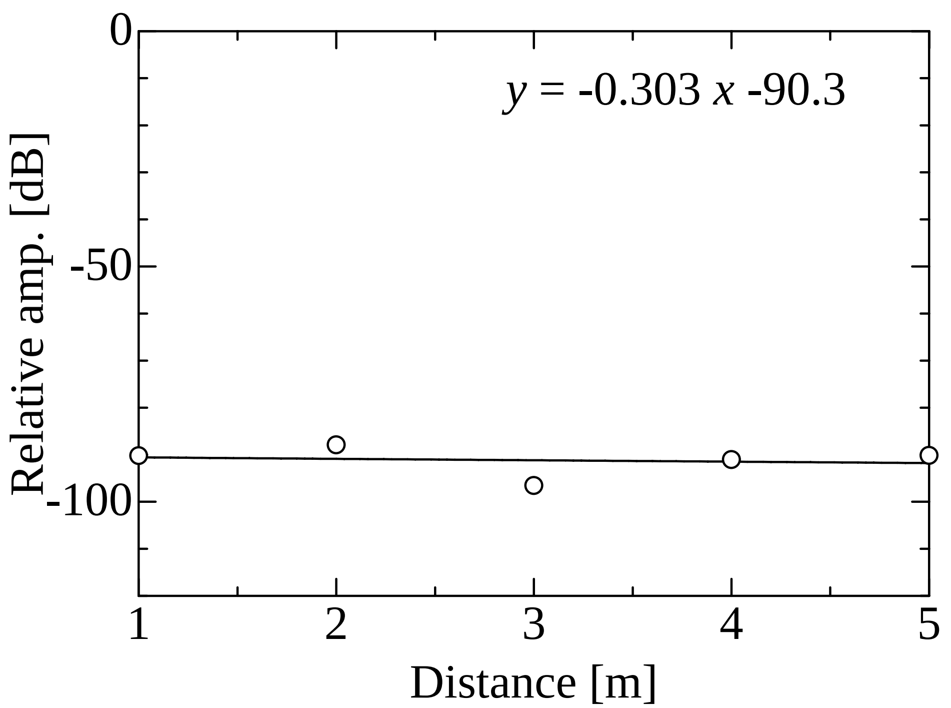


Standard deviation of cluster (σ_1)



Standard deviation of ray (σ_2)

Appendix C: Averaged power of the first ray of S-V response



Antenna beamwidth
Tx: 60 deg, Rx: 60 deg

$$\Omega_0[\mathrm{dB}] = -0.303\,D - 90.3$$

- Ω_0 slightly decreases according to distance