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

Submission Title: [NLOS residential channel model based on TSV model]
Date Submitted: [November, 2006]
Source: [Hirokazu Sawada, Yozo Shoji, Chang-Soon Choi, Katsuyoshi Sato, Ryuhei Funada, Hiroshi Harada, Shuzo Kato, Masahiro Umehira]
Company [National Institute of Information and Communications Technology]
Address [3-4, Hikarino-Oka, Yokosuka, Kanagawa, 239-0847, Japan]
Voice:[+81.46.847.5096], FAX: [+81.46.847.5079], E-Mail:[sawahiro@nict.go.jp]
Re: []

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

Purpose: [Contribution to mmW TG3c meeting.]

NLOS residential channel model based on TSV model

Hirokazu Sawada, Yozo Shoji, Chang-Soon Choi,
Katsuyoshi Sato, Ryuhei Funada, Hiroshi Harada,
Shuzo Kato, and Masahiro Umehira

National Institute of Information and
Communication Technology (NICT), Japan

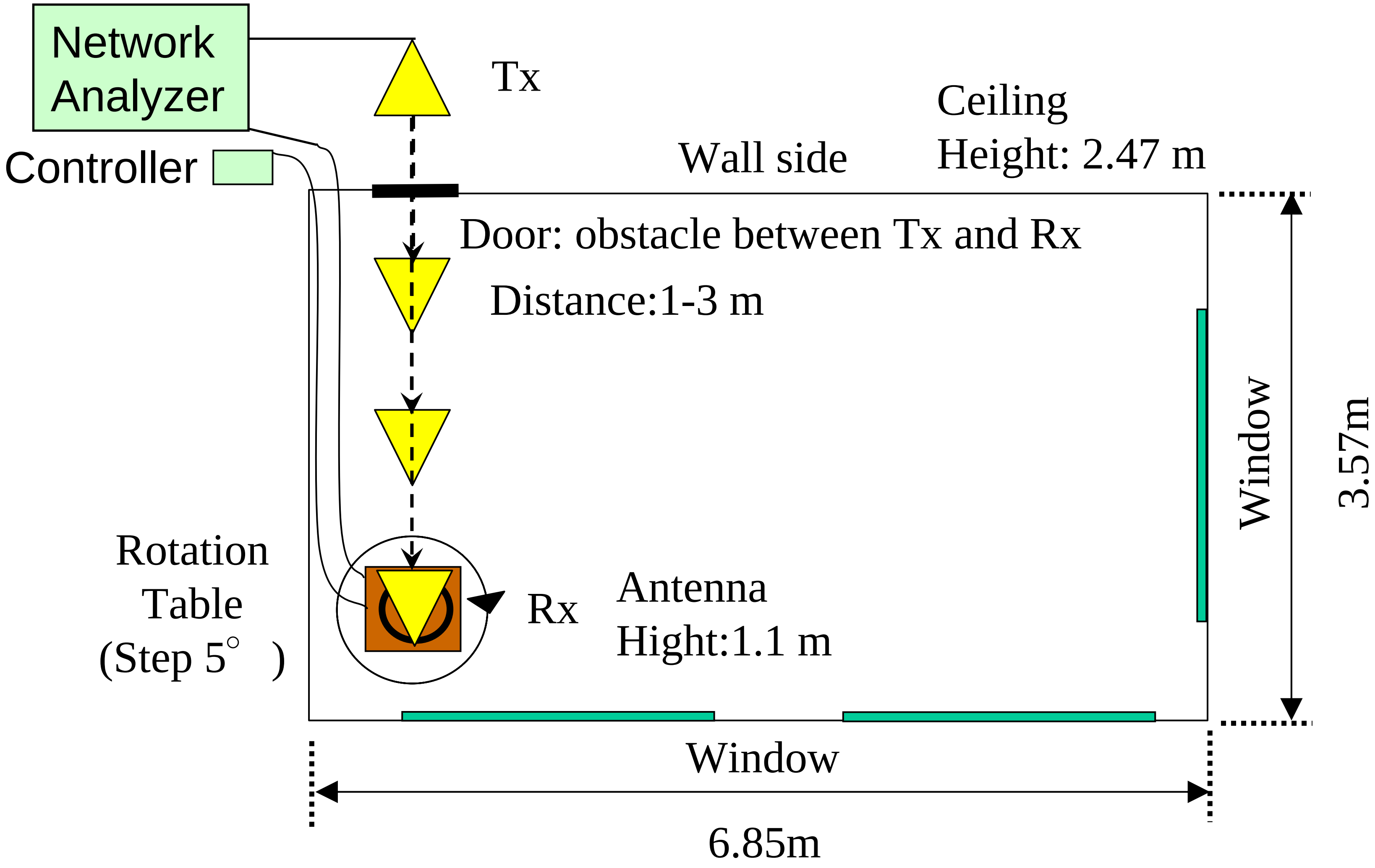
Agenda

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

Background

- TG3c requires NLOS residential channel model
- Tx and Rx are set up in different room but the antennas will be aligned in most likely NLOS residential environment to be considered (UM2)

Measurement environment



Floor plan of NLOS residential environment

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

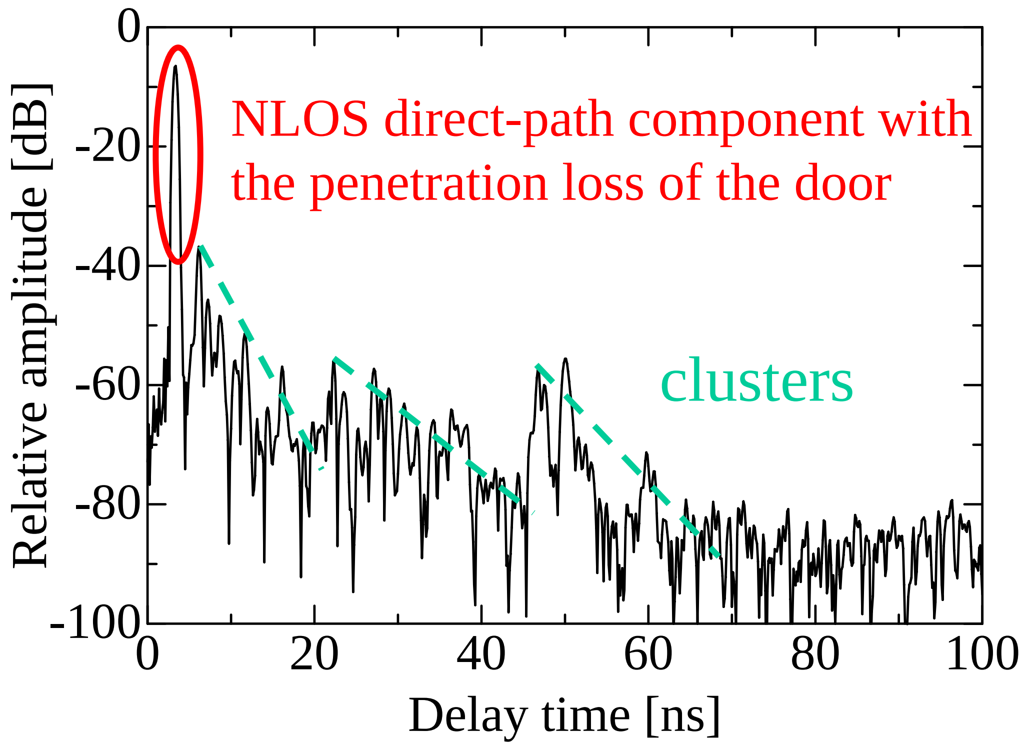
- Calibration performed with 1m reference separation
- Time resolution and distance resolution were determined by bandwidth

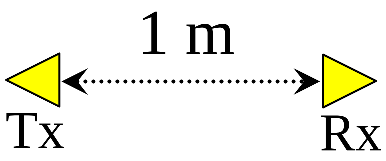
Measurement conditions (cont’)

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

Conical horn antenna
Beam-width 30 deg

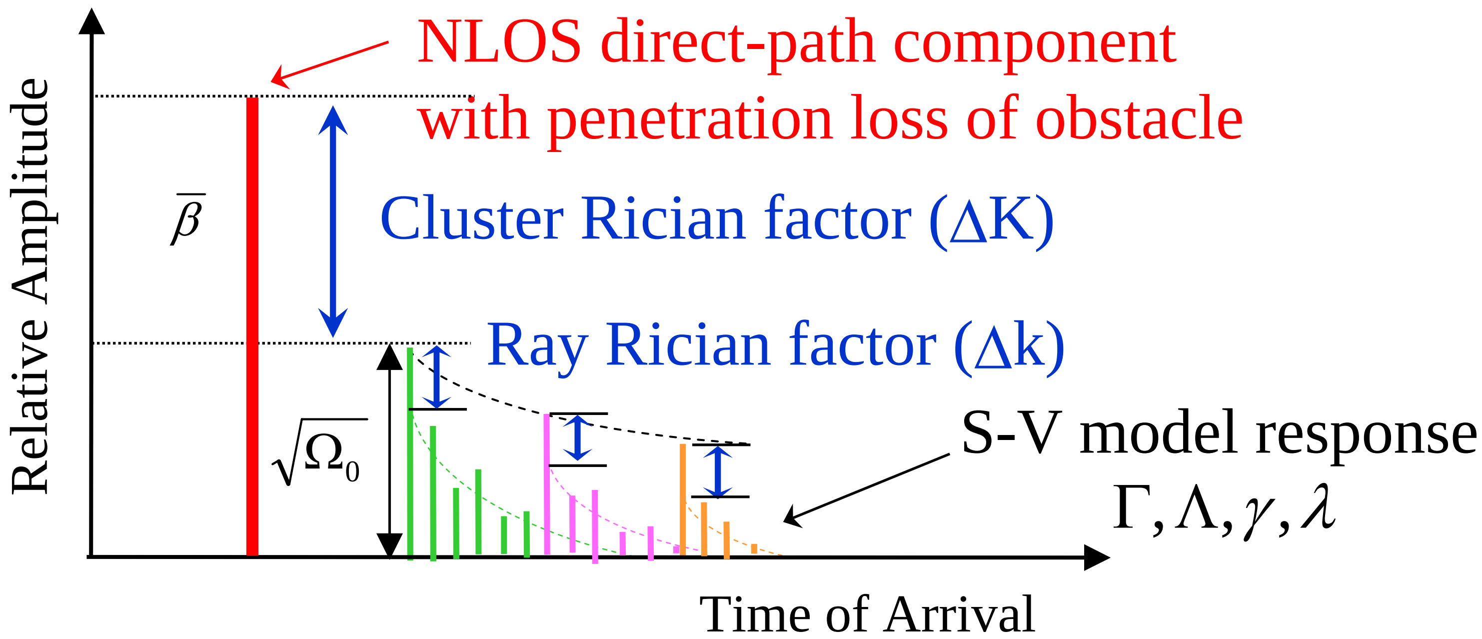
Example PDPs (Power delay profile) in NLOS residential environment (Beam width: Tx=30, Rx=30)





- Direct-path component remains in NLOS measurement
- TSV model can model NLOS residential channels

Impulse response



TSV model can generate channel response for NLOS environment by setting $\Gamma_0 = 0$

TSV model for NLOS residential environment

- For LOS desktop environment (06/297)

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

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

$$\beta\,[\mathrm{dB}] = 20\cdot\log_{10}\left[\left(\frac{\mu_d}{d}\right)\left|\sqrt{G_{t1}G_{r1}} + \sqrt{G_{t2}G_{r2}}\,\Gamma_0\exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{d}\right]\right|\right] - PL_d(\mu_d)$$

Statistical factors in both two-path and S-V

PL_d: Path loss of direct-path

- For NLOS residential environment

Reflection coefficient: $\Gamma_0 \doteqdot 0$

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

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

$$\beta\,[\mathrm{dB}] = 10\cdot\log_{10}(G_{t1}G_{r1}) - PL_d(\mu_d)$$

Statistical factors in only S-V

Refer to Appendix A for each parameter

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	-7.55 d -81.9	5.16 (22.4 dB)	6.49	7.58	5.62	1.02	4.96	15.1	51.0	4

Channel model for NLOS residential environment is available

Refer to Appendix B and C for each parameter

Path loss in direct-path component in NLOS residential environment

$$PL_d(\mu_d)[dB] = PL_d(d_0) + 10 n_d \log_{10}(\mu_d / d_0)$$

Path loss in direct-path component

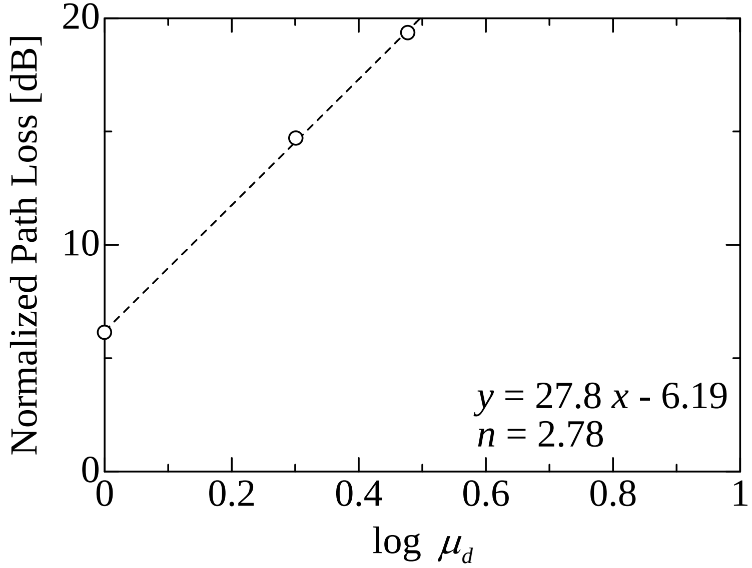


Fig. Path Loss in direct-path

- Path loss at d_0=1m distance

$$PL_d[\mathrm{dB}] = 20\log_{10}\left(\frac{4\pi d_0}{\lambda_f}\right) + 6.19 \approx 74.6$$

$$\lambda_f \approx 4.8\mathrm{mm}\ (f = 62.5\,\mathrm{GHz})$$

- Path loss exponent

$$n_d = 2.78$$

- PL_d includes the penetration loss of door (Attenuation for NLOS residential environment: A_{NLOS} = 6.19 dB)

Summary

- We observed direct-path components still remains although NLOS measurement
- We confirmed TSV model can express NLOS environment
- NLOS residential channel model based on TSV model is 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)

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

PL_d: *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

$$\beta\,[\text{dB}]=20\cdot\log_{10}\left[\left(\frac{\mu_d}{d}\right)\left|\sqrt{G_{t1}G_{r1}}+\sqrt{G_{t2}G_{r2}}\Gamma_0\exp\left[j\frac{2\pi}{\lambda_f}\frac{2h_1h_2}{d}\right]\right|\right]-PL_d(\mu_d)$$

$$PL_d(\mu_d)[\text{dB}]=PL_d(d_0)+10\cdot n_d\cdot\log_{10}\left(\frac{d}{d_0}\right)\qquad PL_d(d_0)[\text{dB}]=20\log_{10}\left(\frac{4\pi d_0}{\lambda_f}\right)+A_{NLOS}$$

A_{NLOS}: Constant attenuation for NLOS

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/NLOS 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

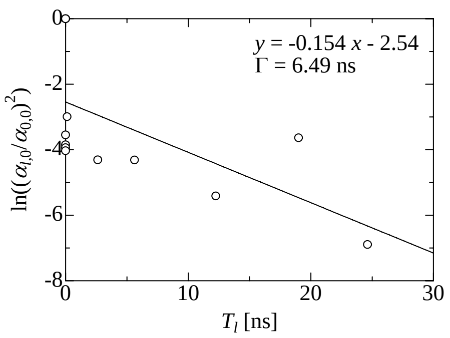
Rician factor (2)

k : ray Rician effect in each cluster

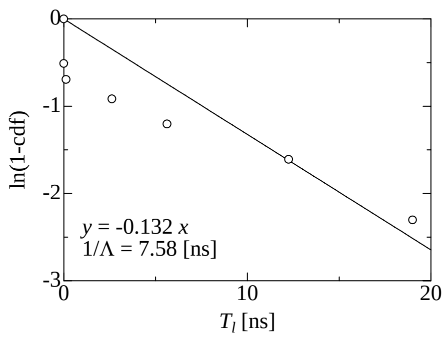
$$K=\frac{\beta^2}{\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\left|\alpha_{l,m}^2\right|\delta(t-T_l-\tau_{l,m})\delta(\varphi-\Psi_l-\psi_{l,m})G_r(0,\Psi_l+\psi_{l,m})}$$

Appendix B: Results of data analysis

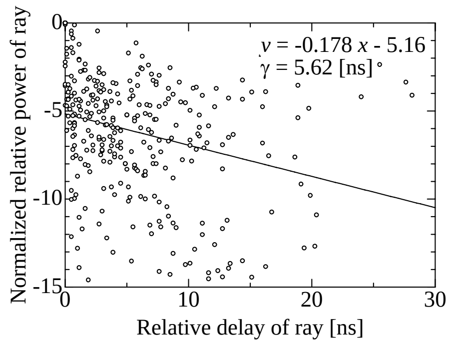
Antenna beamwidth
Tx: 30 deg, Rx: 30 deg



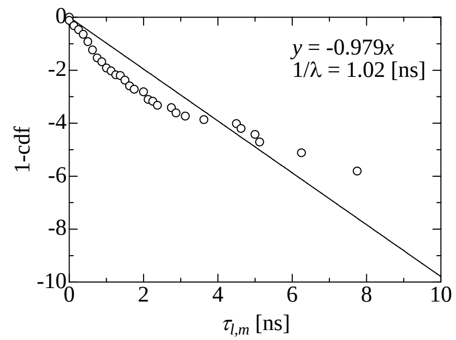
Cluster decay factor (Γ)



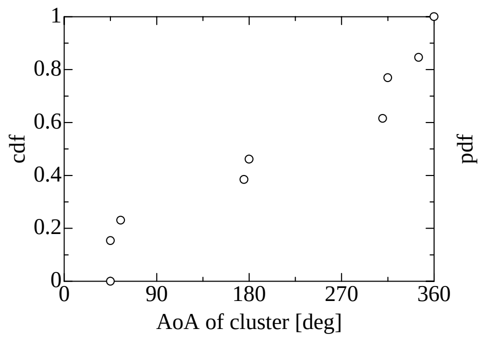
Cluster arrival rate (1/Λ)



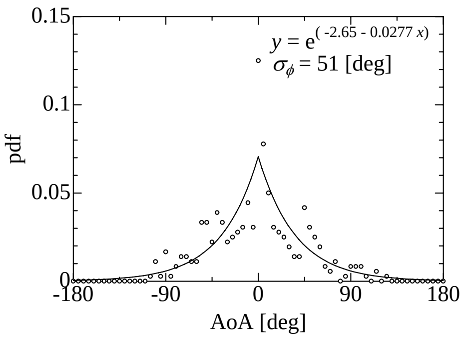
Ray decay factor (γ)



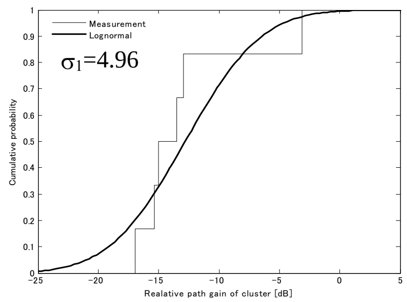
Ray arrival rate (1/λ)



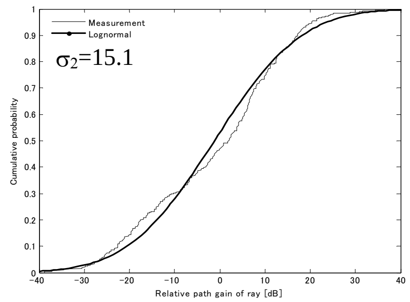
Angle of arrival in cluster (∝Uniform)



Angle spread of ray (σ_ϕ)

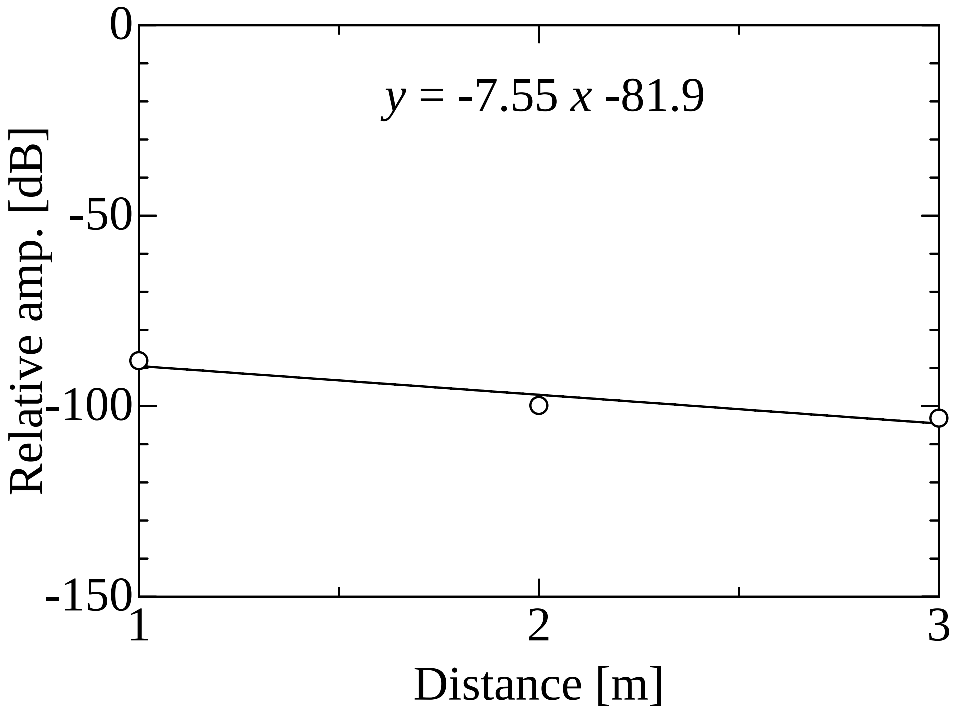


Standard deviation of cluster (σ_1)



Standard deviation of ray (σ_2)

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



Antenna beamwidth
Tx: 30 deg, Rx: 30 deg

$$\Omega_0[\text{dB}] = -7.55\, d - 81.9$$

- Ω_0 slightly decreases according to distance