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

Submission Title: [NLOS office 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 office channel model based on TSV model.]

Purpose: [Contribution to mmW TG3c meeting.]

NLOS office 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

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

Purpose

- To provide re-analyzed NLOS office channel model based on TSV model, and to extract the parameters for the directional antenna

Measurement condition

- Polarization : Vertical
- Antenna height : 1.1 m
- Antenna separation : 10 m
- Tx antenna: always fixed
- Rx antenna: rotated from 0 to 360 with 5 degree step

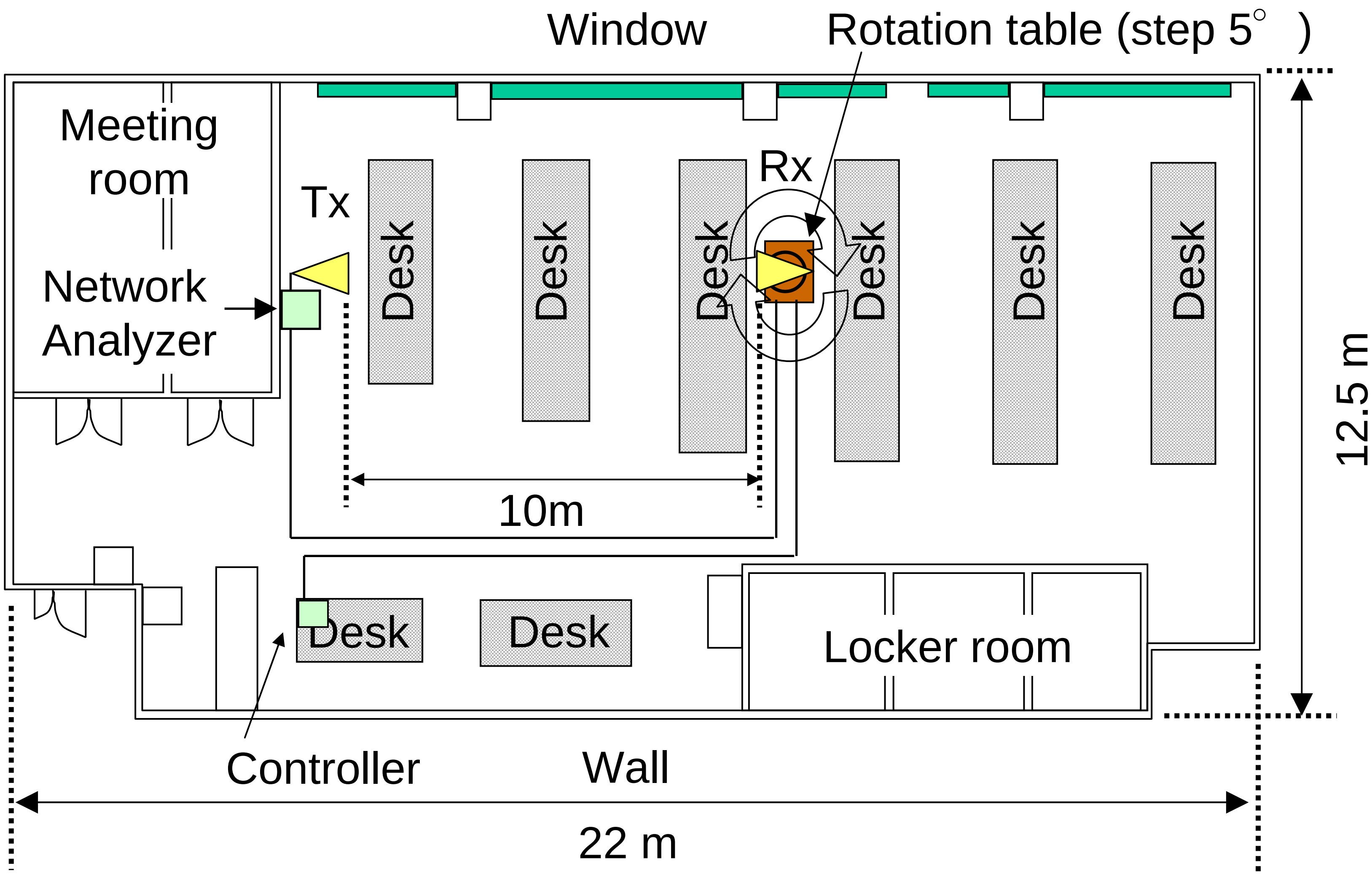
Ref. Doc 06/12

Measurement environment in office

Measurement environment in office (cont’)

Measurement environment in office (cont’)

Measurement environment in office (cont’)



Floor plan of office environment

Measurement condition (cont')

Scenario	Room size
Office (NLOS)	Floor: $22 \times 12.5\ m^2$ Ceiling height: 3.5m

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')

- Tx: Pyramidal horn antenna (3dB beam-width:30 deg) and Omni directional antenna
- Rx: Pyramidal horn antenna (3dB beam-width:15 deg)
- Calibration performed with 1m reference separation

Omni directional

Pyramidal horn

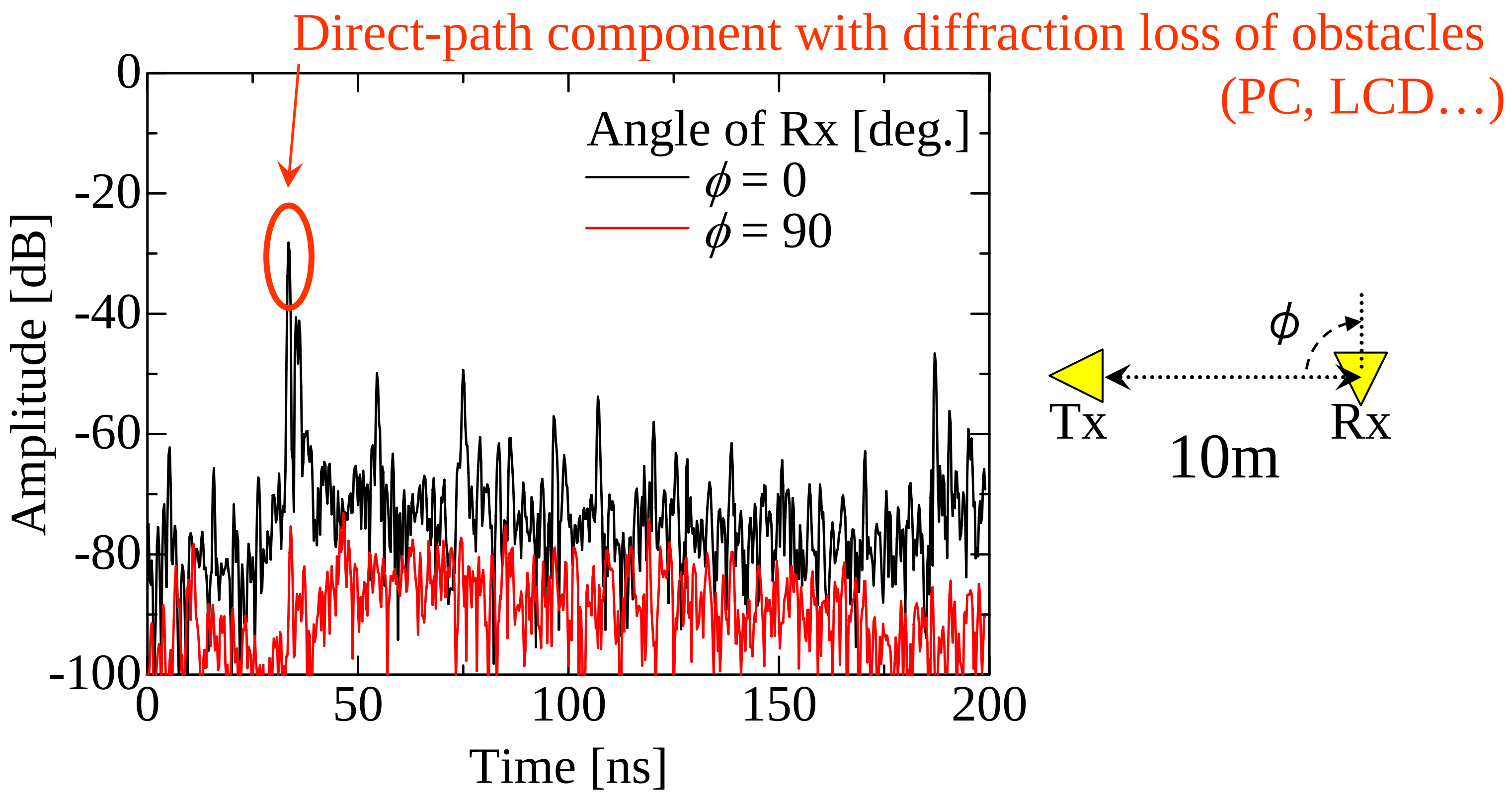
Measurement Data List

Scenario	Antenna beam width		Angle [deg]	PDPs
	Tx [deg]	Rx [deg]		
Office (NLOS)	Omni	15	0,5,…,355	73
	30			72※

・Not available data

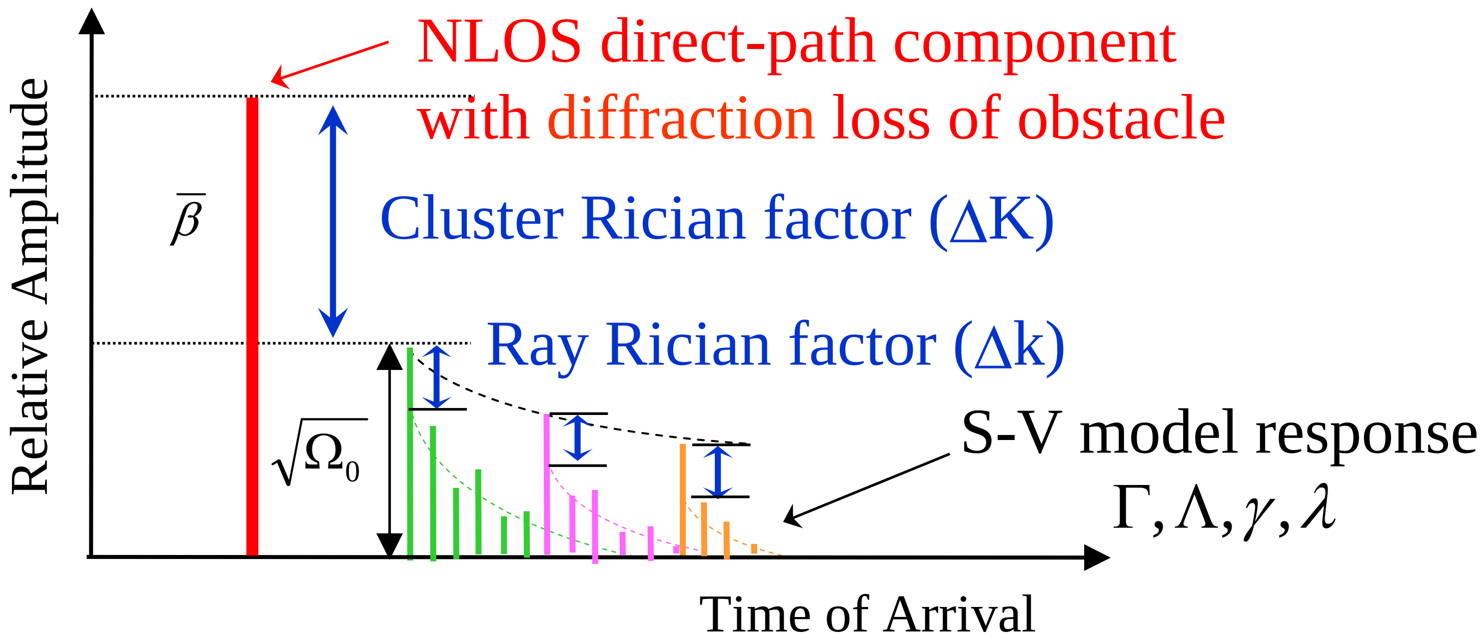
※ 95deg

Example PDPs in office environment (Beam width: Tx=30°, Rx=15°)



- Direct-path components remain in NLOS environment
- TSV model can model NLOS office channels

Impulse response



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

TSV model for NLOS office environment

- For LOS desktop environment (06/297)

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

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

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

Statistical factors in both two-path and S-V

PL_d: Path loss of direct-path

- For NLOS office environment

Reflection coefficient: $\Gamma_0 \fallingdotseq 0$

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

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

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

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	Ω_0(d)@10m [dB]	k (Δk)	Γ [ns]	$1/\Lambda$ [ns]	γ [ns]	$1/\lambda$ [ns]	σ_1 cluster	σ_2 ray	σ_ϕ [deg]	N
Tx:360 Rx:15	-109	4.37 (19.0 dB)	109.2	30.8	67.9	0.29	3.24	6.66	60.2	5
Tx:30 Rx:15	-107.2	4.43 (19.2 dB)	134.0	35.9	59.0	1.32	4.37	6.66	22.2	5

Channel model for NLOS office environment was reanalyzed

Refer to Appendix B

Path loss measurement for NLOS office

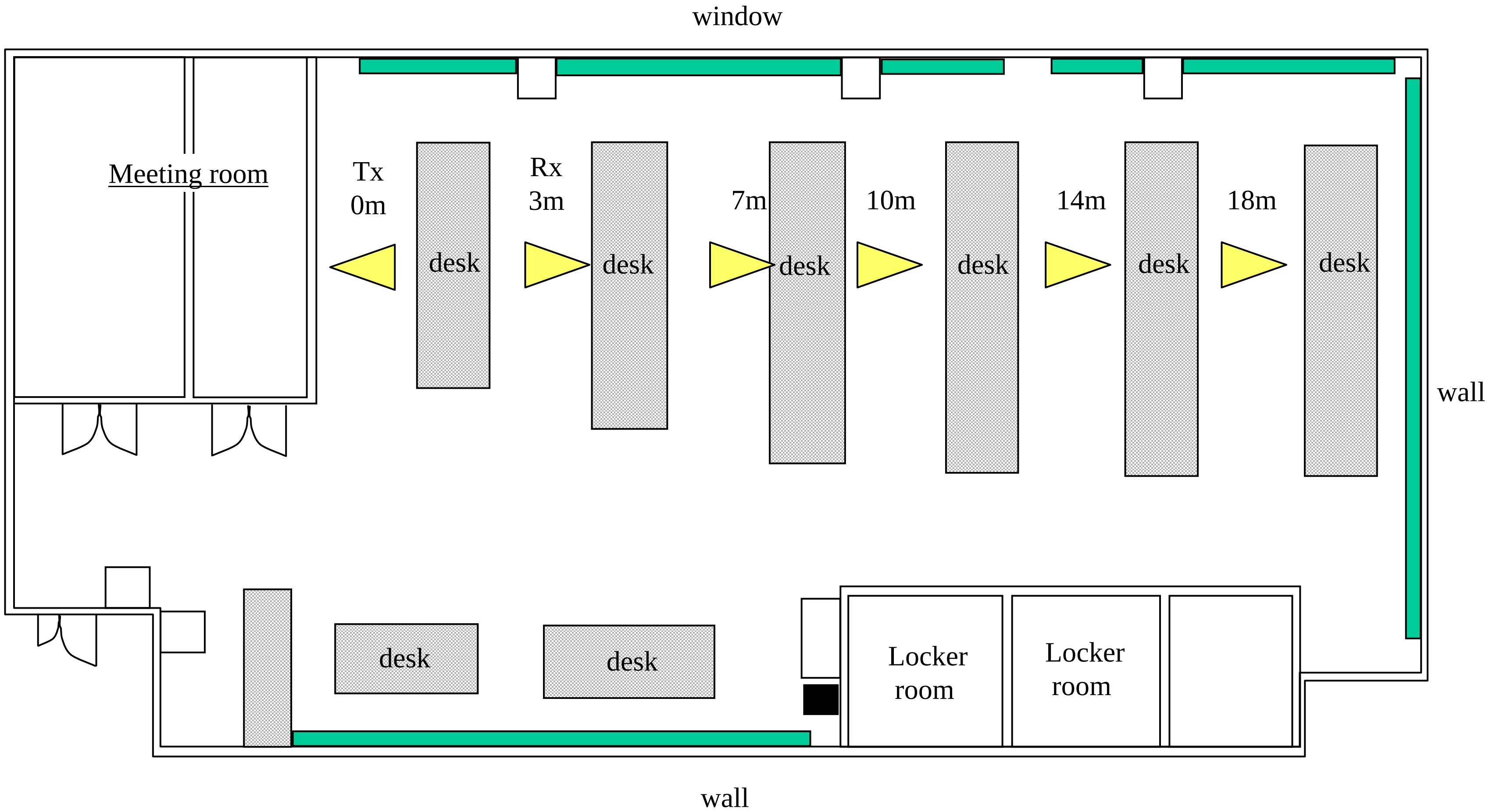


Fig. Floor plan to measure the path-loss

Path loss in direct-path component in NLOS office environment

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

Path loss in direct-path component

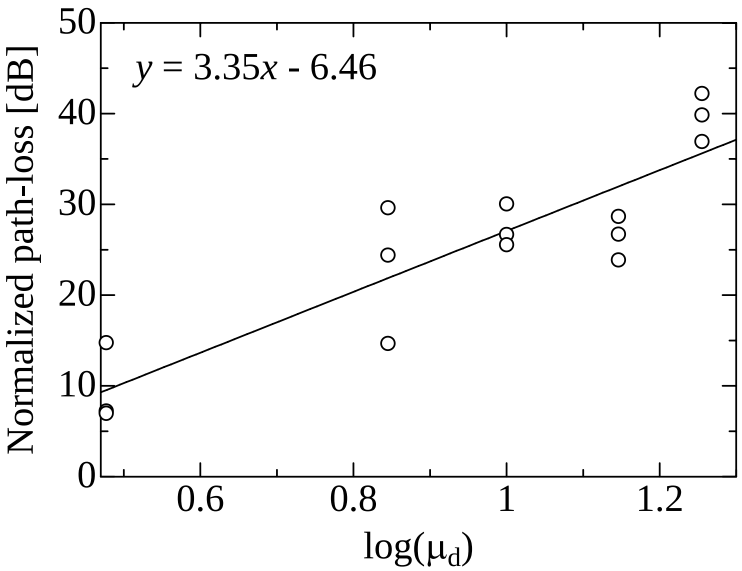


Fig. Path Loss in direct-path

- Path loss at d_0=3m distance

$$PL_d[\mathrm{dB}] = 20\log_{10}\left(\frac{4\pi d_0}{\lambda_f}\right) + 5.56 \approx 77.5$$

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

- Path loss exponent

$$n_d = 3.35$$

- PL_d includes diffraction loss (Attenuation for NLOS office environment: A_{NLOS} = 5.56 dB @ 3m)

Summary of available LOS / NLOS channel models

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

These parts are now available based on TSV-model

Summary

- The parameters for NLOS office channel model was reanalyzed based on TSV-model
- Channel models for all LOS/NLOS 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_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

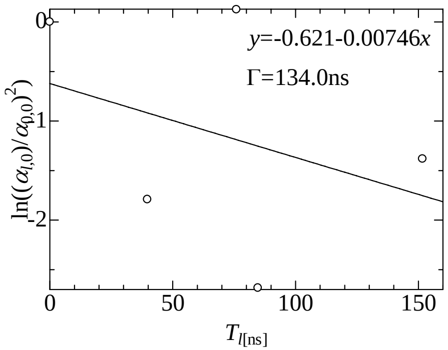
Rician factor (2)

k : ray Rician effect in each cluster

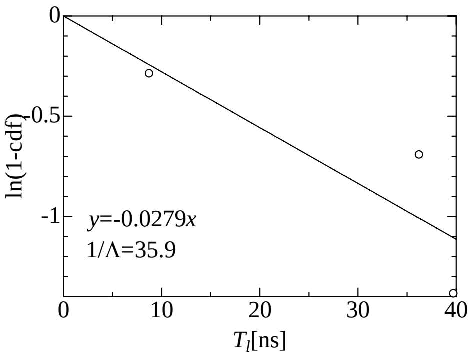
$$K = \frac{\beta^2}{\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}\left|\alpha_{l,m}^2\right|\delta(t - T_l - \tau_{l,m})\delta(\varphi - \Psi_l - \psi_{l,m})G_r(0, \Psi_l + \psi_{l,m})}$$

Appendix B: Results of data analysis

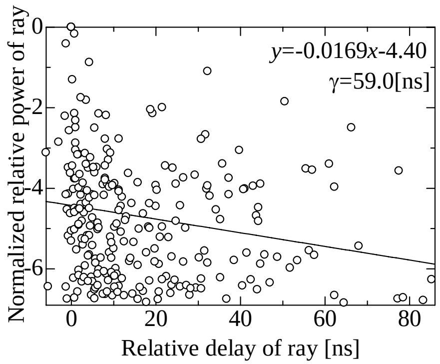
Antenna beamwidth
Tx: 30 deg, Rx: 15 deg



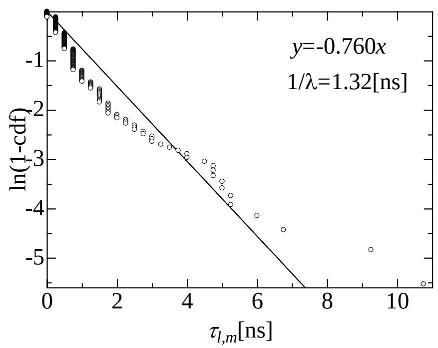
Cluster decay factor (Γ)



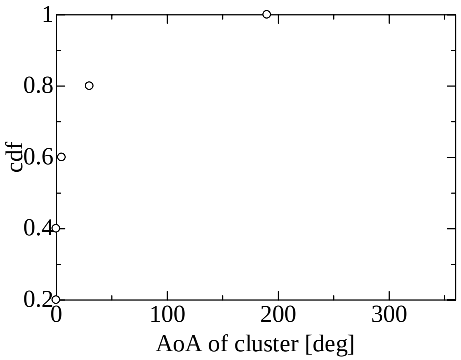
Cluster arrival rate ($1/\Lambda$)



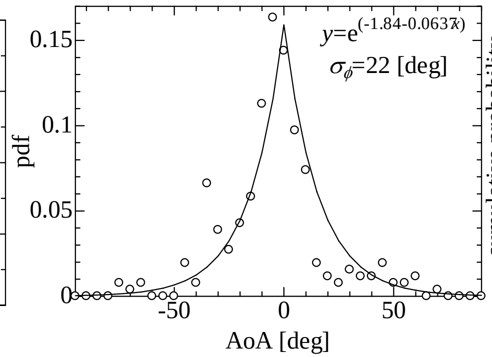
Ray decay factor (γ)



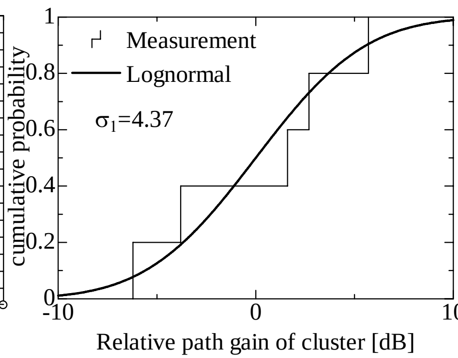
Ray arrival rate ($1/\lambda$)



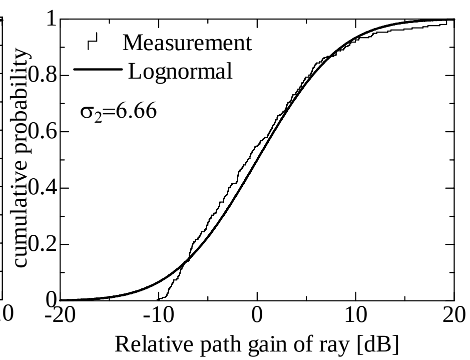
Angle of arrival in cluster (∝Uniform)



Angle spread of ray (σ_ϕ)



Standard deviation of cluster (σ_1)



Standard deviation of ray (σ_2)