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

Submission Title: [Merging two-path and S-V models for LOS desktop channel environments]
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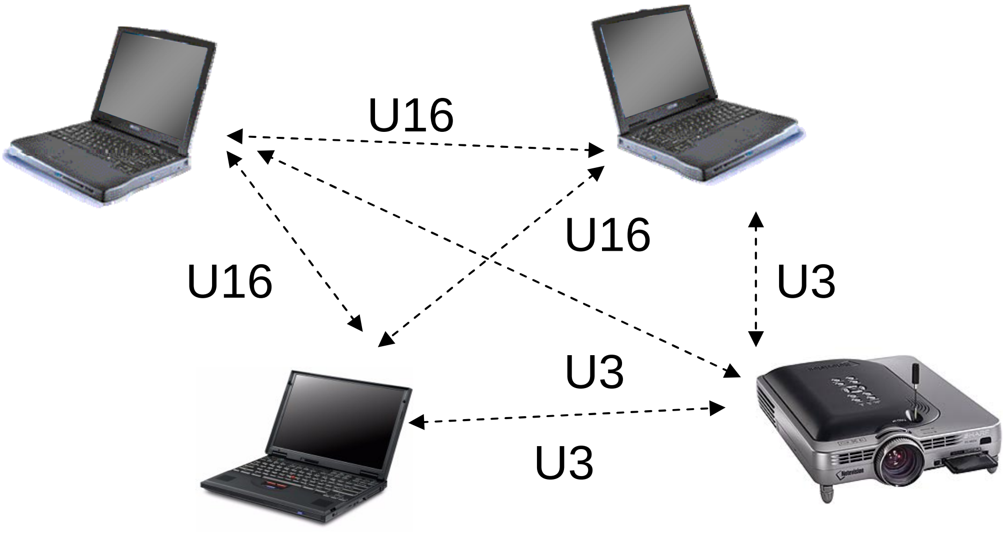
Abstract: [This contribution describes update of the generic channel model merging two-path and S-V models.]

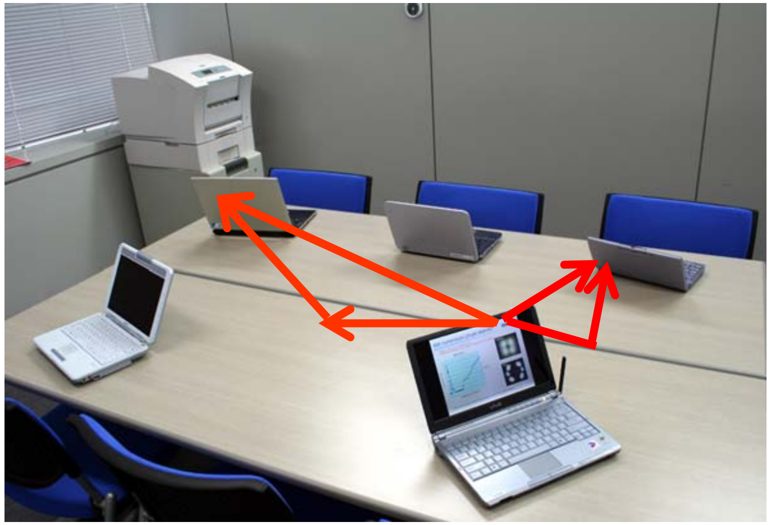
Purpose: [Contribution to mmW TG3c meeting.]

Agenda

- Channel model for LOS desktop environments
- Proposal of TSV model
- Measurement procedure and results
- Extracted TSV model parameters

Importance of channel model for LOS desktop



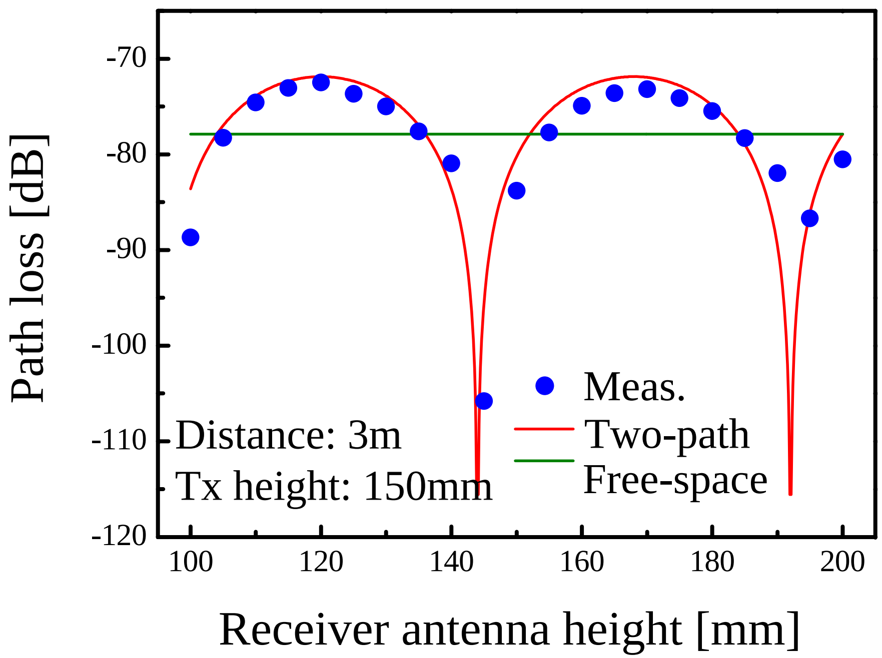


- LOS desktop is one of useful channel environments for TG3c
- Important to develop channel model for LOS desktop

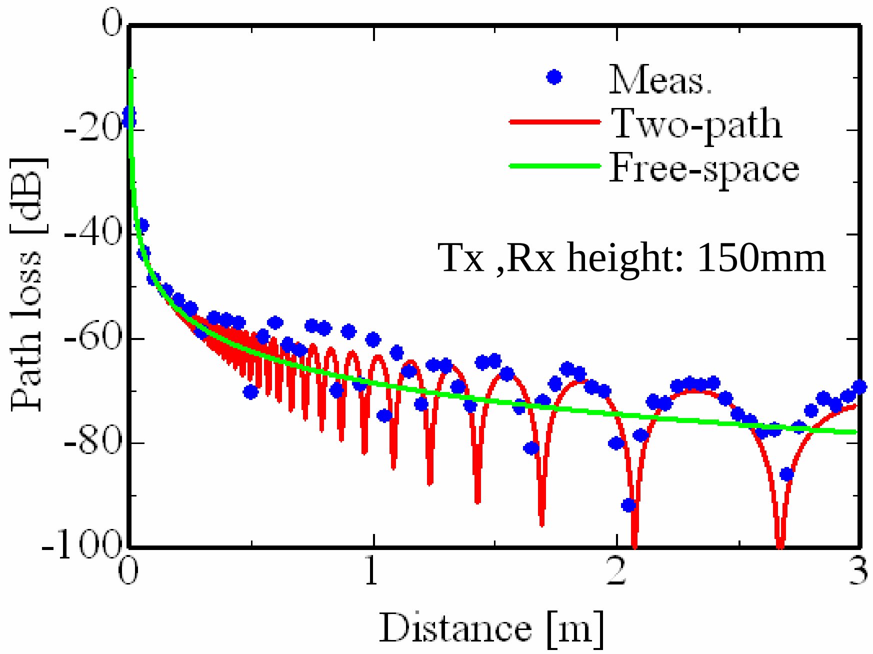
What is suitable channel model for LOS desktop?

- Two-path model is suitable to express LOS desktop environment (06/109)
- Developing statistical two-path model and merging with S-V model was proposed for TG3c generic channel model (06/228)
- This model is named TSV model (Triple SV: Shoji, Sawada, Saleh and Valenzuela model)

Results: Path loss in two-path response



Path loss vs Rx height



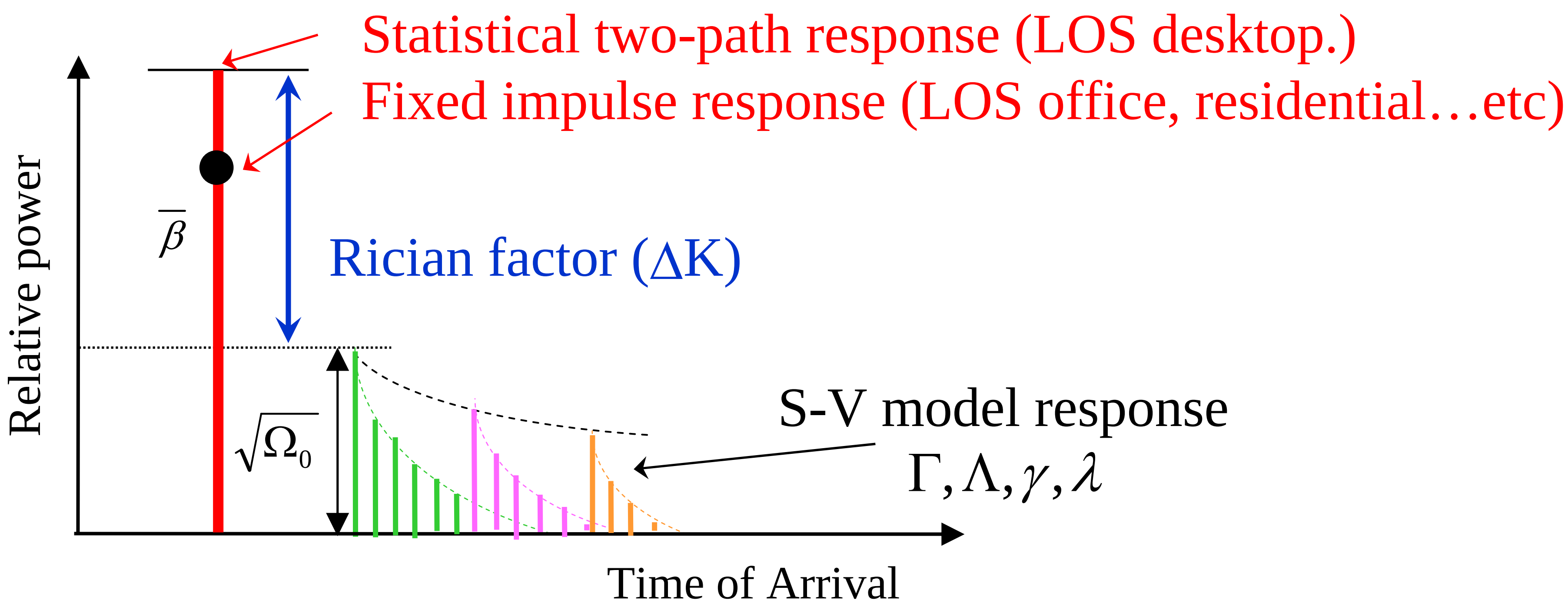
Path loss vs distance

Two-path model is suitable to express propagation phenomena in LOS desktop environment

Proposed TSV model

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

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



Refer to Appendix A for each parameter

Purpose of measurement

- To confirm the validity of TSV model in LOS desktop environments
- To extract TSV model parameters

Measurement conditions

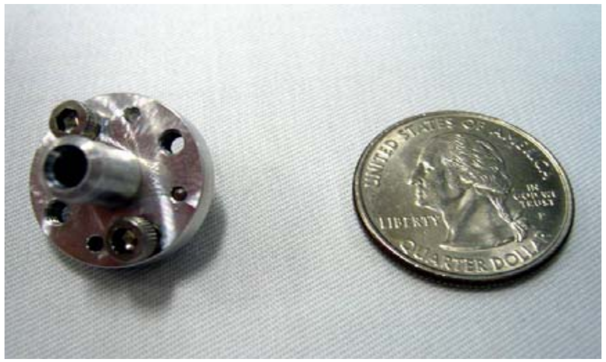
Instrument	HP8510C VNA
Center frequency	62.5 GHz
Bandwidth	3 GHz
Time resolution	0.333 ns
Distance resolution	19.1 cm
# of frequency points	801
Frequency step	3.75MHz
Times of average	128 times

Time resolution and distance resolution were determined by measurement bandwidth

Measurement conditions (cont')

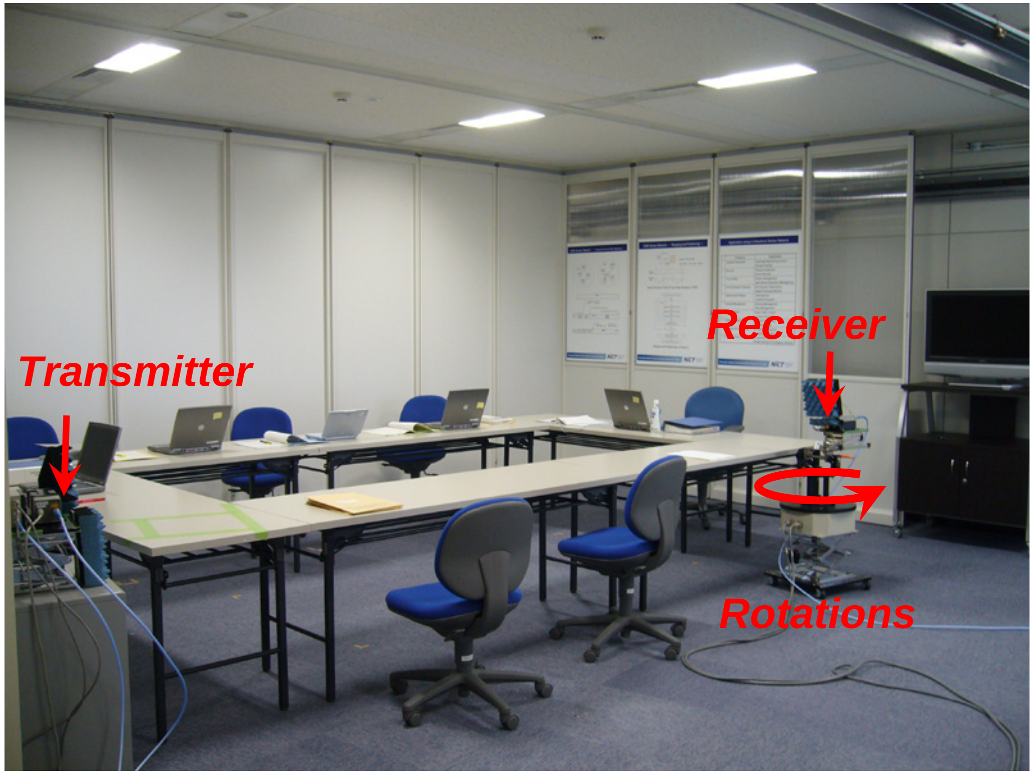
- **Antenna:** Conical horn antenna
- **Polarization:** Vertical
- **Beam-width:** Tx:30 and Rx 30, Tx:60 and Rx60

Conical horn antenna
Beam-width 30 deg



Conical horn antenna
Beam-width 60 deg

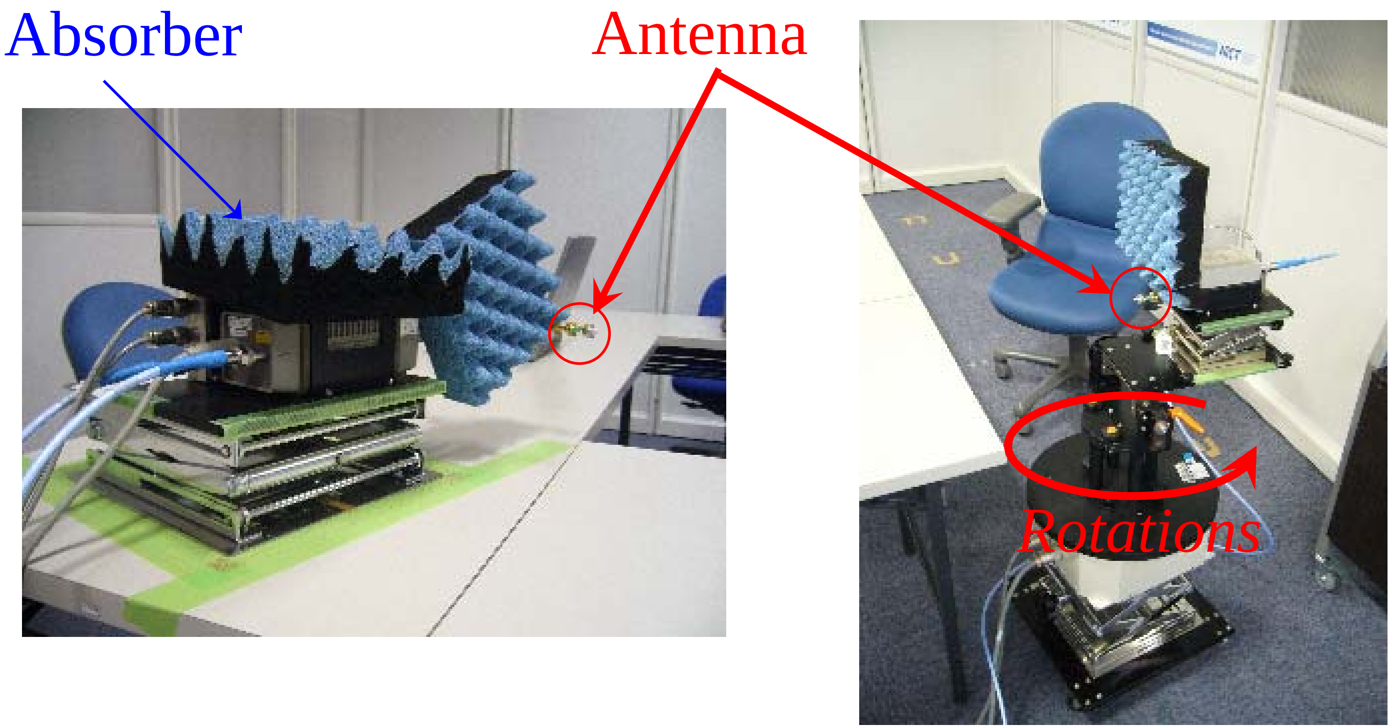
Measurement environment



- Small conference room: 6.4 m × 7.4 m
- Ceiling height: 2.7 m
- Surrounding: metallic wall, glass window
- Floor: Plaster board covered with carpet
- Furniture: Wooden desk, chair, computer, LCD TV, white board

Receiver was rotated from 0 to 360 degree in 5 degree step

Measurement environment

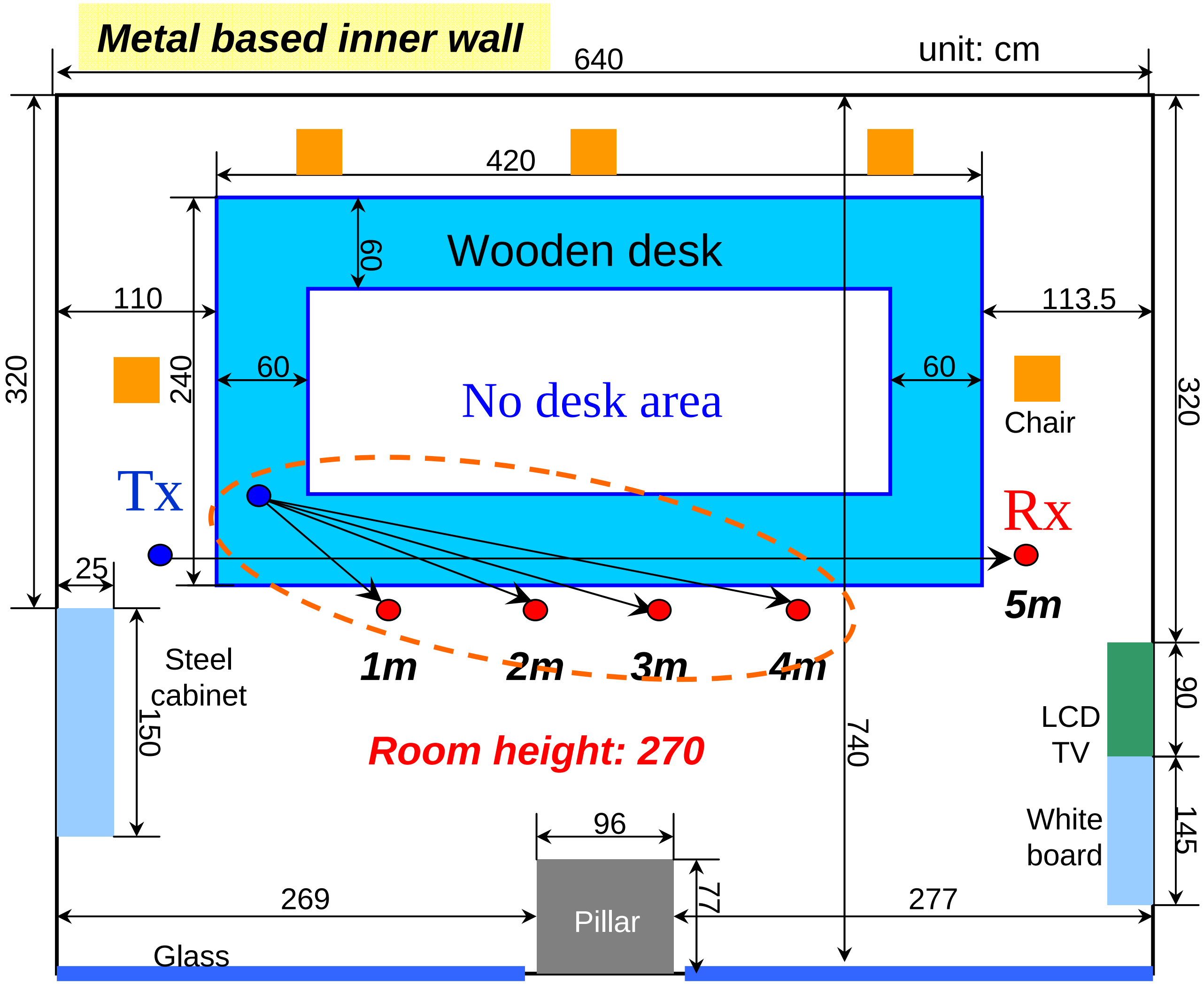


Tx side

Rx side

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

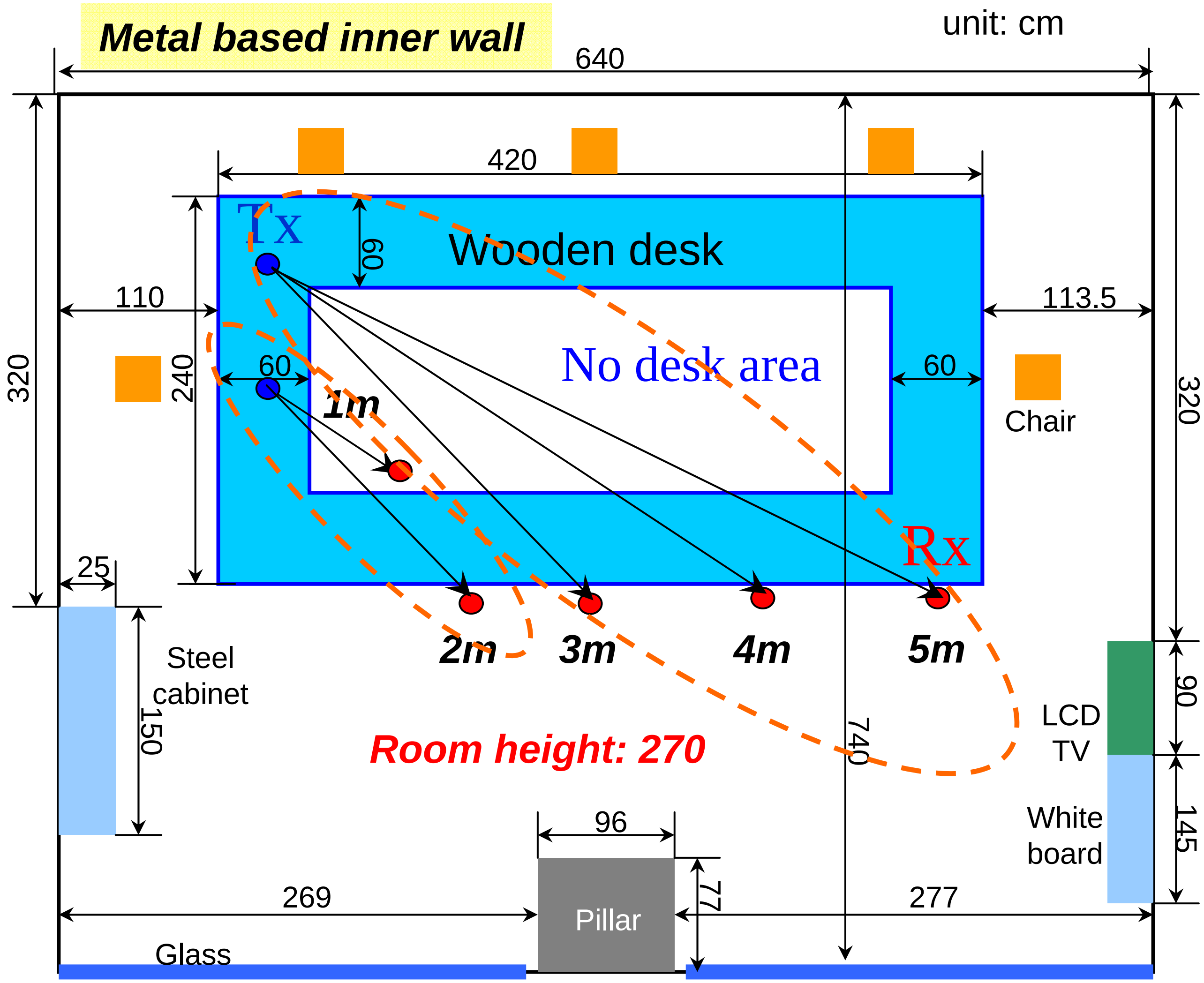
AoA measurement environment (Two-path)



Reflection from the desk

Antenna height from desktop
Tx = 15 cm
Rx = 15 cm

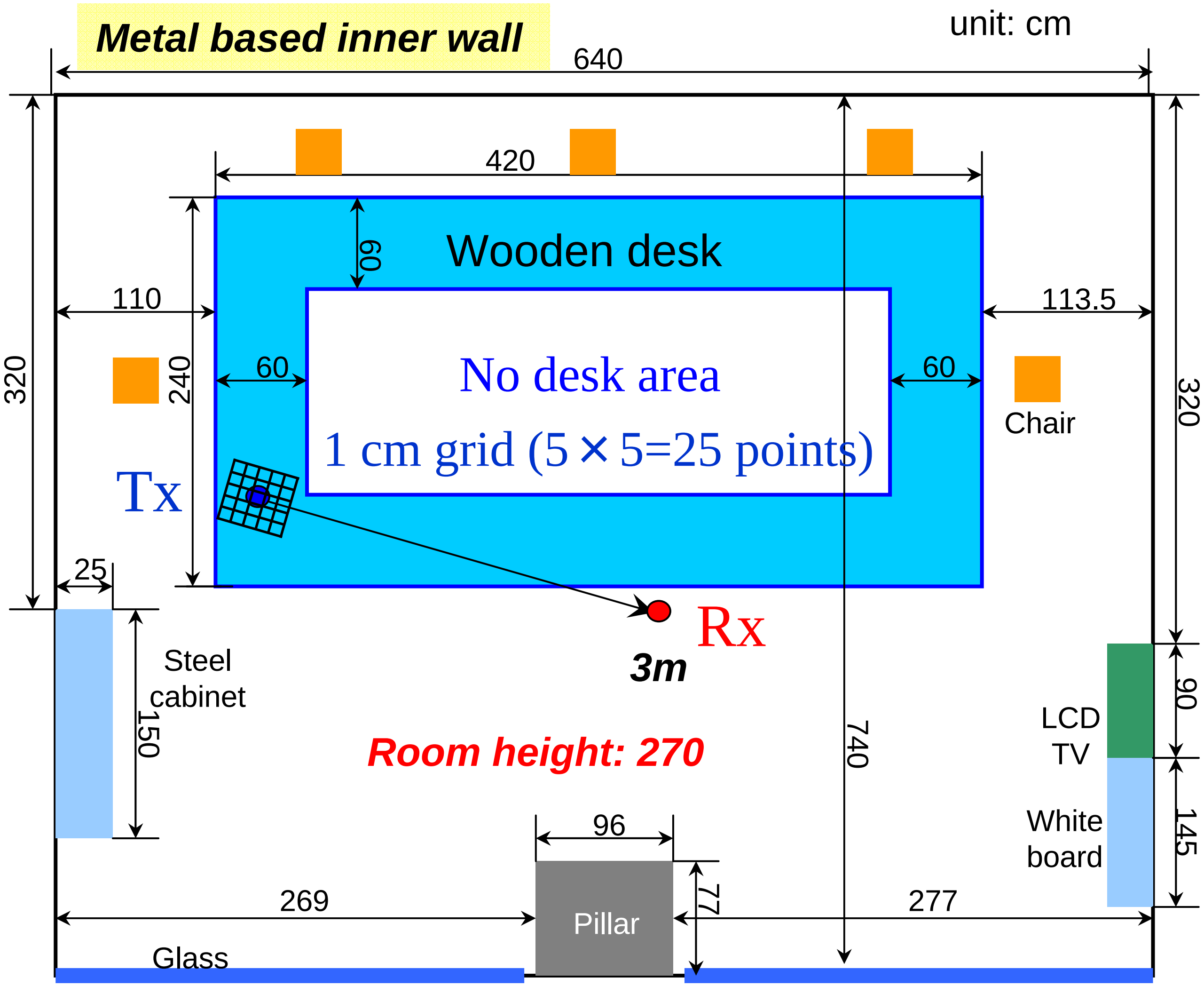
AoA measurement environment (Non-two-path)



No reflection from the desk

Antenna height from desktop
Tx = 15 cm
Rx = 15 cm

AoA measurement environment (Spatial)

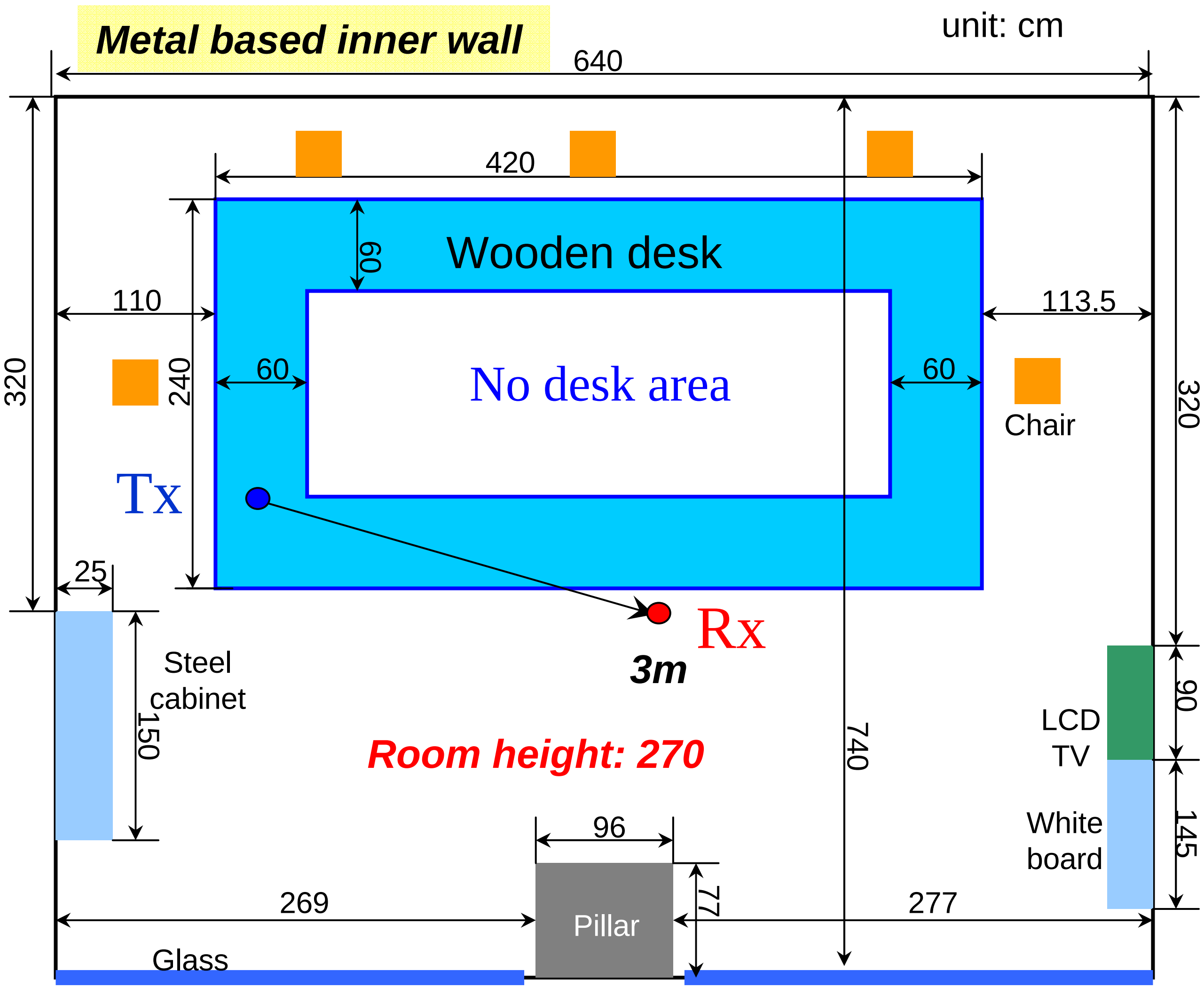


To characterize small-scale fading

Only 3m transmission

Antenna height from desktop
Tx = 15 cm
Rx = 15 cm

AoA measurement environment (Two heights)

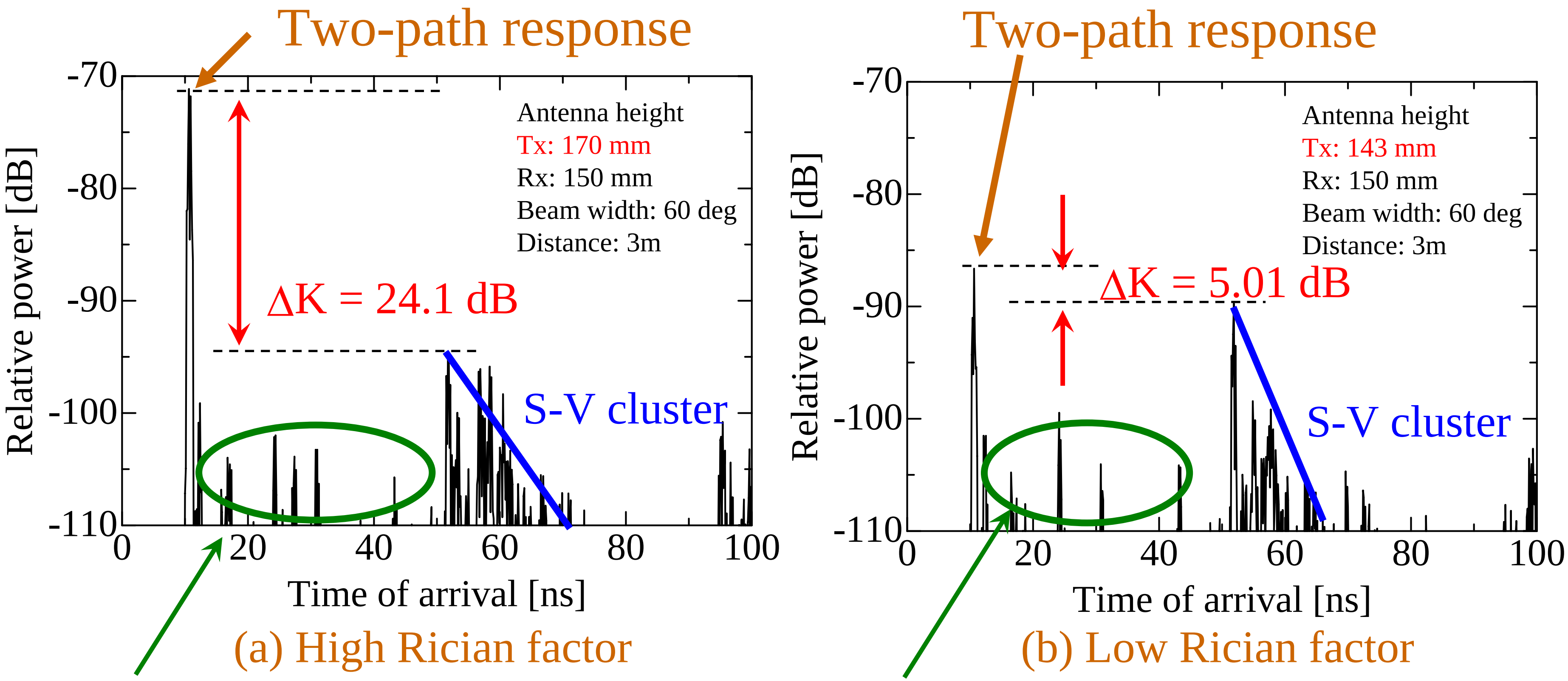


Only 3m transmission

Antenna height from desktop
Tx = 17, 14.3 cm
high- and low-Rician cases
Rx = 15 cm

Measurement results

PDPs for two different antenna heights

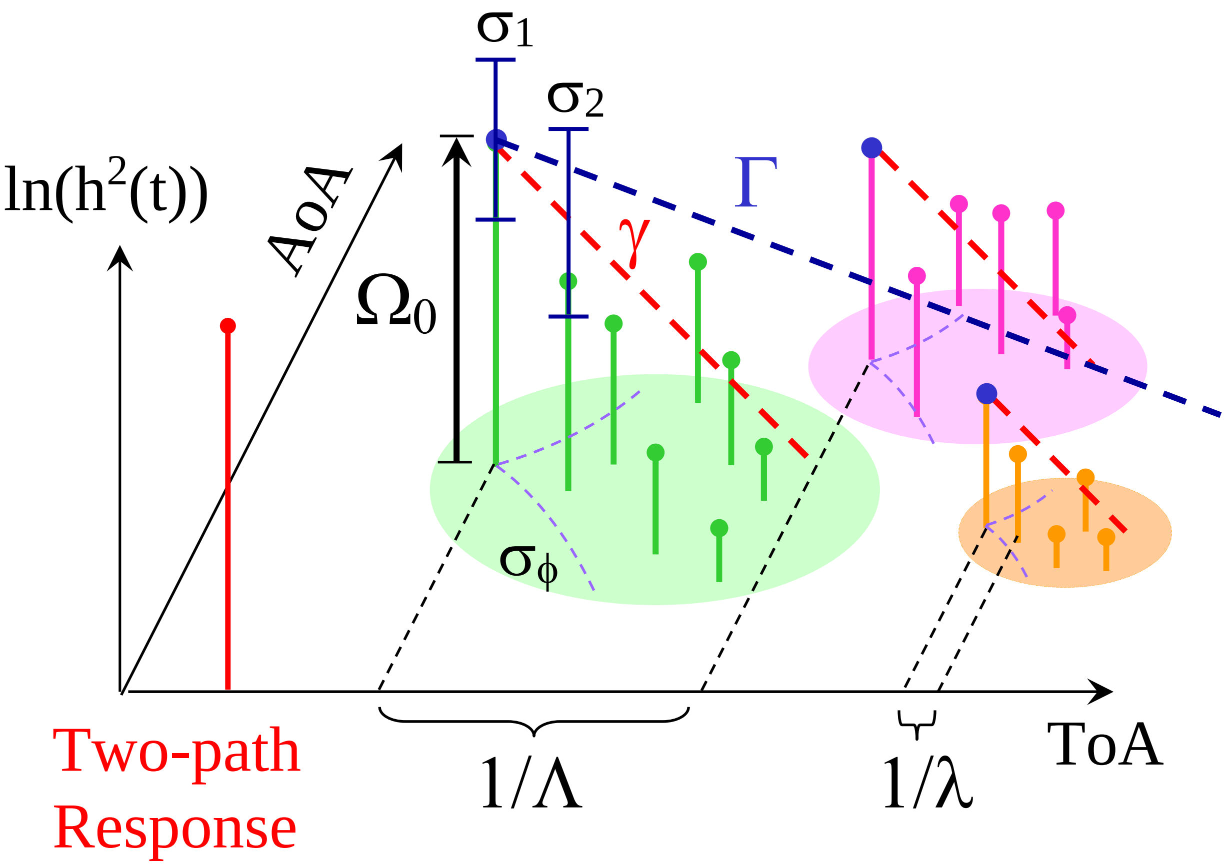


(a) High Rician factor (b) Low Rician factor

Side-lobe effect of window function in IFFT

- ΔK has 19dB dynamic range
- TSV model is well expressing LOS desktop

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

S-V parameters and Ω_0 are required for TSV model

Extracted TSV model parameters

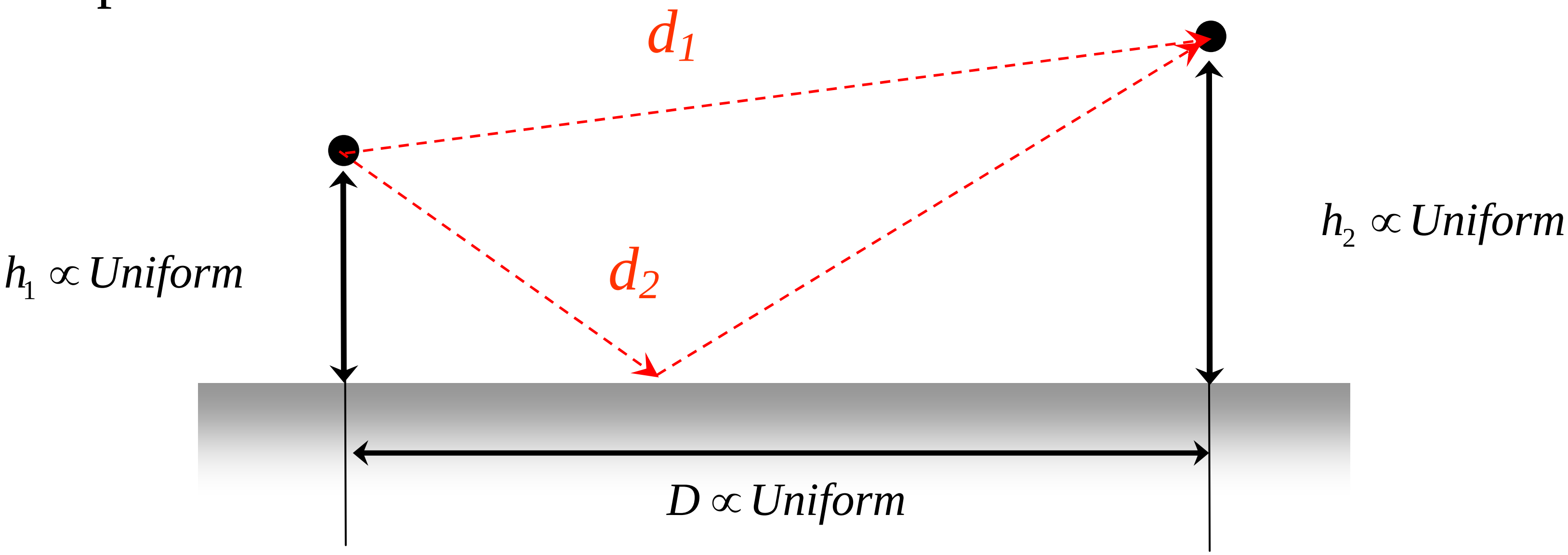
	TSV Model	S-V model oriented parameter							Number of cluster
Parameter	$\Omega_0(D)$ [dB]	Γ [ns]	$1/\Lambda$ [ns]	γ [ns]	$1/\lambda$ [ns]	σ_1 cluster	σ_2 ray	σ_ϕ [deg]	
Tx:30 Rx:30	4.44 D-105	21.1	27.0	8.85	1.56	3.01	7.69	34.6	3
Tx:60 Rx:60	3.46 D-98	22.3	21.1	17.2	2.68	7.27	4.42	38.1	3

Example of ΔK in measurement

	Two-path@3m		Non-two path@3m
Parameter	Max.ΔK[dB]	Min.ΔK[dB]	ΔK[dB]
Tx:30, Rx:30	27.0	10.2	23.7
Tx:60, Rx:60	24.1	5.01	19.6
	Variable		Constant

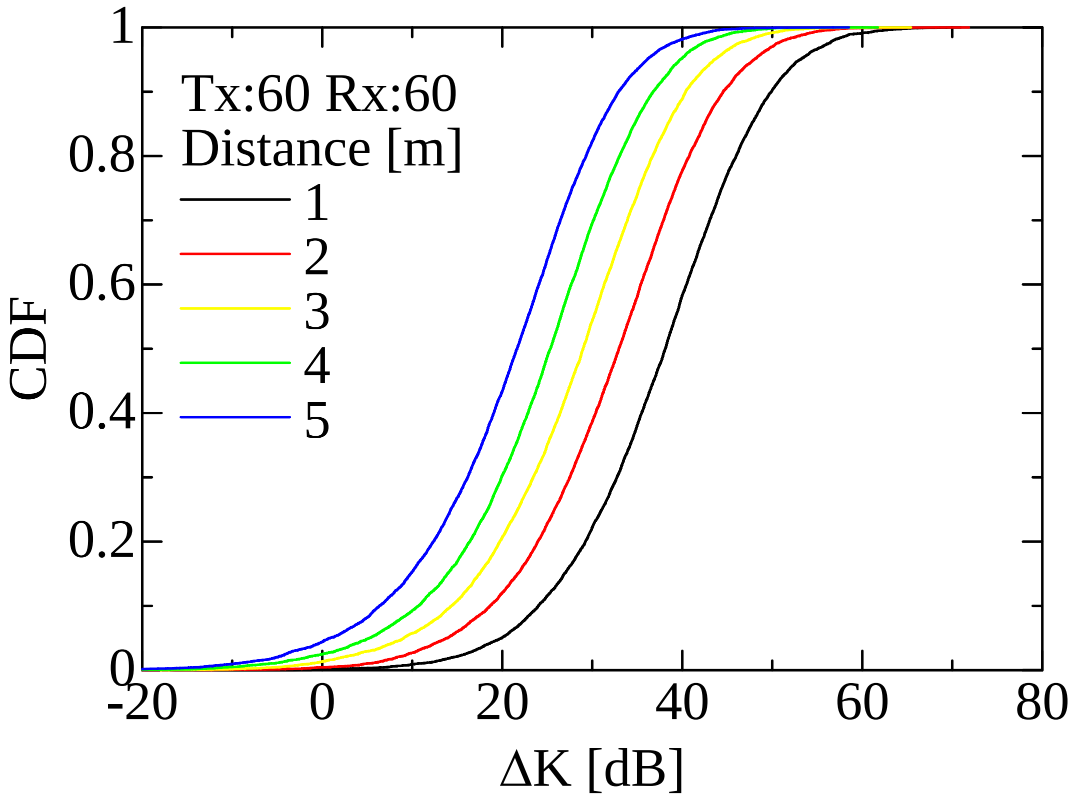
Calculation of ΔK

Extracted TSV parameter and calculated two-path response were used



Assumption: Transceiver position parameters have uniform distribution

Calculated CDF of ΔK



$h_1 \propto Uniform(0, 0.3)$

$h_2 \propto Uniform(0, 0.3)$

$D \propto Uniform$

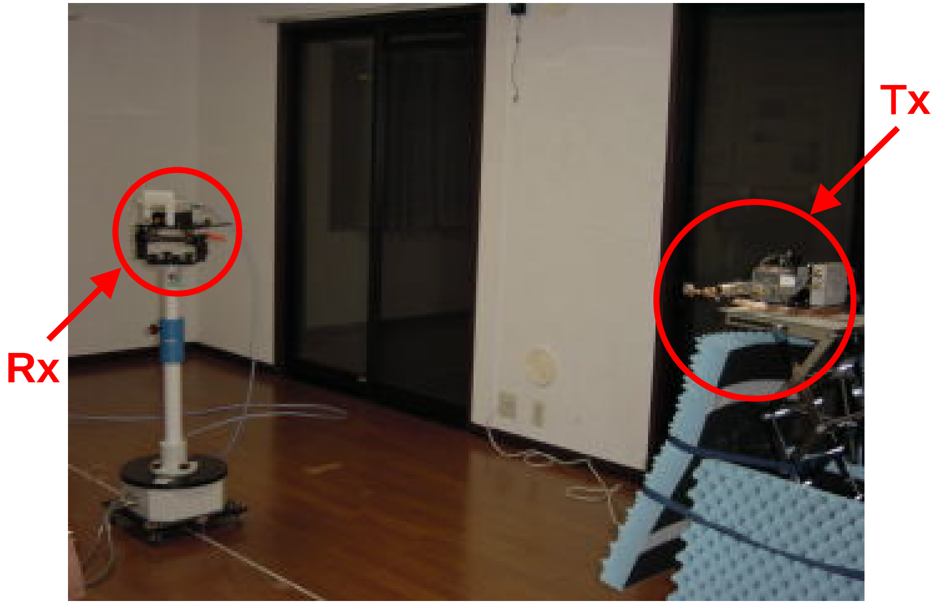
$(\mu_D - 0.3, \mu_D + 0.3)$

Unit [m]

High ΔK can be usually obtained in short range communication

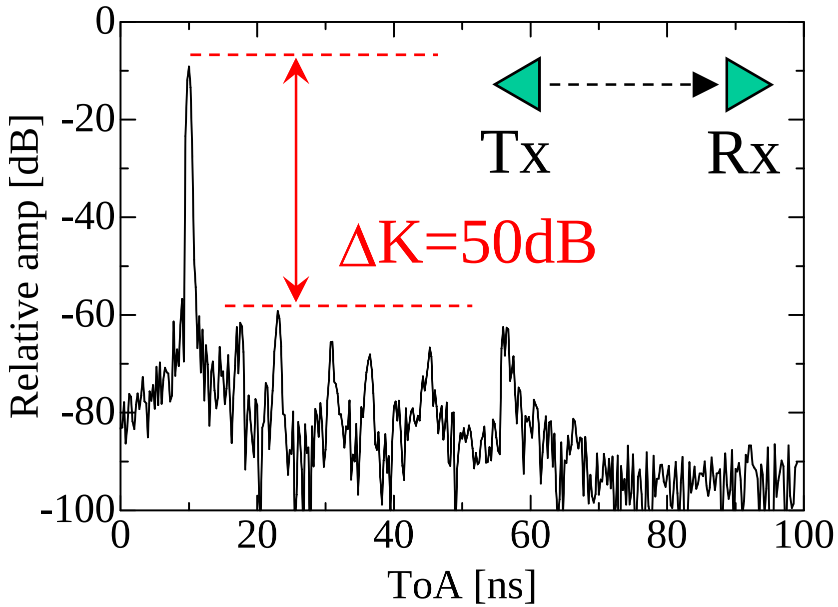
TSV model for LOS residential environments

- TSV model can be applied in any LOS environment
- TSV model parameters for LOS residential environments can be obtained since we have measurement data (06/012)



Residential environment

Large ΔK for LOS environment with high directivity antenna



LOS Residential (NICT data)
Tx: 15 deg Rx: 15 deg

Antenna beamwidth	Max. ΔK[dB]
Tx:15, Rx:15	50.0
Tx:30, Rx:15	39.2
Tx:60, Rx:15	35.4
Tx:Omni, Rx:15	38.7

ΔK is very large in LOS environments with directional antenna

The effect of S-V model response is decreasing in LOS environment

Conclusion

- TSV model is well expressing LOS desktop environments
- Characteristics of variable ΔK were clarified
- TSV model with extracted parameters is now available
- TSV model can be applied for any LOS environment
- MATLAB code for TSV model will be available soon

Appendix A: Definition of TSV model

CIR: (Complex impulse response)

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

$$\overline{|\alpha_{l,m}|^2}=\Omega_0 e^{-T_l/\Gamma}e^{-\tau_{l,m}/\gamma},\ \angle\alpha_{l,m}\propto \text{Uniform}[0,2\pi)$$

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

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

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

Arrival rate: Poisson process

$$p(T_l\,|\,T_{l-1})=\Lambda\exp[-\Lambda(T_l-T_{l-1})],\quad l>0$$

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

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
$|\Gamma_0| \cong 1$: Reflection coefficient (incident angle $\cong \pi/2$)

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)

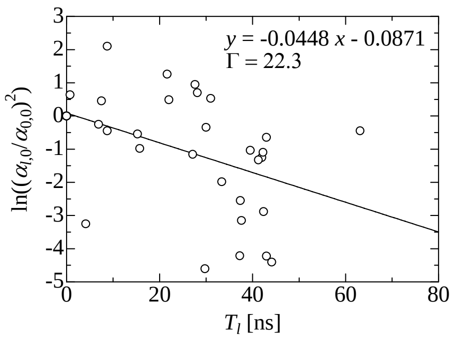
$Gt(\theta,\phi)$: Antenna gain of Tx
$Gr(\theta,\iota)$: Antenna gain of Rx

Rician factor (1)

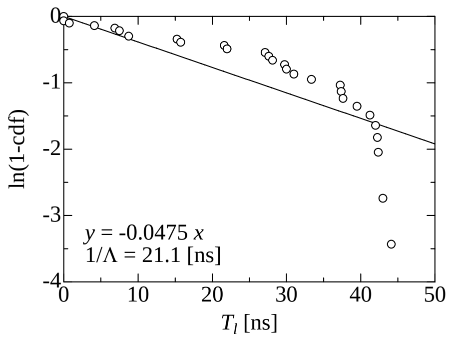
$$K=\frac{\beta^2}{\sum_{l=0}^{L-1}\sum_{m=0}^{M_l-1}|\alpha_{l,m}^2|\,\delta(t-T_l-\tau_{l,m})\delta(\varphi-\Psi_l-\psi_{l,m})G_r(0,\Psi_l+\psi_{l,m})}$$

Appendix B: Results of data analysis

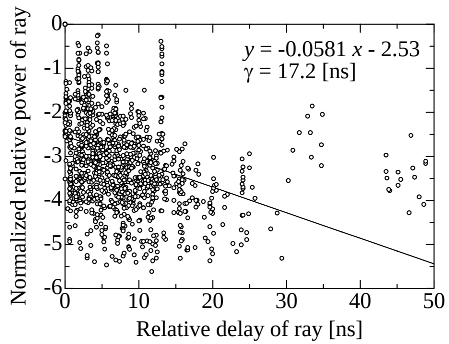
Antenna beamwidth
Tx: 60 deg, Rx: 60 deg



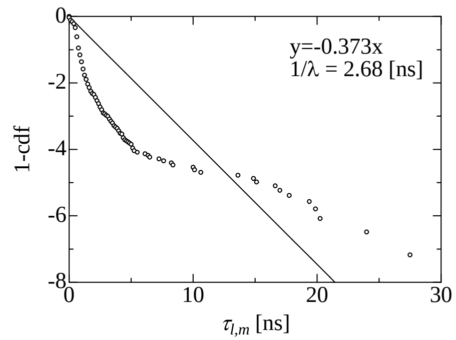
Cluster decay factor (Γ)



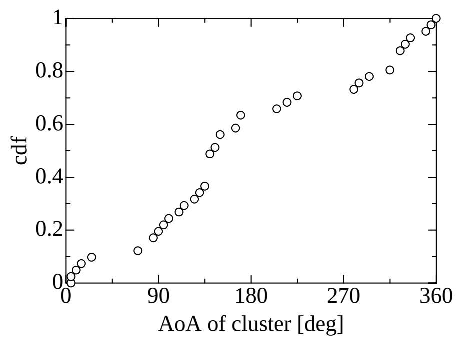
Cluster arrival rate (1/Λ)



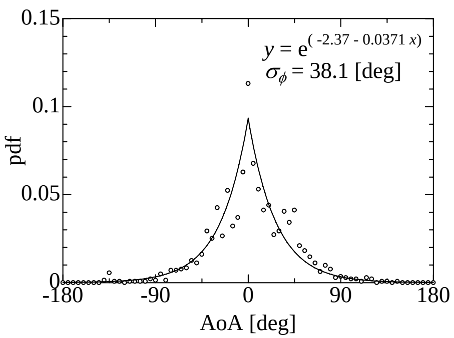
Ray decay factor (γ)



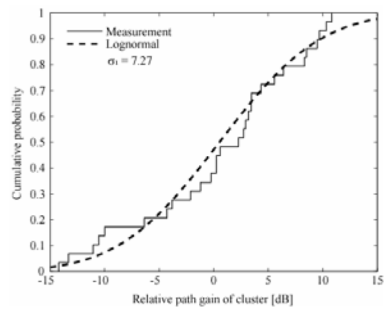
Ray arrival rate (1/λ)



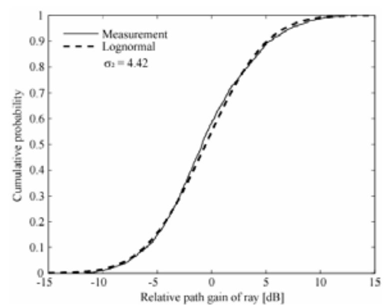
Angle of arrival in cluster (∝Uniform)



Angle spread of ray (σ_ϕ)

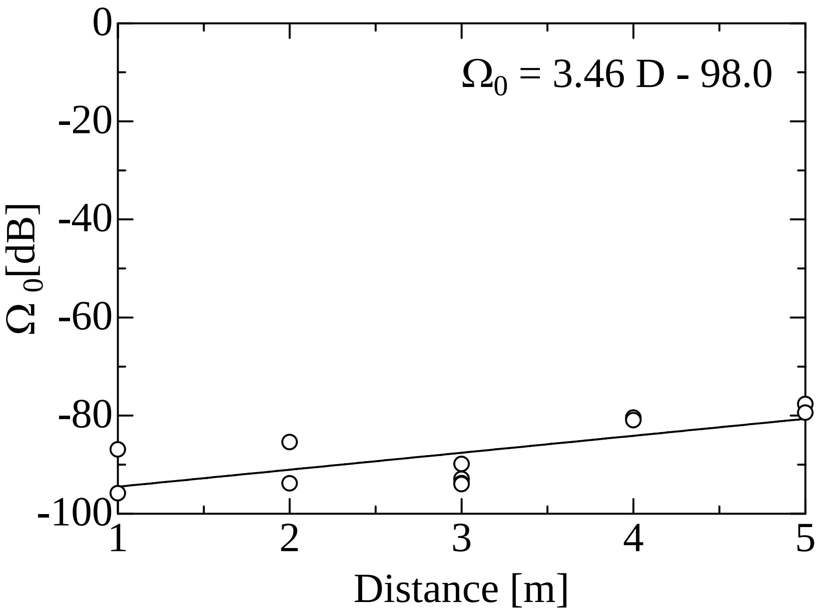


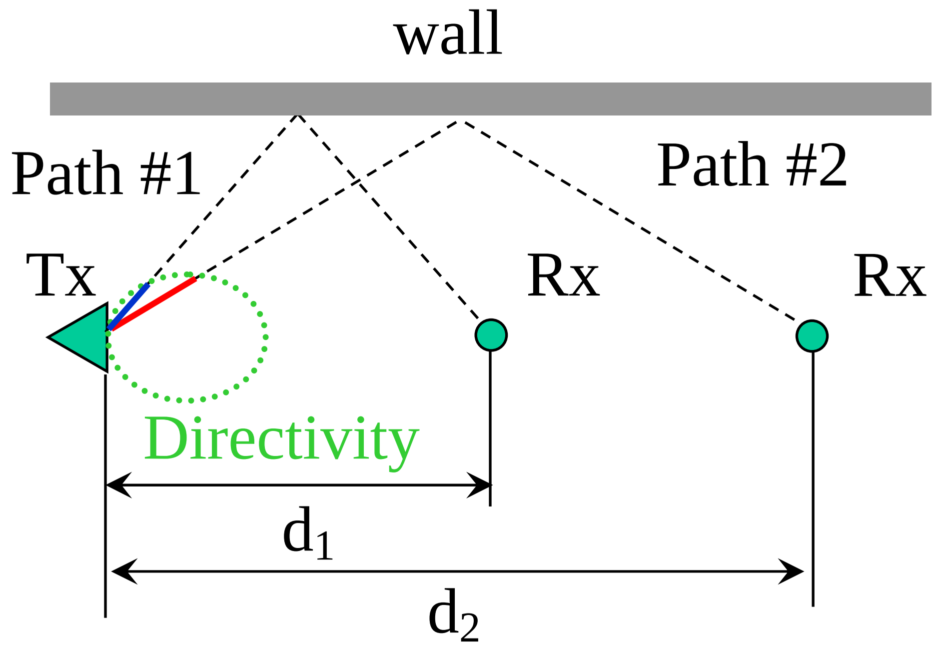
Standard deviation of cluster (σ_1)



Standard deviation of ray (σ_2)

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





- Ω_0 increases due to distance, because directional antenna is used in transmitter
- Conventional S-V model does not consider this effect