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

Submission Title: radio propagation performance of close proximity P2P on 60 GHz band
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Abstract: This document describes measured radio propagation performance of close proximity P2P communication on 60 GHz band for applications of file transfer between CEs, kiosk downloading etc.

Purpose: To discuss radio propagation performance of close proximity P2P on 60 GHz band

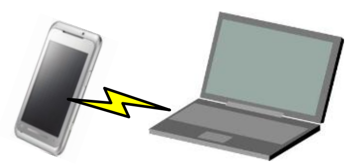
Contents

- **Background for studying channel model in 802.15.3d which focuses close proximity point-to-point, P2P, communication on 60 GHz band**
- **Measurement results of radio propagation performance**
  - **Small form factor antennas**
  - **Antennas are placed inside consumer electronic, CE**

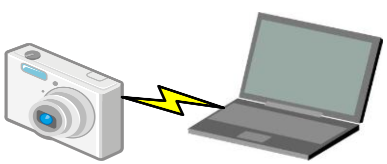
Application Usages and Technical Features on 60 GHz band in 15.3d

- Close Proximity P2P Communication System

Kiosk Download



Mobile Phone Laptop PC



DSC Laptop PC

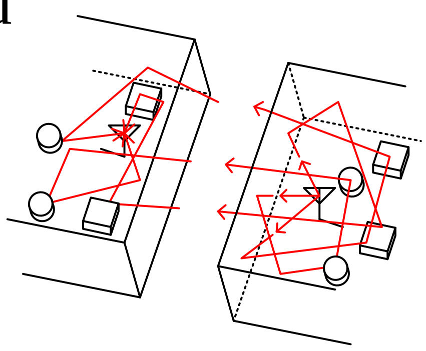
- Technical features
  - **Distance: a few to 5 centimeters** [TBD]
  - Wide unlicensed band: 57 to 66 GHz [TBD]
  - Capability of data-rate: over Gbps to 100 Gbps [TBD]

Ichiro Seto, Toshiba Corporation

Millimeter-wave, mmW, antenna difference

- Conventional radio propagation measurements in 15.3c
  - Reference Antenna : Horn type with FWHM of 30 deg , not small form factor type
  - Transmission distance : more than 1 meter, up to 10 meters

- Close Proximity P2P Communication in 15.3d
  - Applying small form factor antennas to be placed inside CE devices,
    - Tendency of wide-angle radiation
  - Transmission distance : a few to 5 centimeters



mmW antenna of small form factor

- Antenna Type for Single-Input-Single-Output
  - **Wire like monopole, dipole, loop**
  - **Planer like patch**
  - Directional like Horn
  - Slot
- Antenna Radiation Performance we should consider
  - Polarization
    - Horizontal, Vertical, Circle
  - Directivity
    - Full width of half maximum, FWHM
    - Forward / backward
  - Obstacles between TX and RX
    - With metal or without metal which belongs to CE chassis

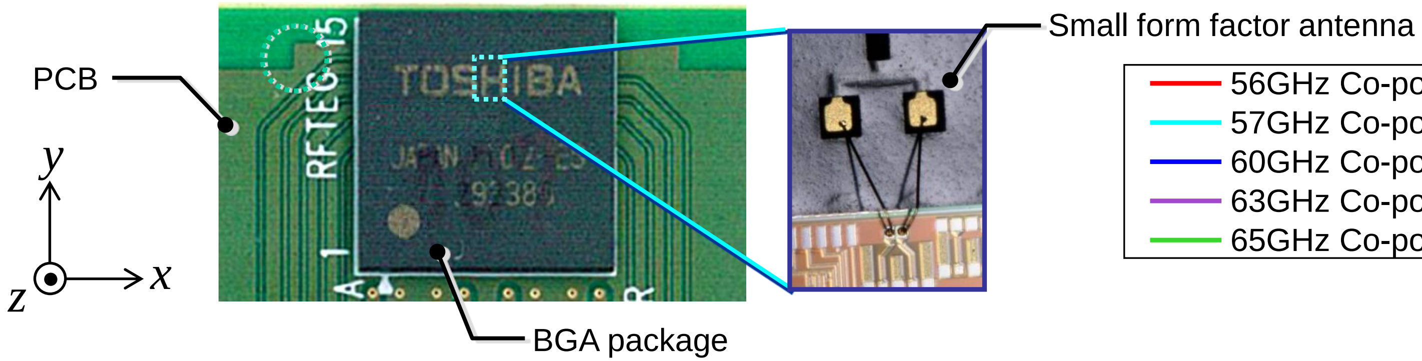
To Study Channel model in 15.3d on 60 GHz band

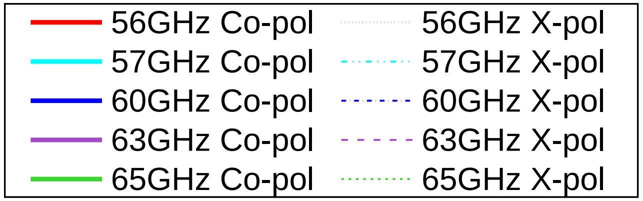
- We should confirm radio propagation performance in close proximity P2P communication concerning
  - Antenna of small form factor like wire or planer type
  - The effects of CE chassis or reflections in CE
  - Transmission distance of a few to 5 centimeters

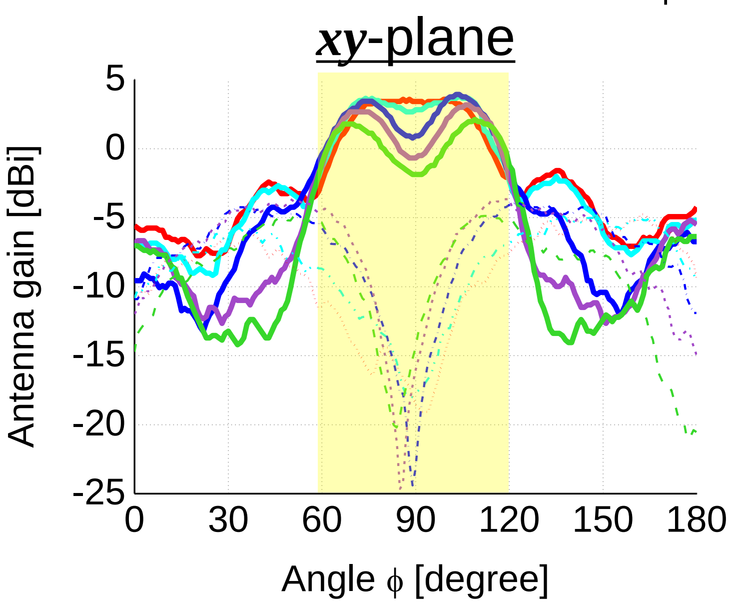
- We show our measurement results in close proximity P2P communication using
  - Loop antenna of wire type
    - FWHM : 60 deg. of forward and backward radiation
  - Antennas are placed inside CE with/without metal chassis
  - Transmission distance of a few centimeters

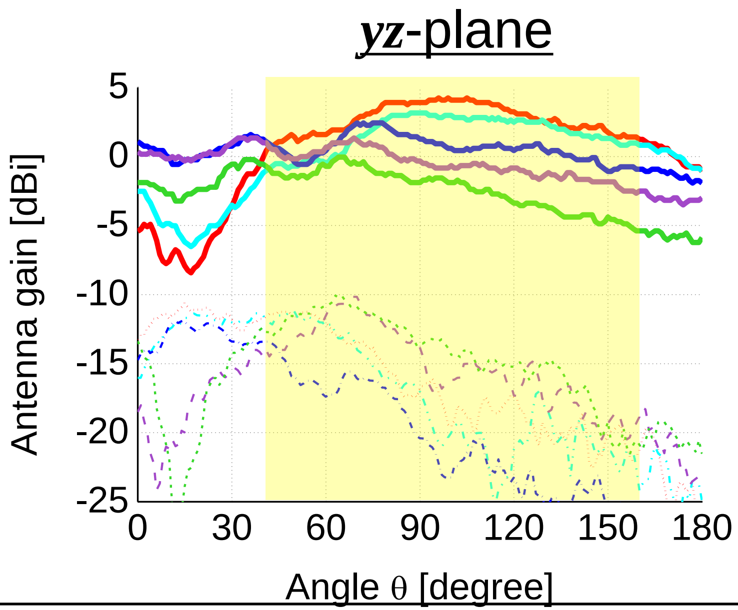
Antenna Type and Radiation Pattern

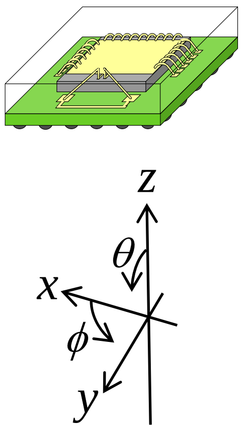
- Loop antenna of wire type having wide-angle radiation





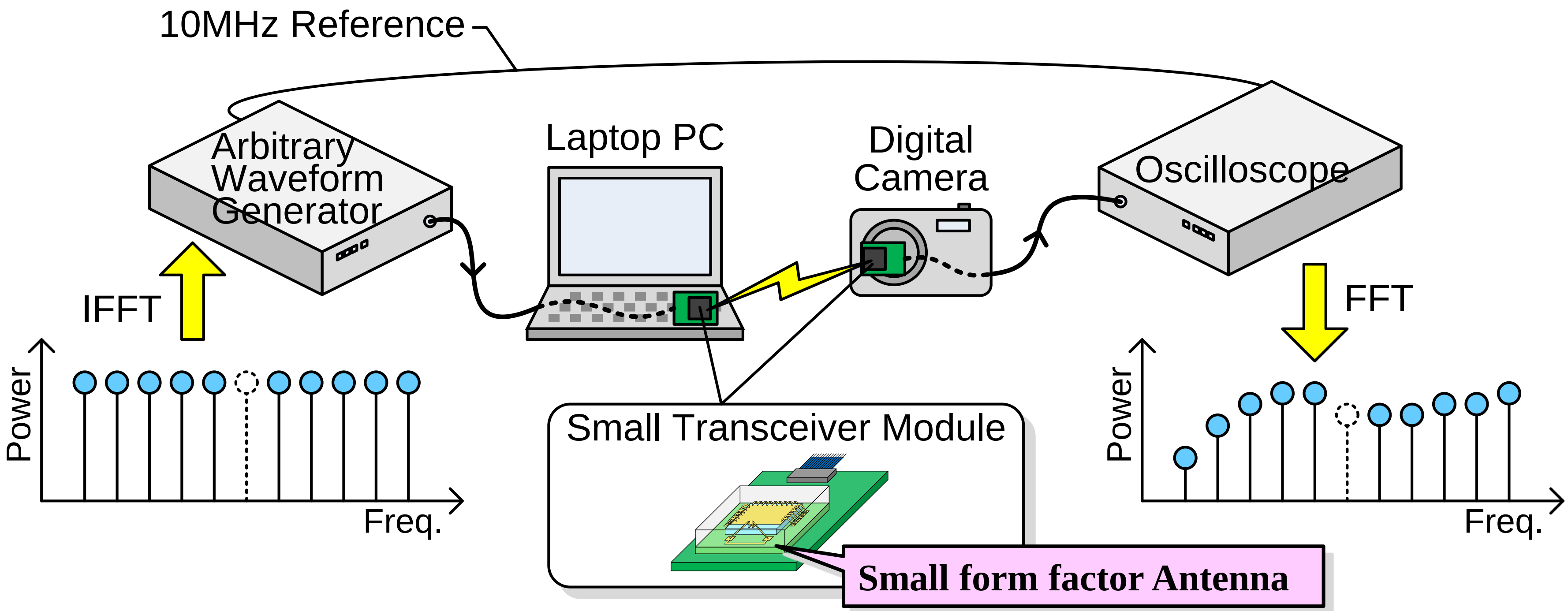






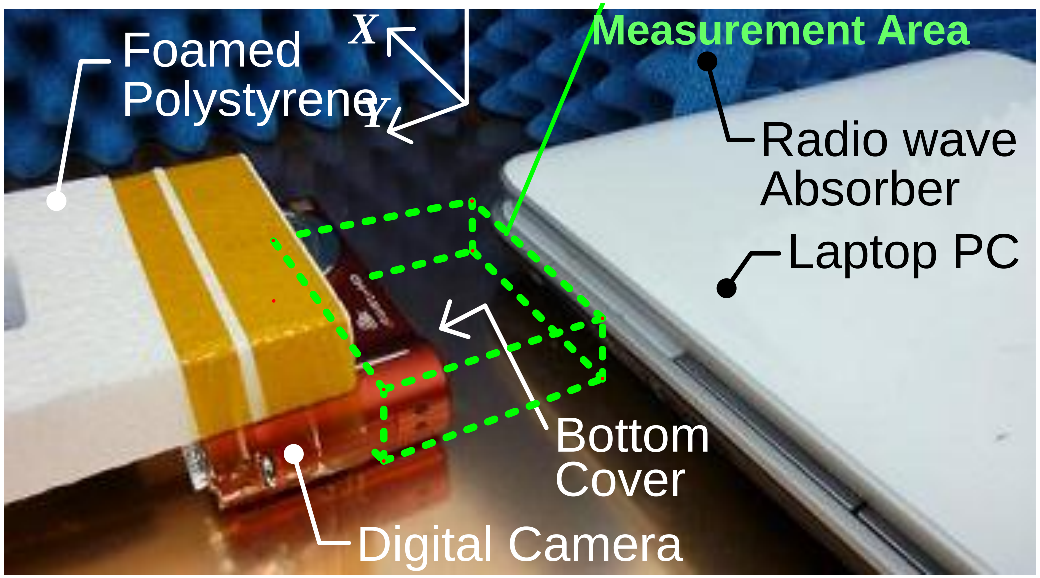
Measurement Setup

- The LSIs having small form factor antennas are placed inside CEs.
- OFDM signals generated by AWG are transmitted via this 60 GHz close proximity channel, and sampled by an oscilloscope.
- By using IFFT to measure 10GHz band frequency spectra, Power Delay Profiles (PDP) with about 0.1nsec resolution are obtained.



Measurement Conditions

- Laptop-PC (for Tx) is fixed on metal desk.
- Digital Camera (for Rx) is moved in the measurement area.
  - Distance(Y) : 10 ~ 40 mm
  - Horizontal (X) and Vertical offset : -15 ~ +15 mm and 0 ~ 6 mm
- Under conditions with or without metal on the cover of CE chassis
- Under condition with antenna polarization align



(a) A Digital Camera and a Laptop PC

(b) with metal on the cover

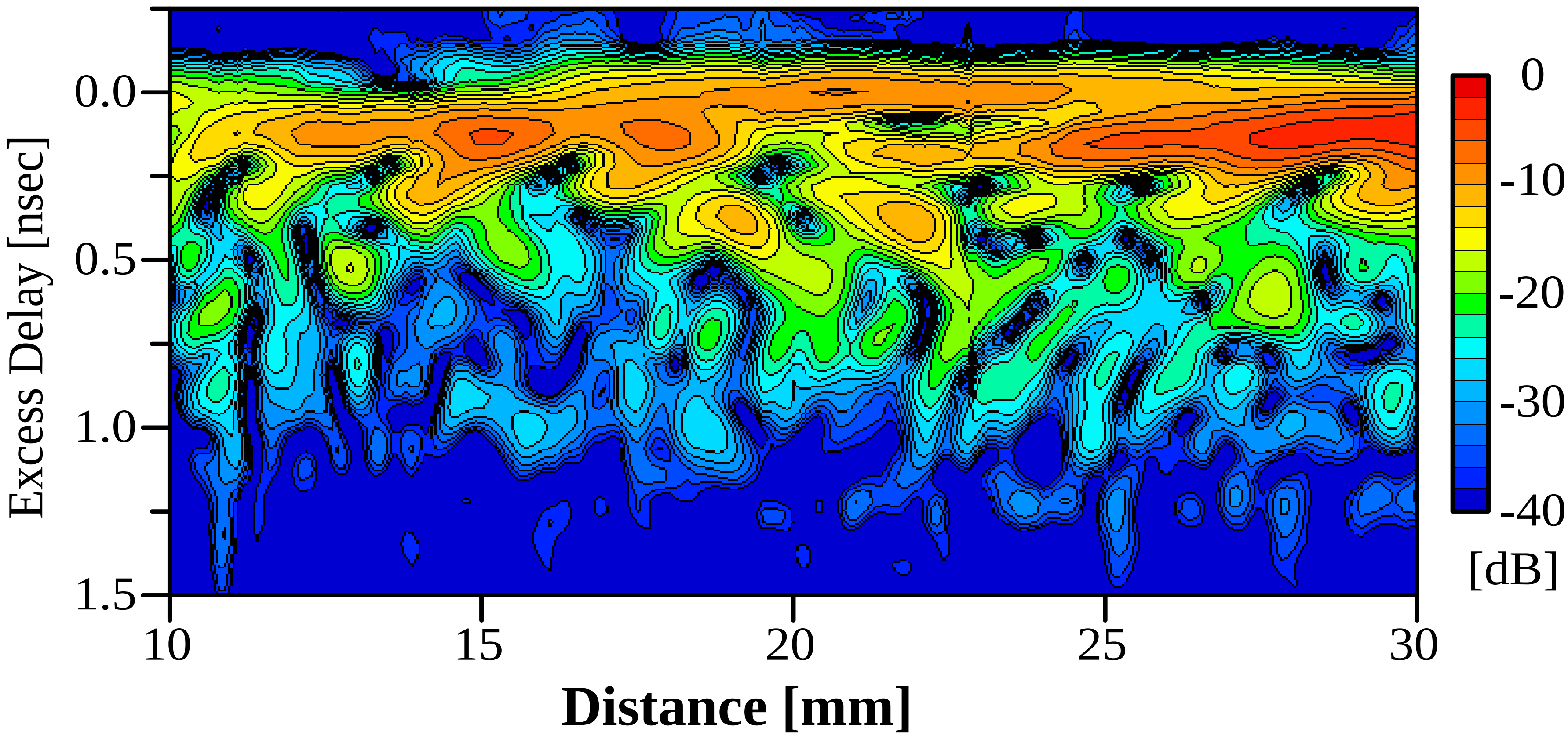
(c) without metal on the cover

Parameters of Measurements

Frequency range	56-66 GHz
Frequency step	15.625 MHz
Tx power	0 dBm
Tx electronic device	Laptop PC
Rx electronic device	Digital camera with and without metal on cover
Measurement range	X: -15~15 mm, Y: 10~40 mm, Z:0~6 mm
Measurement step	0.1 mm, 1.5 mm
Antenna polarization	Horizontal polarization

Example of measured PDP

- Fading in a cycle of about a half wavelength is observed. There are a lot of reflections at devices and a desk.



Averaged Power Delay Profiles (PDP)

- Averaging measured *N* PDPs with

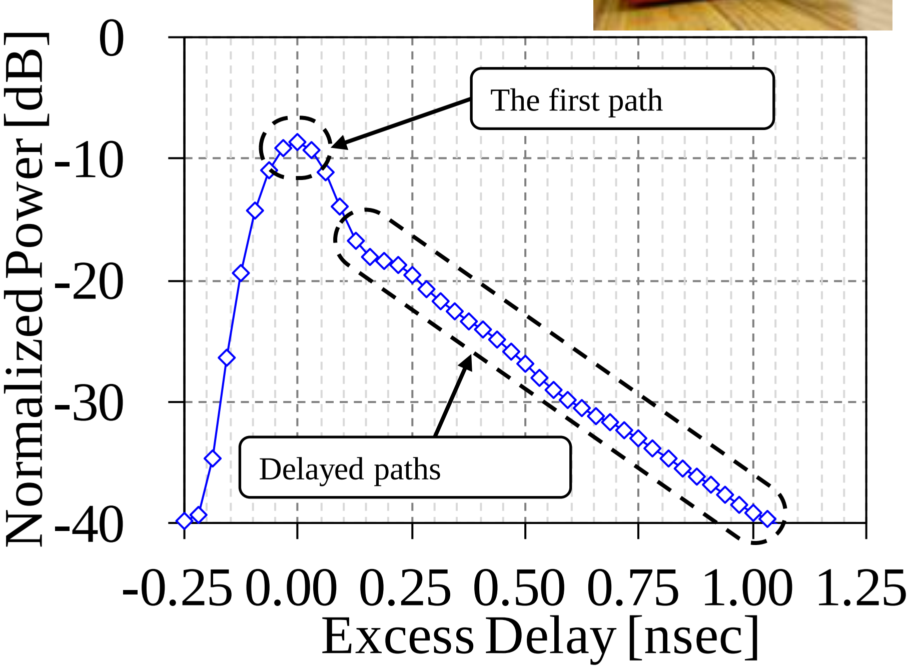
$$\frac{1}{N}\sum_{n=1}^{N}\frac{1}{L_i}P_i\left(t-T_i\right)$$

$P_i(t)$ PDP at *i*-th meas. point.

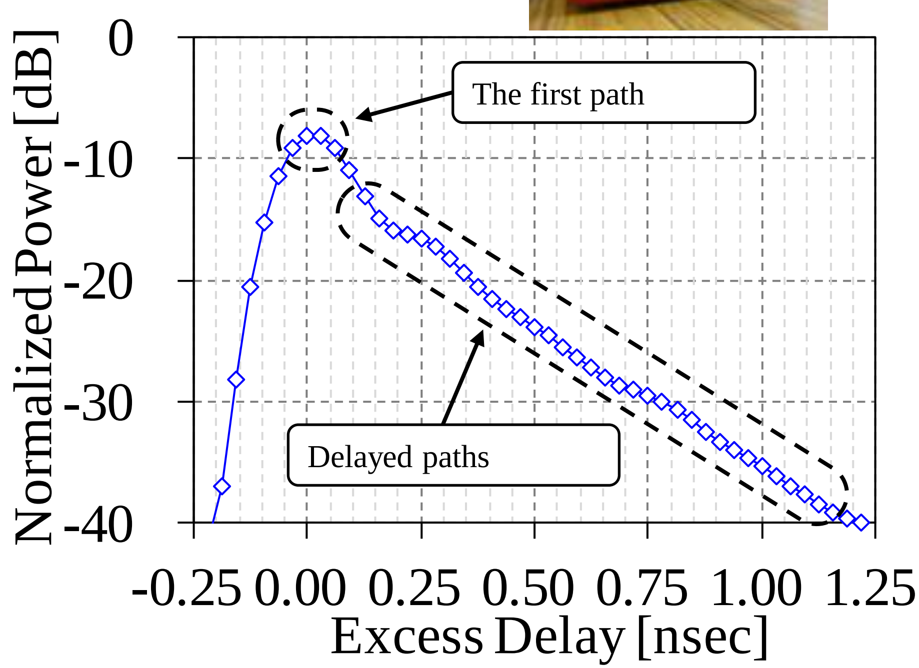
T_i Theoretical delay at *i*-th meas. point.

L_i Theoretical propagation loss at *i*-th meas. point.

Without metal cover

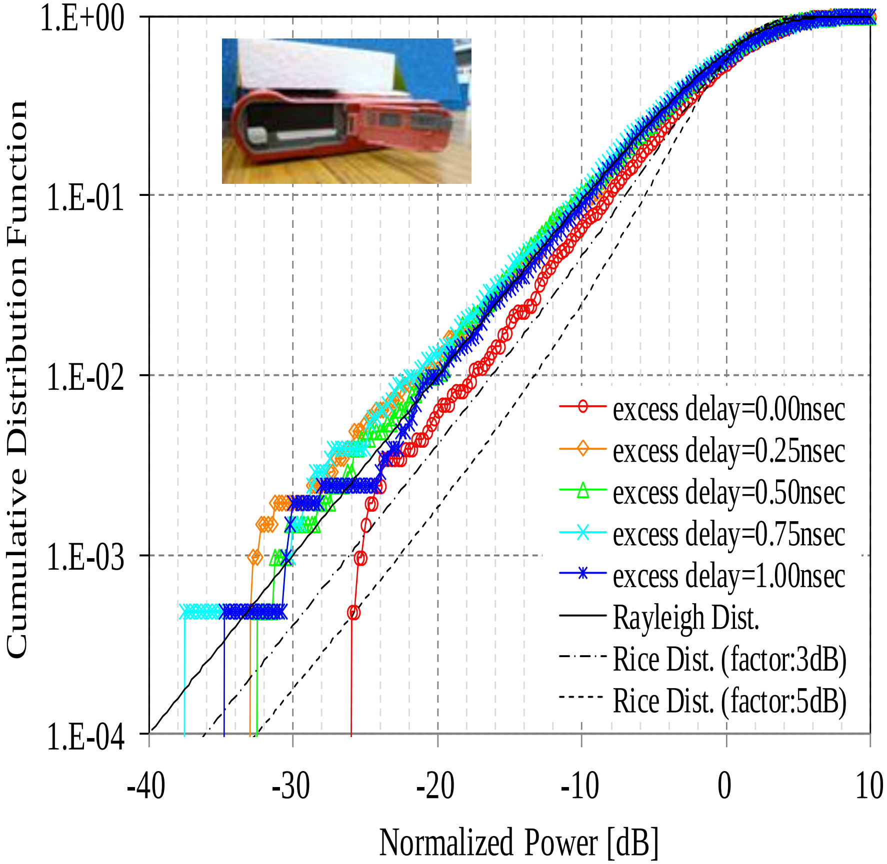


With metal cover

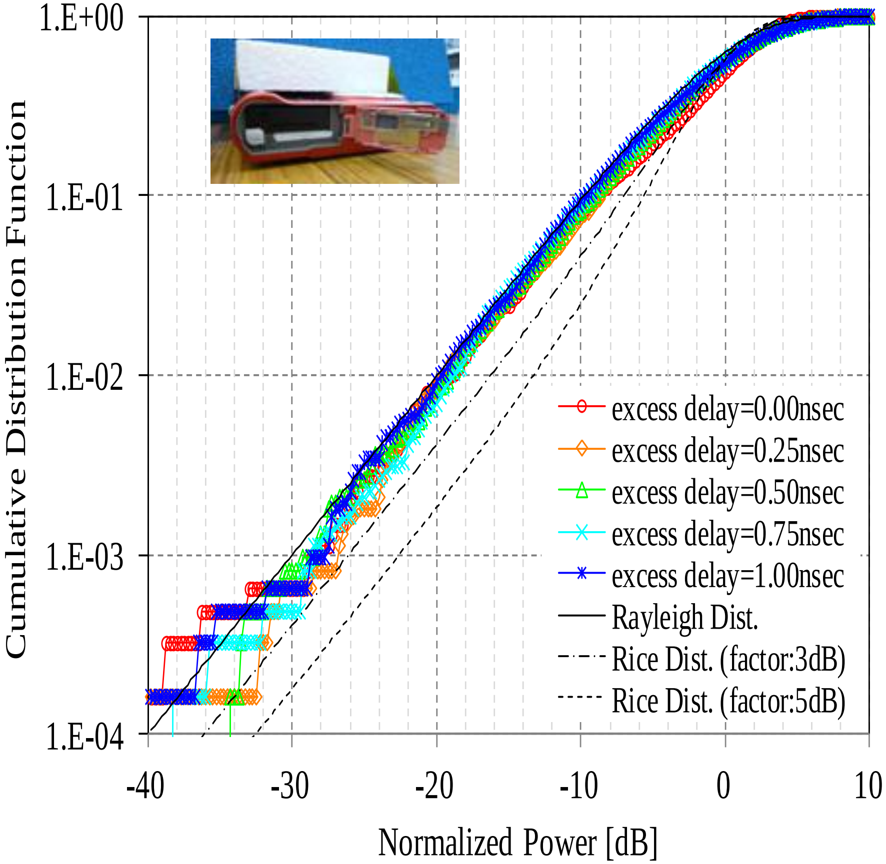


Cumulative Distribution Functions of Each Path Power

Without metal cover

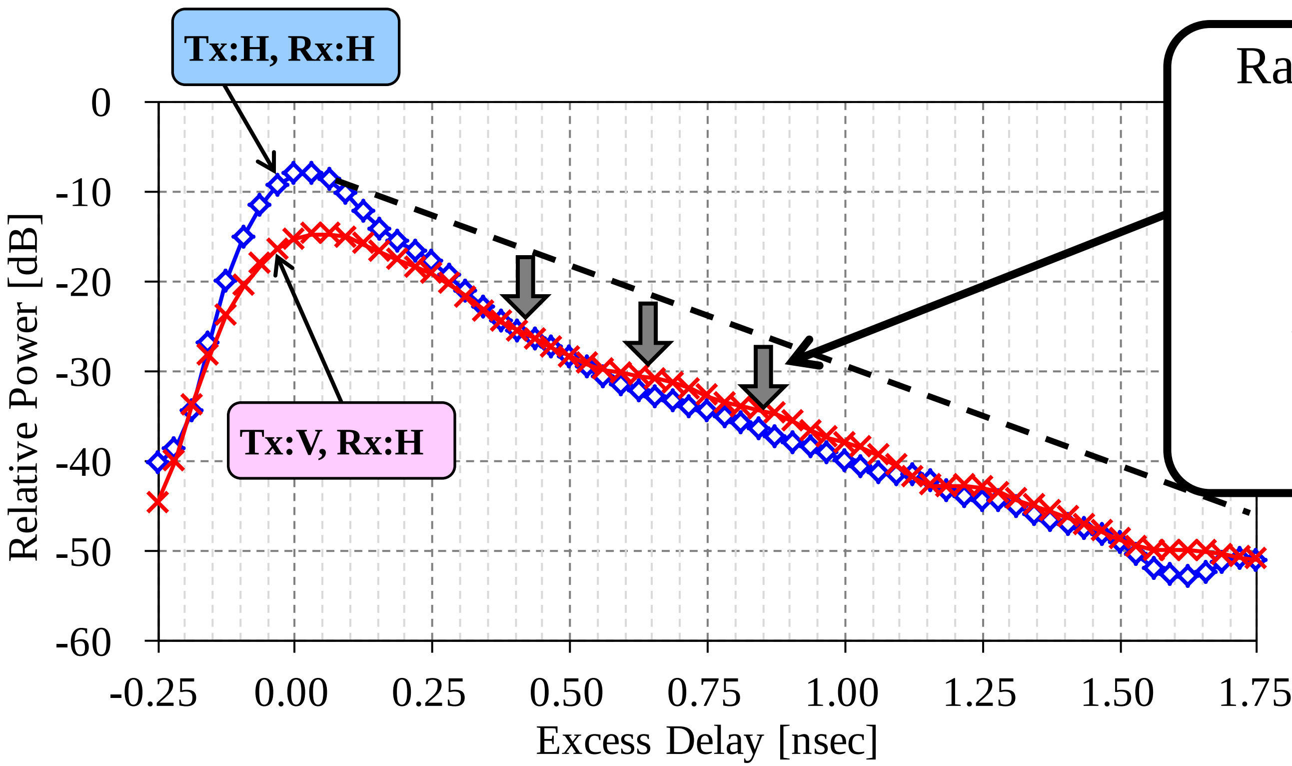


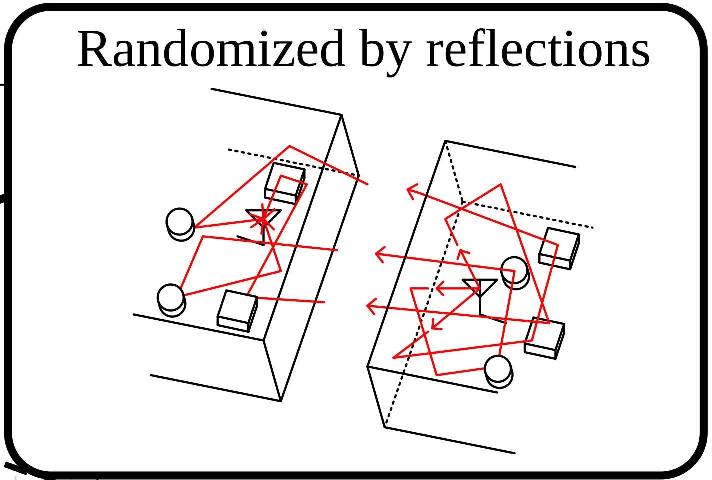
With metal cover



- Delayed Paths : Rayleigh Distribution.
- The first path : Rice or Rayleigh Distribution.

Polarization randomization





0.25nsec => 75mm

PDP Gap exists on the first path. Two PDPs converge over 0.25nsec.

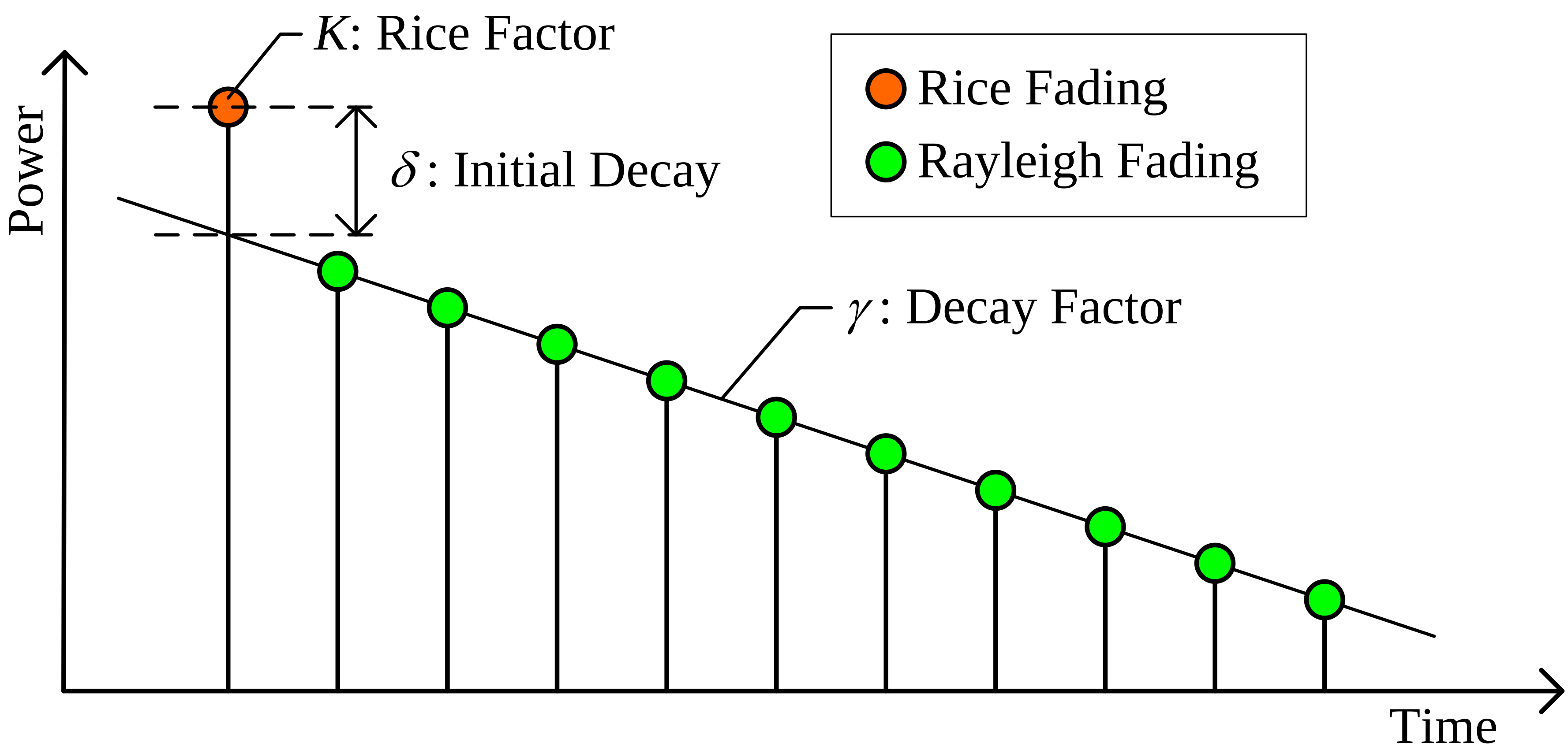
Radio wave polarization is sufficiently randomized on reflections over 0.25nsec inside devices,

Channel Model Idea

$$E\left[|\alpha_n|^2\right] = \begin{cases} 1, & n = 0 \\ 10^{-\delta/10} \cdot e^{-t_n/\gamma}, & 1 \le n \le N-1 \end{cases}$$

α_n : amplitude of ***n***-th path

t_n : delay of ***n***-th path



Calculation of initial decay δ

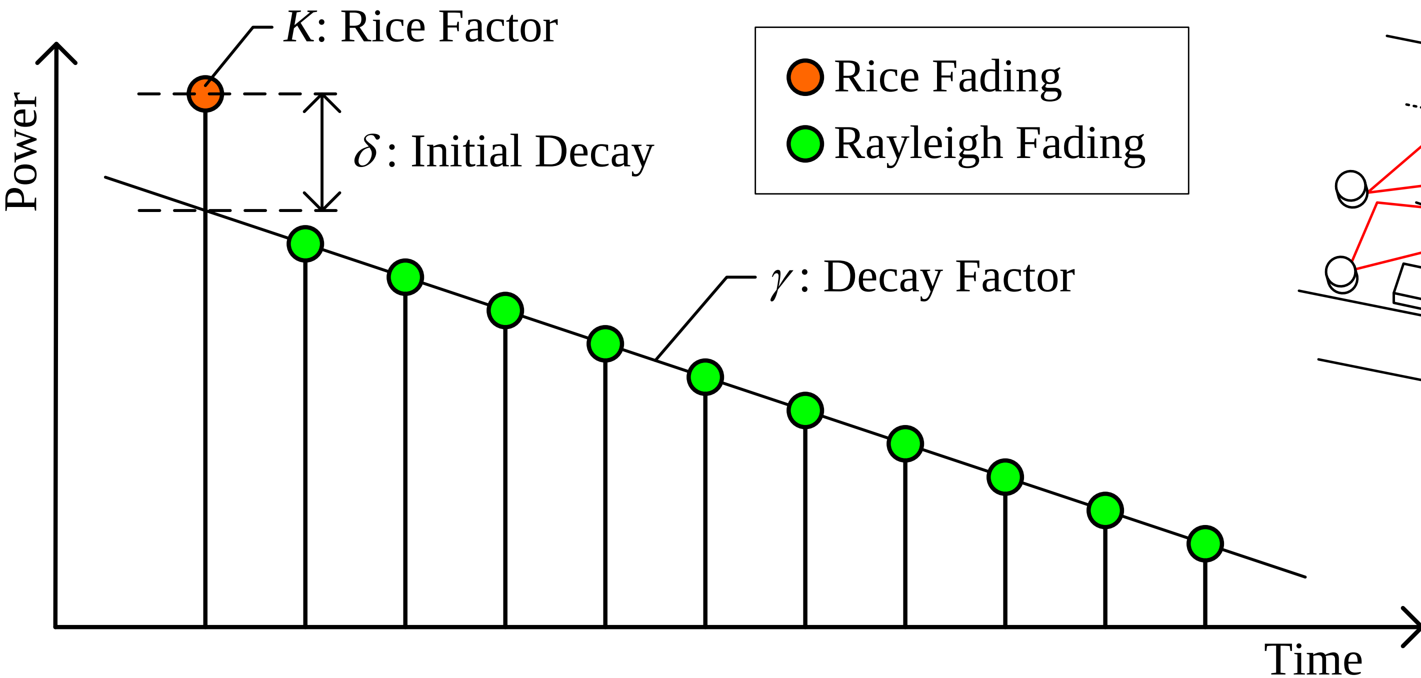
$$\delta = 10 \cdot \log_{10} \frac{\left(G_{Rx,V} G_{Tx,V} + G_{Rx,H} G_{Tx,H}\right)\left(1 + 10^{K/10}\right)}{G_{Rx,V}\left(\frac{G_{Tx,V} + G_{Tx,H}}{2}\right) + G_{Rx,H}\left(\frac{G_{Tx,V} + G_{Tx,H}}{2}\right)}$$

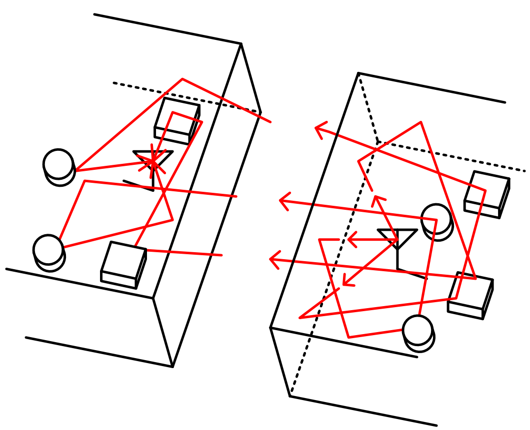
Numerator: Not de-polarized

Denominator: Sufficiently de-polarized

$G_{Tx,H}, G_{Rx,H}, G_{Tx,V}, G_{Rx,V}$: Antenna gain in linear scale for H/V and Tx/Rx.

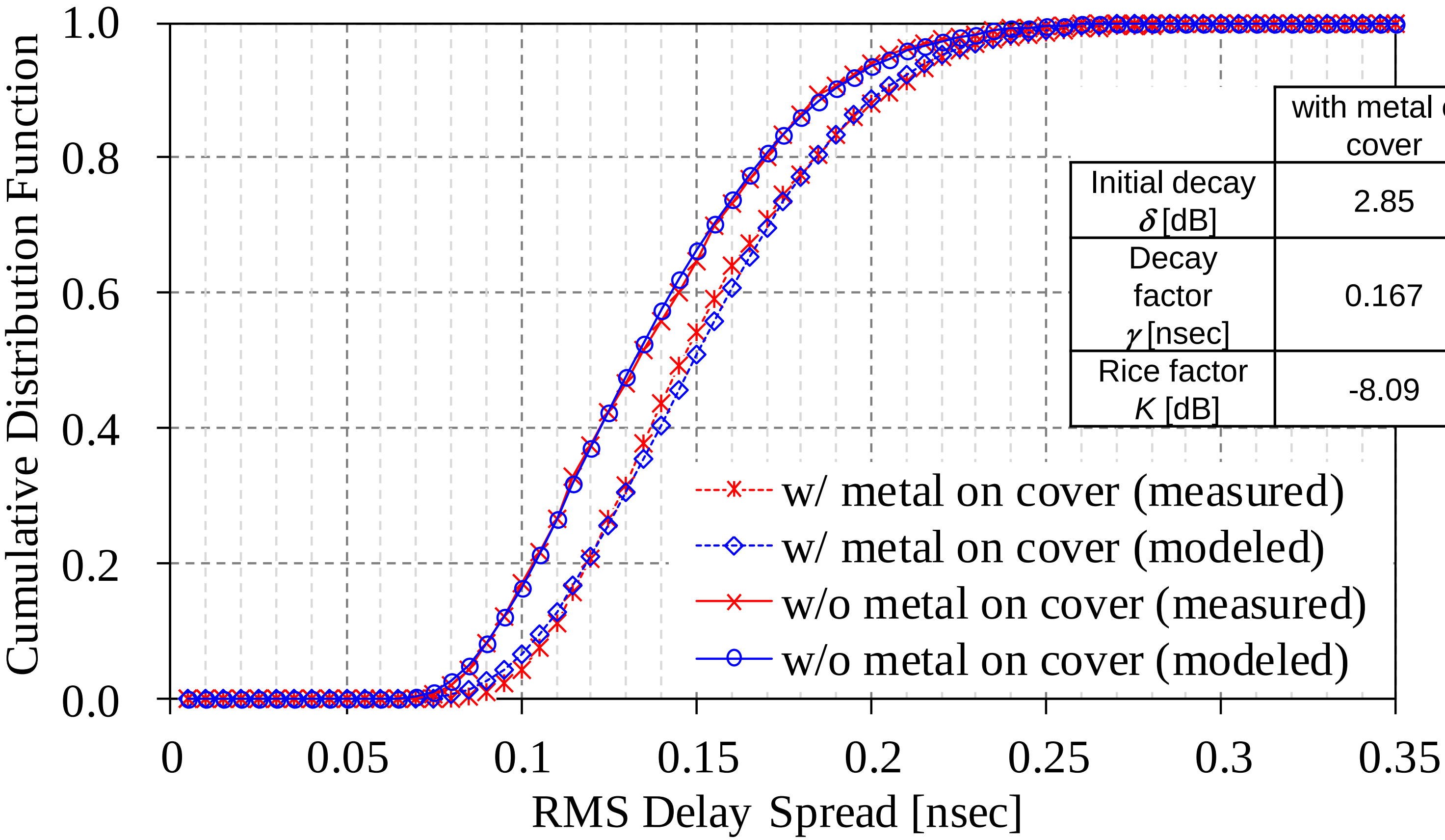
K : Rice Factor





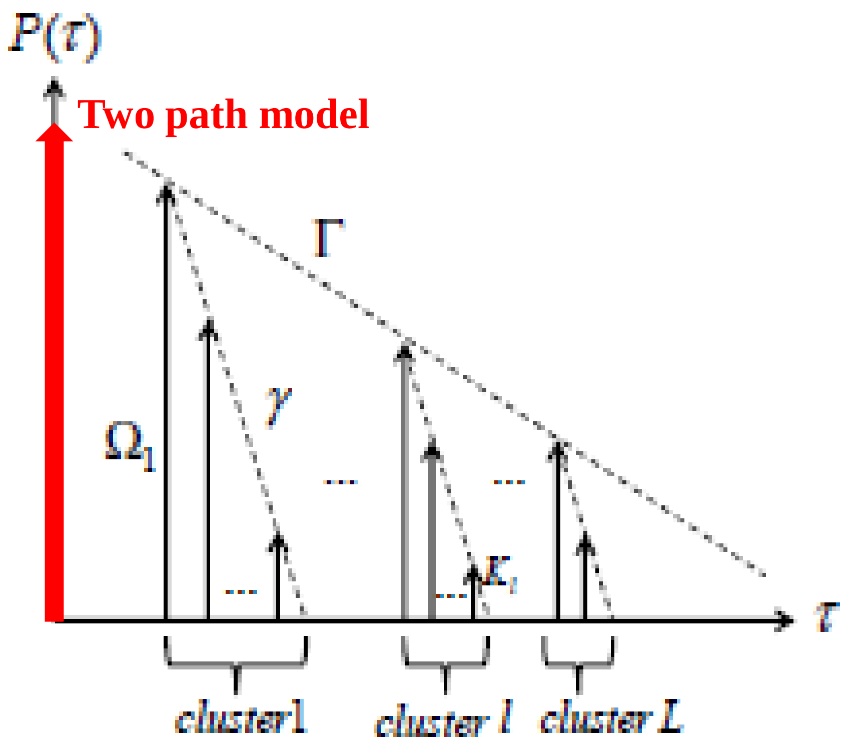
Evaluation of channel model idea

- RMS delay spread were compared by computer simulations.
- We confirmed the proposed model excellently fit the measured data.

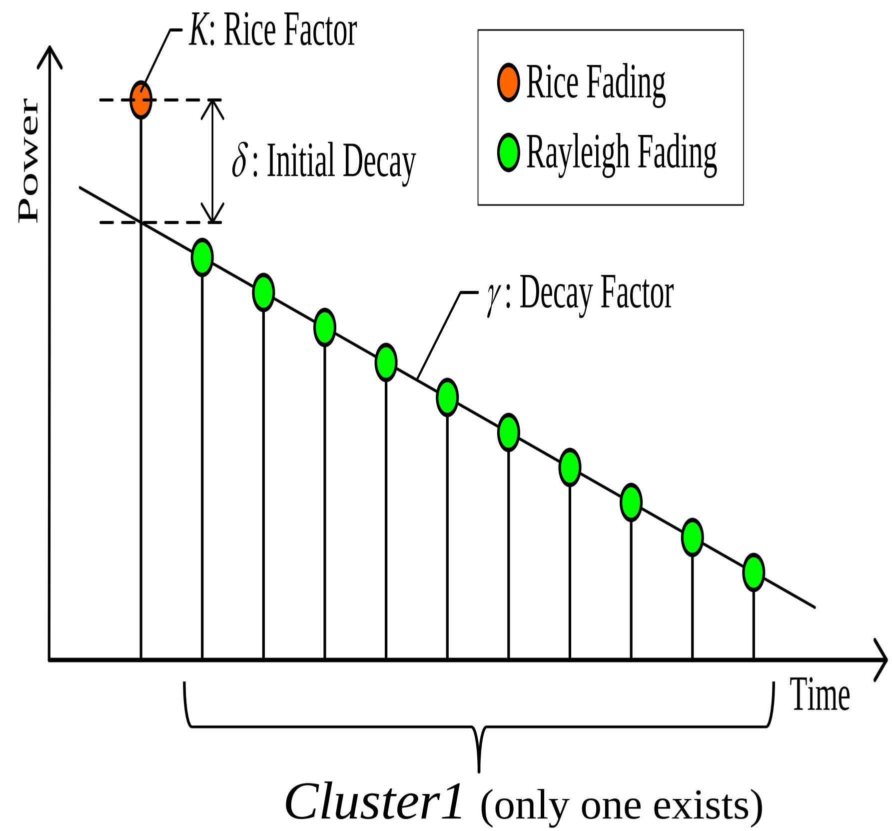


	with metal on cover	without metal on cover
Initial decay δ [dB]	2.85	5.04
Decay factor γ [nsec]	0.167	0.165
Rice factor K [dB]	-8.09	-0.41

Channel model difference



TSV Channel model in 15.3c



Channel model idea in 15.3d
for close proximity P2P communications

Conclusion

- We show measured radio propagation performance
  - with small form factor antenna of wide-angle radiation characteristics
  - Close proximity channel with the effects of CE chassis and desktop
- Measured channel model
  - confirmed that the assumed model excellently fit the measured data
- Channel model
  - We think that new channel model should be defined for close proximity P2P communication on 60 GHz band in 15.3d
  - Further works in 15.3d
    - Define radio propagation environment
    - Study other antenna cases as reference