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

Submission Title: [VLC channel measurement in indoor application]
Date Submitted: [10 July, 2008]
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Abstract: [The overview of the visible light communication (VLC) channel measurement and its measured results. The measured impulse responses are compared with the simulation results.]

Purpose: [Contribution to IEEE 802.15 SG-VLC]

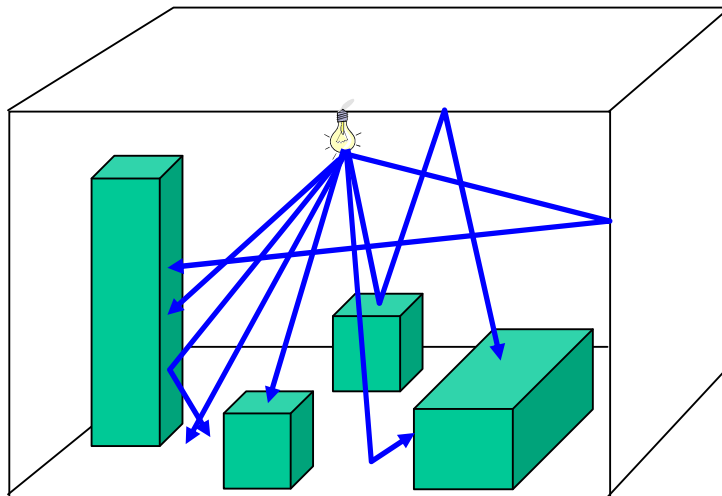# VLC channel measurement in Indoor applications

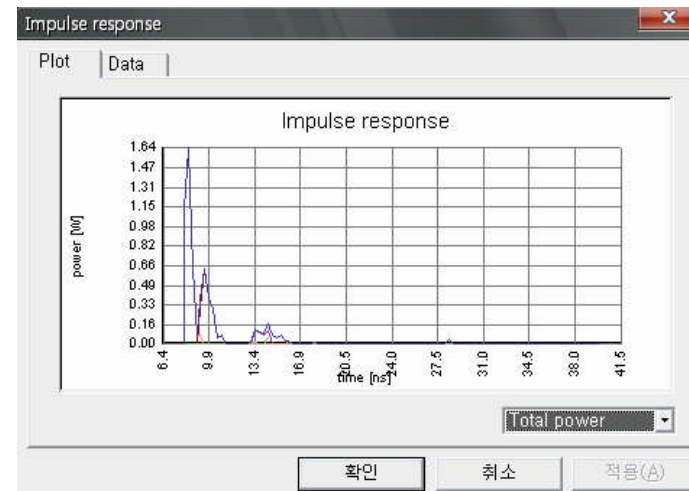## 2008.07.15

Samsung Electronics

Contents

- Introduction
- VCL channel measurement system
  - System configuration
  - Principle of impulse response measurement
  - Measurement environment & scenario
- VLC channel measurement results
  - PN code correlation
  - Impulse response
- Conclusion

Introduction

- – Samsung presented "VLC channel modeling simulation" in the previous meeting.
- – It showed the impulse response results at indoor environment.
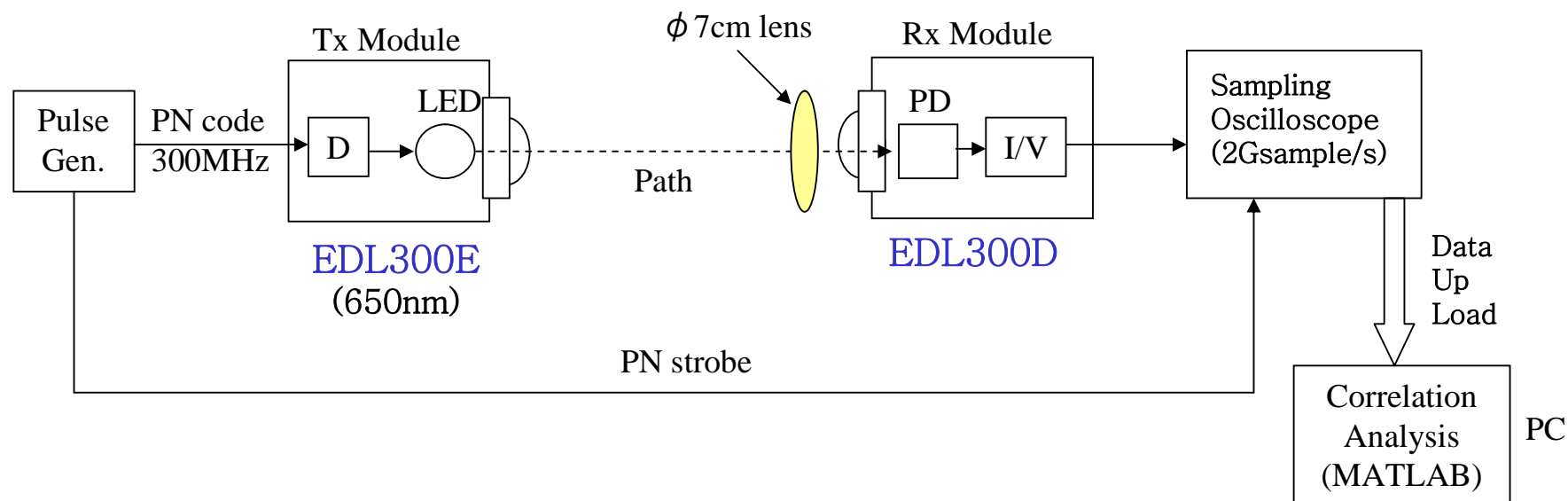- – We had some light propagation measurements for confirming the validity of the simulation.

Simulation Model

Impulse Response

Measurement system configuration

Tx Module

ϕ 7cm lens

Rx Module

| Pulse Gen. | PN code 300MHz | D → LED | Path | | PD → I/V | Sampling Oscilloscope (2Gsample/s) |

EDL300E
(650nm)

EDL300D

Data Up Load

PN strobe

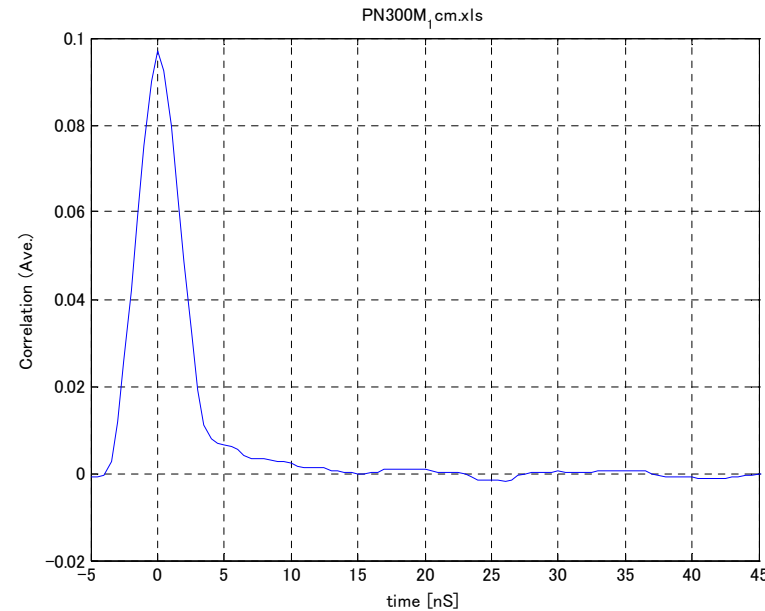Correlation Analysis (MATLAB)

PC

- RC LED and PIN−PD are used for high speed modulation
- PN (Pseudo−Noise) code is sent from Tx with 300MHz code rate
- Received data is sampled by Oscilloscope and analyzed on PC
- PN strobe is used for timing synchronization
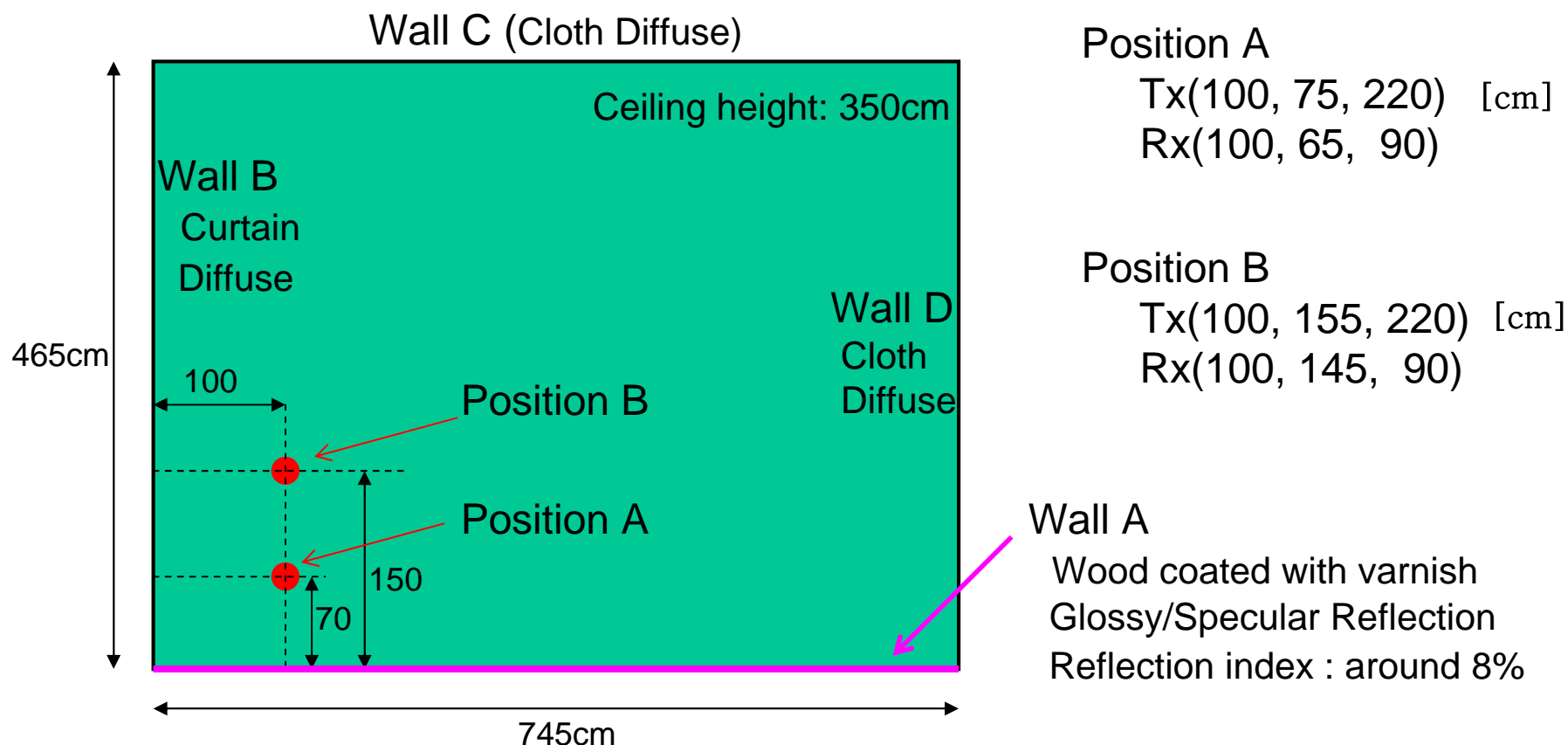
Principle of Impulse response measurement

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PN300M$_1$cm.xls

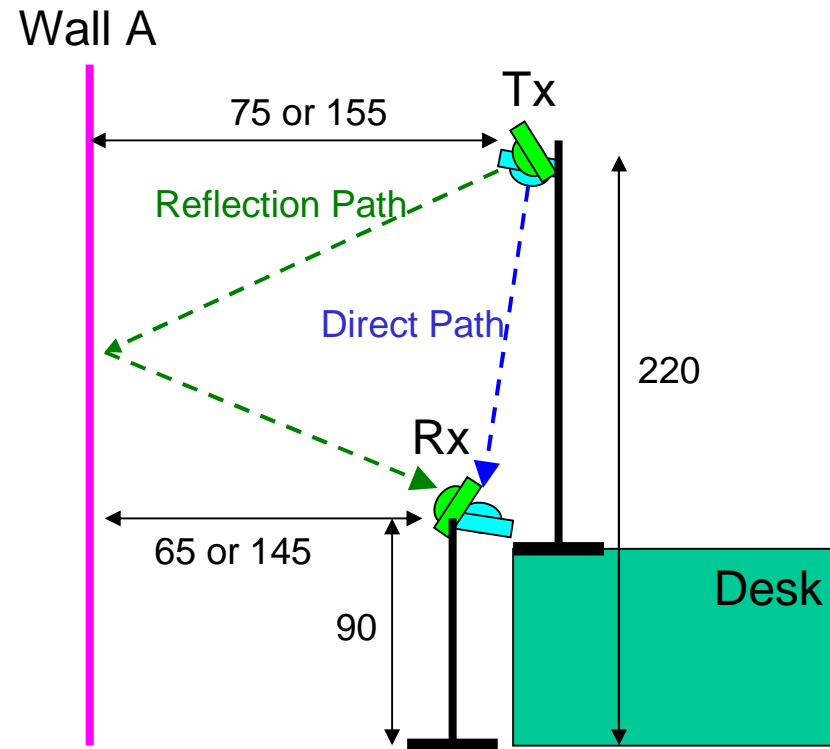Wave form of received PN code   Correlation with PN code

- 'Impulse response' is obtained by calculating the correlation with PN code.
  - The resolution of 'impulse response' is 3.3nS at 300MHz PN code rate.
  - PN code: M sequence (Length : 127, Period : 423nS)

Measurement Environment

Wall C (Cloth Diffuse)

Ceiling height: 350cm

Wall B
Curtain
Diffuse

Wall D
Cloth
Diffuse

465cm

100

Position B

Position A

150

70

745cm

Position A
Tx(100, 75, 220) [cm]
Rx(100, 65, 90)

Position B
Tx(100, 155, 220) [cm]
Rx(100, 145, 90)

Wall A
Wood coated with varnish
Glossy/Specular Reflection
Reflection index : around 8%

Measurement Scenario

Wall A

Tx

75 or 155

Reflection Path

Direct Path

220

Rx

65 or 145

Desk

90

The angles of Tx, Rx are adjusted for measuring the each propagation path.

Directed Light
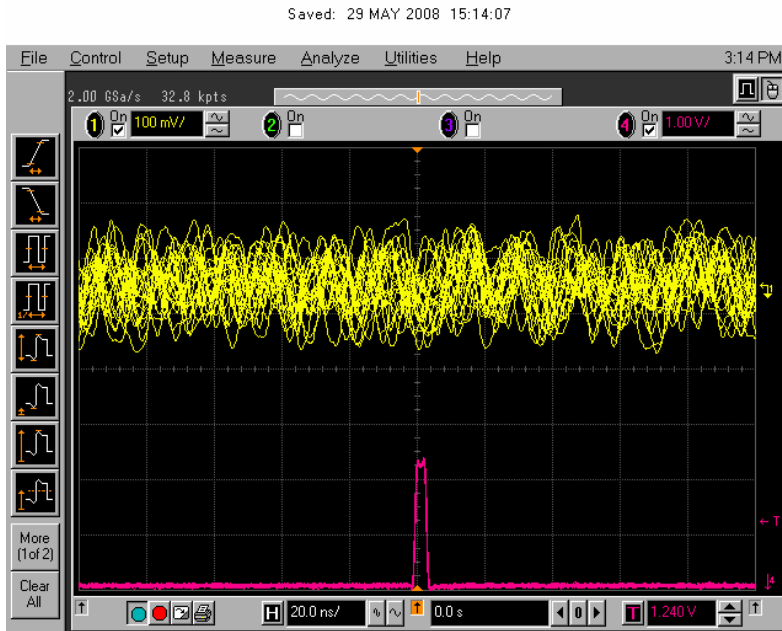

Wave form of received PN code
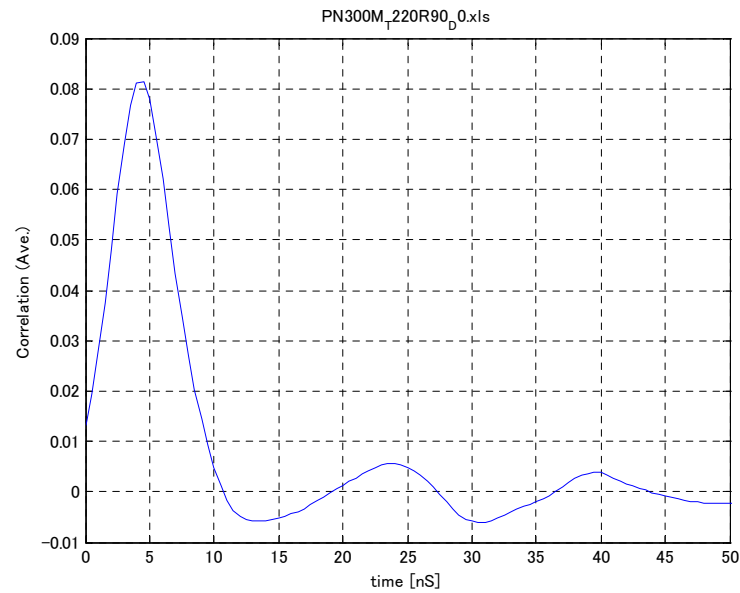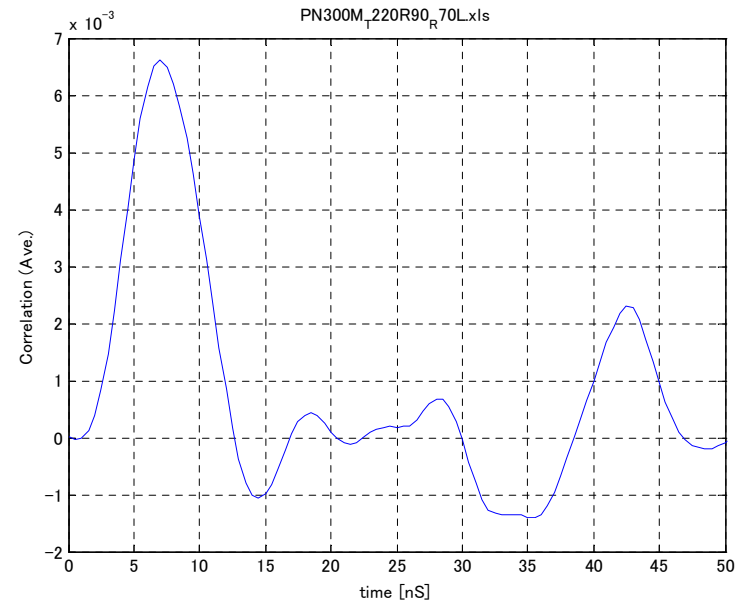

Correlation with PN code

Position A
Tx (100, 75, 220), Rx(100, 65, 90)
PN (300MHz, 127)
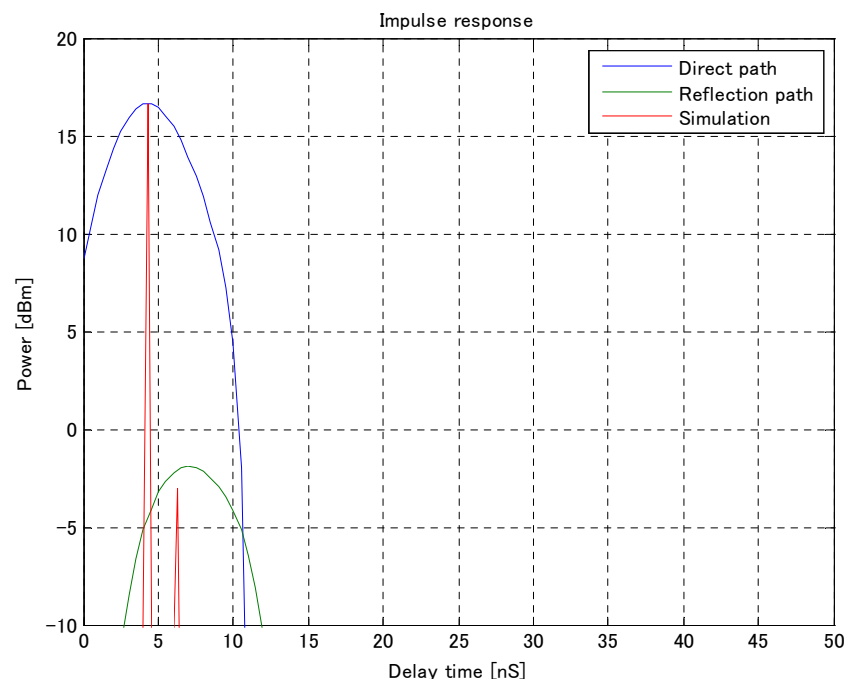
Reflected Light

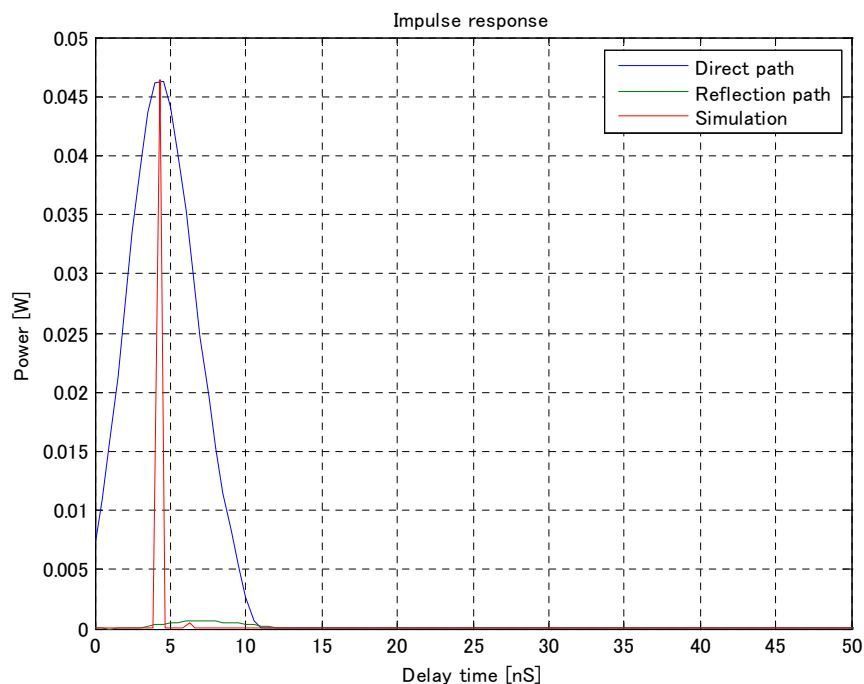Wave form of received PN code

Correlation with PN code

Position A
Tx (100, 75, 220), Rx(100, 65, 90)
PN (300MHz, 127)

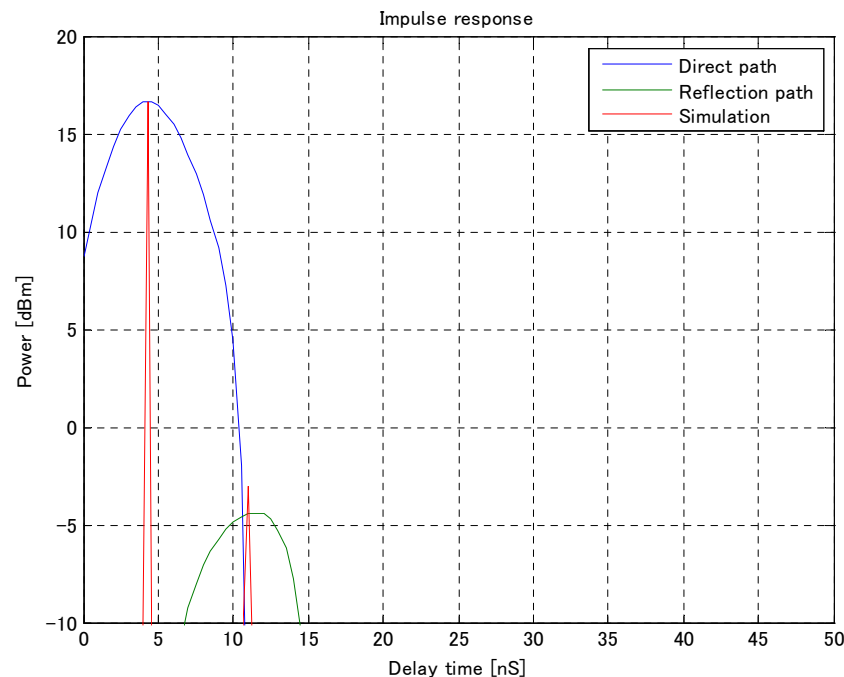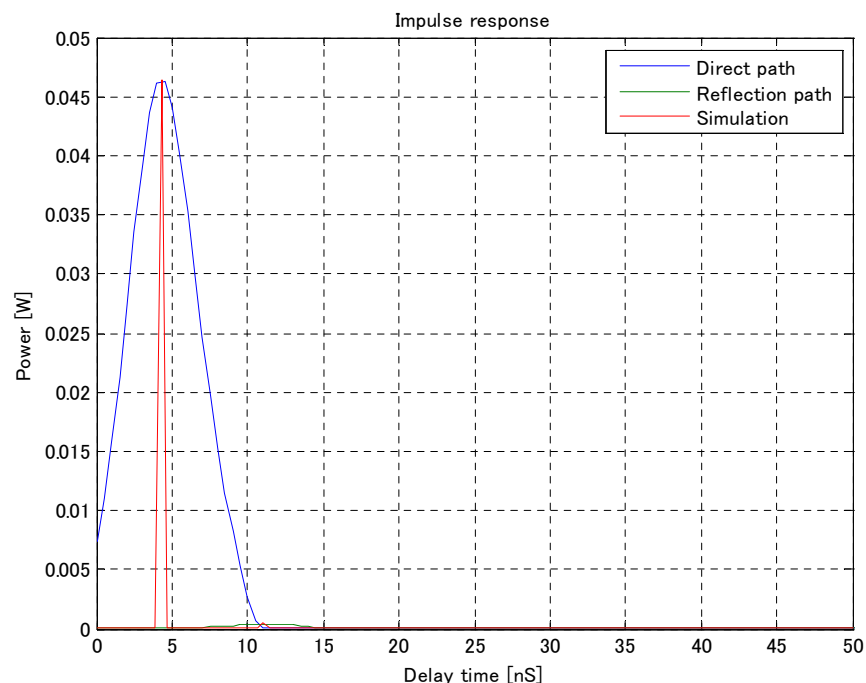# Impulse response   −Position A

Tx (100, 75, 220), Rx(100, 65, 90), PN (300MHz, 127)

Delay time of the Reflected light from the Directed light : 2.6nS
Power ratio of the Reflected light to the Direct light : -18.5dB

Impulse response   −Position B

Tx (100, 155, 220), Rx(100,145, 90), PN (300MHz, 127)

Delay time of the Reflected light from the Directed light : 7.3nS
Power ratio of the Reflected light to the Direct light : -21.1dB

Conclusion

- We had the light propagation measurement for obtaining the impulse response in indoor environment.

- The measured impulse responses had good agreements with the simulation.

- We can say the simulation is useful for expecting the light propagation in indoor environment.

Appendix

| Environment size	Tx height	Rx height	# of Tx and Position	FOV (Device)	TX power	etc
7.45m x 4.65m x 3.5m(H)	2.2m	0.9m	1 (100,75,220) or (100,155,220)	Tx: ±70° (±10°) Rx: ±70° (±10°)	EDL300E 0.5mW	EDL300D PD size: Φ7mm lens and φ70mm lens Wall A Reflection Index:8%

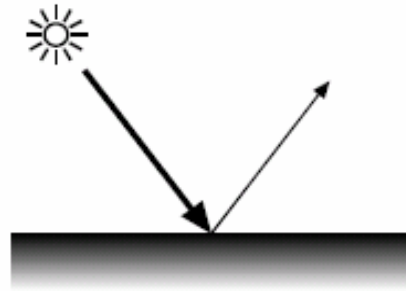Measurement Conditions

Photon model
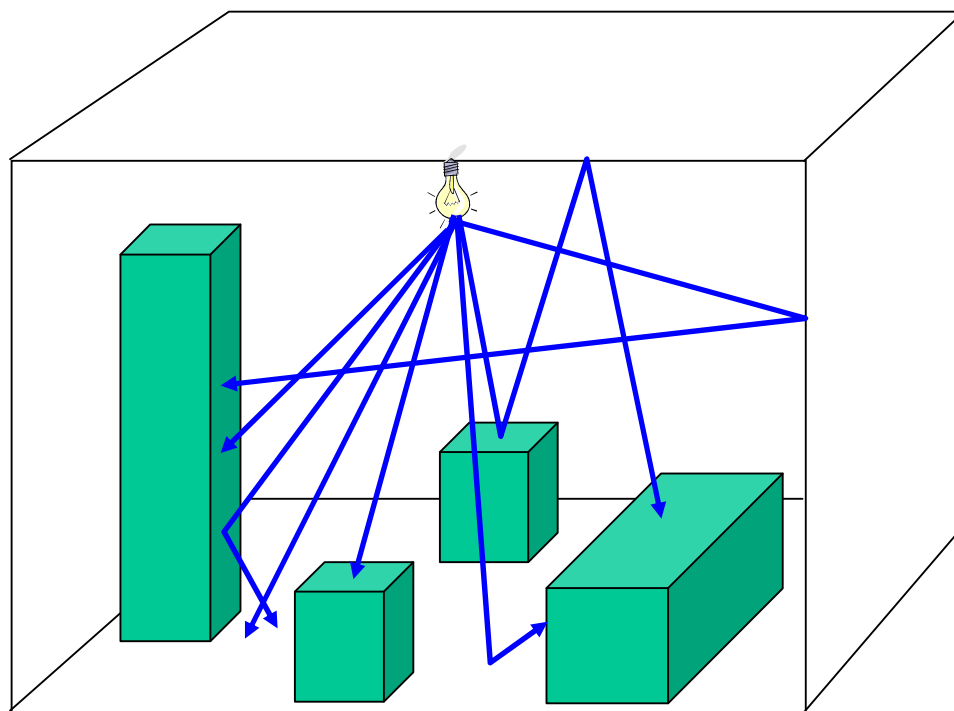
- Trace the light path
  - Photon Model
    - Quantum theory
  - Ray tracing
    - Computer simulation tool
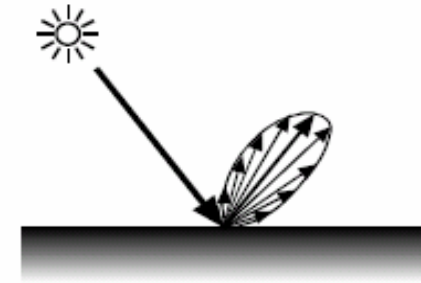   - RF channel modeling method

Reflection Type
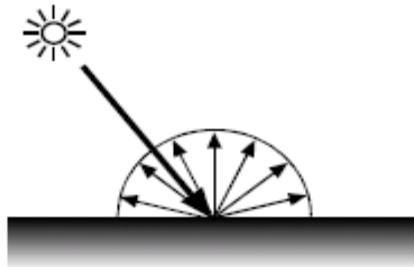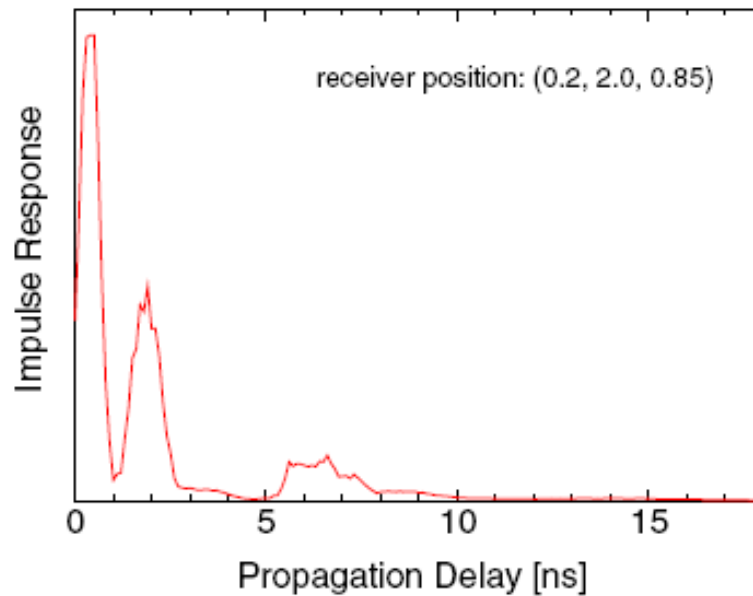

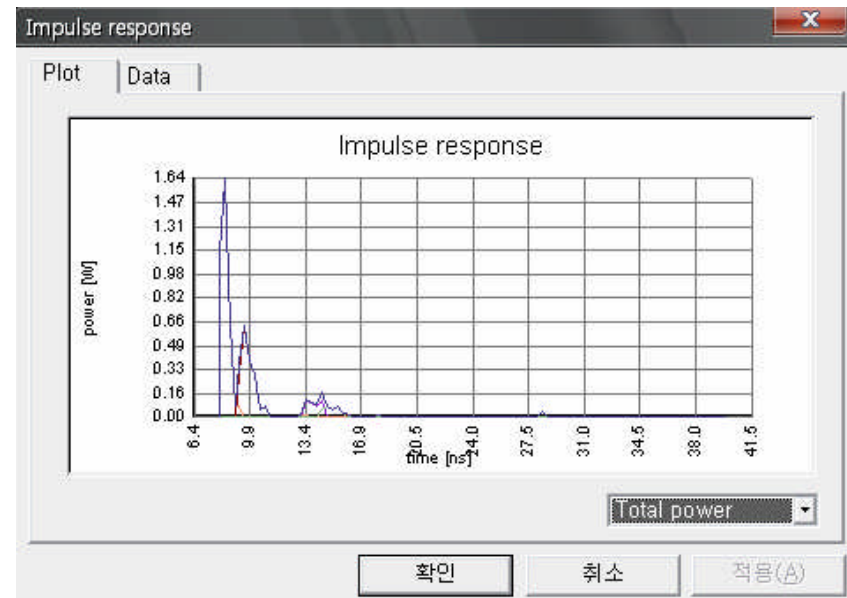diffuse

mirror / specular

glossy / specular

- Diffuse
  - Rough surface
    - Clothing, paper and asphalt road
  - Lambertian reflection

- Mirror/Specular
  - Smooth surface
    - Mirror or calm water
  - Reflection Index

- Glossy/Specular
  - Not diffuse,mirror
  - BRDF(Bidirectional Reflectance Distribution Function)

Impulse response comparison

- (a) Prof. Nakagawa

- (b) Samsung