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**Source:** [(1) Jaeseung Son, Dongjae Shin, Taehan Bae, Hyukchoon Kwon, Euntae Won, (2) Atsuya Yokoi]

Address [(1) Dong Suwon P.O. Box 105, 416 Maetan-3dong, Yeongtong-gu, Suwon-si, Gyeonggi-do, 443-742 Korea, (2)Samaung Yokohama Research Institute]

Voice:[(1)82-31-279-5285, (2)81-45-510-4240]

E-Mail:[(1)js1007.son@samsung.com, (2)atsuya.yokoi@samsung.com]

**Re:** []

**Abstract:** [Results of channel modeling simulation are presented. Home, Cafe are considered. The effect of FOV is also presented. And updated channel measurement results.]

**Purpose:** [Contribution to IEEE 802.15 SG-VLC]

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# VLC channel modeling simulation (Home, Cafe)

2008.09.10

Samsung Electronics

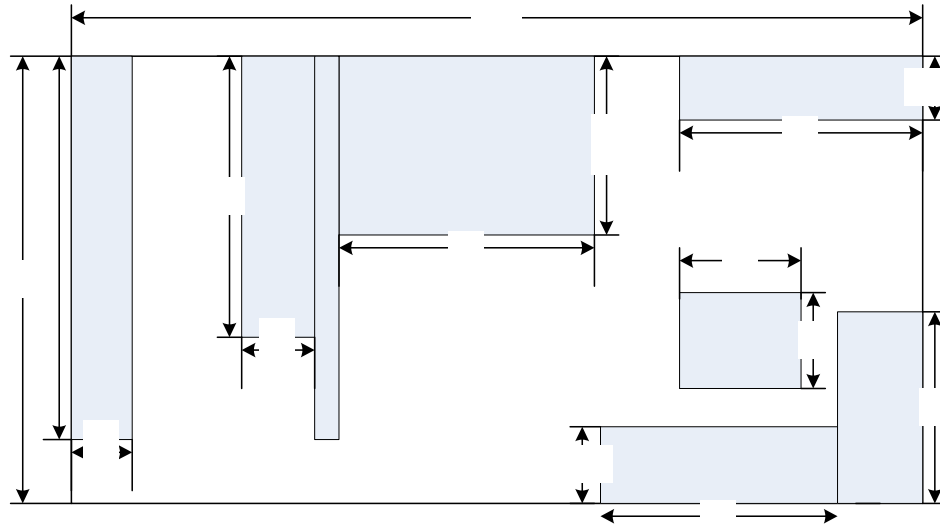
## Contents

- Channel modeling in Home
  - 3D modeling, photon map, impulse response, Tapped delay line model
- Channel modeling in Cafe
- Future Works
- Updated VLC channel measurement results

# VLC Channel Modeling Environments

	Size	Window	Distance between Tx	Indoor brightness
Home	Small	None	Short	Medium
Hospital	Small	None	Short	High
Café	Medium	Window	Long	Low
CD shop	Medium	None	Medium	Low
Museum	Large	Window	Long	Low
Office	Large	Window	Long	High

# Home 3D Modeling

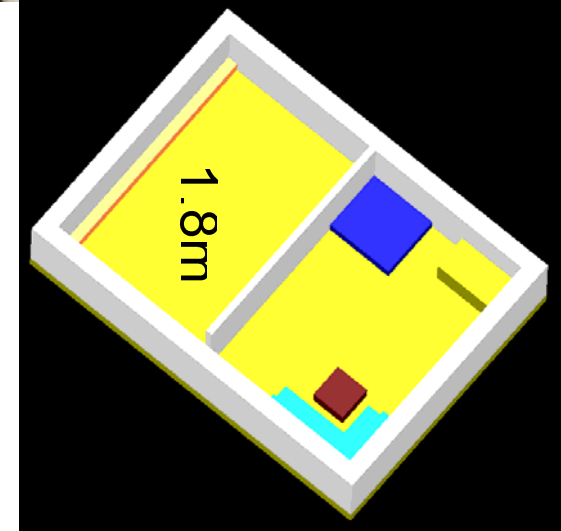


- Plane figure
  - 2 sofas
  - 2 tables
  - 1 exhibition table
  - 1 sink
  - 1 bed

- Application
  - VL-LAN
  - Fixed to infra
  - Mobile to fixed

Bed

2m



Exhibition Table

2m

Submission

0.4  
m

Table

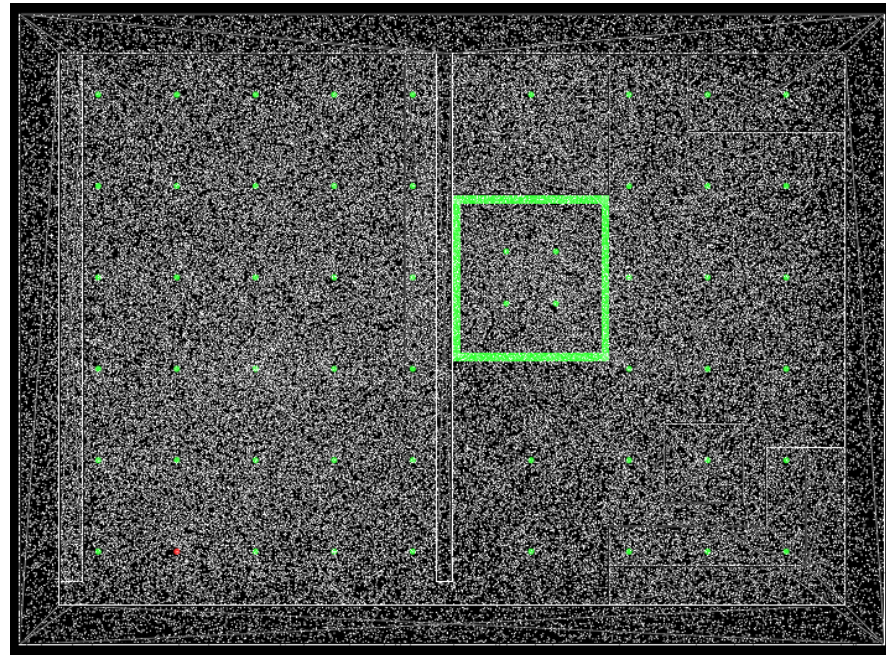
1m

# Simulation Parameters

<b>Size</b>	<b>7m × 10m × 2.5m</b>
<b>Transmitted optical power</b>	<b>100mW</b>
<b>Number of Tx</b>	<b>49 point sources, 4 rectangular sources</b>
<b>Size of Tx</b>	<b>Point source, Rectangular source(2m × 0.1m)</b>
<b>Height of Tx</b>	<b>2.5m</b>
<b>Pattern of Tx</b>	<b>180°</b>
<b>Reflection type</b>	<b>Specular / Mirror reflection</b>
<b>Number of reflection</b>	<b>3 times</b>
<b>Reflection index (Based on color)</b>	<b>Floor: 36% Ceil, Wall: 93% Table: 3% Sink: 93% Sofa: 48%</b>
<b>Rx height</b>	<b>0.5m, 1m</b>
<b>Rx FOV</b>	<b>60°</b>

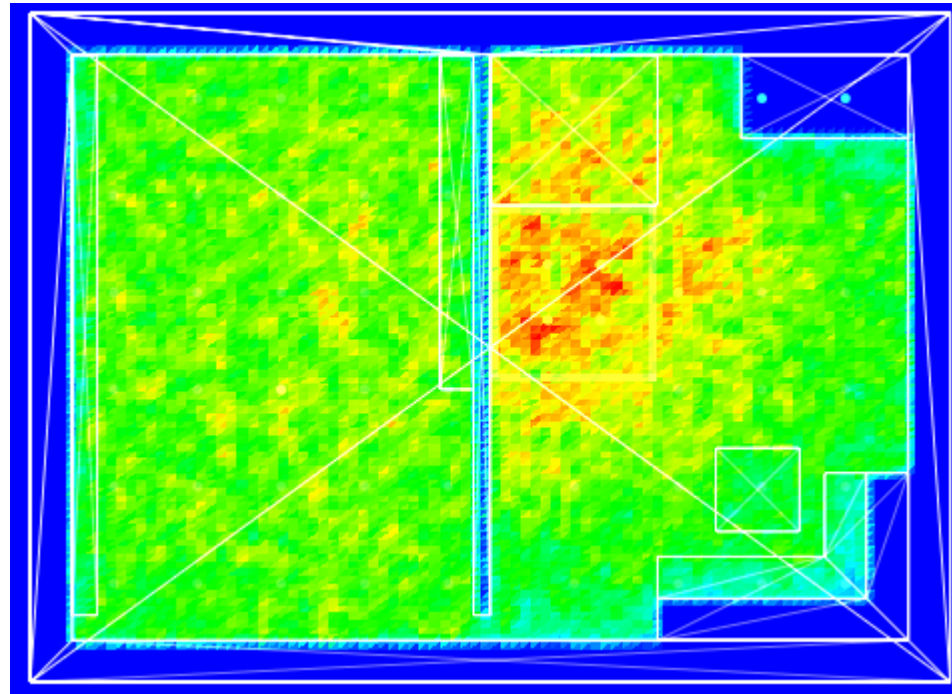
# Photon Map

- Photon map of office environment
  - 4 rectangular LEDs
    - Green rectangular
    - $2\text{m} \times 0.1\text{m}$
  - 49 point sources
  - 2 million photons
- Photon
  - White dot



# Simulation Result(1/3)

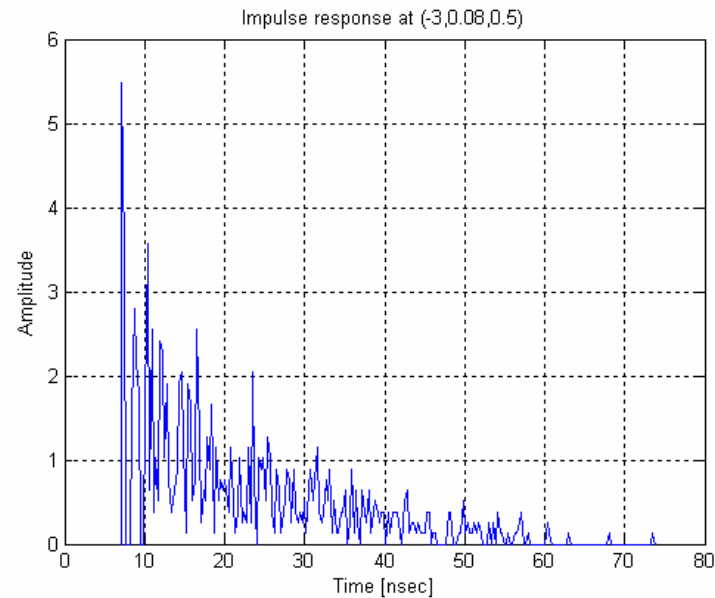
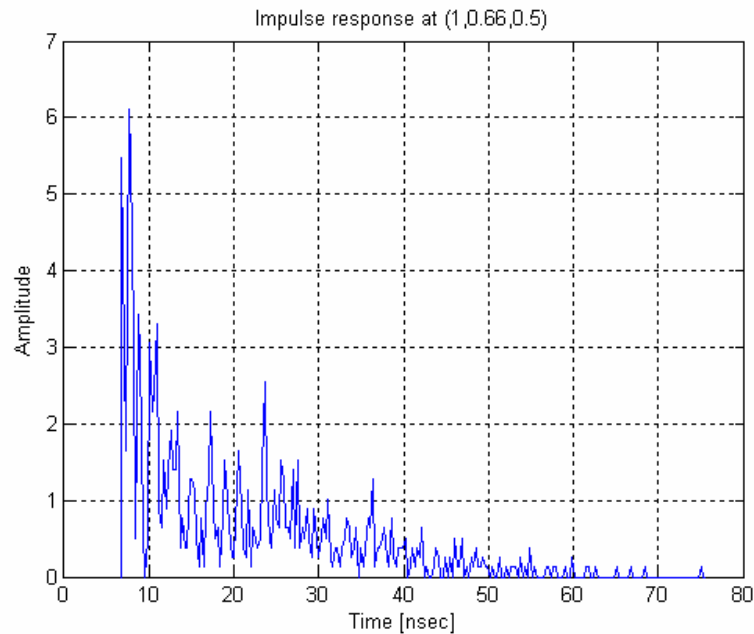
- Power mean at 0.5m
  - 0.5m is for application on the sofa
    - Because of less illumination, received power is smaller.
  - Under the rectangular sources
    - More power received





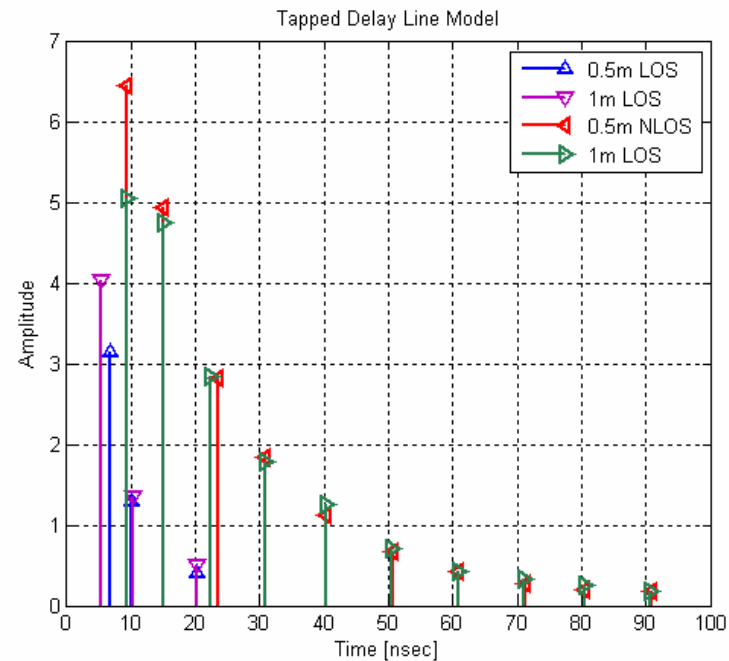
# Simulation Result(2/3)

- Impulse response at (1,0.66,0.5)
  - Under the rectangular sources
- Impulse response at (-3,0.08,0.5)
  - In the kitchen
  - No rectangular source

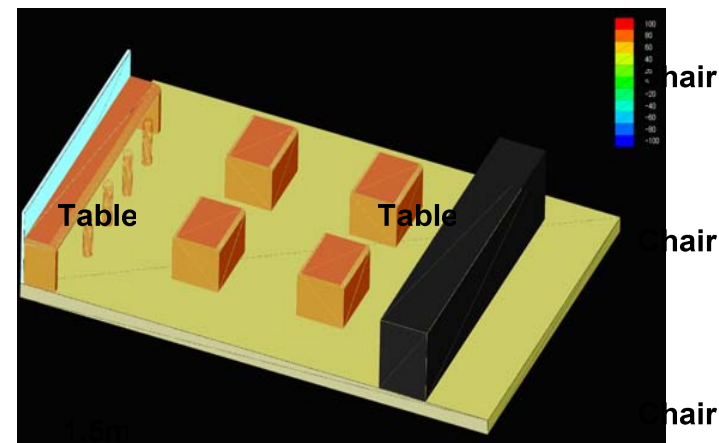
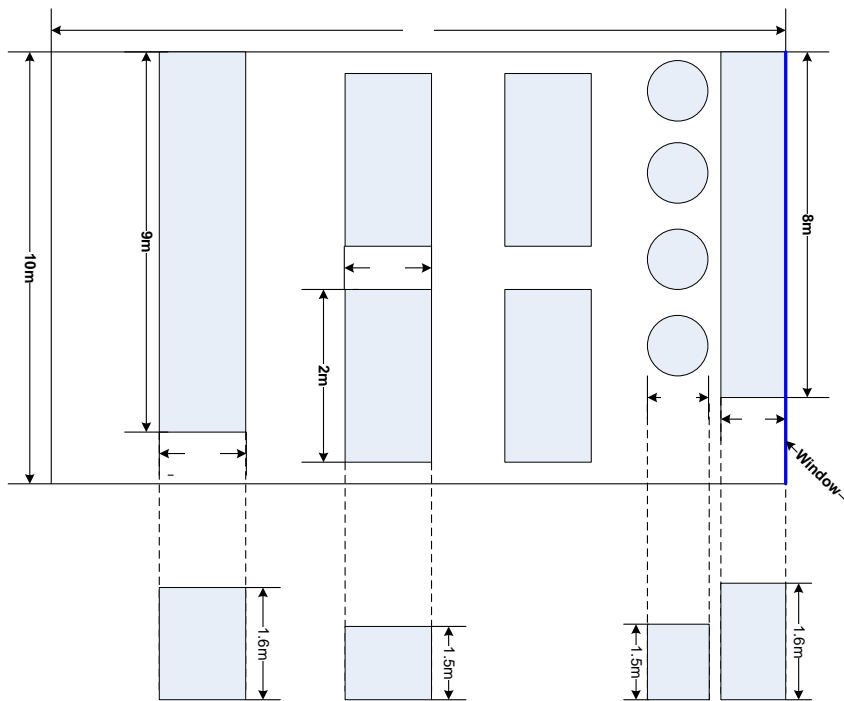


# Simulation Result(3/3)

- TDL (Tapped Delay Line) model
  - Generally, communication channel is continuous time channel
  - Minimum unit delayed discrete time channel model from continuous time channel
    - 100 x 100 blocks
    - Only LOS channel blocks
    - 1 nsec unit for 1Gbps application case



# Café 3D Modeling



- Plane Figure
  - 4 Tables
  - 4 Chairs
  - 1 Exhibition table
  - 1 window table
- Application
  - VLE
  - Exhibition Table
  - Wireless ordering system

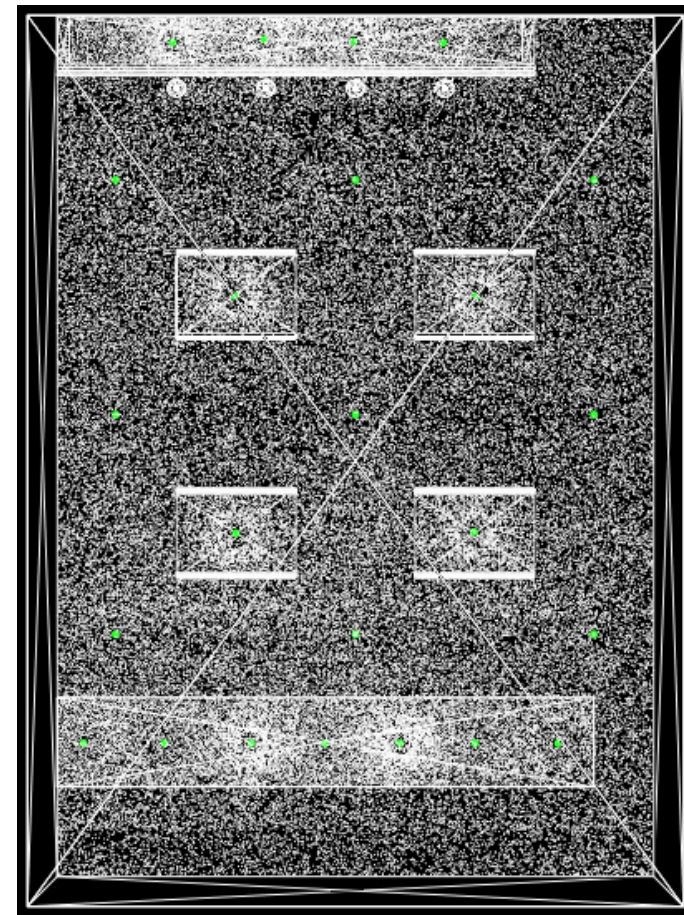
- Cafe 3D modeling

# Simulation Parameters

<b>Size</b>	<b>12.1m x 16.4m x 3.3m</b>
<b>Transmitted optical power</b>	<b>100mW</b>
<b>Number of Tx</b>	<b>25 Txs</b>
<b>Size of Tx</b>	<b>Point source</b>
<b>Height of Tx</b>	<b>2.1m, 2.5m</b>
<b>Pattern of Tx</b>	<b>180°</b>
<b>Reflection type</b>	<b>Specular / Mirror reflection</b>
<b>Number of reflection</b>	<b>3 times</b>
<b>Reflection index (Based on color)</b>	<b>Floor: 12%</b> <b>Ceil: 24%</b> <b>Table: 24%</b> <b>Chair: 93%</b> <b>Exhibition table: 24%</b> <b>Window table: 24%</b> <b>Wall: 12%</b> <b>Window glass: 8%</b>
<b>Rx height</b>	<b>1.5m, 1.7m</b>
<b>Rx FOV</b>	<b>60°</b>

# Photon Map

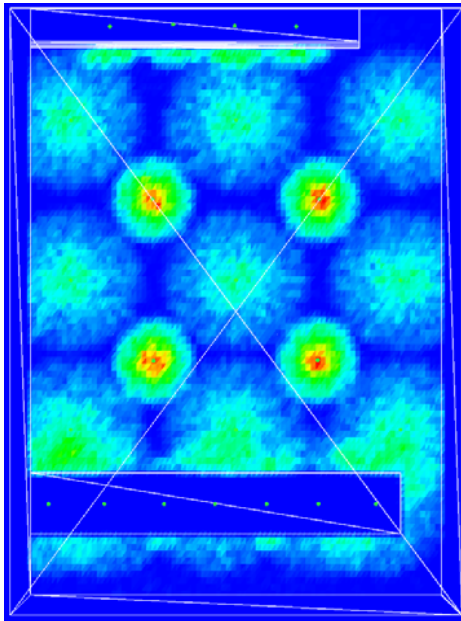
- Photon map of office environment
  - 25 point LEDs
  - 2 million photons
- Photon
  - White dot



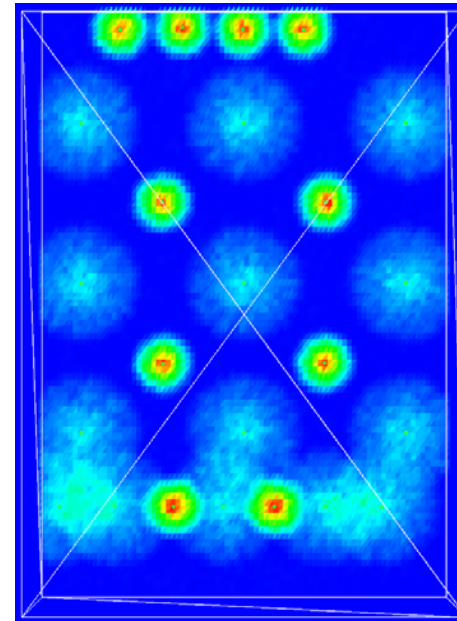
## Simulation Result(1/3)

- Power mean at 1.5m and 1.7m
  - 25 LED TxS
    - 1.5m over the table
    - 1.7m over the window table and exhibition table

(a) 1.5m Table

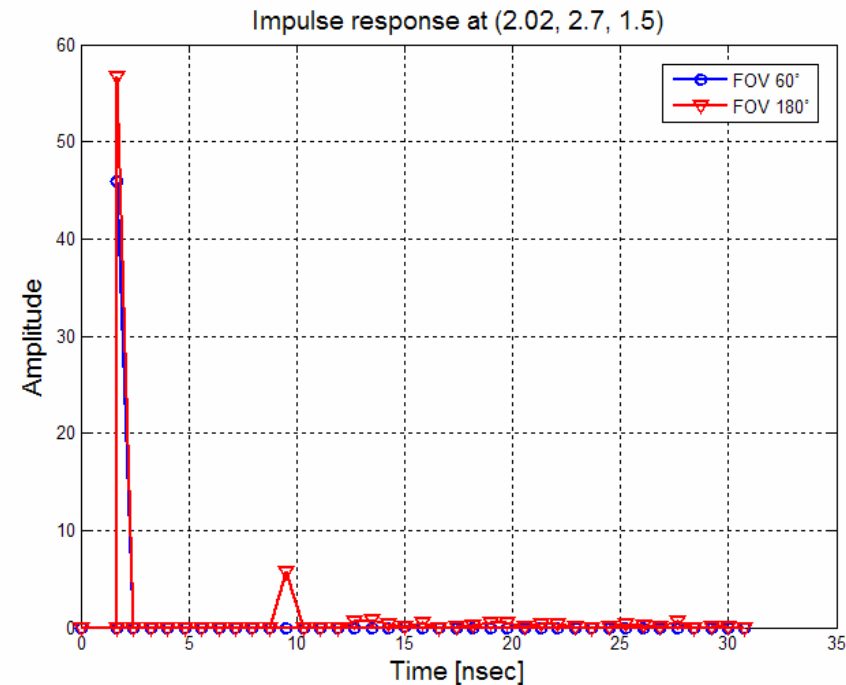


(b) 1.7m Window table



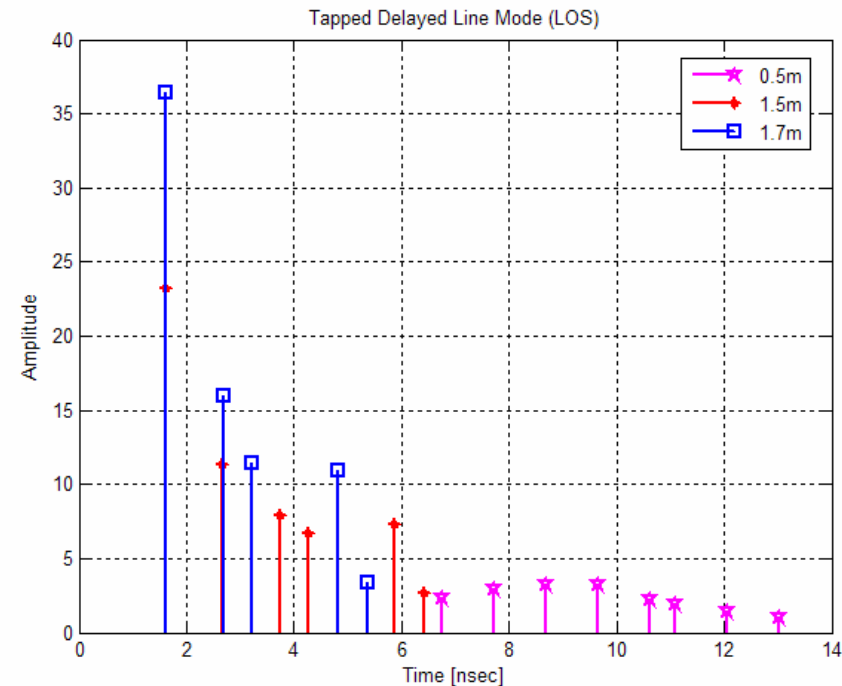
## Simulation Result(2/3)

- Impulse response at (2.02, 2.7, 1.5 )
  - Over the table
  - Little interference from other Tx's because of FOV
    - FOV: 60°



# Simulation Result(3/3)

- TDL (Tapped Delay Line) model
  - Generally, communication channel is continuous time channel
  - Minimum unit delayed discrete time channel model from continuous time channel
    - 100 x 100 blocks
    - Only LOS channel blocks
    - 1 nsec unit for 1Gbps application case
- Lower height, more taps
  - Cause of ISI
  - To reduce ISI, we can narrow FOV





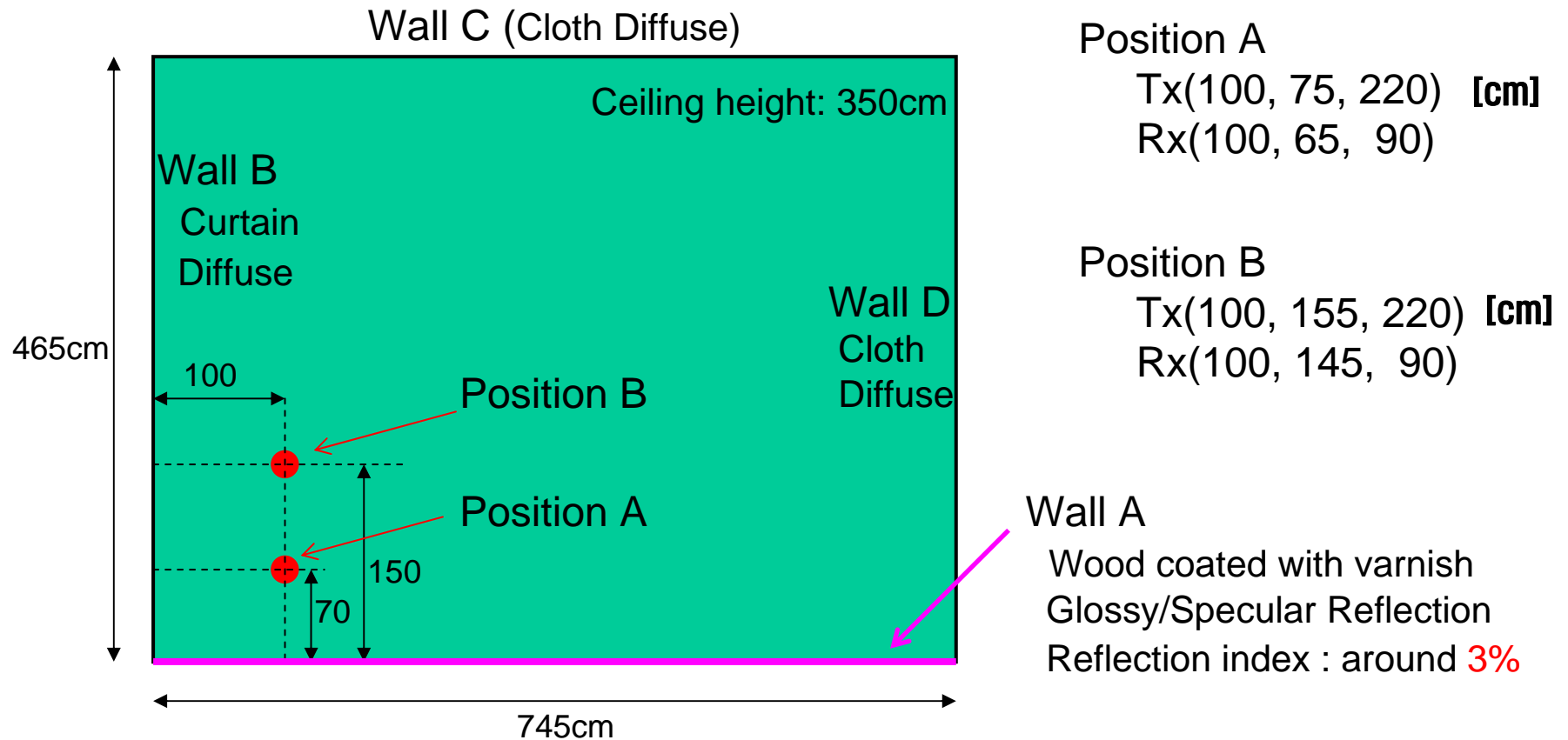
## Future Works

- Channel modeling simulation
  - RGB LED channel modeling
  - Reflection
    - Diffuse, Glossy reflection simulation

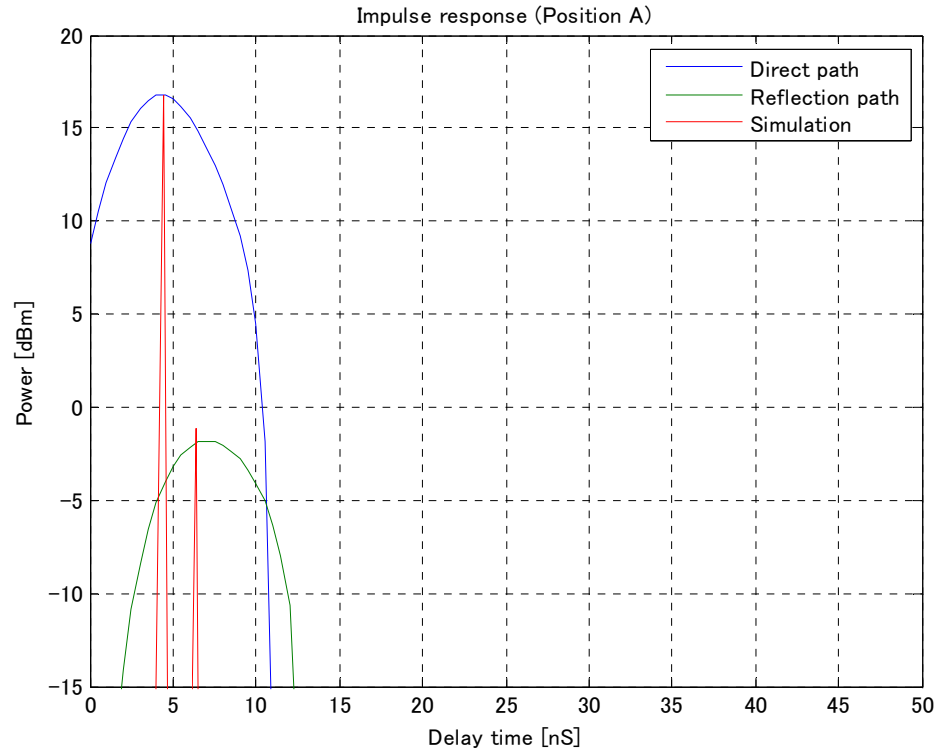
# VLC channel measurement

- Samsung presented about “VLC channel measurement” in the previous meeting.
- We show the comparison between the Simulation & Measurement again for confirming the simulation accuracy.
- We corrected some simulation parameters for fitting the measurement situation.
  - Reflection Index : 8% → 3%
  - FOV (Field of View): 45° → 70°

# Measurement Environment

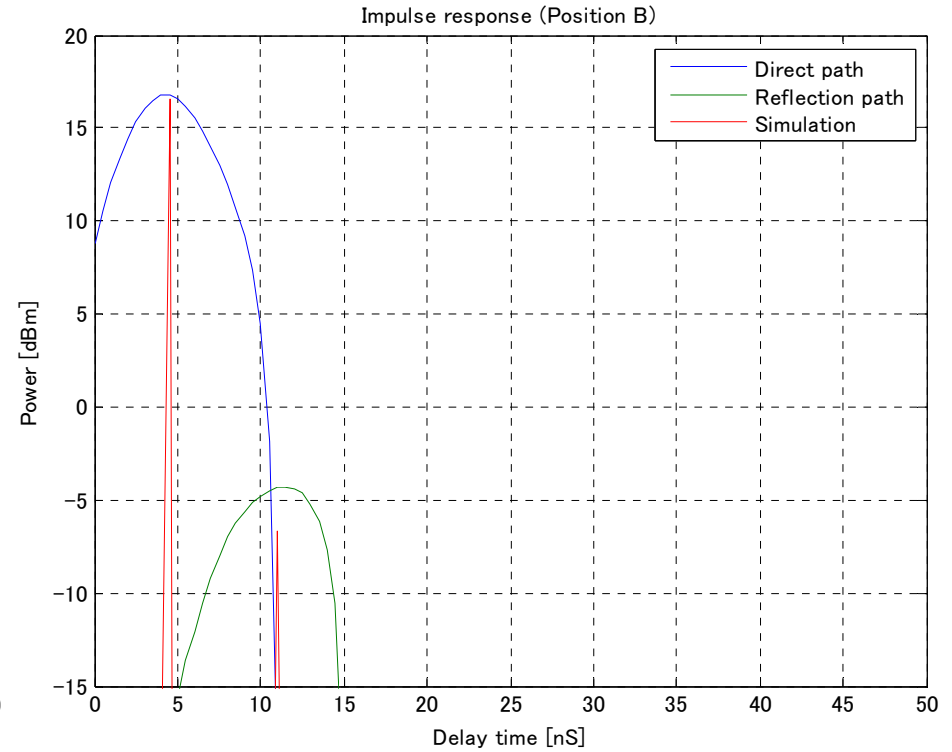


# Impulse response



Position A

Tx (100, 75, 220), Rx(100, 65, 90)



Position B

Tx (100, 155, 220), Rx(100, 145, 90)

\*Simulation: Reflection index 3%, FOV 70degrees

# Simulation vs. Measurement

	Simulation			Measurement		Difference	
	Delay time(ns)	Power (W)	Power ratio	Delay time(ns)	Power ratio	Delay time(ns)	Power ratio
Position A	4.455	0.047078	-17.85dB	4.2	-18.5dB	-0.255	-0.65dB
	6.432	0.000772		6.8		+0.368	
Position B	4.538	0.045843	-23.28dB	4.2	-21.1dB	-0.338	+2.17dB
	10.985	0.000216		11.5		+0.515	

\*Simulation: Reflection index 3%, FOV 70degrees

Thank You~  
Q&A