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

Submission Title: [VLC channel modeling with different reflection types]

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Abstract: [Results of channel modeling simulation are presented with different reflection types. Mirror, diffuse, glossy reflection types are considered.]

Purpose: [Contribution to IEEE 802.15 SG-VLC]

VLC channel modeling with different reflection types

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Samsung Electronics

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  - Mirror
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    - BRDF
- Channel modeling simulation with different reflection types
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    - BRDF
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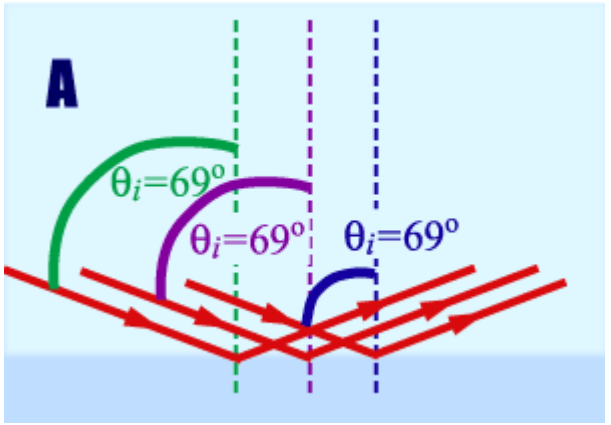
Reflection Type

- Mirror
  - Smooth surface
    - Mirror or calm water
  - Reflection Index
- Diffuse
  - Rough surface
    - Clothing, paper and asphalt road
  - Lambertian reflection
- Glossy
  - BRDF(Bidirectional Reflectance Distribution Function)

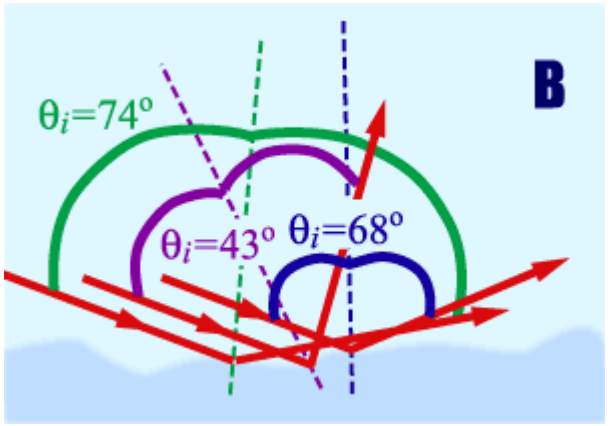
Mirror Reflection

- Mirror reflection is the perfect, mirror-like reflection of light from a surface.
- A single incoming direction is reflected into a single outgoing direction.
  - As the beam strikes the surface, each region of the beam of light will produce the same angle of incidence.
- Such behavior is described by the law of reflection.
- Smooth surface
  - Mirror, calm water
- Reflection Index



Diffuse Reflection

- Reflection of light from an uneven or granular surface
- Incident ray is seemingly reflected at a number of angles.
- Not follow law of reflection
- It is the complement to mirror reflection.
  - Lambertian Reflection
- Rough surface
  - Clothing, paper, asphalt road



Glossy Reflection (1/4)

- Gloss is an optical property, which is based on the interaction of light with physical characteristics of a surface.
- The factors that affects gloss are the refractive index of the material, the angle of incident light and the surface topography.
- Not diffuse, mirror reflection
- BRDF (Bidirectional Reflectance Distribution Function)

Glossy Reflection (2/4)

- BRDF
  - Bidirectional Reflectance Distribution Function
    - 4-dimensional function that defines how light is reflected at an opaque surface
    - Used in computer graphics for photorealistic rendering
  - Simplified BRDF function
    - F0 : reflection at normal incidence.
    - σ : Roughness factor. (σ=0 is perfectly smooth and , σ=1 is very rough and Lambertian.)
    - Ψ : isotropy factor. (Ψ=0 is perfectly anisotropic and Ψ=1 is isotropic.

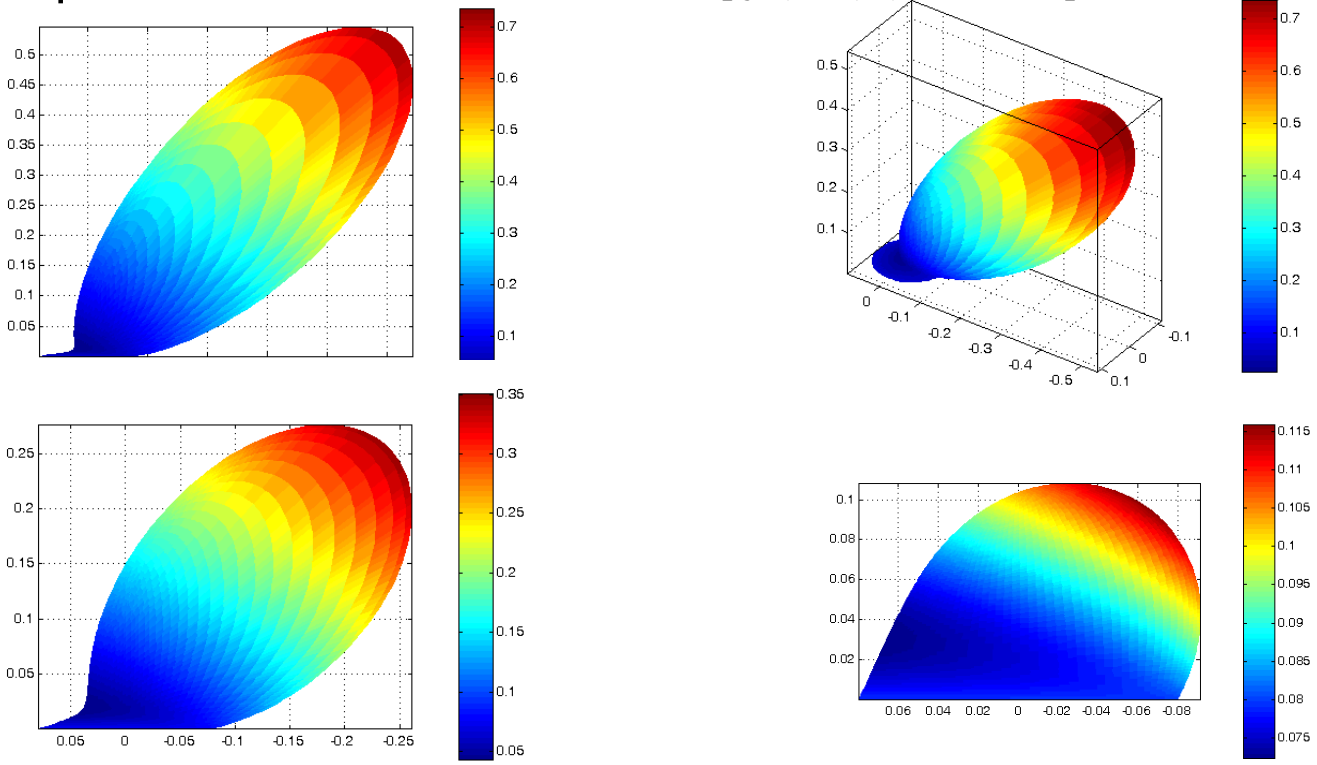
$$f_r(x,\vec{\omega},\vec{\omega}') = S(u)\left\{\frac{d}{\pi} + gD(t,\upsilon,\upsilon',\omega) + sf_{r,s}(x,\vec{\omega},\vec{\omega}')\right\}$$

Glossy Reflection (3/4)

- Schlick's BRDF

$$\theta_i = \frac{\pi}{4}, \quad \sigma = 0.1, \quad \psi = 1$$

σ : roughness (0~1) (0 perfectly smooth, 1 randomly rough)
Ψ : anisotropy (0~1) (0 anisotropic, 1 isotropic)

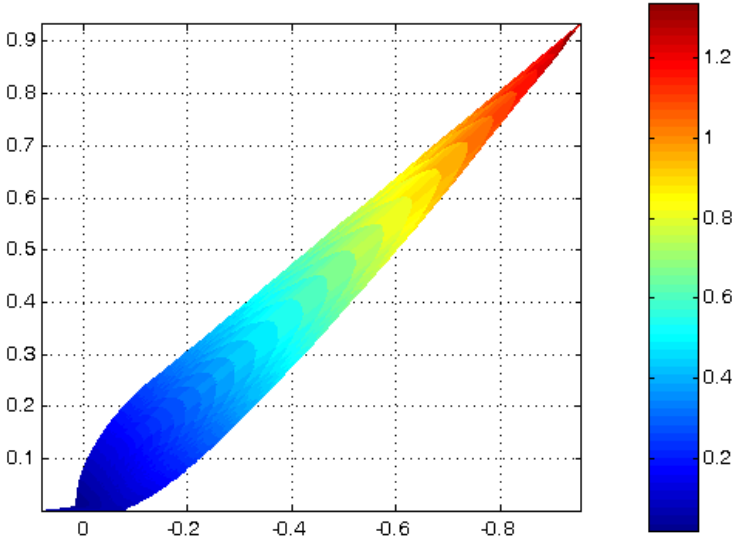


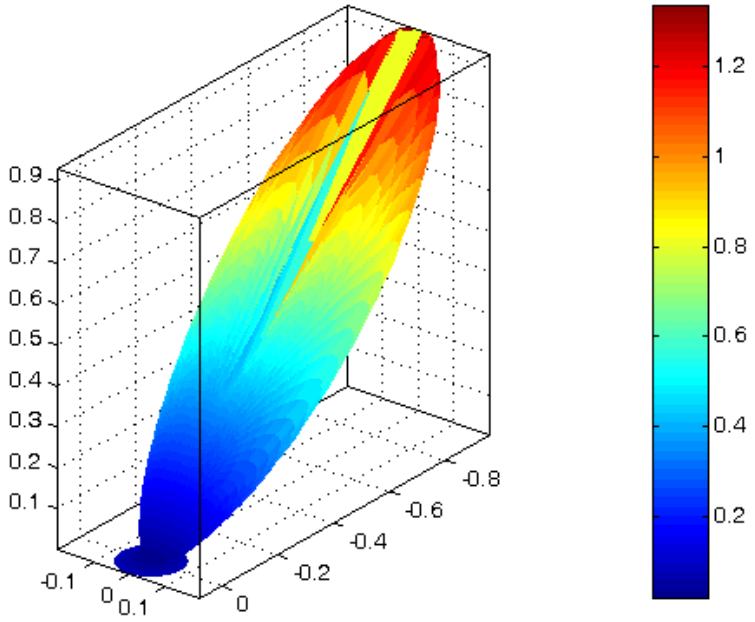
Glossy Reflection (4/4)

- Schlick's BRDF – anisotropic surface

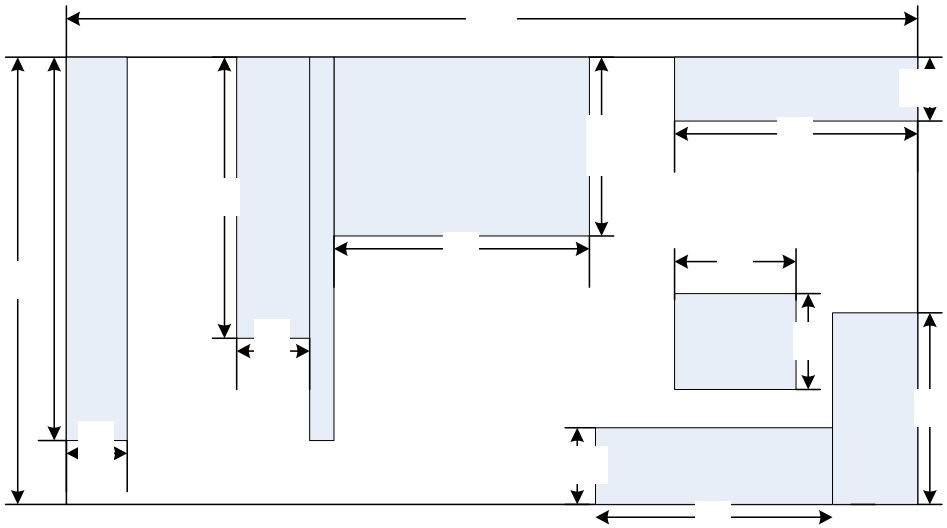
$$\theta_i = \frac{\pi}{4}, \quad \sigma = 0.1, \quad \psi = 0.3$$

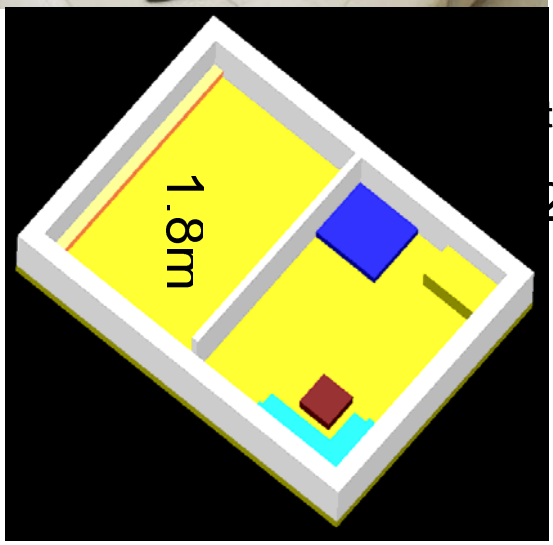
σ : roughness (0~1) (0 perfectly smooth, 1 randomly rough)
Ψ : anisotropy (0~1) (0 anisotropic, 1 isotropic)





Home 3D Modeling

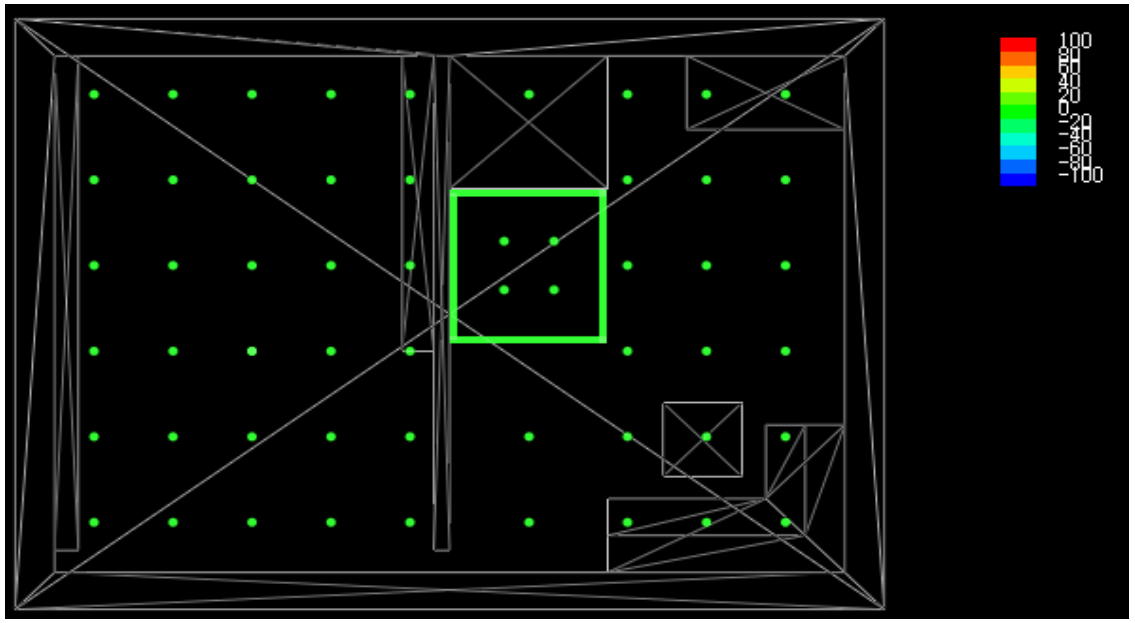




- Plane figure
  - 2 sofas
  - 2 tables
  - 1 exhibition table
  - 1 Sink
  - 1 bed
- Application
  - VL-LAN
  - Fixed to infra
  - Mobile to fixed

Position of illumination

- Txs
  - 49 point sources
  - 4 rectangular sources

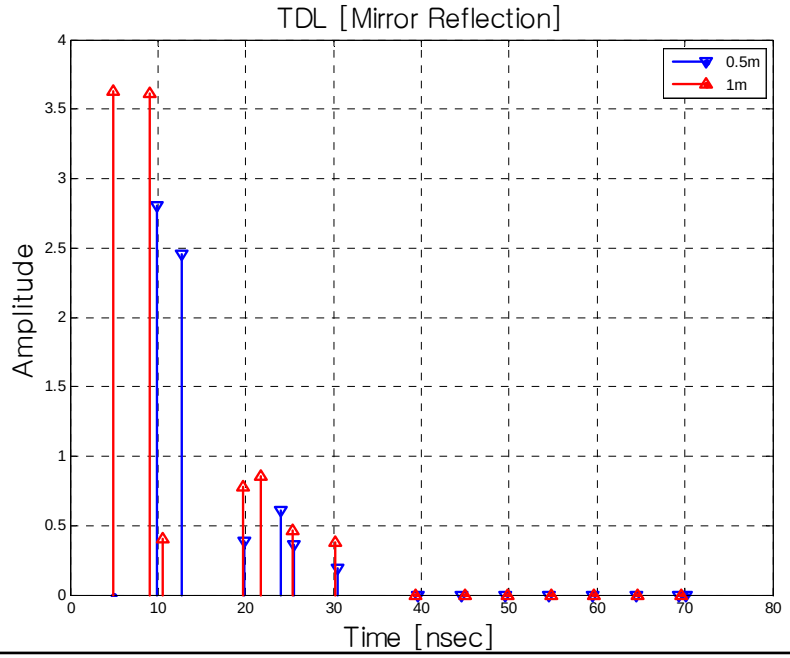


Simulation Parameters

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

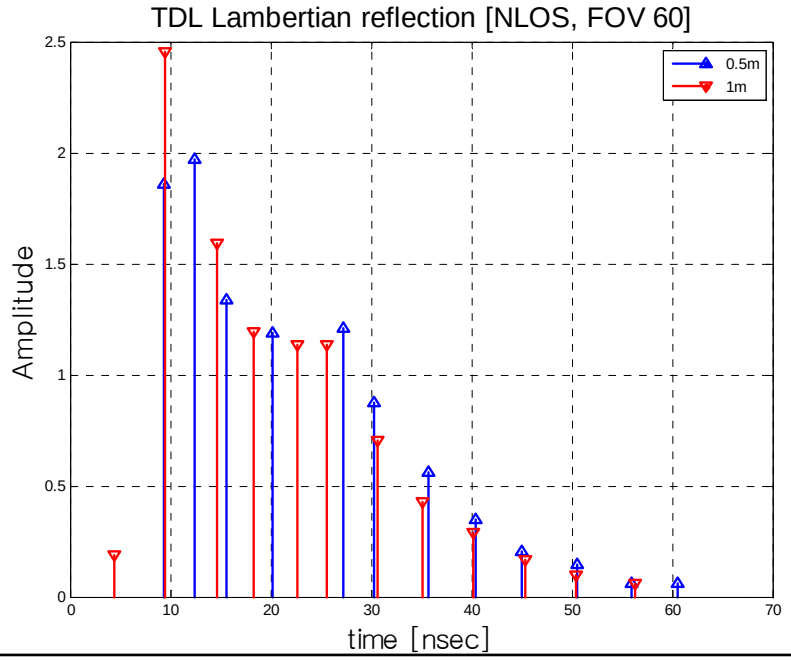
Channel Modeling Simulation – Mirror Reflection

- Mirror Reflection
  - 0.5m: On sofa
  - 1m: Handheld device



Channel Modeling Simulation – Diffuse Reflection

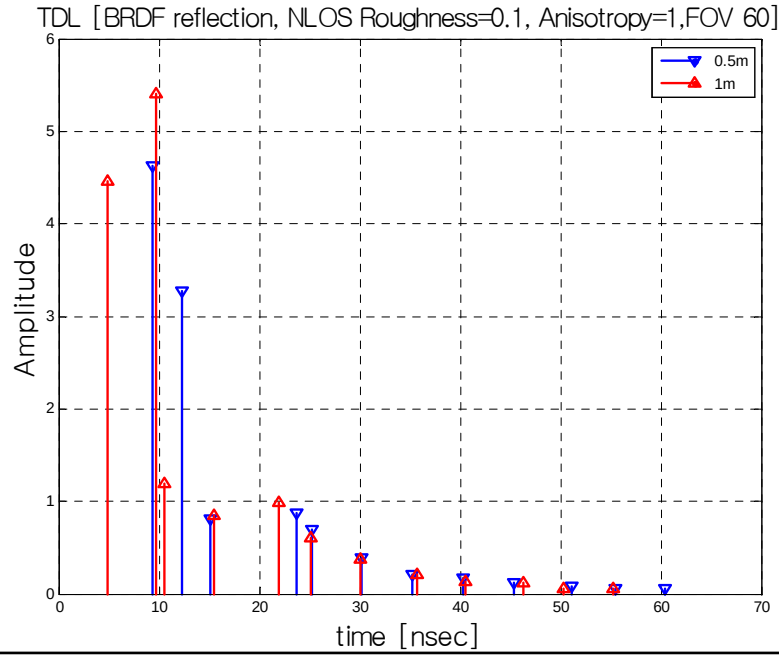
- Lambertian Reflection
  - 0.5m: On sofa
  - 1m: Handheld device



Channel Modeling Simulation – Glossy Reflection

$$\theta_i = \frac{\pi}{4}, \quad \sigma = 0.1, \quad \psi = 1$$

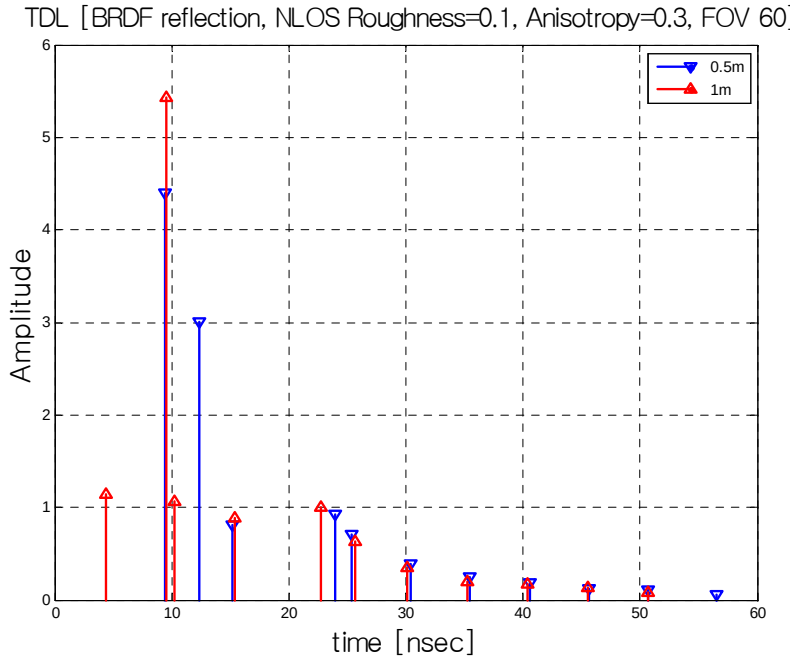
σ : roughness (0~1) (0 perfectly smooth, 1 randomly rough)
Ψ : anisotropy (0~1) (0 anisotropic, 1 isotropic)



Channel Modeling Simulation – Glossy Reflection

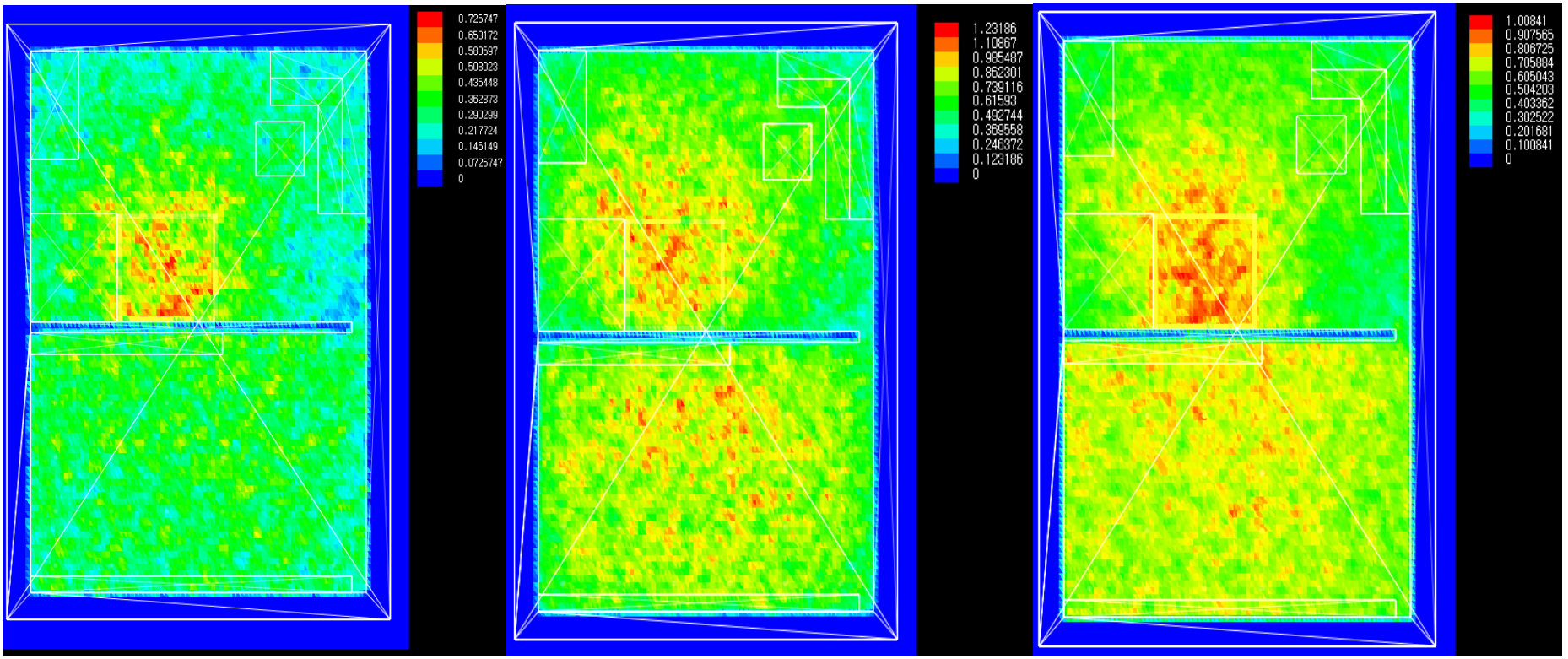
$\theta_i = \frac{\pi}{4}, \quad \sigma = 0.1, \quad \psi = 0.3$

σ : roughness (0~1) (0 perfectly smooth, 1 randomly rough)
Ψ : anisotropy (0~1) (0 anisotropic, 1 isotropic)



Channel modeling comparison

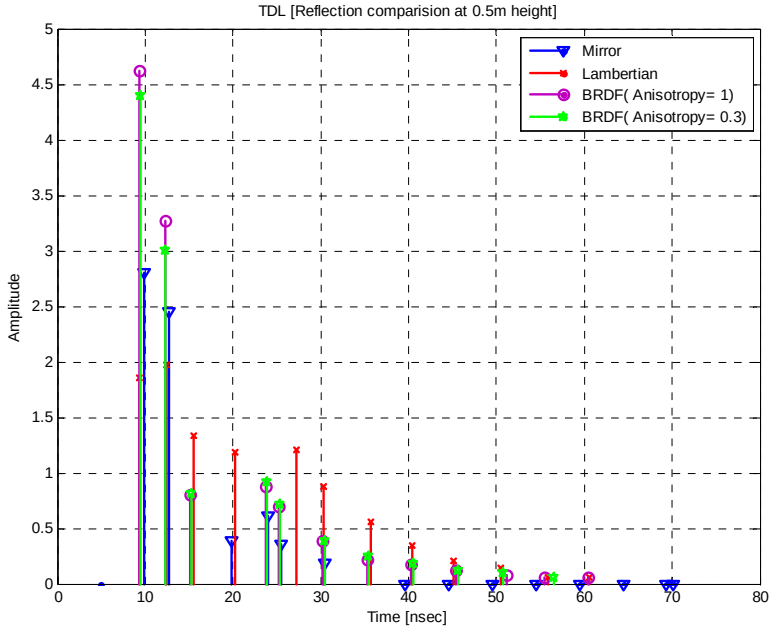
- Power mean
  - 1m: Handheld device

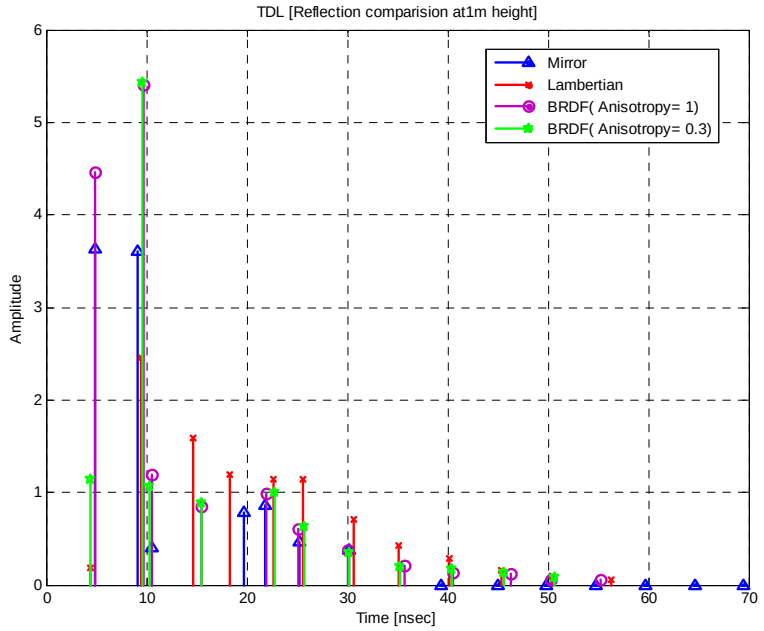


- Mirror/
- Lambertian
- BRDF

Channel modeling comparison

- LOS is out of this proposal
- Only NLOS TDL models are considered.
  - Mirror
  - Lambertian
  - BRDF (Anisotropy=0.3, 1)





Conclusion

- Reflection type
  - Mirror, Diffuse (Lambertian), Glossy (BRDF)
- Channel modeling simulation at different reflection type
- Channel modeling comparison
  - Different reflection types show different TDL model
  - We need to check the VLC system performance at different reflection types.

Future Works

- Channel modeling simulation
  - BER performance comparison
    - To check the influence of reflection type
  - RGB LED channel modeling

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Thank You~

Q&A