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Effects of Building Material Properties on Indoor Radio Channel

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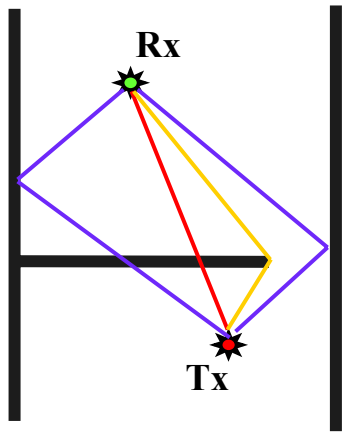
Overview

- Introduction
- Objectives
- Simulation and Results
- Discussion
- Conclusion

Introduction

- Indoor Radio Propagation Channel
  - Multipath
    - Transmission
    - Reflection
    - Diffraction
    - Scattering
- Channel Prediction Models
  - Statistical models
  - Deterministic models
    - Ray-tracing



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Introduction

- Statistical models:
  - Many uncertainties
- Deterministic models:
  - Detailed information of the site is required, such as material properties (dielectric constant, conductivity, and thickness) for each building structure
- Problems
  - How accurate are these models?
  - Large variations for known materials, …

Objectives

- To investigate the effects of different material properties on prediction results,
- To gain a better understanding of the accuracy of models.

Simulation & Results

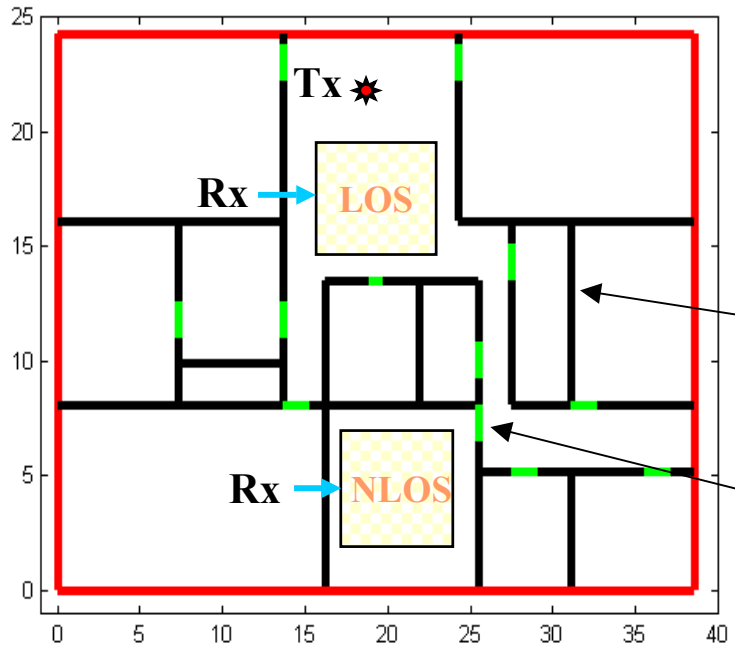
- Published parameters for typical materials
  (900MHz ~ 2500 MHz)

	ε_r	σ (S/m)
Concrete wall	4.0 ~ 9.0	0.001 ~ 0.1
Brick wall	4.4 ~ 8.0	0.001 ~ 0.1
Glass window	3.0 ~ 7.0	0 ~ 0.2
Wooden door	2.0 ~ 5.0	0 ~ 0.01

- Parameters used in simulation
  - Select a set of material parameters as reference values
  - Then change these values by 10%, 20%,…

Simulation Scenario

- A single floor in an office building



Reference Parameters

	ε_r	σ (S/m)
Ext. Wall	6.0	0.05
Int. Wall	**5.0**	**0.02**
Floor/Ceiling	7.0	0.05
Window	4.0	0.001
Door	3.0	0.001

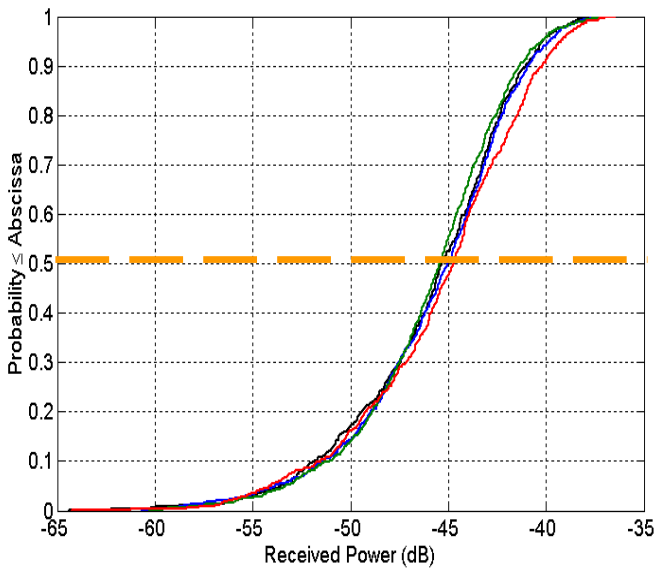
Ray-tracing models

- ***E*** = sum (rays)
  - Amplitude + Phase + Polarisation
  - M transmissions (M=4)
  - N reflections (N=6)
  - L diffraction (L =2)
- A software package developed
  - PC based and computationally efficient.

Effects of Permittivity (LOS) - CDF

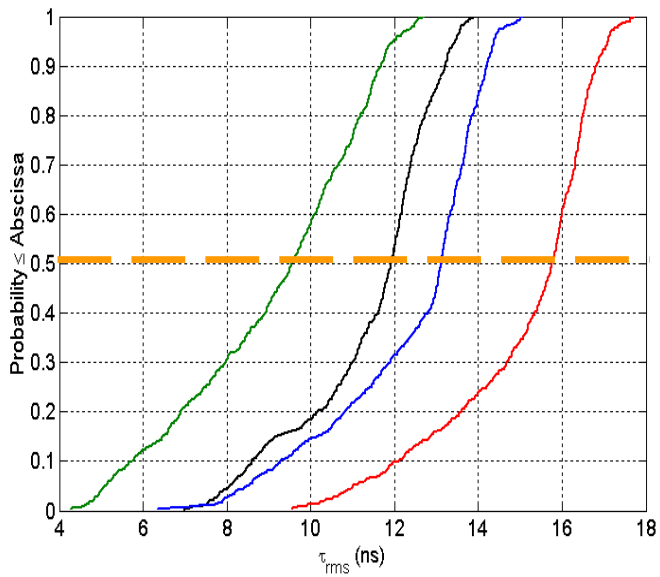
- In LOS case

ε_r — Ref. — 10% inc. — 20% inc. — 50% inc.



Path Loss

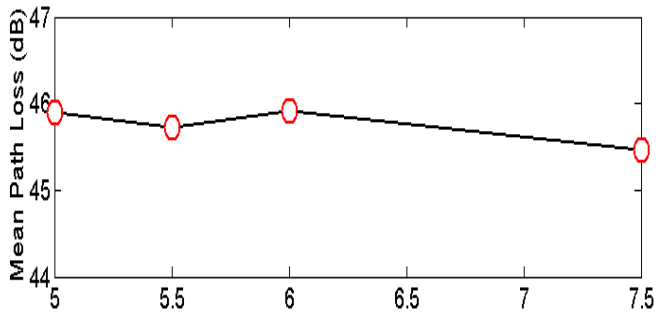
0.5

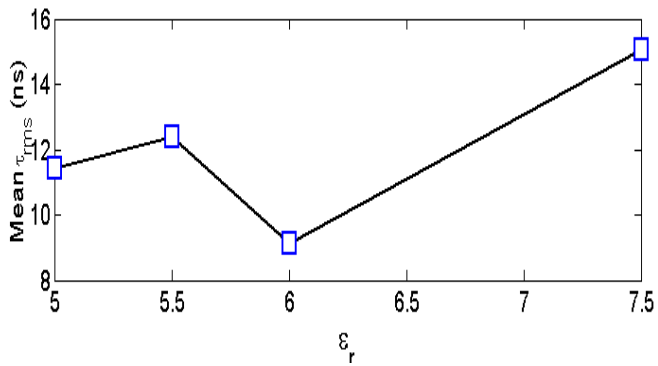


RMS delay spread

Effects of Permittivity (LOS)

- In LOS case





Path Loss

- Small variation (< 1dB)

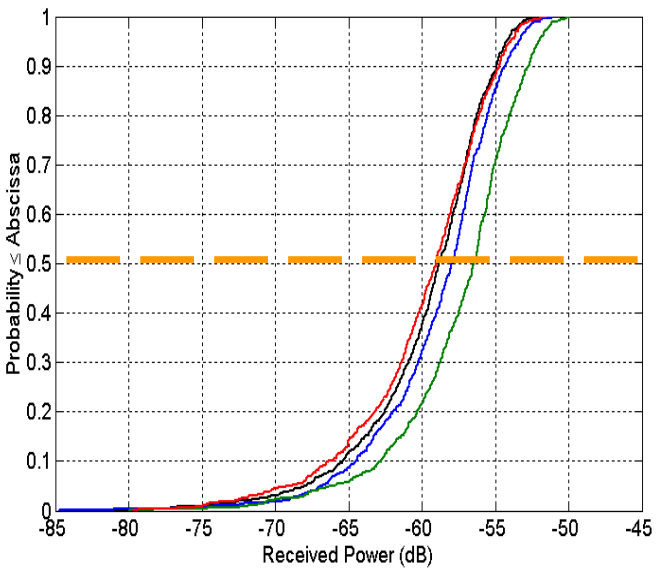
RMS delay spread

- Significant change
- Smallest value at $\varepsilon_r \approx 6$

Effects of Permittivity (NLOS)

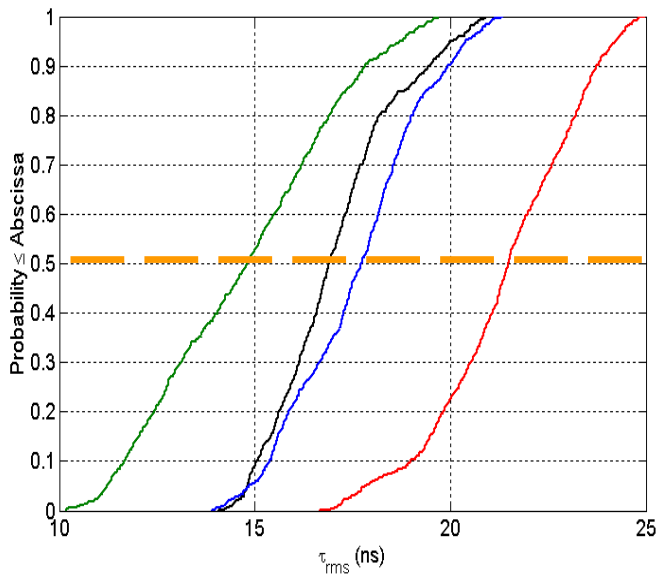
- In NLOS case

ε_r — Ref. — 10% inc. — 20% inc. — 50% inc.



Path Loss

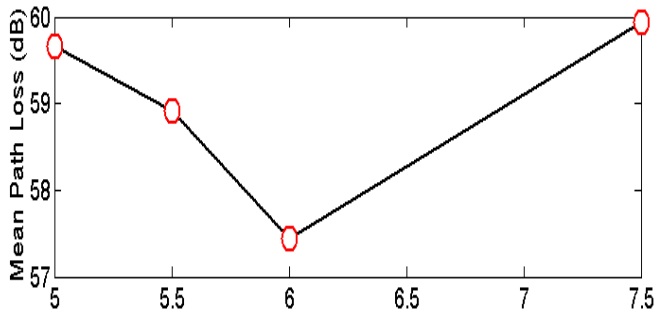
0.5



RMS delay spread

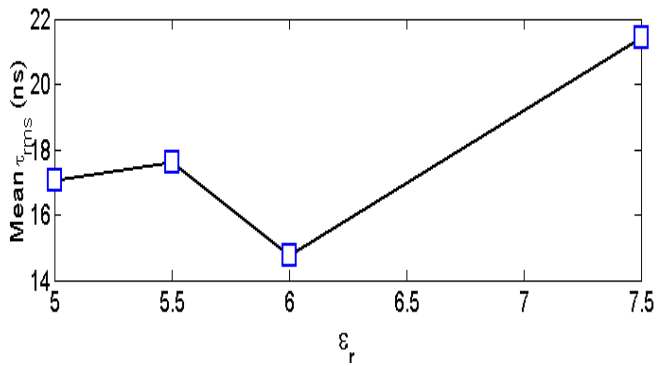
Effects of Permittivity (NLOS)

- In NLOS case



Path Loss

- Few dB variations
- Lowest value at $\varepsilon_r \approx 6$



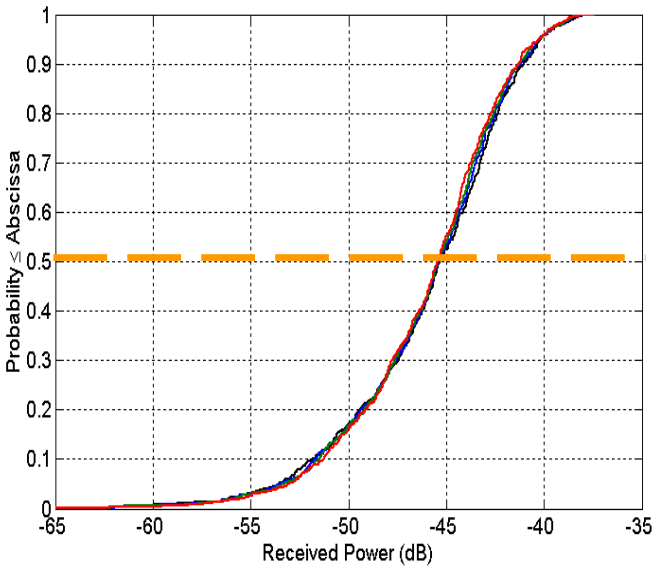
RMS delay spread

- Significant change
- Lowest value at $\varepsilon_r \approx 6$

Effects of Conductivity (LOS)

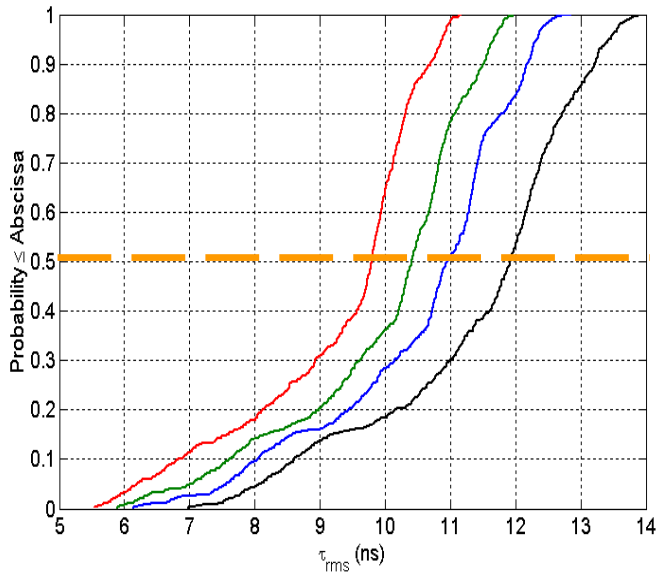
- In LOS case

σ — Ref. — 50% inc. — 100% inc. — 200% inc.



Path Loss

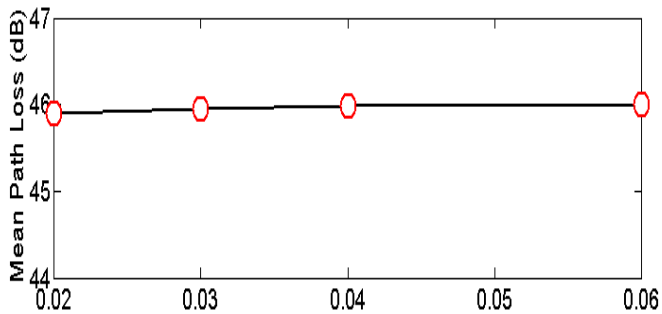
0.5

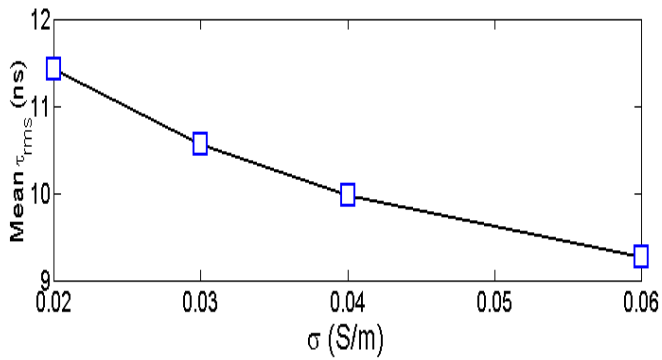


RMS delay spread

Effects of Conductivity (LOS)

- In LOS case





Path Loss

- Small variation (< 1dB)

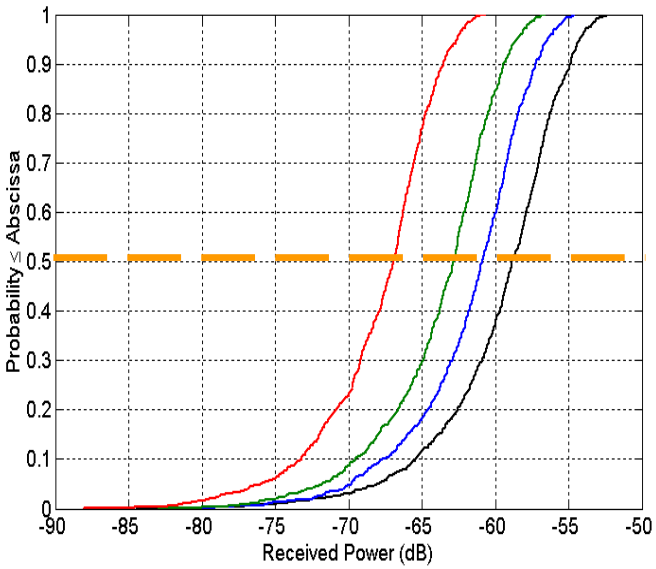
RMS delay spread

- Decreasing trend

Effects of Conductivity (NLOS)

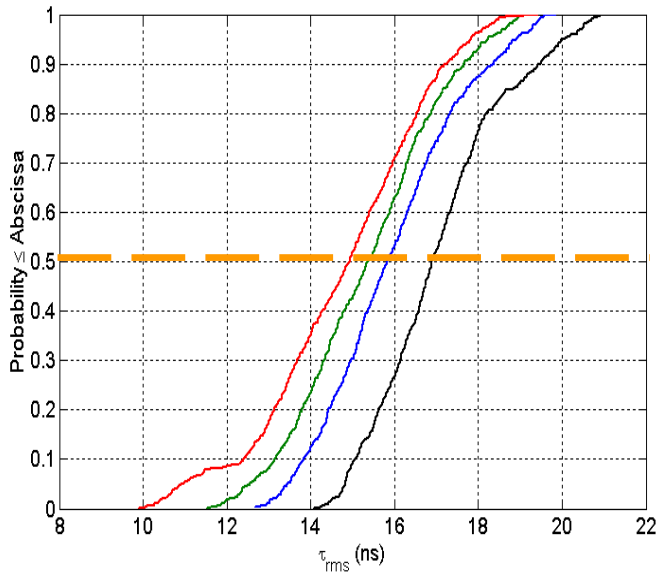
- In NLOS case

σ — Ref. — 50% inc. — 100% inc. — 200% inc.



Path Loss

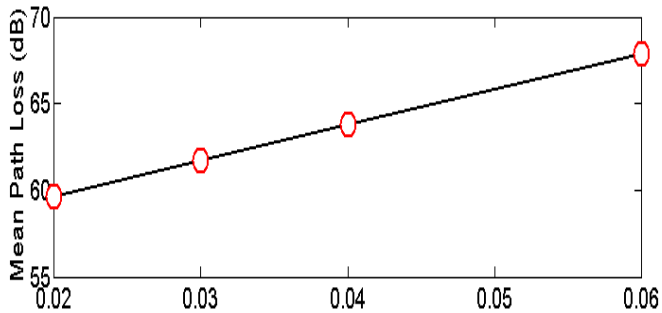
0.5

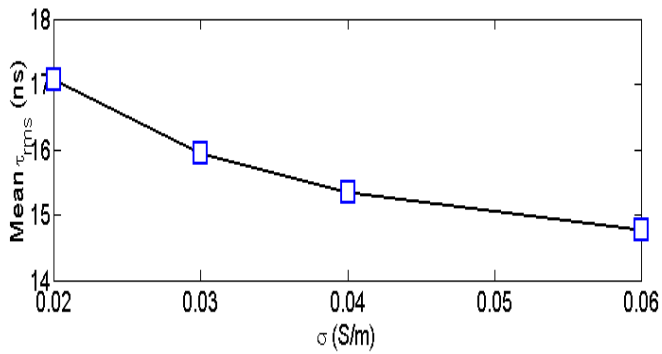


RMS delay spread

Effects of Conductivity (NLOS)

- In NLOS case





Path Loss

- Significant variation
- Increasing trend

RMS delay spread

- Higher value than in LOS
- Decreasing trend

Discussion

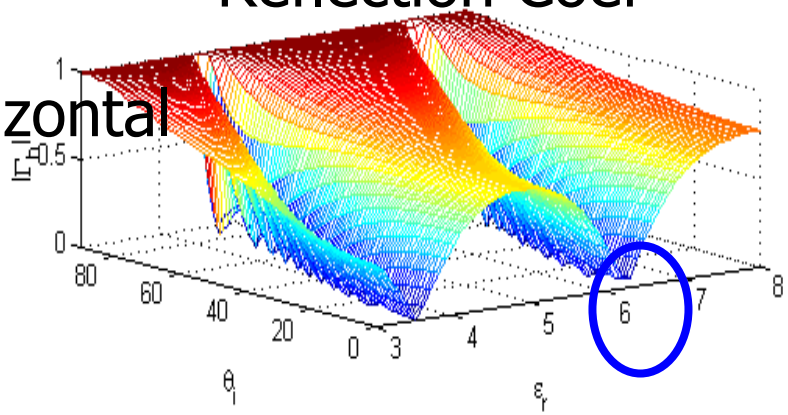
- In LOS case
  - Direct ray dominates the Path Loss
  - Multipath rays affect RMS delay spread significantly
- In NLOS case
  - Multipath rays affect both Path Loss and RMS delay spread
- Irregular variation of Path loss and RMS delay spread ?

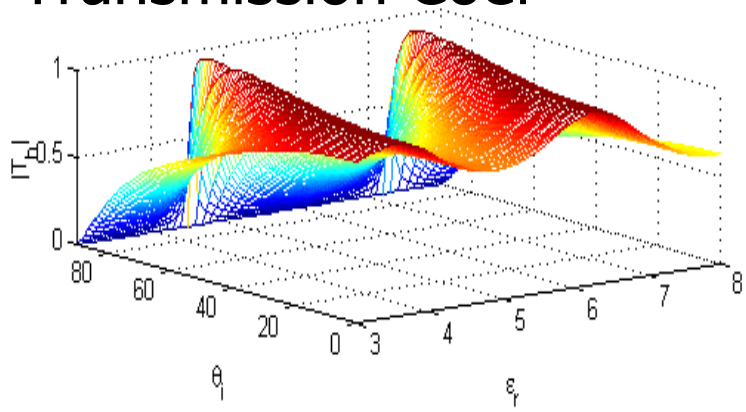
Permittivity Effects

Reflection Coef

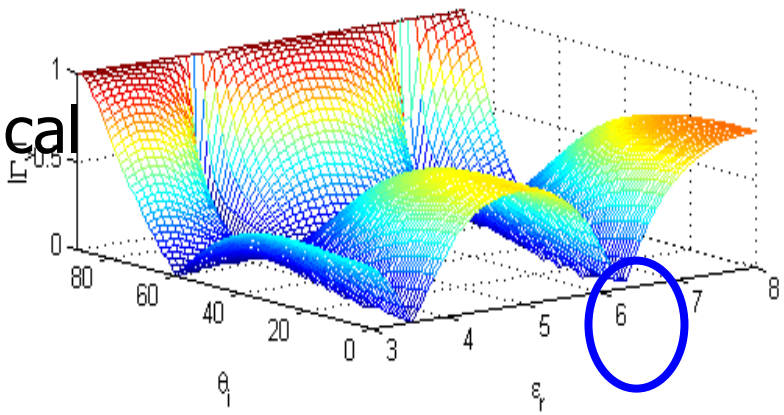
Transmission Coef

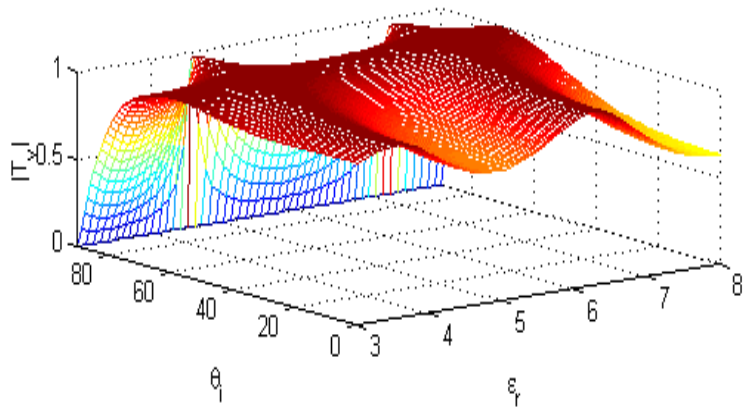
Horizontal





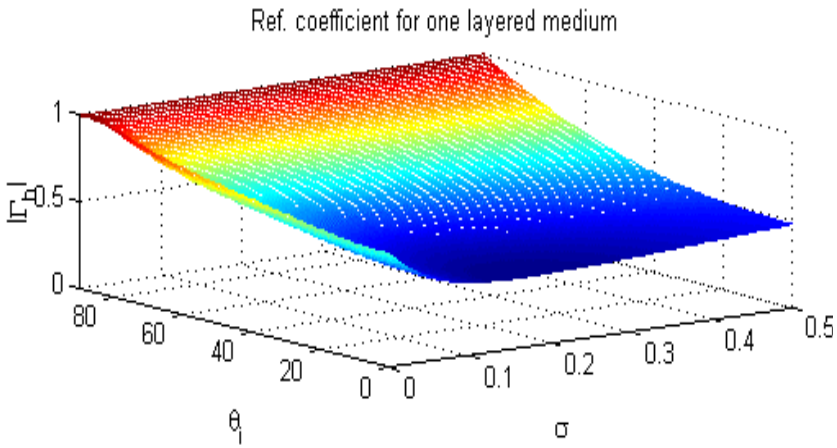
Vertical

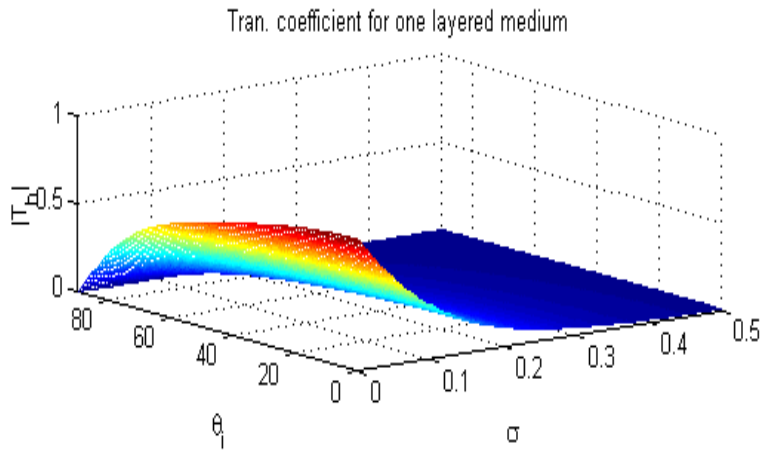


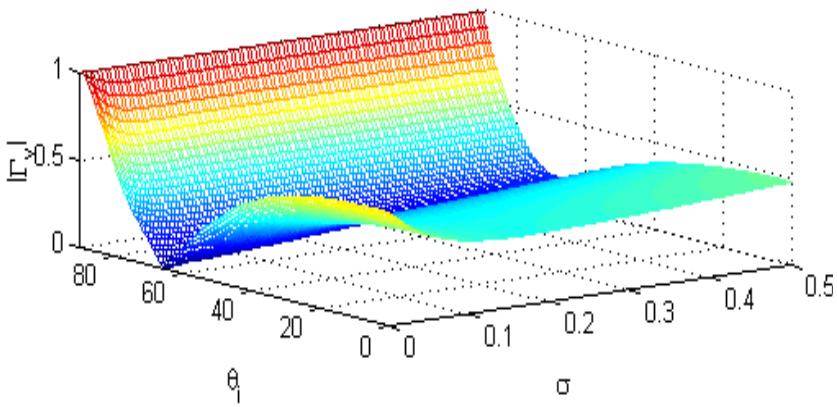


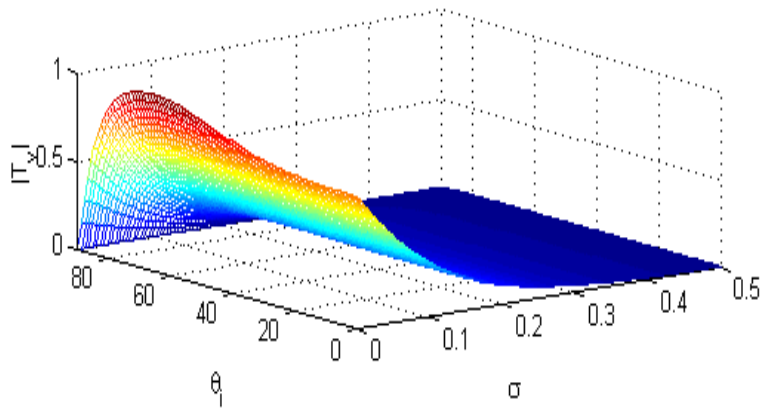
$f = 2$ GHz; $\sigma = 0.0$ S/m; $d = 12$ cm.

Conductivity Effects





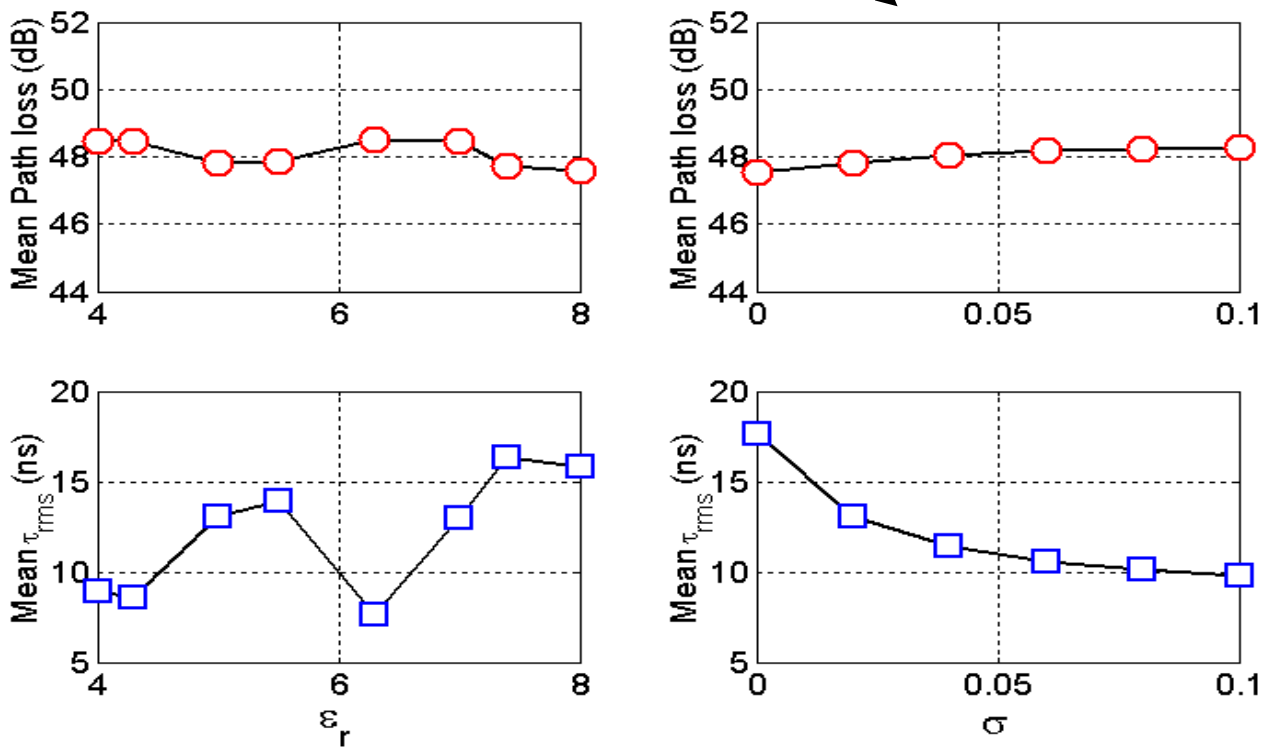




$f = 2$ GHz; $\varepsilon_r = 5.0$; $d = 12$ cm.

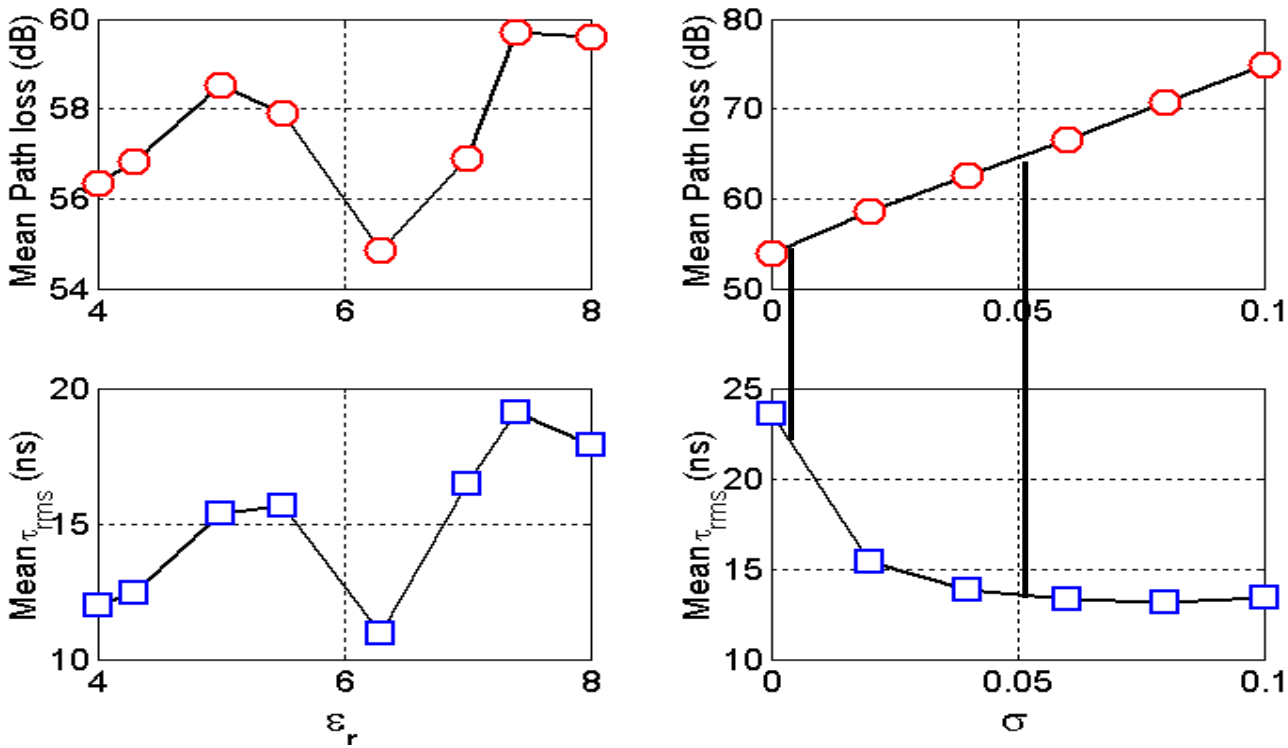
Permittivity/Conductivity Effects (1)

- In LOS case

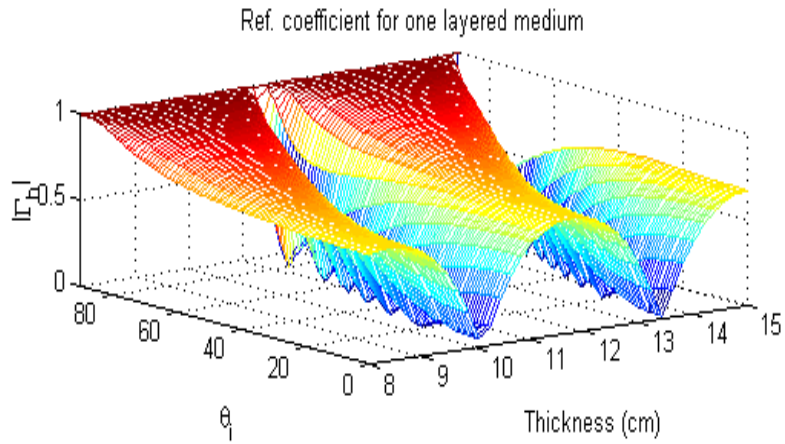


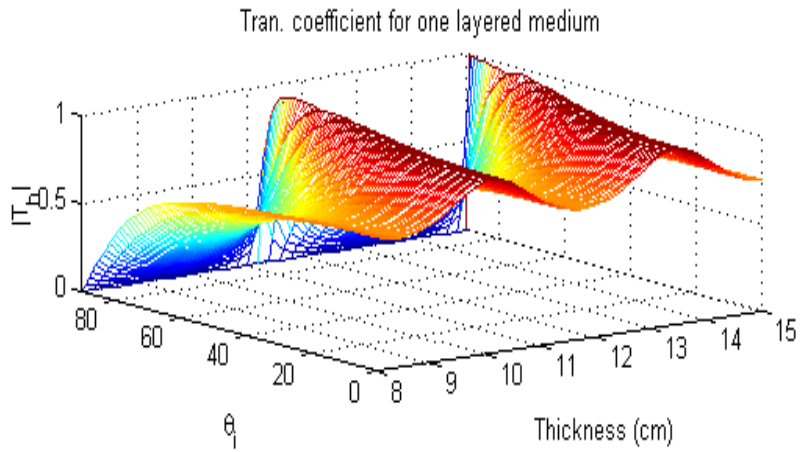
Permittivity/Conductivity Effects (2)

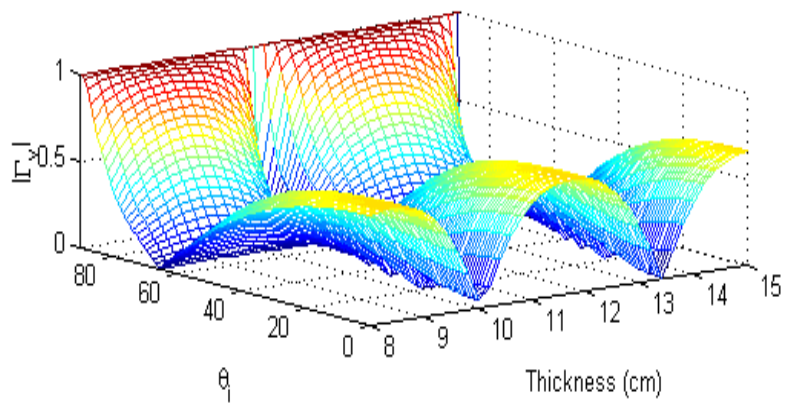
- In NLOS case

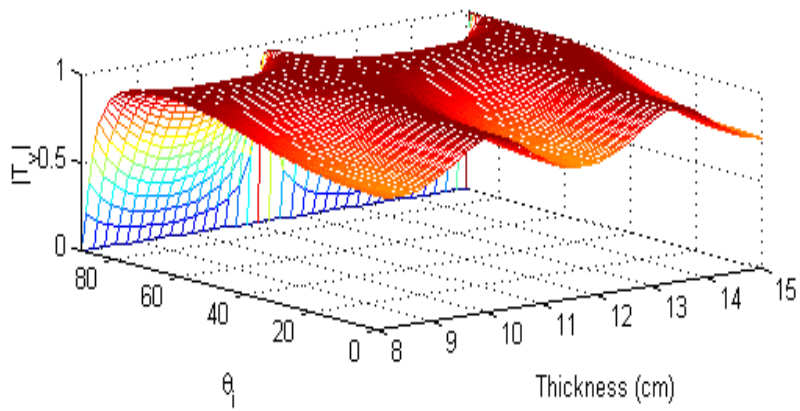


Thickness Effects (1)









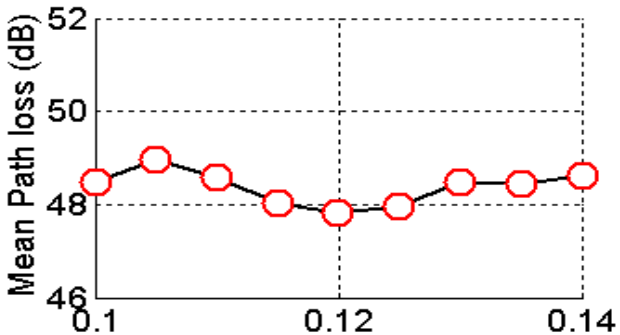
$f = 2$ GHz; $\varepsilon_r = 5.0$; $\sigma = 0.0$ S/m.

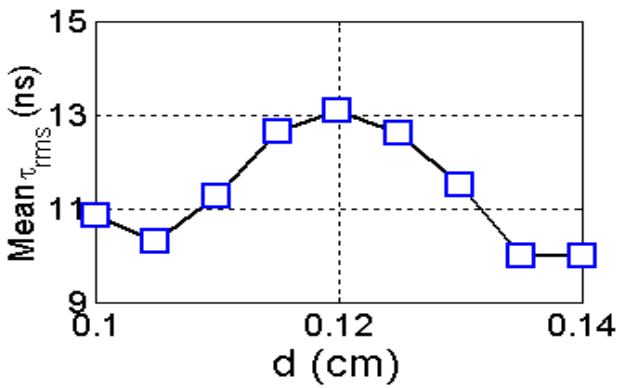
Thickness Effects (2)

- Finite thickness of building structures
  - Resonance/periodic phenomena occurs similar to the effect of permittivity on radio channel characteristics
- But the change of the thickness is also linked to the conductivity
- The thickness effects on the channel characteristics are the combination of the permittivity and conductivity.

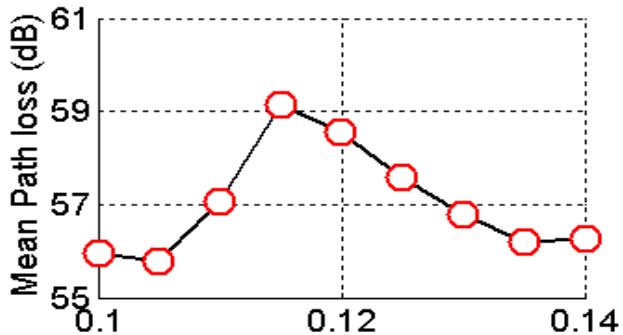
Thickness Effects (3)

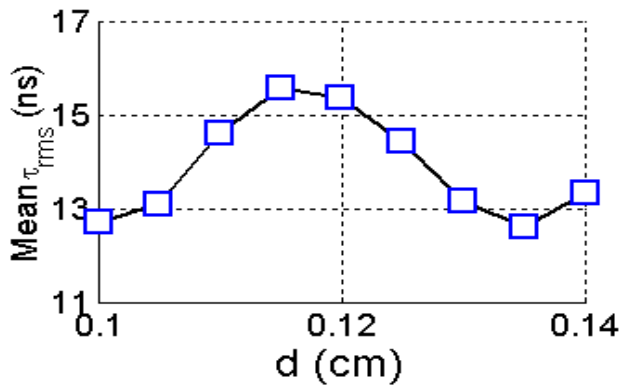
LOS





NLOS





Conclusion

- Path loss and RMS delay spread as functions of dielectric constant, conductivity and thickness have been examined quantitatively.
- Effects could be significant in some cases
  - Permittivity on RMS delay spread (but not path loss)
  - Conductivity on both the path loss and RMS delay spread.

Thank you!