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

Submission Title: Kiosk Channel Modeling

Date Submitted: 8 February 2016

Source: Danping He, Beijing Jiaotong University

E-Mail: hedanping1019@163.com

Re: n/a

Abstract: Discussing kiosk application scenarios, ray tracer calibration and preliminary modeling results.

Purpose: Contribution towards developing kiosk channel model for use in TG 3d

Kiosk Channel Modeling

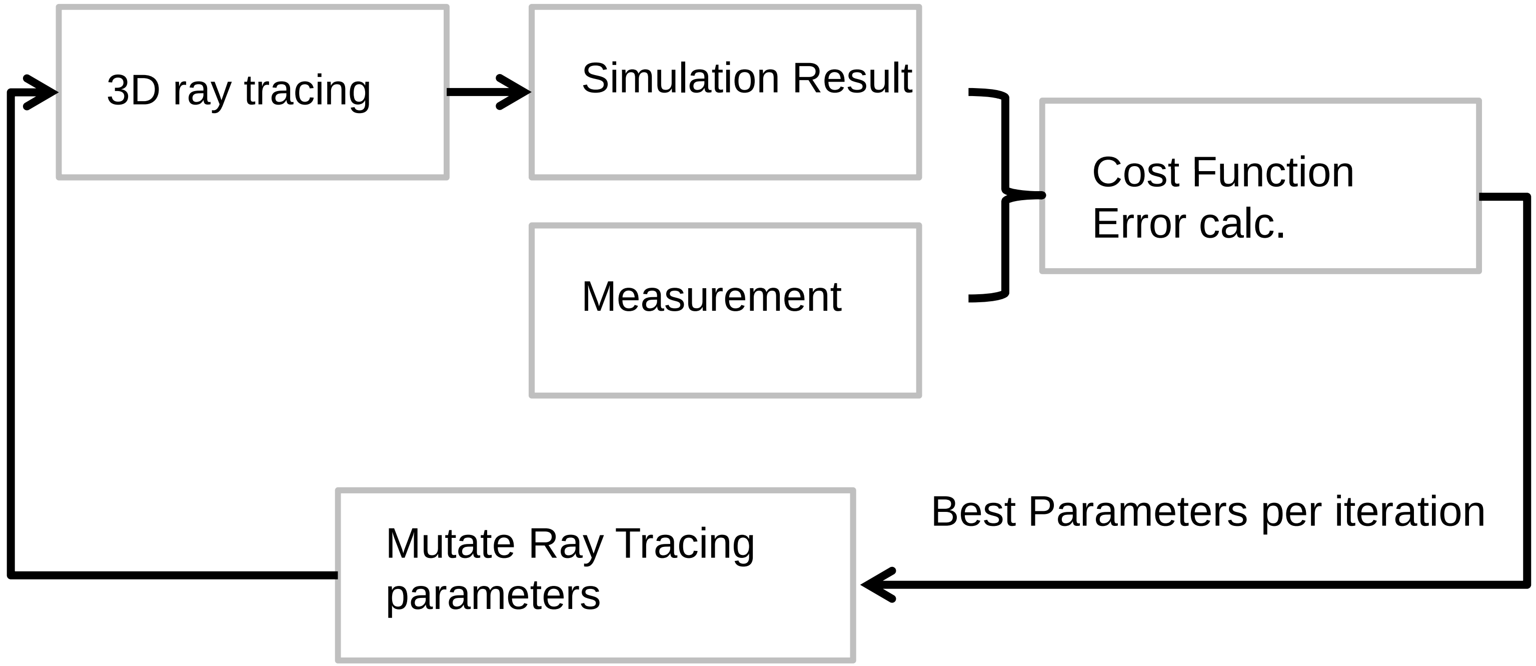
Danping He, Ke Guan, Bo Ai, Zhangdui Zhong
Beijing Jiaotong University
Akifumi Kasamatsu, Hiroyo Ogawa, Iwao Hosako
National Institute of Information and Communications Technology
Dr. Yaita
NTT

Content

1. **Ray Tracer Calibration**
2. Target Scenario Generation
3. Parameter Extraction and modeling
4. Channel Realization

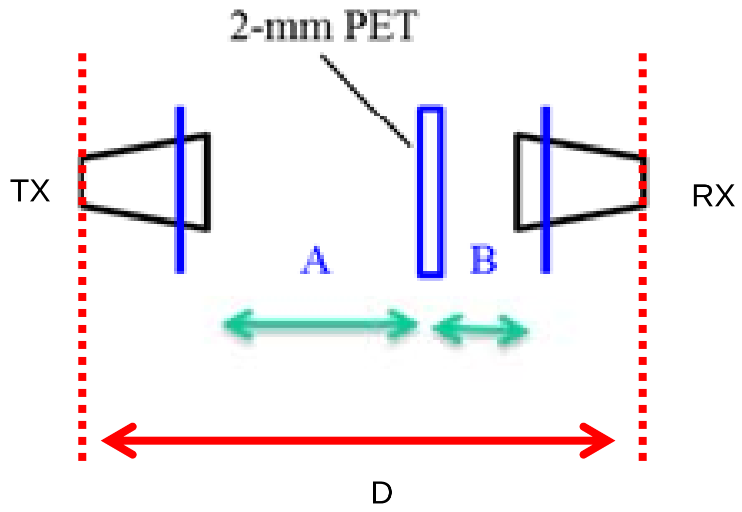
1. Ray Tracer Calibration

Calibration Approach



1. Ray Tracer Calibration

Target scenario for calibration:



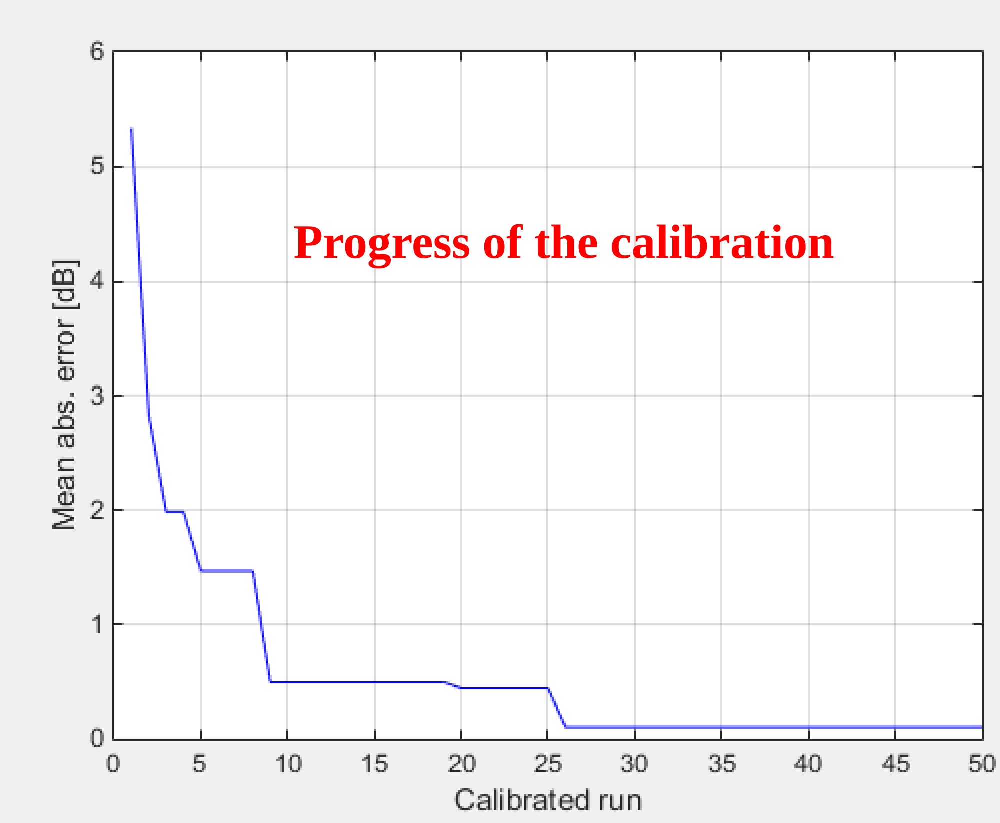
D=0.5139 m
A=0.3800 m
B=0.0880 m

Ray Tracer configuration:

- **Maximum order of reflected ray: 6**
- **Transmitted loss by PET:** A_PET=2.0
- **Higher order reflection coefficient:** NLOS_Coefficient=0.5

Material	ε_r	$\tan\delta$
Metal	1.0	1.0E7
PET	6.4	0.1172

1. Ray Tracer Calibration



Calibrated Result:

Material	ε_r	$\tan\delta$
Metal	2.2120	4.5209E6
PET	1.8667	0.3953

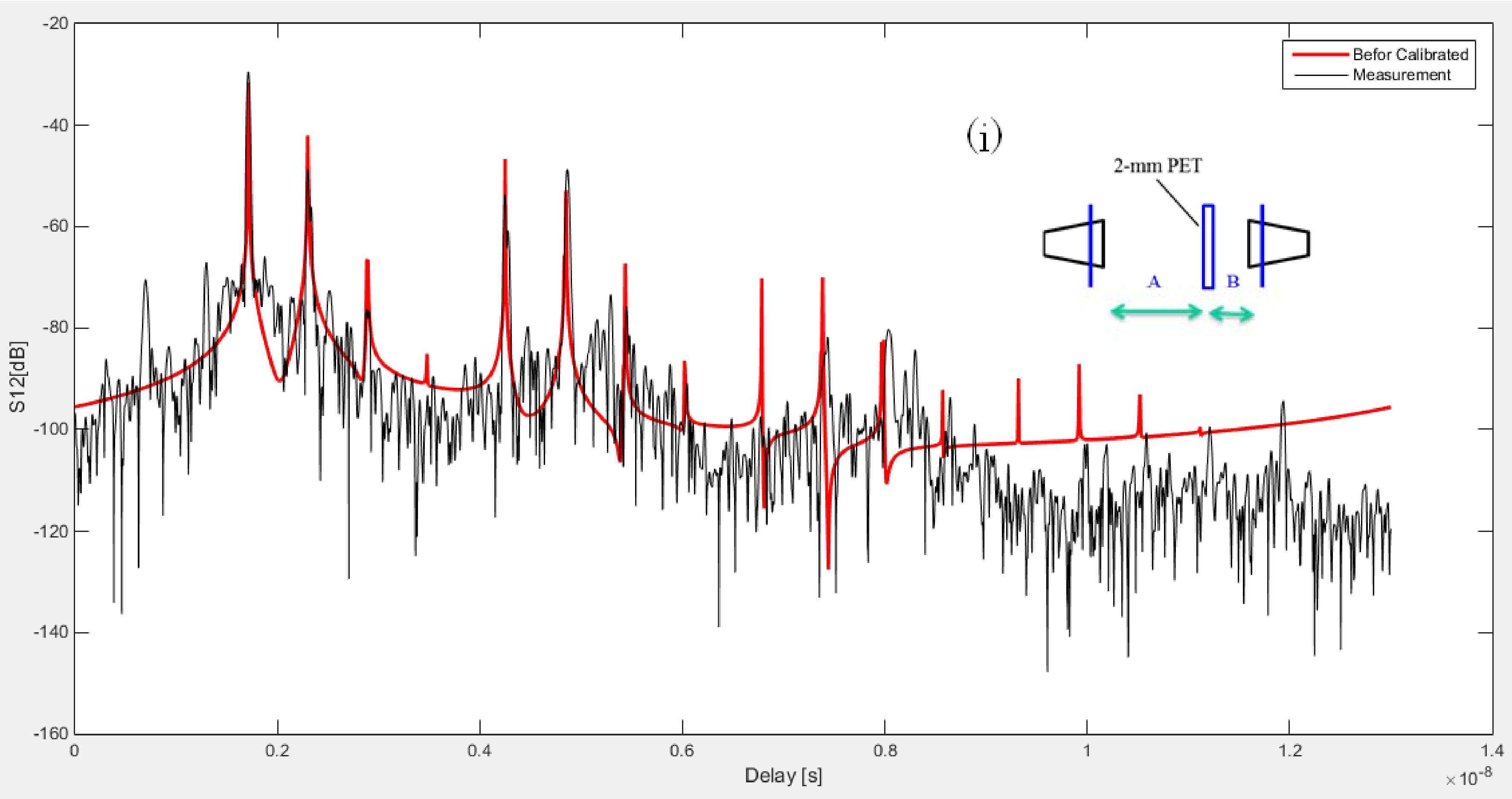
Transmitted loss by PET:
A_PET=1.9890

Higher order reflection coefficient:
NLOS_Coefficient=0.5

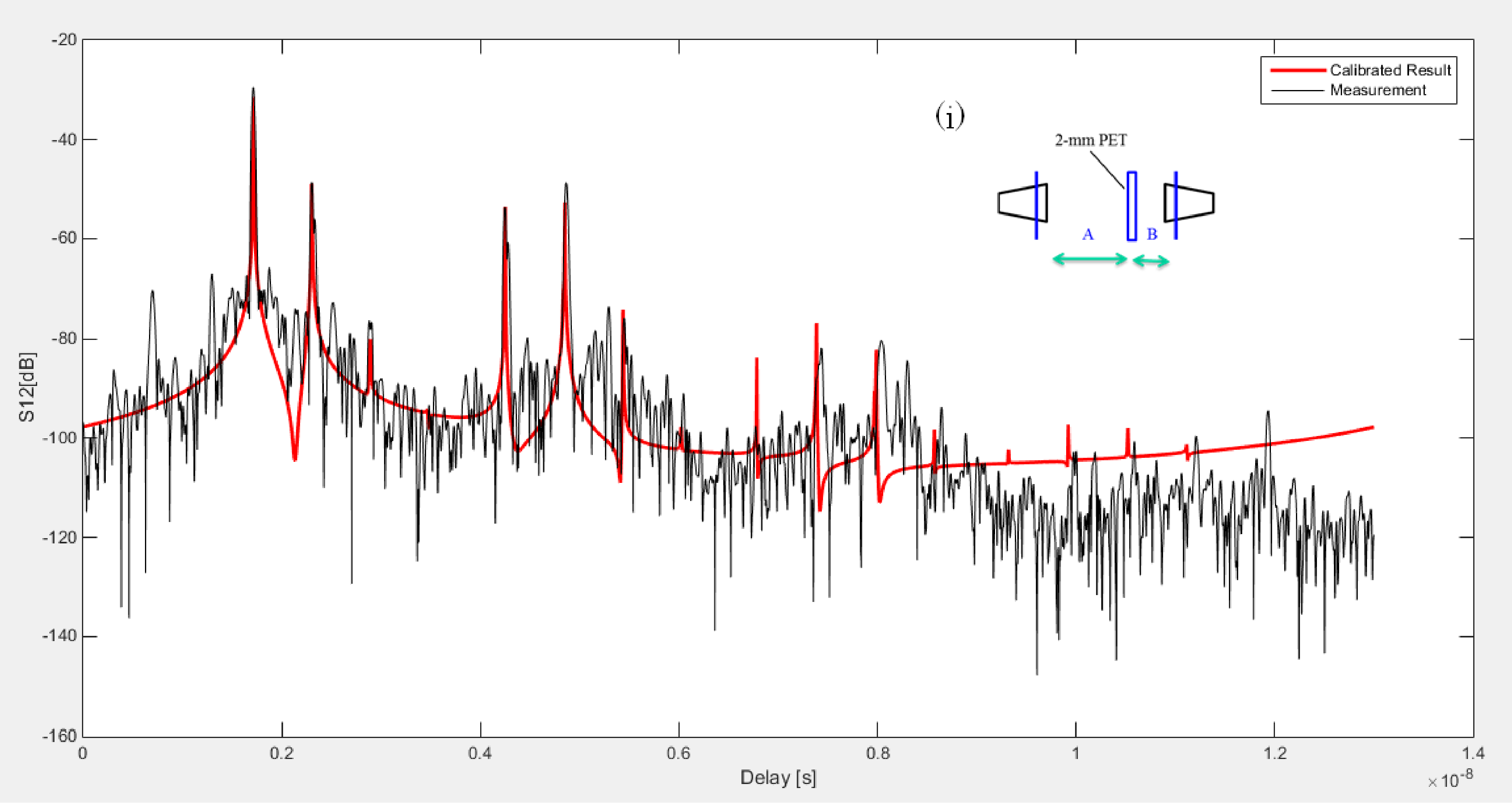
Mean abs. error=0.1027 dB

1. Ray Tracer Calibration

Before Calibration

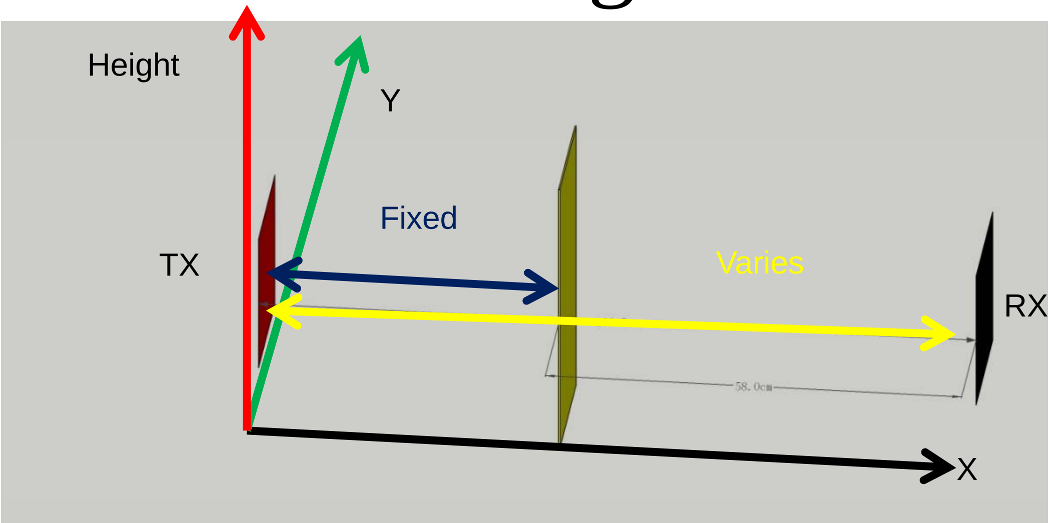


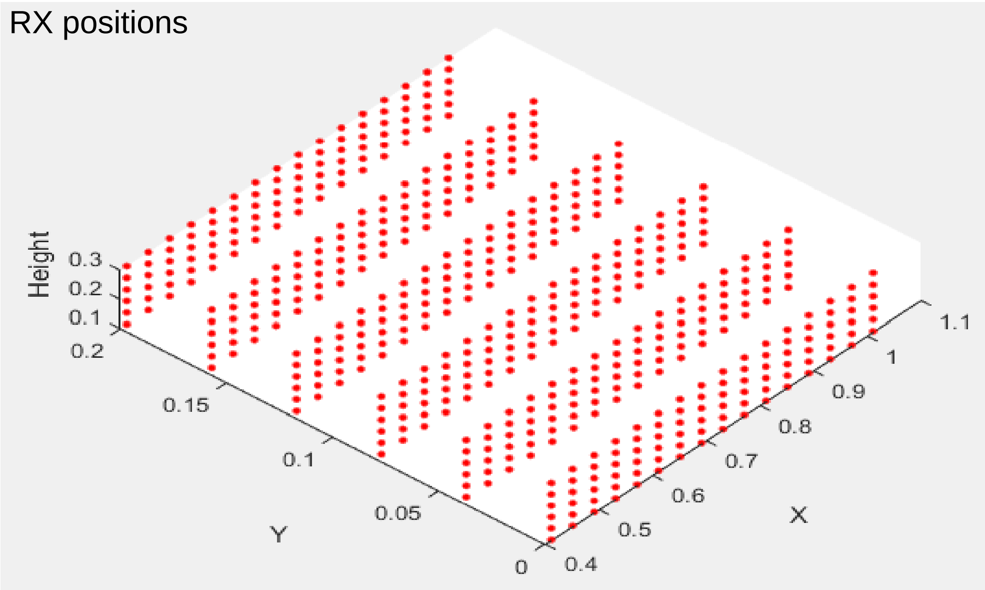
1. Ray Tracer Calibration-After calibration



Content

2. Target Scenario Generation





'All parallel' Scenario

- 3D distance between TX and RX ranges from 0.43~1.3m
- TX position is fixed
- RX and RX metal plate positions vary

$$TX\,(-0.0217, 0.1, 0.2)[m]$$

$$RX\,(x_{RX}, y_{RX}, z_{RX})[m]$$

$$x_{RX} \in [0.4122, 1.0122]$$

$$y_{RX} \in [0, 0.2]$$

$$z_{RX} \in [0.1, 0.3]$$

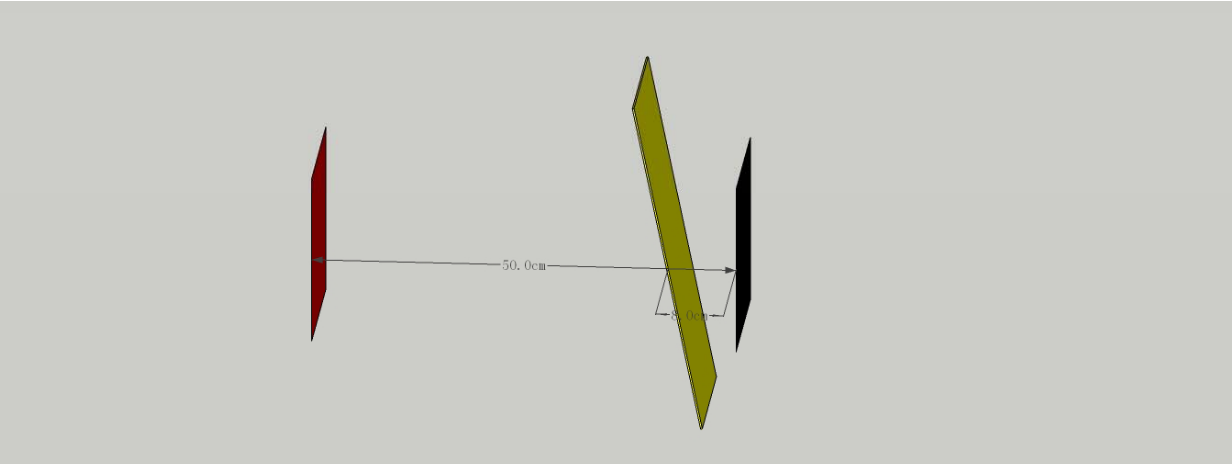
- Frequency Properties

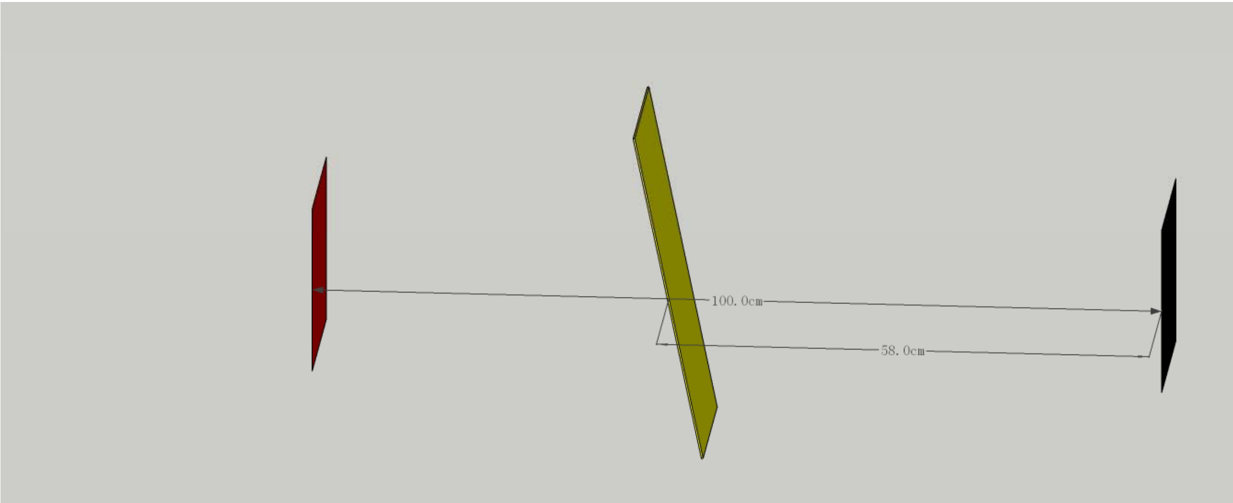
$$f \in [220, \sim 340]\ \text{GHz}$$

$$\tau_{\max} = {3d_{\max}}/{c} = 13\ \text{ns}$$

$$f_{step} = {1}/{\tau_{\max}} < 77\ \text{MHz}$$

2. Target Scenario Generation

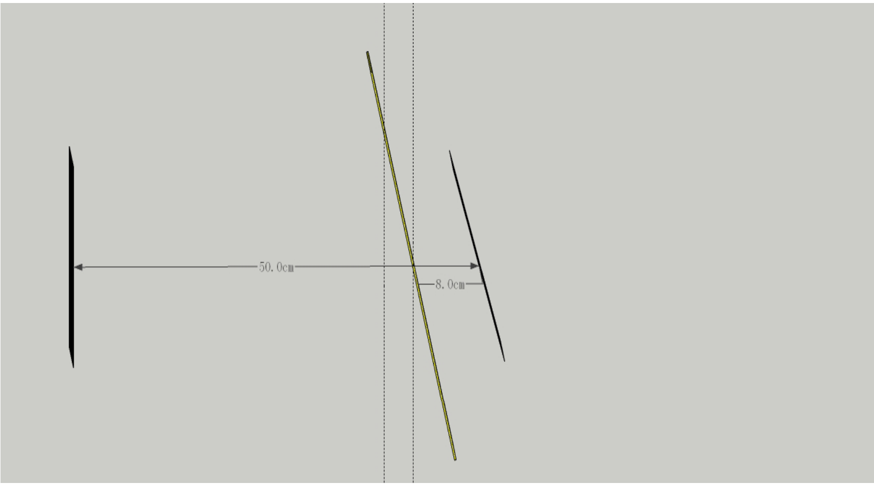


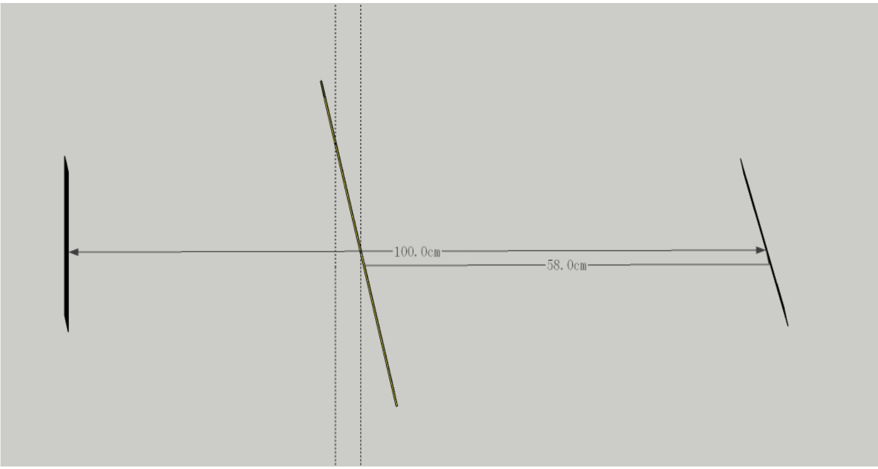


'PET tilted' Scenario

- PET is tilted
- TX and RX points to each other
- TX and PET positions are fixed
- RX position varies

2. Target Scenario Generation





'PET & RX metal tilted' Scenario

- PET and RX are tilted
- TX and PET positions are fixed
- RX position varies

2. Target Scenario Generation

Any comments to the proposed scenarios?

Content

1. Ray Tracer Calibration
2. Target Scenario Generation
3. **Parameter Extraction and modeling**
4. Channel Realization

3. Parameter Extraction

➢ **Spatial path-specific channel transfer function**

$$H_i(f,\phi_{AOA},\theta_{AOA},\phi_{AOD},\theta_{AOD}) = a_i e^{j\varphi_i} D_i(f) e^{-j\pi(f-f_0)}$$
$$\bullet\delta(\phi_{AOD}-\phi_{AOD,i})\delta(\theta_{AOD}-\theta_{AOD,i})$$
$$\bullet\delta(\phi_{AOA}-\phi_{AOA,i})\delta(\theta_{AOA}-\theta_{AOA,i})$$

➢ **Obtain the complete channel transfer function**

All path-CTFs must be weighted with the TX and RX antenna characteristics gTX and gRX

$$H(f) = \sum_{i=1}^{N_{Rays}} H_i \cdot g_{TX}(f,\phi_{AOD,i},\theta_{AOD,i}) \cdot g_{RX}(f,\phi_{AOA,i},\theta_{AOA,i})$$

3. Parameter Extraction-type of path

Statistic overview of different order of rays at different Tx-Rx distance for ‘all parallel’ scenario

	Transmitted	1st order	2nd order	3rd order	4th order	5th order	6th order
Number	1	0	3	0	8	0	21
Added ratio	--	--	30.09%	--	1.98%	--	0.20%

Conclusion:

- We consider only up to 2nd order reflections, due to the high attenuation at higher orders (low added ratio)
- **1** transmitted path and **3** second-order reflection paths should be generated for ‘all parallel’ scenario
- The 3 types of reflection path are :
  - type1 (TX->RX metal->TX metal->RX)
  - type2 (TX->PET->TX metal->RX)
  - type3 (TX->RX metal->PET->RX)

3. Parameter Extraction-amplitude of path

- **Transmitted path attenuation:**

$$f_0 = 300GHz$$

$$a_{trans} = 20\log_{10}\left(\frac{c}{4\pi f_0}\right) - 20\log_{10}(d) - A_{pet}$$

$$= -81.98dB - 20\log 10(d[m]) - \boxed{A_{pet}}$$

Calibrated Attenuation due to PET

- **3 types of second order reflection:**

$$a_{i,\mathrm{Re}\,fl} = a_{trans} - \boxed{\Delta a_{trans}} - \boxed{n_\tau}(\tau_i - \tau_{trans}) + \boxed{\Delta a_i}$$

Δa_{trans} The offset compared with transmitted ray

n_τ Slope along delay, Δa_i Variation of fitting result

Different distribution models for different types of ref. path

3. Parameter Extraction-Cross Polarization discrimination

$$a_{i,\mathrm{Re}\,fl} = \sqrt{a^2_{i,\mathrm{Re}\,fl,co} + a^2_{i,\mathrm{Re}\,fl,cross}} \quad \Rightarrow \quad H_i = \begin{bmatrix} a_{i,co,\theta} & a_{i,cross,\theta} \\ a_{i,cross,\phi} & a_{i,co,\phi} \end{bmatrix}$$

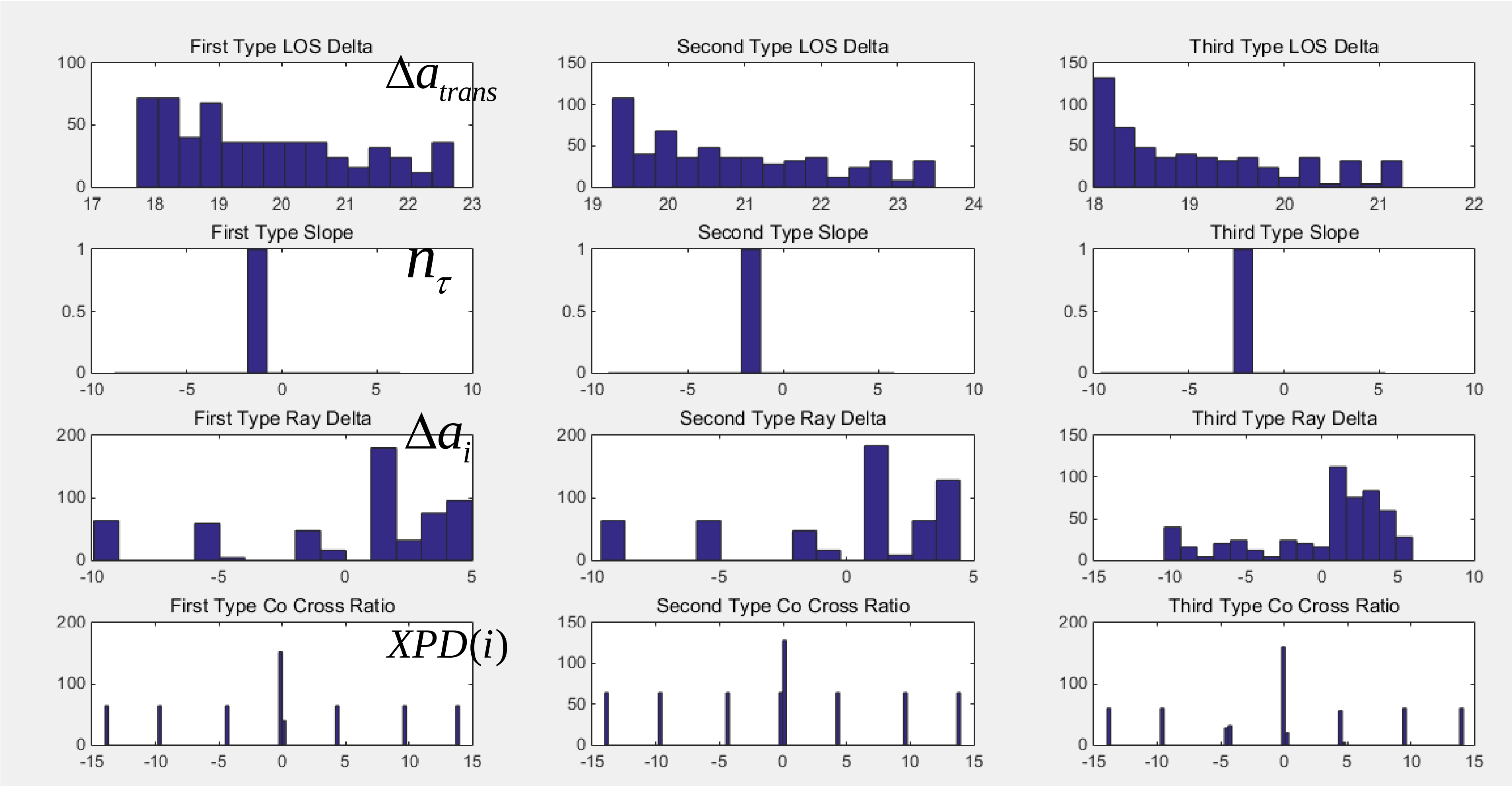
$$a_{i,\mathrm{Re}\,fl,co} = a_{i,\mathrm{Re}\,fl} - 20\log_{10}(1 + \frac{1}{10^{\frac{XPD}{20}}})$$

$$a_{i,\mathrm{Re}\,fl,co} = a_{i,\mathrm{Re}\,fl} - 20\log_{10}(1 + 10^{\frac{XPD}{20}})$$

$$XPD = 20\log_{10}(\frac{a_{co}}{a_{cross}})$$

XPD can be extracted for each ray from RT simulated results

3. Parameter Extraction-Amplitude and XPD



Next Step-> Approximation with proper distribution model

3. Parameter Extraction-Phase

- **Transmitted path attenuation:**

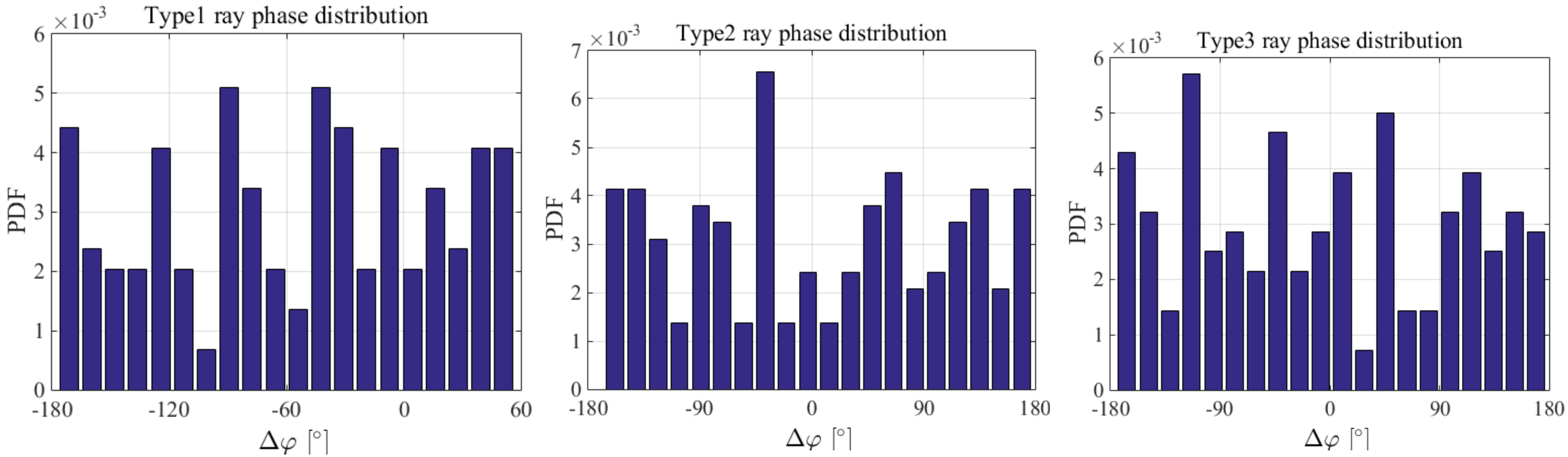
$$\varphi_{trans} = -2\pi f_0 \tau_{trans}$$

- **3 types of second order reflection:**

$$\varphi_{ref} = f(type)$$

3. Parameter Extraction-Phase

- **3 types of second order reflection:** $\varphi_{ref} = f(type)$



- Type1: uniformly distributed between -180 and 60
- Type2 and type3: uniformly distributed between -180 and 180

3. Parameter Extraction-frequency Dispersion

$$D_i(f) = \frac{f_0}{f^{\xi}}$$

Should be extracted from RT simulation

3. Parameter Extraction-AOD and AOA

θ_{AOD} uniformly distributed between $-\arcsin(\frac{0.1}{d[m]})$ and $\arcsin(\frac{0.1}{d[m]})$

ϕ_{AOD} uniformly distributed between $-\arcsin(\frac{0.1}{d[m]})$ and $\arcsin(\frac{0.1}{d[m]})$

AOA should be modeled … could be related with AOD and type of reflection

Content

1. Ray Tracer Calibration
2. Target Scenario Generation
3. Parameter Extraction and modeling
4. **Channel Realization**

4. Channel Realization-Generate CTF

Input

d: Distance between TX and RX in [m]
scenario: scenario type (1: all parallel, 2: pet tilted, 3: pet and RX metal tilted)
f: Frequency vector (f_start:f_step:f_stop)

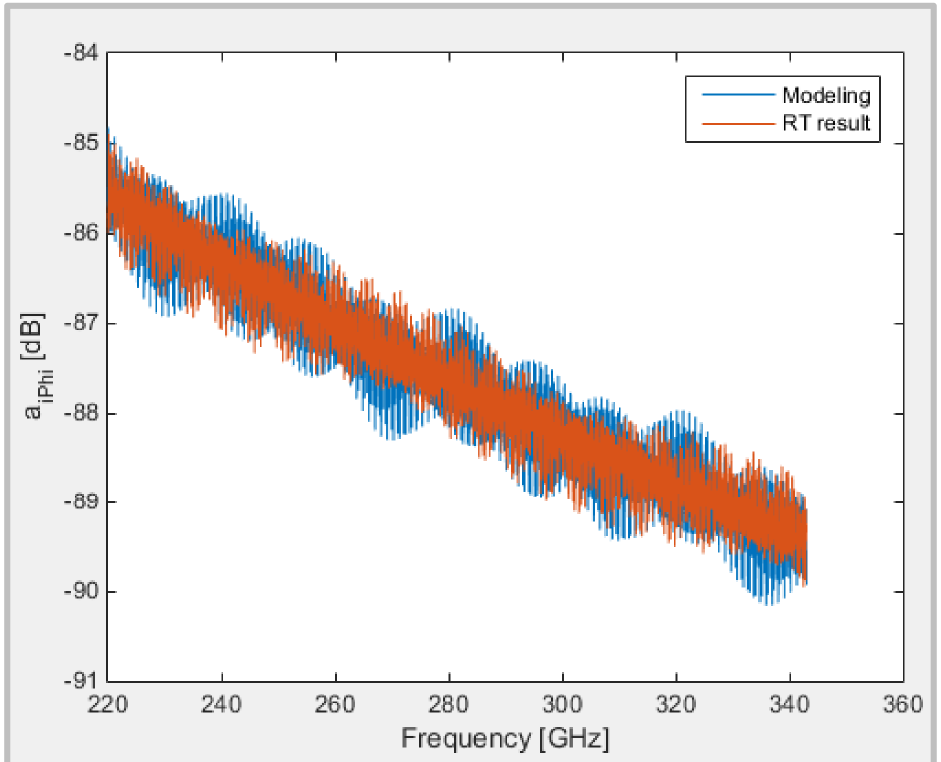
Output

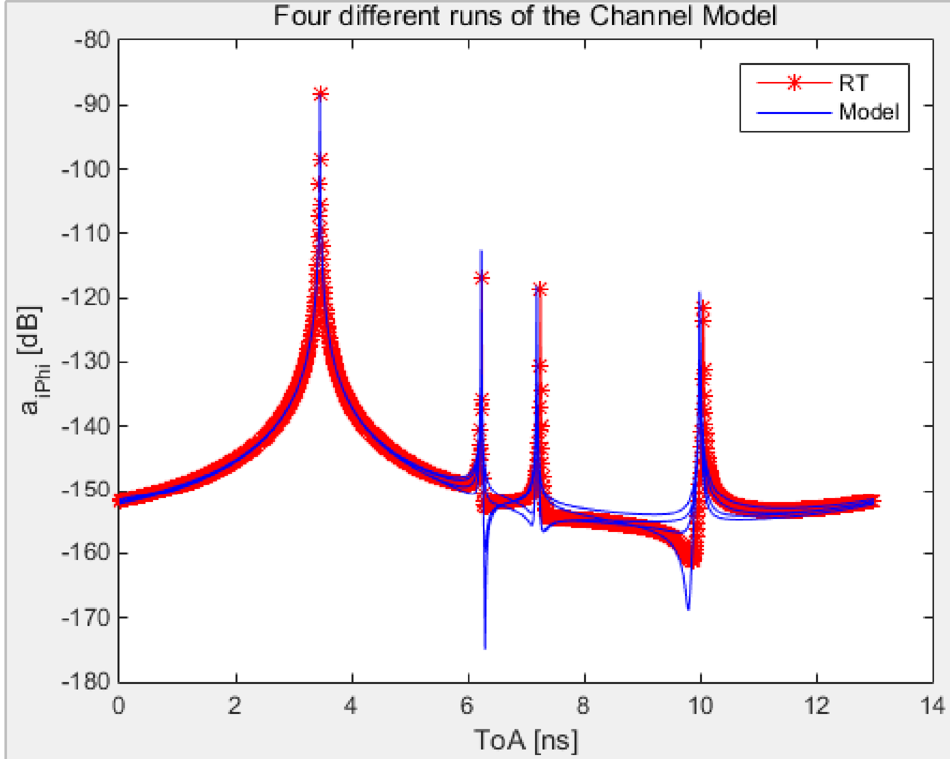
H: Channel matrix
Reflection_Order: Reflection Count Vector
ToA: Time of Arrival Vector in ns
D: Dispersion Factor
AOA,AOD: Angle of arrival/departure

[H,Reflection_Order,ToA,D,a_i_Phi,a_i_Theta,a_i_Theta_Phi,a_i_Phi_Theta,AoA_Phi,AoD_Phi,AoA_Theta,AoD_Theta] = Channel_Realization(d,scenario,f)

In terms of contents, there are many variables could be exported. We should extract those useful for verifying proposals, then derive the format of CTF file.

4. Channel Realization-Single RX $RX\,(1.0122, 0.12, 0.14)$

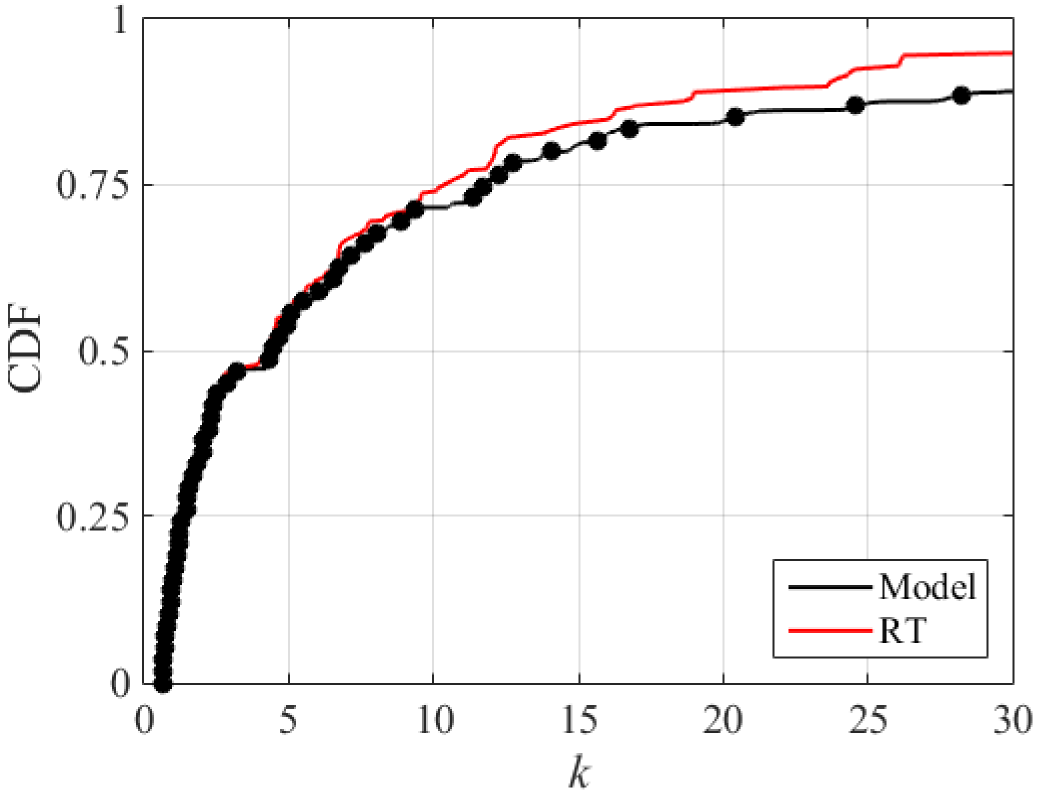




- Amplitude varies with Frequency
- The slopes match well

- Different 4 runs behave slightly differently
- All the 4 runs are able to describe MPCs with accurate delays

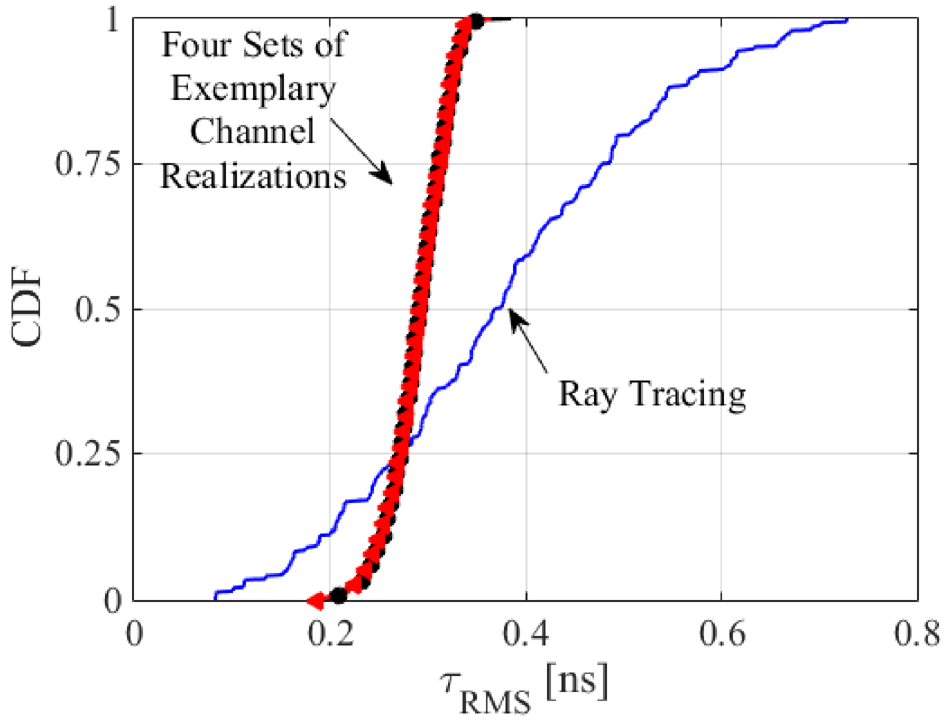
4. Channel Realization-Rician K factor



- 576 points, 10 runs per point
- Average K of the model is compared with the RT simulation

K factor	Theta	Phi
Abs. mean error	0.9092	0.9108

4. Channel Realization-Delay Spread RMS



- 576 points, 10 runs per point
- RMS delay spread is compared with the RT simulation

Delay spread (ns)	Theta	Phi
Abs. mean error	0.0741	0.0759

4. Channel Realization-Generated CTF file

```
802.15 TG 3d Channel Transfer Function
Scenario: Close proximity P2P
Frequency Range: 220 GHz - 340 GHz
Number of Frequency Points: 1601
Polarization: vertical
TX HPBW theta(degree): 11.6
TX HPBW phi(degree): 11.6
RX HPBW theta(degree): 8.9
RX HPBW phi(degree): 10.6
Antenna Gain: 25 dBi

--- Mandatory CTFs ---
kiosk_all_parallel_m1 -0.0038817697572302 - 0.0125866308598099i; -0.0093888304162577 - 0.0084915202581451i; -0.0133817754885043
kiosk_all_parallel_m2 0.0027130009730189 - 0.0007487568674402i; -0.0004414077170469 - 0.0039830916608712i; -0.0035950375243129 -
kiosk_all_parallel_m3 -0.0009695611653634 + 0.0000298058779266i; 0.0010479740404348 + 0.0005368483436764i; -0.0002384744874726 -
kiosk_all_parallel_m4 0.0007894030985617 + 0.0011541424150372i; 0.0009917267116631 - 0.0008822743102912i; -0.0001870283634410 -
kiosk_all_parallel_m5 0.0001207957127449 + 0.0003639396686842i; 0.0000117147523035 - 0.0000828793965477i; 0.0005063551751084 - 0
kiosk_all_parallel_m6 0.0009101551436588 + 0.0160813720624802i; 0.0146334372548618 + 0.0047119972127545i; 0.0105750520713819 - 0
--- Optional CTFs ---
kiosk_all_parallel_o1 -0.0000143844304800 + 0.0002725967518826i; 0.0002831928688255 - 0.0000372093370232i; -0.0000931085963565 -
kiosk_all_parallel_o2 0.0008826400335705 - 0.0000911110277224i; -0.0002906643820451 - 0.0008011688795518i; -0.0006692470412912 +
kiosk_all_parallel_o3 -0.0092379045964721 - 0.0095337503115306i; -0.0123784531868491 - 0.0059966147986020i; -0.0176555849324154
kiosk_all_parallel_o4 -0.0006777671388382 - 0.0007657573503151i; -0.0006341309043254 + 0.0007461358832018i; 0.0007893917505038 +
kiosk_all_parallel_o5 -0.0009802946209899 + 0.0001586786518026i; 0.0002506898472675 + 0.0010070424053594i; 0.0010350013527144 -
kiosk_all_parallel_o6 0.0004208495928627 - 0.0005042806259028i; -0.0005458764451784 - 0.0002369064118402i; -0.0000437769700605 +
```

Scenario name

TX, RX antenna parameters are different

Use case