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

Submission Title: Kiosk Channel Modeling

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Source: Danping He, Beijing Jiaotong University

E-Mail: hedanping1019@163.com

Re: n/a

Abstract: Define kiosk application scenarios and modeling results.

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

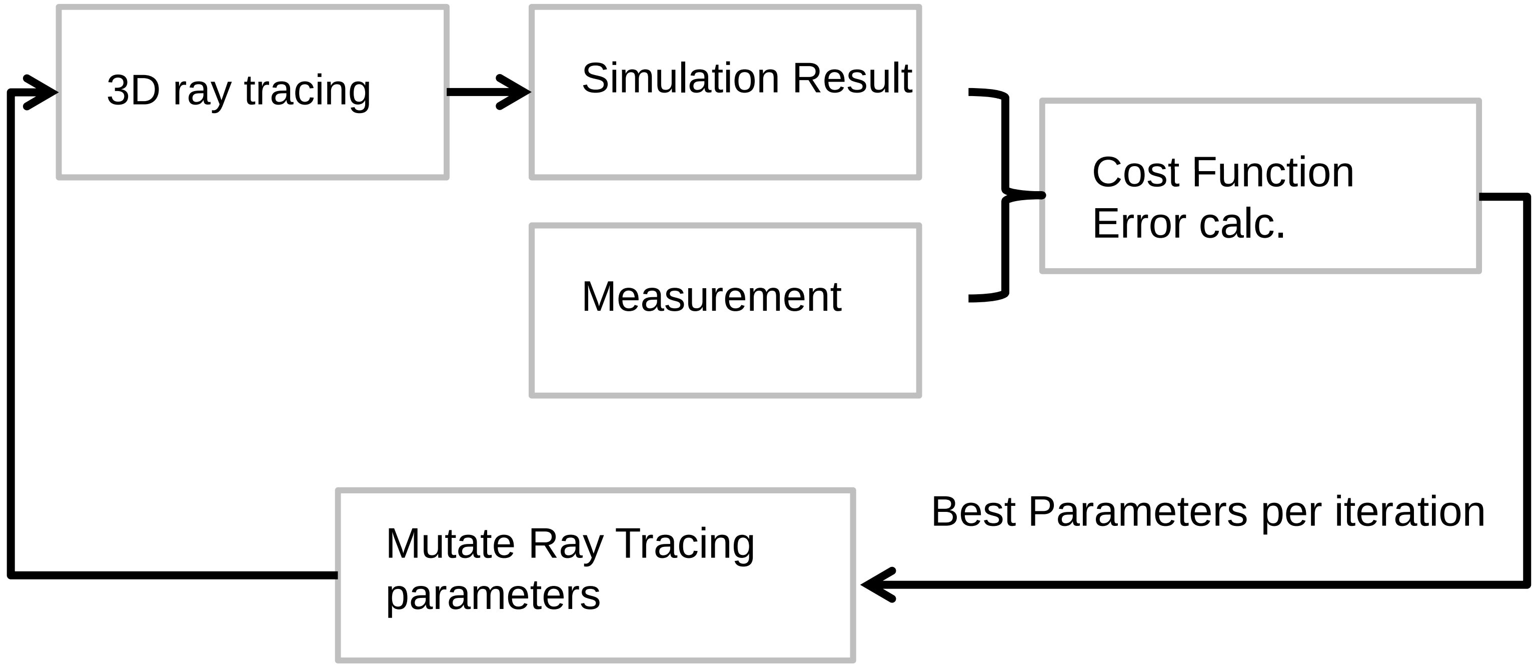
Kiosk Channel Modeling

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

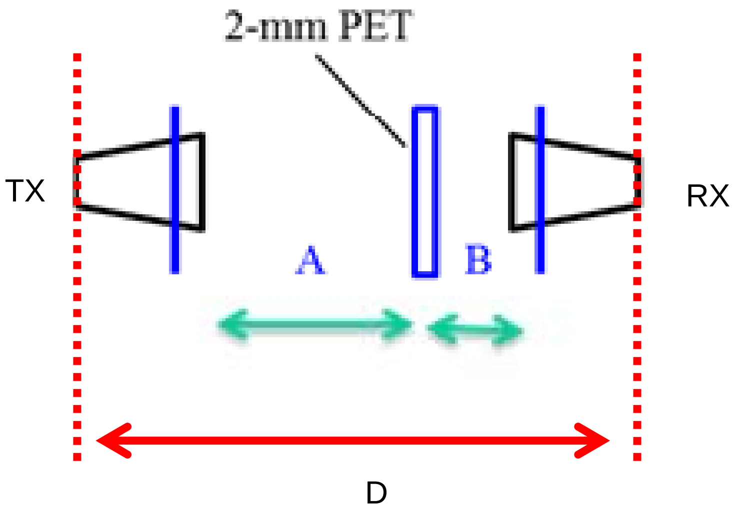
1. Ray Tracer Calibration

Calibration Approach



1. Ray Tracer Calibration

Target scenario for calibration:



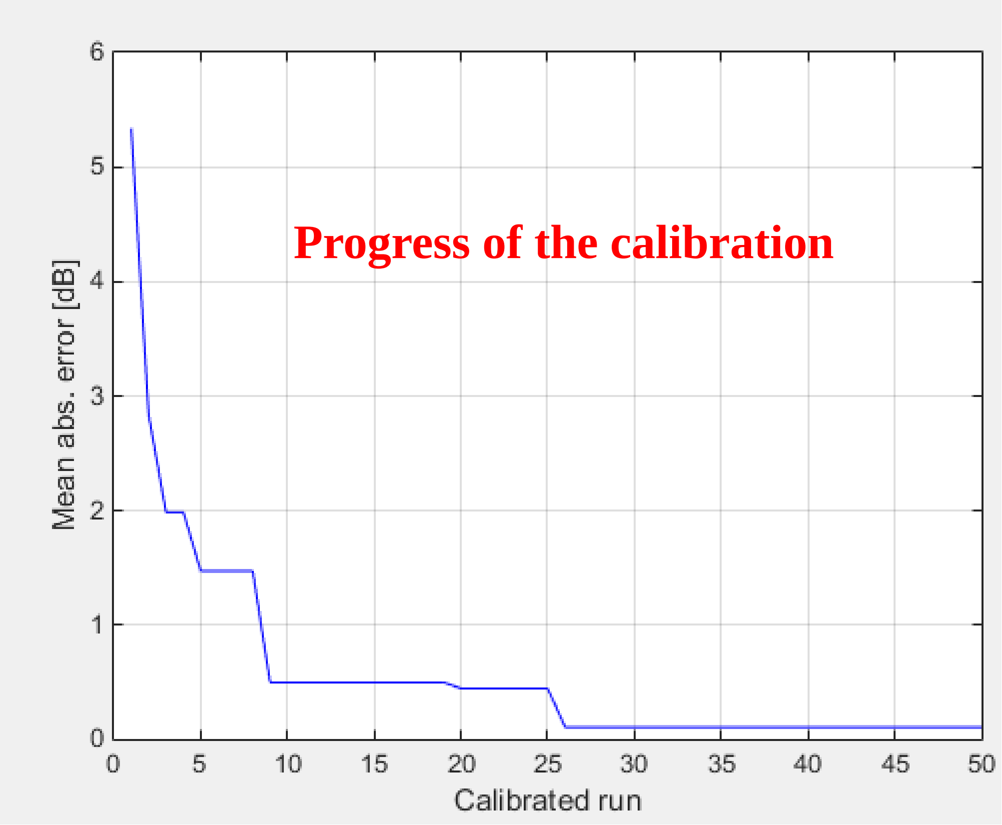
D=0.5139 m
A=0.3800 m
B=0.0880 m

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-Both metal and PET are calibrated



Calibrated Result:

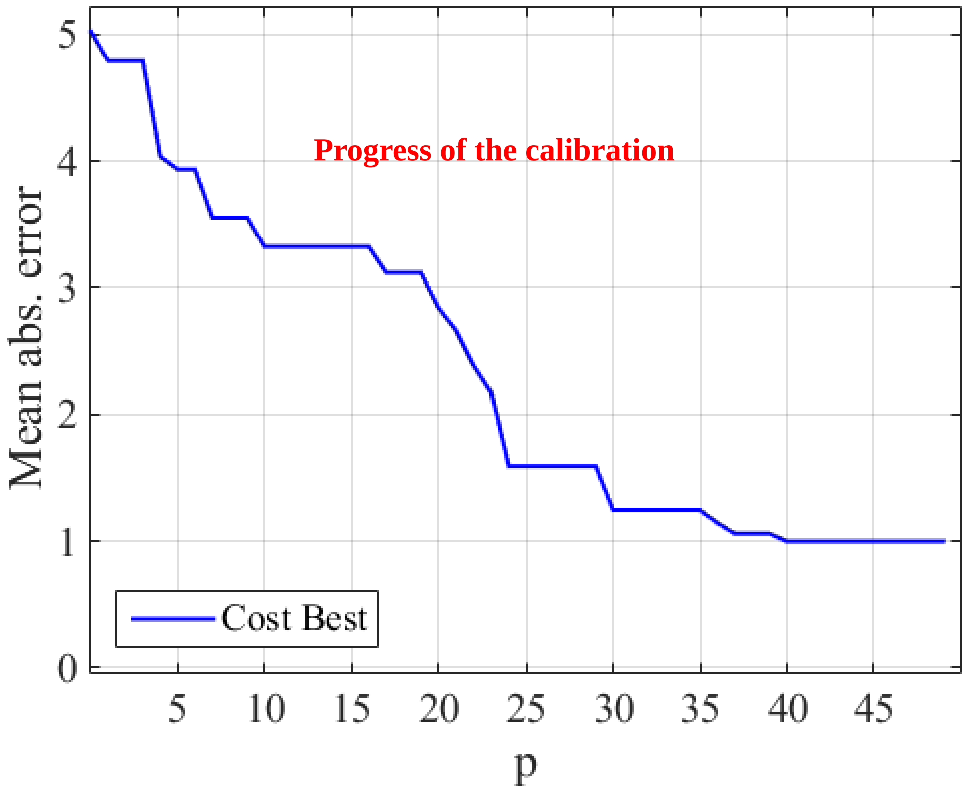
Material	ε_r	$\tan\delta$
Metal	2.2120	4.5209E6
PET	1.8667	0.3953

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-Only PET is calibrated



Calibrated Result:

Material	ε_r	$\tan \delta$
Metal	1	1E7
PET	2.1899	0.1187

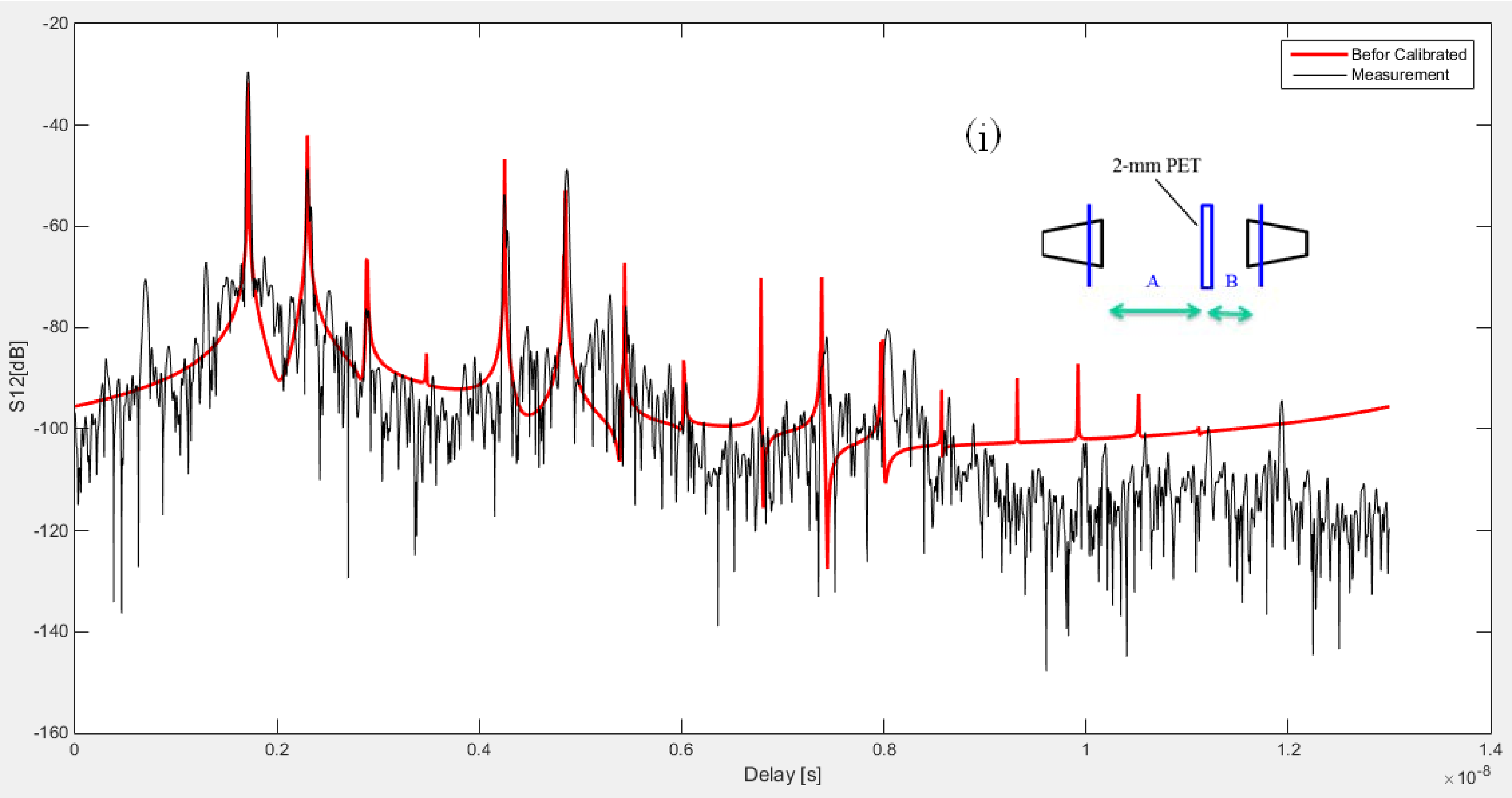
Transmitted loss by PET: A_PET=1.9706

Higher order reflection coefficient: NLOS_Coefficient=0.45

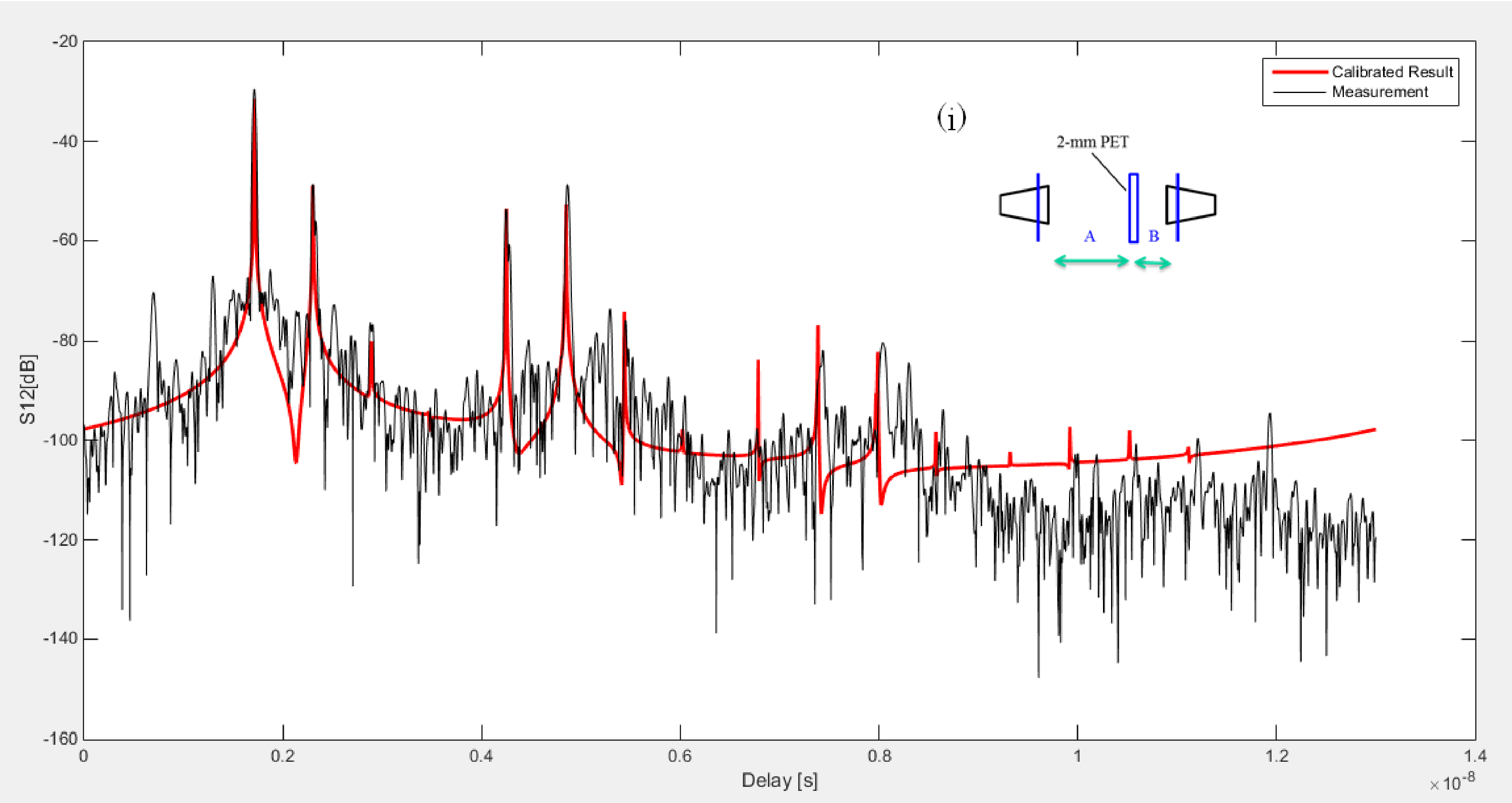
Mean abs. error= 0.9976 dB

1. Ray Tracer Calibration

Before Calibration



1. Ray Tracer Calibration-After calibration

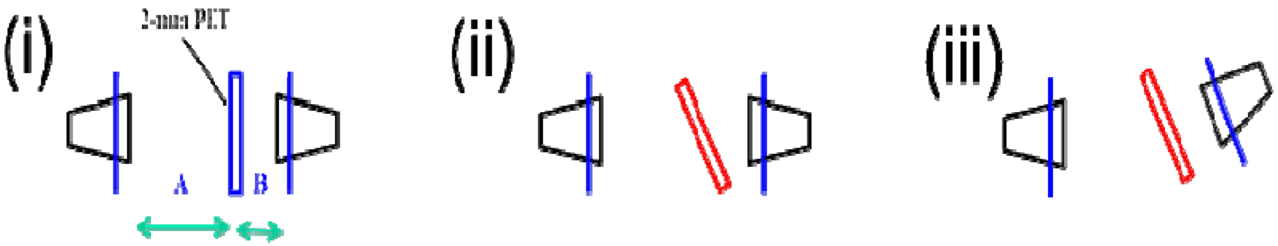


Content

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

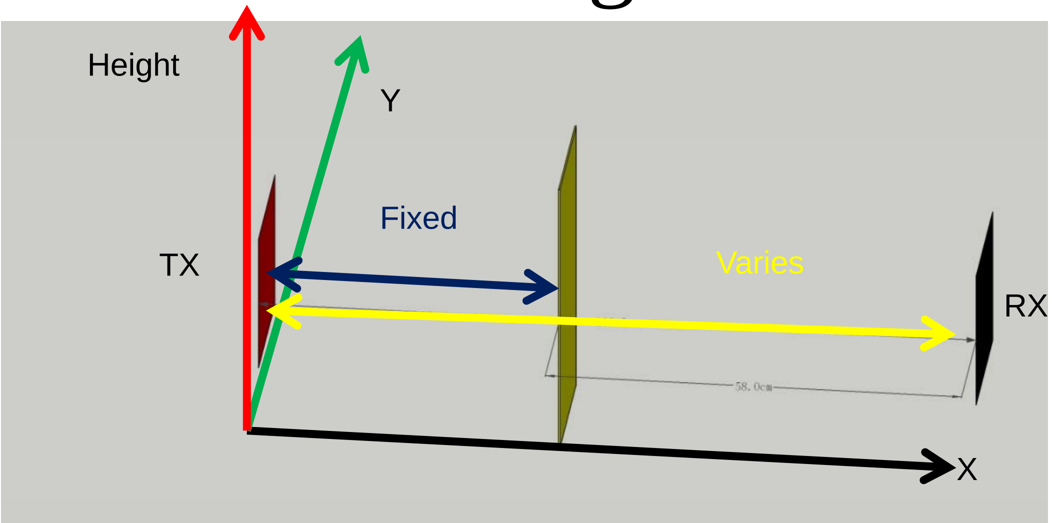
Scenario Definition

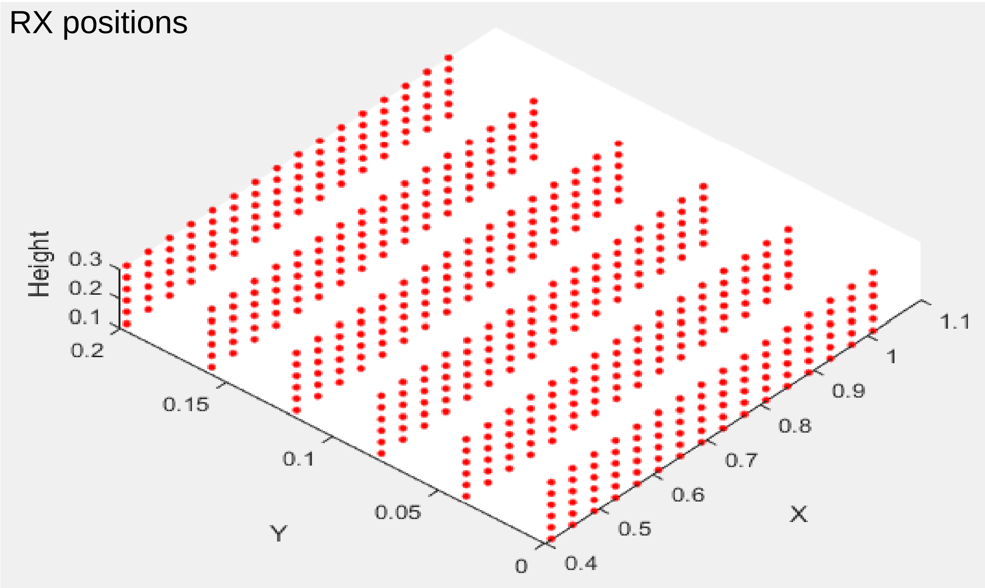
Three scenarios are modeled for Kiosk downloading application



Scenario (i): All the plates are parallel to each other
Scenario (ii): The PET plate is tilted
Scenario (iii): The PET plate, RX antenna and metal plate are tilted

2. Target Scenario Generation





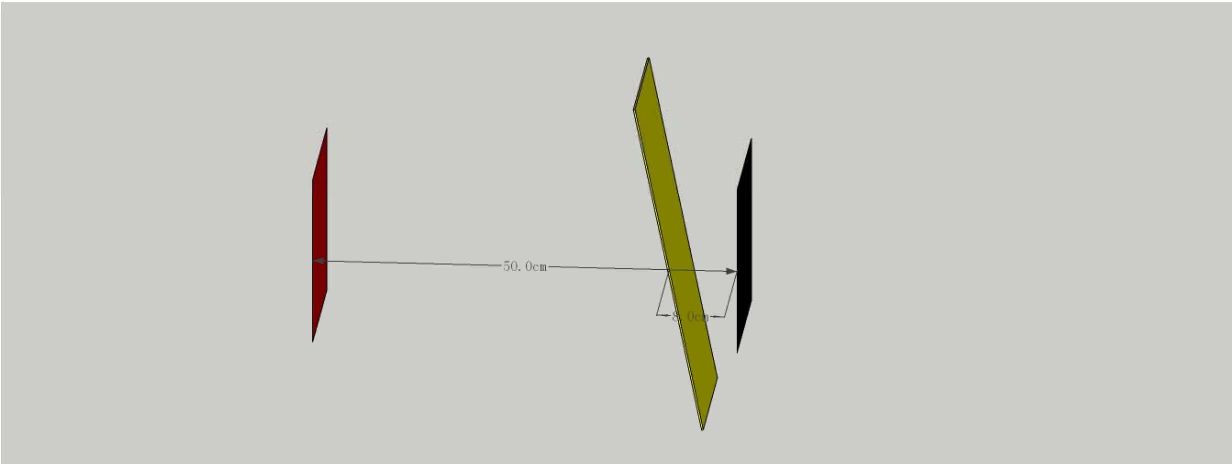
'All parallel'-Scenario (i)

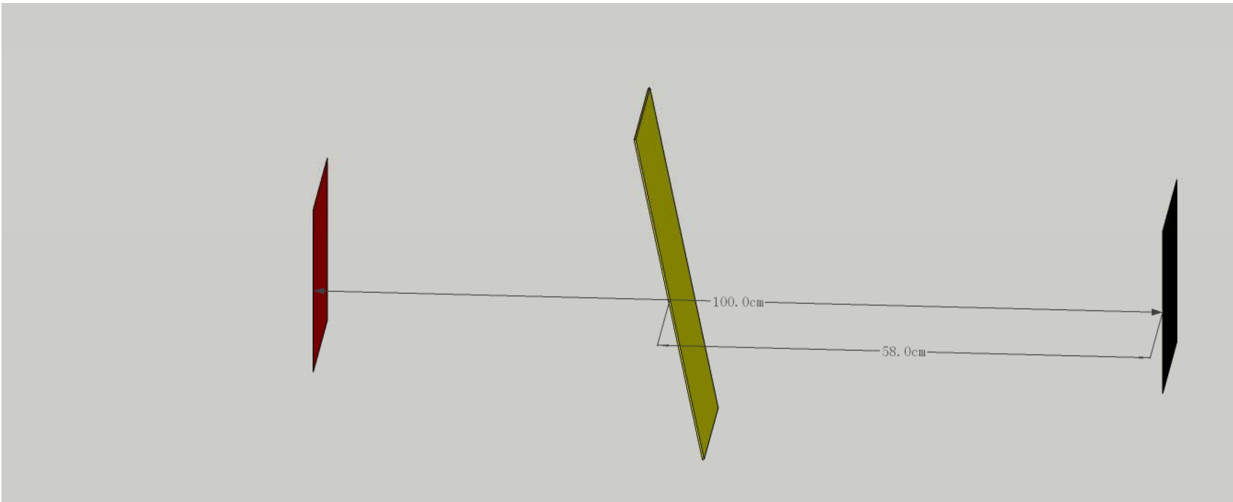
- 3D distance between TX and RX ranges from ~0.41-1.0 m
- TX position is fixed
- RX and RX metal plate positions vary
- Frequency Properties

Range: $f \in [220, \sim 340]$ GHz

Frequency step should be determined by the maximum absolute delay

2. Target Scenario Generation

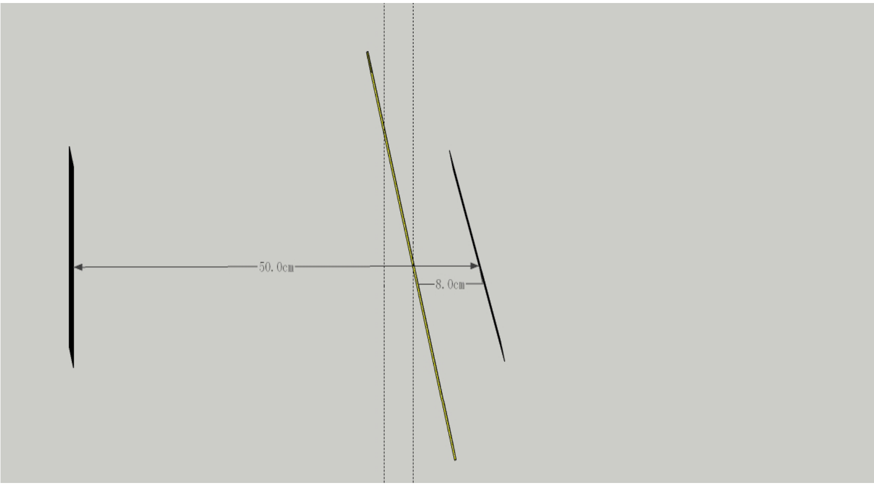




'PET tilted'-Scenario (ii)

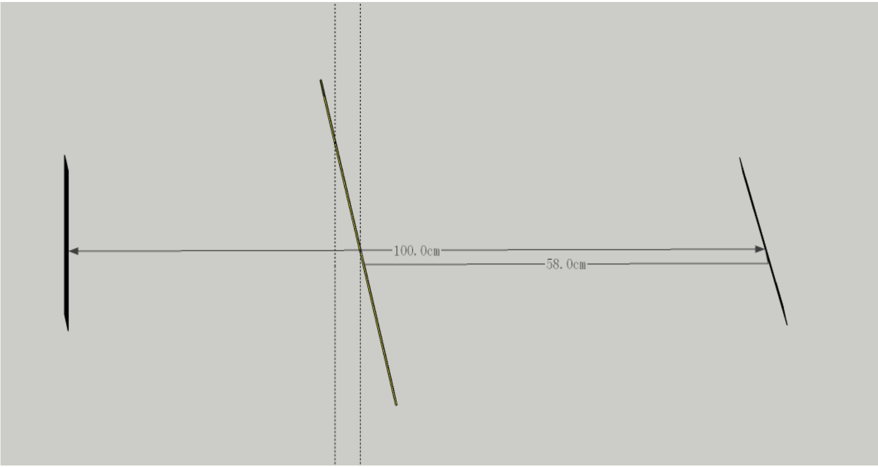
- PET is tilted
- TX and RX points to each other
- TX and PET positions are fixed
- RX position varies

2. Target Scenario Generation



'PET & RX metal tilted' – Scenario (iii)

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



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 scenario (i)

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

Statistic overview of different order of rays at different Tx-Rx distance for scenario (ii)

	Transmitted	1st order	2nd order	3rd order	4th order	5th order	6th order
Number	1	0	<3	0	<8	0	<10
Contribution	--	--	~10%	--	<0.8%	--	~0.00%

Statistic overview of different order of rays at different Tx-Rx distance for scenario (iii)

	Transmitted	1st order	2nd order	3rd order	4th order	5th order	6th order
Number	1	0	<2	0	<4	0	<3
Contribution	--	--	~10%	--	<0.3%	--	~0.00%

3. Parameter Extraction-type of path

Conclusion:

- We consider only up to 2nd order reflections, due to the high attenuation at higher orders (low contribution)
- **1** transmitted path and **3** second-order reflection paths should be generated for 'all parallel' scenario
- The 3 types of reflection path are :

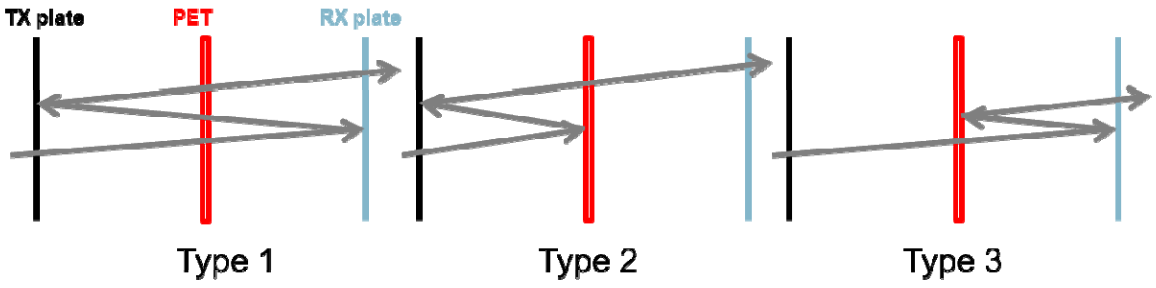
type1 (TX->RX metal->TX metal->RX)

type2 (TX->PET->TX metal->RX)

type3 (TX->RX metal->PET->RX)

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

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



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

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

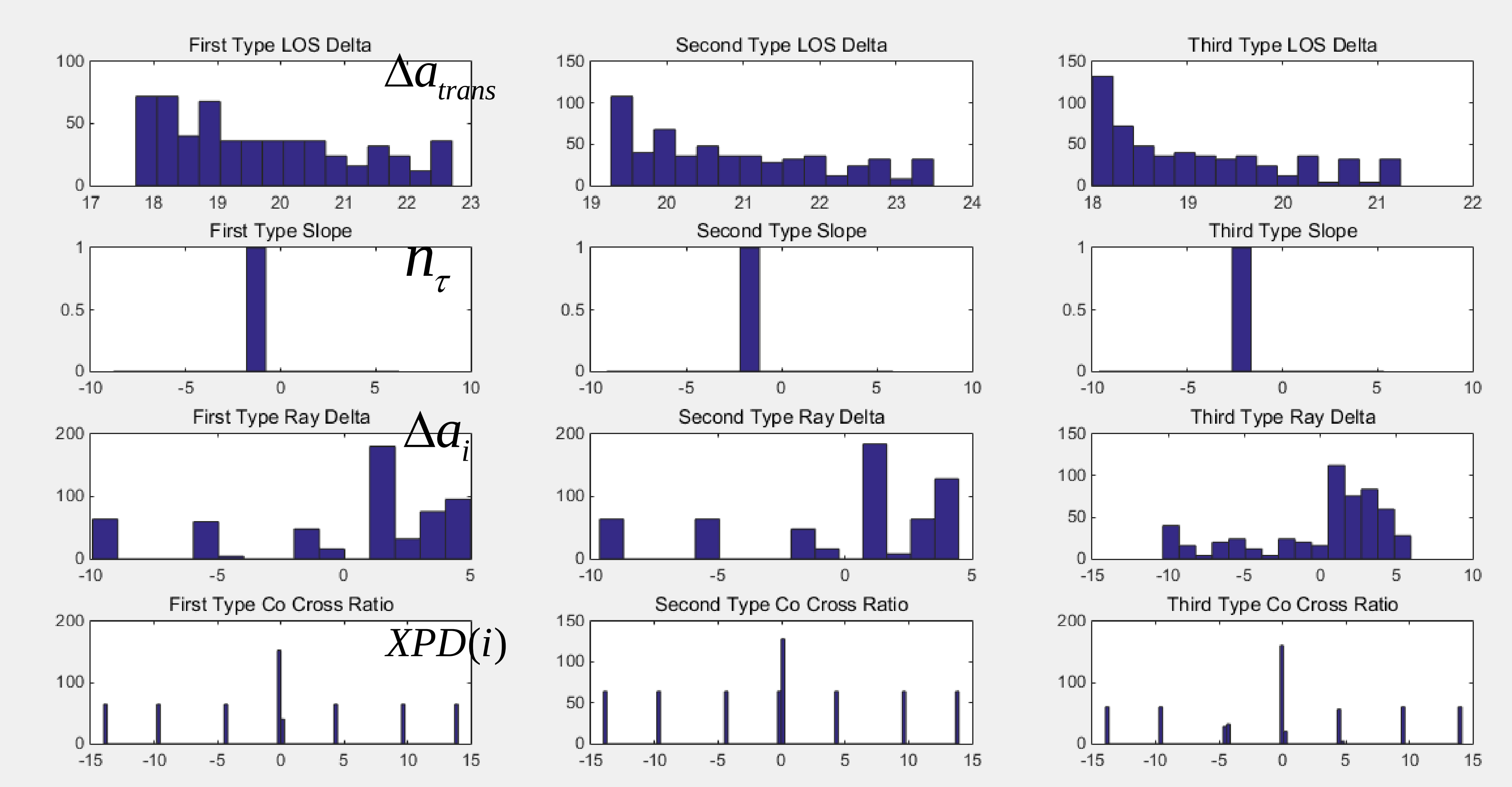
$$a_{i,\mathrm{Re}\,fl,co} = a_{i,\mathrm{Re}\,fl} - 20\log_{10}(1+\frac{1}{10^{\frac{XPD}{20}}})$$

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

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

XPD can be extracted for each ray from RT simulated results

3. Parameter Extraction-Amplitude and XPD



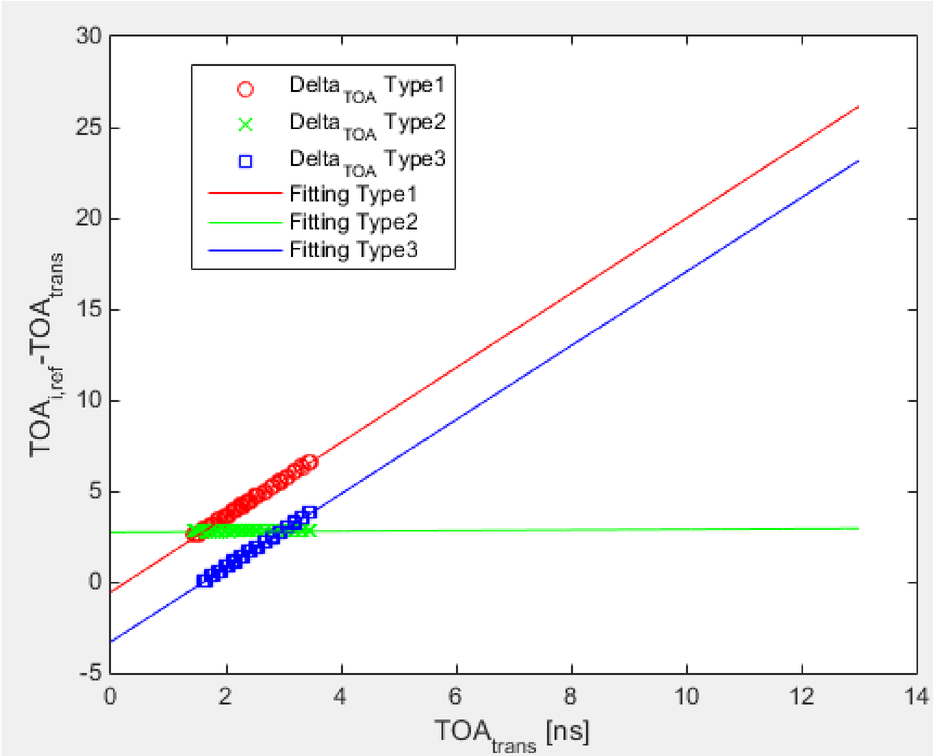
3. Parameter Extraction-TOA

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

- Modeling TOA

$$\tau_i = \tau_{trans} + \Delta\tau(\tau_{trans}, type)$$

$$\Delta\tau(\tau_{trans}, type) = a_{type}\tau_{trans} + b_{type}$$



3. Parameter Extraction-Phase

- **Phase of transmitted path:**

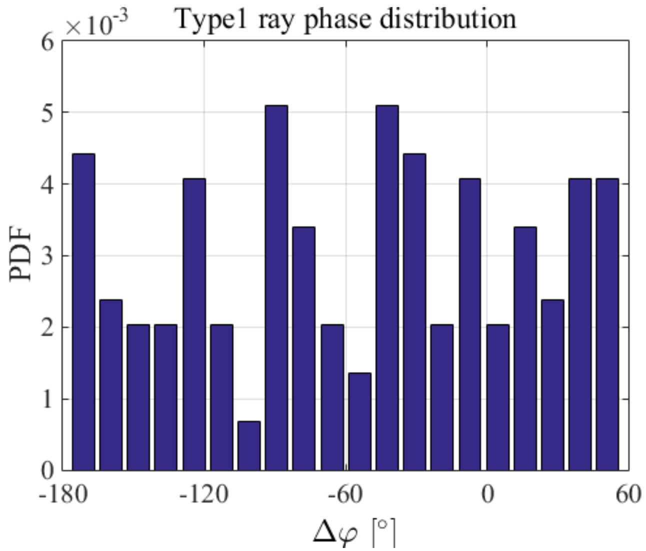
$$\varphi_{trans} = -2\pi f_0 \tau_{trans}$$

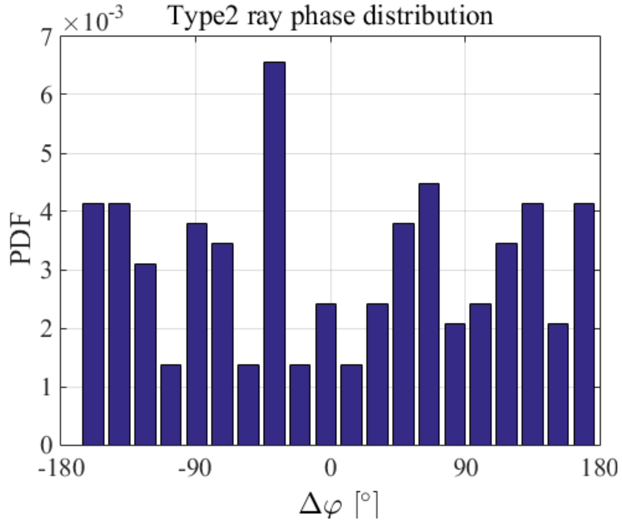
- **3 types of second order reflection:**

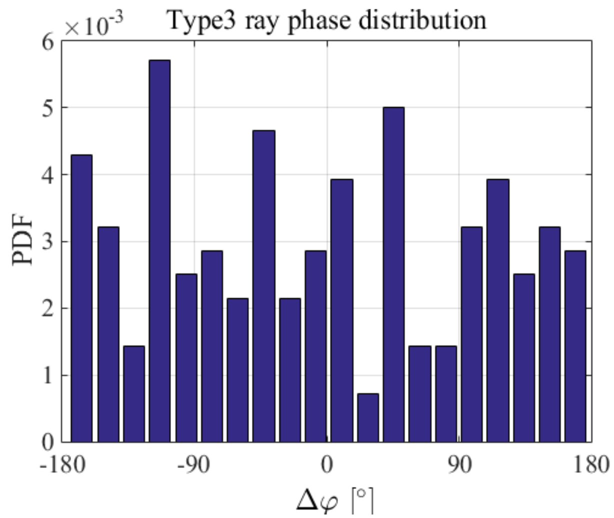
$$\varphi_{ref} = f(type)$$

3. Parameter Extraction-Phase

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



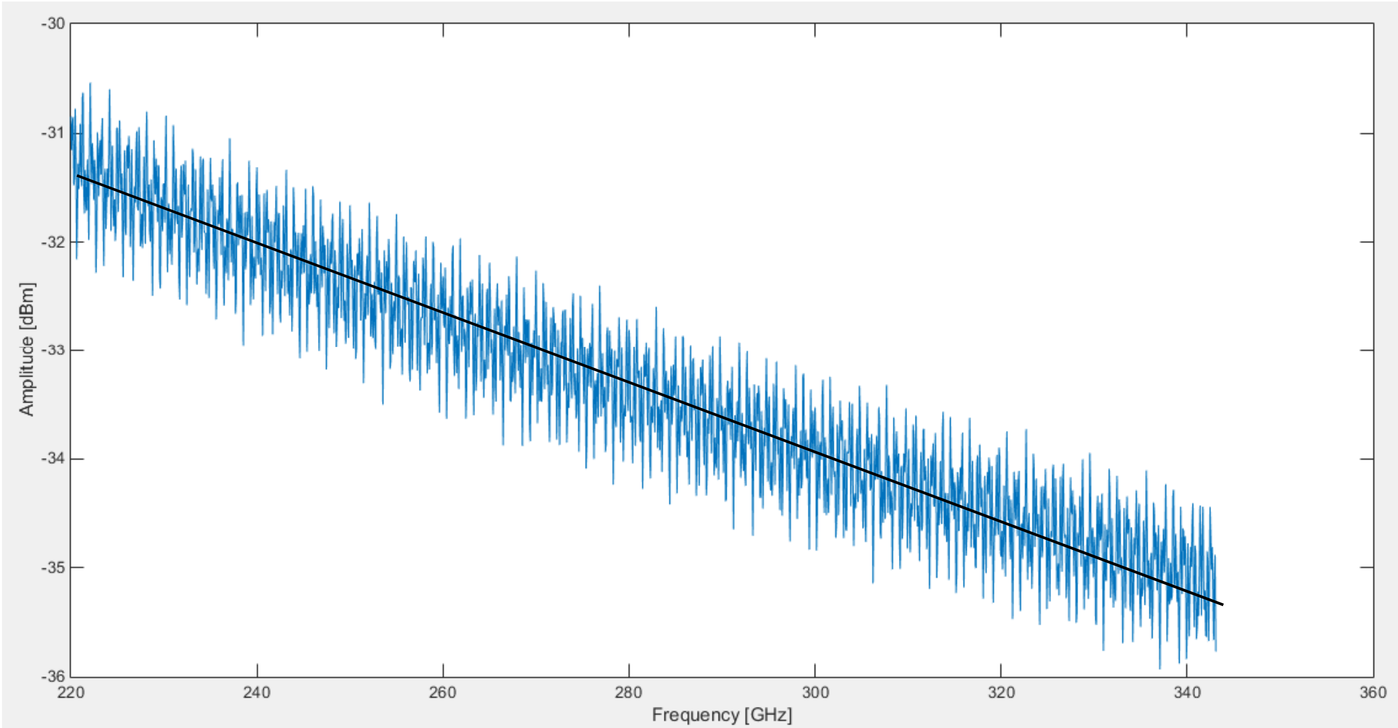




- Type1: uniformly distributed between -180 and 60
- Type2 and type3: uniformly distributed between -180 and 180

3. Parameter Extraction-frequency Dispersion

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



3. Parameter Extraction-AOD and AOA

θ_{AOD} uniformly distributed between $-\arcsin(\frac{0.5H}{d[m]})$ and $\arcsin(\frac{0.5H}{d[m]})$

ϕ_{AOD} uniformly distributed between $-\arcsin(\frac{0.5W}{d[m]})$ and $\arcsin(\frac{0.5W}{d[m]})$

The angle of arrival (AOA) of the transmitted path has strong geometrical relation with AOD, which can be obtained from the tilted angle of RX and the generated AOD.

Taking Scenario (i) as an example

$$\theta_{AOA} = -\theta_{AOD}$$

$$\phi_{AOA} = 180 + \phi_{AOD}$$

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)

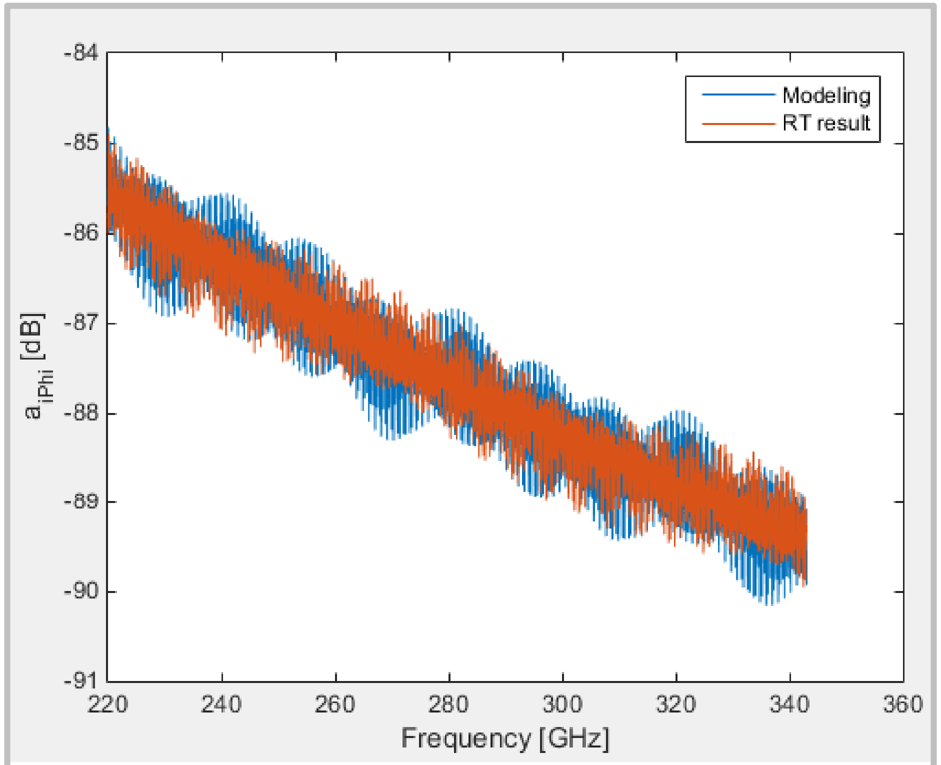
Output

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

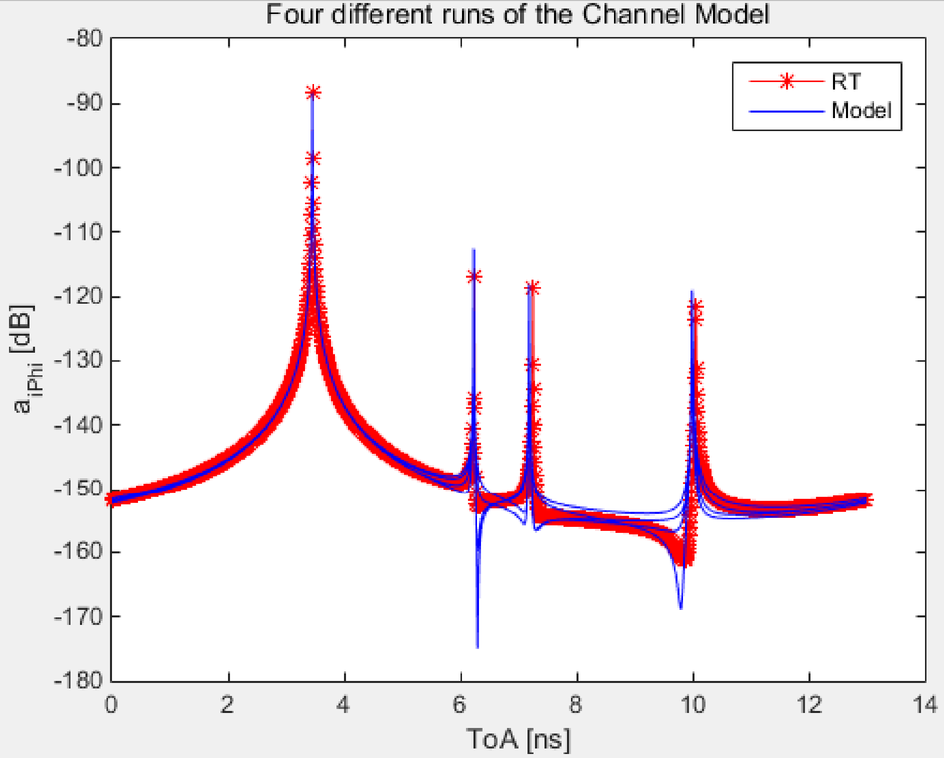
[H,Reflection_Order,ToA,D,a_i_Phi,a_i_Theta,a_i_Theta_Phi,a_i_Phi_Theta,AoA_Phi,AoD_Phi,AoA_Theta,AoD_Theta] = Channel_Realization(d,scenario,f)

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 $RX\,(1.0122, 0.12, 0.14)$



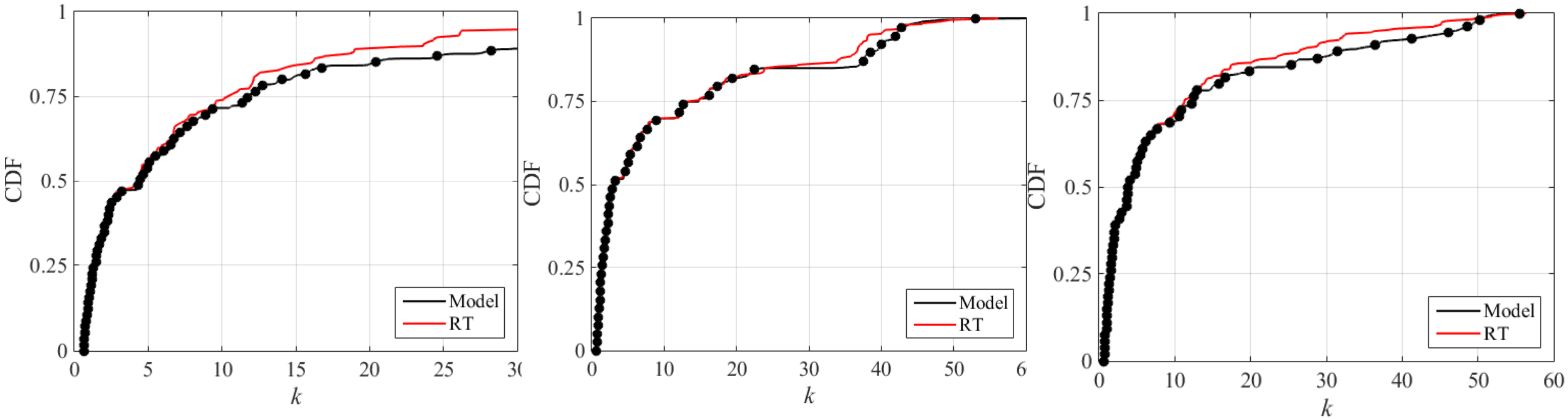
- Amplitude varies with Frequency
- The slopes match well



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

4. Channel Realization-Rician K factor

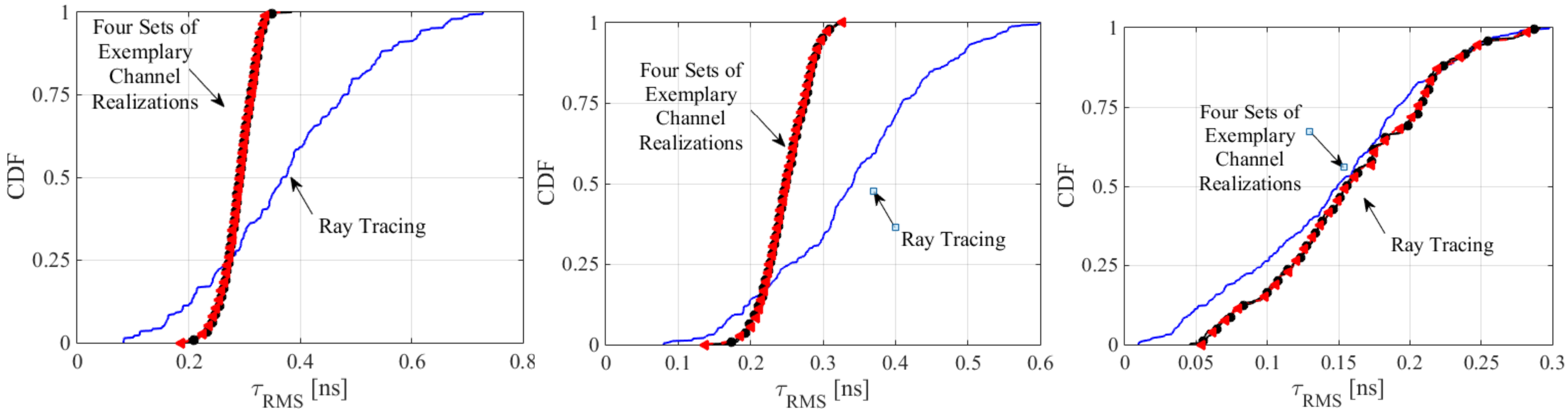
- 396~576 snapshots for 3 scenarios, 10 runs per snapshot
- Average K of the model is compared with the RT simulation



Scenario (i) Scenario (ii) Scenario (iii)

The distribution of K factor of model matches well with that of RT simulations

4. Channel Realization-Delay Spread RMS



Scenario (i) Scenario (ii) Scenario (iii)

The distribution of RMS delay spread of model matches well with that of RT simulations

4. Channel Realization-Generated CTF file

The combinations of TX and RX are:
TX 12 dBi, RX 12 dBi
TX 18 dBi, RX 12 dBi
TX 24 dBi, RX 12 dBi
TX 24 dBi, RX 24 dBi

- 4 combinations are realized for each of the 3 kiosk scenarios, 12 CTFs are generated.
- 10 mandatory CTFs and 100 optional CTFs are realized for each TX RX combination.

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): 11.25
TX HPBW phi(degree): 11.25
RX HPBW theta(degree): 11.25
RX HPBW phi(degree): 11.25
TX Antenna Gain: 24 dBi
RX Antenna Gain: 24 dBi

--- Mandatory CTFs ---
kiosk_S2_m1 -0.0003474348567004 - [illegible]i; -0.0011699323856876 - 0.0011790680613950i; -0.0018869185506856 - 0.0001708749206152i; -0.001503679406767
kiosk_S2_m2 0.0010418187088554 - 0.0012279220398233i; -0.0001977252037881 - 0.0015668772388205i; -0.0013007036132091 - 0.0009471764230780i; -0.001600743951304
kiosk_S2_m3 0.0014042085401766 - 0.0000589995014679i; 0.0008244344304056 - 0.0010715338535887i; -0.0003707331445121 - 0.0014266974716709i; -0.001465877693850
--- Optional CTFs ---
kiosk_S2_o1 -0.001061909169609[illegible]242i; -0.0016877422448802 - 0.0003834422708642i; -0.0015584292026660 + 0.0008066989351557i; -0.000630182277485
kiosk_S2_o2 -0.00144844643984[illegible]450i; -0.0017887798517350 + 0.0000352953533204i; -0.0013622738884471 + 0.0011108625398814i; -0.000363675466611
kiosk_S2_o3 -0.0012242637356245 - 0.0006752160382550i; -0.0014004047704853 + 0.0002172330948514i; -0.0009571296731585 + 0.0012000656127475i; 0.000235131120340
kiosk_S2_o4 0.0017174275876153 0.0007020341566186i; 0.0016162837287008 + 0.0007783404652073i; 0.0005961623529412 + 0.0015531291796497i; 0.000533684231556
kiosk_S2_o5 -0.0014729367306780 - 0.0002104607045955i; -0.0010962560845953 + 0.0007837522247693i; -0.0003723310549391 + 0.0013382503223774i; 0.000802576383964
kiosk_S2_o6 -0.0015623874143822 + 0.0000452305261382i; -0.0009358221798351 + 0.0010875708657868i; 0.0000343566146160 + 0.0014110969319391i; 0.00112897915004
kiosk_S2_o7 -0.0015635952432446 + 0.0003761363180524i; -0.0007089977283233 + 0.0012862384357786i; 0.0003554843781282 + 0.0014279863611867i; 0.00141643038156
kiosk_S2_o8 -0.0014035639757627 + 0.0005762066206208i; -0.0004356297603138 + 0.0013352110636115i; 0.0006324751117651 + 0.0012672201649519i; 0.00153159546747
[illegible]
```

Less than 0.8 m

Less than 1 m

Thank you for your attention

Any comments?