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Abstract: [This contribution describes 60GHz propagation measurement of several condition.]

Purpose: [Contribution to VHT/mmW TG3c joint meeting.]

60GHz Applications and Propagation Characteristics

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Summary

- TG3c has adopted CM2.3 channel model for NLOS residential environments – this was created by eliminating LOS component from LOS channel model, and, later the real measurements validated this as a good channel model for severe communications environments
- This CM2.3 is good for beacon signal transmission from PNC (Picone coordinator) with Omni antenna at both PNC and Device up to 10 m coverage (typical coverage of WPAN)
- NLOS environments could be defined in many other ways according to different applications such as beaconing, desktop environments, intra room communications, long transmission with very high antenna gain –which generates very few delay spread

Agenda

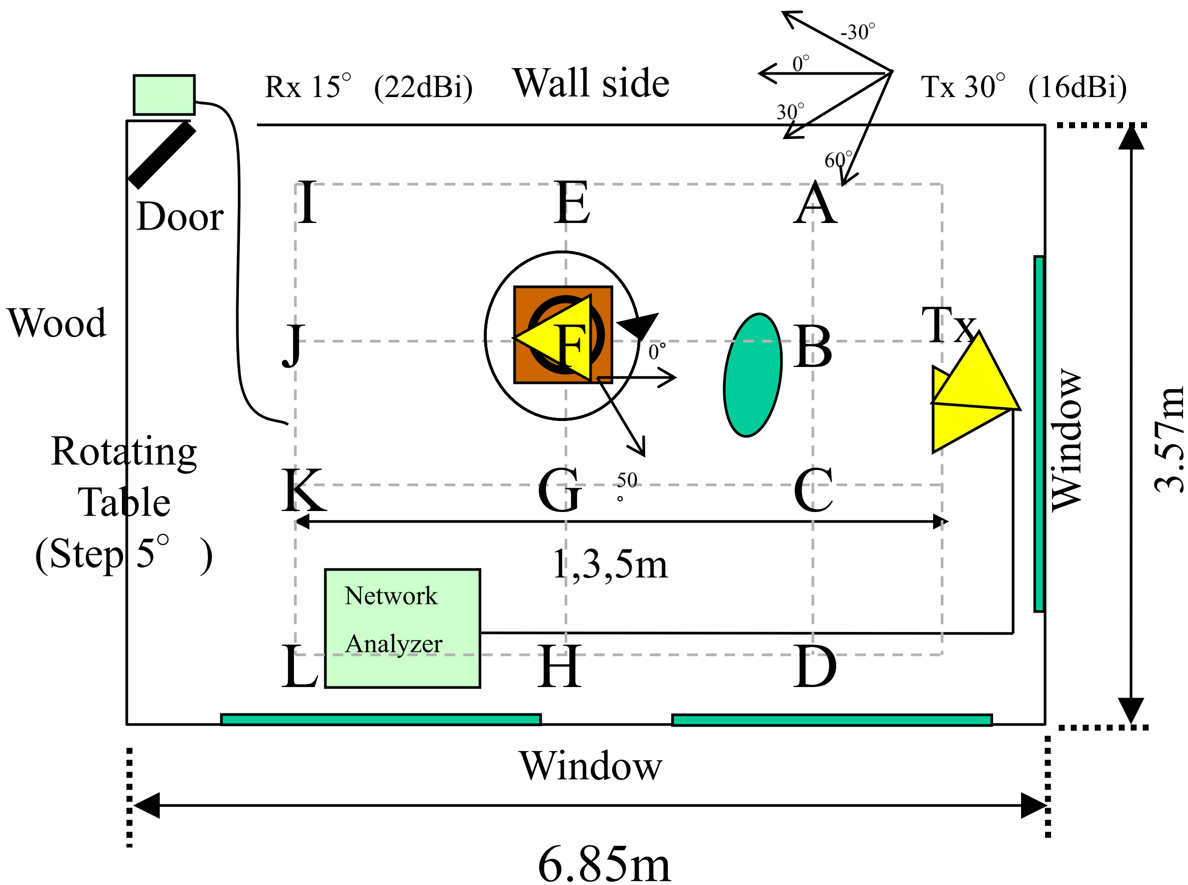
- **Introduction**

1. **CM2.3: A valid NLOS channel model**
   i. **Metal shadowing: Cabinet shadowing**
   ii. **PC shadowing**
2. **Various NLOS environments and measurements**
   i. **Common mode : up 10 m with Omni antenna - beaconing**
   ii. **Long transmission: Door penetration**
   iii. **PC Peripheral: Desktop penetration**
3. **High antenna gain applications**
   i. **Delay spread**
   ii. **Beam forming antenna**

Conclusion

. CM2.3: A valid NLOS channel model

NLOS residential measurement



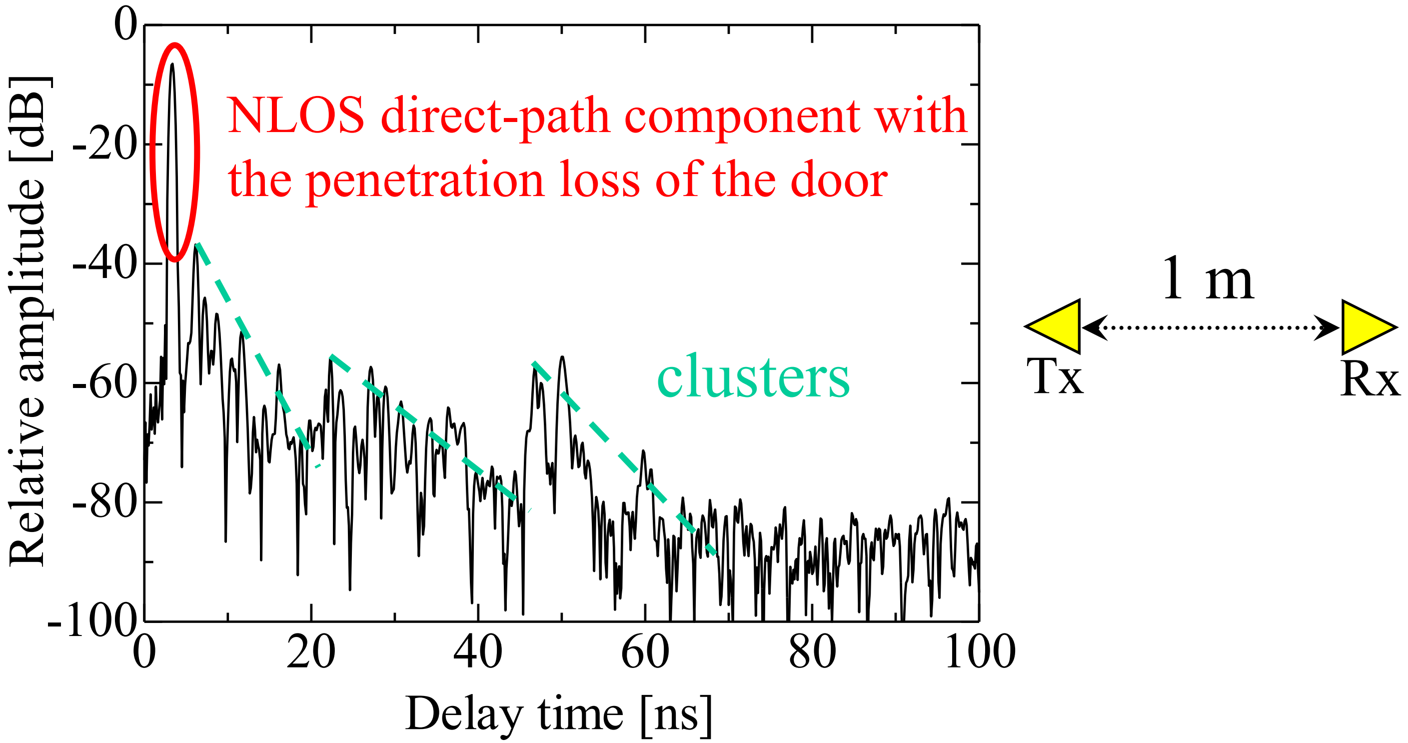
Floor plan of residential environment

Shadowing object

Metal Cabinet

– 70cm X 60cm X 40cm

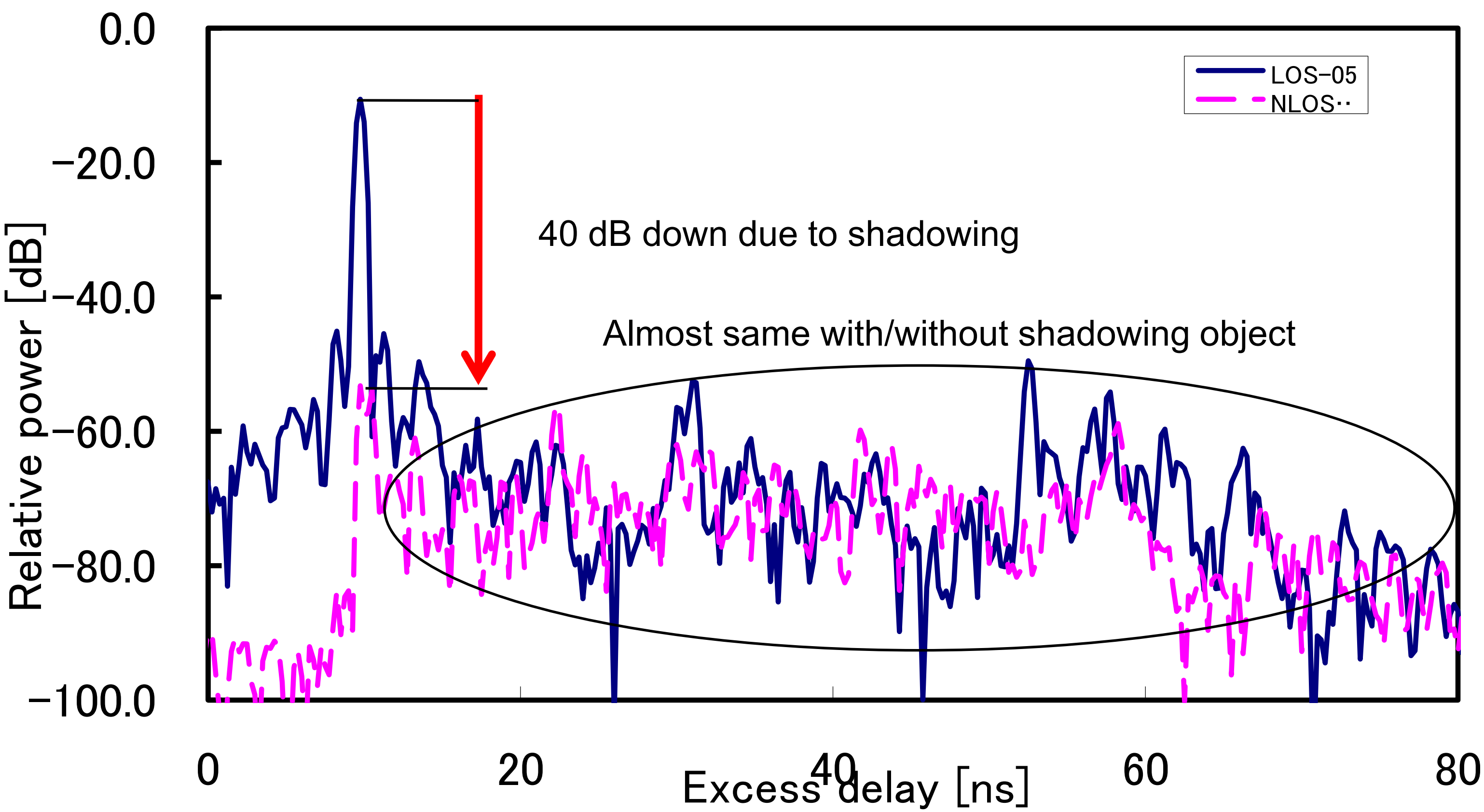
Example PDPs (Power delay profile) in NLOS residential environment (Beam width: Tx=30, Rx=30)



- Direct-path component remains in NLOS measurement
- TSV model can model NLOS residential channels

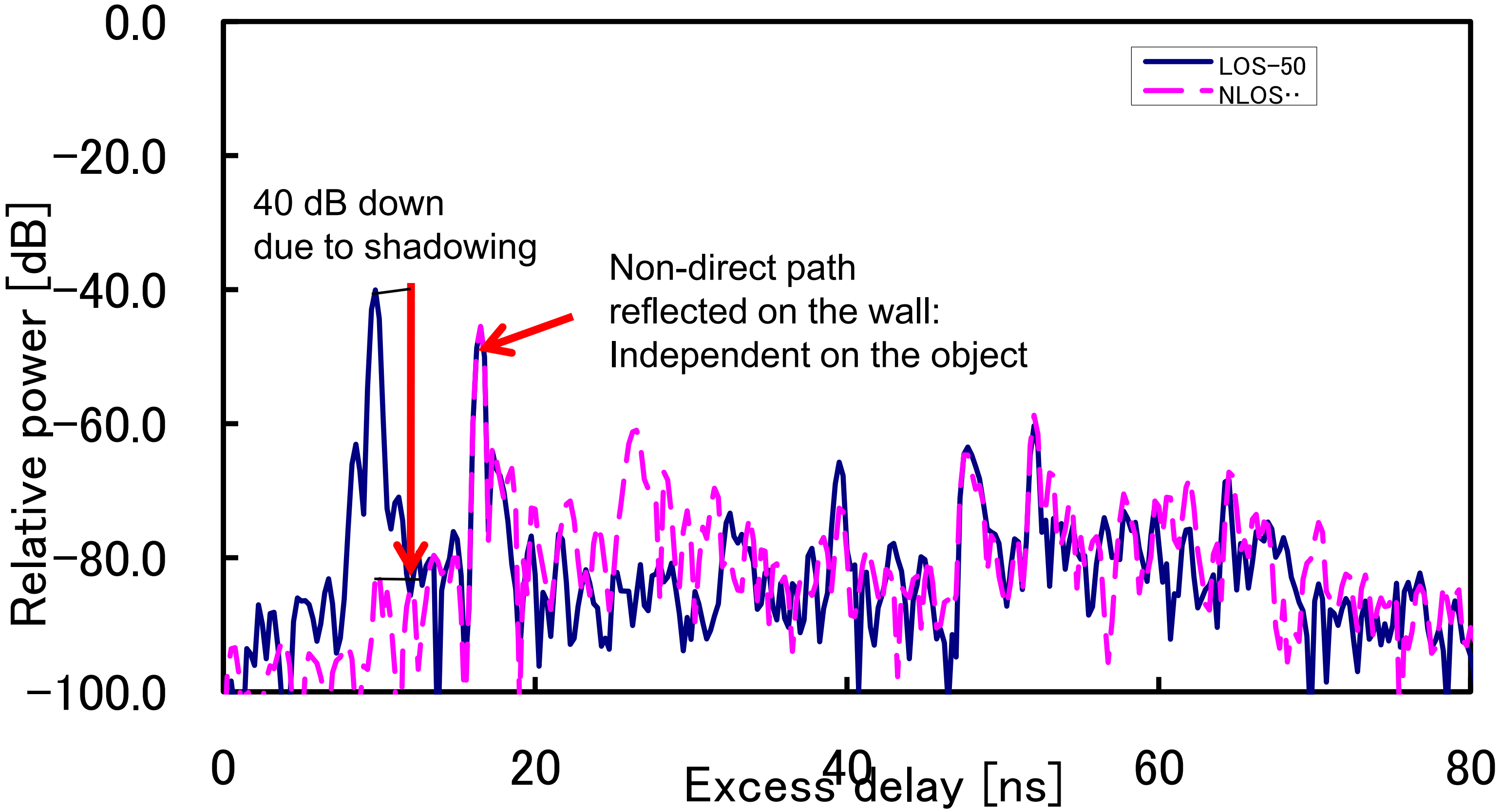
Metal Blocked: Example of Delay profile

Both antenna faced to each other



Metal Blocked: Example of Delay profile

Both antenna faced to wall

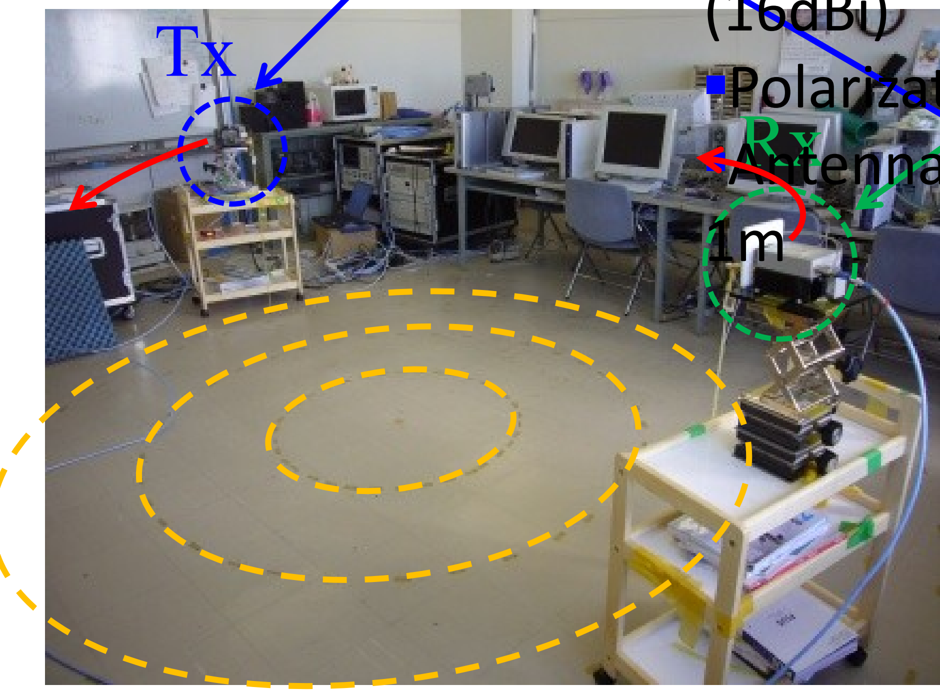


PC Blocking:Measurement environment

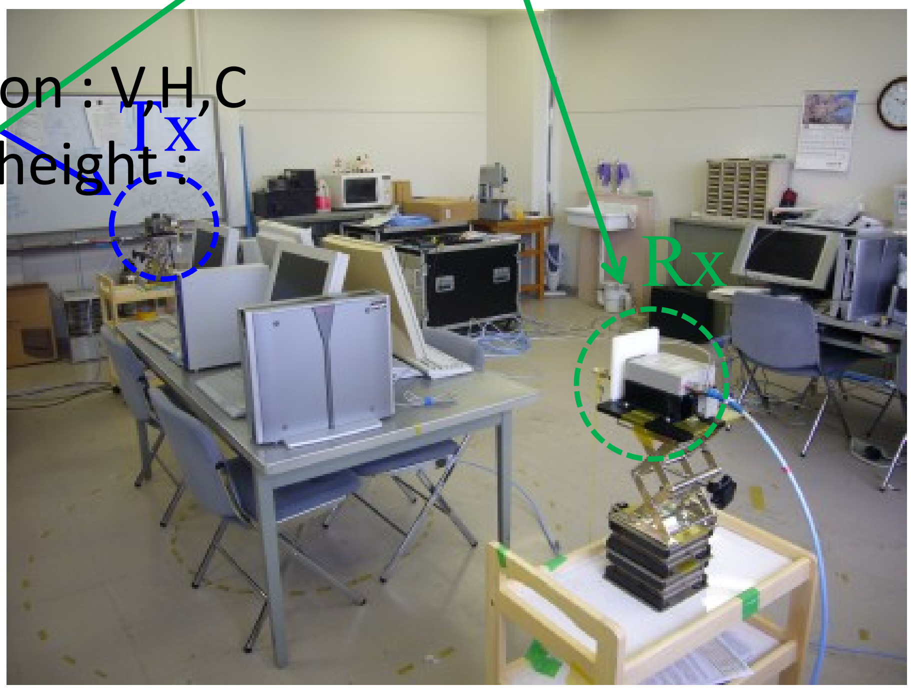
TX antenna

Antenna
- Conical horn antenna
- Beam width : 30°(16dBi)
- Polarization : V,H,C
- Antenna height : 1m

RX antenna



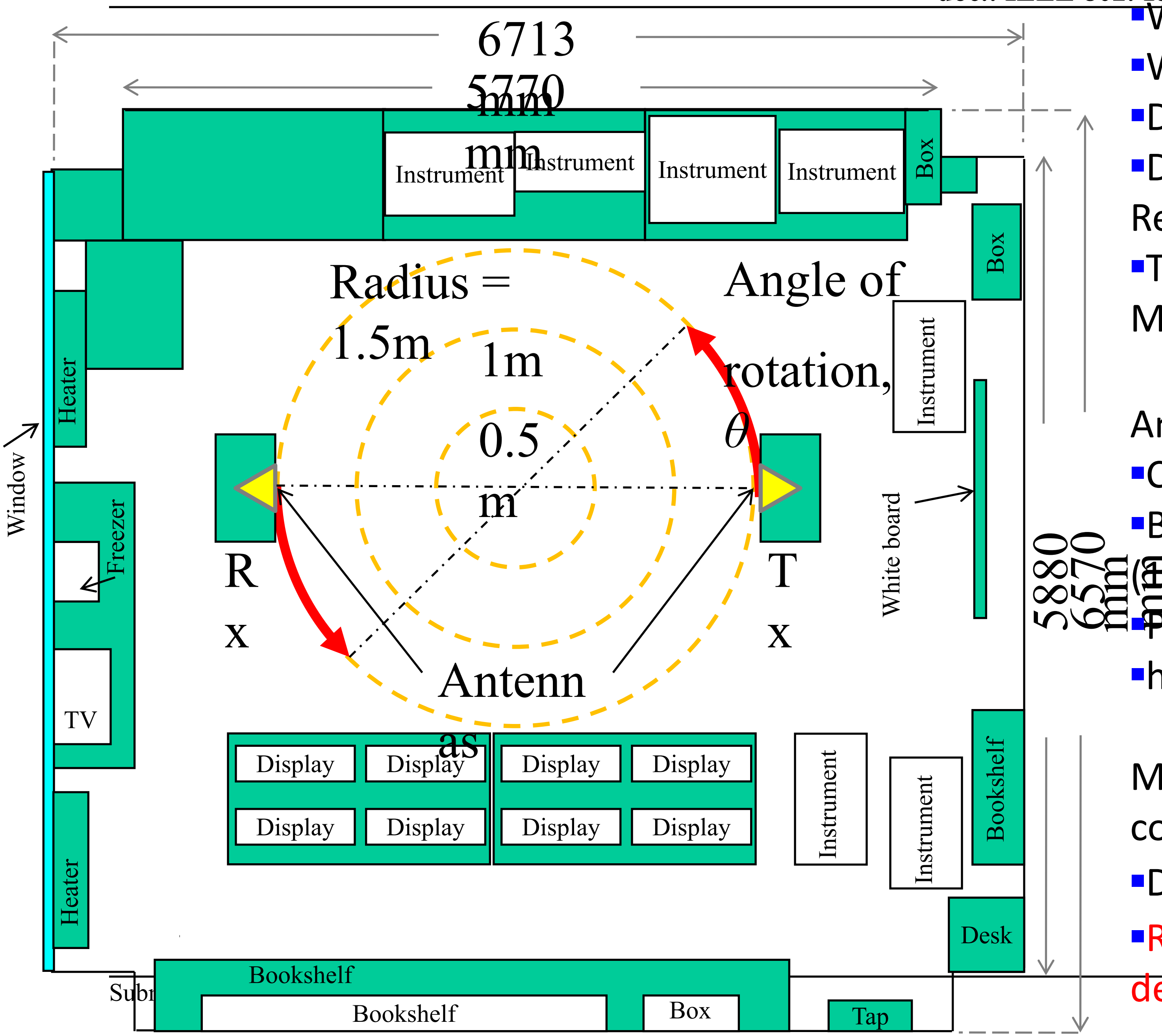
LoS environment



NLoS environment

Shadowing object : PC's

LoS environment

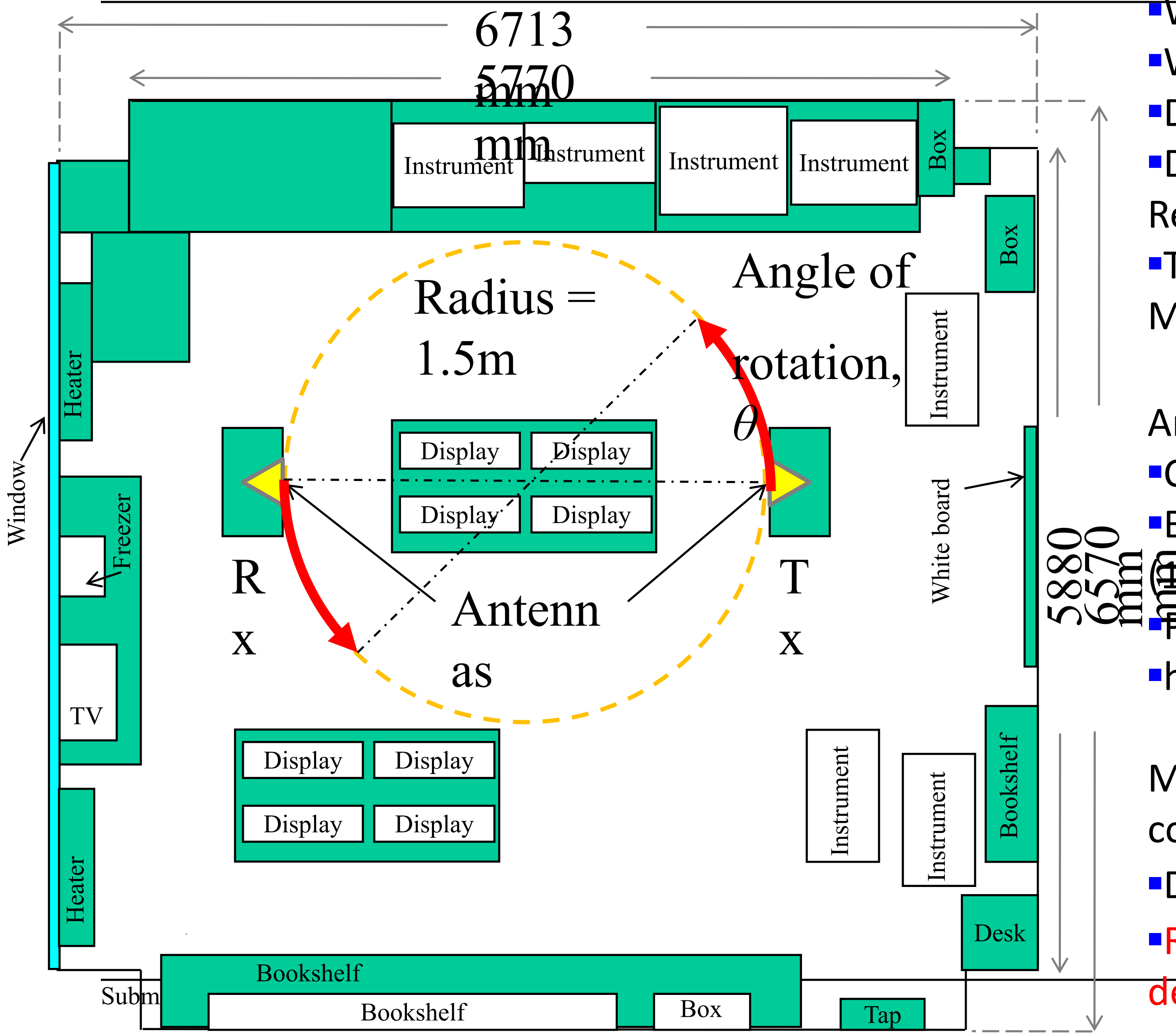


Materials
- Wall, floor : Concrete
- Window : Glass
- Door : wood
- Desk, White board, Refrigerator : Metal
- TV, PC : Plastic + Metal

Antenna
- Conical horn
- Beam width : 30^{o} (16dBi)
- Polarization : V,H,C
- height:1m

Measurement condition
- Distance : 1,2,3m
- Rotation every 10 degree

PC Blocking: NLoS environment



Materials

- Wall, floor : Concrete
- Window : Glass
- Door : wood
- Desk, White board, Refrigerator : Metal
- TV, PC : Plastic + Metal

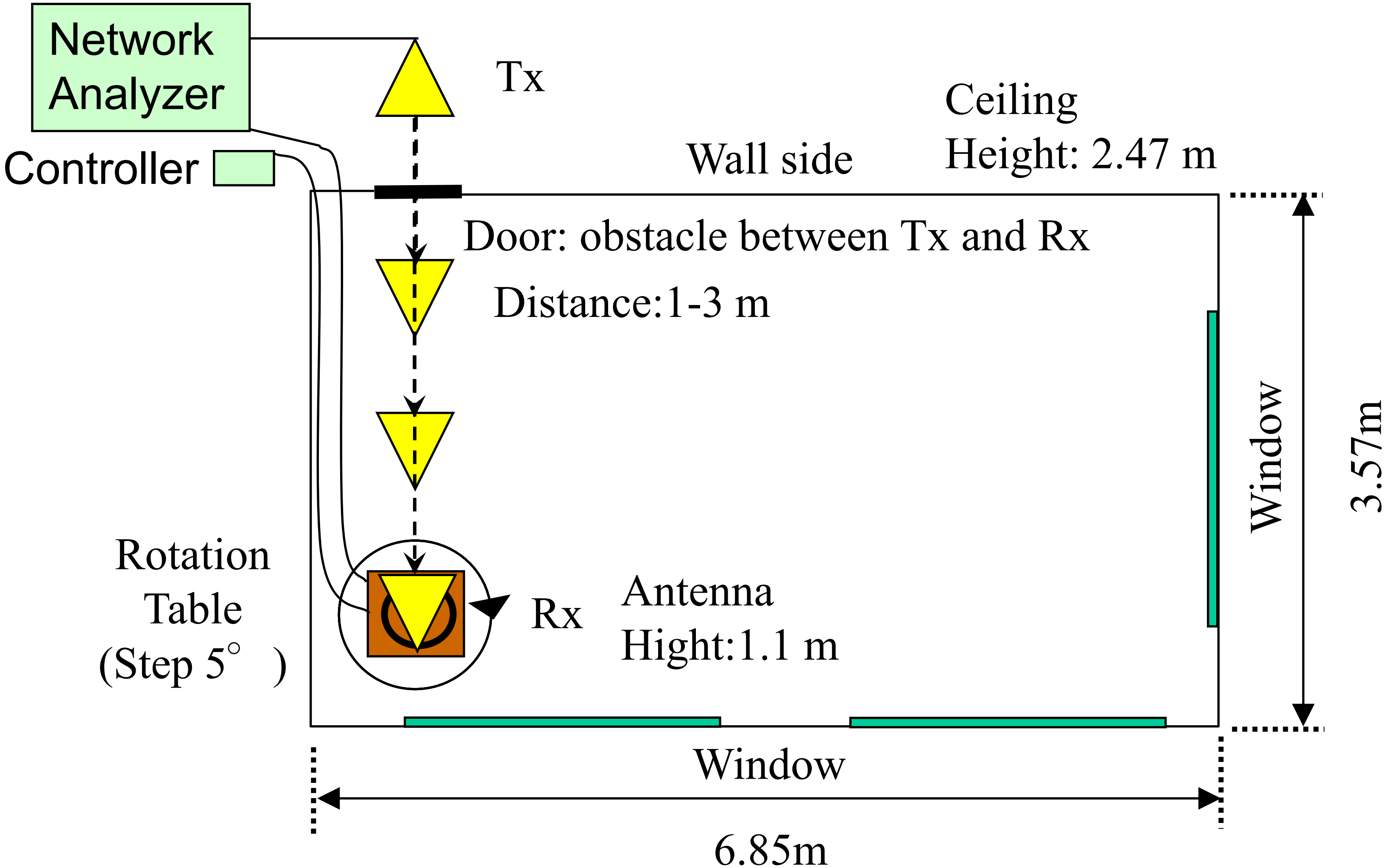
Antenna

- Conical horn
- Beam width : 30° (16dBi)
- Polarization : V,H,C
- height:1m

Measurement condition

- Distance : 3m
- Rotation every 10 degree

NLOS: Door - Measurement environment



Floor plan of NLOS residential environment

Measurement conditions

Instrument	HP8510C VNA
Center frequency	62.5 GHz
Bandwidth	3 GHz
Time resolution	0.333 ns
Distance resolution	19.1 cm
# of frequency points	801
Frequency step	3.75MHz
Times of average	128 times

- Calibration performed with 1m reference separation
- Time resolution and distance resolution were determined by bandwidth

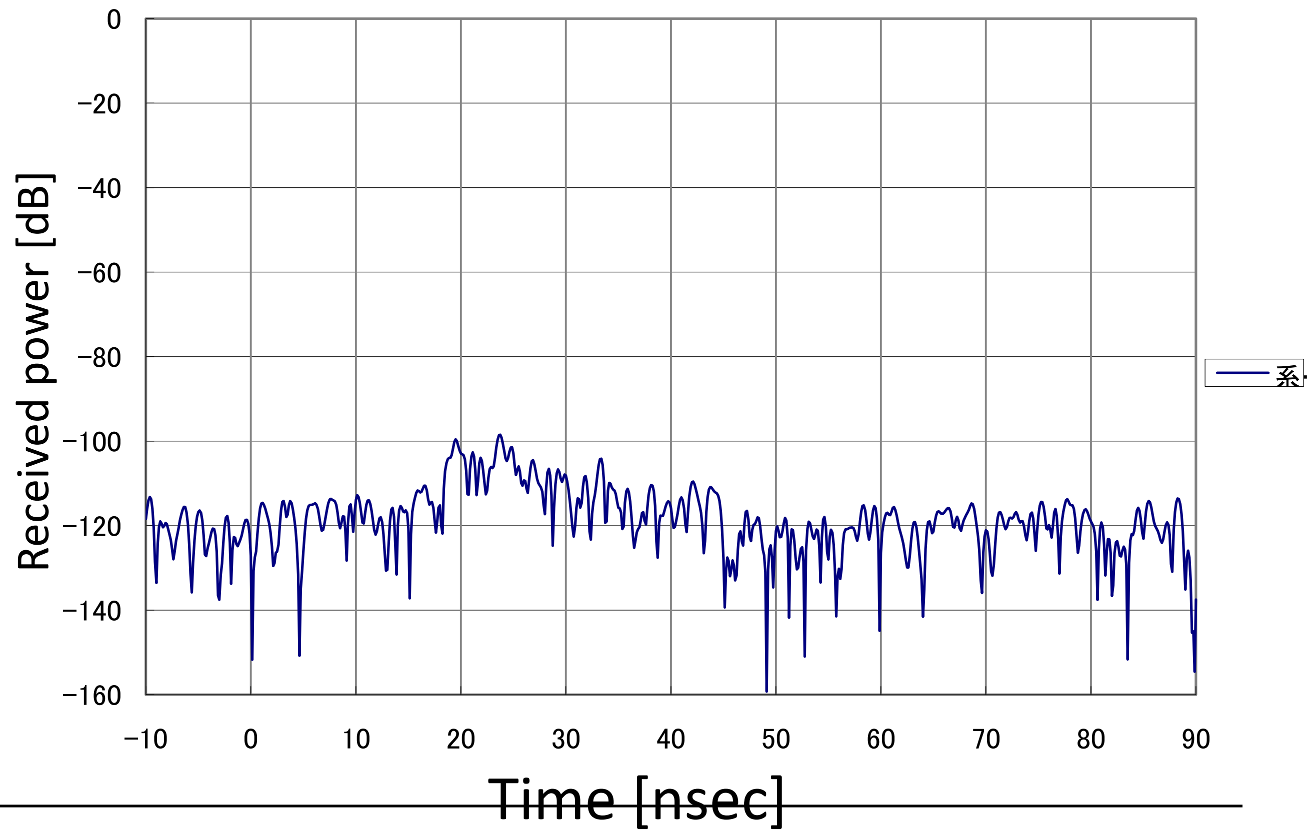
Measurement conditions (cont')

- **Antenna:** Conical horn antenna
- **Polarization:** Vertical
- **Beam-width:** Tx:30 and Rx 30

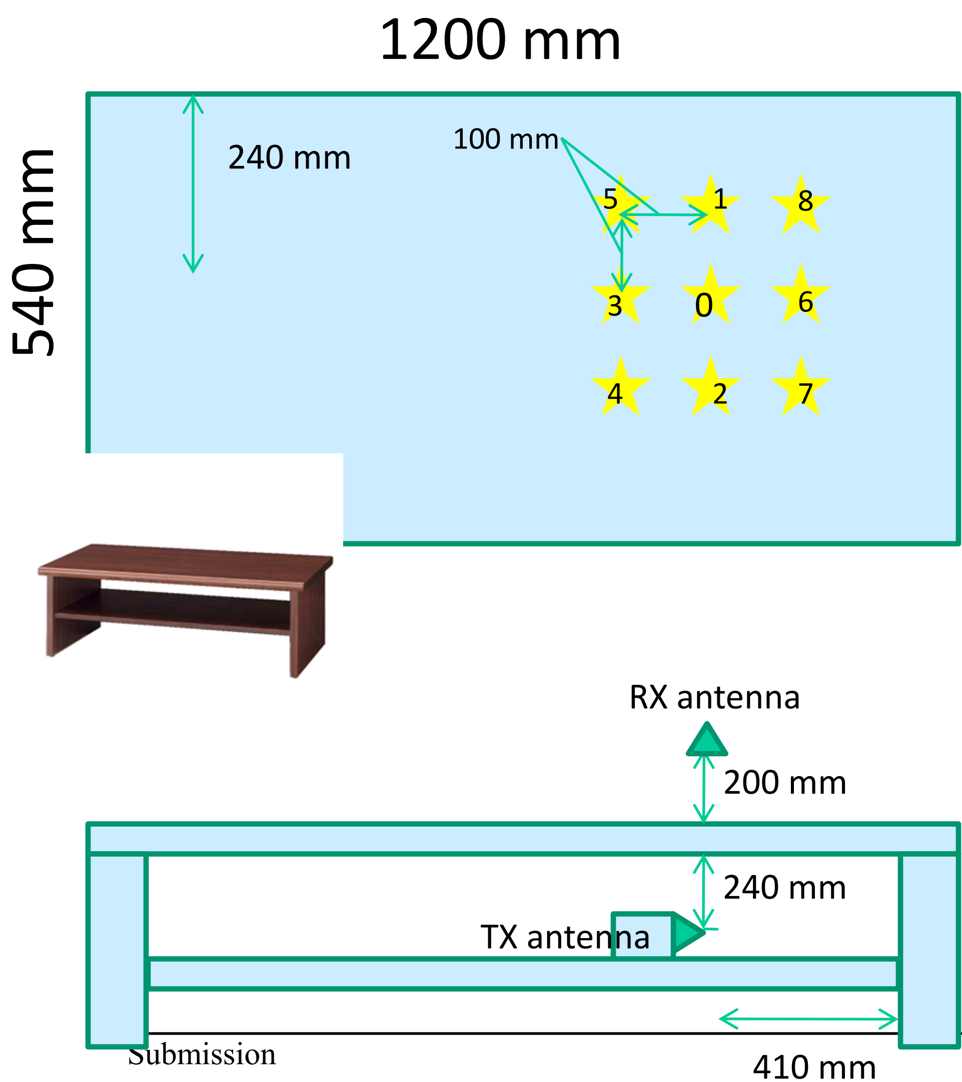
Conical horn antenna
Beam-width 30 deg

NLOS:Penetration measurement ~ Office desktop~

Penetration loss was measured to be more than 50 dB.
TX antenna : Omni(4dBi)), RX antenna : 15 degree(22dBi)

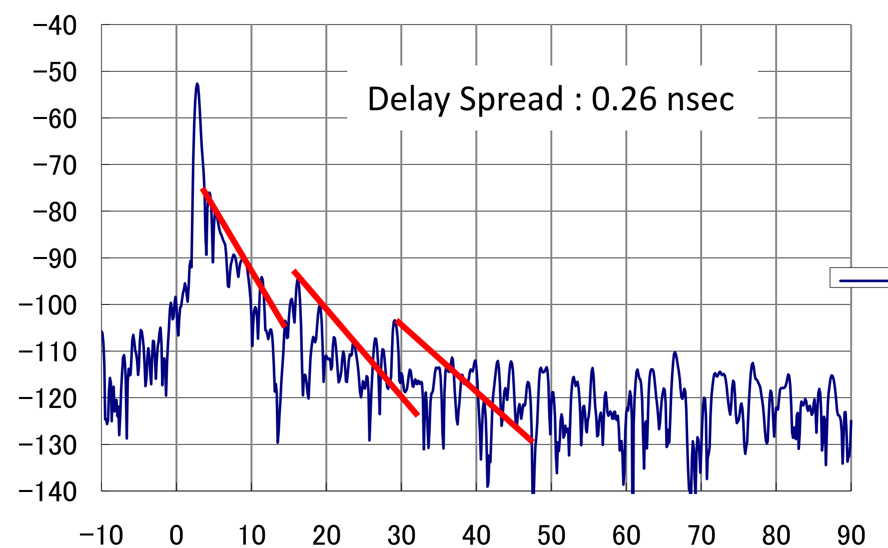


Penetration measurement
~ Low wooden desk ~



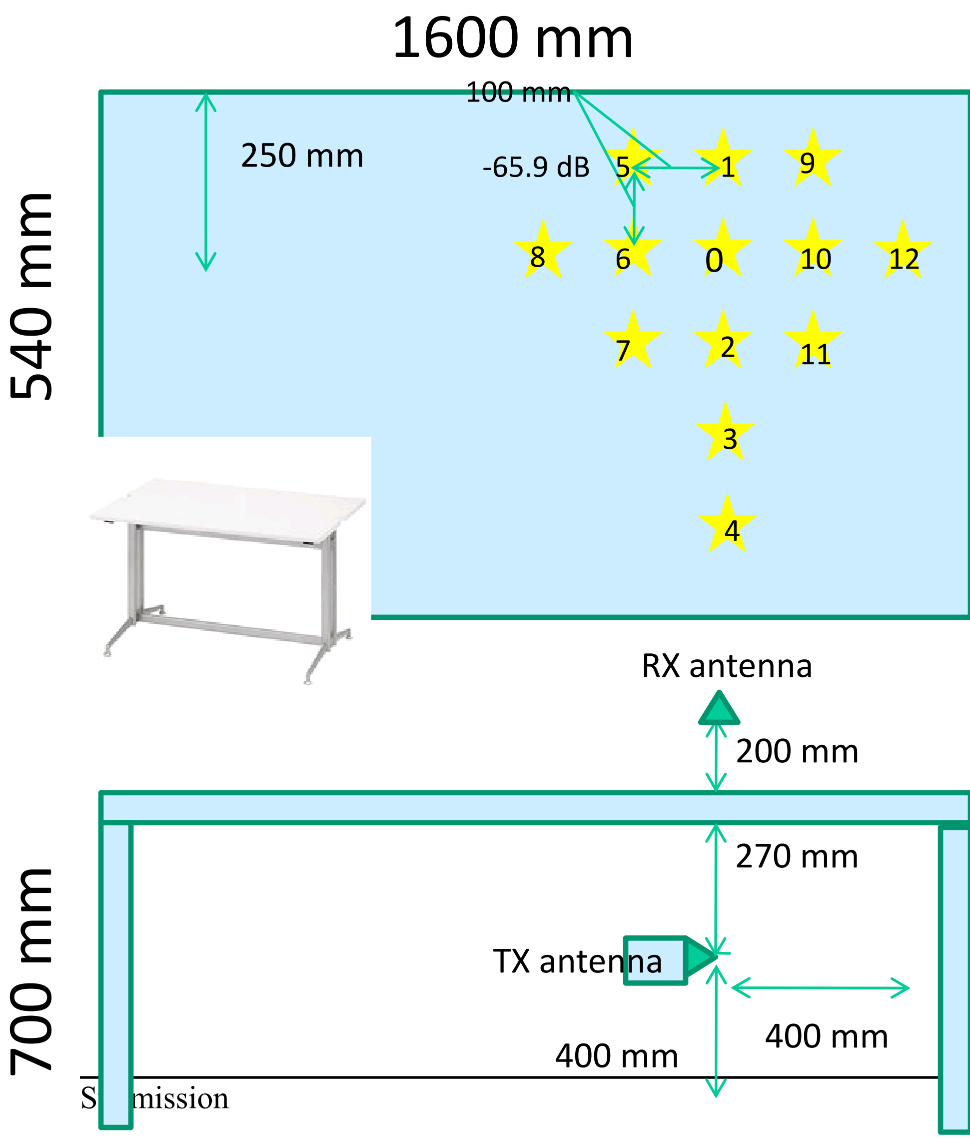
Without desktop (Direct) : -42.2 dB

Position	Received Power[dB]	Loss [dB]
0	-52.7	-10.5
1	-59.7	-17.5
2	-58.7	-16.5
3	-61.1	-18.9
4	-66.2	-24.0
5	-65.9	-23.7
6	-60.5	-18.3
7	-64.9	-22.7
8	-77.0	-34.8



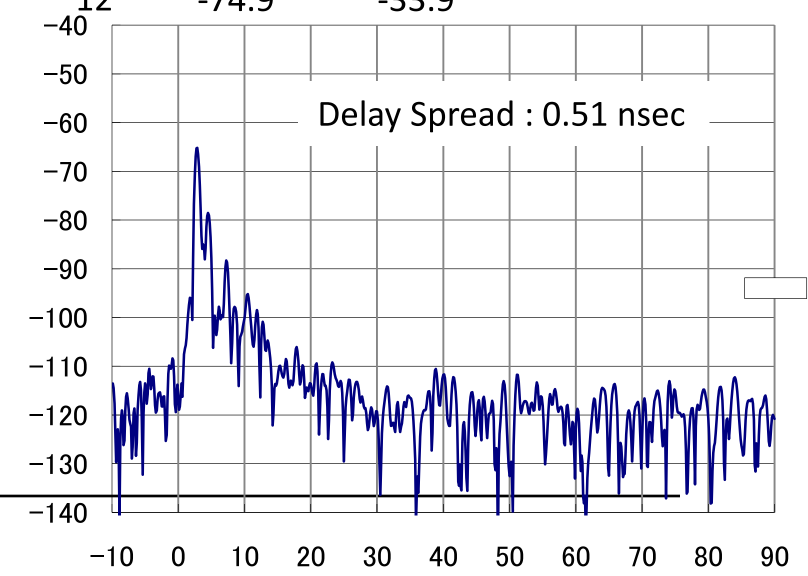
Penetration loss: 10dB

NLOS: Penetration measurement ~ meeting desk ~



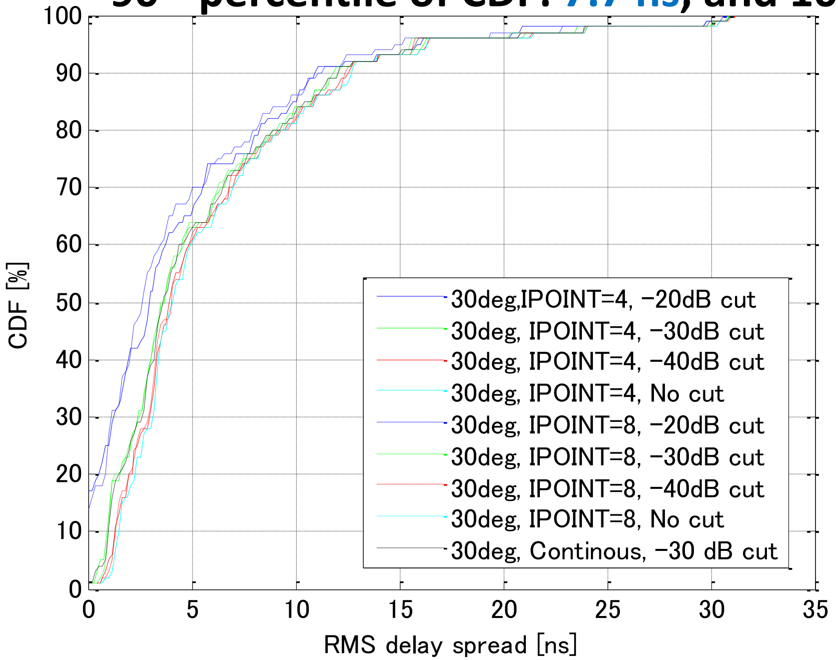
Without desktop (Direct) : -41.0 dB

Position	Received Power [dB]	loss[dB]
0	-65.19	-24.19
1	-66.9	-25.9
2	-71.4	-30.4
3	-76.0	-35
4	-81.8	-40.8
5	-67.4	-26.4
6	-68.7	-27.7
7	-63.5	-22.5
8	-76.4	-25.4
9	-75.9	-34.9
10	-65.3	-24.3
11	-80.3	-39.3
12	-74.9	-33.9

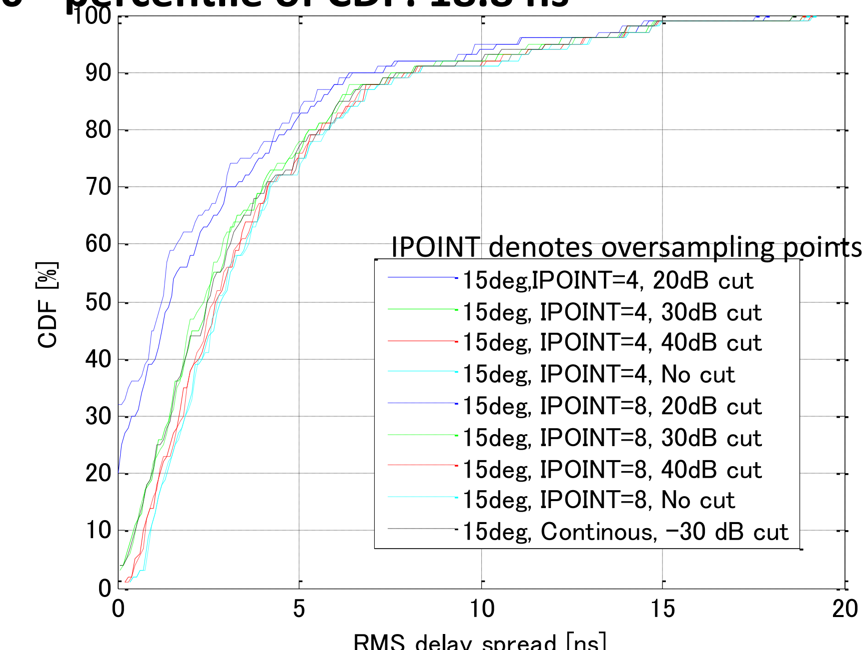


RMS delay spread analysis of CM2.3

- 30 dB cut-off and no cut-off thresholds(*) give no difference in RMS delay spread
- Continuous channel and discrete channels generated from the continuous give no difference in RMS delay spread
- CM2.3 (W_{Rx}= 30deg with -30 dB cut-off threshold) (same result as previous)
  - 90th percentile of CDF: 12.5 ns, and 100th percentile of CDF: 30.8 ns
- W_{Rx} of 15 deg with -30 dB cut-off threshold
  - 90th percentile of CDF: 7.7 ns, and 100th percentile of CDF: 18.8 ns



D_{rms} CDF with 30 deg (Original CM2.3)



D_{rms} CDF with 15 deg

High Antenna Gain applications

To transmit LONG distance such as 30 m, a 30 dBi antenna gain will be required.

In such case, the measured delay spread is very small (a couple of ns with 5 degree HPBW antenna)

Direct as well as reflective wave is good enough for communciations

TG3c specification includes beam forming to track the best and 2^{nd} best beam for more reliable communciations

Conclusion

- NLOS environments may be defined in various ways according to different applications.
- CM2.3 channel model has been validate as a good channel model for beacon signal transmission to cover up to 10 m in NLOS environments with Omni antenna
- Beam forming antenna will resolve delay spread issue a lot