HKT Here To Serve

HKT
5G mmWave (28GHz)
Field Trial

a PCCW Group member

Revision History

Version	Revision Date	Summary of Changes
1.0	20 Sept 2018	First version
2.0	27 Nov 2018	Test Equipment Specification And Radio Parameter Setting added in section 1.3
3.0	28 Nov 2018	Include AAU28A specification (section 1.3.1) Correct the typo in the table of “radio parameter setting for the trial test

1. Introduction

In response to the Hong Kong Government proposal of establishing 5G network in 26GHz to 28GHz frequency band, PCCW has conducted a field trial aimed to explore the radio characteristics of 5G mmWave.

The field trial was conducted in Lai Chi Kok area in the period of 21-May to 22-Jun 2018. And the scope of the test was concentrated on the propagation characteristics, radio signal strength coverage and indoor signal penetration capability of mmWave in some typical environment in Hong Kong.

1.1 Radio propagation characteristics

As the 5G mmWave operate at a frequency range of above 24GHz, the radio propagation may exhibit different characteristics from existing sub 3GHz radio technologies. They include the Line Of Sight (LOS) Propagation Loss, Reflection Loss, Diffraction Loss and Penetration Loss. As a result, data throughput of 5G NR will be varied in different Indoor, Outdoor, Line-Of-Sight and Non-Line-Of-Sight coverage situation.

1.2 Trial Site Location and setup

In the test, PCCW has setup a trial 5G mmWave NR base station transmitting radio signal at 28GHz range in the podium level of Lai Chi Kok Exhange Building, Yuet Lun Street, approximately 18m above ground level.

There are both outward facing and inward facing antenna mount on the building podium. The outward facing antenna was meant to provide outdoor coverage in the building neighbourhood. Cases on LOS, NLOS with different reflection and diffraction will be demonstrated by careful selection of measurement location.

Whereas, the inward facing antenna was meant to provide in building coverage by radio signal transmitted from outdoor antenna penetrating into the building.

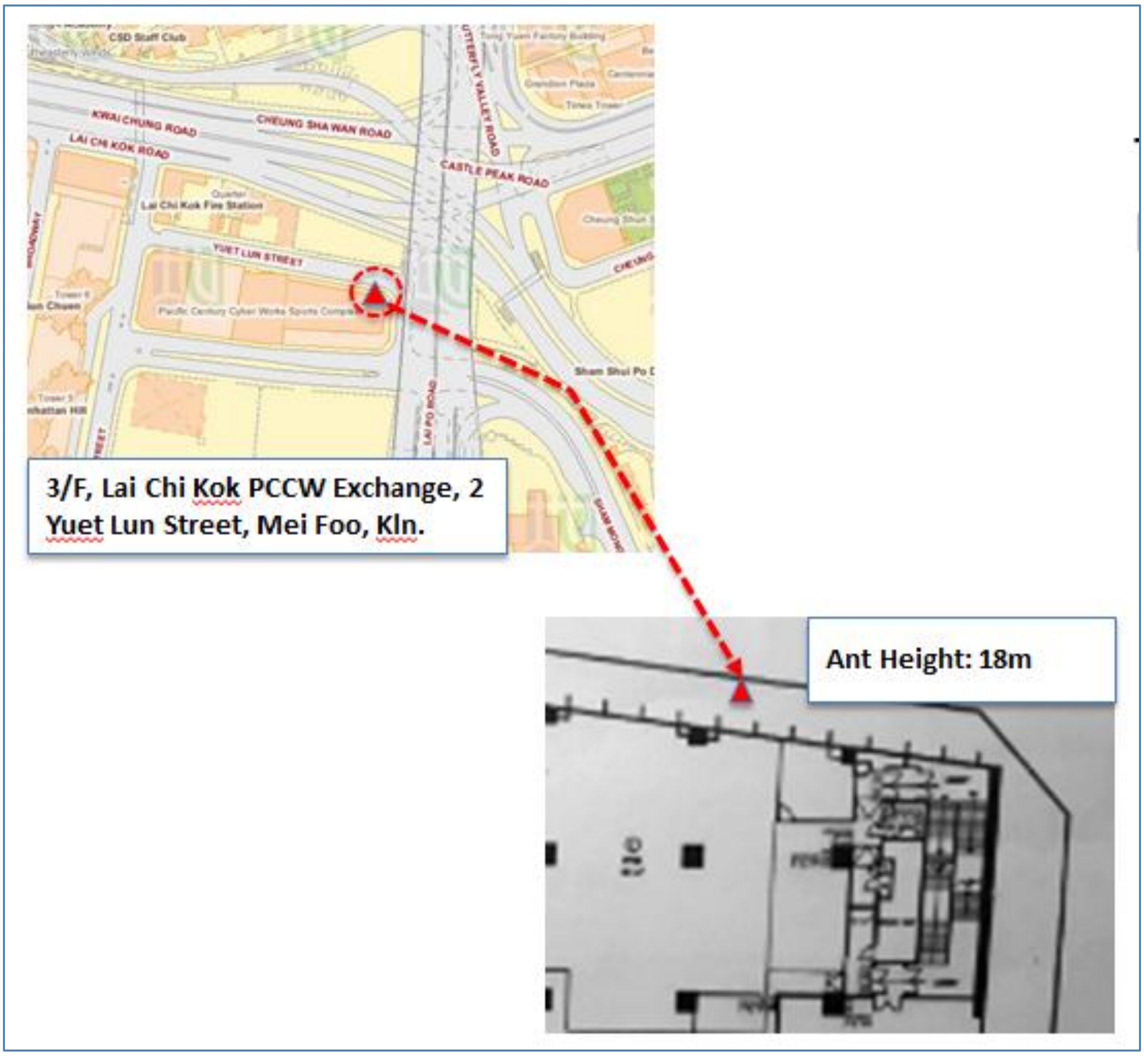


Figure : 5G mmWave NR field trial location

Figure : Antenna mounting viewed from the street

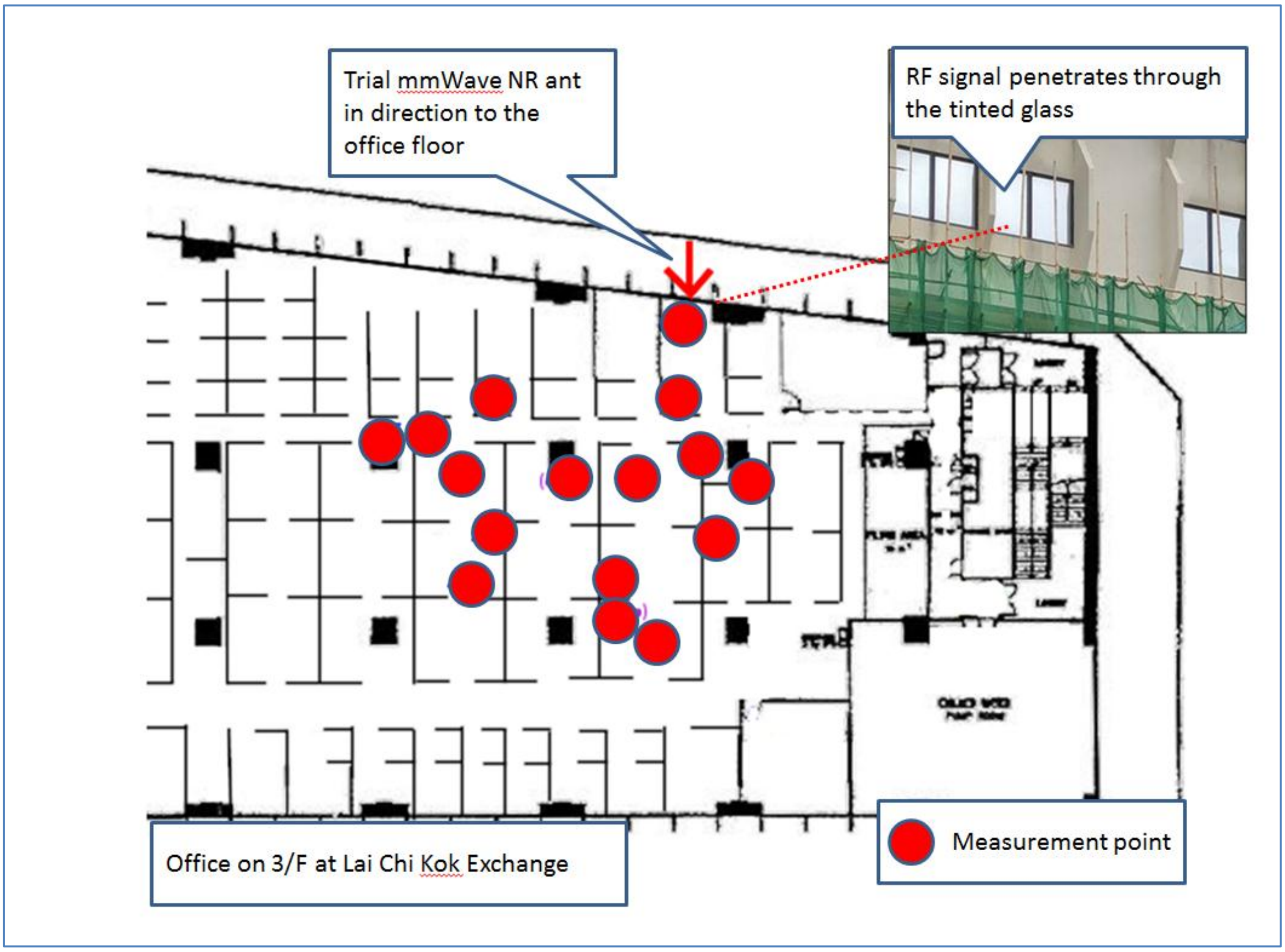
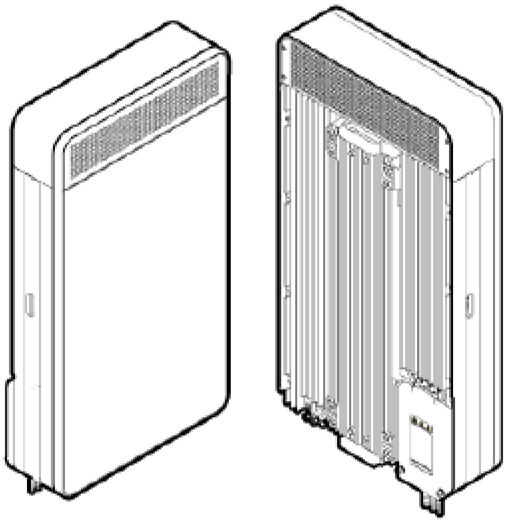


Figure : Measure location of inside the building coverage

1.3 Test Equipment Specification And Radio Parameter Setting

1.3.1 5G NR Side : AAU28A (transmitting equipment for the propagation measurement)



Sub Item	AAU-28G DHBF
Frequency band	26.65GHz~29.19GHz
Max Power(dBm)	36
EIRP(dBm)	62
Antenna Gain(dBi)	26
Tx/Rx configuration	4T4R
BandWidth(MHz)	8*100Mhz
最大功耗(W)	1100W
典型功耗（W）	800W
重量（kg）	41.0kg
尺寸大小（宽*深*高）mm	720(H)*390(W)*116(D)=33L
工作温度	-40℃~+45℃（不带太阳辐射）
散热方式	风扇空冷
输入电源	-48V DC
电压范围	-40V DC ~ -57V DC

1.3.2 Rx Side: TUE (receiving equipment for the propagation measurement)

TUE Specification

Items	Specifications
Operating frequency range	26.65GHz - 29.19GHz，BW 100-800MHz。
Max power consumption	single port17dBm(QPSK),14dBm(64QAM)
T/R	2T4R
Gain	9dBi
EIRP	26dB
Temperature range	-33℃-45℃

Items	Specifications
Frequency Band (GHz)	26.65–29.19
Dimensions (H x W x D)	283 mm x 267 mm x 63 mm

1.3.3 Radio Parameter Setting for the trial test :

Test period: 21-May to 22-Jun 2018.

RF Parameters		
Frequency Range	27.5GHz ~ 28.3GHz	
NR Side	**AAU Max Power**	36dBm
	Bandwidth	8*100MHz
	EIRP	62dBm
	Reference Power	-2.2dBm
TUE Side	**TUE Ant Gain**	9dBi

2. Measurement Results

2.1. Line of sight propagation loss

In this section, RSRP received signal level was measured at selected Line Of Sight measurement point of various distance from the base station antenna. The measured result will be compared again the prediction result from free space propagation loss model. And hence, the Line Of Sight propagation loss will be evaluated.

Three Line Of Sight measurement locations at 30m, 65m and 115m from the Base Station Antenna respectively were selected for 28GHz mmWave RSRP measurement.

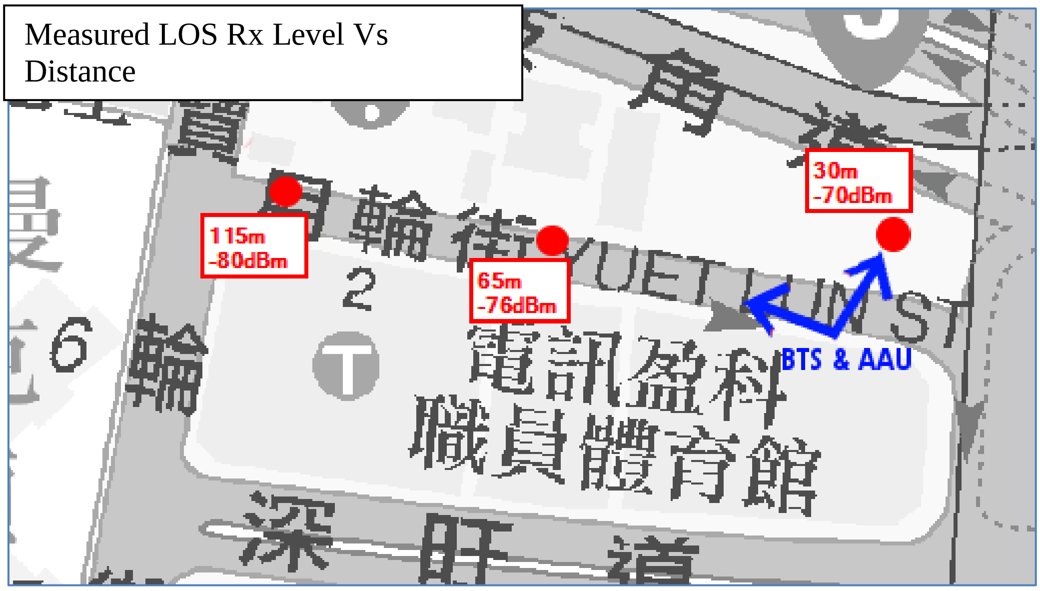


Figure : Selected LOS measurement locations

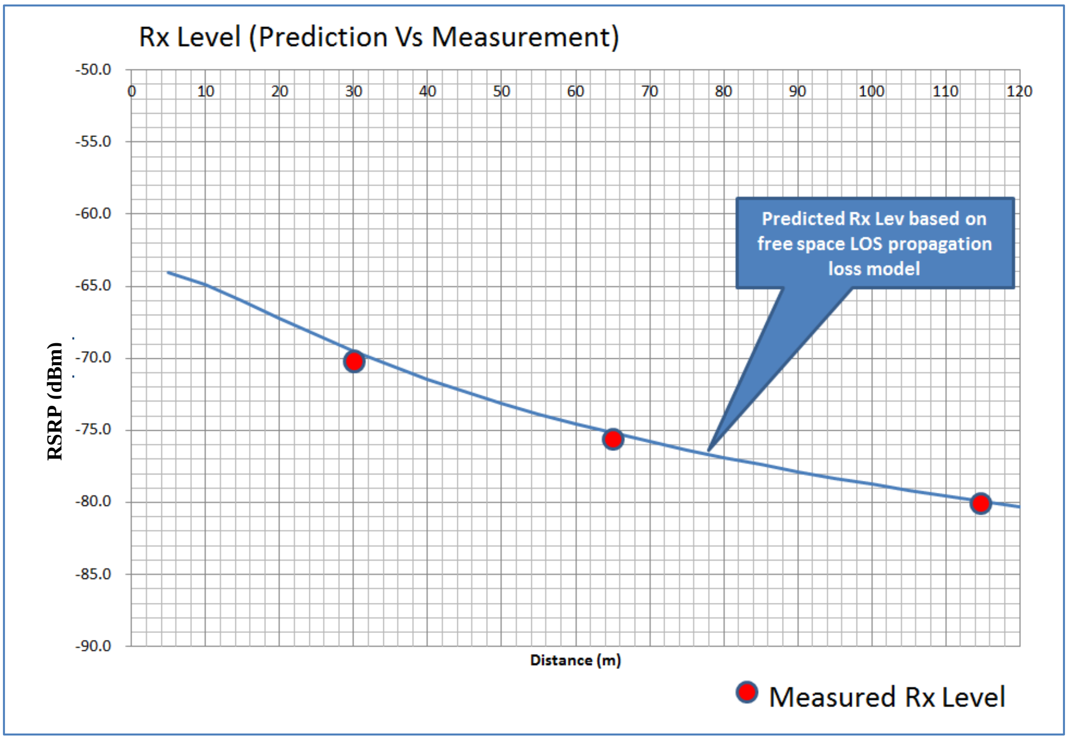


Chart : Measured RSRP vs prediction

Based on the live measure and the free space line of sight path model (see below)

FSPL(dB) = 20Log(d) +20Log(f) + 92.45
where d in Km and f in GHz.

A calibrated LOS path loss model is as below:

Cal. LOSPL(dB) = 20Log(d) +20Log(f) + 92.45 +correction factor
where d in Km and f in GHz; the correction factor is added to 3gpp theoretical estimation, because 3gpp value is peak RSRP within the carrier, while this field measurement is average RSRP over the whole carrier. The correction factor obtained through field test, the peak-to-average RSRP difference, is around 10dB.

The resulted Measured LOS Path Loss match the trend from prediction result.

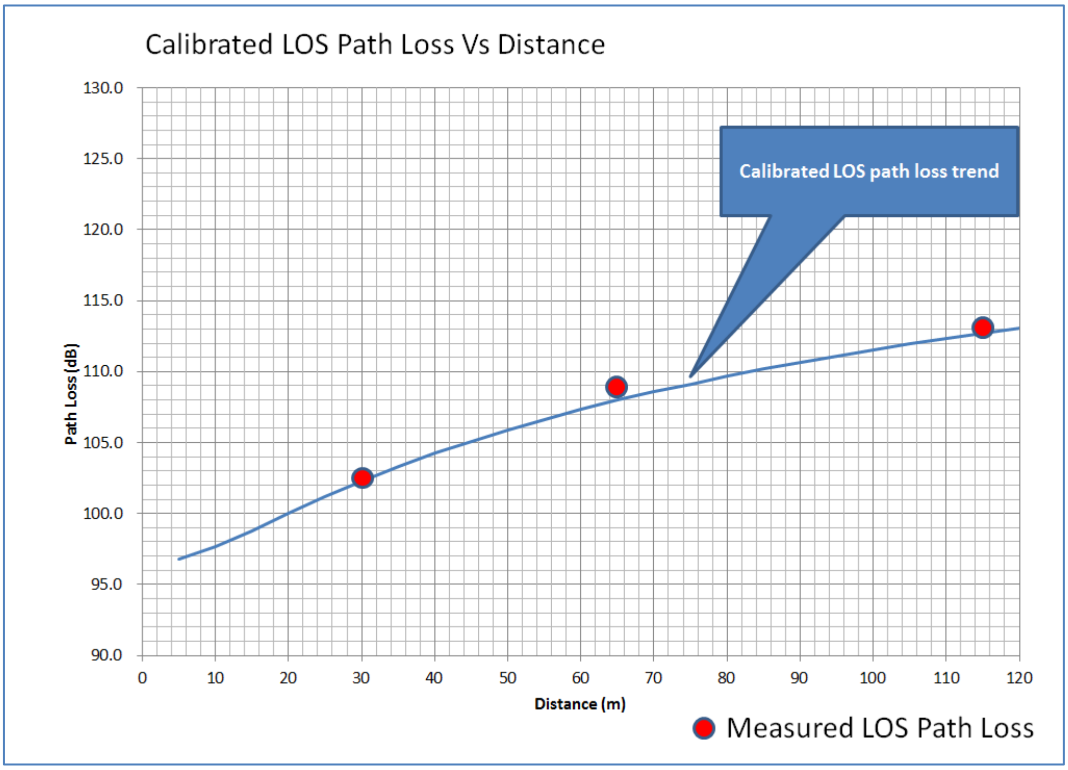


Chart : Calibrated LOS Path Loss vs Distance

2.2. Reflection Loss

The reflection loss is evaluated by comparing the measured RSRP Level of a Non Line Of Sight location with significant building reflection against the predicted RSRP Level of Line Of Site propagation with same propagation distance.

In the set up

- Total path distance = direct path + reflect path = 170m
- Measured RSRP Level behind the concrete blockage with directional Rx antenna facing away from the reflecting building : -100dBm
- Measured Rx lev behind the concrete blockage with directional Rx antenna facing the reflecting building : -91dBm
- Predicted Rx lev (170m) : -83dBm
- Reflection loss = -83dBm – (-91dBm) = 8dB

The building reflection loss is found to be 8dB in the testing scenario.

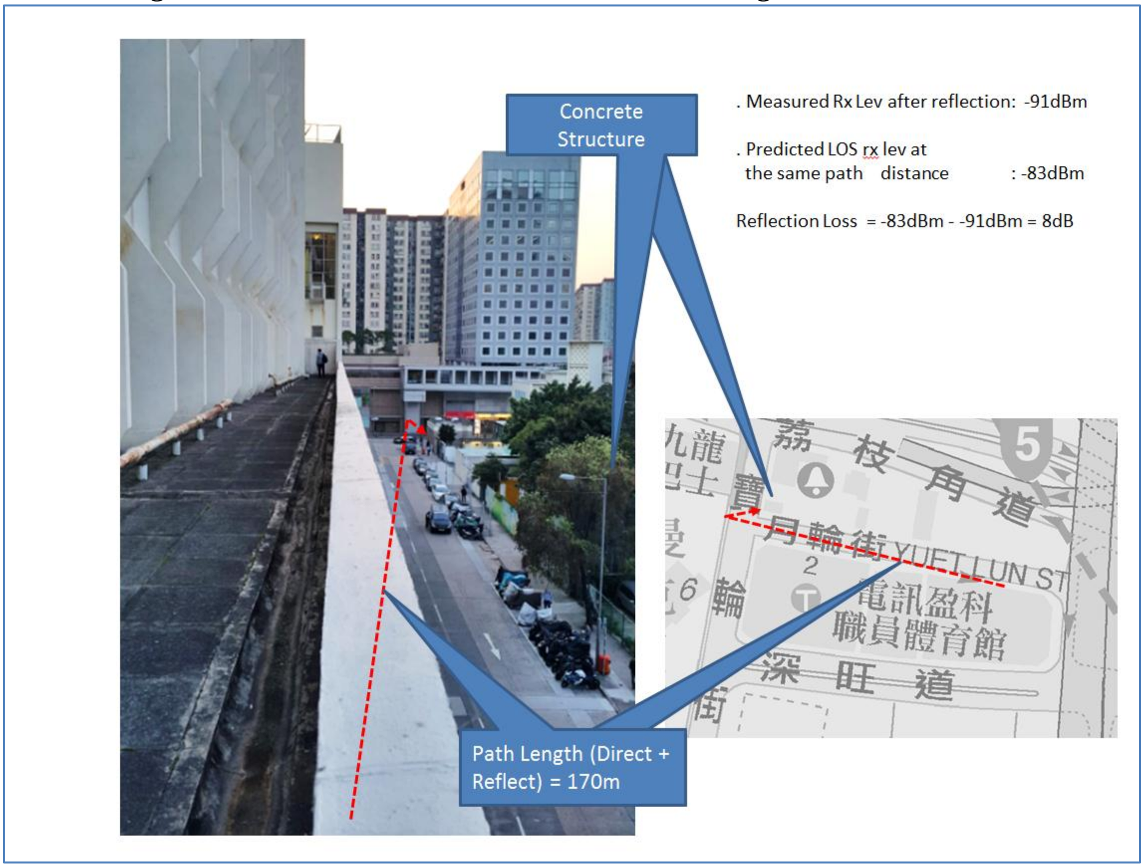


Figure : View and measurement location of Reflection Loss Test

2.3. Diffraction Loss

The Diffraction loss is evaluated by comparing measured RSRP Level at a Non Line Of Site measurement location shadowed by Base Station building podium itself against the Line Of Site measured RSRP Level of same propagation distance.

- Measured RSRP Level measured at the shadowed spot : <= -105dBm
- Measured RSRP Level measured at LOS spot of same distance : -80dBm
- Measured Diffraction Loss: >= (105-85) dB → >=25dB

The field measurement indicates that signal diffraction cause signal drop from 0 to >25dB within a few meter from LOS position to building shadow position.

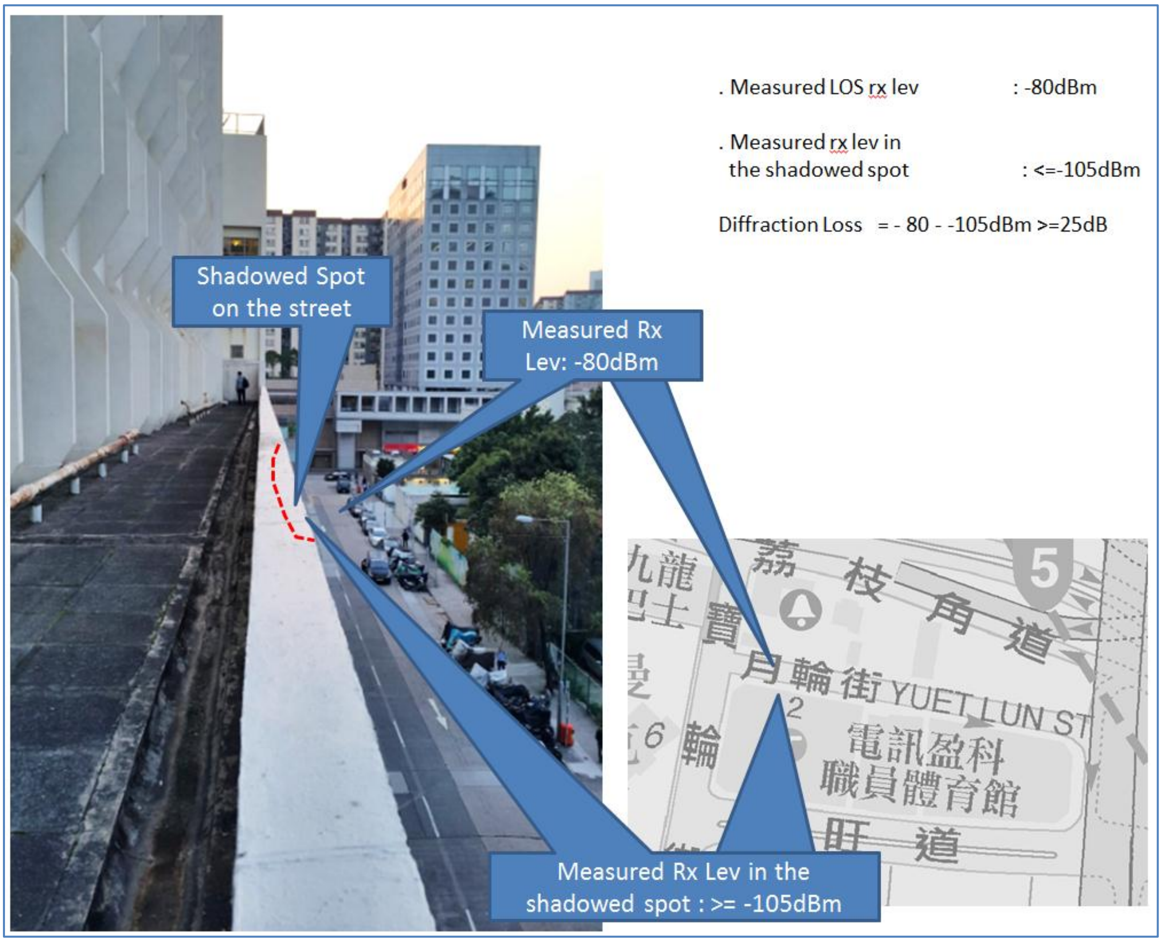


Figure : View and measurement location of Diffraction Loss Test

2.4. Penetration Loss

The Penetration loss is evaluated by comparing the measured RSRP Level at a Line Of Sight measurement position against the measure level at the same position blocked by various material of interest.

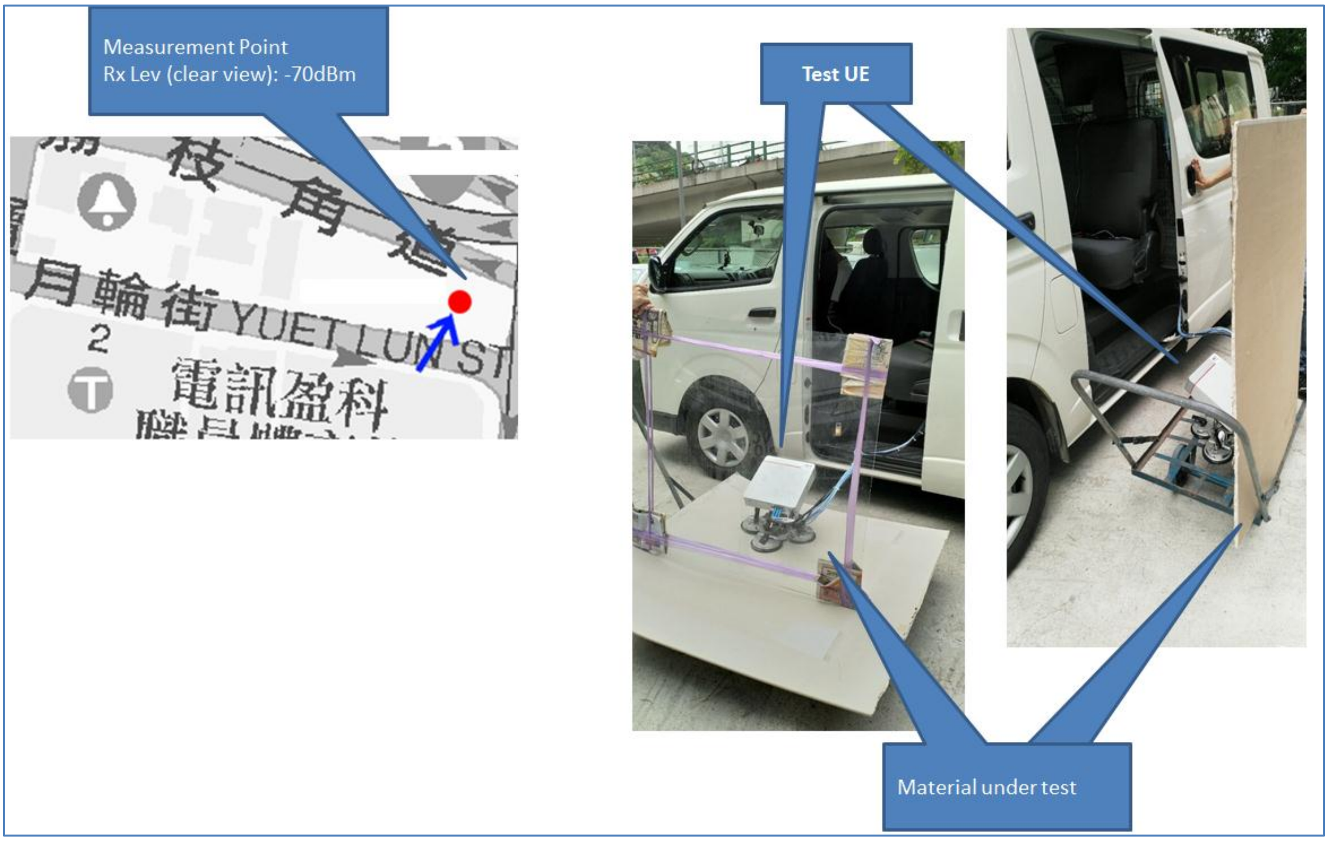


Figure : Measurement location and test setup

The following 7 materials were selected to block the UE receive antenna. And the penetration loss due to material blocking is as below.

Material	Received RSRP	Signal loss
Clear view	-71dBm	---
Clear glass	-75dBm	4dB
Glass with sun shade sticker	-75dBm	4dB
Plasterboard	-73dBm	2dB
Wet towel	-78dBm	7dB
Semi-Wet towel	-75dBm	4dB
Thick wet newspaper	-78dBm	7dB
Thin wet newspaper	-74dBm	3dB

Penetration loss of tinted glass was not tested in this section. However, the result of in building penetration measurement is covered in the next section.

2.5. In Building Penetration Loss

In building penetration loss is evaluated by comparing the outdoor RSRP Level just outside the building window again RSRP Level at various testing position inside the building.

At the first pair of testing position just outside and just inside the window tinted glass, the received level should a decrease from -39dBm to -58dBm. This shows a penetration loss of the tinted glass of 19dB.

More in building testing position were selected to demonstrate the composite result of in building penetration loss due to (a) Tinted Glass Penetration Loss, (b) impact of indoor reflection, (c) impact of in building structure/furniture blockage and (d) impact of indoor path loss vs distance.

Refer to the reference of -39dBm measured just outside the tinted glass and the various measure ranged from -71dBm to as low as <-105dBm which call dropped, the indoor penetration loss ranged from 32dB to >=66dB in the selected testing scenario.

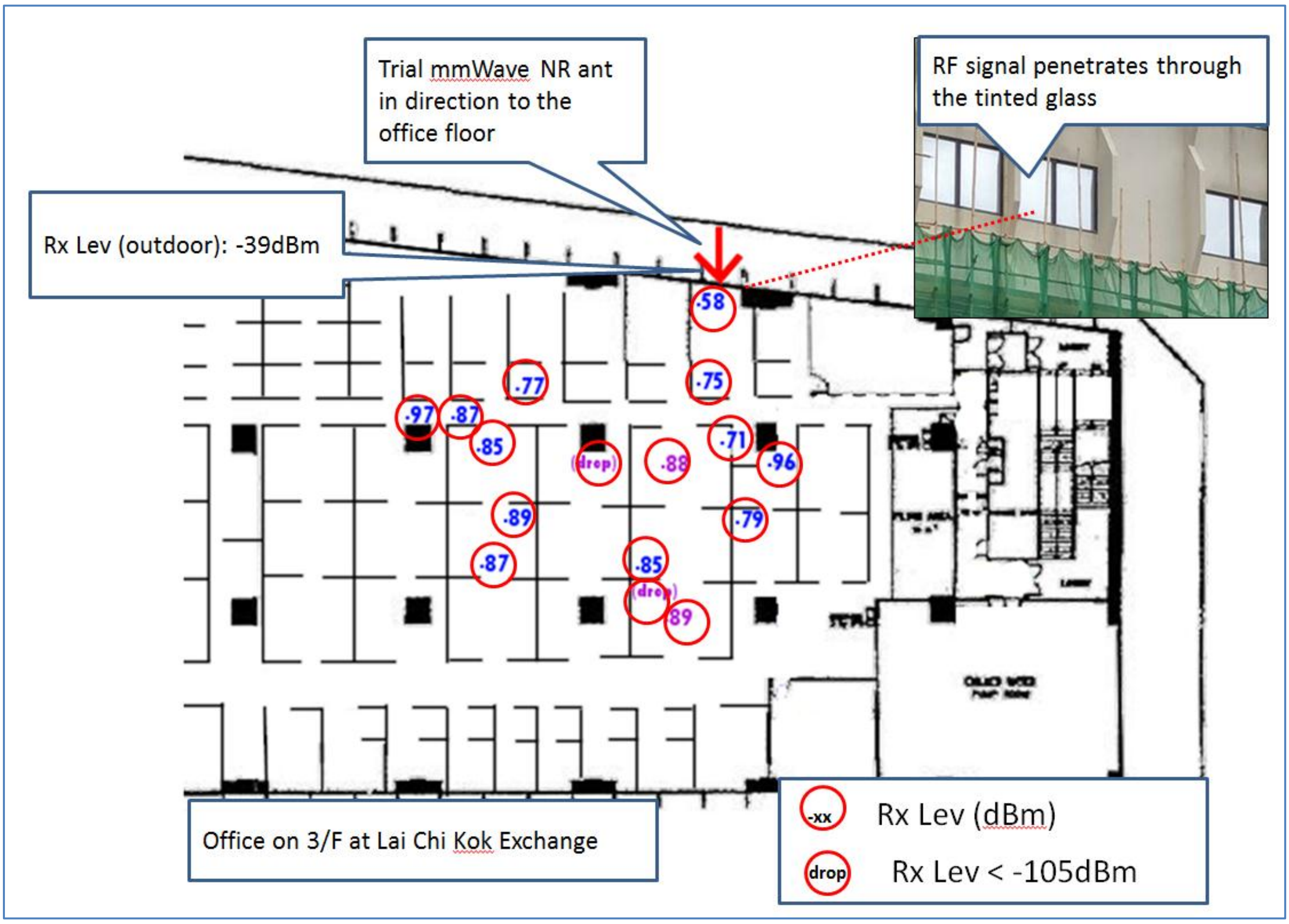


Figure : Measurement location and result of in building measurement

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2.6. Download Throughput

This section compared the download throughput in a few MIMO vs distance scenario with LOS coverage to mmWave NR.

1. Measurement location at 30m with MIMO 4x4

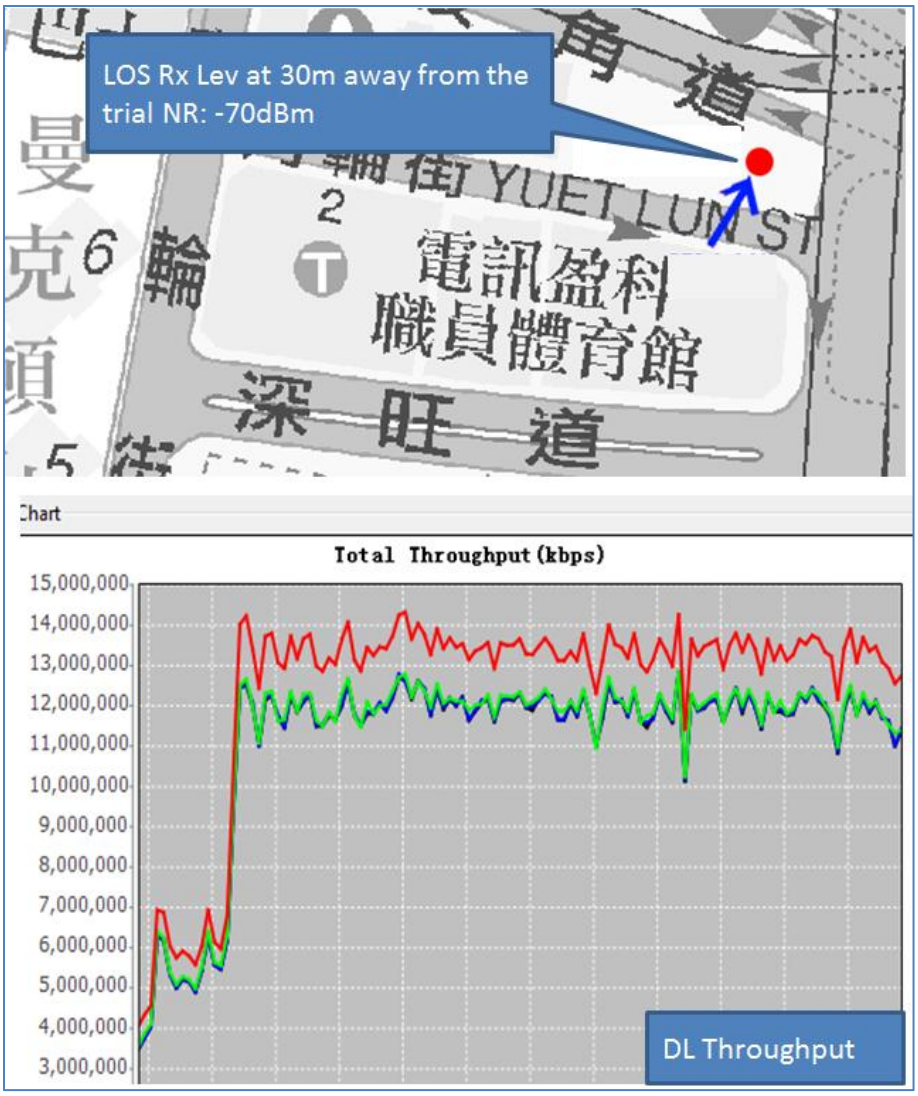

Figure : Measurement location at 30m with MIMO 4x4

2. Measurement location at 30m with MIMO 2x2

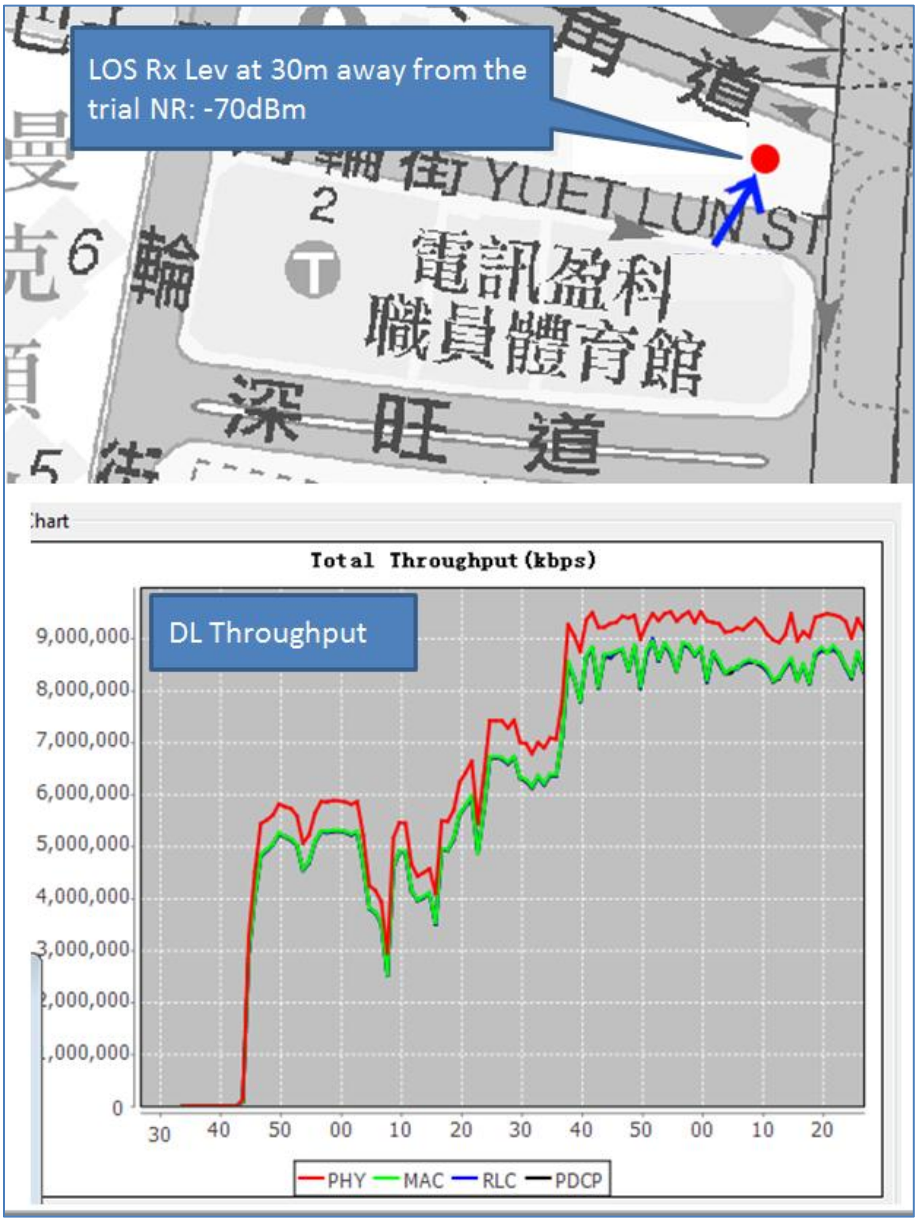

Figure : Measurement location at 30m with MIMO 2x2

3. Measurement location at 120m with MIMO 2X2

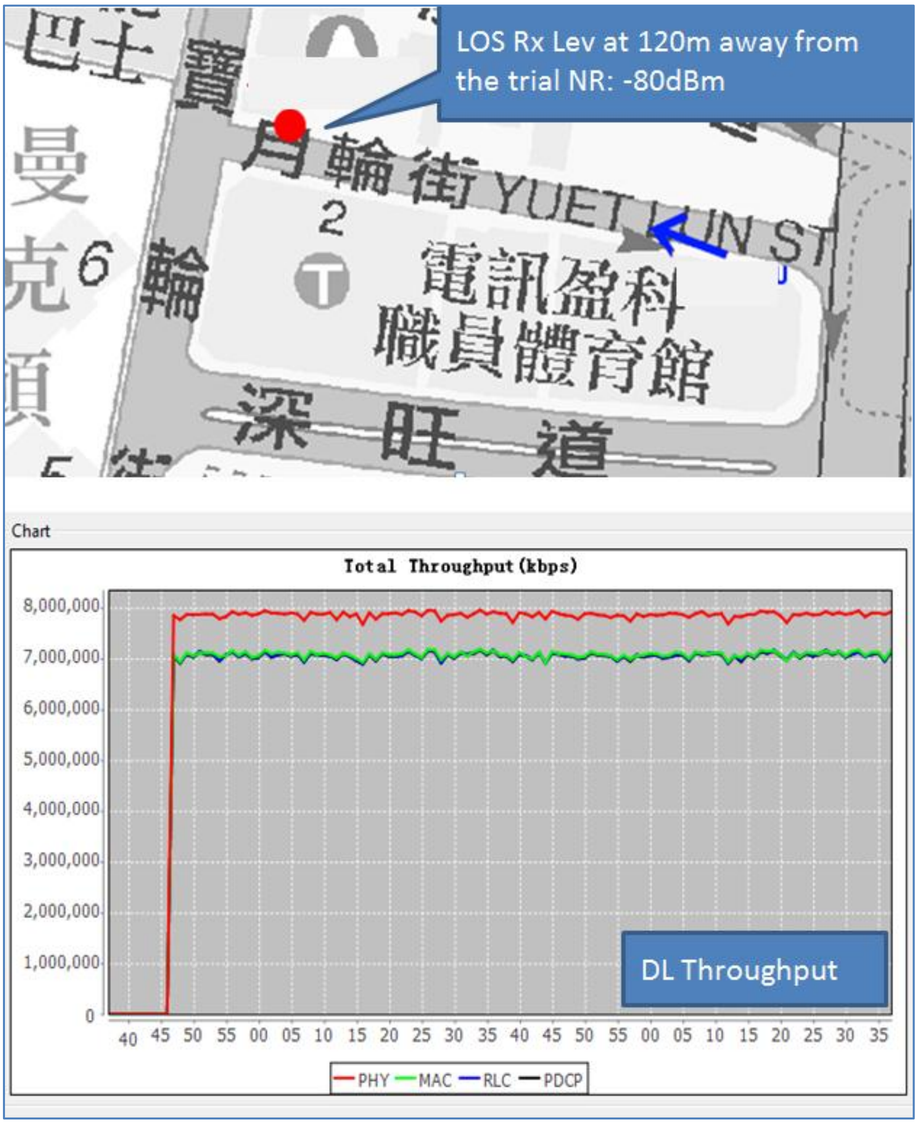

Figure : Measurement location at 120m with MIMO 2x2

Measurements for three scenarios are summarized below.

Distance	Average RSRP	Transmission (MIMO)	Physical layer peak throughput	MAC and RLC layer peak throughput
30m	-70dBm	4T4R	14Gbps	12.9Gbps
30m	-70dBm	2T2R	9.3Gbps	8.7Gbps
120m	-80dBm	2T2R	7.9Gbps	7.1Gbps

3. Finding

After the 5G mmWave NR field measurement, there are some key observations.

For Line-Of-Sight propagation loss, mmWave exhibits path loss similar to free space LOS model , with reference to the results in section 2.1.

In addition, as estimated from the results in section 2.2 and 2.3, in Non Line-Of-Sight situation, mmWave coverage will be mainly provided by possible signal reflection from the fact of comparatively high diffraction loss of mmWave diffraction loss.

Regarding indoor coverage penetration from an outdoor mmWave site, it is found that the penetration loss through tinted glass and concrete column can be up to 19dB and over 30db respectively (results in section 2.4). Indoor signal reflection will become the major remaining way of propagating coverage in indoor environment (results in section 2.5).

As the carrier bandwidth of 5G 28GHz mmWave will be 100MHz, comparing the existing maximum bandwidth for LTE of 20MHz, the radio transmit power per unit bandwidth will be limited to a lower value due to the limitation of hardware amplification capacity. This will limit the effective cell radius of mmWave radio. Together with a higher free space loss compare with sub-3GHz LTE, the effective radius of 28GHz mmWave will be shrunk to approximately 110m (see appendix)

4. Recommendation

The propagation loss on 28GHz mmWave is so much higher than the existing LTE band. It limits effective cell radius down to approximately 110m. Together with a high diffraction loss, 28GHz mmWave is not favorable to serve as a Macro coverage layer.

Besides, the higher penetration loss makes 28GHz mmWave not favorable to provide in building signal coverage served by surrounding outdoor base station.

On the other hand, smaller effective cell radius 28GHz mmWave NR reduced potential interference between adjacent NR. This helps 5G mmWave to serve as a capacity layer at hotspot locations. However, for extensive 5G outdoor coverage and considerable indoor user experience where indoor coverage system are not in place, a mid-band such as 3.5GHz/4.9GHz coverage layer is essential.

5. Appendix

Link Budget Calculation:

Item	Level	Unit	Remark
NR Tx Power per sub-carrier	-2.1	dBm	
NR Antenna Gain	26	dB	
EIRP per sub-carrier	23.9		
Measured system sensitivity per sub-carrier	-105	dBm	
UE Antenna Gain	0	dB	
In Building Penetration	0	dB	Only consider outdoor user
Shadowing Margin	14	dB	
Interference Margin	3	dB	
Allowable Path Loss	111.9	dB	
Cell Radius	110	m	

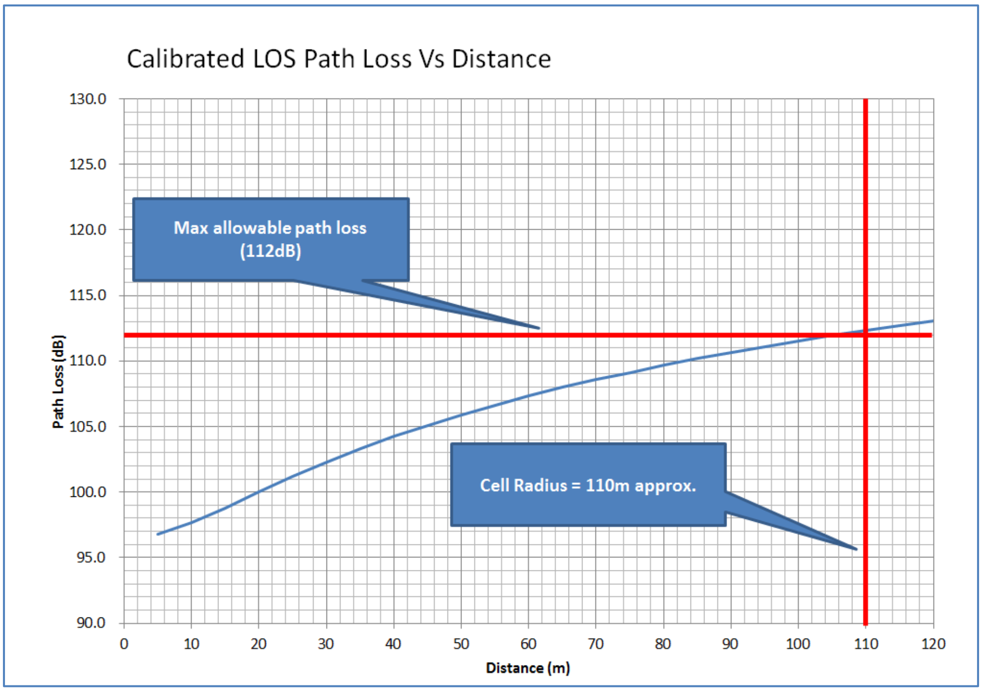

Chart : Calibrated LOS Path Loss vs Distance

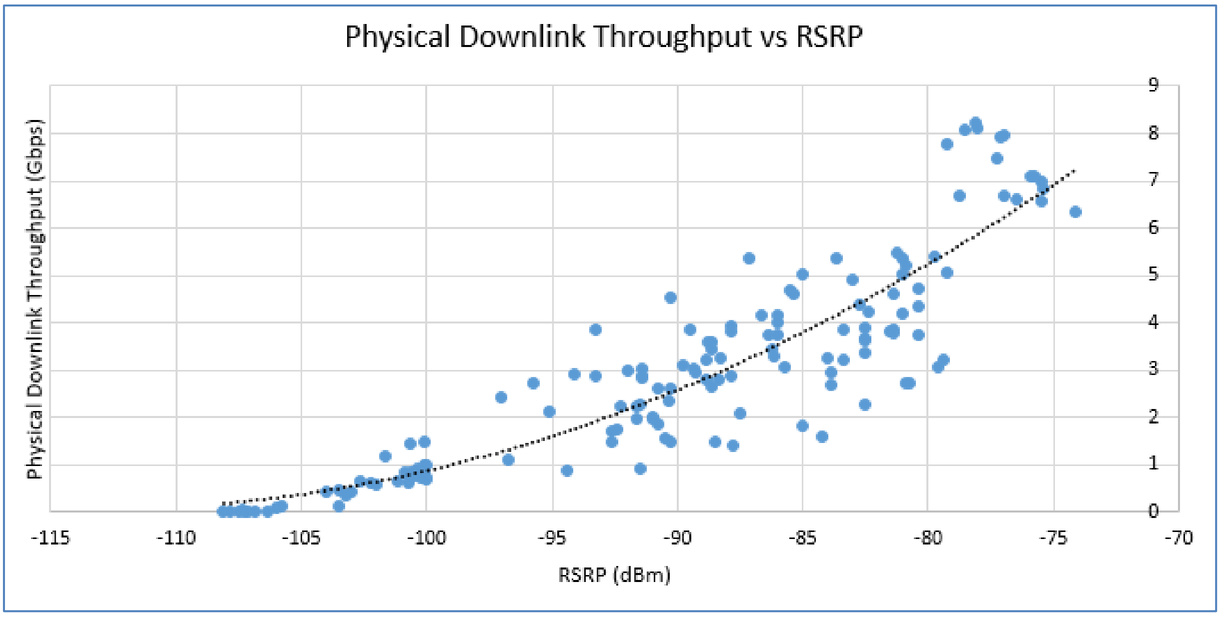

Chart : DL Throughput vs RSRP Plot

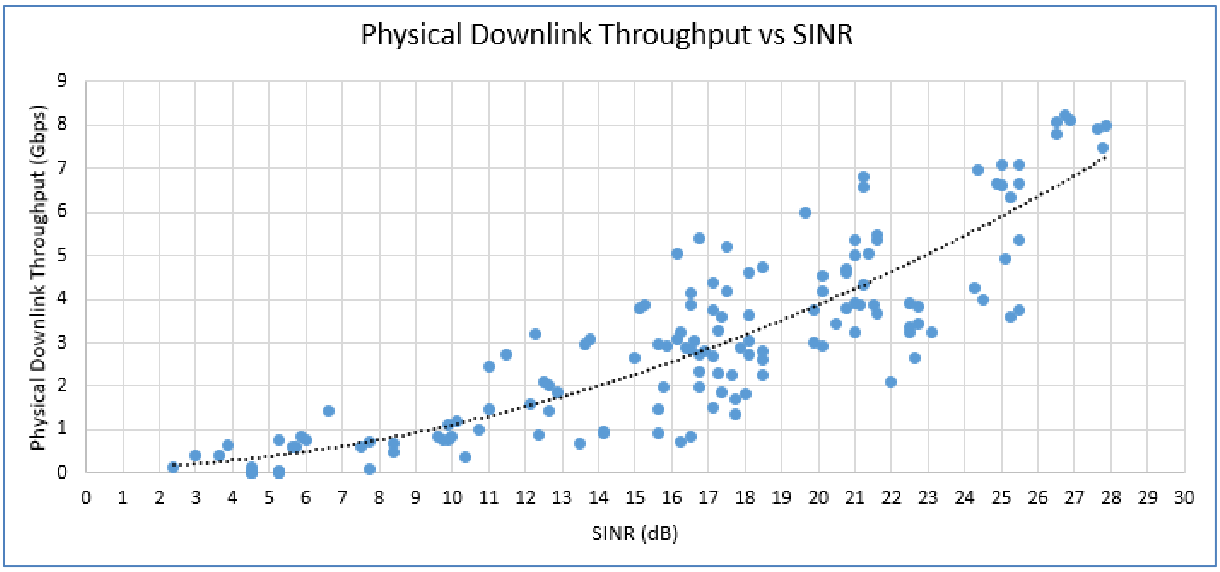

Chart : DL ThroughPut Vs SINR Plot