Delivering the extraordinary

mmWave

Marcos Bacic
South Head for MN Product Sales

The long journey of millimetres

2017-18	2019-20	2021-22
USA Centric. FWA. mmWave	Global. eMBB. cmWave	Global. All use cases. All bands
		
World first 3GPP mmWave	Focus on cmWave (incl FDD)	mmWave for Industry
		
World first 5GTF mmWave (FWA)	Focus on eMBB (and FWA)	Government support for mmWave

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Content

What is mmWave…

- mmWave spectrum around the World
- mmWave vs. cmWave
- Nokia mmWave product portfolio
- Theoretical and field performance
- Why roll out mmWave Radio?

mmWave spectrum around the World

Quick review of Global Regions

Interest in the four 3GPP mmWave (FR2) bands

North America

USA n258 24.25-25.25 GHz
USA n257 27.50-28.35 GHz
USA n260 37.00-40.00 GHz
Canada 27.5-28.35 GHz
‘Frontier Band’

South America

Uruguay n261
Chile n258

Europe

EU n258
Italy n258 26.5-27.5 GHz Jan’20
Finland n258 24.25-27.5 GHz Jun’20
‘Pioneer Band’

MEA

UAE n258 Feb 2020

GCHN

n258 24.5-27.5 GHz

Asia Pacific

Japan n257 27.5-29.5 GHz
South Korea n257 Dec 2018
Australia n258 25.1-27.5 GHz 1Q’21

Large commercial deployment of mmWave

3GPP specified mmWave bands

Band	GHz	Uplink / Downlink (GHz)
n257	28	26.50 – 29.50
n261	28	27.50 – 28.35
n258	26	24.25 – 27.50
n260	39	37.00 – 40.00

North America – Leading the world in mmWave

Nokia has supplied +20k mmWave radios to NAM

24GHz

37, 39, 47GHz

News – SDXCentral

Vendor 1, Vendor 2 and **Nokia** Score AT&T 5G Contracts. Sept 10, 2018

28GHz

37, 39, 47GHz

News – RCRWireless

Nokia touts first commercial 5G cloud RAN deployment (psst – it's Verizon's). Aug 23, 2019

24GHz

37, 39, 47GHz

News - Techradar

T-Mobile and **Nokia** Ink $3.5 Billion, multi-year 5G Network Agreement. July 30, 2018

24GHz

28GHz

37, 39, 47GHz

News - Fiercewireless

U.S Cellular taps **Nokia** for 5G network modernisation. May 5, 2019

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mmWave - Europe footprint

Ref: GSA 5G spectrum for terrestrial networks 1H 2020

First movers with mmWave in Europe

26.5-27.5 auction in Oct 2018

200MHz blocks to Iliad, VF, TIM, Wind/3 and Fastweb.

25.1-27.5GHz auction on 8/6/20

3x 800MHz blocks for national use.

Starting price EUR7m per block

24.25-25.1 reserved for local networks/industry

Frame and UL:DL synchronised *'unless networks do not interfere with one another'.*

mmWave - Rest of the World footprint

Examples outside of NAM

26.5-28.9GHz auction in June 2018
KT, LGU+, SKT 800MHz blocks
Nokia has 5G contracts with all three operators

antel
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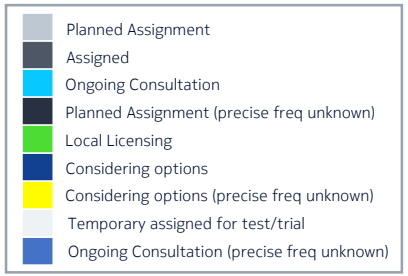
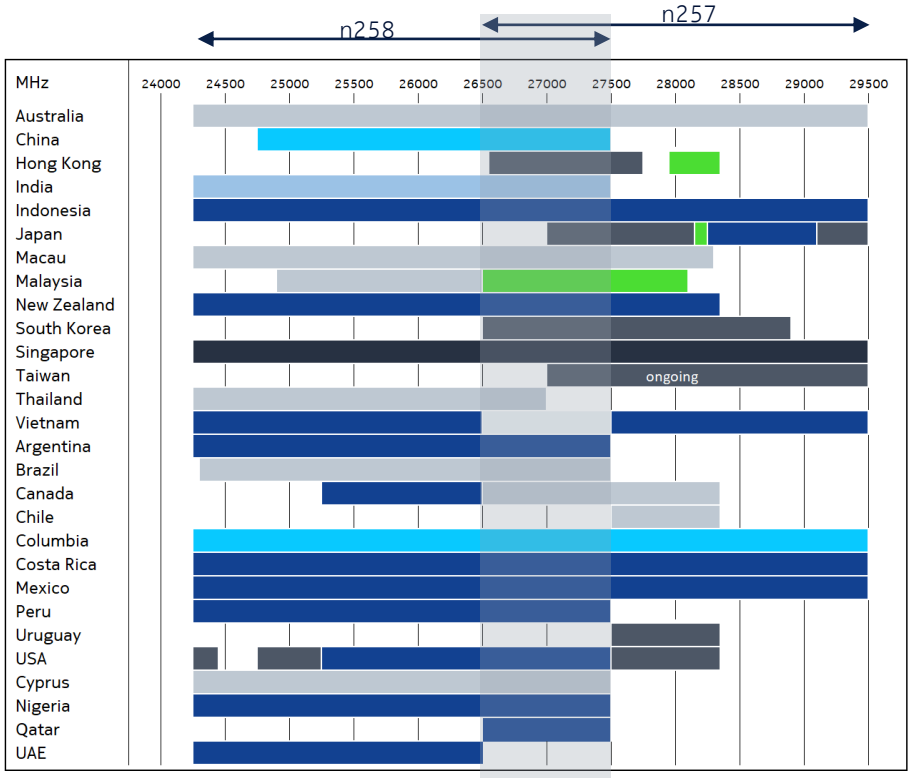
April 2019 Antel becomes the first operator in LAT to make a 5G call on a commercial network.
They used 28GHz and Nokia





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mmWave technology

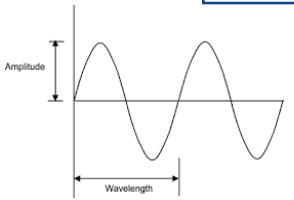
Setting the scene – mmWave

Mobile operator network planning departments need new models and planning tools for mmWave

mmWave name comes from its wavelength,λ

Technically less than 1cm and greater than 1mm (30-300GHz). In 3GPP 5G this is extended down to 24.25GHz

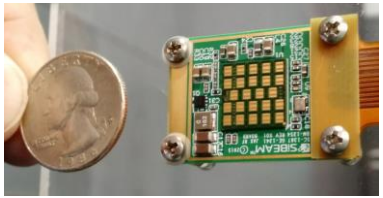
$$\lambda = c/f$$



The wavelength determines the size of antenna elements

Half wave dipole Antenna Element sizes

26GHz = 6mm
3.5GHz = 42.8mm
700MHz = 214mm



mmWave has large, cheap RF Bandwidths.

FR2 3GHz RF BW e.g. n257

FR1 500MHz RF BW e.g. n78

FDD 60MHz RF BW e.g. n1

GSA Spectrum Pricing update April 2020

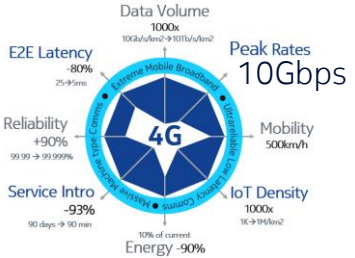
Ave 3.5GHz 0.175 $/MHz/pop[n]

Ave FR2 0.005 $/MHz/pop[n]

mmWave is needed to meet customer ultra-high broadband 5G speeds

1GHz x 10bps/Hz

10Gbps



Problem: As frequency increases then coverage/cell sizes get smaller and you would need more sites

Solution: mmWave supports high gain beamforming antenna arrays to increase coverage/cell sizes.

Benefit: Lots of mmWave spectrum available at much cheaper prices.

~ 35 times cheaper!

Benefit: mmWave is essential to get 1GHz of spectrum. If an operator competes on speed it must get mmWave.

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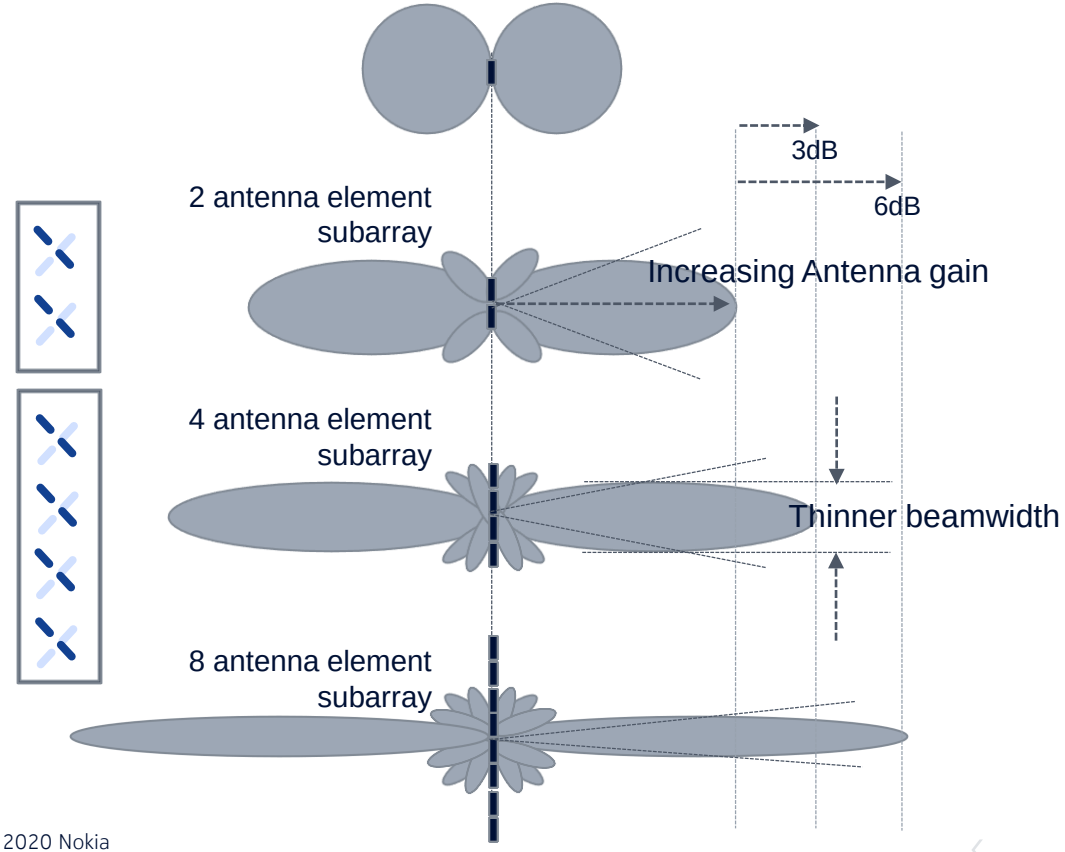
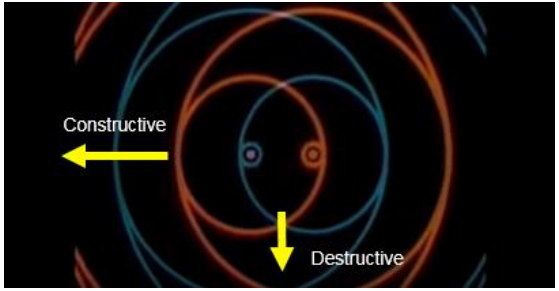
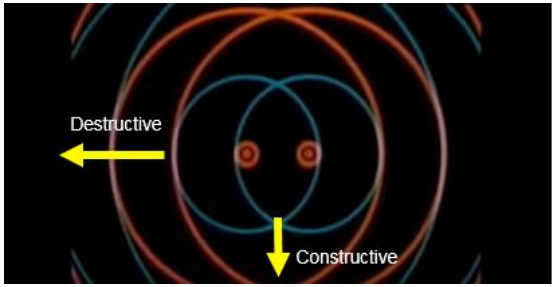
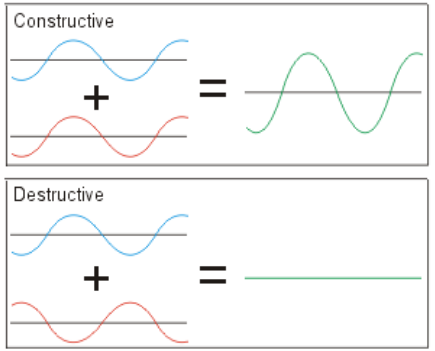
Antenna| Principles



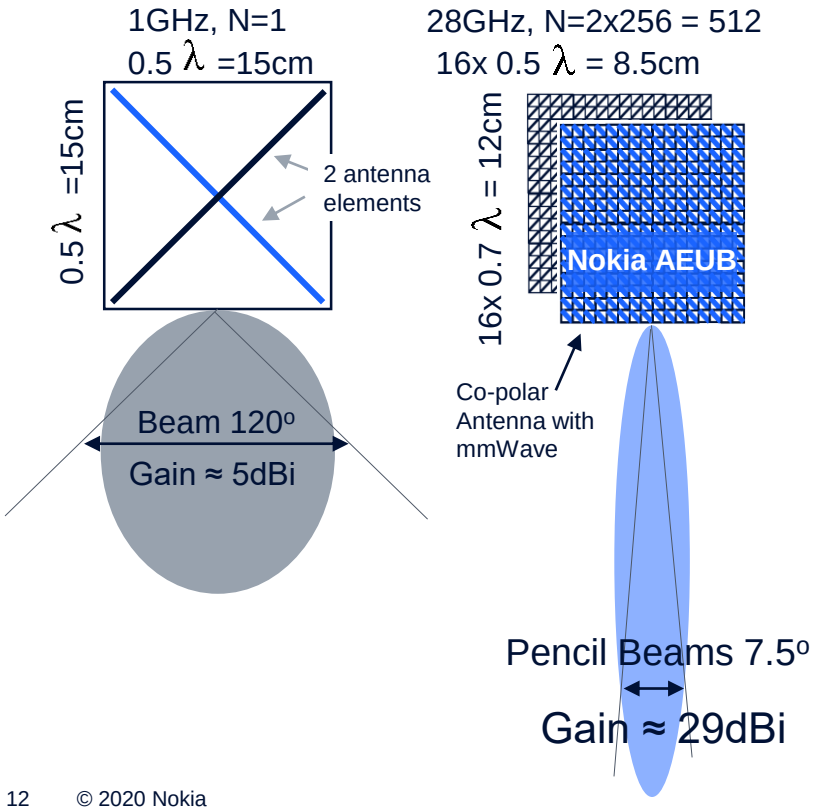


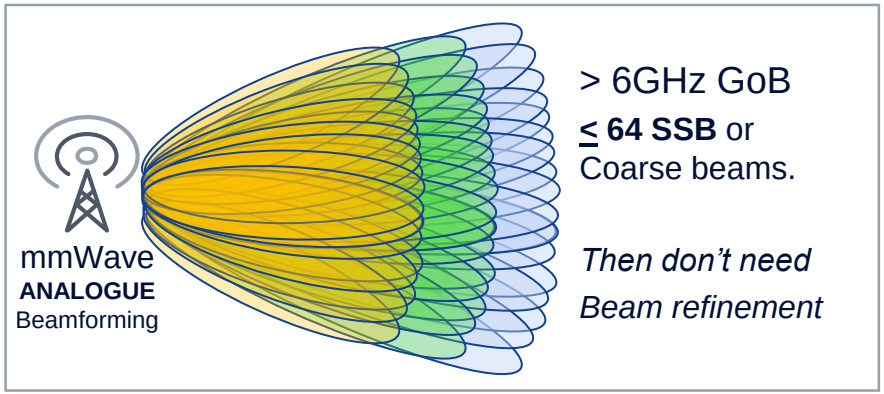


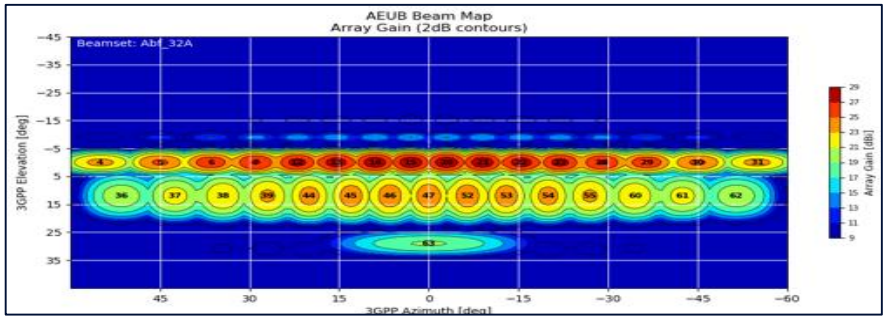


mmWave Antenna Arrays

High gain beams and power consumption







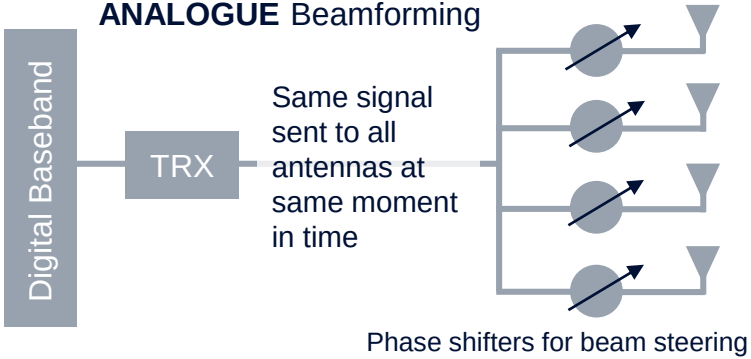
2T2R EIRP 60dBm.

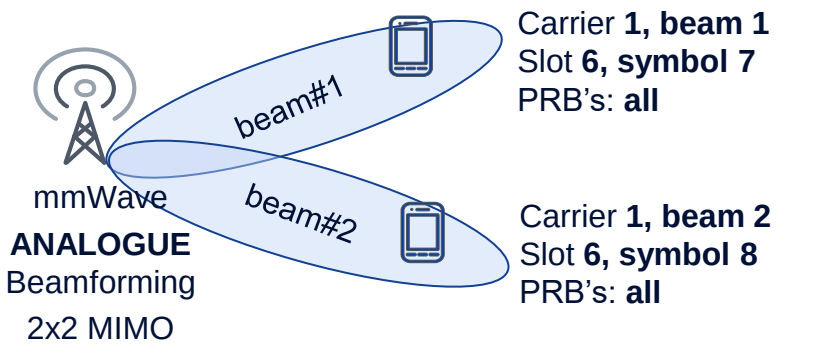
TxP = 60-29=31dBm = 1.26W (0.65W/TRX)

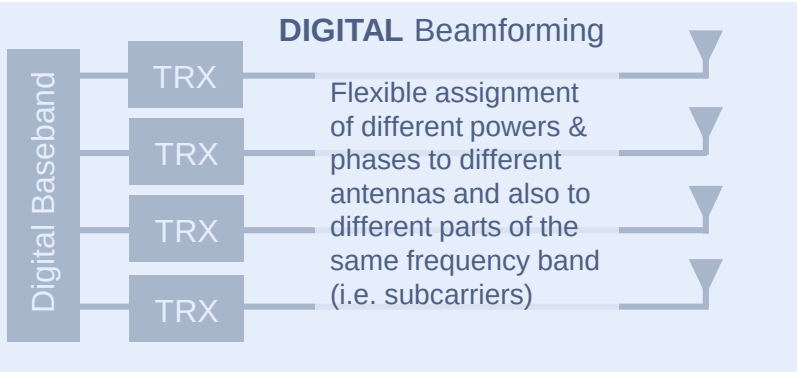
Benefit: mmWave has low power consumption

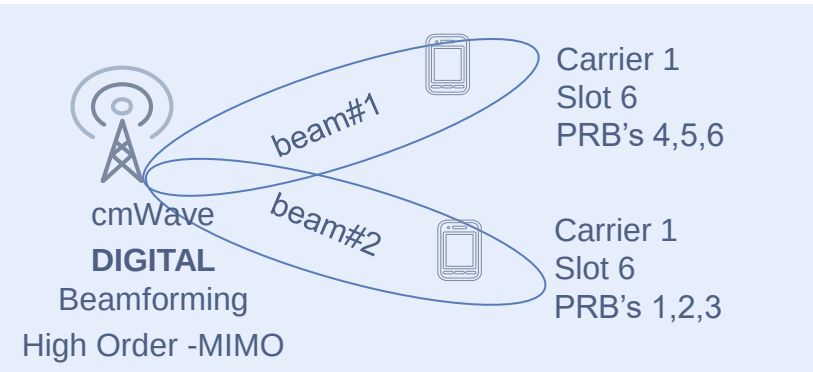
mmWave mMIMO/Beamforming

Analogue Beamforming – one beam at a time per antenna panel. A lot less TRXs.





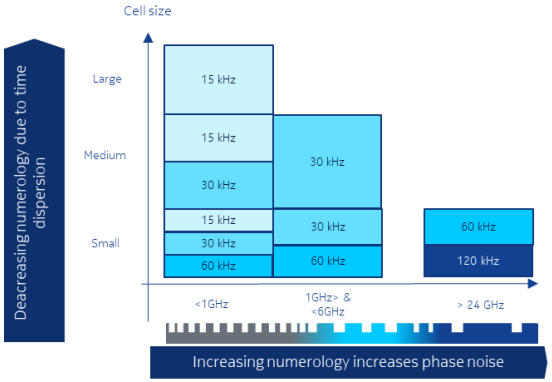




mmWave

Key enabler for Ultra Low Latency

Latency



mmWave devices

CPE and smartphones capabilities coming to the market

mmWave device trends

2019	2020	2021
4CC DL 1CC UL 2x2 DL MIMO	8CC DL 2/4CC UL	FR1+FR2DC/CA
		2022
		FR2 Standalone

mmWave device power classes (EIRP)

PC1	40-55 dBm	Fixed Access
PC2	29-43 dBm	Vehicle
PC3	22.4-43 dBm	Handheld default
PC4	34-43 dBm	High Power non-handheld
FR1	21-25 dBm	cmWave Handheld (ref)

25dBm = 316mW 43dBm = 20W

TrP 23dBm (200mW)

Ant Gain 20dBi max
32 X-Pol AE (or 2x 32 co-polar AE)

More than one panel and best panel chosen to prevent hand shielding the signal

Verizon FR2 FWA update
(Light Reading Jan 2020)

Launched Oct 2018 5GTF
Relaunched Oct 2019 3GPP

DL speed **300**-940Mbps
Range **150**-600metres

Available in 5 cities. Waiting on high power CPE before expanding further

AT&T 5G+ mmWave
(PC News March 2020)

mmWave launched for consumers 5th March 2020.

With two phones:
Galaxy S20 Ultra and S20+

Use Qualcomm chip with 800MHz 2x2 MIMO support

Nokia mmWave: Leading products

Nokia Radio leading products for mmWave

mmWave GEN3

AEUA/F 28GHz
AEWA 39GHz

2T2R, 512 AE's
iBW/oBW 800/800MHz
CPRI fronthaul
54dBm EIRP (Medium)

mmWave GEN4

AEUB 28GHz
AEWB 39GHz

2T2R, 512 AE's
iBW/oBW 1400/800MHz
eCPRI fronthaul
60dBm EIRP (High)
120º coverage

AEUD 28GHz
AEWD 39GHz

AEUE 28GHz
AEWE 39GHz

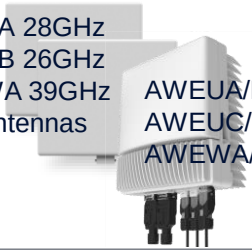
2T2R, 512 AE's
iBW/oBW 1400/800MHz
eCPRI fronthaul
51dBm EIRP (Medium)
Can be used as RAP with ASOD

mmWave GEN5

FW3UE/F 28GHz
FW3WC/D 39GHz

Radio Access Point (RAP)
4T4R, 576 AE's
F1 interface
iBW/oBW 1400/850MHz
63dBm EIRP (High)

FA3UA 28GHz
FA3UB 26GHz
FA3WA 39GHz
Ext Antennas



AWEUA/B 28GHz
AWEUC/D 26GHz
AWEWA/B 39GHz

2T2R, 192 AE's
iBW/oBW 1400/800MHz
eCPRI fronthaul
55dBm EIRP (Medium)

AirScale Medium Power Radio Unit (ASMR)

2T2R

192 Antenna elements (RU) and each Ext Antenna

10/12º Vertical and horizontal boresight beamwidth

±15º -3dB vertical steering

±45º -3dB horizontal steering

1400MHz
Instantaneous bandwidth

800MHz
Occupied bandwidth

210W Typical power consumption. Ext unit 110W typ

Radio unit can connect to up to 2 Extension Antenna units

Each Extension Antenna unit has same 55 dBm EIRP as RU.

RU+Ext Unit = 2T2R 180º Sector
RU+2Ext Unit=2T2R 360º Sector

10 litres 10 kg

55dBm Medium output power/unit

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Maximum Deployment Versatility

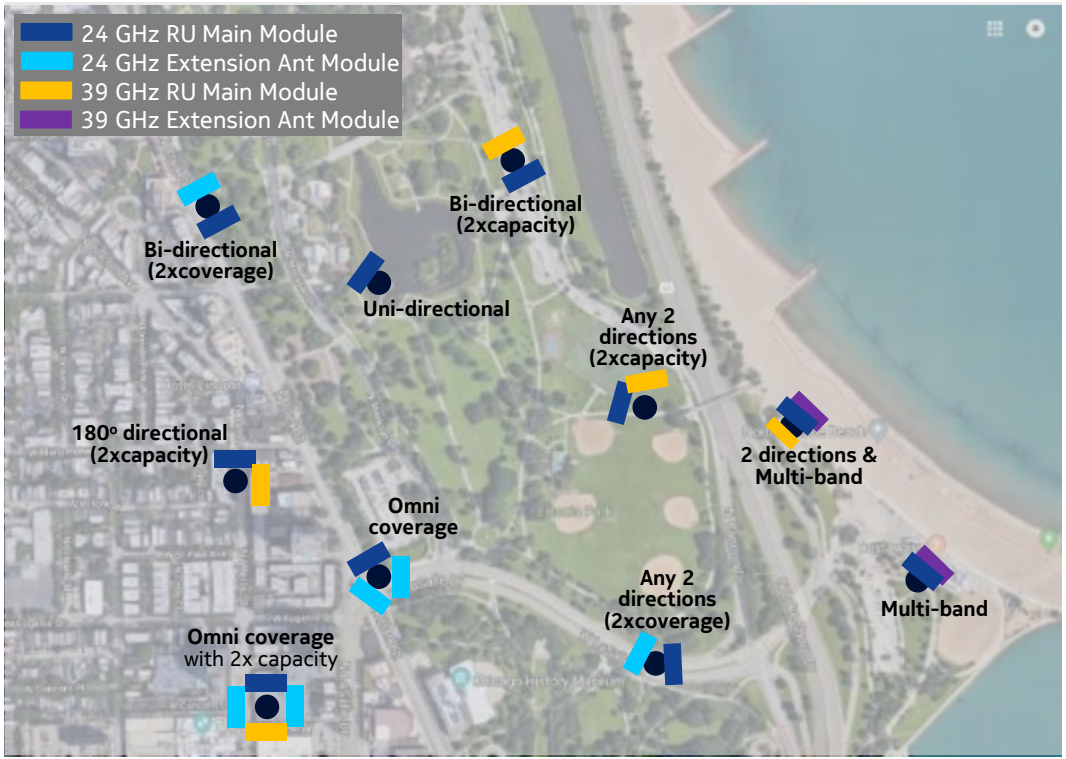
Gen 5 RU supports Multi-band, Uni/Bi-directional & 360o configurations

Deployment options

- Multiple site solutions
  - Main Unit + 2 extension antenna modules to maximize coverage
  - Additional 1 extension RU module to maximize coverage and capacity

- **Multiple coverage options** with 1 or 2 extension modules
  - Omni like coverage
  - Bi-directional, i.e. up and down the streets
  - Directional coverage (any angle)
- **Maximize capacity** via Main unit with 1 extension RU modules

- **Multi-band** capability
  - Main and extension panels can both support 800MHz (i.e., Main as 24GHz, Extension as 39GHz)



AirScale mmWave Radio Access Point (ASMRAP)

4 co-polar panels
Each panel 12x12 elements

576 Antenna elements

8° Vertical and horizontal boresight beamwidth

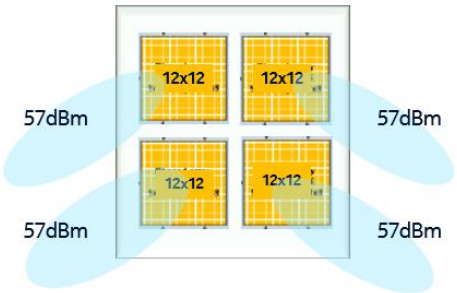
±30° -3dB vertical steering

±45° -3dB horizontal steering

4T4R 2 Transmit 60dBm
4 Transmit 63dBm

63dBm

FW3x
Radio Access Point
RU + ANT + F1



610W AC/DC variants
Active cooling
(low noise, high MTBF)

F1 interface
All-in-One capable

13 litres 13 kg

1400MHz
Instantaneous bandwidth

850MHz (2T2R or 4T4R)
Occupied bandwidth

Preliminary specifications

Field performance: What to expect

mmWave performance

5G NR throughput calculator and measured latency

400MHz
2Gbps

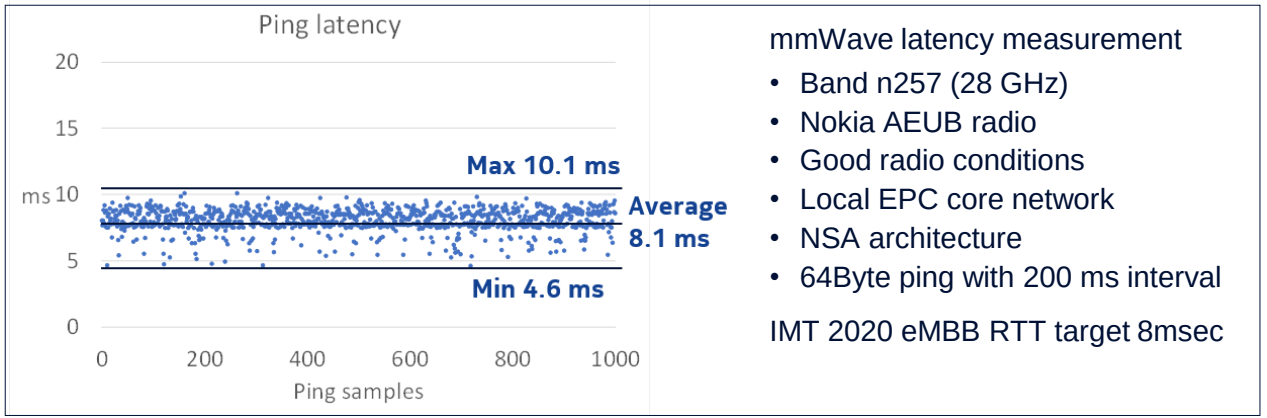
UPLINK cmWave	100MHz
Component Carriers	1
Modulation Order (64QAM)	6
Number of Layers	2
Scaling Factor	0.8
Numerology (30kHz)	1
PRB's (100MHz)	273
Overhead	0.08
Max Downlink	0.75
Based upon 4:1 i.e. 20%	0.15

UPLINK mmWave	200MHz	400MHz
Component Carriers	2	4
Modulation Order (64QAM)	6	6
Number of Layers	2	2
Scaling Factor	0.8	0.8
Numerology (120kHz)	3	3
PRB's (100MHz)	66	66
Overhead	0.1	0.1
Max Downlink	1.42	2.84
Based upon 4:1 i.e. 20%	0.284	0.568

DOWNLINK mmWave	200MHz	400MHz	800MHz
Component Carriers	2	4	8
Modulation Order (64QAM)	6	6	6
Number of Layers	2	2	2
Scaling Factor	0.8	0.8	0.8
Numerology (120kHz)	3	3	3
PRB's (100MHz)	66	66	66
Overhead	0.18	0.18	0.18
Max Downlink	1.29	2.58	5.17
Based upon 4:1 i.e. 80%	1.032	2.064	4.136

800MHz
4Gbps

Max UL
Is 150Mbps enough for industrial applications?



mmWave latency measurement

- Band n257 (28 GHz)
- Nokia AEUB radio
- Good radio conditions
- Local EPC core network
- NSA architecture
- 64Byte ping with 200 ms interval

IMT 2020 eMBB RTT target 8msec

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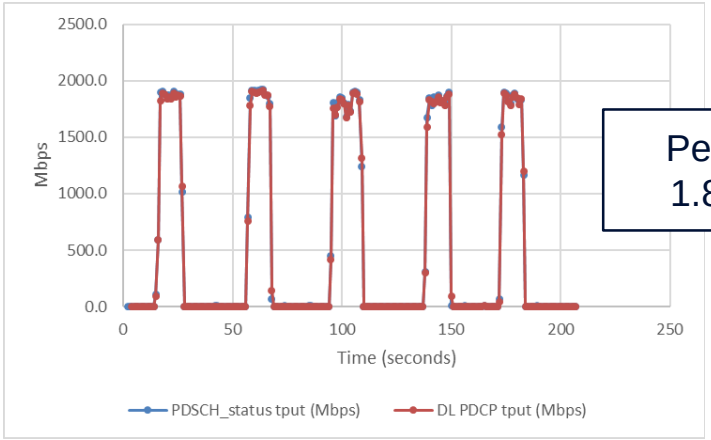
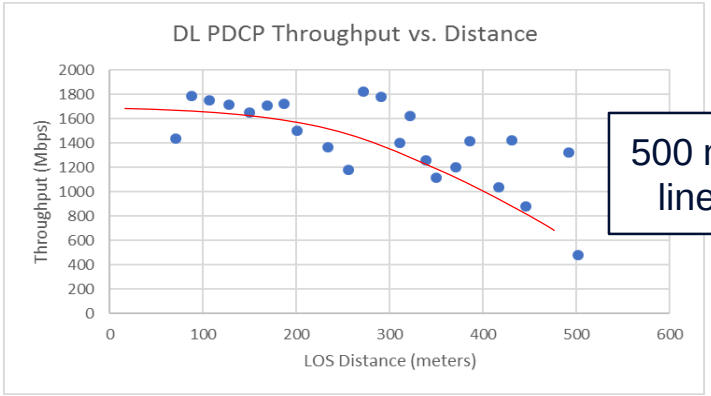
Field performance meeting expectations

5G mmWave data rates with 400 MHz in the field



Peak rate
1.8 Gbps

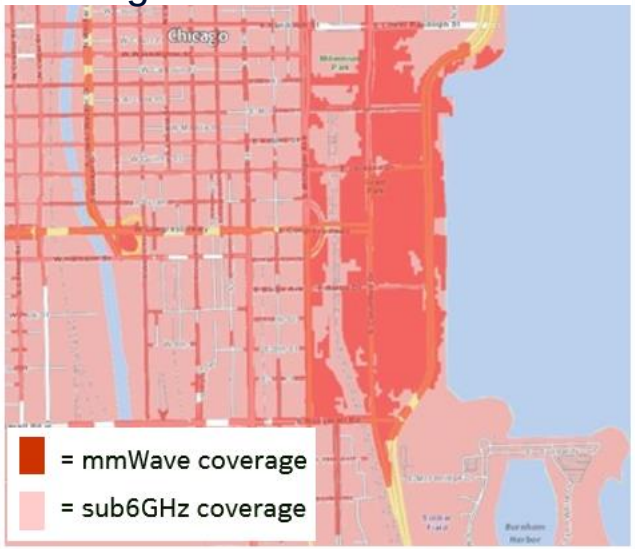


500 m range in
line-of-sight

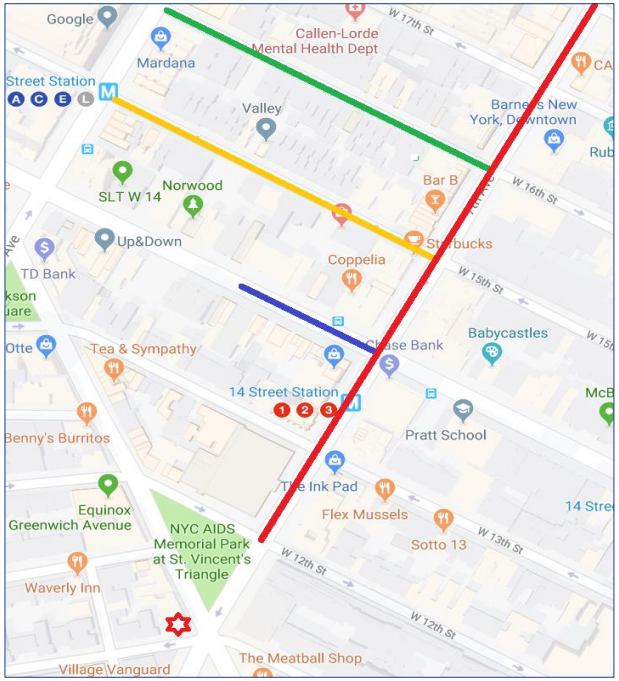
100-150 m range
in dense urban

mmWave propagation and penetration loss

Verizon 28 GHz coverage in Chicago downtown

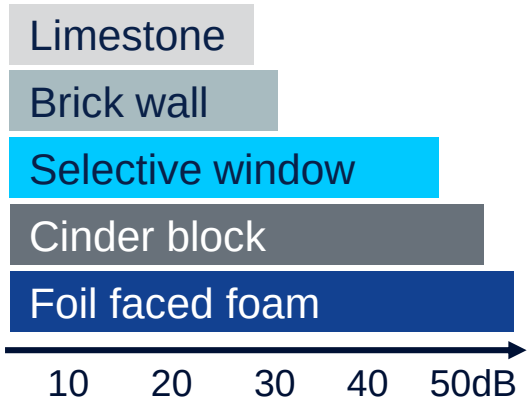


mmWave covers streets, outdoor and open areas



>14dB drop after 10m into corner
>21dB drop after 50m into corner

Building penetration losses



Construction material loss 20-50dB
Softer materials: loss <15 dB

No outdoor-in mmWave coverage

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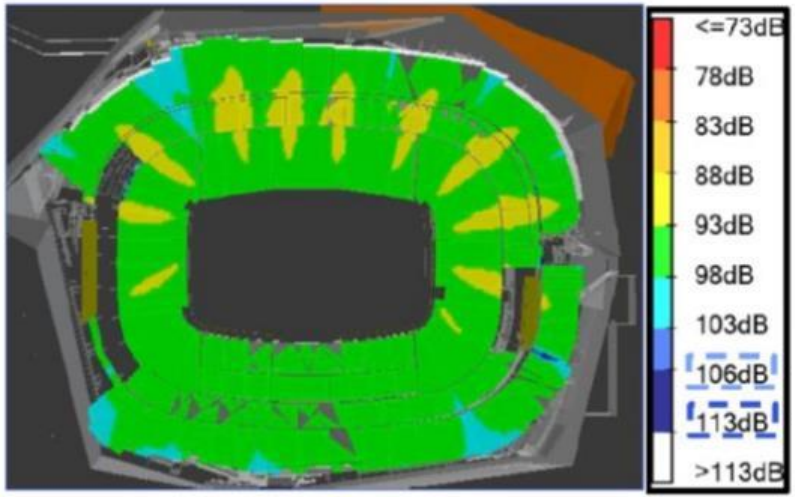
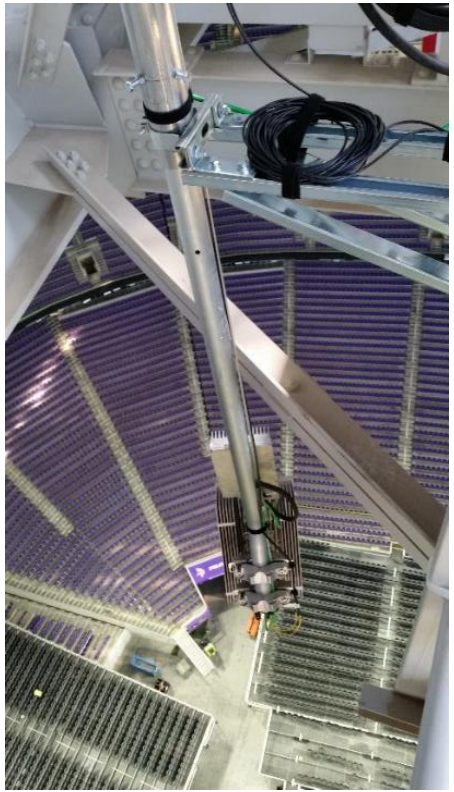
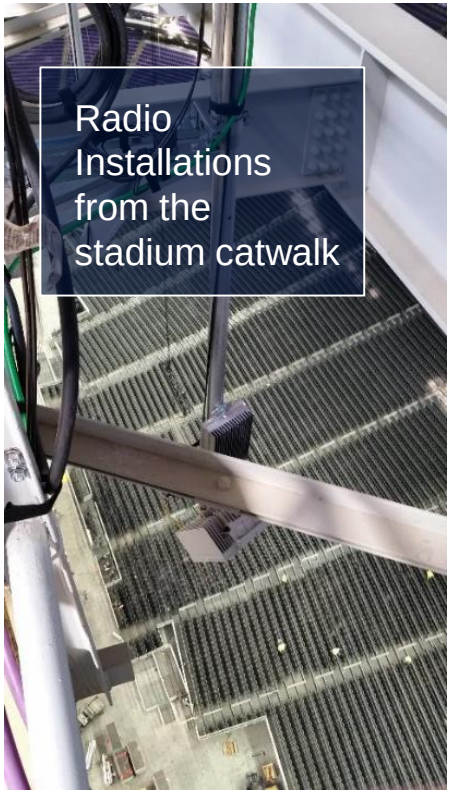
5G mmWave at US Bank stadium in Minneapolis



Seating capacity 67.000

- 100% area with 16 sectors -103 dB
- Data rates: 1.0 – 1.5 Gbps (@ 400 MHz)





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Nokia Irving (TX) field network live testing
28GHz 4CC DL

Distance (m)	Beam ID	L2 DL* (Mbps)
32	63	1863
58	45	1630
60	54	1650
62	53	1640
65	47	1750
75	53	1640
76	21	1843
88	20	1700
90	29	1700
94	23	1900
100	28	1955
106	29	1845
120	28	1800
252	13	1400

Beam ID and Test Locations

Test data gathered at each location:

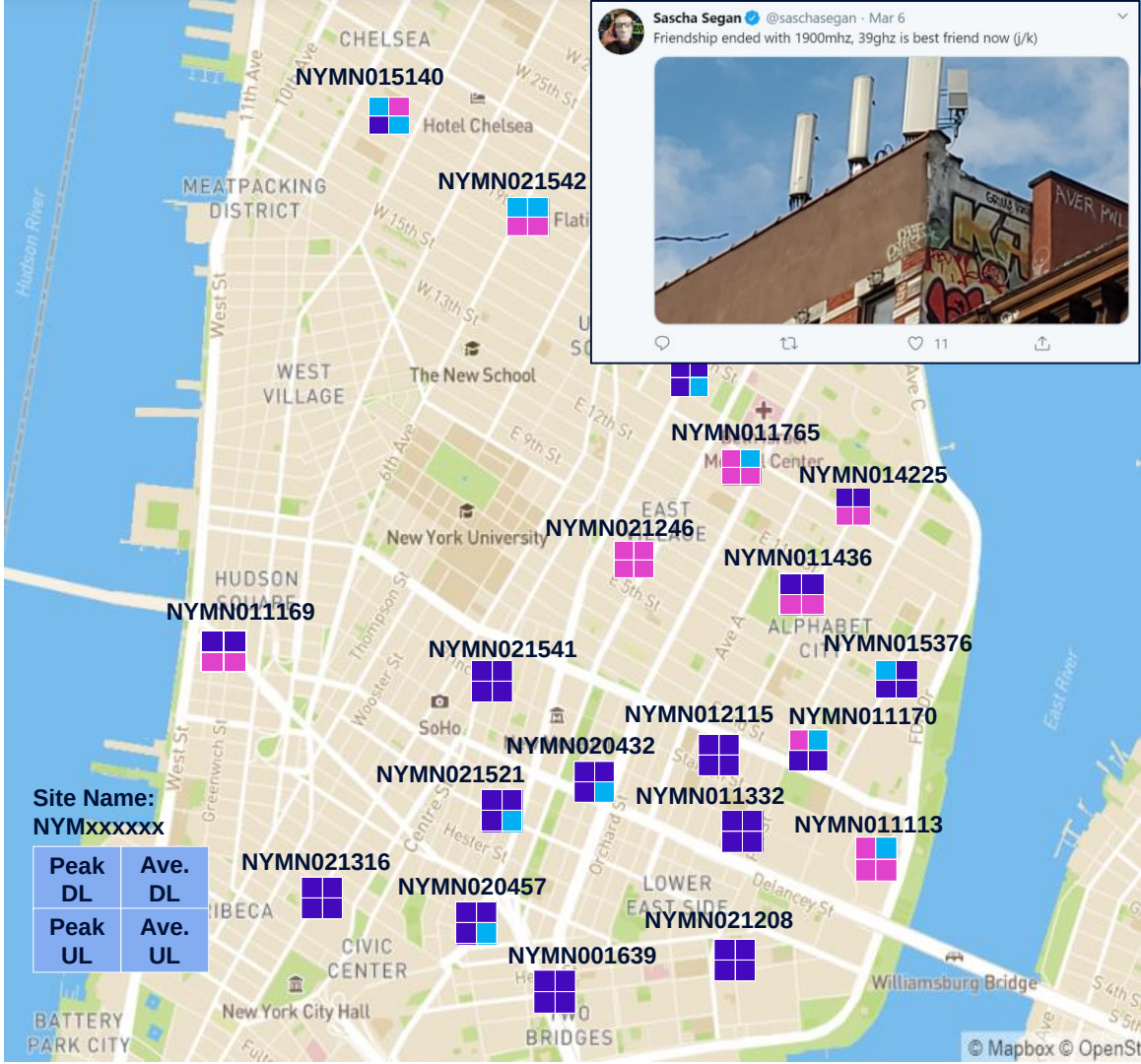
- Beam ID, Distance
- L2 RLC and iperf throughput
- RSRP, MCS, BLER

New York City mmWave

Peak and average throughput 39GHz

- Gen4 Micro Radio - AEWB
- Majority of sites with peak DL in the range of 1,400 to 1,600 Mbps
- Majority of sites with peak UL in the range of 30 to 70 Mbps

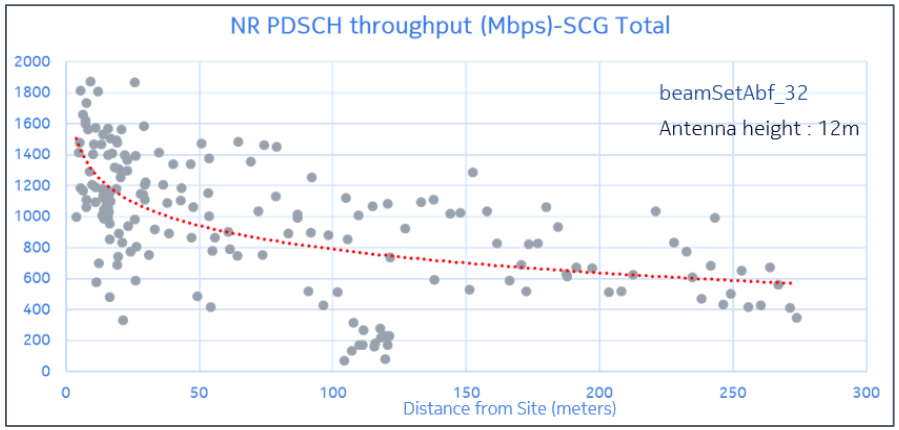
DL Throughput (Mbps)	UL Throughput (Mbps)
1,400 to 1,599	31 to 70
1,300 to 1,399	21 to 30
1,200 to 1,299	11 to 20
1,000 to 1,199	6.5 to 10



MEA field trials n257

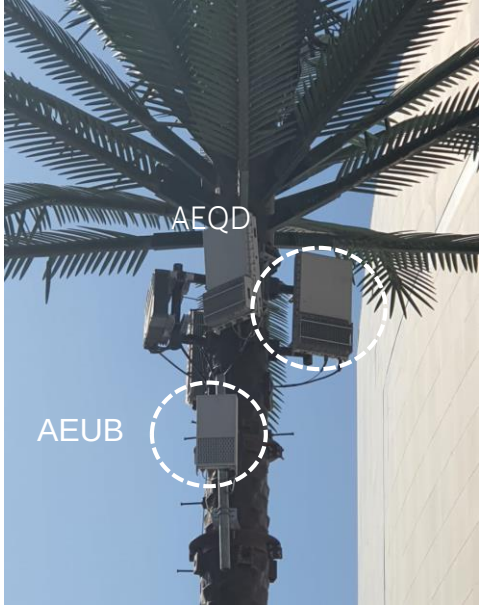
DL 400MHz, UL 100MHz

Mobility test summary



Static test summary

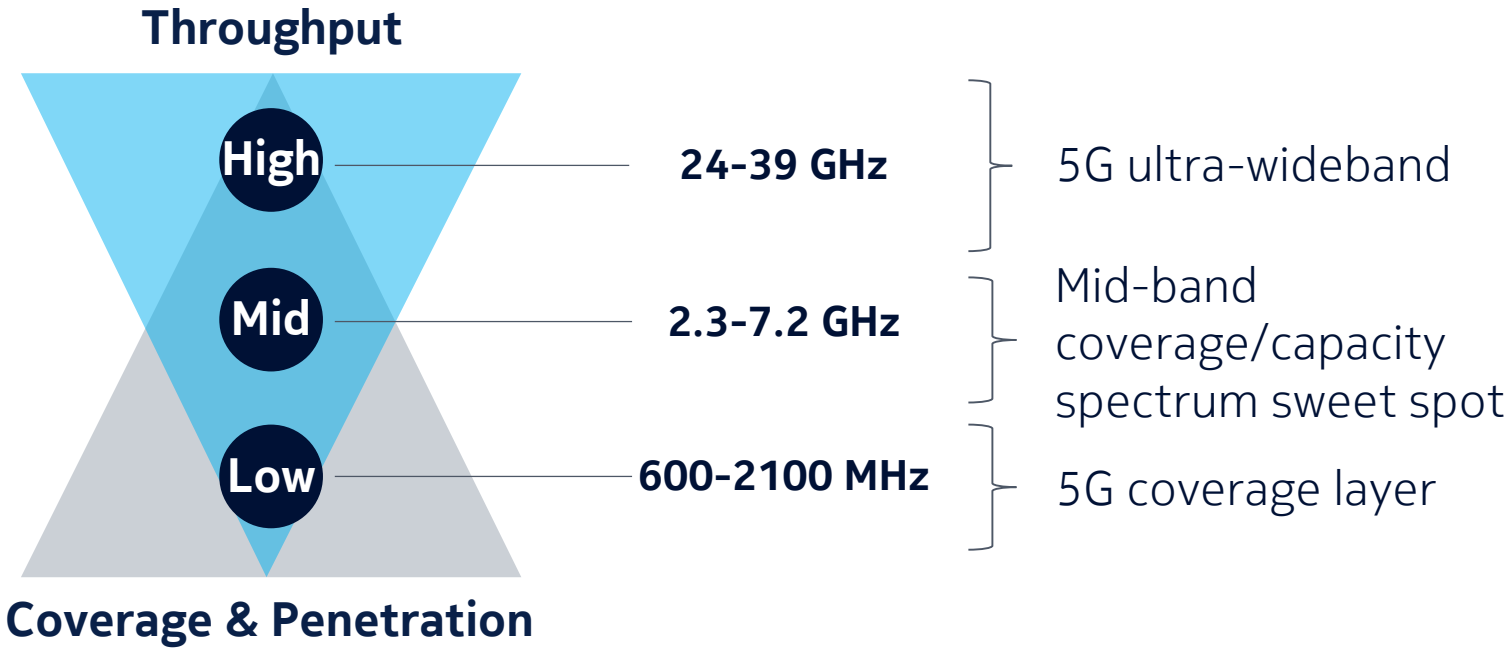
	Ave RSRP	PCell1 DL	SCell1 DL	SCell2 DL	SCell3 DL	PCell1 UL	Total L1 DL
Near Point Max	-65dBm ± 15mtrs	519.586	527.03	527.489	526.657	122.94	2096.13
Mid Point Max	-73dBm ± 50mtrs	509.715	523.119	523.567	521.688	130.33	2078.09
Far Point Max	-85dBm ± 100mtrs	370.421	407.559	409.919	379.36	114.97	1484.17



Why mmWave?

Spectrum availability defines the shape of early 5G deployments

Delivering 5G's full potential needs a mix across low, mid and high bands

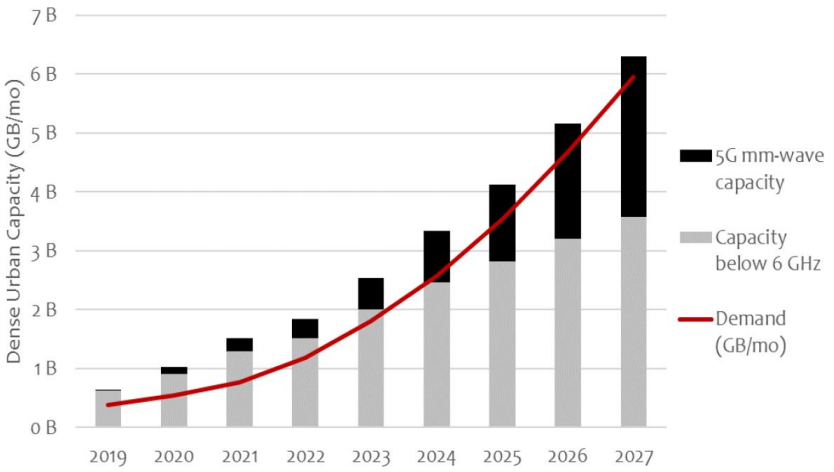


NOKIA

Key drivers for mmWave solutions

Capacity especially in urban areas is increasing exponentially on a yearly basis

5G strategic view: Necessary for mobile capacity



Source: Mobile Experts 5G Business Case Dec 2019

- Low cost spectrum available in large BW's.
- cmWave will not address long term capacity demand.
- Simple and small solution for capacity and coverage holes.
- Available for Enterprise in some countries.
- The competitive pressure and the need for speed.
- Getting the UL speed needed by some industries i.e. greater than 150Mbps

NOKIA

Nokia 5G mmWave
Key take-aways

1

Experience and knowledge to help our customers make the most of their mmWave spectrum and maximise its performance

North America is leading the world in mmWave and Nokia is with all the major networks and mmWave deployments

2

Common AirScale based product portfolio with high performance street side and macro base station solutions

High Power RAP solutions for street side

Medium Power multi-panel macro solutions

3

Full and expanding set of features and functionality evolving on ready made hardware

R&D investment and commitment to the mmWave roadmap.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