Advantages of MMIMO

November, 2019

MIMO: the Magic to Increase Spectrum Efficiency

MIMO Efficiency is limited by min(m,n)

Transmit Matrix

Input: X

$[x_1, x_2, ..x_m]^T$

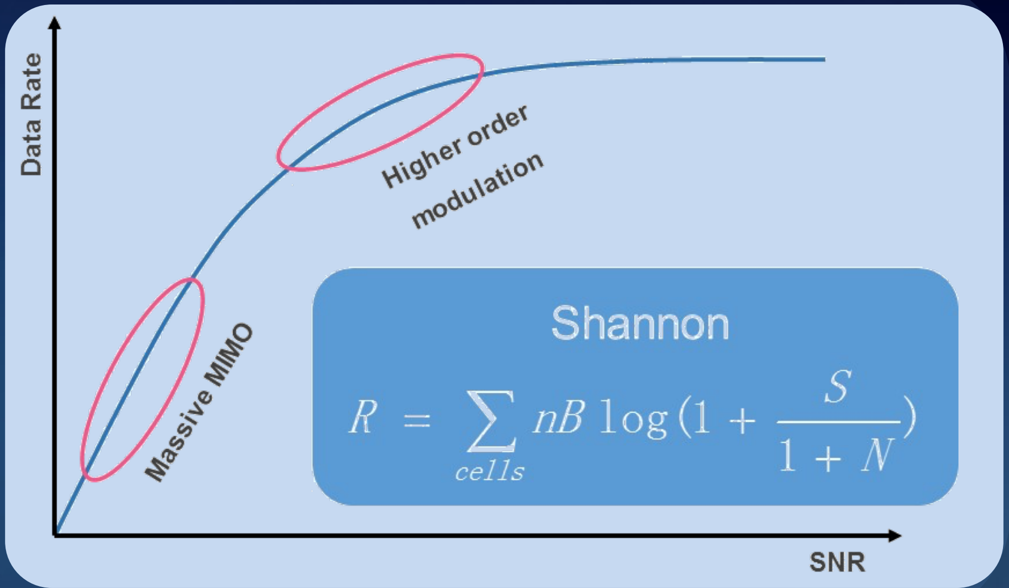
Number of logical transmitters **Number of receivers**

m x n

Output: Y

$[y_1, y_2, ..y_n]^T$

$$H = \begin{bmatrix} h_{11} & \cdots & h_{1m} \\ \vdots & \ddots & \vdots \\ h_{nn} & \cdots & h_{nm} \end{bmatrix}$$

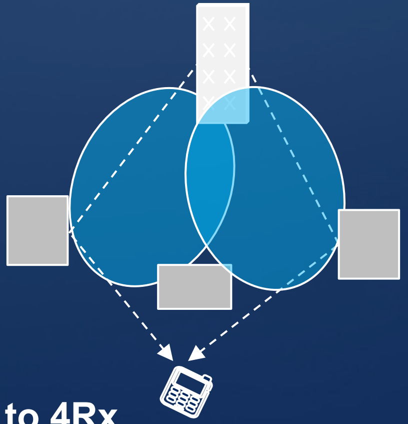


Single-User MIMO

2Rx Smartphones: 2x2 MIMO
2Rx CPEs: 2x2 MIMO
Up to 2 layers MIMO

4Rx CPEs: 4x4 MIMO
Up to 4 layers MIMO

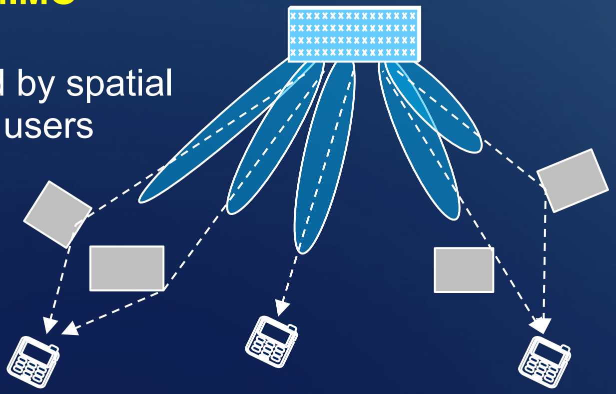
Limited by UE antennas: 2Rx to 4Rx



Massive MIMO / Multi-User MIMO

MIMO Performance is boosted by spatial multiplexing between different users

Up to 16 layers of MU-MIMO with beamforming (MU-BF)



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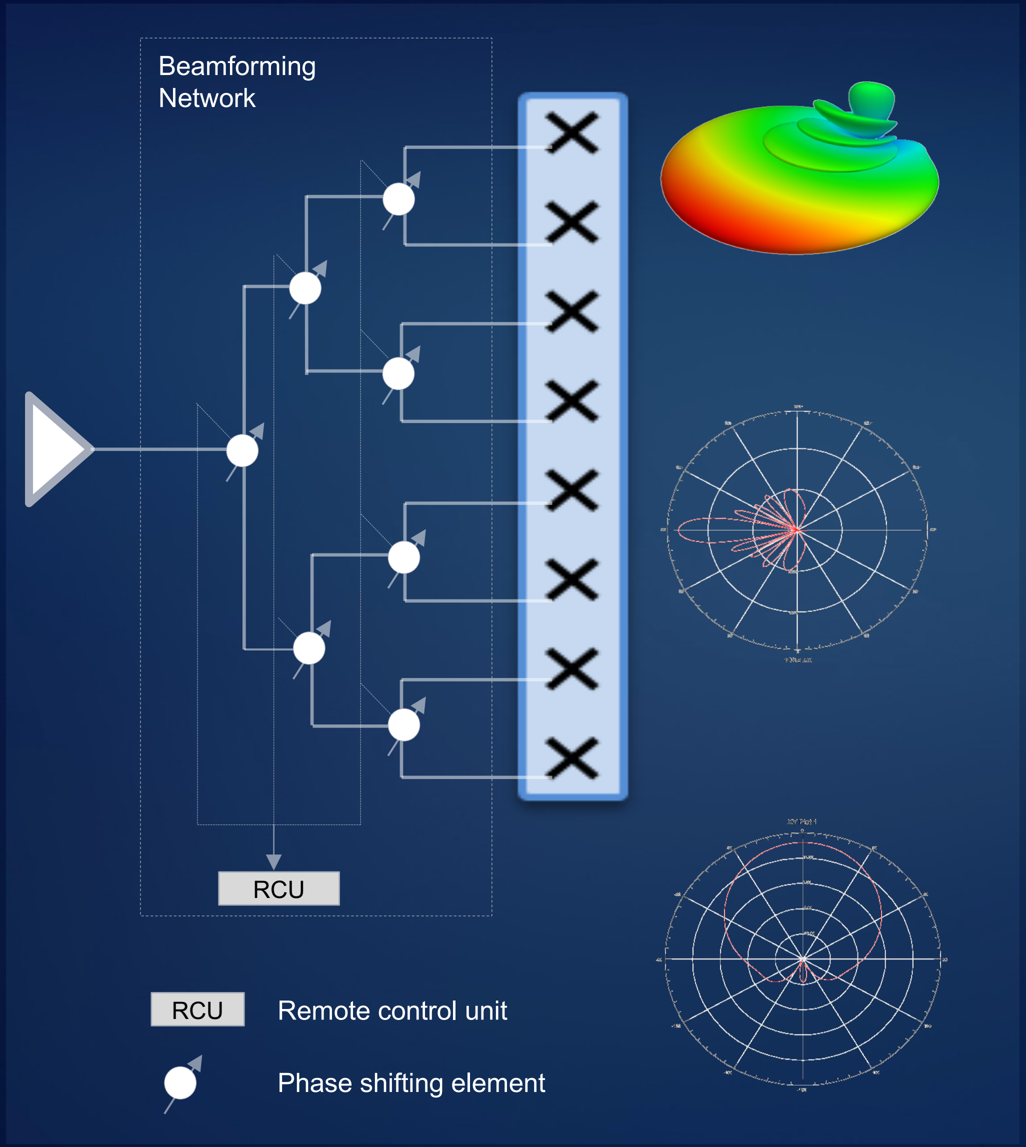
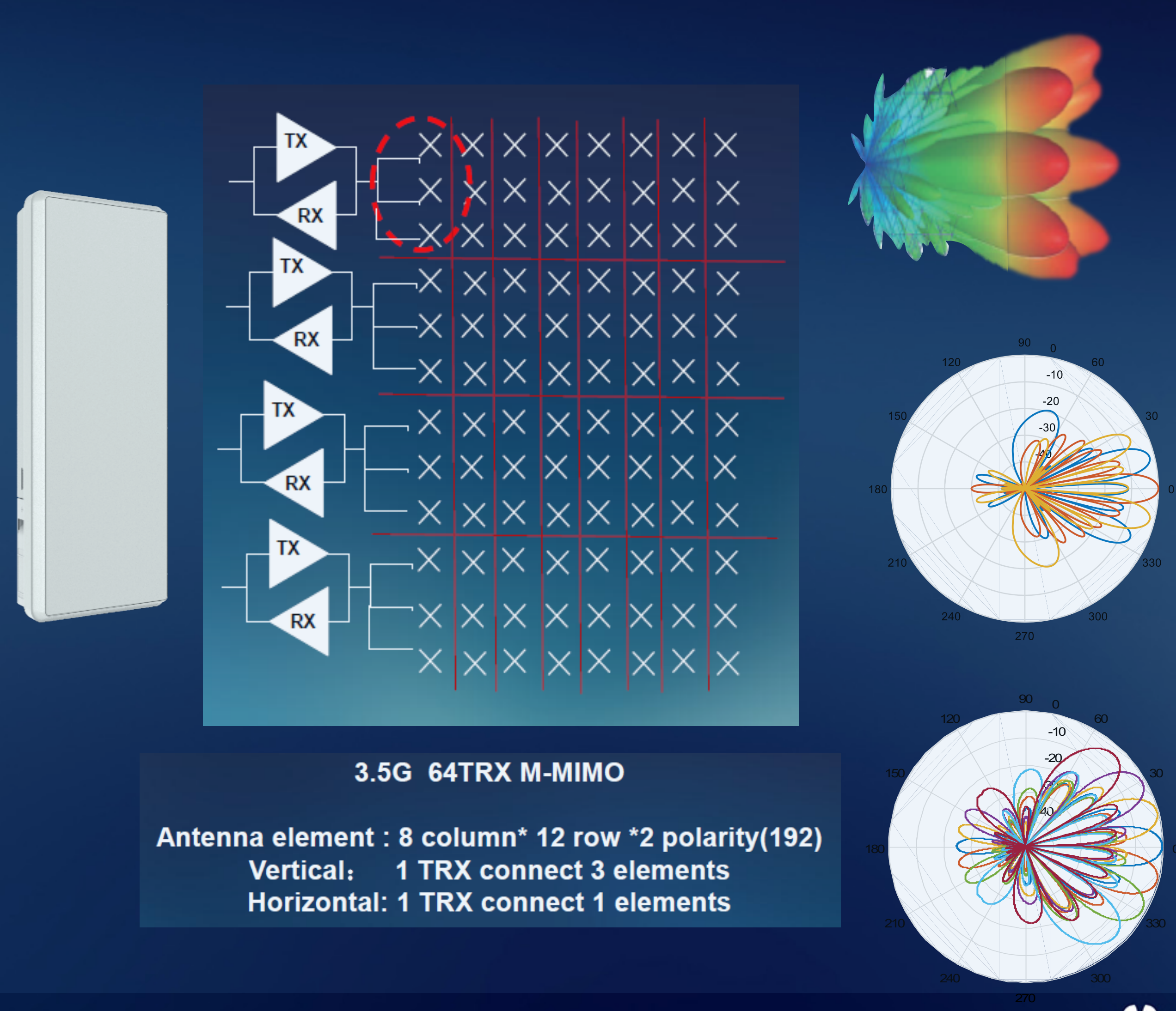
Classical antenna



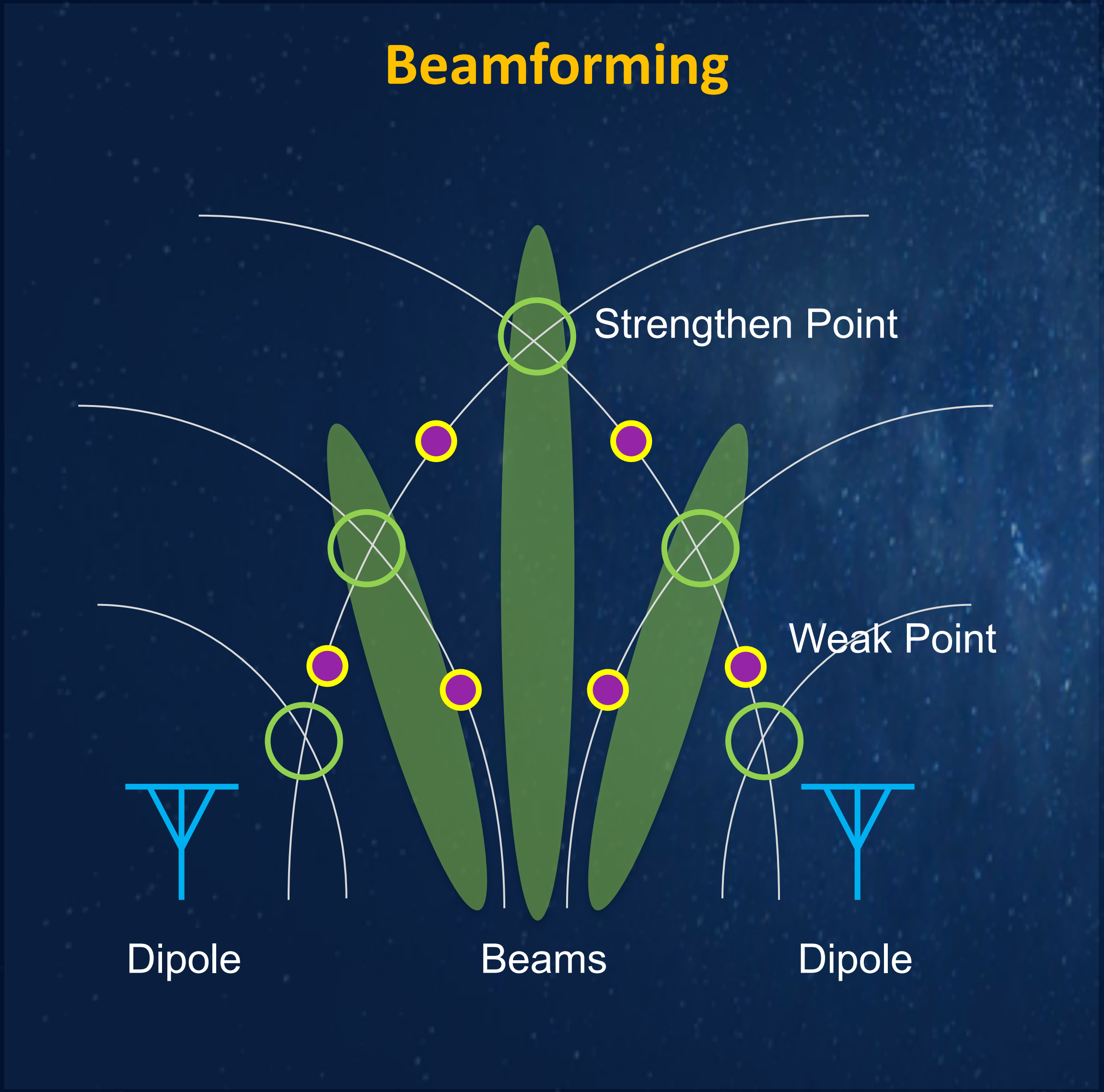
MassiveMIMO antenna

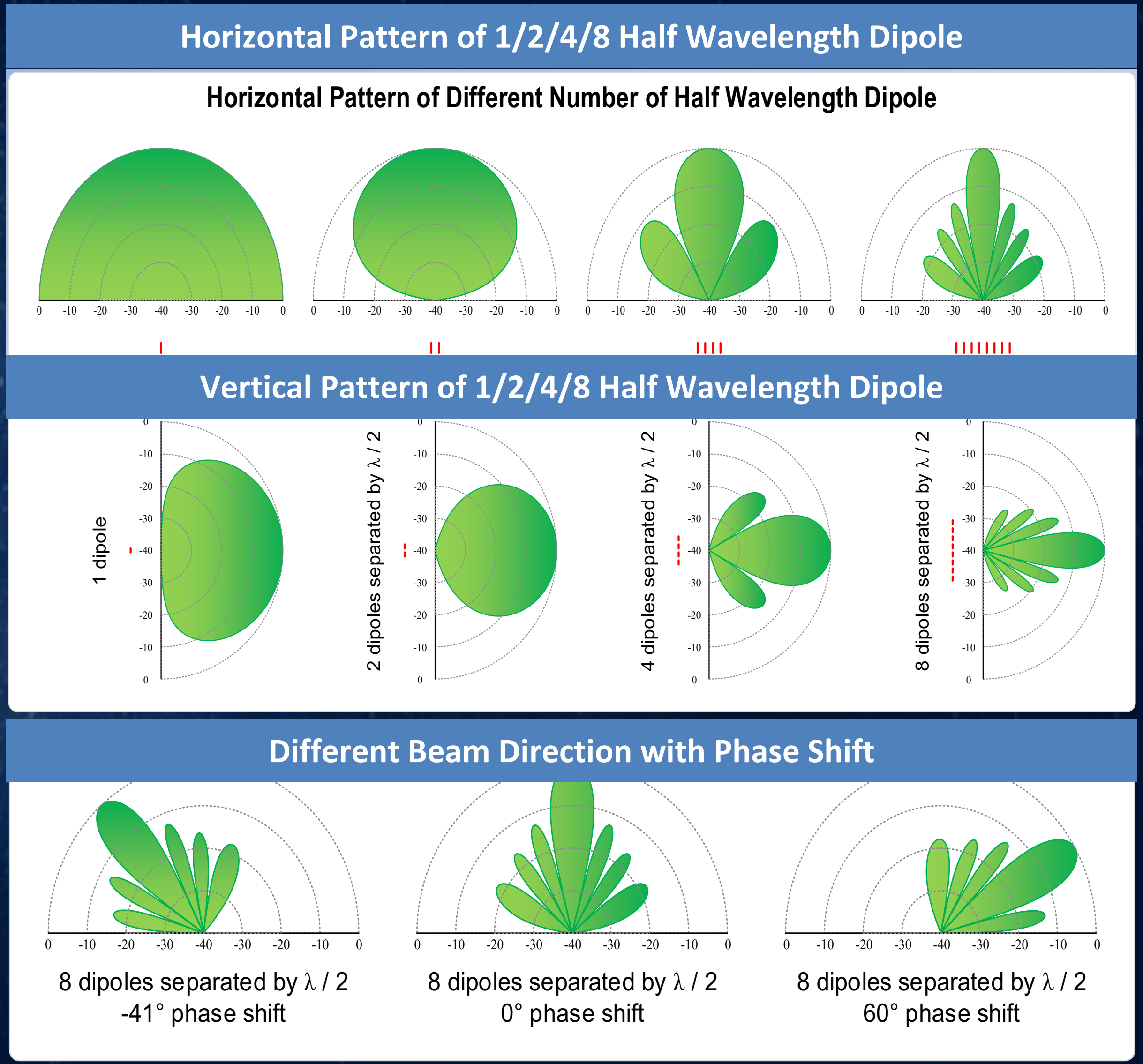


3.5G 64TRX M-MIMO

Antenna element : 8 column* 12 row *2 polarity(192)
Vertical: 1 TRX connect 3 elements
Horizontal: 1 TRX connect 1 elements

Beamforming Made Possible with Massive MIMO





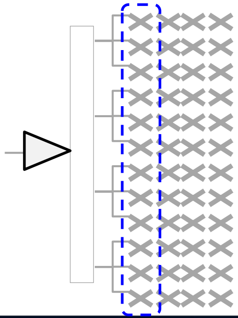
The Architecture Choice of Massive MIMO

8TRX

- Antenna array：

4x12/8H1V

- One array with **12** Elements
- Phase Shifter

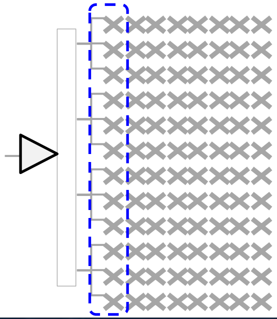


16TRX

- Antenna array：

8x12/16H1V

- One array with **12** Elements
- Phase Shifter

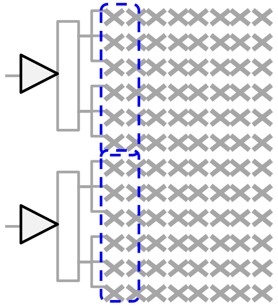


32TRX (**3D-MIMO**)

- Antenna array：

8x12/16H2V

- One array with **6** Elements
- Phase Shifter

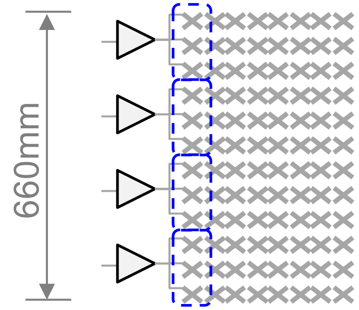


64TRX (**3D-MIMO**)

- Antenna array：

8x12/16H4V

- One array with **3** Elements
- Phase Shifter No

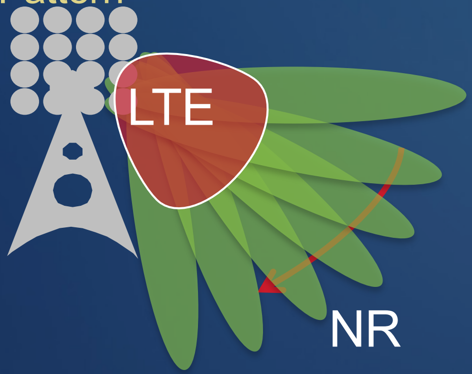


Horizontal: 8T 8H vs. 16T/32T/64T 16H

3D Vertical: 32T 2V vs. 64T 4V

Variety Patterns Group According to Coverage Scenario

16 Typical Beam Patterns Supported



Pattern	Horizontal HPBW	Vertical HPBW	Tilt	Azimuth
Default	105	6	-2~9	0
1	110	6	-2~9	0
2	90	6	-2~9	-10~10
3	65	6	-2~9	-22~22
4	45	6	-2~9	-32~32
5	25	6	-2~9	-42~42
6	110	12	0~6	0
7	90	12	0~6	-10~10
8	65	12	0~6	-22~22
9	45	12	0~6	-32~32
10	25	12	0~6	-42~42
11	15	12	0~6	-47~47
12	110	25	-	0
13	65	25	-	-22~22
14	45	25	-	-32~32
15	25	25	-	-42~42
16	15	25	-	-47~47
17	-	-	UserDef	UserDef

**based on 3.5G 64T64R MM*

Scenario-based Beam Adaptation

Wide Horizontal & further coverage

Narrow vertical beam for further coverage and less interference

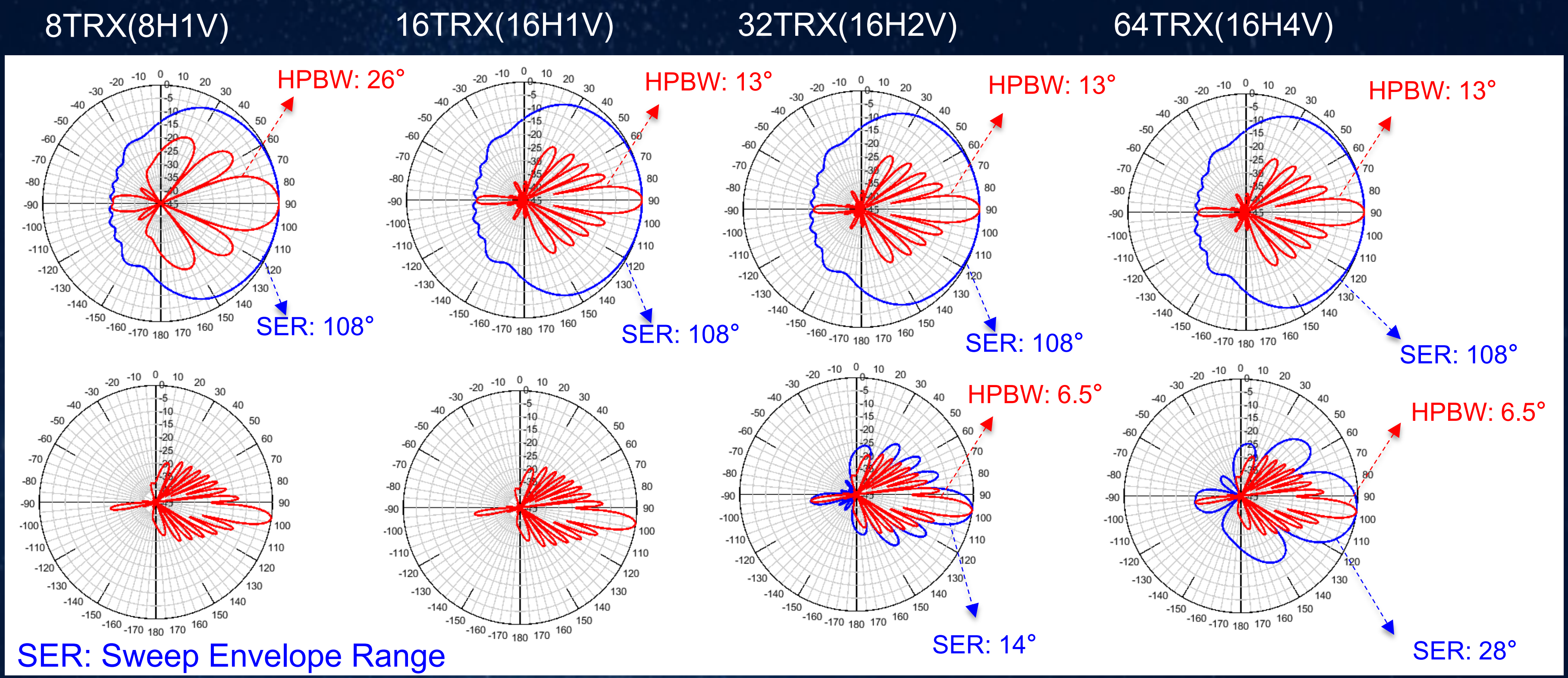
2 Horizontal layer beams for Square + building

4 Vertical Beams for high building coverage

Data Channel Beamforming Pattern and Sweeping Range

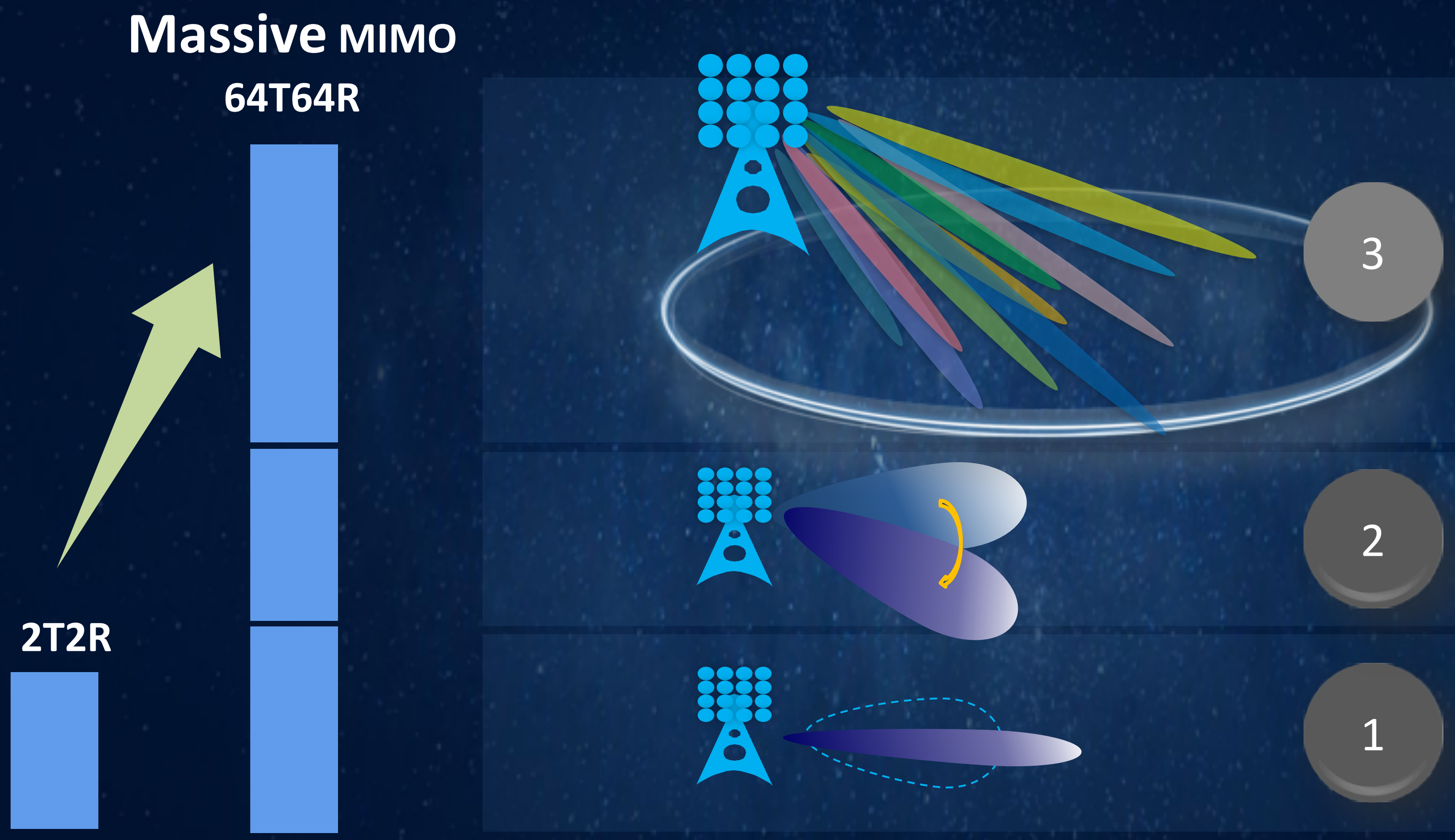
Horizontal Beam

Vertical Beam



	8H1V 0.5λ	16H1V 0.5λ	16H2V 0.5λ (AAU5313)	16H4V 0.5λ (AAU5613)
Array Gain (dBi)	20	23	23.5	24
PDSCH Beam Horizontal HPBW	26°	13°	13°	13°
PDSCH Beam Vertical HPBW	6.5°	6.5°	6.5°	6.5°
Horizontal Beam Sweeping Range (@3dB)	-54°~ 54°(108°)	-54°~ 54°(108°)	-54°~ 54°(108°)	-54°~ 54°(108°)
Vertical Beam Sweeping Range (@3dB)	NA	NA	-7°~7°(14°)	-14°~14°(28°)

Massive MIMO Increases Spectrum Efficiency



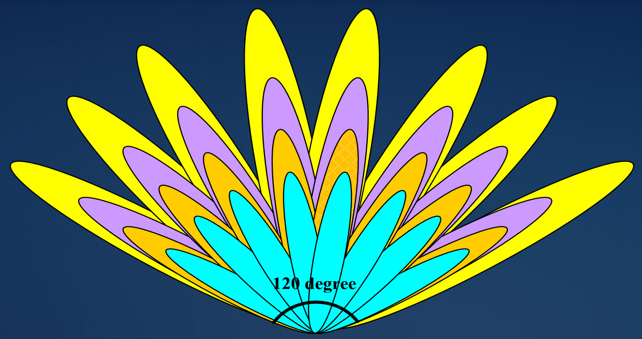
- Multi-user beamforming
- Multiple streams
- ~10x capacity gain (NR 64TRX vs. LTE 2TRX)

- Vertical beamforming
- SINR gain (up to 20dB)

- Horizontal beamforming
- SINR gain (up to 9dB)

Native Massive MIMO User Plane

1. Horizontal plane : 8*2 Polarization



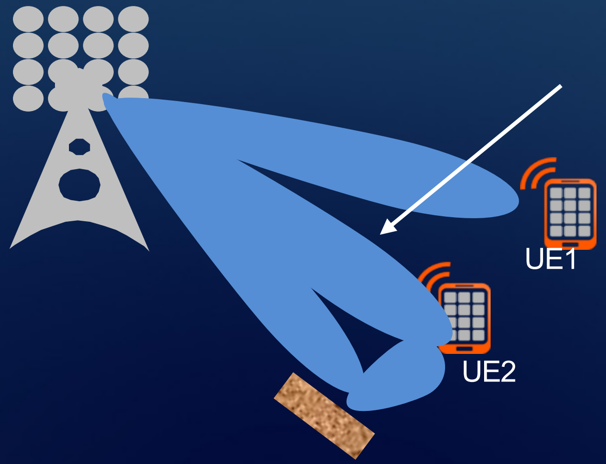
2. Vertical plane: 4 beams

Receives SRS on different beams

- Calculate channel estimation information for UE1 and for UE2

Calculate antenna weights for DL

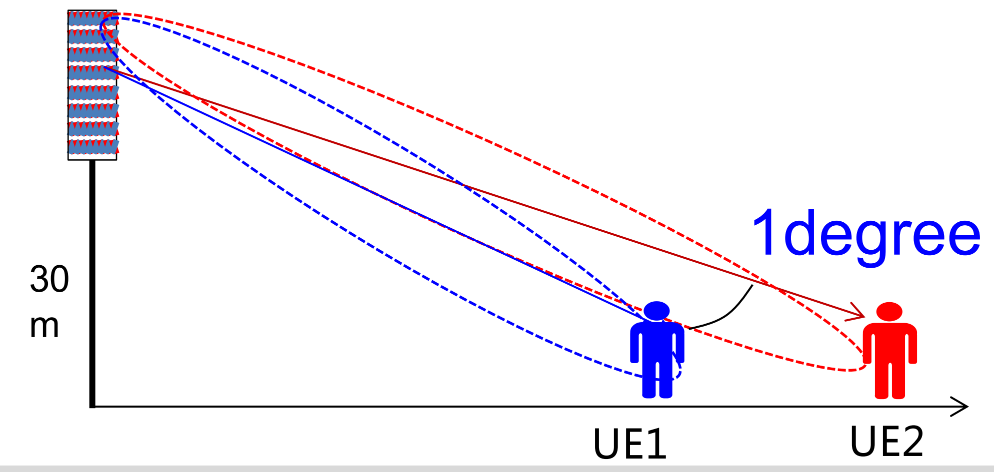
- Based on highest spectrum efficiency
- Pair best users to get orthogonality
- Perform zero forcing to reduce interference



Finding the best combination of users and optimize beam and performe zero forcing in order to maximize spectrum efficiency

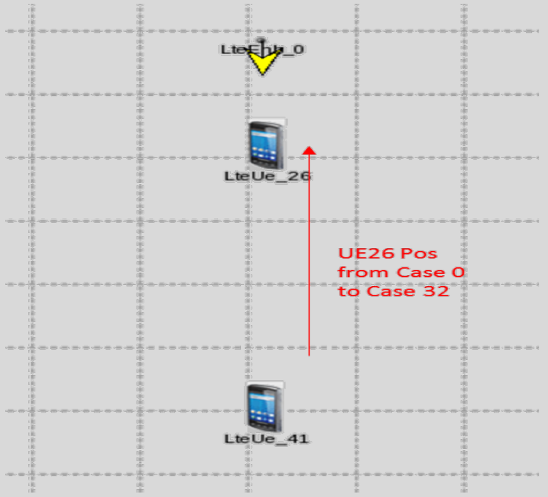
64% Area Can be Matched by Vertical Degrees @ Ground Scenario

Principle Of Vertical CSI Accuracy For Paired UE

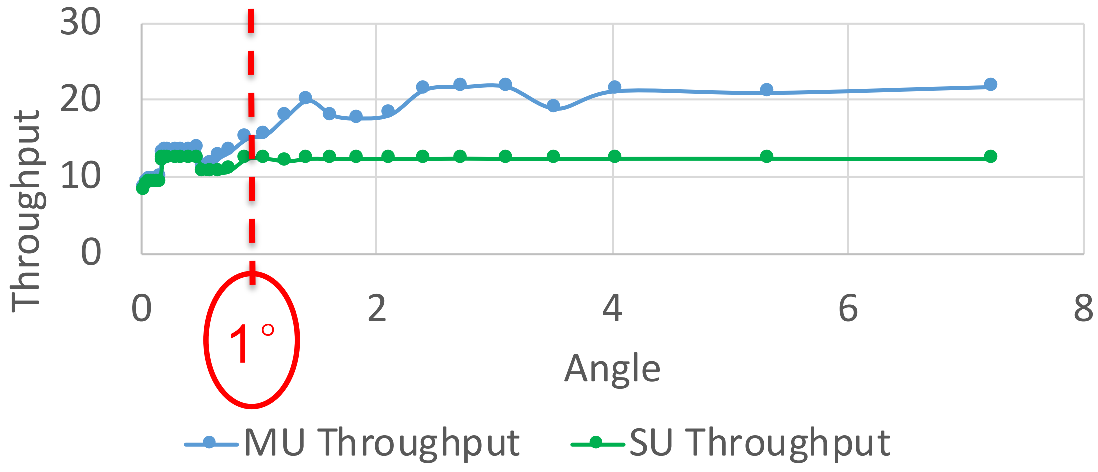


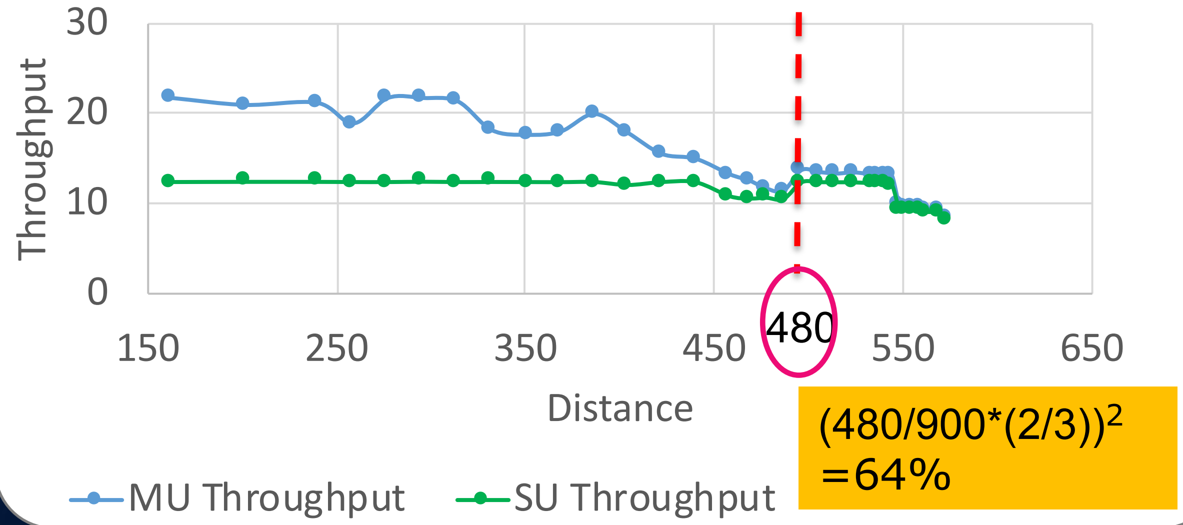
Simulation Assumptions

- 4TRX 2H2V
- UE:1T4R
- Single Cell
- Vertical 2 UE in different position with different tilt difference
- 2Ue in SU MIMO or MU MIMO
- 3GPP 3D UMA
- ISD=900m (600m from site to UE)



Simulation Result

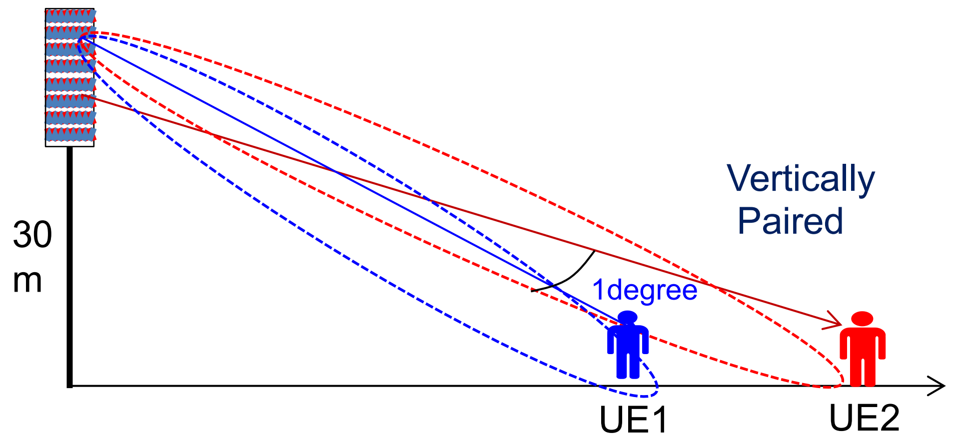




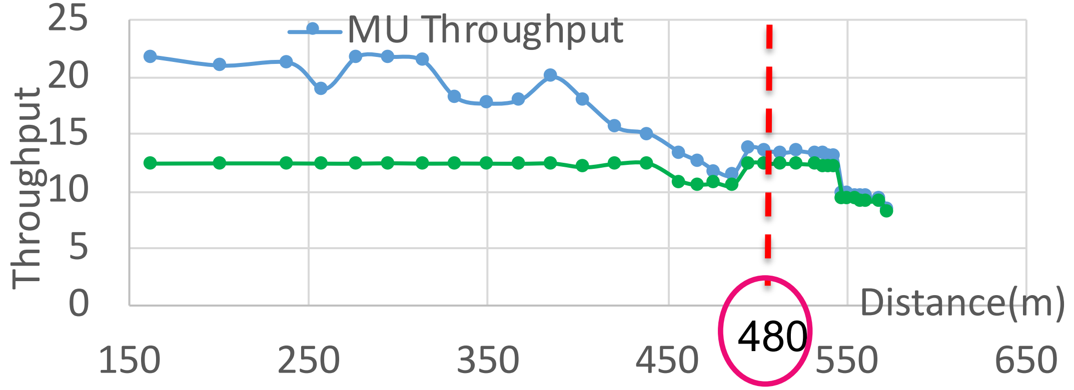
For 900M ISD, Vertical TRX Can Provide Vertical UE Paired in >64% Cell Area

Capacity Gain by 3D MIMO Vertical Beamforming

3D MIMO **Vertical Beam result in more Paired UEs**

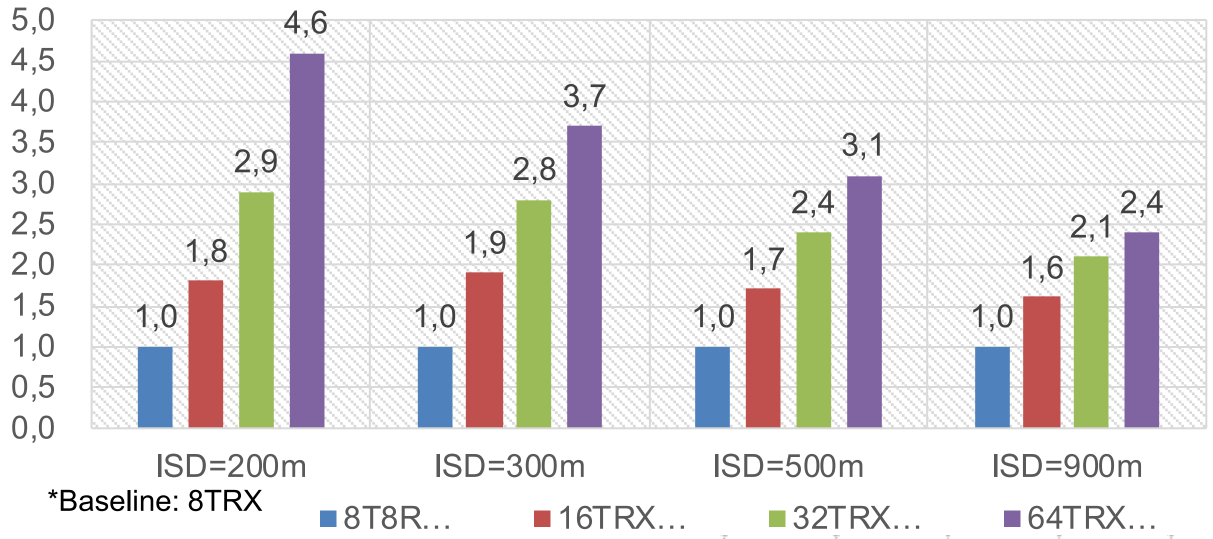


64% Cell Area can achieve MU gain in **900m ISD**



$(480/(900*(2/3)))^2=64\%$

Cell Capacity Gain @ Different ISD



Simulation Assumptions

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- 2 UE in different position with different tilt difference
- 3GPP 3D UMA
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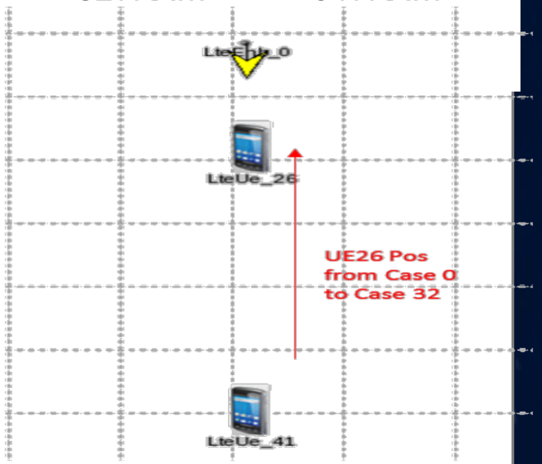
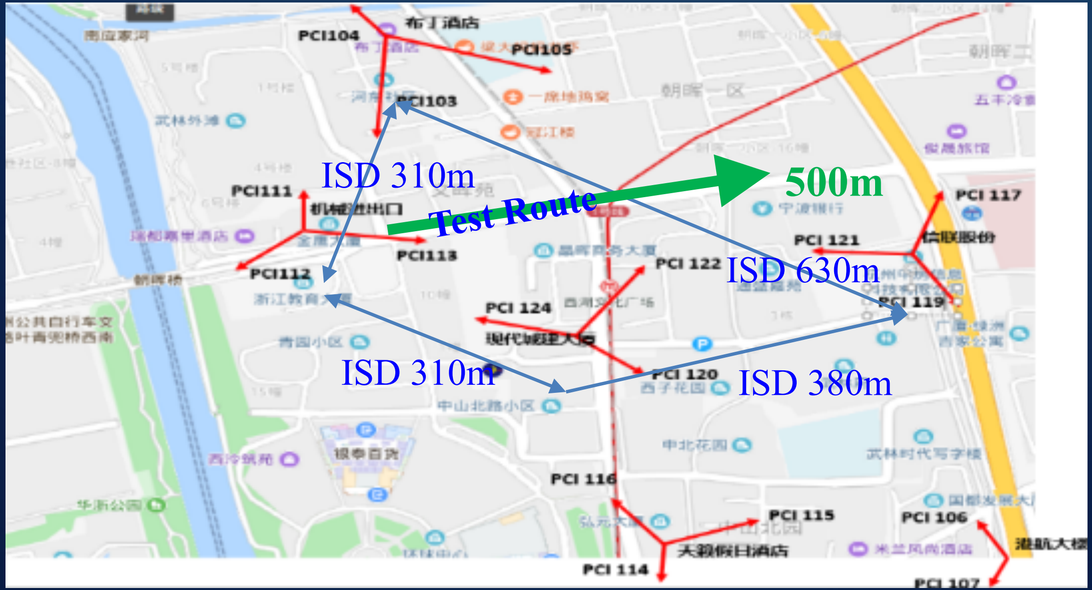


The absolute value of the gain is different with different simulation assumptions

China Hangzhou City Field Trial

Field trial scenario: dense urban

- field area: dense urban 2Km²
- average ISD 300m, 7 Sites, 18 Cells

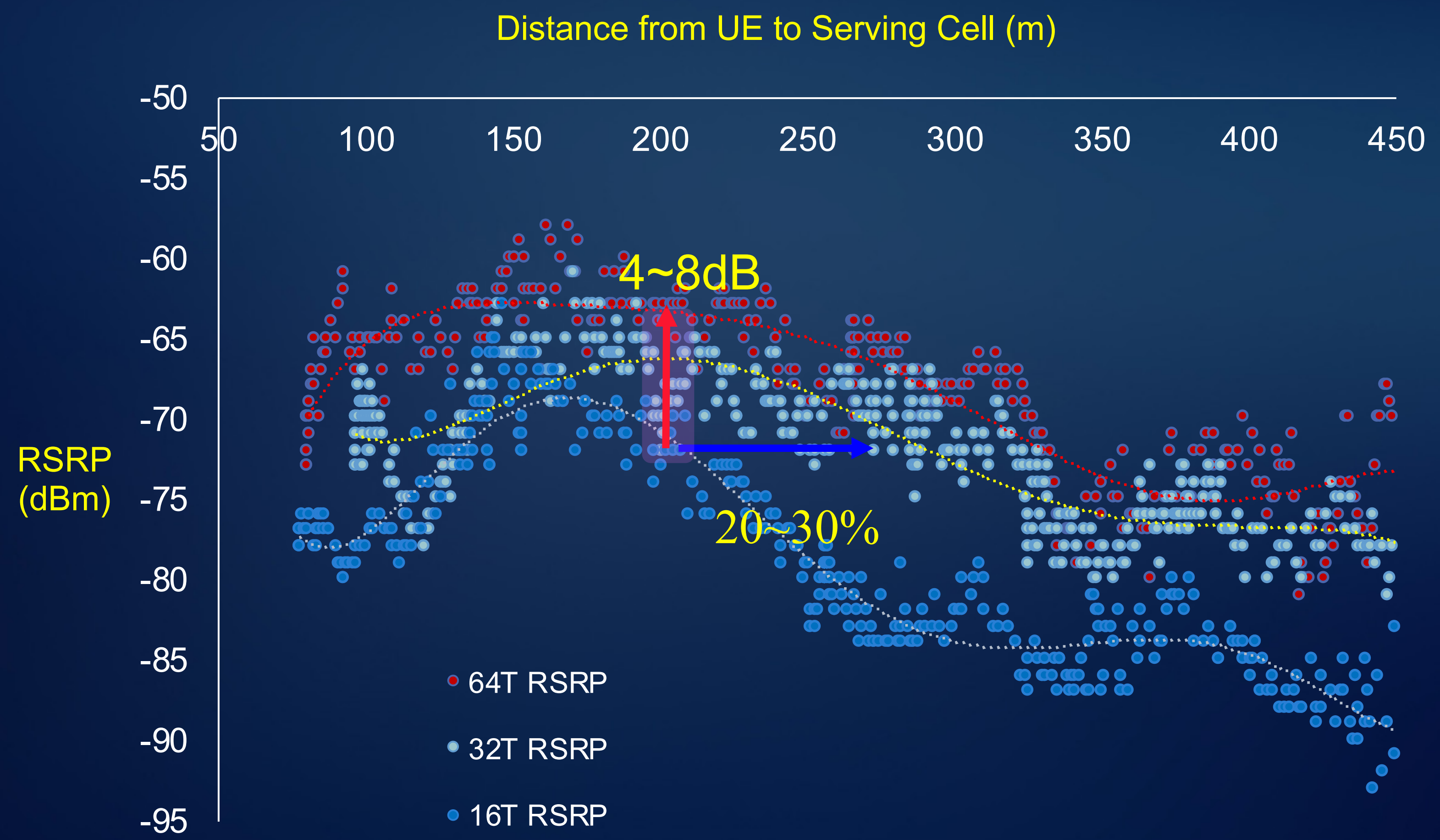


- 32T32R and 16T16R are equivalent modeled by 64T64R
- Considering loss caused by line and phase shifter, 2dB TX power backoff for 16T16R, 1dB power backoff for 32T32R

System Parameter	64T	32T	16T
NR frequency	3.5GHz	3.5GHz	3.5GHz
System Architecture	NSA	NSA	NSA
Bandwidth	100MHz	100MHz	100MHz
Subcarrier Space	30KHz	30KHz	30KHz
Frame Structure	DDDSU (2.5ms)	DDDSU (2.5ms)	DDDSU (2.5ms)
Special Slot Ratio	D:G:U=10:2:2	D:G:U=10:2:2	D:G:U=10:2:2
gNodeB TX Power	53dBm	52dBm	51dBm
AAU TRX Config.	64T64R	32T32R*	16T16R*
UE Antenna	2T4R	2T4R	2T4R
UE TX Power	26dBm	25dBm	24dBm
Traffic Type	Full Buffer	Full Buffer	Full Buffer

O2O scenario: 64T provide 30% cell radius Improvement

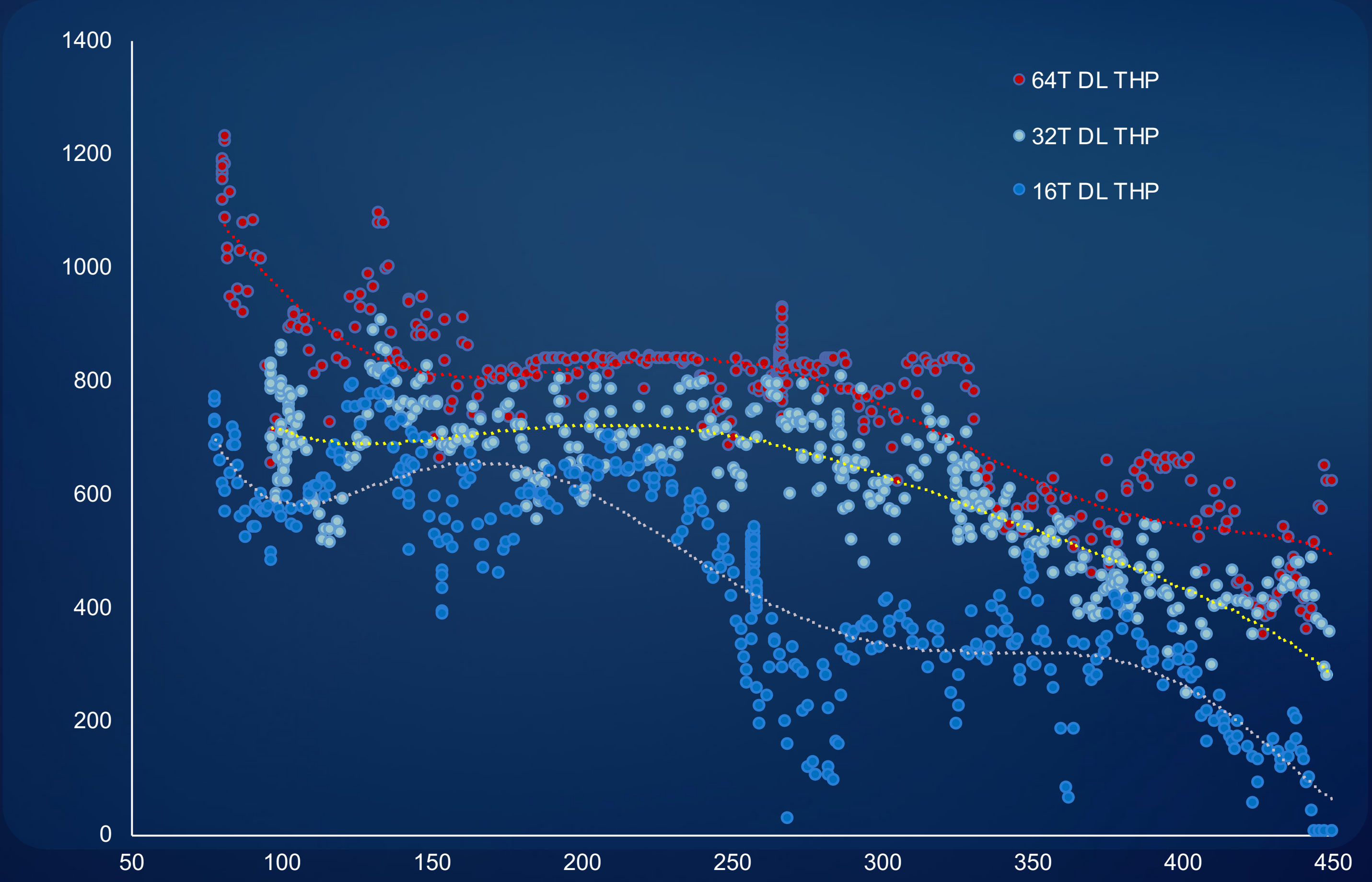
Huawei and Operator M do field test by cooperation in Hangzhou, December of 2018
Neighboring cells 50% loaded, and UE follow test route by walking speed in serving cell



- **32T vs. 16T**
  - 4.1dB gain for cell edge RSRP
  - 3.4dB gain for cell average RSRP
  - ~20% cell radius improvement
- **64T vs. 16T**
  - 8.3dB gain for cell edge RSRP
  - 8.1dB gain for cell average RSRP
  - ~30% cell radius improvement

O2O scenario: 64T provide 36% DL THP improvement

More TRX, Precise Beam, Better Interference Rejection, Better User Experience



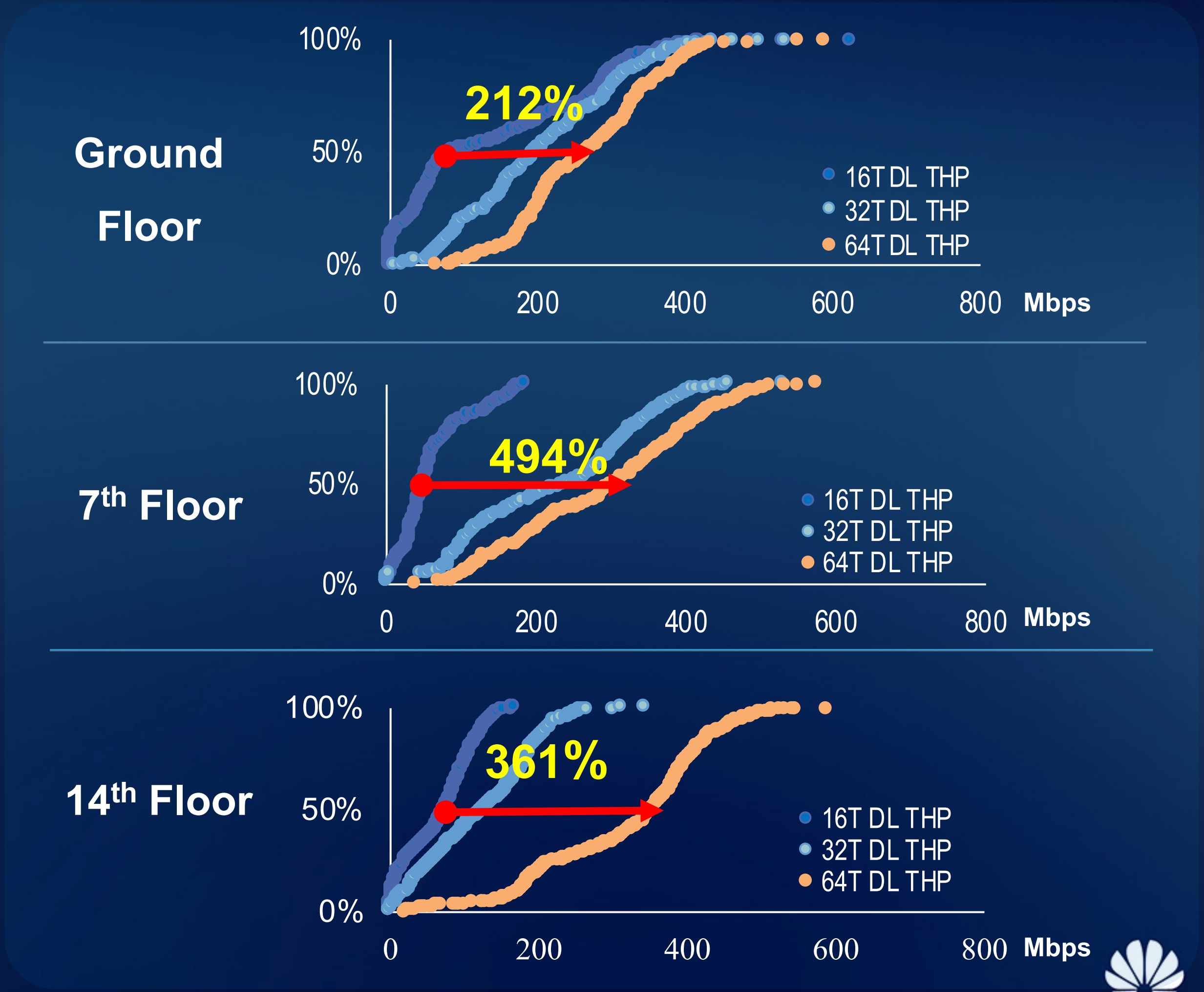
- 32T vs. 16T :
  - 9% cell edge gain
  - **14%** cell average gain
- 64T vs. 16T :
  - 28% cell edge gain
  - **36%** cell average gain

- 50% load interference
- Test Route is mainly LOS street and many test points near rank2 peak THP, which is beneficial for 16T.

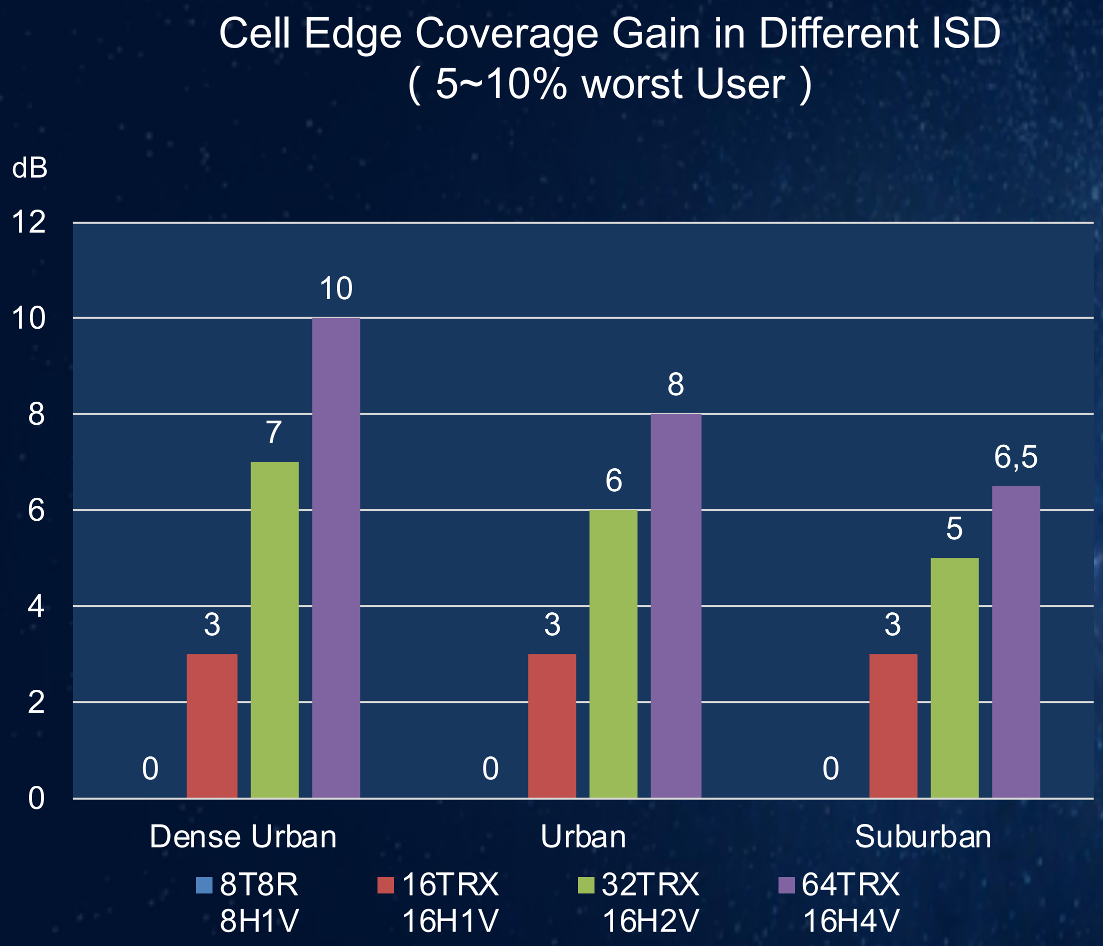
O2I scenario: 64T/32T with 3D coverage improve indoor user experience

CBD Building: 28 floors, 110m

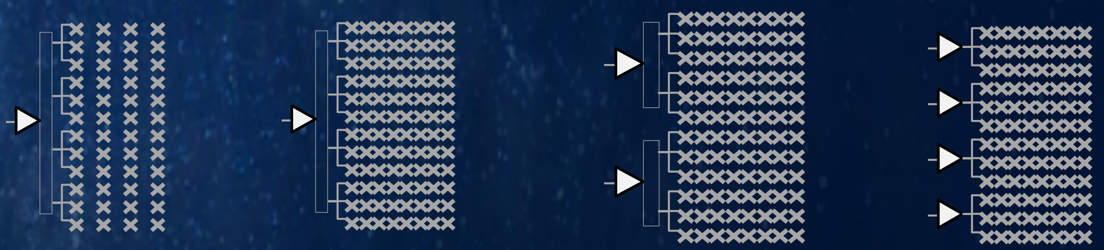
64T/32T with more vertical beams, improve DL THP



Massive MIMO Coverage



- "cell edge user" includes not only far point by geographic, but also the near-middle point located deep indoor or deep fading.
- MaMIMO with high vertical BF freedom will improve the near-middle point deep coverage.



Dense Urban: ISD=200m; Building:15~30 floors
Urban: ISD=500m; Building:4-8 floors
Suburban: ISD=900m Building:2-5 floors;

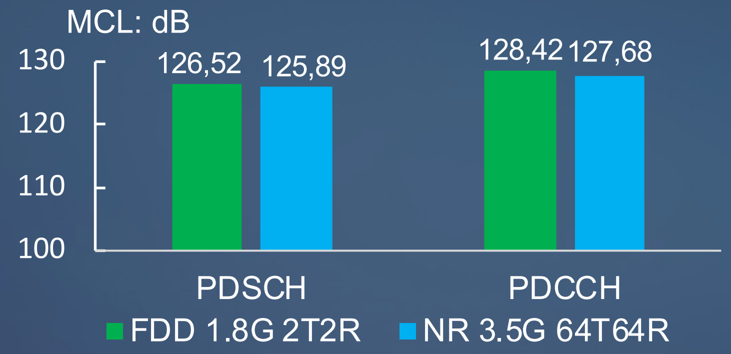
- 64TRX MMIMO has better coverage.
- Coverage of 16TRX is 3dB worse than 32TRX in urban and suburban scenario

Massive MIMO on C-Band Achieves Similar Coverage of LTE DL 1.8GHz

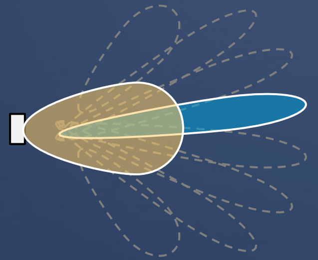
Similar Coverage with LTE

3.5GHz 64T vs 1.8GHz 2T

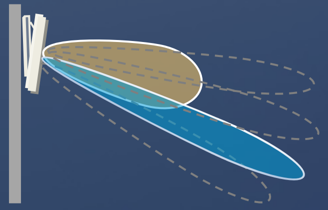
C-Band Tx Power 200W



Horizontal Beamforming

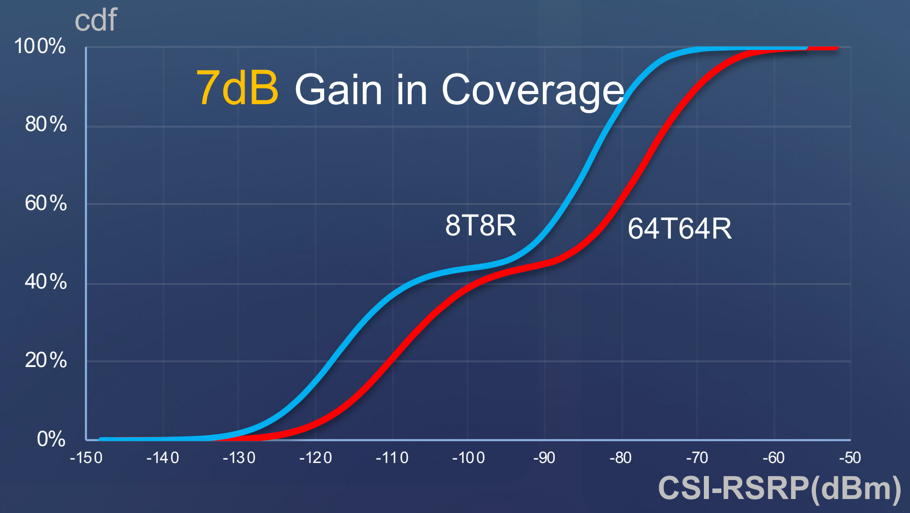


Vertical Beamforming



64T is the Best Choice for Both Capacity and Coverage

64T64R Saves Large Amount of Sites vs 8T8R



AAU Innovation in All Aspects

192Array Elements

2dB Antenna Gain ↑
20% Less Site ↓

Ceramic Filter

64T Weight 40Kg->**35Kg** ↓
64T Volume **-11%** ↓

GaN Amplifier

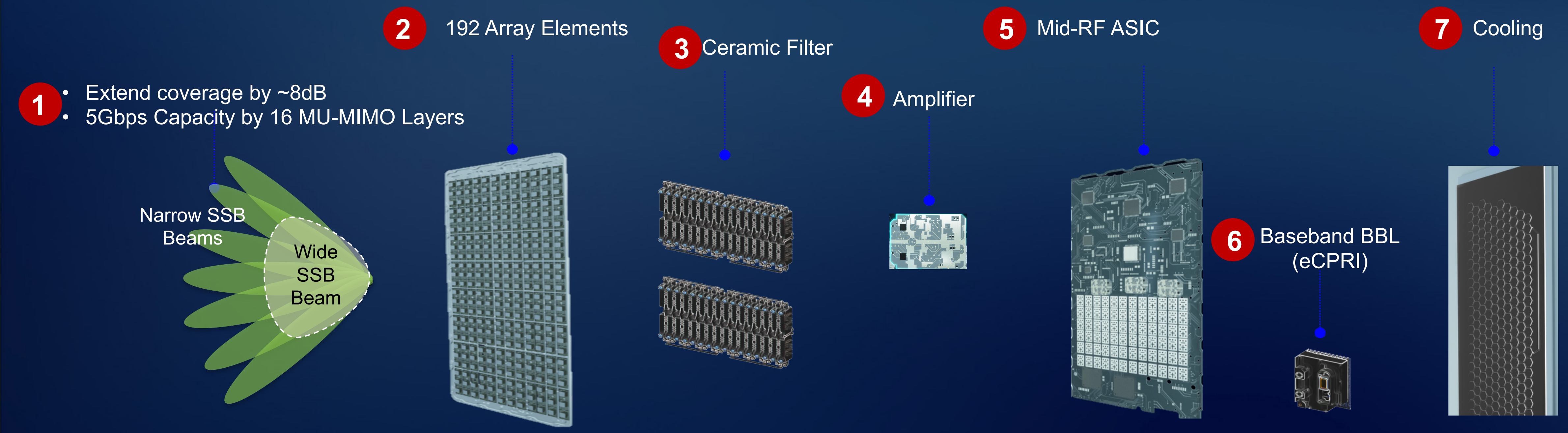
Power Efficiency**10%** ↑
Energy Saving**-20%**↓

7nm Chipset

Wideband (**200M**)
Better Performance

CLC Heat Dissipation

Cooling Efficiency **30%** ↑
Weight and Size:10-15% ↓



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