5G SAR and mmW Phase Array Antenna Design Challenges

Auden Techno Corp.

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Wireless Total Solution Provider

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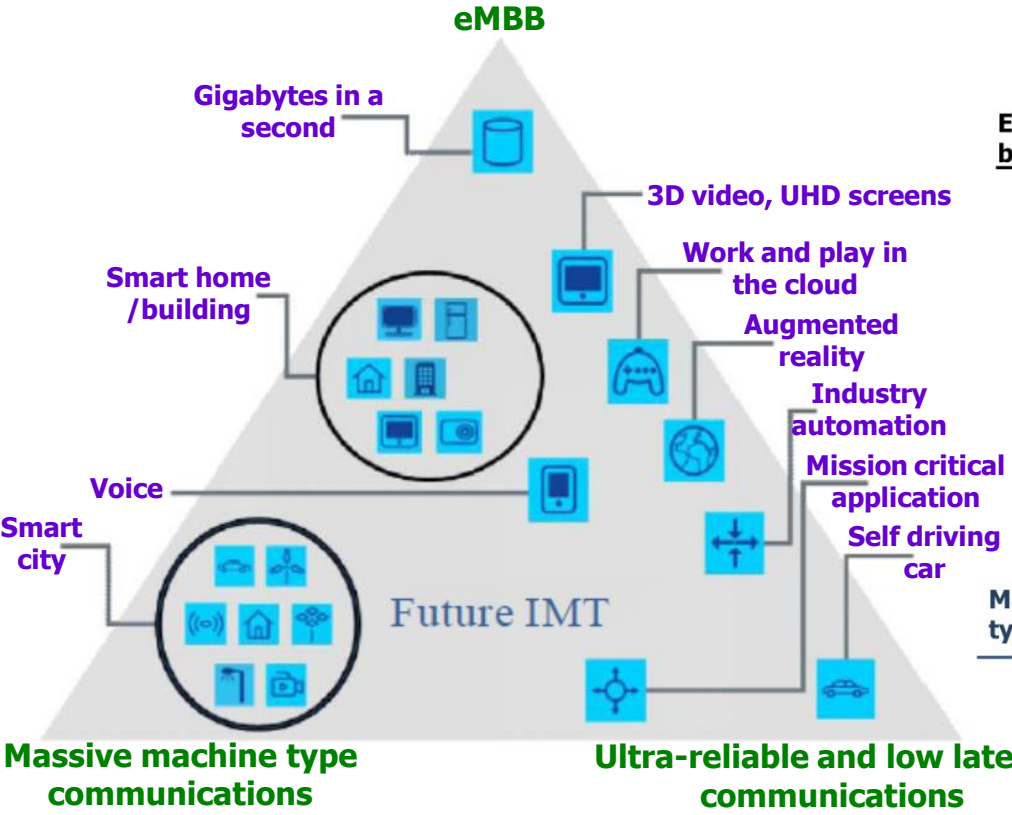
OUTLINE

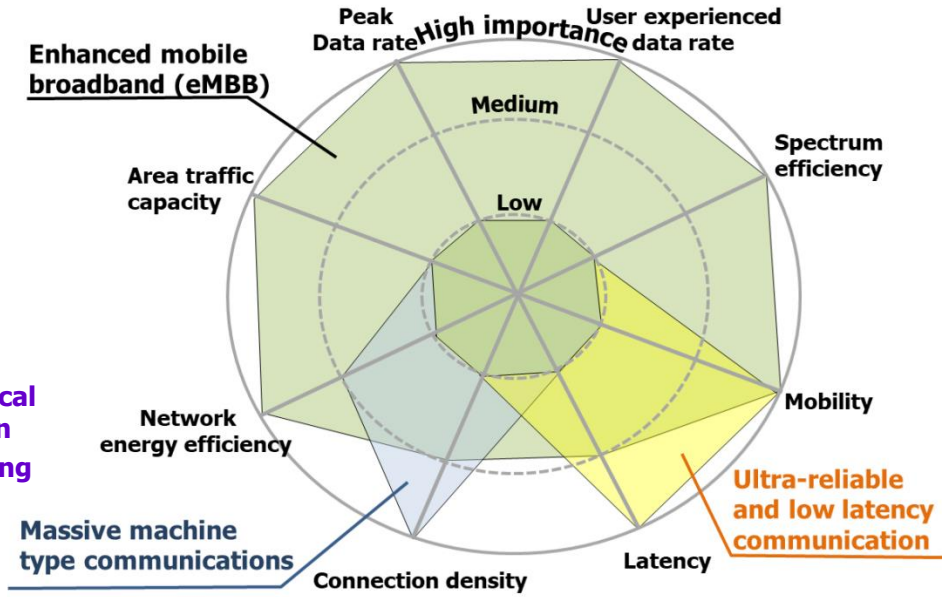
- Introductions
- Design challenge for mmWave antenna array
- Product and development roadmap
- Geometry and general spec. of the array module
- Usage scenario for mmWave AAAM
  - Short range
  - Middle range
  - Long range
- Simulation results for 28G 8x8 AAAM
- Dual band 1x4 array for UE application
- 5G mmWave SAR test equipment (DASY6)

Introductions (1/4)

- Three applications of 5G selected in ITU-R: eMBB, Massive MTC (IoT), Ultra-Reliable LLC
- Key capabilities to realize eMBB: >10Gbps peak user rate, >1000x system rate, energy efficiency
- Indispensible technology to realize eMBB: mmWave



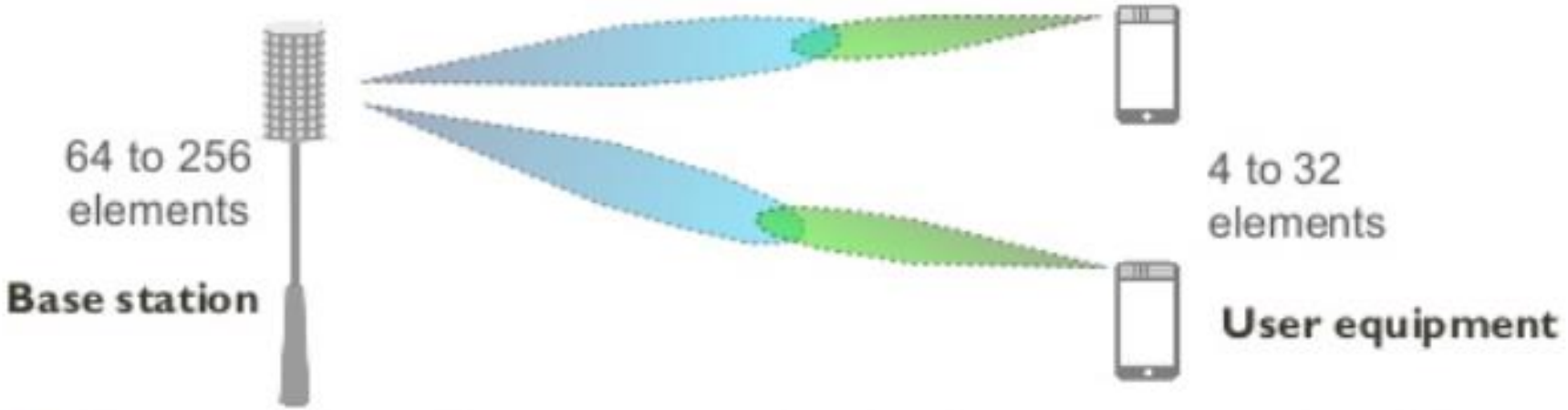
3 Key Use Cases of 5G



The importance of key capabilities in different usage scenarios

Introductions (2/4)

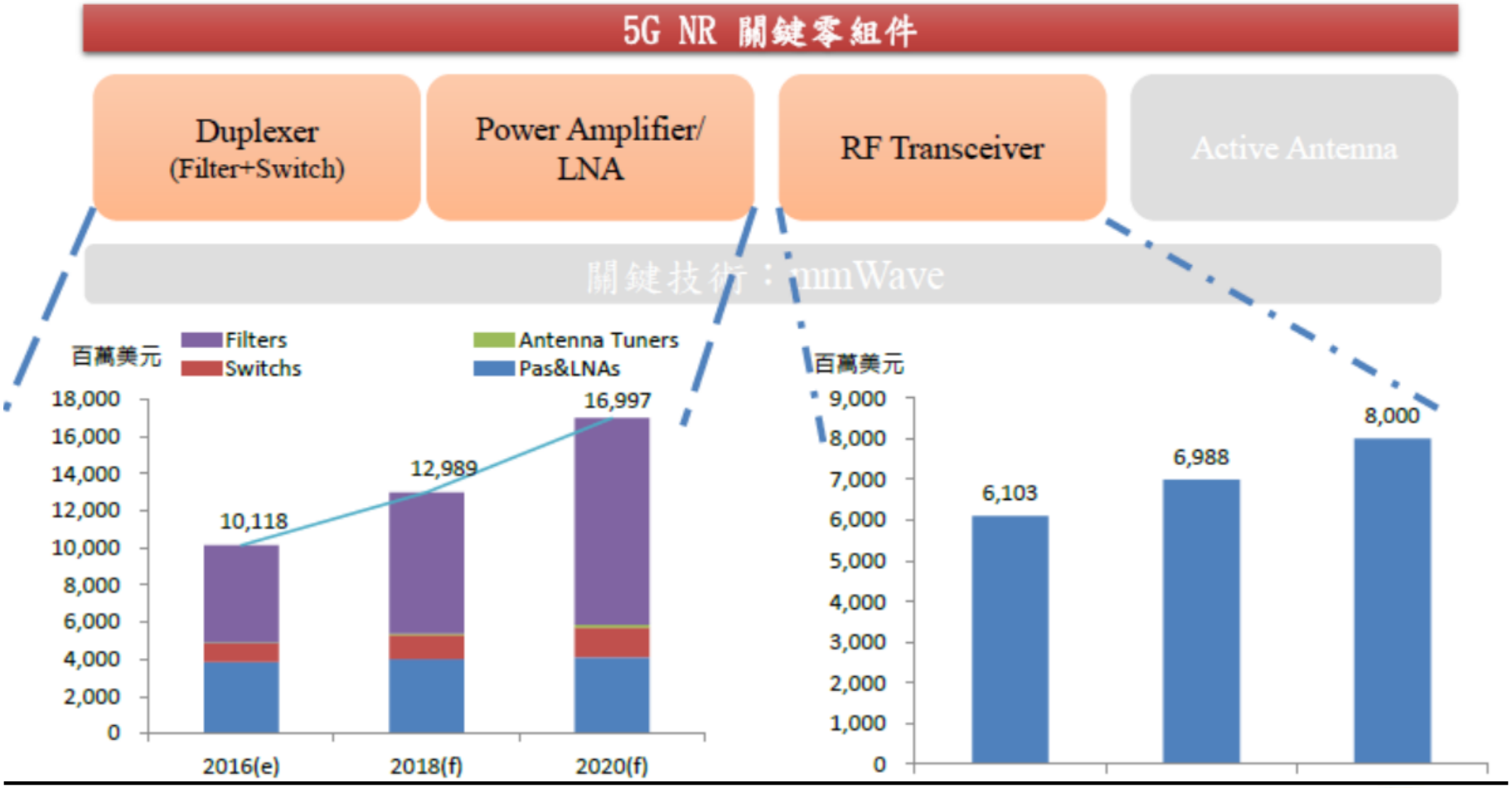
- **There will be 4 to 6 antenna array sectors used in one base station or small cell**



- Large number of antennas used at the base station and mobile station
  - Antennas will be small -> no form factor challenges at the base station
- Directionality of the patterns changes many aspects of system design
  - Physical layer signal processing
  - Mobility management (e.g. initial access and handoff)
  - Interference management

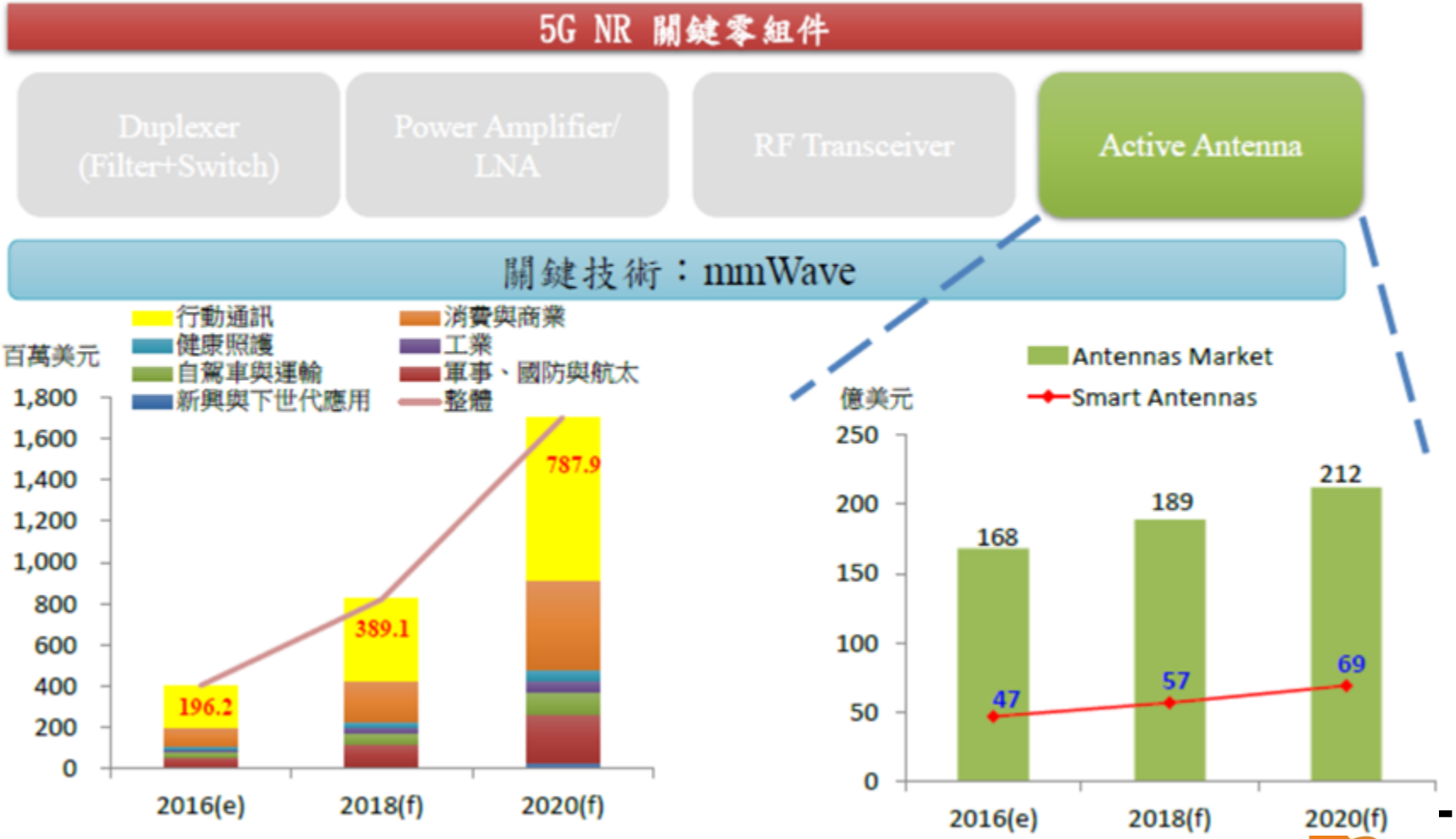
Introductions (3/4)

- 第一波： 5G NR關鍵零組件: RF Transceiver, Power Amplifier/LNA, Duplexer, Smart Antennas, mmWave等組件



Introductions (4/4)

• 第一波： 5G NR關鍵零組件: RF Transceiver, Power Amplifier/LNA, Duplexer, Smart Antennas, mmWave等組件

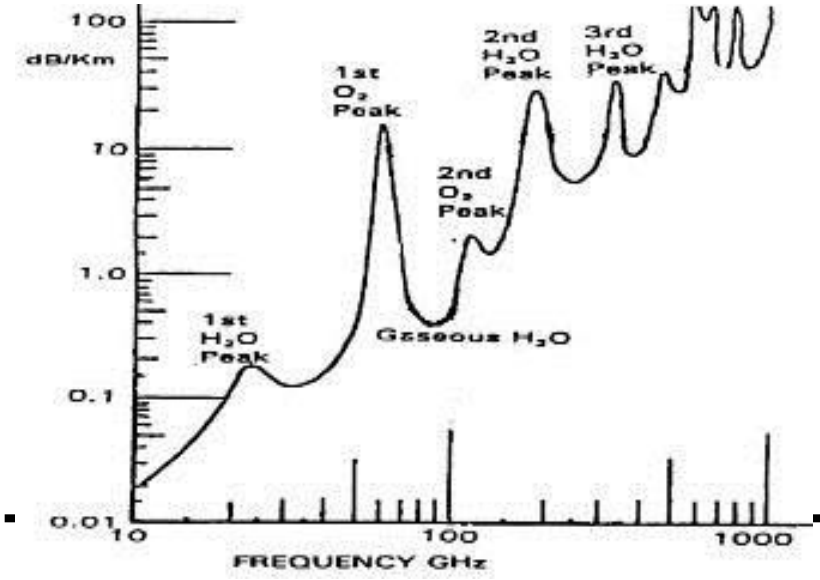


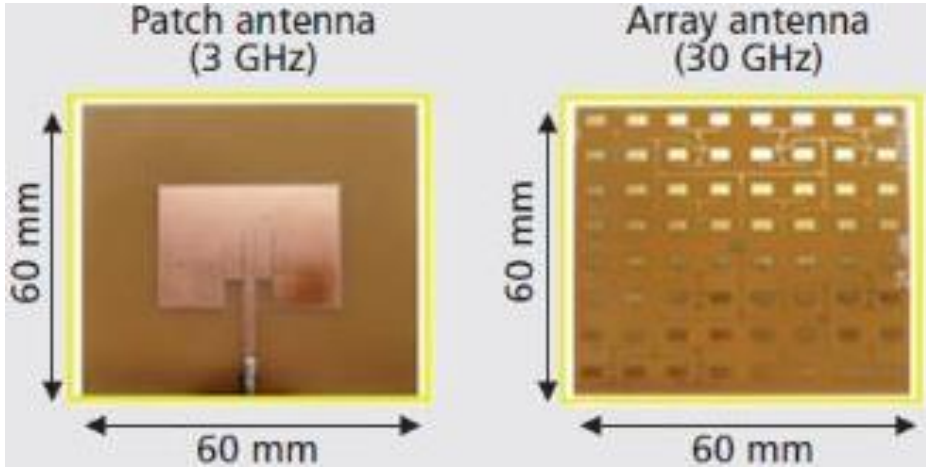
mmWave antenna design challenge (1/8)

Challenges

- Blockage and unknown mmWave channel characteristics
- mmWave antenna array design
- Device modeling and design flow
- mmWave calibration for Massive MIMO and antenna array
- Beamforming and beam-tracking algorithm
- mmWave IC technologies

High path loss due to antenna aperture size and atmospheric absorption

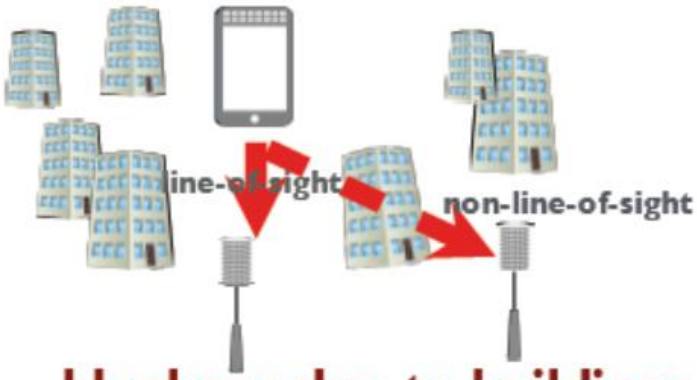




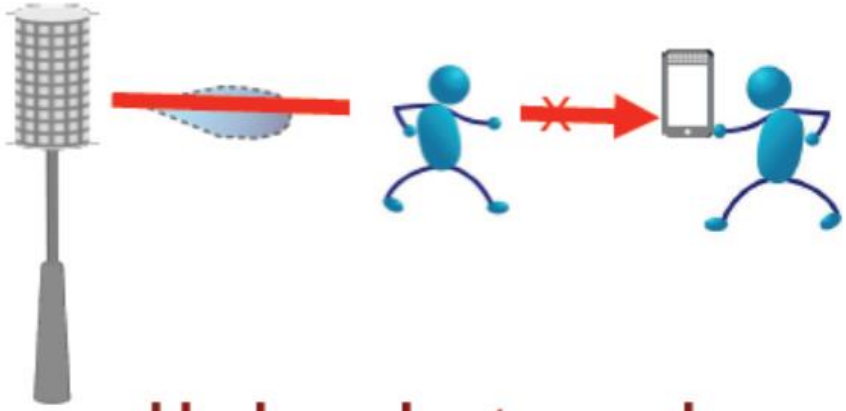
mmWave antenna design challenge (2/8)

- **Blockage and unknown mmWave channel characteristics**

Blockage is a major channel impairment

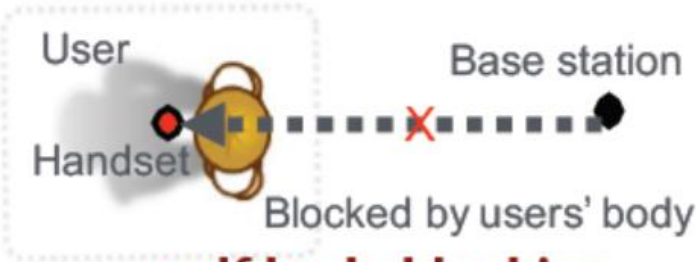


blockage due to buildings



blockage due to people

hand blocking

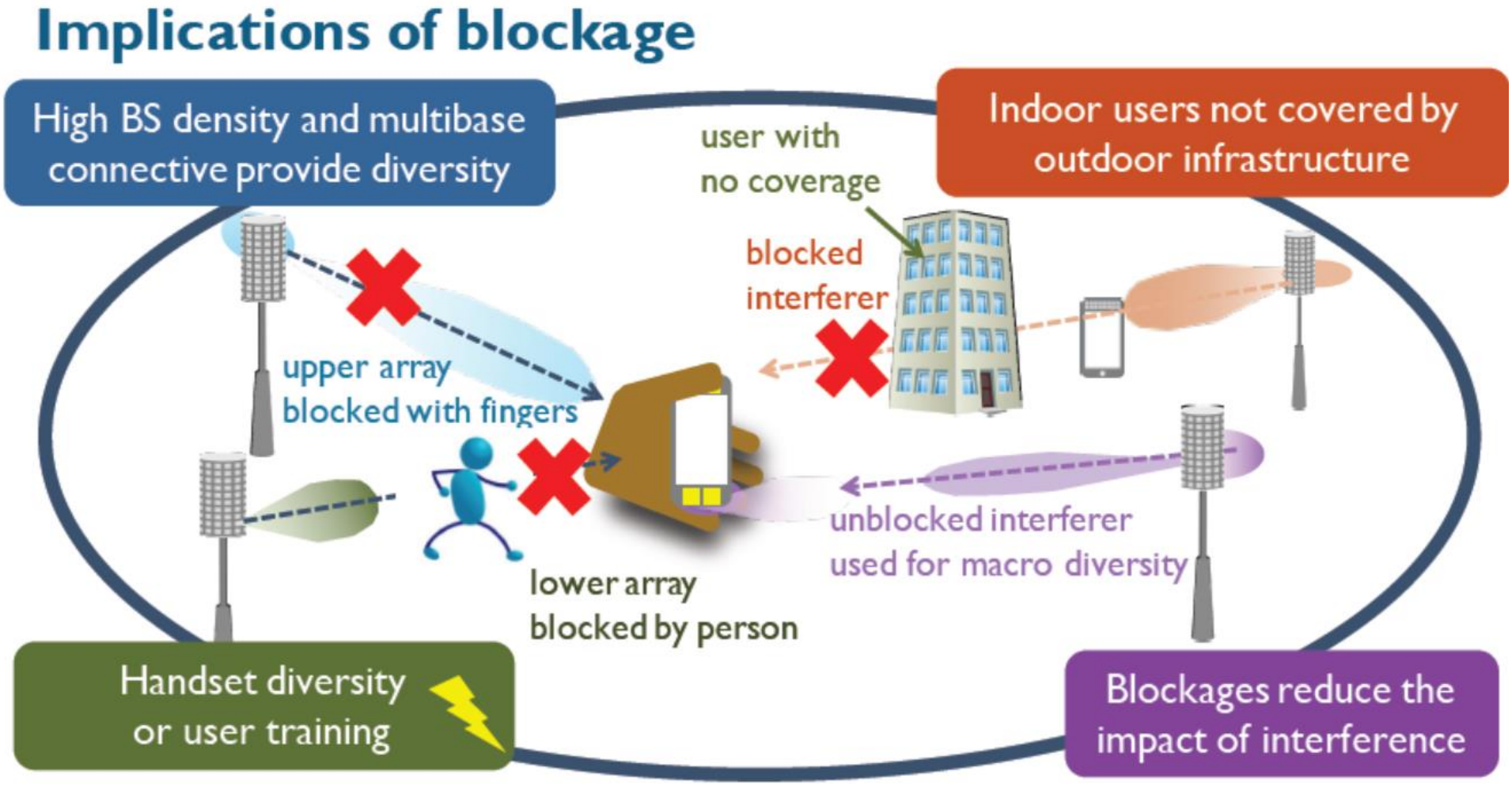


self-body blocking

Need models for blockage & system analysis including blockage

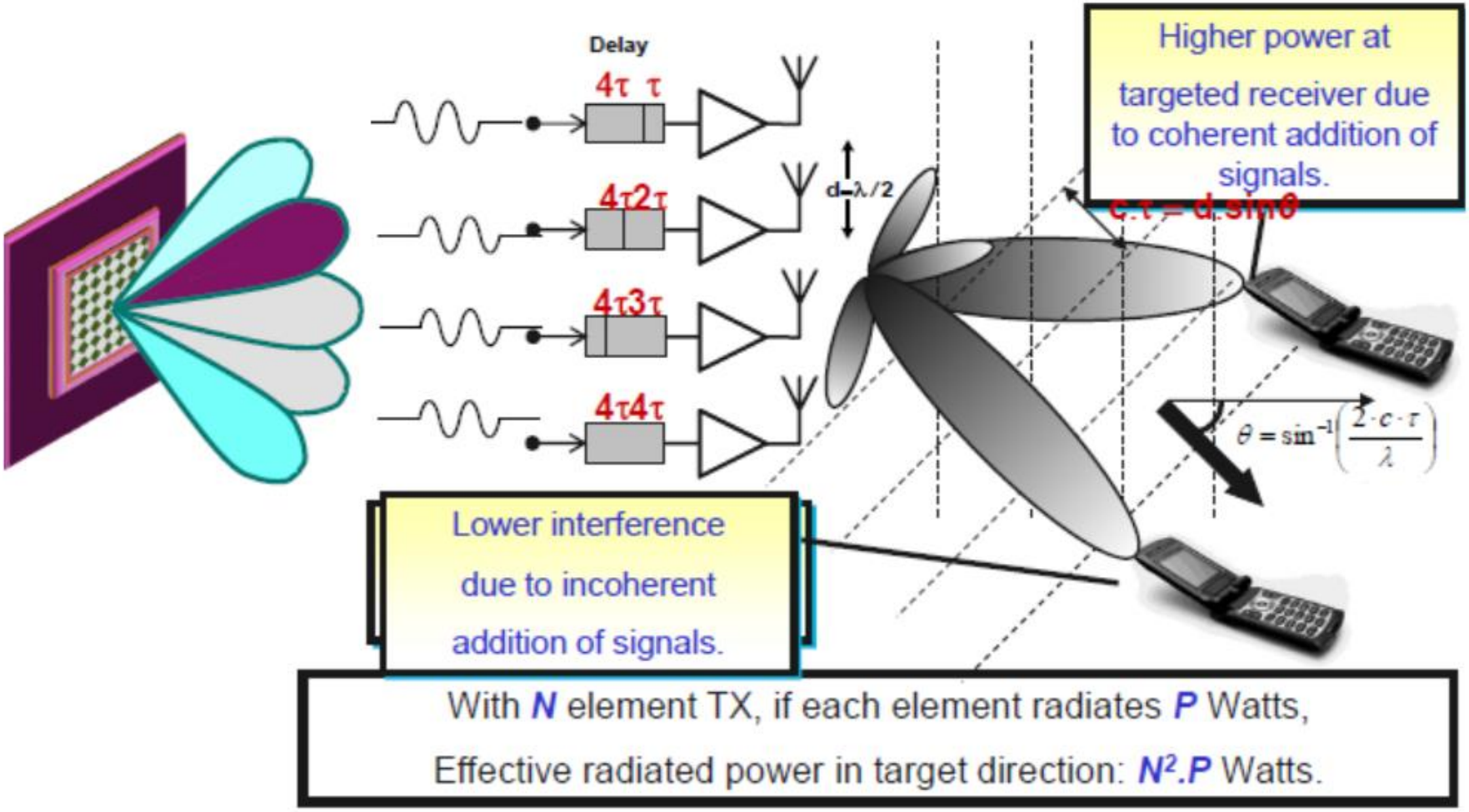
mmWave antenna design challenge (3/8)

- **Blockage and unknown mmWave channel characteristics**



mmWave antenna design challenge (4/8)

- **mmWave antenna array design**



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A. Natarajan, et al., JSSC 2005

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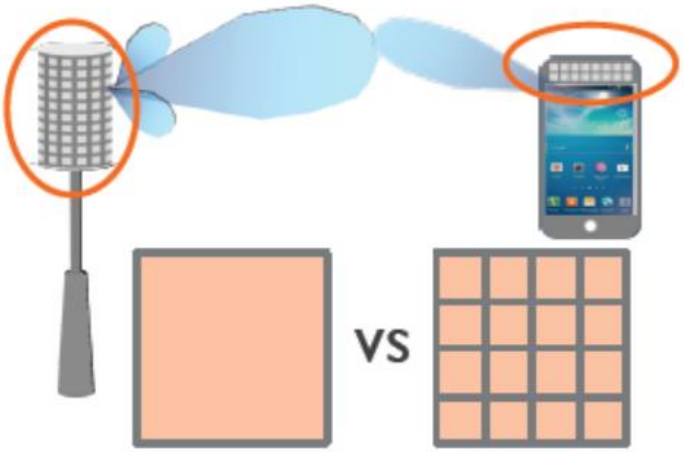
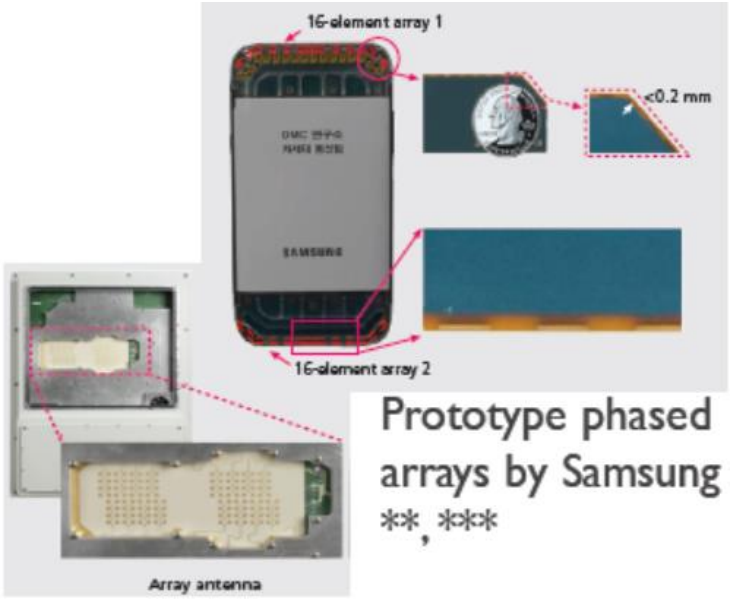
mmWave antenna design challenge (5/8)

- **mmWave antenna array design**



Antenna arrays provide larger aperture

Prototype 64 element dielectric lens by Nokia*



Prototype phased arrays by Samsung **, ***

Early mmWave devices will use simple adaptive beam steering

* Cudak, M. et. al., "Experimental mm wave 5G cellular system," in Globecom Workshops (GC Wkshps), 2014

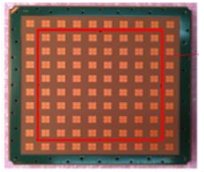
** W. Hong; K. Baek; Y. Lee; Y. Kim; S. Ko, "Study and prototyping of practically large-scale mmWave antenna systems for 5G cellular devices," in IEEE Commun. Mag., 2014

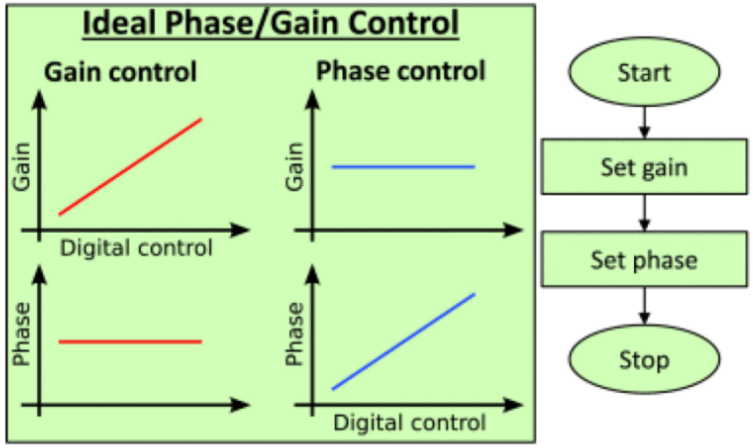
*** W. Roh et al. "Millimeter-wave beamforming as an enabling technology for 5G cellular communications: theoretical feasibility and prototype results," in IEEE *Commun. Mag.*, 2014

**** G. M. Rebeiz et. al. "Millimeter-wave large-scale phased-arrays for 5G systems" Proc. IEEE MTT-S International Microwave Symposium, 2015.

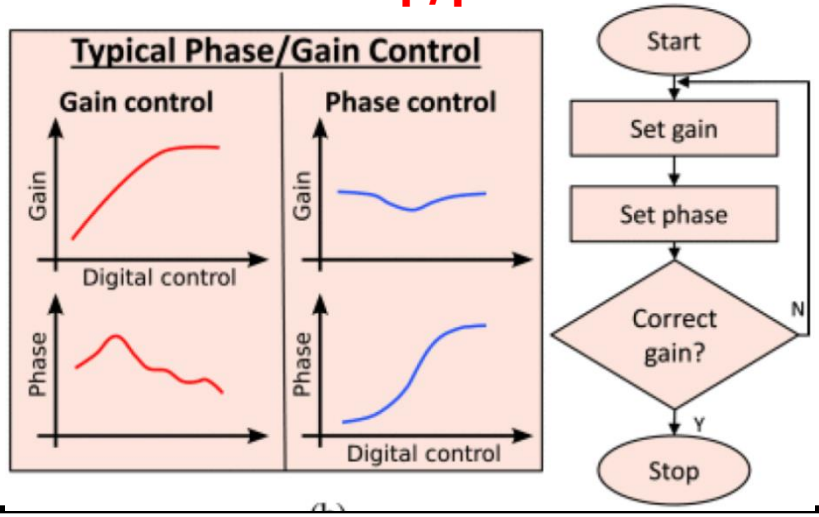
mmWave antenna design challenge (6/8)

- **mmWave calibration for Massive MIMO and antenna array**

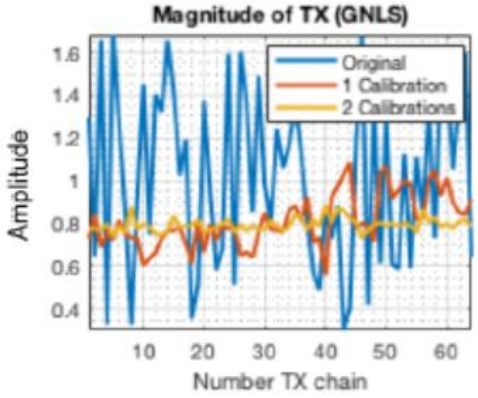


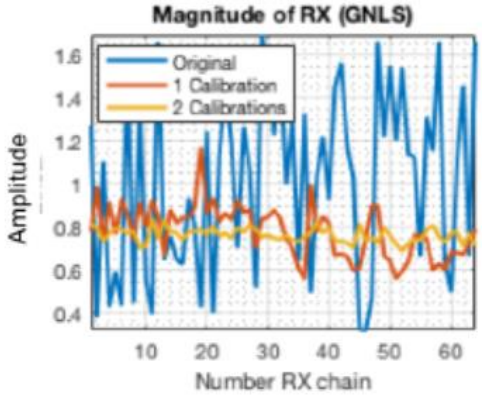


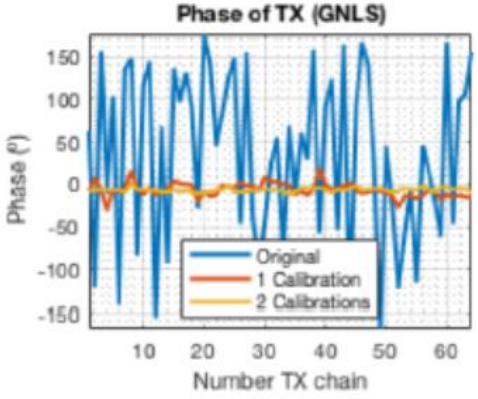
Ideal case for amp/phase control

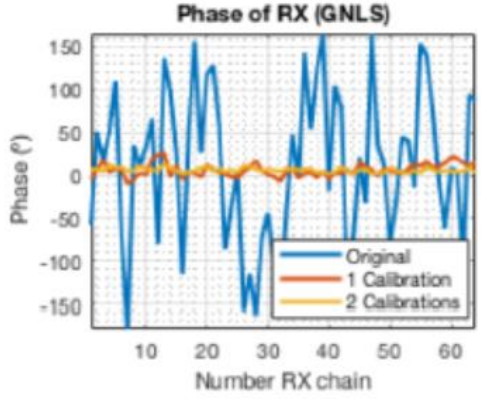


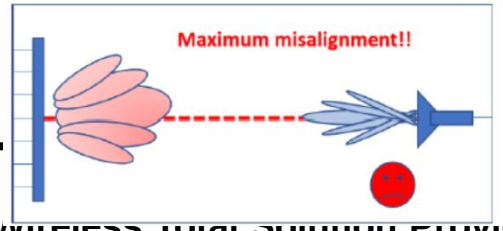
Actual case for amp/phase control

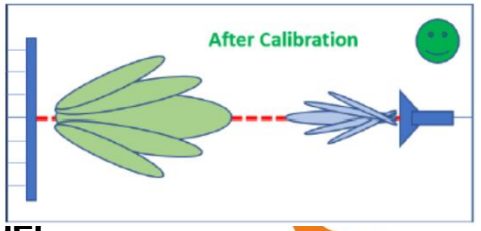






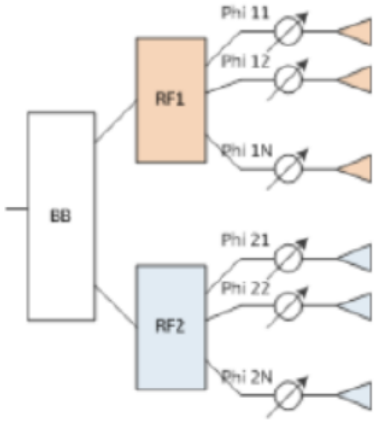


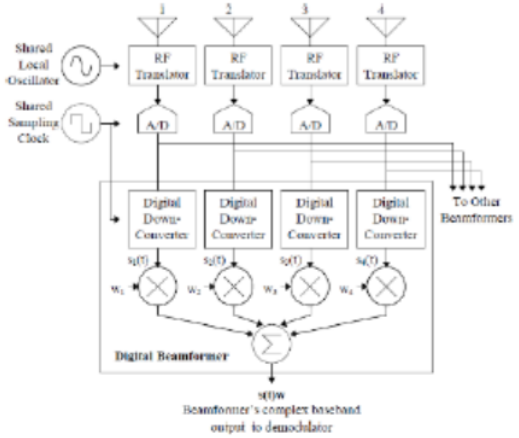


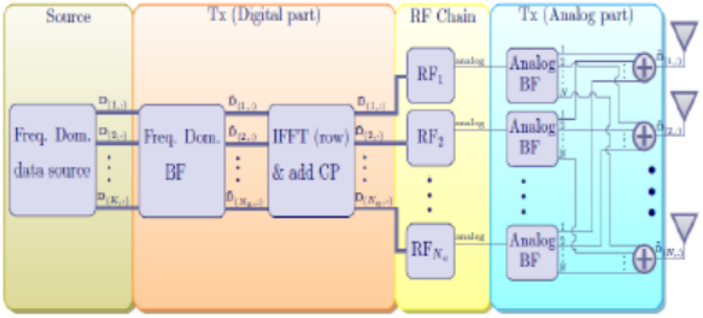


mmWave antenna design challenge (7/8)

- **Beamforming and beam-tracking algorithm**



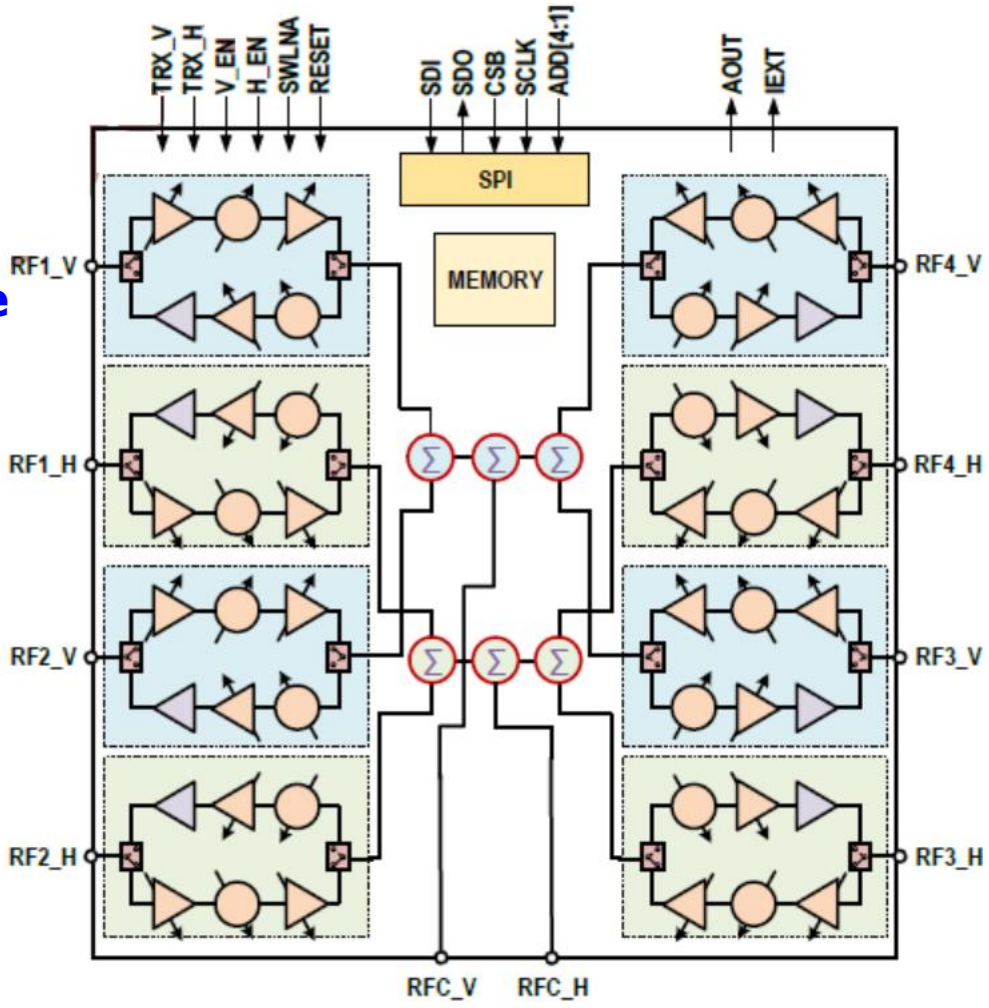




	RF Beamforming	Digital Beamforming	Hybrid Beamforming
Complexity	Low	High (computation intensive)	Medium
Flexibility	Low	High (very high resolution phase shifting and amplitude tapering possible)	High (combined positives of RF and Digital beamforming)
Beam variation	High (due to dependence on analog components)	Low (all control elements in digital domain)	Medium to Low (variations due to analog components can be partially compensated by digital domain correction)
Challenge	High component count and limited flexibility	High computation complexity	Calibration to combine both beamforming states for optimal performance

mmWave antenna design challenge (8/8)

- **mmWave IC technologies**
  - 26.5 ~ 29.5 GHz operation
  - 8 radiation elements
  - 100 ns Tx/Rx switching times
  - 20 ns gain and phase setting time
  - 3o typical RMS phase error
  - 0.4 dB typical RMS gain error
  - 31.5 dB gain attenuation range
  - 4-bit chip address
  - Internal temp. sensor
  - Internal power detection
  - 50 MHz SPI control
  - Programmable on-chip memory



Product & development roadmap

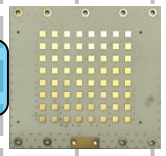
Active Antenna Array Module

Single polarization

Dual polarization

28G 4x4

39G 8x8

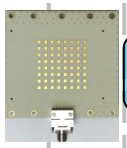


28G 8x8

Dual band 1 x 4 array DK for handheld device

39G 8x8 w U/D converter

AAAM



39G 8x8

28G 8x8

28G 8x8 w U/D converter

mmWave EMC test equipment

CATR Chamber

Pre-test & Certification

Fast calibration algorithm for AAAM

Power density test equipment

2018 1Q 2Q 3Q 2019 1Q 2Q 3Q 2020

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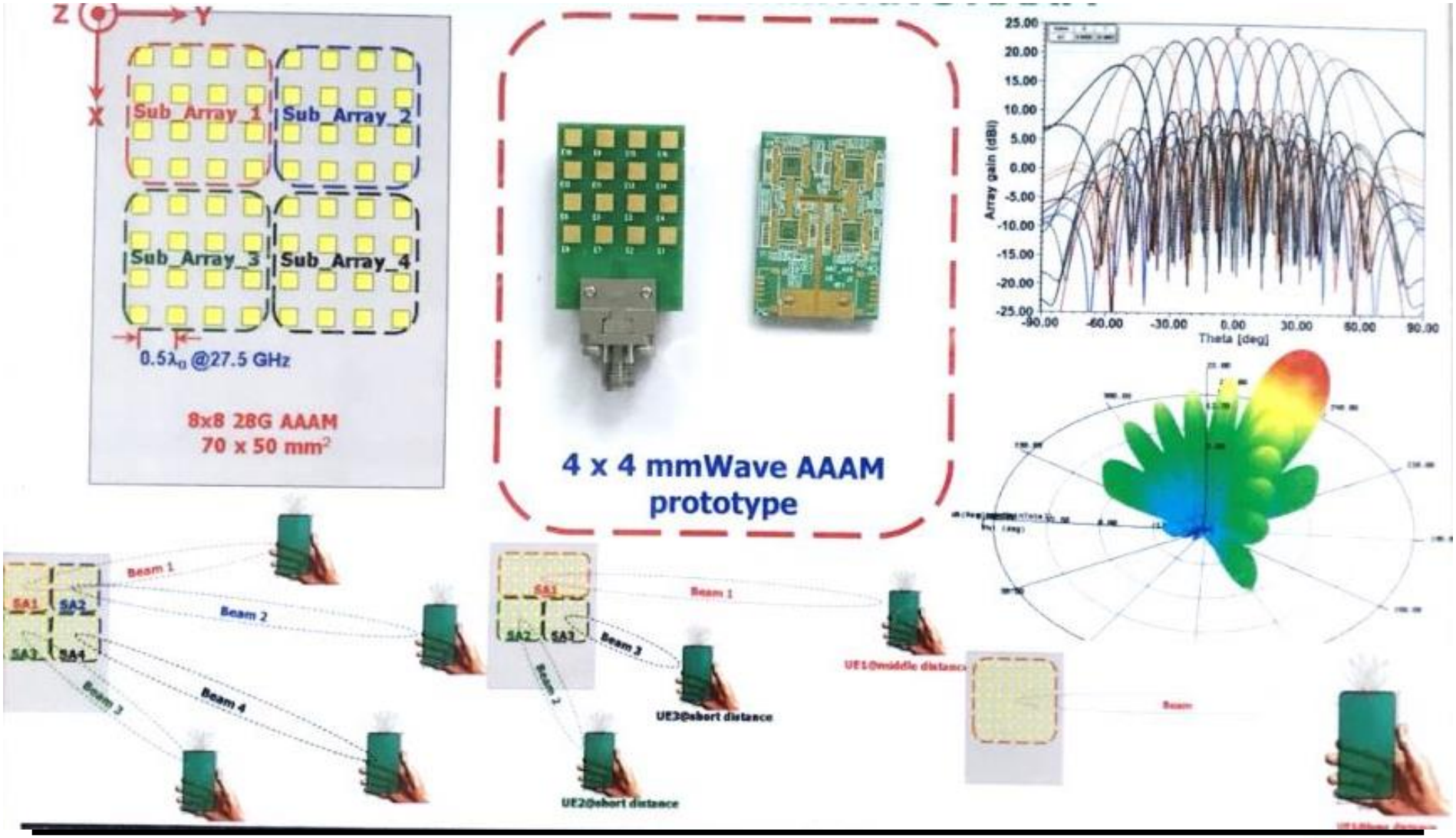
Photo of the 4x4 active antenna array module

-Scalable 28 GHz mmWave AAAM-



2018 Taipei 5G Summit: Auden

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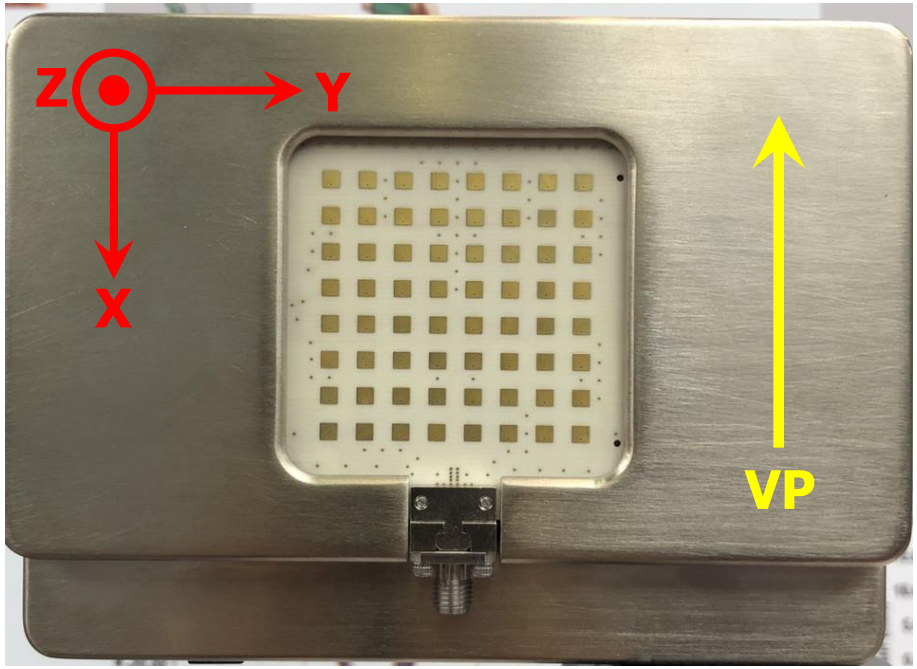
28G 8x8 single polarized array

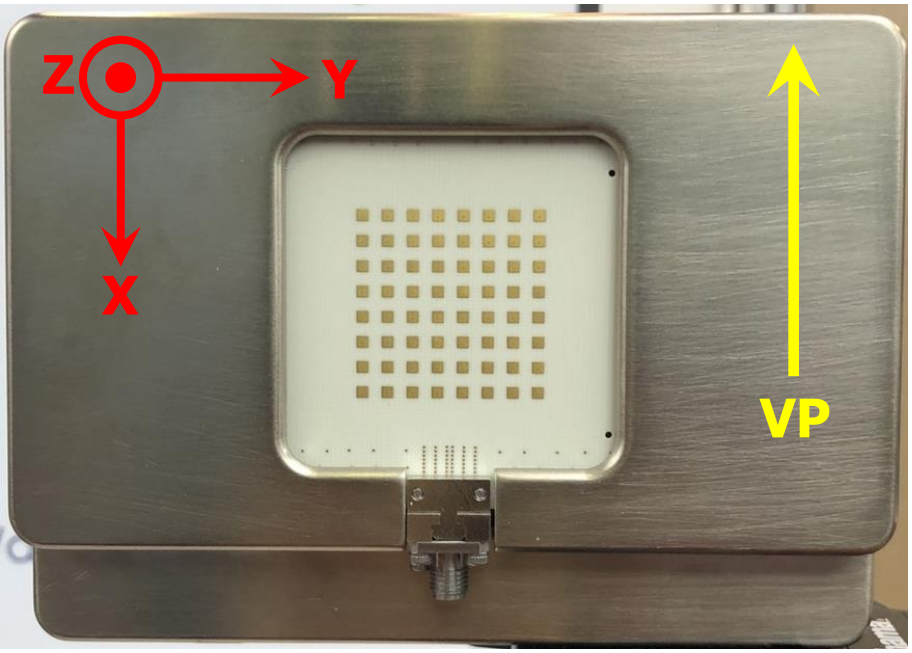
-Scalable 28 GHz mmWave AAAM-



- **Product spec.**
  - 26.5 ~ 28.5 GHz operation
  - Tx/Rx half duplex operation (TDD only)
  - Peak EIRP: +51 dBm (broadside)
  - Linear polarization
  - Horizontal scan angle: ±60°
  - Vertical scan angle: ±60°
  - Programmable beamwidth
  - Fast beam update rate
  - Analog beam-former design
  - SPI interface with 50MHz clock rate

39G 8x8 single polarized array

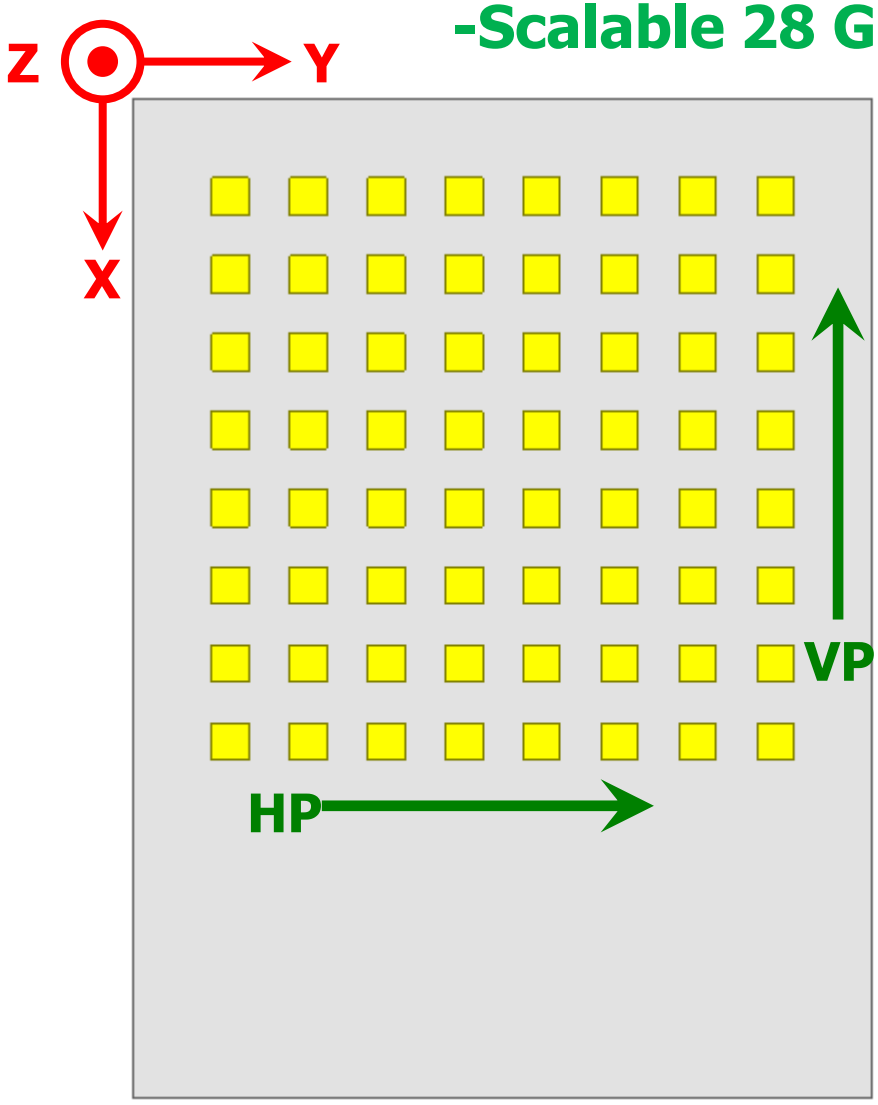
-Scalable 39 GHz mmWave AAAM-



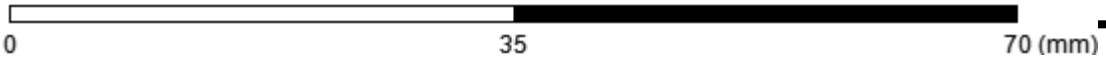
- **Product spec.**
  - 37 ~ 40 GHz operation
  - Tx/Rx half duplex operation (TDD only)
  - Peak EIRP: +51 dBm (broadside)
  - Linear polarization
  - Horizontal scan angle: ±60°
  - Vertical scan angle: ±60°
  - Programmable beamwidth
  - Fast beam update rate
  - Analog beam-former design
  - SPI interface with 50MHz clock rate

28G 8x8 Dual-polarized array

-Scalable 28 GHz mmWave AAAM-

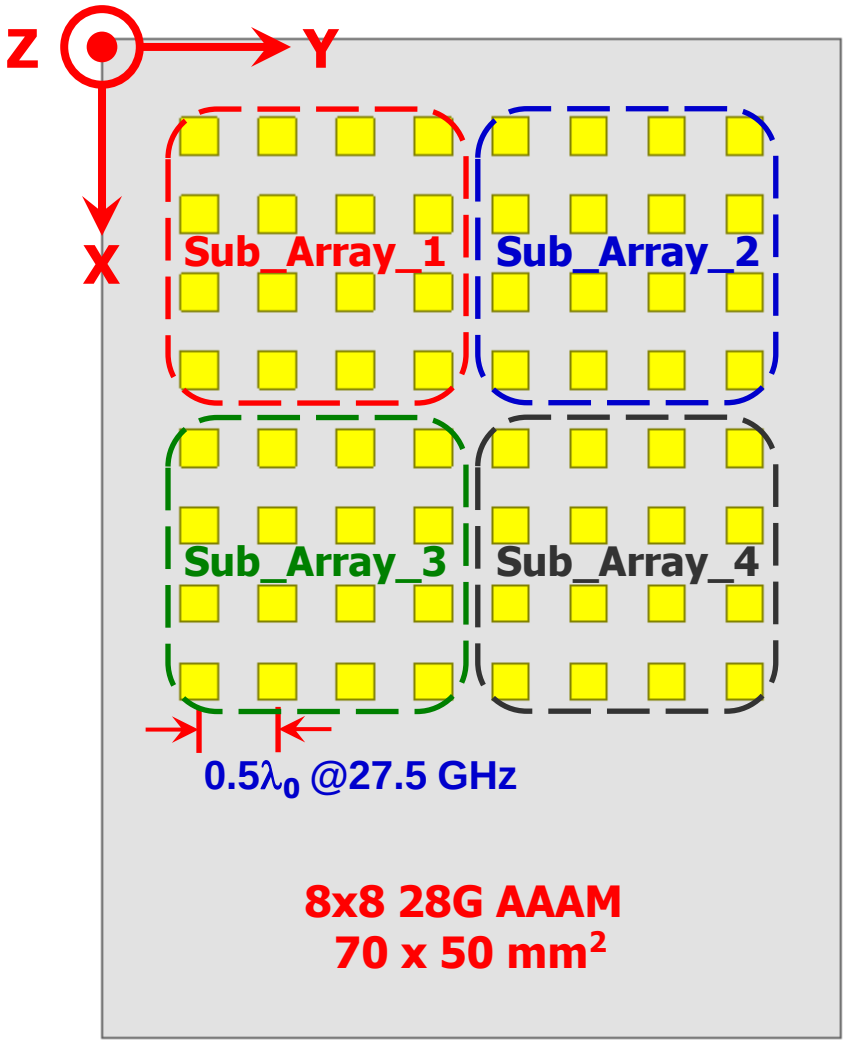


- **Preliminary product spec.**
  - 26.5 ~ 28.5 GHz operation
  - Tx/Rx half duplex operation (TDD only)
  - Peak EIRP: +51 dBm (broadside)
  - Dual polarization (VP + HP)
  - Horizontal scan angle: ±60°
  - Vertical scan angle: ±60°
  - Programmable beamwidth
  - Fast beam update rate
  - Analog beam-former design
  - SPI interface with 50MHz clock rate



28G 8x8 4 channel with U/D converter

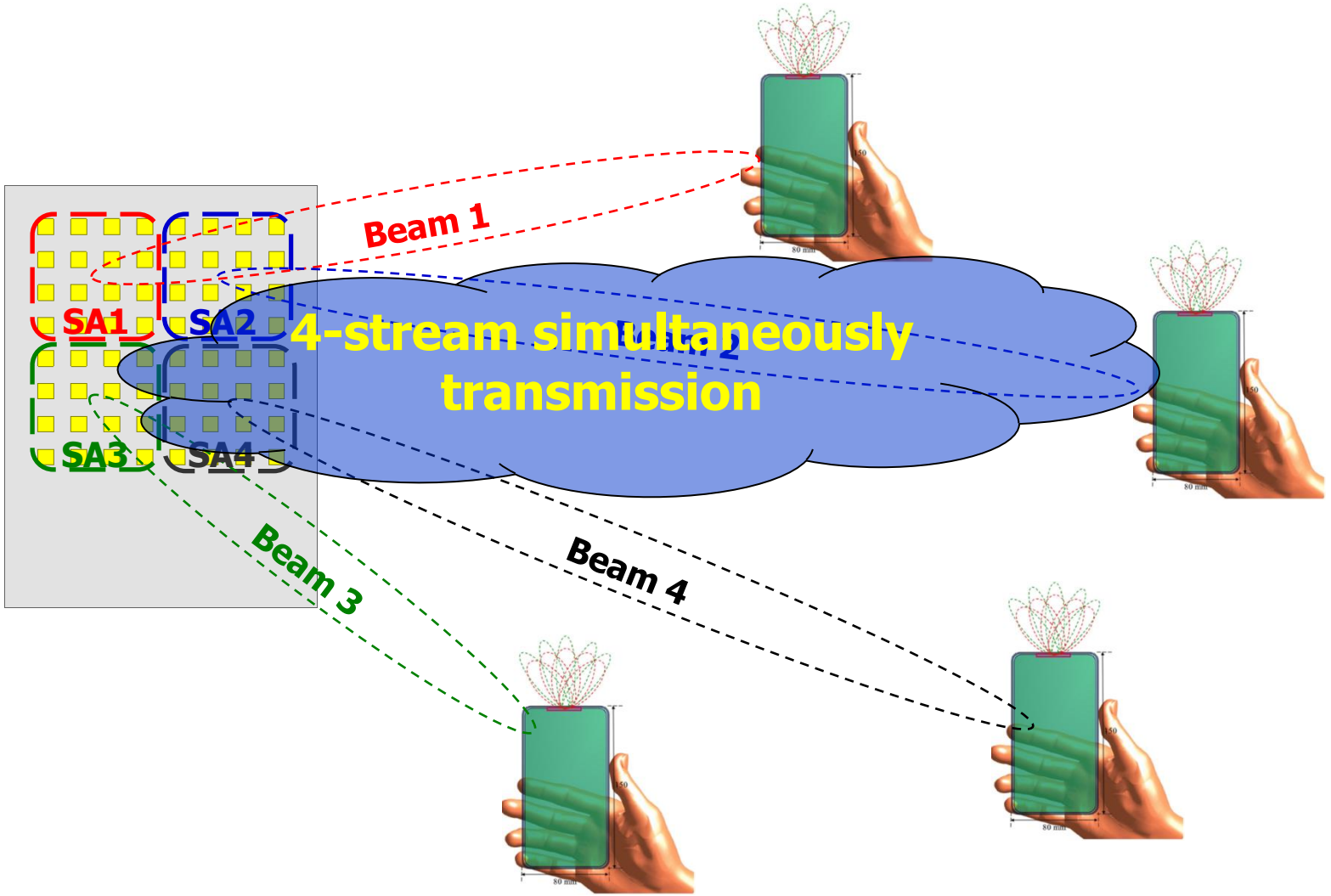
-Scalable 28 GHz mmWave AAAM-



- **Preliminary product spec.**
  - 26.5 ~ 28.5 GHz operation
  - Tx/Rx half duplex operation (TDD only)
  - Peak EIRP: +55 dBm (broadside)
  - Linear polarization
  - Horizontal scan angle: ±60°
  - Vertical scan angle: ±60°
  - Programmable beamwidth
  - Fast beam update rate
  - 4-streams simultaneously transmission
  - Hybrid beam-former design (ABF+DBF)
  - Scalable for residential, non-residential small cell and base station applications
  - 4 channel IF I/O (low loss & low cost)

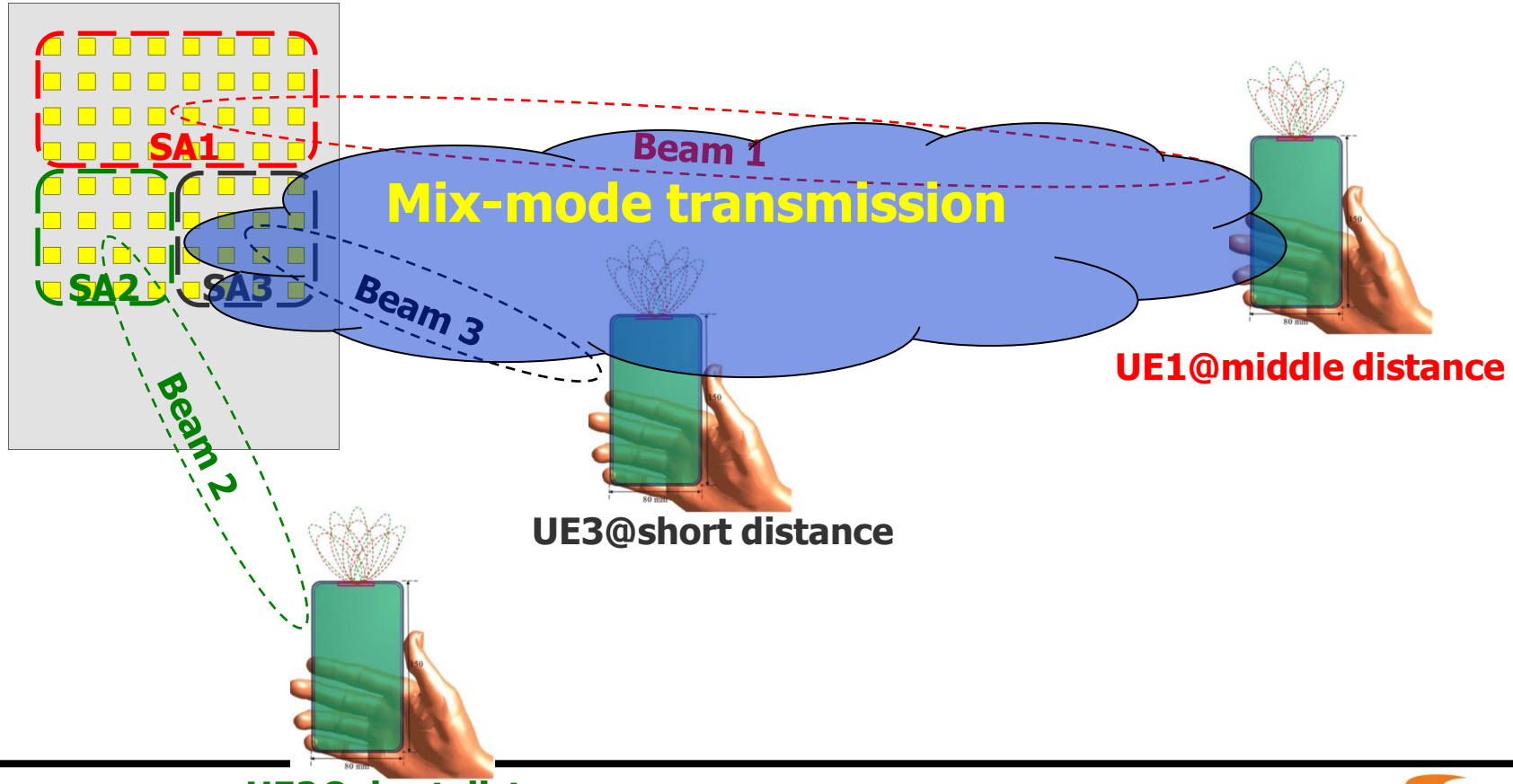
Usage scenario for mmWave AAAM

-Short range-



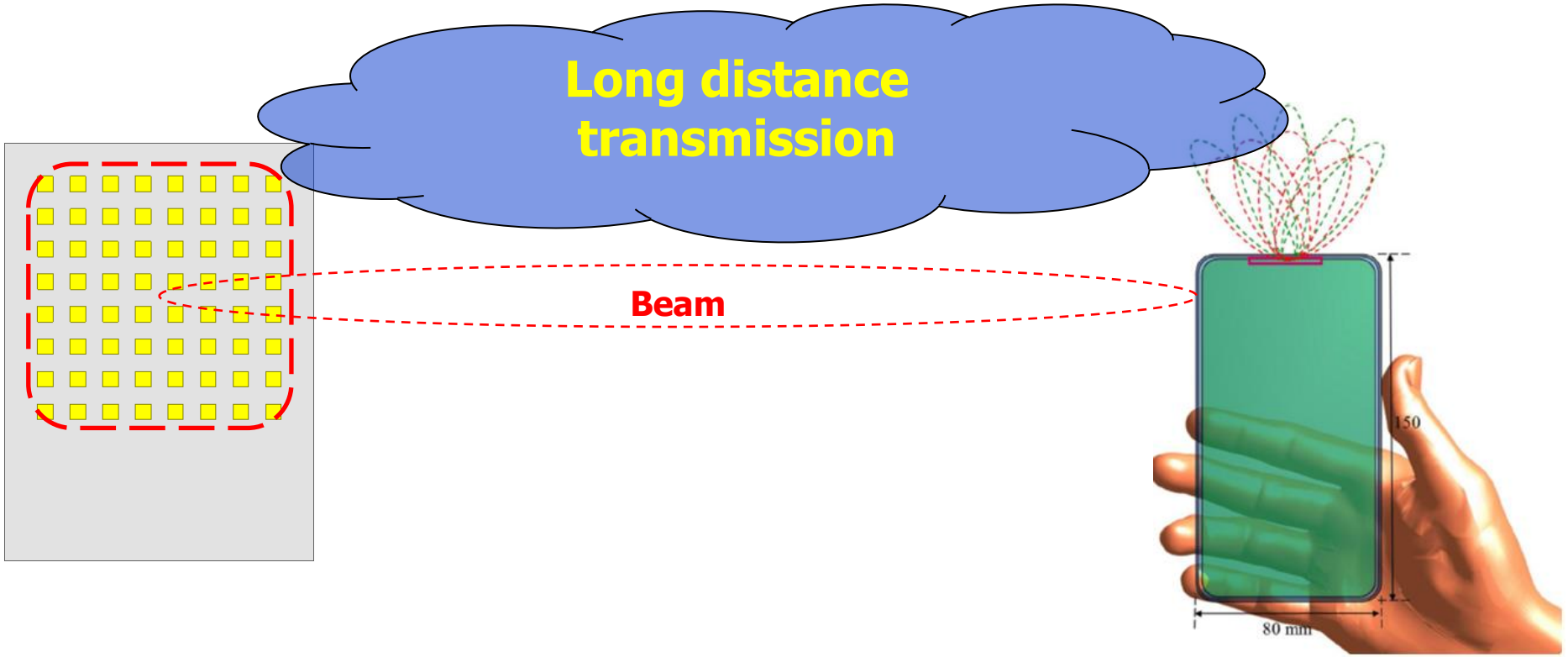
Usage scenario for mmWave AAAM

-Middle range-



Usage scenario for mmWave AAAM

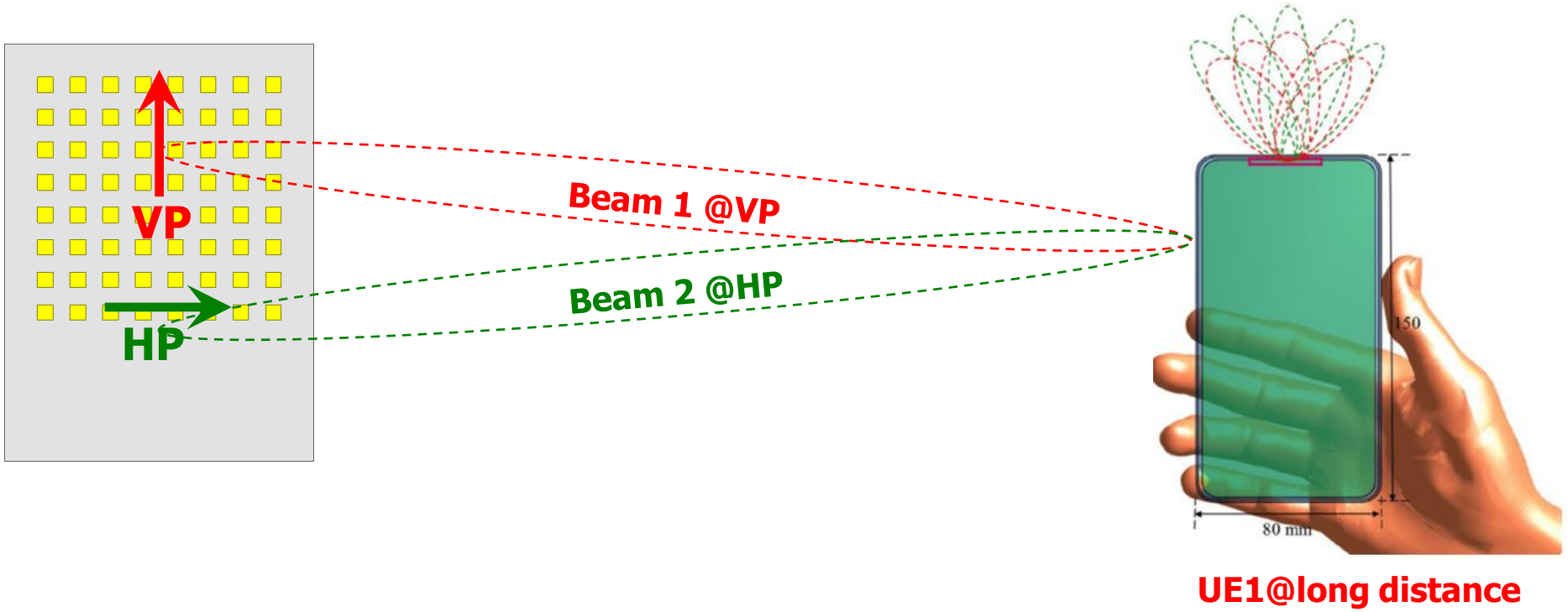
-Long range-



UE1@long distance

Usage scenario for mmWave AAAM

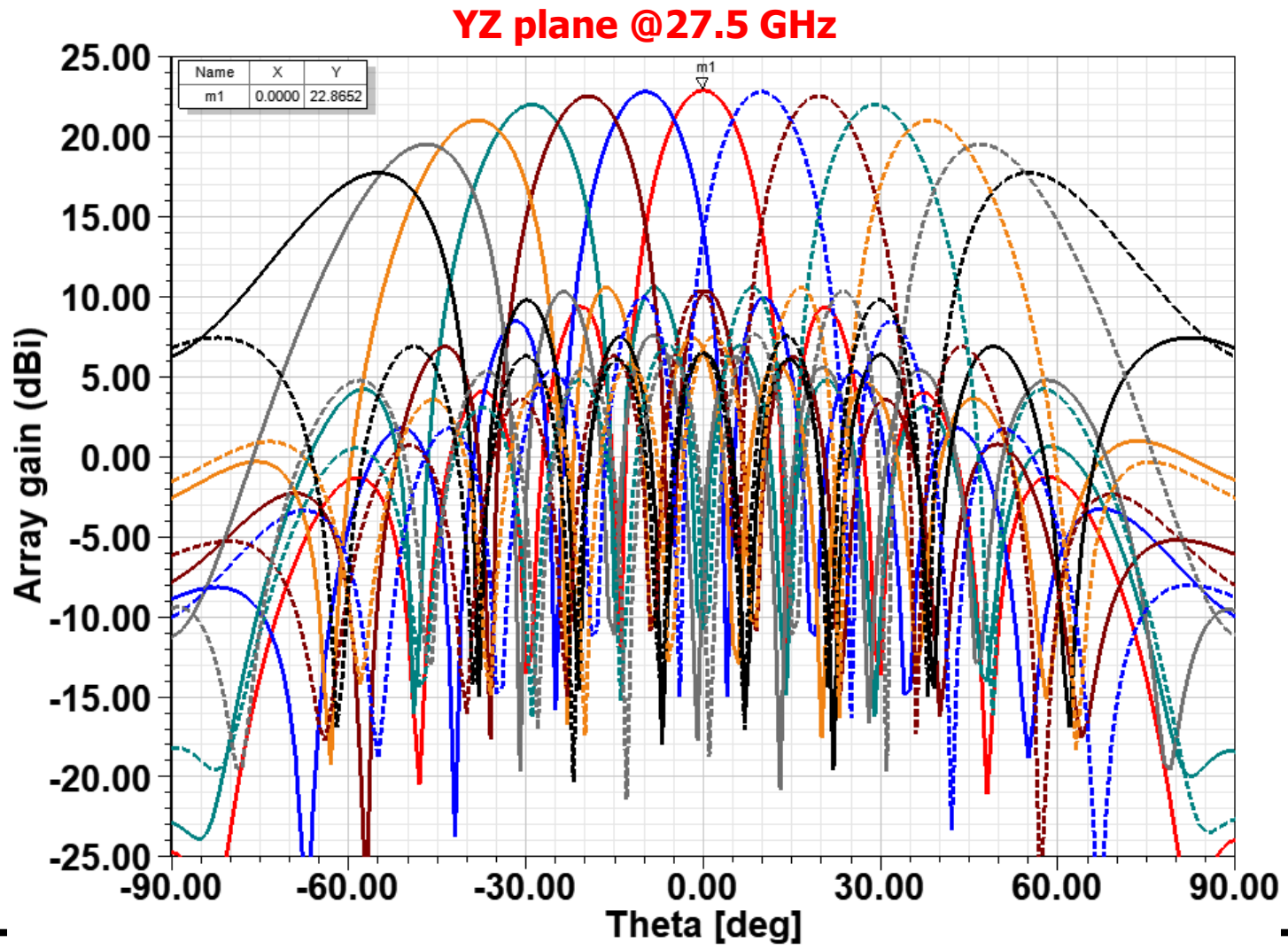
-MU-MIMO application-



UE1@long distance

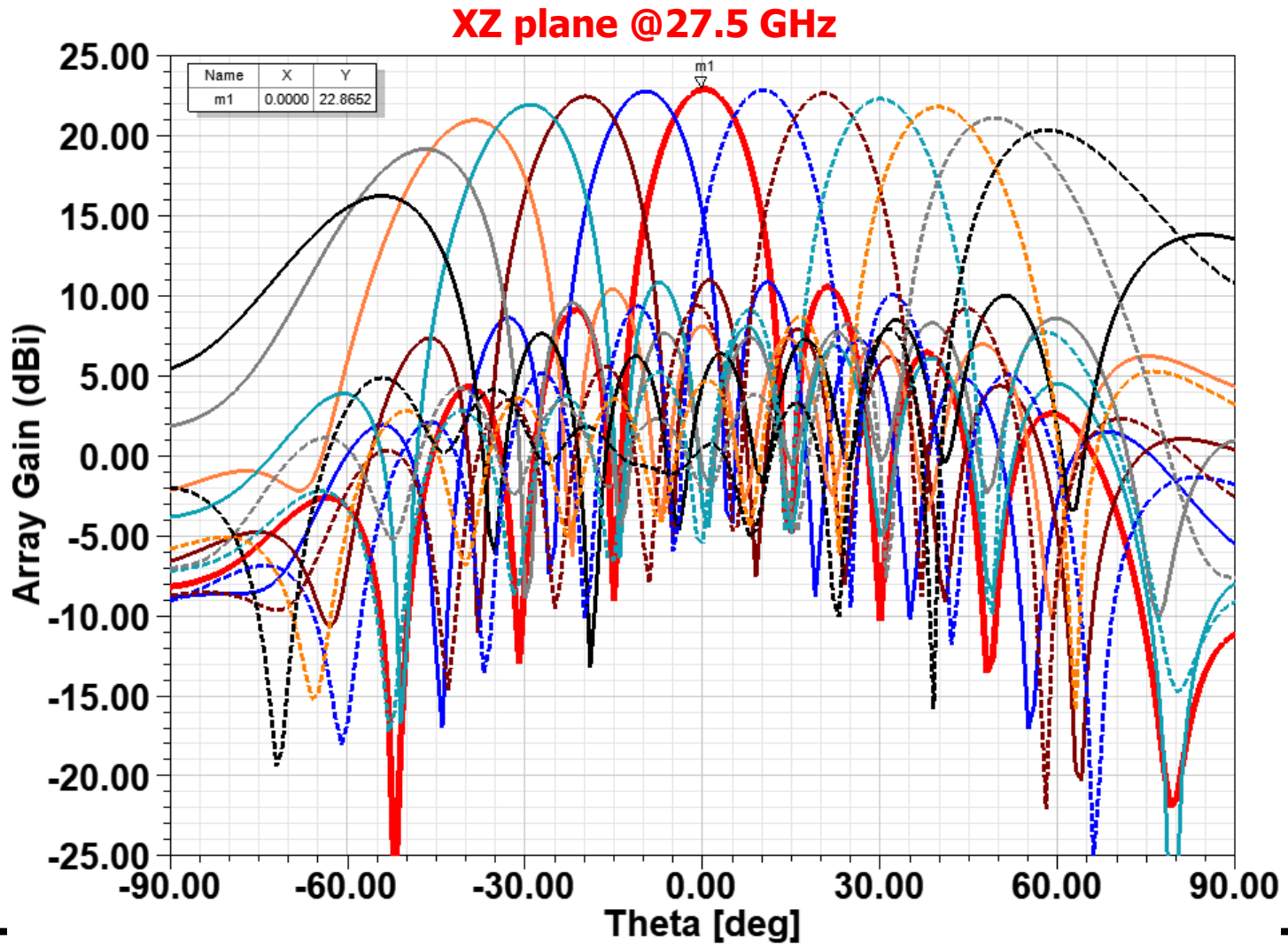
Simulation results for 28 GHz 8x8 array module

-Horizontal Beam Scan-



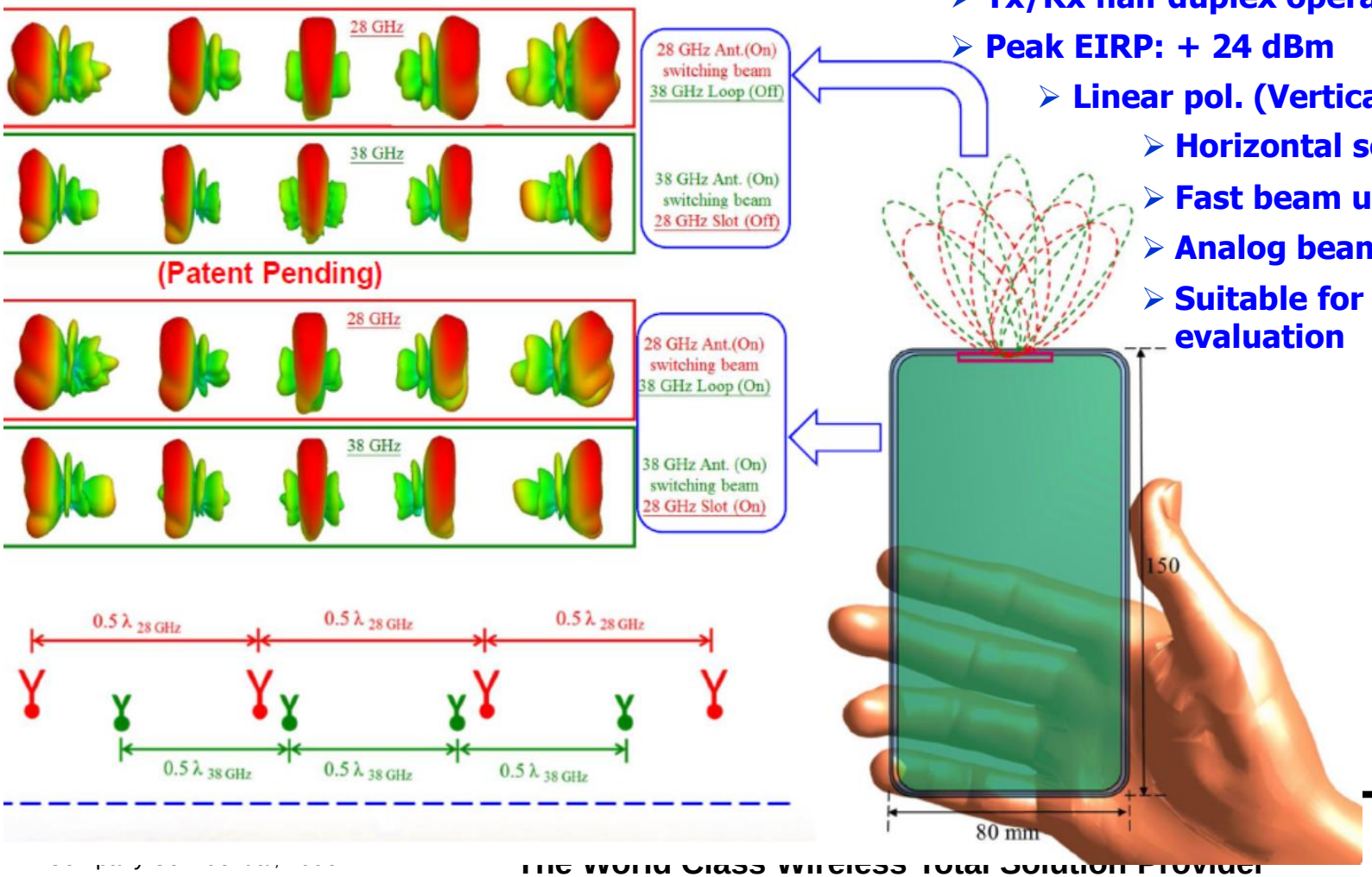
Simulation results for 28 GHz 8x8 array module

-Vertical Beam Scan-



Dual-band linear array DK for handheld

- **Preliminary product spec.**
  - ➢ 26.5 ~ 28.5 GHz & 37 ~ 40 GHz
  - ➢ Tx/Rx half duplex operation (TDD only)
  - ➢ Peak EIRP: + 24 dBm
  - ➢ Linear pol. (Vertical or Horizontal)
  - ➢ Horizontal scan angle: ±40°
  - ➢ Fast beam update rate
  - ➢ Analog beam-former design
  - ➢ Suitable for material evaluation



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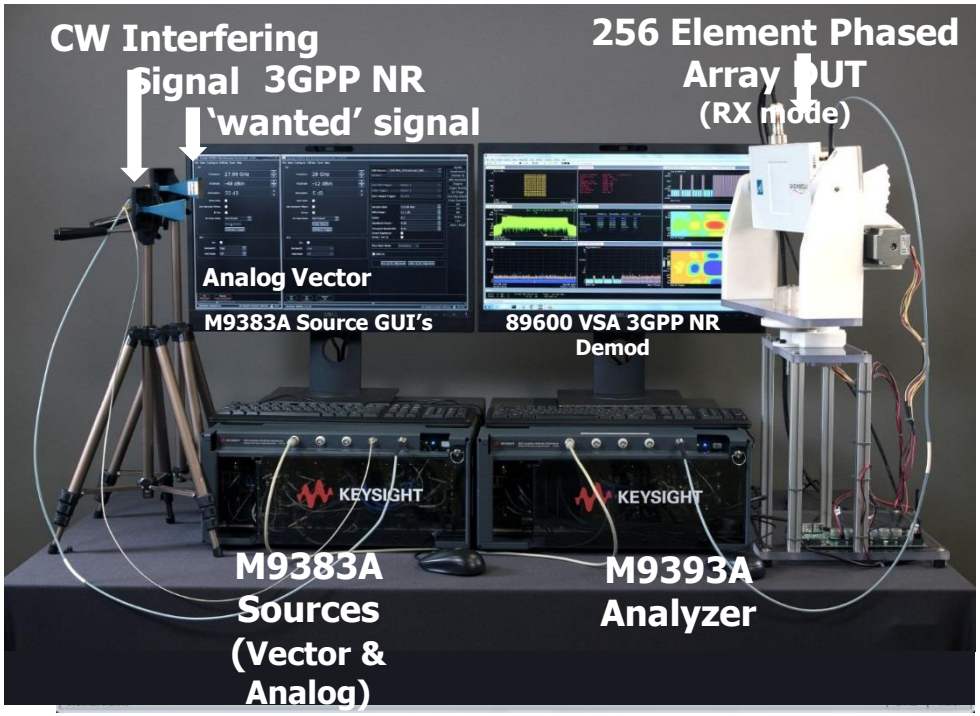
Case Study: Verify Performance on Antenna

Challenge: Base station vendor wanted < 1 % EVM on a Wideband Signal

- Is the waveform created with 5G compliant waveform with numerology, UL, DL scheduling?
- Can the equipment produce clean mmWave signals?
- Performance mmWave measurements?

Solution: Flexible Testbed

- **5G NR compliant waveform generation; N7631C & M9383A**
- **Best-in-class EVM performance; N9040B or M9393A with 89601B (VSA)**
- **Flexible configurations can scale as the standards evolve**



https://www.youtube.com/watch?v=FQBIxIw-nok

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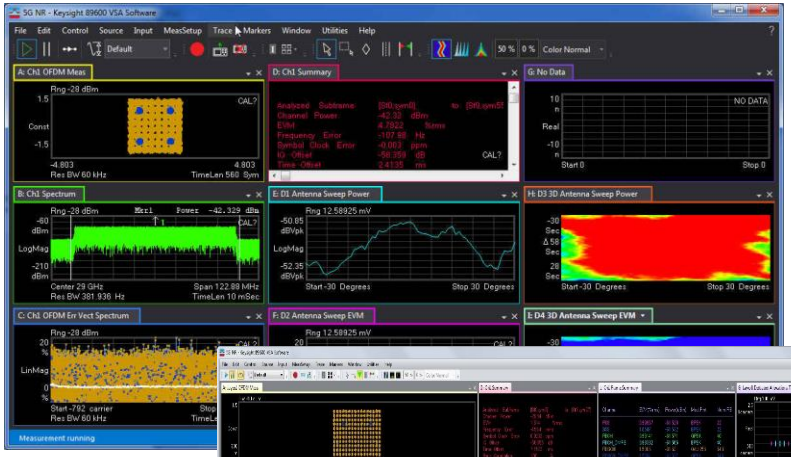
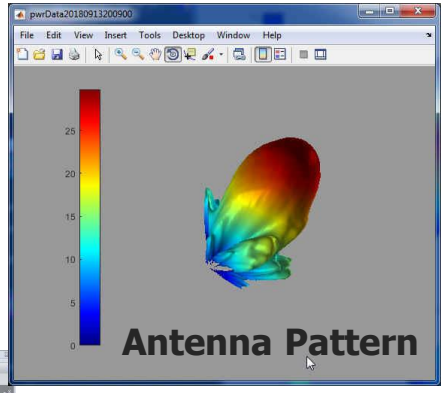
Verify Performance on Antenna

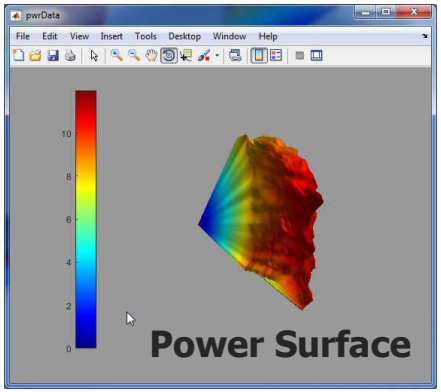
3GPP 5G NR MEASUREMENT DETAIL (EXAMPLES)

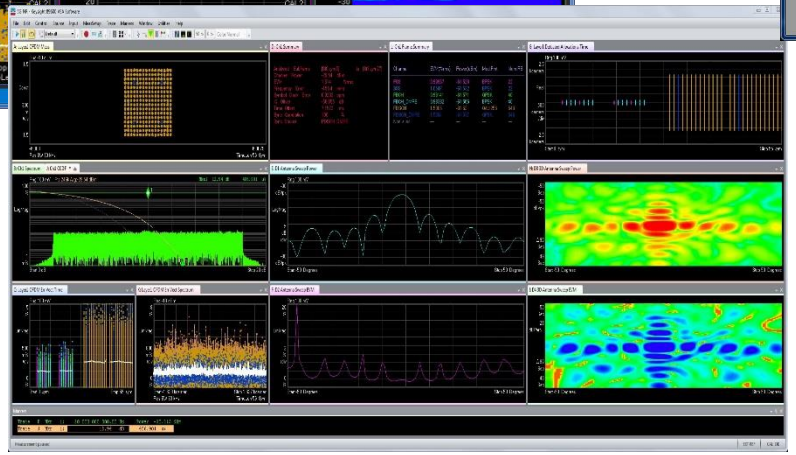
5G NR Downlink
100 MHz BW @ 28 GHz
64/256 QAM payload



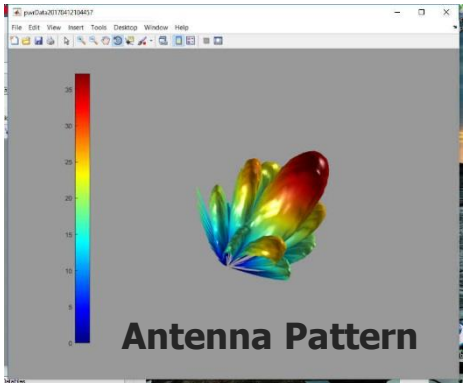
4x4 element array







16x16 element array



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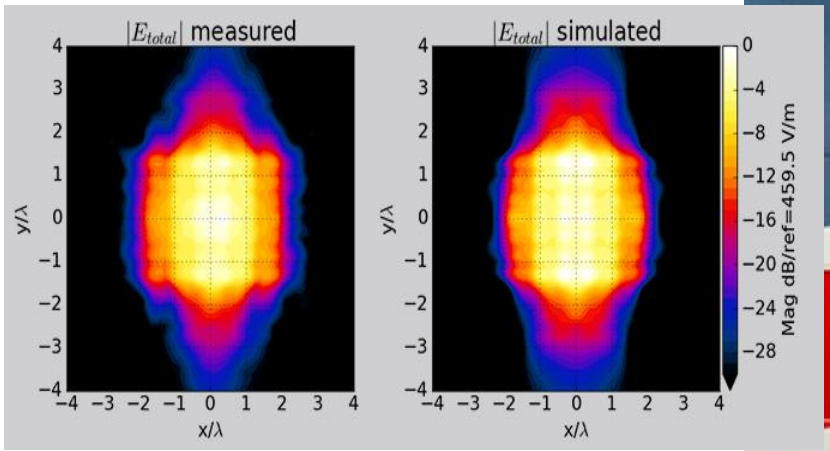
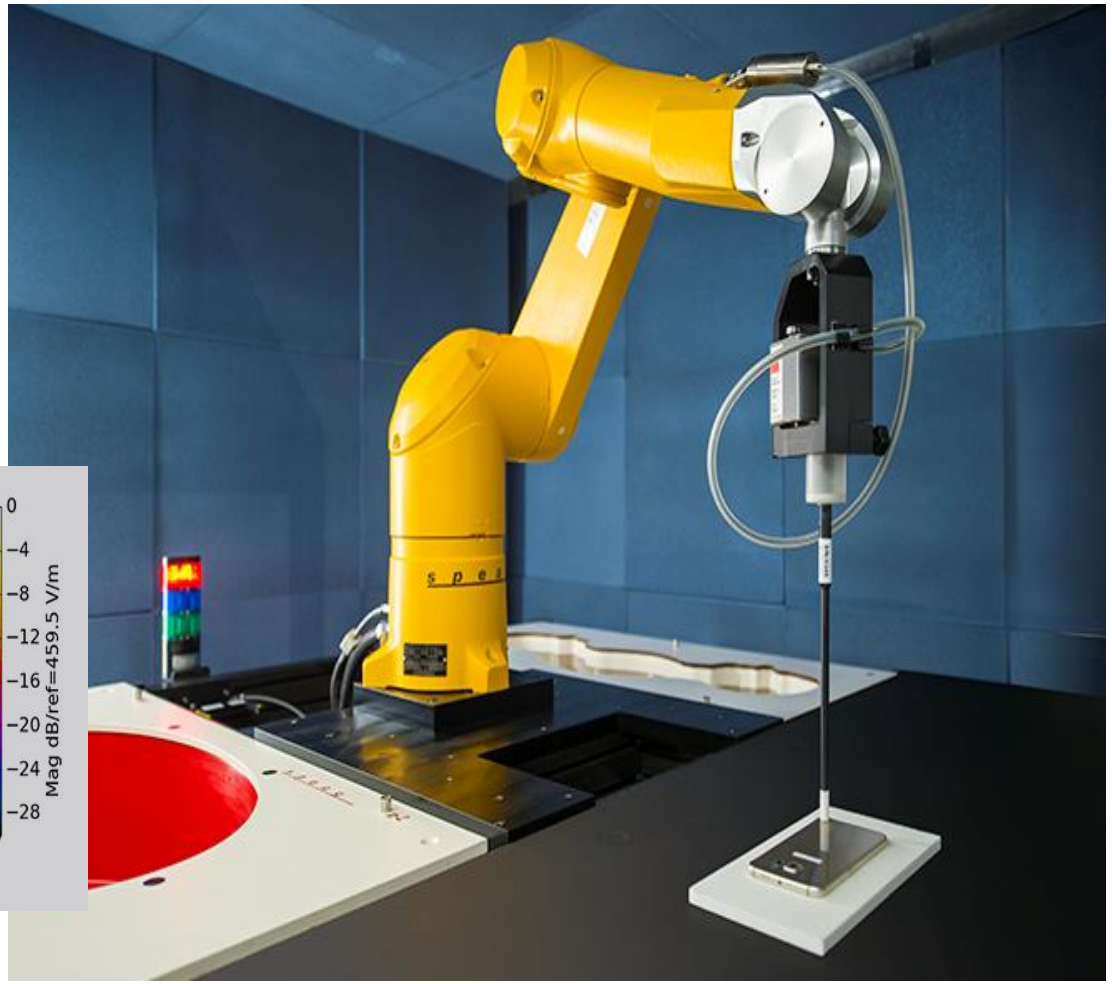
5G 毫米波測試

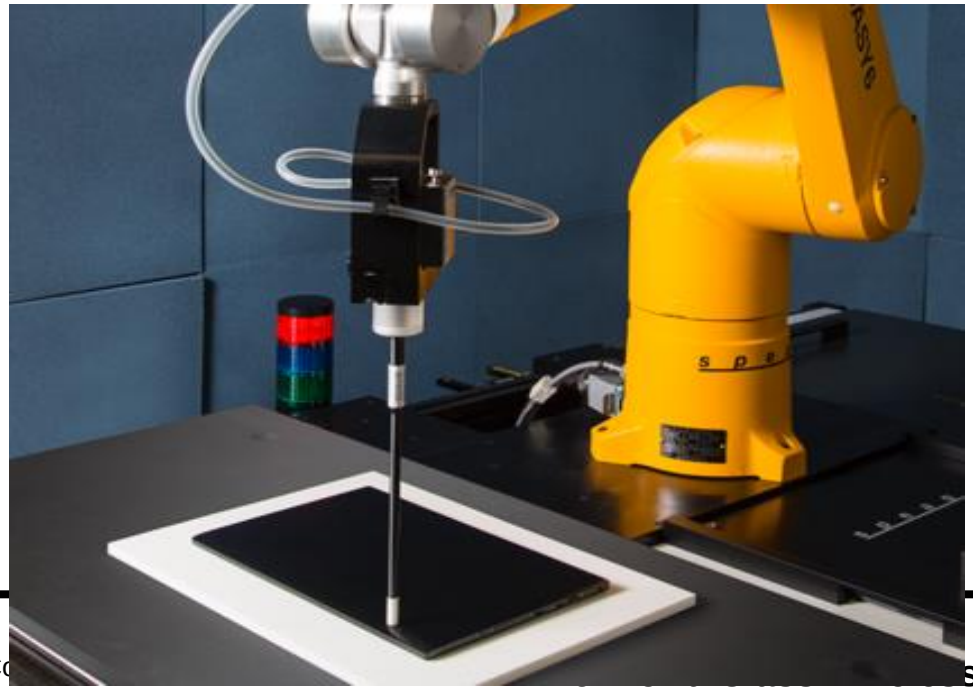
- 頻率0.75-110 GHz
- 使用EUmmWV2探針和軟件許可證
- 符合標準：IEC TR 63170和FCC

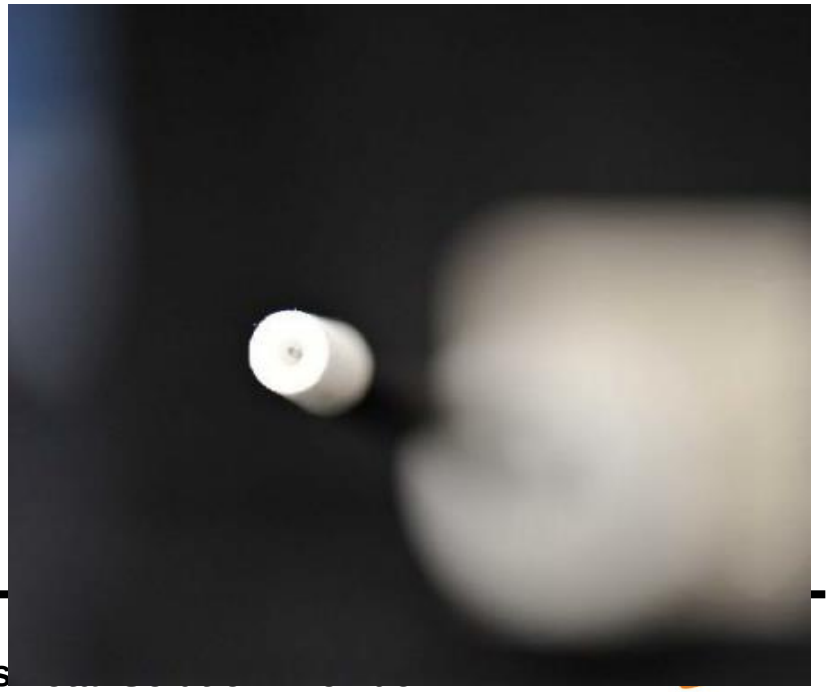




EUmmWV2探棒結合 DASY6系統

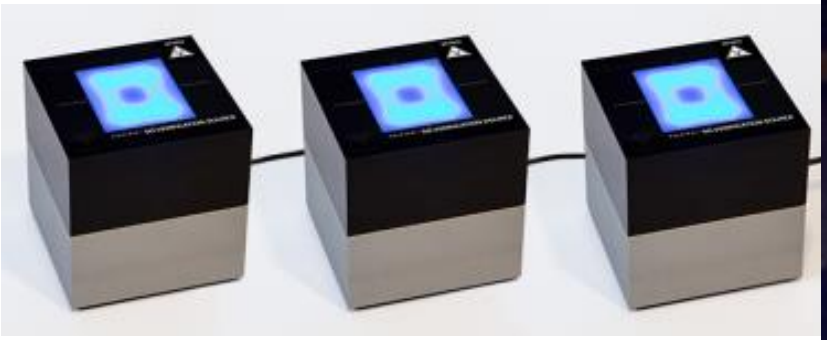
- 頻率範圍：750 MHz - 110 GHz
- 動態範圍：< 20 V/m - 10'000 V/m with PRE-10 (min < 50 V/m - 3000 V/m)
- 線性度: < ±0.2 dB
- 支持SMC校準
- ISO / IEC 17025認可的校準
- 第一種評估近場源功率密度的方法
- 與IEC TR 63170完全兼容

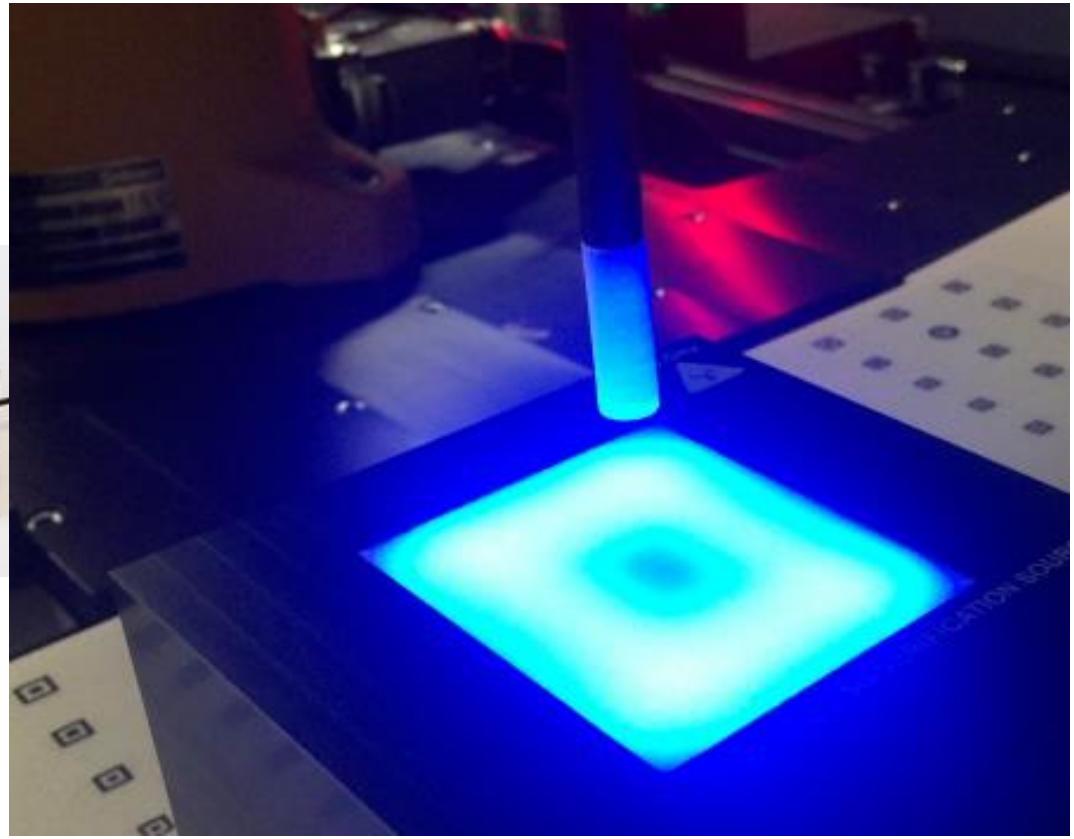




5G System Verification Packages

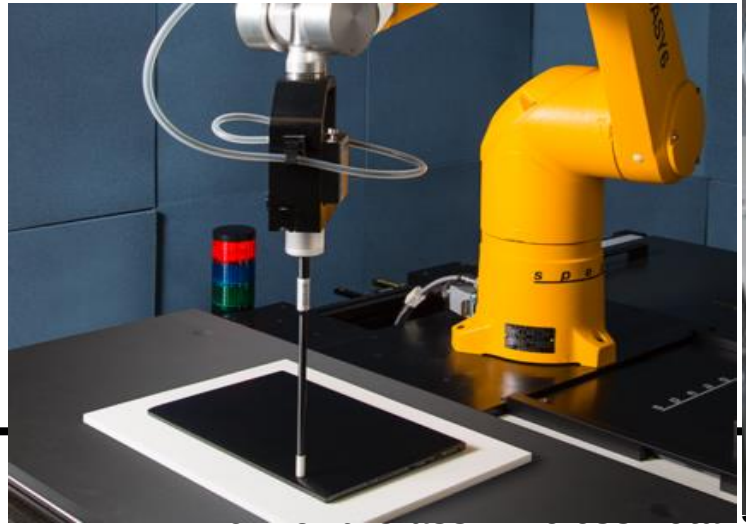
- 10 GHz: 8.2 - 12.4 GHz horn，SMA母接口
- 30, 60, and 90 GHz:獨立的固定頻率源的horn，12 V DC電源
- 與IEC TR 63170完全兼容



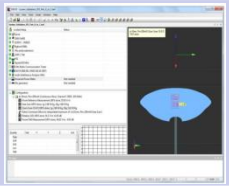
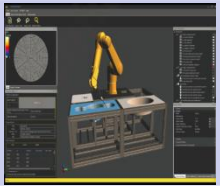


4 MHz - 110 GHz一致性測試的獨特解決方案

- 4 MHz – 10 GHz:cDASY V6.6 +和EX3DV4探棒進行SAR測量
- 10 – 110 GHz:5G軟件測量功率密度
- 兼容SAR標準
  - IEC 62209-1/2/3/U
  - IEEE 1528-2013
  - FCC / CE 法規
  - ICE 62232 (基站天線)
- 兼容功率密度標準IEC TR 63170
- FCC批准了兩種軟體的報告

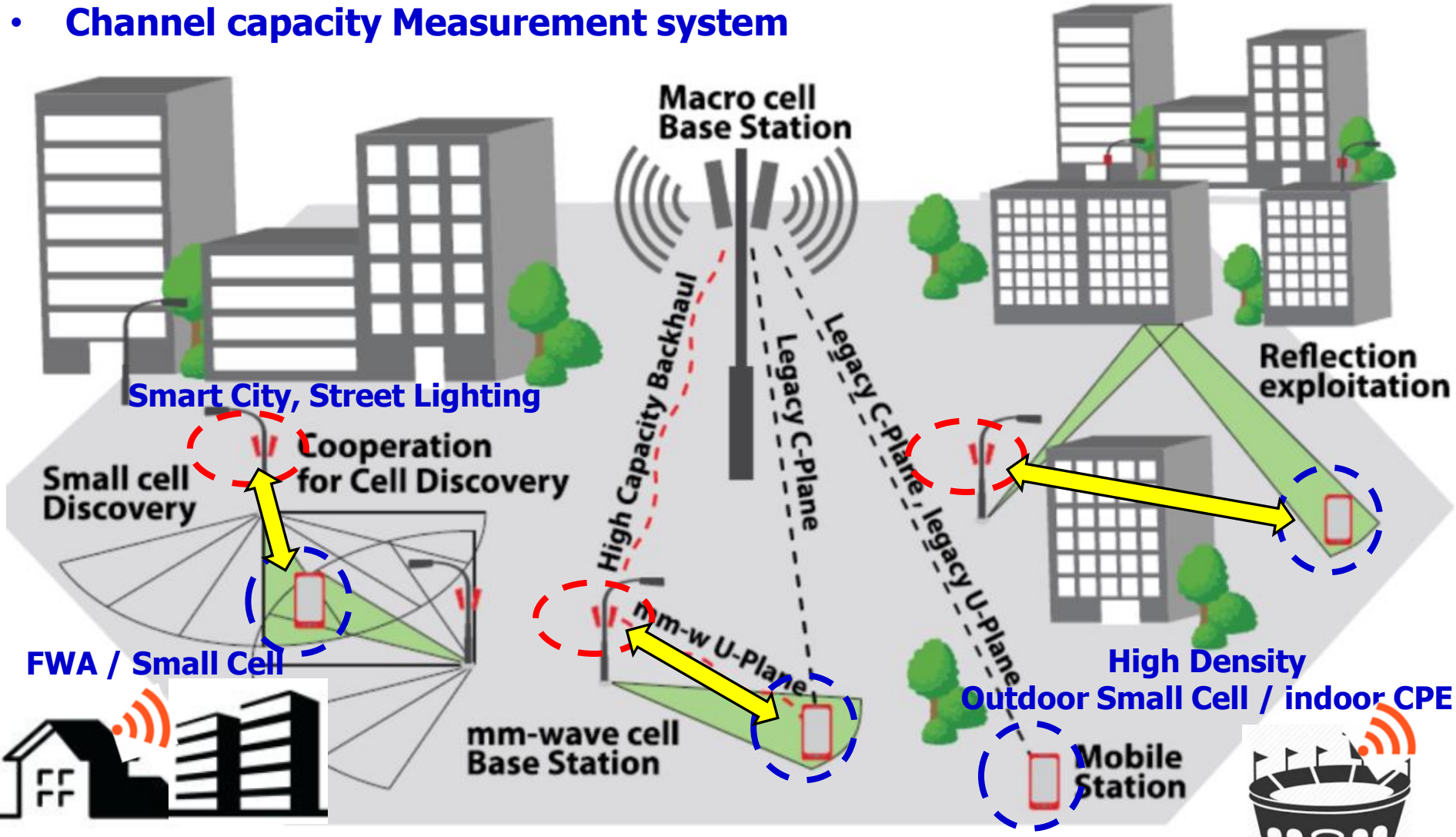


Comparison of DASY52 and DASY6

	DASY52	DASY6
Hard ware		
Phantom 框架	Phantom 與 手臂基座分開	phantom&基座一體框架,穩定度大幅提高
Phantom type	ELI , Sam twin	ELI, SAM twin, wrist , Facedown, Head stand , Twin-SAM Chin-20, BSTP & customized phantom
Mounting device platform	桌面滑動, 滑動不易易造成外觀磨損	滑軌設計, 易於移動製具
定位系統	三點定位	Mother scan : 細部的phantom完整掃描,後續量測不須再做定位
超寬頻組織液(600MHz ~ 6GHz)	可	可
Soft ware		
量測時間	1 channel 15~20 min	Area Scan 提升2~3倍時間/1channel Zoom Scan 提升30%時間/ 1channel
毫米波量測	不可	可, 第五代量測只能建置在DASY6系統
軟體運算	傳統DASY運算方式	結合cSAR介面提供快速量測運算方式
軟體組成	DASY52	DASY52 & cDASY6 並存
出報告	可	可
設備照片	 	 

Auden 28G & 39G mmWave Solution

- Scalable mmWave AAAM for Small Cell & CPE
- Dual Band Antenna Array for UE
- Channel capacity Measurement system



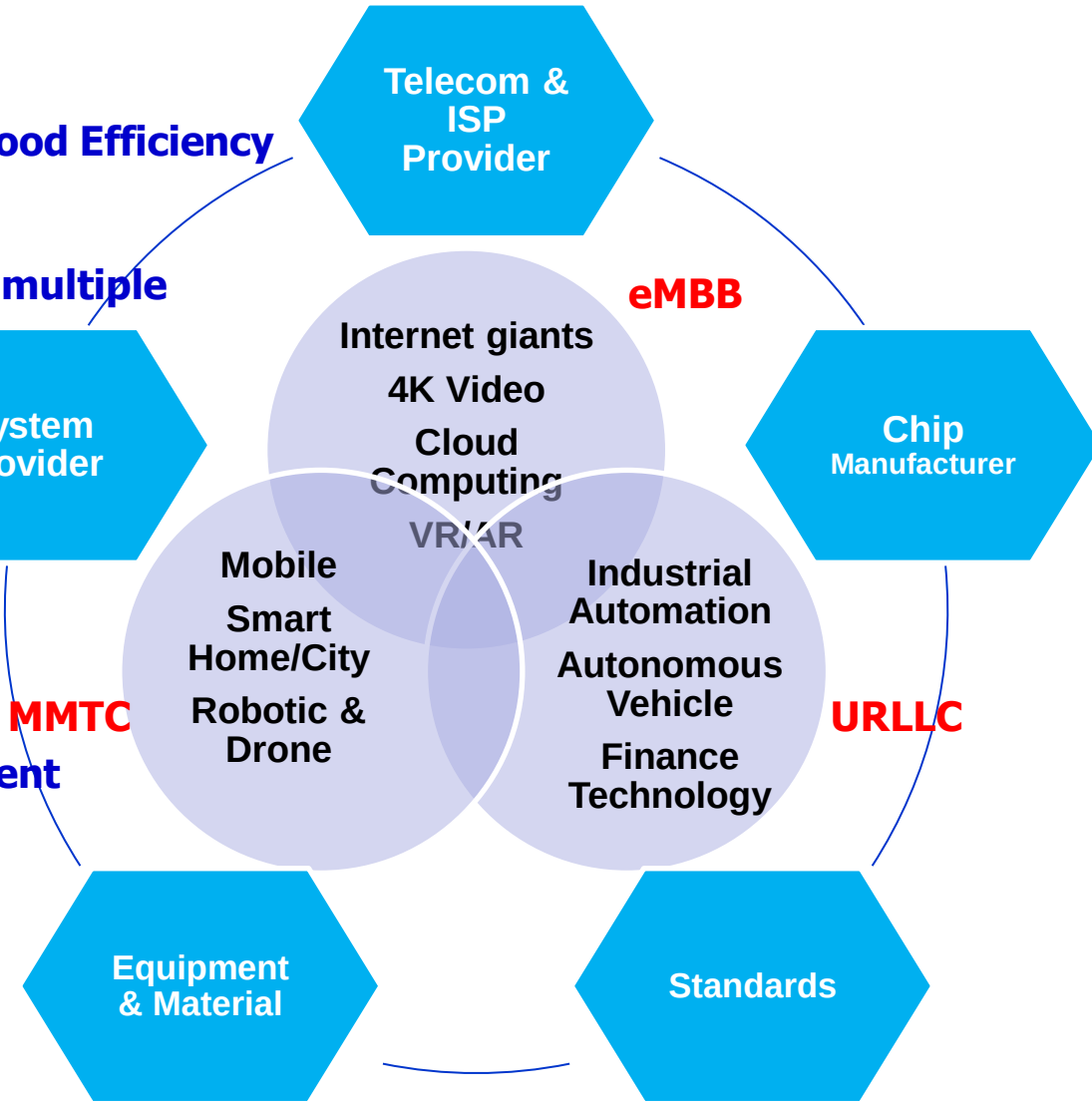
Auden 28G & 39G mmWave Solution for 5G Ecosystem Partner

Significant Advantages

- Controllable transmission Patten - Good Efficiency
- Anti-interference
- Save space for compact size,
- Scalable, customized design Support multiple usage scenarios

Challenges Overcome

- High Cost Cable and Connector
- High Lost
- Thermal and Power Consumption
- Our leading technology of measurement



Antenna, the last mile of wireless solutions and mobility

auden

mmWave solution provider