

Accelerating Design Validation for 5G New Radio

Ken Yong LEE

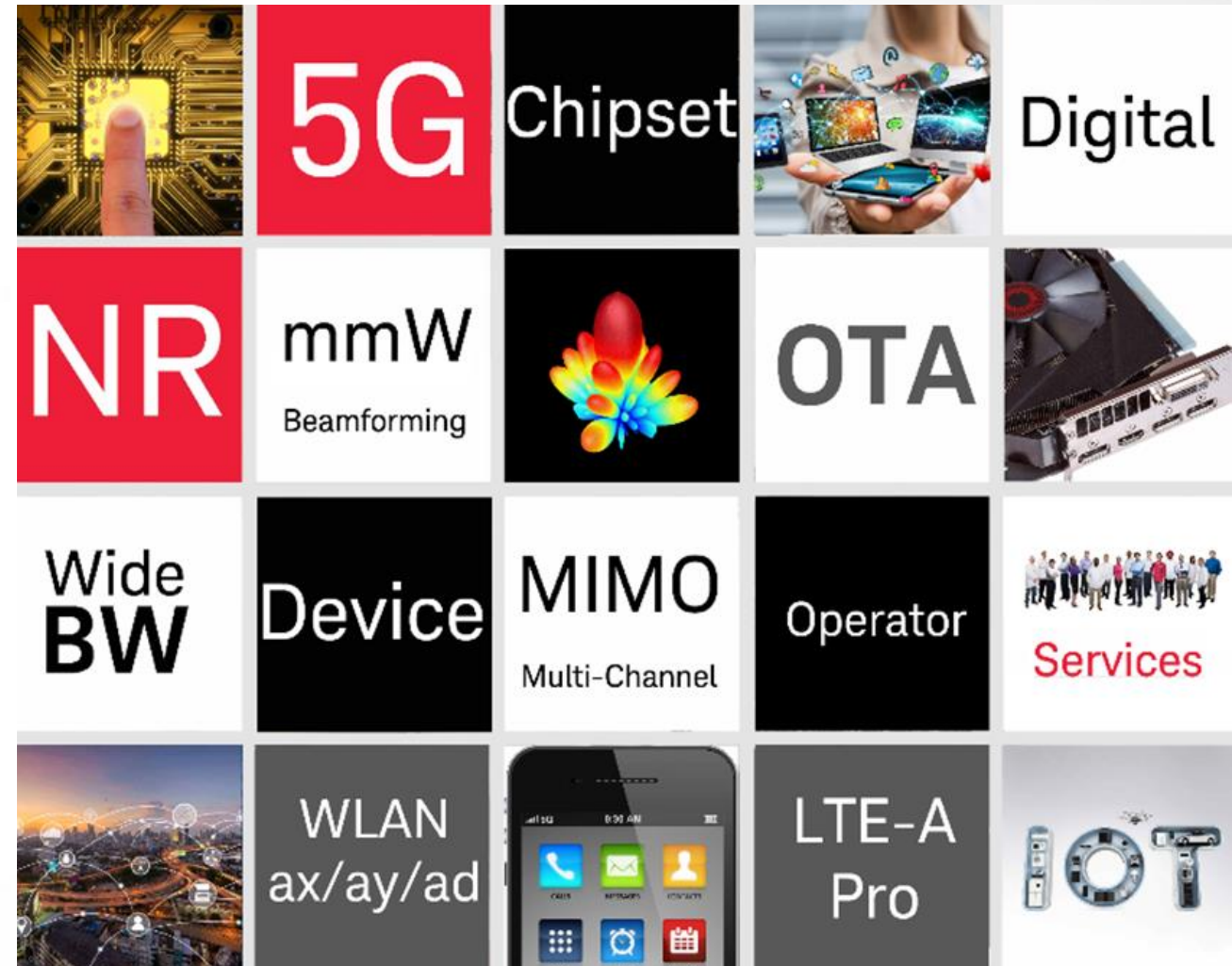
2018

Keysight Technologies



Agenda

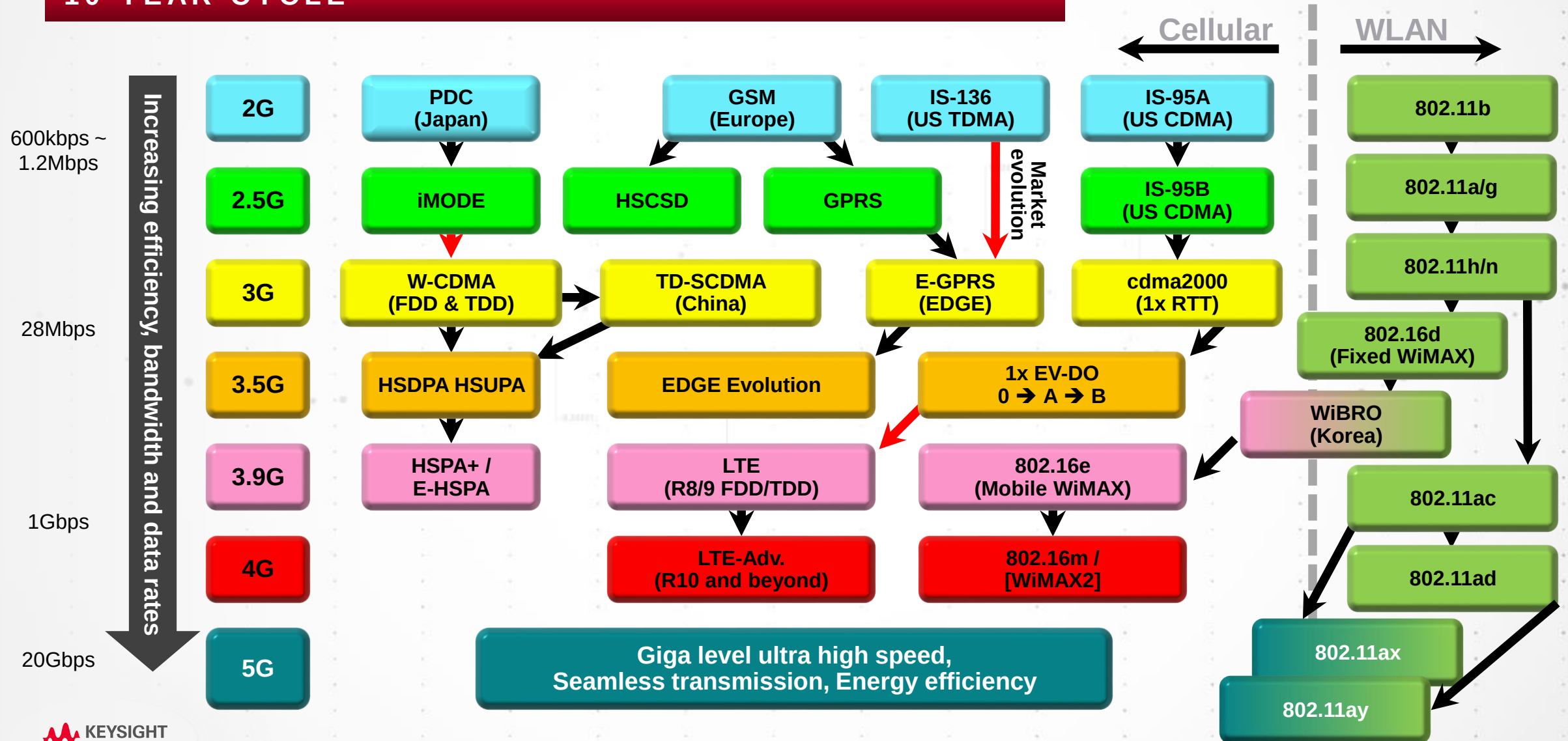
- 5G Market Trends
- 5G New Radio Specification
- Key Measurement Challenges
- Keysight 5G Solutions



5G Market Trends

Wireless Evolution: 1990 to 2020+

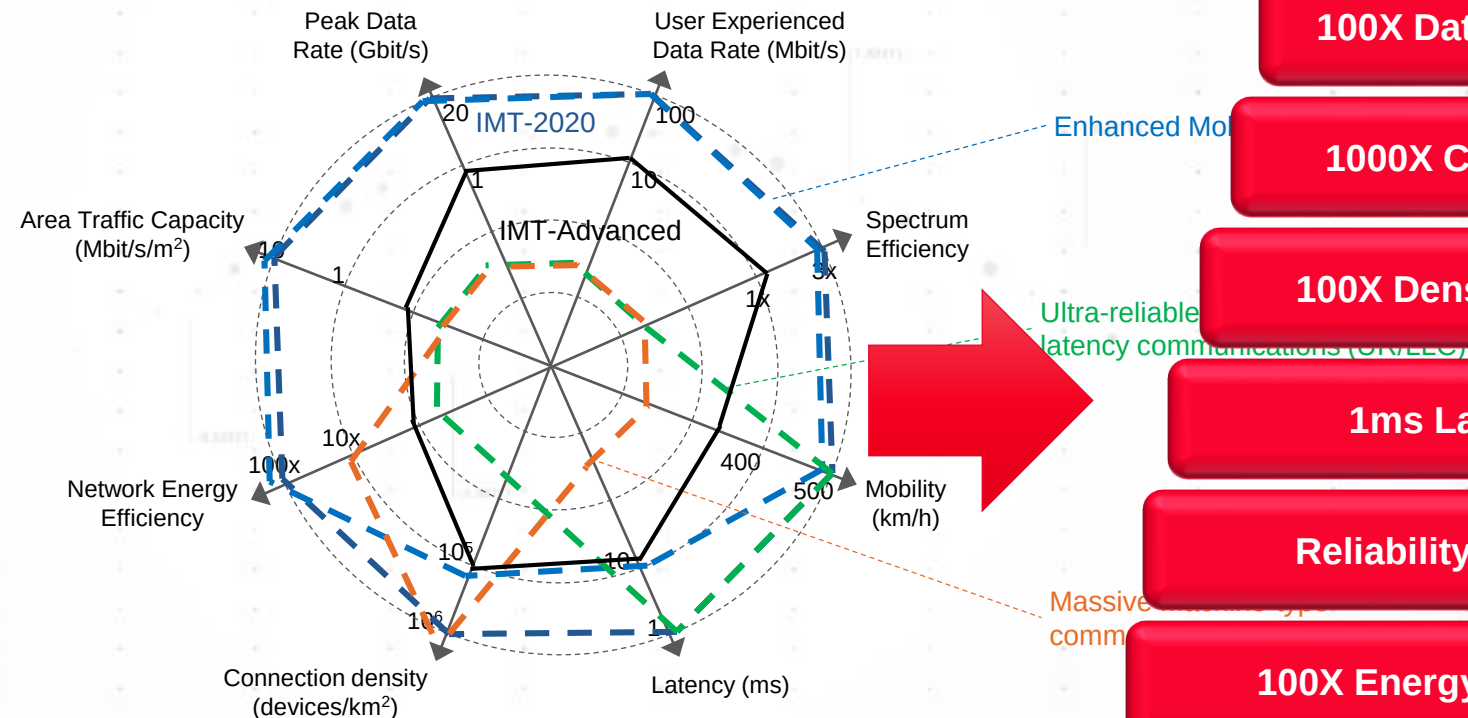
10-YEAR CYCLE



5G KPI and Goals

8 KEY PERFORMANCE INDICATOR AND AGGRESSIVE GOALS

Additional KPI for IMT-2020
Reliability
Average spectral efficiency
Mobility interruption time
Bandwidth
5 th percentile user spectral efficiency



100X Data Rates

1000X Capacity

100X Densification

1ms Latency

Reliability 99.999%

100X Energy Efficiency

5G Use Cases

USE CASES FROM ITU-R IMT-2020

Enhanced Mobile Broadband (eMBB)



- All data, all the time
- 2 billion people on social media
- 20 Gbps peak data rates

Ultra Reliability and Low Latency (URLLC)



- Ultra high-reliability
- Ultra-responsive
- <1 ms air interface latency
- 5 ms E2E latency

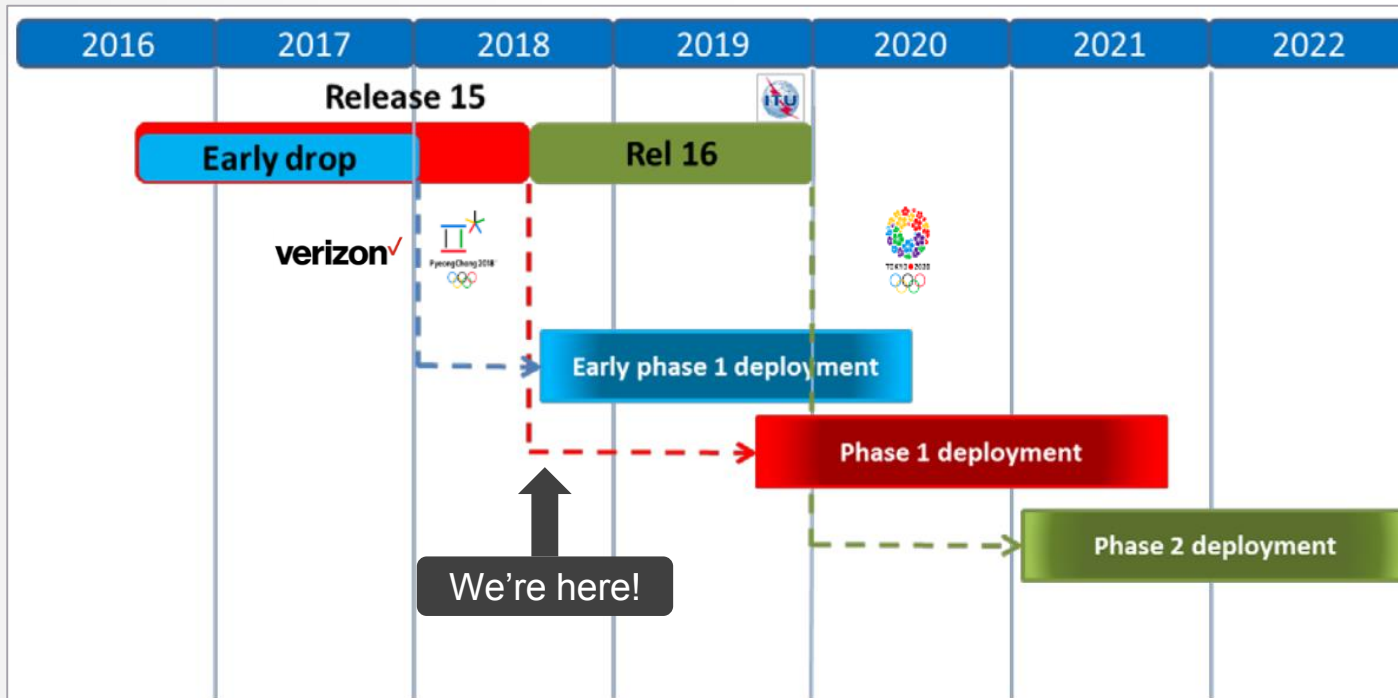
Massive Machine Type Communication (mMTC)



- 30 billion “things” connected
- Low cost, low energy
- 10^6 per km²
- 10-year battery life

3GPP NR Roadmap

ACCELERATED TIMELINES



Source: 3GPP activity towards IMT-2020
http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Documents/S02-1_3GPP%20IMT-2020.pdf

- “Early drop” of Release 15 (Dec 2017) to support emerging market needs
 - NR **Non Stand-Alone** (NSA)
 - Uses 4G Core Network (EPC)
 - LTE **eNB** always acts as a **master**
 - NR **gNB** always acts as a **slave**
- **Release 15 (aka Phase I, by June 2018)**
 - NR **Stand-Alone** (SA)
 - Uses 5G Core Network
 - First phase of expected deployments in 2020
- **Release 16 (aka Phase II, by Dec 2019)**

5G Ecosystems

INTEROPERABILITY IS KEY FOR GLOBAL DEPLOYMENT

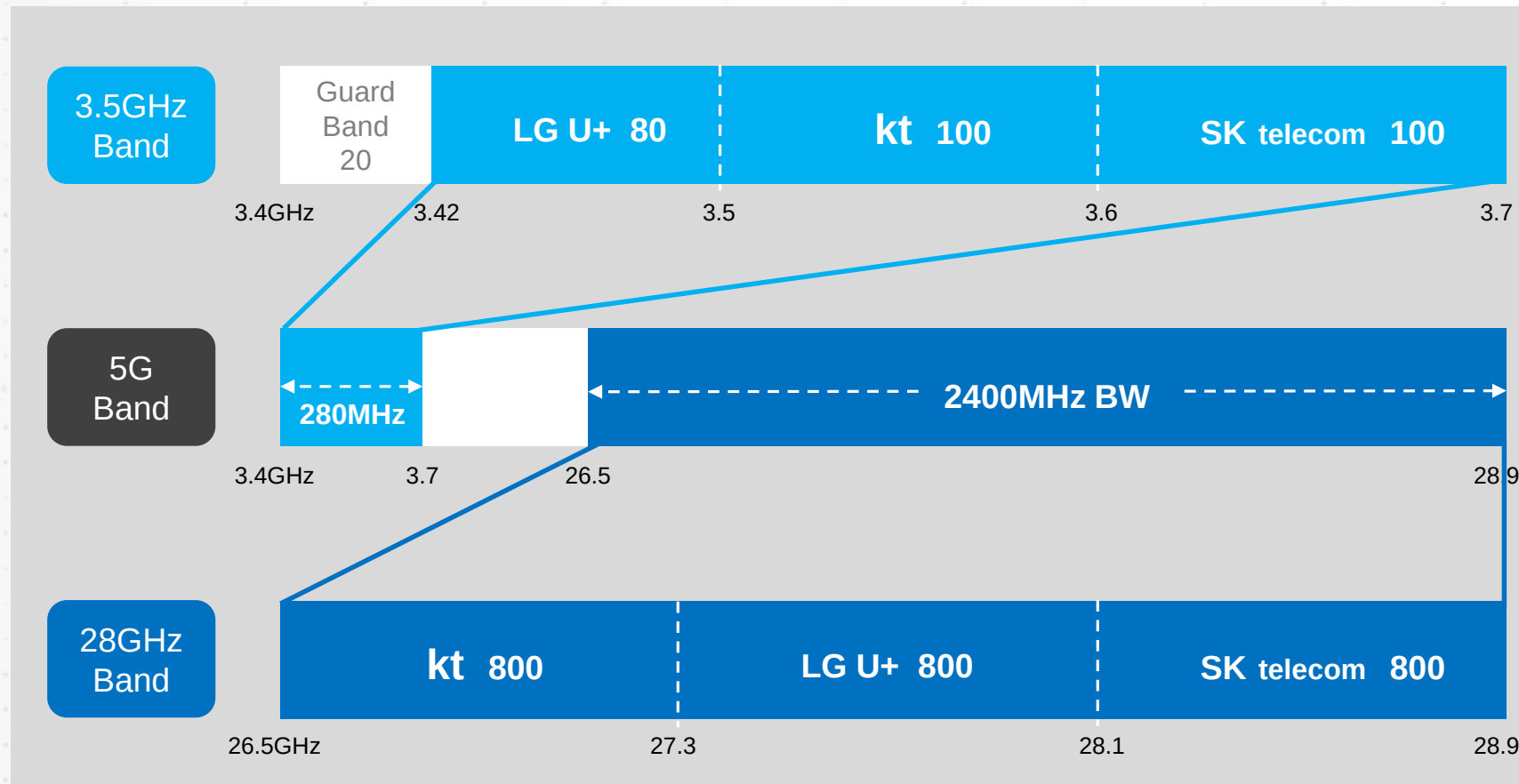
	Sub-6 GHz						mmWave			
Spectrum	0.6 GHz	2.5 GHz	3.4 – 3.7 GHz			4.4 – 4.9 GHz	ISM	28 GHz	39 GHz	
Geography									 	
Carrier	T-Mobile	Sprint	Orange Vodafone	KT SKT	China Mobile	NTT DocoMo KDDI Softbank		Verizon AT&T T-Mobile	KT SKT NTT DoCoMo KDDI Softbank	Verizon AT&T T-Mobile
Commercial Services	2018	2019	2020	2019	2020	2020		2018	2019 2020	2018

5G Frequency Allocations (eMBB)

5G Spectrum Availability < 6GHz										5G Spectrum Availability mmWave							
Region	New			Existing			BW	Total BW		Region	New	New		Existing		BW	Total BW
	Band	F _{LOW}	F _{HIGH}	Band	F _{LOW}	F _{HIGH}	MHz	MHz			Band	F _{LOW}	F _{HIGH}	F _{LOW}	F _{HIGH}	GHz	GHz
Korea		3400	3700				300	300		Korea	n257	26.50	29.50			3.00	3.00
Europe				n38	2570	2620	50	450		Europe	n258	24.25	27.50			3.25	7.85
		3400	3800				400				n259	31.80	33.40			1.60	
Japan				n41	2496	2690	194	1494					40.50	43.50			
		3600	4200				800		Japan			27.50	29.50			2.00	2.00
		4400	4900				500					24.25	24.45			0.20	5.55
US				n71	DL 617 UL 663	DL 652 UL 698	35	1329	US		24.75	25.25			0.50		
				n41	2496	2690	194				27.50	28.35			0.85		
		3100	3550				450			n260	37.00	38.60			1.60		
				48	3550	3700	150				38.60	40.00			1.40		
		3700	4200				500				47.20	48.20			1.00		
China				40	2300	2400	100	790		China	n258	24.25	27.50			3.25	8.75
				41B	2555	2655	100					37.00	42.50			5.50	
		3300	3400				100			Un-licensed		43.50	47.00			3.50	3.50 (China)
		3400	3600	42	3400	3600	200					64.00	71.00	57	64	7.00	7.00 (US)
		4800	5000				200										
										Un-licensed							
Un-licensed					5725	5875	150	150									

Korea 5G Frequency Bands Assigned

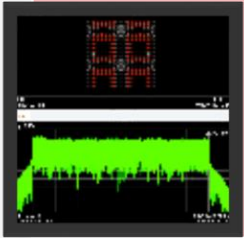
FREQUENCY AUCTION RESULT IN JUNE 2018



5G New Radio Specification

3GPP Release 15 NR Specification

RELEASE JUNE 2018



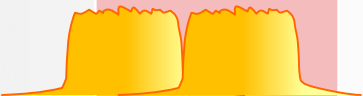
Waveform

CP-OFDM (UL/DL): QPSK, 16QAM, 64QAM and 256QAM

: targeted at high throughput scenarios

DFT-s-OFDM (UL): $\pi/2$ -BPSK, 16QAM, 64QAM and 256QAM

: targeted at power limited scenarios



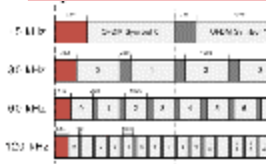
New Spectrum

Sub-6 GHz up to 52.6 GHz

Up to 400 MHz Bandwidth

Up to 16 Component Carriers

Bandwidth Parts enables multiplexing of Services



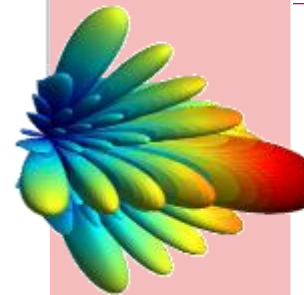
Flexible Numerology

15 kHz*2ⁿ Sub-carrier spacing

1ms subframe

10 ms Frame

Extended Cyclic Prefix



Massive MIMO and Beam Steering

Up to 8x8 MIMO

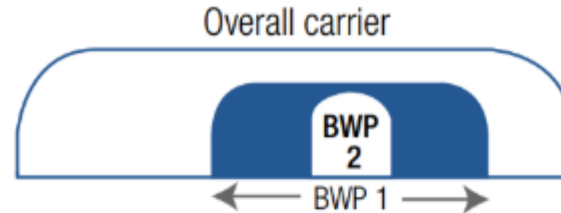
Much greater # antennas on gNB than UE

Beam sweeping

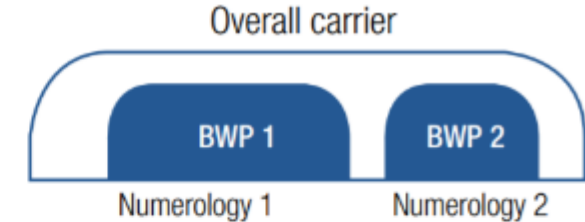
Bandwidth Parts

MULTIPLEXING OF SERVICES ON A SINGLE CARRIER

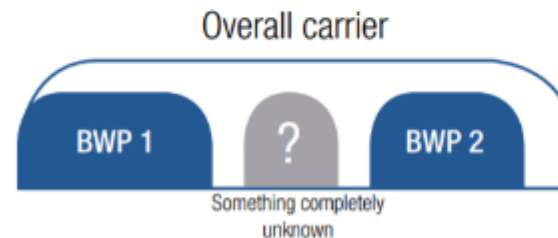
- Carriers sub-divided bandwidth to support **multiple services**
- Each BWP has its own numerology
- Can support 4G, 5G and Wi-Fi
- Introduces new issues with carrier interference



Inserts a reduced device energy consumption for each separate user through using smaller part of the overall carrier.



Overall carrier contains two non-contiguous bandwidth parts with different numerologies.



Non-contiguous spectrum that can have an unknown service inserted.

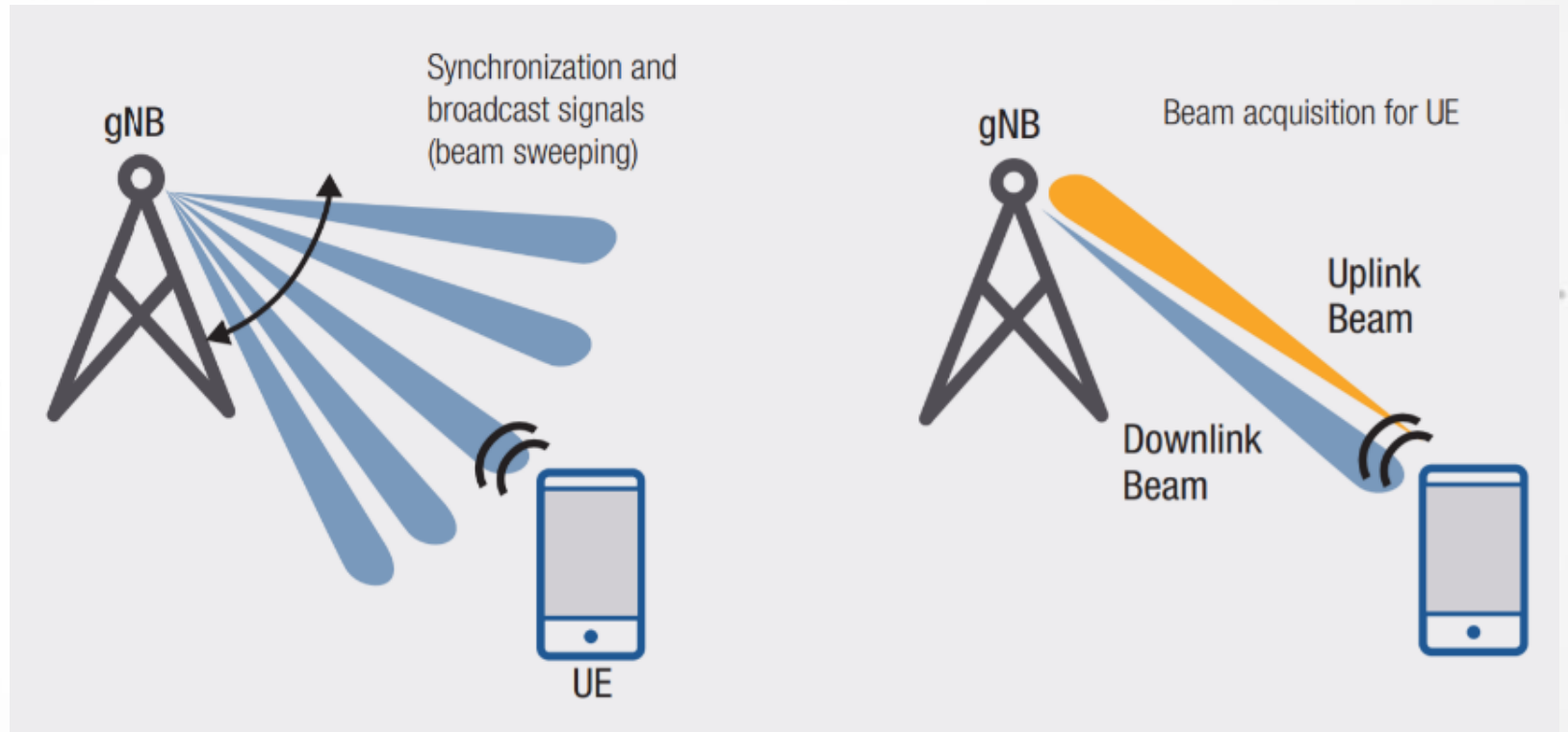


Open bandwidth to support something new or something not yet defined.

Initial Access Procedures

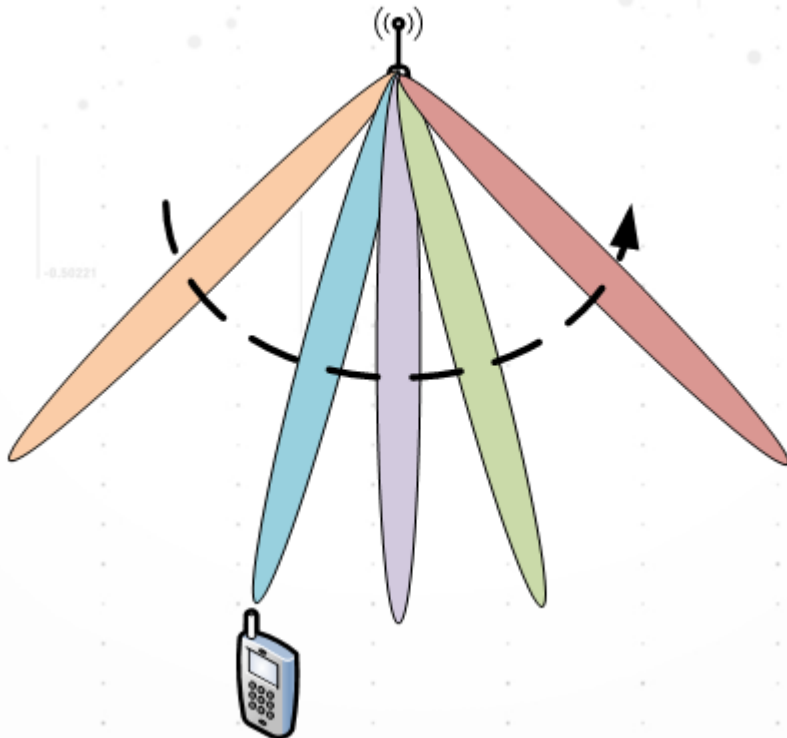
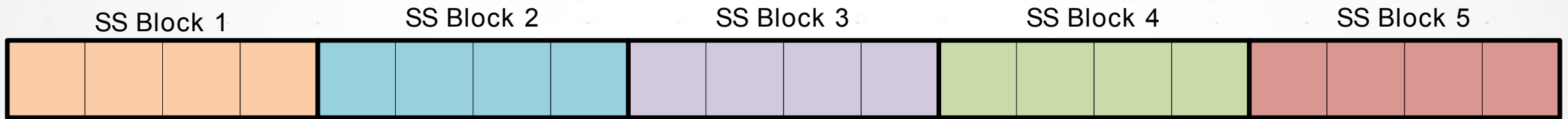
HOW DOES THE UE IDENTIFY THE BEST BEAM

- Beam sweeping transmission in DL
- Beam sweeping reception to identify strongest beam
- UE identifies the best beam

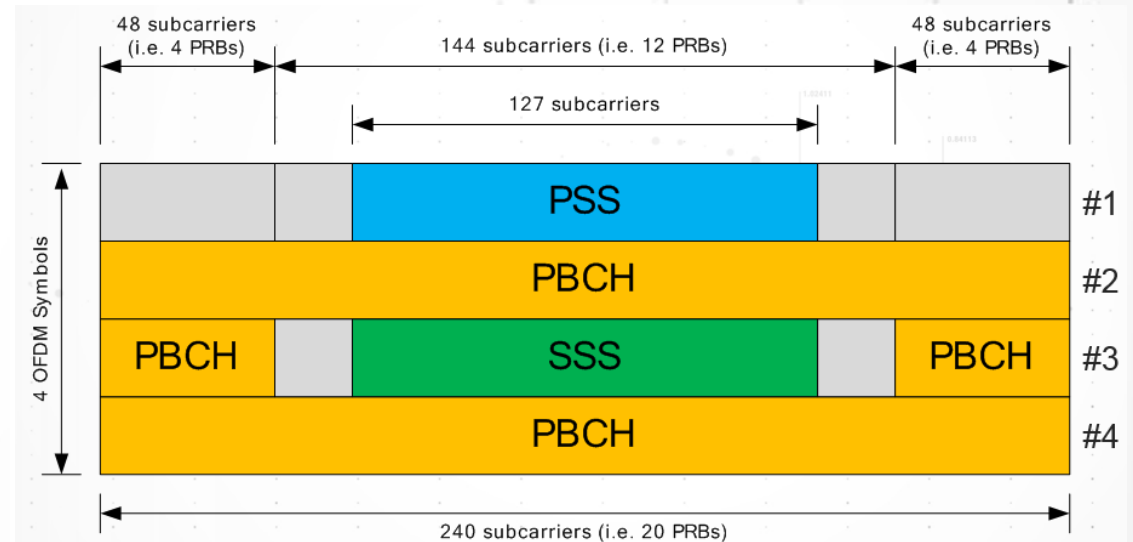


Initial Access Procedures (cont.)

HOW DOES THE UE IDENTIFY THE BEST BEAM



SSB: Synchronization Signal Block



Key Measurement Challenges and Keysight 5G Solutions

Increasing Frequencies: Challenge and Opportunity

Free-space Path Loss

$$Power_{RX} = Power_{TX} + AntGain_{RX} + AntGain_{TX} - \underset{\text{Distance}}{20\log_{10}(4\pi R)} - \underset{\text{Frequency}}{20\log_{10}\left(\frac{f}{c}\right)}$$

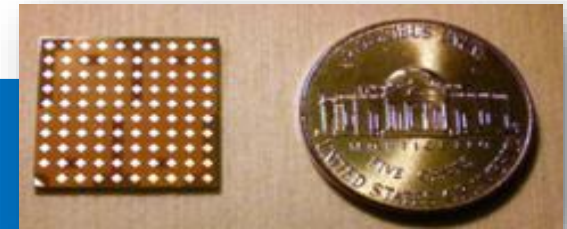
- In words. For a given distance, as the frequency increases, the received power will drop unless offset by an increase in some combination of transmit power, transmit antenna gain, and receive antenna gain.
- The decrease in power as a function of frequency is caused by the decrease in the antenna aperture.

The Good News:

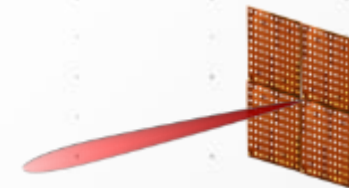
- Higher frequencies → wider bandwidths: faster (5G goal)
- Improve performance in dense crowds (5G goal)
- Antennas elements are smaller and enables massive MIMO/BF

Challenges:

- Greater path loss due to Higher Frequency
- Integrated Noise Power due to Wide Bandwidth
- OTA measurement (No connector RF Access)
- Increased complexity with more antenna elements



IBM 94 GHz Array
Can Tile for Larger Arrays
IBM Press Release, June 2013



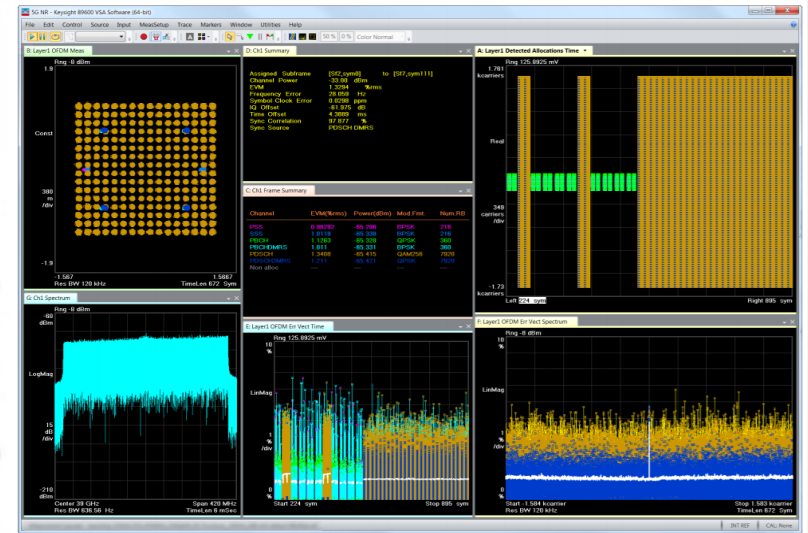
Case Study: Verify Performance on Antenna

Challenge: 1 % EVM on 800 MHz 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?

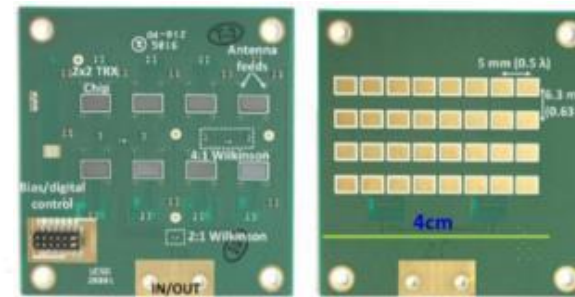
Solution: 5G Flexible Testbed

- 5G compliant waveform generation and analysis
- Signal optimizer calibration
- Best-in-class EVM performance with 1%
- Flexible configurations can scale as the standards evolve

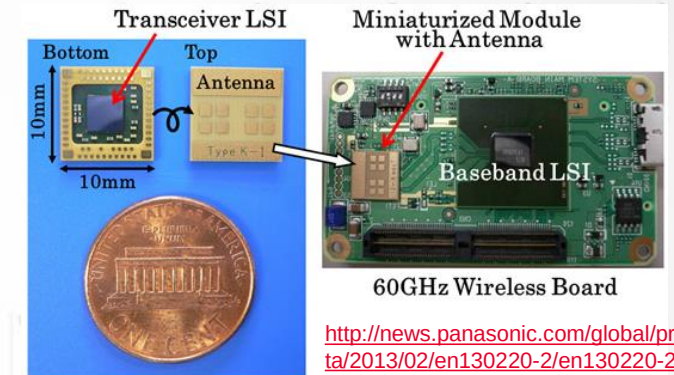


Challenge: Life Beyond Connectors

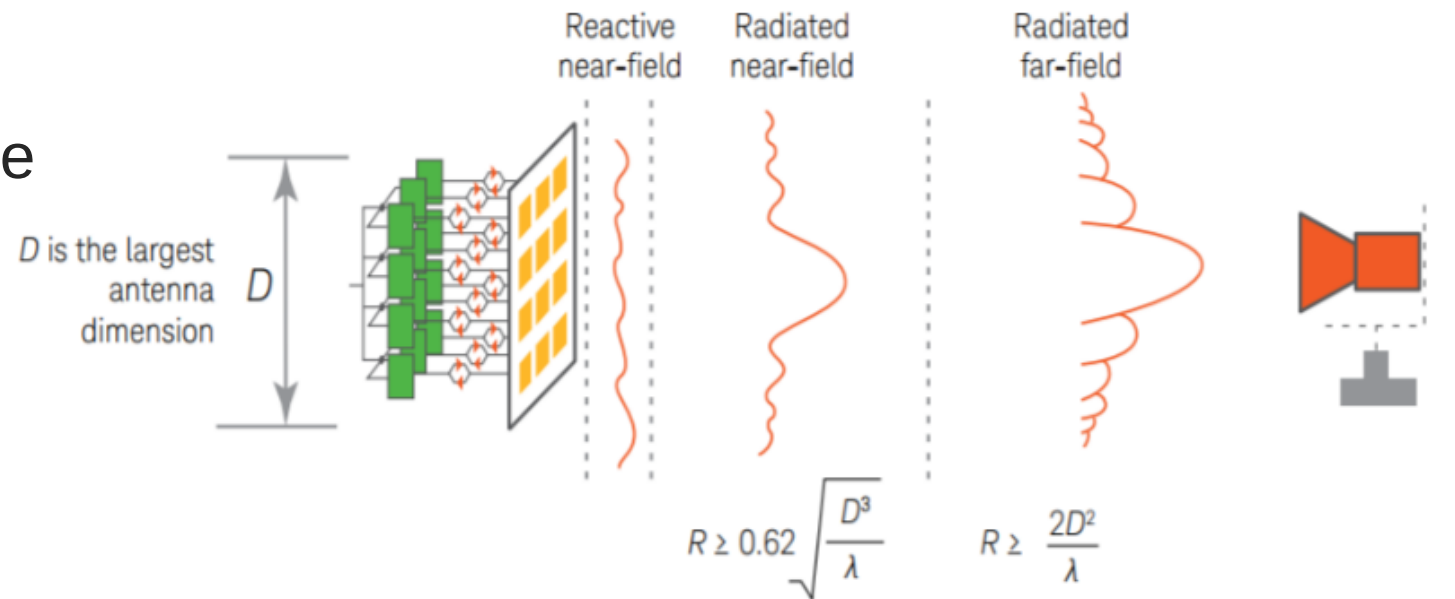
- Greater number of antenna elements with tight integration in ICs, packaging, Antennas
- mmWave components are very small for probing or conducted test
- mmWave far-field distance results in large chambers and excessive path loss



28 GHz RFIC

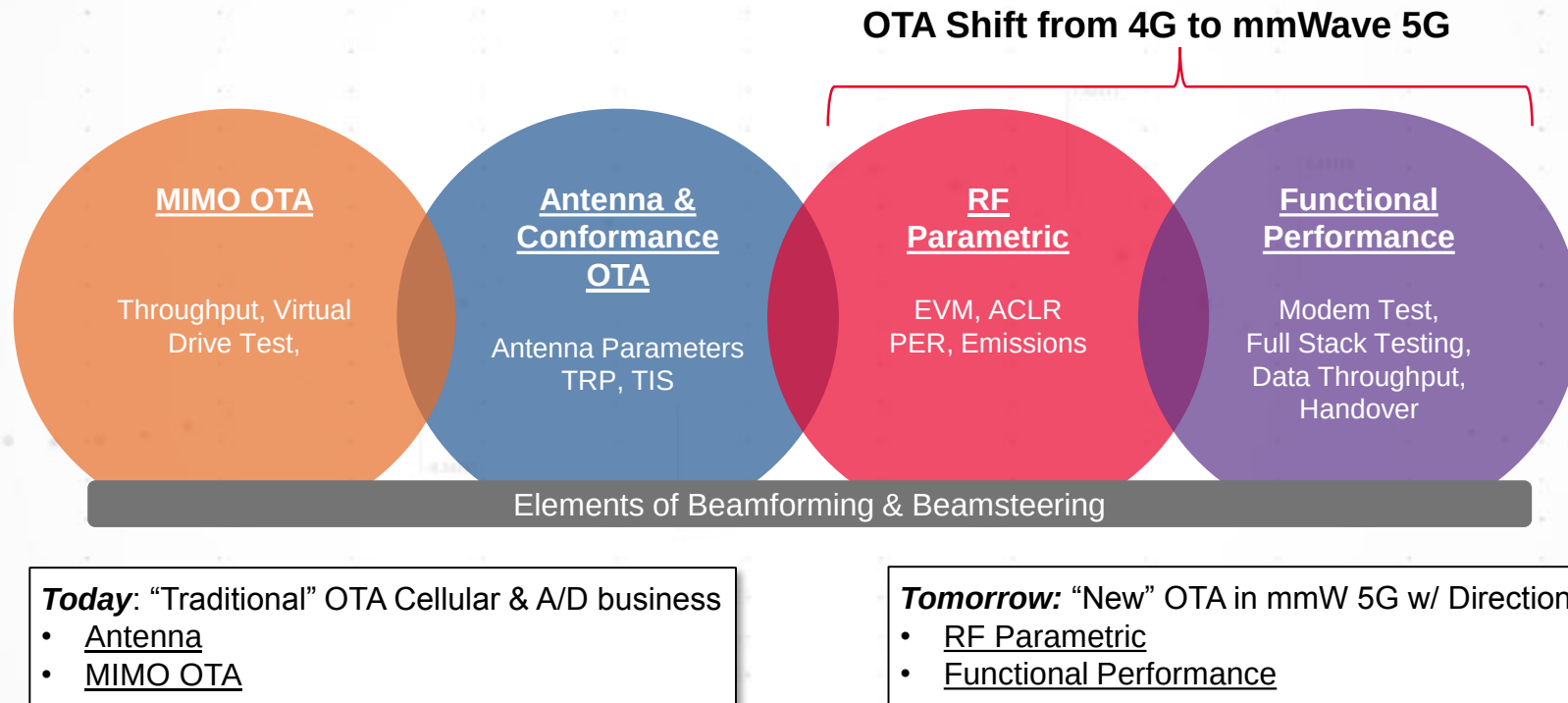


Integrated RFIC



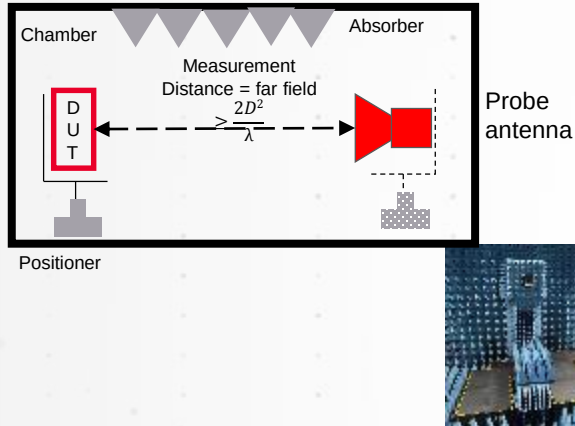
Testing OTA: The Cable is Gone

COMMERCIAL MMWAVE BRING CHANGING PARADIGM IN TEST



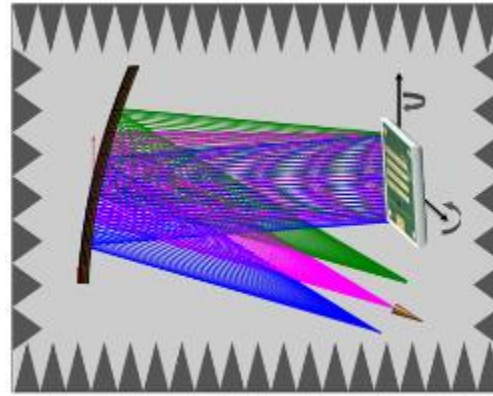
OTA Test Methods

Direct Far Field



- ✓ Antenna beam pattern characterization
- ✓ Beamforming/beamsteering validation
- ✓ RF parametric tests (if S/N high enough)
- ✗ Subject to higher path loss
- ✗ Can be very large at mmWave frequencies

Indirect Far Field



- ✓ Antenna beam pattern characterization
- ✓ Beamforming/beamsteering validation
- ✓ RF parametric tests
- ✓ **Small footprint, Lowest path loss**
- ✗ Rx spatial field generation not defined

Near-Field Scanning



Image courtesy of NSI-MI

- ✓ Antenna beam pattern characterization
- ✓ Beamforming/beamsteering validation
- ✓ RF parametric tests
- ✗ Only on-axis blocking sources possible

Indirect Far Field OTA Test

COMPACT ANTENNA TEST RANGE (CATR)

3GPP
Approved

- The IFF test method based on **compact antenna test range** (CATR) uses a parabolic **reflector** to collimate the signals transmitted by the feed antenna.
- Creates a far-field test environment in a **much shorter distance** and with less path loss than the DFF method.
- Verizon OTA testing solution using CATR



CATR APPROVED - 3GPP TR 38.810

5.2.3 Indirect far field (IFF) method 1

The IFF method 1 creates the far field environment using a transformation with a parabolic reflector. This is also known as the compact antenna test range (CATR). Refer to Annex E for additional information.

5.2.3.1 Description

The IFF measurement setup of UE RF characteristics for $f > 6$ GHz is capable of centre and off centre of beam measurements and is shown in Figure 5.2.3.1-1 below.

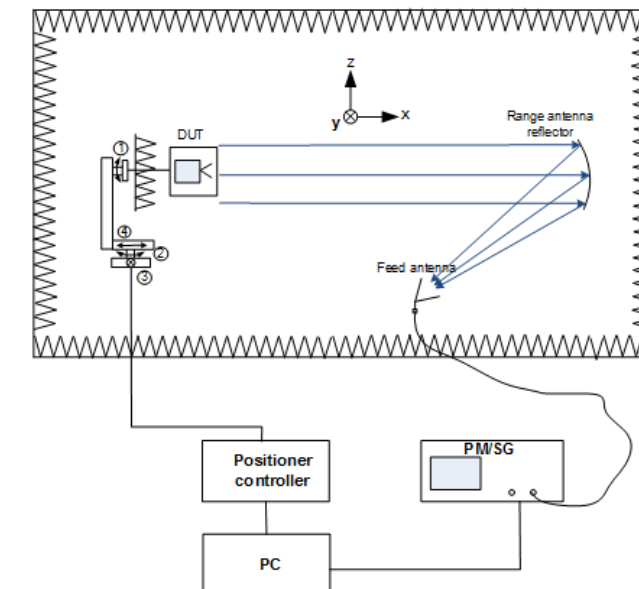


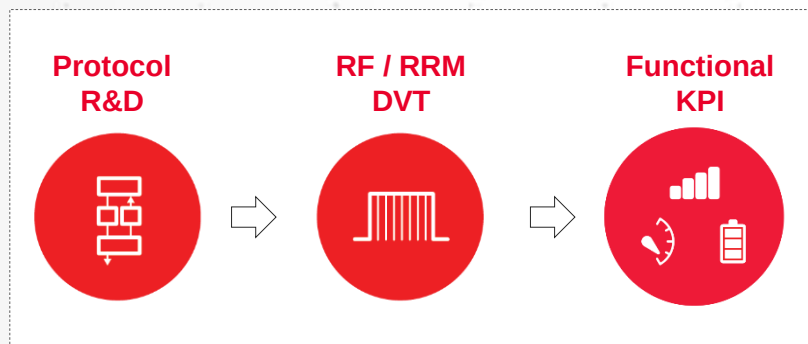
Figure 5.2.3.1-1: IFF method 1 (CATR) measurement setup of UE RF characteristic

**THE STREET'S EXCLUSIVE
LOOK INSIDE
VERIZON'S 5G TESTING LAB**

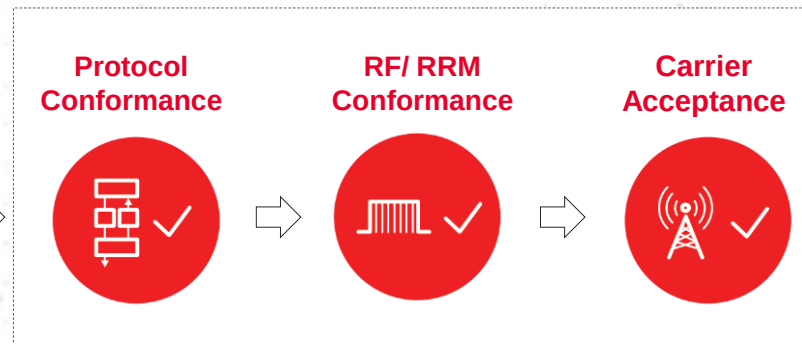
5G Device End-to-End Solutions

TARGETING CHIPSET AND DEVICE WORKFLOW

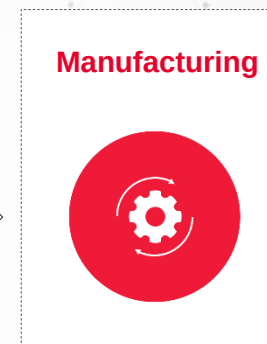
5G Interactive R&D Solutions



5G Device Acceptance Solutions



5G MFG Solutions



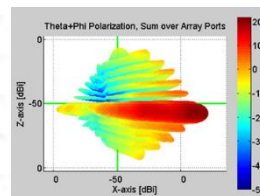
Keysight 1st Solutions across the entire device workflow



Network Emulator



Channel Emulator



mmWave OTA Solutions



Non-Signaling Solution

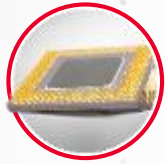
Seamless RF and Protocol Solution
Accumulates engineering know-how

Embodies ecosystem insights
Spans ecosystem with continuous releases

... ACCELERATE TOWARDS NEW 5G DEVICES

Keysight Provides Insight Across the Entire Ecosystem

■ Keysight Classic ■ Ixia ■ Anite



COMPONENTS &
CHIPSETS



DEVICES



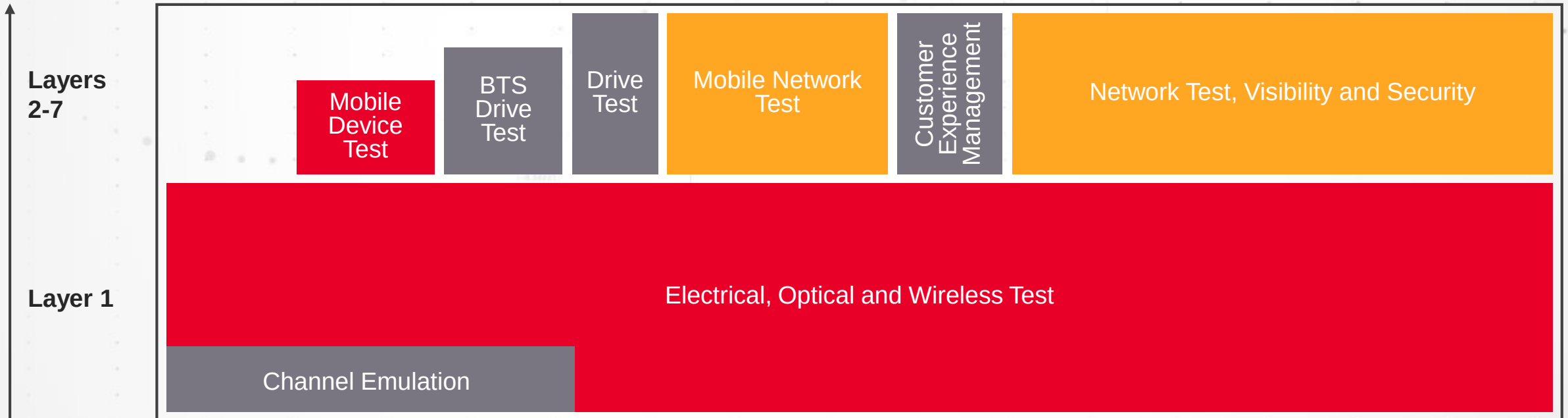
BASE STATIONS



HYPERSCALE AND
DATA CENTERS

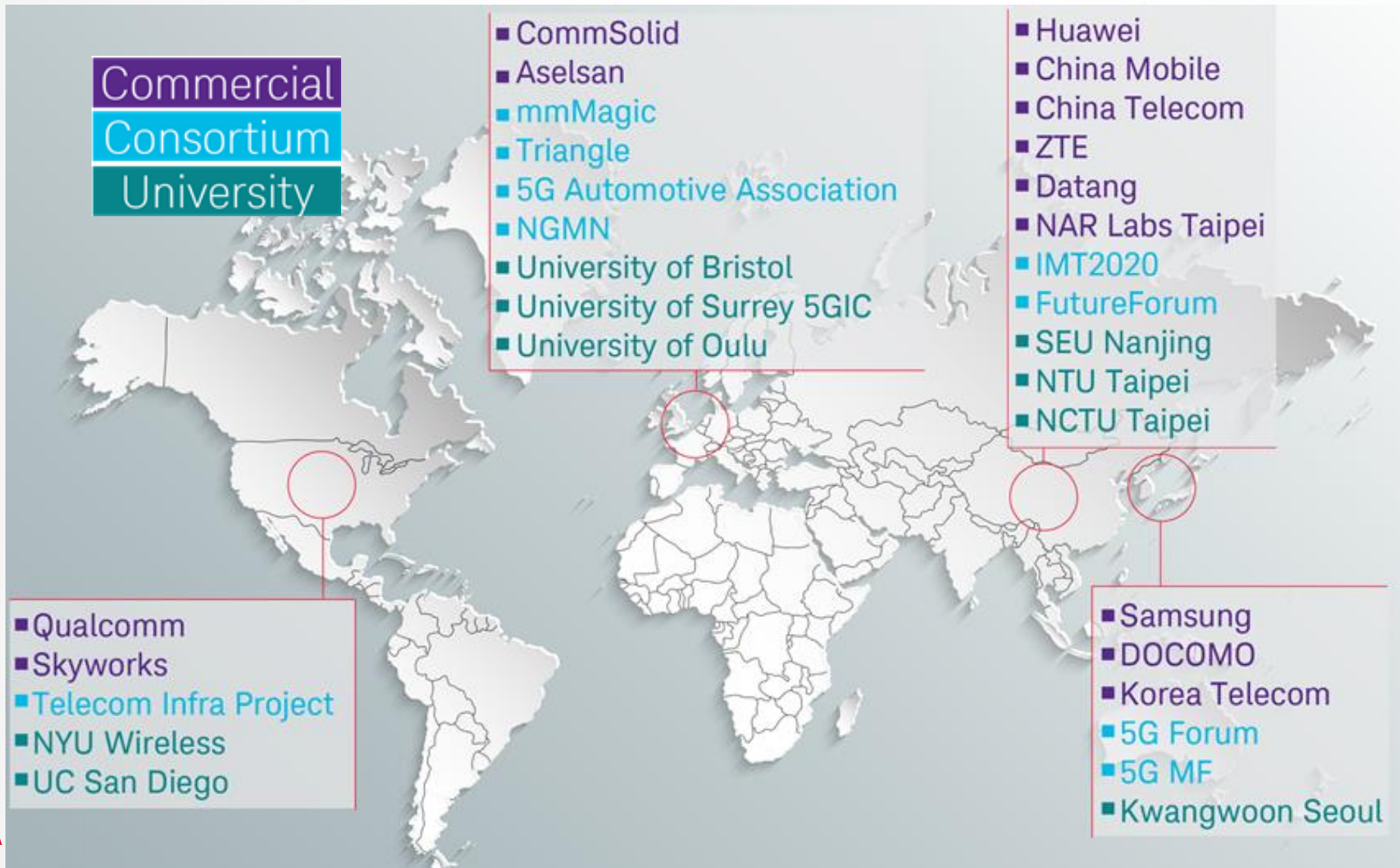


ENTERPRISE



Transforming Your 5G Ideas into Reality

KEYSIGHT 5G PUBLIC COLLABORATIONS



China Mobile

Feb'15~

Korea Telecom

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NTT Docomo

Jul'15~

Huawei

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Samsung

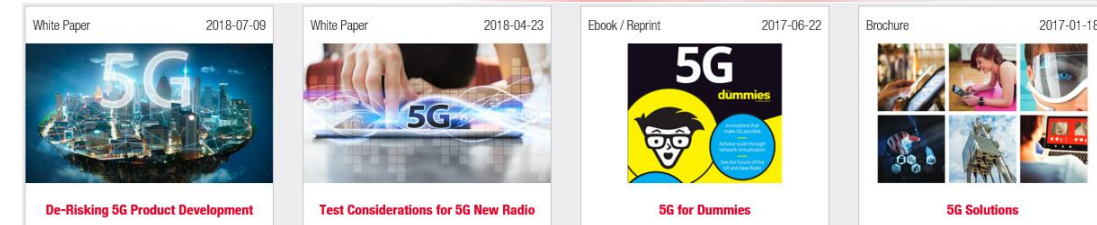
Feb'17~

Qualcomm

Jun'17~



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www.keysight.com/find/5G



Thank You!

[Download 5G Poster Here!](#)

Seven Things You Need To Know About 5G New Radio

5G New Radio (NR), the next-generation wireless standard, requires new technology and performance improvements that will challenge the way you design, test, and optimize.

The NR air interface can work in either standalone or non-standalone mode when an existing 4G network is used for control planes. Standalone mode and non-standalone specifications are planned for 2020.

NR is poised to meet three emerging use cases: enhanced mobile broadband (eMBB), ultra-reliable low latency communications (uRLLC), and massive machine type communications (mMTC). The first 5G specification (3GPP Release 15) focuses on eMBB with throughput and spectral efficiency for eMBB. It also sets a foundation for support of uRLLC and mMTC in later releases with an enhanced air interface.

1 New Spectrum and Bandwidth Impacts Signal Quality

To enable higher data throughput for applications like streaming 4K video and to allow for more cellular capacity, 5G NR enables new frequency ranges up to 100 GHz. Peak 70, adding up to 100 GHz for 5G NR frequencies, along with a more complex bandwidth configuration, including a wider range of channel bandwidths, will impact the way you design, test, and optimize.

Band	Frequency Range	Channel Bandwidth
n26	41.0 – 46.0 GHz and 66.0 – 70.0 GHz	For commercial deployment in 2020, 5G NR channel bandwidths are 100, 200, 400, 800, and 1600 MHz
n257	24.25 – 29.5 GHz	For commercial deployment in 2020, 5G NR channel bandwidths are 100, 200, 400, 800, and 1600 MHz
n261	27.5 – 28.35 GHz	For commercial deployment in 2020, 5G NR channel bandwidths are 100, 200, 400, 800, and 1600 MHz
n260	24.25 – 27.5 GHz	For commercial deployment in 2020, 5G NR channel bandwidths are 100, 200, 400, 800, and 1600 MHz
n262	24.25 – 27.5 GHz	For commercial deployment in 2020, 5G NR channel bandwidths are 100, 200, 400, 800, and 1600 MHz

2 Advanced Beamforming Techniques Requires System-Level Design

5G NR uses advanced beamforming to ensure the path loss is as low as possible. Beamforming requires the system to be designed at the system level, taking into account the physical layer, the network layer, and the application layer. This requires a system-level design approach that considers the entire system, from the physical layer to the application layer.

3 Waveform and Scalable Numerology Means PNPs Challenges

The 5G NR standard uses OFDM with flexible numerology. This allows for a wide range of subcarrier spacings, from 15 kHz to 240 kHz. This flexibility is essential for supporting a wide range of use cases, from eMBB to uRLLC to mMTC. However, this flexibility also introduces challenges for network planning and optimization, particularly in terms of power spectral density (PSD) and interference management.

4 Millimeter Wave Frequencies Require OTA Test

At millimeter wave frequencies, the path loss is significantly higher than at lower frequencies. This requires the use of high-gain antennas and precise beamforming. Over-the-air (OTA) testing is essential for validating the performance of 5G NR systems at these frequencies, as traditional anechoic chamber testing may not be sufficient.

5 Multi-Waveform Coexistence Presents Interference Issues

5G NR will coexist with other wireless systems, including 4G LTE, Wi-Fi, and various IoT protocols. This coexistence introduces complex interference issues that must be carefully managed to ensure the performance of all systems. Network planning and optimization must take into account the presence of these other systems.

6 Network Changes Are Inevitable

5G NR will require significant changes to the network architecture, including the introduction of new network functions and the migration of existing functions to the cloud. These changes will impact the way networks are designed, deployed, and operated.

7 5G Requires Innovation

5G is a transformative technology that will enable a wide range of new applications and services. To fully realize the potential of 5G, there must be continued innovation in both the technology and the business models that support it.