Accelerating Design Validation for 5G New Radio

Ken Yong LEE

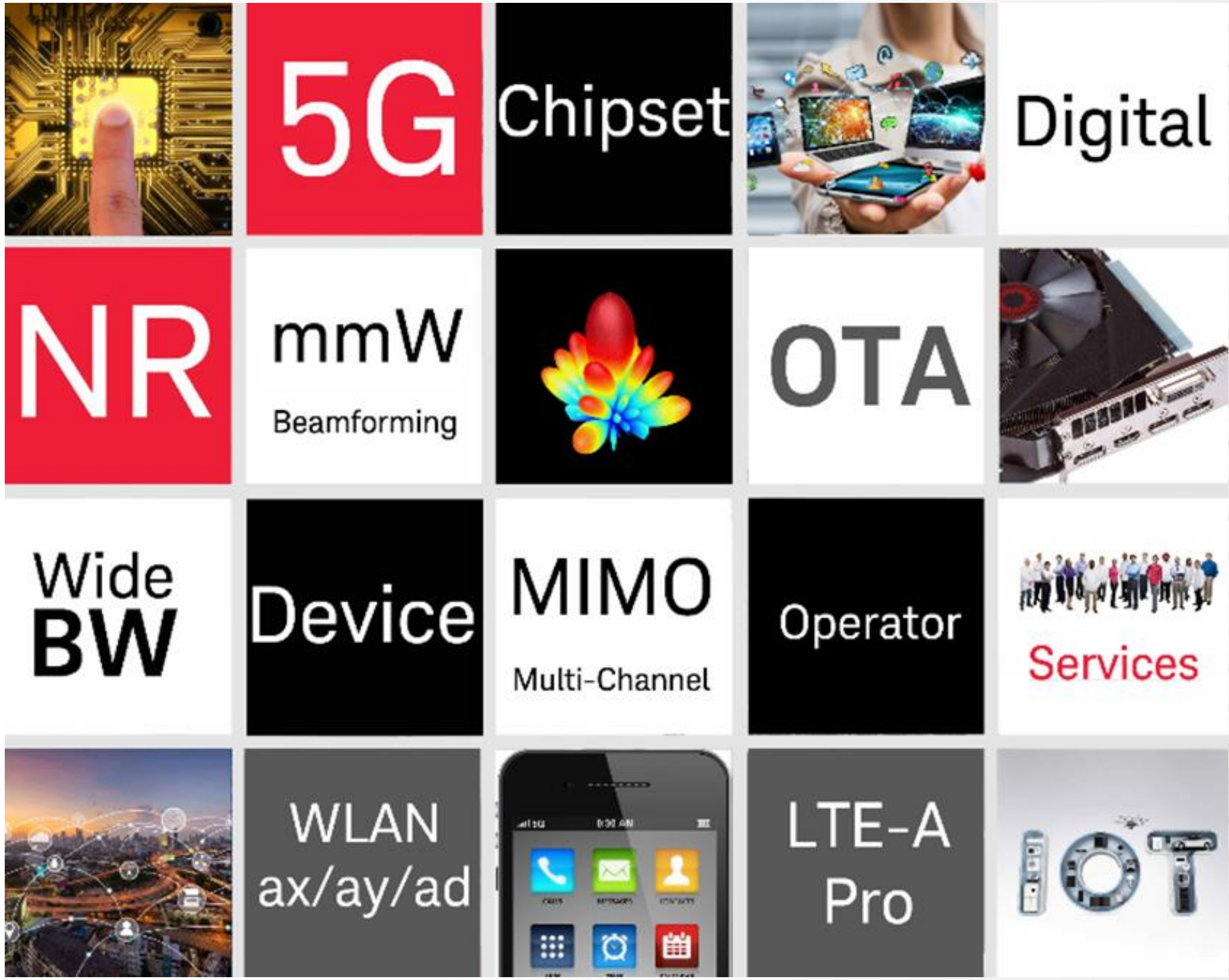
2018

Keysight Technologies

KEYSIGHT
TECHNOLOGIES

Agenda

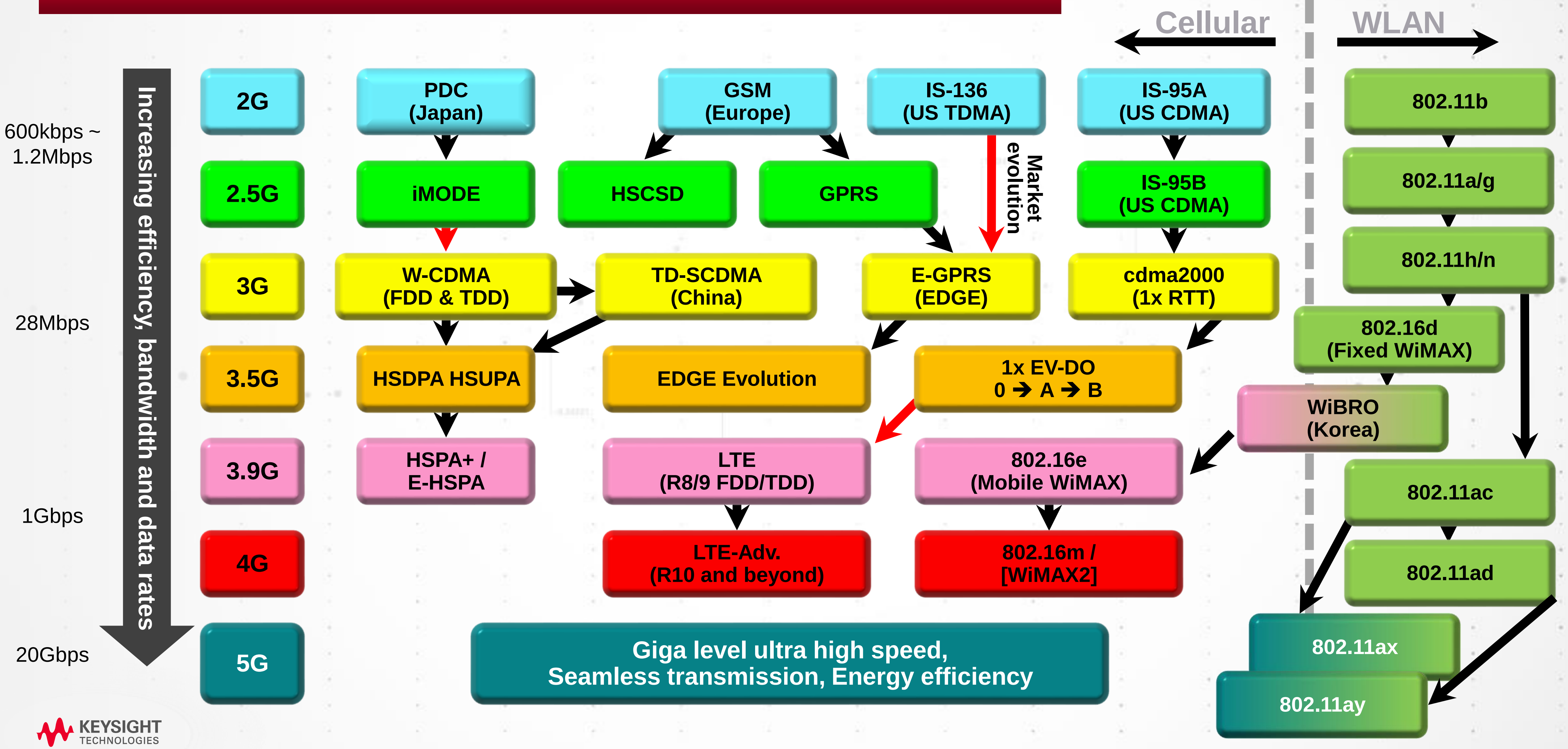
- 5G Market Trends
- 5G New Radio Specification
- Key Measurement Challenges
- Keysight 5G Solutions



5G Market Trends

Wireless Evolution: 1990 to 2020+

10-YEAR CYCLE

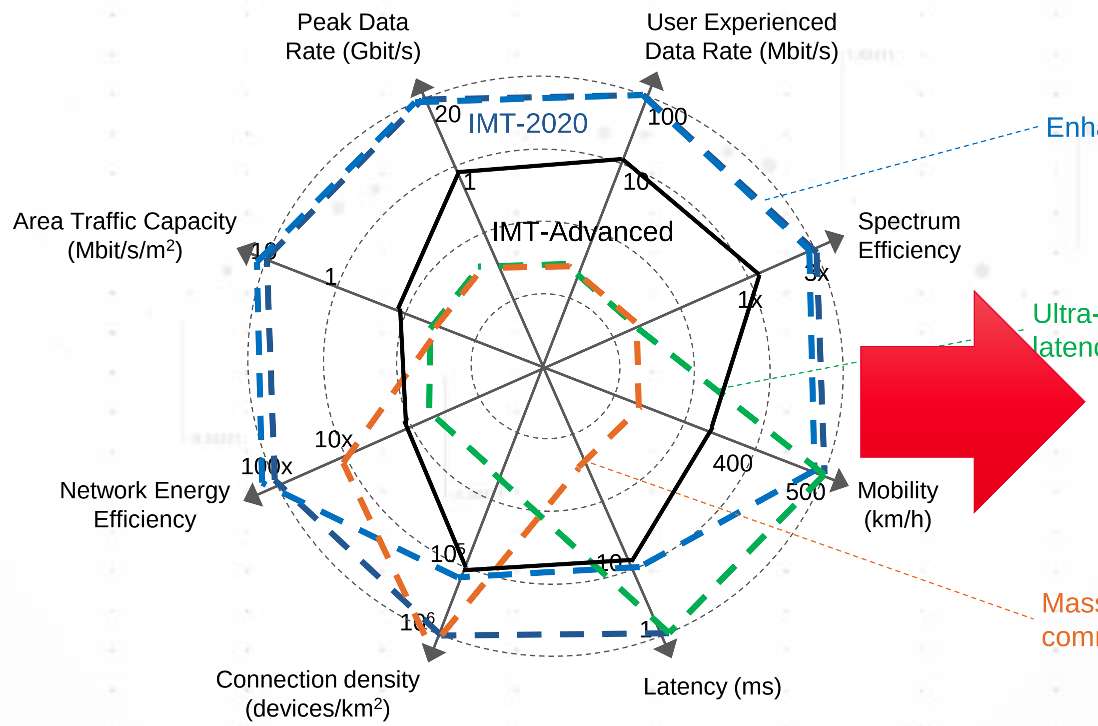


KEYSIGHT TECHNOLOGIES

5G KPI and Goals

8 KEY PERFORMANCE INDICATOR AND AGGRESSIVE GOALS

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

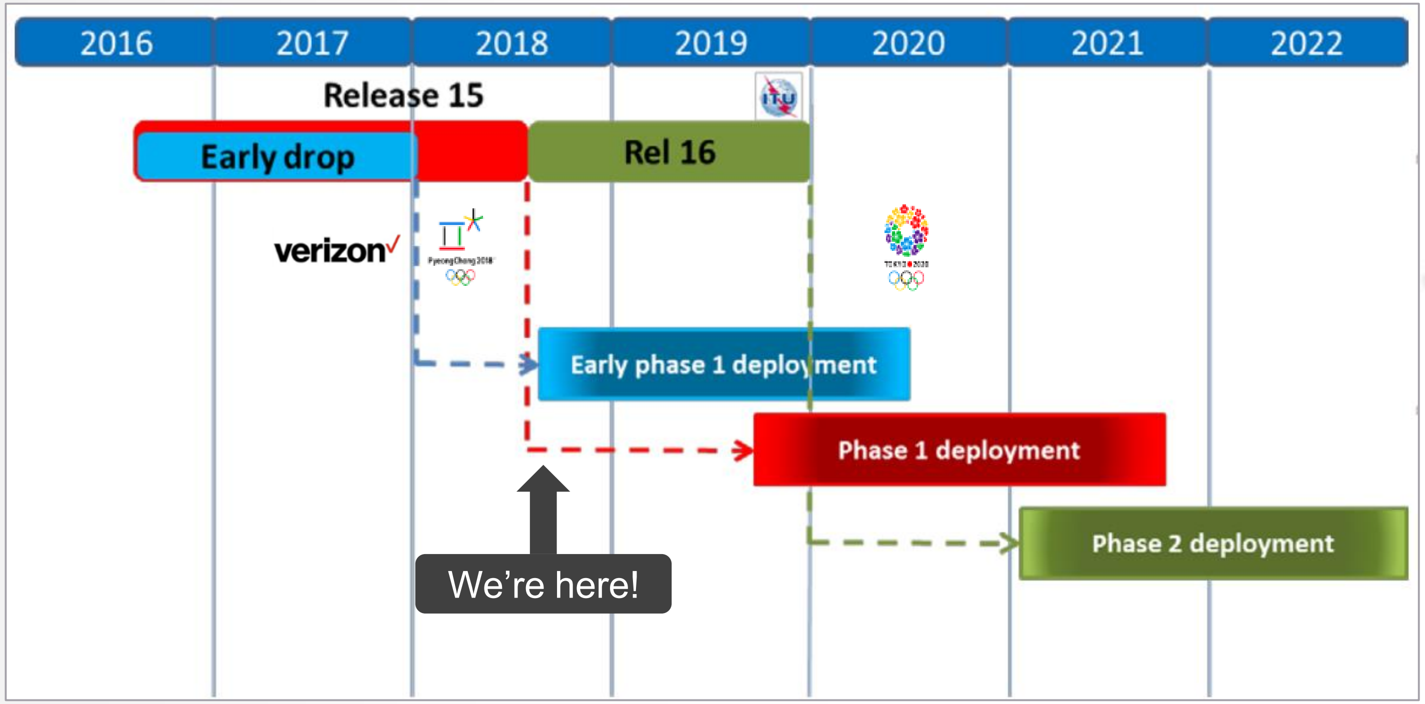
Massive Machine Type Communication (mMTC)

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

Rel. 15 (June 2018)

3GPP NR Roadmap

ACCELERATED TIMELINES

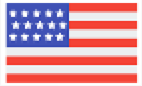
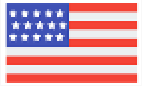
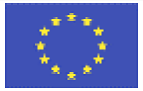
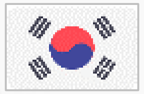
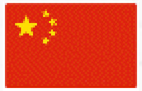
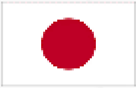
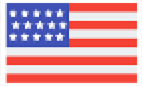
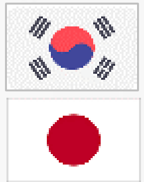
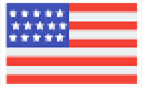


Source: 3GPP activity towards IMT-2020
http://www.itu.int/en/ITU-R/study-groups/rsg5/rwp5d/imt-2020/Documents/S02-1_3GPP%20IMT-2020.pdf

- "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

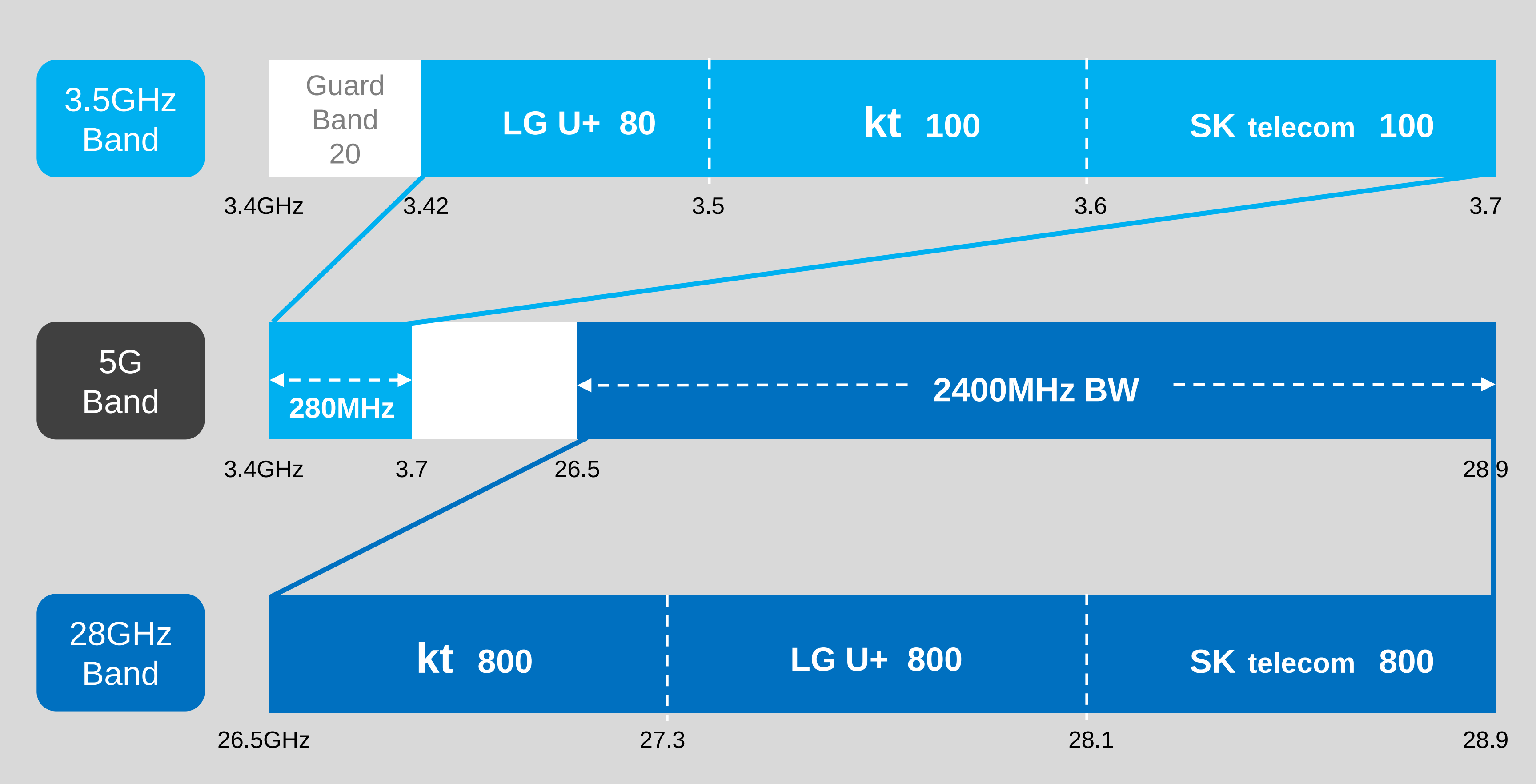
Region	New			Existing			BW	Total BW
	Band	F_{LOW}	F_{HIGH}	Band	F_{LOW}	F_{HIGH}	MHz	MHz
Korea		3400	3700				300	300
Europe				n38	2570	2620	50	450
		3400	3800				400	
Japan				n41	2496	2690	194	1494
		3600	4200				800	
		4400	4900				500	
US				n71	DL 617 UL 663	DL 652 UL 698	35	1329
				n41	2496	2690	194	
		3100	3550				450	
				48	3550	3700	150	
		3700	4200				500	
China				40	2300	2400	100	790
				41B	2555	2655	100	
		3300	3400				100	
		3400	3600	42	3400	3600	200	
		4800	5000				200	
Un-licensed					5725	5875	150	150

5G Spectrum Availability mmWave

Region	New	New		Existing		BW	Total BW
	Band	F_{LOW}	F_{HIGH}	F_{LOW}	F_{HIGH}	GHz	GHz
Korea	n257	26.50	29.50			3.00	3.00
Europe	n258	24.25	27.50			3.25	7.85
	n259	31.80	33.40			1.60	
		40.50	43.50			3.00	
Japan		27.50	29.50			2.00	2.00
US		24.25	24.45			0.20	5.55
		24.75	25.25			0.50	
		27.50	28.35			0.85	
	n260	37.00	38.60			1.60	
		38.60	40.00			1.40	
		47.20	48.20			1.00	
China	n258	24.25	27.50			3.25	8.75
		37.00	42.50			5.50	
Un-licensed		43.50	47.00			3.50	3.50 (China)
		64.00	71.00	57	64	7.00	7.00 (US)

Korea 5G Frequency Bands Assigned

FREQUENCY AUCTION RESULT IN JUNE 2018

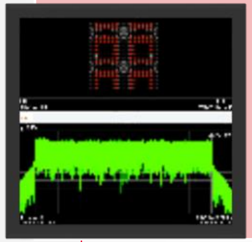


Source: Korea Ministry of Science and ICT

5G New Radio Specification

3GPP Release 15 NR Specification

RELEASE JUNE 2018



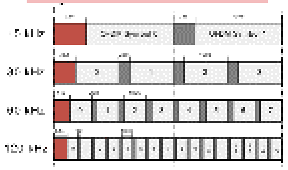
Waveform

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

: targeted at high throughput scenarios

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

: targeted at power limited scenarios



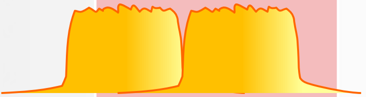
Flexible Numerology

15 kHz*2^n Sub-carrier spacing

1ms subframe

10 ms Frame

Extended Cyclic Prefix



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

Massive MIMO and Beam Steering

Up to 8x8 MIMO

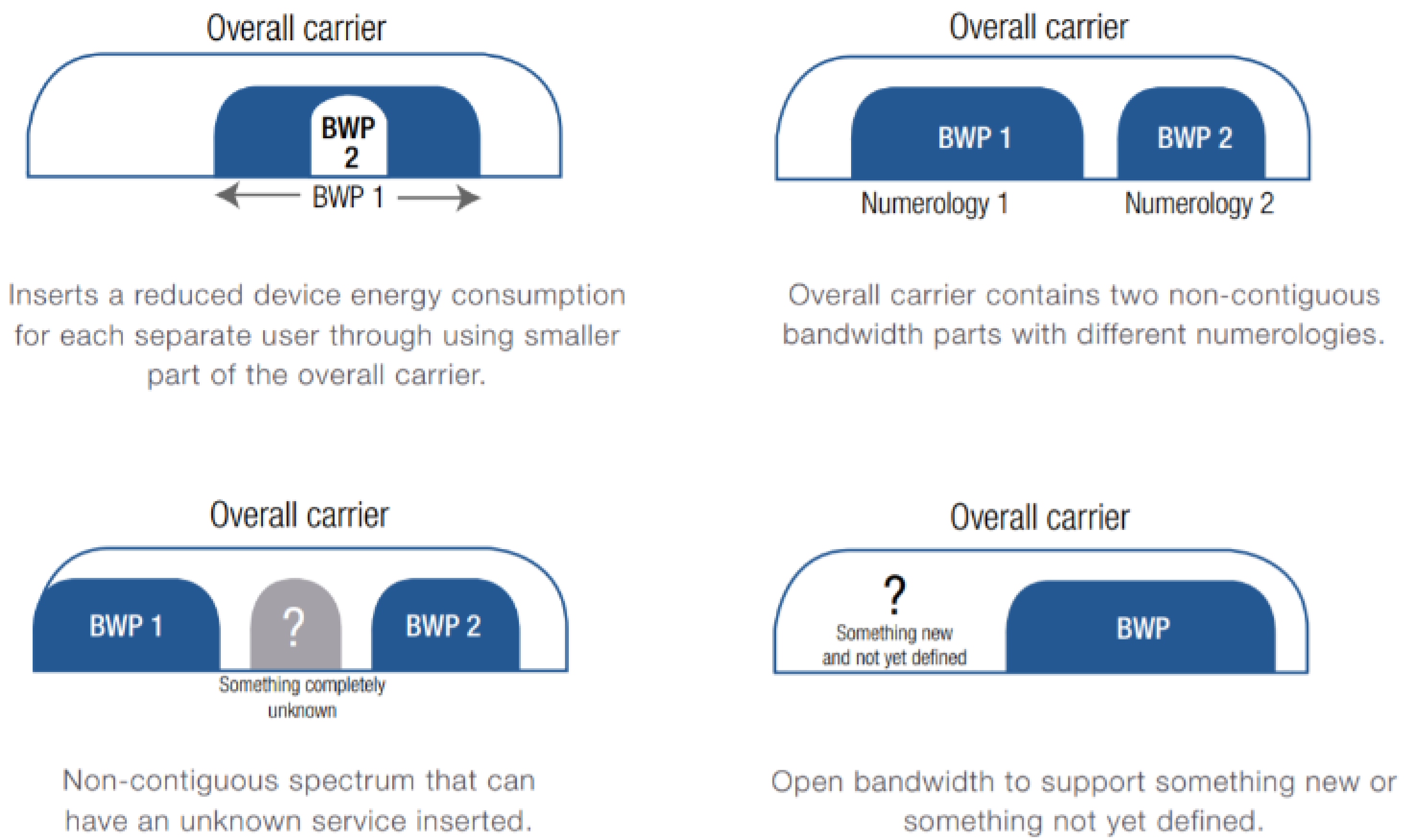
Much greater # antennas on gNB than UE

Beam sweeping

Bandwidth Parts

MULTIPLEXING OF SERVICES ON A SINGLE CARRIER

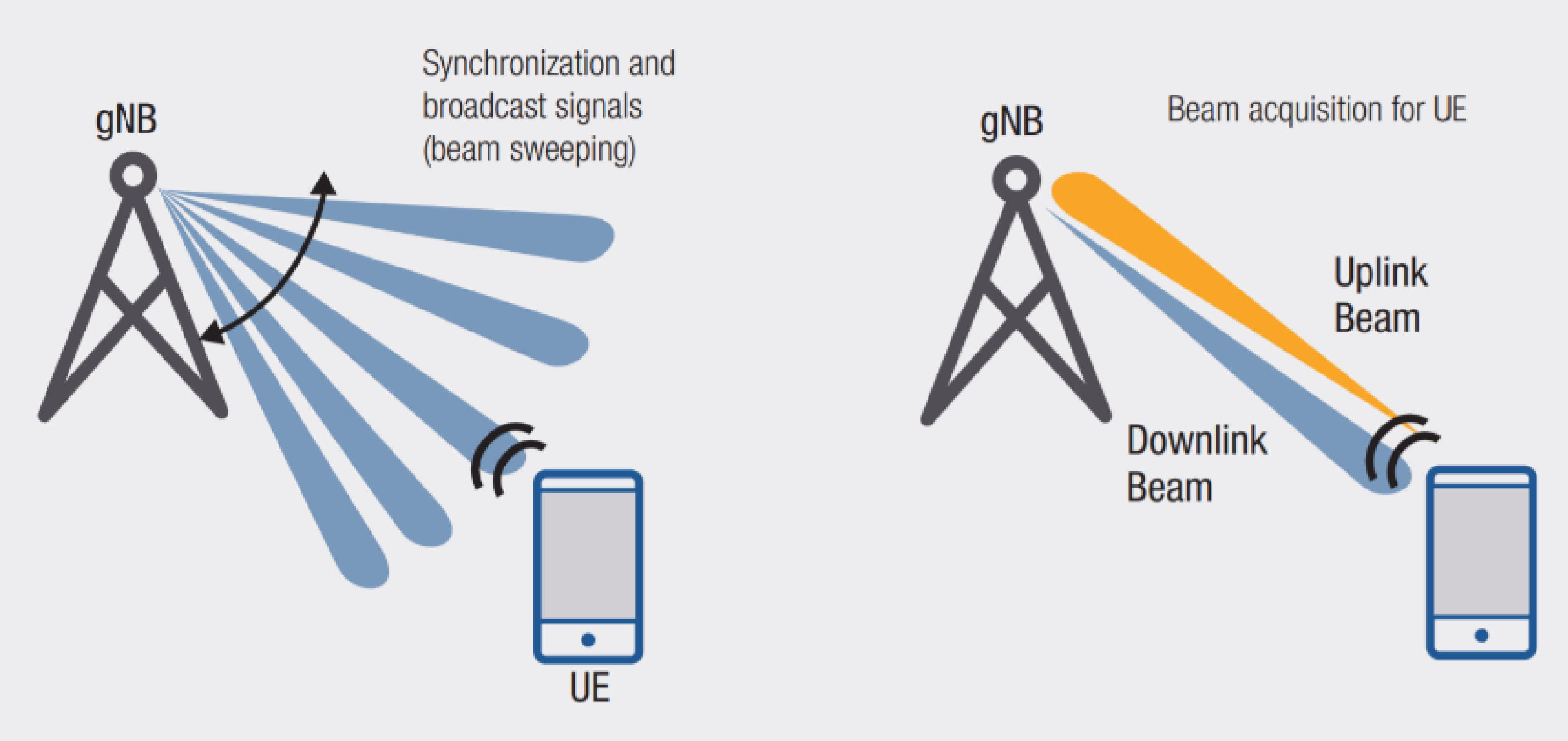
- Carriers sub-divided bandwidth to support **multiple services**
- Each BWP has its own numerology
- Can support 4G, 5G and Wi-Fi
- Introduces new issues with carrier interference



Initial Access Procedures

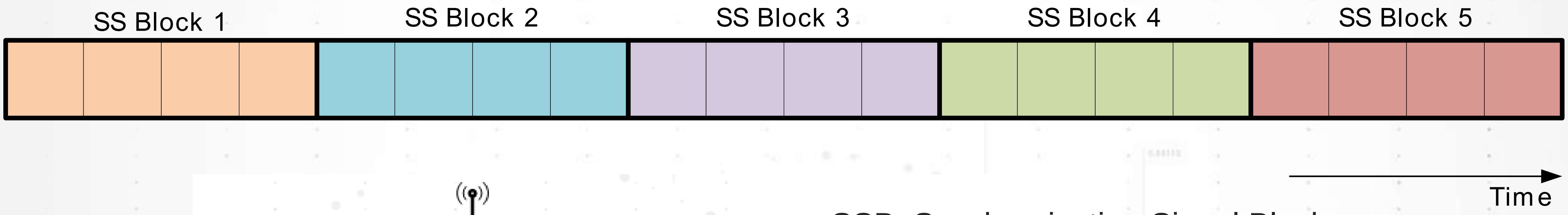
HOW DOES THE UE IDENTIFY THE BEST BEAM

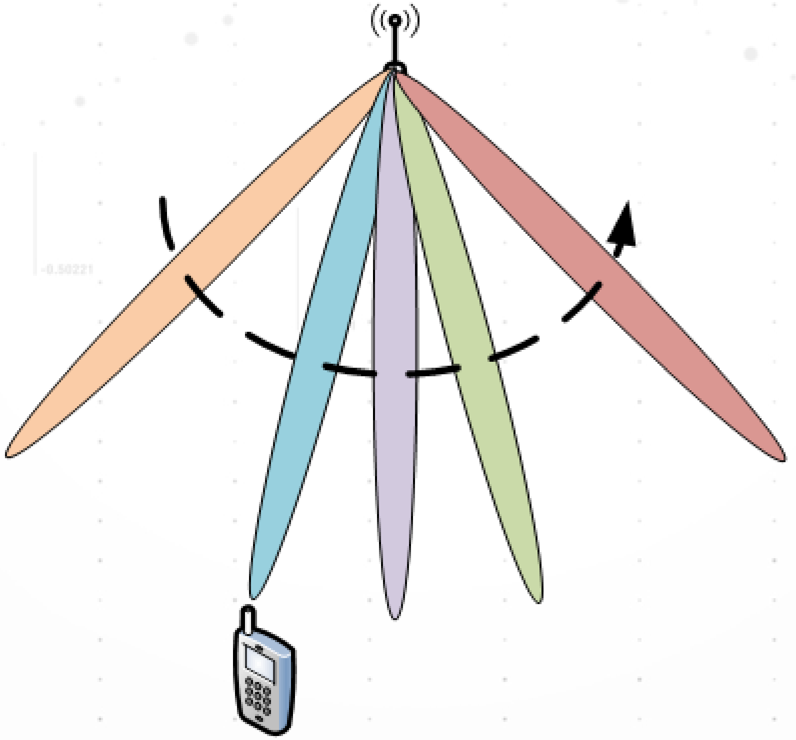
- Beam sweeping transmission in DL
- Beam sweeping reception to identify strongest beam
- UE identifies the best beam



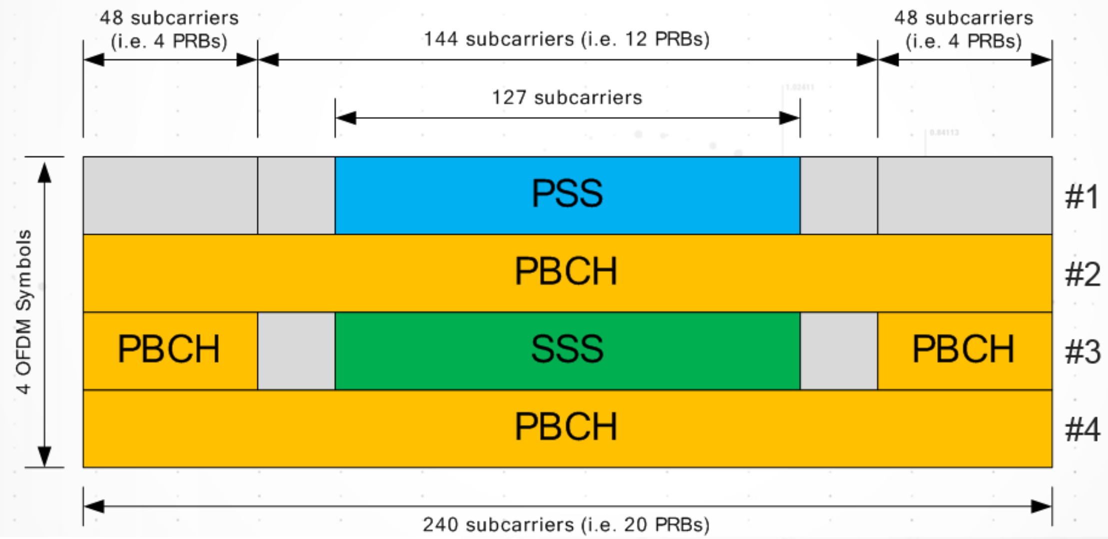
Initial Access Procedures (cont.)

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

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

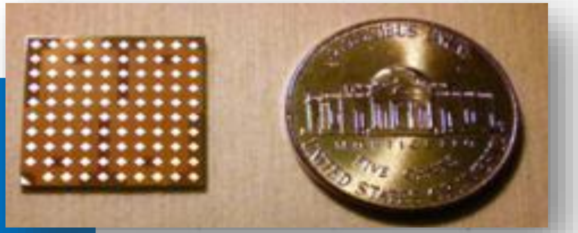
- In words. For a given distance, as the frequency increases, the received <u>power will drop</u> unless offset by an increase in some combination of transmit power, transmit antenna gain, and receive antenna gain.
- The decrease in power as a function of frequency is caused by the decrease in the antenna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

The Good News:

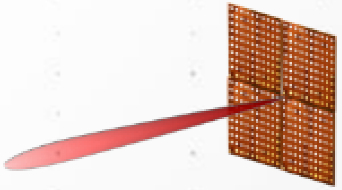
- Higher frequencies → wider bandwidths: faster (5G goal)
- Improve performance in dense crowds (5G goal)
- Antennas elements are smaller and enables massive MIMO/BF

Challenges:

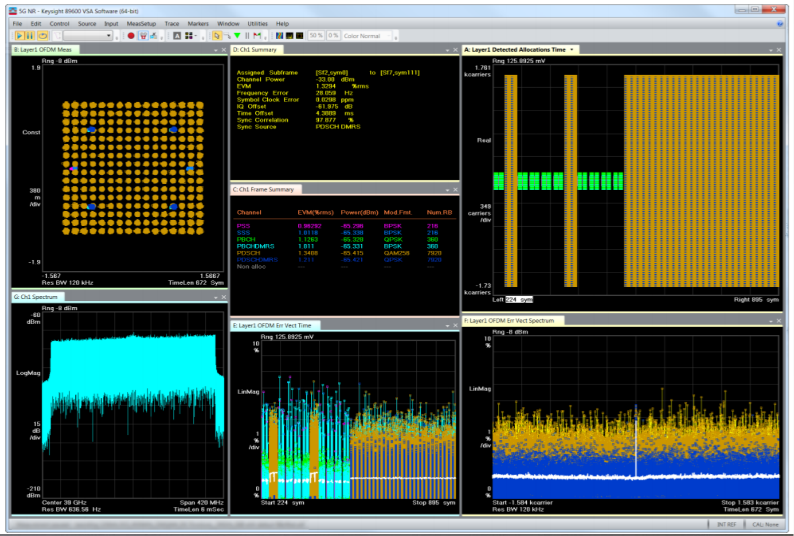
- Greater path loss due to Higher Frequency
- Integrated Noise Power due to Wide Bandwidth
- OTA measurement (No connector RF Access)
- Increased complexity with more antenna elements



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

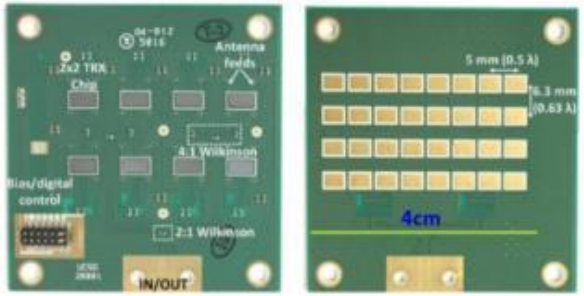
- Is the waveform created with 5G compliant waveform with numerology, UL, DL scheduling?
- Can the equipment produce clean mmWave signals?
- Performance mmWave measurements?

Solution: 5G Flexible Testbed

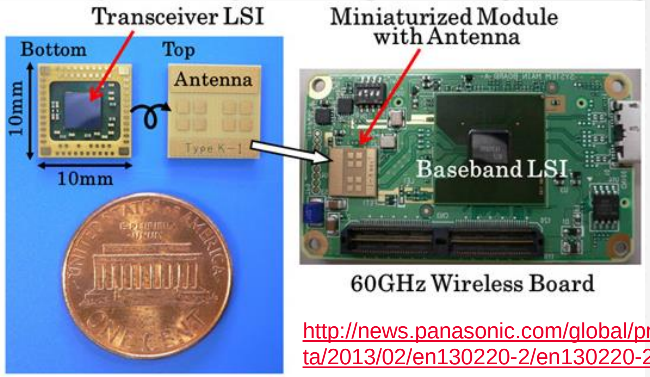
- 5G compliant waveform generation and analysis
- Signal optimizer calibration
- Best-in-class EVM performance with 1%
- Flexible configurations can scale as the standards evolve

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

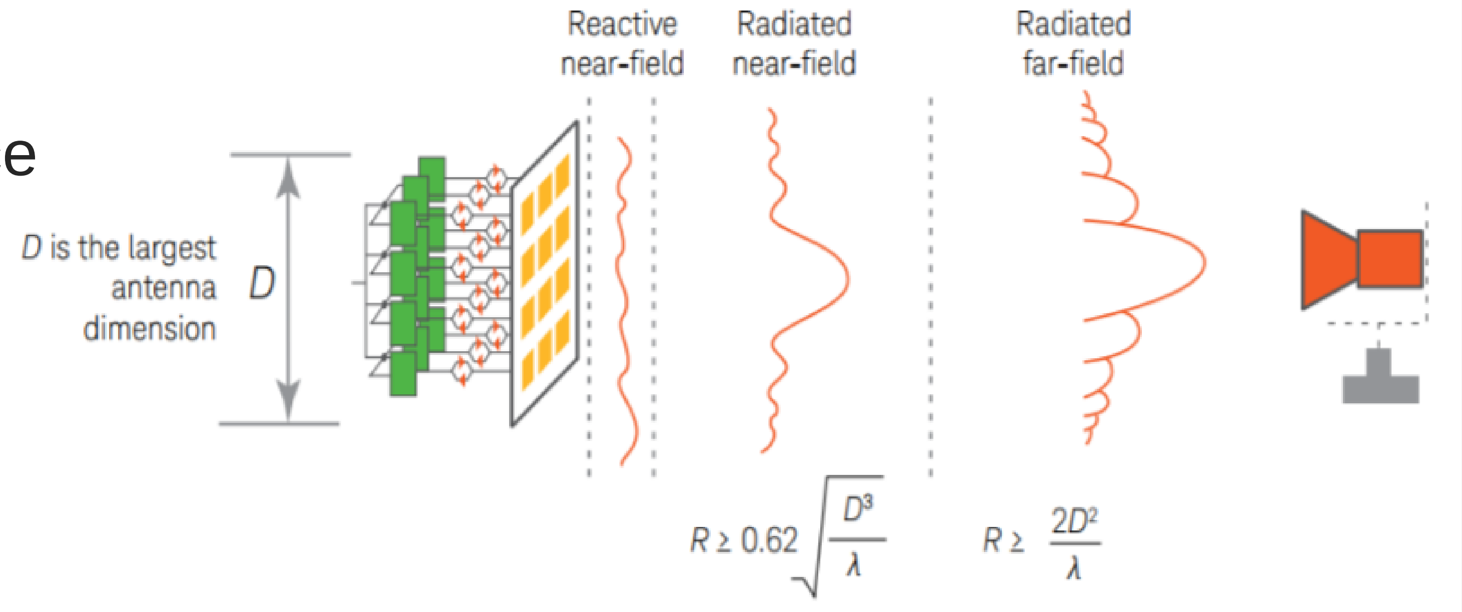


28 GHz RFIC



http://news.panasonic.com/global/press/data/2013/02/en130220-2/en130220-2.html

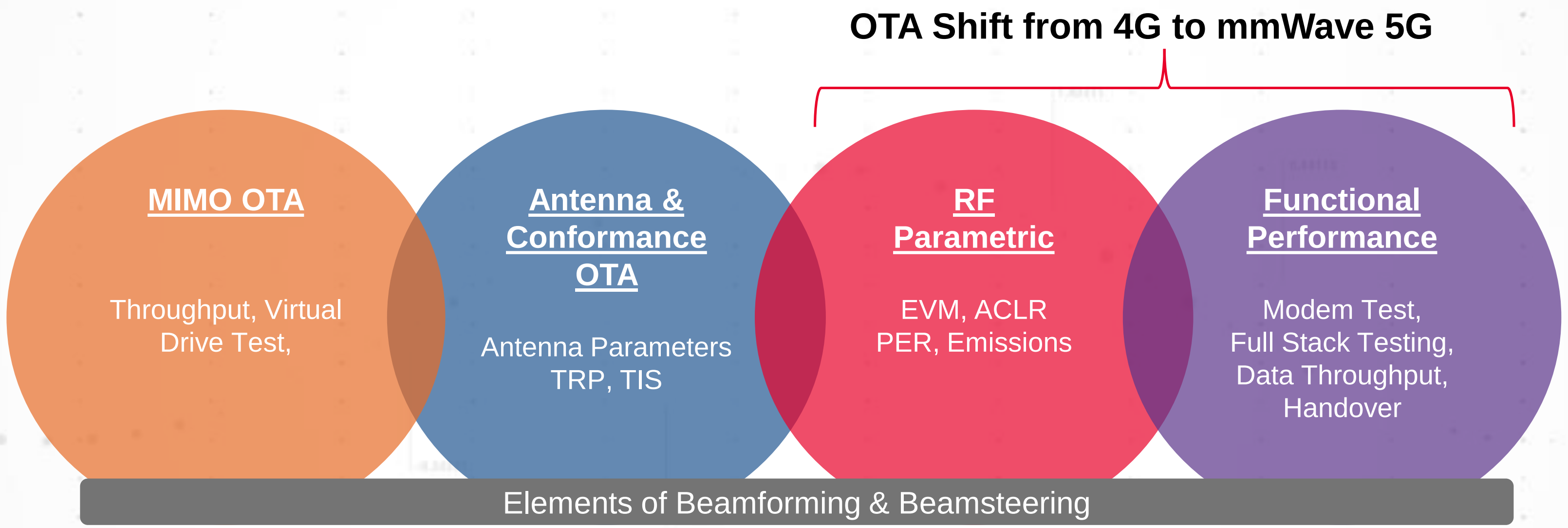
Integrated RFIC



* Image courtesy of Professor G. Rebeiz of U of Ca, SD

Testing OTA: The Cable is Gone

COMMERCIAL MMWAVE BRING CHANGING PARADIGM IN TEST

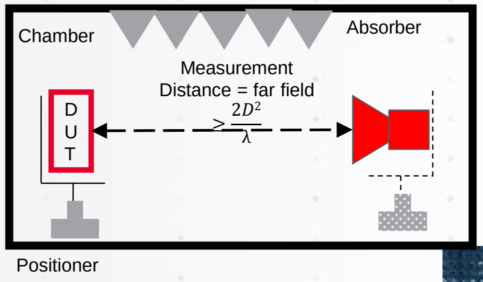


Today: "Traditional" OTA Cellular & A/D business
- Antenna
- MIMO OTA

Tomorrow: "New" OTA in mmW 5G w/ Direction
- RF Parametric
- Functional Performance

OTA Test Methods

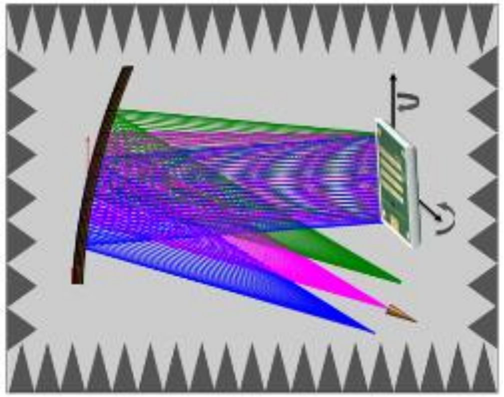
Direct Far Field



- ✓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.

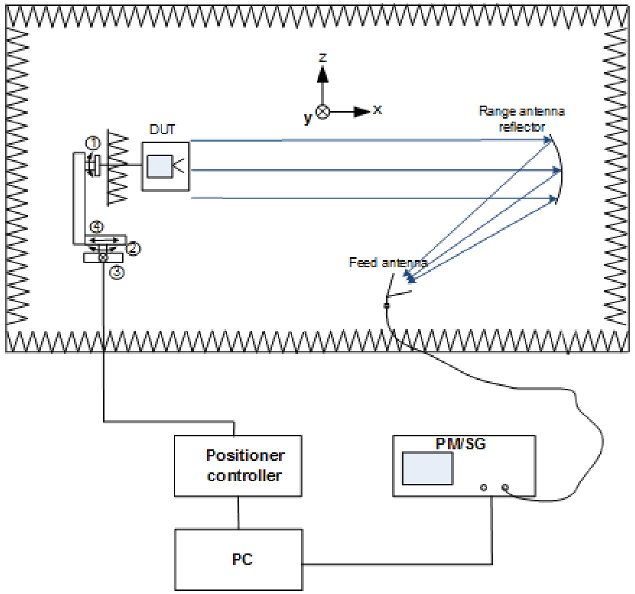


Figure 5.2.3.1-1: IFF method 1 (CATR) measurement setup of UE RF characteristic


TheStreet
THESTREET'S EXCLUSIVE
LOOK INSIDE
VERIZON'S 5G TESTING LAB
KEYSIGHT

5G Device End-to-End Solutions

TARGETING CHIPSET AND DEVICE WORKFLOW

5G Interactive R&D Solutions

- Protocol R&D → RF / RRM DVT → Functional KPI

5G Device Acceptance Solutions

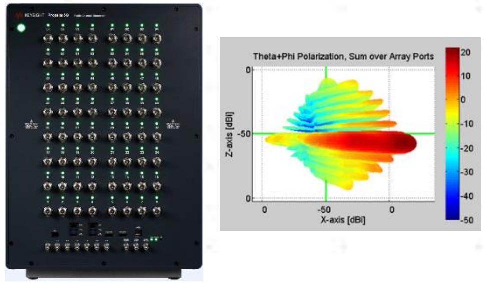
- Protocol Conformance → RF/ RRM Conformance → Carrier Acceptance

5G MFG Solutions

- Manufacturing

Keysight 1st Solutions across the entire device workflow

Network Emulator



Channel Emulator

mmWave OTA Solutions

Non-Signaling Solution

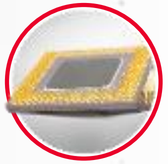
Seamless RF and Protocol Solution
Accumulates engineering know-how

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

Layers 2-7

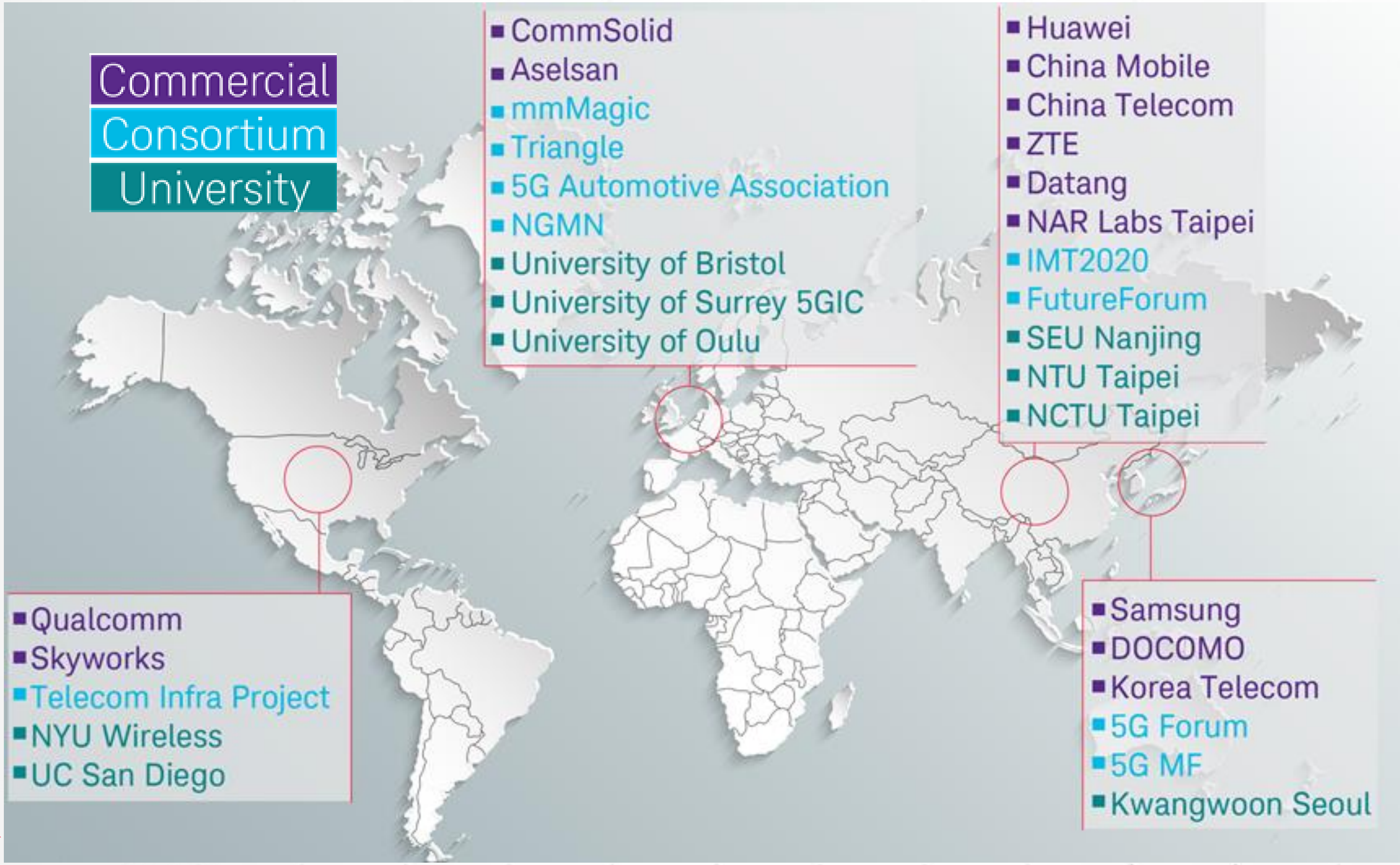
- Mobile Device Test
- BTS Drive Test
- Drive Test
- Mobile Network Test
- Customer Experience Management
- Network Test, Visibility and Security

Layer 1

- Electrical, Optical and Wireless Test
- Channel Emulation

Transforming Your 5G Ideas into Reality

KEYSIGHT 5G PUBLIC COLLABORATIONS



China Mobile Feb’15~

Korea Telecom Jun’15~

NTT Docomo Jul’15~

Huawei Feb’17~

Samsung Feb’17~

Qualcomm Jun’17~

Thank You!

Find more tips and tools at
www.keysight.com/find/5G

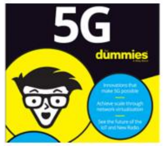
White Paper 2018-07-09

De-Risking 5G Product Development

White Paper 2018-04-23

Test Considerations for 5G New Radio

Ebook / Reprint 2017-06-22

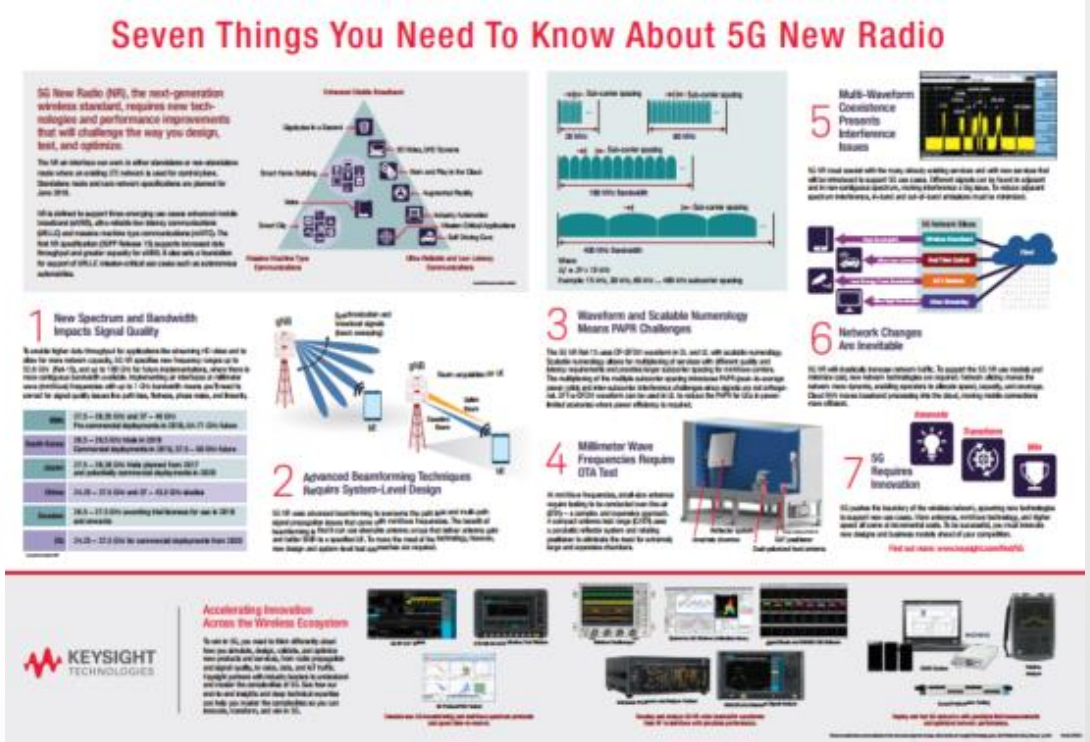


5G for Dummies

Brochure 2017-01-18

5G Solutions

Download 5G Poster Here!



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