KEYSIGHT WORLD 2019

# 5G Network Equipment, Device Standards, and Conformance Tests

*Keysight Technologies*

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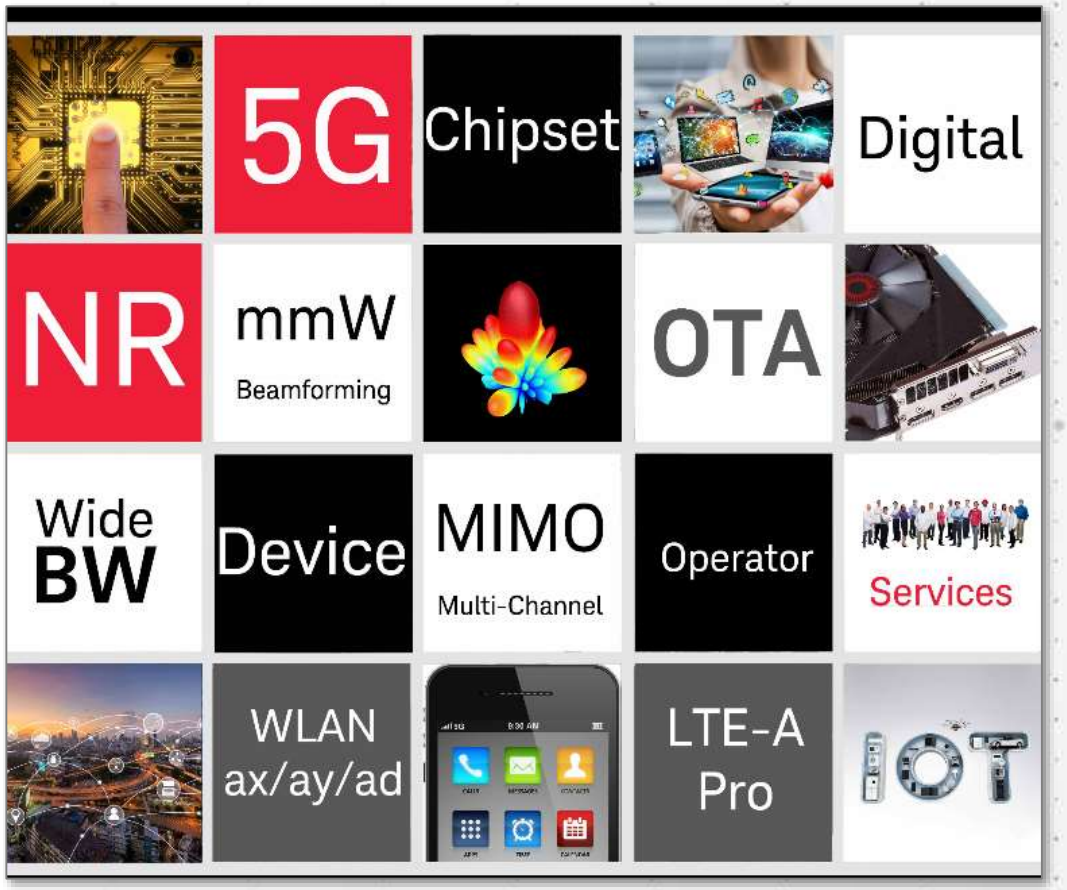
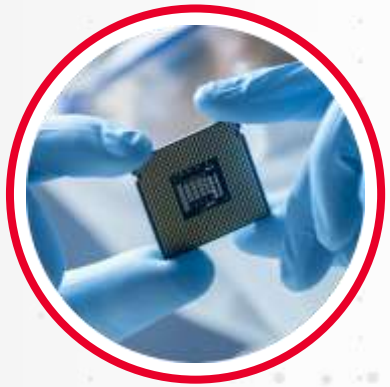
# Agenda

- 5G Ecosystem: Why Conform?
- 5G Standards and Test Requirements
- Base Station Conformance Tests
- Device Conformance and Carrier Acceptance Tests
- Considerations for Radiated Tests
- Summary, Q&A



# 5G Ecosystem

## COMPONENTS & CHIPSETS



Rolling out new designs for sub-6 GHz and mmWave operating bands

## DEVICE MANUFACTURERS

First fixed wireless access mmWave CPE introduced in 2018 and first smartphones to roll out in 2019

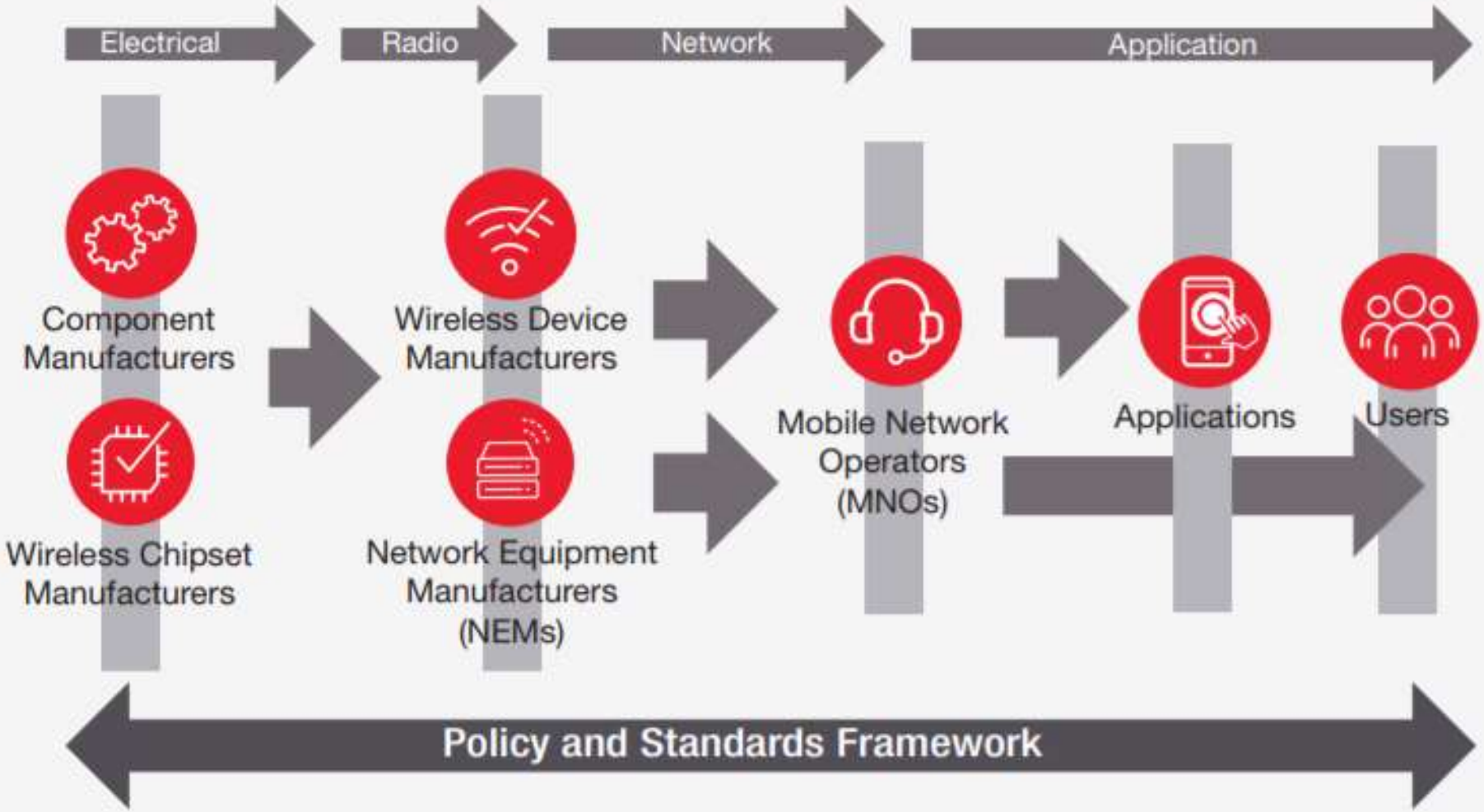
## NETWORK EQUIPMENT MANUFACTURERS

Upgrading existing infrastructure to address NR, massive MIMO, and mmWave operating bands

## MOBILE NETWORK OPERATORS

Accelerating trials and deployment in select cities

# 5G Ecosystem




Performance Requirements

Conformance Tests

Carrier Acceptance Tests

# 5G Standards and Test Requirements

# 3GPP Organization

Today's Focus

| RAN 5G NR Summary Reference Documents | | |
|---|---|---|
| ***TSG RAN*** Radio Access Network | Study Items for New Radio Access Technology | Resulting Specifications |
| **RAN WG1** Radio Layer 1 spec | **TR 38.802** Physical Layer Aspects | **TS 38.201 –TS 38.215** |
| **RAN WG2** Radio Layer 2 spec Radio Layer 3 RR spec | **TR 38.804** Radio Interface Protocol Aspects | **TS 38.300–TS 38.331** |
| **RAN WG3** lub spec, lur spec, lu spec UTRAN O&M requirements | **TR 38.801** Radio Access Architecture and Interface | **TS 38.401 – TS 38.474** |
| **RAN WG4** Radio Performance Protocol Aspects | **TR 38.803** RF and Coexistence aspects | **TS 38.101 – TS 38.173 (+38.307)** |
| **RAN WG5** Mobile Terminal Conformance Testing | **TR 38.80x** | **TS 38.508 – TS 38.533** |
| | | |

# 5G NR Operating Bands

| Operating band | Uplink (UL) BS receive / UE transmit | Downlink (DL) BS transmit / UE receive | Duplex Mode |
|---|---|---|---|
| **n1** | 1920 – 1980 MHz | 2110 – 2170 MHz | FDD |
| **n2** | 1850 – 1910 MHz | 1930 – 1990 MHz | FDD |
| **n3** | 1710 – 1785 MHz | 1805 – 1880 MHz | FDD |
| **n5** | 824 – 849 MHz | 869 – 894 MHz | FDD |
| **n7** | 2500 – 2570 MHz | 2620 – 2690 MHz | FDD |
| **n8** | 880 – 915 MHz | 925 – 960 MHz | FDD |
| **n12** | 699 – 716 MHz | 729 – 746 MHz | FDD |
| **n20** | 832 – 862 MHz | 791 – 821 MHz | FDD |
| **n25** | 1850 – 1915 MHz | 1930 – 1995 MHz | FDD |
| **n28** | 703 – 748 MHz | 758 – 803 MHz | FDD |
| **n34** | 2010 – 2025 MHz | 2010 – 2025 MHz | TDD |
| **n38** | 2570 – 2620 MHz | 2570 – 2620 MHz | TDD |
| **n39** | 1880 – 1920 MHz | 1880 – 1920 MHz | TDD |
| **n40** | 2300 – 2400 MHz | 2300 – 2400 MHz | TDD |
| **n41** | 2496 – 2690 MHz | 2496 – 2690 MHz | TDD |
| **n50** | 1432 – 1517 MHz | 1432 – 1517 MHz | TDD |
| **n51** | 1427 – 1432 MHz | 1427 – 1432 MHz | TDD |
| **n66** | 1710 – 1780 MHz | 2110 – 2200 MHz | FDD |
| **n70** | 1695 – 1710 MHz | 1995 – 2020 MHz | FDD |
| **n71** | 663 – 698 MHz | 617 – 652 MHz | FDD |
| **n74** | 1427 – 1470 MHz | 1475 – 1518 MHz | FDD |
| **n75** | N/A | 1432 – 1517 MHz | SDL |
| **n76** | N/A | 1427 – 1432 MHz | SDL |
| **n77** | 3300 – 4200 MHz | 3300 – 4200 MHz | TDD |
| **n78** | 3300 – 3800 MHz | 3300 – 3800 MHz | TDD |
| **n79** | 4400 – 5000 MHz | 4400 – 5000 MHz | TDD |
| **n80** | 1710 – 1785 MHz | N/A | SUL |
| **n81** | 880 – 915 MHz | N/A | SUL |
| **n82** | 832 – 862 MHz | N/A | SUL |
| **n83** | 703 – 748 MHz | N/A | SUL |
| **n84** | 1920 – 1980 MHz | N/A | SUL |
| **n86** | 1710 – 1780MHz | N/A | SUL |

**New: March 2019: RAN4 extended FR1 up to 7.125 GHz for unlicensed spectrum in U.S and Europe (Release-15)**

**Frequency Range 1 (FR1)**
410 MHz to 7.125 GHz

**Frequency Range 2 (FR2)**
24.25 GHz to 52.6 GHz

| Operating band | Uplink (UL) BS receive / UE transmit | Downlink (DL) BS transmit / UE receive | Duplex Mode |
|---|---|---|---|
| **n257** | 26.5 – 29.5 GHz | 26.5 – 29.5 GHz | TDD |
| **n258** | 24.25 – 27.5 GHz | 24.25 – 27.5 GHz | TDD |
| **n260** | 37 – 40 GHz | 37 – 40 GHz | TDD |
| **n261** | 27.5 – 28.35 GHz | 27.5 – 28.35 GHz | TDD |

Source: 3GPP TS 38.101-1/2, 38.104-1/2

# Overview of 3GPP 5G New Radio Standards

## CONFORMANCE TESTS

### 5G NR RAN Working Groups

| | Study Items for New Radio Access Technology | Specifications |
|---|---|---|
| **RAN1 Radio Layer 1** | TR 38.802 Physical Layer Aspects | TS 38.201 – TS 38.215 |
| **RAN2 Radio Layer 2 and Radio Layer 3** | TR 38.804 Radio Interface Protocol Aspects | TS 38.300 - TS 38.331 |
| **RAN3 Radio Network** | TR 38.801 Radio Access Architecture and Interface | TS 38.401 – TS 38.474 |
| **RAN4 Radio Performance and Protocol** | TR 38.803 RF and co-existence aspects | TS 38.101 – TS 38.173 (+38.307) |
| **RAN5 Mobile Terminal Conformance Tests** | TR 38.80x | TS 38.508 – TS 38.533 |

### 5G NR Conformance Tests

| | |
|---|---|
| **Base Stations**<br>TS 38.141-1<br>TS 38.141-2 | **Part 1**: Conducted testing in FR1<br>**Part 2**: **Radiated** testing for specific base station configurations in FR1 & FR2 |
| **Devices**<br>TS 38.521-1/2/3/4<br><br><br><br><br><br><br>TS 38.523-1/2/3<br><br><br><br><br><br>TS 38.533 | **5G NR UE Radio Transmission & Reception:**<br>1. Range 1 Standalone – FR1 Conducted Tests<br>2. Range 2 Standalone – **FR2 Radiated Tests**<br>3. Range 1 & 2 Interworking operation with other ratios (NSA)<br>– FR1 Conducted & **FR2 Radiated**<br>4. Performance requirements (SA and NSA)<br>– FR1 Conducted & **FR2 Radiated**<br><br>**5GS UE Protocol Conformance**<br>1. Protocol<br>2. Applicability of protocol test cases<br>3. Protocol test suites<br><br>**5G NR Radio Resource Management (RRM)** (SA and NSA)<br>- FR1 Conducted & **FR2 Radiated** |

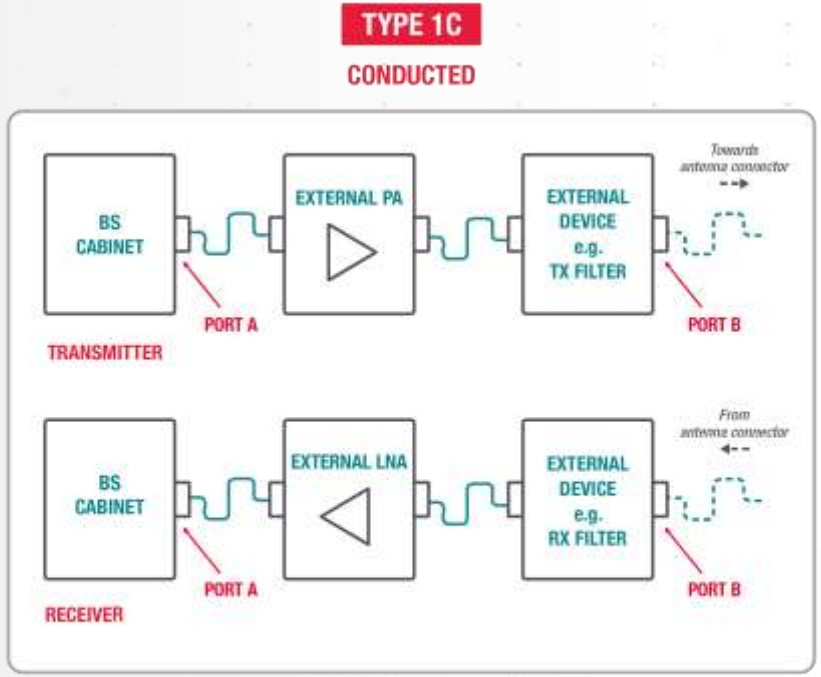
Other UE Conformance docs: TS 38.508-1/2, TS 38.509, TS 38.522

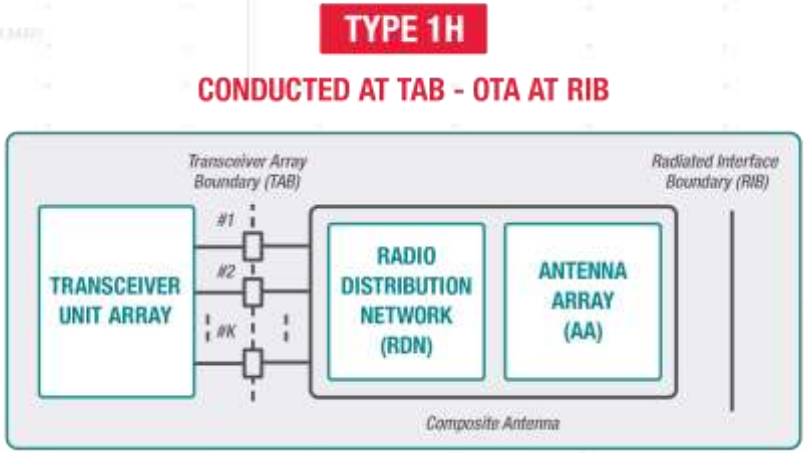
# Base Station Conformance Tests

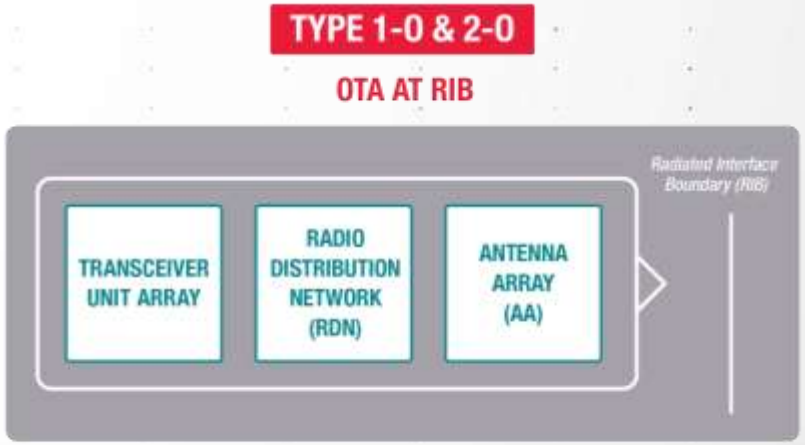
# Base Station Conformance Tests

- Base Station Classes
- Conducted vs Radiated Test

| Type 1-C | Type 1-H | Type 1-0 | Type 2-0 |
|---|---|---|---|
| FR1<br><br>**Only Conducted** requirements defined at individual antenna connectors | FR1<br><br>**Conducted** requirements defined at individual TAB connectors<br>or<br>**OTA** requirements defined by RIB | FR1<br><br>**Only OTA** requirements defined at the RIB | FR2<br><br>**Only OTA** requirements defined at the RIB |



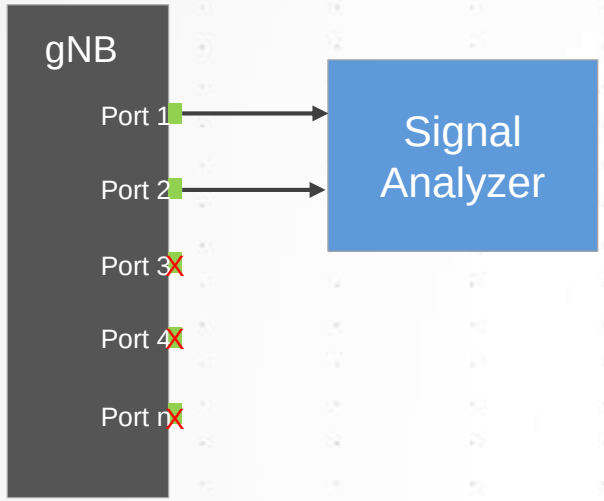
# Base Station Conformance Tests Summary – FR1 & FR2

## CONDUCTED & RADIATED CONFORMANCE TESTS

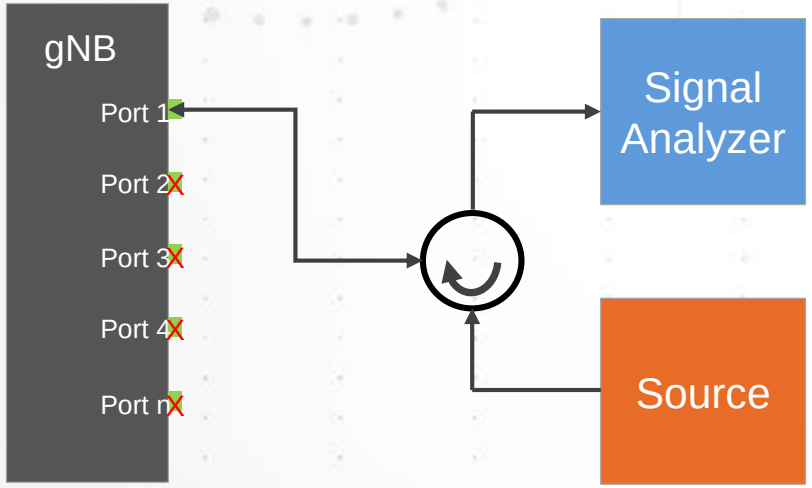
| Transmitter Characteristics (chp 6) | Receiver Characteristics (chp 7) | Performance Requirements (chp 8) |
|---|---|---|
| • **Transmit Power** (TRP, EIRP)<br>• **Output Power Dynamics** (RE Power Control DR / Total Power DR / ...)<br>• **Transmit On/Off Power** (TX Off Power / TX Transient Period)<br>• **Signal Quality** (Freq Error / EVM / Time Alignment Error /...)<br>• **Unwanted Emissions** (Occupied BW / ALCR / Spurious /...)<br>• **Intermodulation** (Interference...) | • **Reference Sensitivity Level**<br>• **Dynamic Range**<br>• **In-Band Selectivity & Blocking Characteristics** (Adjacent Channel Selectivity (ACS))<br>• **Out-of-Band Blocking**<br>• **Spurious Emissions**<br>• **Intermodulation**<br>• **In-channel Selectivity** | • **Performance Requirements for PUSCH**<br>  • Multipath fading propagation for given SNR<br>• **Performance Requirements for PUCCH**<br>  • ACK missed detection<br>  • NACK to ACK detection<br>  • UCI BLER performance (format 2)<br>• **Performance Requirements for PRACH**<br>  • False alarm probability and missed detection |
| **CURRENT STATUS March 2019** | | |
| • **Tx 6.5 OTA Tx on/off power and transient for FR2 still under discussion**<br>• **Test model for Tx test still under discussion** | | **Receiver performance not complete – target June 2019** |

# Examples gNB Conducted Conformance Test Setup

**Transmitter Time Alignment Error Test Config (Chp 6)**

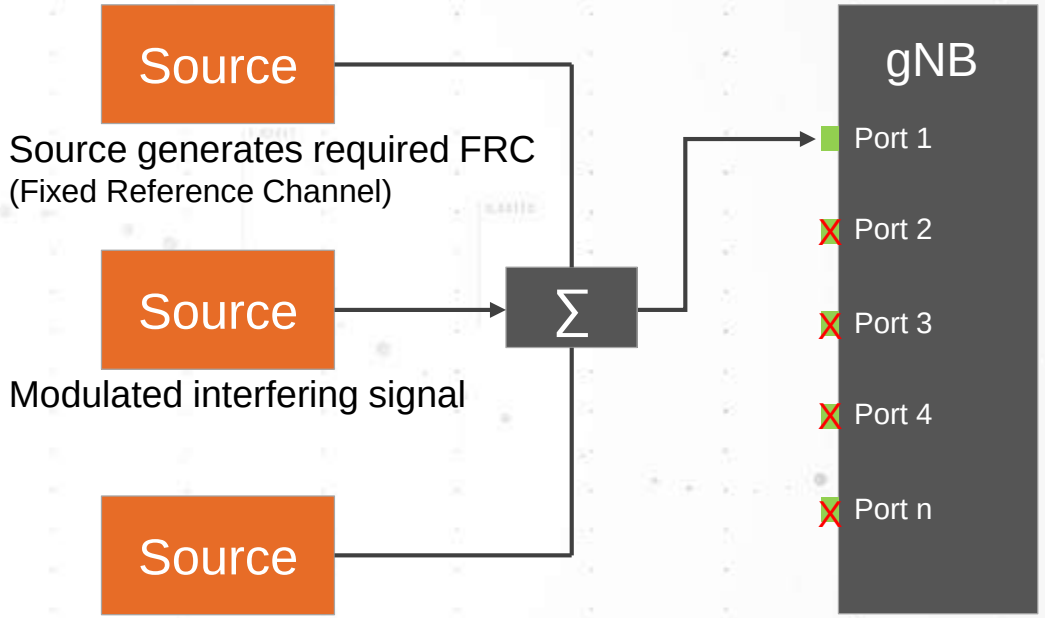



**Transmitter Intermodulation Config (Chp 6)**




Modulated interfering signal

**Receiver Intermodulation Tests (Chp 7)**
(Blocking & Selectivity tests similar)

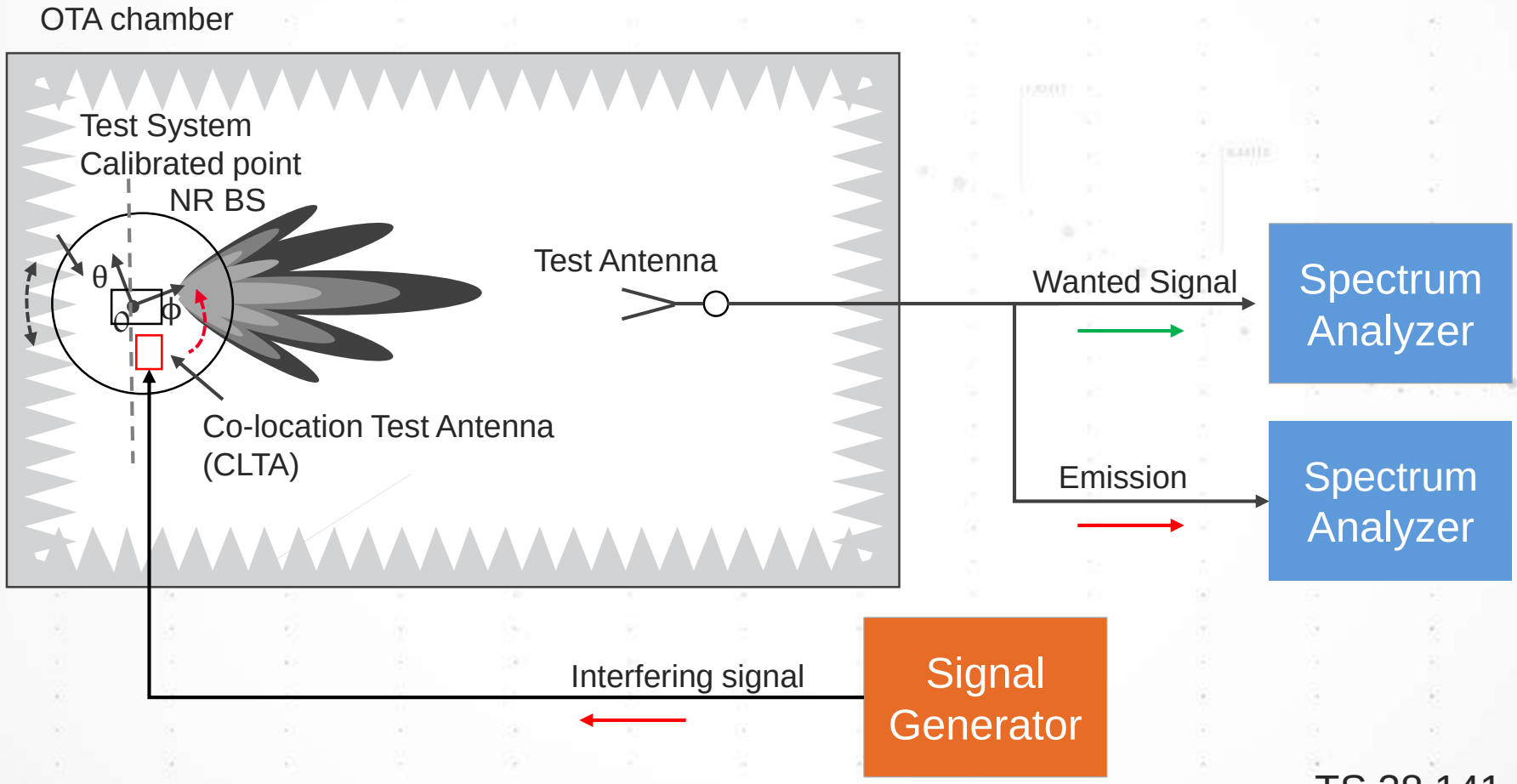



gNB Calculates throughput
(based on CRC)

TS 38.141-1
BS Type 1-C

# Example: gNB Transmitter OTA Test Setup (Chap. 6)

## INTERMODULATION TEST, BS TYPE 1-O & 2-O

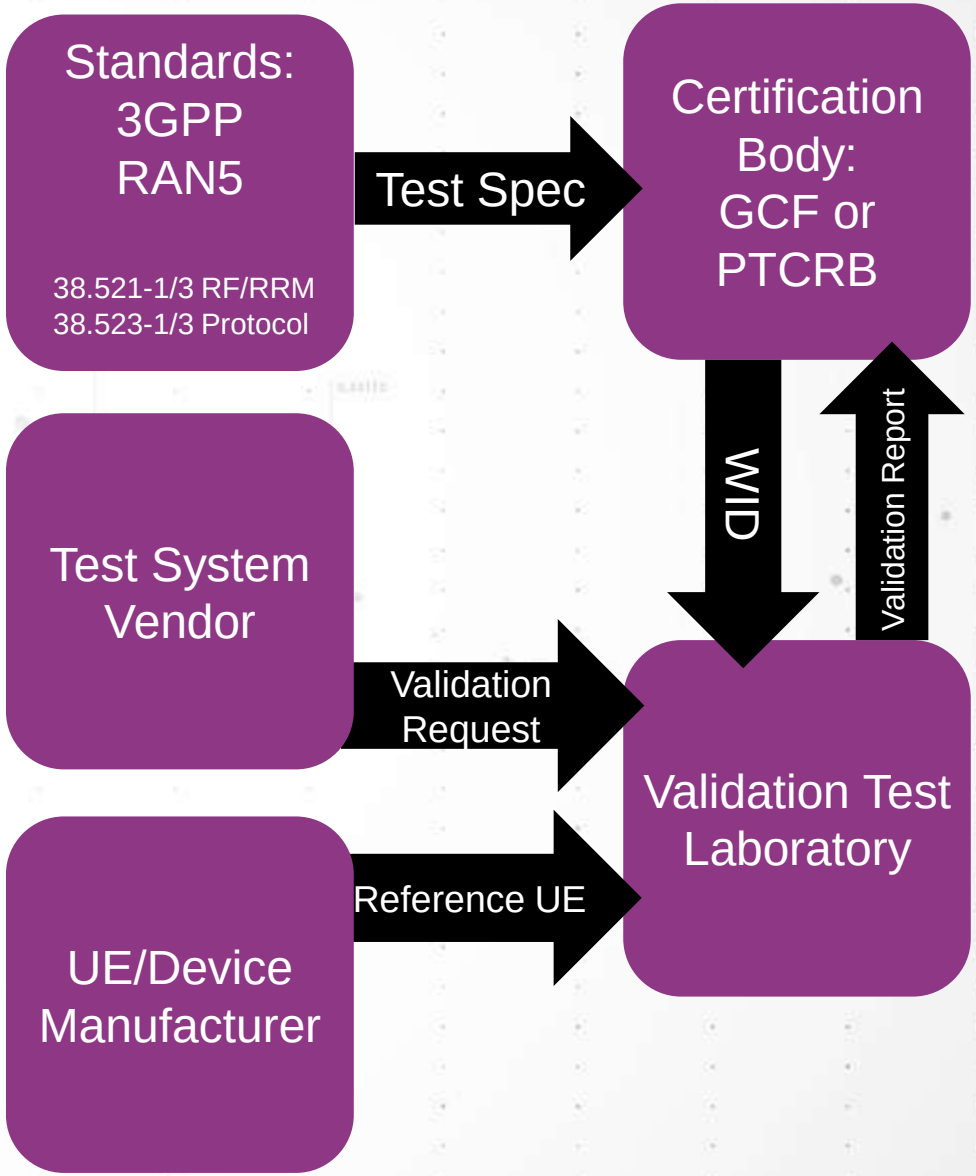



TS 38.141-2

# Device Conformance and Operator Acceptance Tests

# Process to Ensure 5G UE Conformance

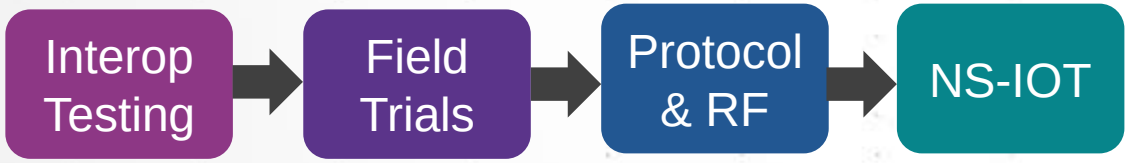
- Standards bodies, certification bodies, test equipment vendors and 5G NR device makers together ensure conformance to 5G specifications
- GCF and PTCRB certification organizations are ready to validate 5G conformance test cases and to start with the certification of the 5G devices



# Carrier Acceptance Tests

- Defined by operators
- Validated by operators

**Typical steps for devices**




KEYSIGHT TECHNOLOGIES

# UE Conformance Tests Summary – 1 of 2

FR1 Conducted Tests
FR2 Radiated Test

## RADIO TRANSMISSION AND RECEPTION

| Transmitter Characteristics | Receiver Characteristics | Interworking Operation | Performance |
|---|---|---|---|
| • **Transmitter Power** (UE Max Output Power, Power Reduction, CA, SUL, UL-MIMO ...)<br>• **Output Power Dynamics** (Min Power, Tx OFF Power, On/OFF Time Mask, Power Control)<br>• **Signal Quality** (Freq Error / EVM / Carrier Leakage, In-Band Emissions, CA...)<br>• **Spectrum Emissions** (Occupied BW / SEM/ ALCR / Spurious /... SUL, UL-MIMO)<br>• **Tx Intermodulation (FR1)** | • **Reference Sensitivity Level** (Intra-band Contiguous, Non-Contiguous, Inter-Band, DC, SUL, UL-MIMO)<br>• **Maximum Input level** (CA, UL-MIMO, Adjacent Channel Selectivity)<br>• **Blocking Characteristics** (In-Band, Out-of-Band<br>• **Spurious Response**<br>• **Intermodulation Characteristics**<br>• **Spurious Emissions**<br>• **Rx Intermodulation (FR1)** | Most of the same Tx and Rx characteristics tests under different carrier aggregation (CA) configuration between 5G NR frequency range 1 and 2 and non-standalone operations with E-UTRA (EN-DC) | **Still being defined** |
| **CURRENT STATUS March 2019** | | | |
| • **Partial Tx test done single carrier, CA later**<br>• **MOP, EIRP, TRP first completed FR2 test** | • **Very little Rx test done, single carrier, CA later**<br>• **No FR2 yet** | • **Partial done for NSA opt 3 DC (some CA, but not complete yet)** | **1 test case close to 100% completed: 2Rx TDD perform – 2x2 MIMO** |

# UE Conformance Tests Summary – 2 of 2

FR1 Conducted Tests
FR2 Radiated Test

## RRM AND PROTOCOL

| Protocol | RRM Test Coverage |
|---|---|
| • **Protocol Idle Mode**<br>• **Layer 2**<br>  • **Random access procedures, DL data transfers, UL data transfers, transport size,**<br>• **Protocol RRC procedures**<br>• **Mobility management**<br>• **Session management** | **Ensures efficient use of the radio resources in standalone (FR1 & FR2) and non-standalone (E-UTRA & 5G NR interworking)**<br><br>• EN-DC option 3 (NR PSCell in FR1)<br>• EN-DC option 3 (NR PSCell in FR2)<br>• SA option 2 (NR Pcell in FR1)<br>• SA option 2 (NR Pcell in FR2) |
| **CURRENT STATUS March 2019** | |
| **Mostly done SA opt 2 and NSA opt 3** | **Still Being Defined**<br>**2 tests are 100% completed** |

# 3GPP 5G NR RF Specification and Test Standard

## CURRENT STATUS

| Spec Number | Title | Current Version Mar-28/2019 |
|---|---|---|
| 38.521-1 | NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone | 15.2.0 |
| 38.521-2 | NR; User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone | 15.2.0 |
| 38.521-3 | NR; User Equipment (UE) radio transmission and reception; Part 3: Range 1 and Range 2 Interworking operation with other radios | 15.2.0 |

# 38.521-1 Clause 6 Transmitter Characteristics

- 6.2 Transmitter power
  - 6.2.1 UE maximum output power
  - 6.2.2 UE maximum output power for modulation / channel bandwidth
  - 6.2.3 UE maximum output power with additional requirements
  - 6.2.4 Configured transmitted power
- 6.3 Output power dynamics
  - 6.3.1 Minimum output power
  - 6.3.2 Transmitter OFF power
  - 6.3.3 Transmit ON/OFF time mask
  - 6.3.4 Power Control
- 6.4 Transmit signal quality
  - 6.4.1 Frequency error
  - 6.4.2 Transmit modulation quality
    - 6.4.2.1 EVM
    - 6.4.2.2 Carrier leakage
    - 6.4.2.3 In-band emissions
    - 6.4.2.4 EVM equalizer spectrum flatness
- 6.5 Output RF spectrum emissions
  - 6.5.1 Occupied bandwidth
  - 6.5.2 Out of band emissions
    - 6.5.2.1 SEM
    - 6.5.2.2 Additional SEM
    - 6.5.2.3 ACLR

# 38.521-2 Clause 6 Transmitter Characteristics

- 6.2 Transmitter power
  - 6.2.1 UE maximum output power
  - 6.2.2 UE maximum output power for modulation / channel bandwidth
  - 6.2.3 UE maximum output power with additional requirements
  - 6.2.4 Configured transmitted power
- 6.3 Output power dynamics
  - 6.3.1 Minimum output power
  - 6.3.2 Transmitter OFF power
  - 6.3.3 Transmit ON/OFF time mask
  - 6.3.4 Power Control
- 6.4 Transmit signal quality
  - 6.4.1 Frequency error
  - 6.4.2 Transmit modulation quality
    - 6.4.2.1 EVM
    - 6.4.2.2 Carrier leakage
    - 6.4.2.3 In-band emissions
    - 6.4.2.4 EVM equalizer spectrum flatness
- 6.5 Output RF spectrum emissions
  - 6.5.1 Occupied bandwidth
  - 6.5.2 Out of band emissions
    - 6.5.2.1 SEM
    - 6.5.2.2 Additional SEM
    - 6.5.2.3 ACLR

# 38.521-2 Clause 6.2.1 UE Maximum Output Power

- Note : Power class 1, 2, 3, and 4 are specified based on the assumption of certain UE types with specific device architectures. The UE types can be found in Table6.2.1-1.

Table 6.2.1-1: Assumption of UE Types

| UE Power class | UE type |
|---|---|
| 1 | Fixed wireless access(FWA) UE |
| 2 | Vehicular UE |
| 3 | Handheld UE |
| 4 | High power non-handheld UE |

# 38.521-2 Clause 6.2.1 UE Maximum Output Power

- The following requirements define the maximum output power radiated by the UE for any transmission bandwidth within the channel bandwidth for non-CA configuration, unless otherwise stated. The period of measurement shall be at least one sub frame (1ms). The requirement is verified with the test metric of EIRP (Link=Beam peak search grids, Meas=Link angle).

**Table 6.2.1.1-1: UE minimum peak EIRP for power class 1**

| Operating band | Min peak EIRP (dBm) |
|---|---|
| n257 | 40.0 |
| n258 | 40.0 |
| n260 | 38.0 |
| n261 | 40.0 |
| NOTE 1: Minimum peak EIRP is defined as the lower limit without tolerance | |

**Table 6.2.1.2-1: UE minimum peak EIRP for power class 2**

| Operating band | Min peak EIRP (dBm) |
|---|---|
| n257 | 29 |
| n258 | 29 |
| n261 | 29 |
| NOTE 1: Minimum peak EIRP is defined as the lower limit without tolerance | |

**Table 6.2.1.3-1: UE minimum peak EIRP for power class 3**

| Operating band | Min peak EIRP (dBm) |
|---|---|
| n257 | 22.4 |
| n258 | 22.4 |
| n260 | 20.6 |
| n261 | 22.4 |
| NOTE 1: Minimum peak EIRP is defined as the lower limit without tolerance | |

**Table 6.2.1.4-1: UE minimum peak EIRP for power class 4**

| Operating band | Min peak EIRP (dBm) |
|---|---|
| n257 | 34 |
| n258 | 34 |
| n260 | 31 |
| n261 | 34 |
| NOTE 1: Minimum peak EIRP is defined as the lower limit without tolerance | |

# 38.521-2 Clause 6.2.1 UE Maximum Output Power

- The maximum output power values for TRP and EIRP are found in Table 6.2.1.1-2 below. The maximum allowed EIRP is derived from regulatory requirements [8]. The requirements are verified with the test metrics of TRP (Link=TX beam peak direction) in beam locked mode and EIRP (Link=TX beam peak direction, Meas=Link angle).

**Table 6.2.1.1-2: UE maximum output power limits for power class 1**

| Operating band | Max TRP (dBm) | Max EIRP (dBm) |
|---|---|---|
| n257 | 35 | 55 |
| n258 | 35 | 55 |
| n260 | 35 | 55 |
| n261 | 35 | 55 |

**Table 6.2.1.[2-4]-2: : UE maximum output power limits 2~4**

| Operating band | Max TRP (dBm) | Max EIRP (dBm) |
|---|---|---|
| n257 | 23 | 43 |
| n258 | 23 | 43 |
| n260 | 23 | 43 |
| n261 | 23 | 43 |

# 38.521-2 Clause 6.2.1 UE Maximum Output Power

- The following requirements define the maximum output power radiated by the UE for any transmission bandwidth within the channel bandwidth for non-CA configuration, unless otherwise stated. The period of measurement shall be at least one sub frame (1ms). The requirement is verified with the test metric of EIRP (Link=Beam peak search grids, Meas=Link angle).

**Table 6.2.1.1-3: UE spherical coverage for power class 1**

| Operating band | Min EIRP at 85%-tile CDF (dBm) |
|---|---|
| n257 | 32.0 |
| n258 | 32.0 |
| n260 | 30.0 |
| n261 | 32.0 |
| NOTE 1: Minimum EIRP at 85%-tile CDF is defined as the lower limit without tolerance | |

**Table 6.2.1.2-3: UE spherical coverage for power class 2**

| Operating band | Min EIRP at 60%-tile CDF (dBm) |
|---|---|
| n257 | 18.0 |
| n258 | 18.0 |
| n261 | 18.0 |
| NOTE 1: Minimum EIRP at 60%-tile CDF is defined as the lower limit without tolerance | |

**Table 6.2.1.3-3: UE spherical coverage for power class 3**

| Operating band | Min EIRP at 50%-tile CDF (dBm) |
|---|---|
| n257 | 11.5 |
| n258 | 11.5 |
| n260 | 8 |
| n261 | 11.5 |
| NOTE 1: Minimum EIRP at 50%-tile CDF is defined as the lower limit without tolerance | |

**Table 6.2.1.4-3: UE spherical coverage for power class 4**

| Operating band | Min EIRP at 20%-tile CDF (dBm) |
|---|---|
| n257 | 25 |
| n258 | 25 |
| n260 | 19 |
| n261 | 25 |
| NOTE 1: Minimum EIRP at 20%-tile CDF is defined as the lower limit without tolerance | |

# 38.521-3 6.1 General

- Unless otherwise stated the transmitter characteristics are specified at the antenna connector(s) of the UE for the bands operating on frequency range 1 and over the air of the UE for the bands operating on frequency range 2.

- The requirements for frequency range 1 and frequency range 2 can be verified separately.

- For the carrier in frequency range 1, requirements can be verified with NR FR2 link disabled.

- For the carrier in frequency range 2, requirements can be verified in OTA mode with LTE connecting to the network by OTA without calibration.

# Considerations for Radiated Tests

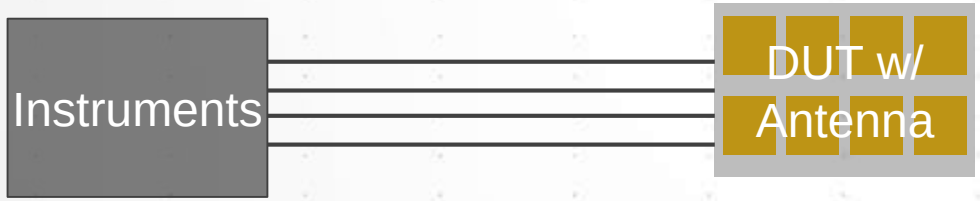
# Paradigm Shift in Test

## RADIATED TEST MOVES TO THE MAINSTREAM

**Discrete components, cabled, easy to test**


**mmWave DUTs now all integrated, no probing connectors, harder to test**

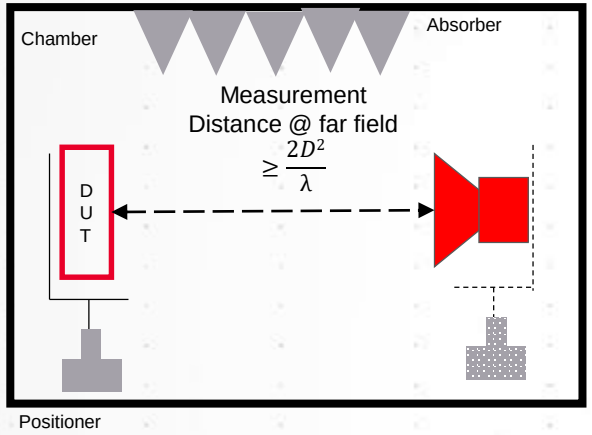

**Connected Test Setup: Preferred for nearly all LTE and NR FR1 Tests**




**Radiated tests mandatory for ALL FR2**

# Radiated Test Methods for FR2 Conformance

## Direct Far Field

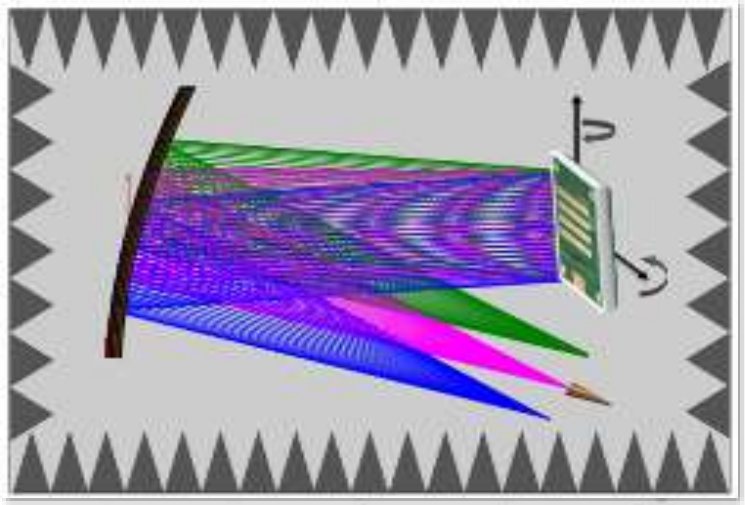



Probe antenna

- ✓Antenna beam pattern characterization
- ✓Beamforming/beamsteering validation
- ✓RF parametric tests (if S/N high enough)

- × Subject to higher path loss
- × Large chambers at mmWave frequencies

## Indirect Far Field

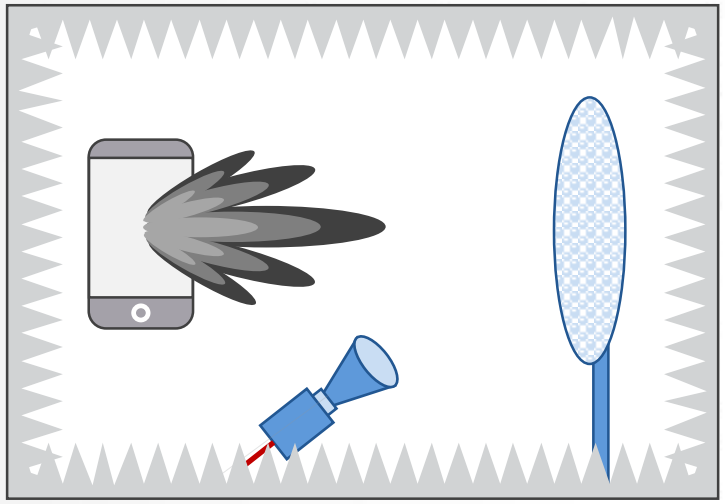


- ✓Antenna Beam pattern characterization
- ✓Beamforming/steering validation
- ✓RF parametric tests
- ✓Small footprint, lowest path loss

- × Rx spatial field generation not defined

# Different Chambers for Different Tests

Compact Antenna Test Range



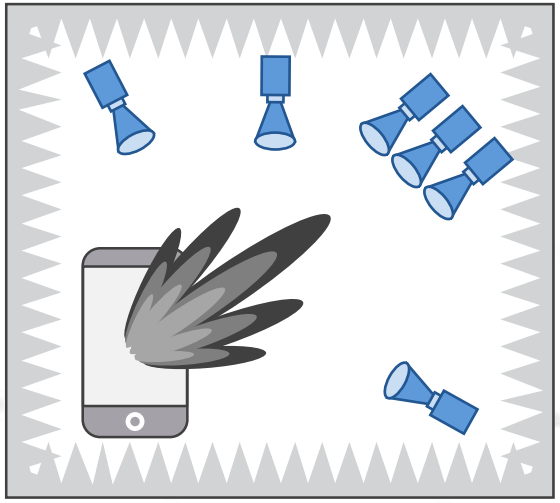
**Indirect Far-Field**

**RF Conformance**

**Frequency:** FR2 24 – 52 GHz (in-band), 6 - 110 GHz (out-of-band)

**Target Devices:** Antennas/ modules, phone, tablets, small gNB

Spatial Multiprobe Anechoic Chamber



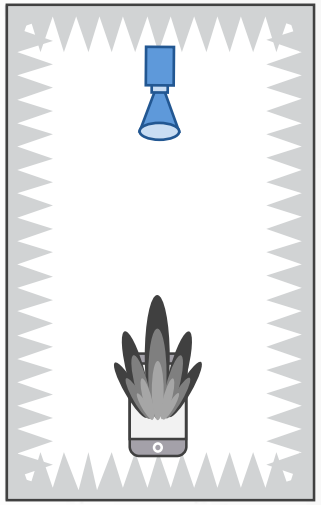
**Direct Far-Field**

**RRM for Multi-AoA**
NR-MIMO

**Frequency:** FR2 24 - 44 GHz

**Target Devices**: Modules, phones, phablets, mobile test platforms

Single AoA DFF



**Direct Far-Field**

**Protocol Test With Single AoA**

**Frequency:** FR2 24 - 44 GHz

**Target Devices:** Modules, phones, phablets, mobile test platforms

# Summary

# Summary

## UNDERSTANDING THE ROAD AHEAD

- Higher frequencies, wider bandwidths, dual connectivity, increased # test cases, increased test times, and OTA all increase test complexity
- Conformance test methods are not complete –many challenges ahead
- Standards continue to evolve. Release-16 is due mid 2020 and early work on Release-17 has begun.

# Keysight 5G Solutions for All Parts of the Ecosystem

## 5G Network Test


Drive Test and Analytics


UE Emulation and Load Test


Network Simulation and Test

## 5G Signaling Validation Test


5G NR Protocol Validation


Radio Signaling Test


5G NR Conformance Test

## Physical Layer Design and Test Solutions


System-Level Simulation


Component Characterization


Digital Conformance Test


Parametric Signal Test


RF and mmWave Radiated Test


Manufacturing Test Automation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