

# 5G Boot Camp

**PART 3:  
7 KEY MEASUREMENT CHALLENGES AND CASE STUDIES**

*Keysight Technologies*

**AUG 2019**

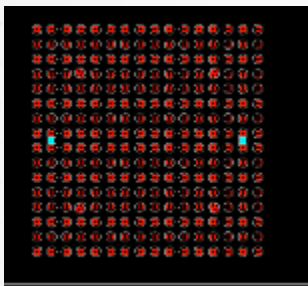
*Philip Chang*



# 7 Key Measurement Challenges

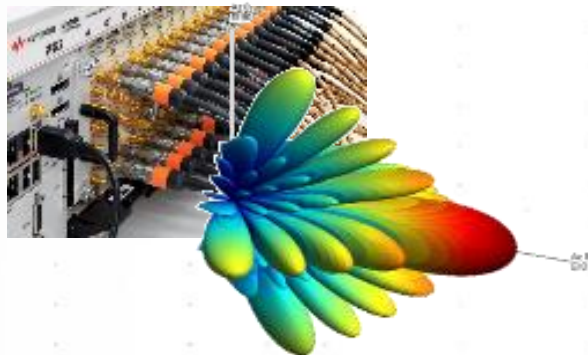
## Signal Quality

*mmW, Waveform, Fidelity*



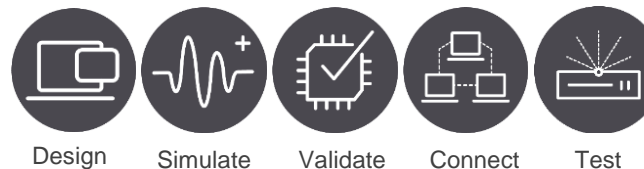
## Lots of Channels

*MIMO/Beamforming*



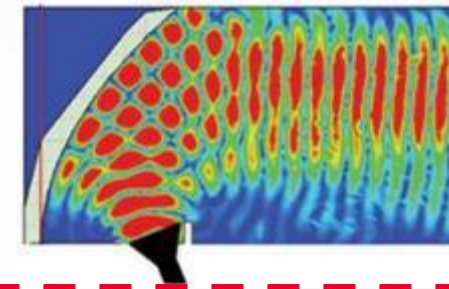
## Connect Design & Test

*Components, Systems*



## Life Beyond Connectors

*Over-the-Air*



## Performance on the Network

*Network Emulation*



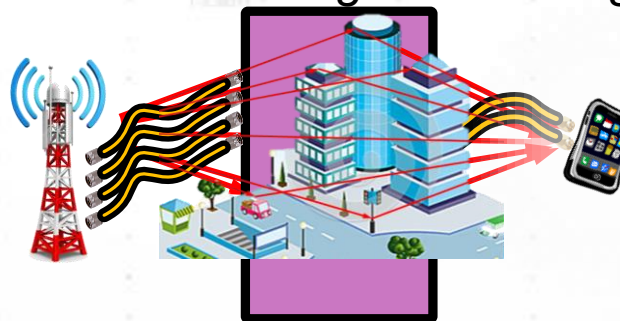
Protocol  
R&D

RF / RRM  
DVT

Functional  
KPI

## Channel

*Characterizing & Emulating*



## Field Testing and

**Drive Test**



# 3GPP UE & gNB Tx Conformance Test requirement docs

3GPP NR UE Tx test requirement	Minimum Requirement (2018-06)	Conformance Requirement (2018-09 draft)*	UE
Part 1: Range 1 Standalone	TS38.101-1 v.15.2.0	TS38.521-1 v.1.0.1	FR1, Conducted
Part 2: Range 2 Standalone	TS38.101-2 v.15.2.0	TS38.521-2 v.1.0.0	FR2, Radiated
Part 3: Range 1 and 2 Interworking operation with other radios	TS38.101-3 v.15.2.0	TS38.521-3 v.1.0.0	FR1 and FR2 CA, EN-DC** FR1 Conducted, FR2 Radiated

(\*) v.1.0.x is still draft or pre-release status. (Official version should be v.15.x.x)  
 (\*\*) EN-DC: E-UTRA and NR Dual Connectivity

3GPP NR BTS Tx test requirement	Minimum Requirement (2018-06)	Conformance Requirement (2018-09 draft)*	gNB
Part 1: Conducted testing	TS38.104 v.15.2.0	TS38.141-1 v.1.0.0	FR1, Conducted
Part 2: Radiated testing		TS38.141-2 v.1.0.0	FR1 and FR2, Radiated

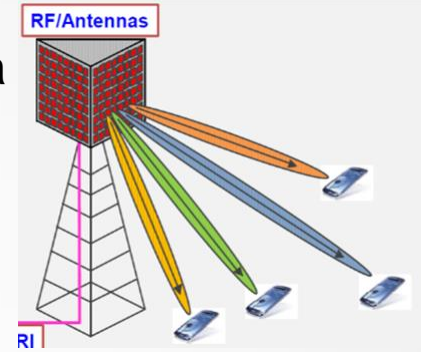
(\*) v.1.0.x is still draft or pre-release status. (Official version should be v.15.x.x)

# Life Beyond Connectors

Free-space Path Loss

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

Active Antenna System (AAS)

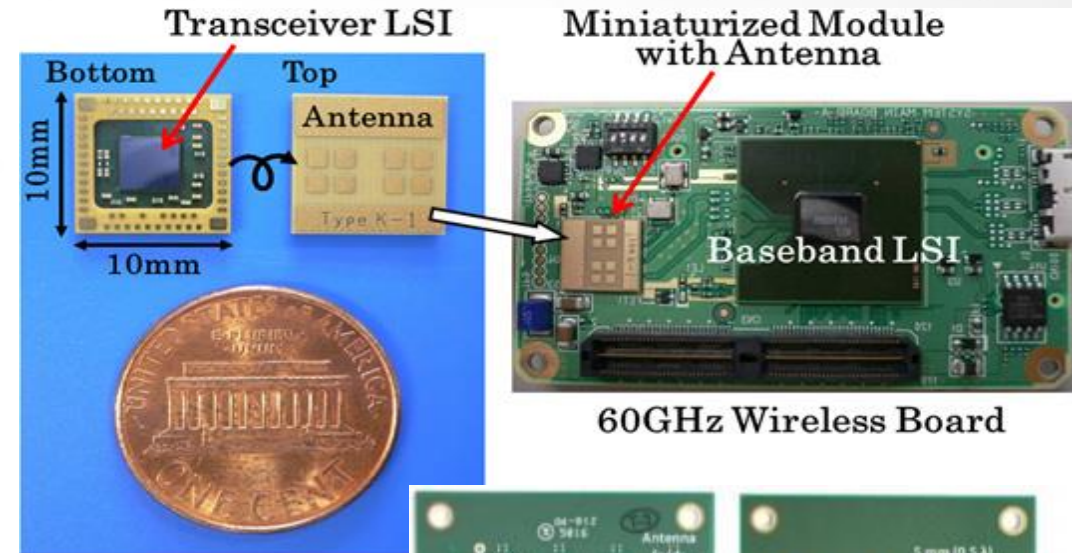


## The Good News:

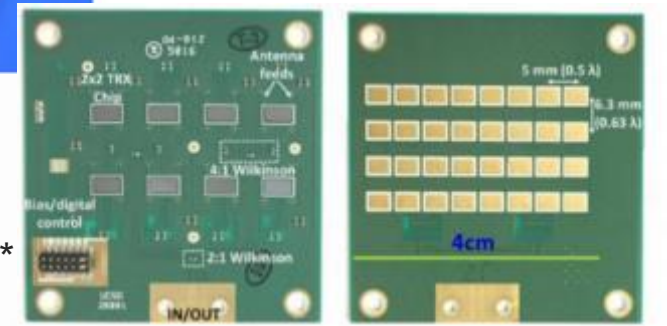
- Higher frequency antenna elements are smaller
- Easier to assemble into electronically steered arrays
- Reduced interference. Energy goes where it's needed
- Improve performance in dense crowds (5G goal)
- Higher frequencies → wider bandwidths: faster (5G goal)

## Challenges:

- Antenna are directional
- Increased complexity with more elements, very small for probing or conducted test
- Multiple antenna arrays required for spherical coverage
- Traditional cabled test methods obsolete – **OTA needed**



28 GHz RFIC\*



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

# Far-Field Test Challenges with mmWaves

**LONGER FAR-FIELD AND HIGHER PATH LOSS**

From Keysight White Paper: OTA Test for Millimeter-Wave 5G NR Devices and Systems

Friis Transmission Equation

$$\frac{P_r}{P_t} = \left( \frac{c}{4\pi R f} \right)^2 G_t G_r$$

What about Path Loss?

Path loss proportional to  $R^2$

Ideal Plane wave is at  $\infty$

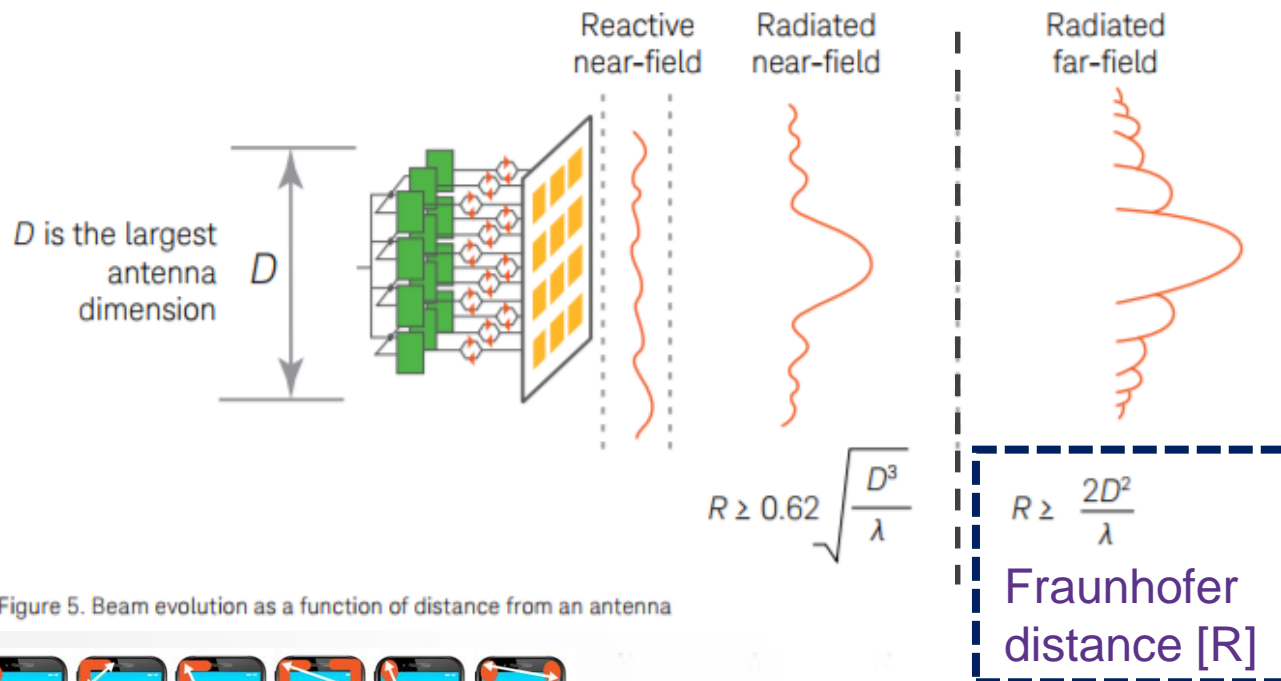
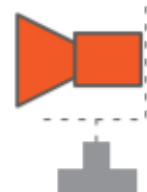


Figure 5. Beam evolution as a function of distance from an antenna



What is D?



Fastback Networks V1000



Facebook Terragraph

$$DFF = 2D^2/\lambda$$

$$DFF = 2 f D^2/c$$

D ↑ → DFF ↑

f ↑ → DFF ↑

Far-Field Distance (m)			
D (mm)	28 GHz	39 GHz	60 GHz
50	0.47	0.65	1
100	1.9	2.6	4
150	4.2	5.9	9
200	7.5	10.4	16
300	16.8	23.4	36.0

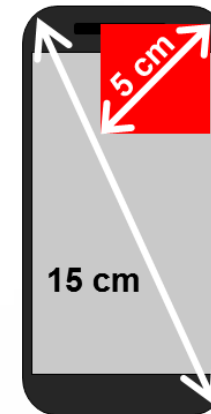
# FR2 Measurement Challenges

## HOW FAR IS THE FAR FIELD?

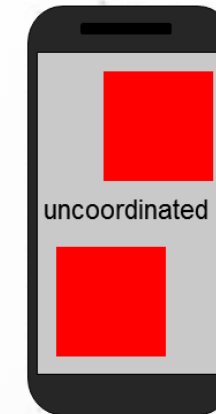
D (cm)	Freq. (GHz)	Far field (m)	Path Loss (dB)	Freq. (GHz)	Far field (m)	Path Loss (dB)	Freq. (GHz)	Far field (m)	Path Loss (dB)
5	2	0.03	8.93	28	0.47	54.77	43	0.72	62.23
10	2	0.13	20.97	28	1.87	66.81	43	2.87	74.27
15	2	0.30	28.01	28	4.20	73.86	43	6.45	81.31
20	2	0.53	33.01	28	7.47	78.86	43	11.47	86.31
30	2	1.20	40.05	28	16.80	85.90	43	25.80	93.35

**TR 38.810** Table 5.3-1: DUT Categories

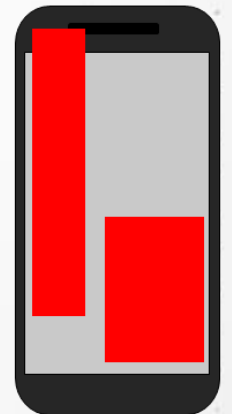
DUT category	Description
Category 1	Maximum one antenna panel with $D \leq 5$ cm illuminated by test signal at any one time
Category 2	More than one antenna panel $D \leq 5$ cm without phase coherency between panels illuminated at any one time
Category 3	Any phase coherent antenna panel of any size (e.g. sparse array)



DUT Cat 1



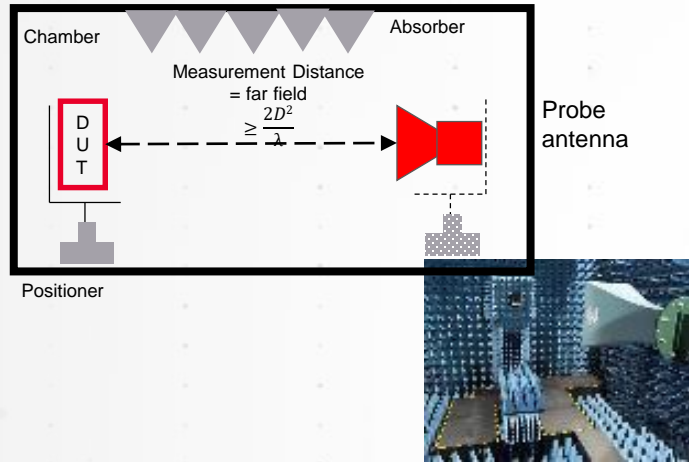
DUT Cat 2



DUT Cat 3

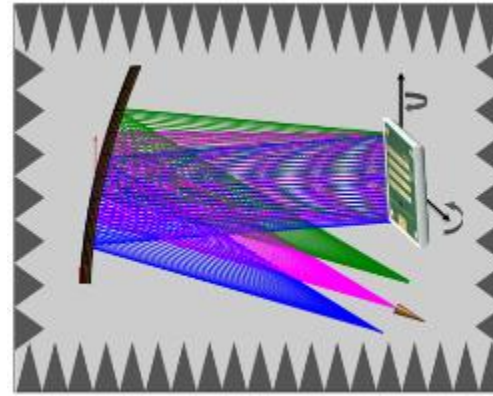
# Common OTA Test Methods

## Direct Far Field



- ✓ Simple design, mature
- ✓ Measurement flexibility;
  - ✓ Antenna beam pattern characterization
  - ✓ Beamforming/beamsteering validation
  - ✓ RF parametric tests (if S/N high enough)
- ✓ How devices operate
- ✗ Subject to higher path loss
- ✗ Can get very large for smaller devices at mmWave frequencies
- ✗ Can be slow (mechanical motion), expensive

## Indirect Far Field



- ✓ Measurement flexibility
  - ✓ Antenna beam pattern characterization
  - ✓ Beamforming/beamsteering validation
  - ✓ RF parametric tests
  - ✓ End-to-End performance (signaling)
- ✓ Small footprint, even for larger devices
- ✓ Lower path loss, better accuracy
- ✗ Slow (limited by mechanical motion)
- ✗ Expensive (slightly more than DFF)

## Near-Field Scanning

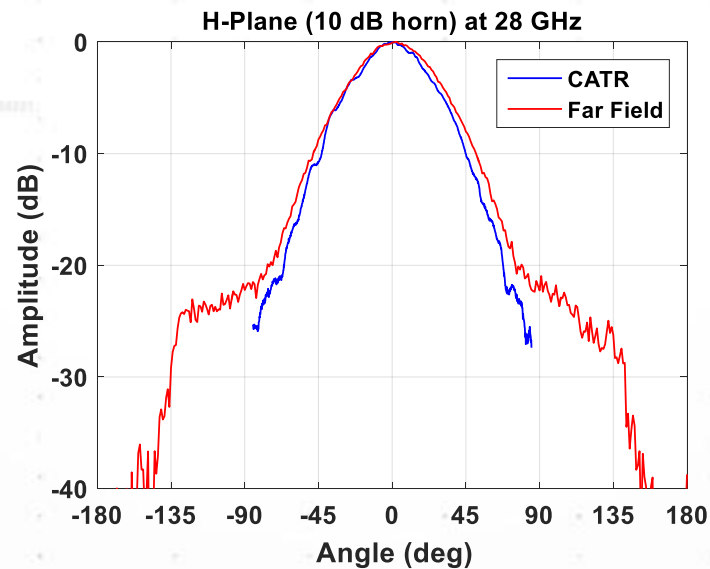
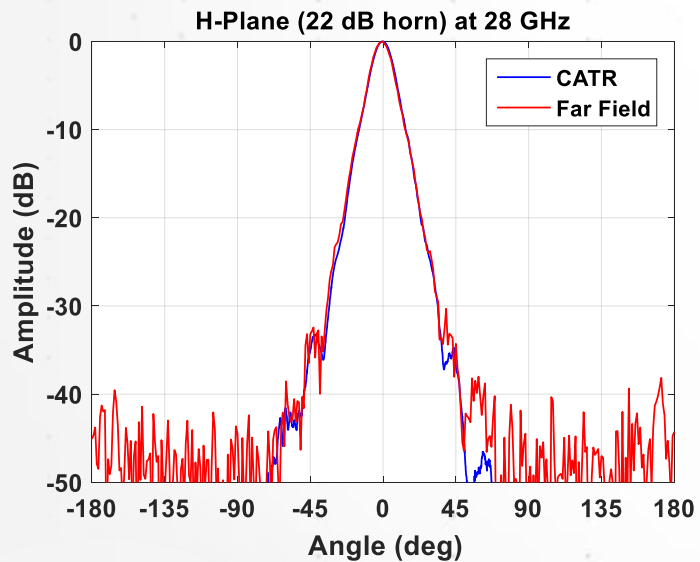
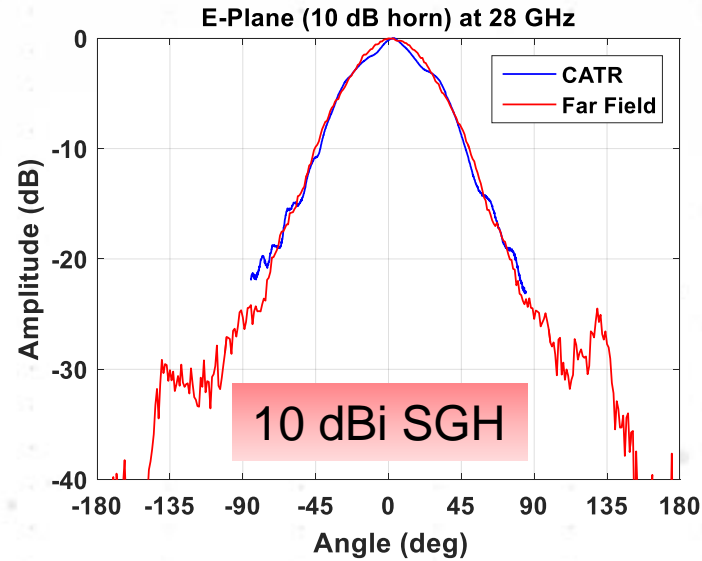
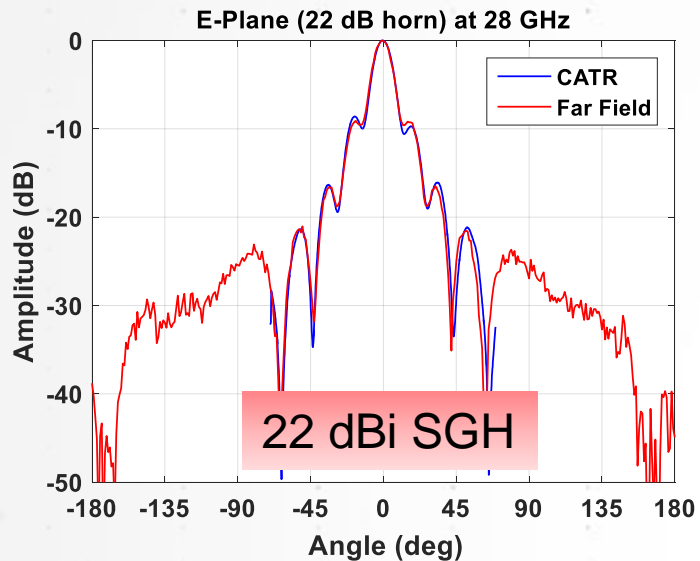


Image courtesy of NSI-MI

- ✓ Small, lower cost (at mmWave?)
- ✓ Passive antenna;
  - ✓ Antenna beam pattern characterization
  - ✓ Beamforming/beamsteering validation
  - ✓ RF parametric tests (with phase recovery)
- ✗ Requires highly accurate positioners for mmWave
- ✗ Applicability to modulated signals
- ✗ Tx tests for active devices
- ✗ Rx tests
- ✗ Can be slow

# Keysight CATR vs. Far Field Range\*

\* <http://allwavecorp.com/AntennaMeasurements.php>



- Comparisons shown for high and low gain horn antennas
- Comparisons show high degree of correlation between the different types of chambers

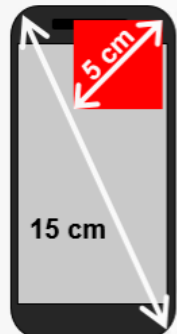
- 22 dB horn : Sage SAR-2013-34-S2
- 10 dB horn : Pasternack PE9851-10

***GREAT CORRELATION !***

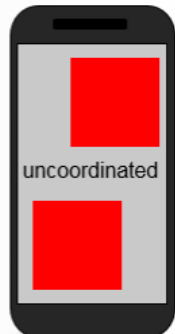


# Measurement Systems for NR UE RF Test

3GPP TR 38.810 STUDY ON TEST METHODS (OTA)



DUT Cat 1



DUT Cat 2



DUT Cat 3

	DFF (Direct Far Field)	IFF (CATR)	NF-TF (Near Field with Transform)
Single panel (Cat 1)	<ul style="list-style-type: none"> <li>Tx / Rx</li> <li>High MU</li> <li>Max D= 5cm</li> <li>UE Declaration Required</li> </ul>	<ul style="list-style-type: none"> <li>✓ Tx / Rx</li> <li>✓ Lowest MU</li> <li>✓ No Declaration (Blackbox)</li> </ul>	<ul style="list-style-type: none"> <li>Tx Only</li> <li>N/A for RX tests</li> <li>Max D= 5cm</li> <li>UE Declaration required</li> </ul>
Multi-panel with no coherence (Cat 2)	<ul style="list-style-type: none"> <li>Tx / Rx</li> <li>Additional MU factor on Rx</li> <li>Max D= 5cm</li> <li>UE Declaration Required</li> </ul>	<ul style="list-style-type: none"> <li>✓ Tx / Rx</li> <li>✓ Lowest MU</li> <li>✓ No Declaration (Blackbox)</li> </ul>	Not Applicable/Approved
Multi-panel with coherence (Cat 3)	Not Applicable/Approved	<ul style="list-style-type: none"> <li>✓ Tx / Rx</li> <li>✓ Lowest MU</li> <li>✓ No Declaration (Blackbox)</li> </ul>	Not Applicable/Approved

**MU = Measurement Uncertainty**

# 3GPP gNB Conformance Tests (TS 38.141-1,2)

## CHAPTER 6,7,8 MEASUREMENT DETAILS

### 3GPP NR gNB Conformance Test Summary

(Conducted & Radiated)

#### Chap 6, Tx Characteristics

- Output Power
- Output Power Dynamics  
(RE Power Control DR / Total Power DR / ...)
- Transmit On/Off Power  
(TX Off Power / TX Transient Period)
- Signal Quality  
(Freq Error / EVM / Time Alignment Error /...)
- Unwanted Emissions  
(Occupied BW / ALCR / Spurious /...)
- Transmitter Intermodulation

#### Summary

- Requires time aligned digitizers  
Or digitizers with wide BW

#### Chap 7, Rx Characteristics Tests

- Reference sensitivity level
- Dynamic range
- Adjacent Channel Selectivity (ACS)
- Blocking characteristics
- Intermodulation characteristics
- In-channel selectivity
- Spurious emissions

#### Summary

- Tests are performed open loop
- Tests require interfering signals
- Performance metric = BLER  
(calculated by eNB)

#### Chap 8, Rx Performance Requirements Tests

- Performance requirements for PUSCH
  - Multipath fading propagation conditions
  - UL timing adjustment
  - HARQ-ACK multiplexed on PUSCH
  - High speed train conditions
- Performance requirements for PDSCH
  - ACK missed detection for single user PUSCH format 2
  - CQI missed detection for PUSCH format 2
  - ACK missed detection for multi user PUSCH format 1a
- Performance Requirements for PDSCH

#### Summary

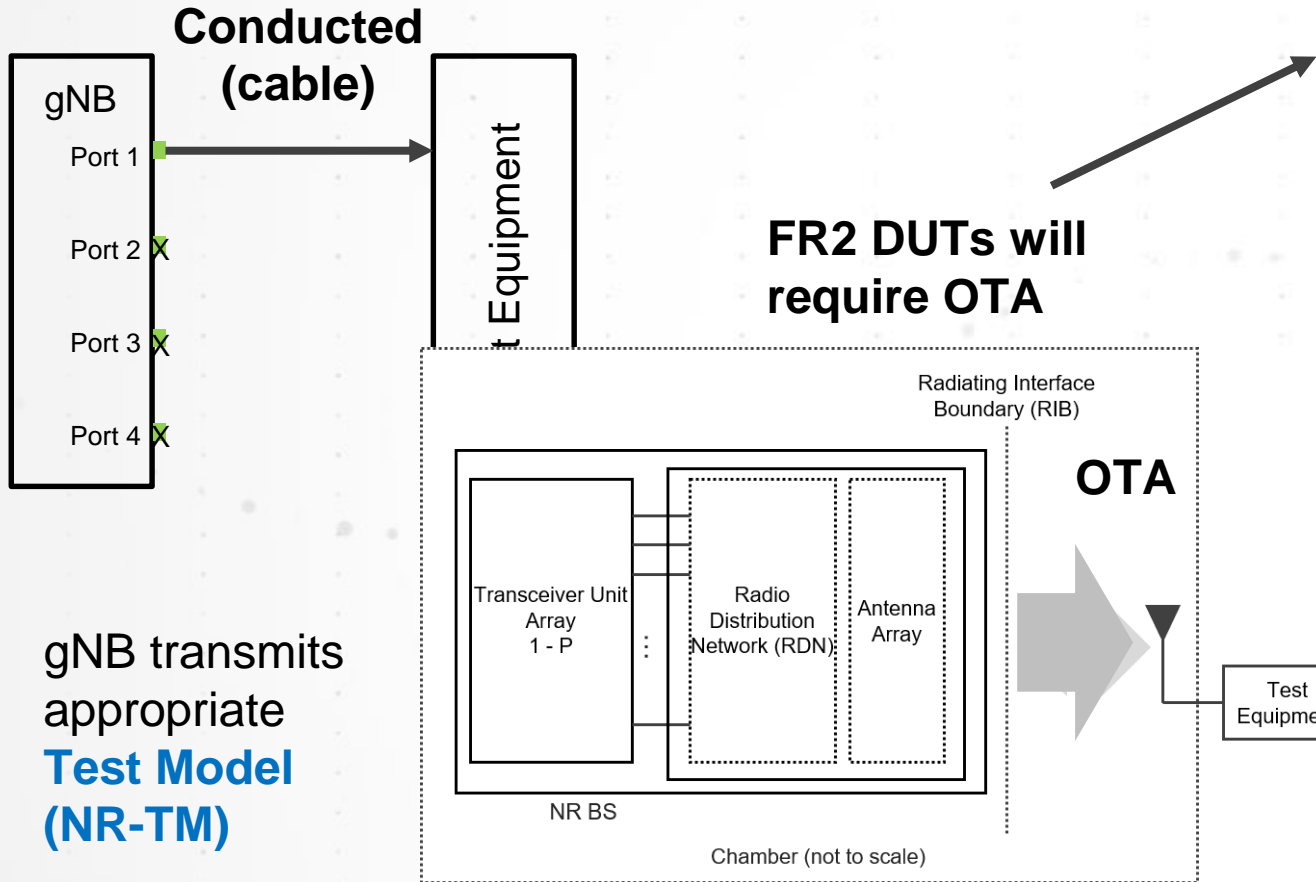
- 3 tests performed closed loop (implies real-time sig gen)
- Tests require fading of 'wanted' & 'interfering' signals
- Performance metric = throughput  
(calculated by eNB)

Chap 8  
Structure not  
defined yet

# 3GPP gNB Transmitter Tests (Chap 6)

3GPP TS 38.141-1 (Conducted)  
**3GPP TS 38.141-2 (Radiated)**

## BASIC CONFIG FOR MOST TESTS



gNB transmits appropriate **Test Model (NR-TM)**

	Parameters	Metric
6.2, 6.3	OTA Base Station Output Power	EIRP TRP
6.4	OTA Output Power Dynamics	EIRP
6.5.1	OTA Transmit OFF Power	EIRP/TRP
6.5.2	OTA Transient Period	EIRP
6.6.2	OTA Frequency Error	EIRP
6.6.3	OTA modulation quality	EIRP
6.6.4	OTA Time alignment error	EIRP
6.7.2	OTA Occupied Bandwidth	EIRP
6.7.3	OTA ACLR	TRP
6.7.4	OTA Out of band Emissions	TRP
6.7.5	OTA Transmitter Spurious Emissions	TRP

*gNB tests will likely follow the eNB very closely with changes added for **FR2 OTA** testing*

# OTA Power Measurements

## TRP AND EIRP

**Total Radiated Power (TRP) value** for the uniform measurement grid:

$$TRP = \frac{\pi}{2NM} \sum_{i=1}^{N-1} \sum_{j=0}^{M-1} [EIRP_{\theta}(\theta_i, \varphi_j) + EIRP_{\varphi}(\theta_i, \varphi_j)] \sin(\theta_i)$$

**EIRP** measured at two orthogonal polarizations

where **N** is the number of angular intervals in the nominal  $\theta$  range from 0 to  $\pi$  and **M** is the number of angular intervals in the nominal  $\varphi$  range from 0 to  $2\pi$ .

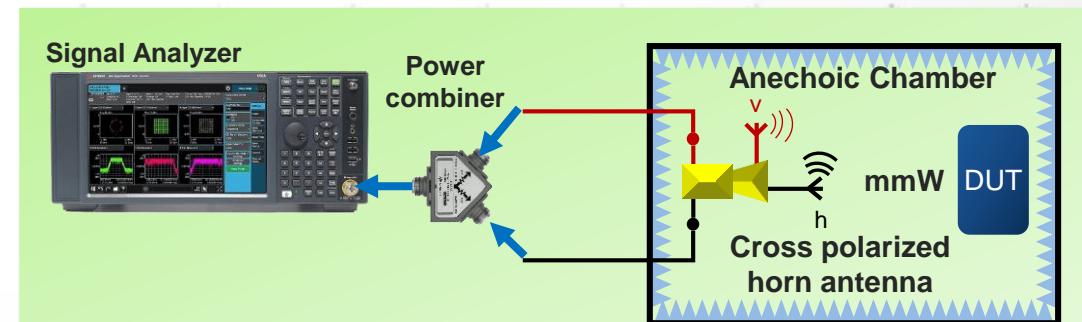
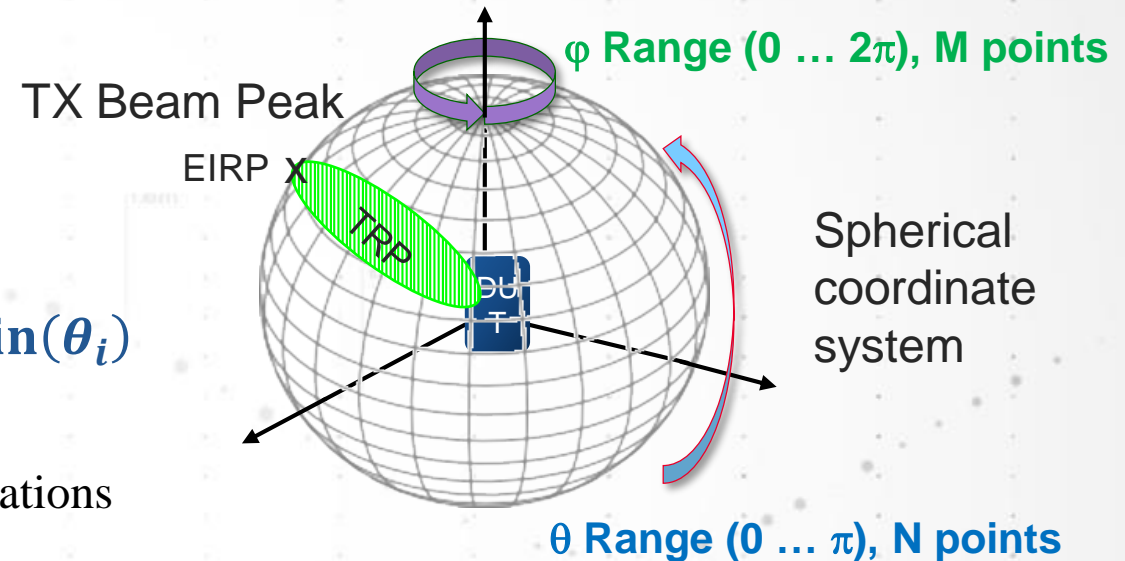
**EIRP = Effective (or Equivalent) Isotropic Radiated Power (usually in dBi).**

Measurement taken at one setting of  $\theta$  and  $\varphi$

Beam Position:

- gNB – declared
- UE - beam locked

**BTS: 3GPP TR37.842 & 843**  
**UE: 3GPP TR38.810**



**This case, SA can make power/spectrum measurement with the Total EIRP directly**

# OTA Measurement – gNB Spatial Requirements

## OTA AAS BS DECLARATION

Example from 3GPP TR 37.843

Example declarations of an OTA Active Antenna System (AAS) BS with multiple beam widths and beam steering capability;

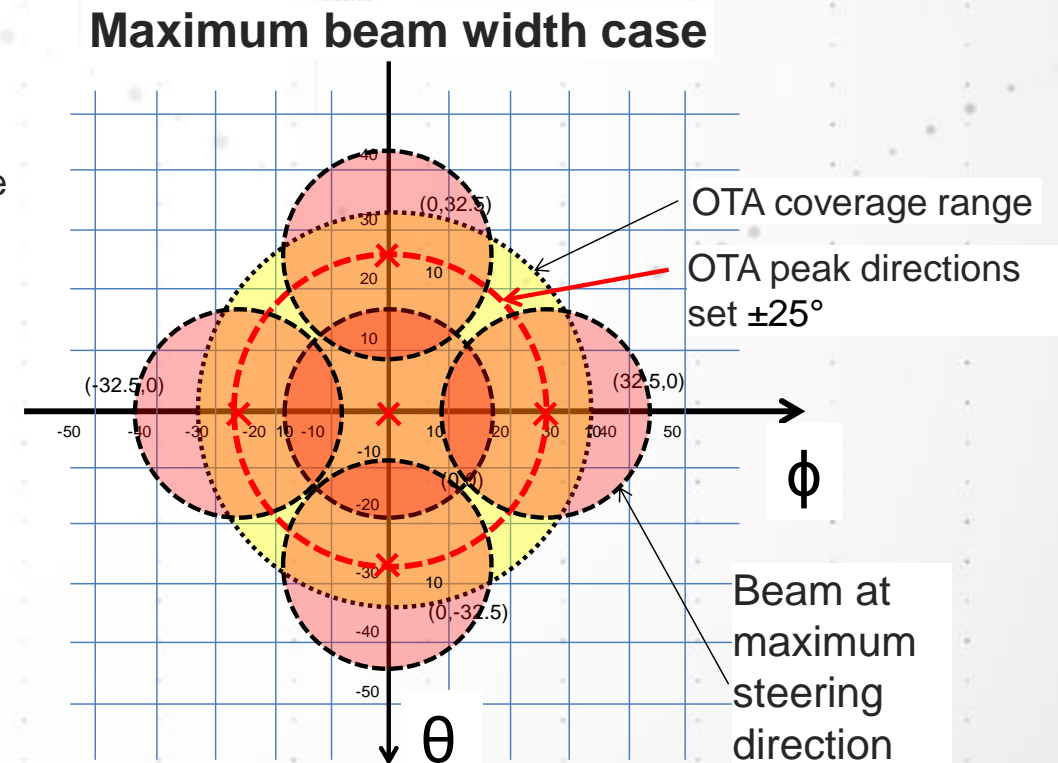
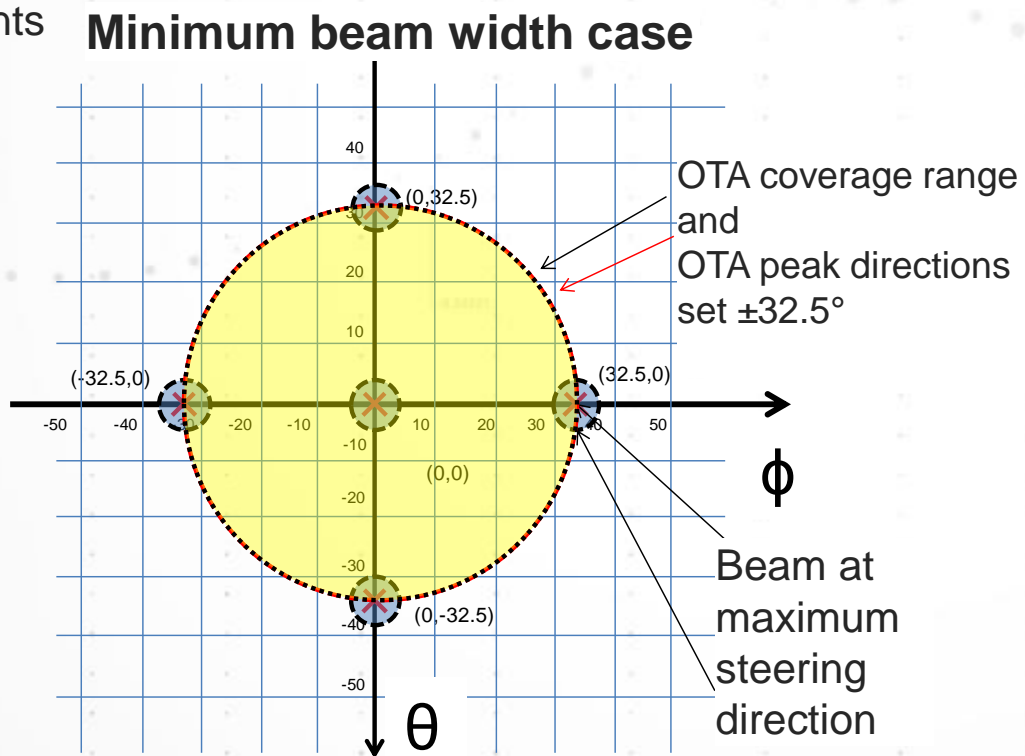
- For the minimum beam width case: beam width ( $\theta$  and  $\phi$ ) =  $10^\circ$ , maximum steering ( $\theta$  and  $\phi$ ) =  $\pm 32.5^\circ$
- For the maximum beam width case: beam width ( $\theta$  and  $\phi$ ) =  $35^\circ$ , maximum steering ( $\theta$  and  $\phi$ ) =  $\pm 25^\circ$

Some Tx measurements made at peak beam position and/or max steering direction;

- Tx Power
- Freq Error
- EVM

Other measurements made at peak beam position and over grid (TRP);

- Tx Power
- ACLR
- Out-of-Band



# What about those NR gNB Test Models?

## TS38.141-1 SECTION 4.9.2 NR TEST MODELS FOR FR1 TDD

Table 4.9.2.2-1:

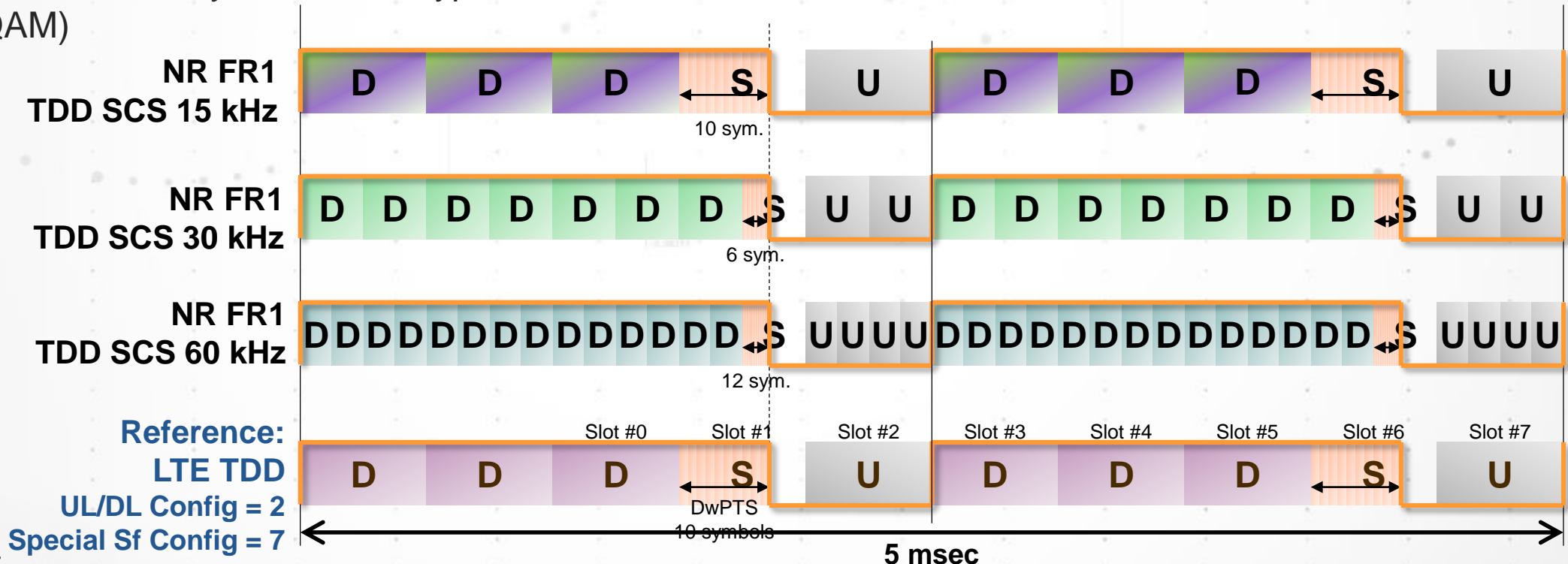
Configurations of TDD gNB test models for NR FR1

Test model for FR1 TDD frame structure is defined but not the physical parameters.

SCS [kHz]	Number of DL slots	Number of DL symbols in S slot	Number of UL symbols in S slot	Number of UL slots
15	3	10	2	1
30	7	6	4	2
60 (Note)	14	12	8	4

Note: There are two S slots. First S slot has 12 DL symbols followed by 2 flexible symbols; second S slot has 6 flexible symbols followed by 8 UL symbols.

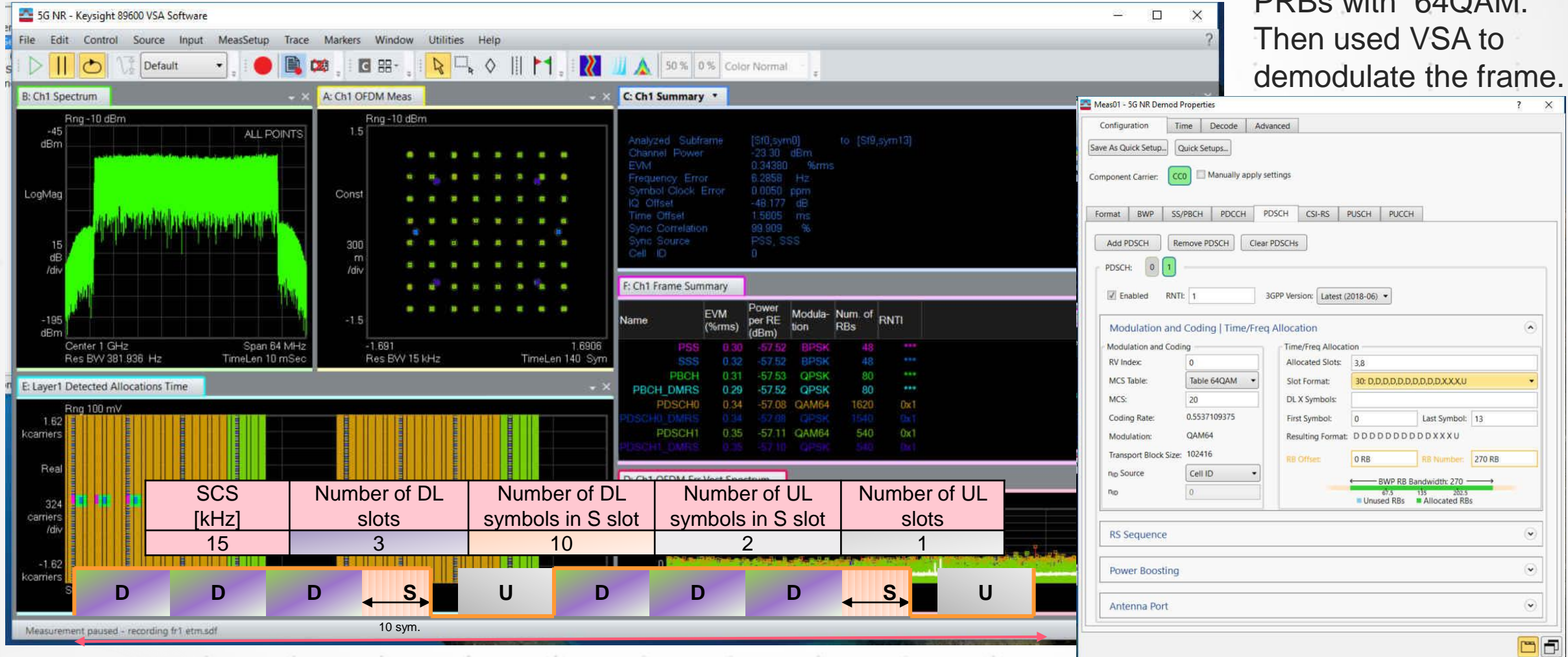
We can generate this frame structure and populate PRB with any modulation type (eg 64 QAM)



# What about those NR gNB Test Models?

## VSA DEMOD OF NR TEST MODEL FOR FR1 50 MHz TDD 64QAM

Used signal studio for 5G NR to generate a FR1 TDD NR-TM frame and filled all PRBs with 64QAM. Then used VSA to demodulate the frame.



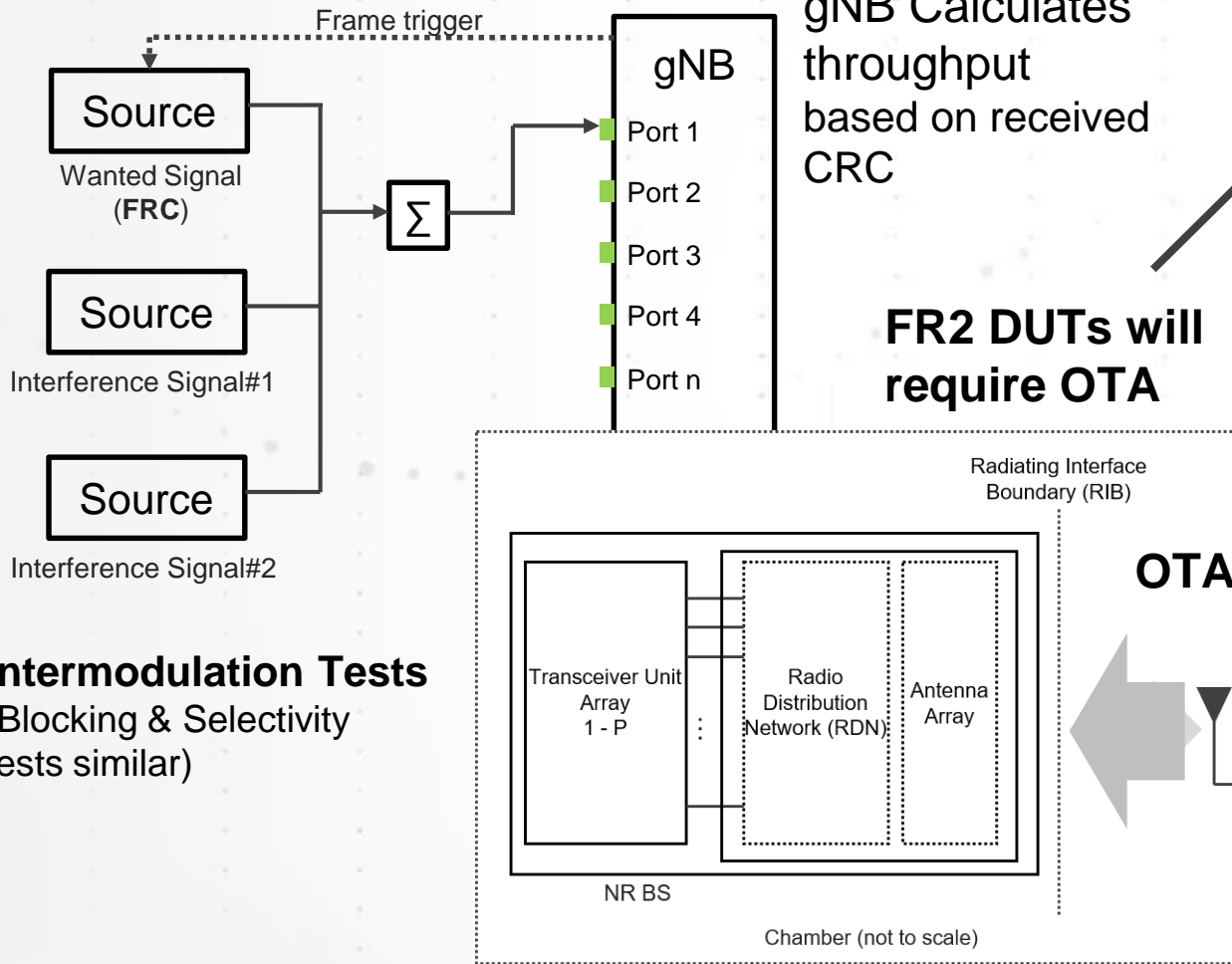
1 Frame = 10 ms = 10 slots

# 3GPP gNB Receiver Characteristics (Chap 7)

## ADDITIONAL TEST CONFIGS

3GPP TS 38.141-1 (Conducted)  
 3GPP TS 38.141-2 (Radiated)

### Conducted (cable)



	Parameters	Metric
7.3	OTA Reference Sensitivity Level	EIS
7.4	OTA Dynamic Range	EIS
7.5.1	OTA adjacent channel selectivity	EIS
7.5.2	OTA in-band blocking	EIS
7.6	OTA Out-of-band Blocking	EIS
7.7	OTA Receiver Spurious Emissions	TRP
7.8	OTA Receiver Intermodulation	EIS
7.9	OTA In-channel Selectivity	EIS

**Intermodulation Tests**  
 (Blocking & Selectivity tests similar)



# OTA Sensitivity Measurements

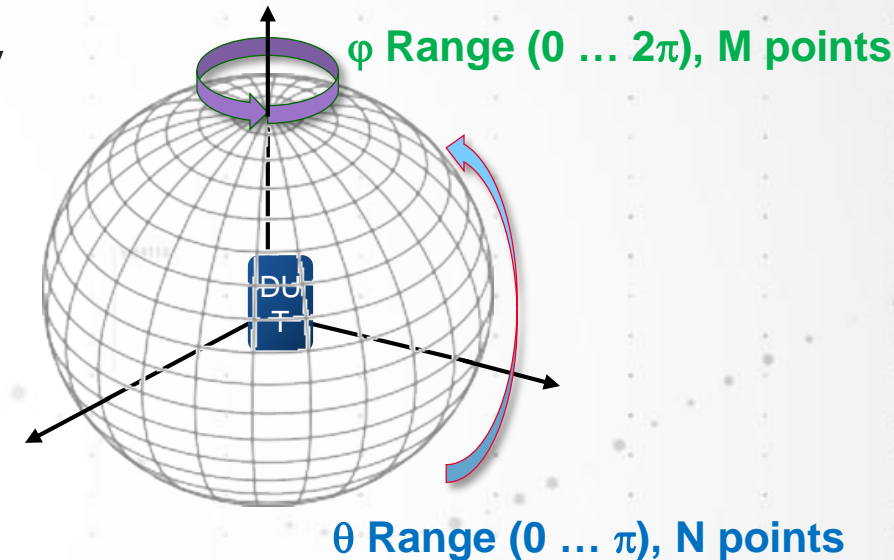
## TIS AND EIS

**Effective Isotropic Sensitivity (EIS)** is the measured sensitivity in a single direction (fixed  $\theta$  and  $\varphi$ ). Usually expressed in dBm.

**Total Isotropic Sensitivity (TIS) value** for the uniform measurement grid:

$$TIS = \frac{2NM}{\pi \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} \left[ \frac{1}{EIS_{\theta}(\theta_i, \varphi_j)} + \frac{1}{EIS_{\varphi}(\theta_i, \varphi_j)} \right]} \sin\theta_i$$

$$TIS = \frac{4\pi}{\int_0^{2\pi} \int_0^{\pi} \left[ \frac{1}{EIS_{\theta}(\theta_1, \phi_1)} + \frac{1}{EIS_{\varphi}(\theta_1, \phi_1)} \right] \sin\theta_1 d\theta_1 d\phi_1}$$



This summation approximation is valid for TIS in the same way as for TRP.

# Fixed Reference Channels (FRC) for gNB Rx Testing

DEFINED IN ANNEX A.X IN TS 38.141-1 & 38.141-2

Annex A (normative):  
Reference measurement channels

## A.1 Fixed Reference Channels for receiver and in-channel selectivity (QPSK, R

The parameters for the reference measurement channels are specified in table A.1-1 for channel selectivity.

The parameters for the reference measurement channels are specified in table A.1-2 for channel selectivity.

Table A.1-1: FRC parameters for FR1 receiver sensitivity and in

Reference channel	G-FR1-A1-1	G-FR1-A1-2	G-FR1-A1-3	G-FR1-A1-4	G-FR1-A1-5	G-FR1-A1-6
Subcarrier spacing[kHz]	15	30	60	15	30	60
Allocated resource blocks	25	11	11	106	51	24
CP-OFDM Symbols per slot (Note 1)	12	12	12	12	12	12
Modulation	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK
Code rate (Note 2)	1/3	1/3	1/3	1/3	1/3	1/3
Payload size (bits)	2152	984	984	9224	4352	208
Transport block CRC (bits)	16	16	16	24	24	16
Code block CRC size (bits)	-	-	-	24	-	-
Number of code blocks - C	1	1	1	2	1	1
Coded block size	2168	1000	1000	4648	4376	2104

Signal Studio Pro for 5G NR  
N7631C

The screenshot shows the Keysight Signal Studio Pro for 5G NR interface. A green box highlights the 'FRC Quick Setup' menu item. The configuration window is open, showing various settings for the reference channels. A dropdown menu is visible, listing nine reference channels (G-FR1-A1-1 to G-FR1-A1-9) with their respective parameters (SCS, RB, Modulation, and Rate). Below the settings, a 'Channel Allocation' graph shows the CRB for u=1 across 20 slots, with SS/PBCH and DL-SCH channels indicated.

**FRC Quick Setup**

Save to 89600 Setup File | **FRC Quick Setup** | Full-filled Config | Hint

**1. General Settings**

- Enabled
- Frequency Offset
- Timing Offset
- Power Boosting
- Initial Phase
- FR1 Receiver sensitivity and in-channel selectivity
- FR1 Dynamic range
- FR2 Receiver sensitivity and in-channel selectivity

**2. Spectrum Control**

- DC Punctured
- Window Beta
- Windowing Method
- Baseband Filter

**3. Cell-Specific Settings**

- Carrier Type
- Cell ID
- Numerology Mode
- Bandwidth
- Numerology

Channel Allocation

CRB for u=1

273

137

0 2 4 6 8 10 12 14 16 18 20 Slot

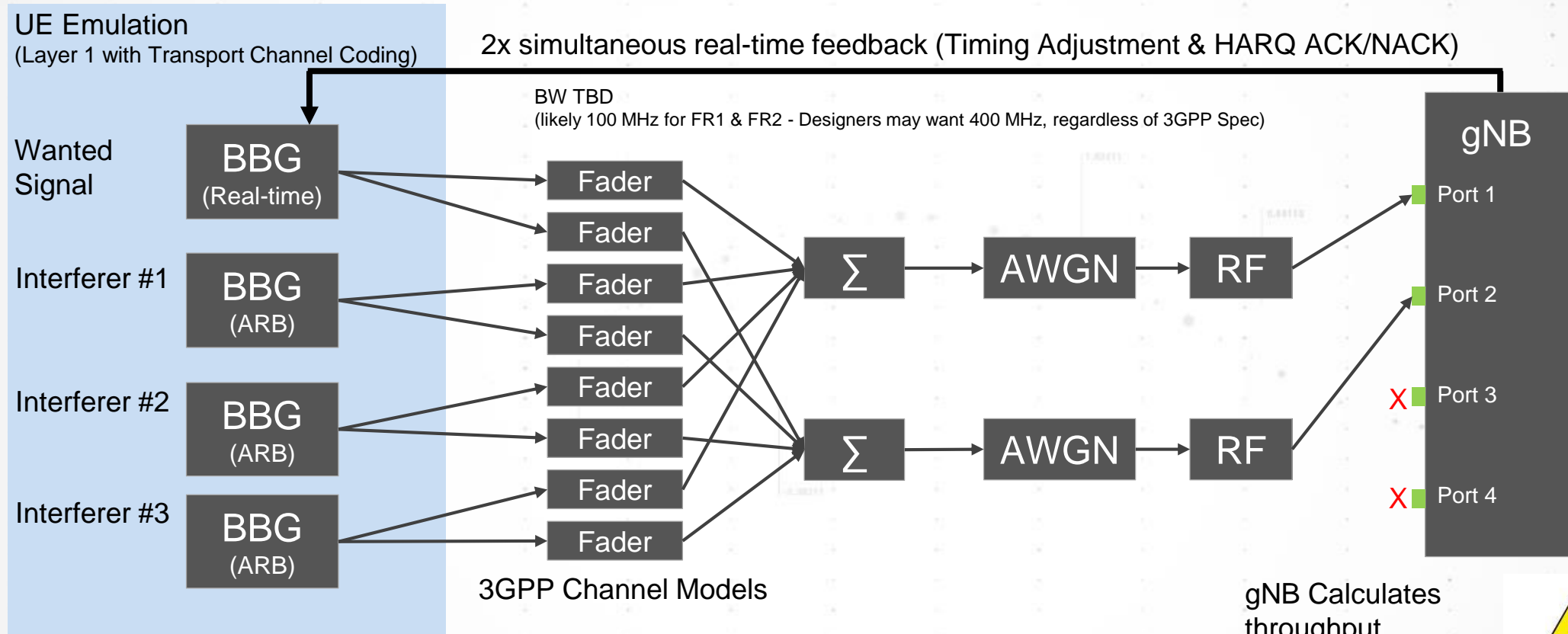
SS/PBCH

DL-SCH

u=1 axis

# 3GPP gNB Receiver Performance Requirements (Chap 8)

## EXAMPLE 4X2 TEST CASE



Do  
this  
OTA!



gNB Calculates throughput (based on CRC)



- FR2 DUTs will require OTA
- Legacy LTE supports 8x8 spatial multiplexing (not required in conformance test but of interest in R&D)
- Depending on gNB capability, some tests require: 1x2, 4x2, 2x2, 3x2, **3x4, 3x8**

# 3GPP UE Conformance Test Requirements: Radiated

TS38.521-2 V.1.0.0 (V.2018-09) - DRAFT

TS38.521-2	Transmitter Test	Measurement	OTA
6.2.1	UE maximum output power	Chan Power	EIRP, TRP
6.2.2	UE maximum output power reduction (MPR)	Chan Power	<FFS>
6.2.3	UE maximum output power with additional requirements	Chan Power	<FFS>
6.2.4	Configured transmitted power	Chan Power	EIRP, TRP
6.3.1	Minimum output power	Chan Power	EIRP
6.3.2	Transmit OFF power	Tx On/Off Power	TRP
6.3.3	Transmit ON/OFF time mask	Tx On/Off Power	EIRP
6.3.4	Power control		EIRP?
6.4.1	Frequency error	Mod Analysis	q- & j- each
6.4.2.1	Error Vector Magnitude	Mod Analysis	q- & j- each
6.4.2.2	Carrier leakage	Mod Analysis	EIRP?
6.4.2.3	In-band emissions (IBE)	Mod Analysis	<FFS>
6.4.2.4, 6.4.2.5	EVM equalizer spectrum flatness, EVM spectrum flatness for pi/2 BPSK with spectrum shaping	Mod Analysis	<FFS>
6.5.1	Occupied bandwidth	OBW	EIRP
6.5.2.1, 6.5.2.2	Spectrum emission mask Additional Spectrum emission mask	SEM	TRP
6.5.2.3	Adjacent channel leakage ratio	ACP	TRP
6.5.3	Spurious emissions	Spur Emissions	TRP

## 3GPP TS 38.521-2 (Radiated) – UE FR2

TS38.521-2	Receiver Test	Metrics	Assumed Link Direction
7.3	Reference sensitivity level	EIS CDF	Each beam peak search grid
7.4	Maximum input level	Beam peak	RX beam peak direction
7.5	Adjacent Channel Selectivity (ACS)	Beam peak	RX beam peak direction
7.6.2	In-band blocking	Beam peak	RX beam peak direction
7.6.3, 7.7	Out-of-band blocking and Spurious response	FFS	FFS
7.9	Receiver Spurious emissions	FFS	TX beam peak direction
7.10	Receiver image	FFS	FFS

FFS – For Further Study

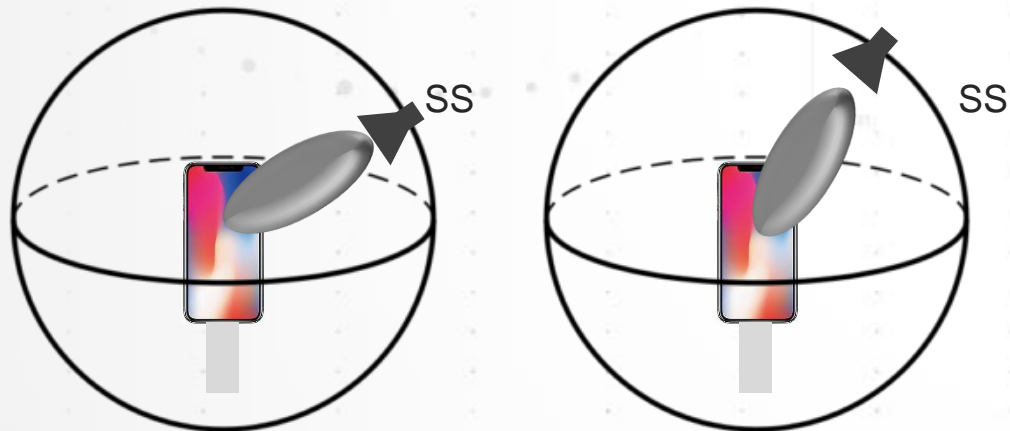
# 3GPP UE Test Requirements: Radiated

## UE BEAMLOCK FUNCTION (UBF)

3GPP TS 38.521-2 (Radiated) –  
UE FR2

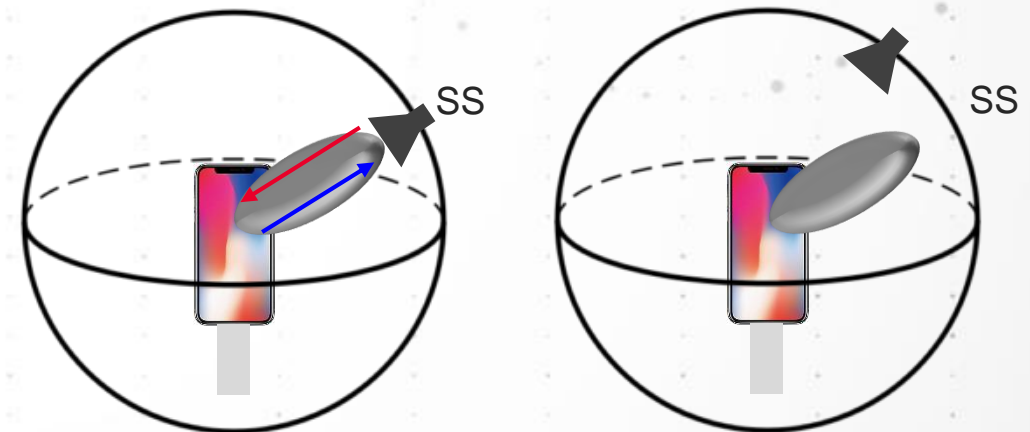
Without UE Beamlock Function (UBF), the UE keeps forming the beam towards the SS

- Required for Spherical Coverage, TX & RX Beam Peak Searches, EIS, EIRP measurements



The **UBF** is intended for making the UE to lock the UE antenna pattern once it has formed a beam towards the base station (SS) direction

- **Required for TRP measurements**
- Recommended to prevent the beam from moving when performing measurements at low SNRs



UE ← Activate Beamlock → SS  
Activate Beamlock Complete →

# Keysight OTA Solutions for mmWave UE Test

FROM R&D TO CONFORMANCE TO CARRIER COMPLIANCE



Rack Mount Test Chamber (RMTC)

- Fits in 19" rack
- 5-cm QZ size
- Single AoA
- Direct far-field
- 1x dual-polarized probe

Light weight, Cable replacement

UE Calibration / Array Calibration / Functional / Protocol Signaling / Performance / Demod tests



Compact Antenna Test Range (CATR) or IFF

- Multiple sizes
- Single AoA
- Indirect Far-field
- 1x dual polarized probe

Black-box testing - 3GPP Approved Solution for RF Test

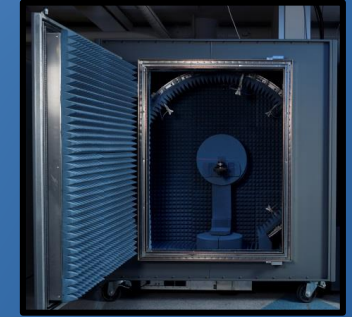
Antenna / RF Parametric / TRP & TIS / Functional (incl. beam tracking) / Protocol testing / Throughput (clean channel)



2D MPAC

- Multiple AoA
- Far-field
- 3-4 dual polarized probe
- 45° 2D arch
- Benchtop installation

Functional (beam forming/ Protocol testing)



3D MPAC

- Multiple AoA
- Far-field
- 4 out of 6 X-polarized probes
- 180° basic 3D or sectorized

Performance test (with fading – 38.901) / RRM (HO & Throughput) / Virtual drive test / Beam Management

# Multi-Channel 5G Testbed for gNB

3GPP CONFORMANCE READY – HIGH PERFORMANCE

## Test Signal

2x2 MIMO at 28 GHz

## Key Features

- 44 GHz Signal Creation / 110 GHz Analysis
- Multi-channel
- High Output Power
- 2 GHz signal Creation BW
- 110 GHz BW Demodulation Analysis
- Swept-tuned measurements to 110 GHz
- Import S-Parameters to de-embed test fixture

## Device Under Test

Cross-polarized 28 GHz phased array



## DC Power Analyzer

**VXG**

44 GHz Dual Ch. Source

**UXR**

110 GHz Oscilloscope

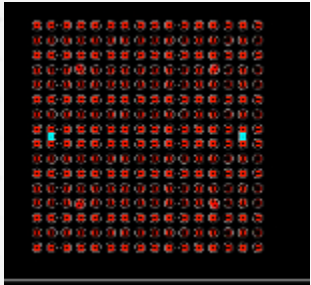
**UXG**

110 GHz Signal Analyzer

# 7 Key Measurement Challenges

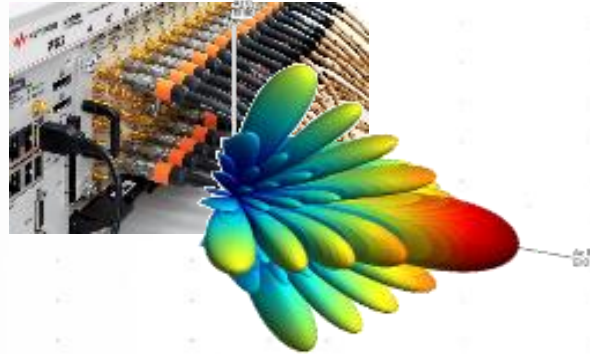
## Signal Quality

*mmW, Waveform, Fidelity*



## Lots of Channels

*MIMO/Beamforming*



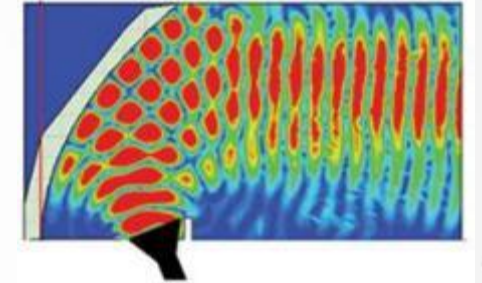
## Connect Design & Test

*Components, Systems*



## Life Beyond Connectors

*Over-the-Air*



## Performance on the Network

*Network Emulation*

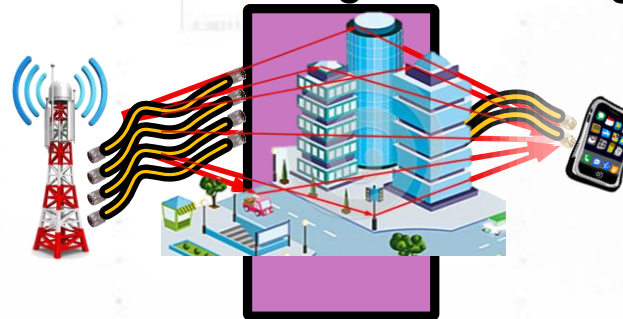


Protocol  
R&D

RF / RRM  
DVT

Functional  
KPI

## Channel Characterizing & Emulating



## Field Testing and Drive Test





# Get the fastest path to 5G Solutions

## TARGETING CHIPSET AND DEVICE WORKFLOW

### 5G Interactive R&D Solutions



### 5G Device Acceptance Solutions



### 5G MFG Solutions



## Keysight 1<sup>st</sup> Solutions across the entire device workflow



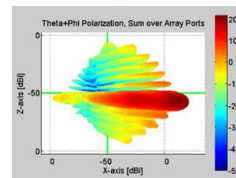
UXM 5G – E7515B

**Network Emulator**



PROPSIM

**Channel Emulator**



CIU



**mmWave OTA Solutions**

RRH



RMTC / CATR / MPAC



EXM – E6640A



VXT-II  
M9410/11A

**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

# 5G Device End-to-End Workflow

## PROTOCOL DEVELOPMENT



**Early protocol development while keeping up with evolving 5G standards;**

- Progress stack and gain insights to optimize performance
- Customize scripts, automate efficiently, and debug quickly
- Leverage work across workflow stages, stay current with standards cost effectively

### Key Features:

- ✓ Earliest availability of new 5G features
- ✓ Replicate desired network behavior whilst reducing test complexity with Built-in Protocol State Machine and Dynamic Control Points
- ✓ L1/L2 parameter change without programming
- ✓ Flexible automation and logging
- ✓ Results viewer

Sub-6 GHz and mmWave - Conducted and OTA

# Modify network behaviour easily

## 5G PROTOCOL R&D TOOLSET



- Allow dynamic L1/L2 parameter changes without the need for programming
- Very useful in early development testing of prototypes

The screenshot displays the 'DL Scheduling' configuration window. At the top, there are tabs for 'General', 'DL Scheduling', and 'UL Scheduling'. The 'DL Scheduling' tab is active. The interface includes several configuration sections:

- Resource Allocation Type:** Fixed (dropdown)
- Transmission Mode:** TM1 (dropdown)
- Resource Block Allocation:** A grid showing resource block allocation for RBs 24-48 and 74-98 across subcarriers 00-99.
- xPDSCH Start Symbol:** Symbol 2 (dropdown)
- xPDSCH Stop Symbol:** Symbol 12 (dropdown)
- xPUCCH Resource Index:** 0 (text input)
- DL PCRS:** No PCRS (dropdown)
- UCI Request Configuration (Using xPUCCH - DCI B1/B2):**
  - Request Type: None (dropdown)
  - CSI-RS/BRRS OFDM Symbol Index: 0 (dropdown)
  - CSI-RS/BRRS Transmission Timing: 1 (text input)
  - CSI-RS/BRRS Process Indicator: Process 0 (dropdown)
  - Beam Switch Indication:
- Allocation Mode Configuration:**
  - Resource Allocation Mode: Normal (dropdown)
  - Trigger One Shot Allocation:
- Antenna Ports Configuration:**
  - Single Layer Transmission: 1 Layer - Port 8 (dropdown)
  - Two Layer Transmission: 2 Layers - Ports 8, 9 (dropdown)
- xPDCCH Search Space Configuration:**
  - DCI Allocation Mode: Dynamic (dropdown)
  - Search Space Index: 0 (text input)
  - Aggregation Level: 2 (dropdown)
  - Ofdm Symbol Index: Dynamic (dropdown)
- Other Parameters:**
  - Fixed MCS Index:  MCS Index: 9 (text input)
  - DL MMIO Fixed Rank:  Rank: Rank 1 (dropdown)
  - HARQ Auto Ack:
  - Scrambling Code Id: 0 (dropdown)

# 5G logging



## 5G PROTOCOL R&D TOOLSET

- Displays all layers of the protocol stack; PHY, MAC, RLC, RRC, PDCP
- Filtering allows the user to view the data of interest
- Advanced search features and bookmarks make debugging easier
- User friendly as all information needed is available in one view

The screenshot shows the Log Viewer application interface. The main window displays a table of log records with columns for Index, Icons, Protocol, Record, Source, Destination, Summary, and Frame. The selected record (Index 66389) is a BCCH-BCH-Message from the RRC protocol. The Details pane on the right shows the structure of this message, including fields like dl-Bandwidth, phich-Config, and spare. The Overview pane on the far right shows a green 'PASS' status. The bottom status bar indicates a log size of 8.3 MB and 1223 records.

Index	Icons	Protocol	Record	Source	Destination	Summary	Frame
66369		Developers AP	Property Set	\\Test Control\De		E-Cell A->ULFrequency = 1950	
66370		Developers AP	Property Set	\\Test Control\De		E-Cell A->ULEarfcn = 18300	
66373		Developers AP	Property Set	\\Test Control\De		E-Cell A->DLFrequency = 2140	
66374		Developers AP	Property Set	\\Test Control\De		E-Cell A->DLEarfcn = 300	
66375		Developers AP	Property Set	\\Test Control\De		E-Cell A->PhysicalLayerCellIdentity	
66376		Developers AP	Property Set	\\Test Control\De		E-Cell A->PhysicalLayerCellIdentityC	
66377		Developers AP	Property Set	\\Test Control\De		E-Cell A->TimingOffset = 0	
66378		Developers AP	Property Set	\\Test Control\De		E-Cell A->AntennaCount = 1	
66379		Developers AP	Property Set	\\Test Control\De		E-Cell A->NumAntennaElements =	
66380		Developers AP	Property Set	\\Test Control\De		E-Cell A->AntennaMapping = ANTI	
66381		Developers AP	Property Set	\\Test Control\De		E-Cell A->Enabled = VARIANT_TRU	
66382		Developers AP	Property Set	\\Test Control\De		E-Cell A->EtwPrimaryNotificationE	
66383		Developers AP	Property Set	\\Test Control\De		E-Cell A->EtwSecondaryNotificatio	
66389		RRC	BCCH-BCH-Message	\\Protocol\3GPP\		MasterInformationBlock	
66390		Developers AP	Property Set	\\Test Control\De		E-Cell A->Macs->Mac [1]->SIs->MI	
66393		RRC	BCCH-DL-SCH-Message	\\Protocol\3GPP\		systemInformationBlockType1	
66394		Developers AP	Property Set	\\Test Control\De		E-Cell A->Macs->Mac [1]->SIs->SII	
66397		RRC	BCCH-DL-SCH-Message	\\Protocol\3GPP\		systemInformation	
66398		Developers AP	Property Set	\\Test Control\De		E-Cell A->Macs->Mac [1]->SIs->SI-	
66401		Developers AP	Method Called	\\Test Control\De		E-Cell A->Signals->AddNew(SignalF	
66403		Developers AP	Method Called	\\Test Control\De		E-Cell A->Signals->AddNew(SignalF	
66405		Developers AP	Method Called	\\Test Control\De		E-Cell A->Signals->AddNew(SignalF	
66407		Developers AP	Method Called	\\Test Control\De		E-Cell A->Signals->AddNew(SignalF	
66408		Developers AP	Method Called	\\Test Control\De		E-Cell A->PhysicalChannels->AddN	
66409		Developers AP	Method Called	\\Test Control\De		E-Cell A->PhysicalChannels->AddN	
66410		Developers AP	Method Called	\\Test Control\De		E-Cell A->TransportChannels->Add	
66411		Developers AP	Method Called	\\Test Control\De		E-Cell A->TransportChannels->Rch	

# 5G Device End-to-End Workflow

## R&D CHALLENGES – RF DVT



### More RF bands, wider bandwidths, and beamforming;

- Wideband calibration and verification
- New waveforms, flexible numerology
- Beamforming & beam management
- More band combination complexity

***DVT = Design Validation Test***

### Key Features:

- ✓ 5G NR support
- ✓ RF Test Application
- ✓ Automation & Scripting
- ✓ Pre-conformance ready
- ✓ Traceability to conformance

Sub-6 GHz and mmWave - Conducted and OTA

# Establish a 5G NR Call



## SINGLE CELL AND CARRIER AGGREGATION

The screenshot displays the Keysight C8700200A 5G NSA Full Stack Test Application interface. At the top, five cell configurations are shown, each with a status indicator (ON/OFF) and a signal strength icon. The first cell is labeled 'Main Cell (LTE)' and the others are 'Secondary Cells (NR)'. The 'Config' tab is active, showing detailed parameters for the selected cell. The 'Frequency' section includes Duplex Mode (TDD), Frequency Range (FR2 (mmWave)), DL Bandwidth (FR1 (sub-6GHz)), DL ARFCN (Custom), DL Frequency (28017.12 MHz), DL Point A (2078659), and Phase Compensation (DL/UL). The 'Power' section includes Reference Signal EPRE (-55 dBm/SCS), Expected UL Power (-20 dBm), and DL Cable Loss (0 dB). The 'Timing' section includes Cell Timing (0 ms) and Uplink Delay (-215 samples). The 'Antenna' section includes DL Physical Antenna Ports (N2) and UL Physical Antenna Ports (N2). A 'Frequency range, band, bandwidth...' callout points to the Frequency Range, Band, and UL Bandwidth fields. A 'Power, Timings, Antenna Ports' callout points to the Power, Timing, and Antenna sections. The bottom status bar shows a configuration error: 'Configuration error: Application configuration file has been changed. Instrument behaviour may not be as expected. (Error 137)'. The bottom navigation bar includes tabs for System, Cell, SSB, PHY, Scheduling, MAC/RLC/PDCP, Data Generation, BLER/Tput, and Tx Meas.

Note: Maximum number of Cells may depend on technology, bands and HW configuration

# Establish a 5G NR Call

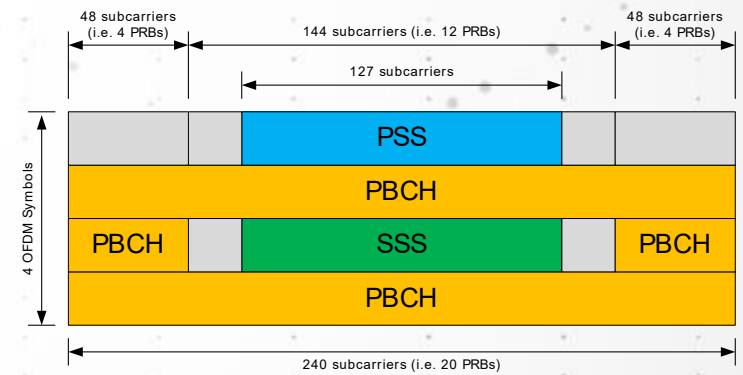
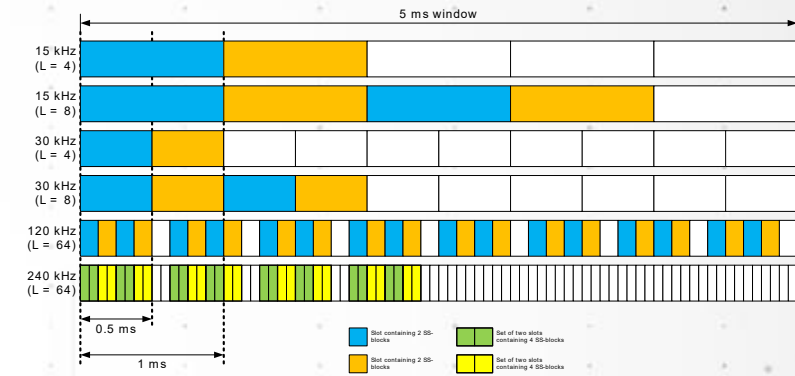


## BEAM CONFIGURATION

**FR1, L = 8**

**FR2, L = 64**

Select SSB position, FR1 and FR2 has different bitmaps



SSB includes 1 PSS, 1 SSS and 2 PBCH OFDM symbols the random access, transmitted over the same single antenna transmission scheme

# Establish a 5G NR Call



## PHYSICAL LAYER PARAMETERS

The screenshot displays the 'PHY' configuration page of the Keysight C8700200A 5G NSA Full Stack Test Application. At the top, five radio bearers are listed with their respective parameters:

- Bearer 1:** PCC / TDD 33, -85.00 dBm/15kHz, BW: 10 MHz, EARFCN: D: 36100, U: 36100.
- Bearer 2:** NSA gNB SN N77, -19.85 dBm/MHz, BW: 100 MHz, Freq: D: 3550.56, U: 3550.56.
- Bearer 3:** NSA gNB SN N257, -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28120.80, U: 28120.80.
- Bearer 4:** NSA gNB SN N257, -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28224.48, U: 28224.48.
- Bearer 5:** NSA gNB SN N257, -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28328.16, U: 28328.16.

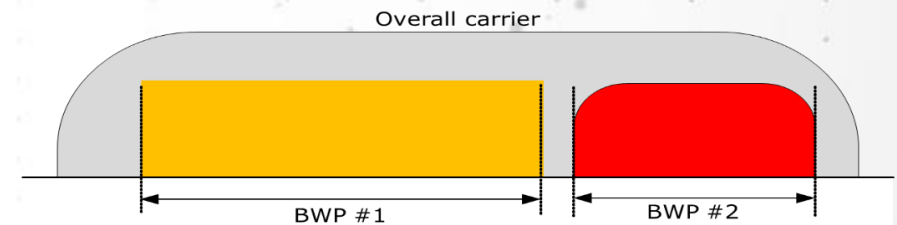
The main configuration area is for the 'Bandwidth Part' (BWP) and is divided into 'Initial Bandwidth Part' and 'Carrier Bandwidth Parts' sections. The 'Initial Bandwidth Part' section includes fields for DL and UL Initial BWP Subcarrier Spacing (set to 1 (30 kHz)), DL and UL Initial BWP Starting CRB (set to 0), and DL and UL Initial BWP Number of PRBs (set to 273). The 'Carrier Bandwidth Parts' section includes fields for DL and UL First Active Bandwidth Part (set to 0).

The 'Configuration' section has radio buttons for 'Downlink' (selected) and 'Uplink'. Below this is a table for configuring multiple bandwidth parts:

Setting	1st Bandwidth Part	2nd Bandwidth Part	3rd Bandwidth Part	4th Bandwidth Part
Enabled:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BWP ID:	0	0	0	0
Starting CRB:	0	0	0	0
Number of PRBs:	273	0	0	0
Subcarrier Spacing:	1 (30 kHz)			
Extended Cyclic Prefix:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The bottom of the interface shows a navigation bar with tabs for System, Cell, SSB, PHY (selected), Scheduling, MAC/RLC/PDCP, Data Generation, BLER/Tput, and Tx Meas. A status bar at the very bottom indicates a configuration error: 'Configuration error: Application configuration file has been changed. Instrument behaviour may not be as expected. (Error 137)'. On the right side of the interface, there are buttons for 'Main', 'Cell On', 'Connect', 'Blind Handover', 'Rx Measurements', 'Utility', and 'Apply'.

Define DL and UL Bandwidth parts; starting CRB, duration expressed in PRBs, Sub Carrier Spacing, Code Prefix



Each BWP consist on a group of contiguous PRBs



# Establish a 5G NR Call

## PHYSICAL LAYER PARAMETERS



The screenshot displays the Keysight C8700200A 5G NSA Full Stack Test Application interface. The top panel shows five 5G NSA signal sources with their respective parameters:

- 1. PCC / TDD 33: -85.00 dBm/15KHz, BW: 10 MHz, EARFCN: D: 36100, U: 36100
- 2. NSA gNB SN N177: -19.85 dBm/MHz, BW: 100 MHz, Freq: D: 3550.56, U: 3550.56
- 3. NSA gNB SN N257: -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28120.80, U: 28120.80
- 4. NSA gNB SN N257: -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28224.48, U: 28224.48
- 5. NSA gNB SN N257: -26.01 dBm/MHz, BW: 100 MHz, Freq: D: 28328.16, U: 28328.16

The main configuration area is divided into several tabs: Bandwidth Part, HARQ, PDSCH, PDSCH DMRS, PDCCH, PRACH, PUSCH, PUSCH DMRS, and PUCCH. The HARQ tab is currently selected, showing DL HARQ and UL HARQ settings. The PRACH tab is also visible, showing PRACH Config settings:

- Enable PRACH:
- Preamble Format: Format A1
- Subcarrier Spacing: 1 (30 kHz)
- Config Index: 81
- uRoot: 0
- Preamble RX Target Power: 0
- Frequency Start: 0
- Msg1 FDM: 1
- Restricted Set Config: Unrestricted
- Zero Correlation Zone Config: 0

The bottom status bar indicates a configuration error: "Configuration error: Application configuration file has been changed. Instrument behaviour may not be as expected. (Error 137)".

HARQ, DL and UL channels and signals configuration

# Establish a 5G NR Call



## SCHEDULING

The screenshot displays the Keysight C8700200A 5G NSA Full Stack Test Application interface. The main window is titled "Keysight C8700200A 5G NSA Full Stack Test Application" and shows a "Scheduling Map" and "Slot Config" view. The "Scheduling Map" shows a grid of radio frames with a "Number of Radio Frames per Repetition" of 8. The "Slot Config" view shows the configuration for a specific slot (Slot index: 0) in the uplink direction. The configuration includes:

- Frame Configuration: FC 0
- Slot index: 0
- Direction: Uplink
- UL Settings:
  - Fixed MCS Index: 0 - QPSK
  - Fixed RB Allocation: 0
  - PUSCH Mapping Type A: 0
  - Time Domain Resource Assignm: 0
  - Bandwidth Part Index: 0
  - DCI Type: Format\_0\_0
  - DCI Allocation Mode: Dynamic
  - DCI Search Space Type: UE Specific Search Space
  - Precoding Info/Number of Layers: -1
- Symbol Start / Length: 0, 14
- RB Allocation Start / Count: 0, 273
- PUSCH Slot Offset K2: 4
- PUSCH Numerology: 1 (30 kHz)
- Aggregation Factor: 0
- Antenna Ports: -1
- DCI Aggregation Level: 1
- SRS Resource Indicator: 0

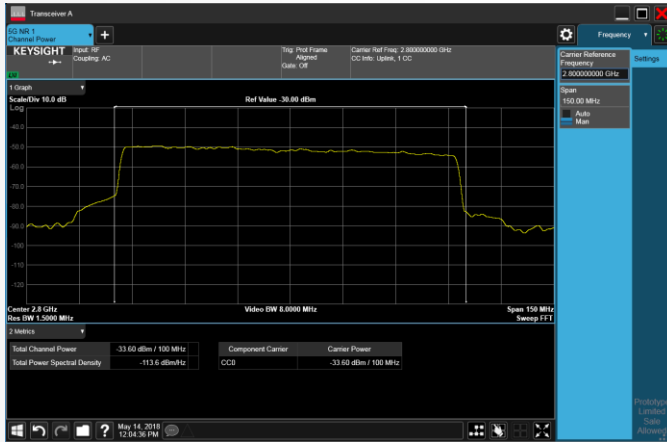
The interface also shows a "Radio Frame Map" and a "Slot Map" at the bottom. The "Slot Map" shows slots 0 through 13, with slots 2, 5, and 9 highlighted in green. The "Radio Frame Map" shows a grid of radio frames with a "Number of Radio Frames per Repetition" of 8. The interface includes a "Main" menu on the right with options like "Cell On", "Connect", "Blind Handover", "Rx Measurements", "Utility", and "Apply". A configuration error message is visible at the bottom: "Configuration error: Application configuration file has been changed. Instrument behaviour may not be as expected. (Error 137)".

# RF test on-a-call

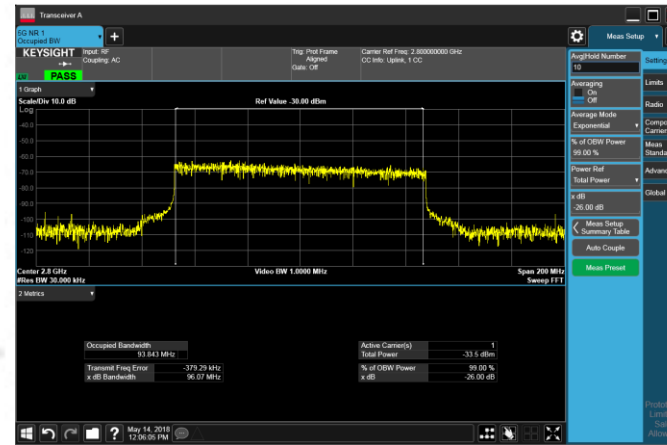


## TRANSMITTER

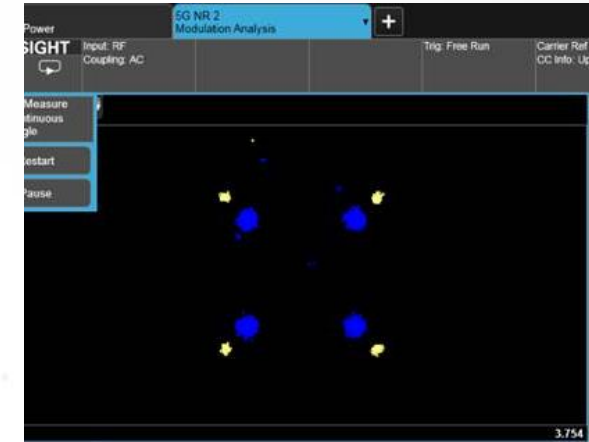
### Channel Power



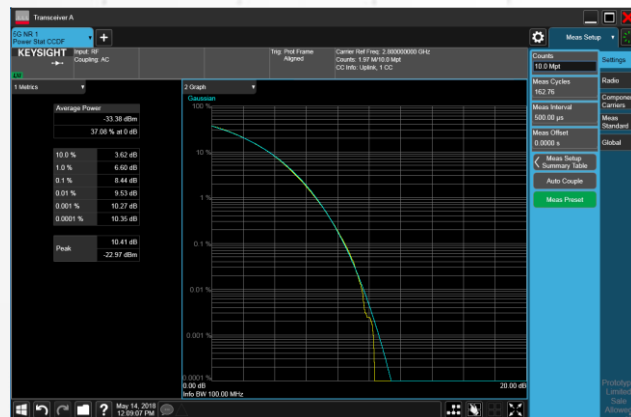
### Occupied Bandwidth



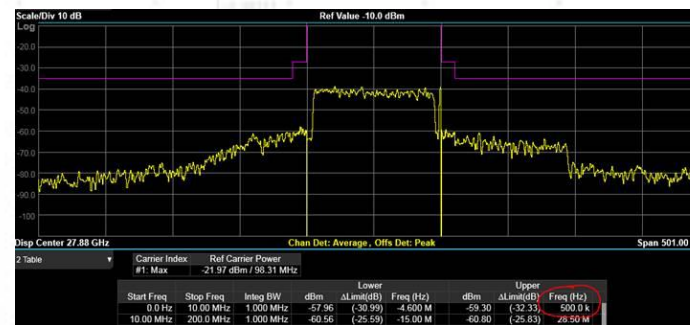
### Modulation Parameters



### Power Statistics



### Spectrum Emission Mask



### IQ Waveform



# RF test on-a-call

## RECEIVER

### Rx Measurements

- Cell Power Selection
- Sensitivity through ACK/NACK count
- BLER is the Rx performance metric
- Throughput



# RF Automation Toolset



The screenshot shows the Keysight RF Automation Toolset interface. The main window is titled 'KEYSIGHT' and has a menu bar with 'File', 'Windows', 'Setting', and 'Help'. Below the menu bar is a toolbar with a play button, a stop button, and a 'CheckBox1' checkbox. The interface is divided into several panels:

- Left Sidebar:** Contains two test mode configurations: 'N78\_SCS30K\_B60M, B80M, B100M' and 'N78\_SCS15K\_B10M, B20M'. Each configuration has a list of test cases with checkboxes.
- TestMode Config Panel:** Has three tabs: 'Test Mode Config', 'Test Condition', and 'Measurement'. The 'Test Mode Config' tab is active, showing a tree view of configuration options for NR and LTE. The 'Test Condition' tab is also visible, showing a table of test conditions.
- Test Cases Panel:** A list of test cases with checkboxes, including '6.2.1 UE maximum output power', '6.2.2 Maximum Power Reduction', '6.3.1 Minimum output power', '6.3.2 Transmit OFF power', '6.4.1 Frequency error', '6.4.2.1 Error Vector Magnitude', '6.4.2.2 Carrier leakage', '6.4.2.3 In-band emissions', '6.4.2.4 EVM equalizer spectrum flatness', '6.5.1 Occupied bandwidth', '6.5.2.2 Spectrum Emission Mask', '6.5.2.4.1 NR ACLR', '6.5.2.4.1 NR ACLR', '7.3.2 Reference sensitivity power level', and '7.4 Maximum input level'.
- Log Panel:** Located at the bottom left, it shows a list of log messages with columns for time, source, and message. It has filters for 'Errors 0', 'Warnings 0', 'Information 0', and 'Debug 16'. The messages include 'PluginManager Found version 1.0.0 of Alita.UXM.xApps.dll [688 us]', 'PluginManager Found version 1.0.0 of Alita.exe [263 us]', 'PluginManager Found version 1.4.227+348d4f73 of Keysight.Tap.Plugins.UXM\_Driver.dll [639 us]', 'PluginManager Found version 1.3.9 of Keysight.Tap.Plugins.UXM5GSteps.dll [720 us]', 'PluginManager Searched 44 Assemblies. [264 ms]', 'PluginManager Loaded Keysight.Tap.Engine. [637 us]', 'PluginManager Loaded Keysight.Tap.Gui.Controls. [231 us]', 'Settings GuiControlsSettings loaded from C:\Users\hongligu\Source\Repos\alita\bin\Debug\Settings\GUI Controls.xml', 'PluginManager Loaded Keysight.Tap.Plugins.UXM\_Driver. [10.3 ms]', and 'PluginManager Loaded Alita. [63.9 us]'.
- ResultsList Panel:** Located at the bottom right, it is currently empty.

## Test Campaign

- Add test cases into one Test Mode Condition
- Add multi Test Mode Condition into Test Plan

## Test Condition

- Set measurement Band, SCS, Bandwidth and Channel
- Load 3GPP default H/M/L channel from database

## Test Cases

- All test cases refer to 3GPP 38.521 chapter 6 and chapter7
- Load 3GPP default test condition like RB Allocation, OFDM type and MCS.

## Test Log Panel

- Error information and SCPI command Logs

## Test Result List

- Result display with P/F indication
- Automatically export result to csv and Excel files.

## Others

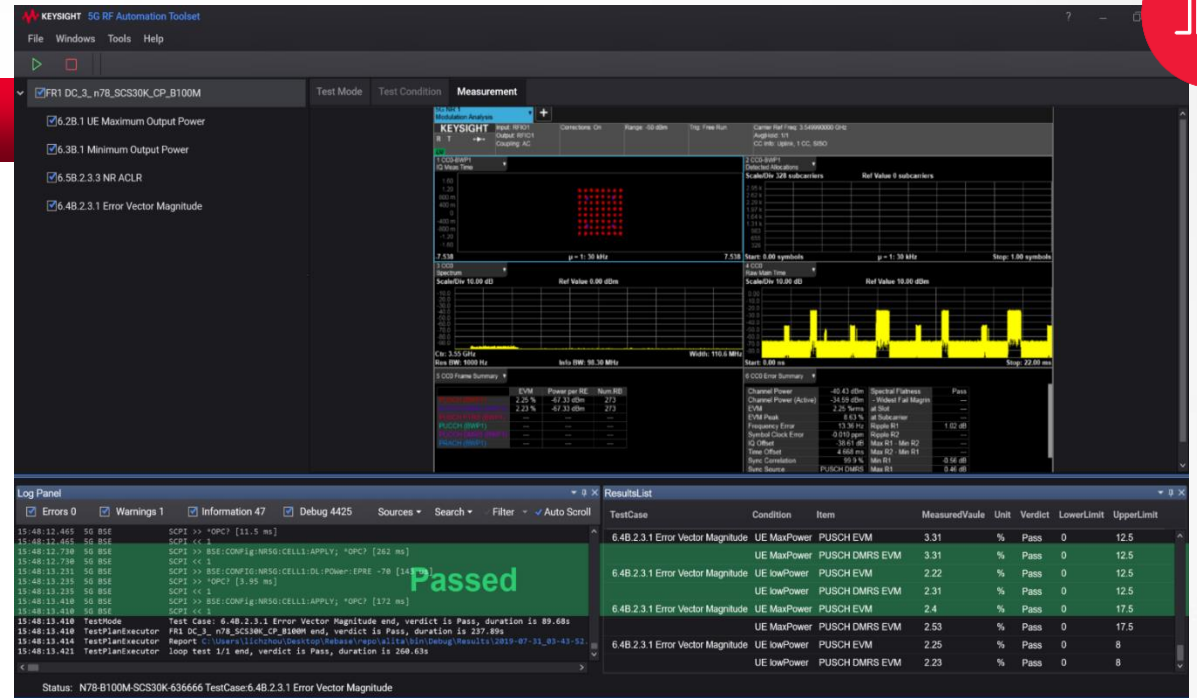
- Support report in text and CSV format
- Support adb command for flight mode

# RF Automation Toolset



## REPORTING TOOLS

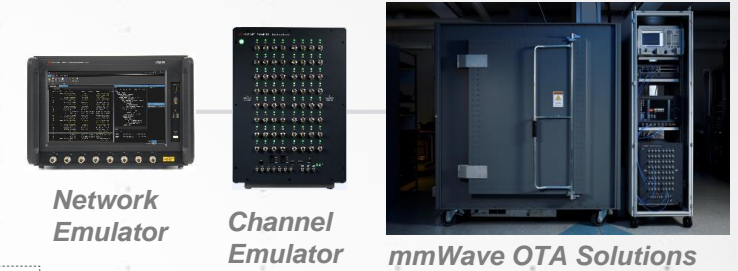
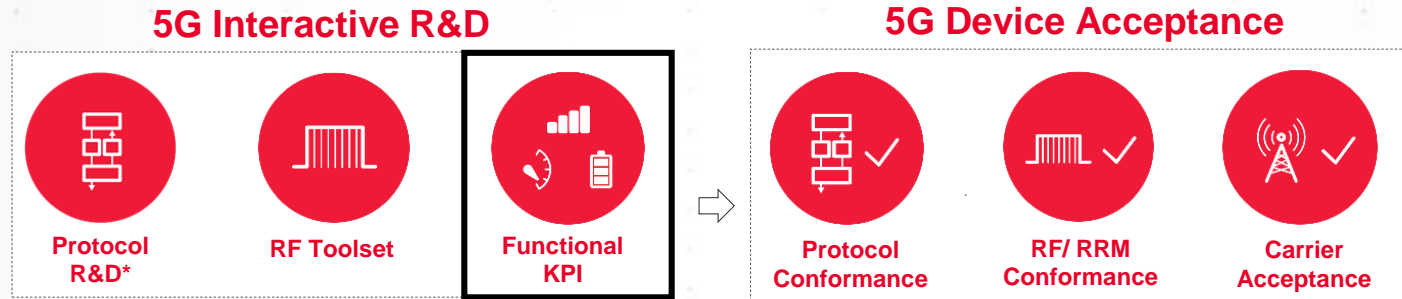
- Real-time measurements (via X-Apps), logs and results are visible in the user interface
- Campaign summary reports may be generated in .csv and .xlsx formats



Time	System	Test Case	Band	Bandwidth [MHz]	SCS [kHz]	ARFCN	Freq [MHz]	Expect Power [dBm]	OFDM	Modulation	RB Allocation	Condition	Item	Lower Limit	Value	Upper Limit	Unit	P/F
2019-07-31T15:58:30	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	InnerFull	UE MaxPower	PUSCH EVM	0	6.66	17.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	5.96	17.5	%	Pass
2019-07-31T15:58:38	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	InnerFull	UE lowPower	PUSCH EVM	0	2.1	17.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.24	17.5	%	Pass
2019-07-31T15:58:47	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	OuterFull	UE MaxPower	PUSCH EVM	0	3.06	17.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	2.78	17.5	%	Pass
2019-07-31T15:58:57	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	OuterFull	UE lowPower	PUSCH EVM	0	2.13	17.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.21	17.5	%	Pass
2019-07-31T15:59:06	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	InnerFull	UE MaxPower	PUSCH EVM	0	4.66	12.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	4.25	12.5	%	Pass
2019-07-31T15:59:14	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	InnerFull	UE lowPower	PUSCH EVM	0	1.99	12.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	1.83	12.5	%	Pass
2019-07-31T15:59:23	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	OuterFull	UE MaxPower	PUSCH EVM	0	3.27	12.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	3.24	12.5	%	Pass
2019-07-31T15:59:33	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	OuterFull	UE lowPower	PUSCH EVM	0	2.23	12.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.15	12.5	%	Pass
2019-07-31T15:59:42	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM64_18	OuterFull	UE MaxPower	PUSCH EVM	0	2.55	17.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	2.51	17.5	%	Pass
2019-07-31T15:59:51	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM64_18	OuterFull	UE lowPower	PUSCH EVM	0	2.19	8	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.29	8	%	Pass

# 5G Device End-to-End Workflow

## FUNCTIONAL KPI



**COMING SOON**

**Support for sustained maximum E2E throughput, meet power consumption goals;**

- Stress test the device at maximum E2E data throughput
- Benchmark battery life performance for different 5G use cases

**KPI = Key Performance Indicators**

### Key Features:

- ✓ Easy to use GUI enables complex tests without the need to define protocol scripts
- ✓ Network configurations optimized to measure device performance
- ✓ Throughput, Battery life, Beam management
- ✓ Flexible automation, including use of external measurement equipment
- ✓ Simple Test case development
- ✓ Use results viewer for off line analysis

Sub-6 GHz and mmWave - Conducted and OTA

# 5G Device End-to-End Workflow

## DEVICE ACCEPTANCE

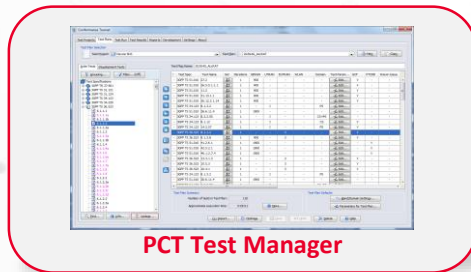
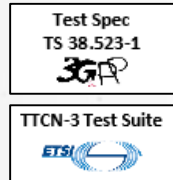
### 5G Interactive R&D



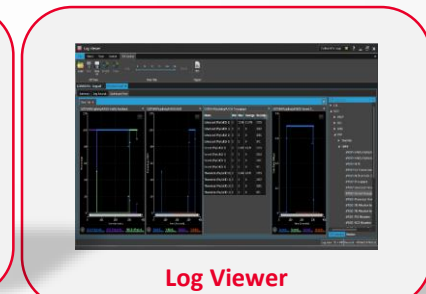
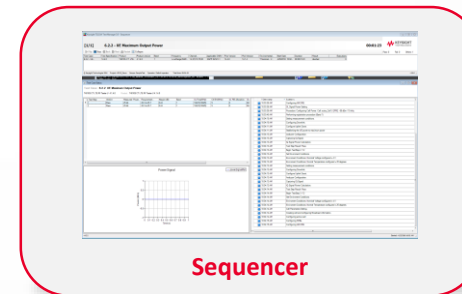
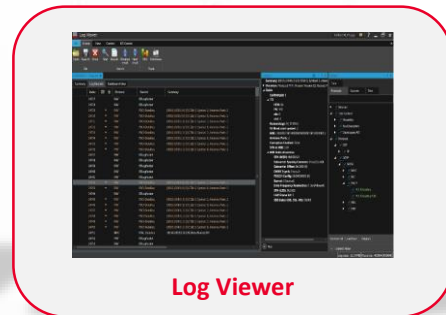
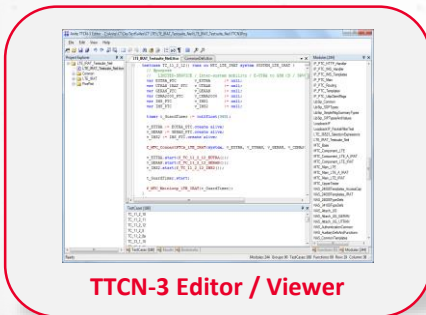
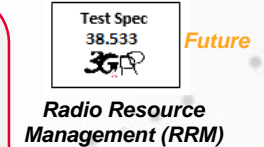
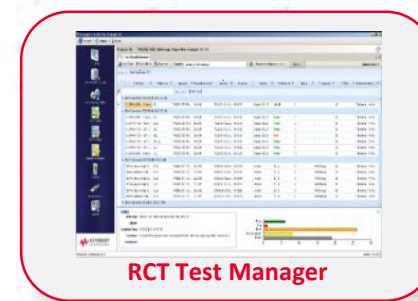
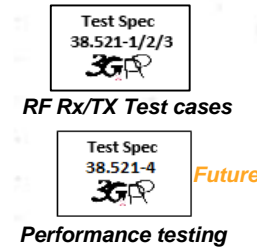
### 5G Device Acceptance



### Protocol



### RF/RRM





# Keysight 5G NR Conformance Test Platform

TP168 INTRODUCED BY AUGUST 2018 IN GCF

GCF-VP Page 2 Version 3.24.0

**Software configuration details**  
All major software components including the component's name shall be listed.

SW Component	Other
Keysight 5G Protocol Conformance Toolset	
Keysight 5G RF/RRM Conformance Toolset	
Test Case Batches	

**Test Vendor Declaration of Test Platform Support and Maintenance**  
The Test Vendor Keysight Technologies, hereby confirms that when TCs validated on this TP are submitted to the GCF, Keysight Technologies will be able to offer support and maintenance for the entire Test Platform, TP 168, Keysight Conformance Toolset.

**Declaration of Test Platform Availability before Test Case Validations**  
The Test Vendor, Keysight Technologies, hereby confirms that the Test Platform, TP 168, Keysight Conformance Toolset with all the required HW and SW units and components are commercially available or will be commercially available prior to the submission of any validated test cases, and that the test platform as described above can be delivered within a reasonable time of an order being placed.

GCF-VP Page 1 Version 3.24.0

**Annex D: New Test Platform Declaration Form**

**Title:** New Test Platform declaration for presentation to the CAG  
**Test Platform Number:** The following TP number has been allocated from the DCC Database: TP 168.  
**GCF Work Item:** The Test Platform is initially intended to provide test capabilities for the following Work Items: WI 501, WI-502, WI-503, WI-504, WI-505.  
**Description:** Keysight Conformance Toolset for 5G Protocol, RF and RRM conformance testing.  
**Source:** Keysight Technologies  
**Date:** 21<sup>st</sup> August 2018  
**For presentation at:** CAG#56 / 23th – 24th October / Lexington, KY, USA

**Test Platform Declaration**

**Test Platform(s) manufacturer, name:** Keysight Technologies, Keysight Conformance Toolset

**Test Platform(s) Details:**  
TP168 represents the Protocol and RF/RRM Conformance Toolset solutions from Keysight Technologies.  
All main components of the test system (hardware and software) are manufactured and supported by Keysight Technologies. The major components of the Test System are detailed below.

**Hardware configuration details**

Hardware Manufacturer	HW Components Name	Other
Keysight Technologies	LXM 5G Wireless Test Set	<a href="http://www.keysight.com/find/5G">www.keysight.com/find/5G</a>
Keysight Technologies	Common Interface IF Unit	
Keysight Technologies	mmWave Transceiver	
Keysight Technologies	OTA Chamber	
Keysight Technologies	Signal Analyzer	
Keysight Technologies	Signal Generator	
Keysight Technologies	Switching Unit	

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# What are your mm-Wave OTA testing needs?

## 5G DEVICE END-END SOLUTIONS



# 5G NES Hardware Components

## 3 KEY BUILDING BLOCKS



### UXM 5G Wireless Test Platform (E7515B)

- <6GHz Frequency range
- Scalable bandwidth 8Tx/4Rx @800MHz, 4Tx/2Rx @1600MHz
- Integrated RFIO + Internal fading
- Support for RF, IF, Host and BBIQ interfaces (slow and full rate)
- Support for 10GbE connectivity



### Common Interfacing Unit (E7770A)

- Same unit for both PROPSIM CE and UXM 5G
- Supports up to 8x heads, with scalability for more
- Flexibility to add new heads to support new bands
- Supports high IF connection (6-12 GHz)



### mmWave Transceiver for 5G (RRH)

- Supports 28, 39 and 40GHz bands
- Compact, bi-directional

# Questions and Resources

## WHERE TO GO FOR HELP

### [www.keysight.com/find/5GMR](http://www.keysight.com/find/5GMR)

- Simulation
  - [www.keysight.com/find/Systemvue](http://www.keysight.com/find/Systemvue)
- Signal Generation:
  - [www.keysight.com/find/N7631C](http://www.keysight.com/find/N7631C)
  - [www.keysight.com/find/N5182B](http://www.keysight.com/find/N5182B)
  - [www.keysight.com/find/N9383A](http://www.keysight.com/find/N9383A)
  - [www.keysight.com/find/M8190A](http://www.keysight.com/find/M8190A)
  - [www.keysight.com/find/M8195A](http://www.keysight.com/find/M8195A)
- Signal Analysis:
  - [www.keysight.com/find/89601B](http://www.keysight.com/find/89601B)
  - [www.keysight.com/find/N9085E](http://www.keysight.com/find/N9085E)
  - [www.keysight.com/find/N](http://www.keysight.com/find/N)
  - [www.keysight.com/find/M9393A](http://www.keysight.com/find/M9393A)
  - [www.keysight.com/find/PXA](http://www.keysight.com/find/PXA)
  - [www.keysight.com/find/UXA](http://www.keysight.com/find/UXA)
- Channel Emulation:
  - [www.keysight.com/find/PropSim](http://www.keysight.com/find/PropSim)
- DVT and Manufacturing;
  - [www.keysight.com/find/E6640A](http://www.keysight.com/find/E6640A)
  - [www.keysight.com/find/M9410A](http://www.keysight.com/find/M9410A)
  - [www.keysight.com/find/M9411A](http://www.keysight.com/find/M9411A)
  - [www.keysight.com/find/S9100A](http://www.keysight.com/find/S9100A)
- Contact your local Field Engineer for;
  - gNB Emulator for UE Testing: (UXM 5G – E7515B)
  - Test chambers
  - mmWave extenders (CIU and RRH)
- Field Testing;
  - [www.keysight.com/find/Fieldfox](http://www.keysight.com/find/Fieldfox)
  - [www.keysight.com/find/NEMO](http://www.keysight.com/find/NEMO)

5G Boot Camp presentations available from:

[www.keysight.com/find/5GBootCampPresentations](http://www.keysight.com/find/5GBootCampPresentations)