



5G Device E2E Workflow Test Solutions

Business Development Manager / Keysight Technologies

Taehyun KIM

5G SUMMIT

5G Scenarios and Use Cases

NEW SERVICES AND CONNECTIVITY PARADIGMS

Courtesy of METIS: 2014

Amazingly Fast

Great Service In a Crowd

Best Experience Follows You

Real-Time & Reliable Communications

Ubiquitous Things Communicating

Mobile Broadband Access



- All data, all the time
- 2 billion people on social media

Massive Machine Communication



- 30 billion “things” connected
- Low cost, low energy

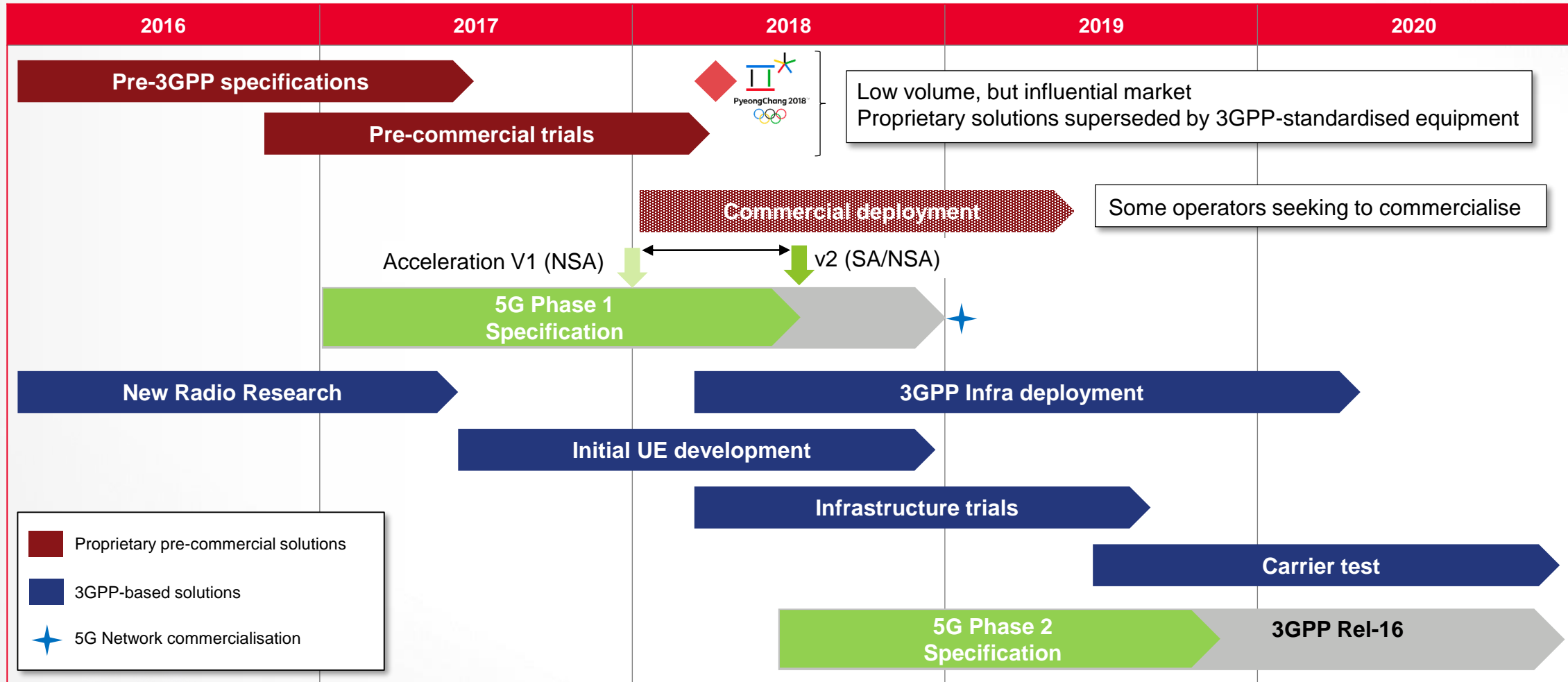
Mission-Critical Machine Communication



- Ultra high-reliability
- Ultra-low latency

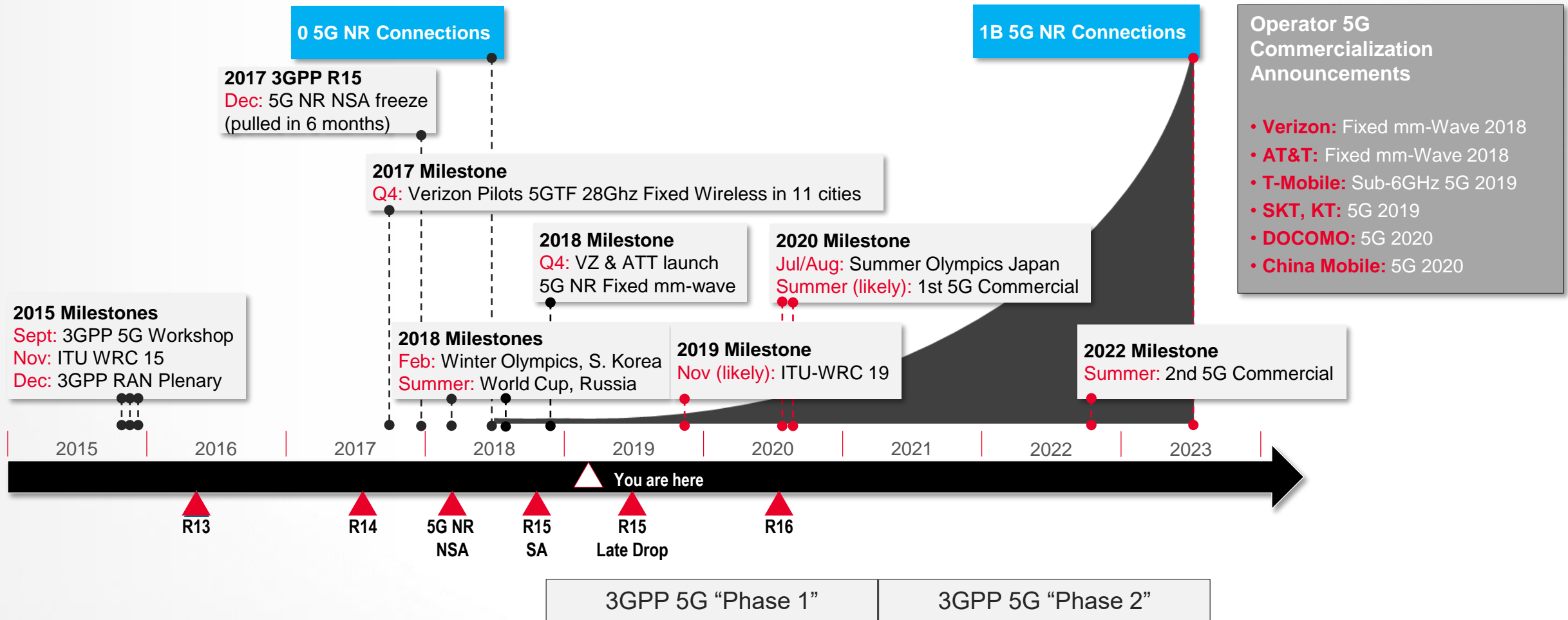
5G Market direction

TIMELINE



5G Timeline

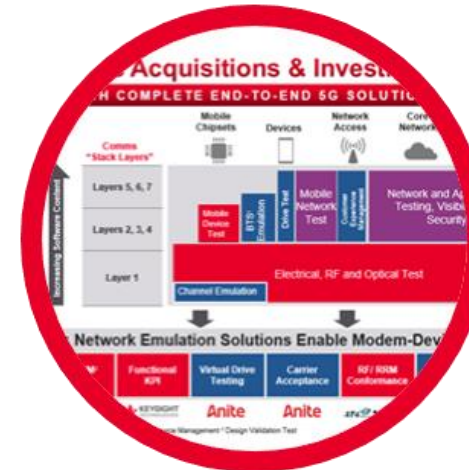
KEY MILESTONES AND CARDINAL DATES



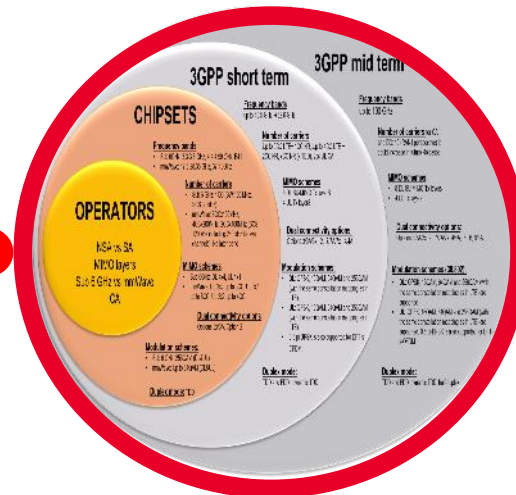
Keysight in 5G



At heart of 5G revolution

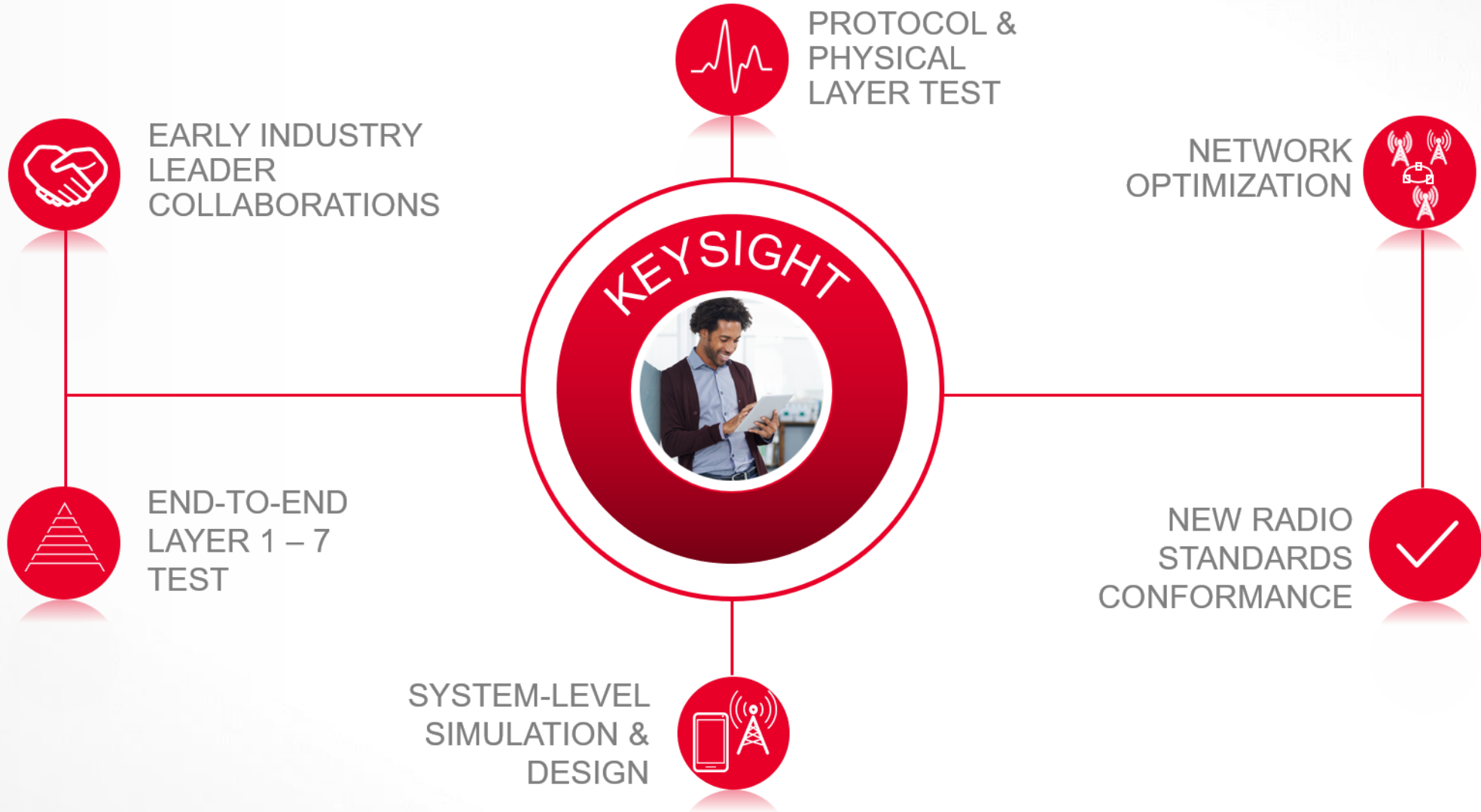


Acquisitions



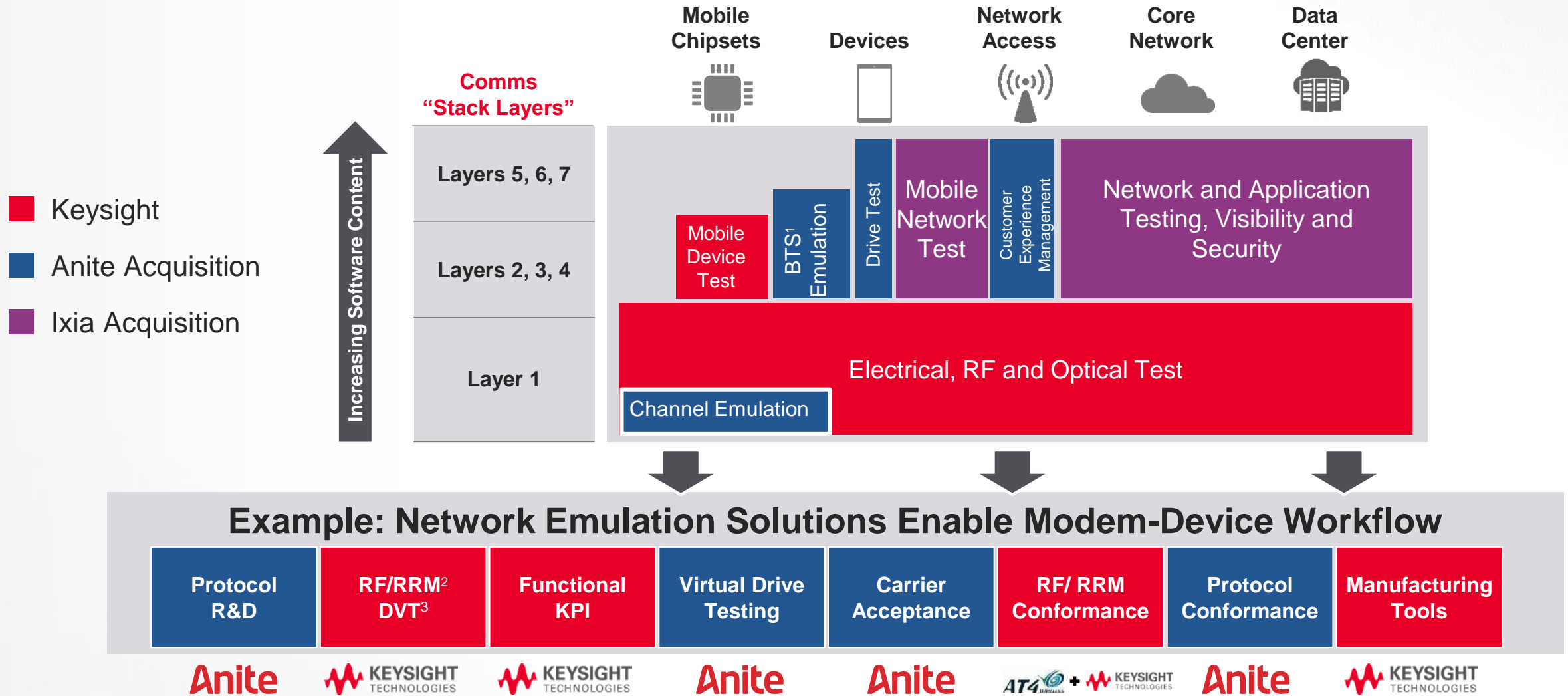
Ecosystem

We Are at the Heart of the 5G Revolution



Keysight Strategic Acquisitions & Investments for 5G

FIRST TO MARKET WITH COMPLETE END-TO-END 5G SOLUTIONS



Ecosystem and features

OPERATORS

NSA vs SA
MIMO layers
Sub 6 GHz vs mmWave
CA

CHIPSETS

Frequency bands

- Sub 6GHz: 3.3-3.8 GHz, 4.4-4.99 GHz, B41
- mmWave: 17.5-28.35 GHz, 37-40GHz

Number of carriers

- Sub 6 GHz: 1CC (BW:100 MHz, SCS:30 kHz)
- mmWave: 8CCx100MHz, 4CCx200MHz, 2CCx400MHz (SCS: 120 kHz including 240 kHz for sync channels). No inter-band

MIMO schemes:

- Sub 6GHz: DL 4x4, UL 1x1
- mmWave: DL 2x2 up to 8CC, UL 1x1 up to 8CC, UL 2x2 up to 4CC

Dual connectivity options:

Options 3x/3A, Option 2

Modulation schemes:

- Sub 6 GHz: 256QAM (DL&UL)
- mmWave: Up to 64QAM (DL&UL)

Duplex mode: TDD

3GPP short term

Frequency bands

up to 43.5 GHz →52.6 GHz

Number of carriers

Up to 5CC LTE+ 1CC NR, Up to 4CC LTE + 2CC NR, xCC NR (x TBD), 2cc UL CA

MIMO schemes

8 DL SU-MIMO Tx layers
4 UL Tx layers

Dual connectivity options:

Options 3/3A/3x, 2, 7/7A/7x, 4/4A

Modulation schemes:

- DL: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE)
- UL: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE)
- 0.5 pi-BPSK is also supported for DFT-s-OFDM.

Duplex mode:

TDD and FDD, dynamic TDD

3GPP mid term

Frequency bands

up to 100 GHz

Number of carriers for CA and DC: 16 (RAN1 perspective) It could increase in future Releases

MIMO schemes:

- 8 DL SU-MIMO Tx layers
- 4 UL Tx layers

Dual connectivity options:

Options 3/3A/3x, 2, 7/7A/7x, 4/4A, 5, 8/8A

Modulation schemes (38.802):

- DL: QPSK, 16QAM, 64QAM and 256QAM (with the same constellation mapping as in LTE) are supported
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Duplex mode:

TDD and FDD, dynamic TDD, half-duplex

CHIPSETS

Frequency bands
up to 43.5 GHz → 52

Number
Up to 5CC
2CC NR, x

OPERATORS

NSA vs SA
MIMO layers
Sub 6 GHz vs mmWave
CA

Frequency bands

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Duplex
TDD and F

3GPP short term

ETS

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Frequency bands

up to 100 GHz

Number of carriers

and DC: 1
could increase

MIMO schemes

- 8
- 4

Modulation schemes:

-
-

Duplex mode:

TDD and

3GPP mid term

Frequency bands

up to 100 GHz

Carriers

1CC NR, Up to 4CC LTE +
(x TBD), 2cc UL CA

MIMO schemes

2x2 MIMO Tx layerS
2x2 MIMO Rx layerS

Dual connectivity options:

Options 3/3A/3x, 2, 7/7A/7x, 4/4A

Modulation schemes:

QPSK, 16QAM, 64QAM and 256QAM
with the same constellation mapping as in
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Dynamic TDD

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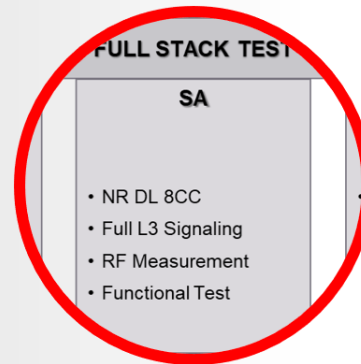
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Modes of operation

Use Cases



L1 parametrization



Proof of Concept



Protocol flexibility

Reference 5G network emulation



Reference 5G Network Emulation

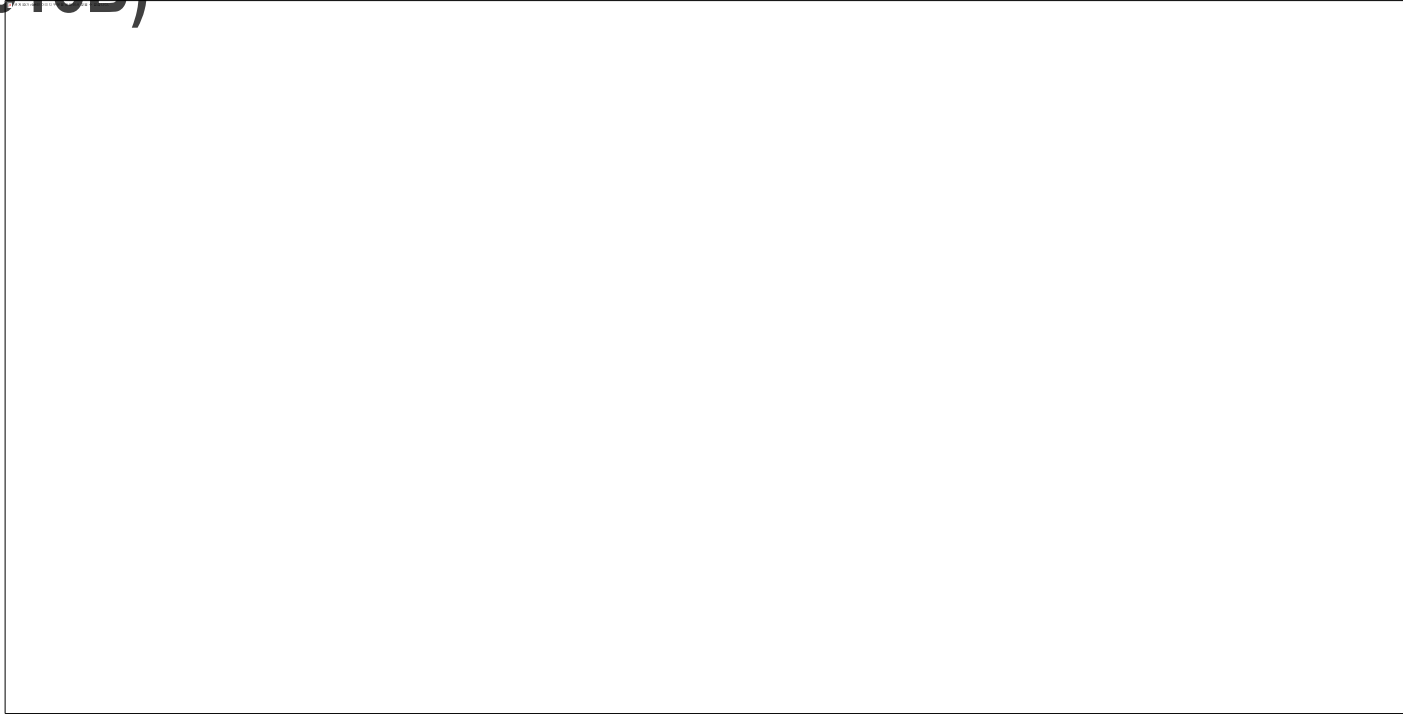
UXM 5G (E7515B)

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

Reference 5G Network Emulation

UXM 5G (E7515B)

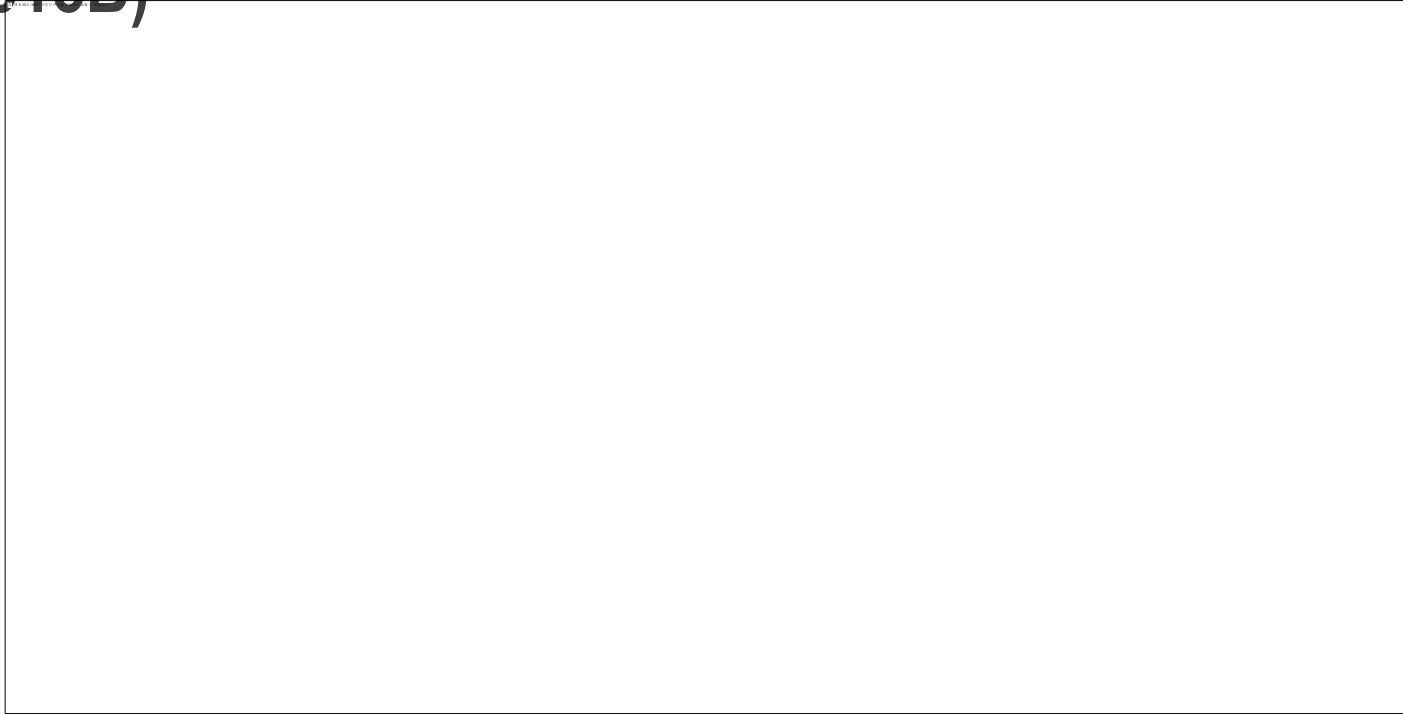


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Interactive Network Emulation

TEST APPLICATION FRAMEWORK

Displays basic cell settings and UE connection status (CONNECTED, IDLE, etc...)

NR Cells Secondary Group

LTE Anchor

Cells Status Bar

The screenshot displays the Keysight C8700200A Test Application Framework - 5G NR interface. At the top, the 'Cells Status Bar' shows five NR cells (N1 to N5) with their respective parameters: PCC / FDD, NSA gNB SN, n257, BW, and Freq. Below this, the 'Config' tab is active, showing various settings for Frequency, Power, and Timing. The 'Cell' tab is selected in the bottom navigation bar, and the 'Tx Meas' sub-tab is active. A 'Main' sidebar on the right contains buttons for 'Cell On', 'Connect', 'Rx Measurements', 'Utility', and 'Apply'.

Change Network Settings in real-time

Network Settings

Navigate through Functions

Measurements

Test Application Use Cases



NETWORK EMULATION

- 5G NonStandalone (NSA)
- 5G Standalone (SA)
- LTE Adv. Pro
- CloT



WORKFLOW

- General purpose
- RCT / RRM building block
- RF Carrier Acceptance



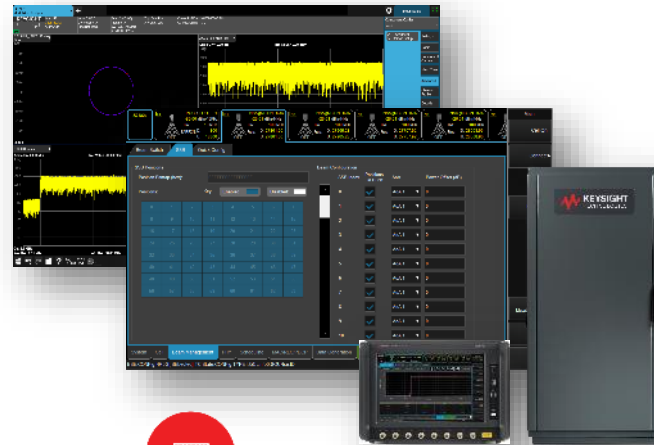
FUNCTIONAL KPI

- E2E Data Throughput
- Voice / Video
- Battery Drain



MODES OF OPERATION

- L1 Test Mode
- Full Protocol Stack
- CW



RF PARAMETRIC

- Transmitter meas
- 3GPP alignment
- MIMO, Carrier Agg
- FR1, FR2



RECEIVER TEST

- BLER / HARQ
- Flexible scheduler
- AWGN
- Fading

Interactive Network Emulation

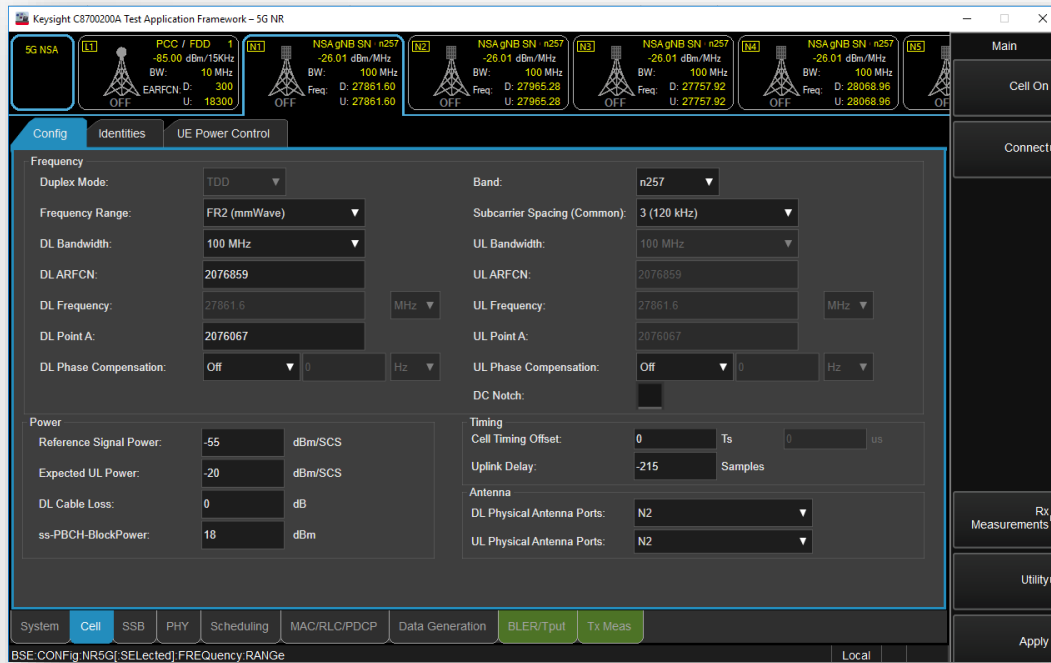


MODES OF OPERATION

CW	L1 TEST	FULL STACK TEST		
<ul style="list-style-type: none">• Path loss calibration• Any port in the System (UXM, CiU, RRH)• Power, Frequency	<ul style="list-style-type: none">• Layer 1 test mode• System information• No L3 signalling established• Rx measurements (BLER/Tput, HARQ)• Tx measurements	NSA <ul style="list-style-type: none">• LTE DL 2CC (Anchor)• NR DL 8CC• Full L3 Signaling• RF Measurement• Functional Test	SA <ul style="list-style-type: none">• NR DL 8CC• Full L3 Signaling• RF Measurement• Functional Test <p><i>Coming soon..</i></p>	LTE <ul style="list-style-type: none">• LTE DL 8CC• Full L3 Signaling• RF Measurement• Functional Test <p><i>Coming soon..</i></p>

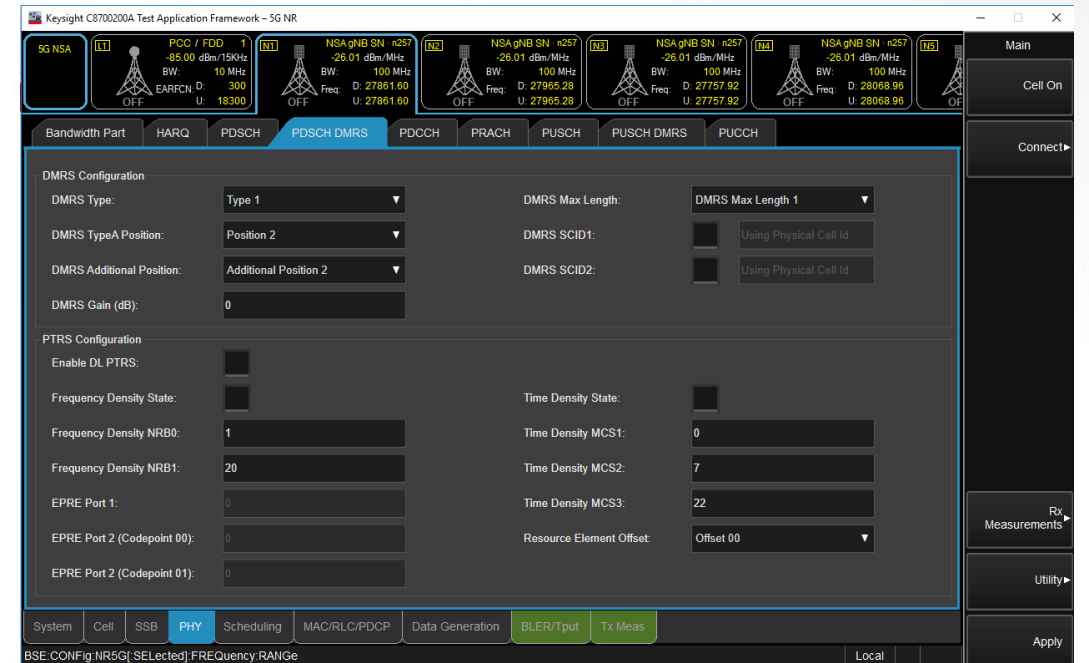
LTE AND NR WITHIN THE SAME NETWORK EMULATOR

Powerful L1 Parametrization



CELL SETTINGS

- FR1, FR2, IF, CUSTOM
- BW
- Power
- Subcarrier Spacing
- 2x2, 4x4 MIMO

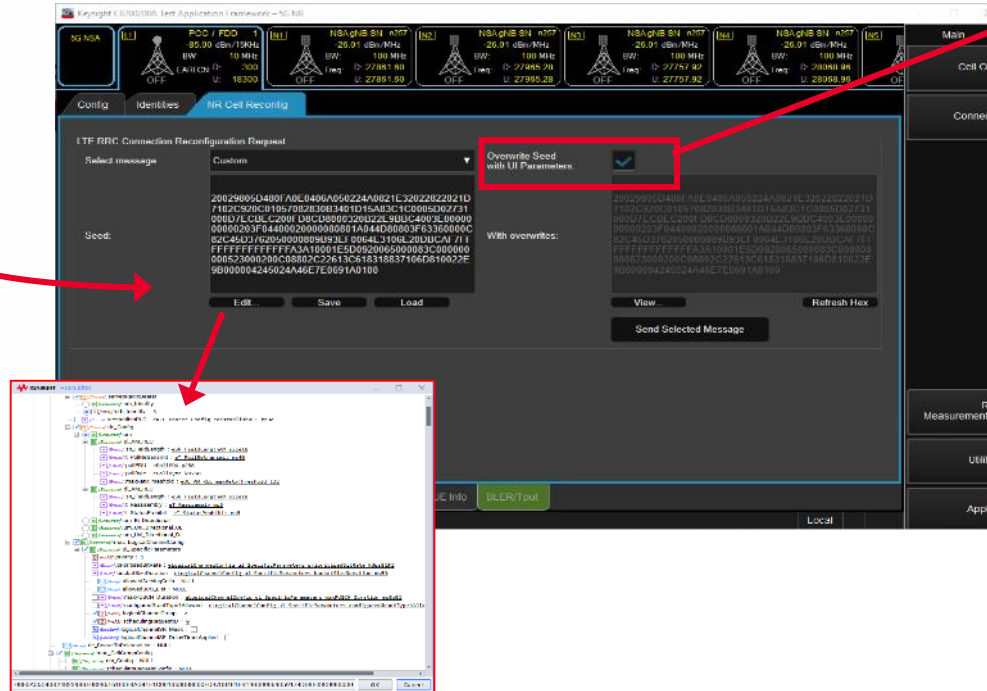
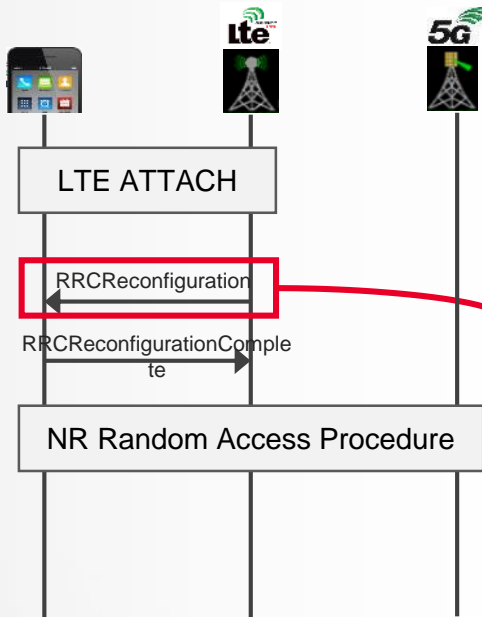


PHYSICAL CHANNELS

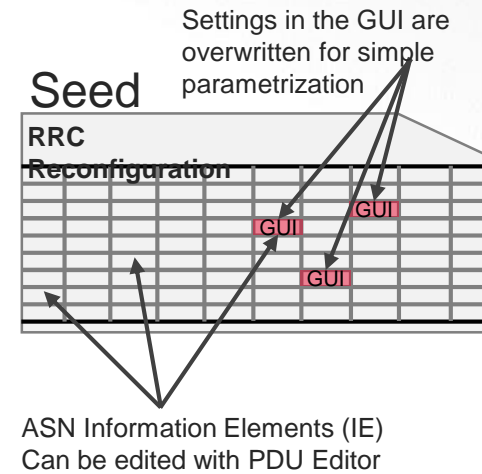
- BANDWIDTH PARTS
- SSB, PDCCH, PDSCH
- PRACH, PUSCH, PUCCH
- CSI RS
- HARQ

Protocol Flexibility

GO DEEPER IN FUNCTIONAL TEST



Integrated and easy to use ASN editor



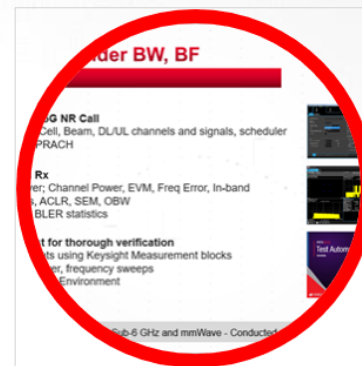
- Ease of use by PDU Editor in the Test App
- With PDU editor you get:
 - Modern look ASN1.0 editor, easy to use (no use of XML directly)
 - Create and further edit your customized protocol messages
 - Tune RRC settings to enable interoperability at early stages
 - Get access to any Information Element not exposed by the Test Application



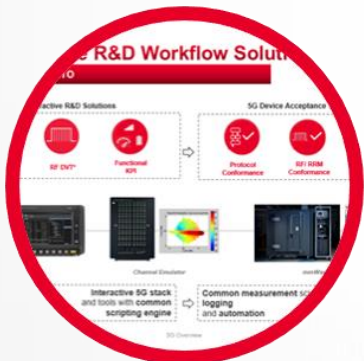
HW components



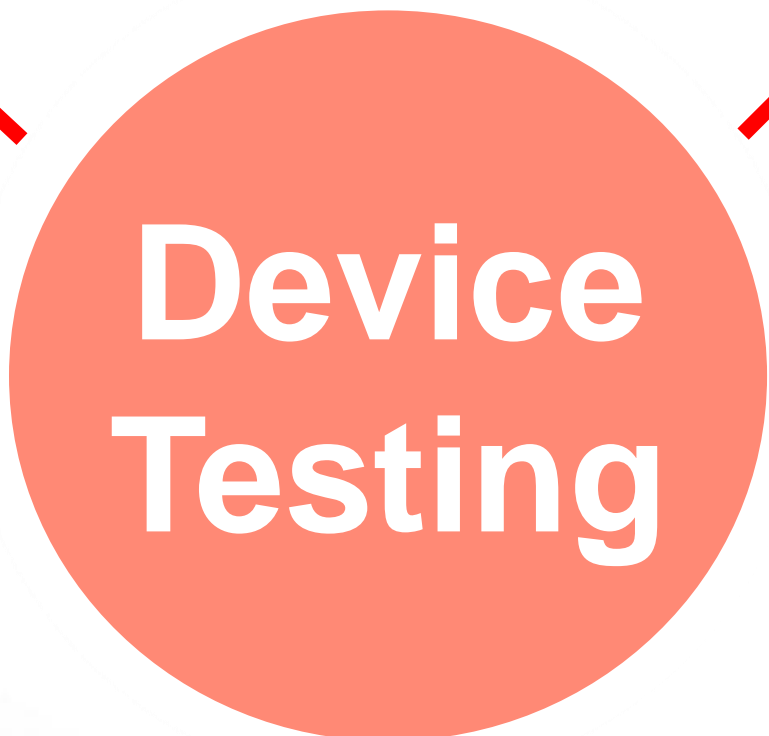
R&D Protocol



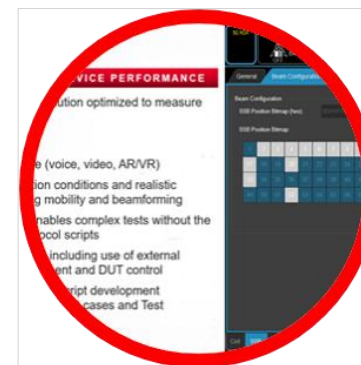
R&D RF



Workflow Solutions



Device Testing



Functional

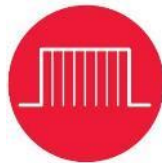
First 5G NR Device R&D Workflow Solutions

END TO END PORTFOLIO

5G Interactive R&D Solutions



Protocol R&D*



RF DVT*



Functional KPI

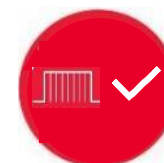
*available



5G Device Acceptance Solutions



Protocol Conformance



RF/RRM Conformance



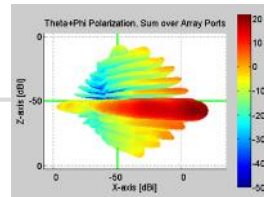
Carrier Acceptance



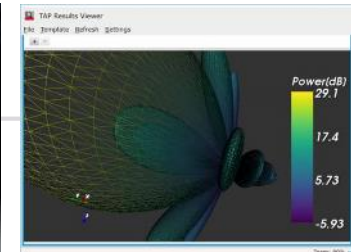
Network Emulator



Channel Emulator



mmWave OTA Solutions



Interactive 5G stack and tools with **common scripting engine**



Common measurement science, logging and automation

5G NES Hardware Components

SCALABLE HARDWARE

FR1

- UXM 5G
- Add PC and 1GB Switch
- Measurements are conducted



FR2

- Add CIU, RRH to FR1 setup
- CATR for emulated far field measurements
- Measurements are over the air



The cable is gone – solutions!

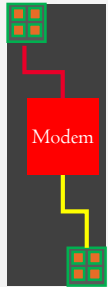
SOLUTIONS OPTIMIZED FOR THE WORKFLOW

CATR

3GPP
Approved



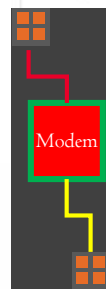
- Indirect Far Field
- Supports black box testing
- Use cases



- RF Parameterics
- Antenna Tests
- TRP/TIS
- Single AoA
- Throughput tests

3GPP APPROVED

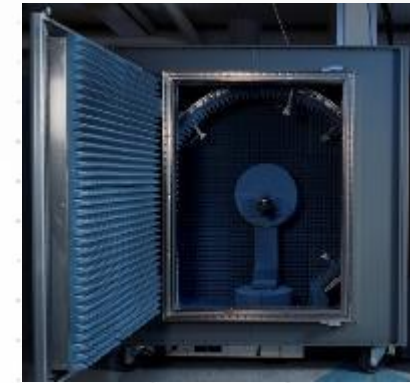
Rack Family – 2D MPAC, RMTC and Mini-RMTC



- Direct Far Field
- Cable replacement tests
- Use cases
 - Protocol Signalling Tests
 - Demod Tests
- Array Calibration
- UE CAL
- Functional Tests

LIGHT WEIGHT

3D MPAC



- Direct Far Field
- Testing with faded environments
- Supports 38.901 based models w Prosim 5G

Use cases

- Throughput test
- HO Performance and NV-IOT
- Beam management

BASED ON SS-MPAC

5G R&D Protocol Toolset

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



Replicate network behaviour

5G PROTOCOL R&D TOOLSET

- Built-in Protocol State Machine and Dynamic Control Points simulates a “Live Network”
- Allows for interactive testing where the behaviour of a device can be investigated in an easy manner to facilitate debugging

Script				
Line	Time	Id	Direction	Details
1				Script Details [NR5G_LTE_PSCellAdd]
2				SIM Information [Explicitly defined]
3	00:00.00			5G User Prompt [Activate NR5G Cell]
4	00:00.00	NR-Cell A		Activate NR5G Cell [NR-Cell A :DL Power = -80 dBm/75kHz]
5	00:00.00	N-Cell A		5G DYNAMIC CONTROL POINT [Continue after User Action]
6	00:00.00			5G User Prompt [Start NR5GUEdemonstrator.exe]
7	00:05.00	E-Cell A		Activate LTE Cell
8	00:00.00	E-Cell A	SS --> MS	RRC Connection Reconfiguration
9	00:00.00			5G User Prompt [Wait, Press Ok to Exit]

Modify network behaviour easily

5G PROTOCOL R&D TOOLSET

- Allow dynamic L1/L2 parameters 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. Below the tabs, there are two dropdown menus: 'Resource Allocation Type' set to 'Fixed' and 'Transmission Mode' set to 'TM1'. A 'Resource Block Allocation' table is shown with columns for RB indices (RB0-24, RB25-48, RB49-74, RB75-99) and rows for subcarriers (0-99). The table shows a grid of blue and white cells representing resource allocation. Below the table, there are several configuration sections: 'xPDSCH Start Symbol' (Symbol 2), 'xPDSCH Stop Symbol' (Symbol 12), 'xPUCCH Resource Index' (0), 'DL PCRS' (No PCRS), 'UCI Request Configuration (Using xPUCCH - DCI B1/B2)' (Request Type: None, CSI-RS/BRRS OFDM Symbol Index: 0, CSI-RS/BRRS Transmission Timing: 1, CSI-RS/BRRS Process Indicator: Process 0), 'Allocation Mode Configuration' (Resource Allocation Mode: Normal, Trigger One Shot Allocation: unchecked), 'Antenna Ports Configuration' (Single Layer Transmission: 1 Layer - Port 8, Two Layer Transmission: 2 Layers - Ports 8, 9), 'MCS Index' (9), 'Rank' (Rank 1), 'HARQ Auto Ack' (checked), 'Scrambling Code Id' (0), 'xPDCCH Search Space Configuration' (DCI Allocation Mode: Dynamic, Search Space Index: 0, Aggregation Level: 2, Ofdm Symbol Index: Dynamic).

5G logging

5G PROTOCOL R&D TOOLSET

- Displays all layers of the protocol stack (PHY/MAC/RLC/RRR/PDCP)
- Filtering allows the user to view the data of interest
- Advanced search facilities and bookmarks make debugging easier
- User friendly as all information needed is available in one view

The screenshot displays the Log Viewer application interface. The main window is titled 'Log Viewer' and contains a menu bar (File, Home, View, Control, KPI Control) and a toolbar with icons for Open, Save As, Close, Find, Results, Previous result, Next result, DPA, and Interleave. Below the toolbar is a search bar and a 'Tools' section. The main area is divided into three panes: a table of log records, a 'Details' pane, and an 'Overview' pane.

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

The 'Details' pane shows the structure of a BCCH-BCH-Message:

- Summary: MasterInformationBlock
- Overview: Protocol: RRC, Version: R15 Jan 2018, Record: BCCH-BCH-Message
- Fields
 - message
 - dl-Bandwidth: n6
 - phich-Config
 - phich-Duration: normal
 - phich-Resource: oneSixth
 - systemFrameNumber: 00000000
 - schedulingInfoSIB1-BR-r13: 0
 - spare: 00000

The 'Overview' pane shows a 'PASS' status. The 'Filters' pane shows a tree view of protocols: 3GPP, LTE, PHY, MAC, RRC, NRSG, HOST, PHY, MAC, RRC.

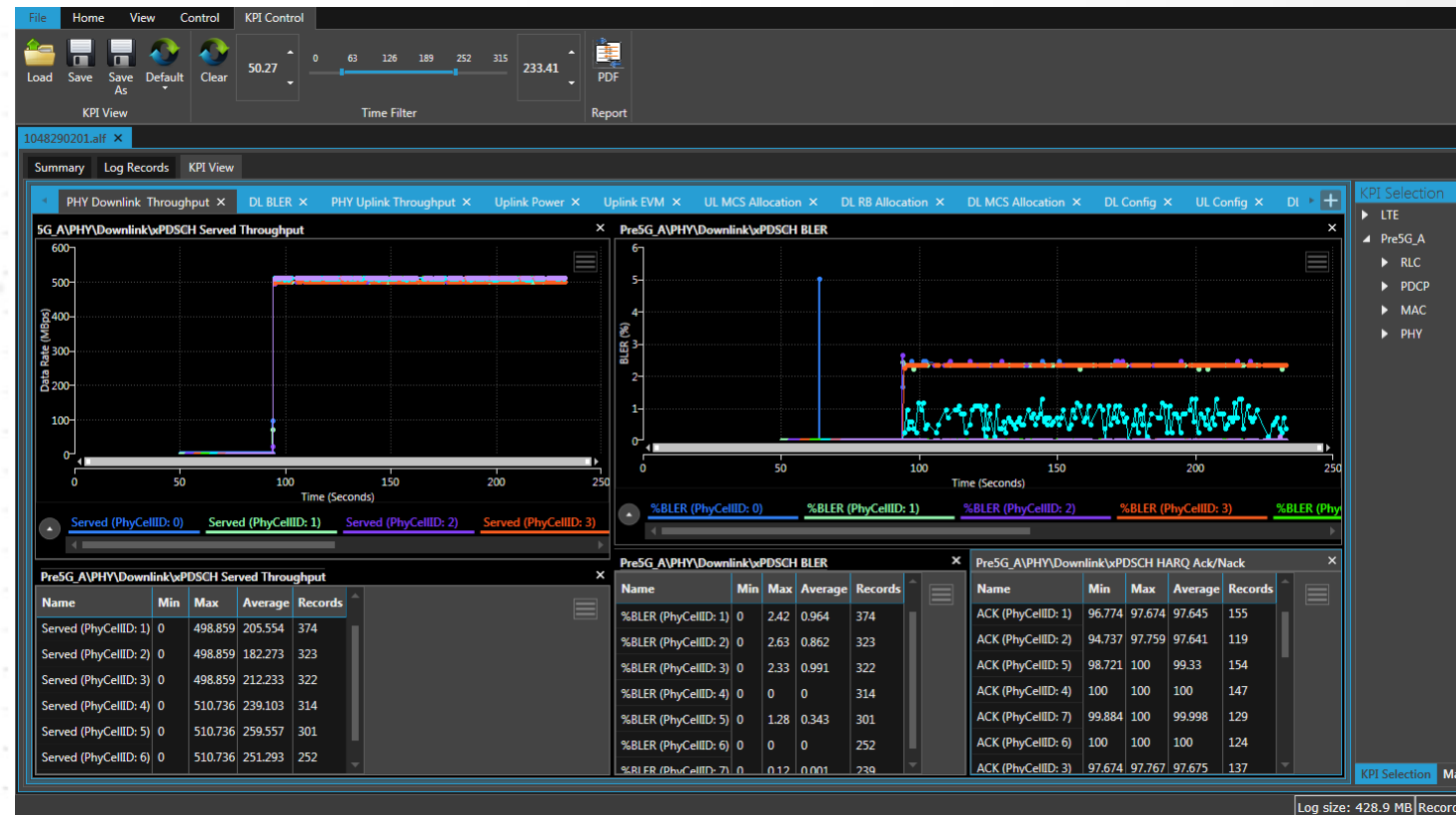
The 'Hex' pane shows the raw data for the selected record: 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F.

Log size: 8.3 MB | Records: 1223(69872)

Dashboard viewer

5G PROTOCOL R&D TOOLSET

- Customised view with multiple graphs
- Enhanced debugging as relationship between various KPIs such as data rate and BLER can easily be seen graphically
- Link from graph to relevant location in the log to facilitate debugging
- Report generation to share results with other teams



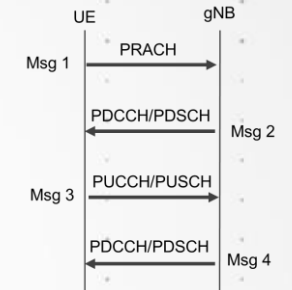
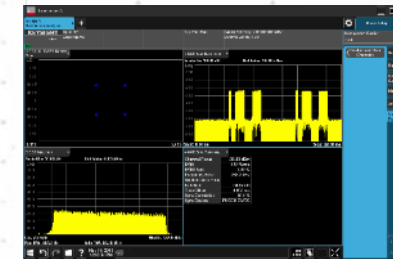
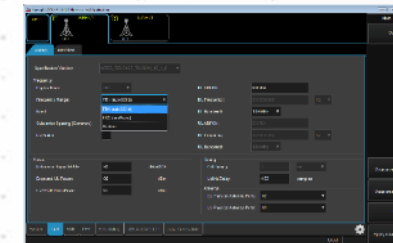
More RF bands, wider BW, BF

SIGNALING RF TEST



More RF bands,
wider bandwidths,
and beamforming

- 1 Establish the 5G NR Call**
 - Configure; Cell, Beam, DL/UL channels and signals, scheduler
 - Complete PRACH
- 2 Test Tx and Rx**
 - Transceiver; Channel Power, EVM, Freq Error, In-band emissions, ACLR, SEM, OBW
 - Receiver; BLER statistics
- 3 Automate test for thorough verification**
 - Create Scripts using Keysight Measurement blocks
 - Test with power, frequency sweeps
 - Test Executive Environment



5G RF DVT Toolset

KEY FEATURES

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

The screenshot displays the Keysight Test Automation Platform interface. At the top, there is a menu bar with 'File', 'Settings', 'Tools', and 'Help'. Below it, the 'Test Plan' is identified as '5G_Tests.TapPlan'. A table lists the test steps:

Step Name	Verdict	Duration	Step Type
Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power	Pass		Wireless Test - 5G \ 3GPP \ 6.2.2 UE Maximum Output Power
Wireless Test - 5G - RF Parametrics.Sensitivity	Pass		Wireless Test - 5G \ RF Parametrics \ Sensitivity
Wireless Test - 5G - RF Parametrics.Transmit Signal Quality	Pass		Wireless Test - 5G \ RF Parametrics \ Transmit Signal Quality

An 'External Test Plan Parameters' dialog box is open, showing a table of parameters:

External Name	Value	Test Step \ Property
Band	1	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ Band
DL Channel Bandwidth	20 MHz	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ DL Channel Bandwidth
Like 3GPP	<input type="checkbox"/>	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ Like 3GPP
Test Environment	<input checked="" type="checkbox"/>	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ Test Environment
Test Frequency	<input checked="" type="checkbox"/>	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ Test Frequency
UL RB Number	1	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ UL RB Number
UL RB Start Position	0	Wireless Test - 5G - 3GPP.6.2.2 UE Maximum Output Power \ UL RB Start Position

The main interface shows three measurement views (VMA 1, VMA 2, VMA 3) and a summary table. VMA 1 shows a constellation diagram. VMA 2 shows an RF Envelope plot with a scale of 10.00 dB and a reference value of 10.00 dBm. VMA 3 shows an Occupied Bandwidth plot with a scale of 10.0 dB and a reference value of 20.00 dBm. The summary table provides the following data:

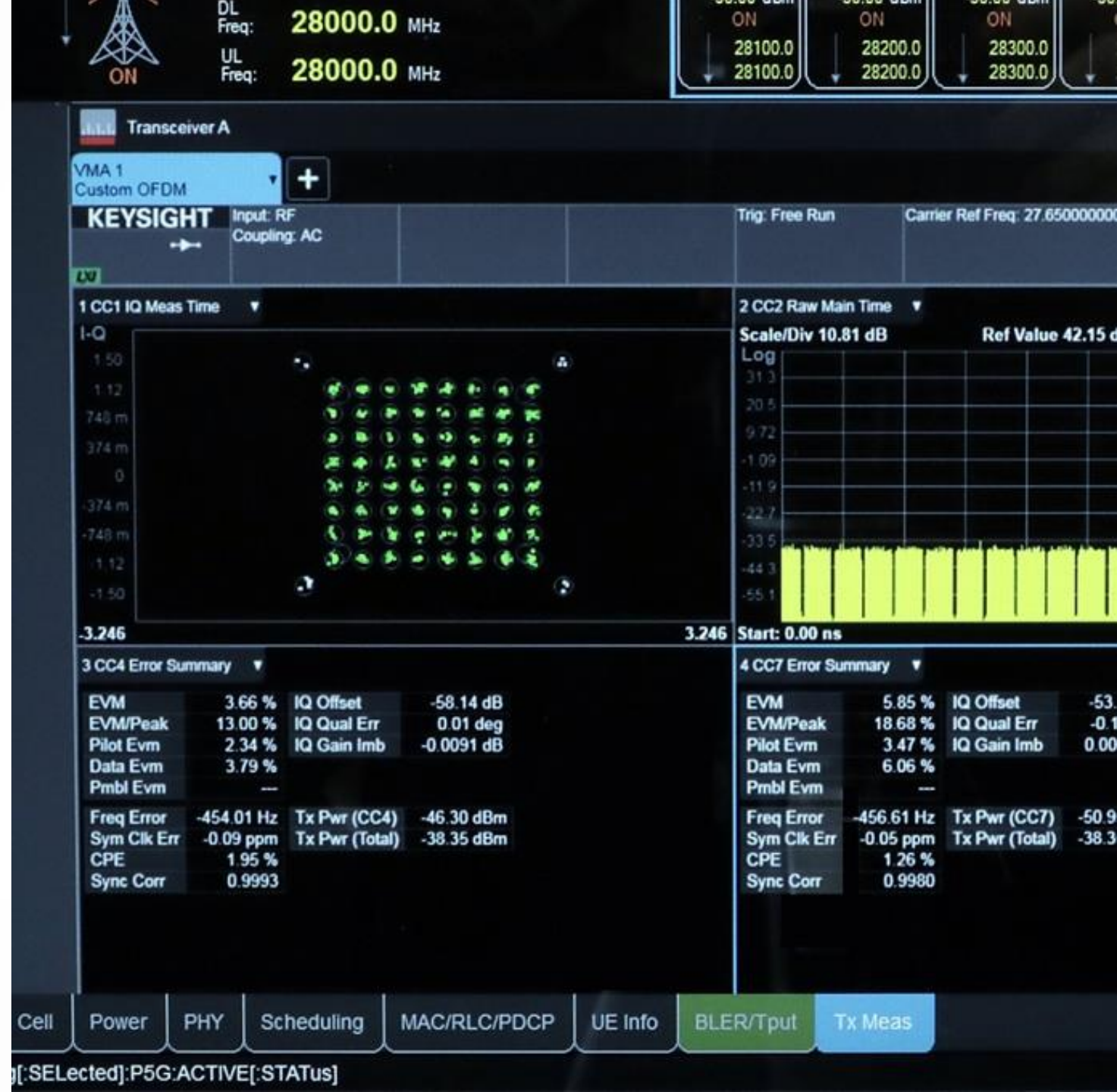
Metric	Value
EVMMER	2.63%
EVMPeak	10.57%
PilotEvm	1.00%
DataEvm	2.73%

Additional metrics shown include: Mean Power (16.05 dBm), Current Data, Occupied Bandwidth (89.143 MHz), Total Power (24.9 dBm), and % of OBW Power (99.00%). The interface also includes a 'Log' section showing 'Errors 0' and a 'Meas Setup' panel on the right with various configuration options.

RF Test Application

5G RF DVT TOOLSET

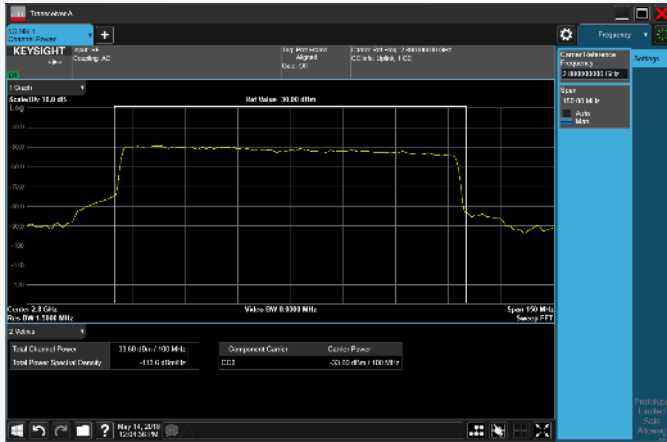
- Flexible manual testing
- On-a-call UL RF measurements
- Common Keysight measurement science through X-Apps
- Automate test set up Keysight 5G Interactive tools



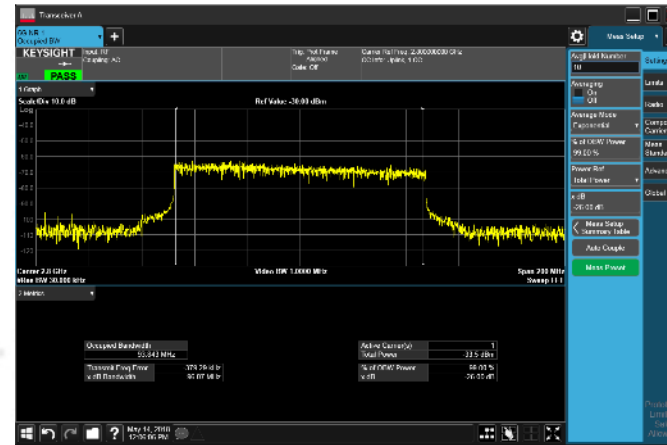
RF test on-a-call

TRANSMITTER

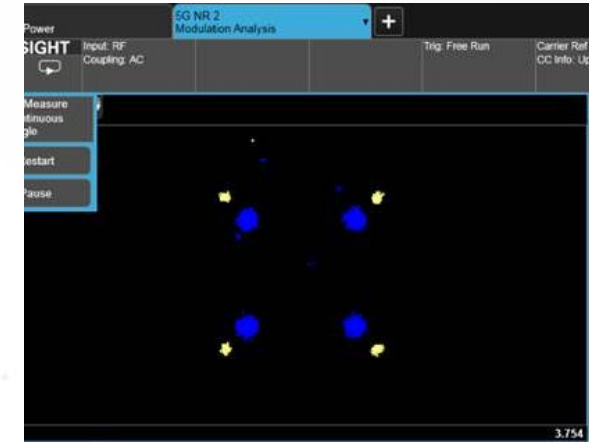
Channel Power



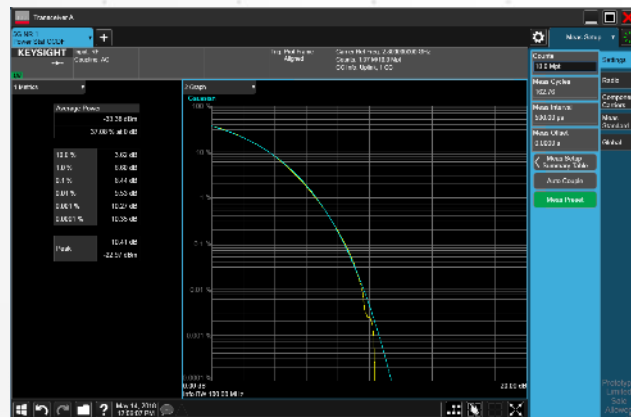
Occupied Bandwidth



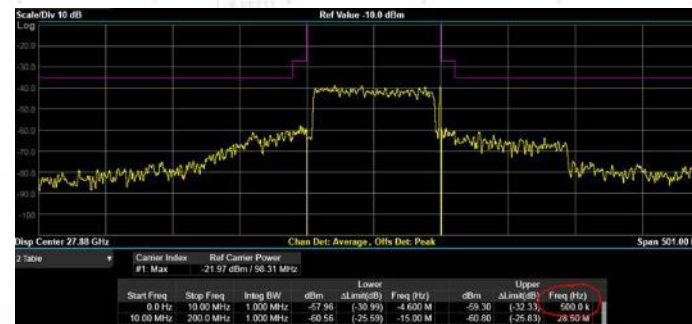
Modulation Parameters



Power Statistics



Spectrum Emission Mask



IQ Waveform



Automation & Scripting

5G RF DVT TOOLSET

- Automate complete test set up include device and mmWave OTA measurements
- Test cases scripting with Keysight measurement tools or customized test steps
- Examples
 - Initial Access
 - Beam Management
 - Downlink Channels demodulation
 - UE reporting
 - Total Radiated Power (TRP)

File Settings Tools Help

Test Plan Untitled *

+ - Run Repeat Completed in 48.49 s

ame	Verdict	Duration	Step Type
5G T-0A.General Settings Pre-5G	Pass	10.99 s	RFT Pre-5G T-0A: Measurement tools for 5GTF \ Common \ General Settings Pre-5G
5G T-0A.DUT Attach	Pass	30.56 s	RFT Pre-5G T-0A: Measurement tools for 5GTF \ Connection \ DUT Attach
5G T-0A.Beam Switching/Mobility	Pass	2.69 s	RFT Pre-5G T-0A: Measurement tools for 5GTF \ Measurements \ RRM Measurements \ Beamforming
5G T-0A.DUT Detach	Pass	4.16 s	RFT Pre-5G T-0A: Measurement tools for 5GTF \ Connection \ DUT Detach

Log

Errors 0 Warnings 0 Information 329 Debug 2553

```
14:53:39.944 RFT Pre-5G T-0A <ParameterConfigured>GeneralSettings.Connectors Mode = Split
14:53:39.944 RFT Pre-5G T-0A <ParameterConfigured>RFT Pre-5G T-0A.DUT Detach.DUT Switch Off/On = False
14:53:39.944 RFT Pre-5G T-0A <ParameterConfigured>RFT Pre-5G T-0A.DUT Detach.DUT Switch Off Delay = 0
14:53:39.944 RFT Pre-5G T-0A <ParameterConfigured>RFT Pre-5G T-0A.DUT Detach.DUT Power Cycle = False
14:53:39.944 RFT Pre-5G T-0A <ParameterConfigured>RFT Pre-5G T-0A.DUT Detach.DUT Power Off Delay = 0
14:53:39.946 RFT Pre-5G T-0A <Workflow>Waiting 2 seconds for cell activation/deactivation...
14:53:41.947 RFT Pre-5G T-0A <Workflow>Setting CELL1 OFF.
14:53:42.097 RFT Pre-5G T-0A <Workflow>Waiting 2 seconds for cell activation/deactivation...
14:53:44.097 RFT Pre-5G T-0A <Workflow>Checking connection status for CELL1 is OFF.
14:53:44.105 TestPlan RFT Pre-5G T-0A.DUT Detach completed with verdict 'Pass'. [4162 ms]
14:53:44.137 Summary ----- Summary of run started 02/05/2018 14:52:55 -----
14:53:44.140 Summary RFT Pre-5G T-0A.General Settings Pre-5G 10992 ms Pass
14:53:44.141 Summary RFT Pre-5G T-0A.DUT Attach 30559 ms Pass
14:53:44.141 Summary RFT Pre-5G T-0A.Beam Switching/Mobility 2691 ms Pass
14:53:44.141 Summary RFT Pre-5G T-0A.DUT Detach 4162 ms Pass
14:53:44.141 Summary -----
14:53:44.141 Summary ----- TestPlan completed successfully in 48.49 s -----
14:53:44.766 Log Resource "Log" closed. [0 ms]
14:53:44.766 5G Log Resource "5G Log" closed. [0 ms]
14:53:44.766 DUT BASIC Resource "DUT BASIC" closed. [0 ms]
14:53:44.767 BSE_P5G Resource "BSE_P5G (TCP/IP0::localhost::hislip2::INSTR)" closed. [1 ms]
```

DUTs DUT BASIC Instruments BSE_P5G RF Chamber Results Log 5G Log

Automation & Scripting

TAP STEPS TO MEASURE RF TX AND RX CHARACTERISTICS

Steps

Search...

- Basic Steps
- DUT_UE
- E7515A
- E7515A-GSM
- E7515A-IoT
- E7515A-LTE
- E7515A-Protocol Analysis
- E7515A-WCDMA
- E7515B
- E7515B-5G-NR
- E7515B-P5G
- Flow Control
- Results
- RF CHAMBER
- RFT 5G NR T-0A: Measurement tools for 5G NR**
- Test

XsaStep_N9020A Add Add Child

▼ RFT 5G NR T-0A: Measurement tools for 5G NR

- Common
- ▼ Measurements
 - 5G NR FR2 Metrics
 - 5G NR Rx
 - 5G NR XSA

▼ Measurements

- ▼ 5G NR FR2 Metrics
 - EIRP Add Add Child
 - Maximum EIRP Add Add Child
 - Minimum EIRP at CDF Add Add Child
 - Minimum Peak EIRP Add Add Child
 - Tx Beam Peak Add Add Child
- 5G NR Rx
- ▼ 5G NR XSA
 - Adjacent Channel Po... Add Add Child**
 - Channel Power Add Add Child
 - Modulation Analysis Add Add Child
 - Occupied Bandwidth Add Add Child
 - Spectrum Emission... Add Add Child

Step Settings

- ▼ Common
 - XSA 5G NR
- ▼ Sweep Settings
 - Continuous Measurement State OF
- ▼ Radio Settings
 - RF Port RF
 - Measurement Direction Up
- ▼ Frequency Settings
 - Center Frequency 28 GHz
 - Measurement Span 200 MI
- ▼ Measurement Settings
 - Multicarrier Measurement
 - Averaging State OF
 - Frequency Range FR
 - Bandwidth 10
 - Frequency Offset 0 Hz
 - IBW 100 MI
- ▼ Trigger Settings
 - Trigger Source Pr
 - Trigger Delay State OF
 - Trigger Delay 0.008C
- ▼ Verdict Settings
 - Enable Verdict
- ▼ Results Settings
 - Generate Report

C870250AA RFT 5G NR T-0A: Measurement tools

TAP PLAN EXAMPLES

Step Name	Verdict	Duration	Flow	Step Type
--- LTE cell configuration ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.LTE Cell Configuration - CELL1				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ LTE Cell Configuration
✓ RFT 5G NR T-0A.LTE DL Scheduler Configuration				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ LTE DL Scheduler Configuration
✓ RFT 5G NR T-0A.LTE UL Scheduler Configuration				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ LTE UL Scheduler Configuration
--- NR cell configuration ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.NR Cell Configuration - CELL2				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ NR Cell Configuration
--- Set UE State ---				Basic Steps \ Log Output
✓ E7515B-5G-NR.LTE.NR Cell Reconfiguration with SgNB Addition				E7515B-5G-NR \ LTE BSE \ Cell Actions \ BSE Procedures \ NR Cell Reconfiguration with SgNB Addition
✓ RFT 5G NR T-0A.NR Set UE State				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ NR Set UE State
✓ If Verdict (NR Cell Connected)				Flow Control \ If Verdict
--- Set Measurement Conditions ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.NR Set Measurement Conditions				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ NR Set Measurement Conditions
--- Search TX Beam Peak ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.OTA Positioning: Spherical Sweep				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ OTA Positioning
✓ RFT 5G NR T-0A.Tx Beam Peak				RFT 5G NR T-0A: Measurement tools for 5G NR \ Measurements \ 5G NR FR2 Metrics \ Tx Beam Peak
--- Positioning and measurement ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.OTA Positioning : Direct Move				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ OTA Positioning
--- Set UE State Disconnect ---				Basic Steps \ Log Output
✓ RFT 5G NR T-0A.NR Set UE State IDLE				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ NR Set UE State
✓ RFT 5G NR T-0A.NR Set UE State IDLE				RFT 5G NR T-0A: Measurement tools for 5G NR \ Common \ NR Set UE State
✓ E7515B-5G-NR.LTE.NR Cell Reconfiguration with SgNB Addition				E7515B-5G-NR \ LTE BSE \ Cell Actions \ BSE Procedures \ NR Cell Reconfiguration with SgNB Addition
✓ E7515B-5G-NR.Activate Cells				E7515B-5G-NR \ General \ Cell Actions \ BSE Procedures \ Activate Cells
✓ E7515B-5G-NR.Activate Cells				E7515B-5G-NR \ General \ Cell Actions \ BSE Procedures \ Activate Cells

NR NSA Connection

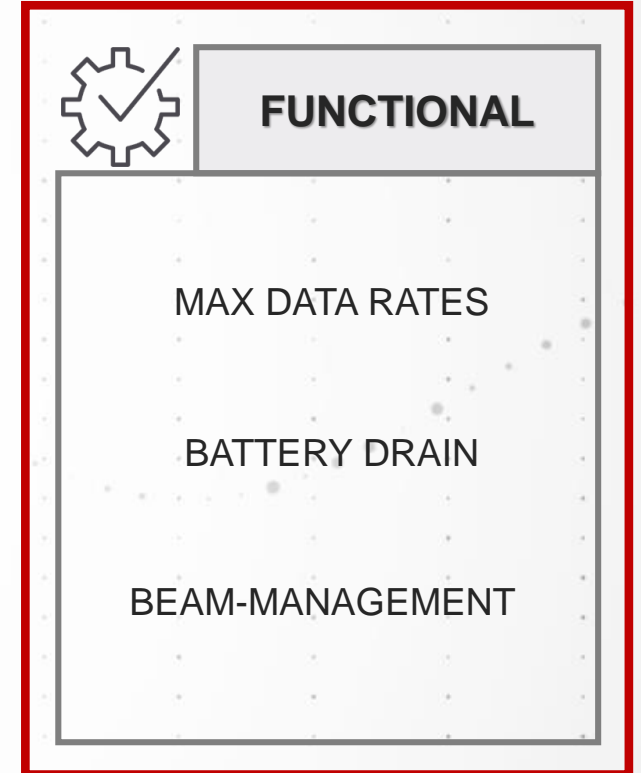
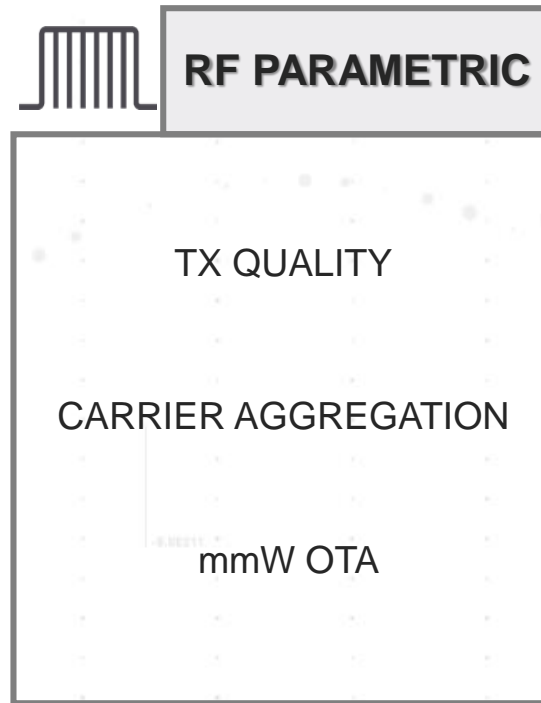
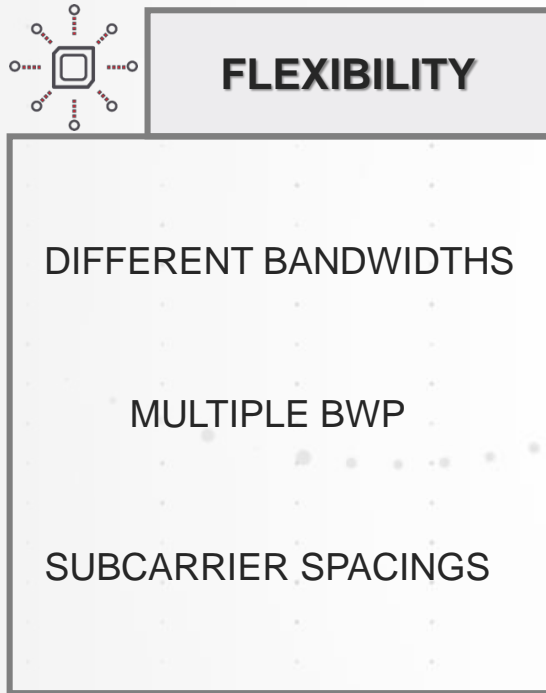
Measurements Conditions

Positioning

Measurement

5G NR Device Verification

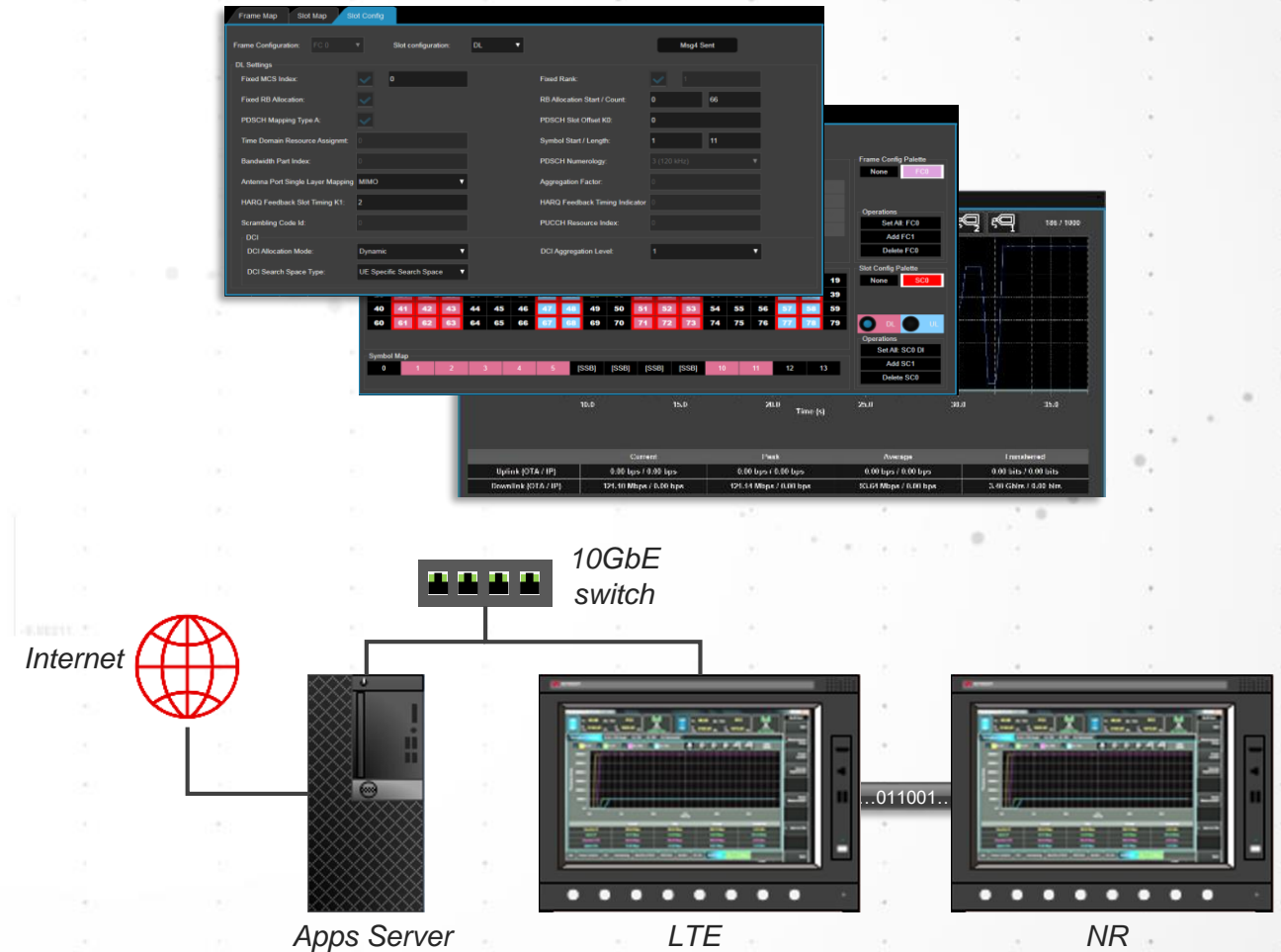
TEST CHALLENGES



Data Throughput Performance

FUNCTIONAL KPI TOOLS

- Benchmark 5G IP data throughput performance in a fully automated environment
- Make sure expected data rates are met in complex scenarios in both LTE and NR cells
- Verify end-to-end receiver performance for different MCS and RB
- Achieve sustained maximum data rate for most common transport protocols (FTP, TCP, UDP, ping)
- Connect to the Internet to test OTT applications
- Automation scripting tool via PathWave Test



Battery Life Evaluation

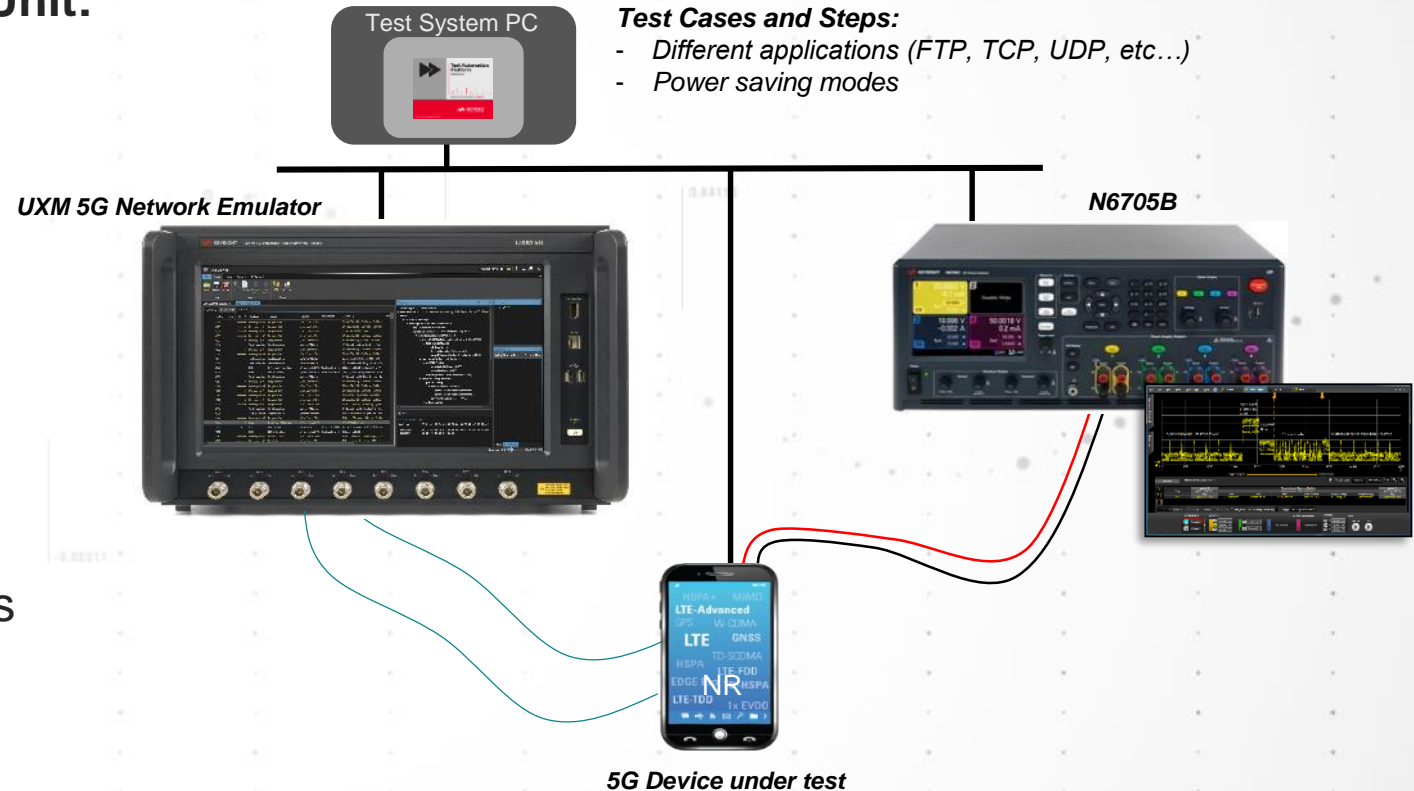
FUNCIONAL KPI TOOLS

Test steps to control Source Measurement Unit:

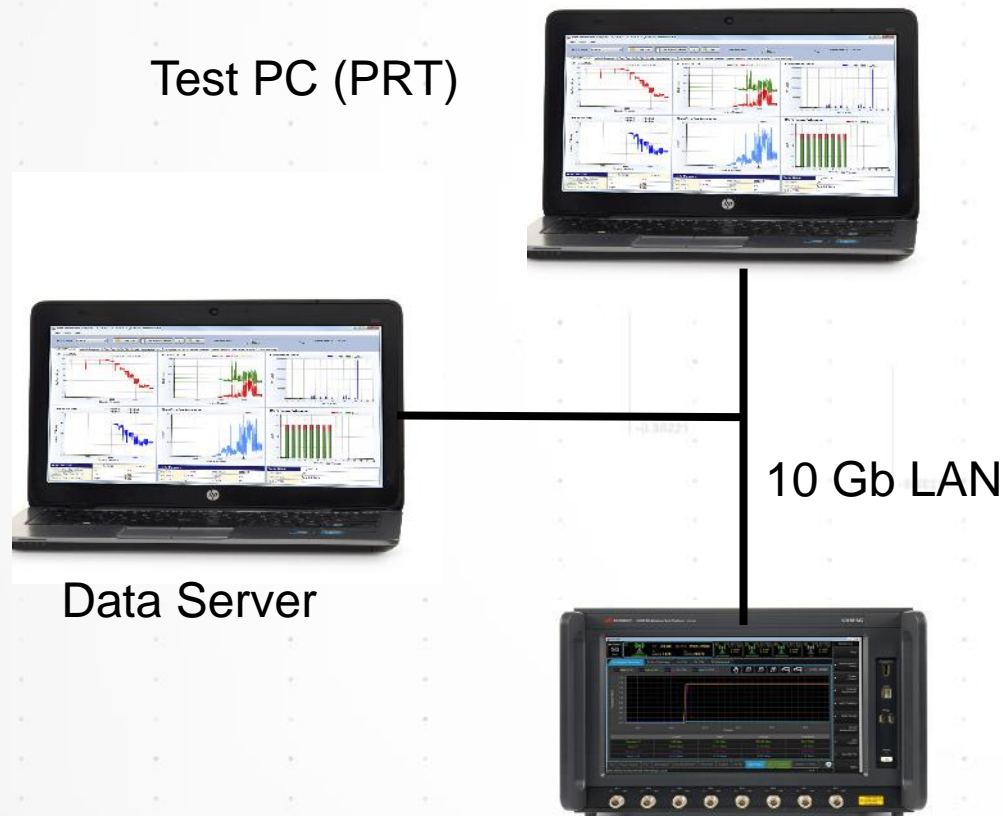
- Time resolution
- Capture duration
- Start / Stop

Keep the power drain controlled under:

- High data rates
- Mobility and beam-management scenarios
- File transfer
- Video streaming, www browsing
- Sleep and power saving modes



Data Throughput Testing



- Recommended setup for **maximum data rate**
- Lower rates (e.g. 600 Mbps) can be achieved without Data Throughput PC by running iPerf / FTP on the external PC
- 4.4 Gbps + proven using 5GTF Spec.
- Designed for 7.8 Gbps as per 3GPP
- Data Throughput PC will act as a slave to the PRT
- Customer has option to connect their **own data server**

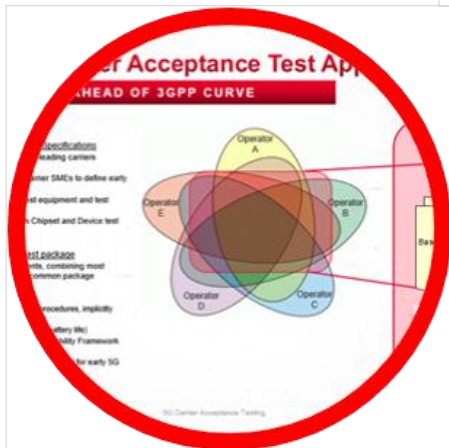
Acceptance Solutions



Protocol Conformance

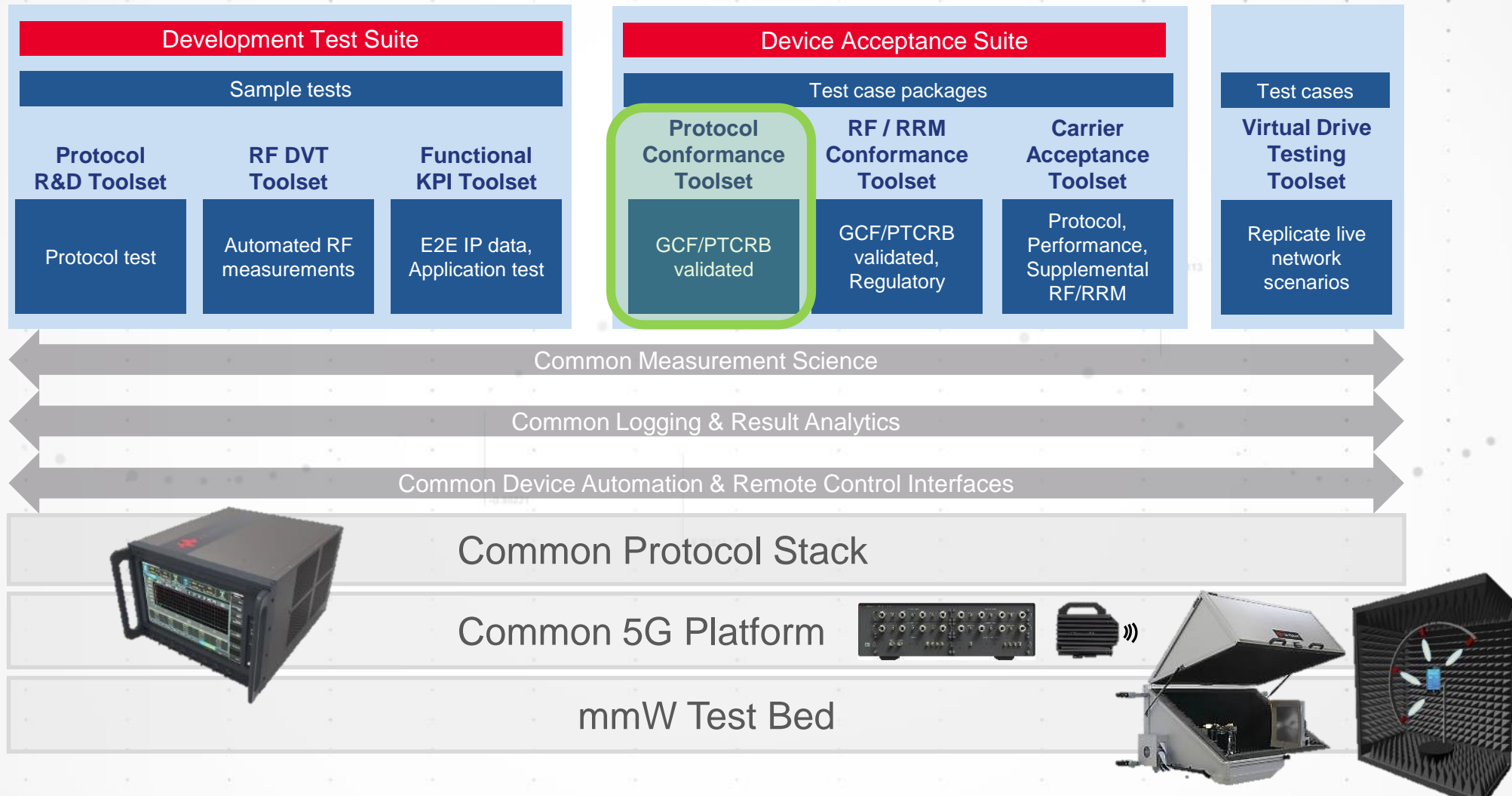


Radio Conformance









Carrier Acceptance

Keysight 5G Network Emulation Solution Portfolio



5G Protocol Conformance Toolset

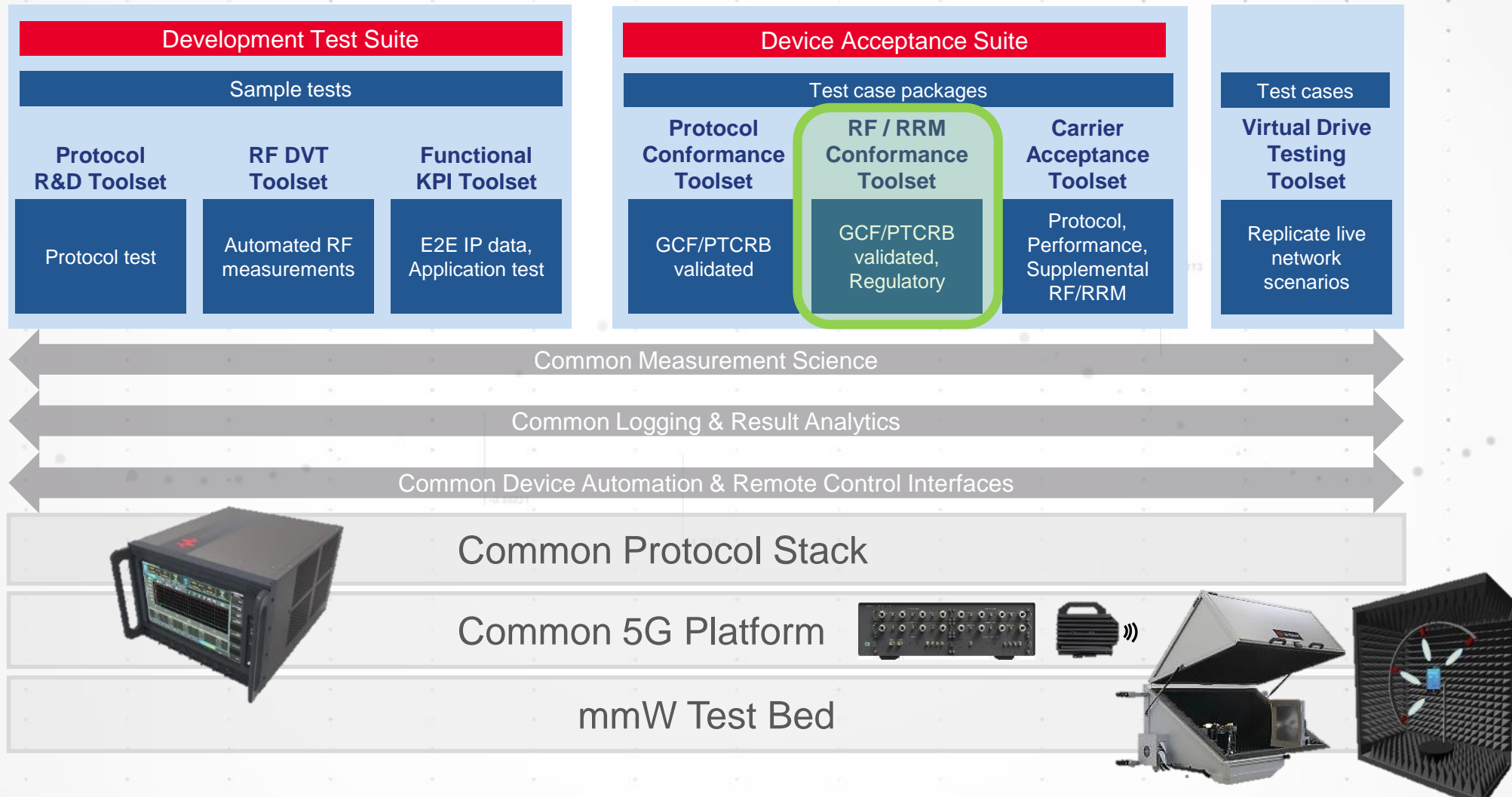
SUPPORTED HARDWARE CONFIGURATIONS

Network Emulators	Notes	5G frequency / test method		
		sub-6GHz / conducted	mmWave / conducted	mmWave / OTA
 <p>UXM 5G</p>	<ul style="list-style-type: none"> Both 5G NR and LTE anchor on same UXM 5G A single UXM 5G can support all 5G PCT test cases defined so far, with spare capacity for additional CCs if required in future 	<ul style="list-style-type: none"> RF cables from UXM 5G to DUT 	 <ul style="list-style-type: none"> CIU upconverts 5G NR signal up to 12GHz IF DUT's 5G antennas connected to CIU DUT's LTE antennas connected to the UXM 5G or DA Combiner 	 <ul style="list-style-type: none"> 28/39 GHz Remote Radio Heads
 <p>UXM 5G + A9000 Rev2.5</p>	<ul style="list-style-type: none"> Allows testing of legacy technologies and 5G 5G test cases on UXM 5G (NR+LTE carriers for NSA) 2G/3G/LTE test cases on A9000 Rev2.5 Target for H1 2019 	 <ul style="list-style-type: none"> Combines RF outputs from UXM 5G and A9000 RF cables from DAC to DUT 	 <ul style="list-style-type: none"> Rack-Mounted Test Chamber 	

4 RRHs required for mmWave interband test cases and band combinations

RMTC chamber approved for single cell test cases at RAN5#80. Decision on multi-cell test cases deferred.

Keysight 5G Network Emulation Solution Portfolio



Keysight 5G Carrier Acceptance Test Approach

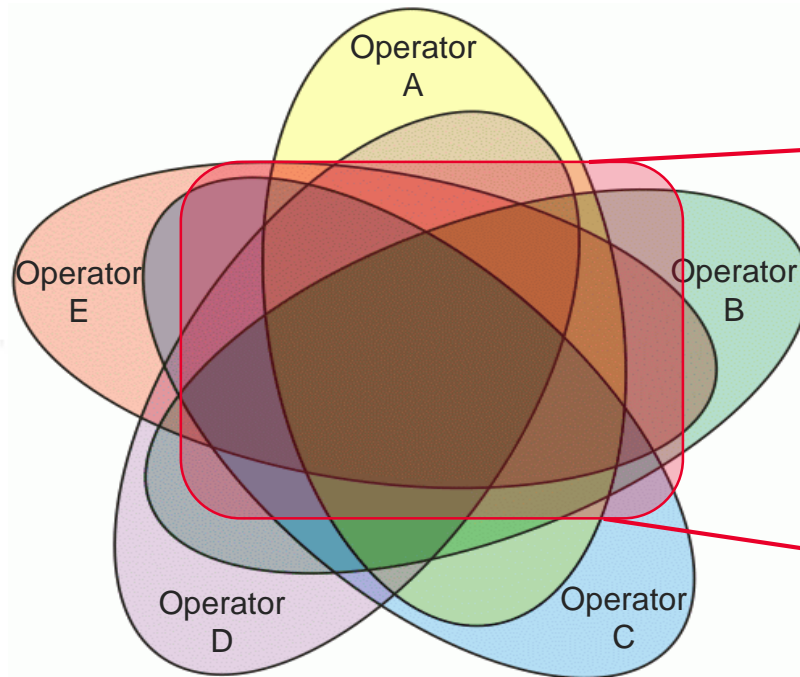
ENABLE 5G TESTING AHEAD OF 3GPP CURVE

1. Carrier-Specific Acceptance Test Specifications

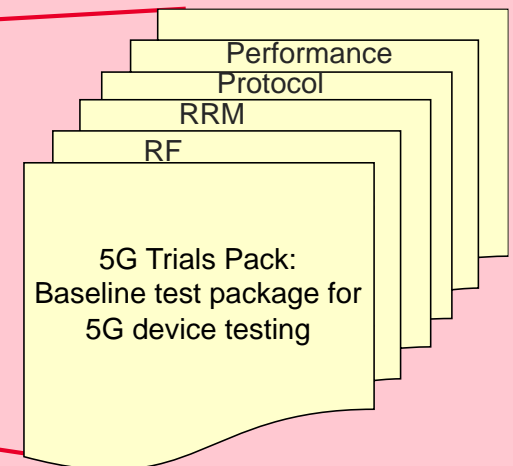
- Focused effort with the industry-leading carriers worldwide
- Close collaboration with the carrier SMEs to define early 5G test plans
- Provide early access to 5G test equipment and test cases
- Maintain good alignment with Chipset and Device test plans

2. 5G Trials Pack: Baseline 5G test package

- Predicts 3GPP test requirements, combining most relevant test scenarios into a common package
 - RF
 - RRM
 - Protocol (focused on layer 3 procedures, implicitly testing lower layers)
 - Performance (data throughput, battery life)
- Implements the NGMN 5G Interoperability Framework test plan
- Promoted as a pre-standard starting point for early 5G device testing



5G Trials Pack



Keysight 5G MNO Engagement

- Keysight is strongly engaged with all of the leading 5G MNOs worldwide.
- Solutions and test cases have already been delivered to many of these MNOs.
- Keysight is also working with chipset vendors to verify these test cases.
- Actively consulting with a number of MNOs to assist in development of their formal 5G device acceptance test plans, which will be announced in 2019.
- 5G Trials pack being promoted to MNOs, to provide them with 5G test capability ahead of 3GPP test case availability.



Solution Portfolio

mmW 5G Non-Signaling Solution

5G End to End Manufacturing Solution

5G Manufacturing Solution Portfolio

CHOOSE YOUR FREQUENCY RANGE

Sub-6 GHz

Sub-6 GHz and mmWave

mmWave



E6640A EXM



E6640A EXM, E7770A CIU, and M1740A RRH



E7760B, and M1740A RRH

mmWave 5G Non-Signaling Solution

E7760B WIDEBAND TRANSCEIVER AND M1740A MMWAVE TRANSCEIVER FOR 5G

Versatile Solution for mmWave 5G

- Verify performance over more than **four 3GPP-defined mmWave bands in one RRH**
- Cover **IF and mmWave** bands in a single solution
- Quickly characterize mmWave antennas with PAVT
- Test **over the air** with Keysight chambers, positioners and antennas and automate the entire solution with one software application
- Confidently test across the workflow with industry-proven measurement algorithms based on **X-Series applications** and simplify 5G measurements with integrated waveform and measurement application software
- Improve efficiency with a remote radio head that can be used with multiple Keysight platforms



5G Test Solutions

NON-SIGNALING TEST

Keysight has unique solutions for 5G test

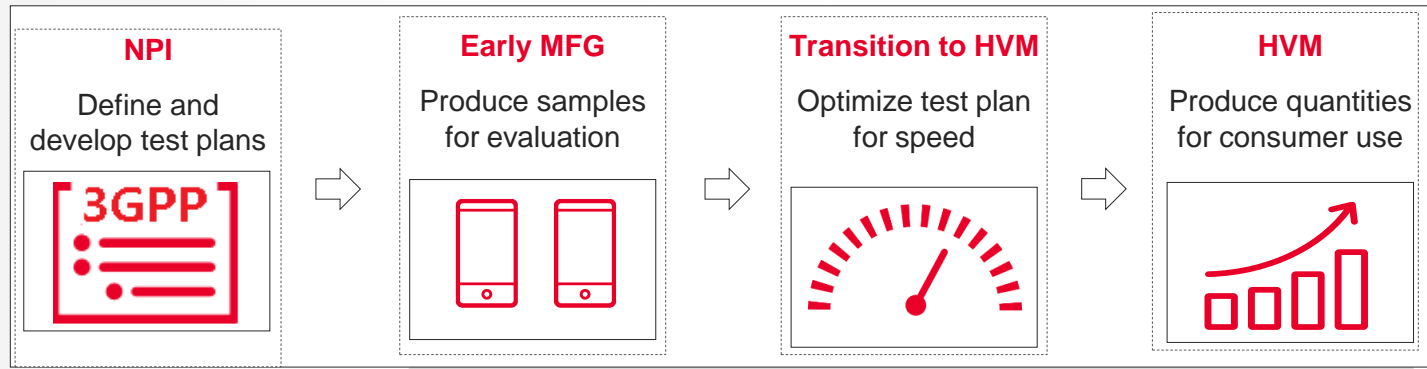
- The only remote radio head covering more than four mmWave bands
- The only solution covering the 40 to 43.5GHz frequency range
- The only single solution combining IF and mmWave test
- Automation with PathWave Test
- Common 5G NR measurement algorithms used across all Keysight platforms



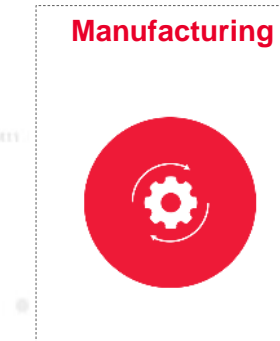
5G End-To-End Manufacturing Solutions

PORTFOLIO

5G MFG Workflow



5G MFG Solutions



EXM Wireless Test Set

plus



CIU and Remote Radio Heads for mmWave

Efficient test plans with **sequencing** and, **no signaling, multiple ports**



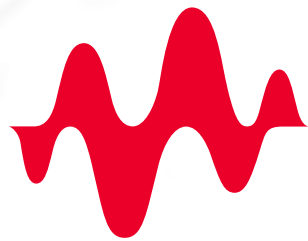
Common measurement science and automation, fast and repeatable

**Why
Keysight?**

WHY Keysight



- Matured and Stable 5G and mmW solution through early engagement
- First 5G NR Engagements with all WW Key chipset vendors
- First 5G NR Engagements with all WW Key Operators
- First 5G NR Engagements with all WW Device Makers
- Leading Activities at Standard body
- Leading position at RCT and PCT validation
- Proved and Verified mfg solution for 5G NR device



KEYSIGHT
TECHNOLOGIES

4.50221