

TECHNICAL OVERVIEW

Keysight 5G Protocol R&D Toolset

Features and Capabilities

Introduction Background

It's an exciting time to be in the wireless industry. The race is on to deploy 5G. New chipsets and devices need to be rolled out at the right cost and time. 5G introduces new challenges related to extended mmWave frequencies, beam management and the need for validating complex, integrated next generation devices in Over-the-Air (OTA) test environments. Use cases for 5G are continuously evolving which means 5G devices need to be characterized and validated to comply with evolving 3GPP NR specifications and mobile operator acceptance plans.

Keysight is helping solve 5G design challenges ahead of each technology wave. We do this by delivering an ongoing stream of timely solutions that span the device ecosystem. The foundation is peaked expertise in 5G technologies, solutions and services—a combination that enables you to accelerate innovation in new-generation devices.

Whether your team is developing the protocol stack for a chipset, or evaluating performance under real-world network conditions, Protocol R&D Toolset provides a solution that has already been proven to the market leaders in 5G. It allows you to test the latest 5G functionality with easy-to-use tools and efficient debugging, leading to reduced time-to-market.



What is Protocol R&D Toolset?

Keysight's Protocol R&D Toolset (PRT) is a comprehensive suite of tools for protocol and application testing of chipsets and devices. Protocol R&D Toolset covers the whole chipset and device development workflow from early prototype testing through to integration and verification.

Protocol R&D toolset enables you to test the latest available 5G features, including beamforming, multiple numerologies and subcarrier spacing. You can efficiently test Layer 2 before the entire stack is completely implemented by using L2 Mode to carry out protocol testing for Layer 2 separately, which means issues can be found and resolved earlier in the design lifecycle leading to reduced R&D costs. Currently, Protocol R&D Toolset supports two types of application testing: high data rate performance (e.g. eMBB use cases) and VoLTE. Protocol R&D Toolset allows you to simulate a real network and then write and execute tests to verify how the chipset and device interacts with the network. Once the tests are executed, detailed logs are automatically generated, thereby facilitating trouble-shooting of issues.

Who benefits from using Protocol R&D Toolset?

- Chipset and device manufacturers for early development testing of specific layers or the full protocol stack as well as for running functional and regression tests
- Test houses for regression testing
- Universities and research institutes for research activities

Automated, Flexible Test and Reporting Tools

Protocol R&D Toolset offers the flexibility to perform testing in a number of different ways. For example, you can:

- Create and edit tests according to your test requirements and run the tests manually or in automation.
- Develop a test in a way that gives you access to the protocol state machine, and when in that state, you can modify Layer 1 and Layer 2 parameters during test execution. This will enable you to test the interaction between Layer 1 on the network and Layer 1 on the device as well as between Layer 2 on the network and Layer 2 on the device. For complete testing of Layer 1, there is a separate application that can be used called Test Application.
- Develop a test using L2 Mode, which is useful when Layer 3 has not yet been implemented in your chipset or device.

This chapter provides an overview of how to use the Protocol R&D Toolset to create, edit and run tests as well as how to modify Layer 1 and Layer 2 parameters during test execution. This chapter also describes L2 Mode and logging. You will also find descriptions of the system set-up for testing with sub-6GHz and mmWave frequencies.

User interface for quick test case creation, editing and execution

No programming knowledge is required to use 5G Protocol R&D Toolset. It offers an easy-to-use graphical user interface that makes it straightforward to create, edit and execute tests specific to your test requirements. The building blocks of a test are called script elements. You create a new test by simply dragging and dropping applicable script elements – the building blocks of a test – into the workspace where you load the script. Each script element can be configured for specific parameters.

	Seriet							
	Script	Line	Time	tel	Direction	Dataile	Description	
		care	THINK	10	Direction	Codet Details (NDEC LTE DCCalls 44)	1 Adjuste NREC Calls Check II	
G		2				Sint Information (Explicitly defined)	1. Activate NK5G Cell2, Start 0	
Control		3	00.00.00			User Promot [Activate NRSG Cell]		
NR5G Cell		4	00:00:00	NR-Cell A		Activate NR5G Cell INR-Cell A :DL Power = -40	FB2	
G Beam Confiduration		5	00:00:00			User Prompt (Start NR5GUEDemonstrator and		0 1 1 1
te NR5G Cell		6	00:00:00	E-Cell A		Activate LTE Cell		Script in
		7	00:00:00	E-Cell A		LTE DYNAMIC CONTROL POINT [Continue after		Workenson
		8	00:00:00	E-Cell A	SS> M	5 RRC Connection Reconfiguration	FR2	workspace
		9	00:00.00	E-Cell A	SS < M	5 RRC Connection Reconfiguration Complete		
		10	00:05.00			User Prompt [wait]		
ts		11	00:02.00	E-Cell A		Deactivate LTE Cell		
	*	12	00:01.00	NR-Cell A		Deactivate NR5G Cell		
fr Cell Power			-					
r cerrower	Deal 7				1			
	keat t	ime trac	je Scra	pt Variables	k .			
	Line	Time		Cell D	rection Tra	ce .		
	1	00.0	8.09				*****	
		00.0	8.09		Ee	exited on SAS 5G Sequencer VS8.0 181		
	1.5							
	i	00.0	8.09		Se	tpt is signed by User Generated		
	1	00.0	e 0.8		Se	tpt is signed by User Generated		
	1 1 1 1 1	00.0	8.09 8.09 8.09		Se	ipt is signed by User Generated		
	1 1 1 3 4	00.0 00.0 00.0 00.0 00.0 00.1 00.1	18.09 18.09 1.33 1.95 N	R Cel A	So MJ AC	Ipt is signed by User Generated	1 - Bandwurdefined - Freque	
	1 1 3 4 4	00.0 00.0 00.0 00.0 00.1 00.1	18.09 18.09 11.33 1.95 N 1.95 N	RCel A RCel A SS	Se MJ AC S→ MS Ma	pt is signed by User Generated NUAL OK PROMPT (Activities NRSG Cell), RESPONSE (OK) TWATE NRSG CELL [FR2] Physical Cell ID-0 ; NRARFCN+207545 techformationBlock	1 : Band-undefined : Freque	
	1 1 3 4 4 5	00.0 00.0 00.0 00.0 00.1 00.1 00.1	18.09 18.09 11.33 11.95 11.95 11.95 11.95 11.95 11.95	R Cel A R Cel A SS	So MU AC S -> MS MJ	işt is aşınad by Üser Generated NULAL OK PROMPT (Activate NRSG Cell], RESPONSE (DK) TÜXTE NRSG CELL (FR2) Physical Cell (D-0: NRARECH-207345 detel förmation/Block NULAL OK PROMPT [Stast NRSGUEDemonistrator and Clock OK], RE	1 : Band-undefined : Freque	
	1 1 3 4 5 6	00.0 00.0 00.0 00.1 00.1 00.1 00.1 00.1	18.09 18.09 11.33 11.95 11.95 11.95 11.95 12 6.12 6.50 12	R Cel A R Cel A SS E Cel A	So MJ AC S -> MS MJ AC	rpt is signed by User Generated NUAL OK PROMPT (Hervies INRSG Cell, RESPONSE (DK) NUAL OK PROMPT (Jack IRR) (Hysical Cell D-0: INRARCIN-207345 are/Homston-Block NUAL OK PROMPT (Jack IRRSGUEDemonstrator and Dick OK), RE NUAL OK PROMPT (Jack IRRSGUEDemonstrator and Dick OK), RE	1 : Band-undefined : Freque SPONSE (OK) Semi-15-L4: RuPower-20	
ot elements	1 1 1 3 4 4 5 6 6	00:0 00:0 00:0 00:1 00:1 00:1 00:1 00:1	8.09 8.09 1.33 1.95 N 6.12 6.50 E 6.50 E	R Cell A R Cell A SS E Cell A SS E Cell A SS	Se	rgt is signed by User Generated NULL, OK PROMPT (Velowin NRISG Cell, RESPONSE (XM) TIVATE NRISG CELL [FR2] Physical Cell (X-6) (NRARCIN-207345 aer/formationaci NULL, OK PROMITY [Sate 11850/JEDemonstrator and Dick OK), RE TIVATE CELL - Band-2: EARPCH: 0L-504 UL-18504 Turbure-18 5	1 : Band-undefined : Freque ISPONSE [Did] GeBm/13kHz RxPower-20	Real time trace
t elements	1 1 1 3 4 4 5 6 6 6	00:0 00:0 00:0 00:1 00:1 00:1 00:1 00:1	809 809 133 195 N 195 N 612 650 E 650 E 650 E	R Cell A R Cell A S Cell A S Cell A S Cell A S Cell A S Cell A	So → MS → MS → MS MI S→ MS MI S→ MS ST MS ST MS ST MS ST MS ST MS ST ST ST ST ST ST ST ST ST S	rpt is signed by User Generated ANUAL OK PROMPT (Jestwale NRSG Gel], RESPONSE (DK) TIVATE NRSG CELL (PR2), Physical Cell (D=2), IRRARCIN-007455 aer/formationBlock NUAL, OK PROMPT (San INSGUEDemonitator and Dick OK), RF TIVATE CELL - Band-2: EARPCN, DL-904 VL-18004 TuPaner-8 8 11	1 : Bard-undefined : Freque SPONSE (DQ S6Bm/196Hz RuPower-20	Real time trace
t elements	1 1 1 3 4 4 5 6 6 6 7	0010 0010 0010 0011 0011 0011 0011 001	809 809 133 195 N 195 N 612 650 E 650 E 650 E 650 E	R Cell A R Cell A S Cell A S Cell A S Cell A S Cell A S Cell A S Cell A	So → MS → MS → MS → MS Si → MS Si € → MS Si E N	ept is signed by User Generated NULL OK PROMPT Vietness INRIG Cell, RESPONSE (DO) TWATE NISS CELL (FR2) Physical Cell (D=0) INRARCIN-201545 and the transformation State NULL OK PROMPT (State INRIGUEDemonstrator and Deix On), FR NULL OK PROMPT (State INRIGUEDemonstrator and Deix On), FR NULL OK PROMPT (State INRIGUEDemonstrator and Deix On), FR NULL OK PROMPT (State INRIGUEDemonstrator and Deix On), FR THE DOI NULL OK PROMPT (State INRIGUEDEMONSTRATE) TE DOI NULL OK CONTROL EDIXIT (State an and unit I late Activa).	1 : Band-undefined : Freque SPONSE[D0] Sdbn/1304a RvPower-20	Real time trace
t elements	1113445666676	000 000 001 001 001 001 001 001 001 001	809 809 133 195 N 195 N 650 E 650 E 650 E 650 E 650 E 650 E	R Cell A R Cell A S Cell A	So	rgt is signed by User Generated NULAL OK PROMPT (Astronen NRSIG Cell), RESPONSE (DK) TIVATE NRSIG CELL (PR2), Physical Cell (D-2), IRRARCIN-4207455 deerformationBack NULAL, OK PROMITY (Back INSGUEDemonitation and Dick OK), RE TIVATE CELL - Band-2: EARFCH: 0L-904 KL-19904 TuPbanen-8 11 12 12 12 12 12 12 12 12 12	1 : Band-undefined : Freque ISPONSE.[DK] SeBm/19.cHz RePower-20	Real time trace
t elements	11134456666768	000 000 001 001 001 001 001 001 001 001	809 809 1133 1195 N 1195 N 650 E 650 E 650 E 650 E 650 E 650 E 653 E 0.70 E 0.93 E	R Cell A R Cell A S Cell A	So MU AC S→ MS S→ MS S→ MS SIE S→ MS SIE EN S→ MS RF	gt is signed by User Generated NULL OK PROMPT (Activities INRISC Gall, RESPONSE (DO) TWATE INRISC GEL, IPR21 Physical Gal (D=0): INRARCIN-201545 werthomationState NULL OK PROMPT (Stat: INRISUE/Elemenators and Dak OO); FE TWATE CELL - Band-2: EAR/CRU 0.0404 UL-18504 TAPbase-89 8 11 12 12 14 15 16 17 17 DYNAMC CONTROL POINT (Sord paused until User Action) 17 DYNAMC CONTROL POINT (Sord paused until User Action) 17 DYNAMC CONTROL POINT (Sord paused until User Action)	1: Band-undefined : Freque SSONSEE[DQ Gellan/13kHz RuPower~20	Real time trace
t elements	111344566667689	000 000 001 001 001 001 001 001 001 001	809 809 1133 1195 N 1195 N 1195 N 1195 N 1195 N 1195 N 1195 N 1195 N 1195 N 150 E 650 E 650 E 650 E 653 E 0.70 E 0.93 E	R Cell A R Cell A SCell A SCell A SCell A SCell A SCell A SCell A SCell A SCell A SCEL	So MS No 	rgt is signed by User Generated MUM, DIX PROMPT (Administ NRSG Cell, RESPONSE DIX TIVATE NRSG CELL (PR2) Physical Cell (D-2): NRARICH-207345 derformationBock NUME, COR PROMPT (Start NRSGUEDemonstrator and Dick CNR, FE TIVATE CELL - Band-2: EARTCH: DL-364 UL-1854 Tuff-timer-8 11 12 TER DYNAME CONTROL POINT (Sorty Daused until User Action) 11 17 DYNAME CONTROL POINT (Sorty Daused until User Action) 17 DYNAME CONTROL CONTROL TO COMPLETE	1 : Band-undefined : Freque ISPONSE.[DN] SdBm/1944z Ru ⁶ ower-20	Real time trace
ut elements	1 1 1 3 4 4 5 6 6 6 6 7 6 8 9 10	000 000 000 001 001 001 001 001 001 001	809 809 1133 1135 N 1195 N 119	RCel A RCel A SCel A SC	So → MS ↔ MS ↔ MS ↔ MS ↔ MS Si ↔ MS Si ↔ MS Si € ↔ MS RF 6 ↔ MS RF M3	gt is signed by User Generated NUAL OK PROMPT (Jechnese INRIG Cell, RESPONSE (DK) TWATE NRISS CELL (PR2) Physical Cell (D=0): INRARCIN-207345 and/second technological Cell (D=0): INRARCIN-207345 and/second Cell (D=0): INRIGUEDEmonitation and Cells (DK) TWATE CELL - Band-2: EARPCR: OL.9604 (L-18064 TAPBower-9) 11 12 12 15 11 12 15 17 17 17 17 17 17 17 17 17 17	1: Band-undefined : Freque SPONSE [DQ] GeBm/13kHz RxPower~20	Real time trace
ot elements	1 1 1 3 4 4 5 6 6 6 6 7 6 8 9 10 11	000 000 000 001 001 001 001 001 001 001	88.09 88.09 18.09 18.09 11.33 11.35 11.35 N 16.12 16.50 16.50 16.50 16.50 16.50 16.53 16.50 10.70 16.53 10.96 16.53 10.96 16.54	RCel A RCel A Seel A	$\begin{array}{c} \text{Se}\\ & \text{HJ}\\ & \text{AC}\\ & \text{AC}$	rgt is signed by User Generated NULL OK PROMPT (Velowin NRSG Cell, RESKOLSE (DK) TIVATE NRSG CELL [F2] Physical Cell (D-6) (NRARCIN-207345 startification) NULL OK PROMIT [Sate INSGUEDemonstrator and Dick OK], F8 TIVATE Cell - Band-2: EARFCH DL-504 UL-1504 Turbure-10 8 TOTAL CONTROL - Band-2: EARFCH DL-504 UL-1504 Turbure-10 10 10 10 10 10 10 10 10 10	1 : Band-undefined : Freque ISPONSE (DK) GBm/1964t RiPower+20	Real time trace
pt elements	1 1 1 1 3 4 4 5 6 6 6 6 6 7 6 8 9 10 11 12	000 000 000 001 001 001 001 001 001 001	809 809 809 1133 1135 650 650 650 650 650 650 650 650 650 65	RCel A RCel A Store A	Se	gt is signed by User Generated ANUAL OK PROMPT (Jestwein NRISG Cell, RESPONSE (DK) TWATE NRISG CELL (PR2) Physical Cell (D=0): NRARCIN-207345 adveffmature0166 NUAL OK PROMPT (Bash INRIGUE/Demonstrator and Dick CR), RE TWATE CELL - Band-2: EARPCR-10.4664 UL-18064 TARPower-0 TH TER DINARC CONTROL POINT (Sortp Seused until User Action) TO YNARC CONTROL POINT (Sortp Seused until User Action) TO YNARC CONTROL POINT (Sortp Seused until User Action) TO YNARC CONTROL POINT (Sortp Seused until User Action) TO YNARC CONTROL POINT (Sortp Seused until User Action) COMBECTOR NEODARGURATION COMMETCION NEOTARGURATION COMMETCION NEODARGURATION COMMETCION NEODARGURATION COMMETCION NEODARGURATION COMMETCION NEOTARGURATION COMMETCION NEOTARGURATION	1 : Band-undelined : Freque ISPONSE (DK) S6Bw/19.Hz RuPower-20	Real time trace



Figure 1 - 5G Protocol R&D Toolset Graphical User Interface makes it easy to create, edit and execute new tests.

Example scripts are delivered with each software release to cover the essential functionality supported by the toolset. You can quickly edit these scripts to create customized tests according to your test requirements.



Script elements for creating customized tests

The flexibility of the tool enables you to configure script elements whilst creating or modifying a script. There are script elements for cell control, RRC and NAS messages, beam configuration and iPerf (for data throughput testing). Programming commands allow you to verify information elements in uplink messages and validate that the UE transmits correct information to ensure that the device behaviour is compliant with the test specification. Once a script has been created, you can run it repeatedly.

Using Keysight's Test Manager, you can set up campaigns to automate the execution of several hundred scripts, which is ideal for regression testing. For further details, please see section titled 'Test Manager and Automation for running large campaigns of tests.

Line	Time	Id	Direction	Details	Description
1				Script Details [NR5G_LTE_PSCellAdd]	1. Activate NR5G Cell2. Start U
2				SIM Information [Explicitly defined]	
3	00:00.00			User Prompt [Activate NR5G Cell]	
4	00:00.00	NR-Cell A		Activate NR5G Cell [NR-Cell A :DL Power = -40 dBm/75kHz]	FR2
5	00:00.00			User Prompt [Start NR5GUEDemonstrator and Click OK]	
6	00:00.00	E-Cell A		Activate LTE Cell	
7	00:00.00	E-Cell A		LTE DYNAMIC CONTROL POINT [Continue after User Action]	
8	00:00.00	E-Cell A	SS> MS	RRC Connection Reconfiguration	FR2
9	00:00.00	E-Cell A	SS < MS	RRC Connection Reconfiguration Complete	
10	00:05.00			User Prompt [wait]	
11	00:02.00	E-Cell A		Deactivate LTE Cell	
12	00:01.00	NR-Cell A		Deactivate NR5G Cell	

Figure 2 - An example of a test in Protocol R&D Toolset.

Cell configuration to configure important network parameters

There are cell configuration script elements for 5G NR and LTE. In the dialog for a cell configuration you can configure cell specific parameters such as band, ARFCNs and cell power. Each script element consists of parameters for one particular cell. Figure 3 shows the cell configuration dialog for a 5G NR cell. The cell configuration allows you to replicate a real network by including several cells in a script with different cell configurations.

Activate NR5G Cell ? ×										
L2 Parameters	1 Parameters	1	MIB	Description	Associated Variables					
Cell Parameters	SSB Informa	tion	Cell De	elay and Offset	RACH Parameters					
Cell Name										
Cell ID	A									
Physical Cell ID	6		\$							
CellGroup Name	G1									
SCell Index	3		¢							
Cell Frequency Para	neters									
BAND	1		A							
Frame Structure	TDD		~							
UL Frequency	28017.120									
DL Frequency	28017.12		÷							
UL ARFCN	2079451		• •							
DL ARFCN	2079451		^ 							
DL Bandwidth (MH:	z) 100		~							
UL Bandwidth (MH:	z) 100		~							
ARFCN Auto Calc										
Cell Power										
Reference Signal FF	PRF (dBm/SCS)	-55.0		•						
Expected Unlink Po	wer (dBm)	-35.0		*						
Enable Cell	the (doin)	35.0	v							
Lilable Cell		-								

Figure 3 - Example of a cell configuration dialog for 5G NR.

Dynamic Control Point to more accurately simulate a live network

By inserting a Dynamic Control Point (DCP) – a type of script element – into a script, you will be able to access the in-built protocol state machine, which provides greater test flexibility for the user. This makes the network emulator act as a live network that is able to handle any uplink messages and respond with appropriate downlink protocol messages. It's important to configure an exit condition for a Dynamic Control Point, see Figure 4. An example of an exit condition is an 'Attach Complete' message, which means that the script exits the Dynamic Control Point and goes to the next line in the test when 'Attach Complete' is received. Alternatively, the DCP can be set so that the user decides when to exit the DCP by clicking on an icon.

You can use Dynamic Control Points for different purposes, including:

- Use DCP to quickly locate the part of the script that is of interest for your testing. For example, if you want to test data throughput there is no need to check each and every message in the attach procedure, which means you can insert a DCP and then insert and check the contents of messages in detail in the data throughput part of the script.
- Perform early development testing where you need to modify Layer 1 and Layer 2 parameters. You can do this using Live Elements, which are script elements that can be used at a DCP only. Once the testing with Live Elements has been completed you can exit the DCP. In this case you would need to configure the DCP in a way that the user decides when to exit the DCP.

Dynamic Control Point ? 🗙											
General	General PS Variables Description										
Name	Name DCP_1										
Exit Con	Exit Condition Attach_Complete										
Exit	Exit on Guard Timer Expiry										
	Hours Minutes Seconds										
	0 🗘 0 🗘 30 🗘										
OK Cancel											

Figure 4 - Script element for Dynamic Control Point.

L2 Mode

L2 Mode allows you to test a chipset for which Layer 3 has not yet been implemented. The L2 configuration can be done for PDCP and RLC layers using a script element, see Figure 5. Examples of tests include:

- Sending duplicate PDUs to the device and checking that the device correctly acknowledges one of the duplicated packets
- Sending PDUs to a device and dropping a sequence of PDUs to see how the device responds
- Sending the PDUs in an incorrect order and checking that the device acknowledges the packets in the correct order
- Verification of received data against PDU payloads defined in the L2 Mode script element

L2 Mode Configuration	? ×
L2 Mode Type	
Cell ID	A •
Select The L2 Mode	PDCP
	RLC
Select The RLC Mode	None 🝷
Select The Generator Mode	None 🔻
Select The Error Mode	Duplicate
	Dropped
Select The Test Mode For RLC AM Mode	RLC_AM_TEST_MODE_NONE *
Select The Test Mode For RLC UM Mode	RLC_UM_TEST_MODE_NONE -
Select The Test Mode For PDCP Mode	PDCP_NORMAL_MODE -
Select The Duplication Interval	3
Select The Start Sequence Number For PDUs To Be Dropped	0
Select The End Sequence Number For PDUs To Be Dropped	0
Verify Data Arrived (Add Data To Be Verified To Rx PDU List)	✓
Specify Total Duration (minutes) Of Verification of Rx PDUs	1
Specify Total Duration (minutes) Of Transmitting The Required PDUs	0 🗘
PDU Information	
Add Tx PDU:	
PDU Value (in Hex)	A
0000	

Figure 5 - Script element for L2 testing.

Live Elements for dynamic testing of lower layer parameters

As mentioned above, you can use Live Elements at a Dynamic Control Point in a test, which gives you the ability to configure Layer 1 and Layer 2 parameters during test execution.

This capability is useful in a number of ways:

- Live Elements display the parameters configured in the script to view which Layer 1 and Layer 2 parameters are used in the script. As the script executes further, the Live Elements display the updated parameters in the script. These can be modified during test execution.
- The user can modify Layer 1 and Layer 2 parameters in the middle of a script. This means the L1<->L1 and L2<->L2 parameters between the device and the network can be tested. Modified parameters can be saved in a script which can be run at a later time.

Test Manager and Automation for running large campaigns of tests

Test Manager offers a user friendly environment to create and update campaigns of tests to run in a sequence. You can save and rerun these campaigns to test the same device with different firmware or test a different device altogether. Test Manager also gives you the ability to parameterize tests, which allows you to override certain parameters for a test during run time. One example of this is the possibility to run the same test in different bands.

You can run tests in automation using Keysight's Terminal Automation Gateway or a customized automation tool. You can easily review results with verdicts and launch test execution log files from Test Manager. Additionally, you can create test reports in excel or html for status reports.

Geysight Protocol R&D T	oolset													
le Iests Tools V	iew Help Campaign Manager	r									1			
mpaign Managers 🍢	New	🕑 🍁 🛶 💠 🦆 🍠 🛛 Tests: Test Verdicts	• Tools: 🗱 🗐 🔑		Pa	nels:	to!	20	a),					
3		+ 0 × Campaign Manager				_					1			
tart 🔳 Stop 🛃 Termi	nal Automation	Pre SG Campaign / Initial Test												Autoscrol
Tests Custom Tests*	Test Campaigns	Test Group Test Name	L	2 abus	P	F	1	E Du	ation 1	Estimate	Automation	Retries	Licence	Information
Pre SG		C++ Hod Tests Measurement Cor	fin 1/1	PASS	1	0	0	0 00	00:34 (00-02-00	Avaiable	0	0	
C++ Host Tests		C++ Host Tests Video Call Over IP	6 1/1	PASS	1	0	0	0 00	00:23	00:02:00	Available	0	0	
E- Pul Stack Tests		C++ Host Tests Data Throughput	1/1	FAIL	0	1	0	0 00	00:22	00:02:00	Available	0	0	
Measurement	coning or IMS	Full Stack Tests Attach	1/1	PASS	1	0	0	0 00	00:22	00:02:00	Available	0	0	
Data Through	out	Full Stack Tests Detach	1/1	PASS	1	0	0	0 00	00:22	00:02:00	Available	0	0	
Attach		Pull Stack Tests Paging	1/1	PASS	1	8	0	0 00	00:22 (00:02:00	Avialable	0	0	
- Detach		Full Stack Tests Closed Loop Data	1/1	PASS	-	0	0	0 00	00:21 (00:02:00	Avaliable	0	0	
- D Paging		Full Stack Tests Data Transmitton	1/1	PASS		0	0	0 00	00:22 0	00:02:00	Avaiable	0	0	
Cosed Loop 1	Data	Full Stack Tests LE Position	1/1	FAB		1	0	0 00	00:23 0	00-02-00	Avaiable	0	0	
	ours	Full Stack Tests LE Position	1/1	PASS	1	0	0	0 00	00:22	00-02-00	Available	0	0	
55						-	-							
C++ Host Tests		20												
B- 1 Full Stack Tests		Annual states in the second												
		Remaining tests: 0 Pass:	9 prosnousive:	y rac	-	LING.	e	W Keb	1051	<u>v</u>				
ests 📓 Results		Total tests in plan: 11, Remaining	time: 0 seconds, Elapsed time	: 4 minute										
meters - UE Position		• 8 x Test Output						1						- 0
Timer	0	Plan Initial Tests ended, see Cam	paign Manager for results											
n_X	0	15:45:52		*******	******	*****	*****		******	******				***
n_Y	0	15:45:52 Executed on 5	AS LTE Sequencer: VS5.1.856	5										
n_Z	0	15:45:52 Script is signed	by User Generated											
x_nx	0	15:45:52							******				******	
xn_Y	0	15:45:54 COMMENT [To	do: Set the UE position and ro	otation her	e.]									
on Z	0	15:45:54 COMMENT [To	do: Check the singal here, PA	ISS or FAIL	accorde	ngly.]								
	1.7	15:45:54 IF (Rotation_)	== 45) evaluated to faise											
		15:45:54 ELSE												
		15:45:54 Intermediary V	erdict: PASS											
		15:45:54 ENDOF	d Failly day and											
		15:45:54 Script Complet	ed: Final Verdict - PASS											
		15/15/57 Cempaign tr	iocu (initial tests of 56 t	ampaign	ų.									





Real Time Trace to view signaling trace during execution

The Real Time Trace (RTT) displays the signaling trace during a test execution. This trace, which is easy to read, is saved in a log called the RTT log. Examples of information being displayed include:

- Active cells and the length of time these cells have been active
- Cell information, such as its NR ARFCN, channel allocation, power levels, synchronisation, and relative frequency offset
- A trace of the Layer 3 messages exchanged in real time between the network and the device. Messages are displayed in a simplified sequence chart and you can decode these messages to view Layer 2 information
- Progress and error messages; Protocol R&D Toolset reports communication failures, protocol errors, and information about the state of the system, and also prompts for user action, such as turning the mobile device on or off
- Measurement reports from the device

Line	Time	Cell	Direction	Trace
1	00:09.05			#Source: C:/MksSandbox/SASNR5G_Trunk/SAS5G/Build/AniteSAS/ResultData/Sequencer Scri
1	00:09.05			#File: C:\AniteSAS\ResultData\Sequencer Scripts\01B_NR5G_RACH_FR2.ssi #
1	00:09.05			
1	00:09.05			Executed on SAS 5G Sequencer: V58.0.168
1	00:09.05			Script is signed by User Generated
1	00:09.05			
1	00:09.05			
3	00:15.94			MANUAL OK PROMPT: [Activate NR5G Cell], RESPONSE: [OK]
4	00:16.54	NR-Cell A		ACTIVATE NR5G CELL [FR2] Physical Cell ID=0 : NRARFCN=2079451 : Band=undefined : Freque
4	00:16.54	NR-Cell A	SS> MS	MasterInformationBlock
5	00:21.24			MANUAL OK PROMPT: [Start NR5GUEDemonstrator and Click OK], RESPONSE: [OK]
6	00:21.66	E-Cell A		ACTIVATE CELL - Band=2 EARFCN: DL=904 UL=18904 TxPower=-85dBm/15kHz RxPower=-20
6	00:21.66	E-Cell A	SS> MS	MIB
6	00:21.66	E-Cell A	SS> MS	SIB1
6	00:21.66	E-Cell A	SS> MS	SIB2
7	00:21.68	E-Cell A		ENTER DYNAMIC CONTROL POINT [Script paused until User Action]
6	00:27.63	E-Cell A		EXIT DYNAMIC CONTROL POINT [User Action occurred]
8	00:27.85	E-Cell A	SS> MS	RRC CONNECTION RECONFIGURATION
9	00:27.87	E-Cell A	SS < MS	RRC CONNECTION RECONFIGURATION COMPLETE
10	00:35.69			MANUAL OK PROMPT:[wait], RESPONSE:[OK]
11	00:37.77	E-Cell A		DEACTIVATE CELL
12	00:39.46	NR-Cell A		DEACTIVATE NR5G CELL
-	00:39.48			Script Completed: Final Verdict - PASS

Figure 7 - Real Time Trace – displaying the signaling trace during a test execution.

Core Logging Tools

For each executed test, the toolset generates test activity as well as diagnostic data that is saved to log files. You can view and analyze the data either during or after the run of a test.

Log Viewer to facilitate troubleshooting

The Log Viewer enables you to view all protocol layers (i.e. PHY, MAC, RLC, PDCP and RRC) in one log. The log viewer has a user-friendly graphical user interface where several windows are displayed in one view (see Figure 8). The filtering functionality allows you to view the protocol layers and test information of interest. You can use any of the default filters or create customized ones. Bookmarks enable you to go back to any record in the log thereby facilitating troubleshooting. The Bookmarks tab displays all bookmarks that have been created.

The following records can be logged in log viewer:

- LTE and NR protocol messages for all protocol layers (PHY, MAC, RLC, PDCP and RRC)
- All information transmitted and received at the air interface, recorded at the MAC/ PHY boundary
- Control information, such as the activation/deactivation of physical and transport channels
- Test System Diagnostic Data

When writing the test in Protocol R&D Toolset, you can select which protocol layers to log in the log viewer.

The log viewer allows you to analyze the results of tests on the test system PC or a separate PC, thereby freeing the test system PC so that it can be used solely for running tests.

The log viewer is a common logging tool also used for other Keysight Network Emulation solutions, including RF DVT Toolset and Functional KPI Toolset.

Log \	Viewe	ar -										Collect KLV Logs 🖬 ? 🗕 🗗 🗙
file Hor	Te 👘	View	Cont	rol K	1 Control							^
Open Save File	A. C.	3 (1	lesulta () Searc	evicios result h	DPA Interleave						
0821280515	- ×								Owtakia.		(a) 1.4 K	Overview X-9 X
Sammany	Iml	Barrorte	100	View	Su	immary of all m	essages and other info	ormation	Fields	10.	8	0 - PASS
	Index	e los	-		Protocol	Record	Source	Destination	 CellGroupConf cellGroupIc 	ig 61		
	785				Test Execution	Test Frendine	Test Control/Developers APU conter		# rk-BearerT	oAddModList: SEQUENCE C	F RLC-Bearer-Config	Previne Relationship Pane
	786				Test Execution	Test Execution	\Test Contro/Developers API\Looper		► RLC-Bes	irer-Config(1)		Fibris + 3 X
	787				Test Execution	Test Execution	VTest Contro/Developers APM.opper		A mac-CellGr	supConfig Co	Detailed	Protocols Sources Text Time
	788				Test Execution	Test Execution	\Test Control/Developers API\Logger		▶ tag-Cor	fiq	message	
	789				Test Execution	Test Execution	\Test Control/Developers API\Logger		▶ phr-Cor	fig: setup =	moodage	Test Control • Generic Event Trace
	790				Test Execution	Test Execution	\Test Control/Developers API\Logger		skipUpi	inkTxDynamic: FALSE		 Internal
					Test Execution	Test Execution	\Test Control/Developers APT\Logger		# spCellConfi	9		✓ Test Control*
	792				Test Execution	Test Execution	\Test Control\Developers APT\Logger		 reconfig off Time 	purationWithSync mAndConstants: celus -		 Preamble
	1195				Test Execution	Test Execution	\Test Control\Developers APT\Logger		≠ spCellG	onfigDedicated		Test Execution
						BCCH-BCH-Message	VProtocol/3GPP/NR\RRC/L3		a initi	alDownlinkBWP		Convert Front Trave
	26080				Test Execution	Test Execution	\Test Control\Developers APT\Logger		4	odcch-Conflig: setup =		
						BCCH-BCH-Message	VProtocoA3GPP\/RRC\L3			controlResourceSetToA	ddModList: SEQUENCE OF Con	Levelopers. Aut
	26176					BCCH-DU-SCH-Message	VProtoco/\3GPP\BRC\L3			searctopaces ronoamo ulsch Confine setun =	ILISE SEQUENCE OF SEARCISES	Filters
	26180					BCCH-DL-SCH-Message	VProtoceA3GPPVRRCVL3		÷.	dmrs-DownlinkForPDSC	H-MappingTypeA: setup =	A V 3GPP
	26425				Test Execution	Test Execution	\Test Control/Developers API\Logger			wrb-ToPRB-Interleaver:	n2	A MUE
	26627				Test Execution	Test Execution	\Test Control/Developers API\Logger			resourceAllocation: reso	urceAllocationType1	 RRC
	26681				Test Execution	Test Execution	\Test Control/Developers APT\Logger			pdsch-AllocationList: SE	QUENCE OF PDSCH-TimeDoma	🔺 📈 NR5G
	26737				Test Execution	Test Execution	\Test Control\Developers APDLogger			rog-Sizer config1		a V RRC
	27128				RRC	RadioBearerConfigDt	VProtoco//3GPP/NRVRRCVL3			prb-BundlingType: stati		KOHOL Message
	27136		-		RRC	ARCReconfigurationDI	VProtocoA3GPP/NRVRRCL3		· · ·			A California Carbola
	2210.0	2			RRC	CellGroupConligBt	VProtocol ASSIV VARIARIZES					
	28011				RRC	DL-DCCH-Message	VProtoco/\3GPP\/RRC\L3		Hex Hex		Heystring	
	28318				Test Execution	Test Execution	\Test Control\Developers APt\Logger		CelkinupContig		Hoxburng	RRCReconfigurationDI
	28319				Test Execution	Test Execution	\Test Control/Developers API\Logger		Address	00 01 02 03 04 05 06	87 68 09 6A 68 6C 60 6E 1	
	28328				Test Execution	Test Execution	\Test Control/Developers APDLogger		00000000	54 40 52 45 20 65 25	05 25 61 61 00 E8 AD 40	Check all Load/Save Original
	28329				Test Execution	Test Execution	(Test Control/Developers API\Logger		00000010	C0 35 30 88 00 04 00	90 81 38 9A A5 48 08 82 4	Loaded None
		_			Ted Frendinn	Test Suecidade	Theorem Control Developers & DNI opport		0000010	00 00 67 C1 11 00 01	24 94 82 80 82 26 68 13 1-	Bookmarks
												Log size: 3.8 MB Records: 87(29000)

Figure 8 - The Log Viewer is useful for debugging.

Dashboard Viewer for efficient debugging

The Dashboard Viewer allows you to display predefined or customized graphs using a list of KPIs that have been captured in Log Viewer. Graphs and data of different KPIs can be displayed in the same view creating a dashboard, see Figure 9. KPI data can be displayed numerically or graphically with a style option, which allows you to select what type of graphs to create, such as a histogram, a time graph or a scatter graph. You have the option of launching a Dashboard Viewer whilst a test is under execution or after a test has been executed.



Figure 9 - Dashboard Viewer shows graphical KPI data in one view.

Hardware Platform

Protocol R&D Toolset runs on Keysight's UXM 5G network emulator, which can simulate both 5G NR and LTE cells. The required test setup depends on:

- The frequencies involved: sub 6GHz, mmWave or IF frequencies
- Capabilities required for the test, for example, number of component carriers and MIMO configuration

One or more of the hardware components in Figure 10 will be part of a test set-up for 5G NR testing.





Test setup for sub-6GHz testing

To create a typical test set up for sub-6GHz frequencies in Standalone (SA) or Non-Standalone (NSA) mode, the Protocol R&D Toolset software is installed on a test system PC that is connected to the UXM-5G network emulator using a switch.





Increase of System Capability

The modular and scalable test system set-up enables you to add another UXM 5G network emulator to increase system capability and test for example additional component carriers and MIMO configurations (see Figure 12).





Test setup for mmWave testing

The use of mmWave spectrum introduces challenges in signal quality as mmWave frequencies cause higher propagation and penetration losses. Devices that support these higher frequencies are complex and have integrated antenna arrays. This leads to the need for Over-The-Air (OTA) testing. To address these challenges, the test set-up requires a UXM 5G network emulator, a Common Interface Unit (CIU) and at least two Remote Radio Heads (RRHs), which are used to up-convert the sub-6GHz frequencies to mmWave frequencies. Up to eight Remote Radio Heads can be connected to a Common Interface unit. There is also an option to include a CIU without the RRHs to generate 6-12GHz for IF testing. Our system currently supports the 28GHz, 39GHz and 43GHz mmWave frequencies. Additional mmWave frequencies will be supported in the future.





Integrated OTA Test Capability Across Sub-6GHz and mmWave Frequencies

Keysight, along with its network of solution partners, provides end-to-end Over-the-Air (OTA) test capability to characterize and validate chipsets, devices, and network equipment at sub-6GHz and mmWave frequencies. Leading system integrators as well as device and network equipment manufacturers use Keysight's OTA test solutions and expertise to develop solutions that meet requirements set by industry bodies (e.g. CTIA, 3GPP and CCSA) and major mobile operators.

Keysight seamlessly integrates measurement science, application expertise, common software tools, automation solutions and industry-leading test platforms to provide the entire wireless ecosystem with end-to-end OTA test capability.

OTA test solutions for devices and their sub-components are purpose-built to address a wide range of RF, demodulation and functional performance test requirements across the entire development, acceptance, and manufacturing workflow for 5G New Radio (NR) design validation.

A combination of hardware and software solutions support a wide range of MIMO OTA methodologies to emulate realistic propagation environments for performance testing a wide range of equipment and its sub-components in a repeatable way. Supported OTA test environments include Compact Antenna Test Range (CATR), multi-probe anechoic cambers (MPAC), reverberation chamber (RC+CE) and Radiated Two-Stage (RTS).

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

