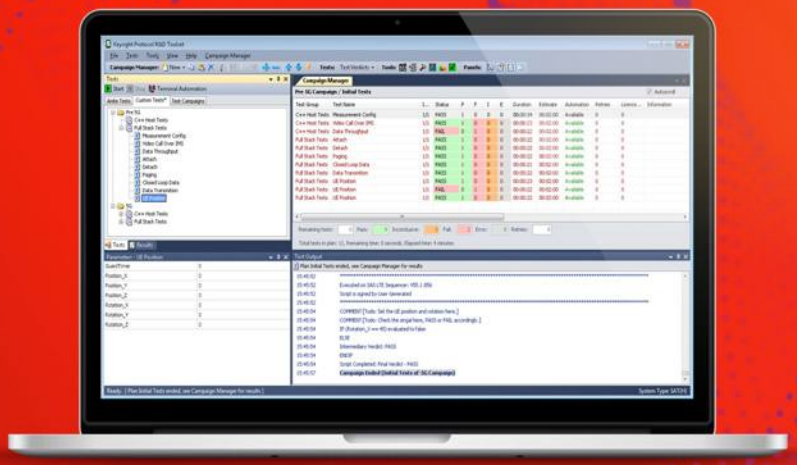

TECHNICAL OVERVIEW

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.

KEYSIGHT TECHNOLOGIES

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.

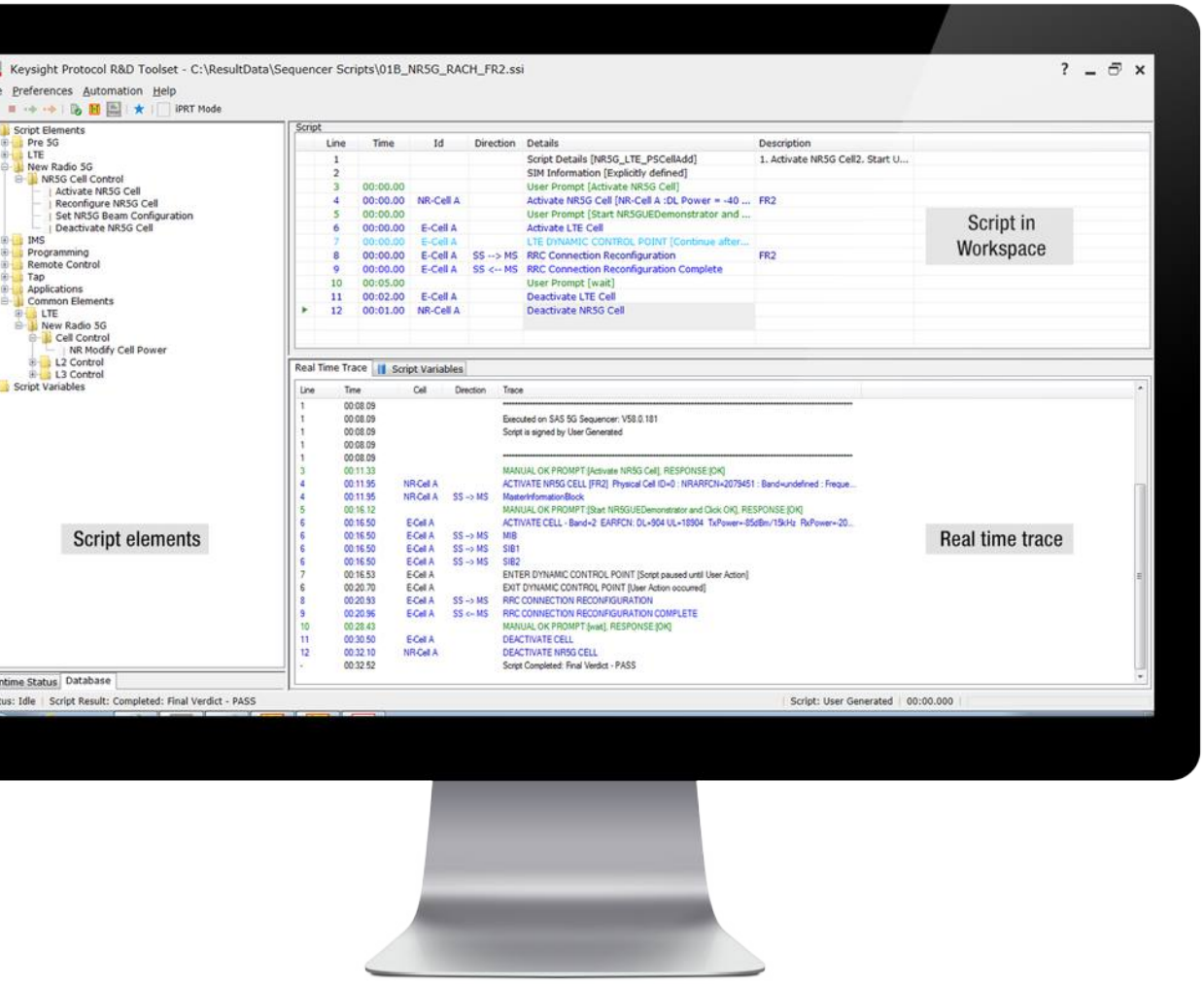

Figure 1 - 5G Protocol R&D Toolset Graphical User Interface makes it easy to create, edit and execute new tests.

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.

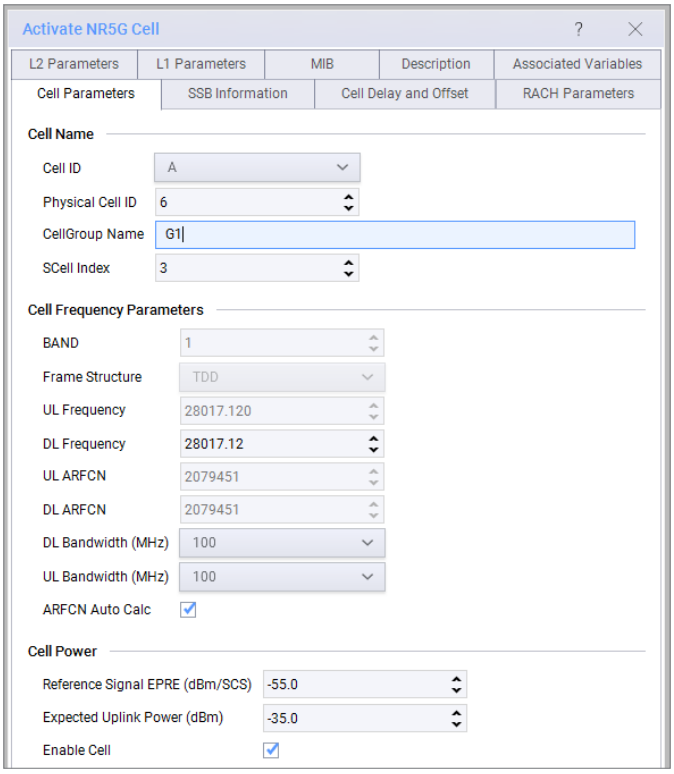

Figure 3 - Example of a cell configuration dialog for 5G NR.

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.

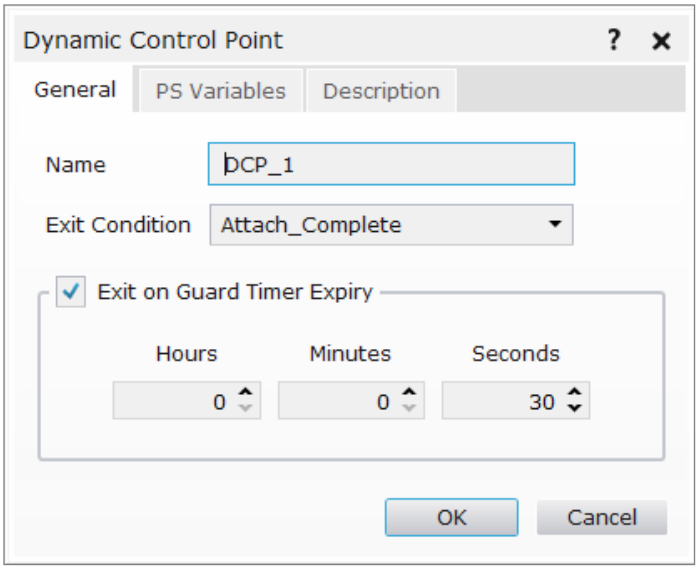

Figure 4 - Script element for Dynamic Control Point.

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

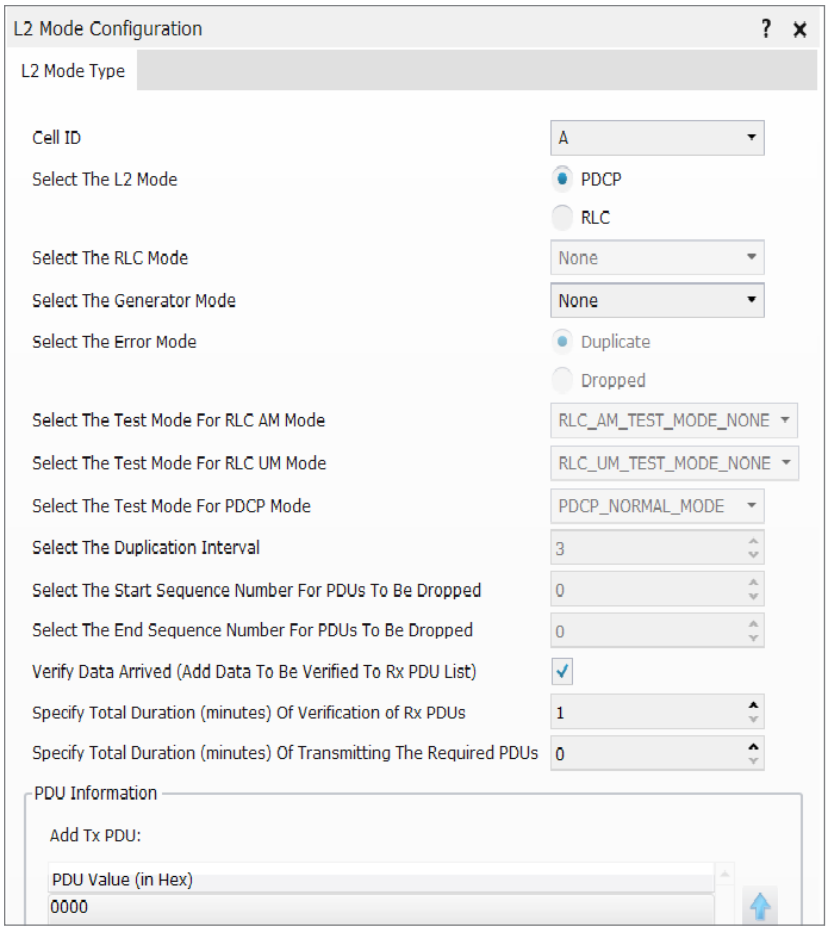

Figure 5 - Script element for L2 testing.

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.

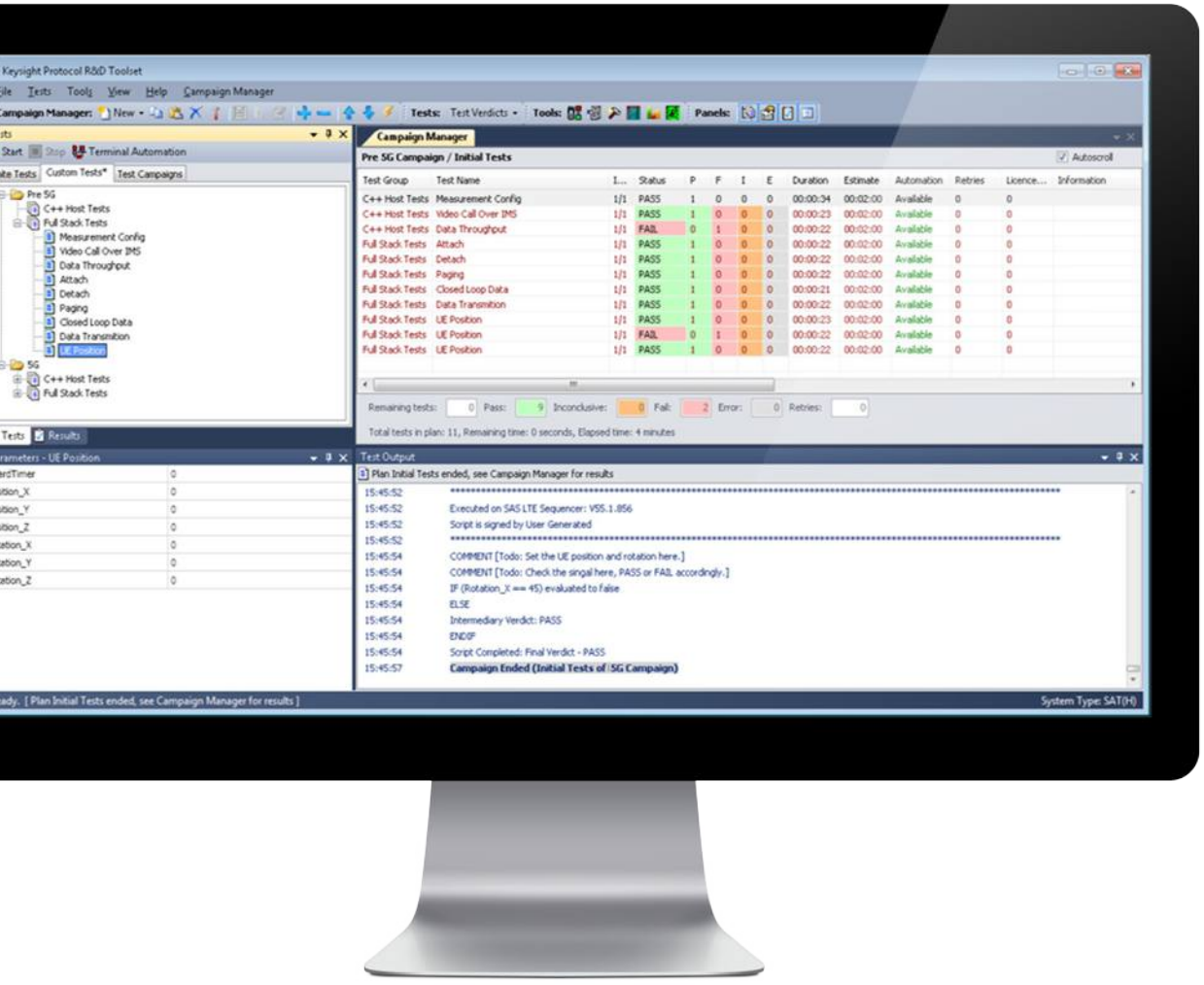

Figure 6 - Test Manager enables you to execute a campaign of tests.

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	MasterInfomationBlock
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.

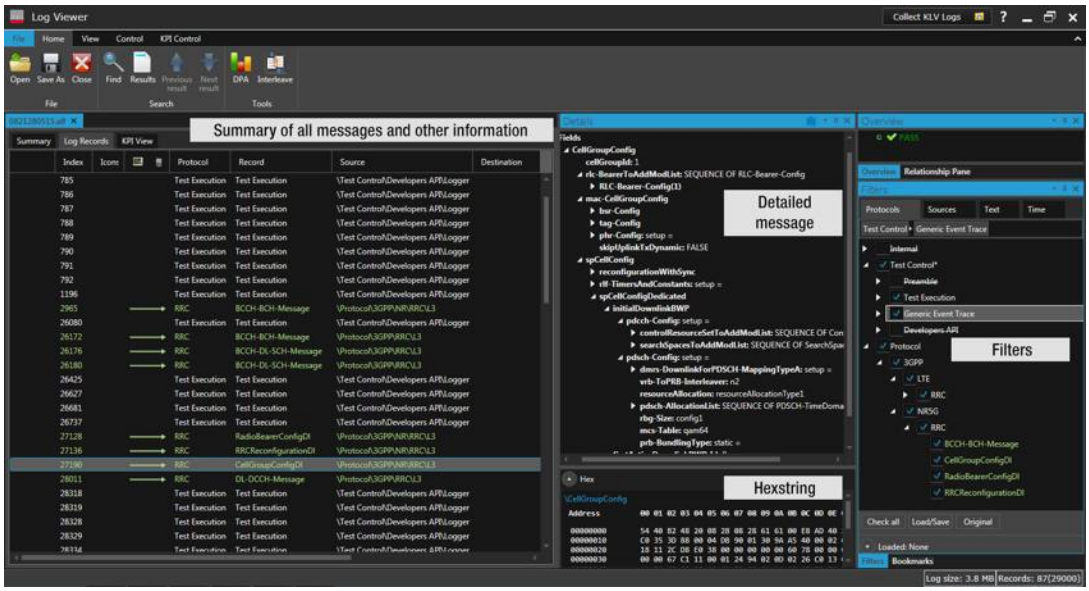

Figure 8 - The Log Viewer is useful for debugging.

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.

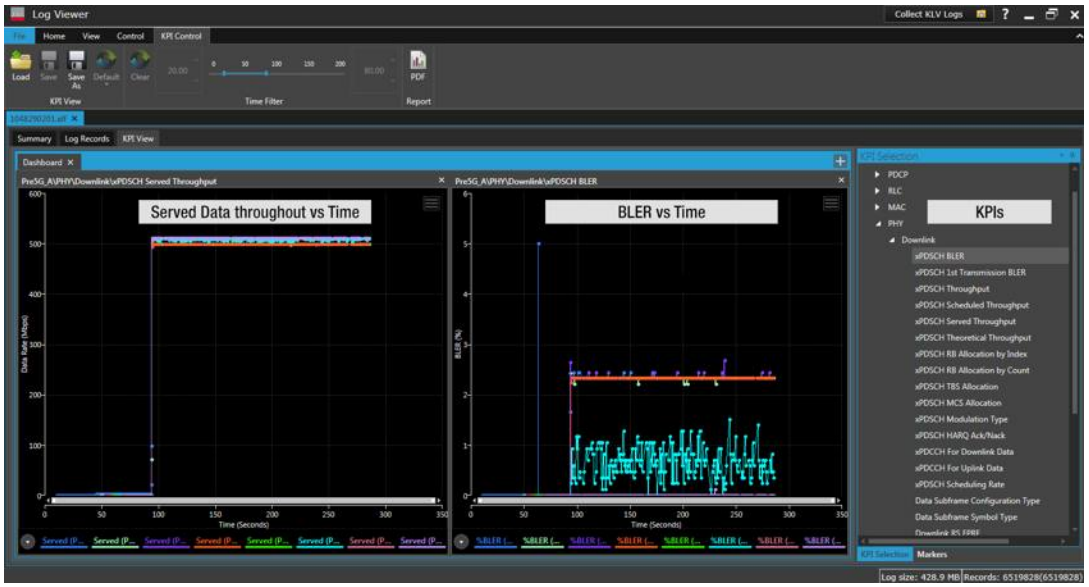

Figure 9 - Dashboard Viewer shows graphical KPI data in one view.

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.

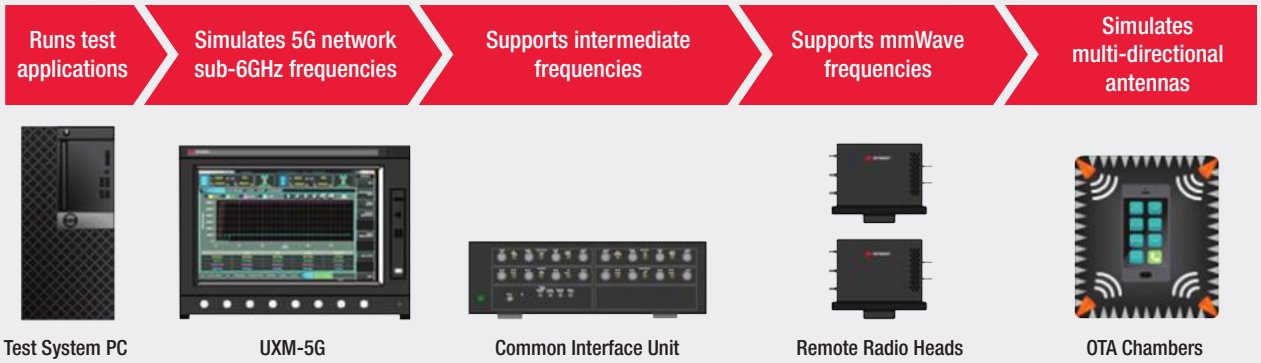

Figure 10 - Hardware components in a 5G NR test system set-up.

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.

Figure 11 - Test setup for sub-6GHz in Standalone or Non-Standalone mode.

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).

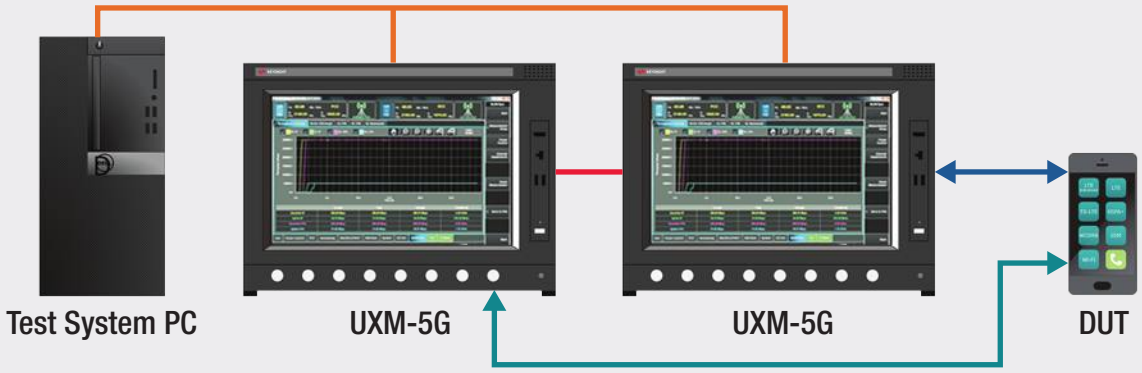

Figure 12 - Sub-6GHz testing with further capabilities.

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.

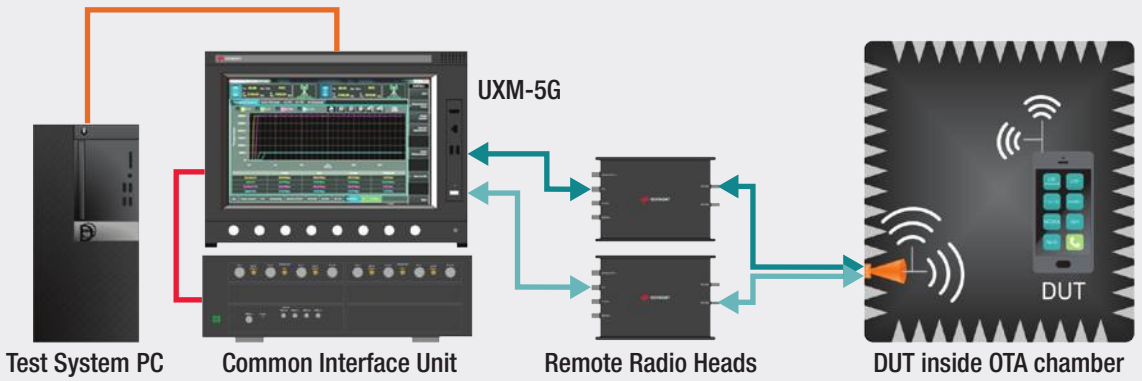

Figure 13 - Test setup for mmWave includes a CIU, at least two RRHs and an OTA chamber.

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

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