TECHNICAL OVERVIEW

S8702A RF Automation Toolset

Keysight's RF Automation Toolset leverages the E7515B UXM 5G Wireless Test Platforms to provide users with a comprehensive range of tests to quickly verify the transmitter (Tx) and receiver (Rx) performance of 5G new radio (NR) and 4G LTE devices in accordance with the 3GPP specifications. The toolset forms part of Keysight's suite of 5G network emulation solutions and offers a flexible and easy-to-use software environment.

3GPP NR Specs

The first version of the 5G New Radio (NR) industry reference standards were completed by 3GPP in July 2018, when Rel.15 was officially released.

The 38.521 test specifications cover the RF requirements for two main 5G NR deployment options:

- Non-Standalone (NSA Opt. 3) makes use of an LTE core network controlling a 5G NR Radio Access Network (RAN)
- Standalone (SA Opt. 2) introduces a new 5G core network and is the first step towards pure 5G NR networks

KEYSIGHT TECHNOLOGIES

Accelerating the transition from prototypes to commercial 5G products

Keysight's RF Automation Toolset leverages the E7515B UXM 5G Wireless Test Platforms to provide users with a comprehensive range of tests to quickly verify the transmitter.

Mobile operators around the world are taking the first steps to turn on their 5G networks using a new Radio Access Technology (RAT). 5G NR devices in different form factors are now available for industry and consumers.

The new RAT fundamentally supports three service categories:

- Enhanced mobile broadband (eMBB)
- Massive machine-type communications (mMTC)
- Ultra-reliable, low-latency communications (UR-LLC)

The radio unit is a critical component in wireless communication systems. It determines what type of services or applications a network can support. 5G offers a wide range of spectral options to address the above use cases to deliver an optimized combination of high capacity, high data rates, ubiquitous coverage and ultra-reliability.

The main spectrum options for 5G, at least in the early deployment phases, exist in sub- 6 GHz bands (3.5 GHz and 4.5 GHz) and in mmWave spectrum at 24 to 28 GHz and 39 GHz using both FDD and TDD technology. Sub-6 GHz frequency spectrum allows mobile operators to support wide-area coverage and services, while higher frequencies provide access to a vast amount of spectrum necessary to achieve very high data rates. The introduction of mmWave bands poses new challenges to RF engineers, as 5G NR devices with phased-arrays and connector-less antennas need to be tested over-the-air.

Early access to 5G RF test tools that allow inspection of RF performance during the design verification phase is key to accelerating the transition from prototypes to commercial 5G products.

Be ready to test now and to scale with an evolving 5G technology

Testing 5G today requires a very high degree of flexibility to adapt to on-going changes in both the requirements and test methodologies. However, this evolution should have minimum impact on overall test costs and schedule. A versatile 5G RF design verification test solution adapts to evolving 5G standards, scales to address sub-6 GHz and mmWave frequencies, and provides optimized testing times to quickly verify a device's RF performance or identify issues.

Keysight's RF Automation Toolset is a comprehensive RF design verification solution that supports Transceiver and Receiver tests for both 5G NR and 4G LTE radio access technologies based on the latest 3GPP 38.521 (5G NR) / 36.521 (4G LTE) test specifications respectively. The toolset relies on the Keysight E7515B UXM 5G Wireless Test Platform or E7515E UXM 5G Base Test Platform and uses its built-in Test Application Framework software environment. Keysight's E7770A Common Interface Unit, M1740A mmWave Transceivers, and test chamber extend the test range to mmWave frequencies.

Based on the Test Application Framework

Keysight's 5G Test Application (TA) Framework allows both touch-based and remote control of the UXM 5G network emulator. Its different operation modes support a wide range of tests, from non-signaling for UE Calibration to full signaling tests, providing a comprehensive set of features for engineers designing RF components and devices. The framework supports 4G LTE as well as both 5G deployment modes, Non-Standalone (NSA) and Standalone (SA), and its full signaling test mode enables users to perform RF measurements while a call is in progress.

The RF Automation Toolset uses this underlying Test Application Framework to control the UXM 5G network emulator and provide a suite of fully-automated Transmitter and Receiver tests that are based on the 3GPP TS 38.521 (5G NR) / 36.521 (4G LTE) test specifications.

Figure 1. Screen capture illustrating a completed 5G NR NSA Random Access procedure using Keysight's 5G Test Application Framework

RF Automation Toolset – Key Features

Keysight's RF Automation Toolset extends the capabilities of the 5G Test Application by providing:

- An intuitive and easy-to-use graphical user interface for creating, configuring and running test campaigns
- A suite of fully-automated RF Transmitter and Receiver tests, based on the 3GPP TS 38.521 / 36.521 for 5G NR and 4G LTE respectively.
- Optimized test execution times, enabling quick inspection of the RF performance of devices
- A report generator in different formats to summarize the results of test campaigns
- Support for both 4G LTE and 5G (Non stand alone and Standalone modes) in the same network emulator, providing a small footprint benchtop solution
- State-of-the art logging, visualization and debugging tools
- Flexible licensing options and tools

Campaign Creation

The RF Automation Toolset user interface allows users to easily create test campaigns by simply adding one or more test modes (e.g. NSA FR1, NSA FR2, SA FR1). This is followed by selecting the target tests and specifying the key network parameters for each test mode, e.g. duplex mode, frequency band, channel bandwidth, high/mid/low band channels, and sub-carrier spacing (SCS).

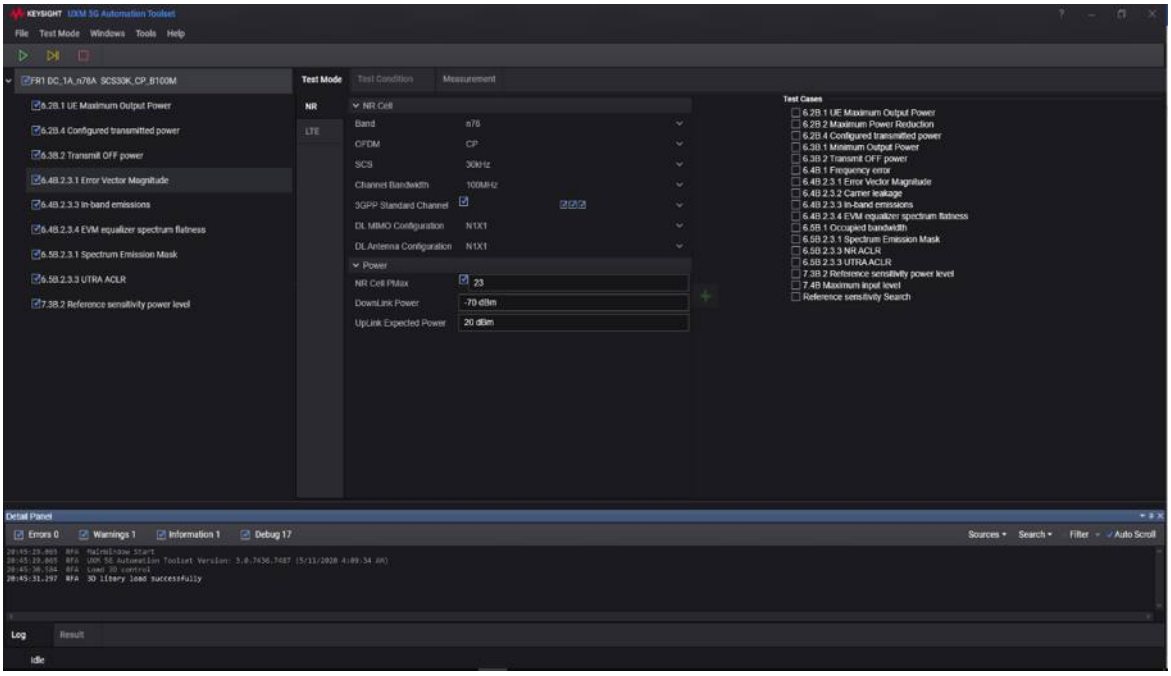


Figure 2. Campaign created by selecting available tests and configuring the Test Mode

Test Configuration

Each test in the campaign may be executed over a range of test conditions specified by the user, resulting in a test generated for each individual test condition. Test conditions provide access to a range of test-specific parameters, including bandwidth, modulation scheme, power levels, and the limits/measurement values against which the pass/fail verdict is assessed. This provides users with the flexibility to focus campaigns on specific conditions requiring further debugging, in order to quickly complete the verification of a device's RF performance.

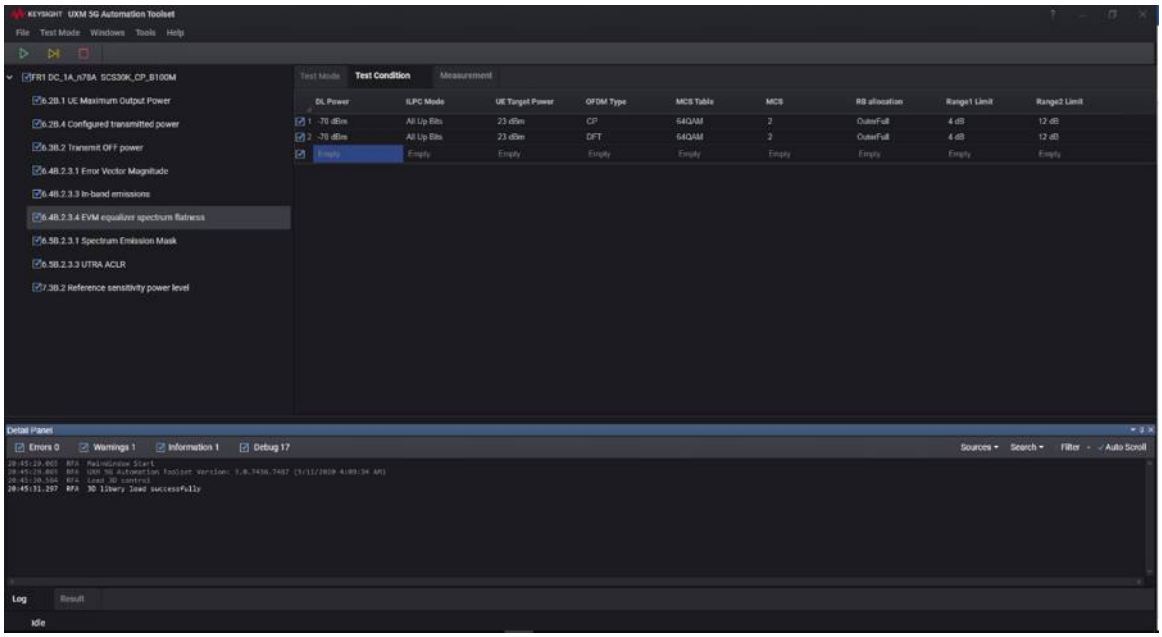


Figure 3. Screen capture illustrating a selection of test conditions

Campaign Management

The RF Automation Toolset also supports a range of test campaign configuration options, including the ability to repeat tests, retry failed tests and stop/pause execution when errors are found.

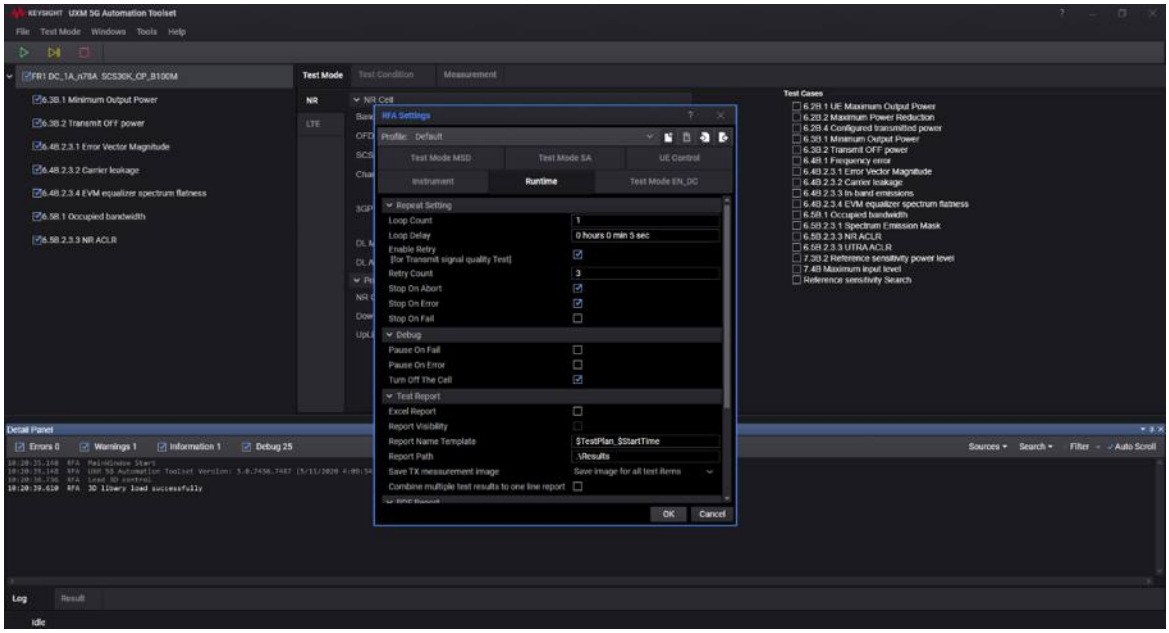


Figure 4. Screen capture illustrating test campaign configuration options

Result Analysis

The Result List area provides real-time information about the test campaign execution progress with relevant information about each individual test result, including a pass/fail verdict for each test based on the user-defined verdict conditions.

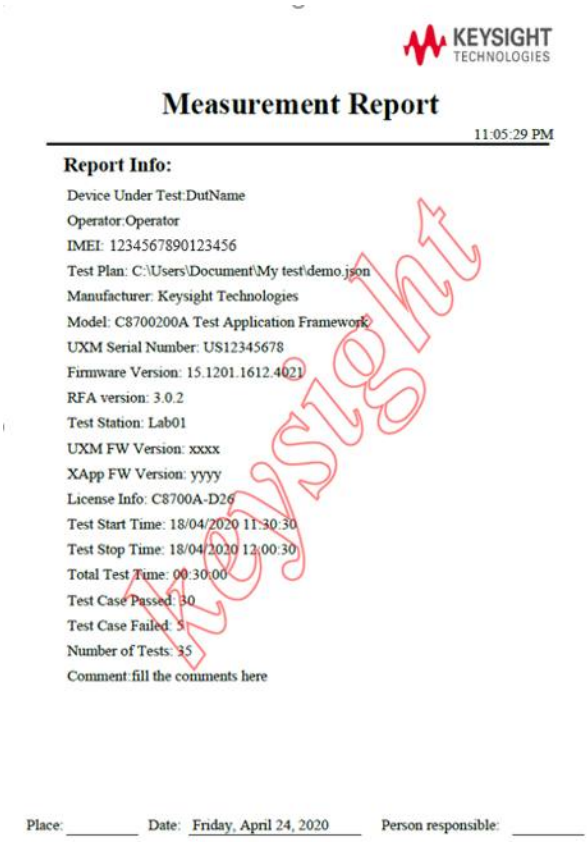
Figure 5. Real-time results information available in RF Automation user interface

Report Generation

For post-campaign analysis, the RF Automaton Toolset allows the generation of summary reports in csv, xlsx and PDF formats.

Time	System	Test Case	Band	Bandwidth [MHz]	SCS [kHz]	ARFCN	Freq [MHz]	Expect Power [dBm]	OFDM	Modulation	RB Allocation	Condition	Item	Lower Limit	Value	Upper Limit	Unit	P/F
2019-07-31T15:58:39	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	InnerFull	UE MaxPower	PUSCH EVM	0	6.66	17.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	5.96	17.5	%	Pass
2019-07-31T15:58:38	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	InnerFull	UE lowPower	PUSCH EVM	0	2.1	17.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.24	17.5	%	Pass
2019-07-31T15:58:47	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	OuterFull	UE MaxPower	PUSCH EVM	0	3.06	17.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	2.78	17.5	%	Pass
2019-07-31T15:58:57	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QPSK_2	OuterFull	UE lowPower	PUSCH EVM	0	2.13	17.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.21	17.5	%	Pass
2019-07-31T15:59:06	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	InnerFull	UE MaxPower	PUSCH EVM	0	4.66	12.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	4.25	12.5	%	Pass
2019-07-31T15:59:14	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	InnerFull	UE lowPower	PUSCH EVM	0	1.99	12.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	1.83	12.5	%	Pass
2019-07-31T15:59:23	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	OuterFull	UE MaxPower	PUSCH EVM	0	3.27	12.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	3.24	12.5	%	Pass
2019-07-31T15:59:33	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM16_10	OuterFull	UE lowPower	PUSCH EVM	0	2.23	12.5	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.15	12.5	%	Pass
2019-07-31T15:59:42	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM64_18	OuterFull	UE MaxPower	PUSCH EVM	0	2.55	17.5	%	Pass
												UE MaxPower	PUSCH DMRS EVM	0	2.51	17.5	%	Pass
2019-07-31T15:59:51	ENDC	6.4B.2.3.1 Error Vector Magnitude	N78	100MHz	SCS30K	636666	3549.99MHz	0	CP-OFDM	QAM64_18	OuterFull	UE lowPower	PUSCH EVM	0	2.19	8	%	Pass
												UE lowPower	PUSCH DMRS EVM	0	2.29	8	%	Pass

Figure 6. Example test campaign report in CSV format for post-execution analysis



KEYSIGHT TECHNOLOGIES

Measurement Report

11:05:29 PM

Report Info:

Device Under Test:DutName
Operator:Operator
IMEI: 1234567890123456
Test Plan: C:\Users\Document\My test\demo.json
Manufacturer: Keysight Technologies
Model: C8700200A Test Application Framework
UXM Serial Number: US12345678
Firmware Version: 15.1201.1612.4021
RFA version: 3.0.2
Test Station: Lab01
UXM FW Version: xxxx
XApp FW Version: yyyy
License Info: C8700A-D26
Test Start Time: 18/04/2020 11:30:30
Test Stop Time: 18/04/2020 12:00:30
Total Test Time: 00:30:00
Test Case Passed: 30
Test Case Failed: 5
Number of Tests: 35
Comment:fill the comments here

Keysight

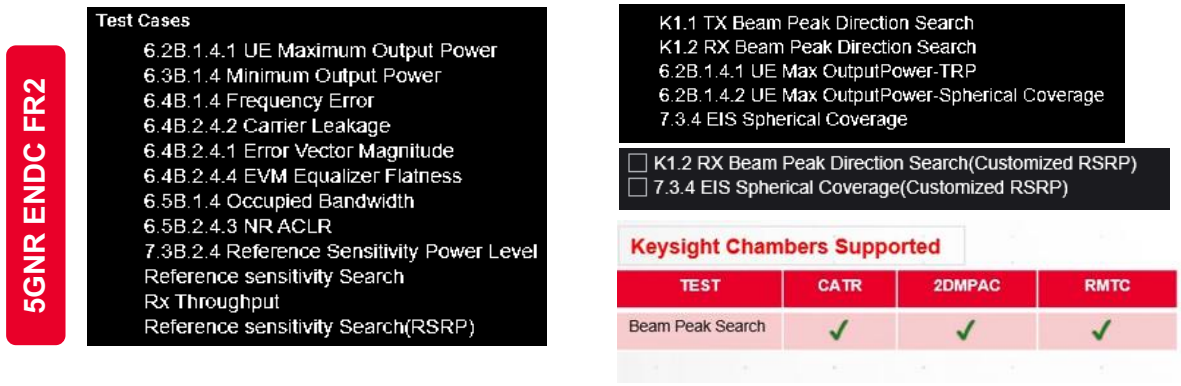
Place: _____ Date: Friday, April 24, 2020 Person responsible: _____

Figure 7. Example test campaign report in PDF format for post-execution analysis

Test Coverage

RF Automation Toolset supports a range of in-band only test packages for 5GNR ENDC (FR1 &FR2), 5GC (FR1) and 4G LTE technologies.

5GNR FR2 ENDC Test Coverage



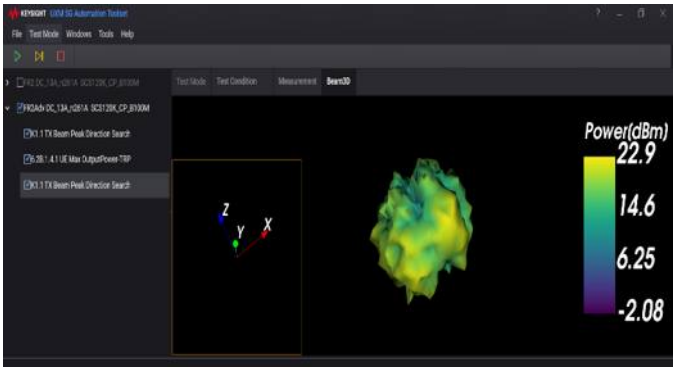


Figure 8. TRP Spherical coverage

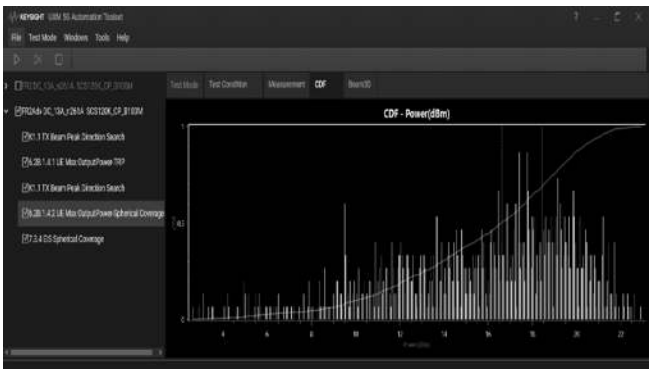


Figure 9. CDF Power distribution graph

5GNR FR1 ENDC Test Coverage

5GNR ENDC FR1

Test Cases

- 6.2B.1 UE Maximum Output Power(NR)
- 6.2B.2 UE maximum output power reduction(NR)
- 6.2B.4 Configured transmitted power(NR)
- 6.3B.1 Minimum Output Power(NR)
- 6.3B.2 Transmit OFF power(NR)
- 6.4B.1 Frequency error(NR)
- 6.4B.2.3.1 Error Vector Magnitude(NR)
- 6.4B.2.3.2 Carrier leakage(NR)
- 6.4B.2.3.3 In-band emissions
- 6.4B.2.3.4 EVM equalizer spectrum flatness(NR)
- 6.5B.1 Occupied bandwidth(NR)
- 6.5B.2.3.1 Spectrum Emission Mask(NR)
- 6.5B.2.3.2 Additional spectrum emission mask(NR)
- 6.5B.2.3.3 NR UTRA ACLR(NR)
- 7.3B.2 Reference sensitivity power level(NR)
- 7.4B Maximum input level(NR)
- Reference sensitivity Search(NR)
- Rx Throughput(NR)
- 6.2.2 UE Maximum Output Power(LTE)
- 6.2.3 Maximum Power Reduction(LTE)
- 6.3.2 Minimum Output Power(LTE)
- 6.5.1 Frequency Error(LTE)
- 6.5.2.1 Error Vector Magnitude(LTE)
- 6.5.2.1A PUSCH EVM with Exclusion Period(LTE)
- 6.5.2.2 Carrier leakage(LTE)
- 6.5.2.3 In-band emissions for non allocated RB(LTE)
- 6.5.2.4 EVM equalizer spectrum flatness(LTE)
- 6.6.1 Occupied bandwidth(LTE)
- 6.6.2.1 Spectrum Emission Mask(LTE)
- 6.6.2.3 Adjacent Channel Leakage Power Ratio(LTE)
- 7.3 Reference Sensitivity level(LTE)
- 7.4 Maximum input level(LTE)
- Reference sensitivity Search(LTE)
- Rx Throughput(LTE)

7.3B MSD for Intermodulation Interference for EN-DC FR1

5GNR FR1 Stand Alone Test Coverage

5GNR STANDALONE FR1

Test Cases

- 6.2.1 UE Maximum Output Power
- 6.2.2 UE maximum output power reduction
- 6.2.4 Configured transmitted power
- 6.3.1 Minimum Output Power
- 6.3.2 Transmit OFF power
- 6.4.1 Frequency error
- 6.4.2.3.1 Error Vector Magnitude
- 6.4.2.2 Carrier leakage
- 6.4.2.3.3 In-band emissions
- 6.4.2.3.4 EVM equalizer spectrum flatness
- 6.4.2.5 EVM equalizer spectrum flatness for Pi/2 BPSK
- 6.5.1 Occupied bandwidth
- 6.5.2.2 Spectrum Emission Mask
- 6.5.2.3 Additional spectrum emission mask
- 6.5.2.4 NR UTRA ACLR
- 7.3.2 Reference sensitivity power level
- 7.4 Maximum input level
- Reference sensitivity Search
- 6.2D.2 Maximum Power Reduction for UL MIMO
- 6.2D.4 Configured transmitted power for UL MIMO
- 6.3D.1 Minimum Output Power for UL MIMO
- 6.3D.2 Transmit OFF power for UL MIMO
- 6.4D.1 Frequency error for UL MIMO
- 6.4D.2.1 Error Vector Magnitude for UL MIMO
- 6.4D.2.2 Carrier leakage for UL MIMO
- 6.4D.2.3 In-band emissions for UL MIMO
- 6.4D.2.4 EVM equalizer spectrum flatness for UL MIMO
- 6.5D.1 Occupied bandwidth for UL MIMO
- 6.5D.2.2 Spectrum Emission Mask for UL MIMO
- 6.5D.2.4 NR UTRA ACLR for UL MIMO

5GNR FR2 ENDC Test Coverage

4G LTE

Test Cases

- 6.2.2 UE Maximum Output Power
- 6.2.3 Maximum Power Reduction(MPR)
- 6.2.4 Additional Maximum Power Reduction(A-MPR)
- 6.2.5 Configured UE transmitted Output Power
- 6.3.2 Minimum Output Power
- 6.5.1 Frequency Error
- 6.5.2.1 Error Vector Magnitude(EVM)
- 6.5.2.1A PUSCH EVM with Exclusion Period
- 6.5.2.2 Carrier leakage
- 6.5.2.3 In-band emissions for non allocated RB
- 6.5.2.4 EVM equalizer spectrum flatness
- 6.6.1 Occupied bandwidth
- 6.6.2.1 Spectrum Emission Mask
- 6.6.2.2 Additional Spectrum Emission Mask
- 6.6.2.3 Adjacent Channel Leakage Power Ratio
- 7.3 Reference Sensitivity level
- 7.4 Maximum input level
- Reference sensitivity Search
- Phase Error
- Rx Throughput
- 7.5 Adjacent Channel Selectivity
- 7.6.1 In-Band Blocking
- 7.6.3 Narrow Band Blocking
- 7.8.1 Wide Band Intermodulation

Ordering Information

The following table lists the RF Automation Toolset software licenses that may be ordered. In addition to these, a UXM 5G Wireless Test Platform and associated software licenses are also required (not listed here).

Model	Description
C8702000A	UXM 5G Automation Toolset
C870250AA	RFA 5G NR T-0A: RF Tx and Rx tests (FR1/FR2)
C870250BA	RFA 5G NR T -0B: Advanced RF Transmitter & Receiver tests (FR2)
C870250CA	RFA 5G NR T -0B: Advanced RF Transmitter & Receiver tests (FR1)
C870200AA	RFA LTE T-0A: RF Transmitter and Receiver Tests

Keysight's 5G RF Solutions

Keysight's Network Emulation Solutions (NES) portfolio offers a range of RF test solutions, covering the entire device development workflow.

Keysight Solution	Chipset development	Device verification	Conformance testing	Carrier acceptance testing
Test application	•	•		
RF automation toolset		•		
RF/RRM DVT and conformance toolset			•	
RF/RRM carrier acceptance toolset				•

Feature/Capability	UXM 5G Test Application	RF Automation Toolset	RF/RRM DVT and Conformance Toolset		RF/RRM Carrier Acceptance Toolset
			DVT	Conformance	
Support for E7515B	•	•	•	•	•
RF Tx and Rx measurements	•	•	•	•	•
RF automated Tx and Rx tests		•	•	•	•
RF spurious and blocking tests			•	•	•
RF demod CSI reporting tests			•	•	•
RRM tests			•	•	•
Test beyond 3GPP-defined limits			•		
GCF/PTCRB validated tests				•	
MNO device acceptance tests					•

Learn more at: www.keysight.com

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