Application Note

PRE-CONFORMANCE TESTING WITH R&S®CMX500 AND CMSEQUENCER

Products:

- R&S®CMX500
- R&S®CMsequencer

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https://www.rohde-schwarz.com/appnote/1C110

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Contents

1 Overview

Compliance and Pre-compliance testing are very important topics during the development of any Wireless Device

In this document the differences between Conformance testing vs. Pre-conformance tests will be explored as well as the Rohde & Schwarz offerings to conduct these tests

For additional information consider consulting the following documents available on GLORIS:

– R&S®CMX500 Base User Manual
– R&S®CMX500 Signaling Manual
– R&S®CMX500 NR FR1 Measurements Manual
– R&S®CMsequencer User Manual

2 Standards

2.1 Need to have comparable results

Since the beginning of wireless communications multiple implementations of Radio technologies were developed to try and achieve long distance communications. This quickly highlighted the issue of mutual compatibility since the devices not only need to understand each other but can also interfere with each other. Soon it became clear that large scale coordination was needed to ensure functional and reliable networks. The solution was the creation of organizations that handle standards at an international and regional level.

2.1.1 Standardization organizations for wireless testing

Organizations can be divided into 3 types

► International Standards Associations

► International Regulatory Bodies

► Regional Regulatory Bodies

It is of absolute importance that wireless devices are tested in compliance with the standards defined by the organizations mentioned above. With the exception of regional requirements, these organizations jurisdiction operate in a global scale, ensuring that the wireless environment is maintained in harmony no matter where the device under test is going to be operating.
If compliance to the standards is not properly verified it is possible devices cause interference on existing networks, which could result in critical infrastructure and services failing. Not only that but it is of ultimate importance that testing is also thoroughly conducted in order to ensure reliable communication from any wireless device. This is advantageous for the economy and critical to save lives in case of emergencies.

Additionally regional requirements vary depending on where the DUT (*Device Under Test*) is intended for operation. These regional requirements are mandated by government regulatory bodies and can result in heavy fines and/or sanctions in case of non-compliance.
The network operators also have their own supplemental tests that go beyond what is defined on international and regional standards to assure a certain degree of QoS (*Quality of Service*) provided to users in their network.

There are many associations that have become the references for the Wireless industry, as an example:

► GCF/PTCRB

– Global Quality standards for device interoperation; GCF is relevant for Europe while PTCRB is the North American counterpart

► 3GPP

– Main Cellular technologies association, takes care of 3G/4G/5G/6G

► FCC

– United States regulatory body for Radio Frequency communications

► ETSI

– European standardization body for 3GPP Standards

► IEEE

– International Electrical engineering association responsible for WiFi standardization

3 Conformance vs Pre-conformance

3.1 Conformance Testing

Whenever a wireless device needs to be certified to be operating inside regulatory limits, tests denominated as conformance testcases are to be performed. Such testcases are developed and researched by the standards associations described in chapter 2 of this document.

Certain regions also can impose local requirements for devices that want to operate within its territory to guarantee interoperability with existing systems like Radar, Air Traffic Control, Emergency Alert systems and other existing networks.

Except for a few countries, most regions in the world require conformance according to the specific standards body. As example the United States requires the conformance to 3GPP standard testcases for devices that operate in the cellular technologies (as in PTCRB certification), additionally it also requires that such devices comply with the region-specific frequency bands emissions as described in FCC CFR 47. Although this document focuses on the Signaling tests (as opposed to non-Signaling tests), there are also conformity tests and standards defined for EMC testing to assure electromagnetic compatibility of the devices and that no device shall disrupt the operation of another one as well as be minimally robust against interference.

These tests require specific instrumentation that emulates a cellular base station in order to setup a connection to the wireless device. Additional instruments like Spectrum Analyzers may be needed for specific out-of-band test cases. On the figure below there is an example of such conformance test systems from Rohde & Schwarz, the supporting Testcase Automation framework in this case is called CONTEST.

Figure 1: Example of Conformance test system TS8980
https://www.rohde-schwarz.com/us/products/test-and-measurement/conformance-test-systems-3gpp-ctia/rs-ts8980-conformance-test-system_63493-8181.html

3.2 Pre-conformance testing

The major motivation of pre-conformance testing is to save money and time. The focus is RF testing very close to the specification rather than providing final acceptance testing. The test setup is simplified, with a more flexible testcase implementation to allow testing even of incomplete, early prototypes. Testing usually starts with transmitter and receiver tests in SISO, with in-band conditions. They can be extended in a second step for multi carrier and MIMO scenarios as well.

Pre-conformance tests are defined to provide a solid confidence level that the implementation of a wireless device will successfully pass at the validation, regulatory or operator acceptance tests, typically done by independent test houses. The goal is detecting any issues that may arise when testing in line with the specification internally before the final conformance tests are done.

The earlier design and implementation errors can be found and fixed in the R&D of a wireless device; less costs are involved. These costs derive from product re-design but added to that from the contracting of test houses used during the final phase of R&D in which Conformance tests are done.
This means a failed validation at a test house is much more costly and should be always avoided, for those reasons it is vital to conduct pre-conformance testing as early as possible in the development cycle. That is especially true in case of a completely new design.

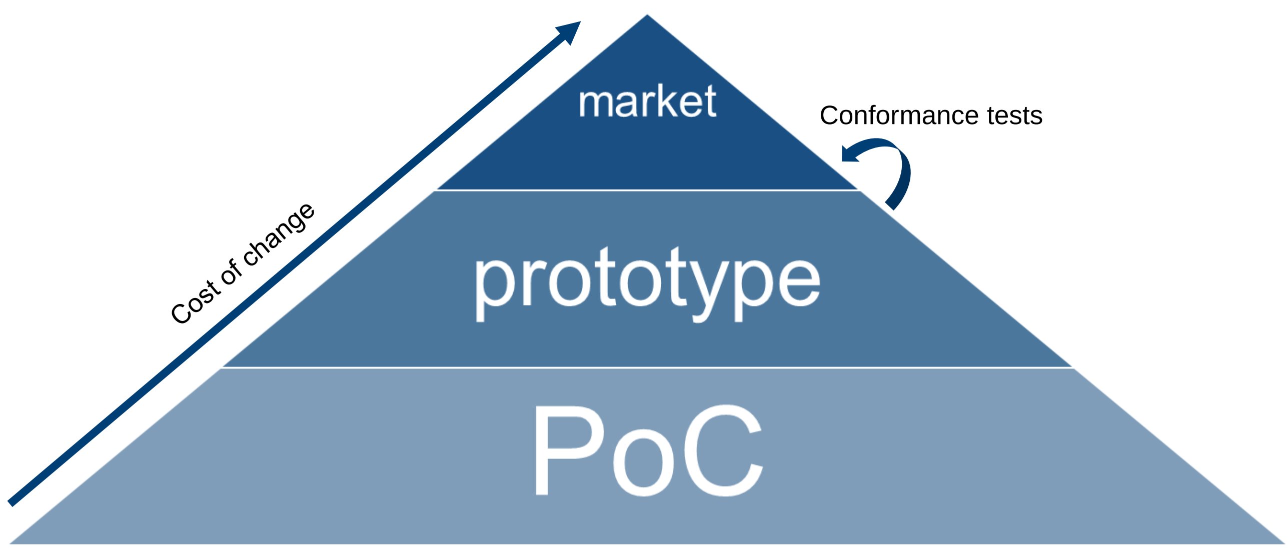


Figure 2: Pyramid of costs in Wireless devices R&D

To simplify the test setup, these "initial tests" are in the so-called "in-band" frequency range, going up the maximal frequency range used by the target wireless standard. These tests can be formed with a single tester like the R&S®CMX500 shown below, which can be easily scaled to many R&D stations.

Out of band tests require a much more complex and expensive setups with filters, spectrum analyzer and signal generators supporting the high out-of-band frequencies to be able to capture spurious at high order harmonics and enable blocking tests simulating high frequency critical interferers.

In the next section we will see an example of Rohde & Schwarz provided pre-conformance solution as illustrated below.

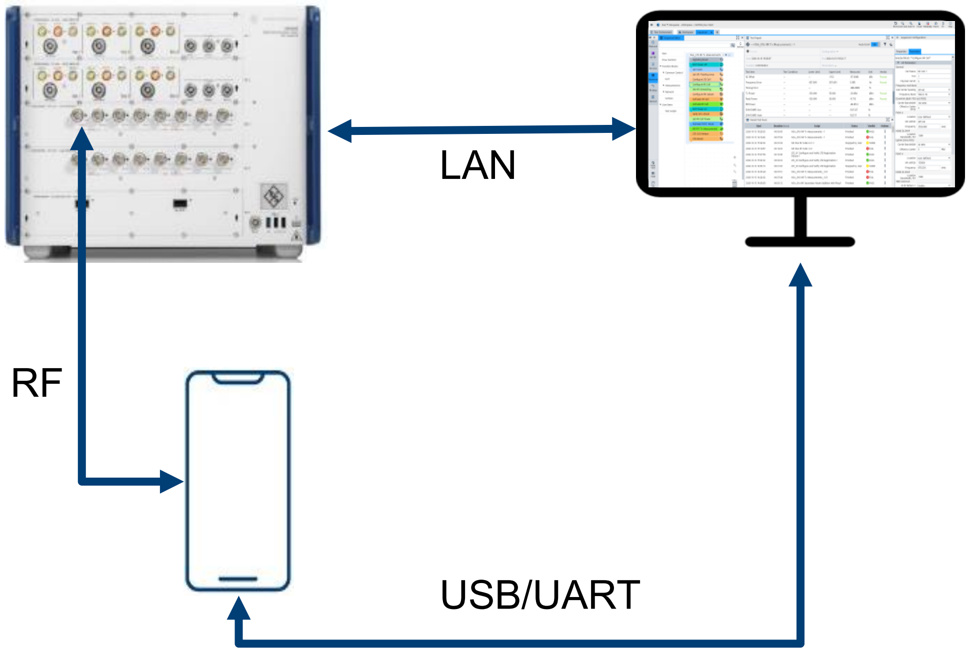


Figure 3: Connection setup of a R&S®CMX500 OBT for pre-conformance testing with UE automation

4 CMsequencer Execution

Using the OneBox tester R&S®CMX500 and with just a few configuration clicks for bands, channels and bandwidth, the R&S®CMsequencer tool provides a comprehensive result report that gives the user a first impression of in-band pre-compliance. This provides beneficial knowledge in the very early stage of verification, before doing more complex system tests or validation.

Although complete Out of Band testing requires additional equipment due to the higher order harmonics to be measured, CMsequencer also supports limited testing within the Hardware frequency range (for FR1 each RF Unit has 400MHz to 8GHz frequency range)

4.1 preconditions to testing

R&S®CMX500 has a quick access interface to the attenuation configuration, this area is named “Library” it is also the place where configuration the DUT profile can be done to select which antennas should contain which bands. For an in-depth guide to configuring the band support per antenna refer to the Base Manual section 8.1.2

To avoid errors originating in the test setup some adjustments are done to compensate for pathloss. An approximated value of 4dB is set manually to account for cables, adapters and combiners in this case

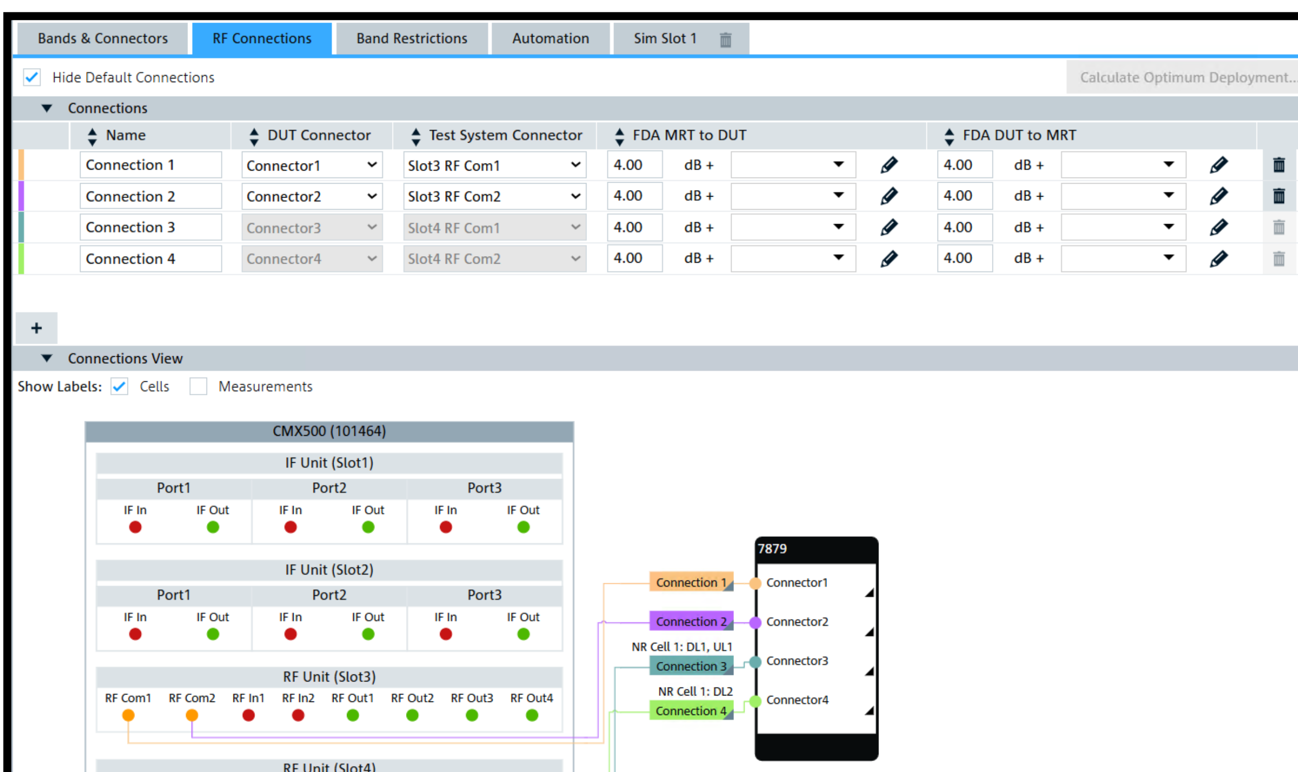


Figure 4: Pathloss setting for the connections to the Device Under Test

The most accurate approach is to measure the attenuation in the used antenna and select it on the drop-down menu.

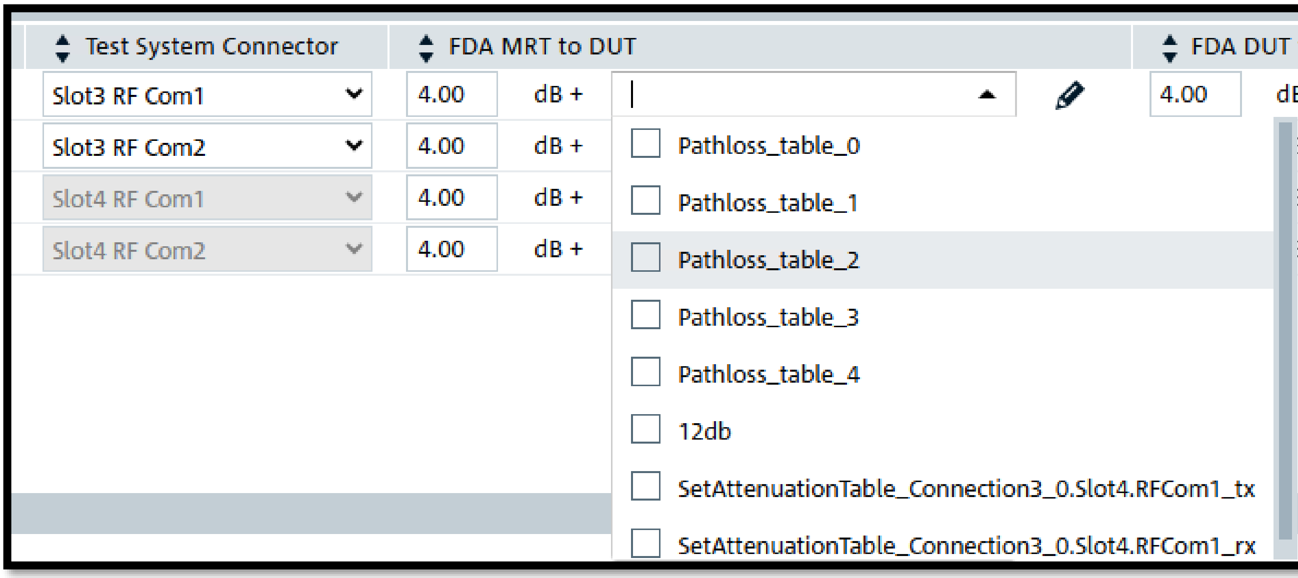


Figure 5: FDA (frequency dependent attenuation) table selection to be applied to a given connector

On the CMsequencer manual section 11.4.3.3 there is more guidance on using Find Attenuation block to measure the pathloss in an automated way

Once having properly configured the connections, the SA call setup block can be used to easily get the Wireless device to connect to a test network and do a BLER (*Block Layer Error Rate*) verification:

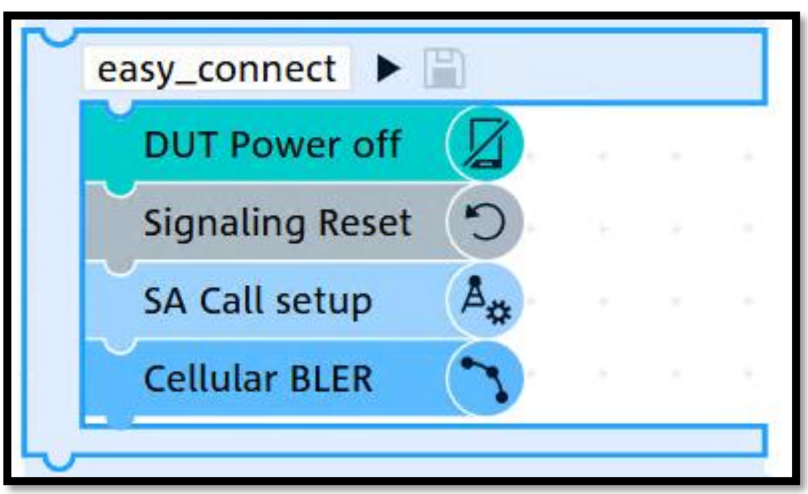


Figure 6: Simple 5G connection with BLER measurement for stability verification

Just configure the block to the target band and bandwidth supported by the device under test to be able to establish a base connection and do the BLER reliability test

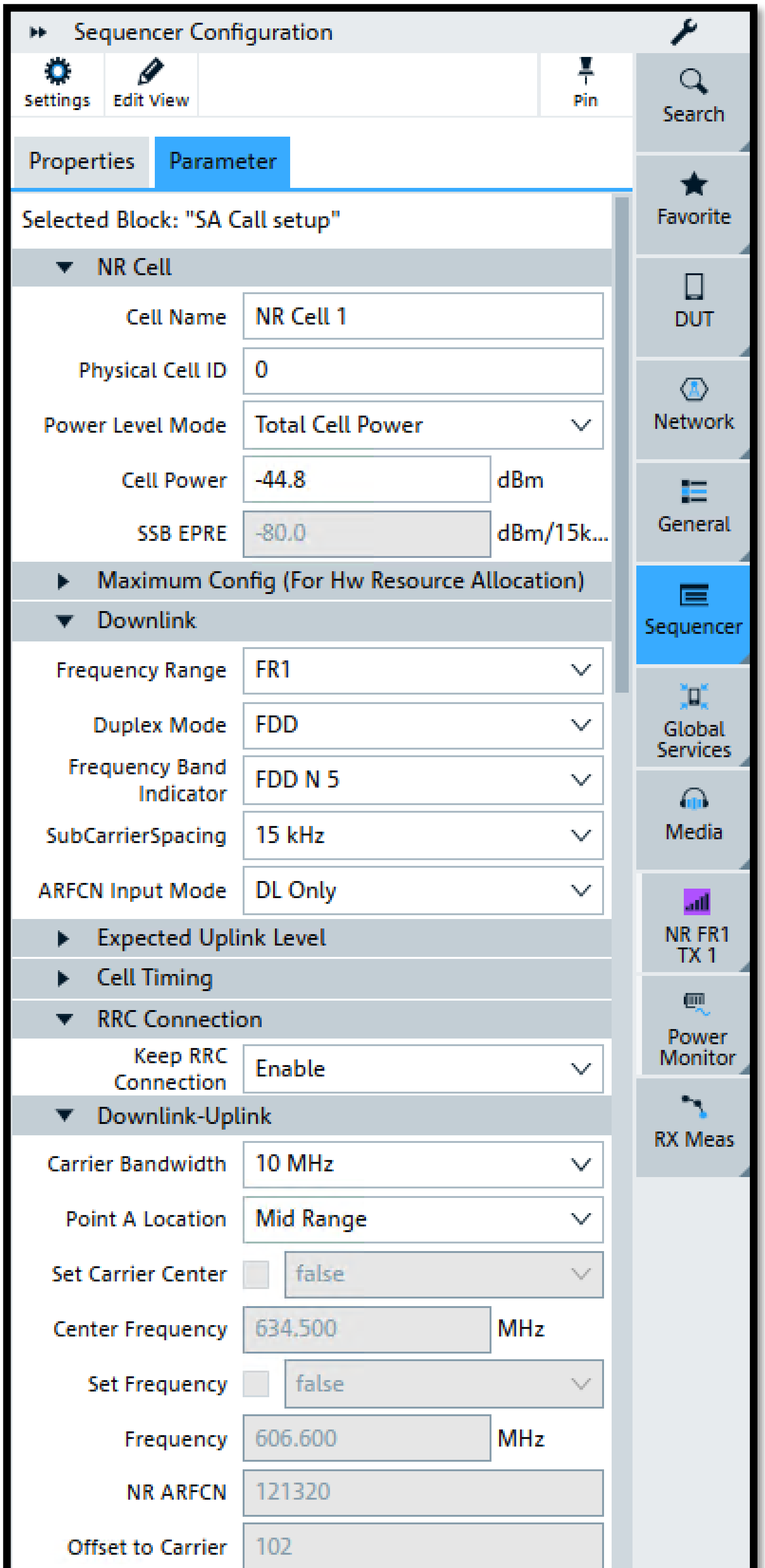


Figure 7: Configuration for band, bandwidth and channel for SA Call Setup

Having confirmed 0% BLER present on the connection with this *sanity test* there is high confidence that there won't be any false failures during the test.

The same test script can be repurposed for the pre-conformance tests by adding the composite block at the end of the sequence as shown in Figure 8

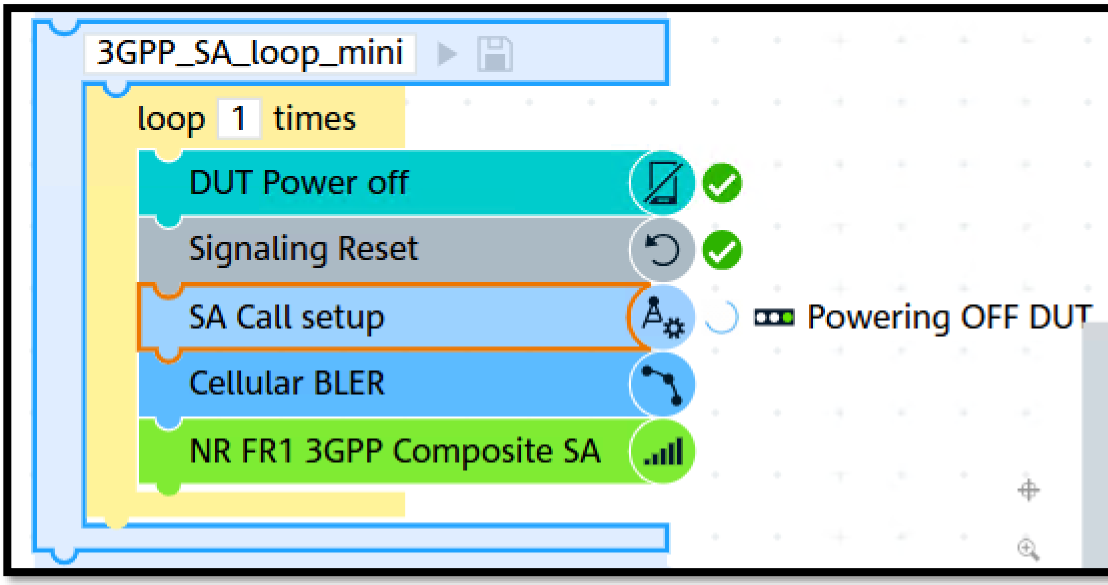
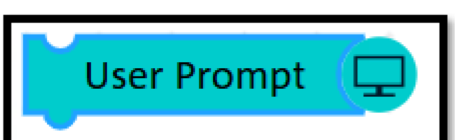


Figure 8: Setup validation test script with added 3GPP Composite block for SA FR1 pre-conformance and a loop wrapper to check repeatability of the results

A prior connection also helps assuring that no basic connection issues will be present during the intended pre-conformance testing so it is important to keep the initial connection part of the script for traceability of errors/failures.

For more granularity the individual procedures are available as well (as shown in the next section) in case there is a need to perform additional fixture and device automation. The only addition necessary would be the User Prompt block, it allows for arbitrary strings to be sent to the automation interface



4.2 R&S®CMsequencer Composite Blocks

R&S®CMsequencer offers pre-conformance for multiple standards in a simple and automatically preconfigured one-click test execution solution. Special composite blocks that automate the test points defined by the organizations mentioned in chapter 2, allow to cover cellular and WiFi using a turnkey solution.

The blocks also allow modification of default configurations and the flexibility to test non-compliant configurations

These Automated Testing packages pre-configure the network scenario, establish the UE connection and measure the Transmitter and Receiver characteristics according to the test cases as defined on the specific standards.
Each composite package also contains an easily configurable GUI with parameters relevant to each of the technology standards.

OBS: the base signaling options are still required in addition to the R&S®CMsequencer licenses i.e. KS600 for 5G NR signaling and KM600 for 5G NR measurements

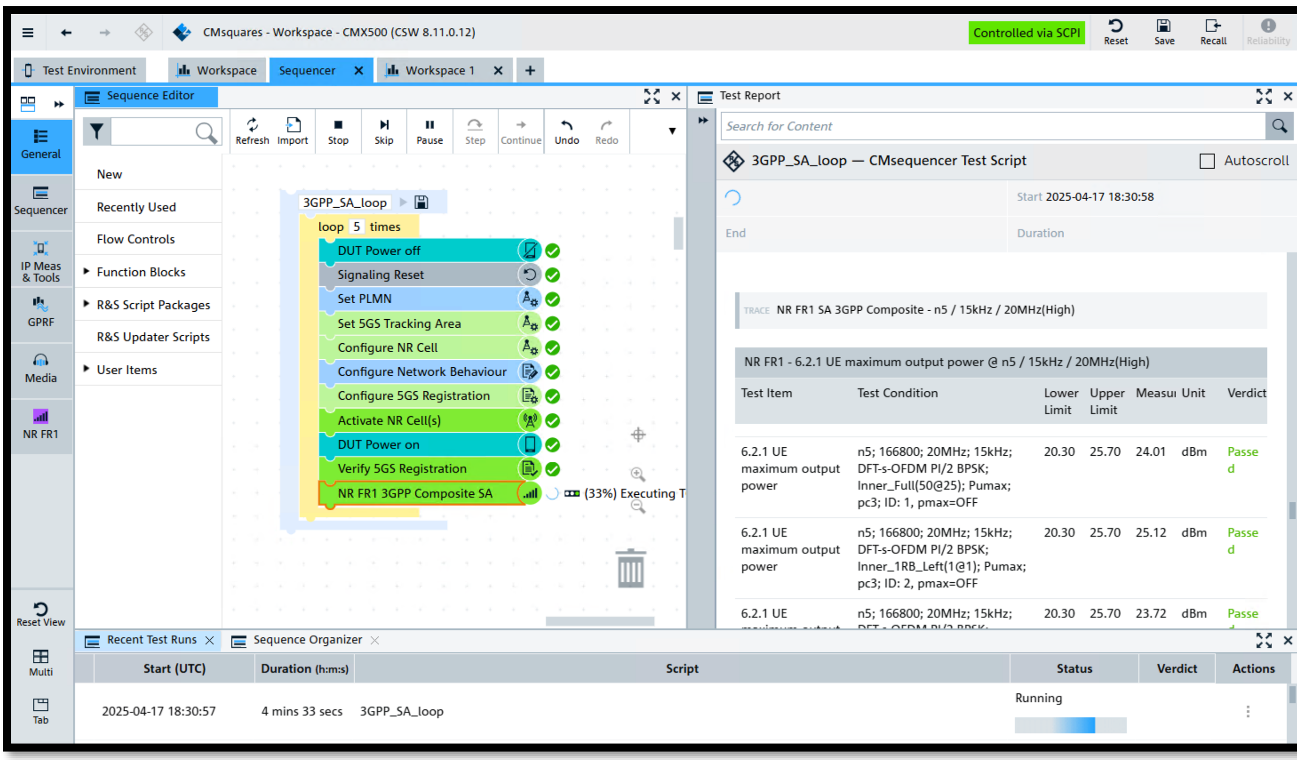


Figure 9: Testcase during execution in CMsequencer composite block

For manual 3GPP testing please refer to the Application note below:
https://scdn.rohde-schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1sl/1SL368_0e_5G_NR_UE_RF_conformance_38.521-3.pdf [1].

4.2.1 Supported standards

The following standards are available for automated testing in R&S®CMsequencer. The required R&S®CMsequencer licenses are listed as well

- ► Composite 3GPP
  - – KC660B for 5G NR NSA 3GPP testing [6]
  - – KC661B for 5G SA 3GPP testing [5]
  - – KC664B for 5G SA Redcap 3GPP testing [5]

► Composite IEEE

– KC350B for WLAN testing [2]

► Composite ETSI RED

– KC653B Radio Equipment Directive European standard [4]

4.2.2 Composite Block settings

The following section shows the options of a general Composite use-case using examples from the 5G NR SA 3GPP testcases

The testcases configurations are most of the time not trivial since they depend on many different configurations with a very specific procedure. As a reference below the table for the configurations of connections in testcase 6.2.1 from ETSI 138.521-1 is highlighted

Table 6.2.1.4.1-1: Test Configuration Table

Initial Conditions			
Test Environment as specified in TS 38.508-1 [5] subclause 4.1		Normal, TL/VL, TL/VH, TH/VL, TH/VH	
Test Frequencies as specified in TS 38.508-1 [5] subclause 4.3.1		Low range, Mid range, High range	
Test Channel Bandwidths as specified in TS 38.508-1 [5] subclause 4.3.1		Lowest, Mid, Highest (NOTE 3)	
Test SCS as specified in Table 5.3.5-1		Lowest, Highest	
Test Parameters			
Test ID	**Downlink Configuration**	**Uplink Configuration**	
	N/A for maximum output power test case	**Modulation (NOTE 2)**	**RB allocation (NOTE 1)**
1		DFT-s-OFDM PI/2 BPSK	Inner Full
2		DFT-s-OFDM PI/2 BPSK	Inner 1RB Left
3		DFT-s-OFDM PI/2 BPSK	Inner 1RB Right
4		DFT-s-OFDM QPSK	Inner Full
5		DFT-s-OFDM QPSK	Inner 1RB Left
6		DFT-s-OFDM QPSK	Inner 1RB Right
NOTE 1: The specific configuration of each RB allocation is defined in Table 6.1-1. NOTE 2: DFT-s-OFDM PI/2 BPSK test applies only for UEs which supports half Pi BPSK in FR1. NOTE 3: For band n28, the Highest test channel bandwidth is replaced by 20MHz due to MPR is always larger than 0dB for 30MHz bandwidth.			

Figure 10: Table 6.2.1.4.1-1 from ETSI 138.521-1 v17.10 TC 6.2.1

There are 6 test steps (labeled as Test IDs) required in this case. The standard also mandates this to be repeated for each of the Lowest/Mid/Highest Bandwidths; and repeat once more for the Lowest/Highest Subcarrier Spacings supported by the DUT.
In test length terms it would mean 6(steps)x3(channels)x3(Bandwidths)x2(SCS)=108 steps per band

All the configurations on each of these test steps are automatically done by R&S®CMsequencer.

4.2.2.1 General Settings

The Composite block is designed to keep the configuration of testcase settings easy and comprehensive. On the general parameters there are options to:

– configure the testcases and band combinations to be executed;

– select the DUT control behaviors for changing configurations inside a testcase;

– select if the graphs generation is active and which graphs should be present on the report;
– select if a test item should be repeated in case of failure.

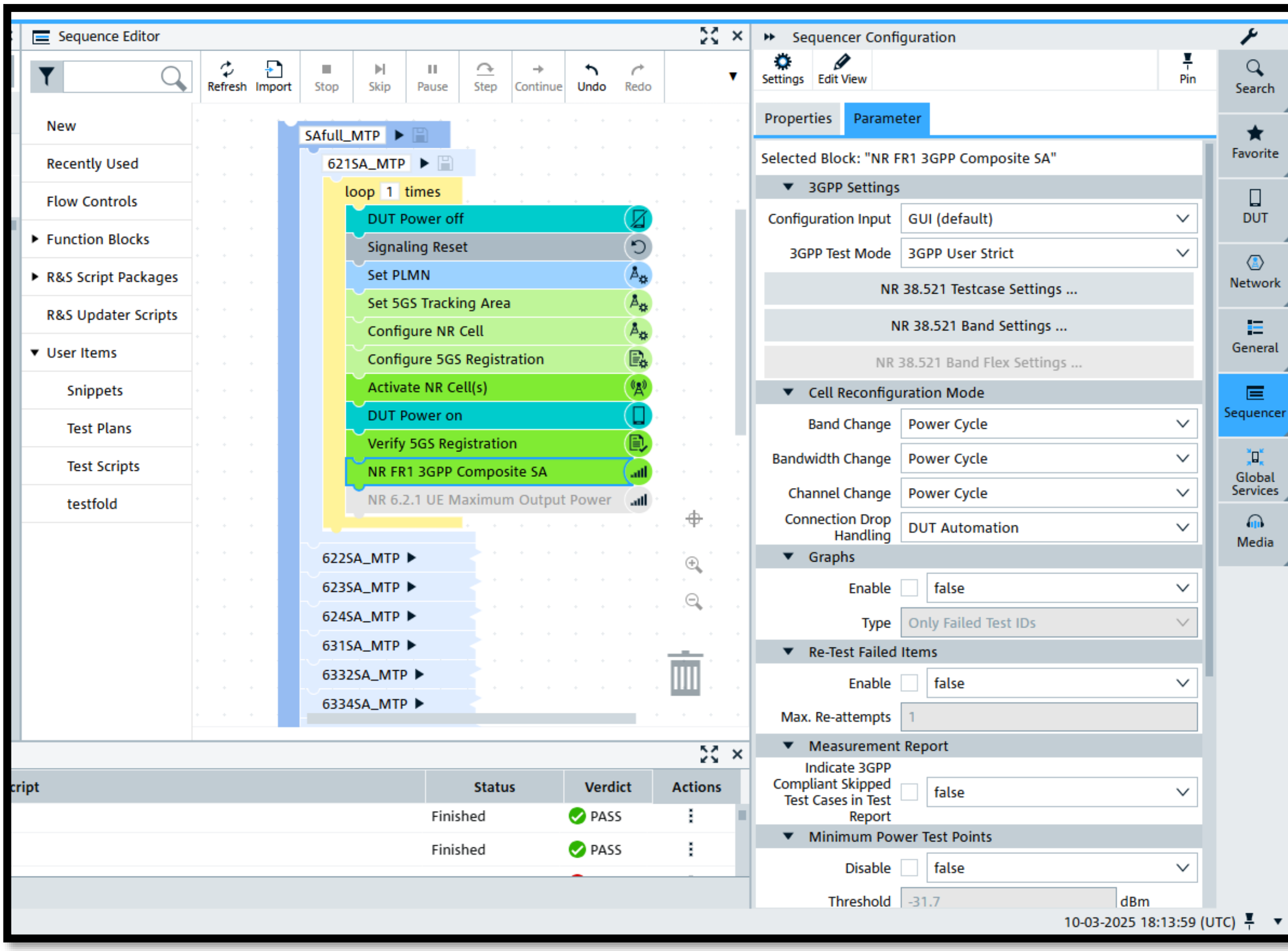


Figure 11: R&S®CMsequencer example test campaign for a pre-conformance 3GPP 5G NR execution

For maximum robustness in device under test configuration changes select “Power Cycle” in Band/Bandwidth/Channel Change. This is especially useful for early prototypes since it forces a airplane mode ON/OFF for each cell configuration change.

For maximum speed and reduced test times select Blind Handover in the Reconfiguration Modes. Use this to achieve maximum test volume. This mode tries to retain the active RRC connection.

4.2.2.2 Composite Block testcase settings

On the testcase settings window the desired testcases can be selected for running the test over, by selecting a root node all testcases underneath it will also be toggled.

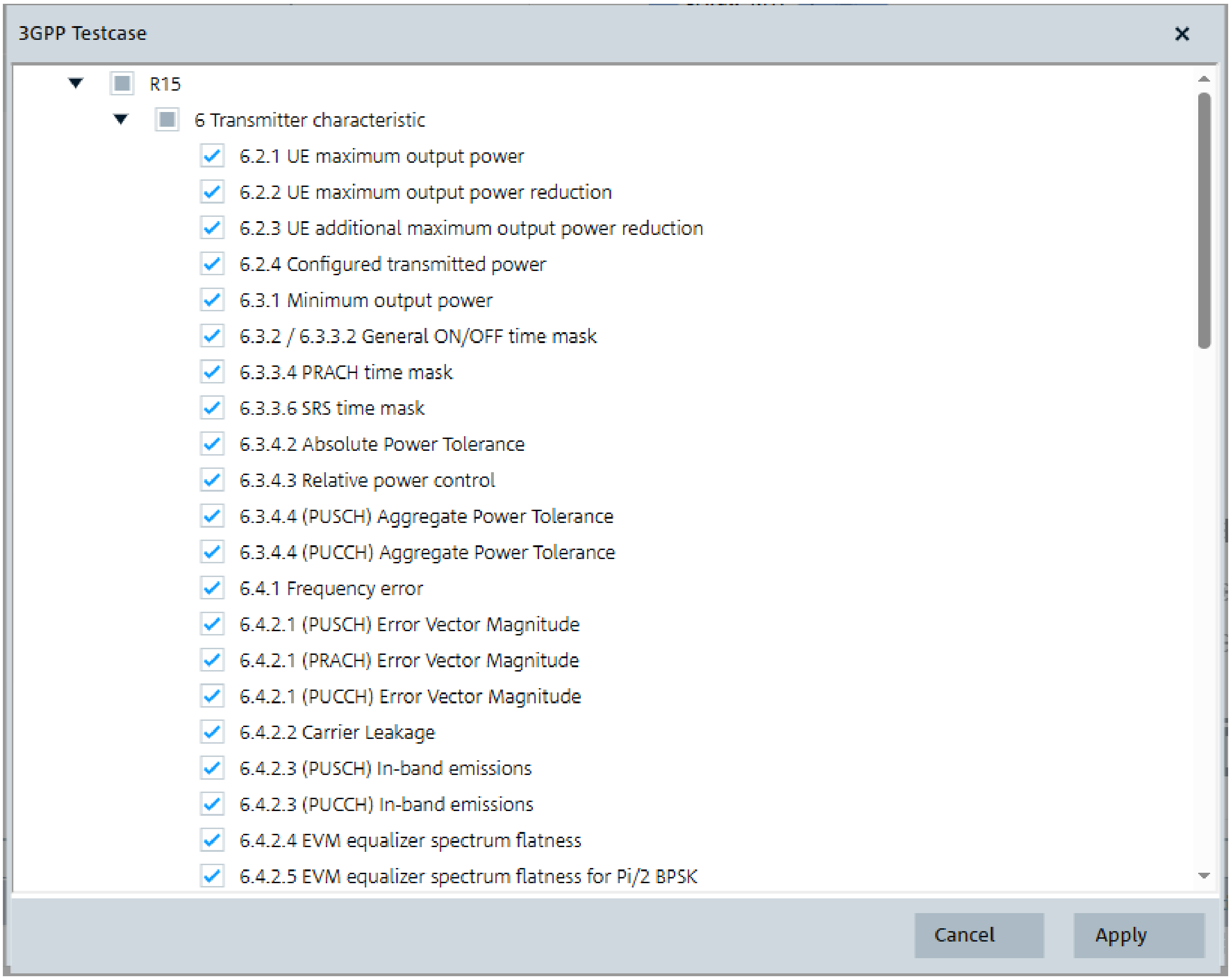


Figure 12: Configuration window for the testcase selection

4.2.2.3 Band Combination settings

On the band combination settings window the desired bands to be run during the test can be selected. In addition the Lowest/Mid/Highest BWs support can be adapted according to the device under test. By default, R&S®CMsequencer will try to use the UECapabilities information for referring the Lowest/Mid/Highest Bandwidths supported as well as optional parameters available on the standard (i.e. pi/2 BPSK or Power class); the customization of those parameters might be needed for specific devices in prototype phase.

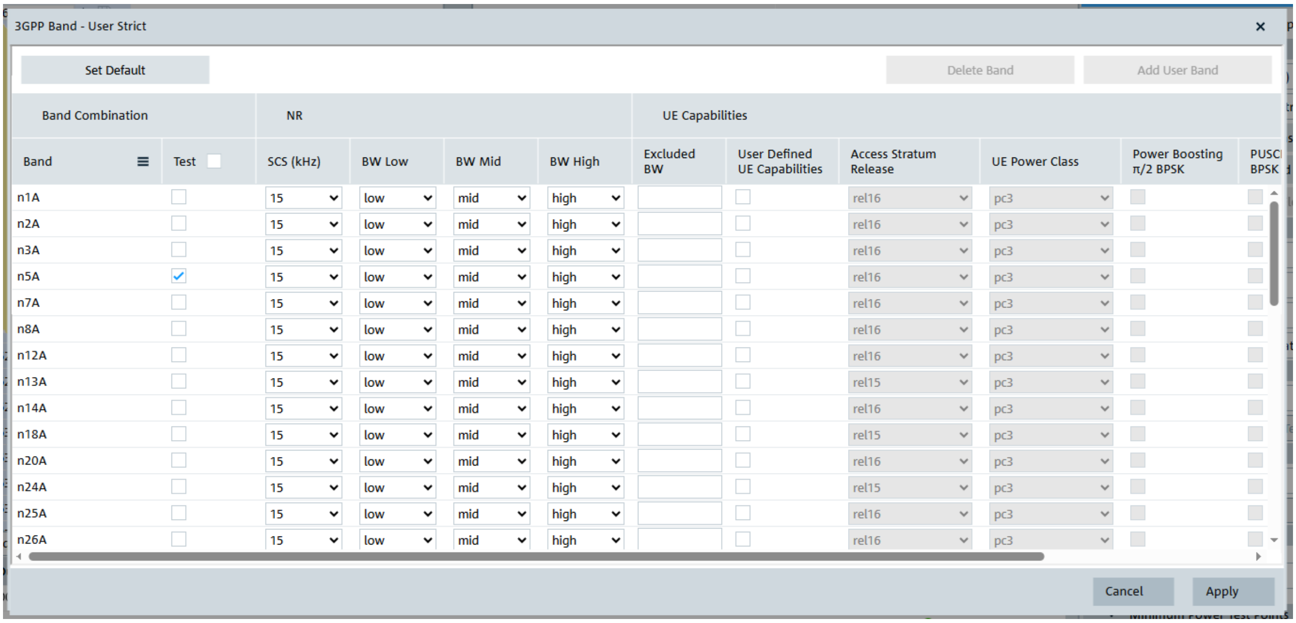


Figure 13: Configuration window for the band selection as well as UE specific configurations

If the default BWs are not supported by the UE as defined by 3GPP in ETSI 138.508-1 tables 4.3.1.0[A/B/C]-1 as shown below, it is necessary to change the BWs in the Composite block configuration window to the specific supported bands to be tested.

Table 4.3.1.0B-1: Low Test Channel bandwidths for each NR band, FR1

NR Band	UE Low Test Channel bandwidth [MHz][1, 1a, 1b]	RedCap and eRedCap UE Low Test Channel bandwidth [MHz][1, 1a, 1b]
n1	5	5
n2	5	5
n3	5	5

Table 4.3.1.0A-1: Mid Test Channel bandwidths for each NR band, FR1

NR Band	UE Mid Test Channel bandwidth [MHz][1, 1a, 1b]	RedCap and eRedCap UE Mid Test Channel bandwidth [MHz][1, 1a, 1b]
n1	25	15
n2	20	15
n3	25	15

Table 4.3.1.0C-1: High Test Channel bandwidths for each NR band, FR1

NR Band	UE High Test Channel bandwidth [MHz][10, 11, 12]	RedCap and eRedCap UE High Test Channel bandwidth [MHz][10, 11, 12]
n1	50	20
n2	40	20
n3	50	20
n5	20[1,14], 25[2]	20

4.2.2.4 Composite Block Flex-Mode

R&S®CMsequencer test solution includes a flexible mode to support tests similar to 3GPP but with configurations that are not yet specified or that are special verifications tests. One example is preemptive testing for a band that has been announced but not yet included in the test specifications (due to ongoing investigations by the 3GPP committee into the appropriate target limits).

For those cases the dropdown selection on the composite block may be changed to “Flex”:

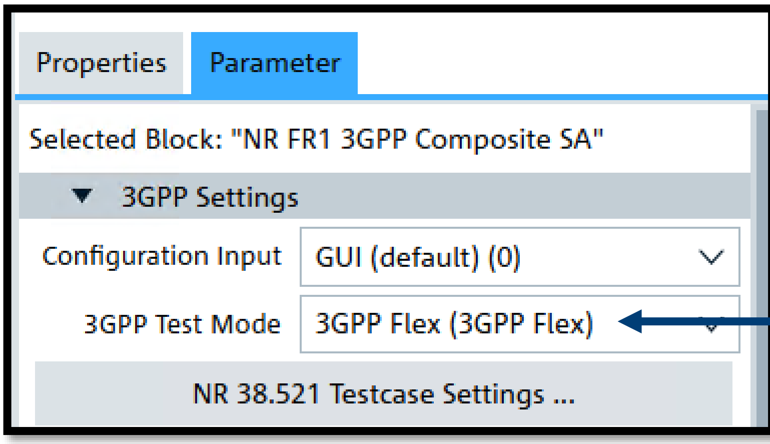


Figure 14: Composite block in Flex mode

In this case the Bands configuration window adapts to allow a more flexible selection of bands:

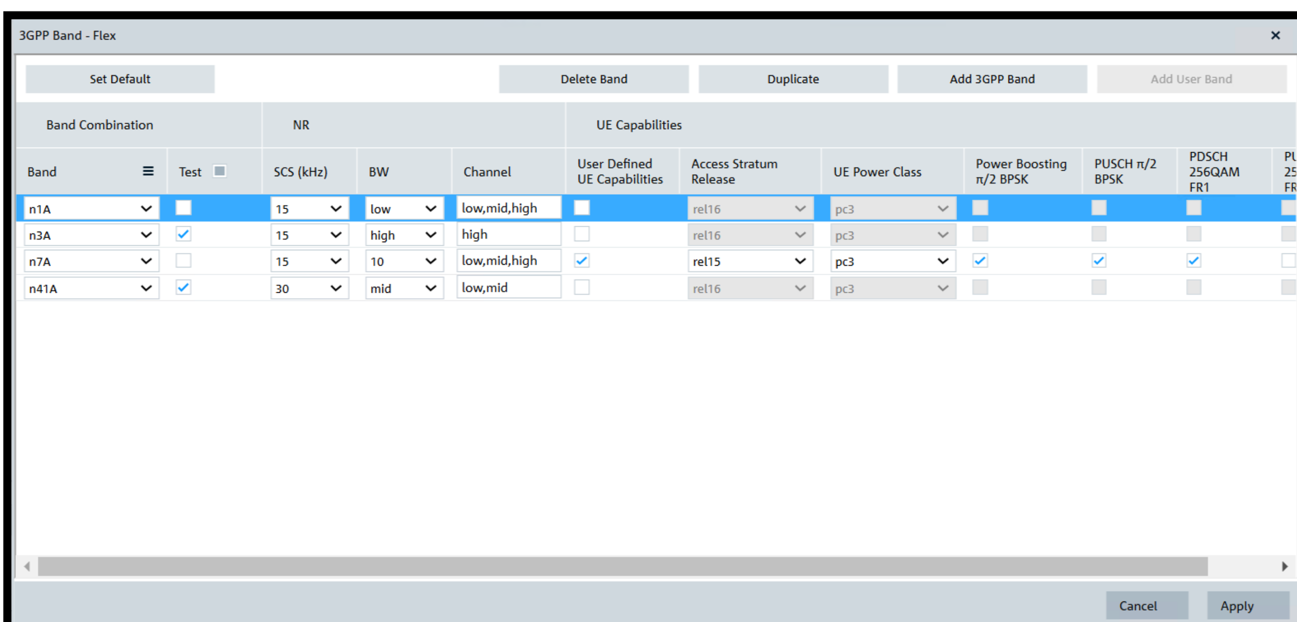


Figure 15: Band combination selection with configurable subset of channels to test

5 Device (DUT) automation

Automated testing is only complete with the automation of the Device Under Test to be able to force it into specific connection states during testing. The R&S®CMX500 supports this through remote commands (integrated in the test procedure) sent to a controlling computer or directly to the device under test.

As the R&S®CMX uses a basic socket connection for issuing commands any Device Control application that is available, be it some Python/C++ script or even Custom Testing Environments can be used on the automation workflow.

Rohde & Schwarz supports the turnkey application named Automation Manager available in GLORIS (R&S customer support area) for download

After having the socket commands server configured, simply toggle the control mode to automatic as shown below and the R&S®CMX will redirect the automation commands to a socket connection to the IP and ports defined instead of displaying the default pop-up solicitation for device interaction.

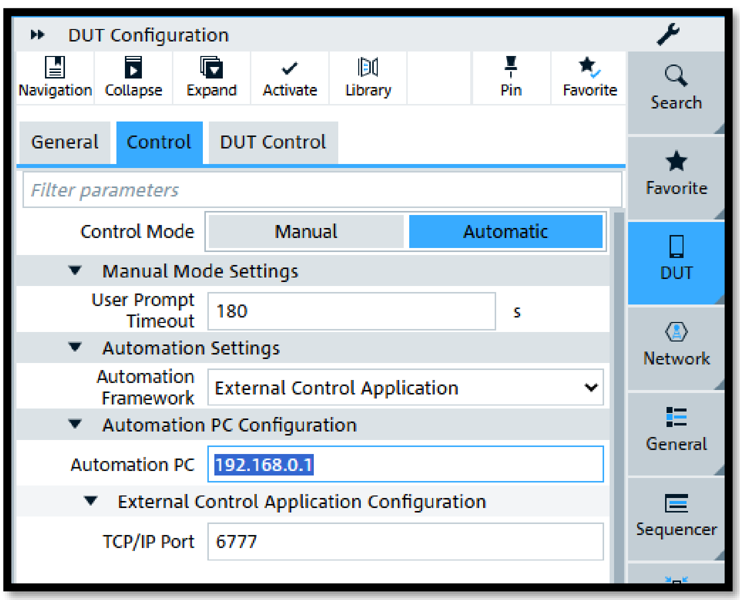


Figure 16: DUT control settings on R&S®CMsquares GUI

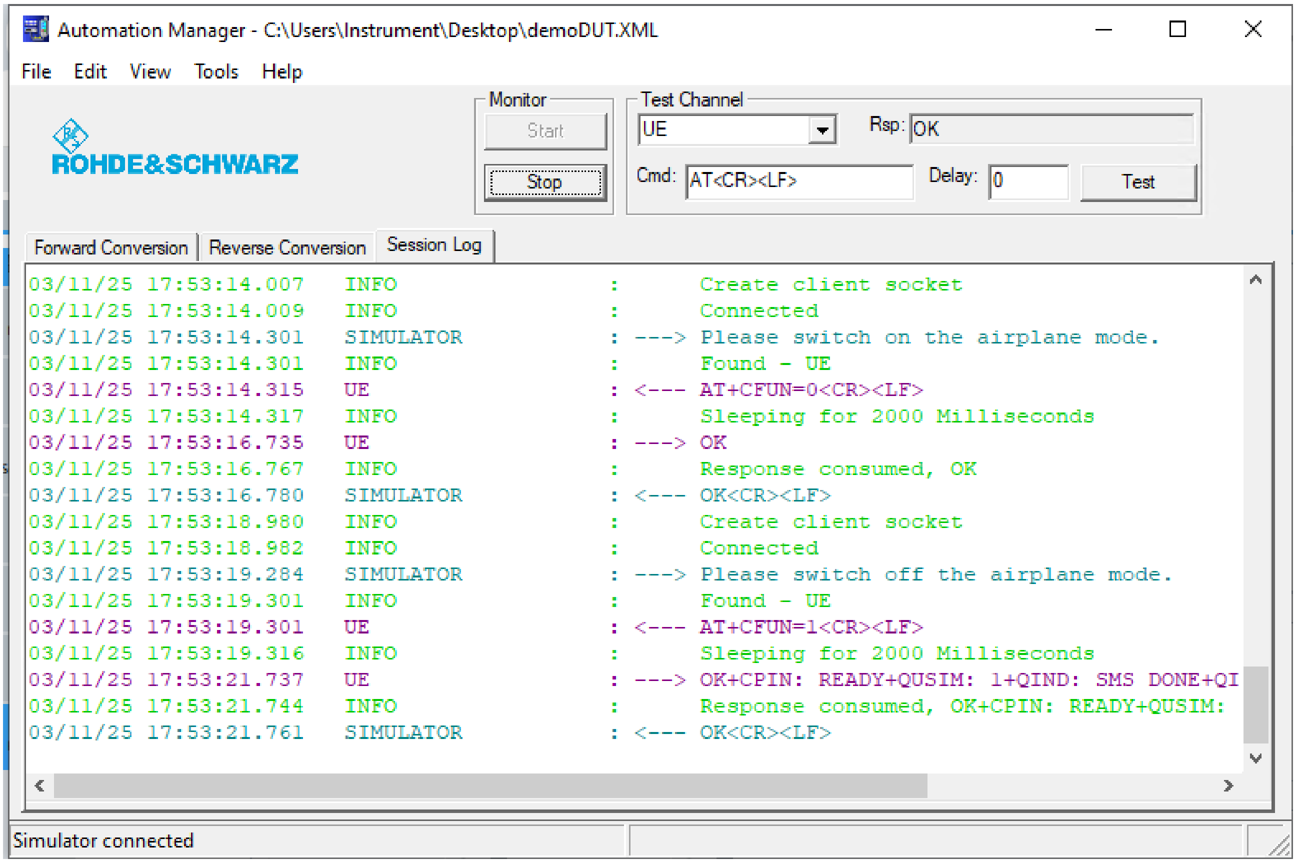


Figure 17: Automation Manager executing AT commands translated from the received automation originated in R&S®CMsequencer

6 Log and report collection

6.1 Report and Log collection

While running tests R&S®CMsequencer automatically creates and organizes test reports and logs.

Those can be directly downloaded in the “Recent Test Runs” window to the computer accessing the system with 2 button clicks, or opened directly in the R&S®CMX500 web interface for visualization.

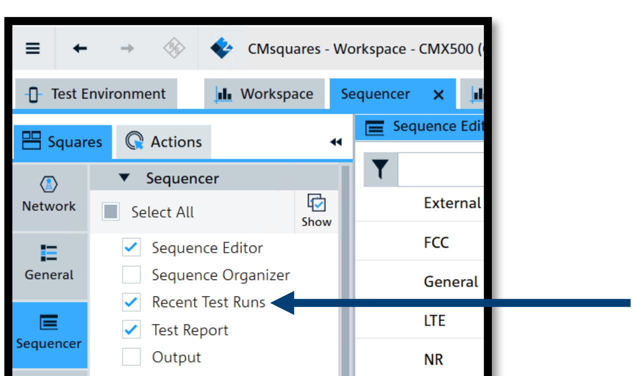


Figure 18: Selection of windows to be displayed in the R&S®CMsequencer

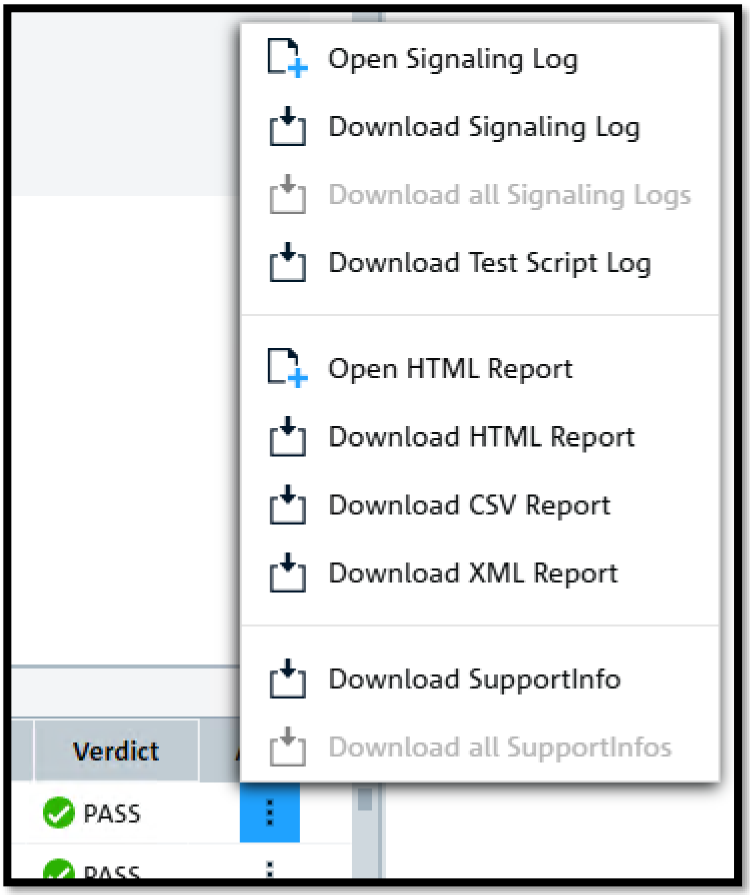


Figure 19: 2-click easy report and log download and visualization

Note that there is no need to use USB drives, the files are transferred directly to the computer accessing the system

An alternative way to collect massive amounts of logs/results is to use the File Explorer available in the web interface of R&S®CMX500 as well:

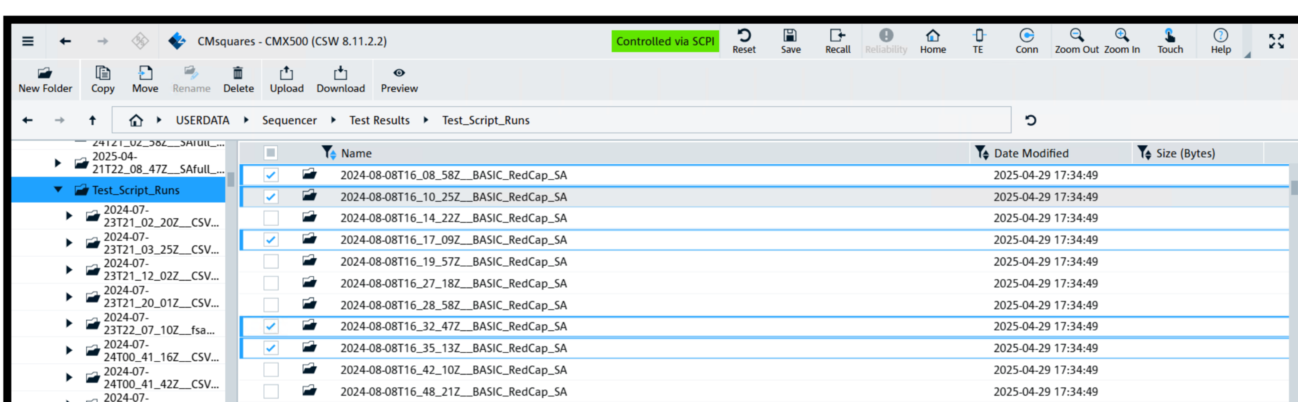


Figure 20: Multi-run download through the File Explorer, R&S®CMsequencer execution files are located at */USERDATA/Sequencer/Test Results/Test_Script_Runs/*

R&S®CMsequencer also self organizes the test plan executions for easier navigation. On this same folder location going 1 level up in the hierarchy we find also the execution folders for each test plan run, these contain all the contained test script runs inside a given test plan

6.2 Report and Log configuration

6.2.1 Post processing

For more concise test results it is possible to generate an Excel on a postprocess step by putting the test script inside a test plan wrapper and add the example "create_xlsx_report_for_plan" snippet at the end:

Figure 21: Test plan extension with the post processing snippet for the results

The xlsx can then be found on the path for the test plan files, in this case */USERDATA/Sequencer/Test Results/2025-05-14T18_35_41Z__3GPP_spreadsheet_summary/*

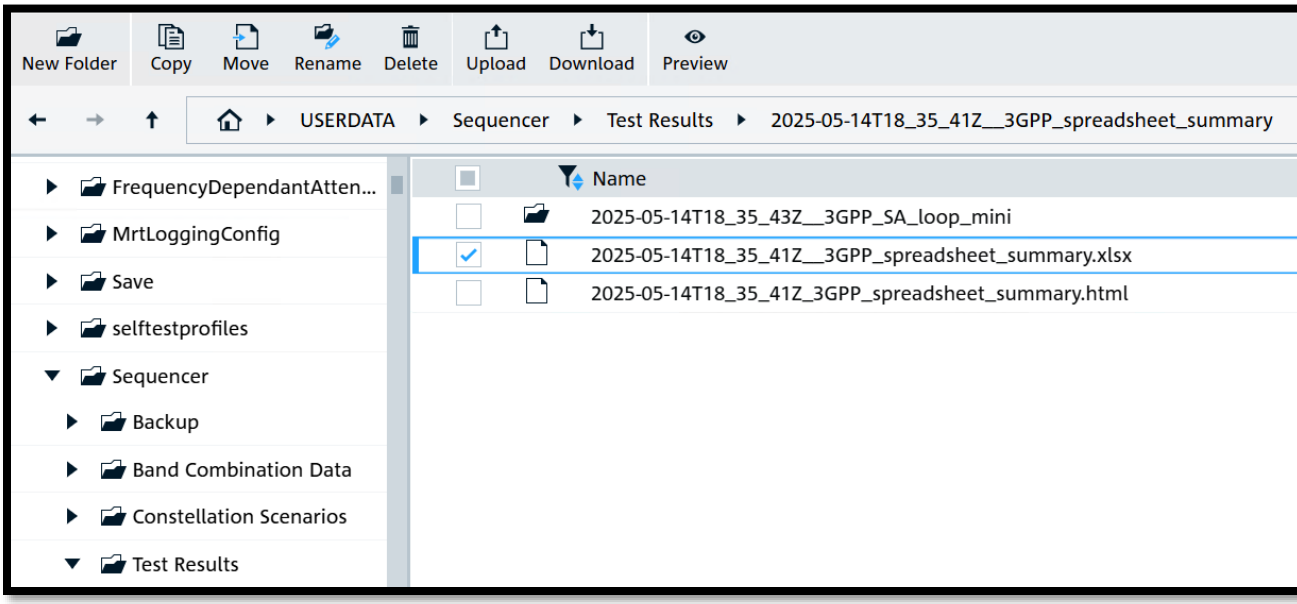
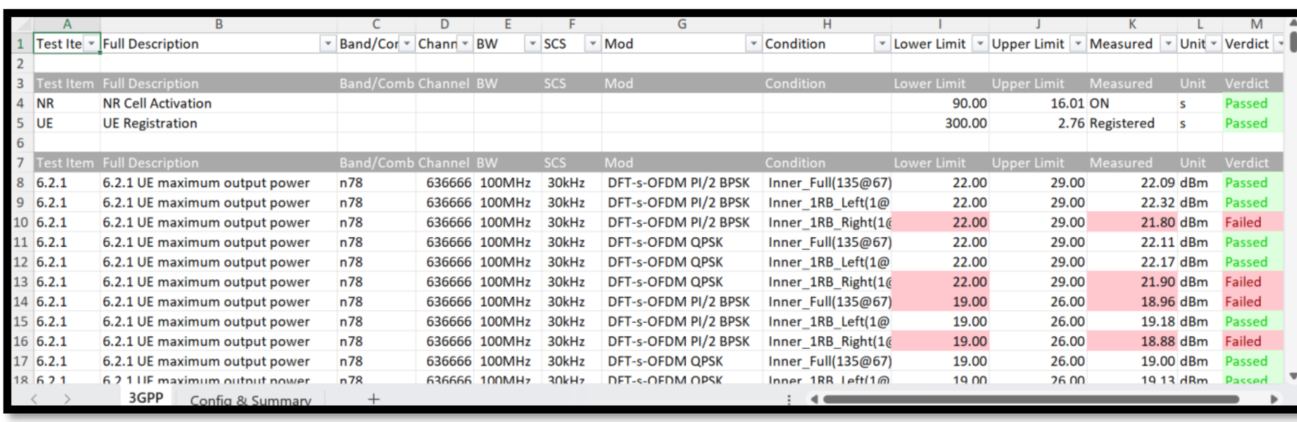


Figure 22: Test plan folder containing all results + the post-processed xlsx



Test Ite	Full Description	Band/Cor	Chann	BW	SCS	Mod	Condition	Lower Limit	Upper Limit	Measured	Unit	Verdict
Test Item	Full Description	Band/Comb	Channel	BW	SCS	Mod	Condition	Lower Limit	Upper Limit	Measured	Unit	Verdict
NR	NR Cell Activation							90.00	16.01	ON	s	Passed
UE	UE Registration							300.00	2.76	Registered	s	Passed
Test Item	Full Description	Band/Comb	Channel	BW	SCS	Mod	Condition	Lower Limit	Upper Limit	Measured	Unit	Verdict
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_Full(135@67)	22.00	29.00	22.09	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_1RB_Left(1@	22.00	29.00	22.32	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_1RB_Right(1@	22.00	29.00	21.80	dBm	Failed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM QPSK	Inner_Full(135@67)	22.00	29.00	22.11	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM QPSK	Inner_1RB_Left(1@	22.00	29.00	22.17	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM QPSK	Inner_1RB_Right(1@	22.00	29.00	21.90	dBm	Failed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_Full(135@67)	19.00	26.00	18.96	dBm	Failed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_1RB_Left(1@	19.00	26.00	19.18	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM PI/2 BPSK	Inner_1RB_Right(1@	19.00	26.00	18.88	dBm	Failed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM QPSK	Inner_Full(135@67)	19.00	26.00	19.00	dBm	Passed
6.2.1	6.2.1 UE maximum output power	n78	636666	100MHz	30kHz	DFT-s-OFDM QPSK	Inner_1RB_Left(1@	19.00	26.00	19.13	dBm	Passed

3GPP | Config & Summary

Figure 23: Example spreadsheet for a run with just TC 6.2.1 enabled

This XLSX spreadsheet is generated with coloring on the Verdict column to facilitate visual identification of failure points and contains filters on each of the columns for easier data traversing/search.

6.2.2 Global CMsequencer settings

The generation of logs and reports can be customized on the settings page under the Sequencer tab:

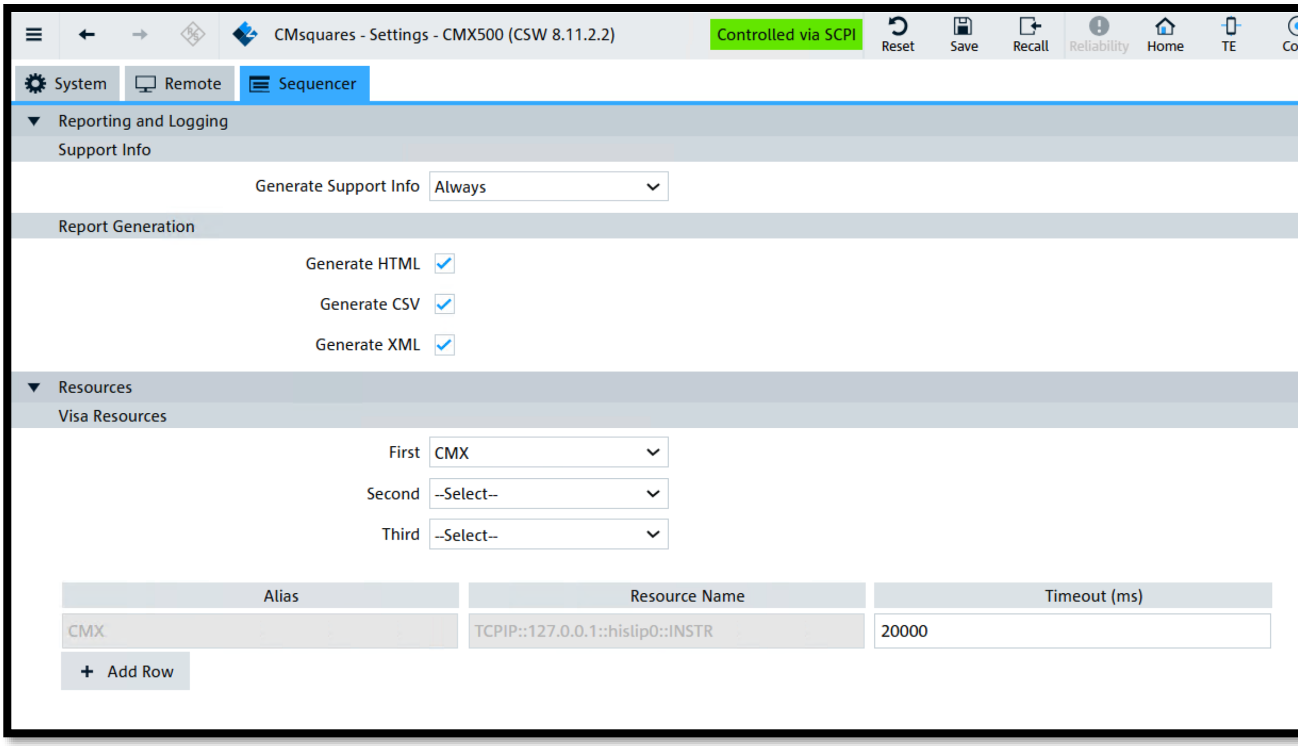


Figure 24: R&S®CMsequencer global settings

For optimizing test time, it is possible to turn log collection off by selecting “Never” under the Generate Support Info selection. Doing so will disable almost all log saving for R&S®CMsequencer runs, in case of issues it is recommended to turn this setting on so adequate support can be provided.

7 Literature

[1] Rohde & Schwarz, "5G NR UE RF conformance 38.521-3," 2021.

[2] IEEE Computer Society, "IEEE Standard for Information Technology Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks Specific RequirementsPart 11: Wireless LAN Medium Access Control Amendment 1: Enhancements for High-Efficiency WLAN," 2021.

[3] FCC, "FCC CFR47".

[4] ETSI EN 301 908-25, "IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 25: New Radio (NR) User Equipment (UE) Release 15," 2024.

[5] ETSI TS 138.521-1 V17.10.0 (2023-10), "5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 1: Range 1 standalone; (Release 17)".

[6] ETSI TS 138.521-3 V17.10.0 (2023-10), "5G; NR; User Equipment (UE) conformance specification; Radio transmission and reception; Part 3: Range 1 and Range 2 interworking operation with other radios; (Release 17)".

8 Ordering information

Designation	Type	Order No.
Base 5G NR signaling	R&S®CMX-KS600B	1222.1672.02
Base WLAN signaling (802.11a/b/g/n/ac)	R&S®CMX-KS350B	1222.7064.02
WiFi6 signaling (802.11ax)	R&S®CMX-KS351B	1222.7070.02
WiFi7 signaling (802.11be)	R&S®CMX-KS352B	1222.7087.02
Base 5G NR Measurement	R&S®CMX-KM600	1222.4013.02
5G NR Measurements for MIMO	R&S®CMX-KM604	1222.5649.02
Base WLAN measurement (802.11a/b/g/n/ac)	R&S®CMX-KM350	1222.7135.02
WiFi6 measurements (802.11ax)	R&S®CMX-KM351	1222.7141.02
WiFi7 measurements (802.11be)	R&S®CMX-KM352	1222.7158.02
Composite 3GPP for NSA	R&S®CMX-KC660	1222.4507.02
Composite 3GPP for SA	R&S®CMX-KC661	1222.4513.02
Composite 3GPP for Redcap	R&S®CMX-KC664	1222.7770.02
Composite ETSI RED	R&S®CMX-KC653	1222.8648.02
Composite IEEE for WLAN	R&S®CMX-KC350	1222.8648.02
FCC Test Cases	R&S®CMX-KC652	1222.8190.02

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Application Note | Pre-conformance Testing with R&S®CMX500 and CMsequencer
Data without tolerance limits is not binding | Subject to change