Application Note

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

Products:

- ► R&S[®]CMX500
- ► R&S[®]CMsequencer

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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:

- ► <u>GCF/PTCRB</u>
 - Global Quality standards for device interoperation; GCF is relevant for Europe while PTCRB is the North American counterpart
- ► <u>3GPP</u> - M
 - Main Cellular technologies association, takes care of 3G/4G/5G/6G
- ► <u>FCC</u>
 - United States regulatory body for Radio Frequency communications
- ► <u>ETSI</u>
 - European standardization body for 3GPP Standards
- ► <u>IEEE</u>
 - 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/rsts8980-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.

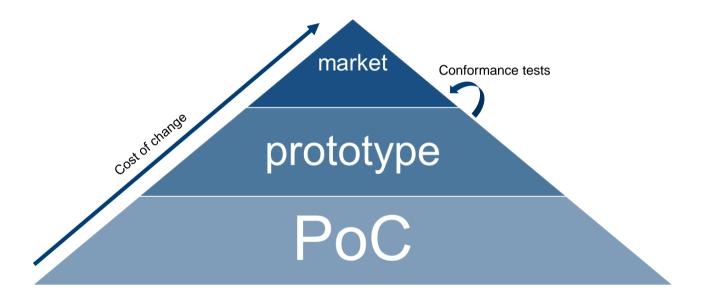


Figure 2: Pyramid of costs in Wireless devices R&D

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.

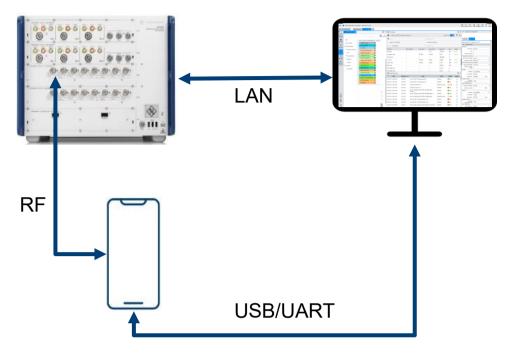


Figure 3: Connection setup of a R&S®CMX500 OBT for pre-conformance testing with UE automation

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

Bands 8	& Connectors	RF Connections	Band Restri	ictions	Automation	Sim	Slot 1 📋									
/ Hide	Default Connectio	ons											Calculate	Optimu	m Deplo	yment
▼ Cor	nnections															
	Name	🔷 DUT Conr	ector 🛔	m Connector	🕈 FDA	MRT to DU	JT			🔷 FDA	DUT to MR	т				
	Connection 1	Connector1	✓ Slo	ot3 RF Com1	1 🗸	4.00	dB +		•	Ø	4.00	dB +		•	Ø	Ŵ
1	Connection 2	Connector2	✓ Slo	ot3 RF Com2	2 🗸	4.00	dB +		•	Ø	4.00	dB +		•	Ø	Î
	Connection 3	Connector3	✓ Slo	ot4 RF Com1	1 🗸	4.00	dB +		•	Ø	4.00	dB +		•	٢	Ŵ
	Connection 4	Connector4	∽ Slo	ot4 RF Com2	2 🗸	4.00	dB +		•	Ø	4.00	dB +		•	Ø	Û
	nnections View els: 🗹 Cells	Measurements														
		Managements														
		CMX500 (
	els: 🗹 Cells 🗌	CMX500 (IF Unit	(Slot1)													
	els: 🗹 Cells 🗌 Port1	CMX500 (IF Unit Por	(Slot1) t2	Port3												
	els: 🗹 Cells 🗌 Port1	CMX500 (IF Unit	(Slot1)	Port3	3 IF Out											
	els: 🗹 Cells 🗌 Port1	CMX500 (IF Unit Por IF Out IF In	(Slot1) t2 IF Out	IF In				7879								
	els: 🗹 Cells 🗌 Port1	CMX500 (IF Unit IF Out IF In	(Slot1) t2 IF Out (Slot2)	IF In	IF Out	C	Connection 1		n							
	Port1	CMX500 (IF Unit Por IF Out IF In IF Unit Por IF Out IF In	(Slot1) t2 IF Out (Slot2) t2 IF Out	IF In Port3	IF Out 3 IF Out		Connection 1	Connecto	-							
	Port1	CMX500 (IF Unit IF Out IF Out IF IF In IF Unit Por	(Slot1) t2 IF Out (Slot2) t2	IF In Port3	IF Out	NR Ce	Connection 2 ell 1: DL1, UL1	Connector	r2							
	Port1 IF In IF In IF In	CMX500 (IF Unit IF Out IF Out IF Out IF Out IF Out RF Unit	(Slot1) t2 IF Out (Slot2) t2 IF Out IF Out (Slot3)	IF In Port3 IF In	IF Out	NR Ce	Connection 2 ell 1: DL1, UL1 Connection 3	Connector	r2							
	Port1	CMX500 (IF Unit IF Out IF Out IF Out IF Out IF Out RF Unit	(Slot1) IF Out (Slot2) t2 IF Out IF Out	IF In Port3 IF In	IF Out	NR Ce	Connection 2	Connector Connector	r2 r3							

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 dropdown menu.

Test System Conr	nector	🛊 FDA	MRT to D	UT 🔶 FDA DU
Slot3 RF Com1	~	4.00	dB +	4.00
Slot3 RF Com2	~	4.00	dB +	Pathloss_table_0
Slot4 RF Com1	~	4.00	dB +	Pathloss_table_1
Slot4 RF Com2	~	4.00	dB +	Pathloss_table_2
				Pathloss_table_3
				Pathloss_table_4
				□ 12db
				SetAttenuationTable_Connection3_0.Slot4.RFCom1_tx
				SetAttenuationTable_Connection3_0.Slot4.RFCom1_rx

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:

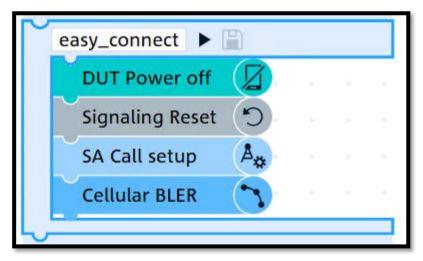


Figure 6: Simple 5G connection with BLER measurement for stability verification

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

✤ Sequencer Confi	guration		×					
Settings Edit View			9					
-			Search					
Properties Parame			*					
Selected Block: "SA C	all setup"		Favorite					
▼ NR Cell	[
Cell Name	NR Cell 1		DUT					
Physical Cell ID	0							
Power Level Mode	Total Cell Power	\sim	Network					
Cell Power	-44.8	dBm	E					
SSB EPRE	-80.0	dBm/15k	General					
Maximum Cor	nfig (For Hw Resource A	llocation)						
 Downlink 			Sequencer					
Frequency Range	FR1	~	<u> </u>					
Duplex Mode	\sim	Global Services						
Frequency Band Indicator	· · · · · · · · · · · · · · · · · · ·							
SubCarrierSpacing								
ARFCN Input Mode	DL Only	~						
 Expected Upli 	nk Level		NR FR1 TX 1					
 Cell Timing 								
 RRC Connection 	on		Power					
Keep RRC Connection	Enable	\sim	Monitor					
 Downlink-Upl 	ink		•					
Carrier Bandwidth	10 MHz	\sim	RX Meas					
Point A Location	Mid Range	\sim						
Set Carrier Center	false	\sim						
Center Frequency	634,500	MHz						
Set Frequency	false	\sim						
Frequency	606.600	MHz						
NR ARFCN	121320							
Offset to Carrier	102							

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

= ←	→ 🛞 💠 CM:	squares - Workspa	ace - CMX500 (CSW	8.11.0.12)						Contro	olled via SCPI	ි Reset	E Save	Recal	Reliability
- Test Er	wironment 🔟 Work	kspace Sequen	ncer 🗙 🛄 Wa	orkspace 1 🗙	+										
	Sequence Editor						$\Sigma \times$		Test Report						23 ×
E	Y Q	ې 🔁	• •	н 🗠	÷ •	¢	•	₩	Search for Content						9
General		Refresh Import	Stop Skip P	Pause Step (Continue Undo	o Redo			3GPP SA LOOD	— CMsequencer Test Sci	ipt				Autoscroll
E	New								•	•					
Sequencer	Recently Used		iPP_SA_loop 🕨 🕻						0		Start 2025-0	04-17 18:3	0:58		
<u>(a)</u>	Flow Controls		loop 5 times						End		Duration				
IP Meas & Tools	Function Blocks		DUT Power off Signaling Rese												
& 10015	R&S Script Packages		Set PLMN		Å _o										- 1
GPRF			Set 5GS Trackir	ng Area	Α.				TRACE NR FR1 SA 3G	PP Composite - n5 / 15kHz / 2	0MHz(High)				
	R&S Updater Scripts		Configure NR C	Cell	٨.				ND ED1 6 3 1 LIE	naximum output power @ n	5 / 15ku- / 1		(ch)		- 1
Media	User Items		Configure Net												
			Configure 5GS						Test Item	Test Condition		Upper Limit	Measu	ı Unit	Verdict
all NR FR1			Activate NR Ce		(A)		\$								_
			DUT Power on Verify 5GS Reg						6.2.1 UE maximum output	n5; 166800; 20MHz; 15kHz DFT-s-OFDM PI/2 BPSK;	; 20.30	25.70	24.01	dBm	Passe d
			NR FR1 3GPP C			a (33%) Ex	⊕ ecutina T		power	Inner_Full(50@25); Pumax					u
				iomposite sit		- (5576) 28	0			pc3; ID: 1, pmax=OFF					I
						1.0			6.2.1 UE maximum output	n5; 166800; 20MHz; 15kHz DFT-s-OFDM PI/2 BPSK;	; 20.30	25.70	25.12	dBm	Passe d
						· · · ·	n - 1		power	Inner_1RB_Left(1@1); Purr	ax;				
~							· · ·			pc3; ID: 2, pmax=OFF					
D Reset View									6.2.1 UE	n5; 166800; 20MHz; 15kHz	; 20.30	25.70	23.72	dBm	Passe
æ	Recent Test Runs ×	Sequence O	-												20 ×
Multi	Start (UTC)	Duration ((h:m:s)				Scri	pt			Stat	us	Vei	rdict	Actions
	2025-04-17 18:30:57	4 mins 33	secs 3GPP_SA_I	loop							Running				
Tab															

Figure 9: Testcase during execution in CMsequencer composite block

For manual 3GPP testing please refer to the Application note below: <u>https://scdn.rohde-</u> <u>schwarz.com/ur/pws/dl_downloads/dl_application/application_notes/1sl/1SL368_0e_5G_NR_UE_RF_confor</u> <u>mance_38.521-3.pdf</u> [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 Environme [5] subclause 4.	nt as specified in TS 38.508-1 1	Normal, TL/VL, TL/VH, TH/VL, TH/VH								
Test Frequencie [5] subclause 4.	es as specified in TS 38.508-1 3.1	Low range, Mid range, High range								
Test Channel B 38.508-1 [5] sub	andwidths as specified in TS oclause 4.3.1	Lowest, Mid, Highest (NOTE 3)								
Test SCS as sp	ecified in Table 5.3.5-1	Lowest, Highest								
		Test Parameters								
Test ID	Downlink Configuration	Uplink Configuration								
	N/A for maximum output	Modulation (NOTE 2) RB allocation (NOTE 1								
1	power test case	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 2: DFT- NOTE 3: For b	s-OFDM PI/2 BPSK test applies	allocation is defined in Table 6.1-1. only for UEs which supports half Pi BPSK el bandwidth is replaced by 20MHz due to	in FR1.							

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;

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DUT

Network

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General

E Sequence

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Global Services

Media

- Х× Sequence Editor Sequencer Configuration Ţ. Settings Edit View CREfresh Import н. M 11. \cap -* T Q . Pin Stop Skip Step Continue Undo . Redo Pause Properties Parameter New SAfull_MTP 🕨 📄 Selected Block: "NR FR1 3GPP Composite SA" 6215A_MTP 🕨 🗎 Recently Used 3GPP Settings loop 1 times Flow Controls Configuration Input GUI (default) \sim DUT Power off Function Blocks Signaling Reset 3 3GPP Test Mode 3GPP User Strict \sim Set PLMN A. R&S Script Packages NR 38.521 Testcase Settings ... Å. Set 5GS Tracking Area **R&S Updater Scripts** NR 38.521 Band Settings ... Å. Configure NR Cell User Items Configure 5GS Registration E. NR 38.521 Band Flex Settings Activate NR Cell(s) (A) Snippets Cell Reconfiguration Mode DUT Power on Band Change Power Cycle \sim Test Plans Verify 5GS Registration E. Bandwidth Change Power Cycle \sim Test Scripts NR FR1 3GPP Composite SA Channel Change Power Cycle \sim NR 6.2.1 UE Maximum Output Power 📶 testfold Connection Drop Handling 0 **DUT** Automation \sim 6225A MTP > Graphs Ð 6235A MTP > Enable false \sim Θ 6245A MTP > Type Only Failed Test IDs \sim 6315A_MTP ► Re-Test Failed Items 63325A_MTP Ш Enable false \sim 63345A MTP Max. Re-attempts Measurement Report 50 × Indicate 3GPP Compliant Skipped Test Cases in Test ript Status Verdict Actions false \sim Finished PASS ŝ Report Minimum Power Test Points Finished PASS ŝ Disable false \sim Threshold -31.7 dBm 10-03-2025 18:13:59 (UTC) 📮
- 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.

3GPP Testcase	×
▼ ■ R15	
 6 Transmitter characteristic 	
6.2.1 UE maximum output power	
6.2.2 UE maximum output power reduction	
6.2.3 UE additional maximum output power reduction	
6.2.4 Configured transmitted power	
6.3.1 Minimum output power	
6.3.2 / 6.3.3.2 General ON/OFF time mask	
6.3.3.4 PRACH time mask	
6.3.3.6 SRS time mask	
6.3.4.2 Absolute Power Tolerance	
6.3.4.3 Relative power control	
6.3.4.4 (PUSCH) Aggregate Power Tolerance	
6.3.4.4 (PUCCH) Aggregate Power Tolerance	
6.4.1 Frequency error	
✓ 6.4.2.1 (PUSCH) Error Vector Magnitude	
6.4.2.1 (PRACH) Error Vector Magnitude	
 6.4.2.1 (PUCCH) Error Vector Magnitude 	
6.4.2.2 Carrier Leakage	
 6.4.2.3 (PUSCH) In-band emissions 	
 6.4.2.3 (PUCCH) In-band emissions 	
✓ 6.4.2.4 EVM equalizer spectrum flatness	
✓ 6.4.2.5 EVM equalizer spectrum flatness for Pi/2 BPSK	-
Cancel	Apply

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.

Set	Default													Delete	e Band		Add User Band	
Band Comb	pination		NR								UE Capab	vilities						
Band	≡	Test	SCS (kH	łz)	BW Lov	v	BW Mid		BW Hig	h	Excluded BW	User Defined UE Capabilities	Access Stratum Release		UE Power Class		Power Boosting π/2 BPSK	PUS BPS
n1A			15	~	low	~	mid	~	high	~			rel16	~	pc3	~		
n2A			15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
13A			15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
15A		✓	15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
17A			15	~	low	~	mid	~	high	~			rel16	~	pc3	~		
18A			15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
112A			15	~	low	~	mid	~	high	~			rel16	~	pc3	~		
n13A			15	~	low	~	mid	~	high	~			rel15	~	рс3	~		
n14A			15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
n18A			15	~	low	~	mid	~	high	~			rel15	~	рс3	~		
120A			15	~	low	~	mid	~	high	~			rel16	~	рс3	~		
124A			15	~	low	~	mid	~	high	~			rel15	~	рс3	~		
125A			15	~	low	~	mid	~	high	~			rel16	~	pc3	~		
26A			15	~	low	~	mid	~	high	~			rel16	~	рсЗ	~		

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	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).

Properties Parame	eter								
Selected Block: "NR FR1 3GPP Composite SA"									
▼ 3GPP Settings									
Configuration Input	GUI (default) (0) 🛛 🗸								
3GPP Test Mode	-								
NR 38.52	21 Testcase Settings								

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:

3GPP Band - Flex	L .															×
Set D	Default							Delete Band	Dupli	icate		A	dd 3GPP Band	Add	l User Band	
Band Combi	ination		NR					UE Capabilities								
Band	≡	Test	SCS (kH	z)	BW		Channel	User Defined UE Capabilities	Access Stratum Release		UE Power	Class	Power Boosting π/2 BPSK	PUSCH π/2 BPSK	PDSCH 256QAM FR1	PL 25 FR
n1A	~		15	~	low	~	low,mid,high		rel16	~	рс3	~				
n3A	~	✓	15	~	high	~	high		rel16	\sim	рс3	\sim				
n7A	~		15	~	10	~	low,mid,high	 Image: A start of the start of	rel15	~	рс3	~	✓	✓	✓	
n41A	~	~	30	~	mid	~	low,mid		rel16	\sim	рс3	\sim				
4																•
1																•
														Cancel	Apply	

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 <u>GLORIS</u> (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.

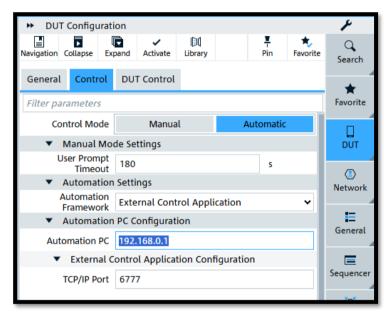


Figure 16: DUT control settings on R&S®CMsquares GUI

ROHDE&SCHWARZ		fonitor Start Stop	Test Channel UE ▼ Rsp: OK Cmd: AT <cr><lf> Delay: 0 Test</lf></cr>
Forward Conversion Reverse Conve	ersion Session Log		
3/11/25 17:53:14.007	INFO	:	Create client socket
3/11/25 17:53:14.009	INFO		Connected
3/11/25 17:53:14.301	SIMULATOR		> Please switch on the airplane mode.
3/11/25 17:53:14.301	INFO	÷	Found - UE
3/11/25 17:53:14.315	UE	1	< AT+CFUN=0 <cr><lf></lf></cr>
3/11/25 17:53:14.317	INFO	÷	Sleeping for 2000 Milliseconds
3/11/25 17:53:16.735	UE	1	> OK
3/11/25 17:53:16.767	INFO	÷	Response consumed, OK
3/11/25 17:53:16.780	SIMULATOR	:	< OK <cr><lf></lf></cr>
3/11/25 17:53:18.980	INFO	1	Create client socket
3/11/25 17:53:18.982	INFO	÷	Connected
3/11/25 17:53:19.284	SIMULATOR	:	> Please switch off the airplane mode.
3/11/25 17:53:19.301	INFO	1	Found - UE
3/11/25 17:53:19.301	UE	1	< AT+CFUN=1 <cr><lf></lf></cr>
3/11/25 17:53:19.316	INFO	1	Sleeping for 2000 Milliseconds
3/11/25 17:53:21.737	UE	÷	> OK+CPIN: READY+QUSIM: 1+QIND: SMS DONE+QI
3/11/25 17:53:21.744	INFO	1	Response consumed, OK+CPIN: READY+QUSIM:
3/11/25 17:53:21.761	SIMULATOR	:	< OK <cr><lf></lf></cr>
			· · · · · · · · · · · · · · · · · · ·

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.

≡ ←	→ 🛞 💠 CN	1squares - W	orkspace - CMX500 (
- []- Test Environment Juli Workspace Sequencer 🗙 Jul							
💾 Squar	es 🕼 Actions	**	Sequence Edit				
	 Sequencer 						
Network	Select All	5how	External				
E	 Sequence Editor 		FCC				
General	Sequence Organ	izer	General				
	 Recent Test Runs 	\leftarrow					
	 Test Report 	1	LTE				
Sequencer	Output		NR				

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

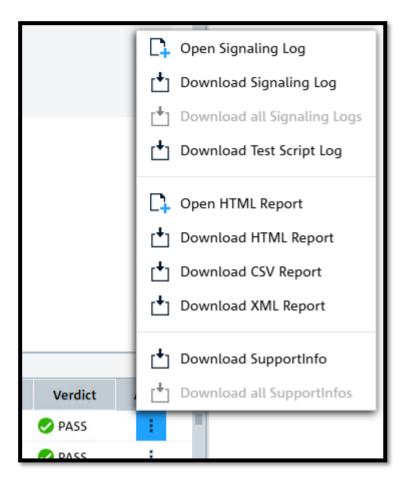


Figure 19: 2-click easy report and log download and visualization

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:

≡ ← → 🛞 💠 CMsqu	ares - CMX500 (CSW 8.11.2.2)	Controlled via SCPI	Save Recall Reliability Home	TE Conn Zoom Out Zoom	In Touch Help
	Î [[↑]] [[↓]] ● lete Upload Download Preview				
← → ↑ 🏠 → USERDATA	Sequencer Test Results Test_Script_Runs			5	
	Name			To Date Modified	Size (Bytes)
21T22_08_47ZSAfull	2024-08-08T16_08_58Z_BASIC_RedCap_SA			2025-04-29 17:34:49	
Test_Script_Runs	2024-08-08T16_10_25Z_BASIC_RedCap_SA			2025-04-29 17:34:49	
► 🖬 2024-07- 23T21_02_20ZCSV	2024-08-08T16_14_22Z_BASIC_RedCap_SA			2025-04-29 17:34:49	
► 2024-07- 23T21_03_25ZCSV	2024-08-08T16_17_09ZBASIC_RedCap_SA			2025-04-29 17:34:49	
23T21_03_25ZCSV	2024-08-08T16_19_57ZBASIC_RedCap_SA			2025-04-29 17:34:49	
► 2024-07- 23T21_12_02ZCSV	2024-08-08T16_27_18ZBASIC_RedCap_SA			2025-04-29 17:34:49	
2024-07- 23T21_20_01ZCSV	2024-08-08T16_28_58ZBASIC_RedCap_SA			2025-04-29 17:34:49	
2024-07- 23T22_07_10Zfsa	2024-08-08T16_32_47ZBASIC_RedCap_SA			2025-04-29 17:34:49	
2024-07-	2024-08-08T16_35_13Z_BASIC_RedCap_SA			2025-04-29 17:34:49	
24T00_41_16ZCSV	2024-08-08T16_42_10ZBASIC_RedCap_SA			2025-04-29 17:34:49	
24T00_41_42ZCSV 2024-07-	2024-08-08T16_48_217BASIC_RedCap_SA			2025-04-29 17:34:49	

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/

← → ↑ 🟠 ► USERDATA	Sequencer Test Results 2025-05-14T18_35_41Z3GPP_spreadsheet_summary
FrequencyDependantAtten	Name
MrtLoggingConfig	2025-05-14T18_35_43Z3GPP_SA_loop_mini
	2025-05-14T18_35_41Z3GPP_spreadsheet_summary.xlsx
Save	2025-05-14T18_35_41Z_3GPP_spreadsheet_summary.html
selftestprofiles	
 Sequencer 	
🕨 🖆 Backup	
Band Combination Data	
Constellation Scenarios	
 Test Results 	

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

	А	В	С	D	E	F	G	Н	1	J	K	L	M 🔺
1	Test Ite 👻	Full Description	▼ Band/Cor ▼	Chann -	BW 👻	SCS 👻	Mod	Condition	Lower Limit 💌	Upper Limit 💌	Measured 💌	Unit -	Verdict 🔄 🚺
2													
3	Test Item												Verdict
4	NR	NR Cell Activation							90.00	16.01	ON :	5	Passed
5	UE	UE Registration							300.00	2.76	Registered :	5	Passed
6													
7	Test Item												Verdict
8	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
9	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
10	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
11	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
12	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
13	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
14	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
15	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
16	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
17	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
18	621	6.2.1 LIF maximum output nower	n78	636666	100MH7	30kHz	DFT-s-OFDM OPSK	Inner 1RR Left(1@	19 00	26.00	19 13	dRm	Passed
	$\langle \rangle$	3GPP Config & Summarv	+					: .	_	_	_		

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

≡	← → 🛞 💠 CMsquares - Settir	gs - CN	1X500 (CSW 8.11.2.2)	Controlled via SCPI	D Reset	E Save	Recall	B Reliability	∱ Home	-D- TE	Cor
۵	System 🖵 Remote 🔚 Sequencer										
•	Reporting and Logging										
	Support Info										
	Generate Support In	Alw	rays 🗸								
	Report Generation										
	Generate HTM	L 🗸									
	Generate CS	/ 🗸									
	Generate XN	L 🗸									
•	Resources										
	Visa Resources										
	Fir	t CM	x ~								
	Secor	dSe	lect 🗸								
	Thi	dSe	lect 🗸								
	Alias		Resc	urce Name			Ti	meout (ms)		
	CMX.		TCPIP::127.0.0.1::hislip0:	:INSTR	20000						
	+ Add Row										

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	Туре	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

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