Application Note

5G NEW RADIO CONDUCTED BASE STATION TRANSMITTER TESTS

according to TS 38.141-1, Rel. 16

Products:

- R&S®FSW
- R&S®FSV3000
- R&S®FSVA3000
- R&S®FSV
- R&S®FSVA
- R&S®FPS
- R&S®SMW200A
- R&S®SMBV100B

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https://www.rohde-schwarz.com/appnote/GFM313

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Contents

1 Introduction

The 5th generation (5G) of mobile networks introduces a paradigm shift towards a user and application centric technology framework.

The goal of 5G New Radio (NR) is to flexibly support three main service families:

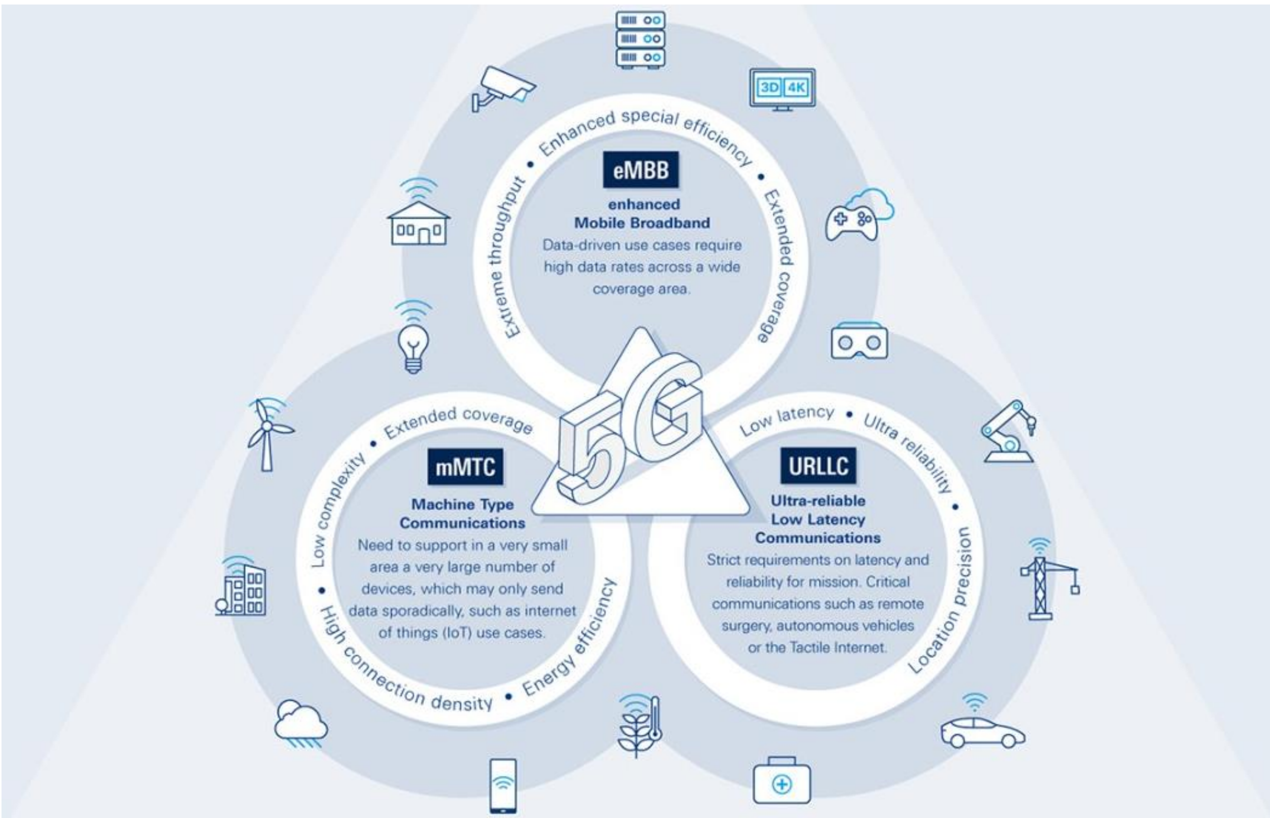


Figure 1: 5G New Radio main service families

- ► Enhanced mobile broadband (eMBB) for higher end-user data rates
- ► Massive machine type communications (mMTC) targets cost-efficient and robust D2X connections
- ► Ultra-reliable, low latency communications (URLLC) supporting new requirements from vertical industries such as autonomous driving, remote surgery or cloud robotics

3GPP, the responsible standardization body, defines the Radio Frequency (RF) conformance test methods and requirements for NR Base Stations (BS) in the technical specifications TS 38.141 which covers transmitter (Tx), receiver (Rx) and performance (Px) testing.

The technical specification **TS 38.141** consists of two parts depending on whether the test methodology has conducted or radiated requirements:

- ► **TS 38.141-1: Part 1** [1]: Conducted conformance testing
- ► **TS 38.141-2: Part 2** [2]: Radiated conformance testing

This application note describes how all mandatory **RF transmitter tests (TS 38.141-1, chapter 6)**, according to Release 16 (V16.3.0), can be performed quickly and conveniently with signal or spectrum analyzers from Rohde & Schwarz by either choosing manual operation or a remote control approach. Moreover, one test case requires an additional signal generator for interferer generation. More information can be found in the respective test case section.

Generally, each chapter is structured in three sections:
First, a short introduction at the beginning of a chapter is covering the scope of the individual test case showing the necessary testing parameters and a schematic test setup. Next, there comes the step-by-step description of the manual testing procedure for manual testing enhanced by device images and screenshots. Last but not least, each test case is closed by the corresponding SCPI commands sequence required for remote operation or the implementation in user-defined test software.

Hereinafter, Table 1 gives an overview of all 5G base station transmitter tests covered individually in this document.

Table 1: conducted BS transmitter tests (TS 38.141-1, chapter 6)

TS 38.141-1	Test	Single carrier (SC)	Multi carrier (MC)
6.2	Base station output power	✓	×
6.3	Output power dynamic range		
6.3.2	RE power control dynamic range	✓	×
6.3.3	Total power dynamic range	✓	×
6.3.4	NB-IoT RB power dynamic range	✓	×
6.4	Transmit ON/OFF power	✓	×
6.5	Transmitted signal quality		
6.5.2	Frequency error	✓	×
6.5.3	Modulation quality	✓	×
6.5.4	Time alignment error	✓	×
6.6	Unwanted emissions		
6.6.2	Occupied bandwidth	✓	×
6.6.3	Adjacent channel leakage power ratio (ACLR)	✓	×
6.6.4	Operating band unwanted emissions	✓	×
6.6.5	Transmitter spurious emissions	✓	×
6.7	Transmitter intermodulation	✓	×

Note: This document covers single carrier (SC) tests only.

Additionally, several software libraries come with this application note. They are meant to demonstrate the remote-control approach of base station testing and are provided as is. See Appendix for further information.

Base station (RF) receiver tests (TS 38.141-1, chapter 7) are described in GFM314.

Base station (RF) performance tests (TS 38.141-1, chapter 8) are described in GFM315.

For further reading

Find a more detailed overview of the technology behind 5G New Radio from this Rohde & Schwarz book [3] and www.rohde-schwarz.com/5G.

2 General Test Conditions

2.1 Safety indication

VERY HIGH OUTPUT POWERS CAN OCCUR ON BASE STATIONS.
MAKE SURE TO USE SUITABLE ATTENUATORS IN ORDER TO PREVENT DAMAGE TO THE TEST EQUIPMENT.

2.2 Base station classes and configurations

The minimum RF characteristics and performance requirements for 5G NR in-band base stations are generally described in 3GPP document TS 38.104 [4].

2.2.1 BS type 1-C and 1-H reference points (TS 38.104, chapter 4.3)

This application note covers conducted measurements only. In [1] and [4] two different base station types are defined for frequency range one (FR1).

2.2.1.1 BS type 1-C (FR1, conducted)

For this type of BS, the transceiver antenna connector (port A) is accessible directly. If any external equipment such as an amplifier, a filter or the combination of both is used, the test requirements apply at the far end antenna connector (port B) of the whole system.

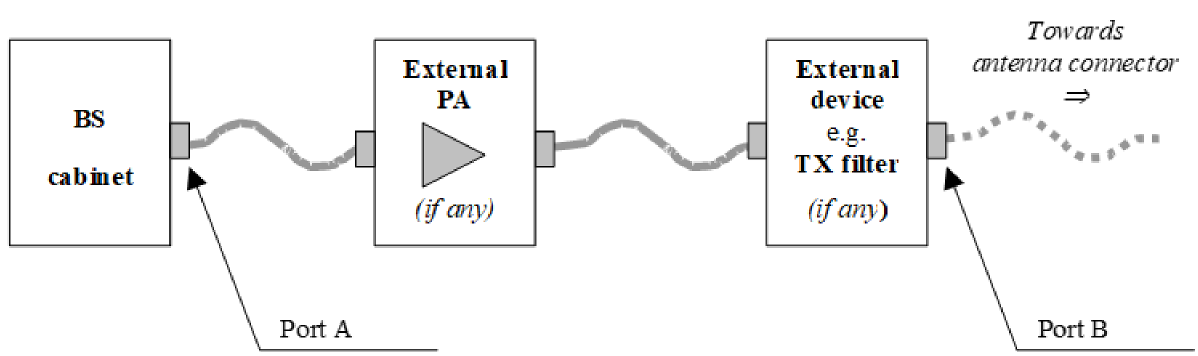


Figure 2: BS type 1-C transmitter interface [1]

2.2.1.2 BS type 1-H (FR1, hybrid)

This base station type has two reference points fulfilling both radiated and conducted requirements.

Conducted characteristics are defined at the transceiver array boundary (TAB) which is the conducted interface between the transceiver unit array and the composite antenna equipped with connectors for conducted measurements. All test cases described in this application note apply to conducted measurements at the transceiver array boundary (TAB).

Radiated characteristics are defined over-the-air (OTA) and to be measured at the radiated interface boundary (RIB). The specific requirements and test cases are defined in TS 38.141-2 [2]. Furthermore, the specific OTA measurements are described in extra Rohde & Schwarz application notes [5] and [6].

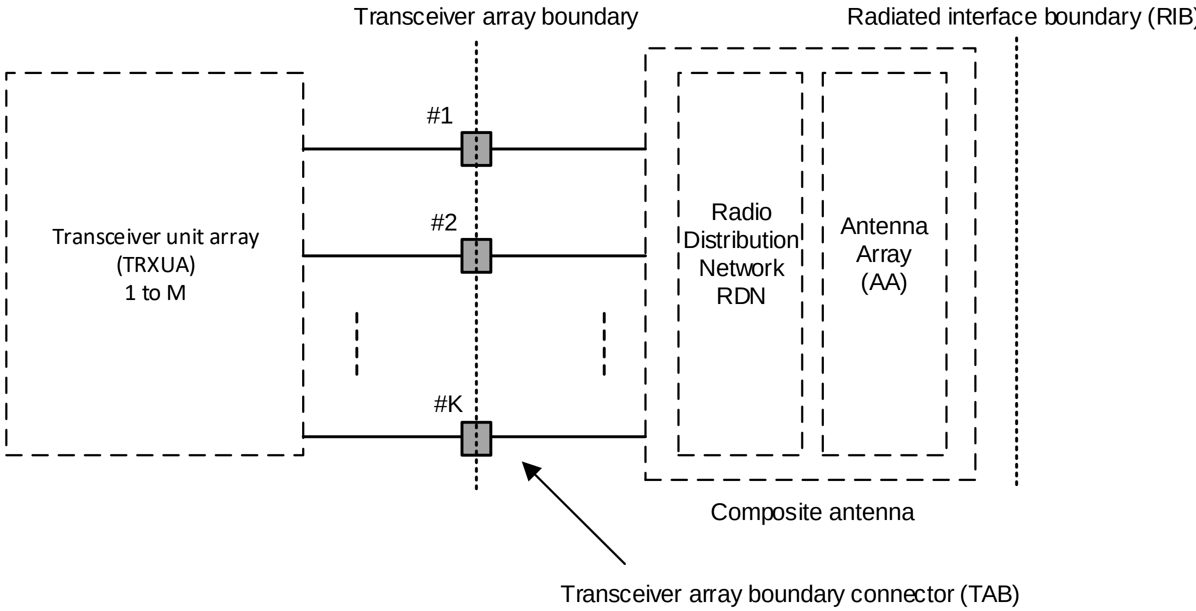


Figure 3: Radiated and conducted reference points for BS type 1-H [1]

2.2.2 BS classes (TS 38.104, chapter 4.4)

This specification distinguishes three different base station classes.

Table 2: Base station classes

Name	Cell size	Minimum coupling loss
Wide area	Macro cell	70 dB
Medium range	Micro cell	53 dB
Local area	Pico cell	45 dB

2.3 5G NR frequency ranges

The frequency ranges in which 5G NR can operate according to Rel. 16 (V16.3.0) are shown in Table 3.

Table 3: Frequency ranges [4], chapter 5

Frequency range designation	Corresponding frequency range
FR1	410 MHz - 7125 MHz
FR2	24250 MHz - 52600 MHz

2.4 R&S devices and options

Any of the following Rohde & Schwarz signal and spectrum analyzers can be used for the tests described in this document:

► R&S®FSW

► R&S®FSV3000 and R&S®FSVA3000

► R&S®FSV and R&S®FSVA

► R&S®FPS

► R&S®VSE Signal Analysis Software

Furthermore, the **5G NR Downlink Measurements** software option is needed:

► R&S®FSW-/FSV3-/FSV-/FPS-/VSE-K144

For further information on R&S signal and spectrum analyzers, please see:

https://www.rohde-schwarz.com/signal-spectrum-analyzers

The **Transmitter Intermodulation Test Case (6.7)** requires an additional interfering signal. This interferer can be generated by any of the following Rohde & Schwarz vector signal generators equipped with **-K144 5G NR software** option:

► R&S®SMW200A

► R&S®SMBV100B

For demonstration purposes any of these signal generators mentioned before can be used to simulate a 5G NR base station as well.

For further information on R&S signal generators, please see:

https://www.rohde-schwarz.com/signalgenerators

The following test equipment and abbreviations are used in this application note:

► The R&S®FSW spectrum analyzer is referred to as the **FSW**

► The R&S®SMW200A vector signal generator is referred to as the **SMW**

3 RF Transmitter Tests (TS 38.141-1, chapter 6)

Specification TS 38.141-1 [1] defines the tests required in the various frequency ranges and positions (**B**ottom, **M**iddle, **T**op) in the operating band. In instruments from Rohde & Schwarz, the frequency range can be set to any frequency within the supported range independently of the operating bands.

Please note that this version of the application note describes single carrier tests (SC) only.

In order to allow comparisons between tests, test models (TMs) standardize the resource block (RB) allocations. For NR, these are called enhanced NR TMs with the frequency range (e.g. NR-FR1-TM1.1). The NR-TMs are stored as predefined settings on instruments from Rohde & Schwarz.

Table 4 provides an overview of the basic parameters for the individual tests numbered by the chapters of TS 38.141-1 and linked to the corresponding chapters in this application note. Both, the required test models (TM) and the frequency positions (B, M, T) to be measured are shown.

Table 4: Transmitter tests covered in this application note

Test Case (TS 38.141-1)	Measurement	TM	Channels	Single carrier	Comment
6.2	Base station output power	TM1.1	B, M, T	Any SC	
6.3	Output power dynamic range				
6.3.2	RE power control dynamic range	TM2 TM2a TM3.1 TM3.1a TM3.2 TM3.3	B, M, T	Any SC	Tested together with 6.5.3
6.3.3	Total power dynamic range	TM2 TM2a TM3.1 TM3.1a	M	Any SC	
6.3.4	NB-IoT RB power dynamic range	TM1.1 TM1.2	B, M, T	Any SC	Tested together with 6.6.4
6.4	Transmit ON/OFF power	TM1.1	M	Any SC	TDD only
6.5	Transmitted signal quality				
6.5.2	Frequency error	TM2 TM2a TM3.1 TM3.1a TM3.2 TM3.3	B, M, T	Any SC	
6.5.3	Modulation quality	TM2 TM2a TM3.1 TM3.1a TM3.2 TM3.3	B, M, T	Any SC	
6.5.4	Time alignment error	TM1.1	M	Any SC	
6.6	Unwanted emissions Unwanted emissions				
6.6.2	Occupied bandwidth	TM1.1	M	Any SC	
6.6.3	Adjacent channel leakage power ration (ACLR)	TM1.1 TM1.2	B, M, T	Any SC	
6.6.4	Operating band unwanted emissions	TM1.1 TM1.2	B, M, T	Any SC	
6.6.5	Transmitter spurious emissions	TM1.1	B, T	Any SC	
6.7	Transmitter intermodulation	TM1.1	M	Any SC	Interferer (SCS:15kHz)

3.1 Complete Tx test setup overview

Figure 4 shows the general test setup for transmitter tests. A FSW spectrum analyzer is used to perform the measurements. A SMW signal generator acts as interferer. Some tests require a modified setup which is described in the respective sections in detail.

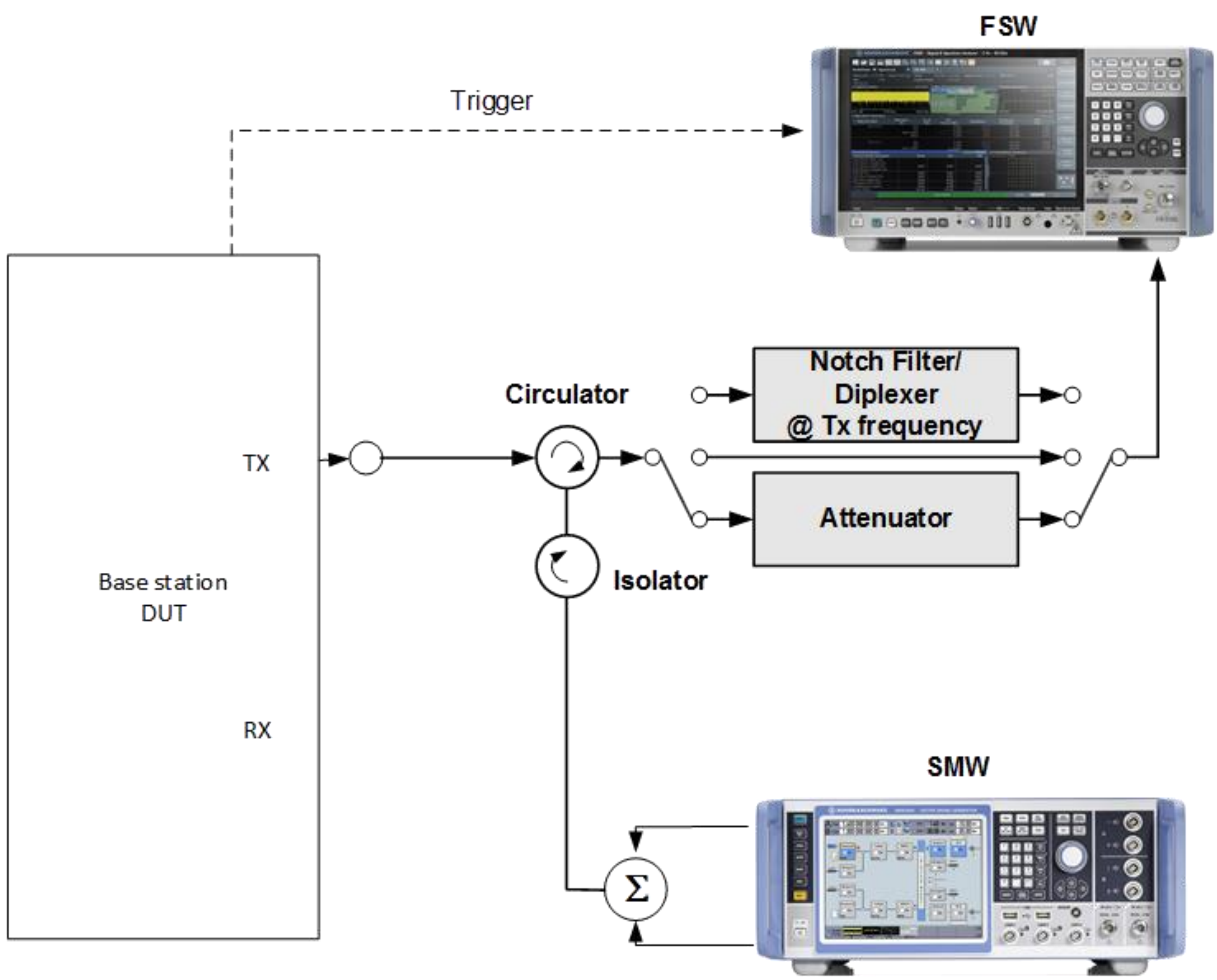


Figure 4: Complete Tx test setup overview

3.2 Recommended R&S devices and options

Table 5: Overview of required instruments and software options

Test Case (TS 38.141-1)	Measurement	Instruments and Options			
		Wanted 5G NR Downlink Signal		Interferer	
		FSW Base Unit	FSW Option	SMW Base Unit	SMW Option
6.2	Base station output power	✓	K144	×	
6.3	Output power dynamic range				
6.3.2	RE power control dynamic range	✓	K144	×	
6.3.3	Total power dynamic range	✓	K144	×	
6.3.4	NB-IoT RB power dynamic range	✓	K144	×	
6.4	Transmit ON/OFF power	✓	K144	×	
6.5	Transmitted signal quality				
6.5.2	Frequency error	✓	K144	×	
6.5.3	Modulation quality	✓	K144	×	
6.5.4	Time alignment error	✓	K144	×	
6.6	Unwanted emissions Unwanted emissions				
6.6.2	Occupied bandwidth	✓, B	×	×	
6.6.3	Adjacent channel leakage power ration (ACLR)	✓	K144	×	
6.6.4	Operating band unwanted emissions	✓	K144	×	
6.6.5	Transmitter spurious emissions	✓, B	×	×	
6.7	Transmitter intermodulation	✓	C	✓	K144

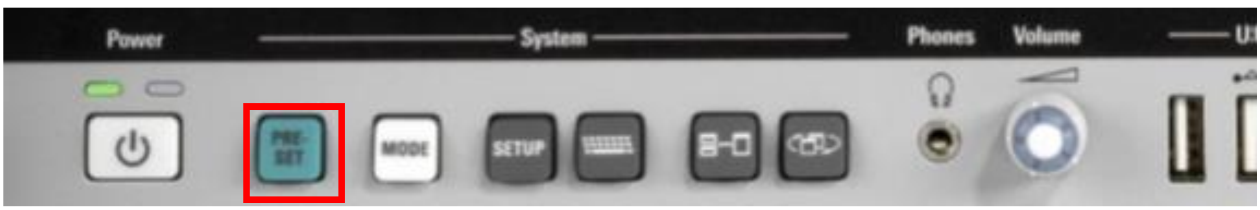
✓: mandatory for the measurement
B: uses basic function: spectrum analyzer mode
C: combined measurements: ACLR, SEM and spurious emissions
×: not applicable for the measurement

3.3 Basic FSW operations

Most of the tests described in this application note follow the same initial steps which are explained hereinafter.

3.3.1 Reset the instrument

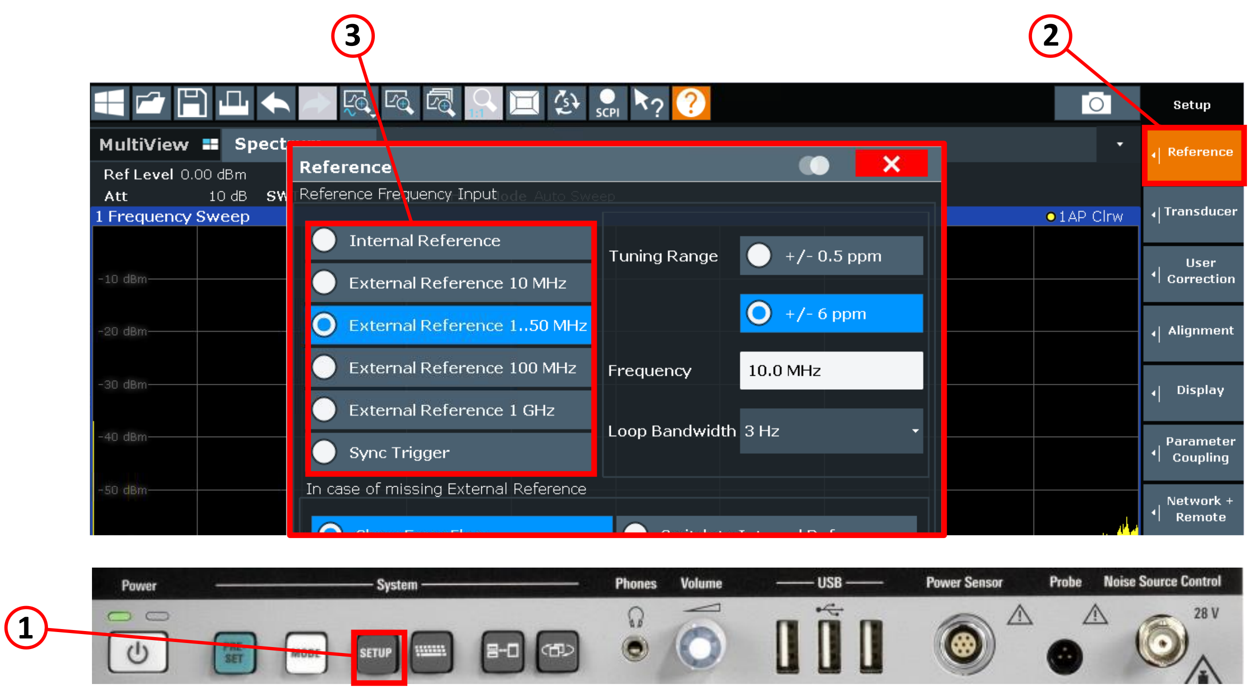
Before executing any test, it is recommended to reset the instrument to the default state by pressing the **PRESET** key at the front panel of the instrument.



3.3.2 Using external references

For some measurements the FSW must be synchronized via an external reference to a high precision time reference. After the external reference signal has been connected to the reference input on the rear panel, it is necessary to change the reference frequency input to **External Reference** by the following steps:

- ► Enter the instrument's setup menu by pushing the ① **SETUP** key on the front panel (1)
- ► Select ② **Reference** from the sidebar
- ► Select the corresponding ③ **External Reference** (10MHz, 1…50MHz, 100MHz, 1GHz) from the list box of the popup windows



3.3.3 Performing a single-shot measurement

The buttons controlling the acquisition status are located on the front panel under **Function Keys** section.

- ► ① **RUN SINGLE** starts a new single-shot measurement and stops the acquisition afterwards.
- ► ② **RUN CONT** starts continuous and repetitive measurements.

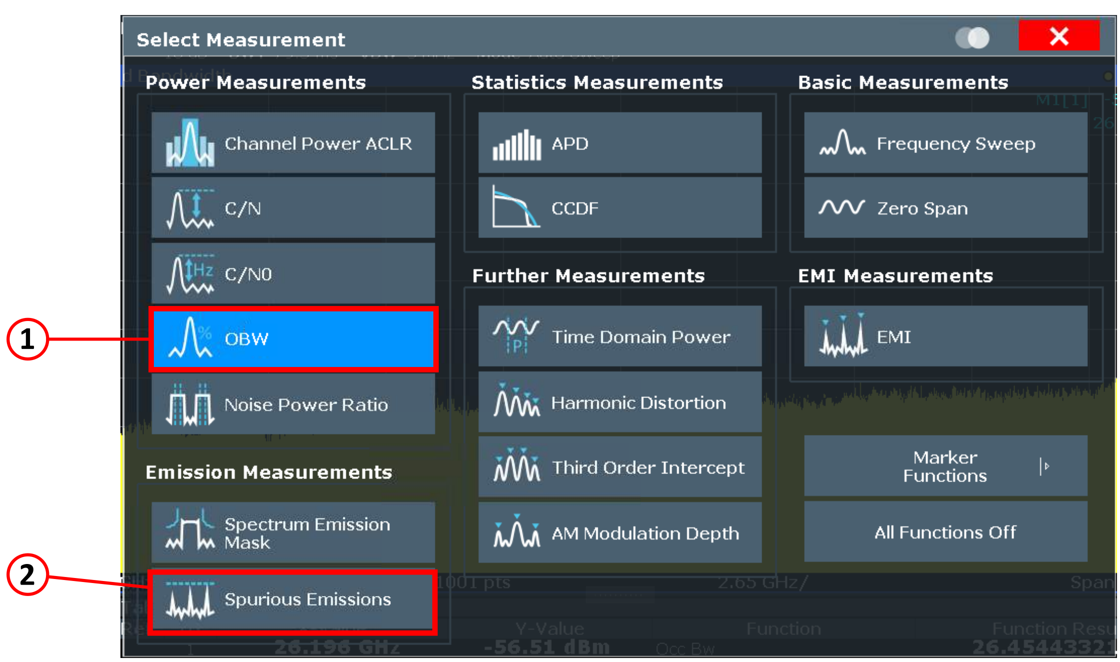
3.3.4 Changing operation and measurement modes

For the following base station transmitter tests different operation modes (**Spectrum** or **5G NR**) are required. The mode which is required for each test is specified in the respective sections.

Depending on the operation mode, different measurements are available. What measurement is required for which test is specified in the respective section. Select the measurement by pressing **Select measurement** at the overview-screen or by pressing **MEAS** key on the front panel of the instrument.

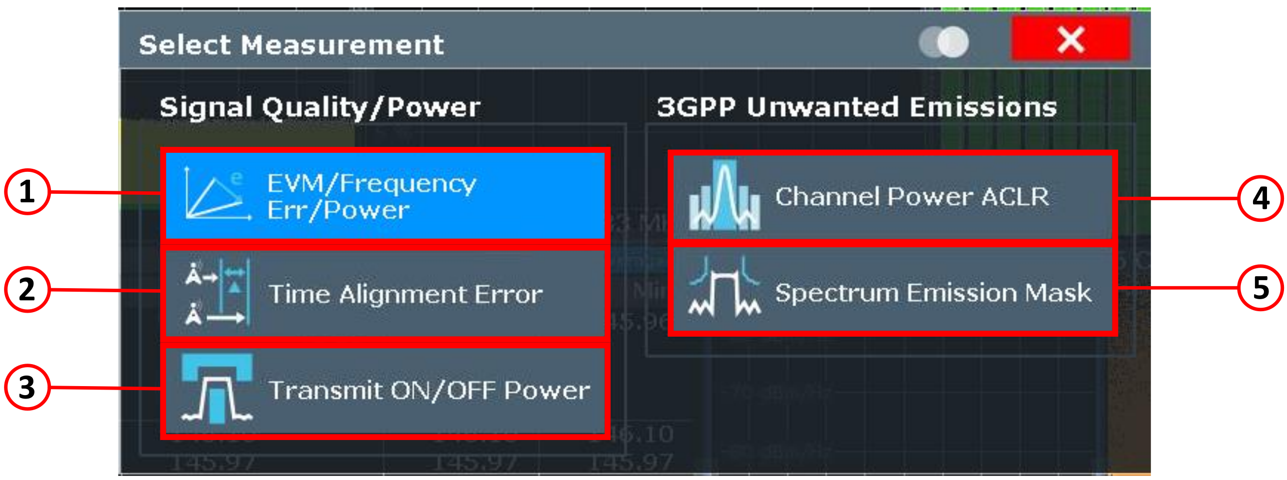
3.3.4.1 Measurements in Spectrum mode

①: Used for Occupied bandwidth (OBW) (6.6.2)
②: Used for Transmitter spurious emissions (6.6.5)



3.3.4.2 Measurements in 5G NR mode

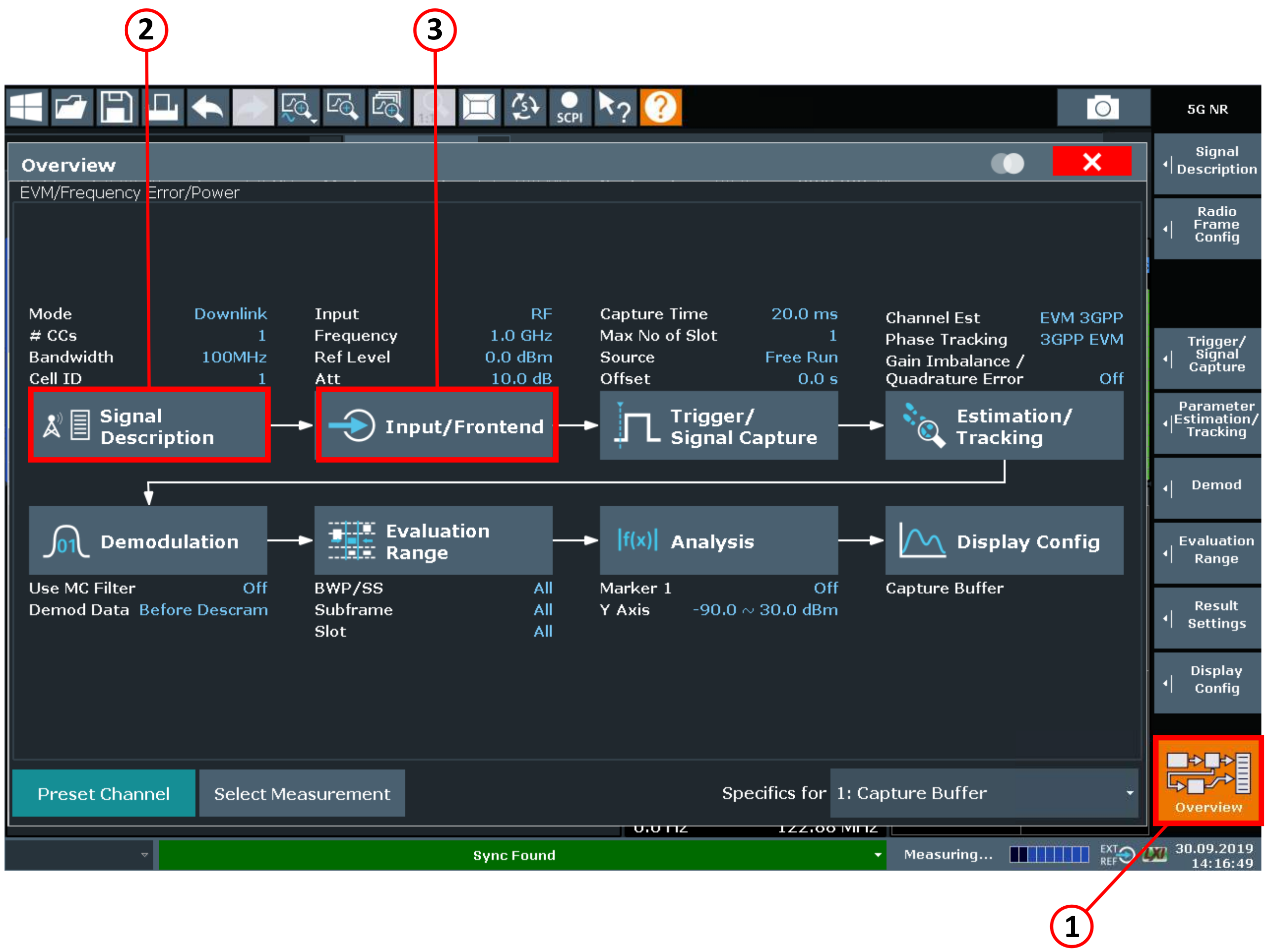
①: Used for Base station output power (6.2), Frequency error (6.5.2) and modulation quality (6.5.3)
②: Used for Time alignment error (TAE) (6.5.4)
③: Used for Transmit on/off power (6.4)
④: Used for Adjacent channel leakage power (ACLR) (6.6.3)
⑤: Used for Operating band unwanted emissions (OBUE) (SEM) (6.6.4)



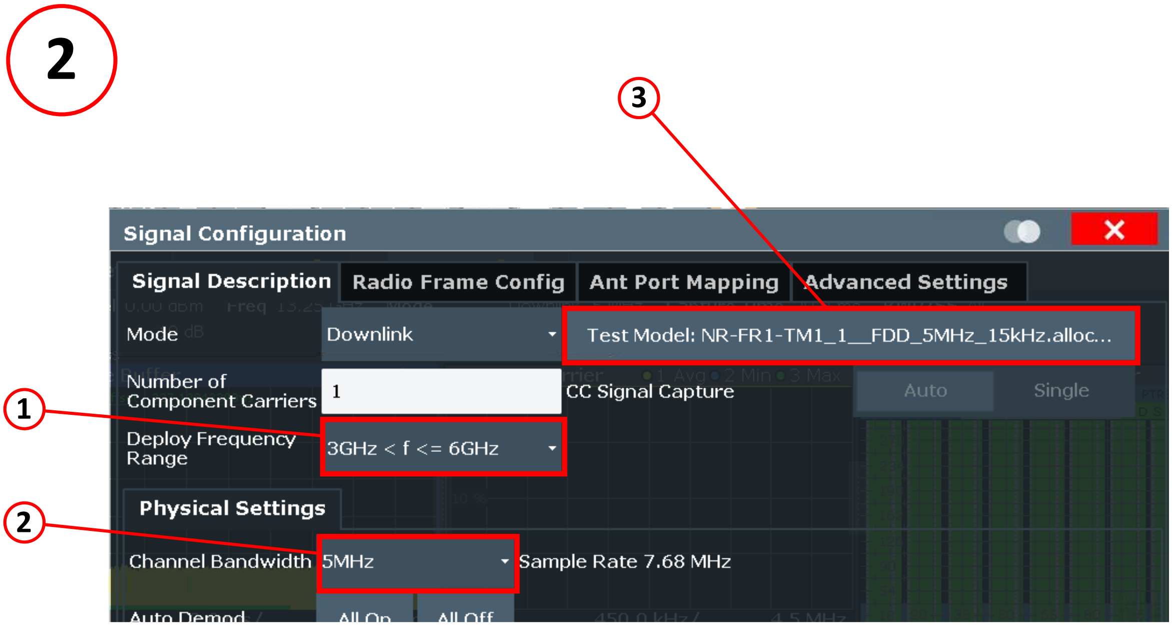
3.3.5 Settings for 5G NR signal analysis

The FSW spectrum analyzer provides an overview-screen where the most important common settings for analyzing a 5G NR signal can be made:

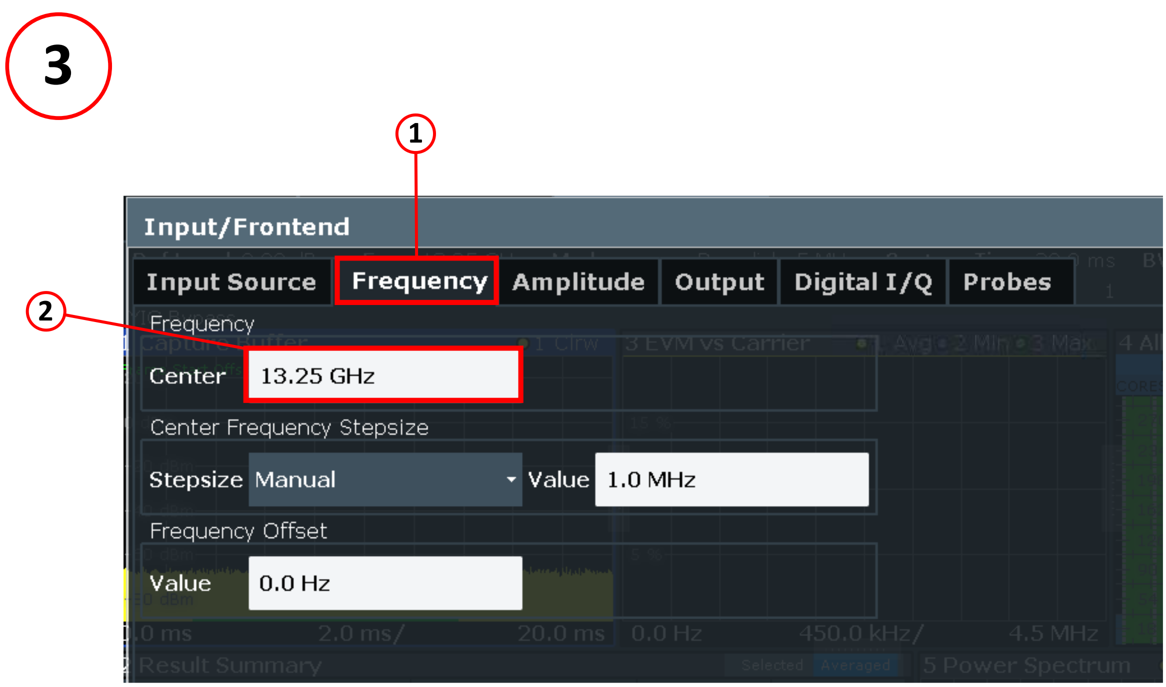
②: Select Deployment, Channel bandwidth and test model
③: Set center-frequency, reference level and FSW attenuation



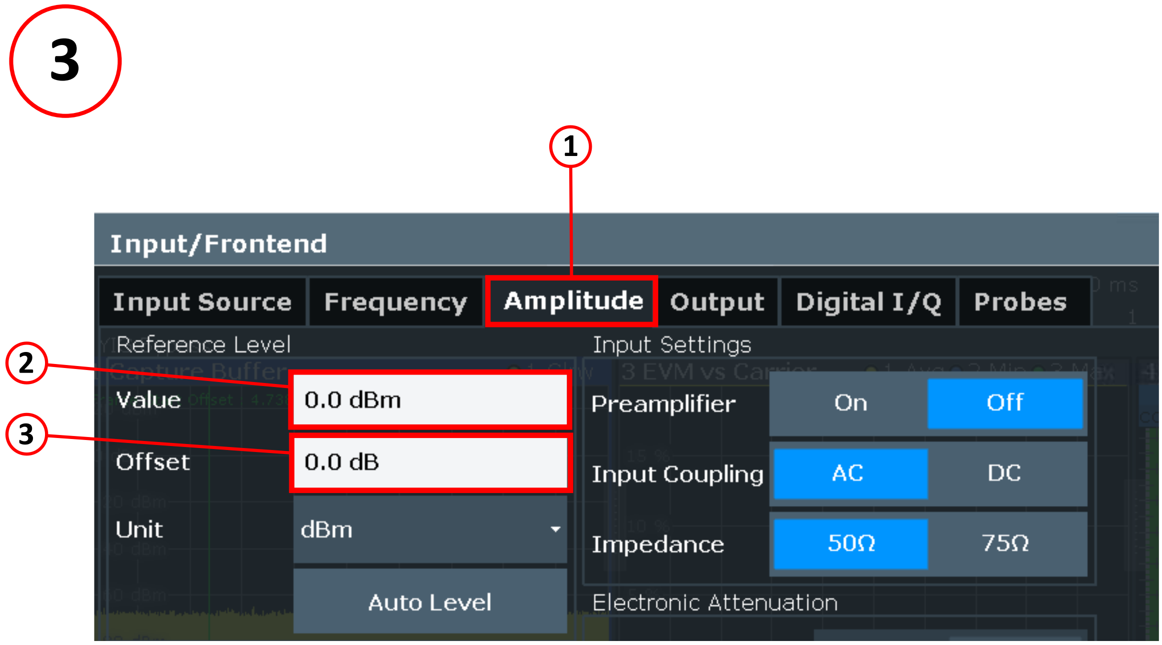
- After selecting ② the **Signal Configuration** tab opens
  - Select ① **Deployment**, ② **Channel Bandwidth**, ③ **Test Model**



- After selecting ③ the **Input/Frontend** tab opens
  - Set the ② **Frequency**



– Set ② **Reference level** and ③ **Reference level offset**



3.4 Remote control operations by using SCPI commands

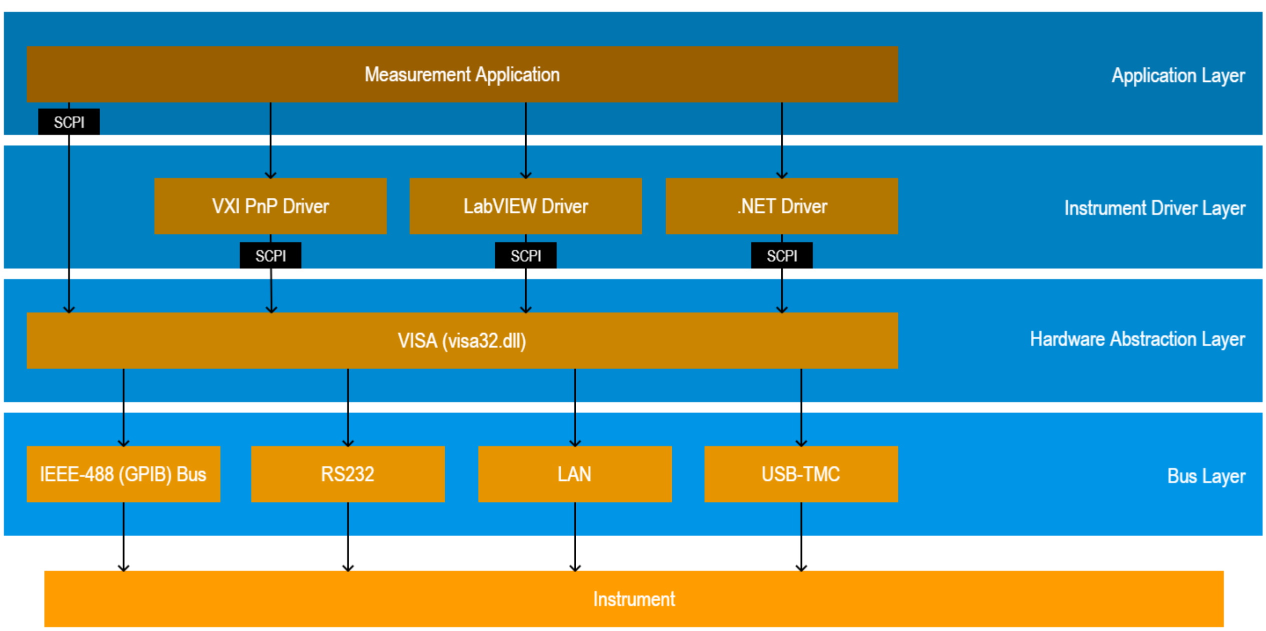


Figure 5: Overview [7]

First released in 1990, the SCPI consortium standardized **SCPI (Standard Commands for Programmable Instruments)** as an additional layer on top of the IEEE 488.2 specification creating a common standard for syntax and commands to use in controlling T&M devices.

SCPI commands are ASCII textual strings sent to an instrument over a physical layer (e.g. GPIB, RS-232, USB, Ethernet, etc.). For further details, refer to the SCPI-99 standard.

All Rohde & Schwarz instruments are using SCPI command sequences for remote control operations. The format used by Rohde & Schwarz is called the **canonical form**. Furthermore, all of our user manuals contain a chapter **Remote Control Commands** which is explaining general conventions and the SCPI commands supported by an instrument. It's also described in there whether the command is available as a set command or a query command or both.

Here, a quick overview [8] of rules to remember by the example of

`'TRIGger<m>:LEVel<n>[:VALue] <Level>'`

- SCPI commands are case-insensitive
- Capital letter parts are mandatory
- Lowercase letters can be omitted (which is then called *short form*)
- Parts within square brackets *'[…]'* are not mandatory and can be left out
- Parts within *'<...>'* brackets are representing parameters
- Multiple SCPI commands can be combined into a single-line string by using a semicolon *';'*
- To reset the command tree path to the root, use the colon character ':' at the beginning of the second command (e.g. `'TRIG1:SOUR CH1;:CHAN2:STATe ON'`)

For further reading

https://www.rohde-schwarz.com/drivers-remote-control

3.5 Base station output power (6.2)

The test purpose is to verify the accuracy of the maximum carrier output power across the frequency range and under normal and extreme conditions.

The power declared by the manufacturer must not exceed the values specified in Table 6. Table 7 shows the allowed tolerances.

Table 6: Declared rated output power

BS class	Rated carrier output power limits		
	BS type 1-C	**BS type 1-H**	
	P_{rated}	$P_{rated,c,sys}$	$P_{rated,TAB}$
Wide area BS	No upper limit		
Medium range BS	≤ 38 dBm	≤ 38 dBm + 10log($N_{TXU,counted}$)	≤ 38 dBm
Local area BS	≤ 24 dBm	≤ 24 dBm + 10log($N_{TXU,counted}$)	≤ 24 dBm

Table 7: Requirements BS output power

Frequency range	Limit (normal conditions)	Limit (extreme conditions)
f ≤ 3.0 GHz	± 2.7 dB	± 3.2 dB
3.0 GHz < f < 6.0 GHz	± 3.0 dB	± 3.5 dB

Test setup

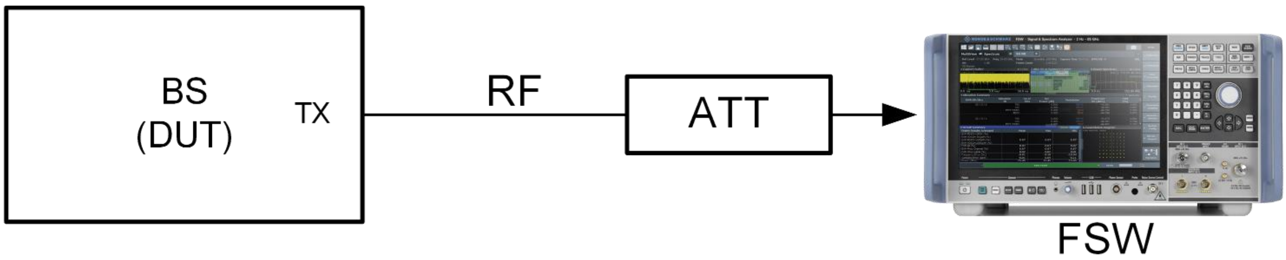
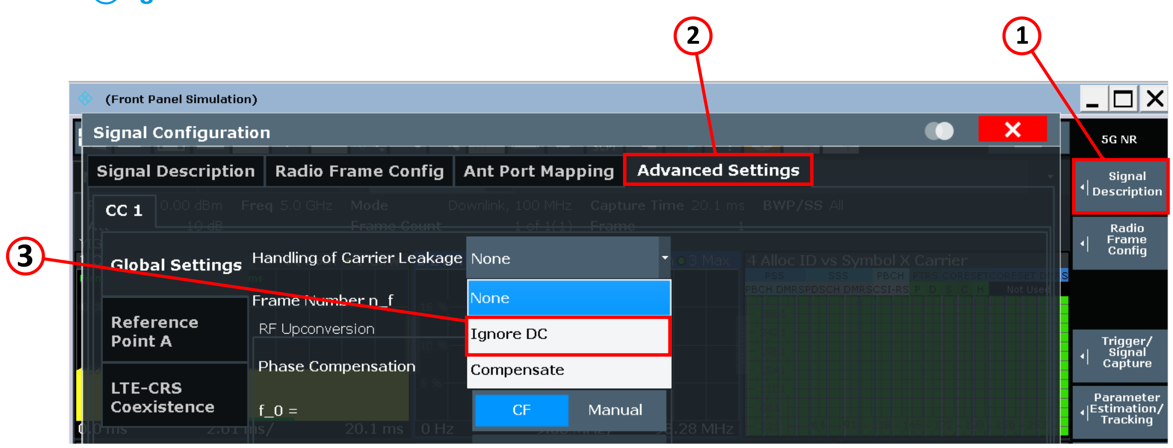


Figure 6: Test setup base station output power

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **EVM/Frequency Err/Power**
3. Select **Test Model**
4. Set **Frequency**
5. Set **Reference level offset** to compensate external attenuation
6. Enable ③ **Ignore DC**



7. Start measurement

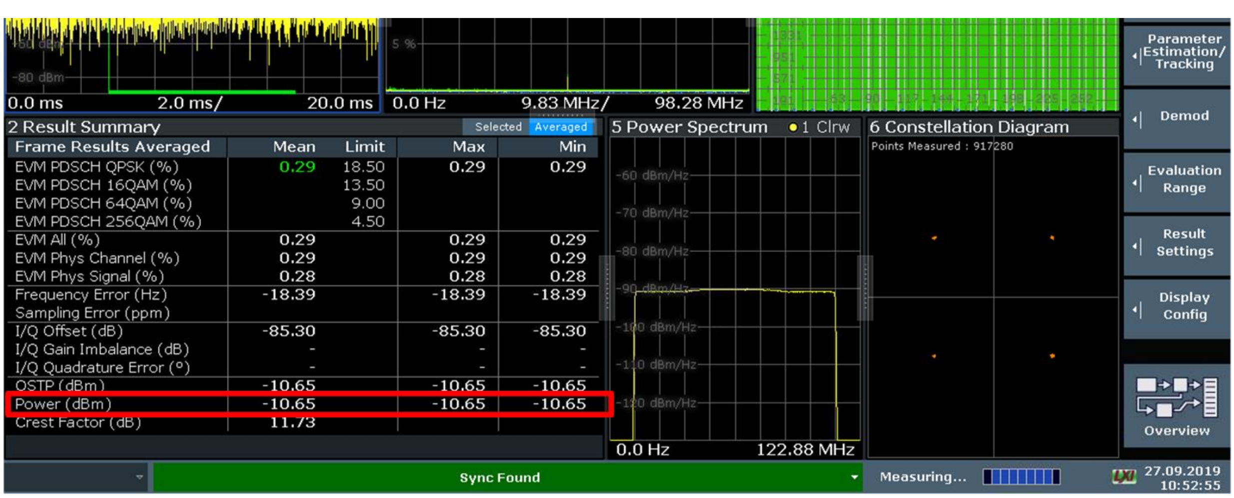


Figure 7: BS output power in the result summary

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement EVM
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]FREQuency:CENTer <Frequency>
INPut:ATTenuation <Attenuation>
CONFigure[:NR5G]:DL[:CC<cc>]:IDC <State>
FETCh[:CC<cc>][:FRAMe<fr>]:SUMMary:POWer:MAXimum?
```

3.6 Output power dynamics (6.3)

3.6.1 RE power control dynamic range (6.3.2)

The RE power control dynamic range is the difference between the power of an RE and the average RE power for a BS at maximum carrier output power ($P_{max,c,TABC}$, or $P_{max,c,AC}$) for a specified reference condition. [1]

No specific test requirements are defined for this test case. The error vector magnitude (EVM) test, as described in 3.8 provides sufficient test coverage for this requirement.

3.6.2 Total power dynamic range (6.3.3)

The total power dynamic range of a base station is the difference between the maximum and the minimum transmit power of an OFDM symbol for a specified reference condition. The upper limit of the dynamic range is the OFDM symbol power for a BS at maximum output power when transmitting on all RBs. The lower limit of the total power dynamic range is the average power for single RB transmission. The OFDM symbol shall carry PDSCH and not contain RS or SSB. [1]

The downlink total power dynamic range for each NR carrier shall be larger than or equal to the levels specified in Table 8.

Table 8: Base station total power dynamic range

NR channel bandwidth (MHz)	Total power dynamic range (dB)		
	15 kHz SCS	30 kHz SCS	60 kHz SCS
5	13.5	10.0	N/A
10	16.7	13.4	10.0
15	18.5	15.3	12.1
20	19.8	16.6	13.4
25	20.8	17.7	14.5
30	21.6	18.5	15.3
40	22.9	19.8	16.6
50	23.9	20.8	17.7
60	N/A	21.6	18.5
70	N/A	22.3	19.2
80	N/A	22.9	19.8

90	N/A	23.4	20.4
100	N/A	23.9	20.9

Test setup

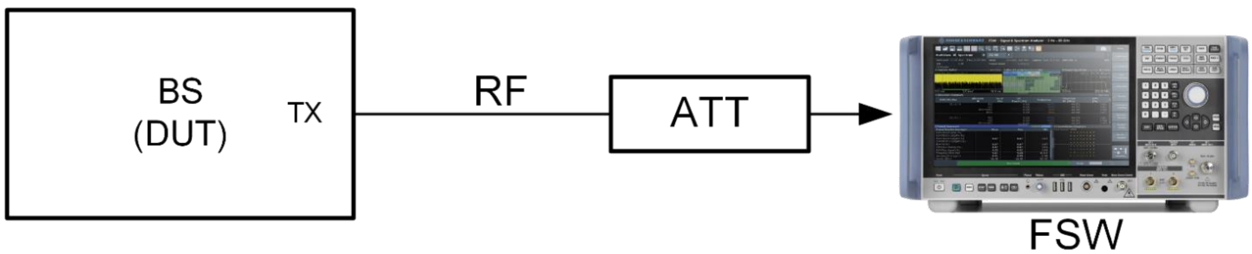


Figure 8: Test setup for total power dynamic range

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **EVM/Frequency Err/Power**
3. Set **Frequency**
4. Select **Test Model**
   Test models for **first measurement**:
   – If 256QAM is supported by base station
     – with power back off: TM 3.1
     – without power back off: TM3.1a
   – If 256QAM is not supported by base station
     – TM3.1

   Test models for **second measurement**:
   – If 256QAM is supported by base station: TM2a
   – If 256QAM is not supported by BS: TM2
5. Start measurement
6. Subtract the OSTP-values of the two measurements:
   Total power dynamic range = $OSTP_{first\ measurement}$ - $OSTP_{second\ measurement}$

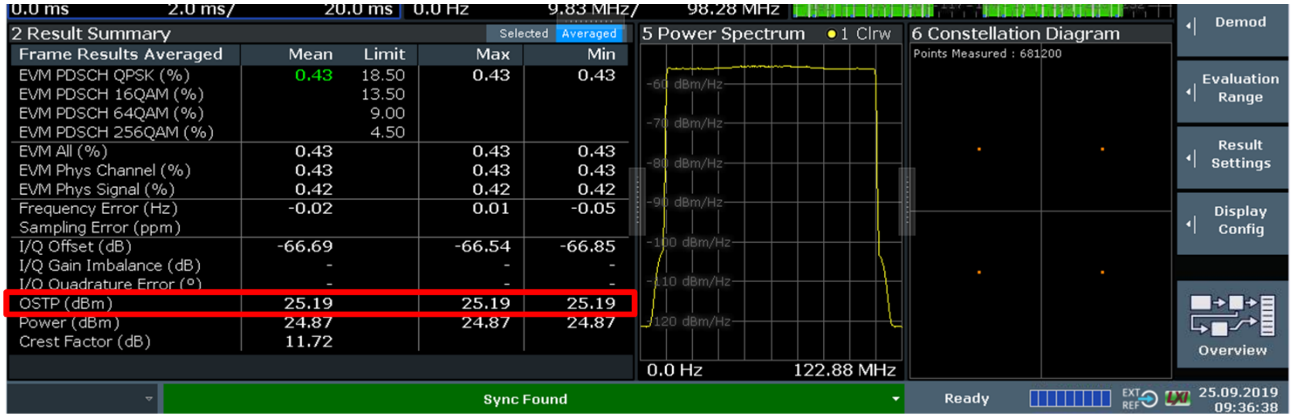


Figure 9: BS output power in the result summary

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement EVM
[SENSe:]FREQuency:CENTer <Frequency>
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
FETCh[:CC<cc>][:ISRC<ant>][:FRAMe<fr>]:SUMMary:OSTP[:AVERage]?
```

3.6.3 NB-IoT RB power dynamic range (6.3.4)

The NB-IoT RB power dynamic range (or NB-IoT power boosting) is the difference between the average power of NB-IoT REs (which occupy certain REs within a NR transmission bandwidth configuration plus 15 kHz at each edge but not within the NR minimum guard band $GB_{Channel}$) and the average power over all REs (from both NB-IoT and the NR carrier containing the NB-IoT REs). [1]

Table 9: NB-IoT RB power dynamic range for NB-IoT operation in NR in-band

BS channel bandwidth (MHz)	NB-IoT RB frequency position	NB-IoT RB power dynamic range (dB)
5, 10	Any	+5.6
15	Within center 77*180kHz+15kHz at each edge	+5.6
	Other	+2.6
20	Within center 102*180kHz+15kHz at each edge	+5.6
	Other	+2.6
25, 30, 40, 50, 60, 70, 80, 90, 100	Within center 90% of BS channel bandwidth	+5.6
	Other	+2.6

This requirement is tested together with Operating band unwanted emissions (OBUE) (SEM) (6.6.4).

3.7 Transmit on/off power (6.4)

Transmit OFF power requirements apply only to TDD operation of NR BS. Transmitter OFF power is defined as the mean power measured over 70/N µs filtered with a square filter of bandwidth equal to the transmission bandwidth configuration of the BS (BW_{config}) centered on the assigned channel frequency during the transmitter OFF period.

N = SCS/15, where SCS is sub carrier spacing in kHz. [1]

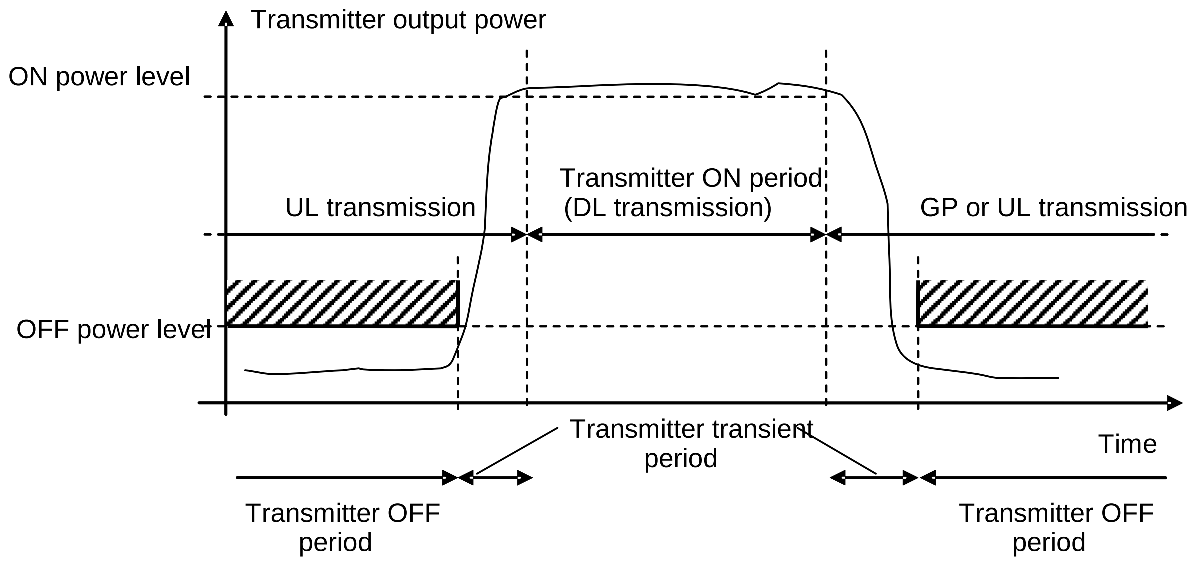


Figure 10: Definition of transmitter ON and OFF periods [1]

Figure 10 shows the definition of the ranges and Table 10 lists the limits.

Table 10: Transmitter OFF power limit

Frequency range	Limit
f ≤ 3.0 GHz	-83.0 dBm/MHz
3.0 GHz < f ≤ 6.0 GHz	-82.5 dBm/MHz

Test setup

Additional hardware is required for this test. An RF limiter is used to limit the power received at the analyzer during the transmitter ON periods. This enables the full dynamic range for the measurements in the OFF periods. In addition, an attenuator can be used to absorb the reflected power for limiters for optimizing the VSWR.

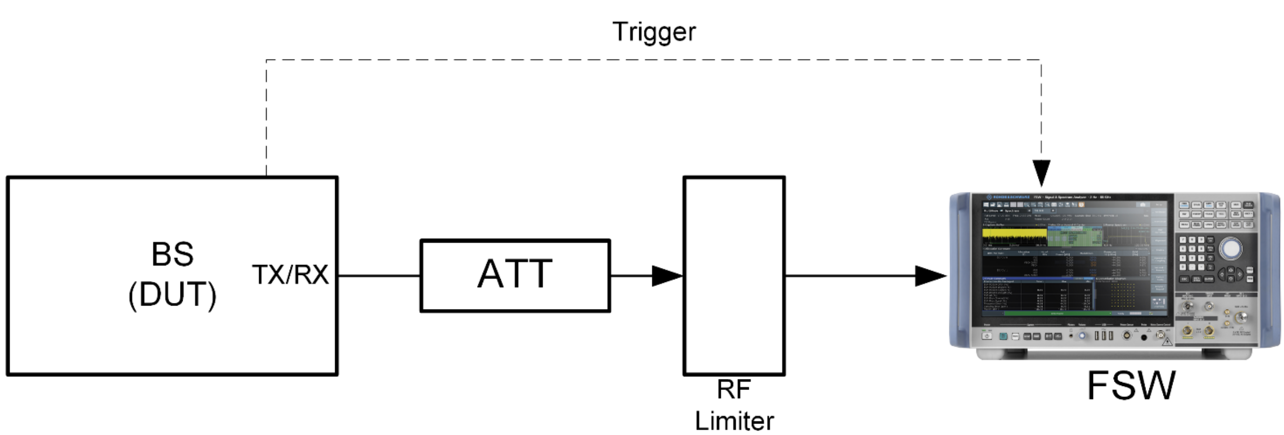
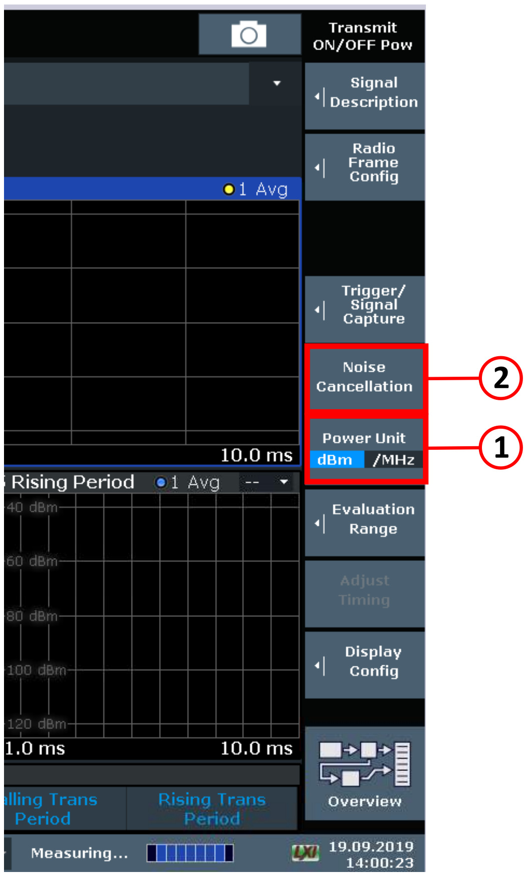


Figure 11: Test setup for transmit ON/OFF power measurements

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **Transmit ON/OFF Power**
3. Set **Frequency**
4. Select **Test model**
5. Select ① **Power unit**
6. It is recommended to enable ② **Noise Cancellation**



7. Start measurement

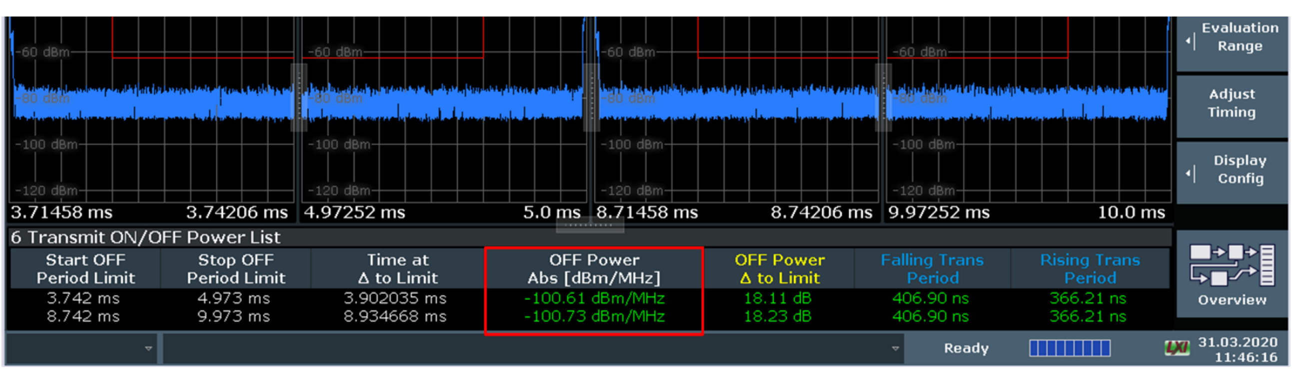


Figure 12: Tx ON/OFF measurement

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement TPOO
SENSe:]FREQuency:CENTer <Frequency>
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]NR5G:OOPower:NCORrection <State>
UNIT:OPOWer <Unit>
TRAC6:DATA? LIST
```

3.8 Transmitted signal quality (6.5)

3.8.1 Frequency error (6.5.2) and modulation quality (6.5.3)

Frequency error is the reading of the difference between the actual NR BS transmit frequency and the assigned frequency. [1]

Table 11 shows the limits for the different base station classes.

Table 11: Frequency error requirements

BS class	Accuracy
Wide Area BS	± (0.05 ppm + 12 Hz)
Medium Range BS	± (0.1 ppm + 12 Hz)
Local Area BS	± (0.1 ppm + 12 Hz)

For this measurement, the FSW must be synchronized via an external reference to a high precision time reference.

Modulation quality is defined by the difference between the measured carrier signal and a reference signal. Modulation quality can be expressed as error vector magnitude (EVM), e.g. the error vector magnitude is a reading of the difference between the ideal symbols and the measured symbols after the equalization. This difference is called the error vector. [1]

Table 12: EVM requirements

Modulation scheme for PDSCH	Required EVM (%)
QPSK	18.5 %
16QAM	13.5 %
64QAM	9 %
256QAM	4.5 %

Test setup

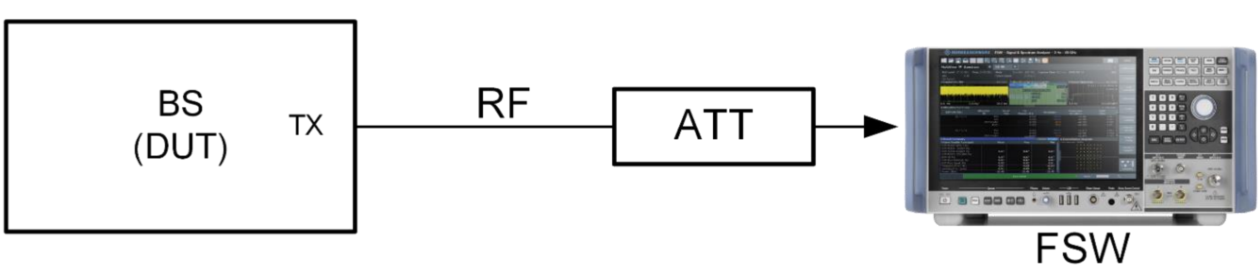


Figure 13: Test setup for frequency error and EVM

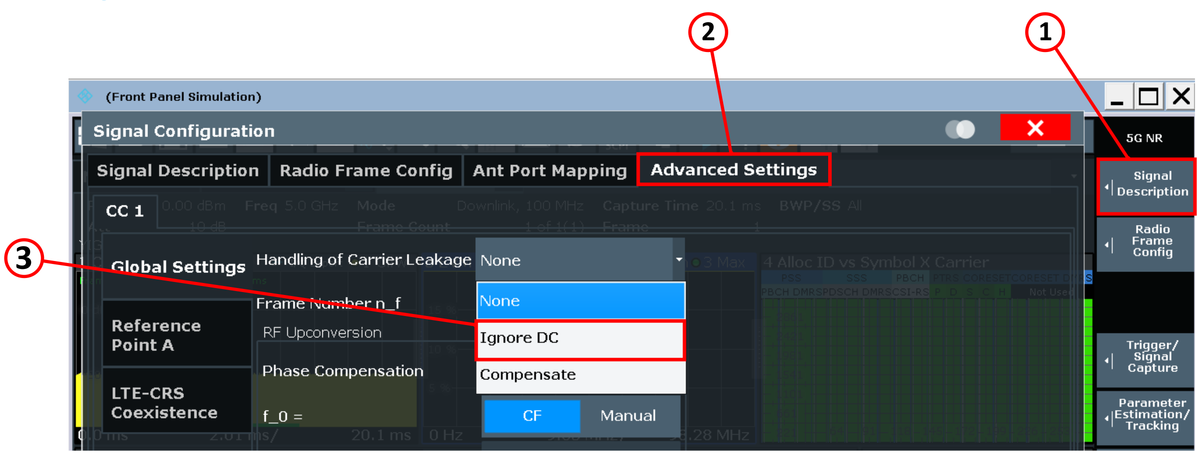
The DUT (base station) transmits with the declared maximum P_{rat}. The following configurations are specified:

Used TM depends on the supported TMs by the base station:

- NR-FR1-TM3.1(a)
- NR-FR1-TM3.2
- NR-FR1-TM3.3
- NR-FR1-TM2(a)

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **EVM/Frequency Err/Power**
3. Select **Test model**
4. Set **Frequency**
5. Enable ③ **Ignore DC**



6. Start measurement

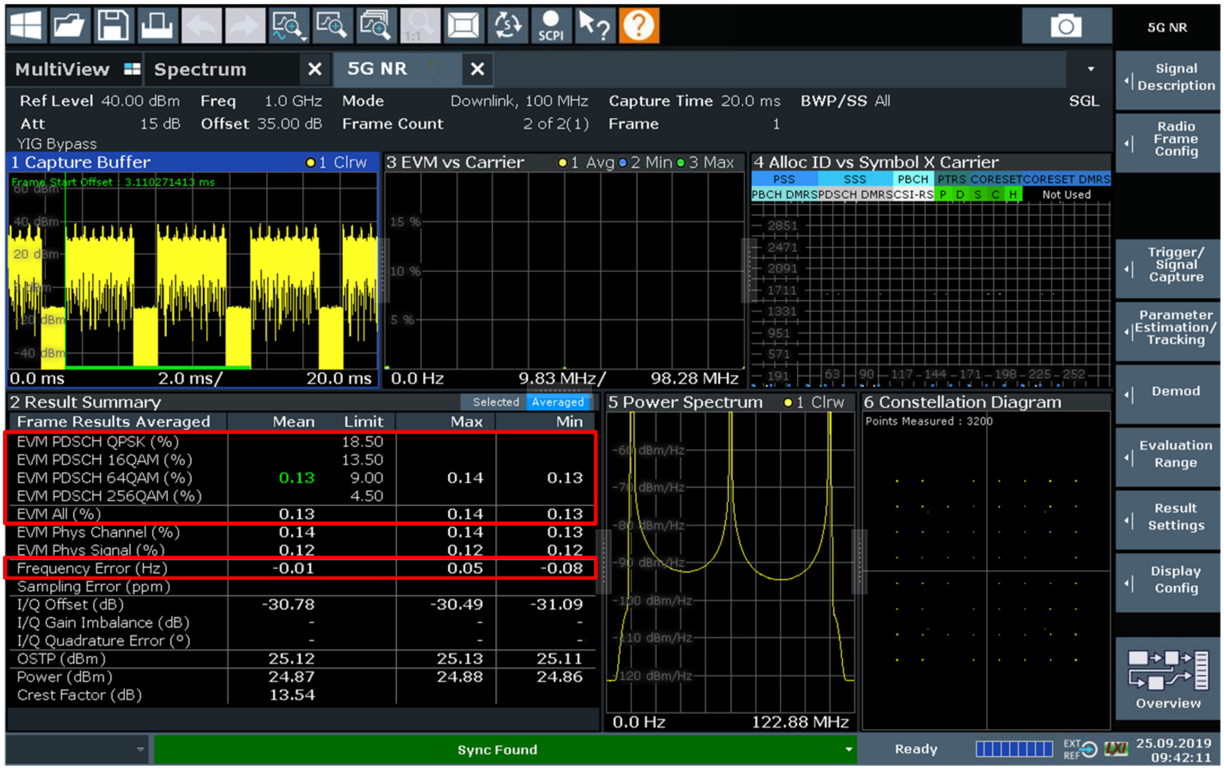


Figure 14: Frequency error (6.5.2) and modulation quality (6.5.3)

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement EVM
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]FREQuency:CENTer <Frequency>
CONFigure[:NR5G]:DL[:CC<cc>]:IDC <State>
FETCh[:CC<cc>][:ISRC<ant>][:FRAMe<fr>]:SUMMary:FERRor[:AVERage]?
FETCh[:CC<cc>][:ISRC<ant>][:FRAMe<fr>]:SUMMary:EVM[:ALL][:AVERage]?
```

3.8.2 Time alignment error (TAE) (6.5.4)

Frames of the NR signals being present at the BS transmitter antenna connectors or TAB connector are not perfectly aligned in time and may experience certain timing differences in relation to each other. [1]

Time alignment error (TAE) is defined as the largest timing difference between any two signals. This requirement applies to frame timing in Tx diversity, MIMO transmission, carrier aggregation and their combinations.

Table 13 lists the limits for various combinations.

Table 13: Time alignment error limits

Transmission combination	Limit
MIMO/Tx diversity at each carrier frequency	90 ns
Intra-band CA with or without MIMO or Tx diversity	285 ns
Intra-band non-contiguous CA with or without MIMO or Tx diversity	3.025 µs
Inter-band CA with or without MIMO or Tx diversity	3.025 µs

The DUT (base station) typically transmits with NR-FR1-TM1.1 with MIMO transmission or carrier aggregation.

Test setup

The following setup is used for this test. The antennas to be measured are connected via one (or more cascaded) hybrid coupler(s). The FSW is connected via an attenuator. To achieve precise measurements, the RF cables being used should be equal in electrical length.

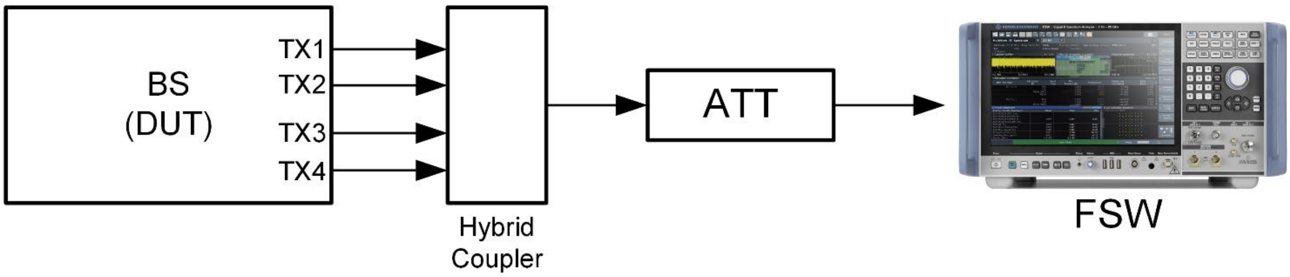


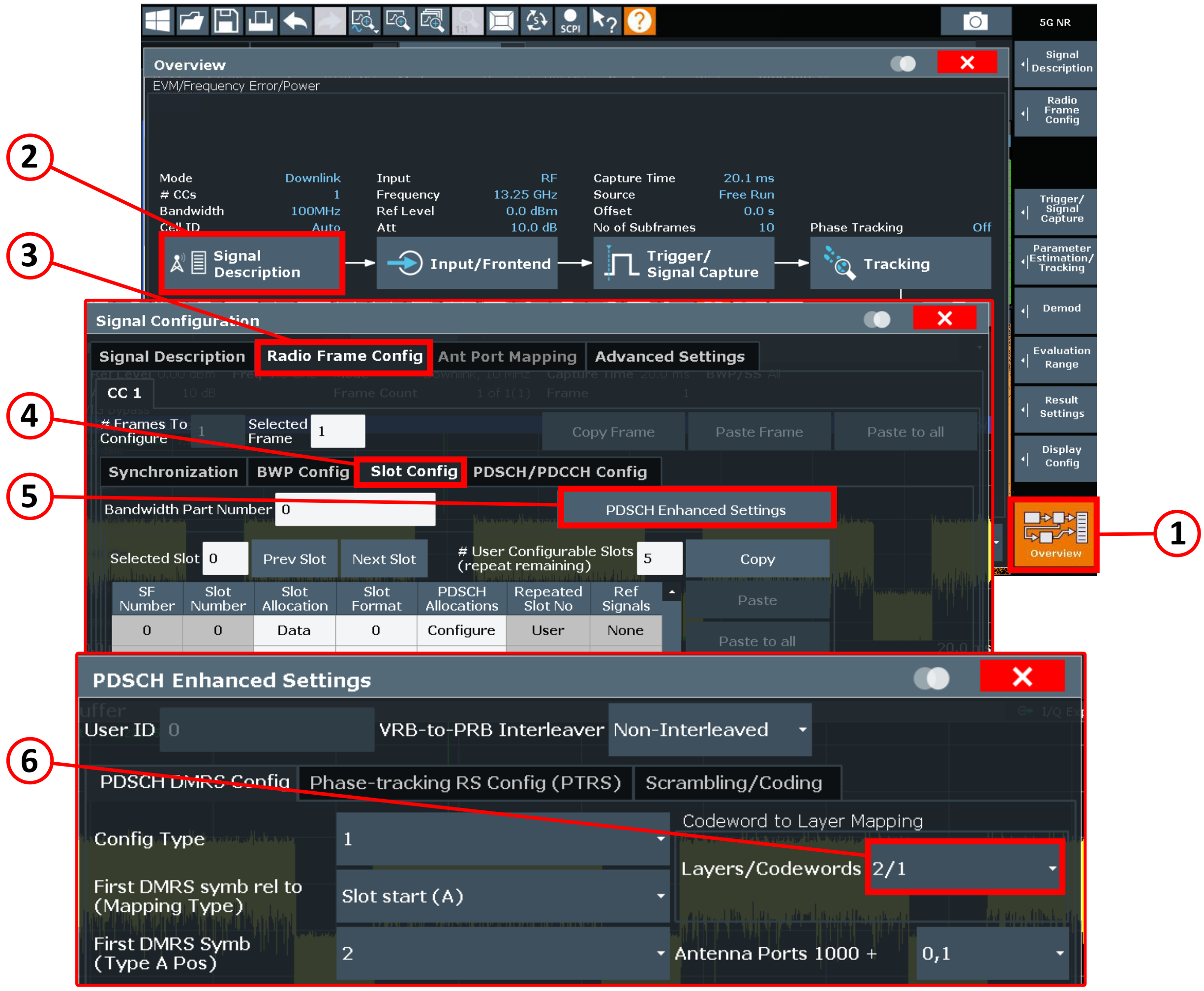
Figure 15: Test setup time alignment error

Up to four antennas can be measured in parallel. The measurement is taken on the reference signal (DM-RS) of the individual antennas and PDSCHs are ignored. The measurement is always relative to one reference antenna.

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **Time Alignment Error**
3. Select **Test model**
4. Set **Frequency**

5. Select the ⑥ **Number of layers**



6. Start measurement

Figure 16: Time alignment error (TAE)

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement TAER
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]FREQuency:CENTer <Frequency>
CONFigure:DL[:CC<cc>]:FRAMe<fr>:BWPart<bwp>:SLOT<sl>:ALLocation<al>:CLMapping
<Mapping>
FETCh:TAERror[:CC<cc>]:ANTenna<ant>MINimum?
FETCh:TAERror[:CC<cc>]:ANTenna<ant>MAXimum?
FETCh:TAERror[:CC<cc>]:ANTenna<ant>[:AVERage]?
```

3.9 Unwanted emissions (6.6)

Unwanted emissions consist of out-of-band emissions and spurious emissions according to ITU definitions. In ITU terminology, out of band emissions are unwanted emissions immediately outside the channel bandwidth resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions. Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emission, intermodulation products and frequency conversion products, but exclude out of band emissions. The out-of-band emissions requirement for the BS transmitter is specified both in terms of adjacent channel leakage power ratio (ACLR) and operating band unwanted emissions (OBUE). [1]

The maximum offset of the operating band unwanted emissions mask from the operating band edge is Δf_{OBUE}. The operating band unwanted emissions define all unwanted emissions in each supported downlink operating band plus the frequency ranges Δf_{OBUE} above and Δf_{below} each band. Unwanted emissions outside of this frequency range are limited by a spurious emissions requirement.

Table 14: Maximum offset of OBUE outside the downlink operating band

BS type	Operating band characteristics	ΔfOBUE (MHz)
BS type 1-C	$F_{DL\_high} – F_{DL\_low} \leq 200$ MHz	10
	$200 \text{ MHz} < F_{DL\_high} – F_{DL\_low} \leq 900$ MHz	40
BS type 1-H	$F_{DL\_high} – F_{DL\_low} < 100$ MHz	10
	$100 \text{ MHz} \leq F_{DL\_high} – F_{DL\_low} \leq 900$ MHz	40

3.9.1 Occupied bandwidth (OBW) (6.6.2)

The occupied bandwidth is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage β/2 of the total mean transmitted power. The value of β/2 shall be taken as 0.5%. [1]

This results in a power bandwidth of 99%.

The measurement of the spectrum is carried out with resolution bandwidth (RBW) of 30 KHz or less and the measurement points mentioned in Table 15.

Table 15: Span and measurement points for OBW measurement

Bandwidth	BS channel bandwidth BWChannel (MHz)				
	5	**10**	**15**	**20**	**> 20**
Span (MHz)	10	20	30	40	$2 \times BW_{Channel}$
Minimum number of measurement points	400	400	400	400	$\left\lceil \frac{2 \times BW_{Channel}}{100kHz} \right\rceil$

The measured bandwidth (OBW) shall be smaller than the nominal bandwidth (see Table 15, top row).

Test setup

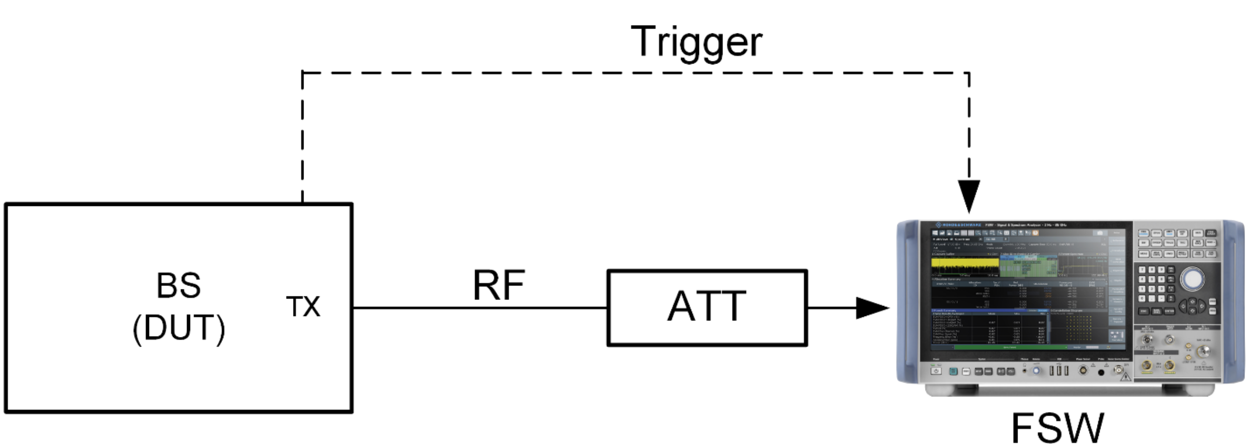
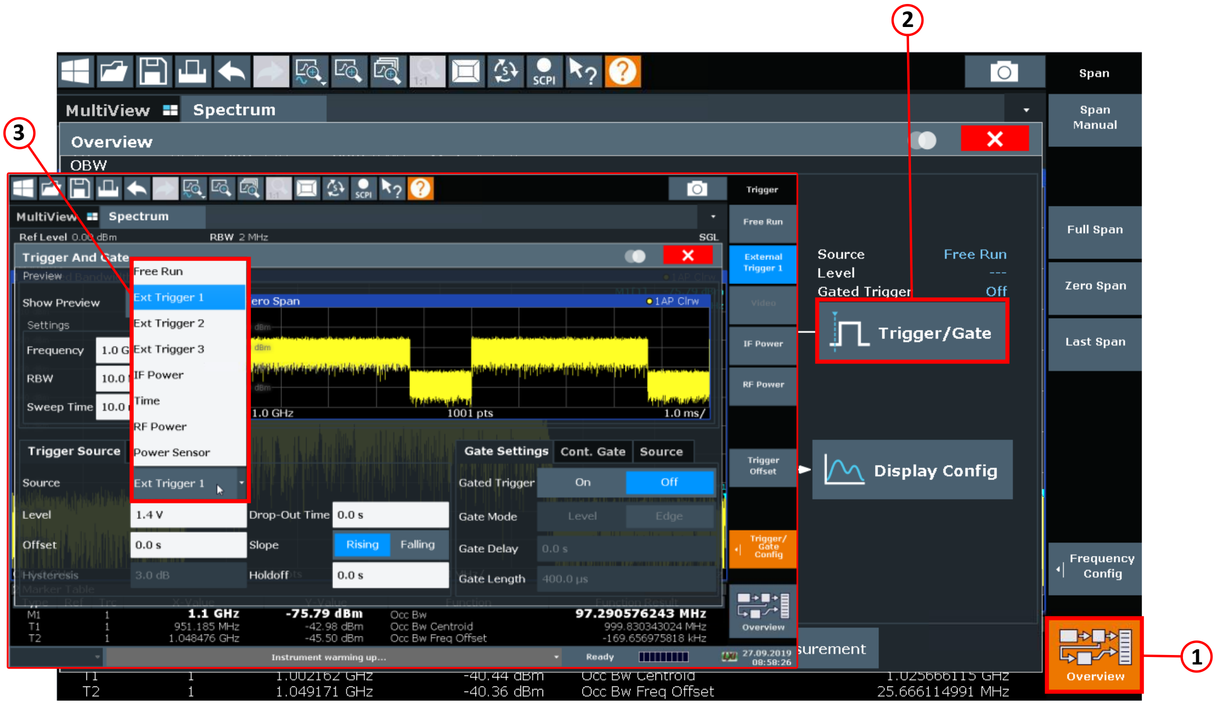


Figure 17: Test setup unwanted emissions

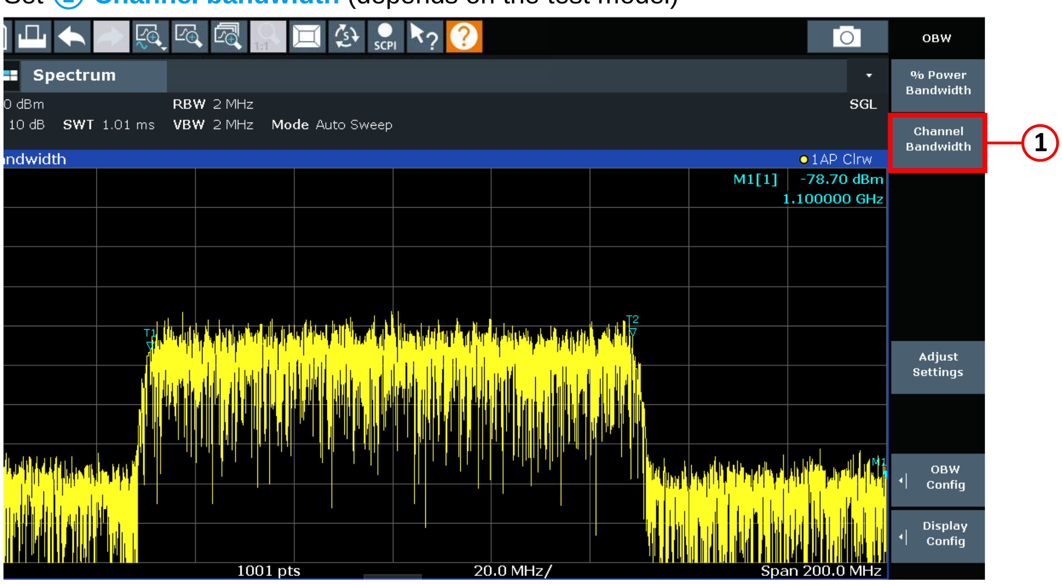
The DUT (base station) transmits with declared rated output power. The test model NR-FR1-TM1.1 is required. For TDD signals, the trigger must be set to external.

Manual testing procedure

1. Select mode **Spectrum**
2. Select measurement **OBW**
3. Set **Frequency**
4. Only for TDD signals: Use ③ **External triggering**



5. Set ① **Channel bandwidth** (depends on the test model)



6. Start measurement

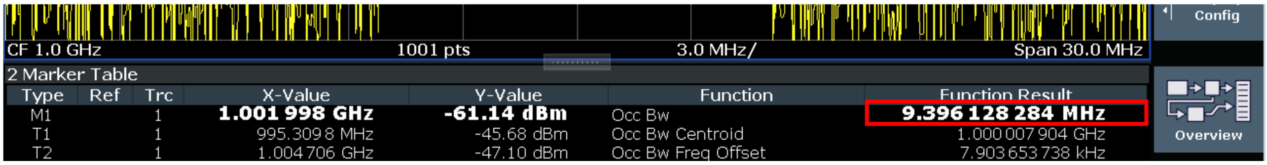


Figure 18: OBW measurement

SCPI commands sequence

```
INSTrument[:SELect] SAN
CALCulate<n>:MARKer<m>:FUNCtion:POWer<sb>:SELect OBANdwidth
[SENSe:]FREQuency:CENTer <Frequency>
TRIGger[:SEQuence]:SOURce <Source>
[SENSe:]POWer:ACHannel:BWIDth[:CHANnel<ch>] <Bandwidth>
CALCulate<n>:MARKer<m>:FUNCtion:POWer<sb>:RESult? OBANdwidth
```

3.9.2 Adjacent channel leakage power (ACLR) (6.6.3)

Adjacent channel leakage power ration (ACLR) is the ratio of the filtered mean power centered on the assigned channel frequency to the filtered mean power centered on an adjacent channel frequency. [1]

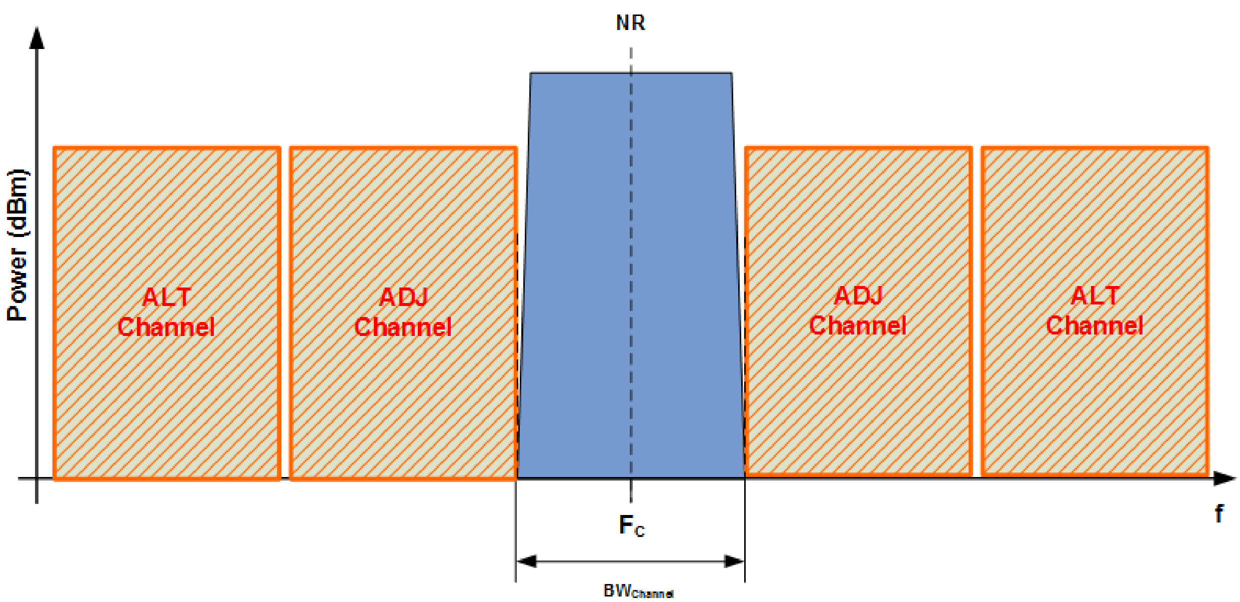


Figure 19: ACLR

Table 16: Base station ACLR absolute basic limit

BS category / BS class	ACLR absolute basic limit
Category A Wide Area BS	-13 dBm/MHz
Category B Wide Area BS	-15 dBm/MHz
Medium Range BS	-25 dBm/MHz
Local Area BS	-32 dBm/MHz

Table 17: Base station ACLR limit

BS channel bandwidth of lowest/highest NR carrier transmitted $BW_{Channel}$ (MHz)	BS adjacent channel center frequency offset below the lowest or above the highest carrier center frequency transmitted	Assumed adjacent channel carrier (informative)	Filter on the adjacent channel frequency and corresponding filter bandwidth	ACLR limit
5, 10, 15, 20	BWChannel	NR of same BW	Square (BW_{Config})	44.2 dB
	2 x BWChannel	NR of same BW	Square (BW_{Config})	44.2 dB
	BWChannel /2 + 2.5 MHz	5 MHz E-UTRA	Square (4.5 MHz)	44.2 dB
	BWChannel /2 + 7.5 MHz	5 MHz E-UTRA	Square (4.5 MHz)	44.2 dB
25, 30, 40, 50, 60, 70, 80, 90, 100	BWChannel	NR of same BW	Square (BW_{Config})	43.8 dB
	2 x BWChannel	NR of same BW	Square (BW_{Config})	43.8 dB
	BWChannel /2 + 2.5 MHz	5 MHz E-UTRA	Square (4.5 MHz)	43.8 dB
	BWChannel /2 + 7.5 MHz	5 MHz E-UTRA	Square (4.5 MHz)	43.8 dB

Test setup

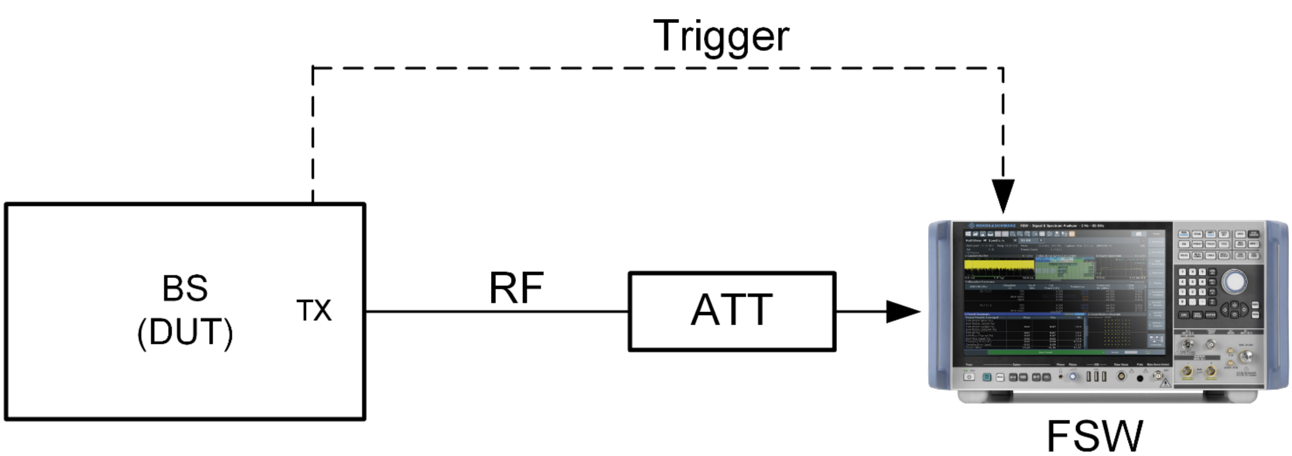


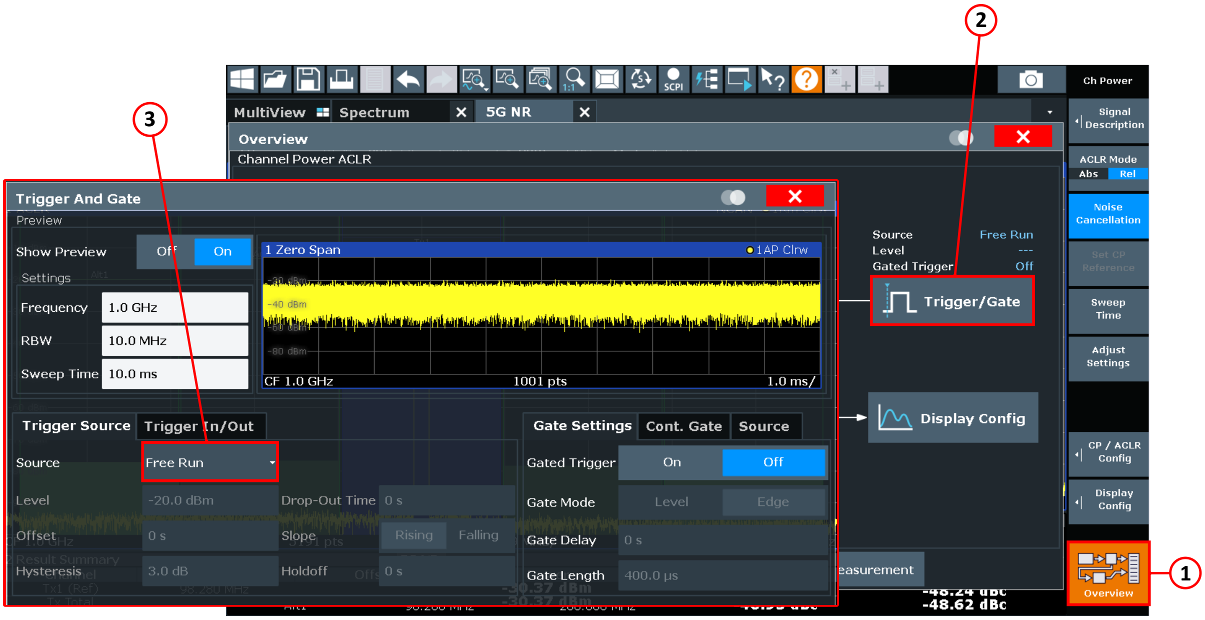
Figure 20: Test setup ACLR

The DUT (base station) transmits with the declared rated power. Test models NR-FR1-TM1.1 and NR-FR-TM1.2 are required. For TDD signals, the trigger must be set to external. Both cases, NR and LTE as adjacent channels, are handled (see Table 17). Both relative and absolute limits apply (see Table 16 for absolute values).

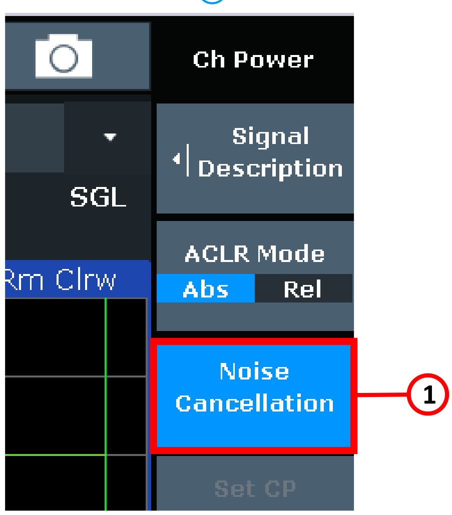
Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **Channel Power ACLR**
3. Select **Test model**
4. Set **Frequency**

5. For TDD signals only: Use ③ **External triggering**



6. You can enable ① **Noise Cancellation**



7. Start measurement

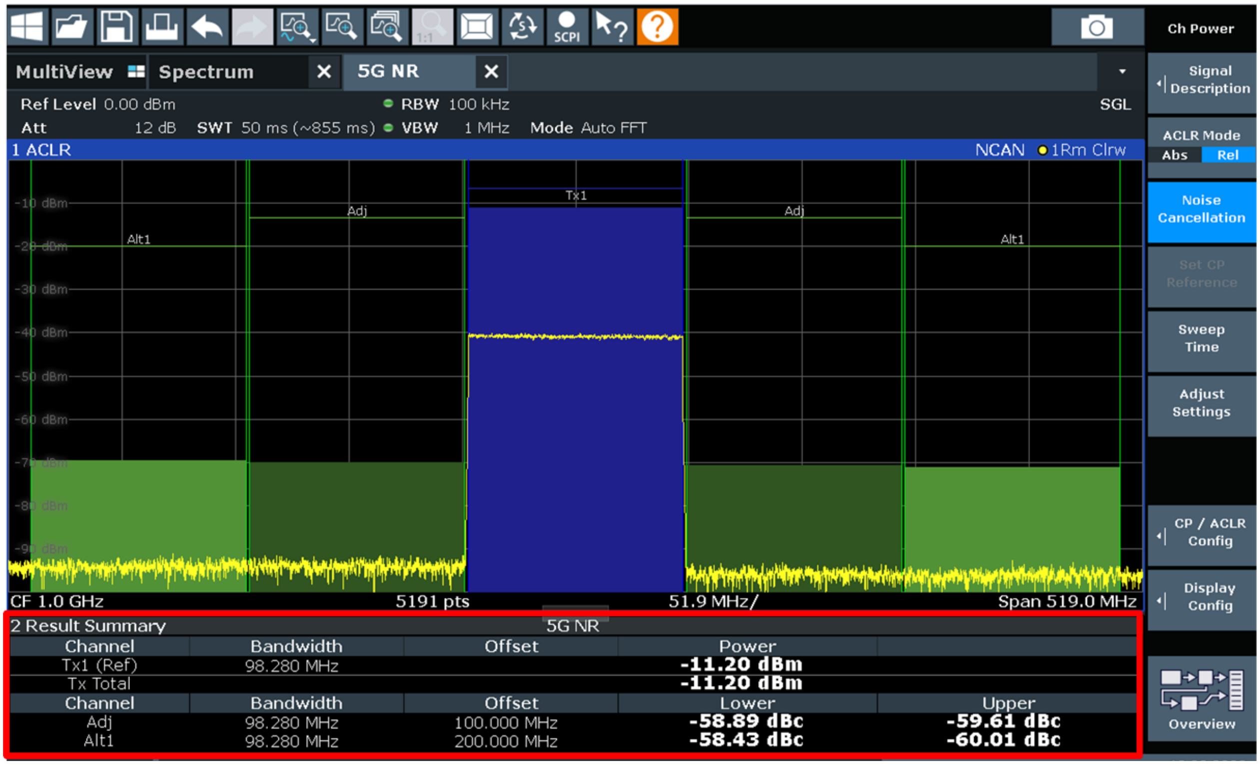


Figure 21: ACLR measurement

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement ACLR
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]FREQuency:CENTer <Frequency>
TRIGger[:SEQuence]:SOURce <Source>
[SENSe:]POWer:NCORrection <State>
CALCulate<n>:MARKer<m>:FUNCtion:POWer<sb>:RESult[:CURRent]? [<Measurement>]
```

3.9.3 Operating band unwanted emissions (OBUE) (SEM) (6.6.4)

Unless otherwise stated, the operating band unwanted emission (OBUE) limits in FR1 are defined from Δf_{OBUE} below the lowest frequency of each supported downlink operating band up to Δf_{OBUE} above the highest frequency of each supported downlink operating band. [1] The values of Δf_{OBUE} are defined in Table 14.

The test requirements shall apply as per categories either A or B. The minimum mandatory requirement is mentioned in subclause 6.6.4.5 [1].

Test setup

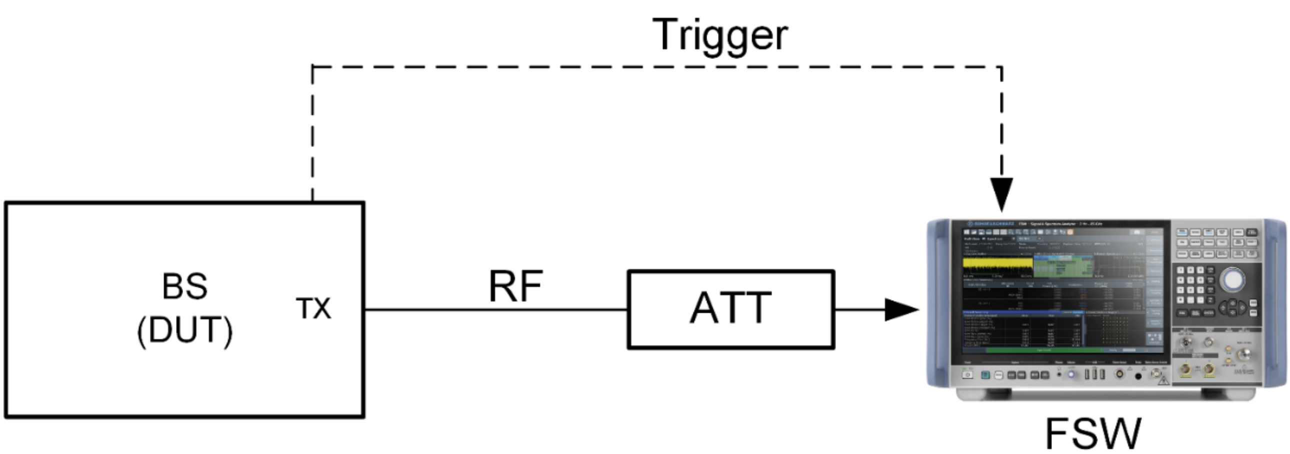
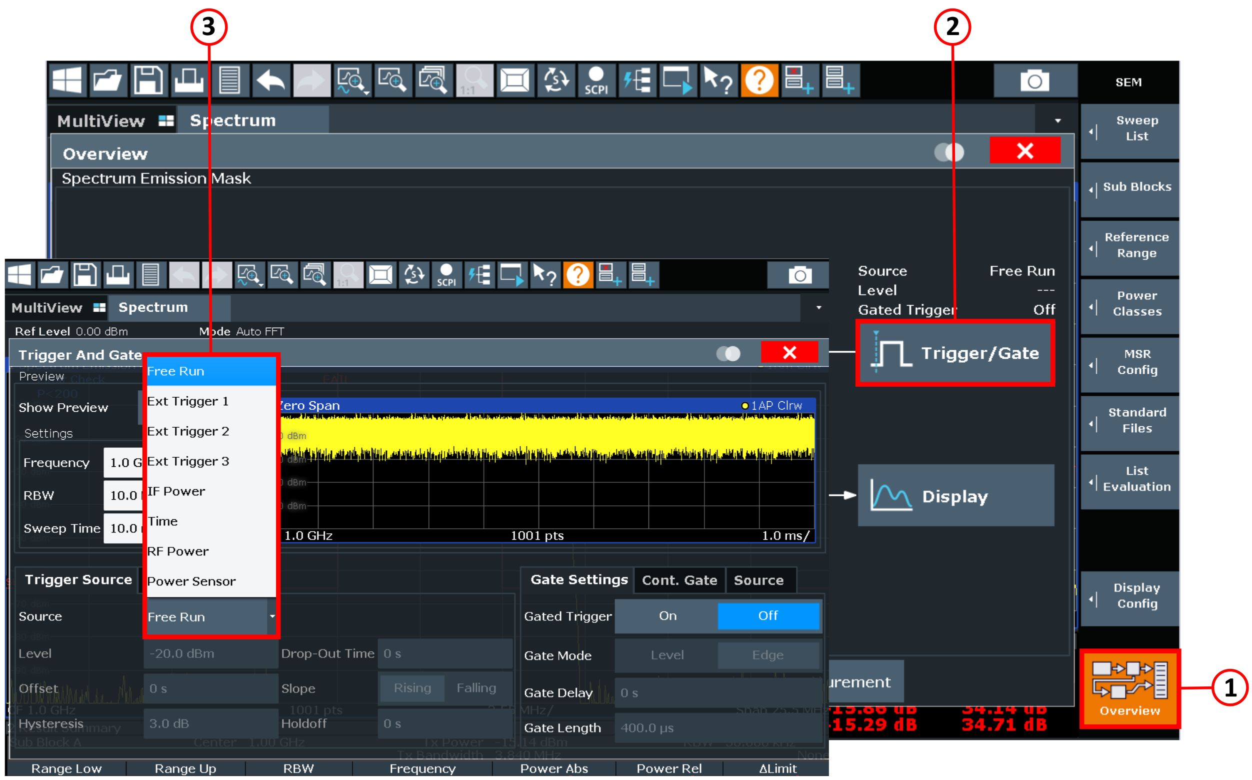


Figure 22: Test setup for SEM

The DUT (base station) transmits with the declared rated output power. The test models NR-FR1-TM1.1 and NR-FR1-TM1.2 are required. For TDD signal, the trigger must be set to external.

Manual testing procedure

1. Select mode **5G NR**
2. Select measurement **Spectrum Emission Mask**
3. Select **Test model**
4. Set **Frequency**
5. For TDD signals only: Use ③ **External triggering**



6. Start measurement

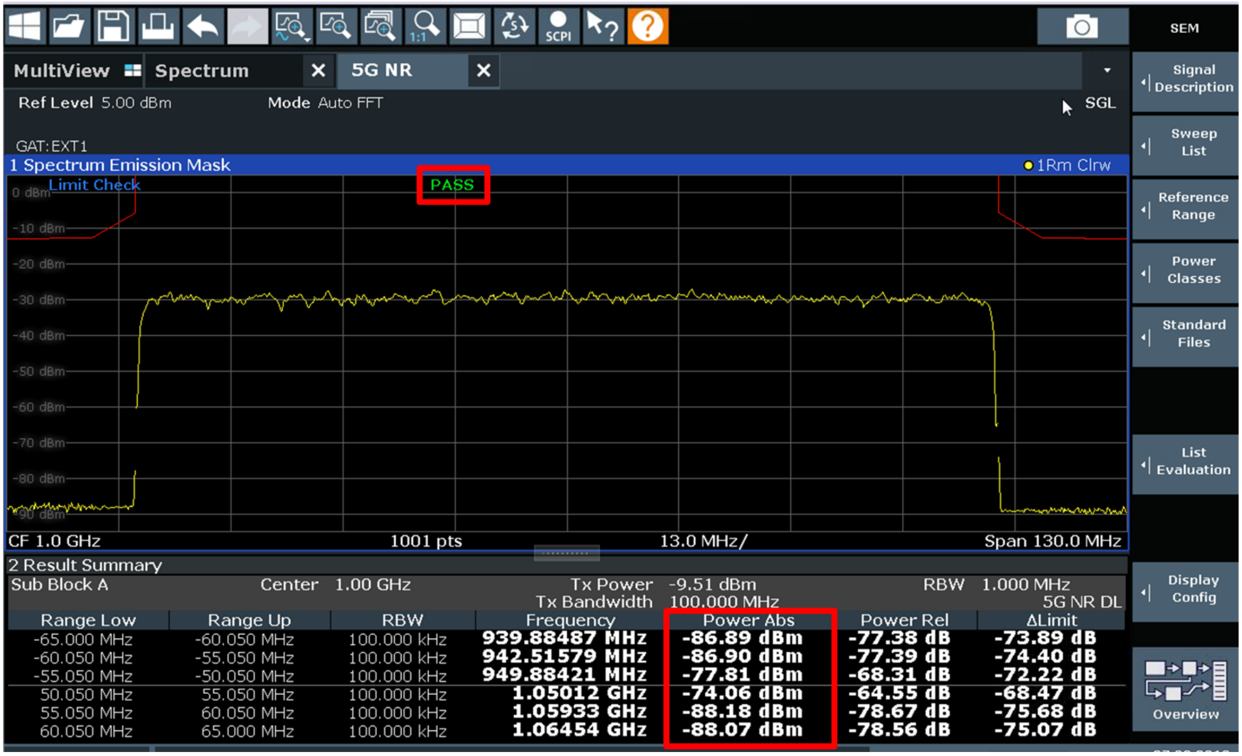


Figure 23: Operating band unwanted emissions

SCPI commands sequence

```
INSTrument[:SELect] NR5G
CONFigure[:NR5G]:MEASurement ESPectrum
MMEMory:LOAD:TMODel[:CC<cc>] <TestModel>
[SENSe:]FREQuency:CENTer <Frequency>
TRIGger[:SEQuence]:SOURce <Source>
CALCulate<n>:MARKer<m>:FUNCtion:POWer<sb>:RESult[:CURRent]? [<Measurement>]
```

3.9.4 Transmitter spurious emissions (6.6.5)

The transmitter spurious emission limits shall apply from 9 kHz to 12.75 GHz, excluding the frequency range from Δf_{OBUE} below the lowest frequency of each supported downlink operating band, up to Δf_{OBUE} above the highest frequency of each supported downlink operating band, where the Δf_{OBUE} is defined in Table 14. For some operating bands, the upper limit is higher than 12.75 GHz in order to comply with the 5^{th} harmonic limit of the downlink operating band. [1]

Table 18: General BS transmitter spurious emission limits in FR1, Category A

Spurious frequency range	Basic limit	Measurement bandwidth
9 kHz – 150 kHz	-13 dBm	1 kHz
150 kHz – 30 MHz		10 kHz
30 MHz – 1 GHz		100 kHz
1 GHz – 12.75 GHz		1 MHz
12.75 GHz – 5th harmonic of the upper frequency edge of the DL operating band in GHz		1 MHz

Table 19: General BS transmitter spurious emission limits in FR1, Category B

Spurious frequency range	Basic limit	Measurement bandwidth
9 kHz – 150 kHz	-36 dBm	1 kHz
150 kHz – 30 MHz		10 kHz
30 MHz – 1 GHz		100 kHz
1 GHz – 12.75 GHz	-30 dBm	1 MHz
12.75 GHz – 5th harmonic of the upper frequency edge of the DL operating band in GHz		1 MHz

The following parameters apply for the protection of the base station receiver additionally.

Table 20: BS spurious emissions basic limits for protection of the BS receiver

BS class	Frequency range	Basic limit	Measurement bandwidth
Wide Area BS	F_{UL_low} – F_{UL_high}	-96 dBm	100 kHz
Medium Range BS		-91 dBm	
Local Area BS		-88 dBm	

Test setup

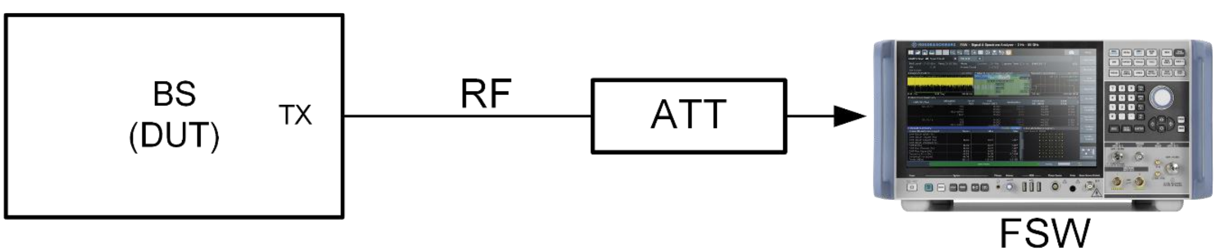


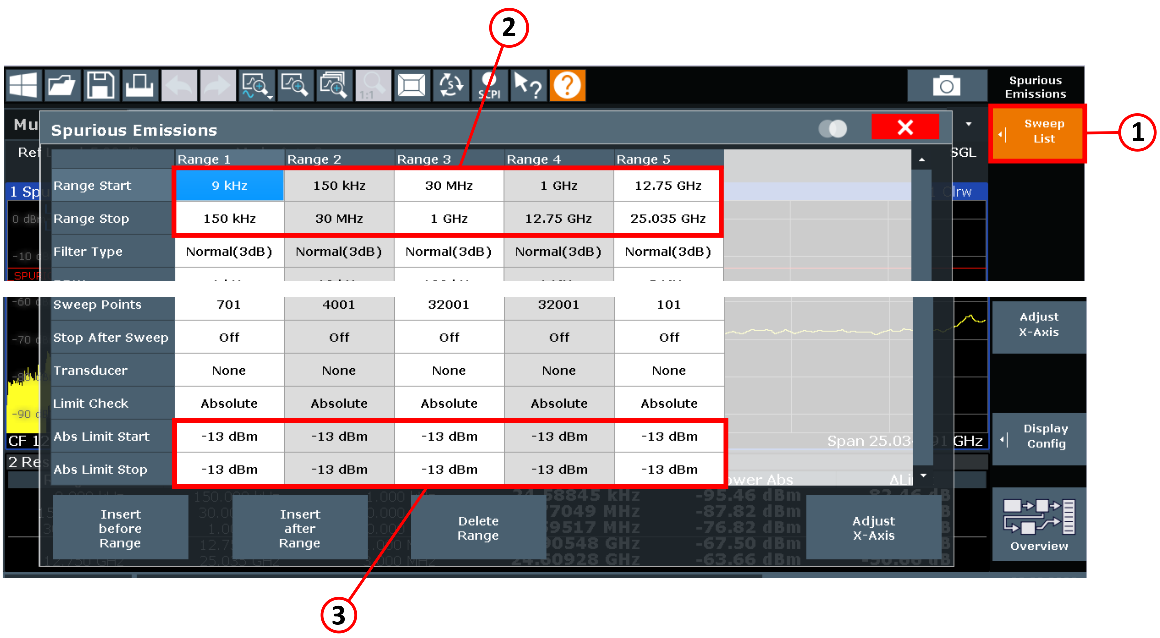
Figure 24: Test setup spurious emissions

The test requires a notch (or a diplexer) filter that suppresses the frequency range of the NR carrier on the base station. This makes it possible to meet high dynamic requirements (e.g. DUT transmits with 24 dBm, limit in protection receiver test -96 dBm → dynamic is 120 dB).

The DUT (base station) transmits with declared rated power. Test model NR-FR1-TM1.1 is required.

Manual testing procedure

1. Select mode **Spectrum**
2. Select measurement **Spurious Emission**
3. Set ② **Frequency ranges** and ③ **Limits** according to Table 18 and Table 19



4. Start measurement

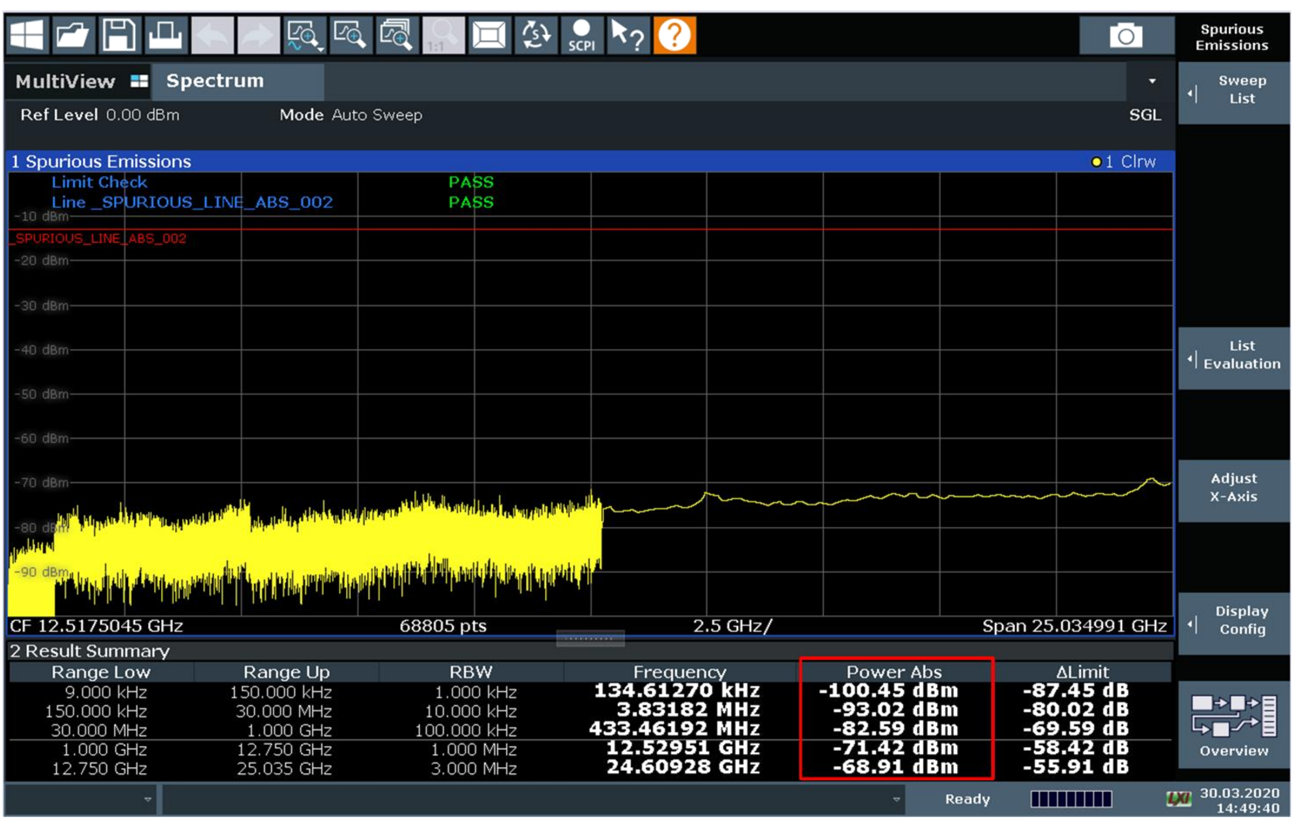


Figure 25: Spurious emissions

SCPI commands sequence

```
INSTrument[:SELect] SAN
INITiate<n>:SPURious
[SENSe:]LIST:RANGe<ri>[:FREQuency]:STARt <Frequency>
[SENSe:]LIST:RANGe<ri>[:FREQuency]:STOP <Frequency>
[SENSe:]LIST:RANGe<ri>[:LIMit]:STARt <Limit>
[SENSe:]LIST:RANGe<ri>[:LIMit]:STOP <Limit>
:SENS:LIST:XADJ;*WAI
:INIT:SPUR
TRACe<n>[:DATA]? LIST
```

3.10 Transmitter intermodulation (6.7)

The transmitter intermodulation requirement is a reading of the capability of the transmitter unit to inhibit the generation of signals in its non-linear elements caused by presence of the wanted signal and an interfering signal reaching the transmitter unit via the antenna, RDN and antenna array.

The transmit intermodulation level is the power of the intermodulation products when a NR signal of the lowest supported channel bandwidth as an interfering signal is injected into an antenna connector at a mean power level of 30 dB lower than that of the mean power of the wanted signal. The interfering signal offset is defined relative to the channel edges.

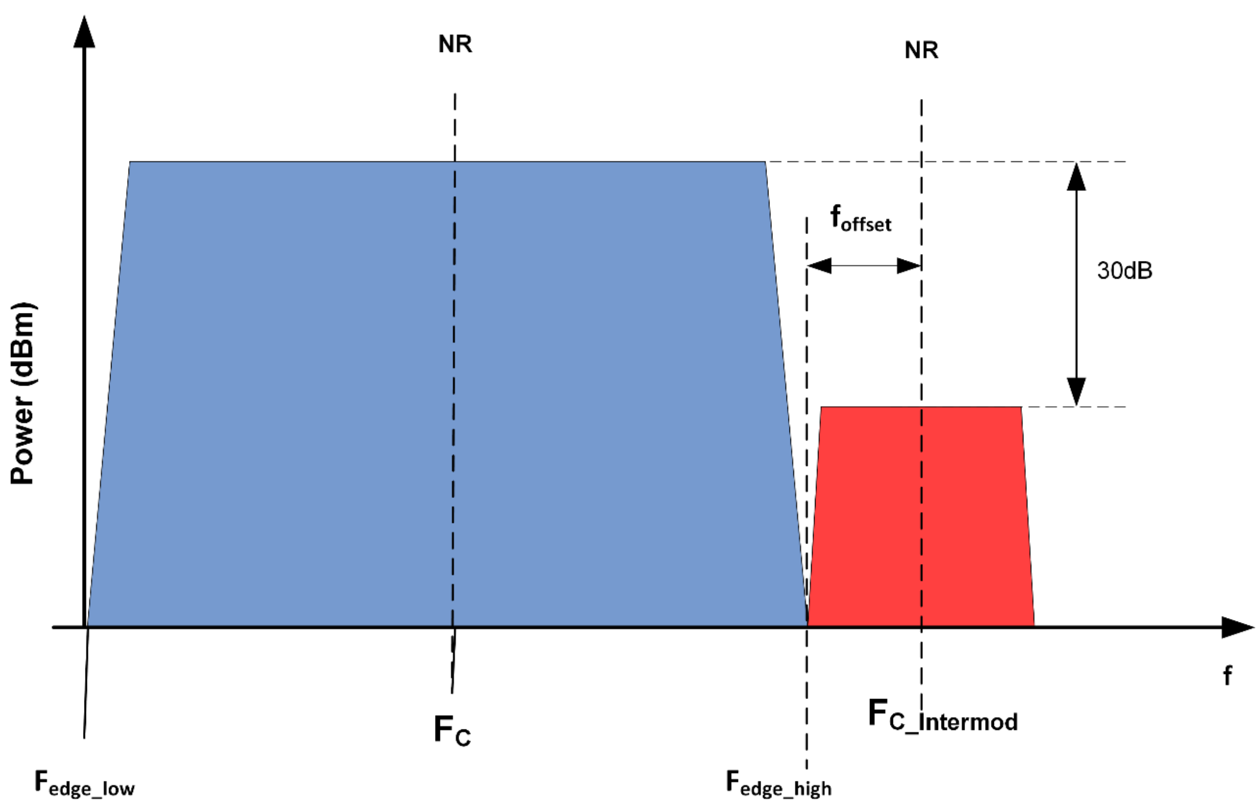


Figure 26: Transmit intermodulation

Table 21: Transmit intermodulation parameters

Wanted signal	Interfering signal	Frequency offset (to channel edge)
NR signal with NR-FR1-TM1.1	NR signal with NR-FR1-TM1.1 with minimum channel bandwidth with 15 KHz SCS level = $P_{rated,t,AC}$ - 30dB	± 0.5 * $BW_{Interferer}$ (n=1)
		± 1.5 * $BW_{Interferer}$ (n=2)
		± 2.5 * $BW_{Interferer}$ (n=3)

Test setup

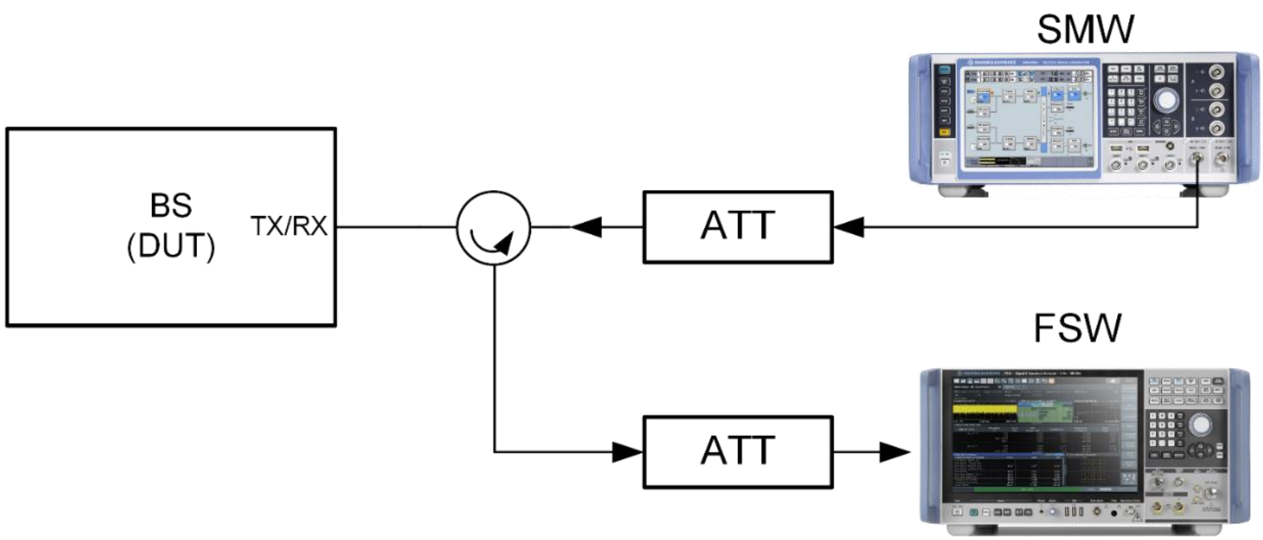


Figure 27: Test setup transmitter intermodulation

► The DUT (base station) generates the wanted signal at F_C with $BW_{Channel}$ and NR-FR1-TM1.1.

► The SMW generates a NR signal with NR-FR1-TM1.1 and the offsets according to Table 21, without interfering frequencies that are outside of the allocated downlink operation band or interfering frequencies that are not completely within the sub-block gap or within the inter RF bandwidth gap.

Measurements

The same conditions apply for these measurements as for:

► Adjacent channel leakage power (ACLR) (6.6.3)

► Operating band unwanted emissions (OBUE) (SEM) (6.6.4)

► Transmitter spurious emissions (6.6.5)

The measurement regions can be limited to the regions containing the intermodulation products.

Table 22: Measurement regions for intermodulation test

Intermodulation products	Center frequency	Intermodulation width
3rd order	2 * F1 ± F2	2 * $BW_{Channel}$ + 1 * BW_{Int}
	2 * F2 ± F1	2 * BW_{Int} + 1 * $BW_{Channel}$
5th order	3 * F1 ± 2 * F2	3 * $BW_{Channel}$ + 2 * BW_{Int}
	3 * F2 ± 2 * F1	3 * BW_{Int} + 2 * $BW_{Channel}$
	4 * F1 ± F2	4 * $BW_{Channel}$ + 1 * BW_{Int}
	4 * F2 ± F1	4 * BW_{Int} + 1 * $BW_{Channel}$
Note: F1: Wanted signal F2: Interferer		

Ranges which are calculated with subtraction and which have small distance to the wanted signal, may overlap with the wanted signal or the interferer (see example in Figure 28). The ranges must be adjusted accordingly. In principle, the following intermodulation products (ranges) can be affected:

- 2 * F1 + F2
- 2 * F1 - F2
- 2 * F2 + F1
- 2 * F2 - F1

The settings are explained in this example:

- Wanted signal: F1 = 2140 MHz with $BW_{Channel}$ = 20 MHz
- Interferer offset: + 2.5 MHz: F2 = 2140 MHz + $BW_{Channel}$/2 + 2.5 MHz = 2152.5 MHz
- Third order
  - 2 * F1 + F2 = 6432.5 MHz, Intermodulation BW = 45 MHz
  - 2* F1 - F2 = 3238.5 MHz, Intermodulation BW = 45 MHz
  - 2 * F2 + F1 = 6445 MHz, Intermodulation BW = 30 MHz
  - 2 * F2 - F1 = 2165 MHz, Intermodulation BW = 30 MHz

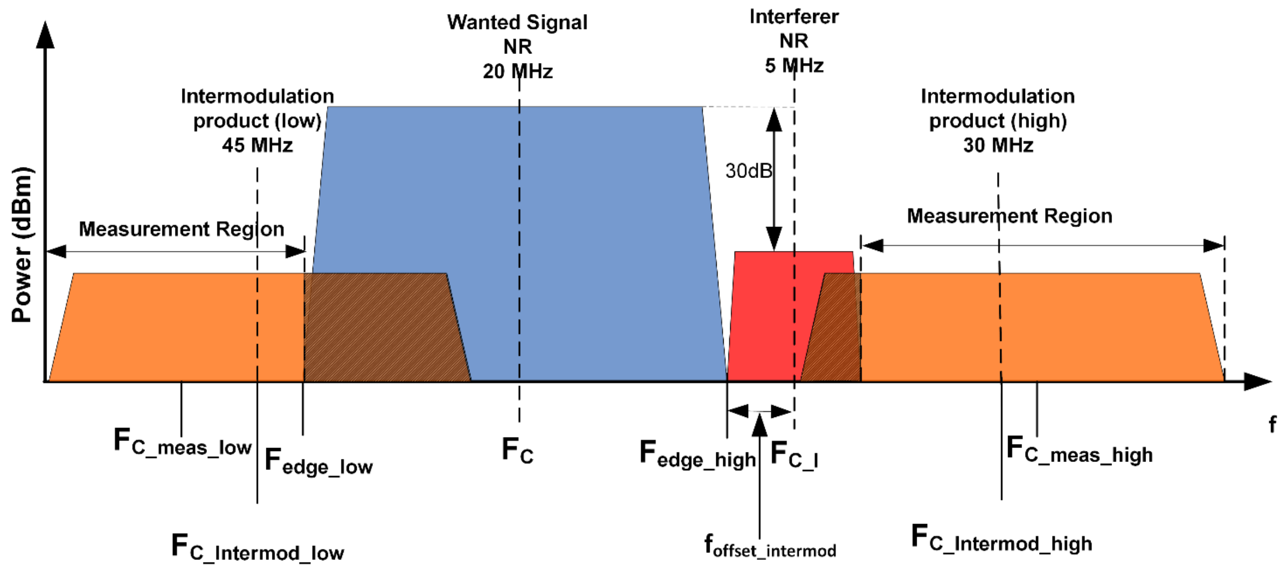


Figure 28: Measurement regions for the intermodulation test. Regions that overlap with the wanted signal or the interferer must be excluded

Manual testing procedure (FSW)

The Manual testing procedure for this test is similar to the procedure which is mentioned in chapter Adjacent channel leakage power (ACLR) (6.6.3), Operating band unwanted emissions (OBUE) (SEM) (6.6.4) and Transmitter spurious emissions (6.6.5).

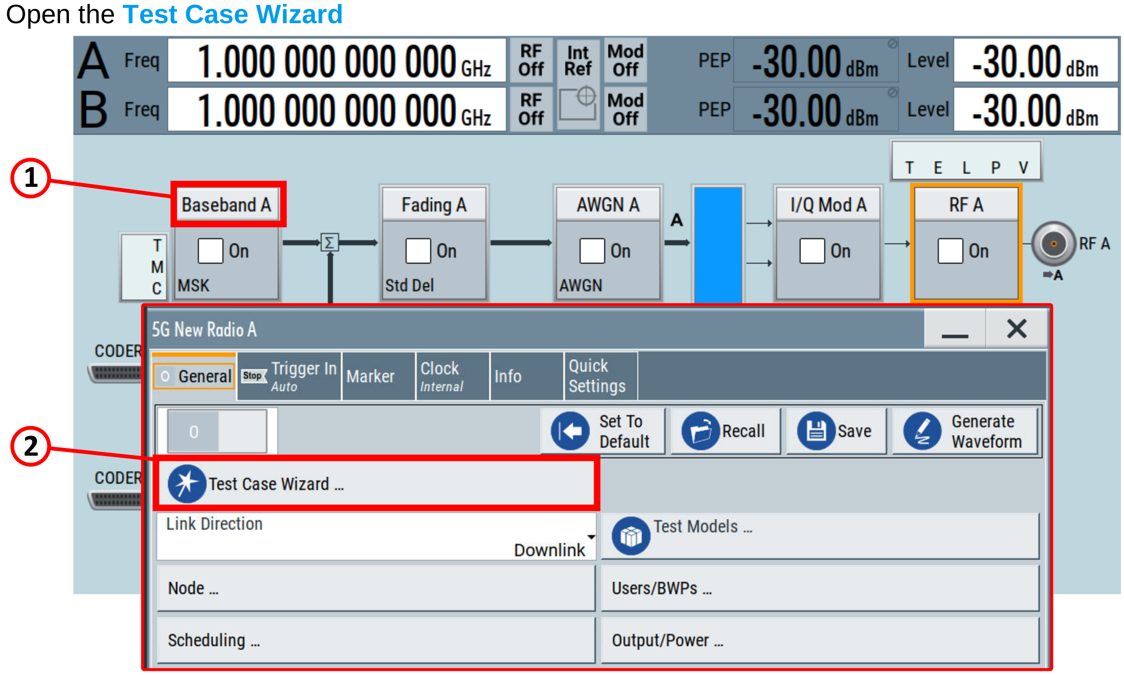
SCPI commands sequence (FSW)

The SCPI sequence is similar to to the sequence which is mentioned in chapter Adjacent channel leakage power (ACLR) (6.6.3), Operating band unwanted emissions (OBUE) (SEM) (6.6.4) and Transmitter spurious emissions (6.6.5).

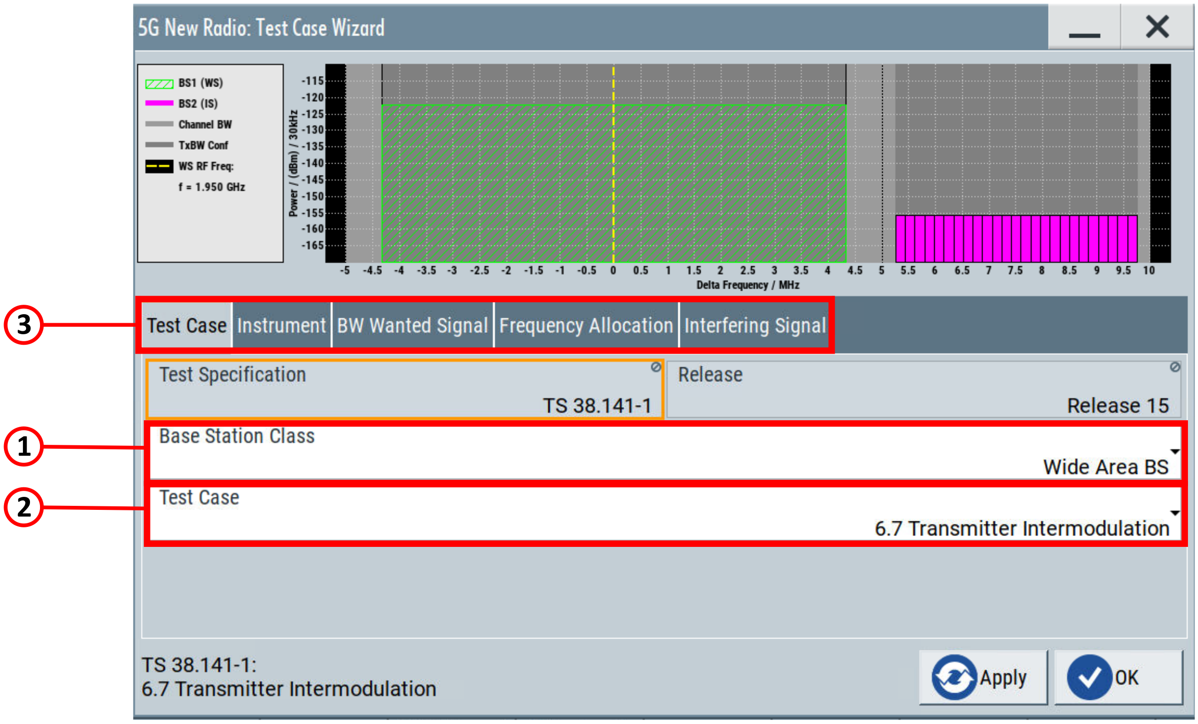
Manual testing procedure (required SMW firmware: higher than 4.70.026.51)

Note: The Test Case Wizard (TCW) is programmed on the basis of TS 38.141-1, Rel. 15. However, because the interferer parameter settings are the same like in TS 38-141-1, Rel 16 V.16.3.0 the TCW can be used.

1. Open the **Test Case Wizard**



2. Select the ① **Base Station Class**, the ② **Test Case** and set the ③ **further settings** through the tabs



SCPI commands sequence (SMW)

```
:BB:NR5G:TCW:BSCLass <BSClass>
:BB:NR5G:TCW:TC TS381411_TC67
:BB:NR5G:TCW:TRIGgerconfig <TrigConfig>
:BB:NR5G:TCW:MARKerconfig <MarkerConfig>
:BB:NR5G:TCW:WS:RFFRequency <WSRFFreq>
:BB:NR5G:TCW:WS:CBW <WSChBw>
:BB:NR5G:TCW:WS:PLEVel <WSPowLev>
:BB:NR5G:TCW:FA:FRALlocation <FreqAlloc>
:BB:NR5G:TCW:IS:BAND <Band>
:BB:NR5G:TCW:IS:OFN <OFN>
:BB:NR5G:TCW:IS:DUPLex <Duplexing>
:BB:NR5G:TCW:APPLy
:OUTPut1:STAT 1
```

Python library

As test case 6.7 Transmitter intermodulation includes several previous explained test cases (6.6.3, 6.6.4 and 6.6.5) the python module TC_6_7.py contains only the interfering generation process. To execute the whole test case, please execute TC_6_7.py, TC_6_6_3.py, TC_6_6_4.py and TC_6_6_5.py.

A code example is shown in A.4.

4 Literature

[1] 3GPP Technical Specification Group Radio Access Network,
"NR Base station conformance testing, Part 1: Conducted conformance testing, Release 16; TS 38.141-1, V16.3.0", 2020.
Available: https://www.3gpp.org/DynaReport/38141-1.htm.

[2] 3GPP Technical Specification Group Radio Access Network
"NR Base Station (BS) conformance testing Part 2: Radiated conformance testing, Release 16; TS 38.141-2 V.16.3.0", 2020.
Available: https://www.3gpp.org/DynaReport/38141-2.htm.

[3] Rohde & Schwarz, 5G NR Technology Introduction, 2019.

[4] 3GPP Technical Specification Group Radio Access Network,
"NR Base Station (BS) radio transmission and reception, Release 16; TS 38.104, V16.3.0", 2020.
Available: https://www.3gpp.org/DynaReport/38104.htm.

[5] Rohde & Schwarz, "5G NR Base Station OTA Transmitter Tests (GFM324)," 2020
Available: https://www.rohde-schwarz.com/appnote/GFM324.

[6] Rohde & Schwarz, "5G NR Base Station OTA Receiver Tests (GFM325)", 2020
Available: https://www.rohde-schwarz.com/appnote/GFM325.

[7] Rohde & Schwarz, "Remote Control and Instrument Drivers"
Available: https://www.rohde-schwarz.com/de/driver-pages/fernsteuerung/uebersicht_110753.html.

[8] Rohde & Schwarz, "Introducing SCPI Commands"
Available: https://www.rohde-schwarz.com/de/driver-pages/fernsteuerung/remote-programming-environments_231250.html.

5 Ordering Information

Type	Designation	Order No.
R&S®FSW43	Signal and spectrum analyzer	1331.5003.43
R&S®FSW-K144	5G-NR downlink measurements	1338.3606.02
R&S®FSV3044	Signal and spectrum analyzer	1330.5000.43
R&S®FSVA3044	Signal and spectrum analyzer	1330.5000.44
R&S®FSV3-K144	5G-NR downlink measurements	1330.7219.02
R&S®FPS40	Signal and spectrum analyzer	1319.2008.40
R&S®FPS-K144	5G-NR downlink measurements	1321.4979.02
R&S®VSE	Signal analysis software	1345.1011.06 or 1345.1105.06
R&S®VSE-K144	5G-NR downlink measurements	1309.9574.06
R&S®SMW200A	Vector signal generator	1412.0000.02
R&S®SMW-B1003	Frequency option	1428.4700.02
R&S®SMW-B10 or **R&S®SMW-B9**	Baseband generator option	1413.1200.02 or 1413.7350.02
R&S®SMW-B13T or **R&S®SMW-B13XT**	Baseband main module option	1413.3003.02 or 1413.8005.02
R&S®SMW-K62	AWGN option	1413.3484.02
R&S®SMW-K144	5G New Radio	1414.4990.02
R&S®SMBV100B	Vector signal generator	1423.1003.02
R&S®SMBVB-B103	Frequency range 8 kHz to 3 GHz	1423.6270.02
R&S®SMBVB-K520	Baseband real-time extension	1423.7676.02
R&S®SMBVB-K144	5G New Radio	1423.8608.02

6 Appendix

A GFM313_Tx_tests Python package

This Python library is providing chapter 6 test cases defined in TS 38.141-1. These Python classes are meant to be integrated easily into existing Python development environment and projects.

By this the time for searching and testing correct SCPI sequences shall be reduced tremendously.

A.1 Terms and conditions

By downloading the Python package, you are agreeing to be bound by the Terms and conditions for royalty free software.

A.2 Requirements

- The following setup is recommended:
- Python version 3.8
- PyCharm IDE
  - The Community Edition version is sufficient
  - https://www.jetbrains.com/pycharm/
- `RsInstrument` Python module is required (1.8.2.45 or higher)
  - pypi.org: https://pypi.org/project/RsInstrument/
  - Further details: How to install / update RsInstrument package

For further reading

Please see the Getting Started remote control example using Python in PyCharm.

A.3 Package structure

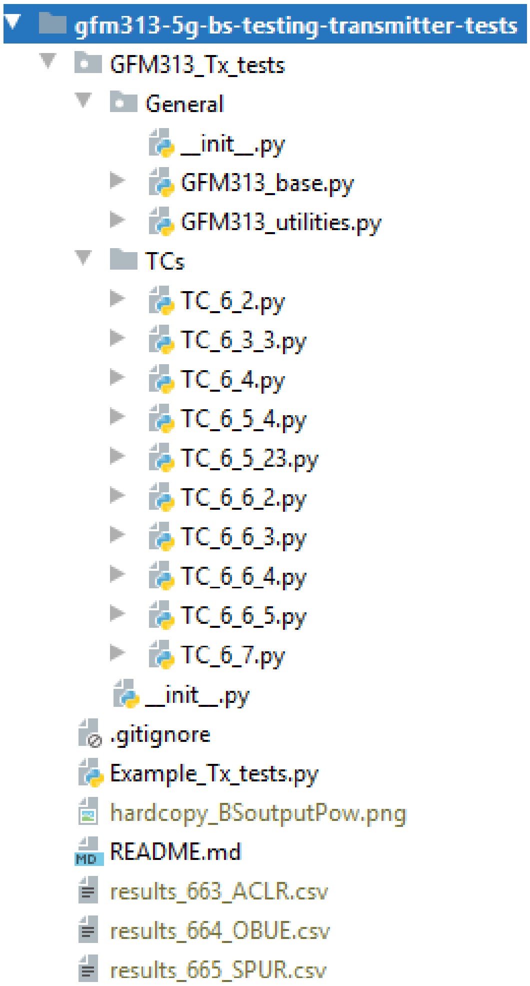


Figure 29: Project tree in PyCharm

A.4 Example_Tx_tests.py

The provided `Example_Tx_tests.py` file shows the usage of this Python library for 5G NR base station transmitter tests.

```
from GFM313_Tx_tests import *

resource_string_FSW_hislip = 'TCPIP::192.168.1.1::hislip0'  # Hi-Speed LAN connection - see 1MA208
resource_string_FSW_vxi11 = 'TCPIP::192.168.1.1::INSTR'  # VXI-11 connection

# Signal generator required for TC 6.7
resource_string_SMW_hislip = 'TCPIP::192.168.1.2::hislip0'  # Hi-Speed LAN connection - see 1MA208
resource_string_SMW_vxi11 = 'TCPIP::192.168.1.2::INSTR'  # VXI-11 connection
resource_string_SMW_usb = 'TCPIP::0x0AAD::0x0119::022019943:INSTR'  # USB-TMC

try:
    # Example for TC 6.2 Base station output power
    # Initialization
    mytest62 = TC62(resource_string_FSW_hislip)
    # Set some test specific parameters
    mytest62.frequency = 1000
    mytest62.reference_level_offset = 3
    mytest62.testmodel = 'NR-FR1-TM1_1__TDD_10MHz_15kHz'
    # Start measurement
    mytest62.start_measurement()
    # Print results
    print(mytest62.return_results())
    # Export results to csv
    mytest62.csv_export()
    # Screenshot of analyzer
    mytest62.hardcopy_analyzer('hardcopy_2')
    # Close the connection
    mytest62.close_analyzer()

except RsException as e:
    print(e.args[0])
else:
    print('Test execution successful')
```

Figure 30: Example_Tx_tests.py

Code example for 6.7 Transmitter intermodulation test case

```
# Example for TC 6.7 Transmitter intermodulation

# Interferer generation with SMW
mytest67 = TC67(resource_string_SMW_hislip)
mytest67.interferer_duplex = 'TDD'
mytest67.frequency = 1200
mytest67.channel_bw = 20
mytest67.apply_swm_configuration()
mytest67.output_on(1)

# Adjacent channel leakage power measurement
mytest663 = TC663(resource_string_FSW_hislip)
mytest663.frequency = mytest67.frequency
mytest663.channelBW = mytest67.channel_bw
mytest663.start_measurement()
mytest663.csv_export()

# Operating band unwanted emissions measurement
mytest664 = TC664(resource_string_FSW_hislip)
mytest664.frequency = mytest67.frequency
mytest664.channel_bw = mytest67.channel_bw
mytest664.start_measurement()
mytest664.csv_export()

# Transmitter spurious emissions measurement
mytest665 = TC665(resource_string_FSW_hislip)
mytest665.frequency_5thharmonic = 17500
mytest665.start_measurement()
mytest665.csv_export()
```

Figure 31: Code example for test case 6.7 Transmitter intermodulation

A.5 Quick Documentation in PyCharm

By pressing the shortcut **Ctrl + Q** the quick documentation can be displayed. This then shows a short description about the corresponding parameter or function.

```
# Adjacent channel leakage power measurement
mytest663 = TC663(resource_string_FSW_hislip)
mytest663.frequency = mytest67.frequency
mytest663.chan
mytest663.star
mytest663.csv_
```

```
Instance attribute frequency of GFM313_Tx_tests.TCs.TC_6_6_3.TC663
frequency: int = 1000
```

Set center frequency in MHz

Figure 32: Quick Documentation

A.6 CSV export function

Every implemented test case class provides a csv-export function. This function delivers an easy table structured overview of the measurement results. The exported .csv-file is stored to the project directory and can be used for further measurement analyzes.

```
mytest62.csv_export()
```

Figure 33: csv-export function call

A.7 Hardcopy function

In addition to the above described csv export function, every test case class provides a hardcopy function. By this the user can easily screenshot the connected spectrum analyzer and store the .png-file with an individual file name to the project directory.

```
mytest62.hardcopy_analyzer('hardcopy_2')
```

Figure 34: Hardcopy function call: Stores a screenshot of the connected analyzer as a .png-file to the project directory

B R&S® QuickStep

The QuickStep software application makes it possible to combine testmodules provided by Rohde & Schwarz into test plans to allow rapid and easy remote control of test instruments. The program needs a R&S License. The testmodules for 5G NR base station tests are free of charge.

B.1 Terms and conditions

By downloading the QuickStep package you are agreeing to be bound by the [Terms and conditions for royalty free software](#).

B.2 Requirements

Operating system:

- ► Windows 10
- ► Windows 8.1
- ► Microsoft Windows 7 (64 bit, SP 1, universal C runtime)

General PC requirements: Standard PC

Remote control interface:

- ► R&S® Visa
- ► LAN connection

B.3 First steps

Please use the provided **test procedure** as a first step. This allows you to skip very basic settings.

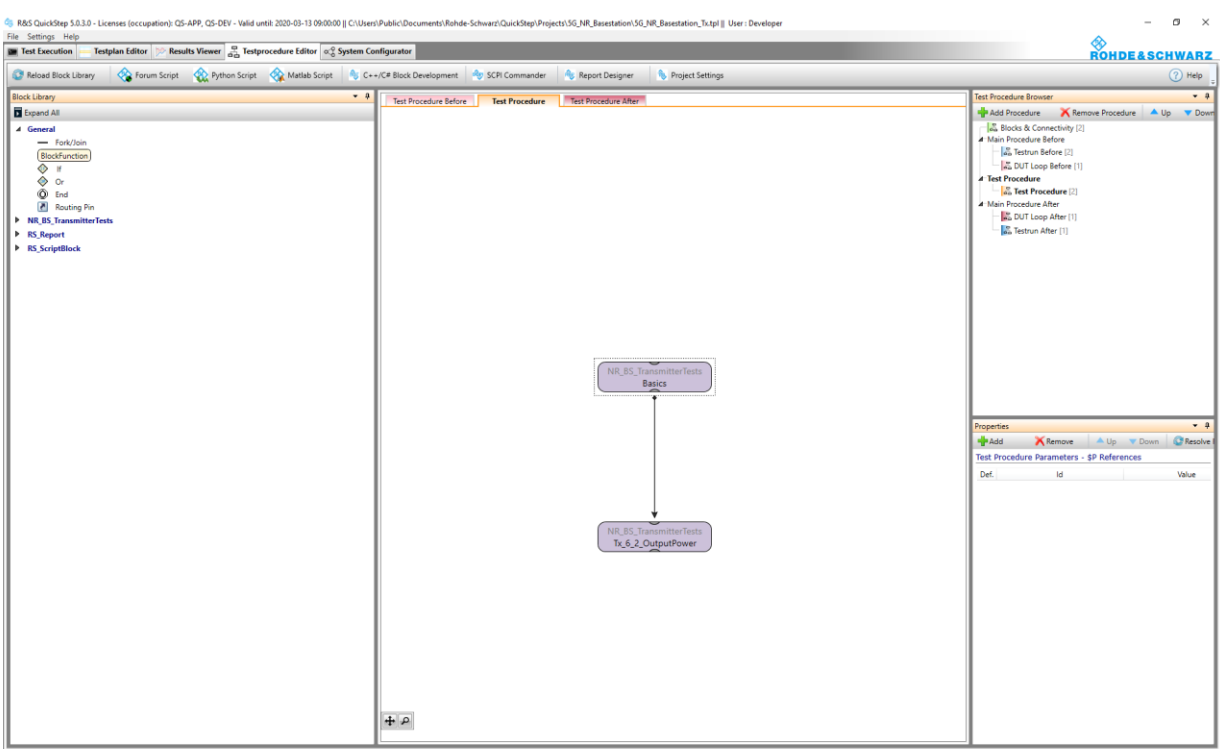


Figure 35: QuickStep overview

You can find all 5G NR base station transmitter tests on the left side under **Block Library NR_BS_TransmitterTests**. In the middle under **Test Procedure**, you can find the active **Testsequence**.

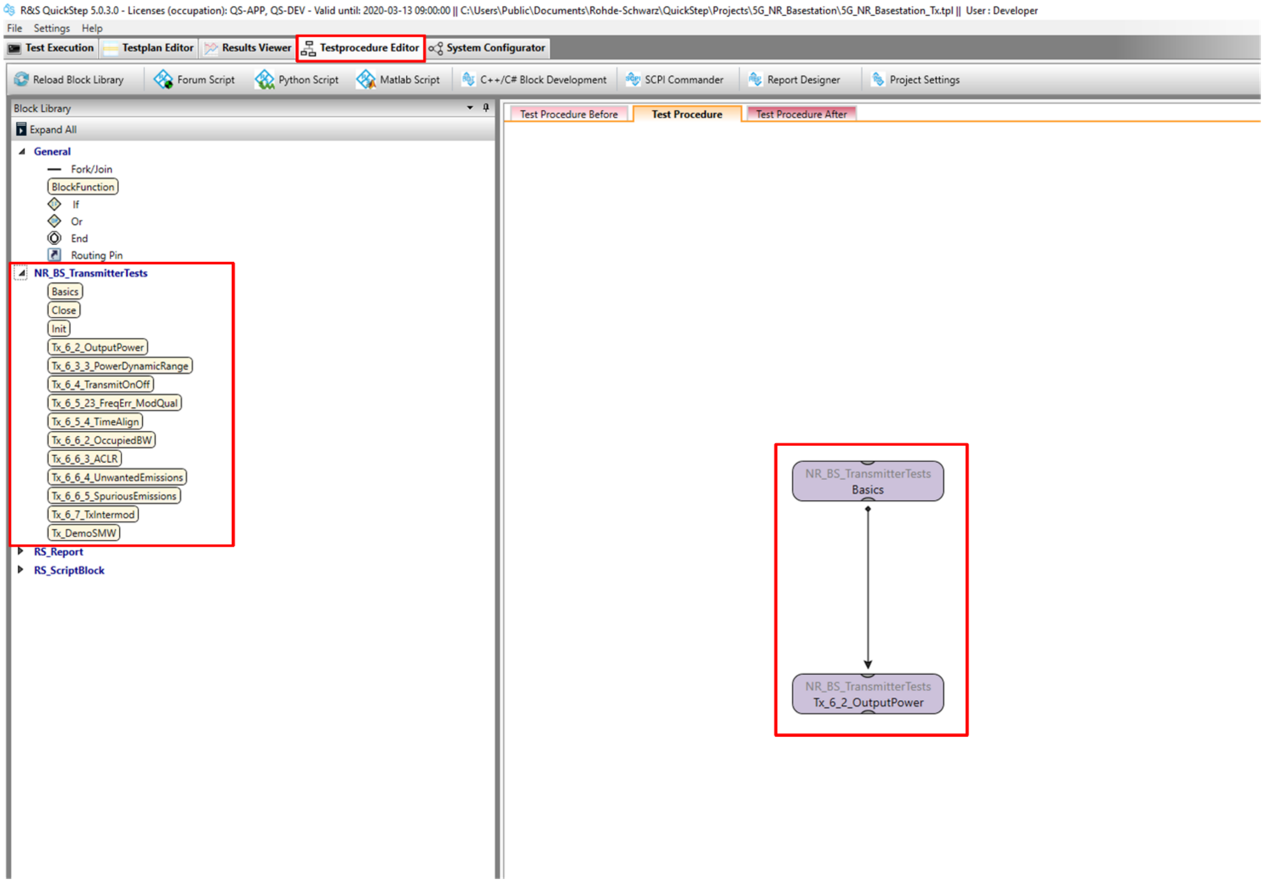


Figure 36: QuickStep test procedure

It is possible to create your own **test procedure** by using drag-and-drop. Select the testmodule from the block library and drag it into the **Test Procedure** section. Please make sure to connect the bottom port of a block to the top port of the next block.

To start a test, go to the tab **Testplan Editor** and click on the button **Single Run**.

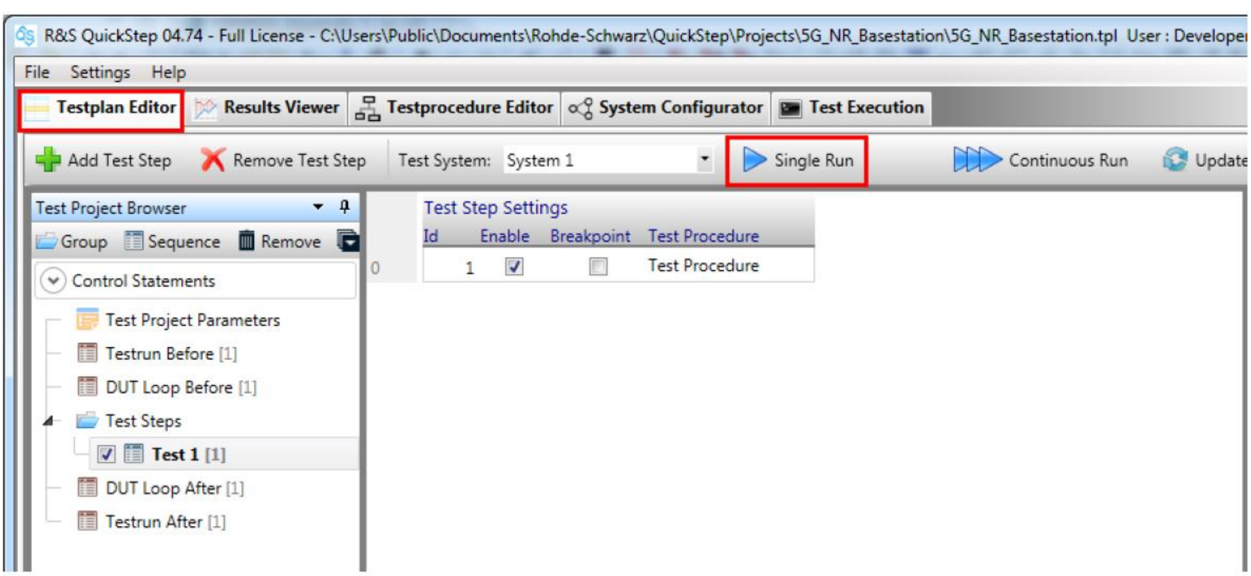


Figure 37: Run a test

After the execution run you can find the results under the tab **Results Viewer**.

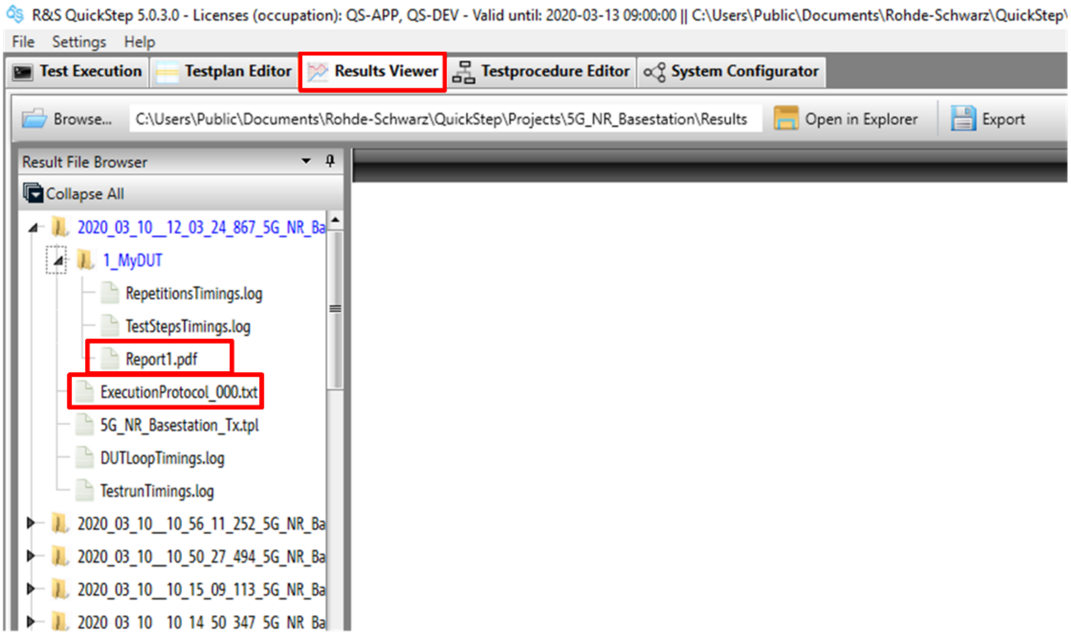


Figure 38: QuickStep results

A click on **<name of report>.pdf** opens the report on the last run.

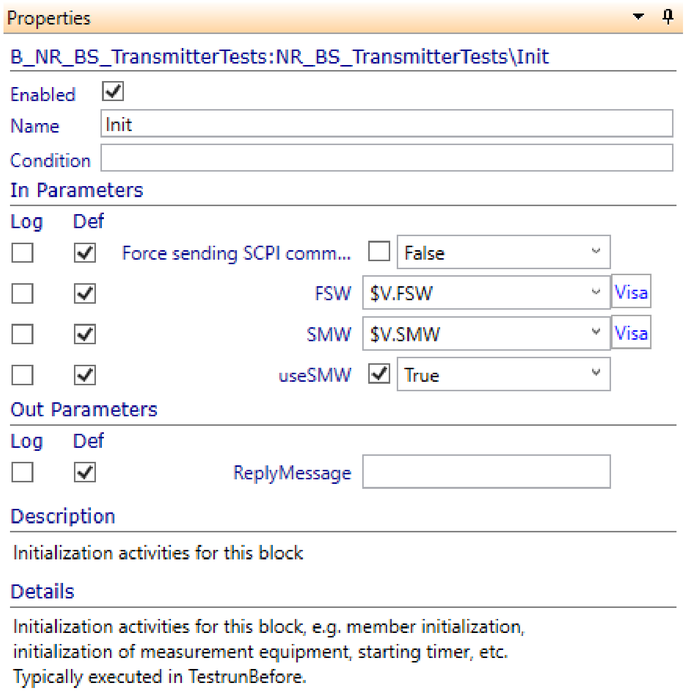
ExecutionProtocol_000.txt shows a protocol of the last run which includes all messages from QuickStep and the sent and received SCPI interactions.

B.4 QuickStep Tx blocks

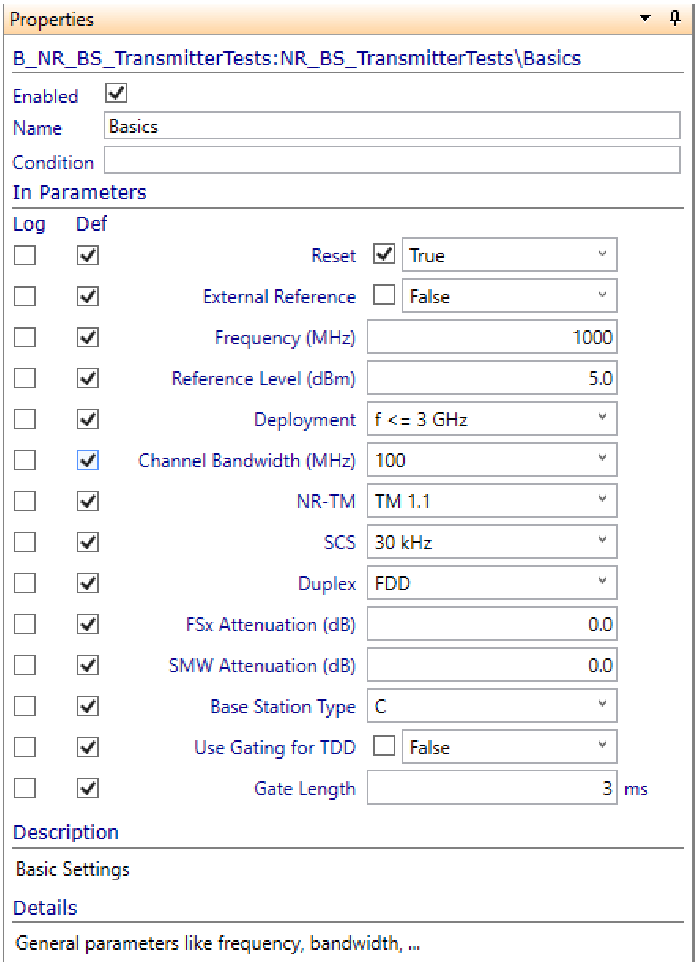
► Initialization

– Block name: Init

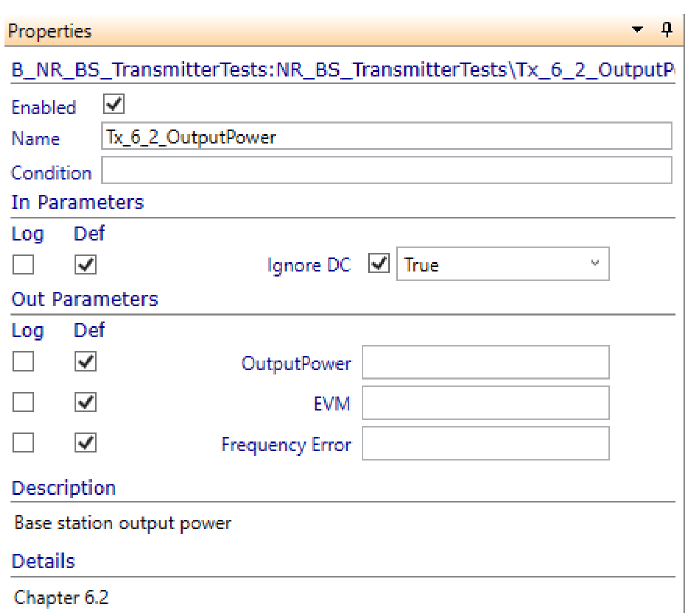
– part of "Testrun Before" Manual testing procedure



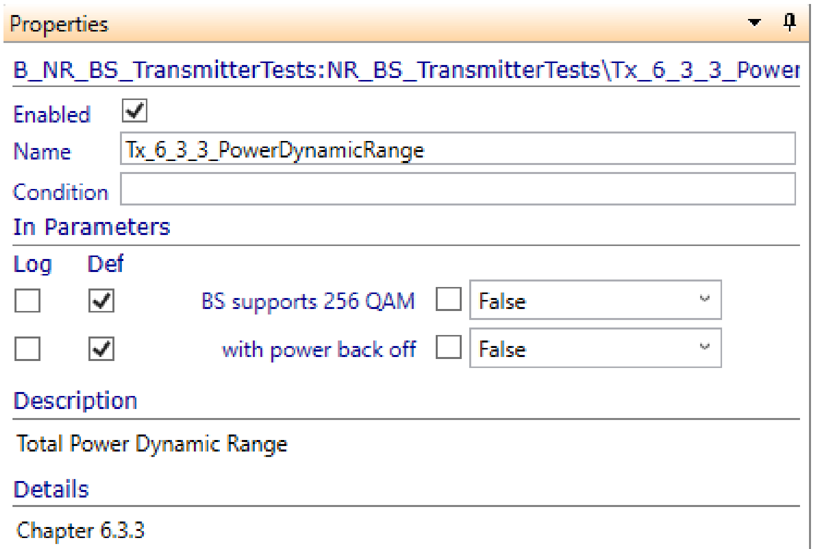
- Basic parameters
  – Block name: Basics
  – provides principal 5G NR settings independently of the further test steps



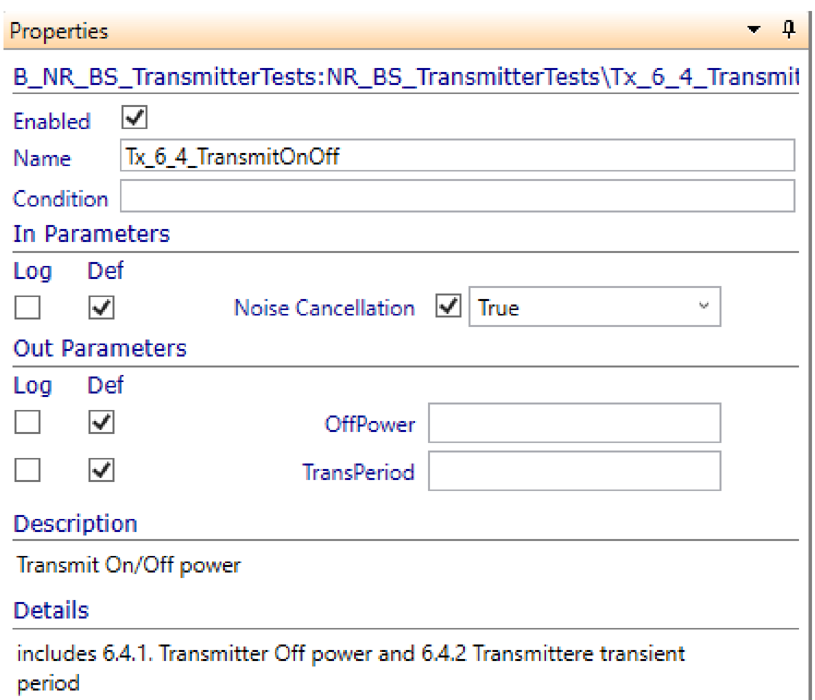
- Test 6.2 Output power dynamics
  – Block name: Tx_6_2_OutputPower



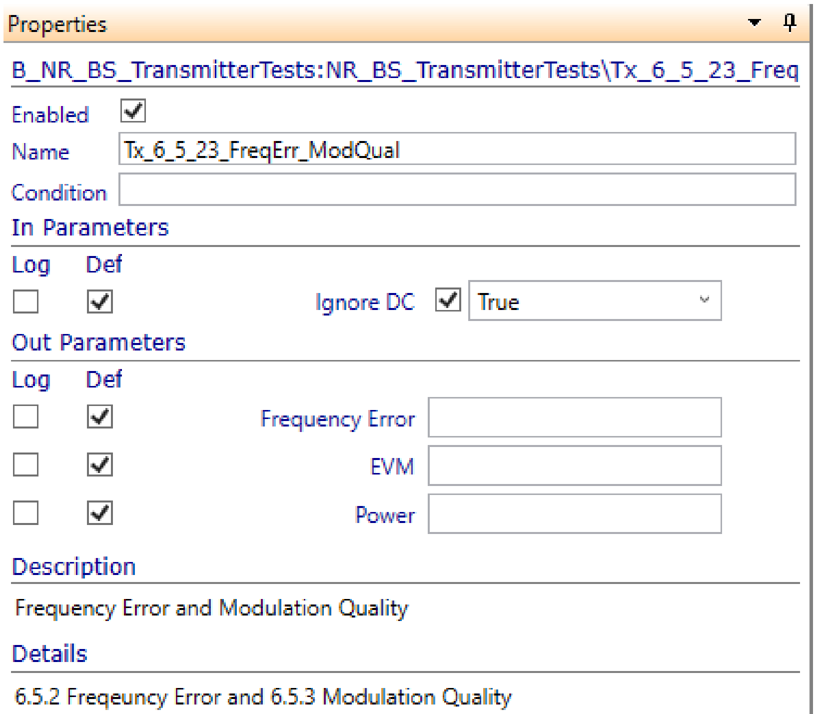
- Test 6.3.3 Total power dynamic range
  - Block name: Tx_6_3_3_PowerDynamicRange



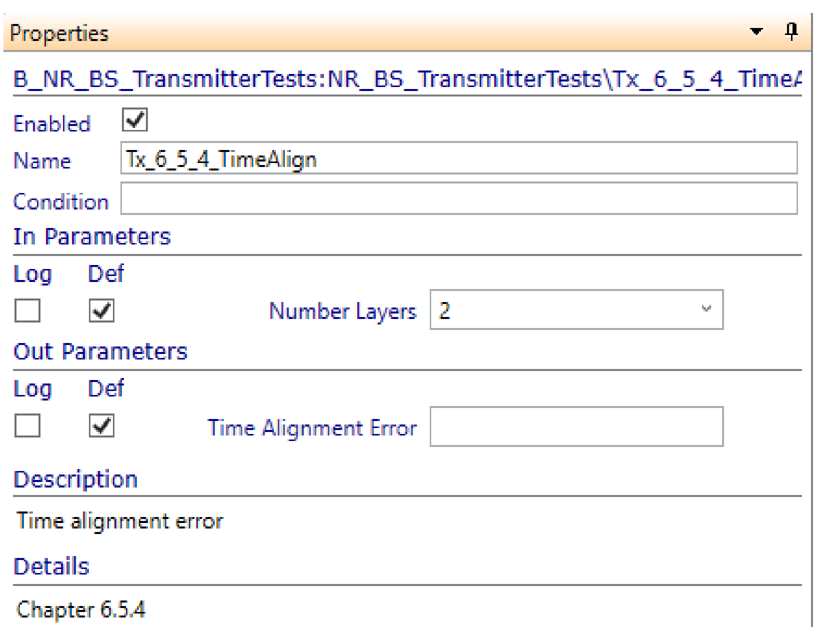
- Test 6.4 Transmit on/off power
  - Block name: Tx_6_4_TransmitOnOff



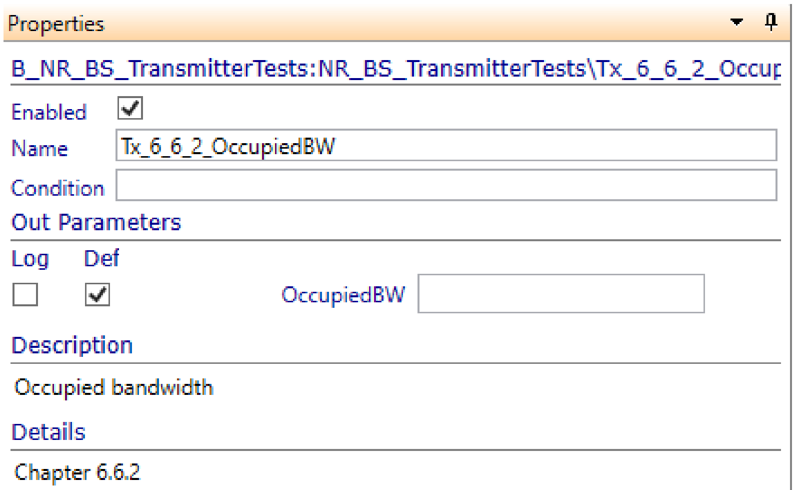
- ► Test 6.5.2 Frequency error and Test 6.5.3 Modulation quality
  - – Block name: Tx_6_5_23_FreqErr_ModQual
  - – Both tests are implemented in one QuickStep test block



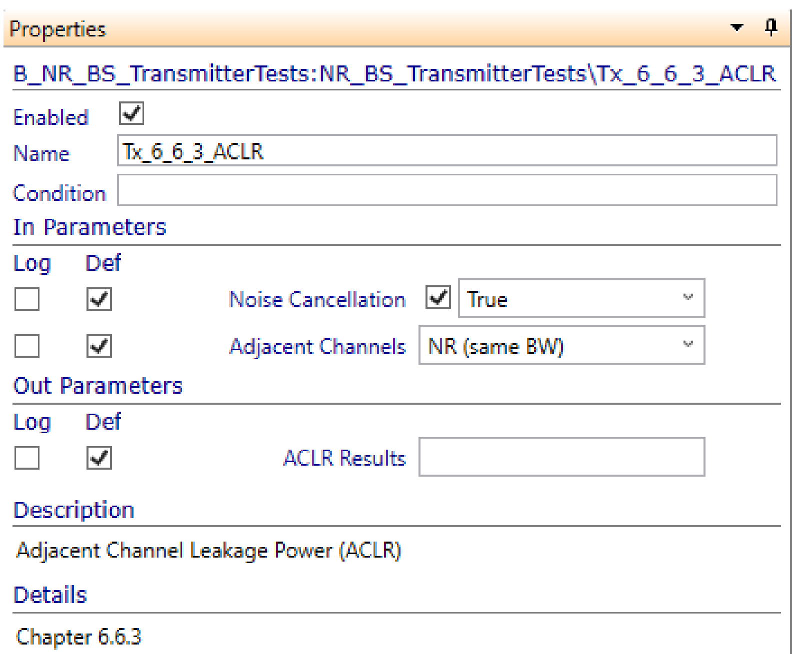
- ► Test 6.5.4 Time alignment error (TAE)
  - – Block name: Tx_6_5_4_TimeAlign



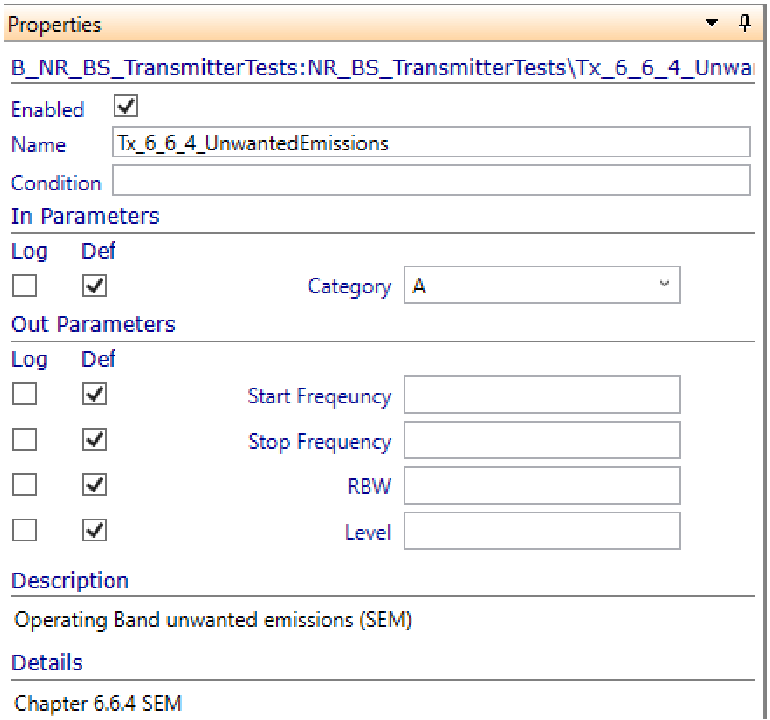
- ▶ Test 6.6.2 Occupied bandwidth (OBW)
  – Block name: Tx_6_6_2_OccupiedBW



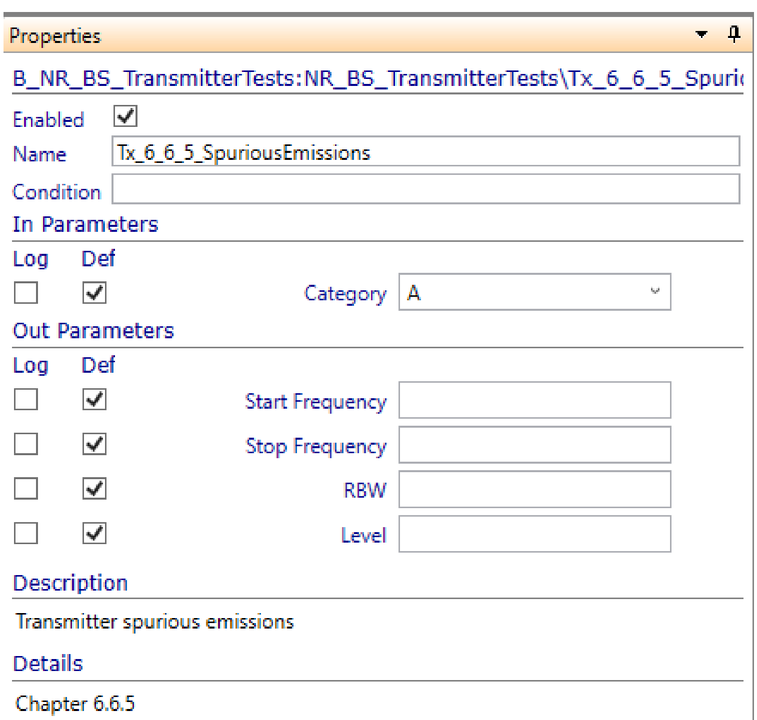
- ▶ Test 6.6.3 Adjacent channel leakage power (ACLR)
  – Block name: Tx_6_6_3_ACLR



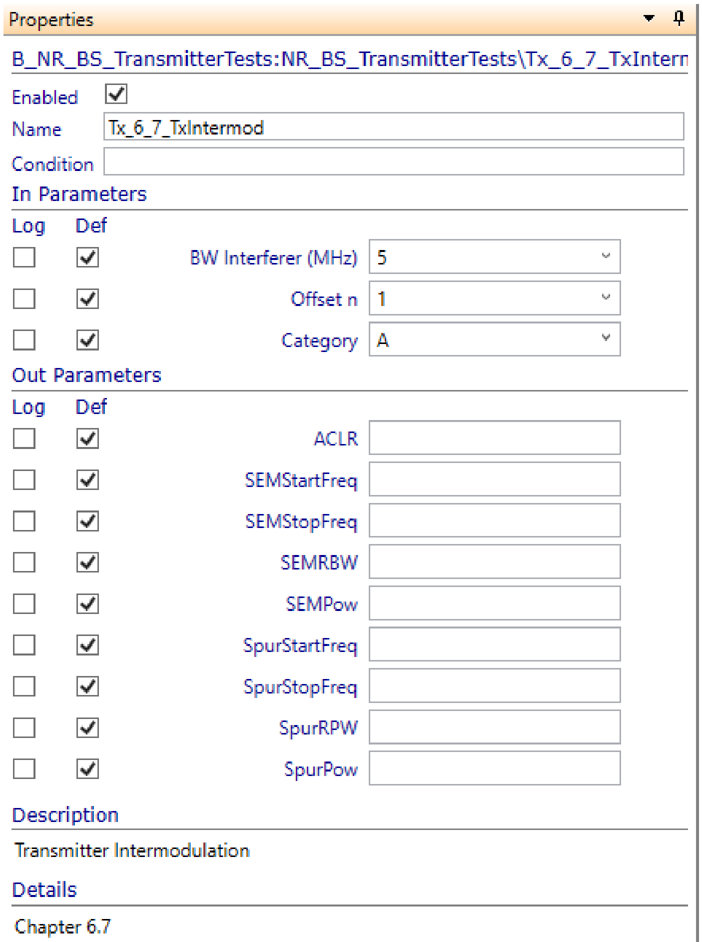
- Test 6.6.4 Operating band unwanted emissions (OBUE) (SEM)
  – Block name: Tx_6_6_4_UnwantedEmissions



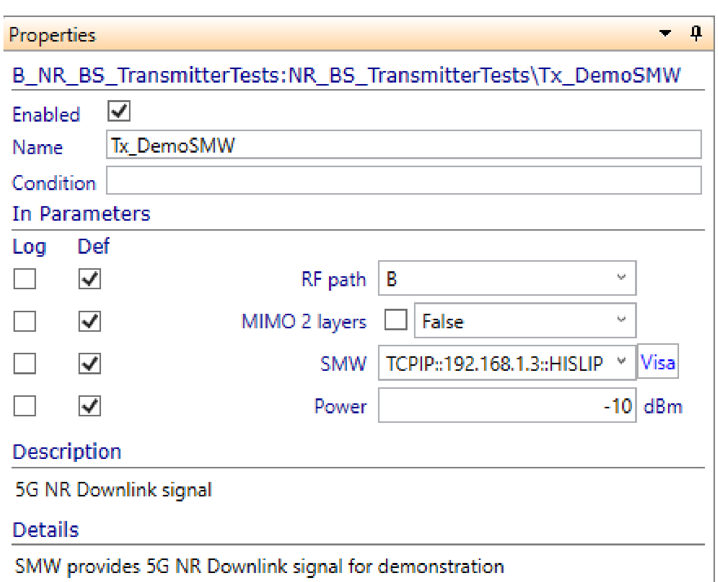
- Test 6.6.5 Transmitter spurious emissions
  – Block name: Tx_6_6_5_SpuriousEmissions



- Test 6.7 Transmitter intermodulation
  - Block name: Tx_6_7_Tx_intermod



- Tx_DemoSMW
  - usage optional
  - with this block it is possible to simulate a base station but please note that not all base station functions can be simulated with a vector signal generator



C Abbreviations

Abbreviation	Description
5G NR	5G New Radio
ACLR	Adjacent channel leakage power ratio
CA	Carrier aggregation
DUT	Device under test
EVM	Error vector magnitude
FDD	Frequency division duplex
FR1	Frequency range 1
MIMO	Multiple input multiple output
OBUE	Operating band unwanted emissions
OBW	Occupied bandwidth
OTA	Over the air
PDSCH	Physical downlink shared channel
P_{rat}	Rated output power
Px-	Performance-
RB	Resource block
RBW	Resolution bandwidth
RF	Radio frequency
RIB	Radiated interface boundary
RS	Reference signal
Rx-	Receiver-
SC	Single carrier
SCS	Subcarrier spacing
SSB	Synchronization signal block
TAB	Transceiver array boundary
TAE	Time alignment error
TDD	Time division duplex
TM	Test model
Tx-	Transmitter-
VSWR	Voltage standing wave ratio

Rohde & Schwarz

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GFM313 | Version 3e | 01.2021
Application Note | 5G New Radio Conducted Base Station Transmitter Tests
Data without tolerance limits is not binding | Subject to change