RADIATED WIRELESS COEXISTENCE TESTING

A step by step HOW TO guide to perform manual and automated wireless coexistence testing.

Products:

- ► R&S®CMW270/290/500
- ► R&S®FSW
- ► R&S®SMW200A
- ► R&S®AdVISE

- ► R&S®BBA130/150/300
- ► R&S®HF907
- ► R&S®IQW100/500
- ► R&S®SAM100

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Contents

1 Introduction

At the end of the year 2020, there were over 20 Billion internet of things (IoT) products in the world operating using the licensed and unlicensed frequency bands. This growth trend is projected to keep steady over the coming years as more and more people adopt to a smarter and more connected lifestyle. This will result in a much busier and challenging RF environment than the one we have today. In order to understand the complexity of the RF spectrum, a white paper was published in 2021 from Rohde & Schwarz [1], which featured RF spectrum activity at multiple locations observed at different times of the day. The locations were selected based on population densities and the amount of known RF transmitters & their frequencies at those locations. It was also concluded that the ISM bands on average have higher channel utilization since most IoT devices take advantage of the unlicensed spectrum. The paper recommended, that while performing wireless coexistence testing, the test conditions should reflect the operational RF environment that the device is intended to operate in. Otherwise, the characterization of RF performance would only reflect ideal case which doesn't exist in real world operation. Since it is not always possible to test all devices in the real world, relevant test methodologies need to be setup to replicate the real world as much as possible.

This will help us get a better understanding of how the receiver of the RF device will behave under different RF conditions. It is also recommended to perform measurements in order to understand the behavior of the device in the future when the spectrum will get even more challenging. Therefore, a through characterization of the capability of the RF receiver to handle in-band and out-of-band interference signals in also of interest.

In terms of regulatory compliance requirements for ensuring wireless coexistence performance, the ANSI C63.27 is currently the only published test standard that provides guidance on how to perform coexistence testing on devices. The test complexity is based up on risk imposed on the user's health in the event of a failure caused by an or a plurality of interference signal. The standard also gives device manufacturers guidance regarding test setups, measurement environments, interference signal types and strategy, performance quality measurement parameters for physical layer using key performance indicator (KPI) and application layer parameters for end-to-end functional wireless performance (FWP).

In this application note, the guidance provided by the ANSI C63.27-2021 version regarding test setup, measurement parameter and interference signal have been followed. It will give the reader a clear idea on how to configure standardized test instruments from R&S in order to generate the wanted signal as well as unintended interference signals and conduct measurement to monitor device performance in terms of PER, ping latency and data throughput.

This application note provides step-by-step instruction on how to perform measurements using conducted and radiated methodology. Both manual and automated instrument configuration approach is explained in this document.

The automation scripts are written using python scripting language and are available for download with this application note, free of charge. Official R&S python packages required to run the scripts are available on the PYPI database.

2 ANSI C63.27 Wireless Coexistence test standard

From a regulatory stand point the awareness towards ensuring receiver performance is slowly gaining momentum. For the EU market, receiver blocking tests are defined in multiple harmonized RED EN standards. However, blocking tests are not yet designed to characterize the device performance in their real-world operating environment. Even though the requirements for the go/no-go tests are quite stringent in nature but it is hard to determine with confidence the future performance of a device in an ever-increasing complex RF reality especially for critical devices that are intended to serve health and safety related applications.

The ANSI C63.27 wireless coexistence test standard provides guidance on how to tackle this challenge head on by describing in detail on how to characterize the behavior for a device (operating using WLAN, LTE & Bluetooth) in various RF operational scenarios in terms of both physical and application layer performance.

The core component of the standard is to create a test plan. The test plan includes the following steps [1]:

1. Identify the intended EM (electromagnetic) environment

2. Determine the FWP (functional wireless performance) of the device

3. Evaluate and determine the risk tier to be used for test complexity

4. Choose a test method (conducted, radiated, multi-chamber or radiated open environment)

5. Determine the relevant intended signal

6. Determine the relevant unintended signals

Before starting with the measurement procedure, each of the points from the above-mentioned test plan needs to be properly defined. Let us take as an example, a wireless patient monitoring system (WPMS) consisting of remote patient unit and central monitoring server/station as our device under test (DUT) in order to further explain the creation of a test plan. The patient monitoring system operates in a hospital using the 2.4GHz WLAN network and is surrounded by other devices also operating over the same frequency band using technologies such as WLAN, Bluetooth and LTE. A spectrum occupancy measurement of a hospital can be made in order to understand the intended operational EM environment of a WPMS. The FWP is selected as the continuous end-to-end transmission of the patient data to the monitoring station. If there is a delay or failure, this results in an alarm going off. WPMS typically transfer IP packet data, thus the packet error rate (PER) and the ping latency can be used as the Key Performance Indicator (KPI) for this corresponding FWP. The ANSI C63.27 standard provides guidance on how to test products that are classified as high risk (Tier 1), moderate risk (Tier 2) and minimum risk (Tier 3). Depending on the risk-based tier evaluation, the device is tested corresponding to the defined severity in terms of interference signals. For the Tier 1 products entailing the highest risk classification, in multiple of the test iterations, the application of three concurrent interference signals is advised.

The standard also provides guidance for the test methods and how to perform the tests. There are four defined test methods. They are conducted test methodology, radiated anechoic chamber (RAC) methodology, multiple chamber test methodology and radiated open environment test methodology.

After performing the measurements, the estimate calculations for the likelihood of coexistence (LoC) and measurement uncertainty need to be made.

3 Test Setup & Configuring Instruments

3.1 Automotive

Modern vehicles these days come with a handful of integrated features designed to provide convenience & safety to the users. The most popular wireless connectivity modules built into modern vehicles these days includes Wi-Fi, Bluetooth and LTE. A few additional components that feature as options in most modern luxury cars to provide keyless entry and wireless battery management systems for BEVs or HEVs also operate on the 2.4GHz frequency band. In order to ensure high reliability of performance of these systems, wireless coexistence testing is needs to be performed at vehicle level using radiated test methodology.

An example test setup is shown in Figure 4.1. The vehicle under test is positioned in the middle of the turntable inside a large semi-anechoic chamber. The chamber antennas are positioned 3m away from the center of the turntable. The test setup is calibrated for pathloss for the different antennas using a spectrum analyzer and signal generator. The power level corrections can be included in the post processing step after measurement is completed.

In this test setup, the CMW500 provides the signaling connection for WLAN/ Wi-Fi, Bluetooth and 4G LTE. The SMW200A is used to generate interference signals. The setup includes a BBA power amplifier in order to amplify the signals coming from the vehicle under test and into the receive path of the CMW. The FSW spectrum analyzer is used to monitor the RF spectrum. The test instruments are all connected to passive high gain highly directive horn antennas. The antennas make radiated testing possible. Optionally, a NRQ6 frequency selective power sensor maybe positioned inside the vehicle, so as not to miss out on weak signal originating from the vehicle that are too faint to be picked up by chamber antenna connected to the spectrum analyzer.
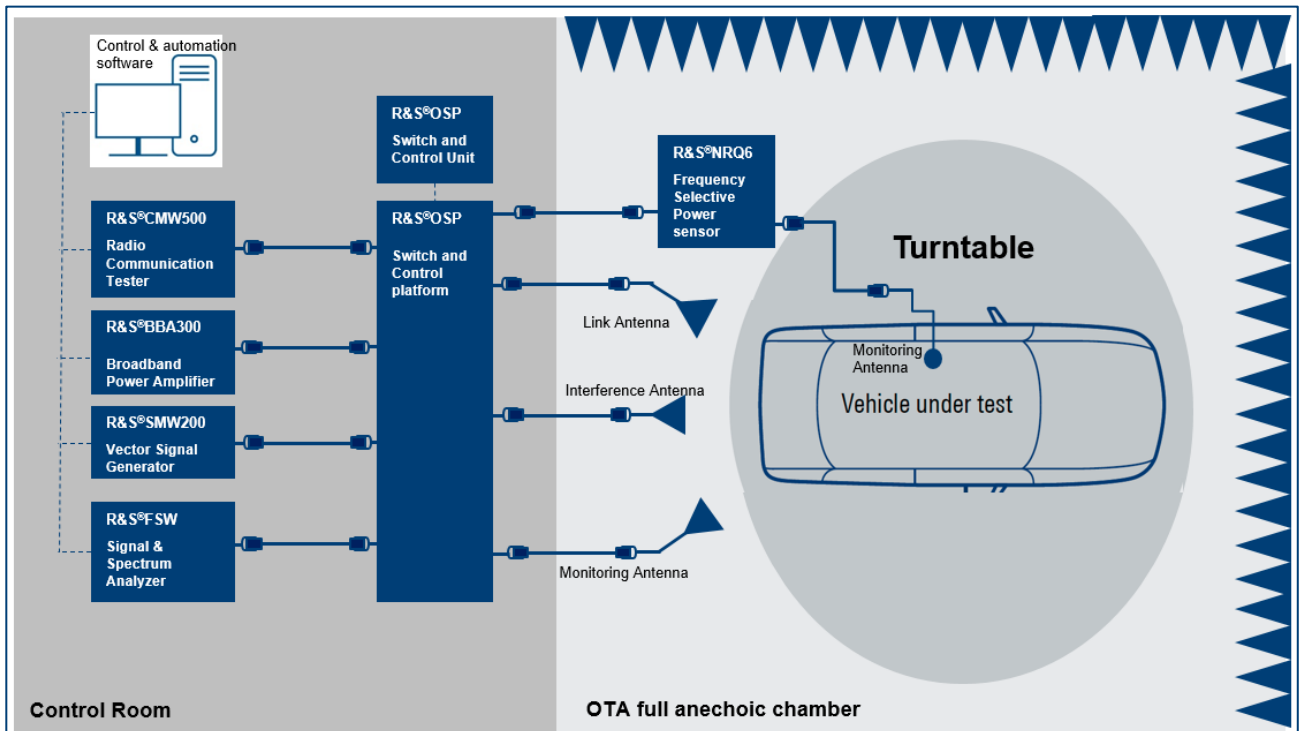

Figure 4.1: Radiated test setup for wireless coexistence at vehicle level for automotive application

The manual and automatic configuration of the test instruments is explained in later section of this application note.

3.2 Consumer electronic products

The consumer electronic industry is evolving and keeping pace with the growing appetite of its customers and is playing a vital role in the enablement of a truly connected world. The internet of things (IoT) trend has finally reached our homes. It has enabled us to remotely access and control household devices from any part of the world as long as it is connected to the internet. Wireless speaker systems, thermostats, home security and monitoring systems, domestic robots, smoke/CO2 detectors, light bulbs, home energy consumption monitors, door locks, refrigerators, laundry machines and water detectors – all these products now come with an integrated wireless communication module that supports some form of WLAN, LPWAN or Bluetooth® technology.

The DUT is placed in a large semi-anechoic chamber. The antenna of the R&S®CMW500 is pointed directly towards the antenna integrated into the DUT. The CMW500 is used to establish an active end-to-end connection with the DUT by emulating a non-cellular network (such as Bluetooth® or WLAN). The BBA150 high power amplifier is optionally used to boost the signal level during radiated testing. A baseline functional performance test is performed and the results for all the relevant KPIs (such as throughput data rate, PER, BLER, video and audio performance) are recorded. In the next iteration, the power level of the wanted signal is reduced to the cell edge condition to replicate the worst-case scenario and the interference signal is introduced using the SMW200A. The SMW200A vector signal generator is used to generate realistic wideband modulated EM interference signals. A spectrum analyzer is used in this test system to monitor the RF spectrum.
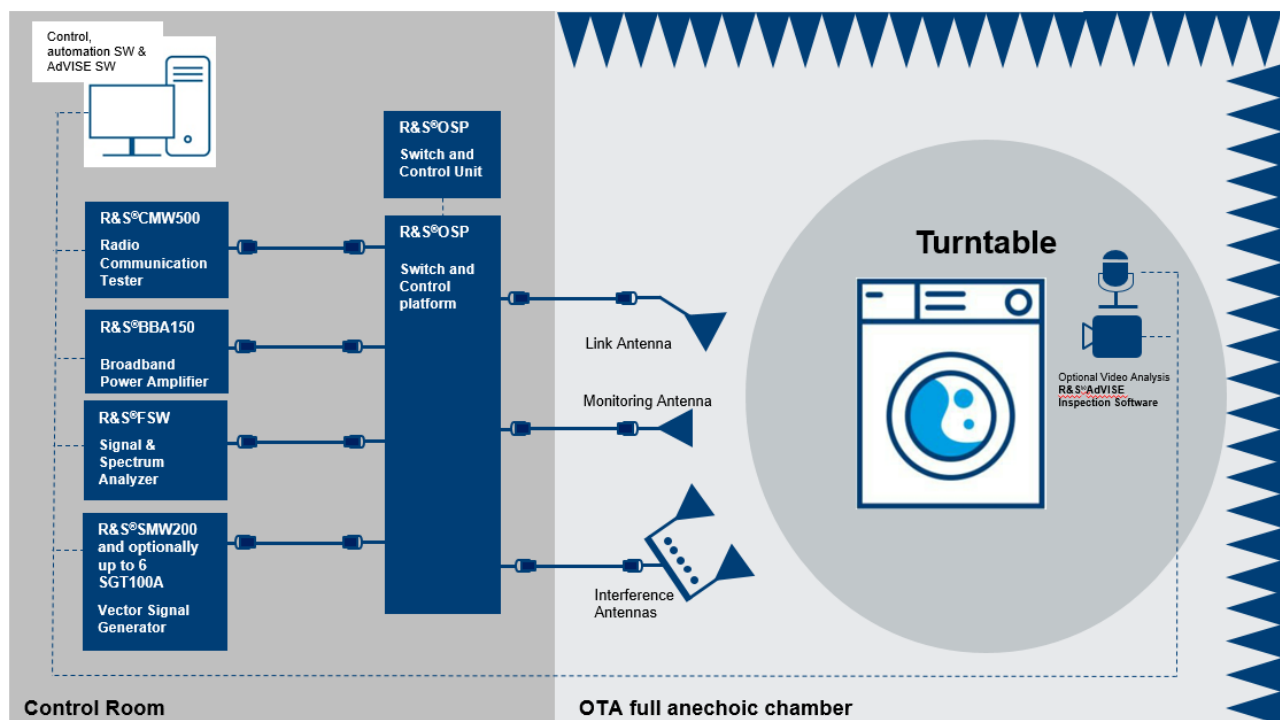

Figure 4.2: Radiated wireless coexistence test setup for consumer electronics application

The manual and automatic configuration of the test instruments is explained in later section of this application note.

3.3 Connected medical devices

The demand for wireless medical applications such as remote patient monitoring, real-time diagnostic analysis, smart surgical systems, and implantable sensors have grown significantly over the last couple of years. Typically, a wireless medical device utilizes both the 400 MHz MedRadio band and the 2.4 GHz MBAN band. The sensor and control data are sent back and forth on different frequency bands. Increasingly, state-of-the-art patient medical devices are taking advantage of commercial standardized technologies such as WLAN, Bluetooth®, Zigbee operating in the unlicensed ISM band.

In order to ensure receiver robustness for wireless medical devices in the US, the FDA recommends product compliance according to the ANSI C63.27 and AAMI TIR69 standards to ensure minimum performance.
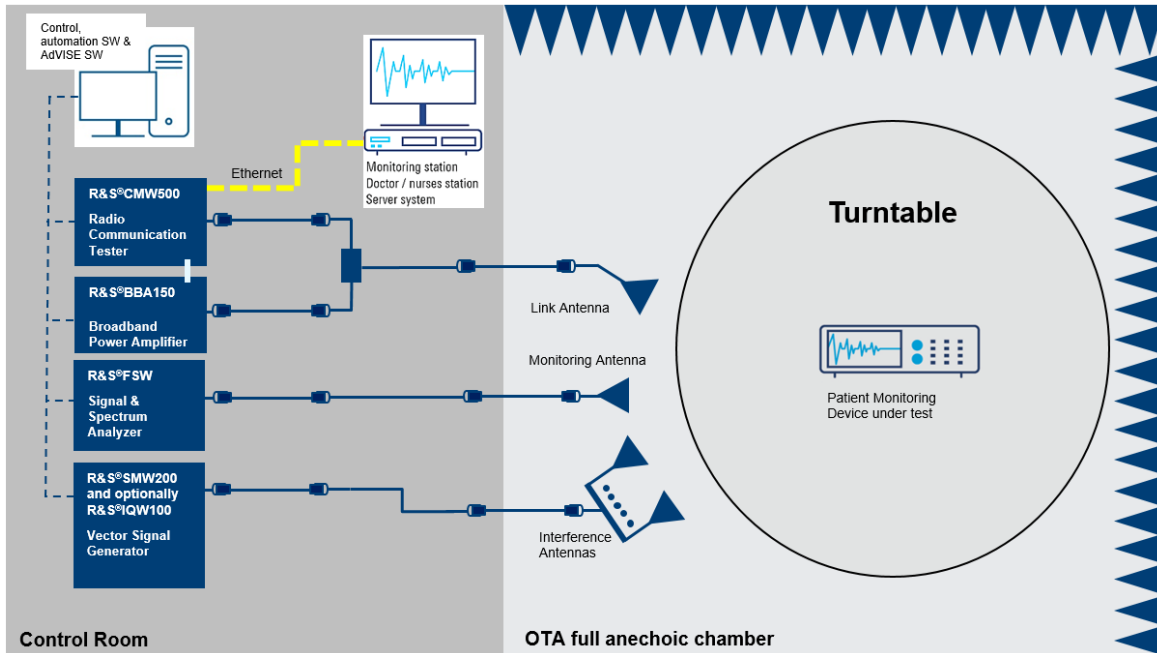

Figure 4.3: Radiated Anechoic Chamber (RAC) test setup for medical patient monitoring system according to ANSI C63.27

Figure 4.3 shows the implementation of the RAC methodology from the ANSI C63.27 standard for testing a wireless patient monitoring system. The patient monitor is connected via a WLAN connection with the CMW500. The CMW is connected to the monitoring station using a wired ethernet cable. Simulated patient data is sent from the patient monitor as multicast packets to the monitoring station using the air interface to the CMW, which is then forwarded via the wired connection replicating typical real-world operation.

The interference signals are generated using an SMW200A VSG. The spectrum is monitored using an FSW spectrum analyzer connected to a chamber antenna. The patient monitoring device is positioned on top of a turntable and at every measurement iteration, the turntable is rotated slightly by 5°-10° and the entire measurement steps for determining physical and application layer KPIs are repeated. The physical layer KPIs include PER and Ping latency and application layer performance include end-to-end data transfer.
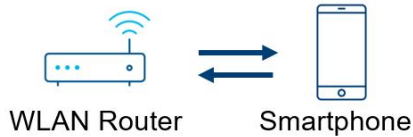
Medical patient monitoring devices operating in hospital may also need to perform handover maneuvers from one access point to the next in order to maintain uninterrupted connectivity while in roaming. Section 4.5 explain how the CMW is used to perform WLAN handover measurements. Additionally, medical devices may sometimes operate in the vicinity of other critical devices. It is recommended by the regulatory agencies to undertake an impact study of how the transmission of two or more co-located devices impact the receiver performance of each individual devices in that location. Using a COTS WLAN router, this is a time consuming and complicated if not impossible task. However, using a CMW this measurement can be performed with ease. Section 4.6 explain how to measure the mutual interference effect of multiple devices simultaneously.

4 Instrument Configurations for testing

In order to understand use cases and connection setups, we will break down the complex coexistence test setups in smaller individual setups.

Figure 4.0: Converting real-world use cases to measurement setup in the lab

Figure 4.0 shows how the real-world tests can be converted to test setup in the lab. The CMW is not only used to replicate any real-world WLAN access point or an LTE base station but it can also be used to perform end-to-end test. The CMW has an internal server that can host video and audio files and transport layer impairments such as jitter and delay can be added if required. This section explains in detail how to configure the wireless connection as well as how to host a video file on the CMW's internal media server.

## 4.1 Wanted Signal (WLAN) Configuration and Monitoring

Hint: For WLAN Signaling (non-cellular) a CMW270 or CMW500 can be used.

4.1.1 Manual Configuration: WLAN personality

a. Initialize by checking the Signaling1 box for WLAN personality from the signaling/generator window (as shown in the figure below)
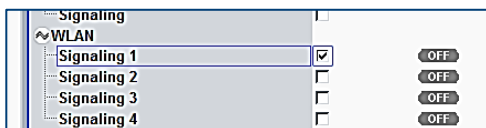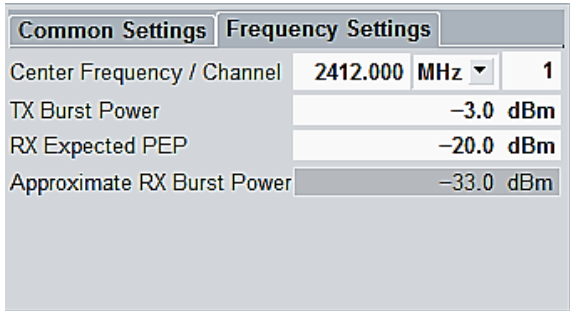

b. Configure the WLAN standard, Channel bandwidth and mode of operation as access point
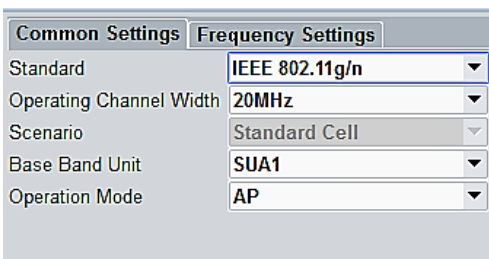
c. Select the WLAN channel and TX Burst power level at which you want to connect to the DUT

Hint: for radiated testing, select the highest TX burst power level and the lowest RX PEP power possible.

d. Configure the TX routing and RX routing as shown below

Hint: if two antennas or a rf power splitter is available chose different connector port for TX and RX signal routing for radiated test setup.
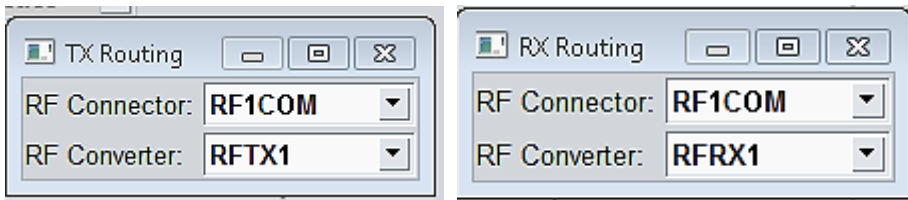
e. Select External Attenuation for Input & Output routed ports.

Hint: positive value signifies power loss and negative value means signal amplification
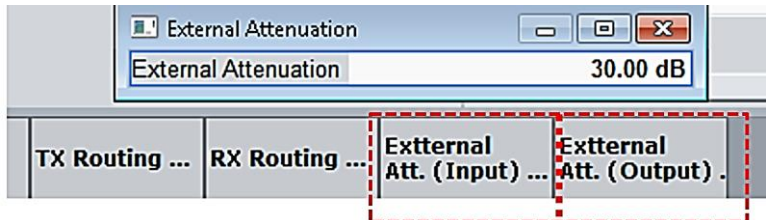
f. Insert SSID name and select the security protocol for the WLAN access point as required
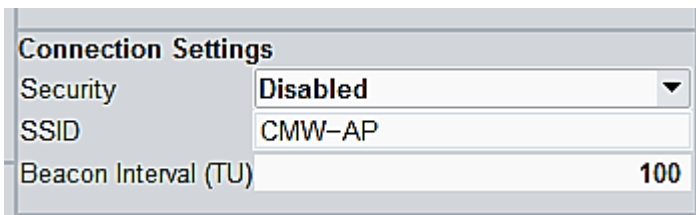
g. At this point switch signaling ON and select the SSID from the WLAN setting on the DUT.

Hint: when a successful connection is established between CMW and DUT, the connection status on the CMW will be updated to Associated. The RX power indicator shows overdriven, under driven or in range status. In case of overdriven power condition, reduce TX burst power and vice versa for under driven condition.
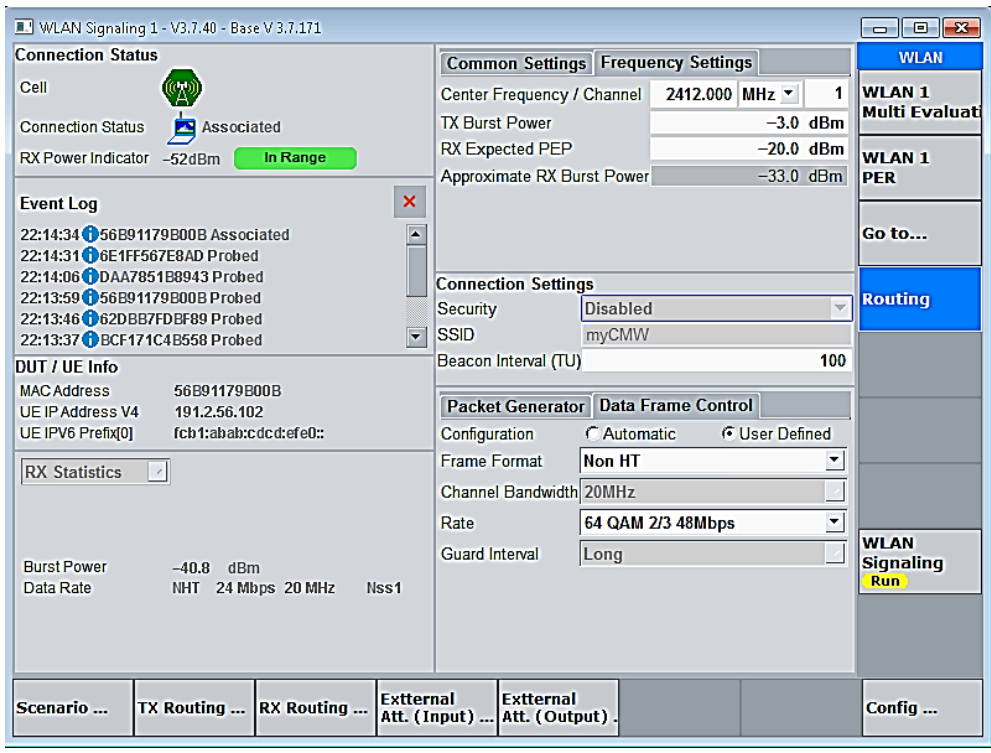
4.1.2 Manual Configuration: WLAN PER Measurement on the CMW

a. Select WLAN 1 PER from the WLAN Signaling Configuration window

b. Select the Modulation Coding Rate with the highest possible modulation scheme supported by the DUT. Select the number of packets to be used for the PER test. Then restart PER measurement from the PER measurement window shown below
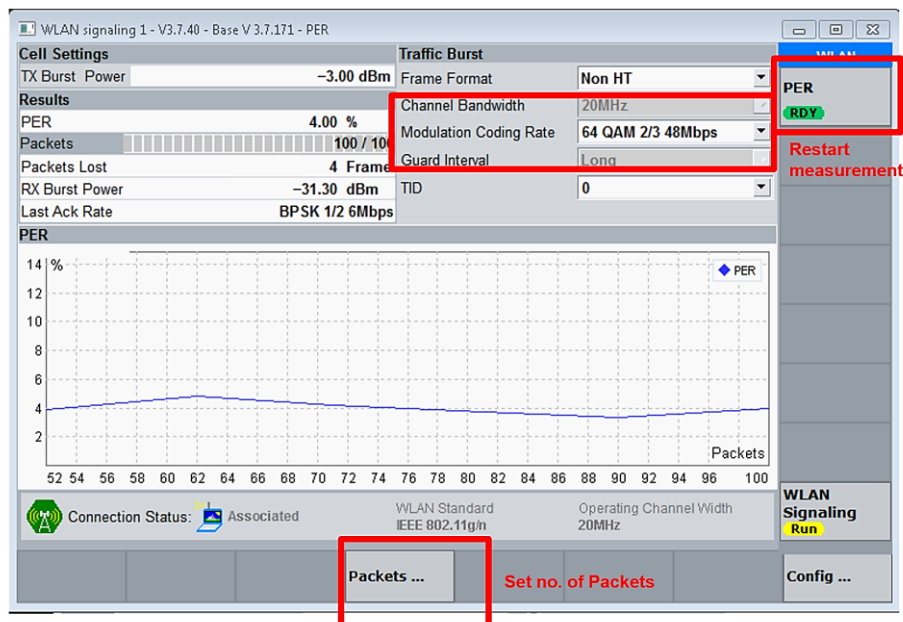
4.1.3 Manual Configuration: DAU for WLAN

a. From system, ⚙, switch ON all the servers (as shown below) and finally switch ON the DAU
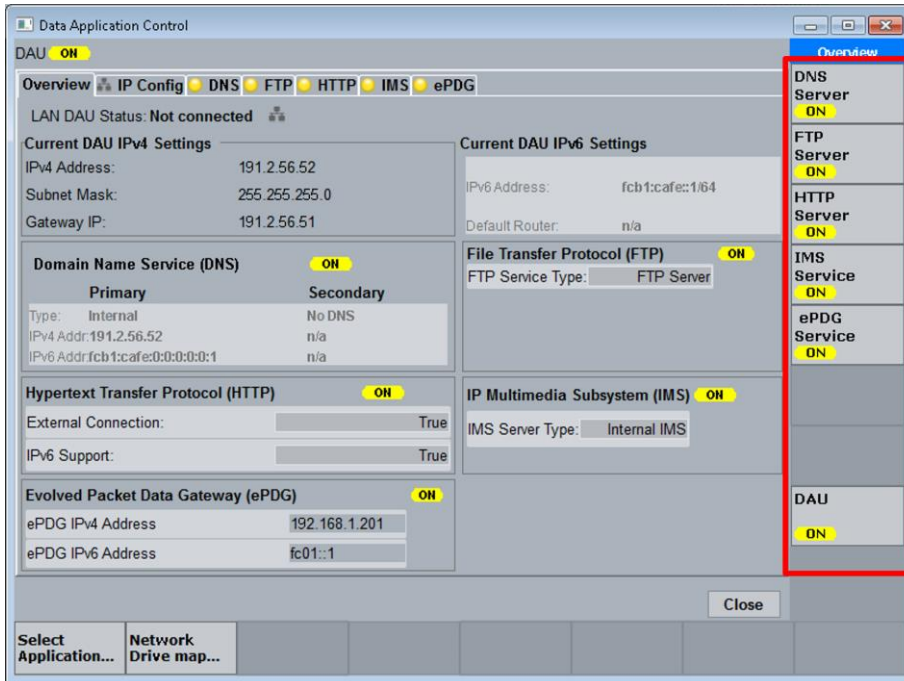
1. Video Streaming using internal CMW Server, ensure HTTP Server is ON

- Next, from windows File Manager in the CMW's Start Menu,
    - Go to Multimedia > Streaming > examples and paste an .mp4 file
    - With this application note, we have provided a 120s long mp4 file
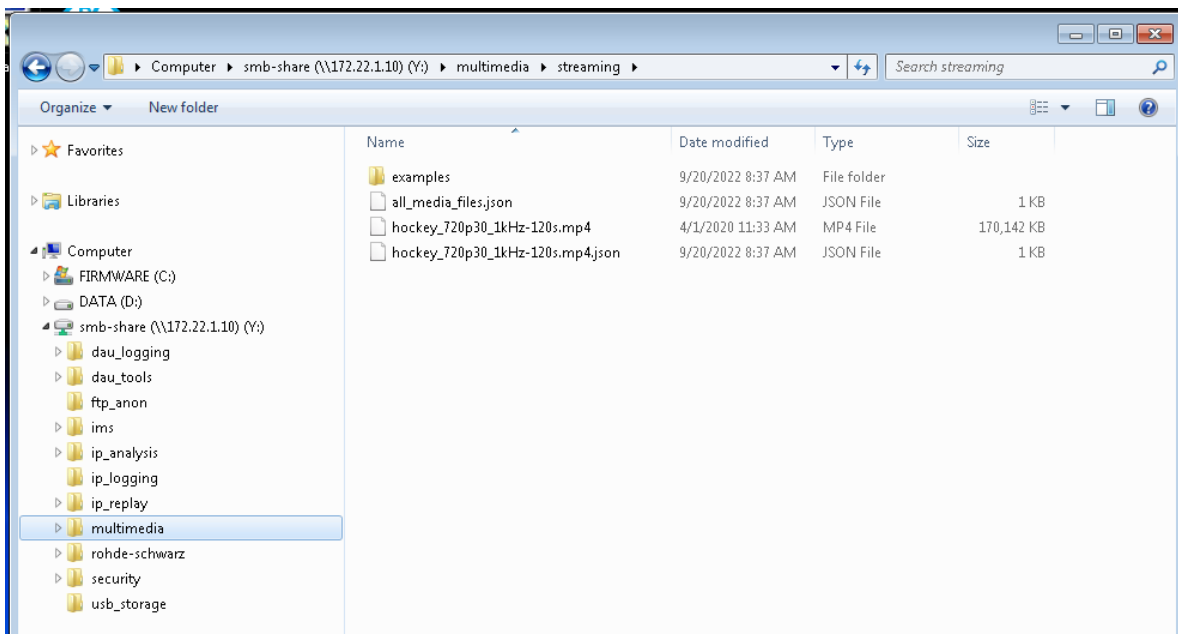
b. After the DUT is associated with CMW, open any internet browser installed on the DUT and search for the following URL

- **https://172.22.1.201/streaming** by default or DAU's IPV4 address (https://191.2.56.52/streaming) in this example

The CMW media server has its own media player and all the files located in the server will show up on the media player library.

Hint: In case of coexistence testing, it is suggested using mp4 files which are longer than 90sec in length and have high resolution.
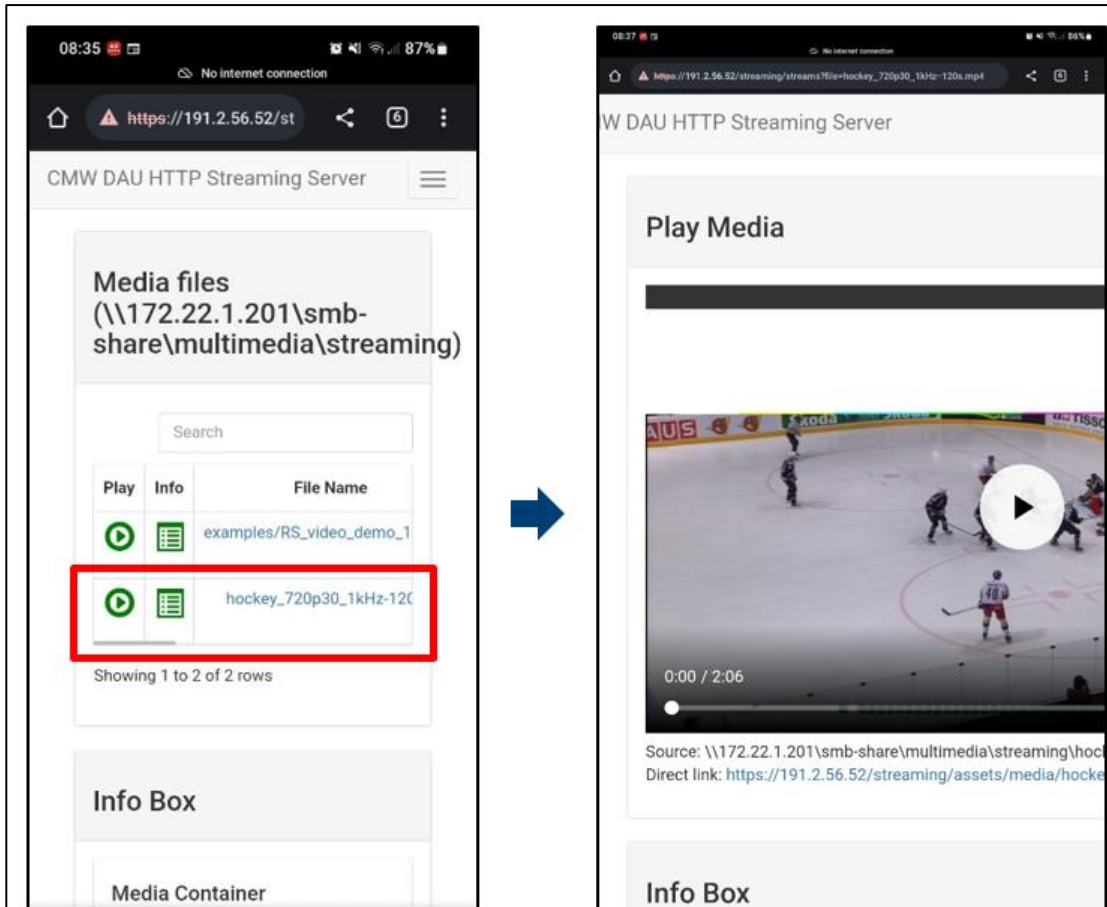
4.1.4 Manual Configuration: WLAN PING Latency measurement

a. From CMW Measurement Selection Panel, select Data Application Measurement 1
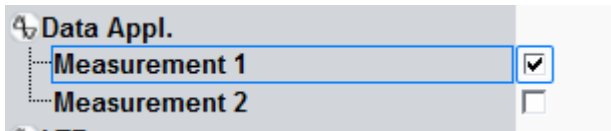
b. From the Measurement configuration window,

- select the appropriate RAN (WLAN Signaling 1)

- configure the destination IP of DUT, Interval, Timeout, Ping Count and Payload

- Switch ON Quality of Service and ensure the WLAN Signaling is ON and DUT is "Associated"

- Switch ON Ping

4.1.5 Automatic Configuration: PER & PING measurement using Python

In order to run the python automation script, R&S VISA needs to be installed on the computer hosting the script.
Python packages: RsCmwWlanSig and time.
Python version: 3.8
R&S CMW options:
H051H,H052S,H054P,H055P,H090H,H100A,H110A,H450H,H500I,H500I,H550N,H554N,H554N,H570B,H570B,H570B,H570B,H590D,H590D,H600B,H605A,H660H,H661H,H690B,KM200,KM300,KM400,KM500,KM750,KM800,KM880,KN400,KS200,KS610,KS650

HINT: CMW instrument and measurement configuration is performed by using SCPI commands. To set parameter, use the function write_str("SCPI") or write_int("SCPI", param=integer_value) and to fetch data use the function query_str("SCPI").

The python script, App_note_Coexistence_testing_WLAN.py, has more functions to check connection status and based on the status, it automatically establishes a connection to the DUT and performs PER/PING/BER measurement.

a. Remote connection to CMW

```python
cmw_wlan = RsCmwWlanSig('TCPIP::10.202.0.222::INSTR', True, False)
print(f'CMW Identification: {cmw_wlan.utilities.idn_string}')
```

b. Configuring CMW WLAN AP, SSID, Routing, external Attenuation, channel, bandwidth and modulation type
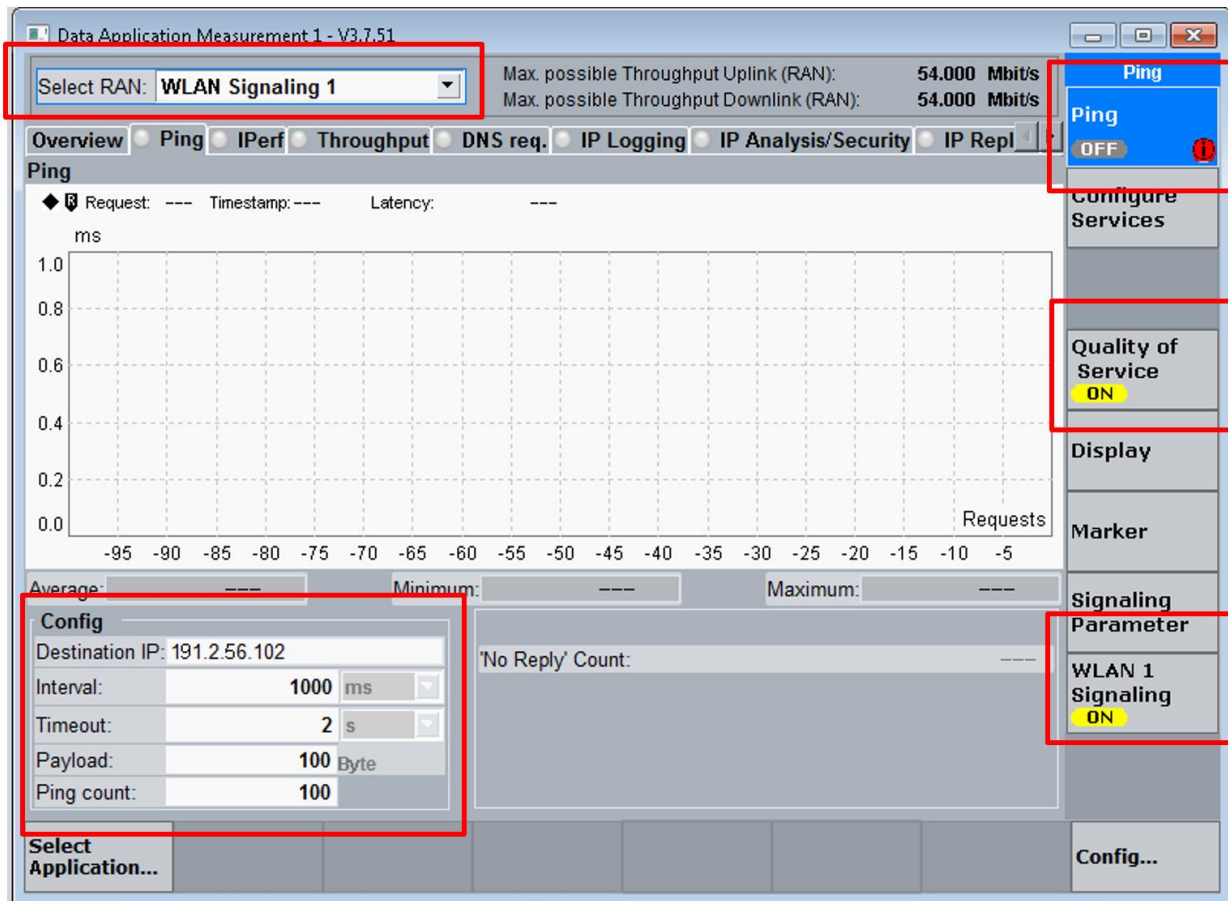
```python
def configure_wlan_connection():
    cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT OFF')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:STAN GNSTd')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:CHAN 1')    #
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EATT:INP -30')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EATT:OUTP -30')
    sleep(2)

    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFSettings:BOPower 14')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EPEP -20')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:DFD ENAB, NHT, BW20, Q6M23, LONG')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:OMOD AP')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:SSID "myCMW"')
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:SEC:PASS DIS, "12345678"')
    cmw_wlan.utilities.write_str('ROUT:WLAN:SIGN1:SCEN:SCEL1:FLEX SUA1, RF1C, RX1, RF1C,
        TX1')
    cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT ON')
```

c. Configuring WLAN PER measurement setting and fetching PER measurement results

```python
def wlan_per_measurement():
    print("############################### WLAN PER Measurement START
###########################")
    status = cmw_wlan.utilities.query_str('FETCh:WLAN:SIGN:PSWitched:STATe?')
    print("connection status",status)
    cmw_wlan.utilities.write_str('INIT:WLAN:SIGN1:PER')  # Start PER Measurement
    sleep(5)
    cmw_wlan.utilities.write_str('STOP:WLAN:SIGN1:PER')  # Stop PER Measurement
    cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:PER:FDEF NHT, BW20, Q6M23')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:PER:PACK 100')      PER_STATUS =
cmw_wlan.utilities.query_str('FETC:WLAN:SIGN1:PER:STAT?')
    a = cmw_wlan.utilities.query_str('FETC:WLAN:SIGN1:PER?')  # 0, PER, Packets sent,
Packets Lost, RX Burst Power
    PER_LIST = nums_from_string.get_nums(a)
    PER = PER_LIST[1]
```

```
    Number_of_packets =PER_LIST[2]
    Packets_Lost = PER_LIST[3]
    RX_burst_power = PER_LIST[4]
```

d. Manually configuring the DAU

```
cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT OFF')
cmw_wlan.utilities.write_str('CONFigure:WLAN:SIGN:CONNection:CTYPe DAPPlication')  #
TESTmode | DAPPlication
cmw_wlan.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:ADDRess:TYPE STAT')  #
configuring static IP
cmw_wlan.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:SMASk
"255.255.255.0"')
cmw_wlan.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:IPADdress
"191.2.56.52"')
cmw_wlan.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:GIP "191.2.56.51"')
# cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT OFF')
sleep(10)
DAU_status = cmw_wlan.utilities.query_str(
    'SENSe:DATA:CONTrol:LAN:DAU:STATus?')  # Return possible = OTConn | CONN
print("DAU Status:", DAU_status)
#Measurement DAU IP-Based Data Test Ping Latency
cmw_wlan.utilities.write_str('SOURce:DATA:CONTrol:STATe ON')  #switching ON Dau
```

e. Configuring WLAN PING measurement setting and fetching PING measurement results

```
def wlan_ping():
    print("############################### WLAN PING Measurement Start
########################")
    cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:RAN "WLAN Sig1"')
    cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:SELect:APP PING')
cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:PING:DIPaddress"191.2.56.102"')
        cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:PING:INTerval 0.2') #0.5 =
500ms, 1=1000ms
    #cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:PING:TIMeout 2')
    #cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:PING:PSIZe 100')
    #cmw_wlan.utilities.write_str('CONFigure:DATA:MEAS:PING:PCOunt 100')
    cmw_wlan.utilities.write_str('INITiate:DATA:MEAS:PING')
    while True:
        state = cmw_wlan.utilities.query_str('FETCh:DATA:MEAS:PING:STATe?')
        if state == "RUN": #and loop_time>0:
            sleep(30)
        elif state == "RDY":
            print("Measurement state switched to:", state)
            no_reply= cmw_wlan.utilities.query_str('FETCh:DATA:MEAS:PING:NRCount?')
            ping = cmw_wlan.utilities.query_str('FETCh:DATA:MEAS:PING:OVERall?')
            PING_list = nums_from_string.get_nums(ping)
            #print(PING_list)
            Relaibility_Indicator = PING_list[0]
            Latency_Min = PING_list[1] * 10 ** PING_list[2]
            Latency_Max = PING_list[3] * 10 ** PING_list[4]
            Latency_Avg = PING_list[5] * 10 ** PING_list[6]
            print("Latency(Average in s):", Latency_Avg)
            print("No Reply:", no_reply)
            print("Latency(Minimum in s):", Latency_Min)
            print("Latency(Maximum in s):", Latency_Max)
            print("############################### WLAN PING Measurement DONE
########################")
            return Latency_Avg, Latency_Min, Latency_Max, no_reply
            break
```
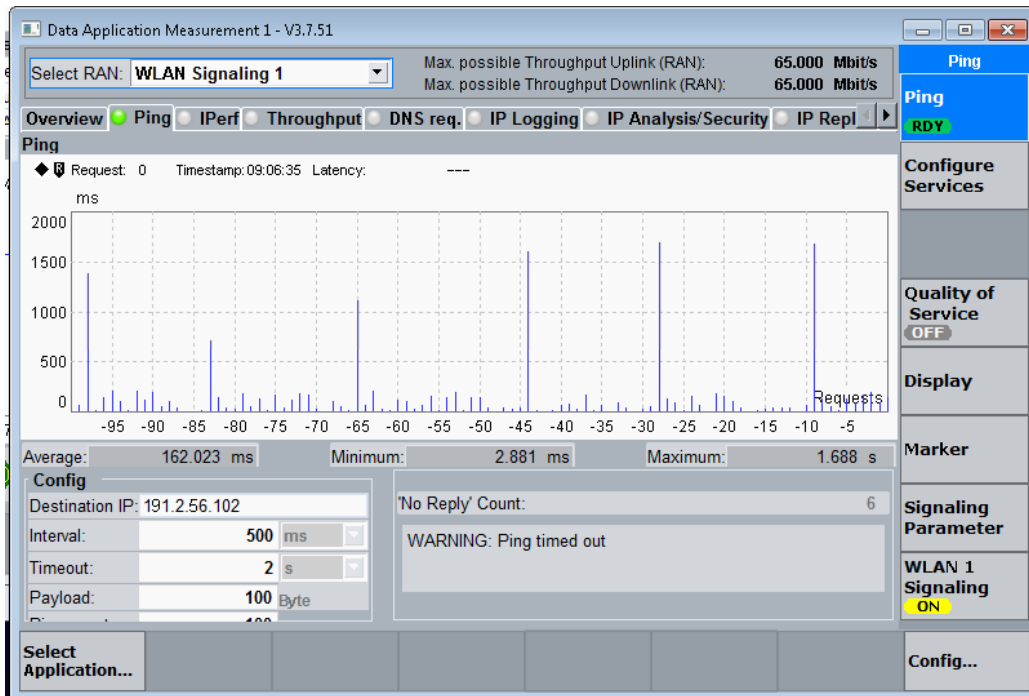
4.1.6 Measurement Results: WLAN PER & PING (manual & automatic)

a. WLAN PER measurement (using manual operation)
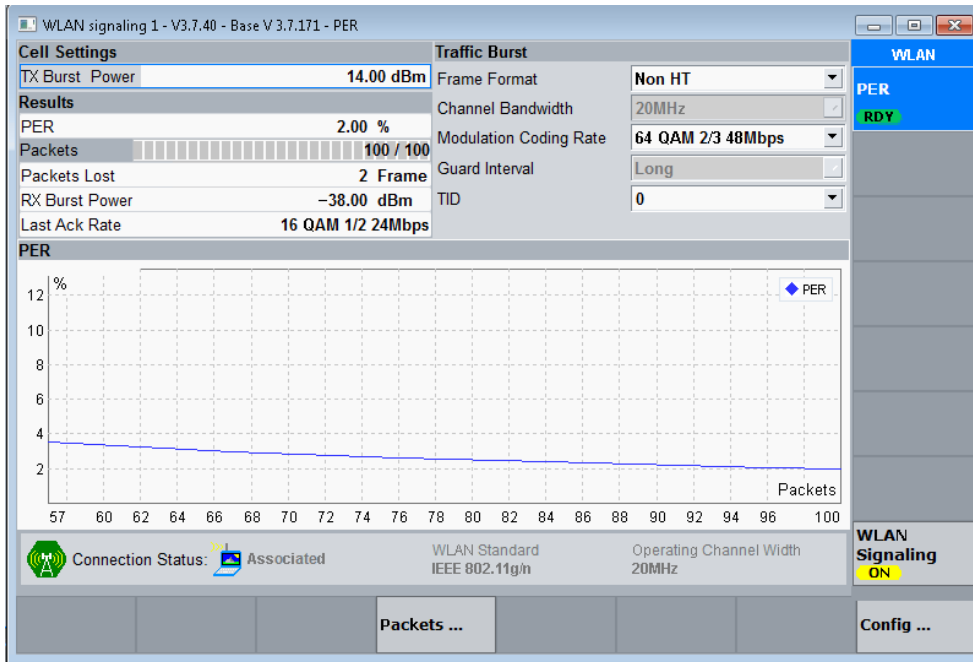
b. WLAN PING measurement (using manual operation)

c. WLAN PER measurement (using automated measurement approach)

```
############################# WLAN PER Measurement START #######################
connection status ASS
PER Measurement from Signalling 1, SSID: myCMW
0, PER, Number of packets, Packets Lost, RX burst power(dBm): 0,2.000000E+000,100,2,-3.800000E+001
Closing python connection but WLAN signalling will be ON. Manual measurements can still be made.
############################# WLAN PER Measurement DONE ########################
Done with all measurement
```

d. WLAN PING measurement (using automated measurement approach)

```
############################# WLAN PING Measurement Start ######################
Measurement Running. waiting for it to finish to pull measurement data. This takes like 2 mins. This msg repeats every 30s.
Measurement Running. waiting for it to finish to pull measurement data. This takes like 2 mins. This msg repeats every 30s.
Measurement Running. waiting for it to finish to pull measurement data. This takes like 2 mins. This msg repeats every 30s.
Measurement state switched to: RDY
Ping Latency:(Relaibility Indicator, Latency: Minimum, Maximum, Average) 0,2.881000E-003,1.688247E+000,1.620226E-001
No Reply Count: 6
############################# WLAN PING Measurement DONE ########################
Done with all measurement
```

4.2 Wanted Signal (LTE) Configuration and Monitoring

Hint: For LTE Signaling (cellular) a CMW290 or CMW500 can be used.

4.2.1 Manual Configuration: LTE personality

a. Initialize by checking the Signaling1 box for LTE personality from the signaling/generator window (as shown in the figure below)
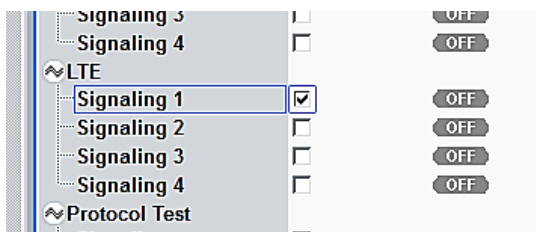
b. Configure the LTE band, channel bandwidth and center frequency
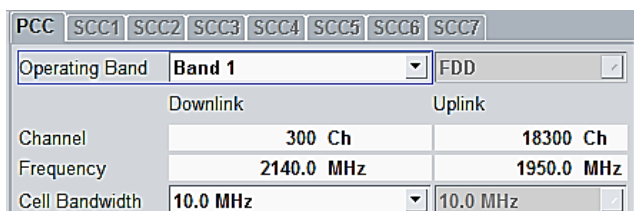
c. Select the LTE channel band power level for Downlink and uplink at which to connect to the DUT

Hint: for radiated testing over greater distance apart, select the highest power levels possible.
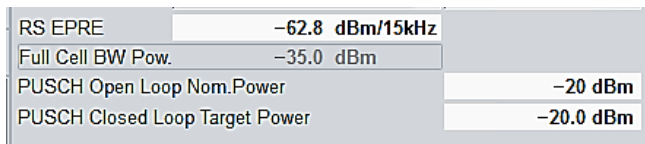
d. Configure the TX routing and RX routing as shown below

Hint: if two antennas or a rf power splitter is available chose different connector port for TX and RX signal routing for radiated test setup
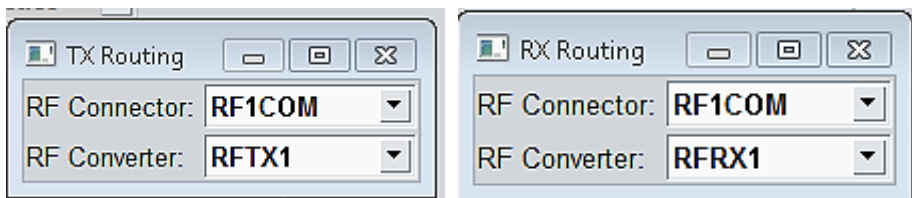
e. Select External Attenuation for Input & Output routed ports.

Hint: positive value signifies power loss and negative value means signal amplification
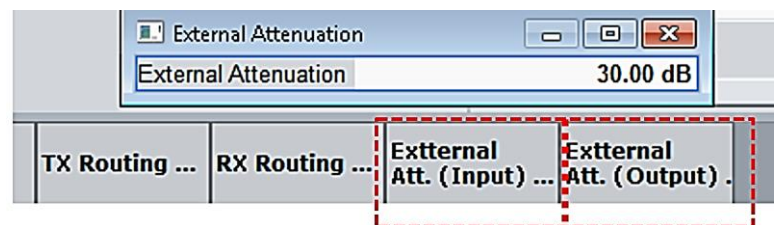
f. Optional: Select Neighboring cell bands. In this example Band 2, 4 & 7 are switched ON from the Config Tab
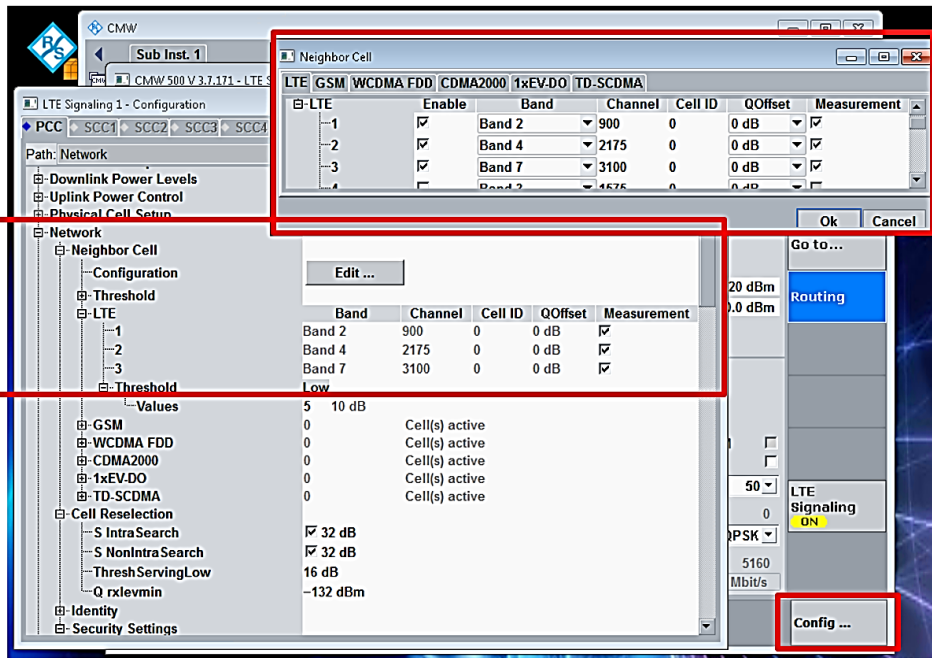
g. At this point switch signaling ON and select the network with the name "R&S 3G network" from the Mobile Network settings on the DUT.

Hint: when a successful connection is established between CMW and DUT, the RRC status on the CMW will be updated to connected. And the packet Switched Status will change to Attached. Select Connect order to activate Test Mode.
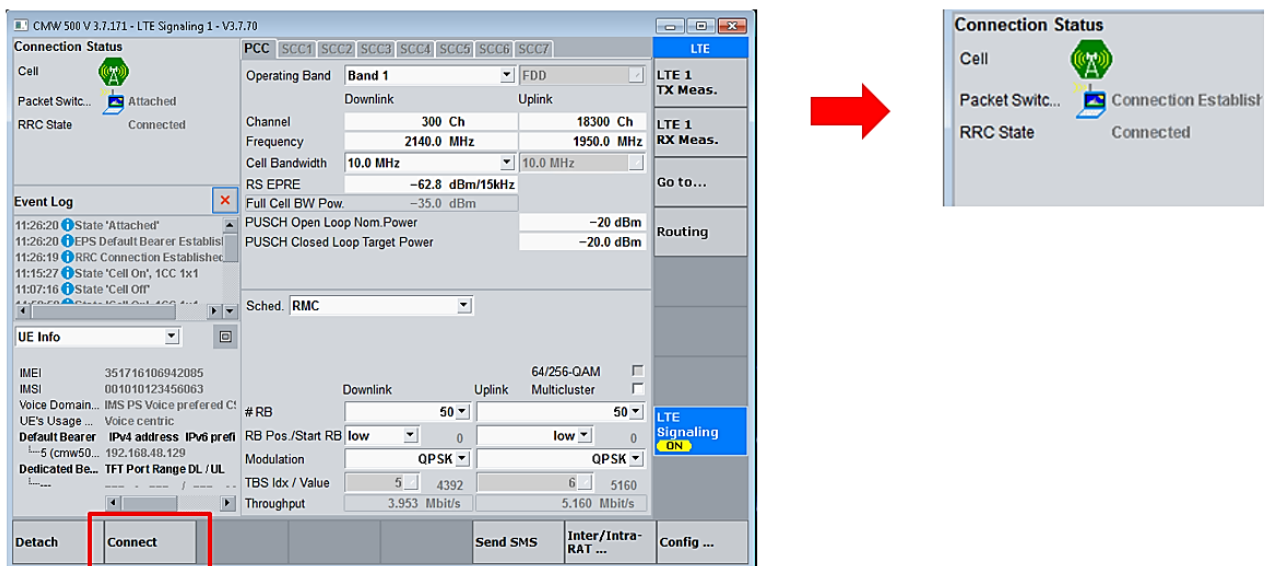
4.2.2 Manual Configuration: LTE BLER & Throughput Measurement on the CMW

a. Select LTE 1 RX Meas. from the LTE Signaling configuration window

b. Switch ON Extended BLER measurement

Hint: From the Signaling Parameters tab in the Extended BLER window, all additional measurement parameters can be selected. However, for BLER and throughput measurement, the default settings are sufficient and switching on measurement is adequate.
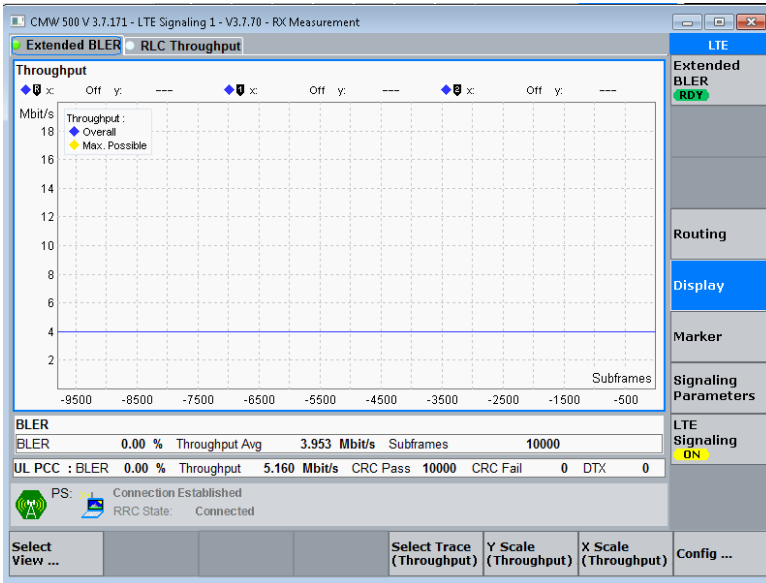
4.2.3 Manual Configuration: DAU for LTE

a. From system, , switch ON all the servers (as shown below) and finally switch ON the DAU
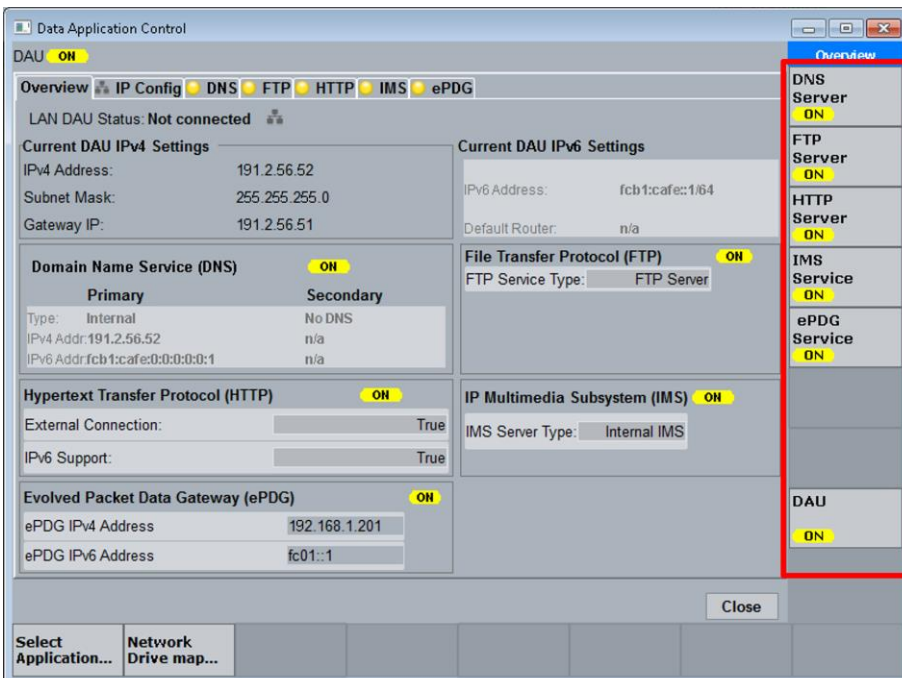
4.2.4   Manual Configuration: LTE PING Latency measurement

a. From CMW Measurement Selection Panel, select Data Application Measurement 1
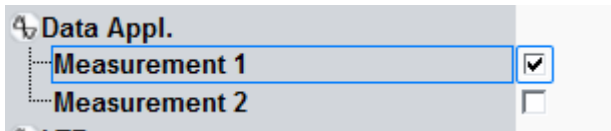
b. From the Measurement configuration window,

- select the appropriate RAN (LTE Signaling 1)

- configure the destination IP of DUT, Interval, timeout, Ping count and payload

- Switch ON Quality of Service and ensure the LTE Signaling is ON and a connection is established with DUT

- Switch ON Ping Measurement
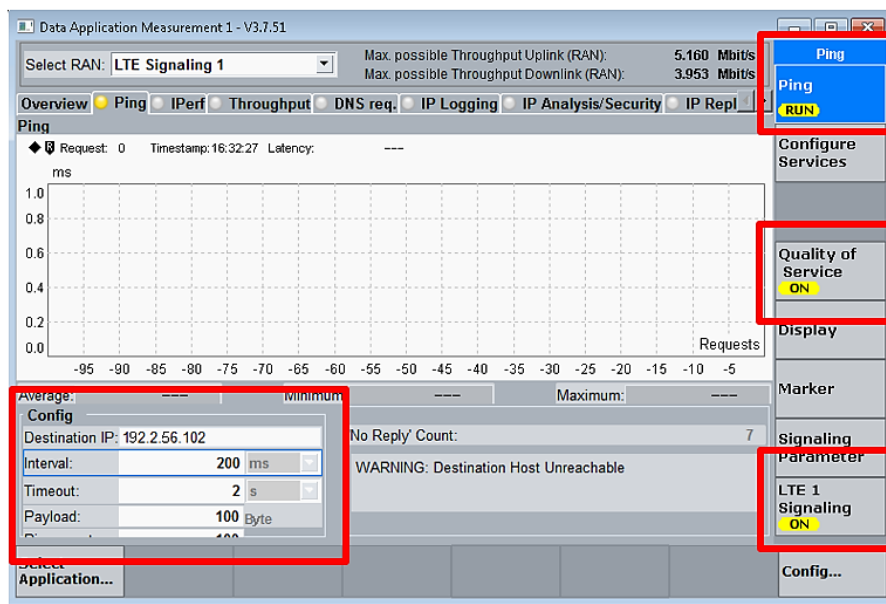
4.2.5   Automatic Configuration: PER & PING measurement using Python

In order to run the python automation script, R&S VISA needs to be installed on the computer hosting the script.
Python Version:3.8
Python packages required: RsCmwLteSig and time.
R&S CMW options:
H051H,H052S,H054P,H055P,H090H,H100A,H110A,H450H,H500I,H500I,H550N,H554N,H554N,H570B,H570B,H570B,H570B,H590D,H590D,H600B,H605A,H660H,H661H,H690B,KM200,KM300,KM400,KM500,KM750,KM800,KM880,KN400,KS200,KS610,KS650

HINT: CMW instrument and measurement configuration is performed by using SCPI commands. To set parameter, use the function write_str("SCPI"),
write_int("SCPI", param=integer_value) and to fetch data use the function query_str("SCPI").

The python script, App_note_LTE.py, has more functions to check connection status and based on the status automatically establishes a connection to the DUT and performs PER/PING/BER measurement.

a. Remote connection to CMW

```
cmw_LTE = RsCmwLteSig('TCPIP::10.202.0.222::INSTR', True, False)
print(f'CMW Identification: {cmw_LTE.utilities.idn_string}')
```

b. Configuring CMW LTE band, Routing, external Attenuation, channel, bandwidth and modulation type

```
cmw_LTE.utilities.write_str('SOURce:LTE:SIGN:CELL:STATe OFF')     #initialize LTE
signalling Personality
# Port & internal signal route selection
cmw_LTE.utilities.write_str('ROUTe:LTE:SIGN:SCENario:SCEL1:FLEXible SUA1, RF1C, RX1,
RF1C, TX1')
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:RFSettings:EATTenuation:INPut 20')    #
Routing Ext. Attenuation
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:RFSettings:EATTenuation:OUTPut 20')   #
Routing Ext. Attenuation
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:DL:PCC:RSEPre:LEVel -20')       #RS EPRE
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:UL:PCC:PUSCH:OLNPower 20')      #PUSCH
Open Loop Nom. Power
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:PCC:BAND OB1')     # Operating Band
cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:CELL:BANDwidth:PCC:DL B100')
#Bandwidth: B014 | B030 | B050 | B100 | B150 | B200
cmw_LTE.utilities.write_str('SOURce:LTE:SIGN:CELL:STATe ON')
sleep(15)

RRC_state = cmw_LTE.utilities.query_str('SENSe:LTE:SIGN:RRCState?')
```

c. Configuring CMW LTE BLER & Throughput Measurement

```
def lte_bler_throughput():
    print("################################# LTE BLER Measurement START
#########################")
    cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:EBLer:REPetition SING')
    sleep(10)
    cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:EBLer:SCONdition NONE')
    cmw_LTE.utilities.write_str('INIT:LTE:SIGN:EBLer')
    sleep(7)

    number_of_loops = 1
    while number_of_loops>0:
    #while True:
        # Fetch BLER result Absolute
        print("Abolute BLER
Results:",cmw_LTE.utilities.query_str('FETCh:LTE:SIGN:EBLer:ABSolute?'))
        # Fetch BLER result relative
        print("Relative BLER
Results:",cmw_LTE.utilities.query_str('FETCh:LTE:SIGN:EBLer:RELative?'))
        number_of_loops = number_of_loops -1
        BLER_throughput = cmw_LTE.utilities.query_str('FETCh:LTE:SIGN:EBLer:RELative?')
# 0, PER, Packets sent, Packets Lost, RX Burst Power
        #Relative BLER Results: 19,INV,INV,INV,INV,INV
        BLER_LIST = nums_from_string.get_nums(BLER_throughput)
        BLER = BLER_LIST[1]
        Throughput = BLER_LIST[2]
        print("BLER:", BLER)
        print("Throughput:", Throughput)
        return BLER, Throughput
```

d. Configuring LTE DAU configuration

```python
def dau_config():
    #Measurement DAU IP-Based Data Test Ping Latency
    #cmw_LTE.utilities.write_str('SOURce:LTE:SIGN:CELL:STATe OFF')
    cmw_LTE.utilities.write_str('CONFigure:LTE:SIGN:CONNection:CTYPe DAPPlication')  #
TESTmode | DAPPlication
    cmw_LTE.utilities.write_str('SOURce:DATA:CONTrol:STATe ON')  #switching ON Dau
    cmw_LTE.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:ADDRess:TYPE STAT') #
configuring static IP
    cmw_LTE.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:SMASk
"255.255.255.0"')
    cmw_LTE.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:IPADdress
"191.2.56.52"')
    cmw_LTE.utilities.write_str('CONFigure:DATA:CONTrol:IPVFour:STATic:GIP
"191.2.56.51"')
    cmw_LTE.utilities.write_str('SOURce:LTE:SIGN:CELL:STATe ON')
    sleep(10)
    DAU_status = cmw_LTE.utilities.query_str('SENSe:DATA:CONTrol:LAN:DAU:STATus?')  #
Return possible = OTConn | CONN
    print("DAU Status:",DAU_status)
```

4.2.6 Measurement Results: LTE PER & PING (manual & automatic)

a. LTE throughput and BLER measurement
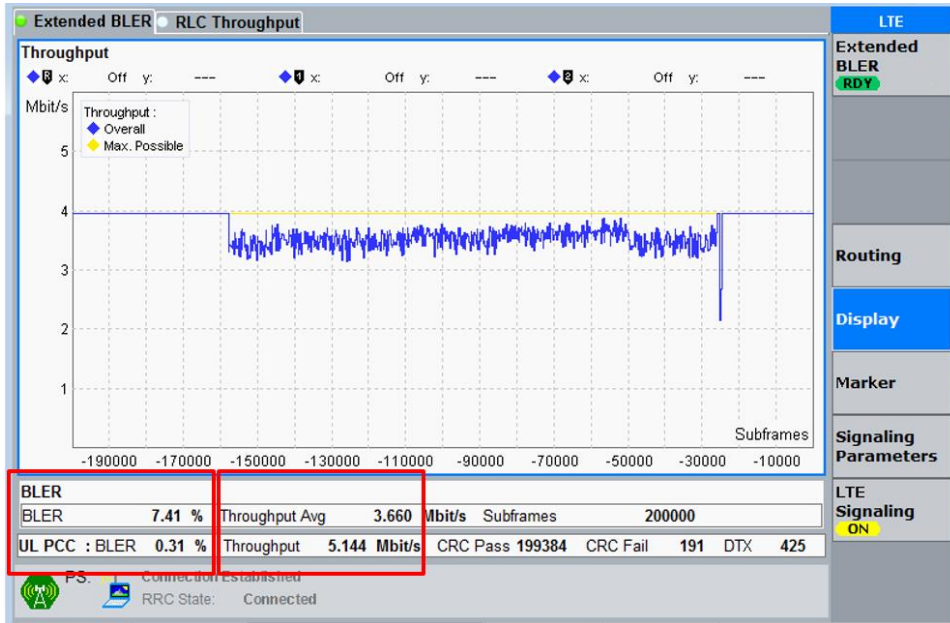
b. LTE based ping latency measurement (using manual operation)
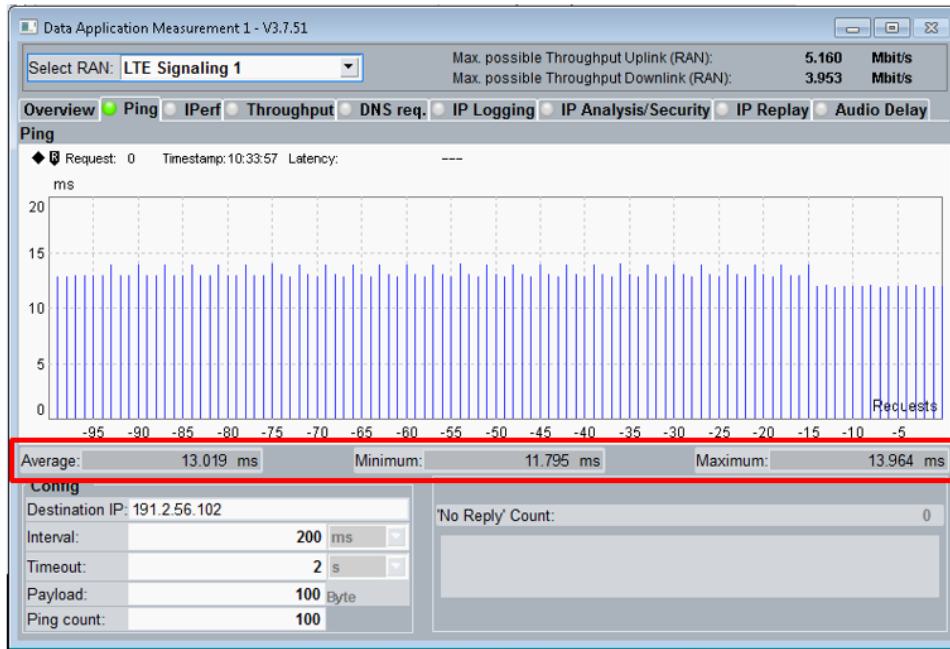
c. LTE based ping latency measurement (using automated operation)

```
############################### LTE PING Measurement Start #######################
Measurement state switched to:  RUN
Measurement Running. waiting for it to finish to pull measurement data. This takes like 2 mins. This msg repeats every 30s.
Measurement state switched to: RDY
Ping Latency:(Relaibility Indicator, Latency: Minimum, Maximum, Average) 0,1.179500E-002,1.396400E-002,1.301891E-002
No Reply Count: 0
############################### LTE PING Measurement DONE ########################
Done with all measurement
```

4.3   Unwanted Signal Configuration (according to ANSI C63.27)

In this section, we will configure the SMW to generate three concurrent interference signals. For this we will first initiate three basebands and route the three basebands through the same RF path A. One in-band EMI and two out-of-band EMI. For the two basebands (out of band interferences), we will configure the offset frequency and gain. Finally, we will configure the center frequency of the RF Path A and power level.

4.3.1   Manual Configuration: Generating three concurrent interference signals

a. From System Configuration > Fading/Baseband Config, select the following settings:

- Mode: Advanced

- Entities: 3, Baseband: 1, Streams: 1

- BB Source Config: Separate Sources
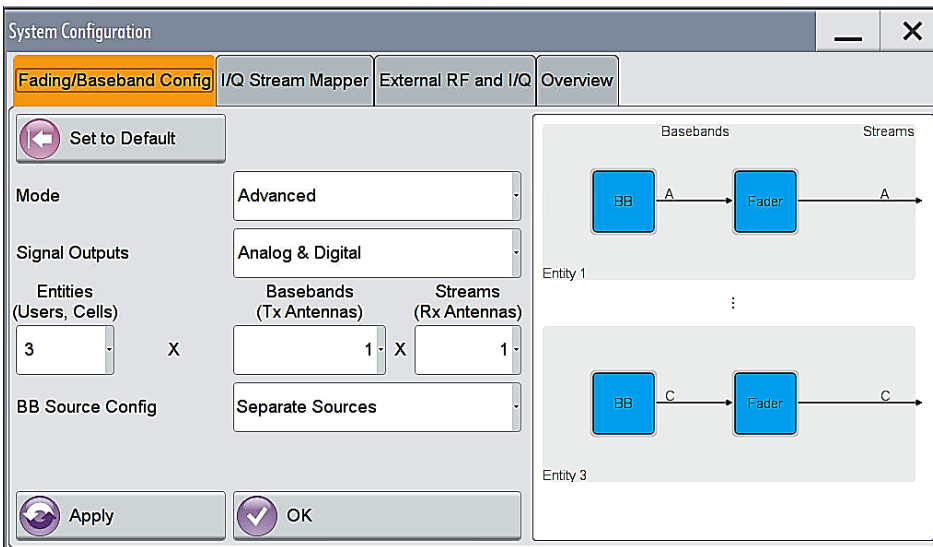
b. Rerouting all three basebands through one common RF output path.

From system configuration > I/Q Stream Mapper, select the following settings:

- For Stream A, B & C, select RF A as output

- Frequency offset: Stream A is in-band

- Frequency offset: Stream B is Out-of-band: -25MHz or -25 000 000 Hz

- Frequency offset: Stream C is Out-of-band: 25MHz or 25 000 000 Hz
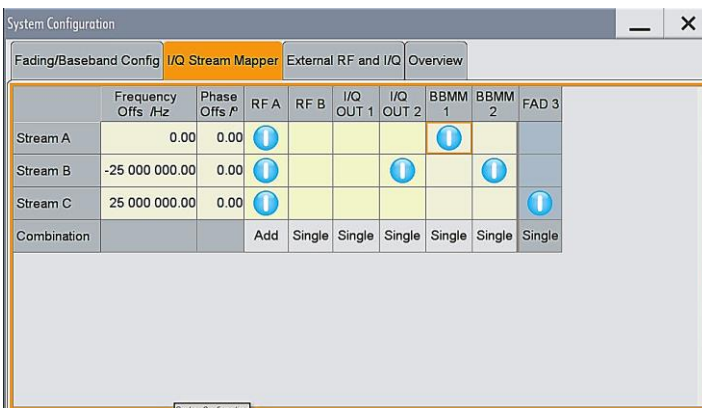
c. Switch on the three Baseband and configure the required personality (WLAN or LTE)

- Input the relevant center frequency for Path A

- Input the relevant power level for Path A

- Select I/Q Mod A ON

- Select RF A ON

Baseband configuration for WLAN (11n) and LTE are explained in the next two sections
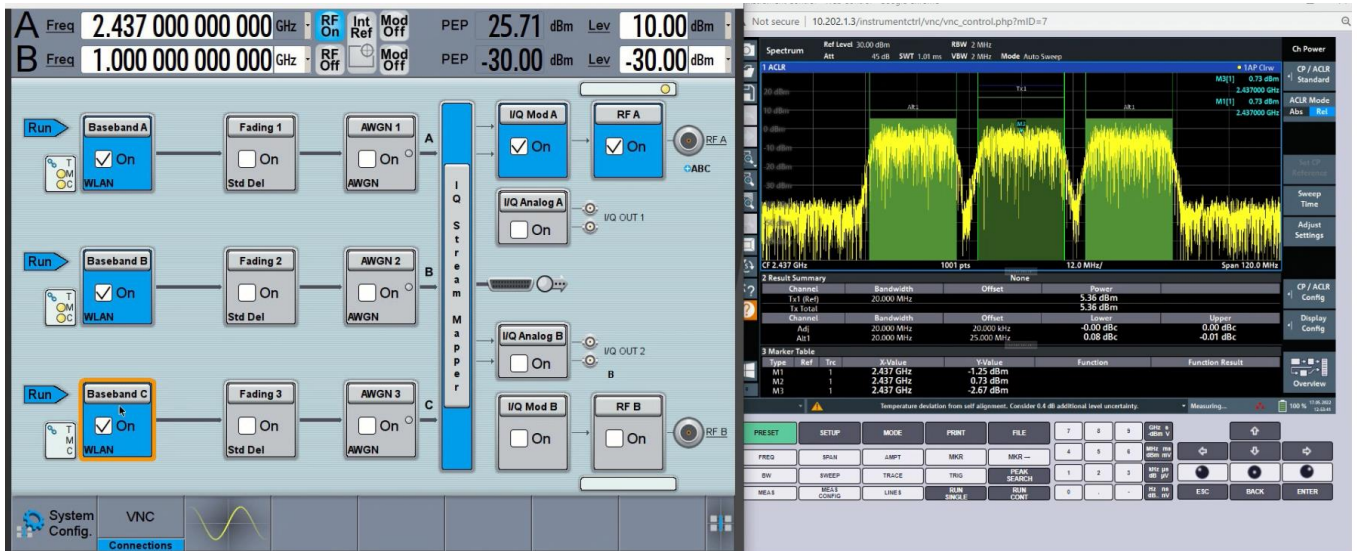
4.3.2   Manual Baseband Configuration: IEEE 802.11n interference signals

a. Configuring WLAN IEEE 802.11n baseband personality

- From the Baseband menu, select IEEE 802.11 personality
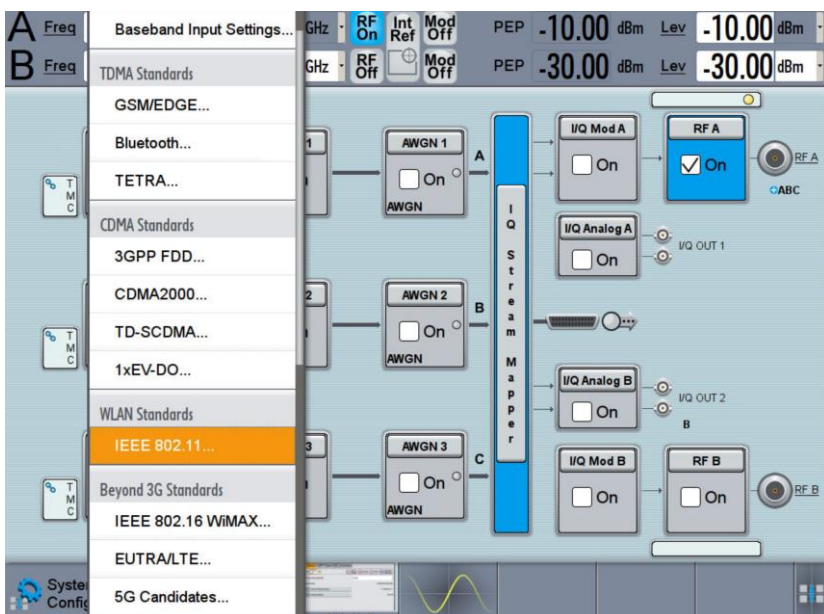
b. Bandwidth selection

- From General > Transmission Bandwidth select either 20 MHz or 40 MHz
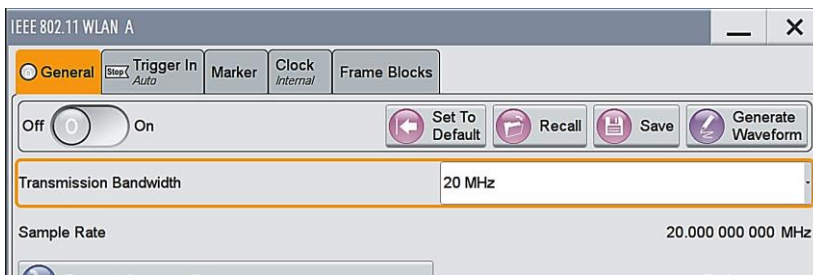
c. IEEE 802.11 standard selection

- From Frame Blocks > Std., select 11n
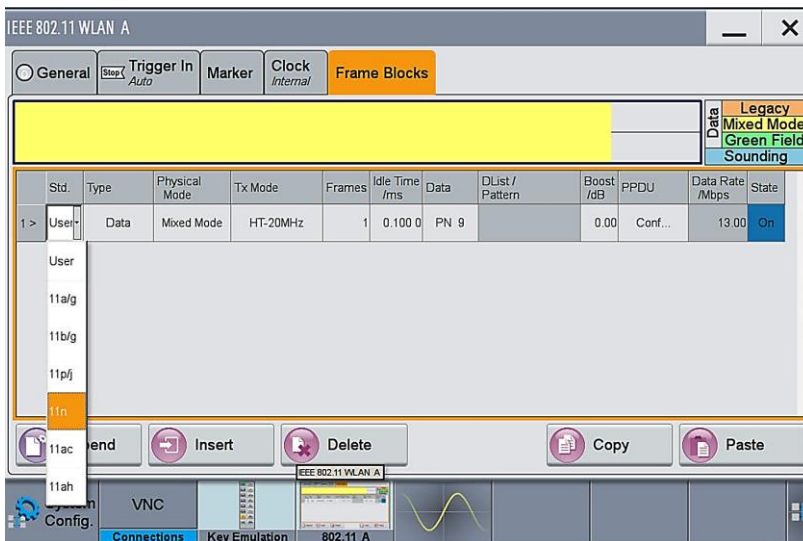
d. Configuration of relevant modulation scheme

- From Frame Blocks > PPDU > Conf… > General > Stream 1, Select 64QAM
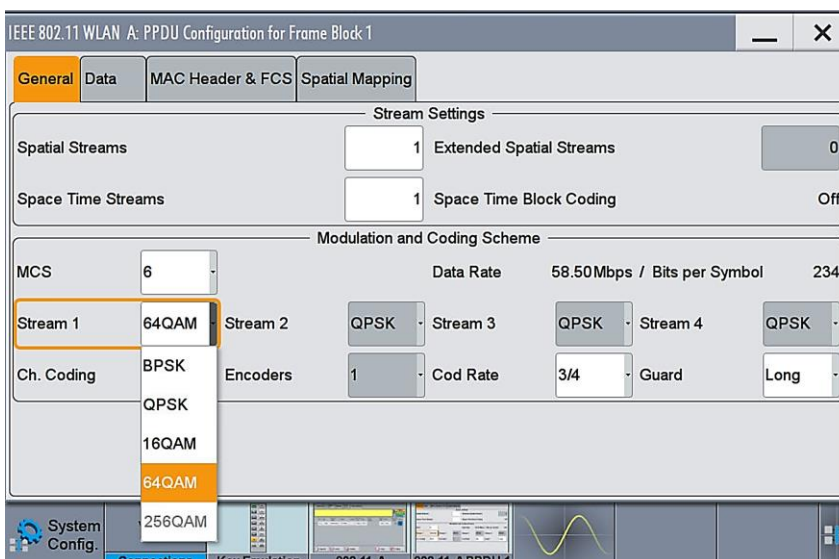
d. Finally, switch ON the baseband configuration

4.3.3 Manual Baseband Configuration: LTE interference signals

a. Configuring LTE baseband personality

- From the Baseband menu, select EUTRA/LTE personality
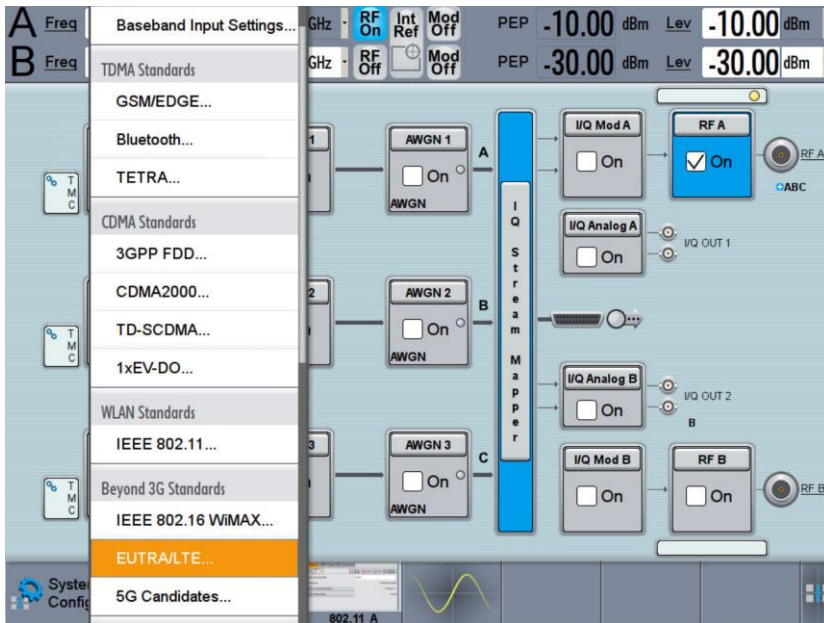
b. Selection of Duplexing Scheme and Link Direction

- From General > Duplexing, select either FDD or TDD

- From General > Link Direction > Downlink or Uplink
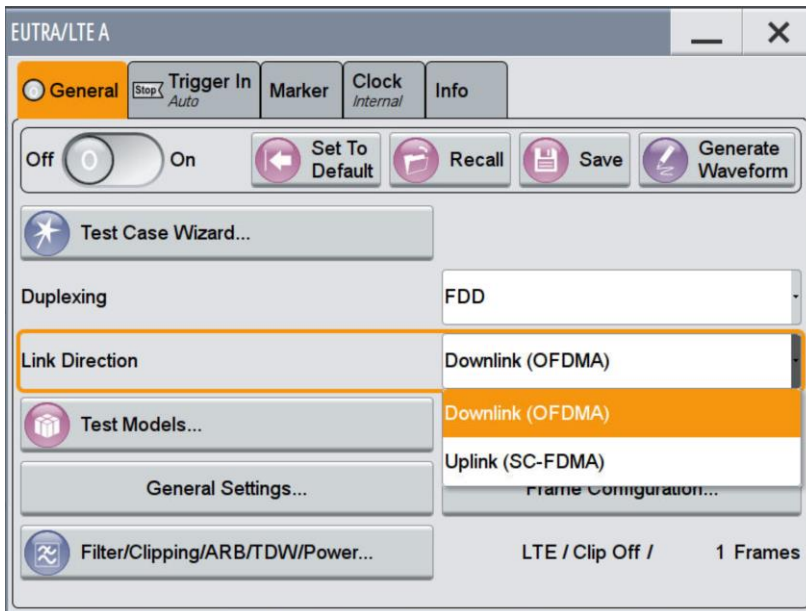
c. Based on Link Direction, Uplink or Downlink, configure for the modulation scheme and bandwidth using the relevant steps as explained in 4.3.3.3.1 (downlink) or 4.3.3.2 (uplink)

4.3.3.1 Configuration LTE: Downlink

a. Modulation Scheme Selection

- From Frame configuration > General> Modulation > 64QAM
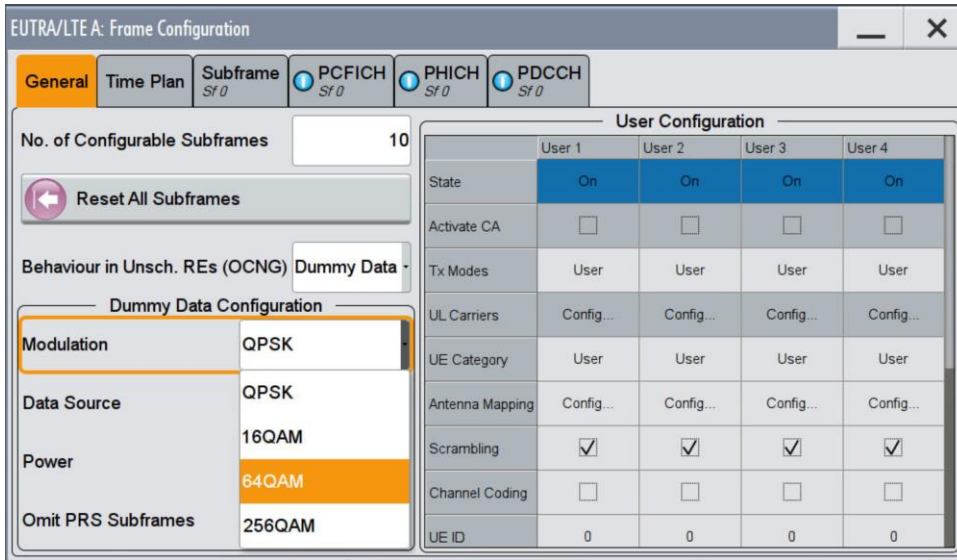
b. Bandwidth Selection

- From General Settings > Physical > Channel Bandwidth, Select 10MHz
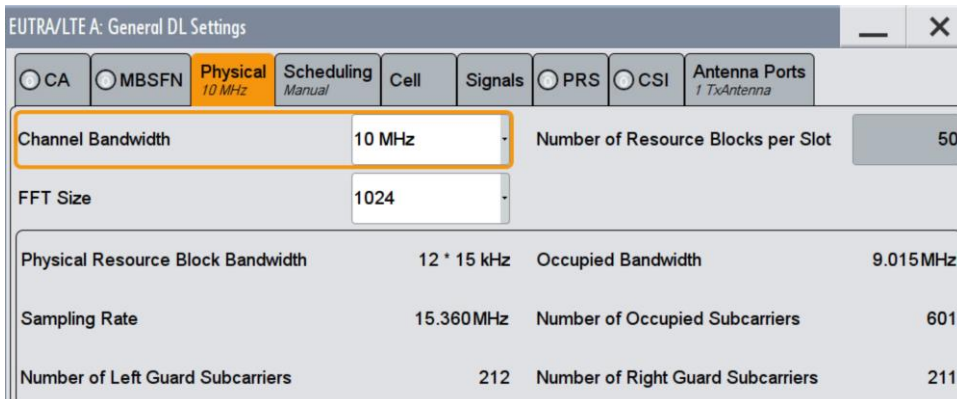
c. Bandwidth Selection

- From General Settings > CA > Bandwidth > 10MHz

d. Finally, switch ON the baseband configuration

4.3.3.2 Configuration LTE: Uplink

a. 3GPP Release selection

- From Frame Configuration > General > UE1 > Select ON

- 3GPP Release: LTE-Advanced
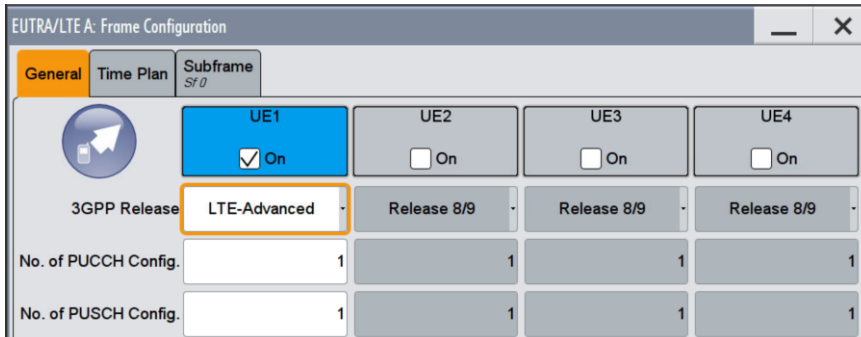
b. Modulation Selection

- From Frame Configuration > Subframe > UE1 > PUSCH > Modulation Format, Select 64QAM

- From Frame Configuration > Subframe > UE1 > PUSCH > No. RB > Input 50
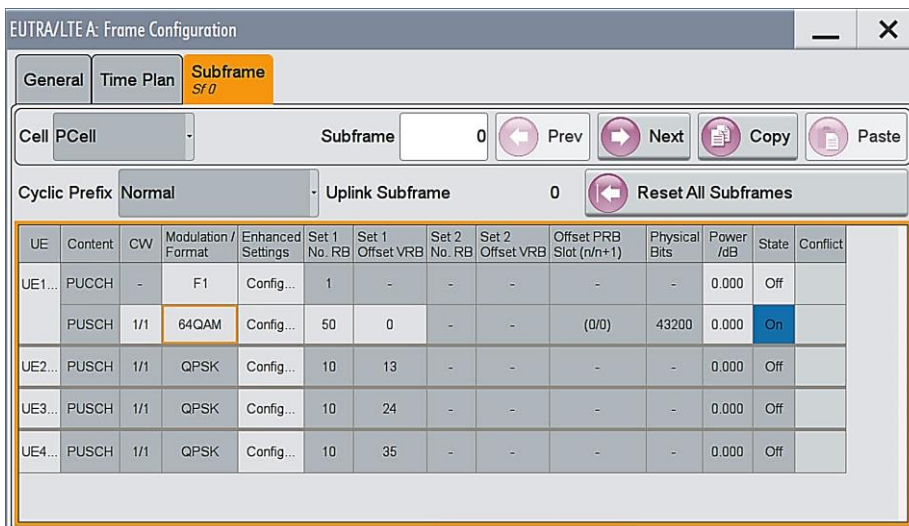
d. Finally, switch ON the baseband configuration

4.3.4 Automatic Configuration: ANSI C63.27 Tier 1, 2 & 3 Interference signal generation

In this section, three python scripts are discussed. They are:

► `SMW_3EMI_WLAN_11n_2_4GHz_1RF_path.py`,

► `SMW_WLAN_3EMI_5GHz_20MHz_BW_ANSI_C6327.py` and

► `SMW_WLAN_3EMI_5GHz_40MHz_BW_ANSI_C6327.py`.

The scripts automate the generation of interference/unwanted signals (supporting both WLAN 11n and LTE) for testing products that are categorized under Tier 1, 2 and 3 operating in the 2.4GHz and 5GHz frequency band. The scripts contain multiple functions. The main function contains a sequence of the functions to automatically configure the SMW.

4.3.4.1 Interference signal for DUT operating in the 2.4GHz Band

a. Remote connection to SMW, insert the IP address of SMW

```
smw = RsInstrument('TCPIP::10.202.0.159::INSTR', True, False)
```

b. Initiating three Basebands and routing them through the same RF path A

```
def smw_baseband_config_3xEntity():
    #### System Config Advanced Mode  #####
    smw.write_str('SCONfiguration:MODE ADV')
    smw.write_str('SCONfiguration:FADing SISO3X1X1')
    smw.write_str('SCONfiguration:APPLy ')

    #### IQ Mapper routing through RF Path A  #####
    smw.write_str('SCONfiguration:OUTPut:MAPPing:RF1:MODE ADD')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:RF1:STReam2:STATe 1')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:RF1:STReam3:STATe 1')


    #### IQ Mapper switch off #####
    smw.write_str('SCONfiguration:OUTPut:MAPPing:RF2:STReam2:STATe 0')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:IQOutput1:STReam3:STATe 0')
```

4.3.4.1.1 Interference Signal: WLAN

c. Configuring all three Basebands to generate WLAN IEEE 802.11n signals

```python
def BB_3WLAN_11n_SMW_config():
    #### Baseband_1 config 11n  #####
    smw.write_str('ENTity1:SOURce1:BB:WLNN:BW BW40')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:STANdard WN')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:STATe 1')


    #### Baseband_2 config 11n  #####
    smw.write_str('ENTity2:SOURce1:BB:WLNN:BW BW40')
    smw.write_str('ENTity2:SOURce1:BB:WLNN:FBLock1:STANdard WN')
    smw.write_str('ENTity2:SOURce1:BB:WLNN:STATe 1')


    #### Baseband_3 config 11n  #####
    smw.write_str('ENTity3:SOURce1:BB:WLNN:BW BW40')
    smw.write_str('ENTity3:SOURce1:BB:WLNN:FBLock1:STANdard WN')
    smw.write_str('ENTity3:SOURce1:BB:WLNN:STATe 1')
```

d. Three concurrent interference signal output for Tier 1 product testing

```python
def smw_24WLAN_EMI_WLAN_tier1():
    BB_3WLAN_11n_SMW_config()
    #### Set 3 concurrent EMI on WLAN Channel 1, 6 & 11    #####
    smw.write_str('SCONfiguration:APPLy')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam3:FOFFset 25000000')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam2:FOFFset -25000000')
    smw.write_str('SOURce1:FREQuency:CW 2437000000')
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -20') #20 dBm EIRP or -20 dBm at the EUT
    print("Done with EMI config.")
```

e. One co-channel interference signal output for Tier 2 product testing

```python
def smw_24WLAN_EMI_WLAN_cochan_tier2():
    BB_3WLAN_11n_SMW_config()
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:STANdard WN')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:ITIMe 0.005')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:MOD1 QAM64')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:STATe 1')
    smw.write_str('ENTity2:SOURce1:BB:WLNN:STATe 0')
    smw.write_str('ENTity3:SOURce1:BB:WLNN:STATe 0')
    #### Set 1 co-channel EMI on WLAN Channel 1, 6 & 11    #####
    smw.write_str('SOURce1:FREQuency:CW 2437000000')
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -20') #20 dBm EIRP or -20 dBm at the EUT
    print("Done with EMI config.")
```

f. One adjacent channel interference signal output for Tier 2 or Tier 3 product testing

```python
def smw_24WLAN_EMI_WLAN_adjchan_tier2_or_3():
    BB_3WLAN_11n_SMW_config()
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:STANdard WN')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:ITIMe 0.005')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:FBLock1:MOD1 QAM64')
    smw.write_str('ENTity1:SOURce1:BB:WLNN:STATe 1')
    smw.write_str('ENTity2:SOURce1:BB:WLNN:STATe 0')
    smw.write_str('ENTity3:SOURce1:BB:WLNN:STATe 0')
    #### Set 1 adj-channel EMI on WLAN Channel 1, 6 & 11    #####
    smw.write_str('SOURce1:FREQuency:CW 2412000000')  #ch1:2412000000 or ch11: 2462000000
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -20') #20 dBm EIRP or -20 dBm at the EUT
    print("Done with EMI config.")
```

4.3.4.1.2 Interference Signal: LTE

g. One lower adjacent channel interference signal output for Tier 1 product testing

```
def smw_24WLAN_EMI_LTE_lower_adj_tier1():
    smw.write_str('OUTPut1:STATe 0')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 0')
    smw.write_str('ENTity1:SOUR1:BB:EUTR:DUPL TDD')
    # smw.write_str('SOUR1:BB:EUTR:DUPL FDD')
    # smw.write_str('ENTity1:SOURce1:BB:EUTR:DL:DUMD:MOD QAM64')
    smw.write_str('ENTity1:SOUR1:BB:EUTR:LINK UP')
    # smw.write_str('SOUR1:BB:EUTR:LINK DOWN')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:BW BW10_00')  # BW1_40 , BW3_00,  BW5_00,
BW15_00, BW20_00
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:UE1:REL LADV')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:CELL0:SUBF2:ALL0:CW1:PUSC:MOD QAM64')
    sleep(3)
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 1')
    smw.write_str('SOURce1:FREQuency:CW 2395000000')
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -17')  # 23 dBm EIRP or -17 dBm at the EUT
```

h. One upper adjacent channel interference signal output for Tier 1 product testing

```
def smw_24WLAN_EMI_LTE_upper_adj_tier1():
    smw.write_str('OUTPut1:STATe 0')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 0')
    #smw.write_str('ENTity1:SOUR1:BB:EUTR:DUPL TDD')
    smw.write_str('SOUR1:BB:EUTR:DUPL FDD')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:DL:DUMD:MOD QAM64')
    #smw.write_str('ENTity1:SOUR1:BB:EUTR:LINK UP')
    smw.write_str('SOUR1:BB:EUTR:LINK DOWN')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:BW BW10_00')  # BW1_40 , BW3_00, BW5_00,
BW15_00, BW20_00
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:UE1:REL LADV')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:DL:DUMD:MOD QAM64')
    sleep(3)
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 1')
    smw.write_str('SOURce1:FREQuency:CW 250100000')
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -17')  # 23 dBm EIRP or -17 dBm at the EUT
```

4.3.4.2 Interference signal for DUT with 5GHz Band and 20MHz Bandwidth

Use the script SMW_WLAN_3EMI_5GHz_20MHz_BW_ANSI_C6327.py in order to automatically configure the SMW for generating interference signals according to Table A.1 as described in the ANSI C63.27-2021 (Annex A.4 page 45).

DUT channel and unintended signal co-channel	Unintended signal (lower channel)	Unintended signal (upper channel)
40	36	44
56	52	60
120	116	124
153	149	157

Table A.1 EUT (20 MHz BW) channels and unintended signal channels used in testing [ANSI C63.27-2021]

a. First, connect remotely to the signal generator and initialize the three Baseband using the steps described in 4.3.4.1 (a) and (b).

b. Configuring three concurrent interference for row 1 in Table A.1

```
def ANSI6327_EUT_WLAN_TABLE_A1_20MHz_40_36_44():
    #### Table A.1  _5GHz_ 20MHz Bandwidth _ Set 3 concurrent EMI on WLAN Channel 40,
36 & 44   #####
    smw.write_str('SCONfiguration:APPLy')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam3:FOFFset 20000000')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam2:FOFFset -20000000')
    smw.write_str('SOURce1:FREQuency:CW 5200000000')  #5200000000,
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -15')
    print("Done with EMI config.")
```

c. The python-based automation code for the remaining rows is included in the script.

d. Tier 1 product testing using unwanted LTE signals

```
def ANSI6327_smw_5GHz_EUT_EMI_LTE_adj_tier1():
    smw.write_str('OUTPut1:STATe 0')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 0')
    smw.write_str('ENTity2:SOURce1:BB:EUTR:STATe 0')
    smw.write_str('ENTity2:SOUR1:BB:EUTR:DUPL TDD')
    smw.write_str('ENTity1:SOUR1:BB:EUTR:DUPL FDD')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:DL:DUMD:MOD QAM64')
    smw.write_str('ENTity2:SOURce1:BB:EUTR:DL:DUMD:MOD QAM64')
    smw.write_str('ENTity2:SOUR1:BB:EUTR:LINK UP')
    smw.write_str('ENTity1:SOUR1:BB:EUTR:LINK DOWN')
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:BW BW10_00')  # BW1_40 , BW3_00, BW5_00,
BW15_00, BW20_00
    smw.write_str('ENTity2:SOURce1:BB:EUTR:UL:BW BW10_00')  # BW1_40 , BW3_00, BW5_00,
BW15_00, BW20_00
    smw.write_str('ENTity1:SOURce1:BB:EUTR:UL:UE1:REL LADV')
    sleep(3)
    smw.write_str('ENTity1:SOURce1:BB:EUTR:STATe 1')
    smw.write_str('ENTity2:SOURce1:BB:EUTR:STATe 1')
    smw.write_str('SOURce1:FREQuency:CW 5765000000') # insert freq= 5765000000,
5600000000, 5280000000, 5200000000
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam2:FOFFset +20000000')  #-
20000000: lower or upper
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer -17')  # 23 dBm EIRP or -17 dBm at the EUT
```

4.3.4.3 Interference signal for DUT with 5GHz Band and 40MHz Bandwidth

Use the script SMW_WLAN_3EMI_5GHz_40MHz_BW_ANSI_C6327.py in order to configure the SMW for generating interference signals according to Table A.1 as described in the ANSI C63.27-2021 (Annex A.4 page 45).

DUT channel and unintended signal co-channel	Unintended signal (lower channel)	Unintended signal (upper channel)
46	38	54
54	46	62
118	110	126
159	151	165 (20MHz BW)

Table A.2 EUT (40 MHz BW) channels and unintended signal channels used in testing [ANSI C63.27-2021]

a. Firstly, connect remotely to the signal generator and initialize the three Baseband using the steps described in 4.3.4.1 (a) and (b).

b. Configuring three concurrent interference for row 1 in Table A.2

```
def ANSI6327_EUT_WLAN_TABLE_A2_40MHz_46_38_54():
    #### Table A.2  _5GHz_ 40MHz Bandwidth _ Set 3 concurrent EMI on WLAN Channel 46,
38 & 54   #####
    smw.write_str('SCONfiguration:APPLy')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam3:FOFFset 40000000')
    smw.write_str('SCONfiguration:OUTPut:MAPPing:STReam2:FOFFset -40000000')
    smw.write_str('SOURce1:FREQuency:CW 5230000000') #5230000000
    smw.write_str('OUTPut1:STATe 1')
    smw.write_str('SOURce1:POWer:POWer 10')
```

c. The python-based automation code for the remaining rows is included in the script.

```
def main():
    smw_connection()
    smw_baseband_config_3xEntity()
    BB_3WLAN_11n_SMW_config()

    ANSI6327_EUT_WLAN_TABLE_A2_40MHz_46_38_54()          #Table A2. Row 1
    #ANSI6327_EUT_WLAN_TABLE_A2_40MHz_54_46_62()       #Table A2. Row 2
    #ANSI6327_EUT_WLAN_TABLE_A2_40MHz_118_110_126()       #Table A2. Row 3
    #ANSI6327_EUT_WLAN_TABLE_A2_40MHz_159_151_165()       #Table A2. Row 4
    smw.close()



main()     #This is the main function call
```

4.4 Monitoring and Pathloss Compensation

To calibrate over the air pathloss of radiated RF signals, a signal generator and a spectrum analyzer is used. Alternatively, a vector network analyzer may also be used. In this section, we are technically measuring S21 but using signal generator and spectrum analyzer.

Two antennas connected to the test instruments are placed inside an anechoic chamber. The transmit (TX) antenna connected to the SMW vector signal generator (VSG) and is positioned in the middle of the turntable. The TX antenna is pointing directly towards the receive (RX) antenna and is separated by a distance of 3m or 6m. The RX antenna is connected to a spectrum analyzer (such as the FSW) as shown in Figure 4.1.

The TX station sweeps a CW signal over a predefined frequency range. On the FSW, the corresponding frequency response is recorded.

The pathloss is calculated by subtracting the power received and power transmitted, using the formula

Pathloss = Pr – Pt (where Pr = received power and Pt = transmit power)

The compensated transmit power of the DUT at the source is calculated by applying pathloss compensation in the post processing step by subtracting the power received and the calculated pathloss, using the formula

Compensated_Pt = Pr – Pathloss
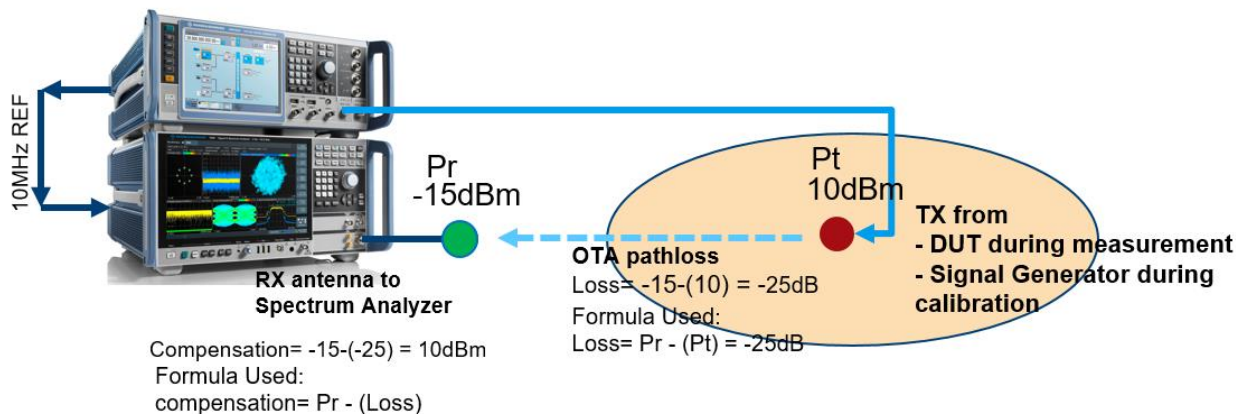
Figure 4.1 Test setup for pathloss compensation and calculation for after pathloss compensation

Methodology:

- Connect a 10MHz Reference from the SMW to the FSW using a BNC cable
- FSW: Define the frequency span of interest on the FSW and set trace to max hold
- SMW: set a constant power level and sweep over the predefined frequency span (using corresponding number of frequency steps as number of points on the FSW)
- FSW: Export the trace or peak marker reading
- Perform calculation using the formulas above on the series data

Consideration:

For the receive side: The Pr is the power that is coming in to the port of the FSW. It does not account for the cable loss, LNA and RX antenna gain or losses originating due to antenna pointing error.

For the transmit side: Pt = Pout – cable loss + (optional power amplifier gain)

- where Pout is the power level set on the SMW

It is a tedious measurement challenge to perform manually because in order to increase the resolution and precision of the calibration, selection of a large number of points (1000+) is recommended. The python script OTA_Pathloss_Compensation.py is an automated way to perform the pathloss calibration and compensation as described in this section.

The script contains multiple functions / methods to do specific configuration tasks and in the main function the relevant functions are called in correct sequence.

The important functions are:

```
calibrate_pathloss(start_freq, stop_freq, Pout)
```
This function configures the FSW and the SMW, to perform the calibration of the pathloss between the user defined start and stop frequency using the output TX power.

```
measure_radiated_power_from_EUT(start_freq, stop_freq)
```
This function configures the FSW, to perform the spectrum monitoring measurement between the user defined start and stop frequency.

The compensation maybe be calculated by using either trace data or marker data

```
TRP_EUT_Compensate_trace()
```
This function performs the compensation calculation and plots the data. The compensation is based on trace data reading on the FSW.

```
TRP_EUT_Compensate_marker()
```
This function performs the compensation calculation and plots the data. The compensation is based on marker data reading on the FSW.

```
compare_meaurement_compensation()
```
This function compares between actual measurement data with and without compensation calculation.

```
main(start_freq= 2350000000 , stop_freq= 2550000000, Pout= 10)
```
This function runs a sequence of functions in order to calibrate, measure and compensate the pathloss. The Start frequency, stop frequency and Pout value needs to be defined only once in the main function. All the other functions will import the value automatically.

In order to run this script, input the correct IP addresses for SMW & FSW. Insert the relevant parameters in the main function call at the bottom of the script and set the correct sequence of functions in the **def main()** function.

Figure 4.2 shows the application of the **function: compare_measurement_compensation()**. The green plot is the compensated data and the blue plot is the actual measured data without compensation applied as recorded on the FSW.
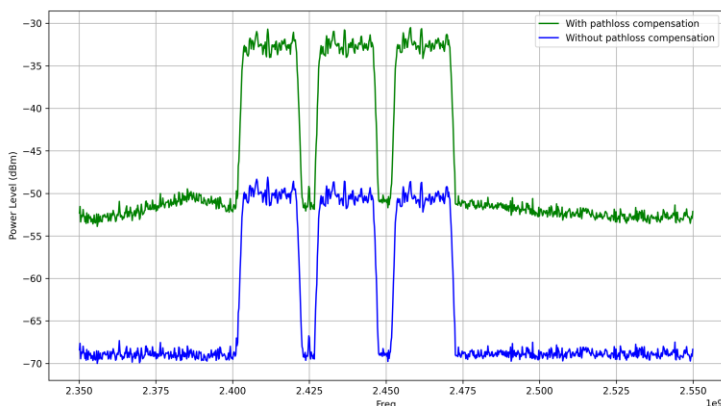

Figure 4.2 Comparison plot of the measured data with and without compensation calculation

4.5 WLAN Handover Testing

WLAN devices that need to operate in hospitals, shopping malls, large airport terminals and in other similar relatively large spaces where multiple wireless access points are deployed with the same SSID and network security configuration, some medical devices are typically configured to perform handover operation while roaming from one coverage area to the next. In this example one such handover scenario example is implemented using the CMW. The device under test initially connects to an access point (AP) but is continuously scanning for other nearby access points. When the RSSI value drops for the AP drops below a certain pre-defined threshold, the wireless device initiates the handover procedure and associates itself with an AP with a higher RSSI value.
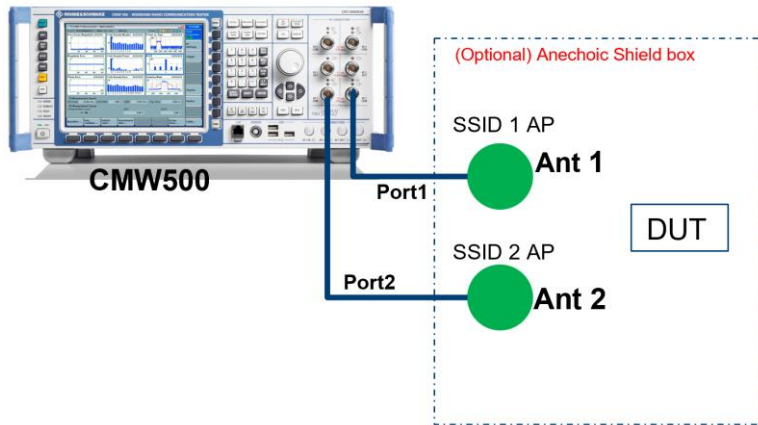
Figure 4.3 Test setup for performing WLAN handover testing

Using a CMW500 with two signaling unit it is possible to perform handover test with as many simulated SSIDs as required. Figure 4.3 shows the test setup used for testing WLAN handover from one access point to the next. Flashing an SSID profile on to the WLAN personality can be done in a matter of seconds and the power drop off is realized without having to use external variable attenuators.
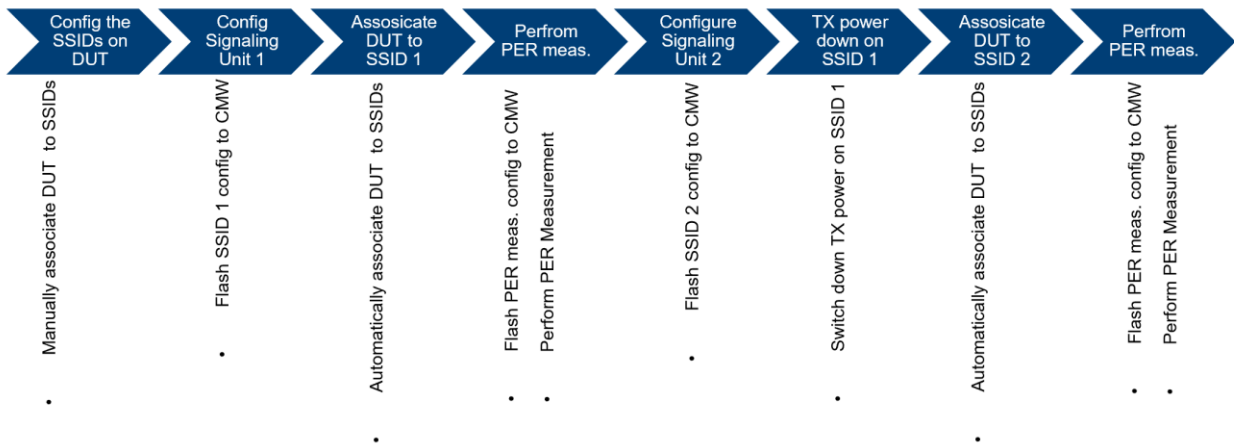
Figure 4.4: Workflow of the sequence of events for a handover operation to take place

In order to test for a handover operation, the DUT needs to connect to SSID 1 and the quality to connection is evaluated by performing a PER measurement. Next the power level of SSID 1 is slowly decreased and simultaneously the power level of SSID 2 is increased. At the point, where the power level of the SSID 1 is below the predefined threshold level, the DUT should initiate the handover procedure to and associate itself to SSID 2. After a successful handover operation to the second access point, another PER test is performed to evaluate the quality of the connection. This workflow sequence is shown in Figure 4.4.

In terms of test method implementation, the fastest way to flash a SSID profile to the WLAN personality of the CMW is through automatic configuration. The python script, WLAN_Handover_Test.py , shows an example to remotely connect a DUT to a CMW with two signaling units and performs the test according to the workflow described in Figure 4.4.

    a.   Flash the SSID 1 Profile to the signaling unit 1

```
#WLAN Signaling Window 1
cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT OFF')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:STAN GNSTd')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:CHAN 1')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EATT:INP -20')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EATT:OUTP -20')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFSettings:BOPower 4')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:RFS:EPEP -20')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:DFD ENAB, NHT, BW20, Q6M23, LONG')
#D1MBit | D2MBits | C55Mbits | C11Mbits | BR12 | BR34 | QR12 | QR34 | Q1M12 | Q1M34 |
Q6M23 | Q6M34
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:OMOD AP')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:SSID "myCMW"')
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:CONN:SEC:PASS DIS, "12345678"')
cmw_wlan.utilities.write_str('ROUT:WLAN:SIGN1:SCEN:SCEL1:FLEX SUA1, RF1C, RX1, RF1C,
TX1')   # Routing of TX and RX
cmw_wlan.utilities.write_str('SOUR:WLAN:SIGN1:STAT ON')
```

    b.   Performing PER measurement on the DUT after successful association

```
cmw_wlan.utilities.write_str('INIT:WLAN:SIGN1:PER')   # Start PER Measurement
sleep(5)
cmw_wlan.utilities.write_str('STOP:WLAN:SIGN1:PER')   # Stop PER Measurement
cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:PER:FDEF NHT, BW20, Q6M23')   # Set

cmw_wlan.utilities.write_str('CONF:WLAN:SIGN1:PER:PACK 100')   # PER Measureent Setting
number of Packets
PER_STATUS = cmw_wlan.utilities.query_str('FETC:WLAN:SIGN1:PER:STAT?')
a = cmw_wlan.utilities.query_str('FETC:WLAN:SIGN1:PER?')   # 0, PER, Packets sent, Packets
Lost, RX Burst Power
cmw_wlan.utilities.query_str('FETC:WLAN:SIGN1:PACK?')   # LAST ACK rate
#b=cmw_wlan.utilities.query_str('READ:WLAN:SIGN1:PER?')
print('PER Measurement from Signaling 1, SSID: myCMW')
print(a)
```

    c.   Flash new SSID 2 profile to the signaling unit 2

    d.   Slowly switch down the power on signaling unit 1

```
burst_power= 4
cmw_wlan.utilities.write_int('CONF:WLAN:SIGN1:RFS:BOP', param= burst_power)
while burst_power >= -120.1:
    #print(burst_power)
    cmw_wlan.utilities.write_int('CONF:WLAN:SIGN1:RFS:BOP', param=burst_power)
    burst_power = burst_power - 1
```

    e.   Perform PER measurement on the DUT after successful association on the SSID 2

4.6 Mutual Interference measurement

When multiple connected devices operate in close proximity to one another, the wireless transmission of one device may negatively affect the overall receiver performance of the other device and vice versa. This is especially significant for critical medical devices and the impact on receiver performance of co-located devices need to be documented. Figure 4.5 shows the test setup that is used to recreate the real-world RF scenario inside a test chamber and simultaneously perform PER measurement on both devices to determine the extent of the degradation in performance.

Figure 4.5: Real world scenario mutual interference effect recreated in the test chamber

As shown in Figure 4.5, the victim device is co-located at a distance of 20.32cm (8 inches) apart from another transmitting device. The two devices are operating on the same frequency and WLAN channel. Using the CMW, we generate two simultaneous access point networks. The CMW requires at least two signaling units for performing this measurement. DUT1 is connected to AP1 generated from the signaling unit 1 and DUT2 is connected to the signaling unit 2. Each signaling unit can associate multiple devices in parallel but the PER measurement is only possible for the last associated device. But by using two signaling units, it is possible two run two simultaneous PER measurement on two different DUTs in parallel.

The two access points are configured almost similarly to each other with only a slight variation in output power and SSID name (to additionally verify that the DUTs are connected to different signaling units). The devices need to be manually connected to the WLAN SSID only the first time. After that the automation script maybe used for establishing a connection and performing PER measurements.

The automatic configuration of the two access points and PER measurement routine can be found in the python script *Mutual_Interference_Effect_WLAN.py*. The main function below shows the sequence of functions/methods from the script.

```python
def main():
    WLAN_Signaling1_config() #("WLAN Sig 1 Config")
    sleep(6)
    PER_Meas_signalling1()
    WLAN_Signalling2_config() #("WLAN Sig 2 Config")
    sleep(6)
    PER_meas_signalling2()
    print("Starting Both S1 & S2 transmissions")
    init_meas_PER_Sig_1n2()
```

Figure 4.6 shows the PER measurement of two devices located in close proximity to one another. Both devices are operating on WLAN ch1. Device 1 is connected using QPSK modulation and device 2 is connected to the CMW AP using 64QAM modulation. The received power level reported by device 1 is -69.5dBm and by device 2 is -55.3dBm. Device 1 is transferring 5500 packets end-to-end over the network and device 2 is transferring 2000 packets.

The PER measurement is firstly switched on for device 1 and is allowed to run for a short period until a baseline is created before the PER measurement for device 2 is switched on. This results in a steep increase in the loss of received packets in case of device 1 and device 2 averages a PER is over 29% which is significantly higher than the acceptable limit of 10%.
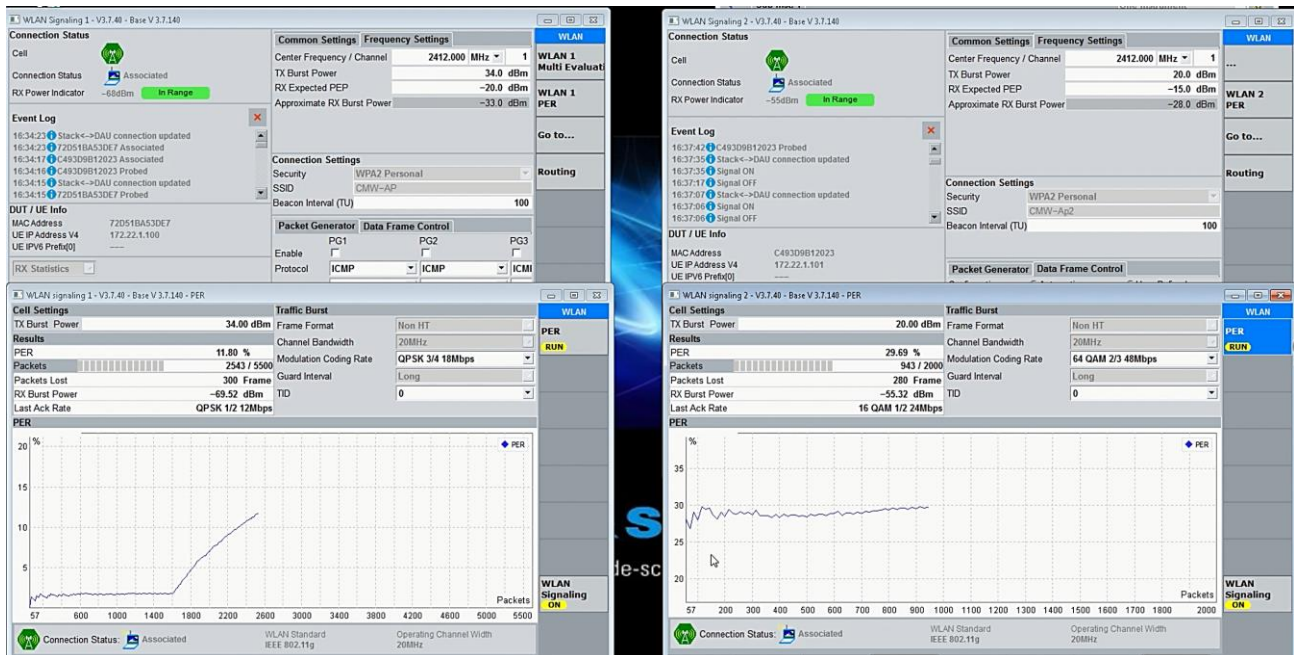

Figure 4.6: Simultaneous PER measurement on multiple devices located in close proximity

4.7 UV Curve Measurements

The concept of UV shaped curves was introduced in the white paper [1] and further demonstrated through measurements in [3]. In this section, the automated measurement steps are explained. The script, UV_CURVE_MEASUREMENT_AN.py contain two functions that enable to automatically execute the measurement procedure described in the white paper.

The function PERsearch() performs a power sweep of the TX burst power from the CMW to the DUT and returns a list of values for the corresponding PER and csv file with the data is also saved simultaneously. This helps us identify the sensitivity of the receiver.

Hint: If the measurement doesn't stop and keeps on looping then the sweep power limits need to be readjusted and power level needs to be reduced.

The two TX burst power values for which the PER performance is slightly over 10% is -36dBm and -37dBm. To this value add 6dB back-off and set the TX Burst power of -30dBm for the UV curve measurement.

```
      0    1
0  -30   10
1  -31   13
2  -32   13
3  -33   14
4  -34   10
5  -35    2
6  -36   13
7  -37   16
8  -38   48
9  -39   81
```

The function, UV_curve_measurement(), sweeps the EMI power (from the SMW) at every frequency point in the range 2.4GHz to 2.425GHz with steps of 5MHz and returns a dictionary of PER values at different EMI power levels as shown below. It also saves a CSV file with the data.

- Manually select CMW TX Burst power to DUT: -30dBm (DUT connected to WLAN Ch1, 64QAM) and run the function

```
           0                                          1
0  2400000000  {-10: 11, -9: 11, -8: 10, -7: 10}
1  2405000000  {-10: 14, -9: 17, -8: 10, -7: 29}
2  2410000000  {-10: 16, -9: 18, -8: 15, -7: 17}
3  2415000000  {-10: 13, -9: 17, -8: 12, -7: 20}
4  2420000000  {-10: 11, -9: 13, -8: 20, -7: 17}
5  2425000000  {-10: 16, -9: 17, -8: 10, -7: 8}
```

Index, Frequency {EMI_pwr1: PER, EMI_pwr2: PER…}

- Manually select CMW TX Burst power to DUT: -28dBm (DUT connected to WLAN Ch1, 64QAM) and run the function

```
           0                                      1
0  2400000000  {-10: 4, -9: 5, -8: 6, -7: 5}
1  2405000000  {-10: 8, -9: 8, -8: 3, -7: 7}
2  2410000000  {-10: 5, -9: 3, -8: 4, -7: 3}
3  2415000000  {-10: 5, -9: 7, -8: 6, -7: 4}
4  2420000000  {-10: 4, -9: 11, -8: 3, -7: 4}
5  2425000000  {-10: 3, -9: 8, -8: 3, -7: 1}
```

Index, Frequency {EMI_pwr1: PER, EMI_pwr2: PER…}

Using this data, the in-band and out-band EMI power handling graph for the receiver test can be plotted for a desired PER values and the UV performance of different receivers may be compared. This data is valid for a value of 10% to 13% PER.
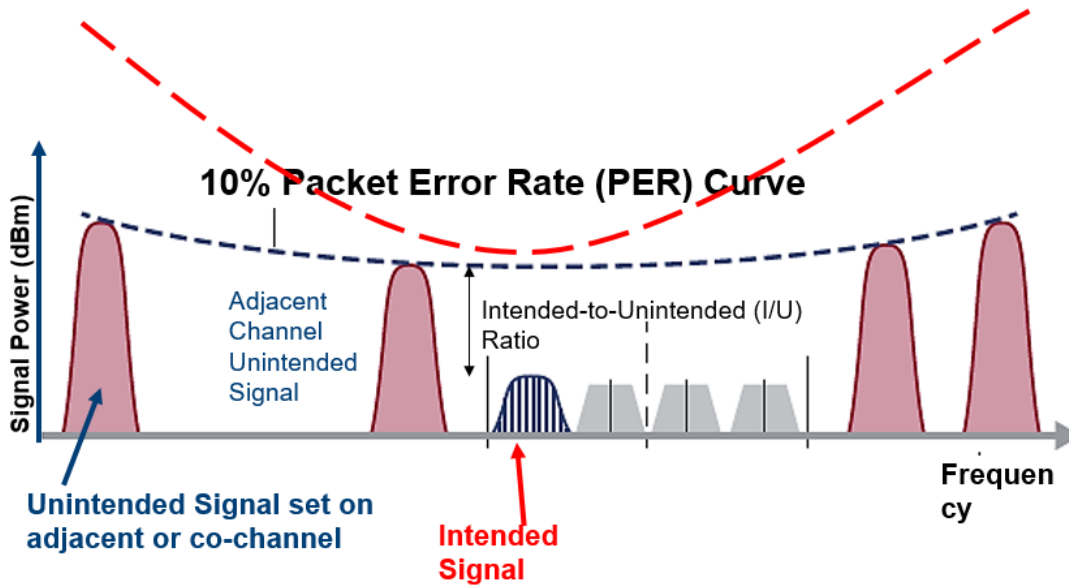
4.8 Radiated RF Measurement 101

In this section, we will talk about how to transform conducted measurement setups to radiated test setups. In order to perform radiated measurements, a few key aspects need to be considered. They are link budget calculation, high power amplifier selection and antenna selection.

4.8.1 OTA Link Budget Calculation

Figure 4.7 shows a simplified block diagram of a conducted and a radiated test setup and the relevant losses that must be taken in consideration. In order to transform a conducted measurement setup in to an OTA test setup, the cable that connects the measurement equipment to the DUT is replaced using a power amplifier and an antenna. Focusing on the measurement equipment side, in case of bidirectional communication, a bi-directional amplifier is required or two uni-directional amplifiers are used. In the transmit direction a high-powered amplifier is used and in the receive direction a low noise amplifier is used. The measurement equipment could be a communication tester (CMW), a vector signal generator (SMW) or a spectrum analyzer (FSW). In case of a CMW, two amplifiers are required for two-way communication. In case of SMW, one power amplifier is required to amplify the outgoing/transmitted signal and for the FSW, one LNA is required to amplify the incoming receive signal.
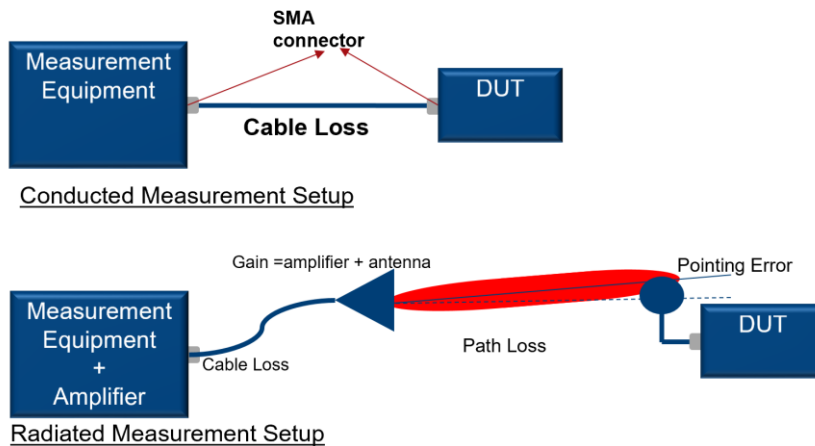

Figure 4.7: Simplified conducted and radiated test setups and the corresponding losses

In case of conducted test setup, the measurement equipment is connected to the DUT using an RF cable. There are no antennas involved and the RF antenna port of the test instrument is directly connected to the RF antenna port of the DUT, bypassing the antennas. Therefore, the only form of loss, originates from the cable and the RF adapters (SMA or N connector as shown in the figure 4.7).

In order to replace this cable, the measurement instrument requires an amplifier, which is then connected to a measurement antenna via cable. This results in some increased gain from the power amplifier and the antenna. The antenna gain varies depending on the type of antenna used. Typically, in anechoic chambers, high gain and highly directional horn antennas are used. The losses originate from the cable loss connecting the test instrument to the antenna, since in anechoic chamber setup typically very long cable stretches are used. Other sources of loss are the over the air path loss and the antenna pointing error.

As a result,

Pr = Pt + Gain (amplifier & antenna) – Losses

Rohde & Schwarz provides a free of charge tool to roughly calculate the Link Budget.

https://www.rohde-schwarz.com/us/applications/field-strength-and-power-estimator-application-note_56280-15837.html

Using this tool, it is possible to make an ideal case Link Budget calculation. The tool only calculates for CW signal transmission in ideal case. Therefore, the cable loss and pointing error is not considered. But is helpful to get an idea about the power dynamics required for OTA transmissions. For our purposes, we are working with high bandwidth signals and not with CW signals. Therefore, from the calculator tool, the power received and power transmitted values can be considered as channel power, i.e. power distributed over the entire bandwidth of the signal.

Figure 4.8: Link budget calculation for WLAN Channel 1 inside a 3m anechoic chamber

In Figure 4.8, a calculation example of a WLAN ch1 transmission in an anechoic chamber is shown. The measurement antenna is 3m away from the DUT. The power transmitted out from the antenna is 23dBm. The antenna gains are 14dBi for transmit antenna and 1dBi for the receive antenna. Thus, resulting in a received power level of -11.63dBm. This can be considered as the channel power over the 20MHz bandwidth at 2.412GHz.

4.8.2   Amplifier Selection

Power amplifiers help to boost up the RF signal power level to reach a desired radiated field strength at the DUT. They also help to main a stable link while performing radiated measurements.

Rohde & Schwarz offers multiple power amplifiers that are suitable for boosting up the transmit power for wireless coexistence testing application.

Figure 4.9 Rohde & Schwarz power amplifier portfolio for coexistence testing application

Figure 4.9 shows the amplifier portfolio that are suitable of coexistence testing. Depending on the amplifier, it is possible to amplify RF signals up to 20GHz with the SAM100 or up to 6GHz with the BBA amplifier series.
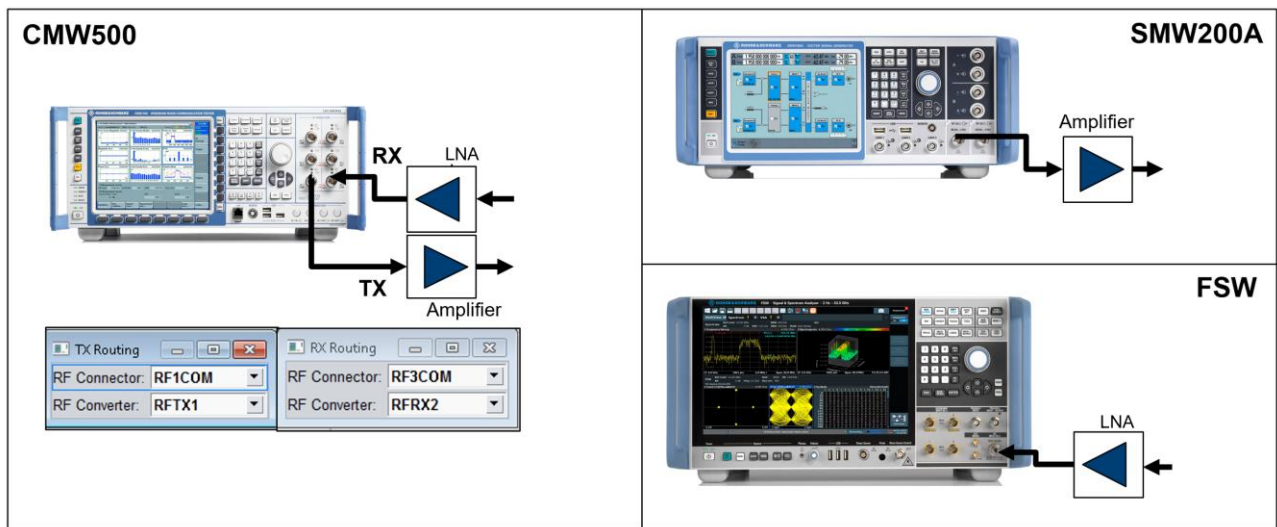

Figure 4.10: Amplifier connection to different measurement equipment

Figure 4.10 shows how power amplifiers can be connected to the different measurement equipment in order to boost the signal level when ever required.

For the CMW: the signal can be split in to downlink and uplink components by routing the signals through the different ports and the amplifiers are connected in the correct direction to amplify the signals. This means, the TX signal from the CMW passes through the amplifier and is transmitted out via the antenna. In the opposite direction, the signal from the antenna passes a low noise amplifier (LNA) and travels to the CMW RX port. In the receive direction, make sure to check the power level before feeding that into the receive port of the CMW. It is highly recommended to use a RF attenuator to protect the CMW RF port, as the power handling capability of the RF port might be lower than the power amplifiers output level.

For the VSG(SMW200A): the signal from the SMW is routed through the power amplifier before being transmitted via the antenna.

For the FSW: the signal from the antenna is typically routed directly to the FSW. The use of an LNA in between the antenna and FSW might not be required since the FSW can fitted with a preamplifier and has a high dynamic range. But if you do use an external COTS LNA, that is if the signal level is so low that a desired SNR is not met even after the use of the preamplifier, make sure to check the power level that is feeding into the receive port of the FSW. It is highly recommended to use a RF attenuator to protect the FSW RF port, as the power handling capability of the RF port might be lower than the power amplifiers output level.

	BBA300	BBA130	BBA150	SAM100
RF Input Port (Type)	N-female*	N-female*	N-female*	2.92mm/3.5mm female
RF Output Port (Type)	N-female*	N-female*	N-female*	2.92mm/3.5mm female
Input Power for nominal output	0 dBm	-3.4 dBm	- 3.4 dBm	-4 dBm
Nominal. Output Power*	+41.76 dBm or 15W	+46.5dBm or 45W	+44.8dBm or 30W	+43 dBm or 20W
Data sheet	Data Sheet	Data Sheet	Data Sheet	Data Sheet

Table: 4.1 Quick facts guide from the different power amplifiers in the coexistence test portfolio

Table 4.1 shows the RF connector types, nominal input power and maximum output power for different amplifier types from Rohde & Schwarz.

4.8.3   Antenna Selection

For coexistence testing, two antenna models are recommended from the R&S measurement antenna portfolio.

The HF907 and HF918 are both high gain directional antennas that are suitable for this application depending on the power level and use case. The HF907 is typically used for indoor applications while the HF918 is normally preferred for outdoor test application. The Table 4.2 is a quick fact guide to explain the capability of the two antennas. Since most coexistence testing is performed in indoor conditions, thus the HF907 is more frequently used for testing. Figure 4.11 shows the antenna radiation pattern at different frequencies.

	HF907	HF918
Gain	**5 dBi to 14 dBi** **+11dBi @ 6GHz**	**7 dBi to 15 dBi** **+14dBi @ 6GHz**
Frequency Range	800MHz - 18GHz	800MHz- 18GHz
Polarisation	Linear	Linear
Max. Input power @10GHz	200 W CW	130 W CW
Operating Temperature	–10°C to +50°C	–30°C to +55°C
Data sheet	Data Sheet	Data Sheet

Table 4.2 Quick facts guide from the antennas that are suitable for radiated coexistence test application
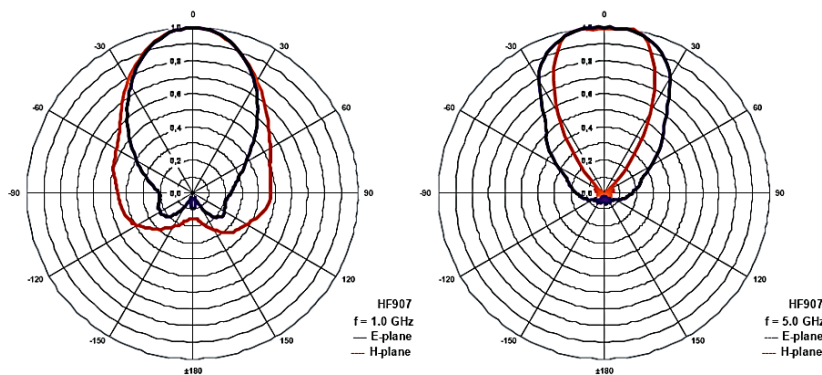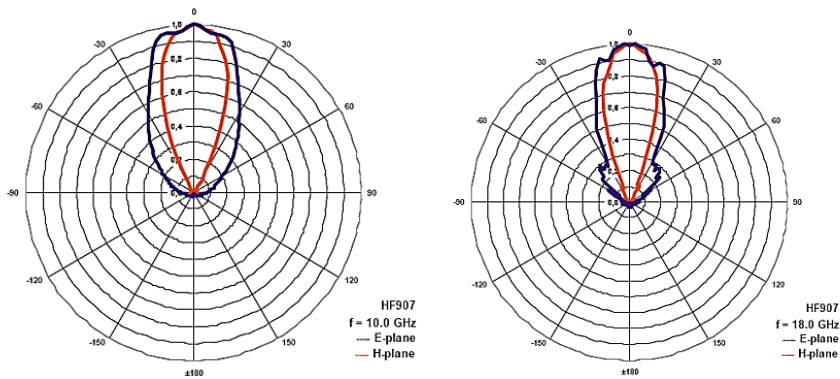
Figure 4.11 Antenna Radiation Pattern from the HF907 at different operational frequencies

4.9 Recreate field conditions in the lab with Record & Playback solution

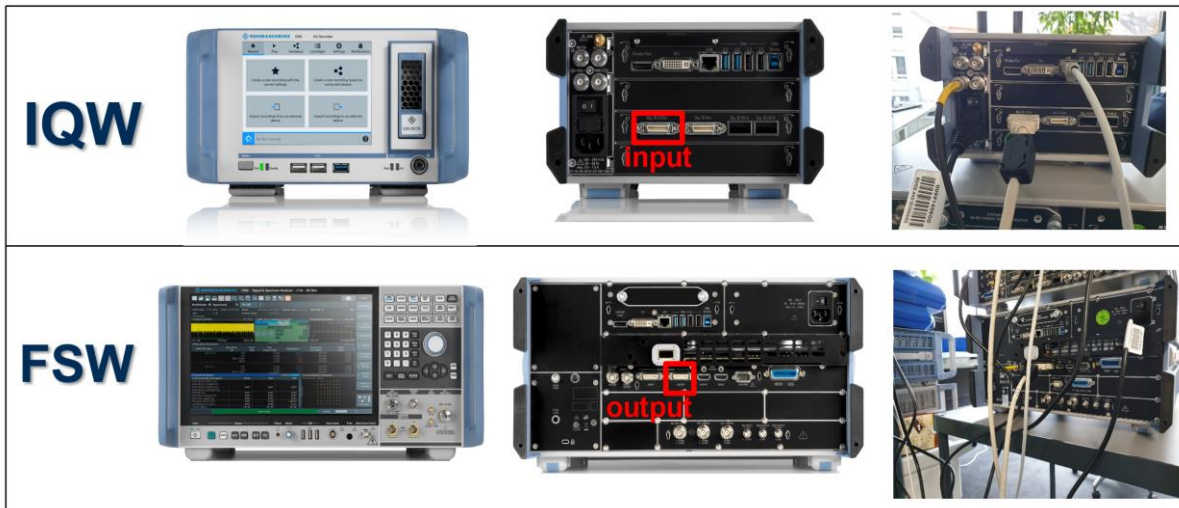a. Real-world RF spectrum recording using FSW & IQW

Figure 4.12 Real-world RF Spectrum recording setup

Figure 4.12 shows the test setup for recording the RF spectrum using the IQW and the FSW. The IQW is a digital IQ recorder and the FSW serves as the RF frontend for the IQW. The IQW is frequency agnostic which means the frequency range is dependent on the frequency range of the spectrum analyzer. The record length depends on the memory depth of the IQW. The frequency resolution of the recording can be configured using the spectrum analyzer.
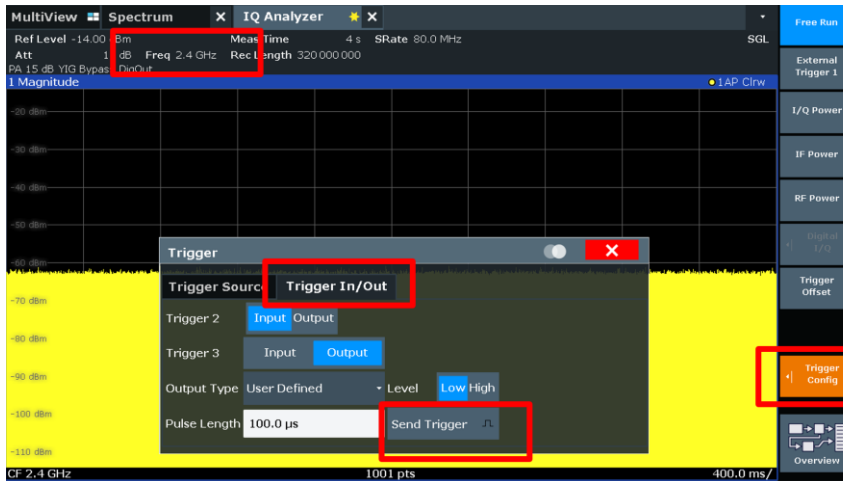
- Connect the Digital IQ output of the FSW to the Digital IQ Input of the IQW (as shown in Figure 4.12)

On the FSW,

- From MODE , select the IQ Analyzer personality
- From Data Acquisition,
    - Sample rate = 80MHz, Analysis BW : 64MHz, Relevant Meas. Time, record length& RBW
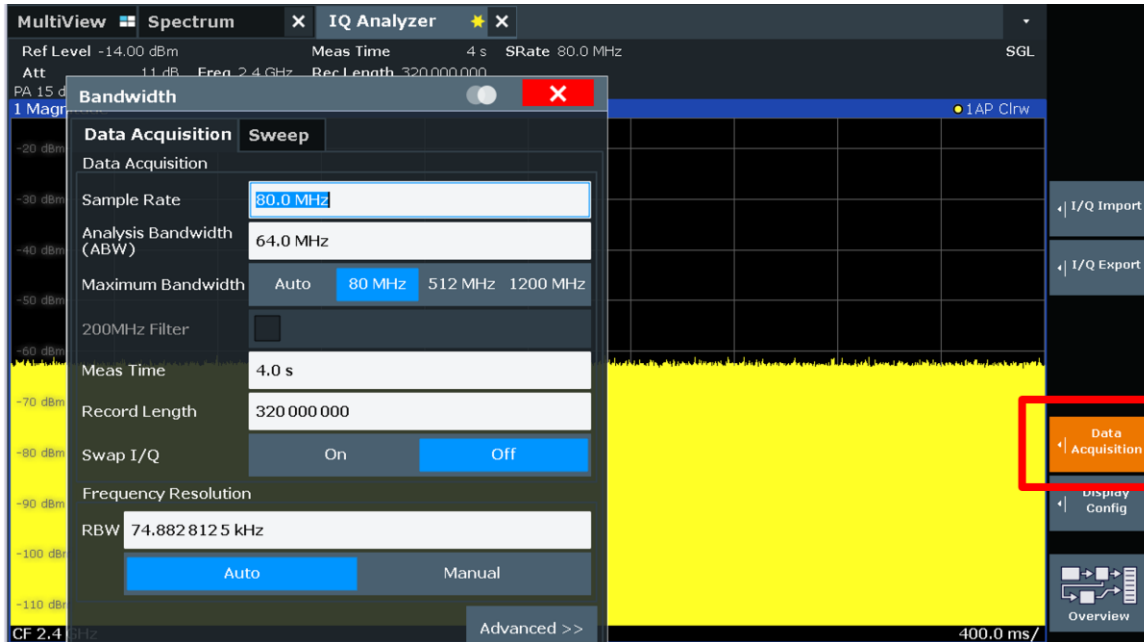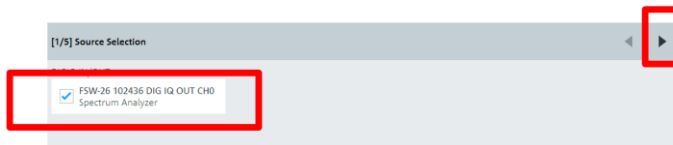
o Set the RF center frequency as required

o From the trigger config menu, select the appropriate trigger setting

On the IQW,

- Press Record > Create a new recording based connected device

- Follow the interactive 5 step configuration setting

    1. Source selection: check the connected FSW and then click next symbol

    2. Device Configuration: the IQW should automatically import the FSW settings and select next
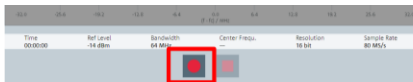
3. Select Manual Trigger and hit Next

4. In step 4, define the filename for the record file

5. In step 5, you will get the overview window of your selections. If everything is OK then press "Go to recording"

- To Record press the Record button and from FSW trigger window, press send trigger

b. Real-world RF spectrum playback in the lab using SMW & IQW

Figure 4.13 Real-world RF Spectrum playback setup

Figure 4.13 shows the test setup for playback of the recorded RF spectrum using the IQW and the SMW. The IQW is a digital IQ recorder/streamer and the SMW serves as the RF frontend for the IQW. The IQW is frequency agnostic which means the frequency range is dependent on the frequency range of the vector signal generator. The playback length depends on the size of the recorded file but it can be configured for looped playback.

- Connect the Digital IQ output of the IQW to the Digital IQ Input of the SMW (as shown in Figure 4.13)

On the SMW,

- From System Config > External RF and I/O, the IQW100 will be automatically detected> Hit Config.
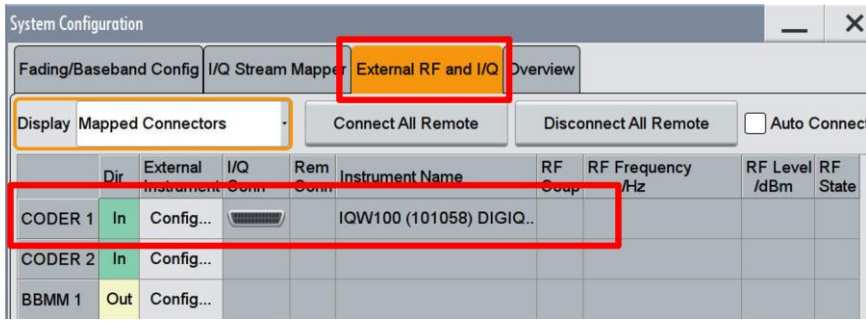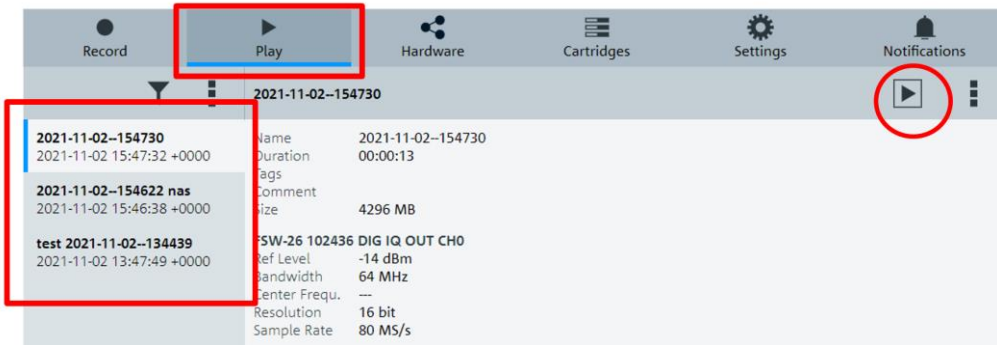
- From BB Input A, select Baseband Input setting > config the 4 windows as in the pictures below.

  o General > State > On

  o Sample Rate > Source : User Defined, Value: 100MHz

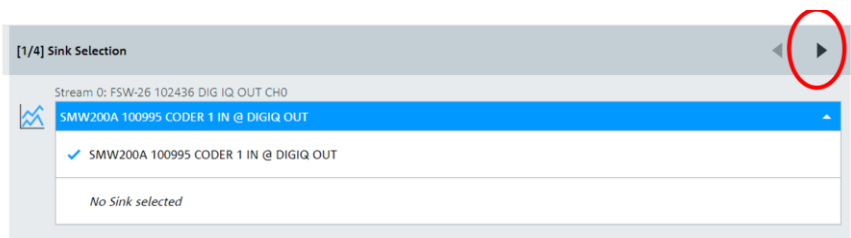 o Input Level > DIG IQ Auto Setting > ON
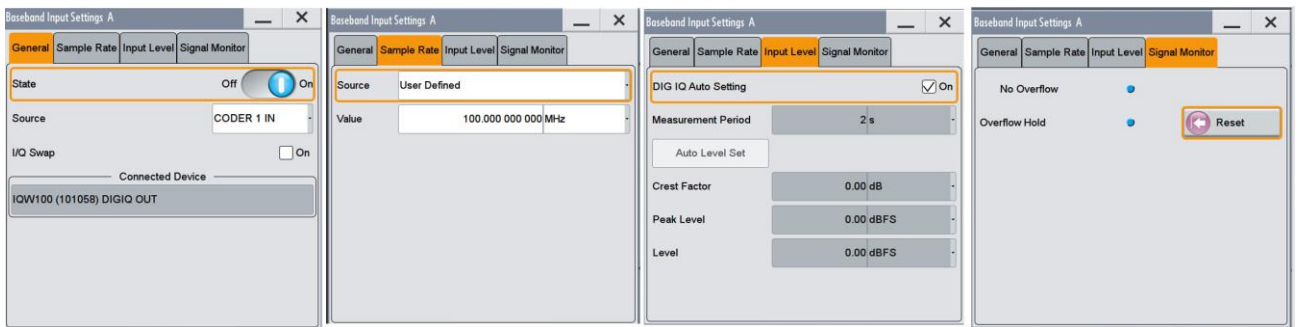
- RF Frequency: 2.4GHz , BB Input A: ON, IQ MOD A : ON, RF A: ON

On the IQW,

- Press Play > a list of available recording will be available

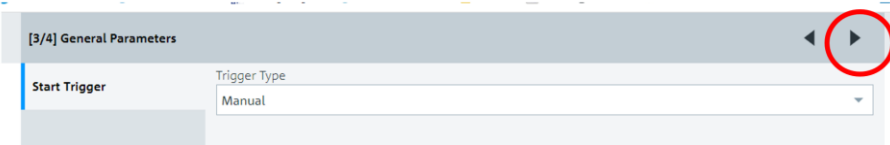- Select the relevant file and follow the interactive 4 step configuration setting

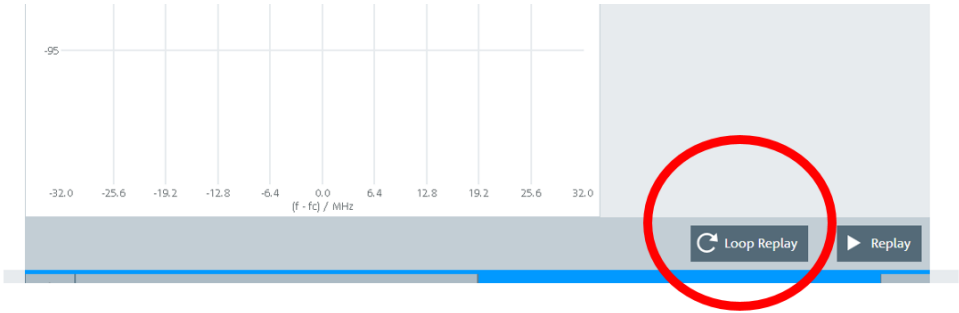 1. Sink selection: check the connected SMW and then click next symbol

2. Device Configuration: the IQW will automatically export the settings to the SMW
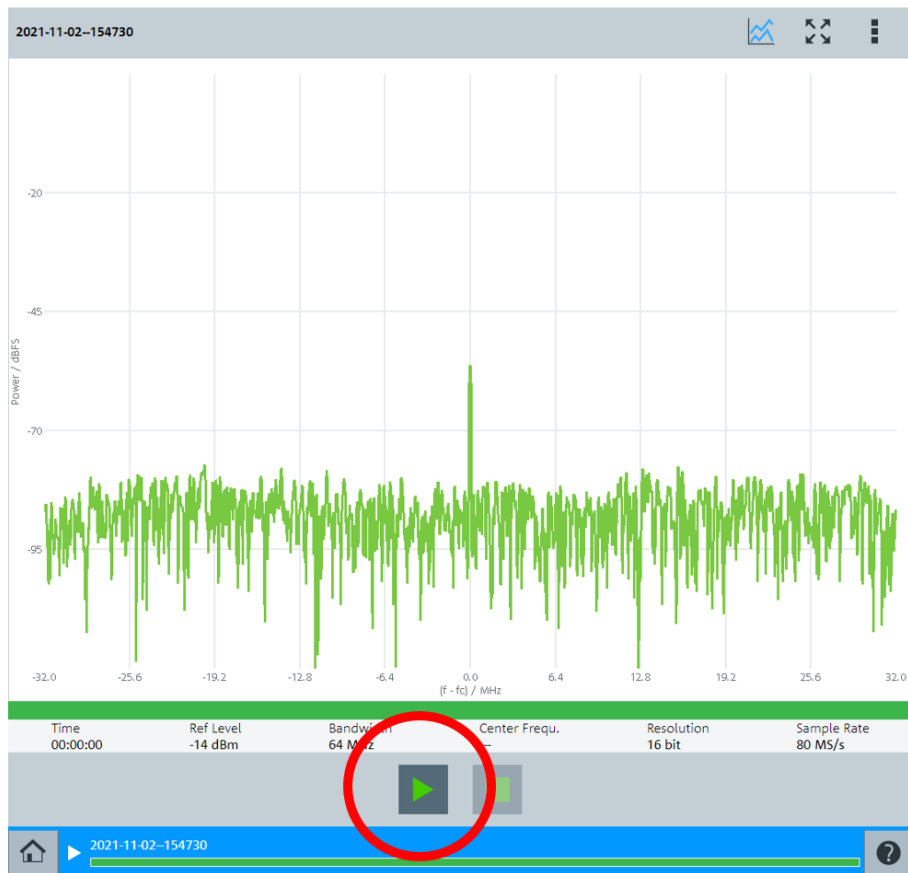

3. Select Manual Trigger and hit Next

4. In step 4, Overview window, select Loop Replay or just single play

5. In order to play the recorded file, press the play button

4.10 Video disturbance detection using R&S®AdVISE SW

A very common application layer KPI used for coexistence testing is the video streaming quality. But this is not the only parameter that is of interest on the application layer. Light intensity changes, alarms/audio stimulus, blinking lights etc. are also used as an indicator of failure of operation. These functional wireless performance (FWP) parameters need to be monitored, detected flawlessly and documented. The R&S®AdVISE SW does exactly that. Figure 4.14 shows an example where a DUT is streaming a video file via the CMW WLAN AP. The video file is hosted on the internal server of the CMW. The DUT is interfered by a signal generated from the SMW. The AdVISE SW is running on the host computer and gets its input from the HD webcam which is pointed directly at the screen of the DUT. The Region of Interest (ROI) for detecting a certain KPI is defined on the software itself.


Figure 4.14: Measurement Setup for detecting video disturbances caused by RF interference signal

For our example, we are using a time coded video file. Whenever the video stream freezes and buffers because the interference signal causes an increase in PER, the observation box turns from green to red. The list of detected failure is also documented at the reporting tool in the software.

On the R&S®AdVISE GUI,

- Under "Test Configurations" create a new test configuration
  - Enter test name and description
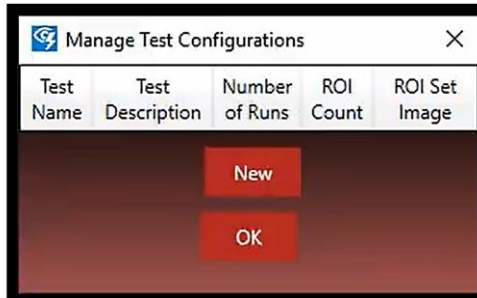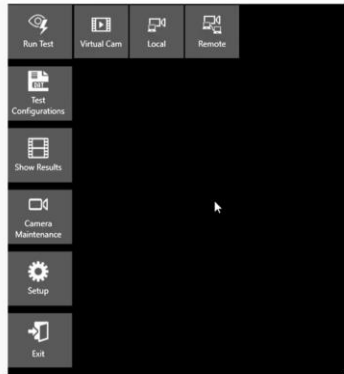
- From Run Test > Select local camera > Add ROI
- From the List of ROI > Select Motion Freeze

- Select the region where the motion freeze is noticeable with the mouse cursor. In our example, we selected the time code at the bottom of the frame. Whenever, a freeze is detected the rectangular box turns from green to red.

Hint: In parallel to the video test, a PER test can be initiated on the CMW in order to correlate the corresponding PER performance.

5 Literature

[1] Wireless coexistence testing based on IoT device application use cases by Naseef Mahmud, White Paper, Rohde & Schwarz. Download Here

[2] "American National Standard for Evaluation of Wireless Coexistence," in *ANSI/USEMCSC C63.27-2021 (Revision of ANSI C63.27-2017)* , vol., no., pp.1-87, 17 May 2022, doi: 10.1109/IEEESTD.2022.9777636. Download Here

[3] Mahmud Naseef, Alan Moskofian, Pascal Hervé, Georgios Kokovidis, Dennis Mendoza, Dennis Mendoza," RF Coexistence Testing on Wireless Medical Patient Monitoring Device", 2022 International Symposium on Electromagnetic Compatibility – EMC EUROPE Download Here

6 Glossary

AP	Access Point		**FWP**	Functional Wireless Performance
ISM	Industrial, Scientific and Medical Band		**CMW**	R&S®CMW270 or R&S®CMW290 or R&S®CMW500
CH / Ch	Channel		**SMW**	R&S®SMW200A
FWP	Functional Wireless Performance		**FSW**	R&S®FSW
KPI	Key Performance Indicator		**BBA**	R&S®BBA130/150/300
WLAN	Wireless Local Area Network		**SAM**	R&S®SAM100
EMI	Electromagnetic Interference		**IQW**	R&S®IQW100/500
PER	Packet Error Rate		**RAC**	Radiated Anechoic Chamber
VSG	Vector Signal Generator		**GUI**	Graphical User Interface
SA	Spectrum Analyzer		**ROI**	Region of Interest
LNA	Low Noise Amplifier		**TX**	Transmit
QAM	Quadrature Amplitude Modulation		**RX**	Receive
CW	Continuous Wave		**OTA**	Over the air
IoT	Internet of things		**RF**	Radio Frequency
ANSI	American National Standards Institute		**QPSK**	Quadrature Phase Shift Keying
COTS	Commercial off the shelf		**LPWAN**	Low-power wide-area network
DAU	Data Application Unit of CMW		**RED**	Radio Equipment Directive
RAN	Radio Access Network		**SUA**	Signaling Application Unit of CMW
COTS	Commercial Off the Shelf			

7 Ordering Information

For ordering individual equipment or a full turn key coexistence testing solution, please get in touch with your local Rohde & Schwarz sales representative or customer support.

For questions regarding test setup, test configuration, hands on demo, regarding automation scripts or presentation requests contact the author directly at mahmud.naseef@rohde-schwarz.com.

For training requests, please contact the training center at Rohde & Schwarz directly at the link provided.

Ordering Info:

Intended / Wanted Signal

- Generating wanted signal: WLAN requires a CMW270 or CMW500 with 1xSignaling Unit and WLAN personality and RX PER measurement included in the personality.

- Generating wanted signal: LTE requires a CMW290 or CMW500 with 1xSignaling Unit and LTE personality and the RX throughput, BLER measurement is included in the personality

- Measuring PING and HTTP & FTP server: Requires Data application Unit (DAU) is valid for CMW270/290/500

Interference/EMI/Unintended Signal

- Generating 3xInterference signal and routing through on RF port is only possible using the SMW: B1006+ B13T+ B9/B10+ K525 + K76 + K703 + K19

- Generating WLAN and LTE according to ANSI C63.27: requires the relevant personality option K54 and K119

- If you need only one interference signal you can also choose a SMBV or SGT instead of SMW.

Signal Monitoring

- You may choose from the spectrum analyzer portfolio FSW, FSVA or FPL

- For monitoring purpose: FSW8, B4, B24, B71, B160, B517 , optional 512R

Antenna

- For radiated testing: HF907, HZ-1 , HL025Z1

IQ Recorder

- Minimum requirement: IQW100, BC103, B40G, DIGIQ-HS, SMU-Z6, K110

Amplifier

You can choose between the BBA family (BBA130/150/300) or the SAM100 depending on your requirement of frequency and amplification

- BBA300: DE/CDE15(15W) or DE/CDE25(25W)

- SAM100: 0220-20 (20W)

AdVISE Visual inspection Software

- Advise-PC License dongle

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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