

Application Note

VOICE OVER NR AUDIO QUALITY MEASUREMENT WITH POLQA

Test Solutions Based on R&S®CMX500 Platform

Products:

- ▶ R&S®CMX500
- ▶ R&S®CMW500
- ▶ R&S®CMX-ZG180
- ▶ R&S®CM-Z91

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Abstract

The evolution of mobile communication enters 5G New Radio (NR) era with pivotal features. Voice call service is however still considered as an indispensable element for mobile devices and worldwide network operators continue to maintain the voice service for their subscribers. In comparison to other Over-the-Top (OTT) voice services, such as WhatsApp®, Teams® etc., Voice over NR (VoNR) and Voice over LTE (VoLTE) maintain QoS, support well established handover mechanism and emergency call, and do not require to pre-install OTT app on the phone.

In order to provide premium voice service and enhance the superb user experience, audio tests on mobile devices are essential before the product launch. Different audio test aspects among which acoustic, functional, performance and field tests need to be considered.

This application note describes the performance test with focus on VoNR audio quality measurement via electrical interface of the mobile device. The test solution is based on R&S®CMX500 with its integrated POLQA algorithm.

The remainder of this document is organized in the following structure

Chapter 1 briefly introduces some background information with respect to audio service and testing

Chapter 2 gives an overview on the system requirements of the POLQA measurements

Chapter 3 describes the preparations for the POLQA measurements on the system

Chapter 4 presents the POLQA measurements by using different interfaces of R&S®CMX500

The following abbreviations are used in this application note:

- ▶ R&S®CMX500 wideband radio communication tester is referred to as CMX500
- ▶ R&S®CMsequencer graphical scripting interface is referred as CMsequencer
- ▶ R&S®CMsquares web based graphical user interface is referred to as CMsquares
- ▶ R&S®XLAPI scripting interface is referred to as XLAPI

Readers of this application note are assumed to have basic knowledge of CMX500 and 5G VoNR. If not, please refer to CMX500 user manual [1] [2] and R&S 5G VoNR white paper [3], respectively.

Disclaimer

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1 Introductions

1.1 Audio Testing at a Glance

Several aspects of audio testing need to be considered to meet the quality requirements of a user equipment (UE), namely, acoustic, functional, performance and field testing as shown in Figure 1-1.

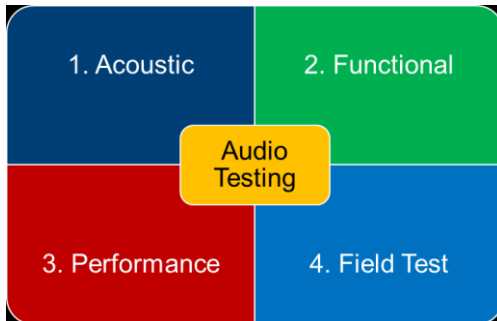


Figure 1-1 Overview of audio testing aspects

1. Acoustic test focuses on the measurement of UE's electro-acoustic characteristics in compliance with technical specification 3GPP TS 26.131 [4] and test specification TS 26.132 [5], it focuses on overall loss/loudness ratings, sensitivities/frequency characteristics, sidetone characteristics, acoustic echo control, distortion, delay etc. The main characteristic of these tests is the acoustic, over-the-air audio "link" between the UE and the audio analyzer/generator.
2. Functional test aims to check the basic functionality of the session establishment (IMS session), call handling including Mobile Originated (MO) and Mobile Terminated (MT) which is the focus for R&D tests typically.
3. Quality-centric performance testing evaluates how performant is the device under test (DUT¹), as well as benchmarks different DUT's voice quality. 3GPP specified audio performance testing in TR26.954 [6] in a conducted way. These tests are supported in CMsequencer (KF690 script package). On top of that, mobile network operators usually have their own tailored version of audio performance test requirements, e.g. ATT, VzW. Those audio test requirements are also well covered in R&S[®]CONTEST². Typical use cases for an audio performance and robustness test are
 - Performance and robustness test for VoNR & VoLTE with IP Impairments / Fading
 - Concurrent voice and data service
 - Codecs
 - R&D regression tests against new software release and new codec implementation, e.g. EVS codec
4. Last but not least, audio quality testing as part of the field test scope, namely Mobile Network Testing (MNT) based on QualiPoc³, provides extensive real time voice quality testing to reflect the end-user experience within a live network.

As per definition of TS26.132 [5], electrical interface is defined as an analogue or digital access to a UE, which allows injecting and capturing signals electrically instead of through an acoustical interface. The

¹ The term DUT and UE are interchangeable in this document

² R&S[®]CONTEST is a software offers versatile automatic test capabilities for standalone instruments and test systems.

³ QualiPoc is a multifunctional smartphone-based tool from R&S[®] for troubleshooting voice and data service quality and RF optimization.

interface can be either wired (analogue, digital) or wireless (digital). The purpose of this interface is to connect a separate device (typically a headset), which provides a receiver and transmitter for telephony. All audio quality test solutions presented in this document utilize the electrical interface.

Acoustic, functional and field test are out of scope here. If interested, please refer to the following materials to get more detailed information.

- ▶ Acoustic audio testing based on CMX500 and Head acoustics labCORE®, refer to [7]
- ▶ Audio functional testing on CMX500, refer to [8]
- ▶ Field testing using QualiPoc, refer to [9]

This application note focuses purely on the audio performance testing.

1.2 Voice Service Deployment Scenarios in NR

As illustrated in Figure 1-2, various voice service deployment scenarios in NR need to be considered depending on the network deployment situation.

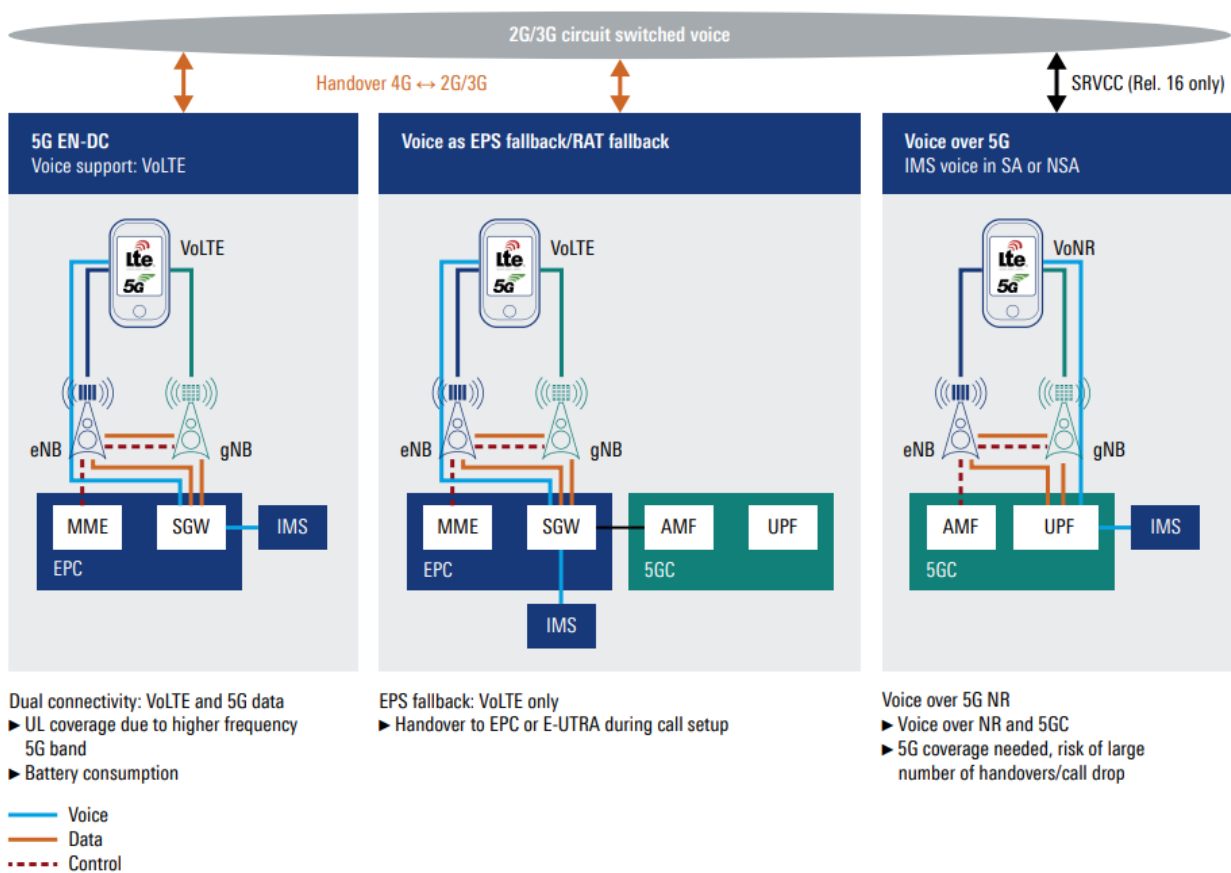


Figure 1-2 Voice service deployment scenarios in NR [3]

5G EN-DC (Voice over LTE)

In EN-DC mode (option 3) or NSA mode, UE is registered on LTE and NR that is enabled to provide more bandwidth for data connections. This mode is commonly adopted by the network operators at their early 5G network deployment stage. IMS is connected to Evolved Packet Core (EPC). Under this kind of network deployment, VoLTE service is actually provided.

Voice as EPS fallback/RAT fallback (EPS fallback redirection/handover)

Voice as Evolved Packet System (EPS) fallback refers to the voice service deployment scenario that UE performs EPS fallback from NR in SA mode when voice service is required. This kind of voice service is adopted to bridge the gap at the early SA roll-out phase when no IMS support is available in NR and/or no continuous NR coverage is guaranteed. In EPS fallback, gNB redirects or performs a handover to LTE. UE is then able to use the voice service in LTE, i.e. VoLTE. After the voice session is terminated, UE returns back to NR network.

A similar approach to EPS fallback is a so-called RAT fallback. In this case, NR triggers a redirection or handover procedure to eLTE when UE uses voice service. UE moves back to NR after the voice service is terminated.

Voice over 5G (Voice over NR)

VoNR is the ultimate voice service approach in NR. It works in SA mode and 5G Core (5GC) supports IMS. Both voice and data services are provided by 5GC and gNB.

In this document we will be focusing on audio quality measurement based on VoNR.

1.3 IP Multimedia Subsystems (IMS)

The bearer agnostic IMS stands for IP Multimedia Subsystems. It is a standardized architectural framework (cf. 3GPP TS22.228 and TS23.228) for delivering multimedia communications such as voice, video, messaging and other real-time services over IP networks.

All-IP concept was introduced at the time when LTE was deployed. This enables the IMS to be fully integrated into the LTE core network (EPC). 5G inherits all-IP concepts from LTE. Therefore, IMS is naturally also a key entity for the 5G network.

One of the biggest advantages of adopting IMS is its' ability to setup and ensure quality of service (QoS) for each application. The task of IMS is to establish, control and maintain a protocol data unit (PDU) session, including all relevant data bearers with corresponding QoS flow for best end-user quality experience [3].

Session Initiation Protocol (SIP) is the signaling mechanism for IMS. It creates, modifies, maintains and terminates the session, and essentially negotiates a session between two call participants.

The media transfer itself is managed by RTP/RTCP protocol.

Figure 1-3 illustrates a basic IMS Mobile Originated (MO) session flow chart. For Mobile Terminate (MT) call, the messages in the call flow remain the same while the role of UE and IMS is interchanged.

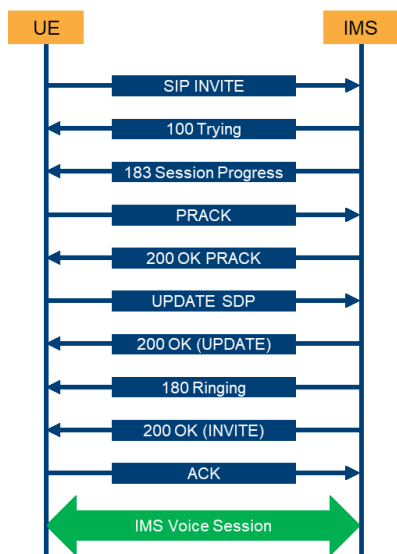


Figure 1-3 IMS Mobile Originated (MO) call flow [10]

1.4 Speech Codecs

Speech coding is a method to compress the digital audio signal optimized for speech. It is essential for the transmission efficiency over band limited wireless channels, e.g. widely used in wireless mobile communication technology.

A transceiver building block that deals with the speech coding and decoding is called speech codec. It is developed along with the evolution of the mobile communication standard. Adaptive Multi-rate Narrowband (AMR-NB) or AMR was a speech codec initially adopted by 3GPP in 1999 and widely used in GSM and UMTS. Adaptive Multi-rate Wideband (AMR-WB) speech codec (ITU-T G.722.2 codec) is based on AMR-NB and provides improved speech quality and wideband audio bandwidth. As a successor of AMR-WB, a fullband speech codec, Enhanced Voice Service (EVS) was developed collaboratively by several companies in the mobile communication industry and research institutes. It is of high robustness to delay jitter (with jitter buffer) and packet losses (with channel aware coding to mitigate the channel errors). A landscape of speech codecs with respect to the bandwidth of each codec type is illustrated in Figure 1-4. In addition, Table 1-1 gives a tabular view of speech codes used in the mobile communication world.

- ▶ 300 – 3400 Hz = Narrowband (NB)
- ▶ 50 – 7000 Hz = Wideband (WB)
- ▶ 50 – 14000 Hz = Super wideband (SWB)
- ▶ 20 – 20000 Hz = Fullband (FB)

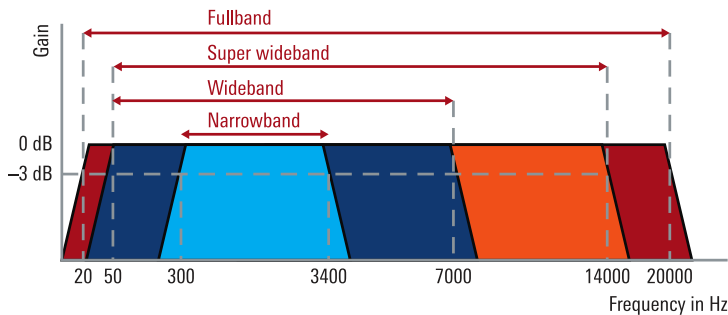


Figure 1-4 Landscape of speech codecs

Codec	Frequency Range	Bandwidth	Bit Rate (kbit/s)	Comment	3GPP Specification	
AMR-NB	300-3400 Hz	NB	4.75 / 5.15 / 5.90 / 6.70 / 7.40 / 7.95 / 10.20 / 12.2	Standard voice	TS 26.071 TS 26.090	
AMR-WB	50-7000 Hz	WB	6.6 / 8.85 / 12.65 / 14.25 / 15.85 / 18.25 / 19.85 / 23.05 / 23.85	HD voice	TS 26.171 TS 26.190	
EVS Primary Mode	20-4000 Hz ⁴	NB	VBR ⁵	5.9	HD+ / Ultra HD voice	TS 26.441
			CBR ⁶	7.2 / 8 / 9.6 / 13.2 / 16.4 / 24.4		
	20-8000 Hz ⁴	WB	VBR	5.9		
			CBR	7.2 / 8 / 9.6 / 13.2 / 13.2 channel-aware / 16.4 / 24.4 / 32 / 48 / 64 / 96 / 128		
50-14000 Hz	SWB	CBR	9.6 / 13.2 / 13.2 channel-aware / 16.4 / 24.4 / 32 / 48 / 64 / 96 / 128			
20-20000 Hz	FB	CBR	16.4 / 24.4 / 32 / 48 / 64 / 96 / 128			
EVS AMR-WB IO Mode	20-8000 Hz ⁴	WB	CBR	6.6 / 8.85 / 12.65 / 14.25 / 15.85 / 18.25 / 19.85 / 23.05 / 23.85		

Table 1-1 Overview of speech codecs

⁴ Refer to <https://voiceage.com/EVS.html>

⁵ Variable Bit Rate (VBR)

⁶ Constant Bit Rate (CBR)

EVS operates in primary mode or AMR-WB interoperable (IO) mode. The latter is a mode that supports backward compatibility with the AMR-WB capable endpoints with 9 operation rates. EVS primary mode supports 37 operation rates among which NB and WB allows addition variable bit rate (VBR) at around 5.9 kbit/s in average.

EVS codec offers superior audio quality in comparison to AMR-WB and AMR-NB. EVS SWB starting at code rate 9.6 kbit/s already outperforms the AMR-WB 23.85 kbit/s [11].

1.5 Audio Quality Assessment (POLQA)

1.5.1 General Information

POLQA (Perceptual Objective Listening Quality Analysis), a voice quality standard according to ITU-T recommendation P.863 [12], was initially standardized in 2011. The latest edition POLQA V3 was finalized in 2018.

The POLQA algorithm facilitates a model to predict speech quality by means of digital speech signal analysis. The prediction of the perceived quality in objective measurement should be as close as possible to subjective quality measurement through subjective listening test. POLQA utilizes the full reference algorithm to rate the degraded or processed speech signal, e.g. degradation through voice coding/decoding, non-ideal radio channel, IP impairments etc., with the reference signal based on sample-by-sample basis. The merit of the final voice quality is then given as MOS (Mean Opinion Score) which is provided in the scale from 1 (bad) to 5 (excellent) as given in Table 1-2.

Quality of Speech	Score
Excellent	5
Good	4
Fair	3
Poor	2
Bad	1

Table 1-2 Speech mean opinion score (MOS)

Figure 1-5 gives an overview of basic concept of audio quality assessment using POLQA algorithm. For more information about POLQA, please refer to [12] and [13].

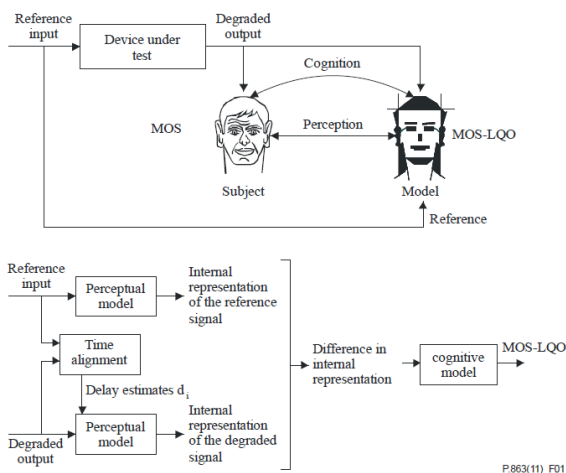


Figure 1-5 Basic concept of audio quality assessment using POLQA algorithm according to ITU-T P.863 [12]⁷

⁷ MOS-LQO stands for MOS Listening Quality Objective based on POLQA. It is synonymous with MOS in this document.

1.5.2 Reference Speech Signal

Recommended reference speech signals (files) are taken from ITU-T P.501 Annex D having following characteristics:

- ▶ Include active and pause part in the speech sample
- ▶ Typical spoken sentences with syllable and word structures in multiple languages
- ▶ Two male and two female speakers with two sentences each

As recommended in [12], the reference signal level is -26 dBov. It should be avoided to use either too high level (causing amplitude clipping) or too low level (low signal-to-noise ratio SNR).

1.5.3 Operational Modes

Two operational modes are specified by [12], i.e. NB and FB mode.

The main difference between both modes is the bandwidth of the reference speech signal used by the model as well as the frequency range where distortions will be detected.

Testing NB codec under NB mode and FB mode results in different MOS value due to difference in MOS scaling (MOS-LQO_f and MOS-LQO_n). For instance, MOS-LQO_n 4.0 in NB mode has a corresponding MOS-LQO_f 3.5 in FB mode for a NB codec. Moreover, NB mode is backwards compatible to predecessor audio quality method PESQ (ITU-T P.862). In each operational mode, the achievable MOS value is saturated as given in Table 1-3.

Operational Mode	Scale	Saturated MOS with POLQA V3
Full-band (FB) mode	MOS ACR fullband scale (MOS-LQO _f)	4.8
Narrow-band (NB) mode	NB scale comparable to ITU-T P.862 (MOS-LQO _n)	4.5

Table 1-3 Saturated MOS value in different operational mode [12]

Majority of application cases adopt FB operational mode for audio quality assessment. For sake of simplicity, the general term MOS is applied in the remaining of this document.

2 System Requirements

R&S offers a compact audio quality measurement solution (see Figure 2-1) that consists of following hardwares:

- ▶ CMX500 OBT (see Chapter 2.1.1)
- ▶ Audio test accessories
 - External media endpoint (see Chapter 2.1.2)
 - Headset cable set (see Chapter 2.1.3)



Figure 2-1 Neat audio quality measurement test solution using CMX500 OBT

2.1 Hardware Requirements

2.1.1 CMX500 (OBT lite, OBT & OBT plus)

CMX500 One-box Tester (OBT) is a scalable radio communication test platform (see Figure 2-2). Depending on the hardware capability, several hardware variants are supported as follows:

- ▶ CMX500 OBT lite: One RF unit and optionally one IF unit
- ▶ CMX500 OBT: Two RF units and optionally two IF units
- ▶ CMX500 OBT plus: Three RF units and optionally two IF units

It is mandatory to equip one RF unit to support LTE and NR FR1. In case NR FR2 needs to be supported, additional IF unit(s) should be equipped.



Figure 2-2 R&S®CMX500 One-Box Mobile Radio Tester (OBT lite, OBT and OBT plus)

For more detailed information about the minimum hardware and software configuration (CMX500 OBT lite), please refer to Table 6-1 in Chapter 6.

2.1.2 External Media Endpoint (CMX-ZG180A)

The external media endpoint (CMX-ZG180A) is a soundcard for LTE and NR audio tests with hot plugging support. It provides analog input and output interfaces (see Figure 2-3 and Table 2-1) with up to 8.7 V_{peak}. Two channels (1 x right channel, 1 x left channel) can be connected to the soundcard. Currently, only the left channel is used for audio measurement.



Figure 2-3 CMX-ZG180A external media endpoint (left: front view / right: rear view)

Designation	Comment
Analog input	2 channels via XLR (full scale: +18 dBu / impedance: 18 kΩ / 8.7V _{peak} , 6.15V _{rms})
Analog output	2 channels via XLR (full scale: +18 dBu / impedance: 40 kΩ / 8.7V _{peak} , 6.15V _{rms})

Table 2-1 Description of external media endpoint

The order information of this accessory can be found in Table 6-2 of Chapter 6.

2.1.3 Headset Cable Set (CM-Z91)

R&S headset cable set (CM-Z91, see Figure 2-4) consists of four cables in total for connecting the headset interface of a mobile phone to the XLR sockets on the rear panel of the R&S CMX-ZG180A. Details can be found in [14]. The cable set covers all common pin assignments for different impedance requirements of mobile phones. Please refer to the descriptions in Table 2-2 to learn more about the usage of each cable.



Figure 2-4 Headset cable set (upper: cable 1 with 33 Ohm load / lower: cable 2, 3 or 4)

Item	Load	Description	Comment
Cable 1	33 Ω	It connects female XLR to male XLR and adds a load of 33 Ω to the connection	If your DUT expects a load of 33 Ω at its audio output (typical headphone impedance), insert this cable into the path from the DUT to the audio input of the R&S CMX-ZG180A.
Cable 2	10 kΩ	Cable 2, 3 and 4 differ in the loads in the audio input path to the DUT microphone input.	Plug the 3.5mm jack of the cable to DUT's headphone jack. Select the proper cable (cable 2, 3 or 4) so that the DUT recognizes the plugged 3.5mm jack as a headset.
Cable 3	4.5 kΩ		
Cable 4	1.5 kΩ		

Table 2-2 Description of headset cable set (CM-Z91)

The order information of this accessory is given in Table 6-2 of Chapter 6.

2.2 Software Requirements

The CMX500 firmware is delivered as a CSW software package. For audio quality measurement, CSW version greater than 7.40 is required.

3 Preparations

3.1 Cabling

The system cabling of CMX500 OBT is illustrated in Figure 3-1 which is also valid for other OBT variants. For more detailed information, please refer to [2].

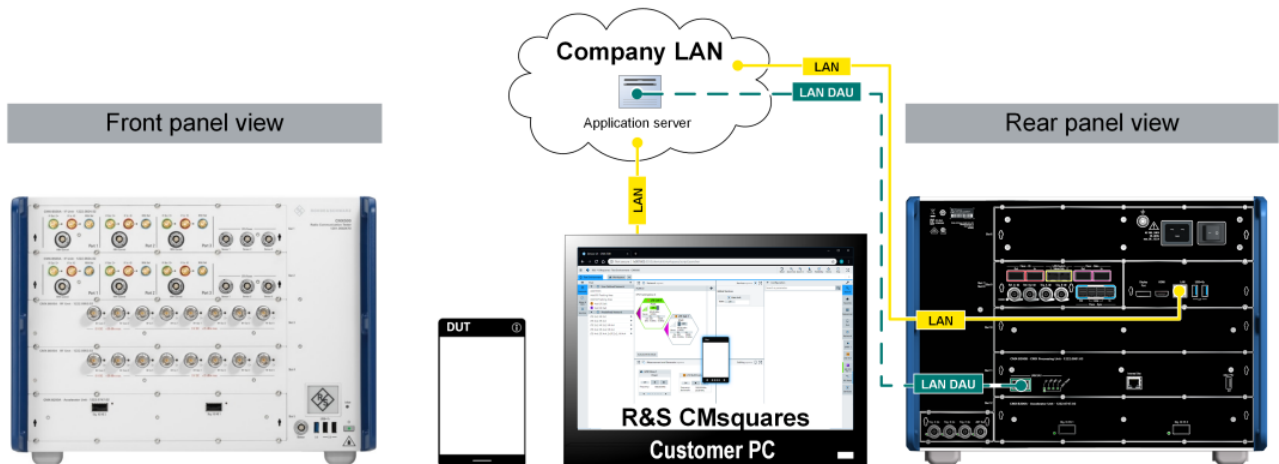


Figure 3-1 System cabling of CMX500 OBT

Use USB dual cable shown in Figure 3-2 to connect the USB sound card with CMX500.



Figure 3-2 USB dual cable

The cabling between CMX500 and DUT via sound card is shown in Figure 3-3 and Figure 3-4.

- ▶ Connect the black Type C connector in 'DAU 3.0' port of CMX Processing Unit (CMX-B300B)
- ▶ Connect Type B connector to external USB sound card
- ▶ Yellow connector is not needed

Note: Between CMX500 and USB sound card, do not use USB hubs, USB "cutters" etc. in between.

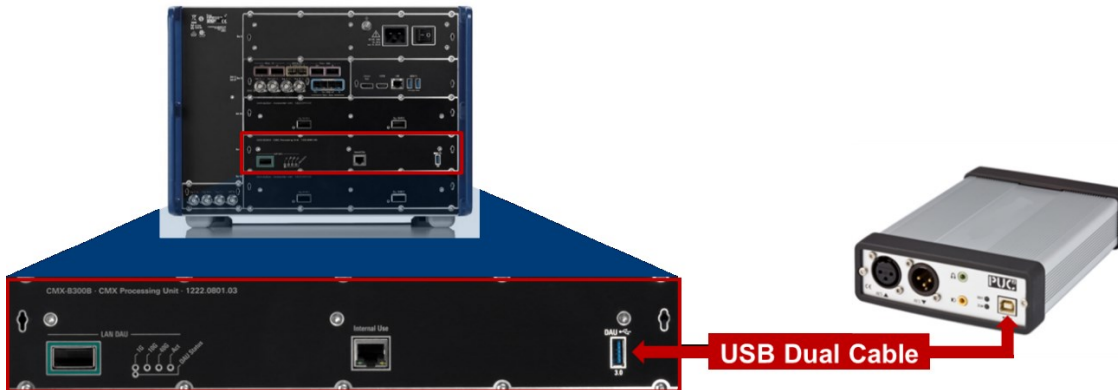


Figure 3-3 Cabling of USB sound card and CMX500 (on CMX-B300B) with USB dual cable

Use the left channel of the USB sound card to/from the DUT with the delivered headset cable (see Chapter 2.1.3). Select one of the cables out of cable 2, 3 and 4 and optionally the cable 1 to connect. It depends on your DUT audio jack. The cabling between DUT and sound card is shown in Figure 3-4 below.

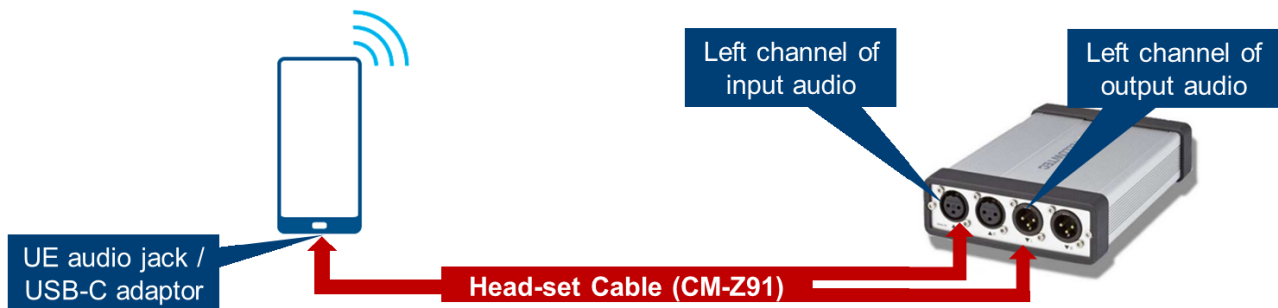


Figure 3-4 Cabling between USB sound card and DUT

3.2 Software Installation

Follow the installation instructions in Chapter 'Software update' given in [2] to complete the CSW software installation on CMX500.

3.3 Configurations

In principle, following configuration steps need to be performed prior to audio quality measurement:

- ▶ DUT management
- ▶ Network creation and cell configuration
- ▶ IMS configuration

3.3.1 DUT Management

In CMSquares, a DUT object needs to be created and activated to reflect the mapping of DUT antenna layout and physical RF connections to CMX500. It provides the flexibility of the RF connections. Example shown in Figure 3-5 indicates that the LTE and NR signaling coming from/to CMX500 RCom1 of RF unit slot3 and RCom1 of RF unit slot 4 is routed to/from the associated DUT antenna, respectively.

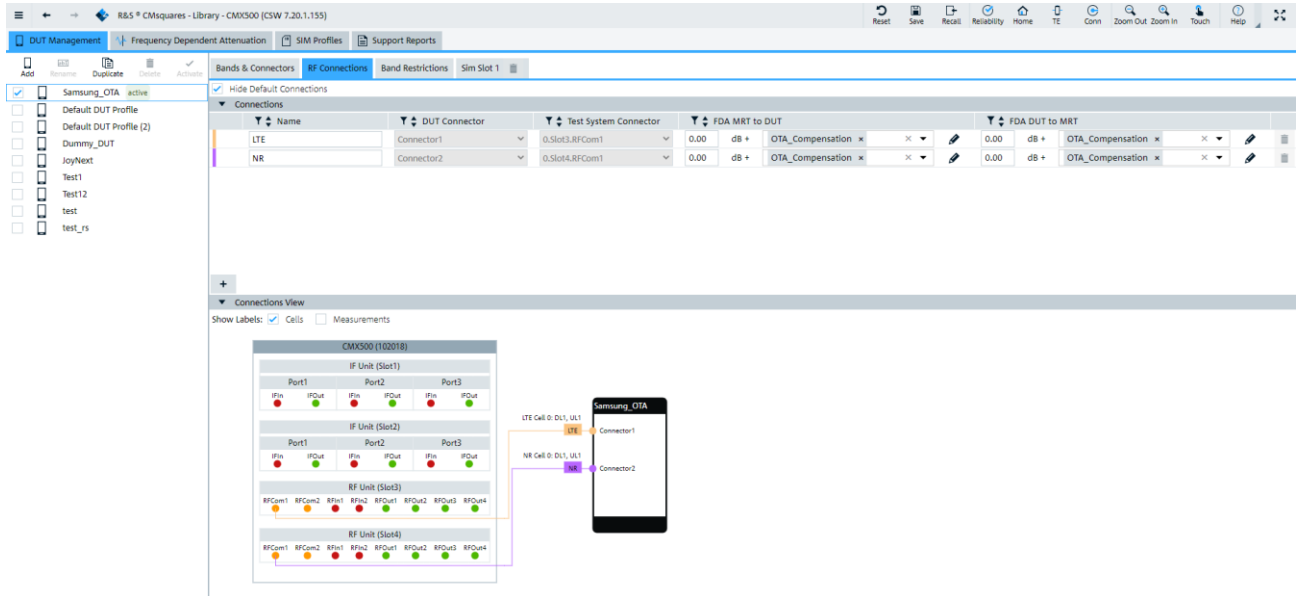


Figure 3-5 Example of DUT management

For more details about the usage of the DUT management, please refer to Chapter 7.2 DUT management in [1].

Note: The creation and activation of proper DUT object in DUT management is the prerequisite of further testing on CMX500.

3.3.2 Network Creation and Cell Configuration

This step is essential to allow a DUT to be registered on CMX500 (network emulator). Depending on the voice service deployment scenario (cf. Chapter 1.2), proper network topology needs to be created and the associated cell configurations have to be performed. Please refer to the R&S Application Note SL364 [8] to learn more about this part.

3.3.3 IMS Service Configuration

Configure the IMS service properly. Otherwise, the IMS voice call cannot be established.

Access to the IMS settings (see Figure 3-6): In CMSquares Test Environment > Global Services > IMS tab

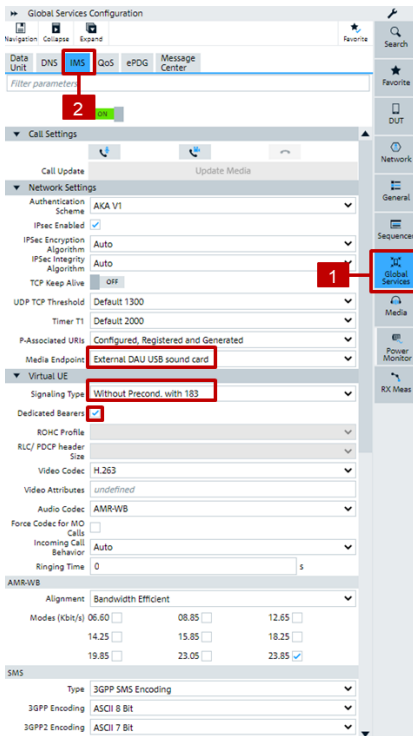


Figure 3-6 IMS service configurations in CMsquares

Most important settings are:

- ▶ Media Endpoint: External DAU USB sound card
- ▶ Signaling Type: specify whether a voice call session is established with or without quality-of-service preconditions or whether early media is used, e.g. 'Without Precond. with 183'. For setting details please refer to CMX500 application test user manual [14].
- ▶ Dedicated Bearer: Enables the automatic setup of a dedicated bearer, if a VoIMS connection is established. For calls with precondition, you typically need a dedicated bearer. For setting details please refer to CMX500 application test user manual [14].

Note:

"External DAU USB sound card" shall be set for Media Endpoint. Otherwise, POLQA calibration will fail.

4 Calibrations and POLQA Measurements

4.1 Principles

Figure 4-1 illustrates the principle of the audio test with integrated POLQA algorithm on the CMX500 from a high-level perspective. Prior to POLQA measurement, audio level calibration needs to be performed in order to have the degraded signal (for POLQA assessment) measured at the similar level as the reference signal that should be around -26 dBov (see Chapter 1.5.2). Both audio level calibration and subsequent POLQA measurement have to be conducted in DL and UL direction separately. The DUT is connected to the CMX500 via an RF link (4G or 5G) and via an analog audio cable.

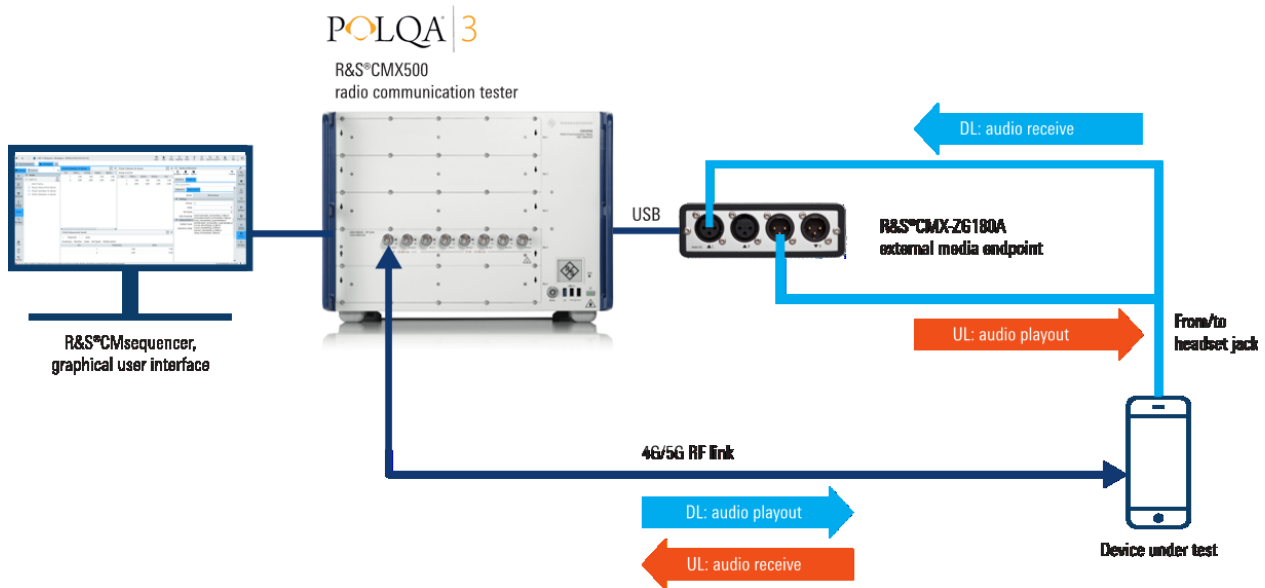


Figure 4-1 Integrated POLQA® uplink (UL) and downlink (DL) measurements with R&S®CMX500 one-box radio communication tester

4.1.1 Downlink Calibration and POLQA Measurement

4.1.1.1 Audio Level Calibration

Before the calibration starts, make sure that the DUT volume is set to 70-75% of the maximum volume.

The whole downlink audio level calibration is carried out in four steps as shown in Figure 4-2.

POLQA Downlink Measurements

CMX500 + internal audio measurement

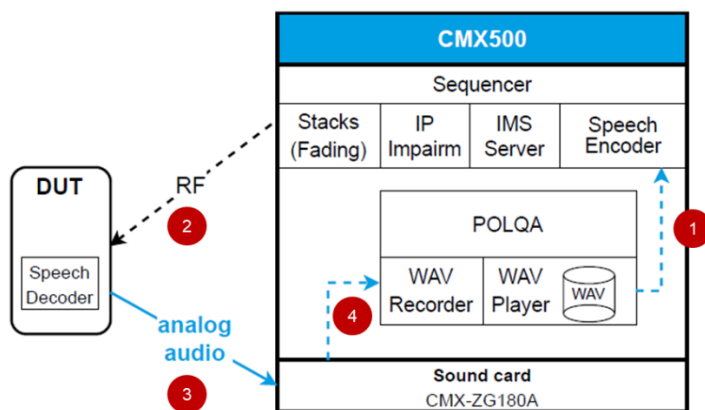


Figure 4-2 Block diagram of downlink audio level calibration and POLQA® measurement

1. Reference audio waveform file is encoded by speech encoder on CMX500 (set reference speech sequence per ITU-T P.501 Annex D)
2. The audio package is sent over the air interface from CMX500 to DUT
3. The decoded analog audio signal (via speech decoder on DUT) is captured at the sound card input channel

- The sound card performs the A/D conversion of the audio signal. The digital audio signal is then fed into the waveform file recorder on CMX500.

In Step 4, DL calibration routine on CMX500 measures the received audio signal level and adjust the analog signal level so that the received audio signal level reaches -26 dBov. In the end, the DL calibration routine delivers following results:

- Analog input quality → target is to have level 'In Range'
- Analog input level in Volt

Note

- ▶ If the calibration fails, try a headset cable with another load (see Chapter 2.1.3)
- ▶ Changing of DUT volume setting after the calibration invalidates the calibration

4.1.1.2 Downlink POLQA Measurement

DL POLQA measurement should only be started after successful DL level calibration (see Chapter 4.1.1.1).

The same procedure as shown in Figure 4-2 applies to DL POLQA measurement that delivers MOS value as the result.

4.1.2 Uplink Calibration and POLQA Measurement

4.1.2.1 Audio Level Calibration

As shown in Figure 4-3, uplink audio level calibration is carried out in four steps:

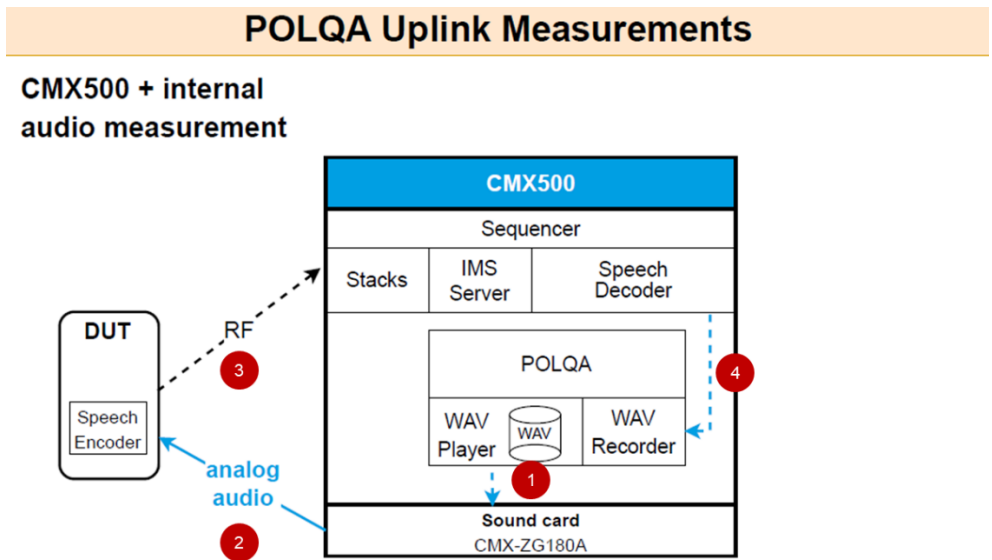


Figure 4-3 Block diagram of uplink audio level calibration and POLQA® measurement

- Reference audio waveform file is played out via sound card
- Analog audio signal is fed to DUT via audio cable from sound card output channel
- DUT encodes the audio using its speech encoder and sends the audio package over the air interface from DUT to CMX500
- CMX500 decodes the received audio package and audio signal is recorded by waveform audio recorder

In Step 4, UL calibration routine on CMX500 measures the sound level of the received digital audio signal. The procedure requires manual iteration by the user through adjusting the analog output level (at the sound card) until a maximal digital signal level is reached without clipping or distortion (at the UE).

Note

- ▶ A recommended start value for the analog output value at the sound card for the POLQA UL calibration is 0.3V, if the cable 2 (10 kΩ load, see Chapter 2.1.3) is used.
- ▶ If the calibration fails, try to adjust the output level of the sound card and restart the calibration.

4.1.2.2 Uplink POLQA Measurement

Same as downlink, UL POLQA measurement should only be started after successful UL calibration (see Chapter 4.1.2.1).

The same procedure as shown in Figure 4-3 applies to UL POLQA measurement that delivers MOS value in the end.

4.2 Using CMSquares

In CMSquares (CMX500 Web-based GUI), test configurations and measurements are performed with user interventions (manual mode).

To access to CMSquares from a Web browser on a host PC, make sure that both host PC and CMX500 have the IP address⁸ assigned in the same network segment. Enter either IP address or hostname⁹ of CMX500 in address field of Web browser on host PC. It opens CMSquares' home page (see Figure 4-4). Click on 'Test Environment' application enters the CMSquares' interactive mode.

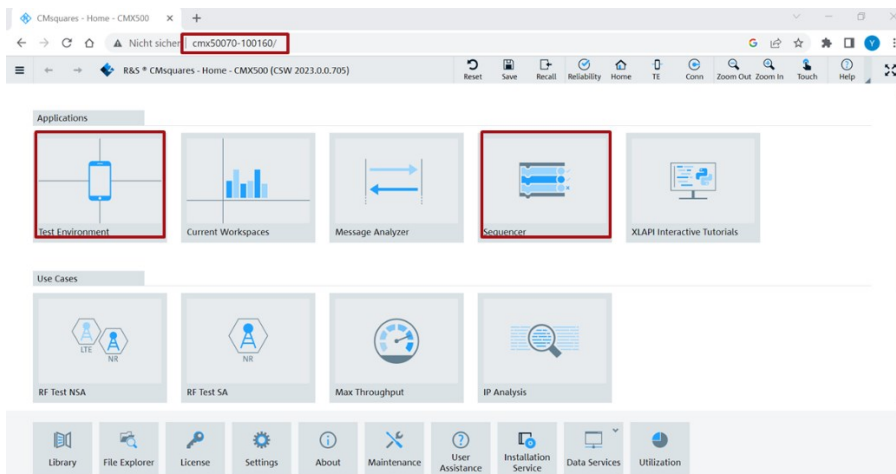


Figure 4-4 CMSquares homepage with access to test environment and CMsequencer

On the home page, click on application 'Sequencer' will redirect the user to the CMsequencer mode (the test solution based on CMsequencer is described in Chapter 4.3).

⁸ The IP address of CMX500 can be read out on the display at the lower right corner of the instrument while the instrument is running.

⁹ Naming convention of CMX500 hostname is CMX50070-<serial number of CMX500>, e.g. CMX50070-100160 where 100160 is the serial number

4.2.1 Downlink Calibration and POLQA Measurement

Perform downlink calibration and POLQA measurement by following steps:

1. Select and load 'POLQA DL' scenario with the steps shown in Figure 4-5

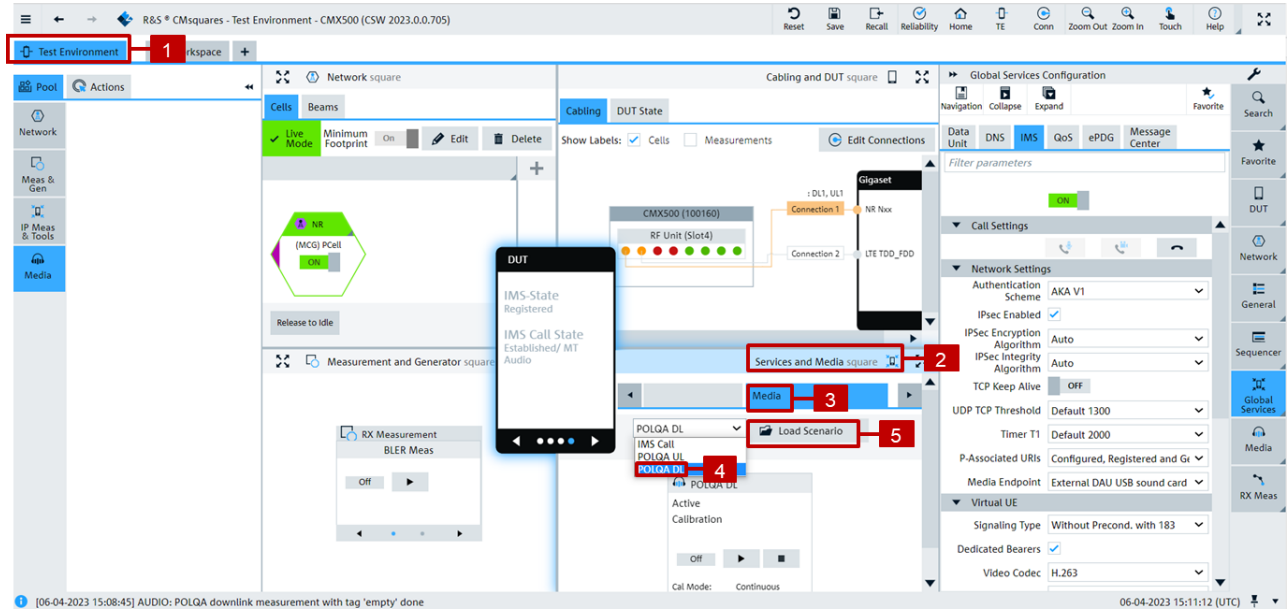


Figure 4-5 Select and load 'POLQA DL' scenario

2. Initiate an IMS MO or MT call

First of all, make sure that IMS service is configured properly (see Chapter 3.3.3) and DUT is in IMS registered state (see green marked fields in Figure 4-6).

Then, initiate an IMS MT call by following steps indicated in Figure 4-6 (red marked) and accept incoming call on DUT.

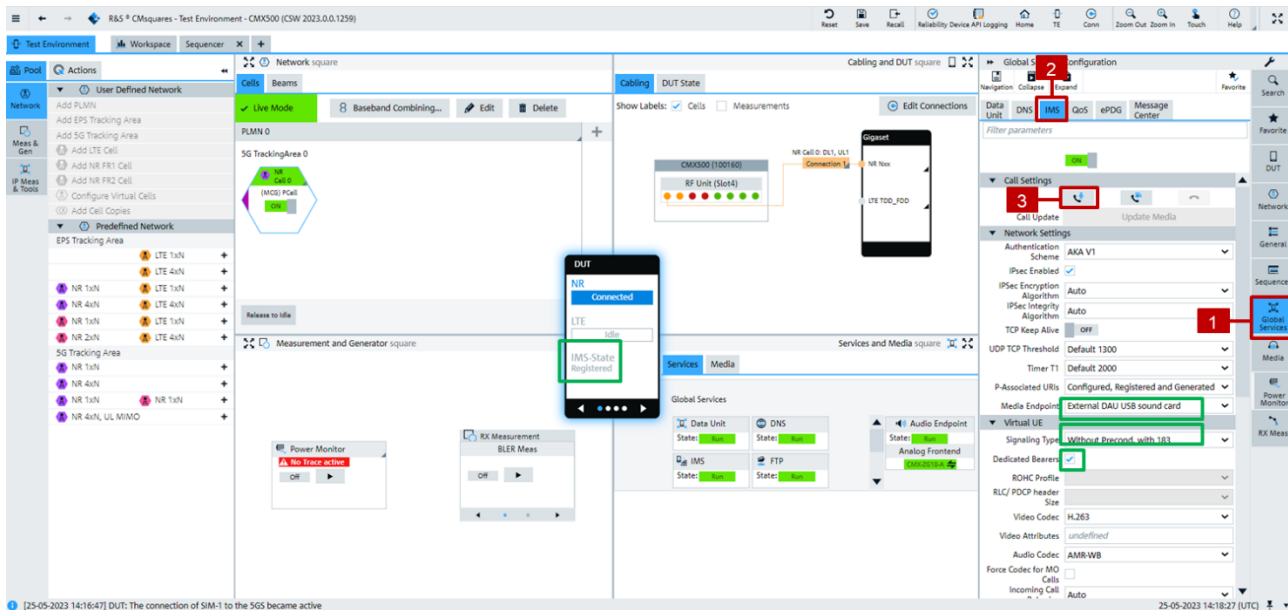


Figure 4-6 Initiate an IMS MT voice call with proper IMS settings (DUT is in IMS registered state)

Alternatively, IMS MO call can be placed on DUT. In this case, the incoming call will be automatically accepted by the IMS server on CMX500 per default.

3. Perform POLQA DL calibration with the steps indicated in Figure 4-7

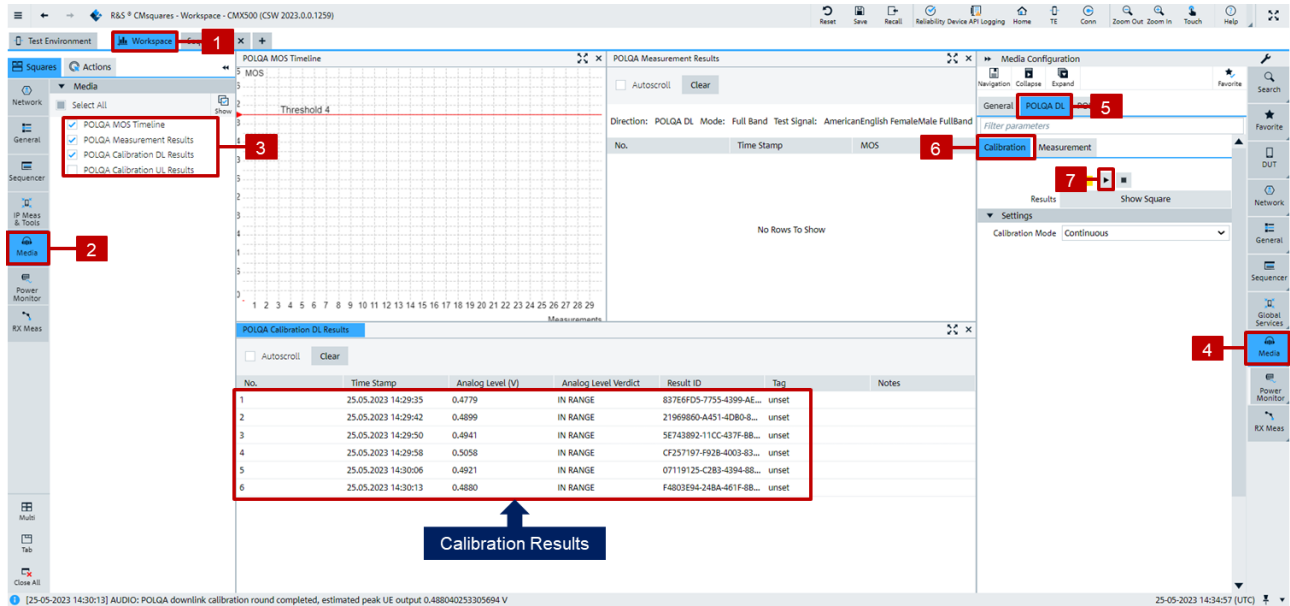


Figure 4-7 Perform DL audio level calibration

Target of DL calibration is to achieve 'IN RANGE' analog level that is indicated in 'Analog Level Verdict' column of the 'POLQA Calibration DL Results' square.

Note

If the analog level shows 'Too High' or 'Too Low', try to adjust the volume of the DUT and restart the calibration until that the analog level shows 'IN RANGE'. Sometimes, several iterations of such adjustment need to be performed.

4. Perform POLQA DL measurement with the steps shown in Figure 4-8

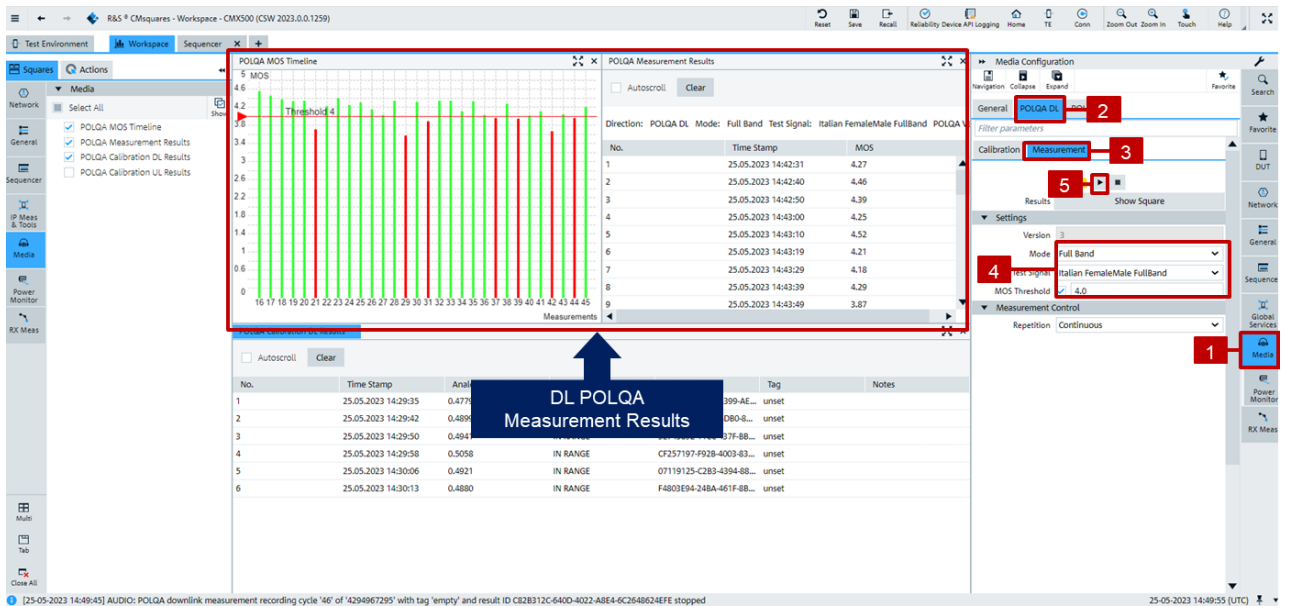


Figure 4-8 Perform POLQA DL measurement

Measured DL MOS values are presented in both 'POLQA Measurement Results' and 'MOS Timeline' squares. The measurement example in Figure 4-8 illustrates that individual measurement runs are above or below the target MOS of 4.0.

4.2.2 Uplink Calibration and POLQA Measurement

The whole procedure is quite similar to the downlink measurement as described in Chapter 4.2.1.

1. Select and load 'POLQA UL' scenario with the steps indicated in Figure 4-9

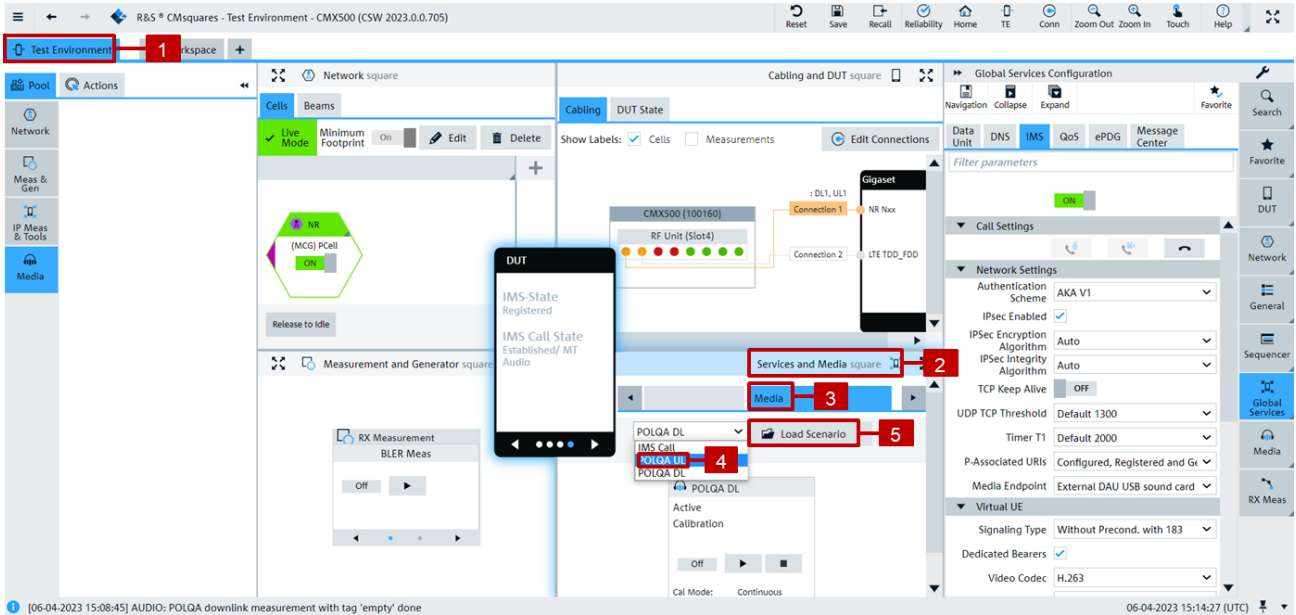


Figure 4-9 Select and load 'POLQA UL' scenario

2. Initiate an IMS MO or MT call (same procedure as in DL case shown in Step 2 on page 21)

3. Perform POLQA UL calibration with the steps indicated in Figure 4-10

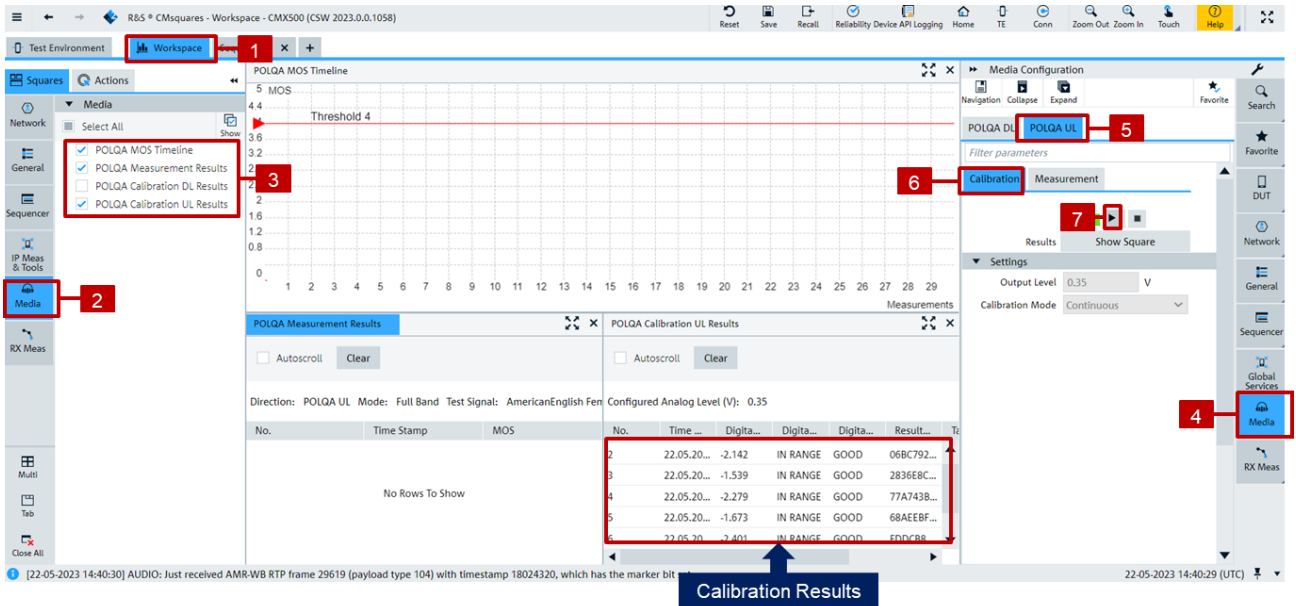


Figure 4-10 Perform POLQA UL calibration

Targets of UL calibration are:

- Digital Level Verdict → In Range
- Digital Signal Quality → Good

They can be inspected in the 'POLQA Calibration UL Results' square.

Note

If the digital level verdict or digital signal quality shows some other status, then try to adjust 'Output Level' in the POLQA UL Calibration Setting square and restart the calibration. Sometimes, several iterations of such adjustment need to be performed until the UL calibration targets are met.

4. Perform POLQA UL measurement with the steps indicated in Figure 4-11

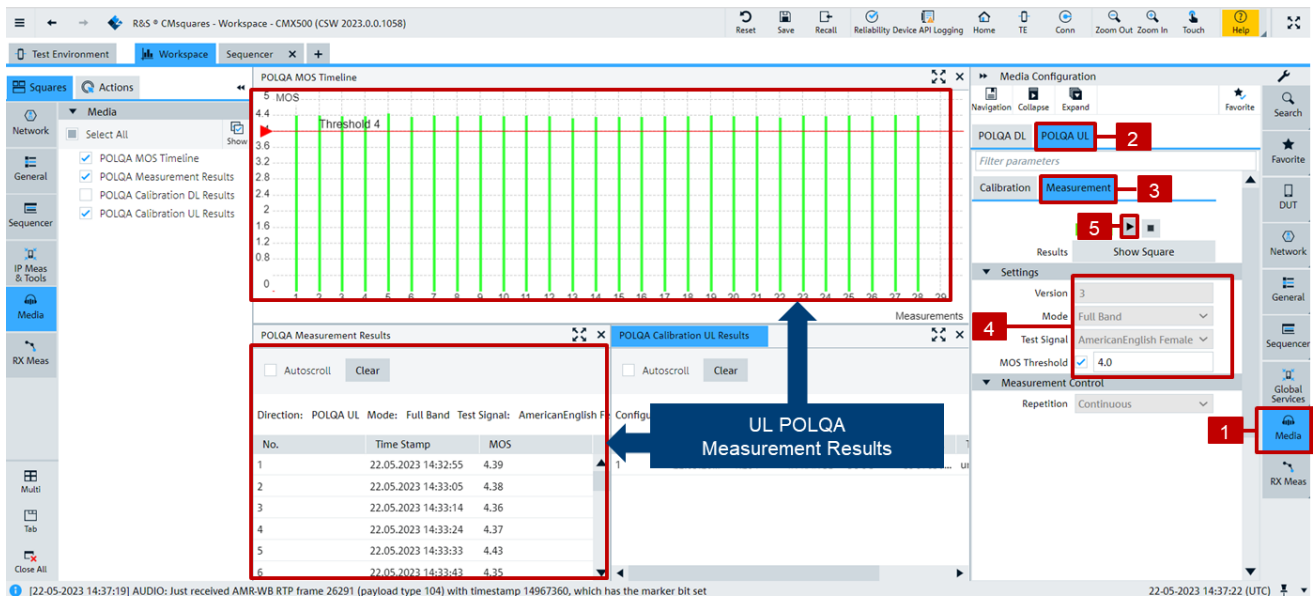


Figure 4-11 Perform POLQA UL measurement

Measured UL MOS values are presented in both 'POLQA Measurement Results' and 'MOS Timeline' squares. The measurement example in Figure 4-11 shows that each individual run delivers a result above the target MOS of 4.0.

4.3 Using CMsequencer

CMsequencer enables the test automation on CMX500. User can create, configure and execute test scripts in CMsequencer. The test scripts realize test cases. They can be handled stand-alone or can be arranged in an ordered sequence in a test plan. When executing a test plan, the test scripts are executed one by one according to the order given in the test plan.

POLQA measurements including the audio level calibration in CMsequencer can be performed using off-the-shelf scripts. If desired, user can create own script by adopting provided CMsequencer building blocks.

After CSW software is installed on CMX500, CMsequencer environment is accessible by selecting 'Sequencer' application from CMsquares homepage (see Figure 4-4). Off-the-shelf POLQA CMsequencer scripts can be found in KF690 script package (access: In 'Sequence Editor' square > R&S Script Packages > KF690). Two types of the scripts are included

- ▶ XLAPI script in form of sequencer block (parameterization through `.rsxp` file or YAML file)
- ▶ Sequencer scripts (parameterization through parameter settings of each individual CMsequencer building block), 3GPP-like scripts (3GPP TR 26.954)

An overview of both script types in CMsequencer is given in Figure 4-12.

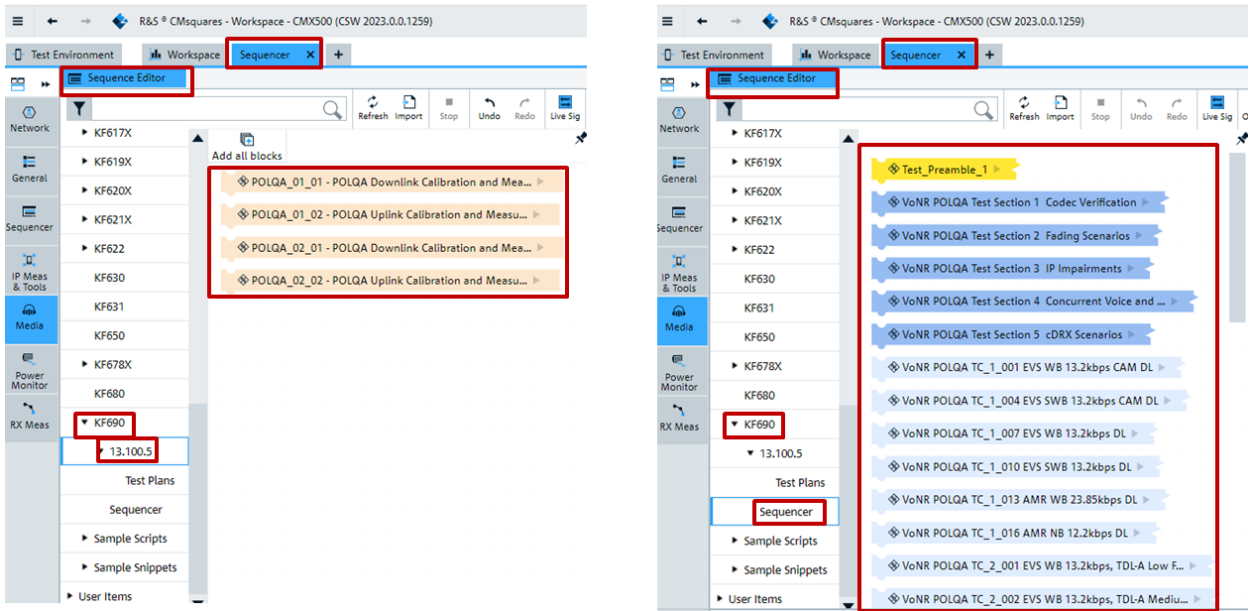


Figure 4-12 Overview of off-the-shelf CMsequencer scripts in KF690 (left: XLAPI scripts / right: Sequencer scripts)

4.3.1 XLAPI Scripts in CMsequencer

As the name already implies, POLQA XLAPI scripts in CMsequencer are originated from the XLAPI scripts and can be executed directly in CMsequencer in standalone mode or integrated as building block in sequencer script.

The actual supported POLQA XLAPI scripts are listed in Table 4-1.

XLAPI Test Script Title	Comment
POLQA_01_01 - POLQA Downlink Calibration and Measurement	NSA VoNR (1 LTE + 1 NR Cell)
POLQA_01_02 - POLQA Uplink Calibration and Measurement	NSA VoNR (1 LTE + 1 NR Cell)
POLQA_02_01 - POLQA Downlink Calibration and Measurement - SA VoNR	SA VoNR
POLQA_02_02 - POLQA Uplink Calibration and Measurement - SA VoNR	SA VoNR

Table 4-1 List of POLQA XLAPI test scripts in CMsequencer

Each XLAPI test script can be parameterized by using one of the two methods shown in Figure 4-13.

- ▶ Enter network or test parameters (YAML representation) in plain text in 'Input Parameters' field
- ▶ Specify a YAML file (.rsxp) including its full path in 'Execution Parameters' field by entering string "--test-param-files", "xyz.rsxp"¹⁰

¹⁰ Placeholder. The YAML filename with .rsxp as file extension including its full path needs to be specified here.

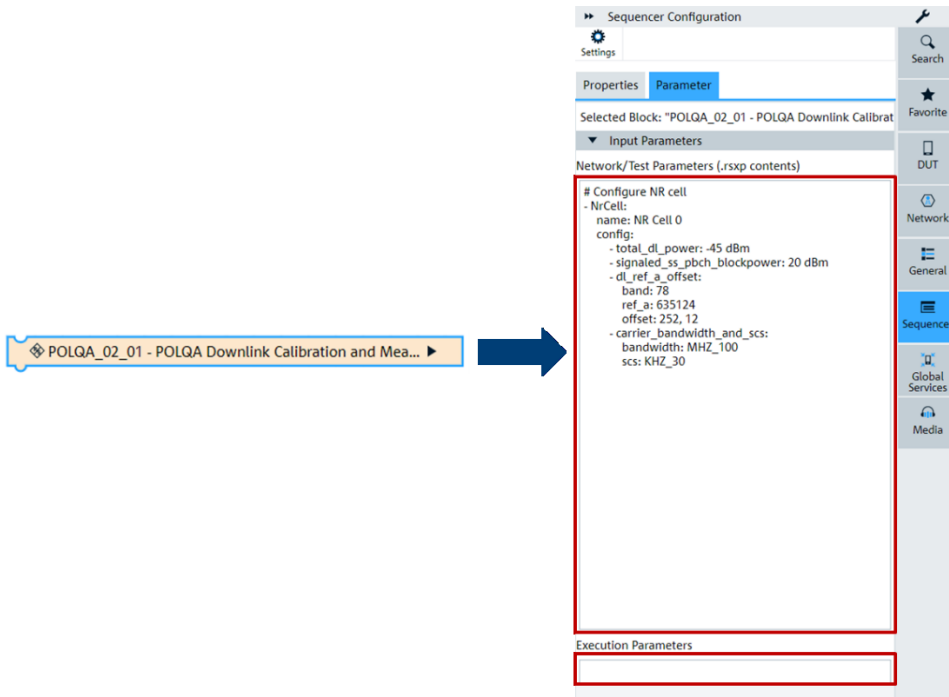


Figure 4-13 Parameterization of a XLAPI script in CMsequencer

To compose a system conform YAML (.rsxp) file, it is highly recommended to check the definition of 'Test Parameters' which is accessible by following steps:

1. Make sure that you have XLAPI package installed on your local PC. If not, please refer to XLAPI user manual [15] for package installation
2. Navigate to XLAPI installation folder C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\<XLAPI version>
3. Click on shortcut XLAPI Help. In the opened XLAPI help document page, select the 'Test Parameters' section (see Figure 4-14)

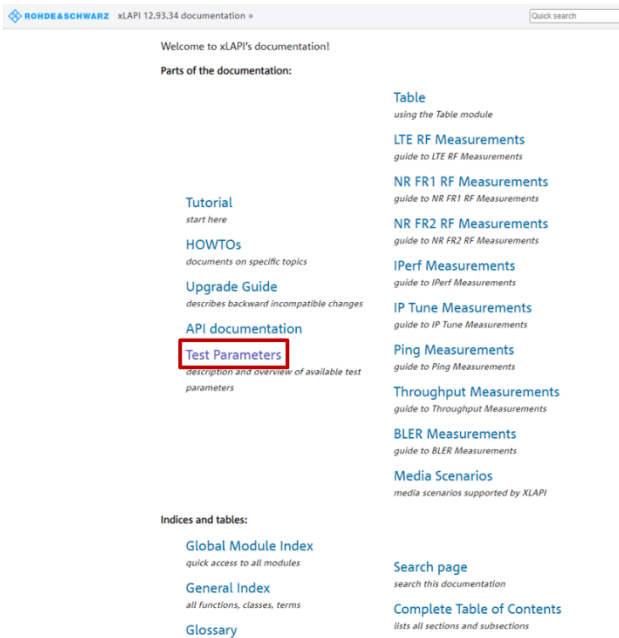


Figure 4-14 'Test Parameters' section in XLAPI help document

For more information about YAML file creation, please refer to Chapter 5.3.1 of XLAPI user manual [15].

4.3.2 Sequencer Scripts in CMsequencer

Sequencer scripts in KF690 package contain 5 test sections covering POLQA measurements under different test conditions, such as pure speech codec verification, under fading channel, with IP impairments, concurrent voice and data service or with cDRX. These scripts are 3GPP like as specified in [6].

The actual supported POLQA sequencer scripts are listed in Table 4-2 below.

Test Section Number	Test Section Title	Test Script Number	Test Script Title
1	Codec Verification	1	EVS WB 13.2kbps CAM DL
		4	EVS SWB 13.2kbps CAM DL
		7	EVS WB 13.2kbps DL
		10	EVS SWB 13.2kbps DL
		13	AMR WB 23.85kbps DL
		16	AMR NB 12.2kbps DL
2	Fading Scenarios	1	EVS WB 13.2kbps, TDL-A Low Fading DL
		2	EVS WB 13.2kbps, TDL-A Medium Fading DL
		3	EVS WB 13.2kbps, TDL-A High Fading DL
		4	EVS WB 13.2kbps, TDL-B Low Fading DL
		5	EVS WB 13.2kbps, TDL-B Medium Fading DL
		6	EVS WB 13.2kbps, TDL-B High Fading DL
		7	EVS WB 13.2kbps, TDL-C Low Fading DL
		8	EVS WB 13.2kbps, TDL-C Medium Fading DL
		9	EVS WB 13.2kbps, TDL-C High Fading DL
		10	AMR WB 23.85kbps, TDL-A Low Fading DL
		11	AMR WB 23.85kbps, TDL-A Medium Fading DL
		12	AMR WB 23.85kbps, TDL-A High Fading DL
		13	AMR NB 12.2kbps, TDL-A Low Fading DL
		14	AMR NB 12.2kbps, TDL-A Medium Fading DL
		15	AMR NB 12.2kbps, TDL-A High Fading DL
3	IP Impairments	1	EVS WB 13.2kbps, Pkt Loss 0.01, Jitter 10ms, DL
		2	EVS WB 13.2kbps, Pkt Loss 0.02, Jitter 40ms, DL
		3	EVS WB 13.2kbps, Pkt Loss 0.03, Jitter 40ms, DL
		7	AMR WB 23.85kbps, Pkt Loss 0.01, Jitter 10ms, DL
		8	AMR WB 23.85kbps, Pkt Loss 0.02, Jitter 40ms, DL
		9	AMR WB 23.85kbps, Pkt Loss 0.03, Jitter 40ms, DL
4	Concurrent Voice and Data Scenarios	1	EVS WB 13.2kbps, Concurrent Services DL
		3	AMR WB 23.85kbps, Concurrent Services DL
5	cDRX Scenarios	1	EVS WB 13.2kbps, cDRX ON 40ms DL
		3	AMR WB 23.85kbps, cDRX ON 40ms DL

Table 4-2 List of POLQA test scripts in CMsequencer

The structure of a POLQA test plan in CMsequencer is presented in Figure 4-15 that comprises a snippet and one or multiple test scripts.



Figure 4-15 Structure of a POLQA test plan in CMsequencer

A snippet is created as a shortcut that contains frequently used actions and function blocks. In the above structure, the snippet performs NR cell setup, cell configuration, SIM profile and IMS server configuration etc. After the snippet is completely executed, DUT should be in 5G and IMS registered state. In each test script, to carry out the calibration and POLQA measurement task, it should contain key POLQA building block 'POLQA Calibration' and 'POLQA Measurement'.

In following descriptions, most important settings of involved building blocks are highlighted.

Configure IMS Server

Make sure that 'Media Endpoint' is set to 'External DAU USB Sound Card' in parameter setting of 'Configure IMS Server' building block as shown in Figure 4-16.

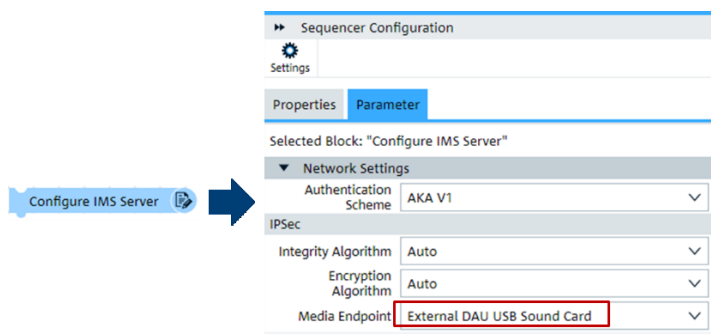


Figure 4-16 Parameter settings of CMsequencer building block 'Configure IMS Server'

Establish Call

Figure 4-17 presents example parameter settings of building block 'Establish Call' where following items need to be considered primarily.

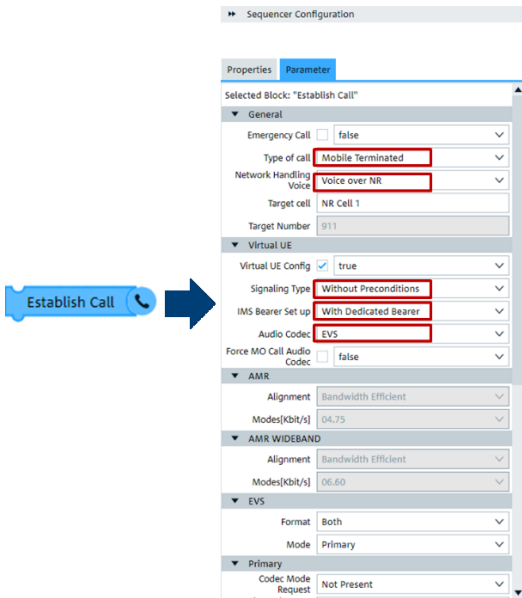


Figure 4-17 Example parameter settings of CMsequencer building block 'Establish Call'

- ▶ Set type of call (Mobile Terminated or Mobile Originated)
- ▶ Specify network handling for voice (cf. Chapter 1.2), e.g. Voice over NR. Depending on the selected voice service deployment, the involved standalone NR cell (in VoNR case) or non-standalone NR and LTE cell (VoLTE, EPS fallback/RAT fallback case) needs to be created beforehand, typically the network is included in the snippet part of the script
- ▶ Specify Signaling Type (UE implementation dependent), e.g. 'without preconditions'
- ▶ Select proper signaling type (UE implementation dependent) and IMS bearer setup (selection between 'with dedicated bearer' and 'without dedicated bearer')
- ▶ Specify the audio codec that is used for voice call, e.g. EVS. The relevant setting fields of the selected codec type are enabled and need to be configured properly based on the codec test requirements

POLQA Calibration

Figure 4-18 shows the parameter settings of building block 'POLQA calibration'.

Configure direction of POLQA calibration ('Downlink' or 'Uplink'). In case 'Uplink' direction is selected, it is necessary to set the Analog Output Level of the external USB sound card in the configuration field. Through adjusting analog output level to ensure that uplink POLQA calibration reaches 'In Range' status.

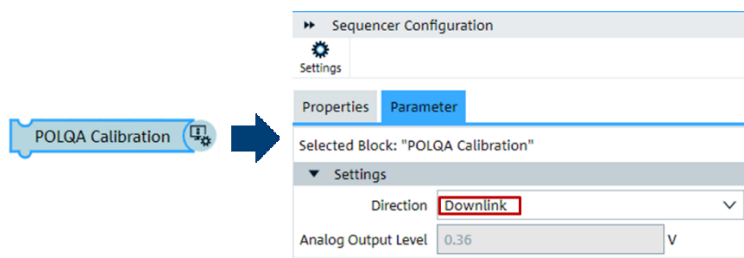


Figure 4-18 Parameter settings of CMsequencer building block 'POLQA Calibration'

POLQA Measurement

Figure 4-19 exhibits the parameters of building block 'POLQA Measurement' where following settings need to be considered essentially.

- ▶ Configure direction of POLQA measurement ('Downlink' or 'Uplink')

- ▶ Specify bandwidth: Full Band or Narrow Band
- ▶ Select a test signal (compliant to ITU-T P.501 Annex D) from the drop-down list
- ▶ Define MOS pass criteria (minimum MOS value), e.g. 3.5

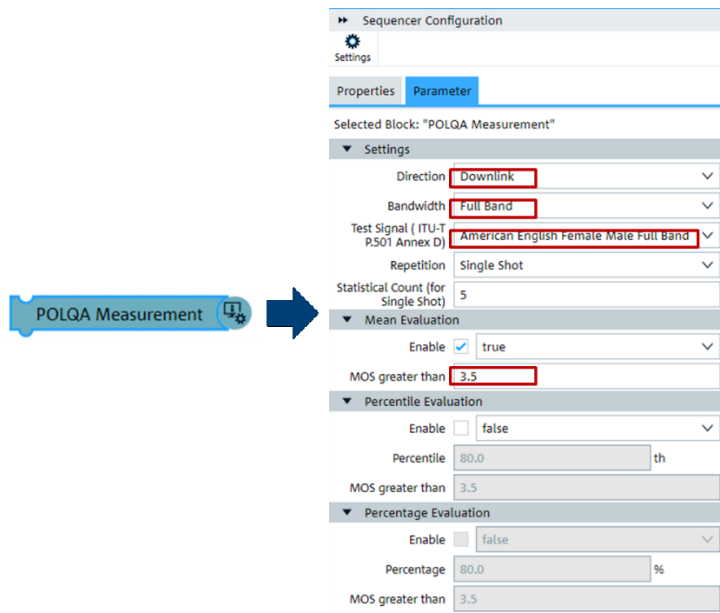


Figure 4-19 Parameter settings of CMsequencer building block 'POLQA Measurement'

In case building block 'POLQA Calibration' and 'POLQA Measurement' are required for creating your own CMsequencer test script, they can be found in 'Sequence Editor' square > Function Blocks > Measurements > Audio Quality (see Figure 4-20)

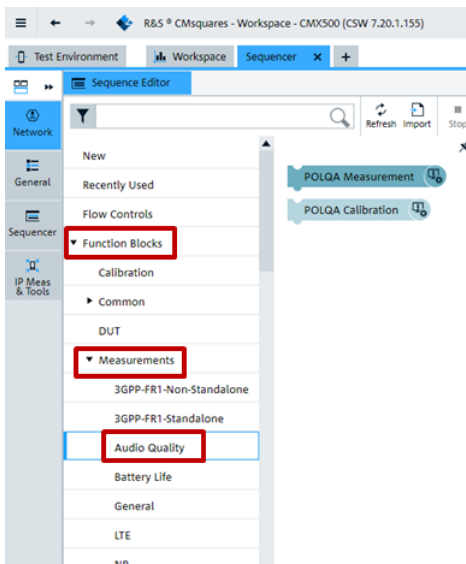


Figure 4-20 Location of 'POLQA Measurement' and 'POLQA Calibration' building block in CMsequencer

4.3.3 Report of Calibration and POLQA Measurement

A test report is generated after the test script is terminated in CMsequencer.

An example given in Figure 4-21 shows that the DL POLQA calibration is passed with 'In Range' analog input quality and 0.36V measured analog input level. The average MOS value is 4.45.

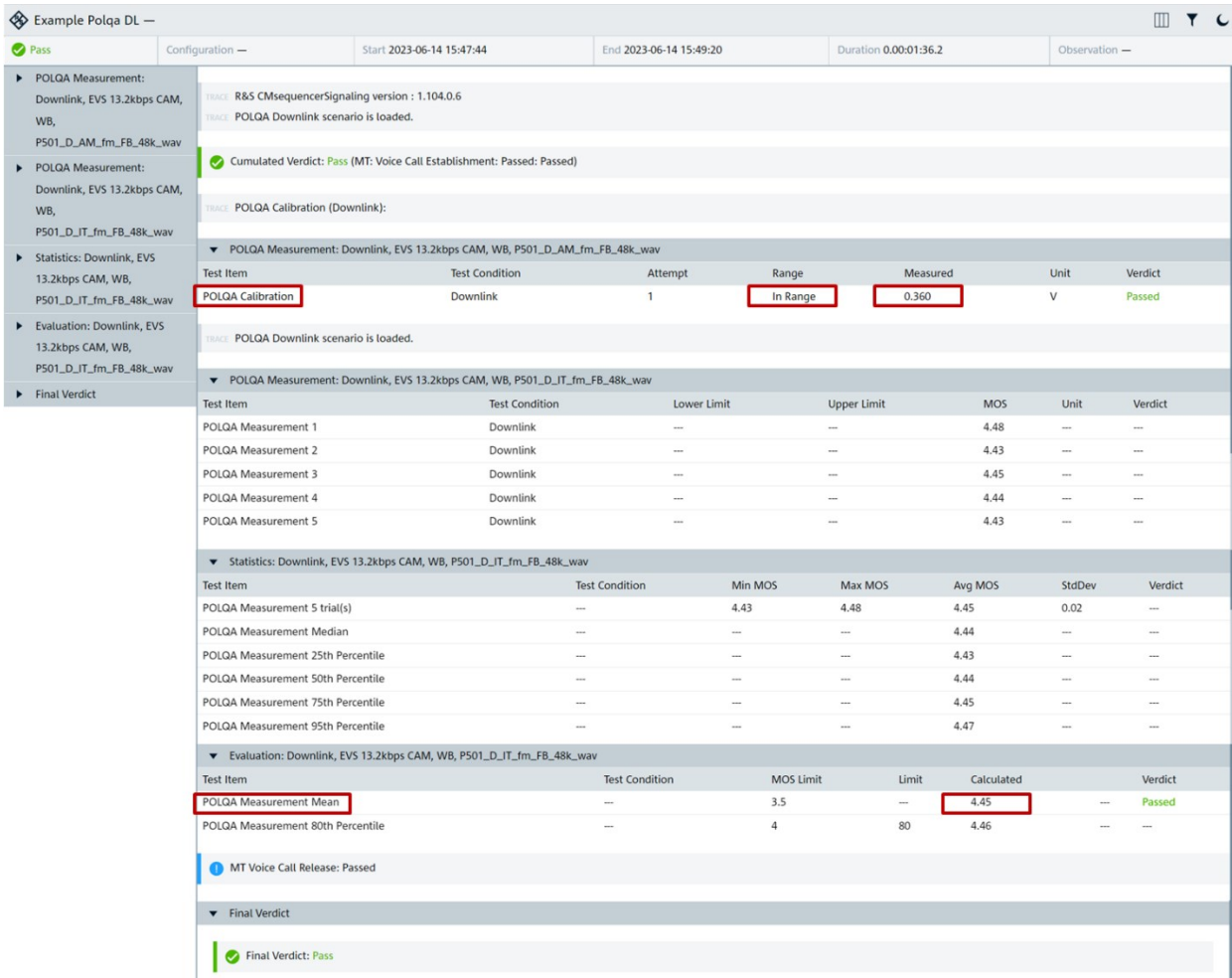


Figure 4-21 Example of DL calibration and POLQA measurement test report in CMsequencer

Figure 4-22 gives a test report example of uplink calibration and POLQA measurement that indicates the passed calibration result with 'In Range' digital level verdict, 'Good' digital signal quality and measured -2.882 dB digital level, as well as the average UL MOS value of 4.26.

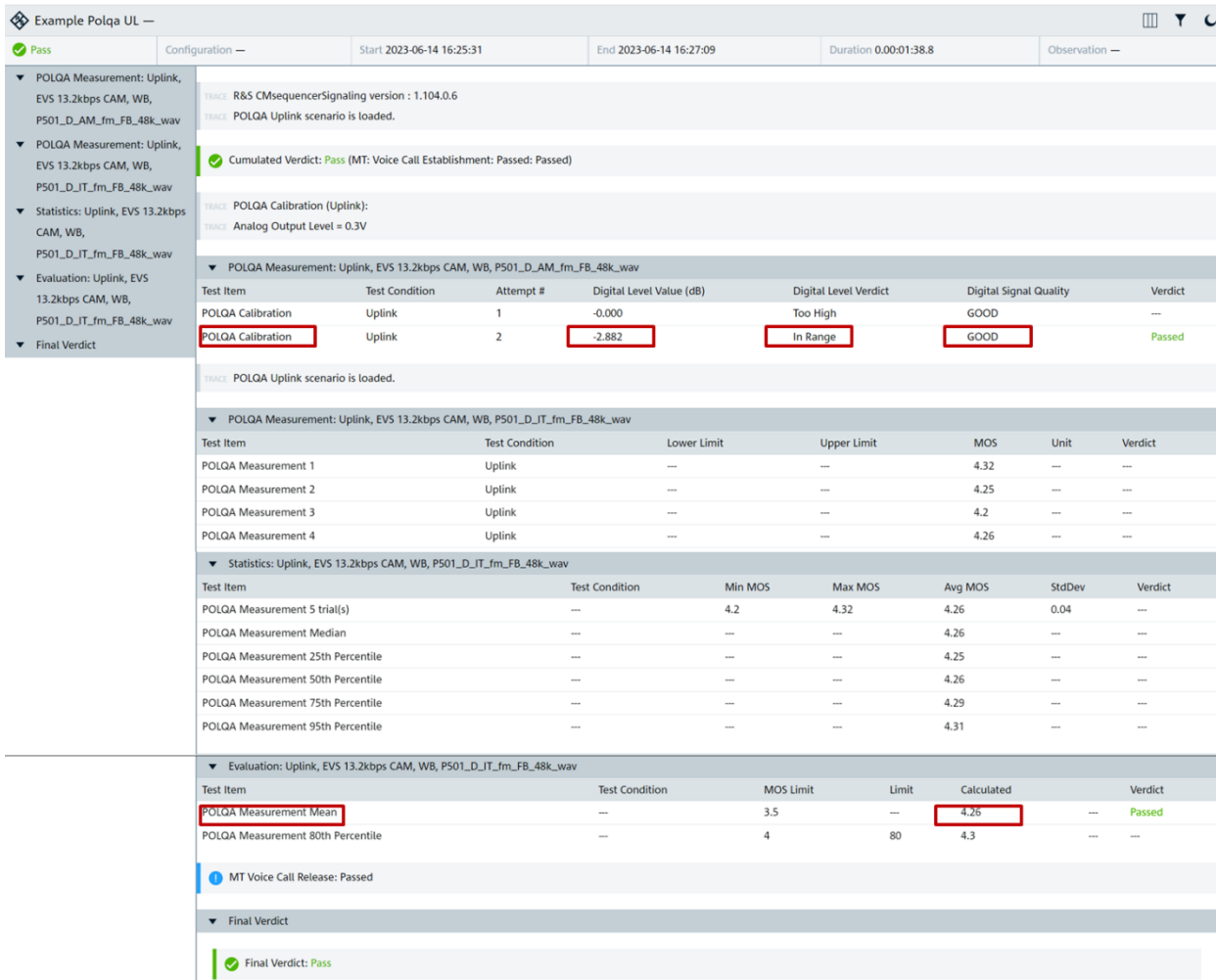


Figure 4-22 Example of UL calibration and POLQA measurement test report in CMsequencer

4.4 Using XLAPI Script

On CMX500, it is also possible to utilize XLAP which is a Python based scripting language to create, modify and run POLQA test scripts from XLAPI environment.

Off-the-shelf XLAPI POLQA scripts are included in KF690 package with the test coverage as listed in Table 4-1 on page 25. The advantage of solution described in this chapter is that the user can have direct access to the POLQA script and if desired, can modify and create own XLAPI script. This provides a level higher flexibility.

More details about the XLAPI, please refer to XLAPI user manual [15].

4.4.1 Walk Through the XLAPI Environment

4.4.1.1 Package Installation on Control PC

Make sure that the XLAPI script package KF690 is installed on your local windows PC. Following package installation aspects need to be respected:

- ▶ In order to ensure the compatibility between XLAPI and CSW version, dependency of XLAPI version to CSW shall be checked either in Installation Service on CMX500 or in Installation Manager on your local PC

Figure 4-23 shows the steps to check XLAPI dependency in Installation Manager

1. In Installation Manager, click on 'Details' page
2. Enter keyword 'CSW' in the software search field
3. Select 'CSW Signaling' software and choose the CSW version that is installed on the CMX500, e.g. 7.20.1.270
4. In the right-most 'Dependencies' panel, the compatible XLAPI version is shown, e.g. 12.93.36.0

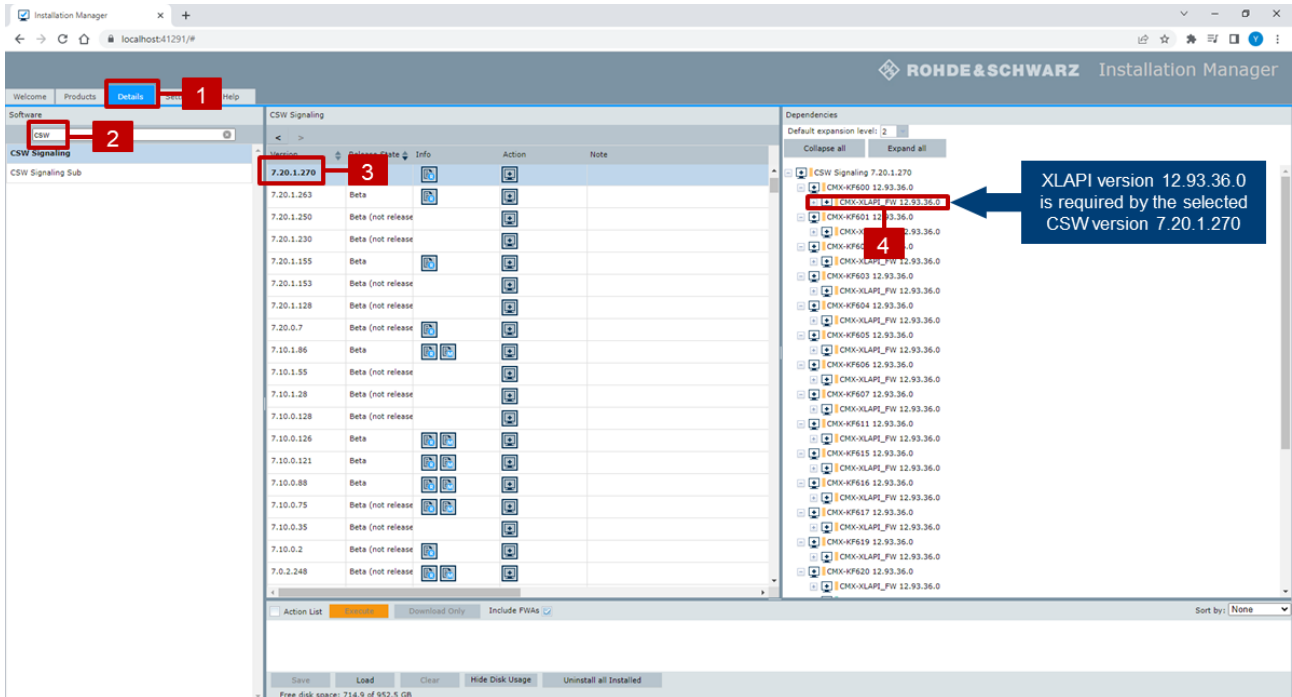



Figure 4-23 Check XLAPI version in Installation Manager

- ▶ The XLAPI version identified in previous steps shall be installed on local windows PC via Installation Manager (Refer to Chapter 3.1 in XLAPI user manual [15]). The installation contains packages:
 - CMX-KF600 for required XLAPI basic components
 - CMX-KF690 POLQA audio quality script package

Alternatively, the installation can also apply other methods, i.e. installation XLAPI as Python module, installation XLAPI in a user-defined virtual environment, please refer to Chapter 3.2 and 3.3 in [15] for more detailed information.

Figure 4-24 shows the steps to select and install the XLAPI packages from the Installation Manager

1. In Installation Manager, click on 'Details' page
2. Enter keyword 'CMX-KF6' in the software search field
3. Select the script package 'CMX-KF600' from the search result and go to Step 4.
4. Find the proper XLAPI version (e.g. 12.93.36.0) and click on the Action icon  to add to the action list window. Go back to Step 3 to add 'CMX-KF690' package in the action list
5. Install all the packages contained in the action list by pressing 'Execute' button

6. Follow the instructions during the installation process to complete the package installation

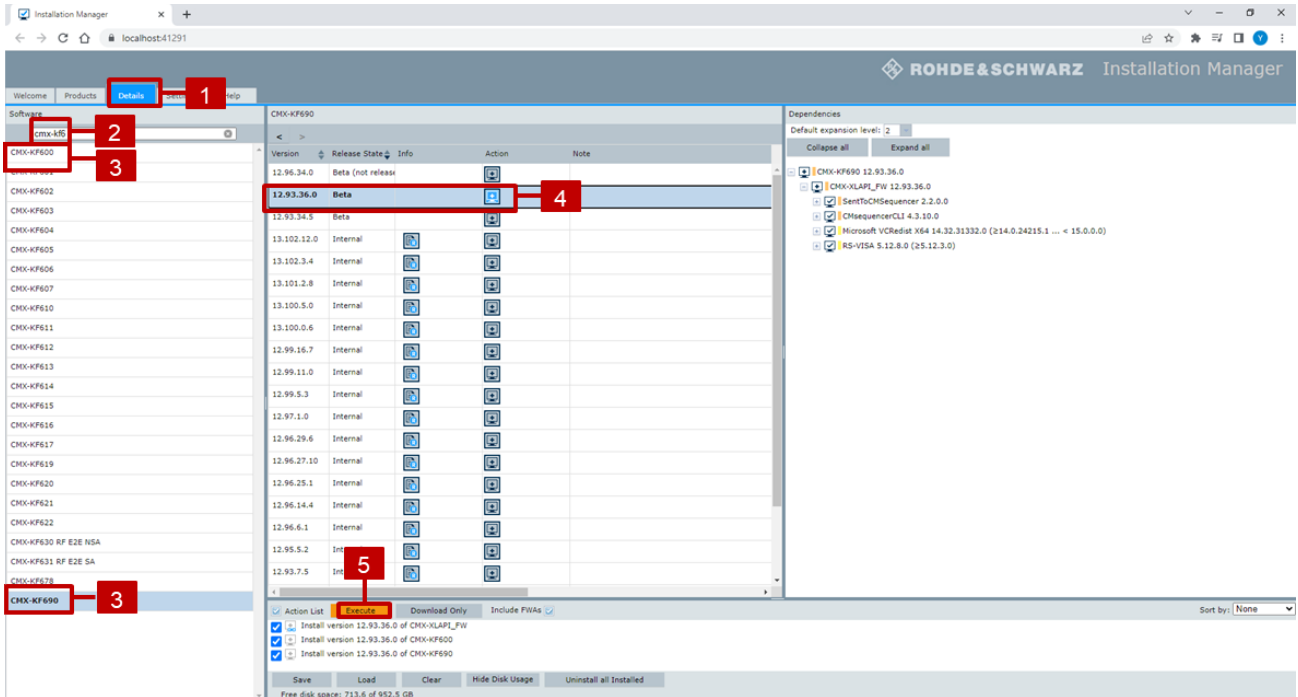


Figure 4-24 Select and install XLAPI packages in Installation Manager

4.4.1.2 Load an XLAPI Project in PyCharm

Precondition:

PyCharm Community Edition (PyCharm in short) as integrated development environment (IDE) is recommended to be installed on local control PC. PyCharm is built on open source and free downloadable from <https://www.jetbrains.com/pycharm/download>

Follow the steps below to load an XLAPI project in PyCharm

- ▶ Launch PyCharm on control PC and go to File > Open (Figure 4-25)

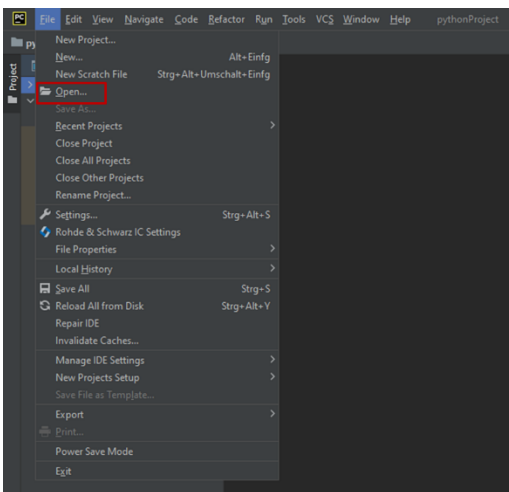


Figure 4-25 Open project in PyCharm

- ▶ In the opened window, navigate to XLAPI installation folder `C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\<XLAPI version>`, select the XLAPI version that intends to be opened (e.g. 12.93.36) and press 'OK' to proceed (Figure 4-26)

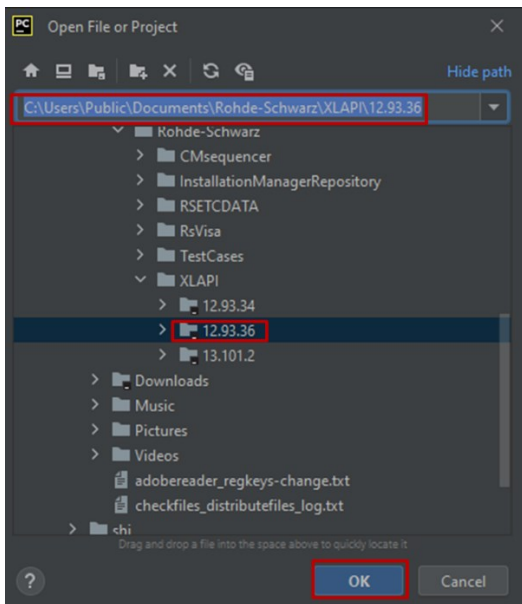


Figure 4-26 Select a project

- ▶ The POLQA XLAPI scripts are located in folder `appl\script_packages\cmx-kf690` under the XLAPI tree structure (Figure 4-27)

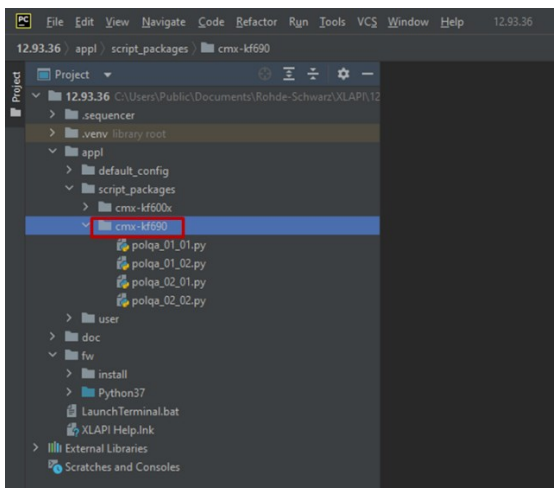


Figure 4-27 Location of CMX-KF690 POLQA script package

4.4.1.3 Run Test Script in PyCharm

There are several ways to execute an XLAPI script

- ▶ Interactively applying script code from the IDE (PyCharm)
- ▶ Starting a script from the IDE (PyCharm)
- ▶ Starting a script from the Command Line Interface
- ▶ Interactively applying script code from the Command Line Interface
- ▶ Executing a script on CMX500 via CMsequencer (see Chapter 4.3.1)

In the subsequent text, we will be giving an example on how to run a script remotely on CMX500 from PyCharm running on a control PC. For the other execution methods, please refer to XLAPI user manual [15].

Preconditions before running the script are:

- ▶ Control PC can reach CMX500 via LAN. This can be verified by pinging the CMX500's IP address or CMX500 hostname from the PC
- ▶ On CMX500, the proper DUT object is configured and activated (cf. Chapter 3.3.1). An example is given in Figure 3-5. For more details of the operation, please refer to CMX500 user manual [1].

Use one of the two methods mentioned below to execute a test script in PyCharm.

1. Method 1 (in PyCharm Terminal)

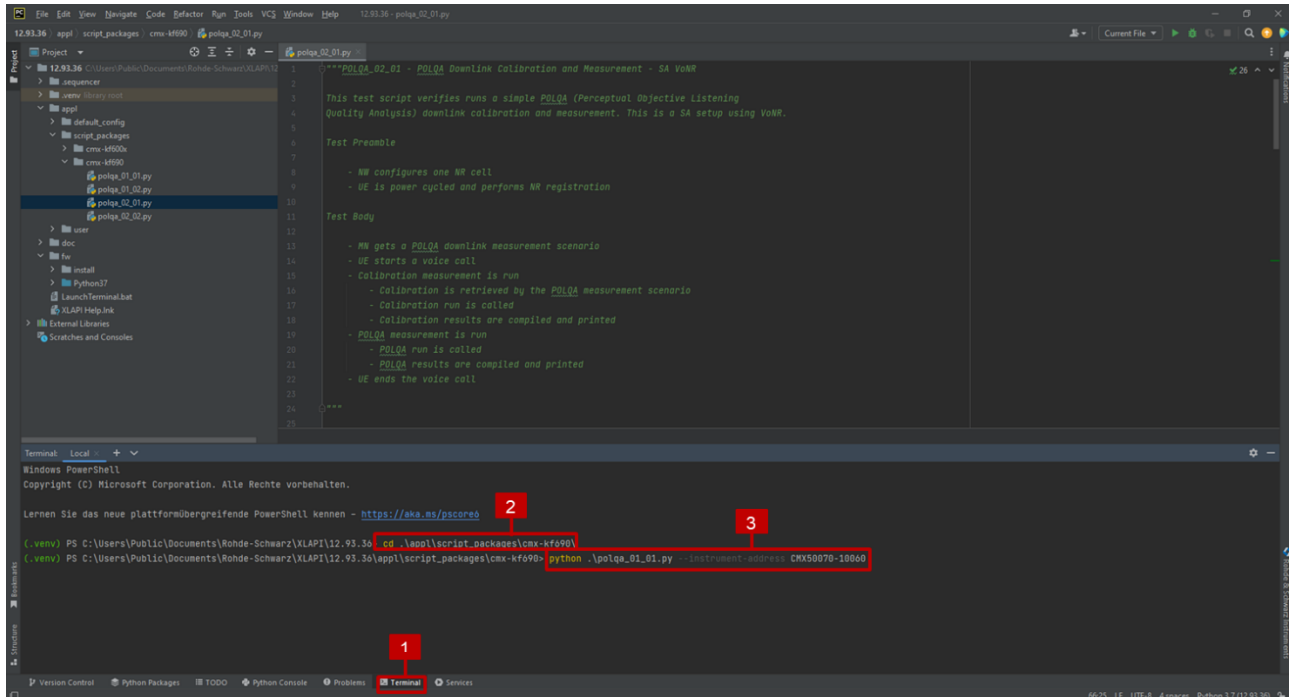


Figure 4-28 Run a script in PyCharm Terminal from a remote PC

1. Open PyCharm Terminal
 2. Change to the folder where POLQA script is located (`cd .\appl\script_packages\cmx-kf690\`)
 3. Issue command:

```
python <XLAPI script name> --instrument-address <hostname or IP address of the CMX500>
```
- ### 2. Method 2 (modify run configuration)

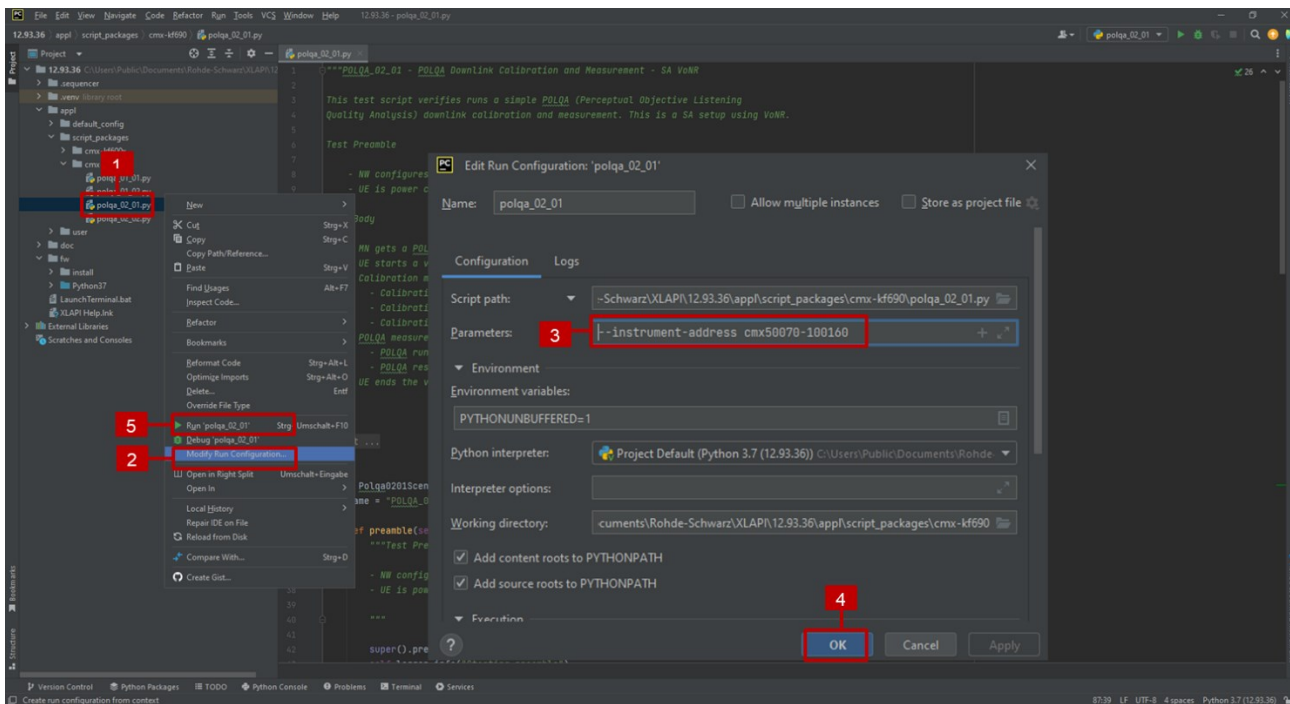


Figure 4-29 Run a script from a remote PC by specifying execution argument in PyCharm

1. Select XLAPI script that intends to be executed
2. Right mouse click on the script and select 'Modify Run Configuration' option in the pop-up menu
3. In 'Parameters' field of the opened window, enter string `--instrument-address <hostname or IP address of the CMX500>`
4. Press 'OK' to confirm the configuration
5. Right mouse click on the script again and now select 'Run' option to execute the script

4.4.2 Results of Calibration and POLQA Measurement

Results of calibration and POLQA measurement are included in the output of the XLAPI script execution in the end.

In the examples shown below in Figure 4-30 and Figure 4-31 present the calibration and POLQA measurement report in DL and UL, respectively. In the DL report, the calibration part is passed (Analog Input Quality is 'In Range') and the measured MOS value is 4.31. While in the UL report, the calibration is passed (Digital Level Verdict is 'In Range' and Digital Signal Quality Verdict is 'Good') and the final MOS value achieves 4.31 in this case, too.

```

19 [INFO] ----- Preamble -----
20 [INFO] Starting preamble
21 [INFO] Step 1: Powering off the DUT
22 [INFO] Powering off the UE
23 [INFO] Step 2: Starting all cells
24 [INFO] Starting all cells
25 [INFO] Starting Network Emulation
26 [INFO] RF Connectors:
27 -----
28 | CMX (100160) |
29 -----
30 | RFCom1: NR0 DL1, UL1 | RFCom2: | RFIn1: | RFIn2: | RFOut1: | RFOut2: | RFOut3: | RFOut4: |
31 -----
32 [INFO]
33
34 | NR Cell 0 Configuration
35 |-----+-----|
36 | | Configuration Info |
37 |-----+-----|
38 | Band | n78 (FR1 TDD) |
39 |-----+-----|
40 | Carrier 0 | SCS 30.0 kHz |
41 |-----+-----|
42 | Bandwidth | 100.0 MHz (273 RBs) |
43 |-----+-----|
44 | Reference point A | 630942 (3.46413 GHz) |
45 |-----+-----|
46 | Absolute frequency SSB | 633696 (3.50544 GHz) |
47 |-----+-----|
48 | DL SSB EPRE | -80.0 dBm |
49 |-----+-----|
50
51
52 [INFO] Starting NR cell 'NR Cell 0'
53 [INFO] Step 3: Powering on the DUT
54 [INFO] Powering on the UE
55 [INFO] Step 4: Register NR Cell on 5GS
56 [INFO] [Signaling] Starting NR registration on NrCell NR Cell 0
57 [INFO] [Signaling] Completed NR registration on NrCell NR Cell 0
58 [INFO] Starting IMS registration procedure
59 [INFO] Completed IMS registration procedure
60 [INFO] ----- Testbody -----
61 [INFO] Starting Testbody
62 [INFO] Starting Downlink POLQA Scenario
63 [INFO] Starting Voice Call
64 [INFO] Proceeding with default call configurations
65 [INFO] [Signaling] Starting MT Voice Call - Ringing
66 [INFO] Accept incoming audio call.
67 [INFO] [Signaling] Completed MT Voice Call
68 [INFO] Running Calibration
69 [INFO] Getting Calibration Results
70 |-----+-----|
71 | POLQA calibration result | value |
72 |-----+-----|
73 | ID | E9079E1D-7AAB-4823-A9EA-71AAE047F7CB |
74 |-----+-----|
75 | Tag | unset |
76 |-----+-----|
77 | Analog Input Quality | In Range |
78 |-----+-----|
79 | Analog Input Level | 507.46 mV |
80 |-----+-----|
81 [INFO] Running POLQA Measurement
82 [INFO] Getting POLQA Measurement Results
83 |-----+-----|
84 | POLQA result | value |
85 |-----+-----|
86 | POLQA Version | 3 |
87 |-----+-----|
88 | POLQA MOS | 4.31 |
89 |-----+-----|
90 | POLQA MOS type | MOS-LQO Full Band |
91 |-----+-----|
92 | POLQA tag | unset |
93 |-----+-----|
94 | POLQA ID | 512E263B-66B7-4AD1-B924-4552304E0BA2 |
95 |-----+-----|
96 [INFO] Ending Voice Call
97 [INFO] [Signaling] Completed MT release of Voice call successful
98 [INFO] Verdict: PASS: POLQA calibration and measurement completed.
99 [INFO] ----- Postamble -----
100 [INFO] #####
101 [INFO] Final verdict: PASS: POLQA calibration and measurement completed.
102 [INFO] -----
103 [INFO] C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\13.101.2\venv\lib\site-packages\xlapi\scenario.py:238: 2023-06-14T17:49:44.215834 - NONE: Initial NONE
104 [INFO] C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\13.101.2\appl\script_packages\cmx-kf690\polqa_02_01.py:112: 2023-06-14T17:51:36.351884 - PASS: POLQA calibration and measurement completed.
105 [INFO] #####
106 [INFO] ----- System Shutdown -----
107 [INFO] Closing NE and log files ...
108 [INFO] NE log directory: @LOG/2023-06-13T10-14-22Z/sfa/NetworkEmulation11
109 [INFO] Message log file: @LOG/2023-06-13T10-14-22Z/sfa/NetworkEmulation11/signaling.msglog
110 [INFO] CMX Mars log URL: http://cmx50070-100160/cmxmars/?mlPath=/home/instrument/fw/log/2023-06-13T10-14-22Z/sfa/NetworkEmulation11/signaling.msglog&actId=@0&topMsgTbl=@0&topMsgMsc=@0
111 [INFO] XLAPI log file: file:///C:/Users/shi/AppData/Local/Temp/Rohde-Schwarz/xlapi/polqa_02_01.2023-06-14_17-50-08/xlapi.log
112
113 Process finished with exit code 0

```

Figure 4-30 Example of DL POLQA calibration and measurement test report after running XLAPI script in PyCharm

```

19 [INFO] ----- Preamble -----
20 [INFO] Starting preamble
21 [INFO] Step 1: Powering off the DUT
22 [INFO] Powering off the UE
23 [INFO] Step 2: Starting all cells
24 [INFO] Starting all cells
25 [INFO] Starting Network Emulation
26 [INFO] RF Connectors:
27 -----
28 | CMX (100160) |
29 -----
30 | RFCom1: NR0 DL1, UL1 | RFCom2: | RFIn1: | RFIn2: | RFOut1: | RFOut2: | RFOut3: | RFOut4: |
31 -----
32 [INFO]
33
34 NR Cell 0 Configuration
35 +-----+
36 | | Configuration Info |
37 +-----+
38 | Band | n78 (FR1 TDD) |
39 +-----+
40 | Carrier 0 | SCS 30.0 kHz |
41 +-----+
42 | Bandwidth | 100.0 MHz (273 RBs) |
43 +-----+
44 | Reference point A | 630942 (3.46413 GHz) |
45 +-----+
46 | Absolute frequency SSB | 633696 (3.58544 GHz) |
47 +-----+
48 | DL SSB EPRE | -80.0 dBm |
49 +-----+
50
51
52 [INFO] Starting NR cell 'NR Cell 0'
53 [INFO] Step 3: Powering on the DUT
54 [INFO] Powering on the UE
55 [INFO] Step 4: Register NR Cell on SGS
56 [INFO] [Signaling] Starting NR registration on NrCell NR Cell 0
57 [INFO] [Signaling] Completed NR registration on NrCell NR Cell 0
58 [INFO] Starting IMS registration procedure
59 [INFO] Completed IMS registration procedure
60 [INFO] ----- Testbody -----
61 [INFO] Starting Testbody
62 [INFO] Loading Uplink POLQA Scenario
63 [INFO] Starting Voice Call
64 [INFO] Proceeding with default call configurations
65 [INFO] [Signaling] Starting MT Voice Call - Ringing
66 [INFO] Accept incoming audio call.
67 [INFO] [Signaling] Completed MT Voice Call
68 [INFO] Running Calibration
69 [INFO] Getting Calibration Results
70 +-----+
71 | POLQA calibration result | value |
72 +-----+
73 | ID | A652F46A-9821-46E3-B008-1E580B020DA |
74 +-----+
75 | Tag | unset |
76 +-----+
77 | Measured Digital Level Verdict | In Range |
78 +-----+
79 | Measured Digital Level | -1.29 dB |
80 +-----+
81 | Analog Output Level | 250 mV |
82 +-----+
83 | Measured Digital Signal Quality Verdict | GOOD |
84 +-----+
85 [INFO] Running POLQA Measurement
86 [INFO] Getting POLQA Measurement Results
87 +-----+
88 | POLQA result | value |
89 +-----+
90 | POLQA Version | 3 |
91 +-----+
92 | POLQA MOS | 4.31 |
93 +-----+
94 | POLQA MOS type | MOS-LQO Full Band |
95 +-----+
96 | POLQA tag | unset |
97 +-----+
98 | POLQA ID | 99E78915-3B1A-4C48-B369-DEA738B84A5B |
99 +-----+
100 | POLQA analog output level | 250 mV |
101 +-----+
102 [INFO] Ending Voice Call
103 [INFO] [Signaling] Completed MT release of Voice call successful
104 [INFO] Verdict: PASS: POLQA calibration and measurement completed.
105 [INFO] ----- Postamble -----
106 [INFO] #####
107 [INFO] Final verdict: PASS: POLQA calibration and measurement completed.
108 [INFO] -----
109 [INFO] C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\13.101.2\venv\lib\site-packages\xlapi\scenario.py:238: 2023-06-14T17:24:16.226423 - NONE: Initial NONE
110 [INFO] C:\Users\Public\Documents\Rohde-Schwarz\XLAPI\13.101.2\appl\script_packages\cmx-kf690\polqa_02.py:112: 2023-06-14T17:25:57.821531 - PASS: POLQA calibration and measurement completed.
111 [INFO] #####
112 [INFO] ----- System Shutdown -----
113 [INFO] Closing NE and log files ...
114 [INFO] NE log directory: @LOG/2023-06-13T10-14-22Z/sfa/NetworkEmulation10
115 [INFO] Message log file: @LOG/2023-06-13T10-14-22Z/sfa/NetworkEmulation10/signaling.msglog
116 [INFO] CMX Mars log URL: http://cmx50070-100160/cmxmars/?m1Path=/home/instrument/fw/log/2023-06-13T10-14-22Z/sfa/NetworkEmulation10/signaling.msglog&actIe=0&topMsgTb1=0&topMsgMsc=0
117 [INFO] XLAPI log file: file:///C:/Users/shi/AppData/Local/Temp/Rohde-Schwarz/xlapi/polqa_02.2023-06-14_17-24-41/xlapi.log
118
119 Process finished with exit code 0
120

```

Figure 4-31 Example of UL POLQA calibration and measurement test report after running XLAPI script in PyCharm

5 Literature

- [1] R&S, "R&S®CMX500 Radio Communication Tester User Manual".
- [2] R&S, "R&S®CMX500 Radio Communication Tester Getting Started".
- [3] R&S, "5G Voice over New Radio (VoNR)," [Online]. Available: https://www.rohde-schwarz.com/solutions/test-and-measurement/wireless-communication/cellular-standards/white-paper-5g-voice-over-new-radio-vonr-_254723.html.
- [4] 3GPP, "3GPP TS26.131 V18.0.0 (2022-12); Terminal acoustic characteristics for telephony; Requirements (Release 18)".
- [5] 3GPP, "3GPP TS26.132 V18.0.0 (2022-12); Speech and video telephony terminal acoustic test specification (Release 18)".
- [6] 3GPP, "3GPP TR26.954 V17.0.0 (2022-04), Test plan for speech quality and delay through a headset electrical interface (Release 17)".
- [7] Headacoustics Application Note, "Establish 5G / LTE connection to labCORE via R&S®CMX500 OBT".
- [8] R&S Application Note, 1SL364, "Voice Call Aspects in 5G New Radio Networks".
- [9] R&S, "QualiPoc Android," [Online]. Available: https://www.rohde-schwarz.com/products/test-and-measurement/network-data-collection/qualipoc-android_63493-55430.html.
- [10] "EventHelix.Com," [Online]. Available: https://www.eventhelix.com/ims/ims-to-ims-call/ims_ims_call_focus_on_UE_network.pdf.
- [11] Fraunhofer IIS, "Technical paper, Enhanced Voice Services (EVS) Codec," [Online]. Available: https://www.iis.fraunhofer.de/content/dam/iis/de/doc/ame/wp/FraunhoferIIS_Technical-Paper_EVS.pdf.
- [12] ITU-T, "P.863 (03/2018), Methods for objective and subjective assessment of speech and video quality, Perceptual objective listening quality prediction".
- [13] R&S White Paper 1MA202, "Next-Generation (3G/4G) Voice Quality Testing with POLQA®".
- [14] R&S, "R&S®CMX500 Application Tests User Manual".
- [15] R&S, "R&S®CMX500 XLAPI Scripting Interface User Manual".
- [16] "Wikipedia - Phone connector (audio)," [Online]. Available: [https://en.wikipedia.org/wiki/Phone_connector_\(audio\)](https://en.wikipedia.org/wiki/Phone_connector_(audio)).
- [17] R&S Application Note, "Test Automation Tool for POLQA® and PESQ® Speech Quality Tests".
- [18] R&S Application Note, 1MA204, "Voice over LTE (VoLTE) Speech Quality Measurements".
- [19] R&S, "5G NR eBook," [Online]. Available: <https://www.rohde-schwarz.com/5G-ebook>.
- [20] ITU-T, "P.863.1 (06/2019), Methods for objective and subjective assessment of speech and video quality, Application guide for Recommendation ITU-T P.863".
- [21] R&S, "R&S®CMX-KF690B CMsequencer Script Package User Manual".

6 Ordering Information

Minimum HW/SW configuration of setup for audio quality setup based on CMX500 OBT (CMX500 OBT lite configuration)¹¹

Designation	Qty.	Type	Order No.
CMX500 Radio Communication Tester			
Radio Communication Tester	1	CMX500	1201.0002K70
CMX500 Basic Assembly	1	CMX-PB70H	1222.0676.09
Accelerator Unit	1	CMX-B200A	1222.0747.02
CMX Processing Unit	1	CMX-B300B	1222.0801.03
RF Unit; 400 MHz - 8 GHz; 4xTx 1 GHz iBW and 2x Rx 250 MHz	1	CMX-B600A	1222.0953.02
CMX Application test Featureset 1 (SL)	1	CMX-KA100	1222.1595.02
CMX Audio Enabler (SL)	1	CMX-KA180	1222.4165.02
CMX Audio POLQA Measurement (SL)	1	CMX-KA181	1222.4936.02
NR Signaling, NSA Mode Enabler Basic Level (SL)	1	CMX-KS600B	1222.1672.02
NR Signaling, SA Mode Enabler Basic Level (SL)	1	CMX-KS601B	1222.2327.02
Audio Verification Script for CMsequencer	1	CMX-KF690B	1222.4442.02
External media endpoint audio	1	CMX-ZG180A	1222.4313.02

Table 6-1 Minimum HW/SW configuration for audio quality testing based on CMX500 OBT lite

Designation	Qty.	Type	Order No.
External Media Endpoint	1	CMX-ZG180A	1222.4313.02
Headset Cable Set	1	CM-Z91	1212.3050.02

Table 6-2 Accessories for audio quality testing

¹¹ Recommended test setup

7 Appendix

A Audio Jack and Plug

Audio jack, also known as phone connector, phone jack, audio jack, headphone jack or jack plug, is a family of electrical connectors typically used for analog audio signals. A plug, the male connector, is inserted into the jack, the female connector (see [16]).

Audio Plug Versions

There are four types of commonly used audio plugs. The name of the audio plug indicates one tip (T), zero to three rings (R) and one sleeve (S) conductors.

- ▶ Two-pole version (TS)
Transmit mono audio signal
- ▶ Three-pole version (TRS)
Balanced mono or unbalanced stereo signal
- ▶ Four-pole version (TRRS)
Support unbalanced stereo audio and microphone signal at the same time. It is commonly used in smartphones.

Products according to the two following standards are available on the market:

- CTIA (Cellular Telecommunications and Internet Association)
- OMTP (Open Mobile Terminal Platform)

As shown in Table 7-1 and Figure 7-1, two standards differ in their respective pin layout.

Standard	Tip	Ring 1	Ring 2	Sleeve	Pin Layout Name
CTIA	Left audio	Right audio	Ground	Microphone	LRGM
OMTP	Left audio	Right audio	Microphone	Ground	LRMG

Table 7-1 Standards of four-pole audio plug version (TRRS)

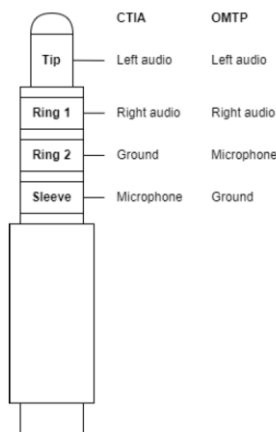


Figure 7-1 Four-pole audio plug

Mobile phones nowadays typically make use of an automatic audio jack detection switch which detects the locations of the ground and microphone poles on the audio plug and automatically routes them to the appropriate connections.

- ▶ Five-pole version (TRRRS)
Support balanced stereo audio. Professional audio systems.

Audio Plug Size

The outside diameter of sleeve conductor is considered as the audio plug size. There are four sizes 2.5 mm, 3.5 mm, 4.4 mm and 6.35 mm.

In mobile phone, the common size is 3.5 mm with TRS or TRRS type audio plug.

Other Audio Plugs

- ▶ Audio lightning jack



Starting from iPhone7, all models are equipped with audio lightning jack (with built-in DAC) for audio transmission without distortion or compression. Thus, improved audio quality.

- ▶ USB-A

Headset with USB-A jack has a built-in amplifier. Primarily for gaming on laptop/PC to provide clear and resonant audio quality, not for mobile phone due to high power-consumption.

- ▶ USB-C



Similar to Audio lightning jack, USB-C is adopted for some of the mobile phone vendors, e.g. Samsung, Xiaomi, Huawei etc. to enhance the audio quality.

Table 7-2 shows the compatibility of CMX-Z91 (TRRS plug, in compliance with 4-pole CTIA standard) with different types of the jacks.

Jack (↓) / Plug (→)	4-pole CTIA (TRRS, e.g. CMX-Z91)
3-pole	Headphones: OK / Mic: n/a
4-pole CTIA	Headphones: OK / Mic: OK
4-pole OMTP	Headphones: n/a / Mic: n/a

Table 7-2 Compatibility of audio jacks and CMX-Z91 TRRS plug (OK = compatible, n/a = non-compatible or non-functional)