

# Acoustic Test Software for Mobile Phones in Service and Repair

## Application Note

### Products:

- R&S®UPV
- R&S®UPV-K1
- R&S®UPV-K61
- R&S®UPV-K63
- R&S®CMW500

This application note provides software and instructions for a simple check of the acoustic performance of mobile phones. It targets mainly service centers and repair workshops which have to perform incoming tests of defective mobile phones and final tests of repaired mobiles. A focus is set on short test times and ease of use, without compromising accuracy and repeatability of results.

### Note:

Please find the most up-to-date document on our homepage <http://www.rohde-schwarz.com/appnote/1GA69>.

This document is complemented by software. The software may be updated even if the version of the document remains unchanged

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# 1 Introduction

## 1.1 Purpose of this application note and software

This application note provides software and instructions for a simple check of the acoustic performance of mobile phones. It targets mainly service centers and repair workshops which have to perform incoming tests of defective mobile phones and final tests of repaired mobiles. A focus is set on short test times and ease of use, without compromising accuracy and repeatability of results.

The tests play speech test signals in uplink and / or downlink direction and record the degraded signal at the decoder output of the R&S®CMW500 wideband radiocommunication tester (network side) or at the artificial ear, respectively.

Evaluation of the degraded signals comprises perceptual speech quality evaluation according to ITU-T P.862 (ITU-T, 02/2001) (PESQ®) or ITU-T P.863 (ITU-T, 09/2014) (POLQA®, recommended) and calculation of loudness ratings according to ITU-T recommendation P.79 (ITU-T, 11/2007). The former includes rating the effect of linear and nonlinear distortion. The latter detects gain errors in the transmission path.

## 1.2 Background

### 1.2.1 Perceptual speech quality evaluation

Perceptive speech quality evaluation methods emulate the subjective judgement of speech quality by a large number of listeners.

POLQA® and PESQ® are objective perceptual speech test methods.

A **speech** test method rates the quality of a speech signal as opposed to a conversational rating where impairments like round-trip delay are judged for their impact on a conversation.

A **perceptual** test method delivers results which assess degradations the same way as human beings would do. Non-perceptual test methods usually determine physical entities like voltage level.

A possible implementation of a perceptual test is a subjective listening test, e.g. according to ITU-T P.800. In a subjective test, speech signals are presented to subjects under standardized listening conditions (level, playback equipment) with a well-defined judgement task or question. Such a task could be to categorize the quality of a presented speech signal according to the question “how good does the voice sample sound?” into one of five steps between 5 = “Excellent” and 1 = “Bad”. The answers from many subjects are averaged to obtain a so-called “MOS” (Mean Opinion Score).

An **objective** perceptual speech test method implements a complex algorithm which predicts results expected from subjective tests by applying psychoacoustic and perceptive models to the degraded test signals. The algorithm is verified by comparing

the results to MOS scores obtained in subjective listening tests. A mapping function may be applied for better matching between the objective and subjective MOS scores.

PESQ® and POLQA® are so-called full-reference test methods. They analyze the original (“Reference”) speech signal and the degraded signal and compare attributes extracted from both for obtaining an assessment of the degradation.

POLQA® is standardized in ITU-T P.863 (ITU-T, 09/2014). An application guide is available in ITU-T P.863.1 (ITU-T, 09/2014-1).

## 1.2.2 Loudness ratings

Loudness ratings are perceptive attenuation values for the speech signal in the sending and receiving path of the mobile phone.

The sending sensitivity is measured by comparing the third-octave spectrum of the speech test signal at the network side (output signal) to the spectrum at the mouth reference point (input signal). The receiving sensitivity is obtained by comparing the third-octave spectrum of the sound pressure at the earpiece of the mobile phone (output signal) to the third-octave spectrum of the test signal at the network side (input signal). The loudness ratings are calculated from the sending and receiving sensitivity by applying a psychoacoustically motivated frequency weighting, depending on the transmission direction, and adding the weighted third-octave components according to the psychoacoustic loudness summation.

For details of the sensitivity measurement see ITU-T recommendation P.64 (ITU-T, 11/2007).

For details of the loudness rating calculation see ITU.T recommendation P.79 (ITU-T, 11/2007).

## 1.3 Prerequisites

### 1.3.1 Prerequisites on the R&S®UPV

The R&S®UPV audio analyzer must be equipped with option UPV-K1 (universal sequence controller) and at least one of the options UPV-K61 (PESQ) or UPV-K63 (POLQA) according to the desired evaluation method(s).

### 1.3.2 Prerequisites on the R&S®CMW500

In addition to all hardware and software options for the signaling of the desired radio access technology or technologies the R&S®CMW500 must be equipped with audio board and speech codecs. For voice over LTE (VoLTE) the data application unit (DAU) is also required.

For details on the configuration of the R&S®CMW500 please contact your R&S account manager.

## 1.4 Preparations

### 1.4.1 Installation of the application program

Copy the installer file “1GA69\_xxx.msi” to an appropriate folder on the D: partition of the hard disk of the R&S® UPV audio analyzer, e.g. “D:\R&S Software\Application Programs”. Start the installer and follow the instructions on the screen.

The installer creates shortcuts “Acoustic Check” on the desktop and in folder “R&S UPV Applications” of the programs menu.

### 1.4.2 Configuring a quick launch button for starting the application

This step is optional and simplifies the start of the application program out of the UPV firmware window.

The R&S® UPV audio analyzer offers 8 quick launch buttons which can be utilized either for loading pre-defined setups or for starting pre-defined macros. The quick launch buttons are on the toolbar which is either displayed permanently on top of the UPV window (can be set in “Utilities → Config Panel”) or appears on the right side when the mouse is moved to the right edge of the UPV window.

The assignment of the buttons can be defined in “Utilities → Quick Launch Config ...”:

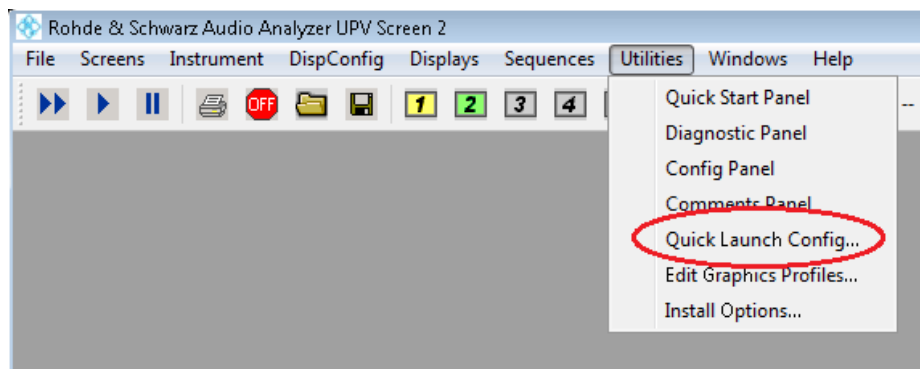


Fig. 1-1: Starting the Quick Launch Config Panel

This menu opens the following configuration panel:

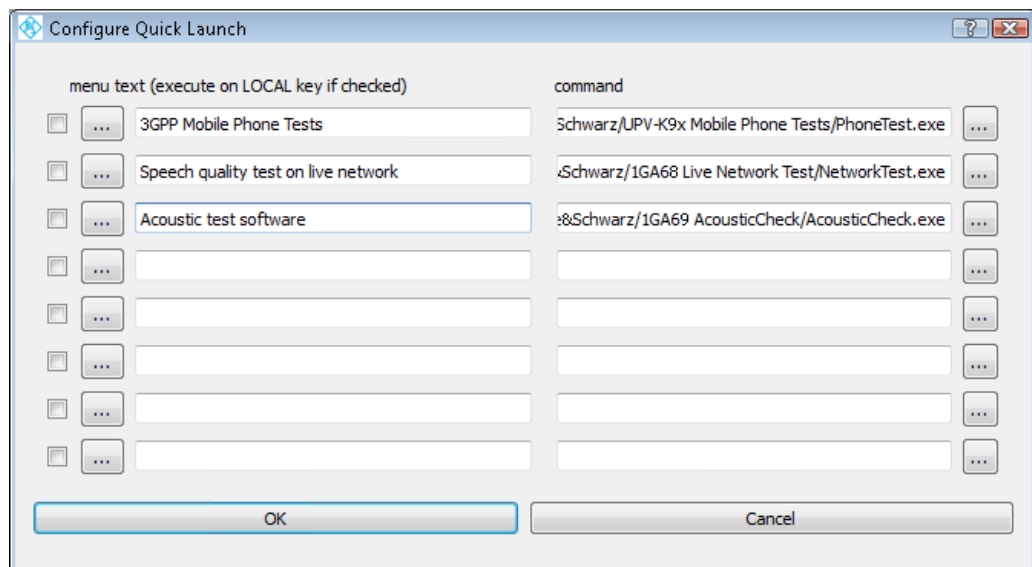


Fig. 1-2: Quick Launch Config Panel

Use the “...” buttons on the right side to browse to the executable “C:\Program Files\Rohde&Schwarz\1GA69 Acoustic Check\AcousticCheck.exe”. The “...” buttons on the left side can be utilized to specify icons on the buttons. Text entered in the text box on the left side will be displayed as tool tip text for the respective button when the mouse cursor hovers over the area of the button.

### 1.4.3 Test setup

The test setup comprises audio analyzer, wideband radiocommunication tester and acoustic test equipment. Artificial ear and artificial mouth can be part of a head-and-torso simulator (HATS) or discrete devices (artificial ear type 3.2 high-leak and artificial mouth according to ITU-T P.51) mounted on a loudness rating guard-ring position (LRGP) test head. A head-and torso simulator provides more realistic frequency response and loudness rating results, whereas the repeatability of results is better with the use of a more abstract type 3.2 high-leak artificial ear.

Note that the test definition 3GPP TS 26.132 for measuring the acoustic performance of GSM, WCDMA and LTE mobile phones mandates the use of a HATS. All modern mobile phones commercially available today are optimized to meet the minimum requirements set forth in 3GPP TS 26.131, using a HATS for the measurement. Furthermore, speech quality tests on acoustic interfaces with ITU-T P.863 require a HATS with diffuse field equalization. Therefore an LRGP test head with artificial mouth according to ITU-T P.51 and artificial ears type 3.2 are regarded in this document as a substitute for a HATS. Diffuse field equalization for POLQA evaluation and DRP-ERP correction for loudness rating calculation in downlink direction are applied as if a HATS were used. Resulting deviation from type approval tests with a HATS have to be taken into account when defining the pass / fail limits.

The test head or HATS, respectively, should be situated in an acoustic enclosure together with the mobile phone under test. The enclosure should be sufficiently anechoic and provide acoustic isolation to the outside. The required attenuation value of the acoustic isolation in the speech frequency range depends on the level of acoustic noise outside.

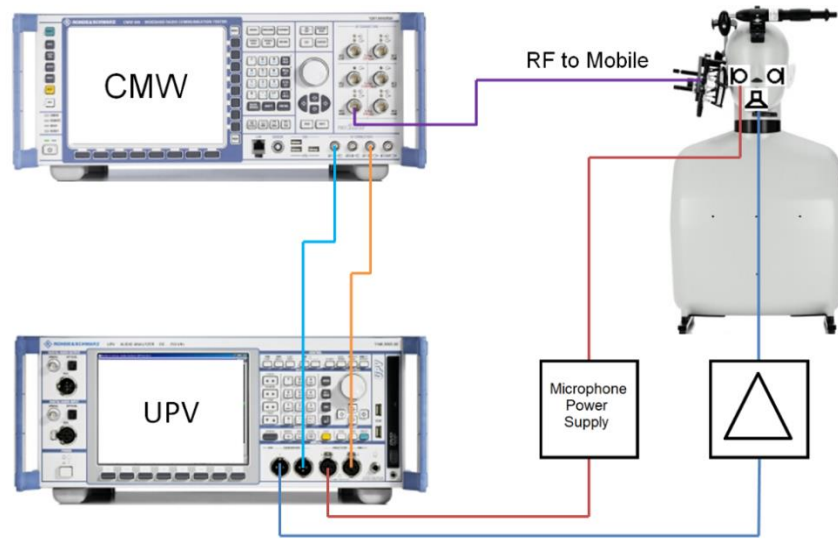


Fig. 1-3: Test setup for acoustic check

## 2 Calibration

This application note describes a test system for checking the functionality of acoustic devices in mobile phones. Besides the R&S®UPV audio analyzer, such a test system comprises acoustic devices like artificial ear, artificial mouth and measurement microphone, as well as R&S®CMW500 wideband radio communication tester.

To achieve correct test signal levels and loudness rating results, calibration of the external components is indispensable. This section describes the calibration steps necessary in preparation for the tests.

Calibration functions are available in the “Calibration” tab of the application program.

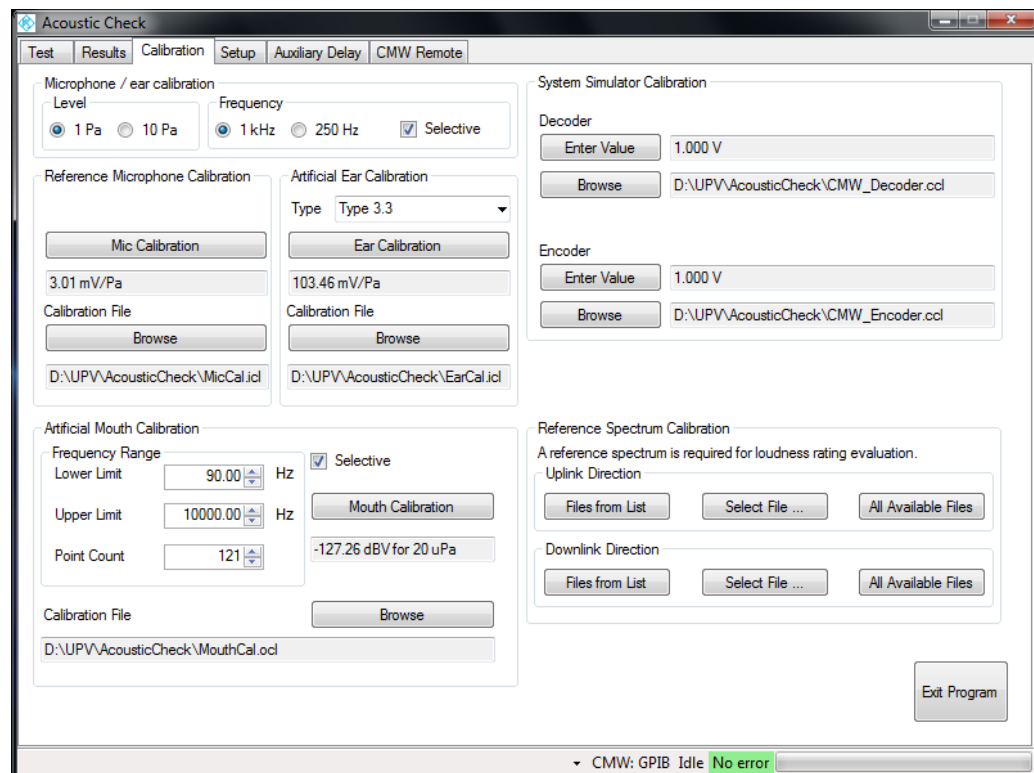


Fig. 2-1: “Calibration” tab of the application program

### 2.1 Calibration of the measurement microphone

A measurement microphone is required for measuring the sound pressure at the mouth reference point (MRP) during calibration of the artificial mouth.

Use a ½” measurement microphone as reference microphone for the calibration of an artificial mouth according to ITU-T P.51. Use a ¼” measurement microphone for the calibration of an artificial mouth according to ITU-P.58 being integral part of a head-and-torso simulator (HATS).

- Insert the measurement microphone fully into the adapter of the sound level calibrator and switch on the calibrator. A ½” adapter or ¼” adapter is required



according to the microphone diameter.



Fig. 2-2: Insertion of a 1/4" measurement microphone into the calibrator with adapter

- Select the acoustic calibration level (1 Pa or 10 Pa) and calibration frequency according to the sound pressure and frequency generated by the acoustic calibrator in use.
- Checkbox "Selective" should be enabled unless the frequency of the sound generated in the acoustic calibrator is neither 1 kHz nor 250 Hz.
- Click the "Mic Calibration" button in the "Reference Microphone Calibration" group box.
- The application program measures the microphone output voltage and calculates the microphone sensitivity according to the calibration level selected in the "Level" group box.
- Specify a name for the file storing the calibration value of the reference microphone and click "Ok".

## 2.2 Calibration of the artificial mouth

- Connect the reference microphone via power supply or conditioning amplifier to UPV analyzer input 1.
- Fix the reference microphone in front of the artificial mouth with the center of the membrane at the Mouth Reference Point (MRP).
  - **Discrete Mouth according to ITU-T P.51**  
Fit the reference microphone at right angles to the mouth at the mouth reference point (MRP) using the gauge consisting of two metal sheets supplied with the mouth. If the reference microphone is a diffuse field type microphone (e.g. B&K 4131 or 4134), it must be positioned at right angle because diffuse field or pressure-calibrated microphones have a flat frequency response with sound from random incident direction and therefore exhibit an emphasis on high frequencies with frontal sound incidence. If the reference microphone is a free field microphone, it must be mounted in the axis of the sound outlet of the artificial mouth.



Fig. 2-3: Position of a diffuse-field or pressure-field measurement microphone for the calibration of the P.51 artificial mouth



Fig. 2-4: Position of a free-field microphone for the calibration of the P.51 artificial mouth

- **HATS Mouth according to ITU-T P.58**  
Clamp the 1/4" reference microphone in the fixture attached to the HATS.

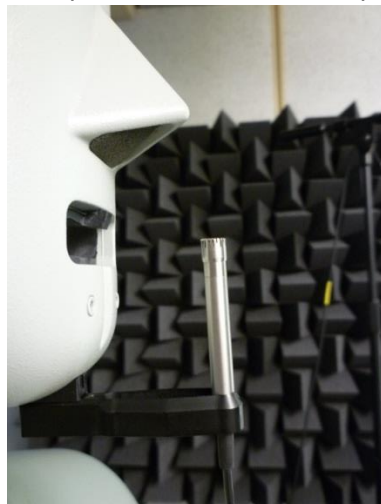


Fig. 2-5: Position of the reference microphone for calibration of the HATS artificial mouth

- Select the calibration frequency range. Minimum for wideband telephony is 100 Hz to 8000 Hz.
- Checkbox “Selective” should be enabled in order to improve immunity against acoustic background noise in the test box.
- Click the “Mouth Calibration” button.
- The application program measures the sensitivity of the loudspeaker of the artificial mouth and the frequency response at -4.7 dBPa. The inverse frequency response is applied as equalization and the equalized frequency response is measured again. The equalization is updated with the inverse deviation from this measurement, and the equalized frequency response is measured once more as final check.
- Specify a name for the file storing the calibration value of the artificial mouth and click “Ok”.

## 2.3 Calibration of the artificial ear

Before starting the calibration of the artificial ear, select the type of artificial ear in the “Type” combobox of the “Artificial Ear Calibration” group box.

### 2.3.1 Artificial ear type 3.2

- Connect the microphone of the artificial ear to R&S®UPV analyzer input 1 via a microphone power supply or conditioning amplifier.
- Set the “Type” combobox to the type of artificial ear in use.
- Connect the sound level calibrator tightly to the artificial ear using the adapter DP0939 and switch on the calibrator.

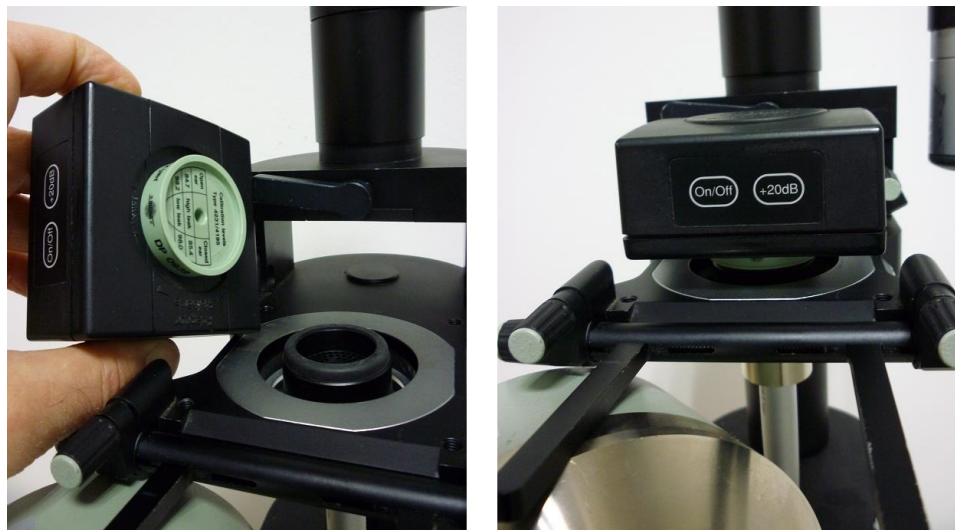


Fig. 2-6: Mounting of the calibration with adapter part DP0939 on the type 3.2 artificial ear

- For calibrators providing a sound pressure level of 114 dB (10 Pa), the “10Pa” radiobutton must be checked. In all other cases the “1 Pa” radiobutton must be checked.
- Click the “Ear Calibration” button.
- The output voltage of the microphone in the ear is measured and the sensitivity displayed with reference to 1 Pa. If the voltage measured is below 3 mV or fluctuating by more than 0.2 dB, an error message is displayed. Possible error sources are, for example, a switched-off microphone power supply or a disabled calibrator. In this case, the program requests that the test be repeated. After switching on the microphone power supply, wait approx. 20 s before restarting the calibration.
- Specify a name for the file on the hard disk in which the measured reference value is stored.

### 2.3.2 Artificial ear type 3.3

- Connect the microphone of the artificial ear to R&S®UPV analyzer input 1 via a microphone power supply or conditioning amplifier.
- Set the “Type” combobox to the type of artificial ear in use.
- Remove the pinna from the artificial ear according to the manufacturer’s instructions

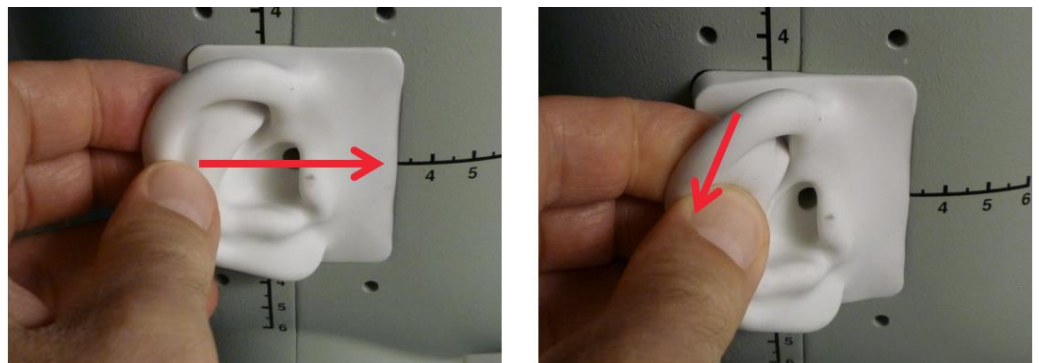


Fig. 2-7: Removal of the pinna for calibration of the artificial ear type 3.3

- Connect the sound level calibrator tightly to the artificial ear using the adapter UA-1546 and switch the calibrator on.

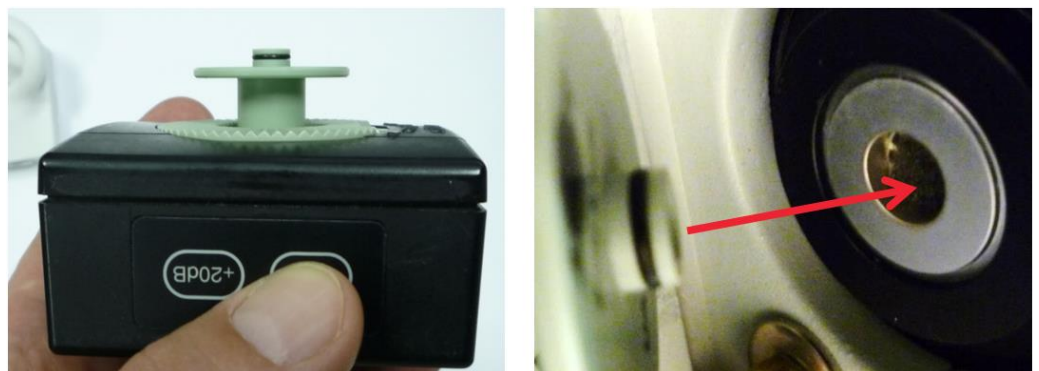


Fig. 2-8: Insertion of the calibrator with adapter part UA-1546 into the ear simulator

- Click the “Ear Calibration” button.
- The output voltage of the microphone in the ear is measured and the sensitivity displayed with reference to 1 Pa. If the voltage measured is below 3 mV or fluctuating by more than 0.2 dB, an error message is displayed. Possible error sources are, for example, a switched-off microphone power supply or a disabled calibrator. In this case, the program requests that the test be repeated. After switching on the microphone power supply, wait approx. 20 s before restarting the calibration.
- Specify a name for the file on the hard disk in which the measured reference value is stored.

## 2.4 Calibration of CMW audio input and output levels

Click the “Enter Value” button for the decoder calibration and enter the full-scale peak output voltage set in the audio measurement of the R&S®CMW500.

Specify a name for the file on the hard disk in which the value is stored.

Click the “Enter Value” button for the encoder calibration and enter the full-scale peak input voltage set in the audio measurement of the R&S®CMW500.

Specify a name for the file on the hard disk in which the value is stored.

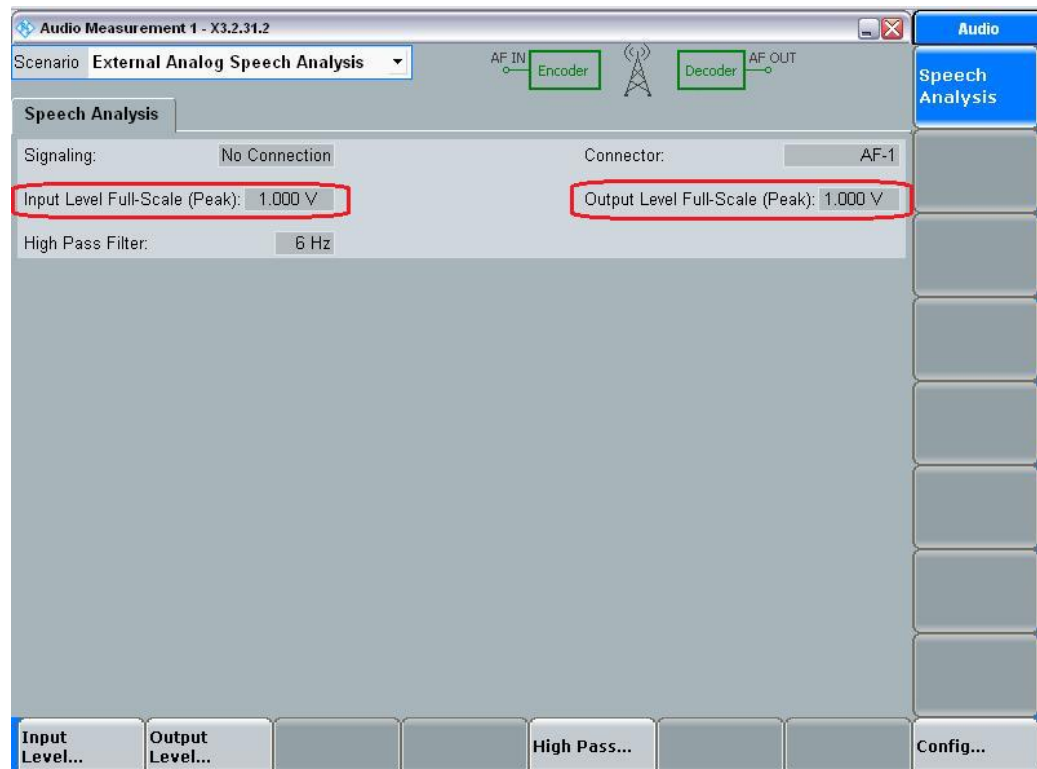


Fig. 2-9: Audio measurement window of the R&S®CMW500

## 2.5 Reference spectrum calibration

The sensitivity measurement on which the loudness rating calculation is based, requires the spectrum at the input of the transmission path as reference.

For each speech signal the reference spectrum has to be analyzed twice, at the mouth reference point for uplink and at the speech coder input for downlink.

Each reference spectrum calibration can be performed for all files in the signal list, for a single file select by a file dialog, and for all files present in the working directory.

### 2.5.1 Uplink

For the uplink reference spectrum calibration an appropriate measurement microphone has to be placed at the mouth reference point and connected to UPV analyzer input 1 via a power supply or conditioning amplifier.

Regarding the placement of the reference microphone depending on the type of the artificial mouth, see 2.2.

After the measurement microphone has been placed and connected, click one of the buttons "Files from List", "Select File" or "All Available Files" in the Uplink group box.

### 2.5.2 Downlink

The downlink reference spectrum calibration just analyzes the file content and does not require any preparations on the test setup.

Click one of the buttons "Files from List", "Select File" or "All Available Files" in the Downlink group box.

## 3 Test Configuration

### 3.1.1 CMW remote control

CMW remote control is used for automatically obtaining the MEID (IMEI) number of the mobile phone under test from the protocol of the mobile connection.

The CMW remote control connection can be configured and established in the “CMW Remote” tab.

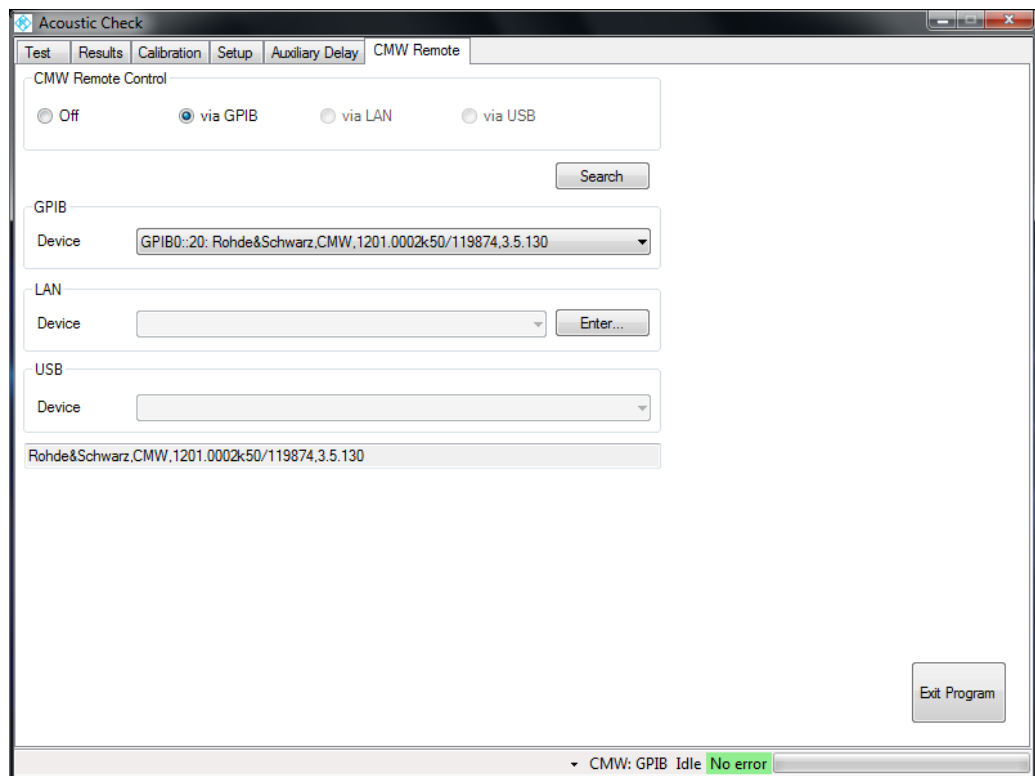


Fig. 3-1: “CMW Remote” tab of the application program

A remote control connection to the R&S®CMW500 can be established via GPIB, LAN or USB interface.

To find available devices on GPIB and USB, the “Search” button initiates a VISA search for available CMW instruments. The combo boxes in the respective group boxes allow the selection of the desired individual instrument.

For a LAN connection, find the IPv4 address of the R&S®CMW500 using the “IPCONFIG” command in a DOS command box on the R&S®CMW500 and enter it in the application program, using the “Enter” button in the “LAN” group box.

After successful establishing the remote control connection, the ID string of the selected R&S®CMW500 is displayed in the text box on bottom.

### 3.1.2 Auxiliary delay measurements

An auxiliary delay measurement is performed once for uplink and once for downlink for each measured mobile phone. The resulting end-to-end delay value is used for synchronizing the aperture of the acquisition in the audio analyzer with the time of arrival of the signal at the analyzer input.

The parameter of the auxiliary delay measurement can be modified in the “Auxiliary Delay” tab of the user interface.

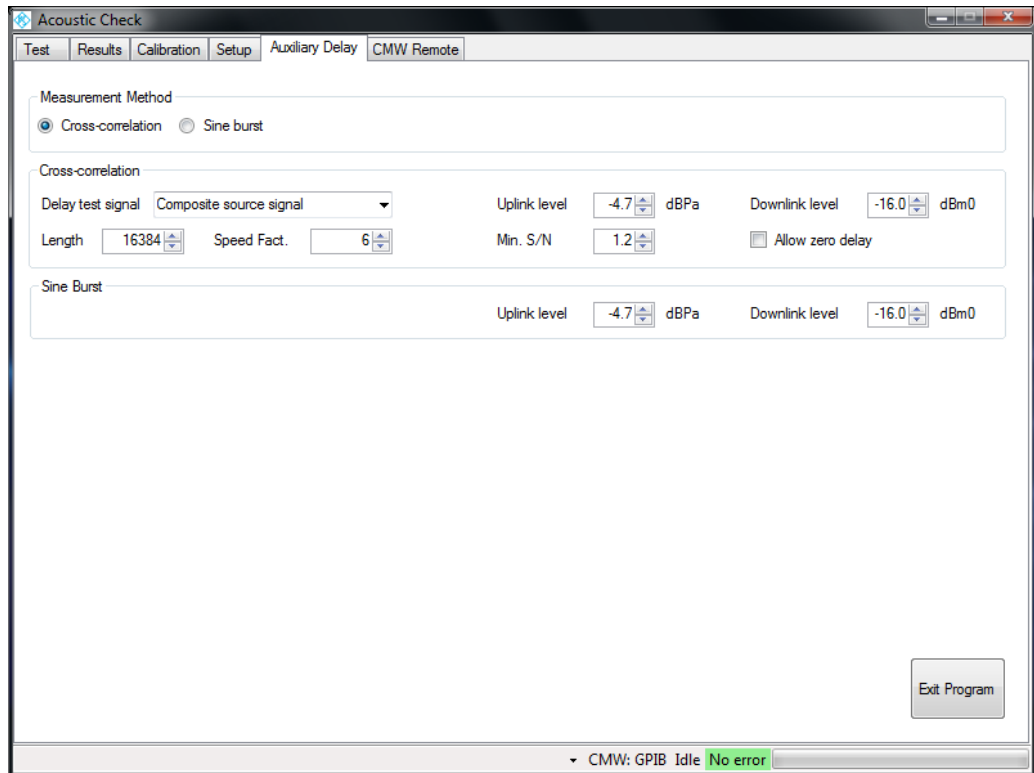


Fig. 3-2: Auxiliary Delay tab of the application program

It is recommended to keep the default settings of the parameters, unless the auxiliary delay measurement fails due to certain circumstances like a special speech codec.

The delay can be measured with cross-correlation or with a sine burst and a level threshold.

For the cross-correlation method there are two test signals available, an artificial composite source signal which consists of a voiced part with a periodic signal and a pseudo-random noise part. For the cross-correlation operation the calculation length and speed factor (undersample factor) can be modified. Both factors influence the calculation effort and the noise immunity. The speed factor also influences the resolution of the result.

The signal to noise (S/N) is the ratio between the amplitude of the highest cross-correlation peak and the amplitude of the second-highest cross-correlation peak. The “Min. S/N” value determines which results are regarded as valid. In case of an invalid delay result the measurement will terminate with an error message.



“Allow zero delay” should only be checked if the measurement is performed on a (cable) connection from UPV generator to UPV analyzer without propagation delay. If this checkbox is not checked, a delay result of 0 ms is regarded as invalid.

### 3.1.3 Setup tab

The setup tab allows configuration of test signals to be used, evaluation type etc., and limits as pass / fail criteria.

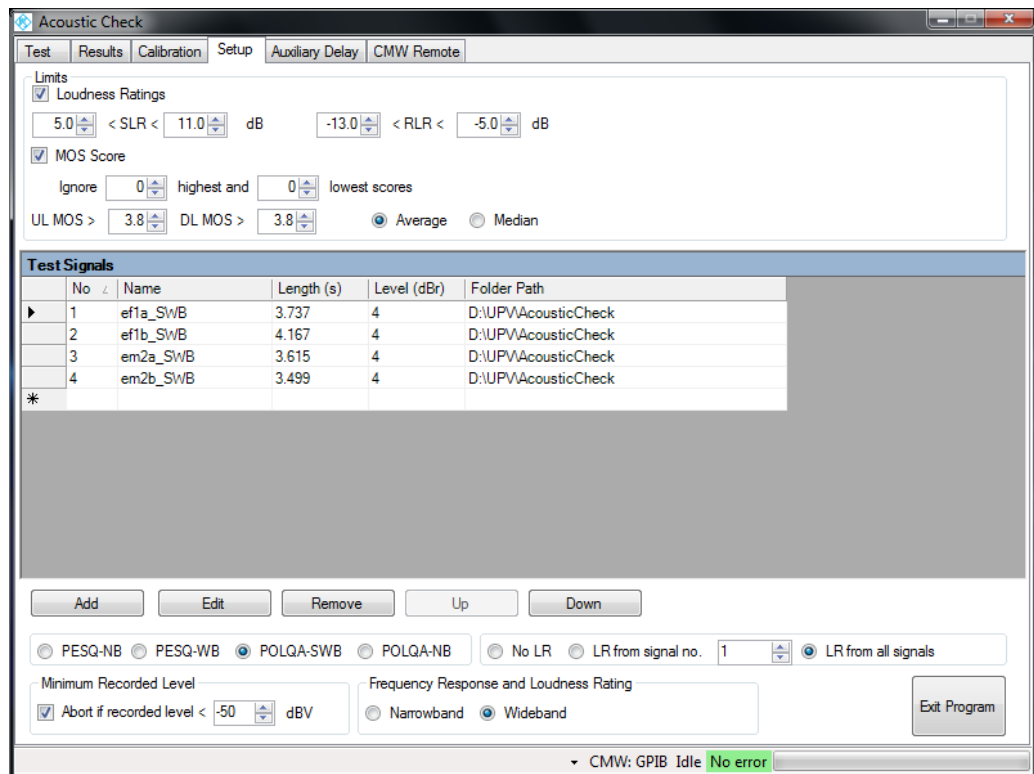


Fig. 3-3: Setup tab of the application program

Upper and lower limits can be set separately for sending loudness rating and receiving loudness rating.

The MOS scores from all speech files in the list can be statistically evaluated by ignoring a specified number of highest scores and a specified number of lowest scores, and calculating the average or median of the remaining scores. This statistic result can be subject to a minimum check. The lower limit can be specified separately for each direction.

For the speech quality evaluation PESQ in NB or WB mode and POLQA in NB and SWB mode can be applied. Note that a correct rating of acoustic impairments can only be obtained with the SWB mode of POLQA. PESQ and the NB mode of POLQA have not been trained and evaluated for this purpose.

Finally the sensitivity and loudness rating calculation can be either omitted, or one of the test signals can be evaluated or all. Evaluation is available either in narrowband or wideband mode.

## 4 Test execution

The test tab of the application program provides controls for entering DUT information, starting tests and displaying results.



**Fig. 4-1: Test tab of the application program**

In the “Operator” group box, the name of the operator can be entered to be stored in the protocol in connection with result data.

Manufacturer number, model and mobile equipment ID can be entered in the “Device under Test” group box. The “Keep” checkbox can be activated in order to re-use the manufacturer and model entry for a number of devices tested subsequently.

If the “Import MEID from CMW” checkbox is activated, the MEID is queried in the beginning of each test through remote control from the R&S®CMW500.

Tests can be started in the “Test Control” group box either for the uplink direction or for the downlink direction or for both. The tests will be performed with the signals from the signal list and the settings from the “Setup” tab.

## 5 Results

The “Results” tab gives an overview over available results.

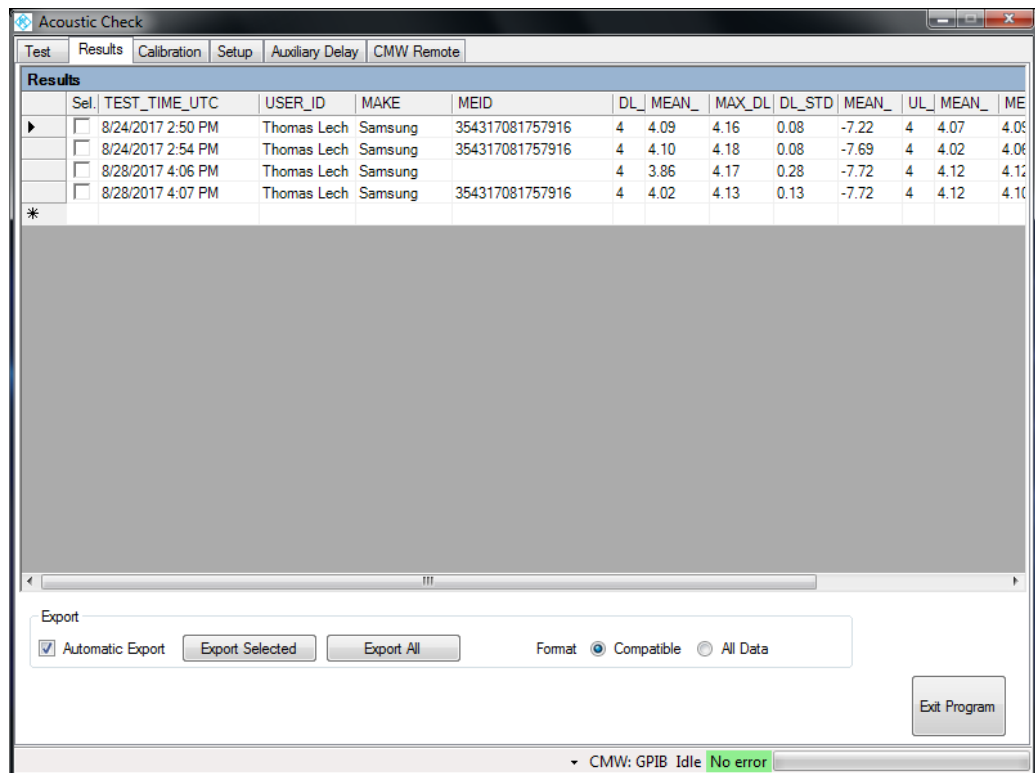


Fig. 5-1: Results tab of the application program

Results from the overview can be exported to ASCII files (comma-separated .csv files or tab-separated .txt files) in two different formats. If “Automatic Export” is activated, the result of each test is immediately appended to an existing ASCII file.

Shows the table columns of the “All Data” format.

TEST_TIME_UTC
MEID
Model
Manufacturer
Operator
Date Time
Verdict
UL MOS Verdict
SLR Verdict
DL MOS Verdict
RLR Verdict
Count
Mean SLR
Mean RLR
Mean UL MOS
Mean DL MOS
Median UL MOS
Median DL MOS
UL Std. Dev.
DL Std. Dev.
SLR
RLR
UL MOS
DL MOS
Max. UL MOS
Max. DL MOS

Fig. 5-2: Table columns of the ASCII export file in “All Data” format.

## 6 Literature

- [1] **ITU-T** Application guide for Recommendation ITU-T P.863 // P.863.1. - Geneva : ITU, 09/2014-1.
- [2] **ITU-T** Artificial Mouth // P.51. - Geneva : ITU, 08/96.
- [3] **ITU-T** Calculation of loudness ratings for telephone // P.79. - Geneva : ITU, 11/2007.
- [4] **ITU-T** Determination of sensitivity/frequency characteristics of local telephone systems // P.64. - Geneva : ITU, 11/2007.
- [5] **ITU-T** Head and torso simulator for telephonometry // P.58. - Geneva : ITU, 05/2013.
- [6] **ITU-T** Perceptual evaluation of speech quality (PESQ): An objective method for end-to-end speech quality assessment of narrow-band telephone networks and speech codecs // P.862. - Geneva : ITU, 02/2001.
- [7] **ITU-T** Perceptual objective listening quality assessment // P.863. - Geneva : ITU, 09/2014.

## 7 Ordering Information

Designation	Type	Order No.
Audio analyzer	R&S®UPV	1146.2003.02
Universal sequence controller	R&S®UPV-K1	1401.7009.02
Speech quality measurement PESQ	R&S®UPV-K61	1401.7309.02
Listening quality analysis POLQA	R&S®UPV-K63	1402.1156.02
Wideband Radio Communication Tester	R&S®CMW500	1201.0002K50

## Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries.

The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

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## Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership



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