

Calibration Tool for PESQ Speech Quality Tests Application Note

Products:

R&S®UPV	R&S®UPV-K61
R&S®UPV66	R&S®UPL-Z1
R&S®UPV-K1	R&S®CMU200

PESQ® measurements employ a level adaptation algorithm and are hence widely insensitive to absolute level. However, if the tests are performed via a speech codec, the driving level of the codec has an influence on the MOS result. Therefore careful alignment of the level is required. This application note provides an application program which runs on the Audio Analyzer R&S®UPV or R&S®UPV66 and can be used to calibrate signal levels for the PESQ® measurement.

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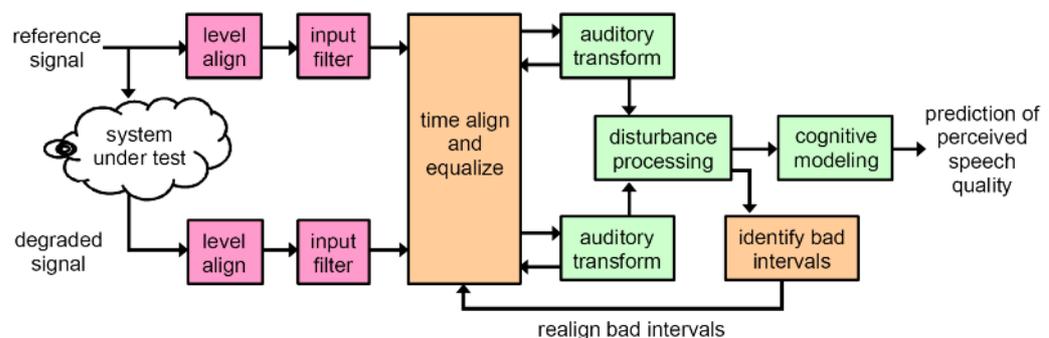
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1 PESQ® Measurements

1.1 Perceptual Evaluation of Speech Quality

“Perceptual evaluation of Speech Quality” (PESQ®¹) is a psychoacoustic evaluation method for determining the degree of degradation in speech transmission. It is standardized in ITU-T P.862.

The method compares the degraded signal at the output of the transmission chain to the original signal at the input. An overview over the algorithm is given in Fig. 1.



First, the absolute level of each signal is normalized. After initial filtering simulating the typical telephone sending response, delays between the signals are eliminated and the average overall spectrum of the degraded signal is equalized to be the same as that of the original signal. After that, both signals are divided into sub-intervals which are subject to frequency transform to yield a series of spectra over time. The scales of the spectra are transformed to psychoacoustic units. The frequency scale is transformed into the pitch scale and the power scale is transformed into the loudness scale. The comparison of these spectra leads to a series of quality figures over time, which is summarized to a single number, the PESQ® raw score.

In order to obtain results which are comparable to the MOS (“Mean Opinion Score”) values of listening tests, the PESQ® score values are re-scaled using a scaling function defined in ITU-T P.862.1. The result of this re-scaling is called the PESQ® MOS-LQO.

A detailed application guide is available in ITU-T P.862.3. ITU-T P.862.2 defines a variant of the algorithm for wideband telephony (approx. 7 kHz bandwidth).

1.2 PESQ® on the R&S® Audio Analyzer UPV

The PESQ® algorithm according to ITU-T P.862 is available on the R&S® Audio analyzer UPV, called herein below “UPV”, as keycode option UPV-K61. A description of all parameters is given in the current manual of the UPV. A detailed application guide is available in application note 1GA49.

¹ PESQ® is a registered trademark of OPTICOM Dipl.-Ing. M. Keyhl GmbH, Germany and of Psytechnics Ltd., UK

1.3 Signal level and PESQ

Due to the level alignment, the PESQ® algorithm itself is rather insensitive to absolute levels. Despite this fact, the signal level on the transmission path under test may heavily influence the PESQ® result. Overdriving the transmission path causes degradation by clipping. A low level on the transmission path may cause degradation by noise. In particular in cases where speech codecs, noise suppression and other signal processing is involved, a reproducible signal level on the transmission path may be prerequisite for reproducible PESQ® results.

This application note provides an application program which runs on the Audio Analyzer R&S®UPV or R&S®UPV66 and can be used to calibrate signal levels for the PESQ® measurement. For the R&S® Universal Radio Communication Tester CMU200, called herein below “CMU”, calibration routines are provided which make use of the “Decoder Cal” and “Encoder Cal” functions. For loopback measurements and equipment other than the CMU, a so-called “In / Out – Calibration” is provided which determines approximate full-scale input and output levels of the transmission path from the saturation point of the input-output curve.

The application program allows to load a prepared setup and enter the generator reference value and analyzer range according to the determined full-scale values. Furthermore it allows to specify a test signal and the test signal level relative to the reference.

2 Using the Application Program

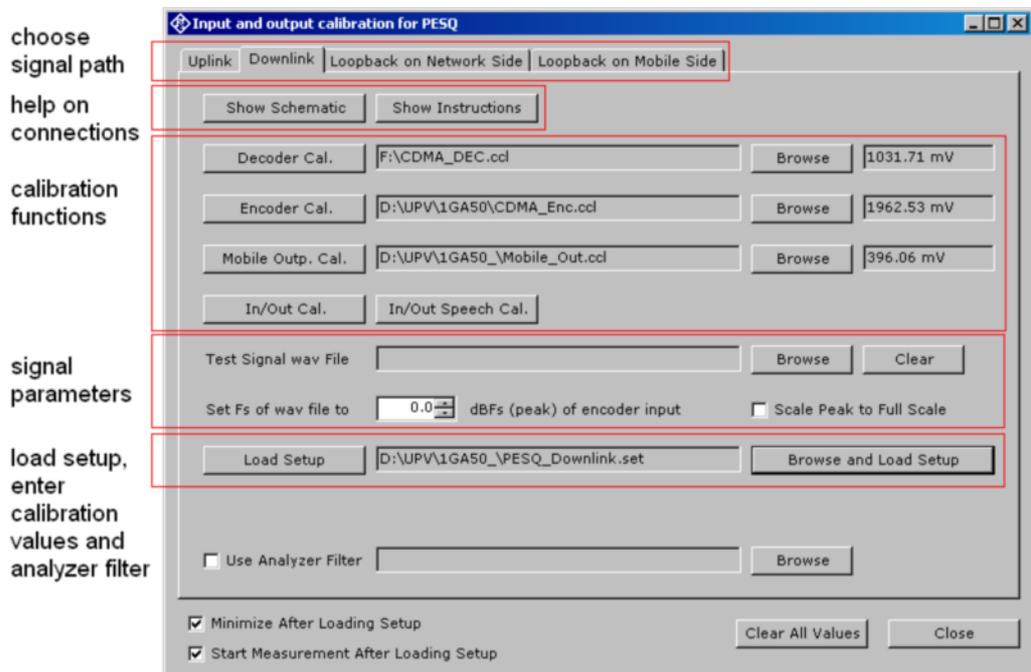
2.1 Installation

Copy the installer “1GA50.msi” to the UPV hard disk, e.g. to “D:\R&S Software”, and start the installer. Follow the instructions on the screen.

The installer creates the program directory “C:\Program Files\Rohde&Schwarz\1GA50” with all required files. Furthermore the installation creates shortcuts on the desktop and in subfolder “R&S UPV Applications” in the program menu.

Upon the first start of the program, a subdirectory “1GA50” will be created in “D:\UPV\User” which contains all related user data like UPV setups, program settings and files with calibration data.

2.2 User Interface



The main window of the application program provides four tabs according to the four transmission types “uplink”, “downlink”, “Loopback on Network Side” and “Loopback on Mobile Side”. Each tab provides the appropriate calibration functions for the respective transmission type.

Two help buttons on each tab give instructions in schematic and in text how to set up the connections.

The next section of the user interface provides a row for each required calibration value. The value, if available, is shown on the respective right end. The buttons on the left end start the required calibration routines. In the center, a textbox shows the name of the file which stores the current calibration value. Stored values can be loaded using the "Browse" buttons.

Another section follows which allows to specify a wave file to be used as test signal file, and the full-scale value of the wave file relative to the determined full-scale value of the signal path input.

The last section in each tab handles the setup to be used for the test. The text box in the center shows the file name. With the "Load Setup" button, the setup is loaded to the UPV, the generator reference value, signal file name and voltage value are entered and the analyzer range is set appropriately. To load a setup from a file different from the one shown in the text box, use the "Browse and Load Setup" button.

The two checkboxes below the tabs allow to automatically minimize the window of the application program after the setup has been loaded, and/or to start a (single) measurement immediately afterwards.

The program memorizes all settings and calibration values in a special file from where they are loaded when the program starts. The button "Clear all Values" can be used to clear the settings and calibration values in all tabs.

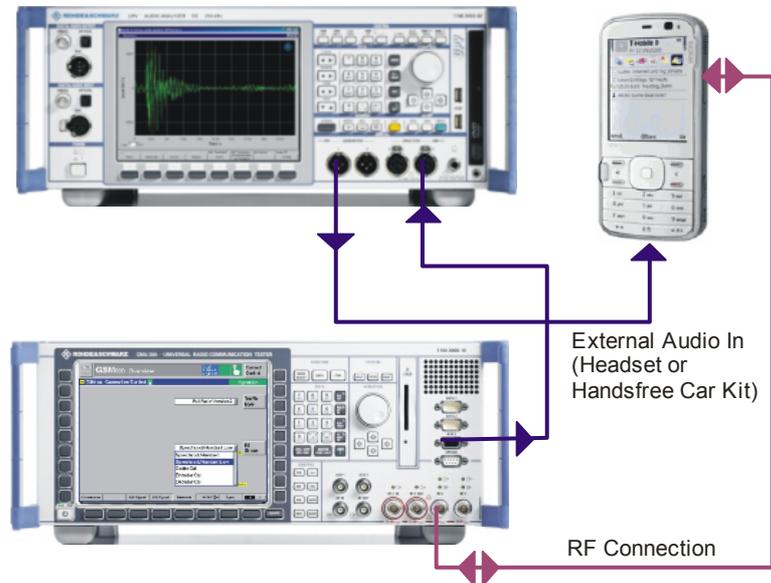
2.3 Choosing a signal Path

Besides the traditional transmission directions "uplink" (also called "sending", seen from the mobile phone's point of view) and "downlink" (also called "receiving"), the application program also handles setups with loopback of the signal. The loopback may be established on the network side (CMU) or on the mobile side.

In the following section, the connections and settings are described for use of the CMU as network interface. Each transmission direction requires an RF connection between CMU and mobile phone.

In other situations other equipment may be connected in a similar matter.

2.3.1 Uplink



Connect:

- UPV generator output 1 to mobile input (headset or handsfree car kit connector)
- CMU speech output to UPV analyzer input 2, using link handler cable 1117.4082.00

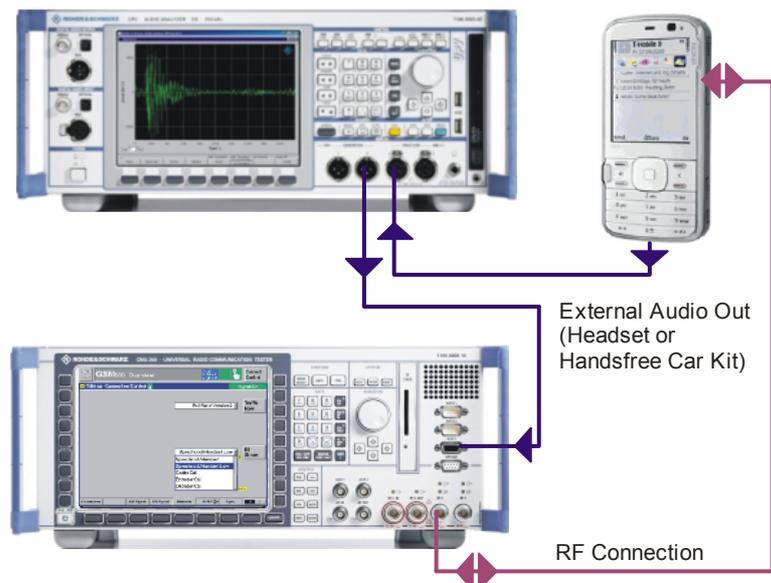
Use adapter 1117.4124.00 for link handler 2 if required.

Establish call from the CMU to the mobile.

For the PESQ measurement set the speech coder to "Handset Low".

For the calibration functions follow the instructions on the screen.

2.3.2 Downlink



Connect:

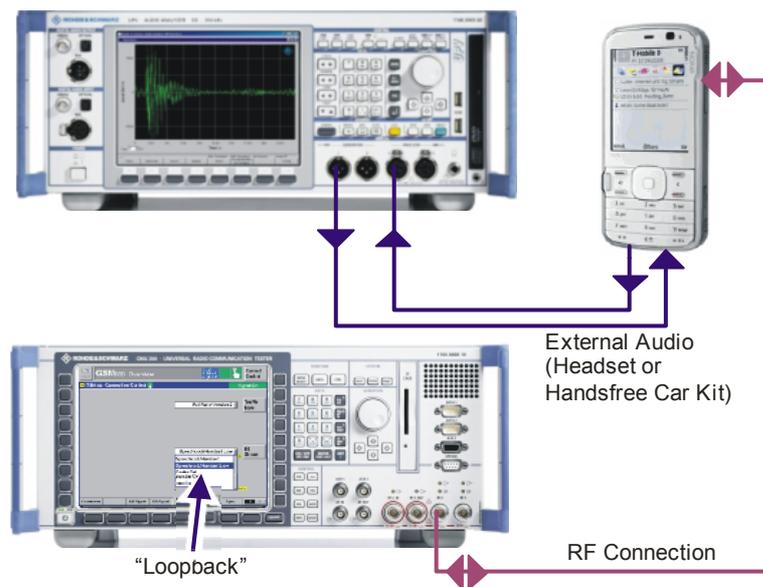
- UPV generator output 2 to CMU speech input, using link handler cable 1117.4082.00
Use adapter 1117.4124.00 for link handler 2 if required.
- mobile output (headset or handsfree car kit connector) to UPV analyzer input 1

Establish call from the CMU to the mobile.

For the PESQ[®] measurement set the speech coder to "Handset Low".

For the calibration functions follow the instructions on the screen.

2.3.3 Loopback on the Network Side



Connect:

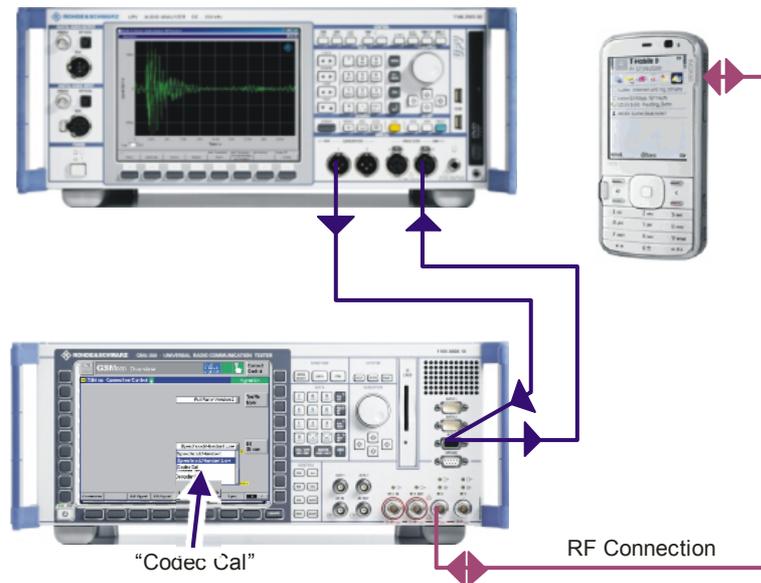
- UPV generator output 1 to mobile input (headset or handsfree car kit connector)
- mobile output (headset or handsfree car kit connector) to UPV analyzer input 1

Establish call from the CMU to the mobile.

For the PESQ[®] measurement set the speech coder to "Loopback".

For the calibration functions follow the instructions on the screen.

2.3.4 Loopback on the Mobile Side



Connect:

- UPV generator output 2 to CMU speech input, using link handler cable 1117.4082.00
- CMU speech output to UPV analyzer input 2, using link handler cable 1117.4082.00

Use adapter 1117.4124.00 for link handler 2 if required.

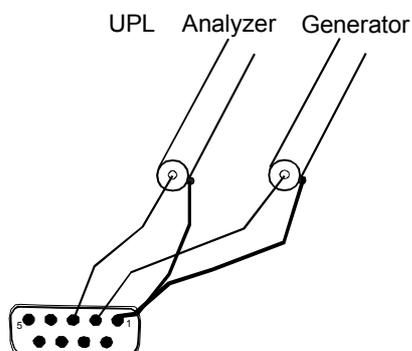
Establish call from the CMU to the mobile.

For the PESQ[®] measurement set the speech coder to "Codec Cal".

For the calibration functions follow the instructions on the screen.

2.3.5 Connection Cable between UPV and CMU Speech Connector

A cable with male (analyzer) and female (generator) XLR connector is required for connection of the UPV to the "Speech" connector of the Digital Radio Communication Tester CMU. The schematic is as shown below:



Instead of XLR connectors, BNC connectors can be used in connection with UPL-Z1 XLR-to-BNC adapters.

The cable as shown is configured for connection to link handler #1 in the CMU. Depending on the CMU hardware, link handler #2 in the CMU can also be used for GSM; in this case, pin 5 of the DB9 connector has to be connected to the UPV generator instead of pin 2, and pin 6 of the dB connector has to be connected to the UPV analyzer instead of pin 3.

The described cable (part no. 1117.4082.00) and an adapter for link handler #2 (part no. 1117.4124.00) is enclosed in option UPV-K9 (Base SW for mobile phone tests).

2.4 Calibration Functions

start calibration	calibration file name	load calibration value from file	calibration value
Decoder Cal.	F:\CDMA_DEC.ccl	Browse	1031.71 mV
Mobile Input Cal.	D:\UPV\1GA50\CDMA_MobileIn.ccl	Browse	92.19 mV
M. I. Speech Cal.	Calibration Level <input type="radio"/> -16 dBm0 <input checked="" type="radio"/> -26 dBm0		
In/Out Cal.	In/Out Speech Cal.		

mobile input calibration using speech signal overall calibration function based on in-out curve speech level to be adjusted

For each signal path, the appropriate calibration functions are displayed.

2.4.1 Decoder Calibration

This calibration value is required for uplink measurements, for the encoder calibration and mobile input calibration routines and for measurements with loopback on the mobile side.

For decoder calibration, the application program measures the peak full-scale output of the speech decoder circuit on the network side (CMU), which is connected to UPV analyzer input 2. The CMU must be set to "Decoder Cal" (in GSM "Traffic Mode" on the "Network" tab, in WCDMA "Voice Settings → Voice Source" in the "BS Signal" tab, in CDMA2000 "Primary Service Class → Speech Service → Service Option 3 → Voice Coder" in the "Service Cfg." Tab). This operation mode requires an active call to the mobile under test. In other setups, the analog output on the network side must be configured to output a full-scale 2 kHz sinewave signal.

If the "Decoder Cal" button in the application program is clicked, the measurement routine starts. In case of an instable measurement result, a warning message is output, and the routine is aborted without storing the result. If a stable result is obtained, a file selector allows to choose an appropriate location and file name. The working directory "D:\UPV\1GA50" should be the preferred location for these files.

The decoder calibration value is alternatively obtained with the "In / Out Calibration" routines of uplink or loopback on the mobile side.

2.4.2 Encoder Calibration

This calibration value is required for downlink measurements and for measurements with loopback on the mobile side. A valid decoder calibration value is prerequisite for the calibration routine.

For encoder calibration, the application program adjusts the voltage at output 2 of the UPV generator to the encoder circuit on the network side (CMU) such that the full-scale decoder output voltage is measured at UPV analyzer input 2. The CMU must be set to "Encoder Cal" (in GSM "Traffic Mode" on the "Network" tab, in WCDMA "Voice Settings → Voice Source" in the "BS Signal" tab, in CDMA2000 "Primary Service Class → Speech Service → Service Option 3 → Voice Coder" in the "Service Cfg." Tab). This operation mode requires an active call to the mobile under test. In other setups, the analog output on the network side must be configured to loop back the signal from the input to the output with a gain of 1.

If the "Encoder Cal" button in the application program is clicked, the measurement routine starts. If the full-scale decoder output voltage cannot be adjusted, a warning message is output, and the routine is aborted without storing the result. If a stable result is obtained, the routine additionally measures the full-scale output voltage from the electric interface of the mobile. File selectors allow to choose appropriate location and file names for both result values. The working directory "D:\UPV\1GA50" should be the preferred location for these files.

The encoder calibration value is alternatively obtained with the "In / Out Calibration" routines of downlink or loopback on the mobile side.

2.4.3 Mobile Input Calibration

This calibration value is required for uplink measurements and for measurements with loopback on the network side. A valid decoder calibration value is prerequisite for the calibration routine.

For mobile input calibration, the application program adjusts the voltage at UPV generator output 1 to the mobile under test such that the full-scale decoder output voltage is measured at UPV analyzer input 2. The CMU must be set to "Handset Low" in GSM ("Traffic Mode" on the "Network" tab), to "Speechcodec Low" in WCDMA ("Voice Settings → Voice Source" in the "BS Signal" tab) and to "8k Enhanced (Low)" in CDMA2000 ("Primary Service Class → Speech Service → Service Option 3 → Voice Coder" in the "Service Cfg." Tab), respectively. This operation mode requires an active call to the mobile under test. In other setups, the analog output on the network side must be configured to provide a signal connection from the mobile under test to the network output.

2.4.3.1 Mobile Input Cal.

When the “Mobile Input Cal” button in the application program is clicked, the measurement routine for mobile input level calibration with sine signal starts. If the full-scale decoder output voltage cannot be adjusted, a warning message is output, and the routine is aborted without storing the result. If a stable result is obtained, a file selector allows to choose an appropriate location and file name for the result value. The working directory “D:\UPV\1GA50” should be the preferred location for these files.

The mobile input calibration value is alternatively obtained with the “In / Out Calibration” routines of downlink or loopback on the mobile side.

2.4.3.2 M. I. Speech Cal.

For codecs which do not transmit a sinewave signal with sufficient fidelity, this button provides a calibration method using natural speech. The RMS level sent from UPV generator output 1 to the mobile input is adjusted such that the CMU decoder output connected to UPV analyzer input 2 corresponds to the dBm0 level selected in the “Calibration Level” field. The standard speech level is -16 dBm0. However, some mobiles with low sending sensitivity or with dynamic compression algorithms do not allow to reach this level. In this case the calibration level of -26 dBm0 can be used. This level is expected to be within the linear operating range of the uplink path.

2.4.4 In / Out Calibration

For each transmission direction, an “In / Out Calibration” routine is offered for the case that the network interface is not accessible (loopback on the network side), or does not provide the “Encoder Cal” and “Decoder Cal” routines.

In the case of uplink or loopback on the network side, the input of the transmission path in the electric input of the mobile under test, connected to UPV generator output 1. In case of downlink and loopback on the mobile side, the input of the transmission path is the speech coder input on the network side (CMU), connected to UPV generator output 2.

In case of uplink or loopback on the mobile side, the output of the transmission path is the speech decoder output on the network side (CMU), connected to UPV analyzer input 2. In case of downlink or loopback on the network side, the output of the transmission path is the electric output of the mobile under test, connected to UPV analyzer input 1.

The “In / Out Cal.” Button starts the calibration routine. A pulsed 1 kHz tone is swept in amplitude, starting from a high voltage which is gradually decreased. In an ideal case, the curve of output level (logarithmic scale of the output voltage) over input level exhibits an almost horizontal branch at high levels due to the saturation of the transmission path and a diagonally rising branch at medium levels. Full-scale input and output voltage can be determined from the intersection point of the asymptotes of both branches.

If the calibration routine is successful, file selectors allow to choose appropriate location and file names for both result values. The working directory “D:\UPV\1GA50” should be the preferred location for these files.

Also the In / Out calibration is provided in two versions: with pulsed sinewave and with natural speech as test signal.

2.4.5 Loading Calibration Values from File

The “Browse” button in each calibration line allows to load previously stored calibration values for each calibration type. The file name of the loaded value is entered in the text box in the center of the line. If the application program is ended, all calibration values and file names are stored in a file and reloaded at the next start of the application program.

2.5 Loading a Setup and Starting a Measurement

2.5.1 Configuring the Test Signal

The application program allows to specify an appropriate wave (*.wav) file as test signal for the PESQ[®] test. The file must have a sample rate of 8 or 16 kHz for narrowband tests (all settings according to P.862 and P.862.1) and 16 kHz for wideband (all settings according to P.826.2). The specified wave file should contain speech signal with approximately 8-10 seconds length.

The test signal file can be selected after clicking the “browse” button in the respective line. The name of the selected file is entered in the text box in the center of the line. If no file name is specified (empty string in the text box), no wave file is loaded to the UPV setup which means that the wave file specified in the loaded setup will be used. The textbox can be cleared using the “Clear” button on the right end of the line.

The full-scale level of the test signal relative to the full-scale level at the input of the transmission path under test is specified in the numeric up/down control in the next line of the user interface. If the wave file is not normalized (i.e. the full-scale value is not reached in the wave file), the specified full-scale value will not be reached at the UPV generator output. The wave file can be normalized in the UPV generator after loading by activating the checkbox “Scale Pk to FS” in the UPV setup to be loaded.

If the test signal has a high crest factor, a full-scale generator output voltage higher than the full-scale input voltage of the transmission path under test (i.e. positive level difference in the numeric up/down control) may be required for optimal PESQ result. In this case the positive effect of the higher average level has more influence than the detrimental effect of temporal clipping at the signal peaks.

2.5.2 Choosing an equalizer filter

For uplink and loopback on the network side a filter can be loaded to the generator for approximate equalization of a speaker response, e.g. in case an artificial mouth is used to send the signal to the microphone of the mobile under test.

For downlink and loopback on the network side another filter can be loaded to the analyzer for DRP-ERP correction of an artificial ear or for diffuse field or free field equalization of a head-and-torso simulator (HATS).

Click the associated “Browse” button to specify the desired filter file, which will automatically be loaded after a setup has been loaded. In folder “D:\UPV\1GA50” some equalization filters are provided for the HATS. “4128C.npz” provides an equalization for the average mouth frequency response of HATS type 4128C. “33_DIFF.npz” and “33_ERP.npz” provide the standard diffuse field equalization and DRP to ERP correction for the type 3.3 artificial ear.

2.5.3 Options to be Carried out after Loading the Setup

The application program can be configured to minimize the window of its user interface after loading a setup (“Minimize After Loading Setup”). This allows to control and watch the UPV window with the result displays.

If preferred, a single measurement can be started immediately after loading a setup (“Start Measurement After Loading Setup”).

2.5.4 Loading a Setup

The button “Browse and Load Setup” in the last line of the tab area opens a file selector which allows to specify a UPV setup for the respective signal path. For each of the four types, an example setup is present in subfolder “D:\UPV\1GA50”.

After selecting an appropriate file, the name is entered in the text box in the center of the line and the setup is loaded to the UPV. Thereafter, the relevant calibration value of the respective input of the transmission path is entered as generator reference voltage, the specified wave file is loaded to the “Play” function of the generator and the specified relative peak voltage is set in “dBr” units. The analyzer range is set to accommodate the maximum output voltage of the transmission path under test as specified in the relevant calibration value.

After changes in the calibration values, in the specification of the test signal and/or in the selection of a filter to be applied, the UPV setup specified in the text box can be re-loaded using the “Load Setup” button.

3 Working with the Source Code (Project Files)

3.1 Installing and opening the project

Depending on the version of Visual Basic .NET on the UPV (delivered with option UPV-K1 Universal Sequence Controller) choose either "1GA50_VB2003.zip" or "1GA50_VB2005.zip". Unzip the file with a program which restores the original folder structure and copy the complete folder to the UPV hard disk, e.g. to "D:\Visual Studio Projects".

Open the file "1GA50_CMU_Cal.sln" in the Visual Basic development environment. To see the source code, right-click on "Form1.vb" in the Solution explorer and click "View Code". With "View Designer", the user interface is shown.

3.2 Running the program from the debugger

The program uses files in "D:\UPV\1GA50" on the UPV hard disk. If the program has already been installed and run on the UPV, this directory has been created. If not, unzip the file "1GA50_Files.zip", create the folder "D:\UPV\1GA50" on the UPV hard disk and paste the unzipped files there before starting the program in the debugger for the first time.

The program can be started in the "Debug" menu" with item "Start" or "Start Without Debugging".

4 Literature

- R&S® UPV Operating Manual
http://www2.rohde-schwarz.com/en/service_and_support/downloads/download_search/
- Application Note 1GA47, “Calibrating Measuring Microphones and Sound Sources for Acoustic Measurements with Audio Analyzer R&S® UPV”
http://www2.rohde-schwarz.com/en/service_and_support/Downloads/Application_Notes/
- Application Note 1GA49, “Psychoacoustic Audio Quality Measurements Using R&S®UPV Audio Analyzer”
http://www2.rohde-schwarz.com/en/service_and_support/Downloads/Application_Notes/
- ITU-T P.862 (2001), “Perceptual evaluation of speech quality (PESQ): An objective method for end-to-end speech quality assessment of narrow-band telephone networks and speech codecs”, <http://www.itu.int>
- ITU-T P.862.1 (2003), “Mapping function for transforming P.862 raw result scores to MOS-LQO”, <http://www.itu.int>
- ITU-T P.862.2 (2005), “Wideband extension to Recommendation P.862 for the assessment of wideband telephone networks and speech codecs”,
<http://www.itu.int>
- ITU-T P.862.3 (2005), “Application guide for objective quality measurement based on Recommendations P.862, P.862.1 and P.862.2”, <http://www.itu.int>

5 Ordering Information

Ordering Information		
Type of instrument		
Description	Instrument type	Ordering number
Audio Analyzer	R&S®UPV or R&S®UPV66	1146.2003.02 1146.2003.66
XLR/BNC Adapter Set	R&S®UP-Z1MF	1411.3306.02
Universal Sequence Controller (optional, recommended for acoustic calibration tool)	R&S®UPV-K1	1401.7009.02
SW for PESQ Measurements	R&S®UPV-K61	1401.7309.02
Universal Radio Communication Tester	R&S®CMU200	1100.0008.02

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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