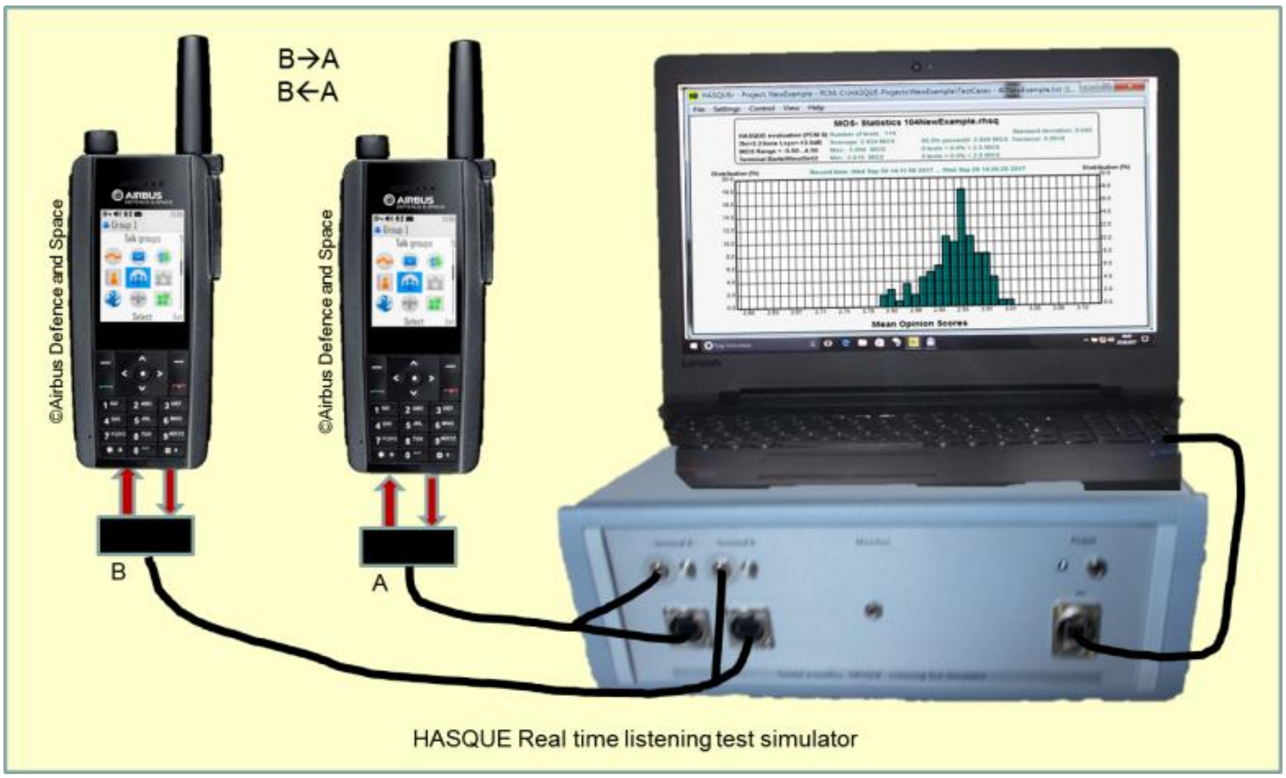
Sound acoustics

Research, Development, Implementation

Recommendations for a reliable quality evaluation of TETRA-Terminals with HASQUE measurement systems



Content

Abstract

The HASQUE - measurement system provides precise results without remarkable tolerance window. Measurement tolerances are introduced mainly by terminal properties and the interface adaptation to the measurement system.

This report concludes recommendations for a reliable quality evaluation of TETRA - terminals within a tolerance margin of about 1 percentage.

The influence of the TETRA codec, the terminal under test and the level adaptation onto the tolerance margin are discussed.

An efficient hardware test program of the HASQUE measurement system with special measurement methods for quick examination and error analysis ensures proper operation of the terminal under test before quality evaluation is carried out with false hardware operating conditions.

A wizard aided level adaptation between terminal and measurement system ensures optimal operating conditions for correct SNR and distortion analysis to reach terminal specific parameterization with reproducible quality measures.

The last chapter concludes the main rules for precise quality evaluation.

Tolerance influences

Measurable quality differences might occur by operational and principle reasons.

Principle reasons for additional tolerance variations by listening test simulation of TETRA terminals can be limited by statistic means.

Operation reasons for additional tolerance variations can be limited with the aid of available test and aligning functions, proper terminal settings and the application of suitable reference samples.

These tolerance reasons are watched closer in the following:

Measurement tolerances by TETRA principle

Weakest link in the line of principle reasons is the TETRA codec [1, 2, 3, 4]. The evaluated quality measures vary by the equidistant block processing with 10 ms signal portions. More or less audible errors are introduced dependent on how critical excitations are positioned within these time slots which might be persuaded as distortions or hearing adequate quality differences.

In order to find the tolerance properties of such phase dependent quality variations the Tetra Codec was simulated with one and the same reference sample with a stepwise phase shift of 1 ms.

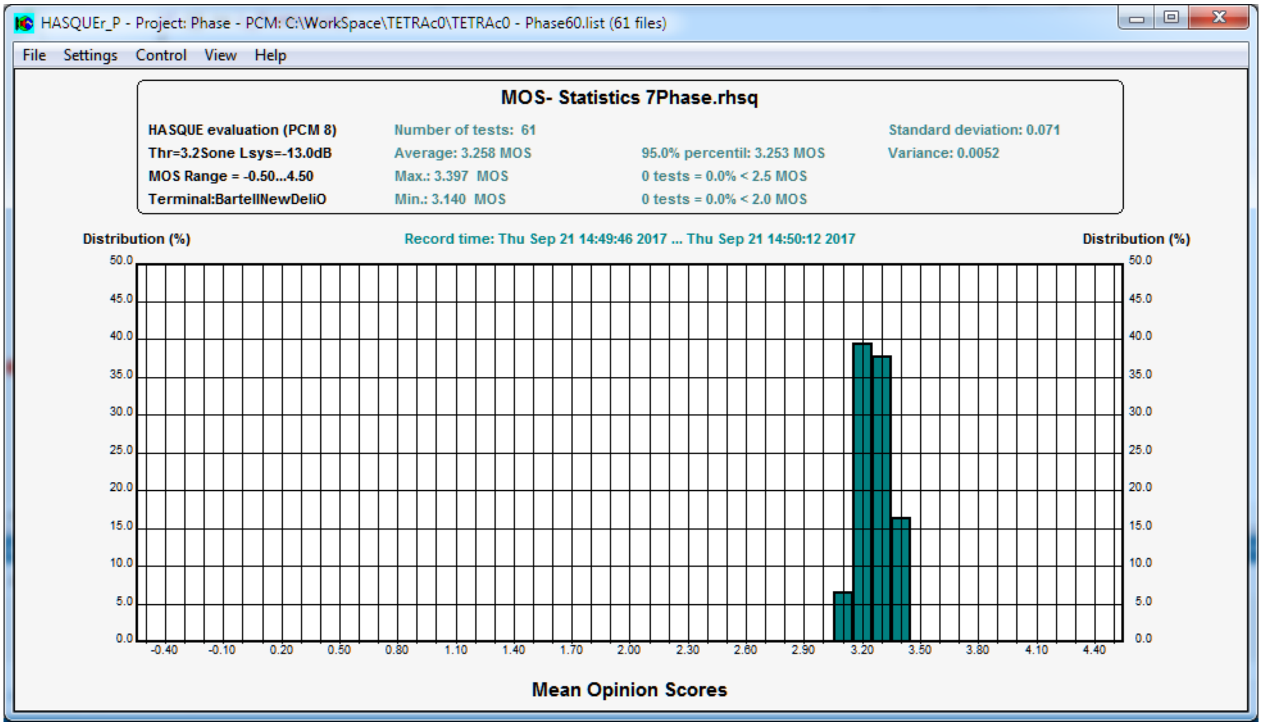


Figure 1: Phase dependent quality variations of the TETRA codec

The results of the simulation are shown in Figure 1. The estimated quality measures of the simulated TETRA codec (without hardware periphery) vary in the range of 5% dependent on the phase. These measured variations correlate with subjective recognized quality variations.

Hence for a representative statement about the quality of a terminal it is necessary to repeat the evaluation with each test sample multiple times. Following results arise at equal distribution of the phase shifting:

Number of measurements	MOS deviation	Tolerance (%)
1	0.25	5
5	0.05	1
10	0.025	0.5
100	0.0025	0.05

Table 1: Results with TETRA codec

I. e. a low measurement tolerance of less than 1% requires the averaged quality measure of about 10 measurements per sample.

Tolerance variations by operation reasons

A correct operation of the measurement system and the terminal under test is decisive for reproducible quality evaluation. Quality variations might be introduced by following influences:

1. Reference recordings
2. Terminal influences:
   Encoding
   Speech Item Talk Time
   Battery charge
   Receiving loudness
   PTT- response time
3. Hardware connections
4. Interface adaptation between measurement system and terminal
   Adaptation of the measurement signal to the input sensitivity of the terminal
   Adaptation of the output level of the terminal to the input sensitivity of the measurement system

Reference samples

Reference samples [1] represent the hearing properties of a healthy human ear. Band limited, distorted or noisy reference signals are equivalent to a hearing impairment or comparable with ear muffs we would carry during listening tests and hence are not suitable for quality evaluation of audio systems.

The measured quality can differ by more than 10% with useless reference signals why the usage of reference samples according to ITU-T [9] are urgently recommended.

It is compulsory to apply the same selection of reference samples to achieve comparable results and hence to avoid tolerance variations by different signal excitations.

Terminal influences

Certain properties, options or programmable functions of the terminals under test might influence the quality strongly. A comparable quality evaluation requires comparable operating conditions.

Terminal options

Encoding produces Stolen Frames which introduce audible distortions in spite of error concealment if the sample differs between „stolen" and former signal block. The averaged quality is reduced and a short signal interrupt is audible.

Results with encoding are not comparable with clean signal streams without masked interrupts.

Speech Item Talk Time is a programmable speech time limitation which might introduce very strong quality degradations, if too less determined. In such a case the whole utterance of a sample can be lost which is perceived as speech interrupt.

Quality measurements shall be carried out only if the speech item talk time of the terminal under test is greater than the recording time of the reference sample plus the maximum possible signal delay over the whole measurement system.

Terminals with volume control

The volume control range of terminals with adjustable receiving loudness might be very large for a reasonable compensation of weak received signal (low speaker) that the output signal of the terminal under test overrides the maximum possible output level at nominal level, leading to audible distortions.

As these distortions are caused at the terminal output it is impossible to compensate it by level adaptation at the measurement input. The quality in such a case is strongly degraded as it can be perceived and measured. Measurement results with different volume are not comparable.

HASQUE makes a precise control of the terminal volume possible with the aid of the Husky wizard (see Automatic level adaption) making distortion free measurements possible.

Reproducible measurements must be carried out with same volume in order to avoid quality variations by different distortions.

Battery charge

Two radio devices were evaluated one by the next continuously until one radio device switched off due to low battery charge after about three hours for 1046 quality evaluations.

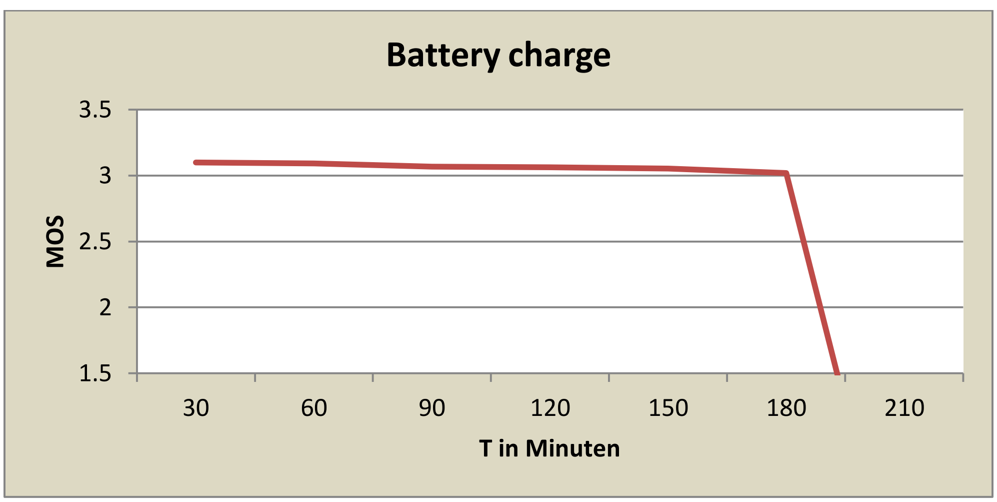


Figure 2: Quality influence by battery charge

The quality of battery powered audio devices reduces dependent on the battery charge from 3.1 to 3.0 in the MOS scale until break down. This corresponds with a tolerance of 2%. About 2 of 1000 quality break downs of 30% could be observed during battery discharge.

Due to this behavior it is recommended to carry out quality evaluation of battery charged terminals only with full batteries.

PTT-Response time

PTT controlled terminals require an individual response time. Proper operation with clean undistorted speech signal transfer is not immediately possible after pressing the PTT switch due to the switching response time and the signal latency. This response time must be taken into account with the programmable measurement control which can be performed by the HASQUE task editor in order to prevent strong quality degradation between 0.1 and 4 in the MOS scale.

Hardware operation

Signal cable - shield and grounding

The HASQUE hardware is fitted with isolated symmetrically signal interfaces in order to prevent interference by radio or hum. In spite of this it is necessary to take care that the measurement signal will not be superimposed by distortion via cables, connectors or grounding loops.

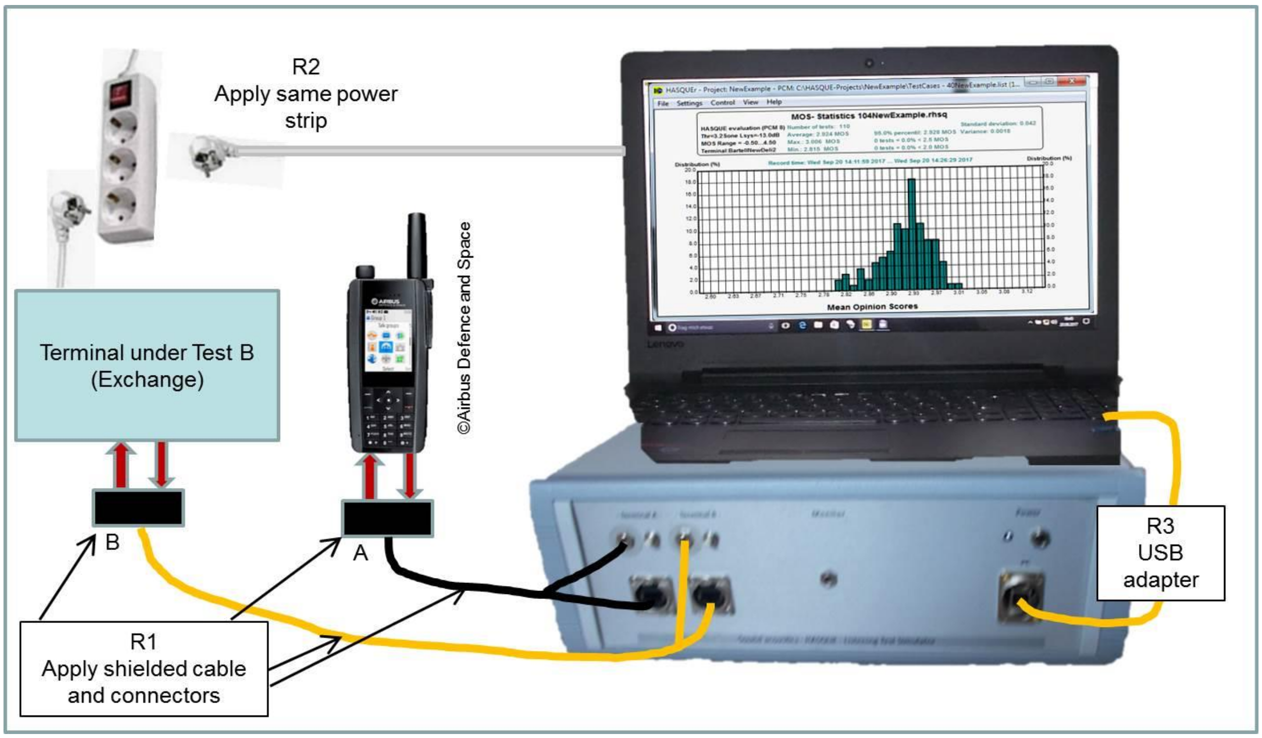


Figure 3: Examples for correct undistorted hardware operation

Above figure shows examples for different arrangements with following possible properties:

a) The HASQUE SW operates on a Laptop with power plug isolated from the ground.
b) The terminals under test operate with rechargeable battery

c) The applied PC and the terminal under test operate with main voltage. The signal ground is isolated from the main power supply ground.
d) The applied PC and the terminal under test operate with main voltage. The signal ground is connected with the main power supply ground.

To achieve clean results under above indicated operating conditions following is recommended:

1. Signal cables and connectors should be shielded in any case (a-d). Especially terminals with asymmetrically interfaces and high input sensitivity need proper shielding for undistorted measurements.
2. All devices which are involved in a measurement and operate with main supply voltage (c-d) should be connected with the same power strip in order to prevent possible hum loops.
3. In most critical cases (d with inducted ground loop) it is possible to apply an USB isolator in order to switch of disturbing hum loop over the USB connector. In many cases it is possible to overcome this expense with reasonable connections.

Hum can be detected during hardware test in the frequency domain by a peak at 50 Hz and radio distortions are visible as noise in the time domain.

Electrical Contacts

A bad connection between signal in- and output of the terminals and the measurement system lead in any case to quality degradations up to total breakdown. Most dangerously are slightly oxidized contacts because low quality degradations of only 0.2 in the MOS scale (this can be introduced from time to time by weak crackle noise due to oxidized contacts) might not be recognized as contact problem but as quality property of the terminal under test.

Due to this reason regular examinations and if necessary contact cleanings of measurement connectors are recommended.

Level adaptation between measurement system and terminals

A wrong sending level of the measurement system leads in any case to quality loss. If the level is too high, distortions or strong AGC variations can occur, and a low level increases the quantizing noise and reduces the signal to noise ratio (SNR).
Currently are terminal in action with up to 40 dB different input level sensitivity. Many terminals consist of a programmable interface, impairing the possibility for wrong signal excitation.

The receiving level of different terminals depend not only from the volume control with a range of >25dB, but also from the operating condition with a level difference of 20 dB between headset or handheld. Too less signal excitation level at the measurement system input leads to poor SNR and too high levels to audible distortions.

A correct manual adaptation between terminal and measurement system in both directions is difficult and expensive as several iterations between measurement and adjustment are necessary to achieve proper quality measures. In spite of precise manual level adaptation of the same terminal at two different times the averaged MOS ranged between 2.6 and 3.1. Examinations of today show a tolerance window of >10% with manual based level adaptations of the terminals to be evaluated.

This high tolerance window can be reduced to about 1% with the aid of the automatic level adaptation of the HASQUE measurement system.

Hardware test and terminal adaptation

The first step after connecting the HASQUE measurement system with a new terminal to be evaluated is a hardware test in order to ensure an error free operation of the whole involved hardware. Only after this first step, the signal levels between terminal and measurement system can be adapted with the aid of the automatic level adaptation. These two tasks can be carried out within few minutes with the aid of the HASQUE measurement system.

Hardware test

Measurements in time domain

The hardware test is carried out with the aid of a special test signal for both directions A→B and B→A. The test starts with A→B test and can be controlled with the aid of the PTT keys in the HASQUE GUI by left mouse button.

The test signal is a so called Bartlett burst signal which was developed by Sound acoustics and which is suitable to measure level, distortion and SNR in spite of sine wave suppression (is implemented in some radio devices) and in spite of the modulation properties of the TETRA codecs.

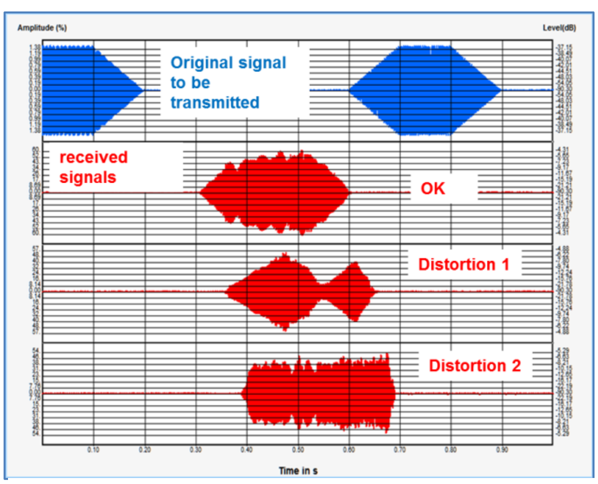


Figure 4: Error diagnostic with Bartlett burst

Moreover the Bartlett burst offers an easy graphically diagnostic possibility for the judgment of the signal transfer properties.

A proper transfer function indicates a received hexagon with low amplitude modulation (AM) as indicated in figure 4 with OK. The low AM of the TETRA codec produces no remarkable harmonics. With the aid of a special distortion analysis from Sound acoustics with compensation of the measurement error by equidistant frequency analysis a THD of less than 0.1% can be measured.

Distortion 1 indicates a strong deformation pointing to a connection error between terminal and measurement system. This distortion cannot be detected reliable with the aid of the distortion analysis and must be evaluated graphically. In case of these distortions, the wires and connectors between measurement system and terminal must be checked.

Distortion 2 indicates too high signal levels as the hexagon is deformed to a rectangle. This deformation can only be detected with the distortion analysis, if no automatic gain control (AGC) of the terminal under test is involved. With AGC the same figure might appear, however the quality might be also reduced by about 0.3 …0.5 in the MOS scale due to the audible breathing of the AGC which must be eliminated by correct level adaptation.

Measurements in frequency domain

The whole frequency response between two terminals can be checked in both directions with one mouse click as shown in figure 5. Differences between transmitted (blue) and received (red) spectra can be observed with one view. In the marked range between 300-3500 Hz are no remarkable interrupts or peaks. The low modulation is introduced by the TETRA codec. Some terminals show an increase of the spectral magnitude with frequency for enhanced speech recognition. The transfer function is ok.

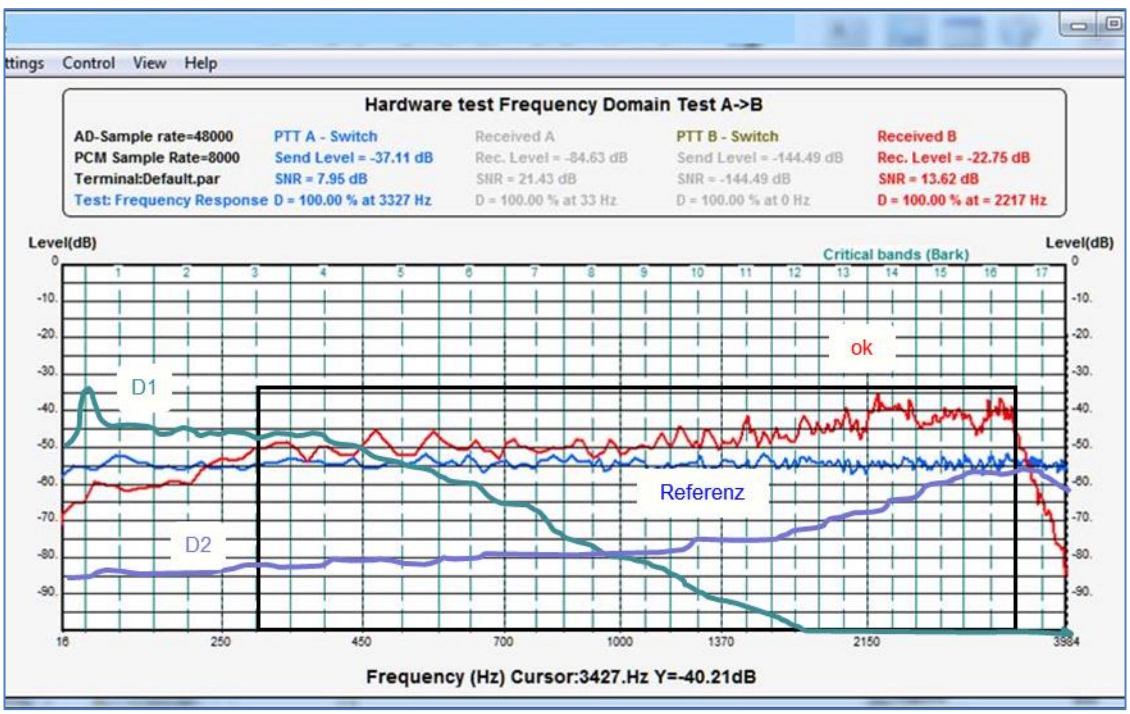


Figure 5: Transfer functions

Strong quality degradation is indicated, if the frequency response is deformed as indicated with the dull sounding D1 or as indicated with the shrill sounding D2 transfer function.

These kinds of distortions point to extreme hardware connection errors or defect components which must be eliminated.

Automatic level adaption

Level adaptation between terminal input and measurement system output and vice versa is needed for distortion free measurements. HASQUE provides for this task the Husky Wizard leading through the necessary steps for a reliable interface adaptation.

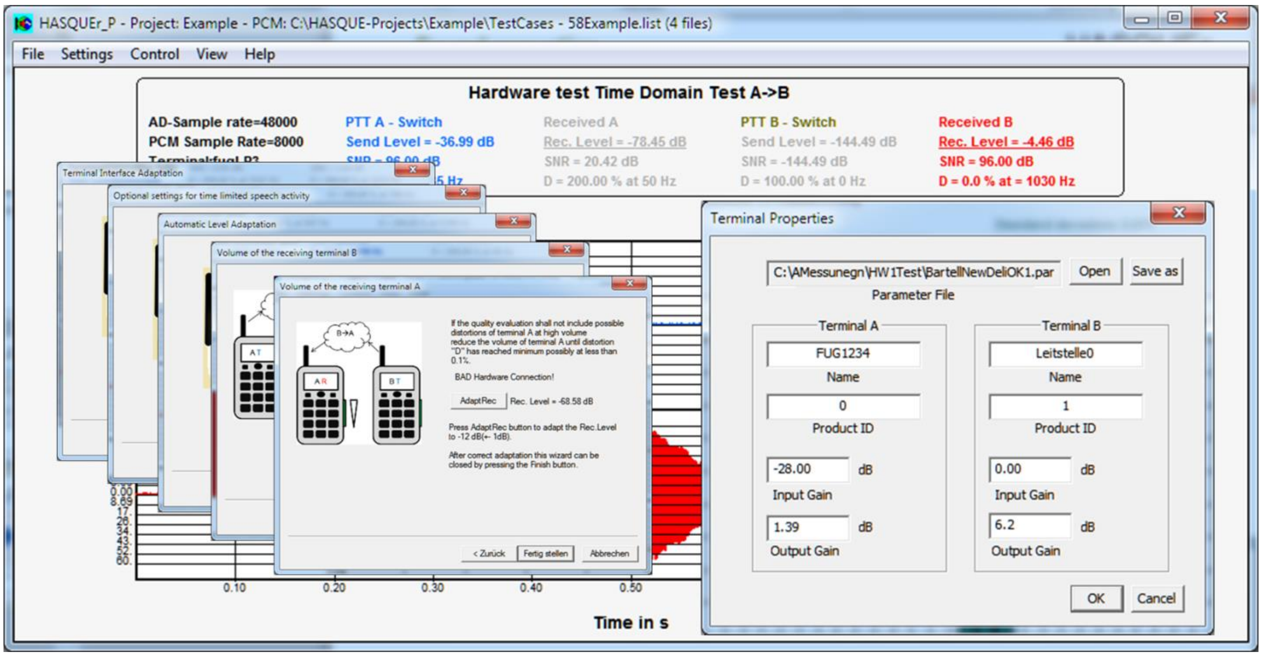


Figure 6: Automatic level adaptation with wizard

The wizard can be started with the menu item Control/Start Automatic Level Adaptation which is only available during running hardware test. This means the hardware tester must have been started before.

The wizard carries out following steps:

1. Reset PTT and signal steaming
2. Optional: Settings for terminals with time limited signal activity
3. Automatic Level Adaptation of terminals A and B
4. Control volume of terminal B and set rec. gain B
5. Control volume of terminal A and set rec. gain A
6. Create Parameter file

Following the instructions of the wizard leads to correct level adaptation for reliable quality evaluation of the connected terminals with a tolerance about <1%, if the hardware is connected with the terminals hum free with shielded cables.

Conclusion:

A reliable quality evaluation of TETRA terminals with low tolerance window of about 1% is possible if following conditions are fulfilled:

- Reference recordings
  - Apply same composition of reference samples according to the recommendations ITU-T P.862 for comparable results
  - Each reference signal should be repeated at least 10 times per measurement in order to reach < 1% tolerance window.
- Terminal settings
  A comparable quality evaluation requires comparable operating conditions.
- Prevent measurement errors
  - Battery powered terminals must be charged
  - The response time of the PTT function must be taken into account by the programmable measurement control
  - Avoid radiated interference by shielded cables and connectors
  - Avoid hum and ground loops: Apply same power strip for all not battery powered devices which are involved in the measurements, use possibly Laptop with ground free power supply or use USB Isolator in case of strong grounding problems.
  - Apply clean connectors with clean contacts
- Carry out precise level adaptation between terminal and measurement system

A prober measurement operation can be ensured with the aid of the HASQUE hardware tester within view minutes, indicating the transfer function and properties of the terminals under test with one view.

A correct level adaptation is supported by the HASQUE measurement system. The automatic level adaptation replaces time expensive manual level adjustment with 10% tolerance window by the wizard aided HASQUE program in three minutes for both terminals under test with about 1% tolerance

Literature

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Figures