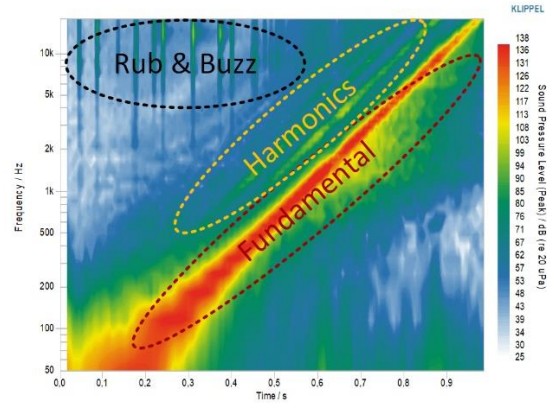


FEATURES

- Time-frequency analysis (auditory filter bank)
- Full acoustical fingerprint of defects (e.g., *Rub&Buzz*)
- Easy 3D limit setting
- Ambient noise detection
- Compatible with *Time Frequency Analysis* (TFA) post-processing module



BENEFITS

- Sensitive defect detection
- Optimize Rub&Buzz filter settings
- Detect excitation frequency and spectral content of distortion for root cause analysis

DESCRIPTION

The *Spectrogram 3D Limits* is an add-on feature for the *Sound Pressure (SPL)* Task of the *Klippel QC* Software. In addition to the standard results of the SPL Task, the 3DL performs a time-frequency analysis of the measured chirp response using an auditory filter bank which is based on human hearing. In contrast to common *Short-Time Fourier Transform* (STFT) this filter bank delivers a superior time resolution for identifying impulsive distortion (*Rub&Buzz*).

The resulting spectrograms provide diagnostics of the spectral fingerprint of any abnormal sound and distortion produced by the device under test (DUT). Testing is made easy through three-dimensional limits that are automatically calculated based on approved reference units.

For a chirp signal, both the excitation frequency (time point) as well as the dominant spectral content of any distortion are identified easily in the provided *Exceedance* plots that indicate where the spectrogram limits are exceeded. Diagnostics is simplified by the provided 2D projection plots based on the *Exceedance*.

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CONTENT

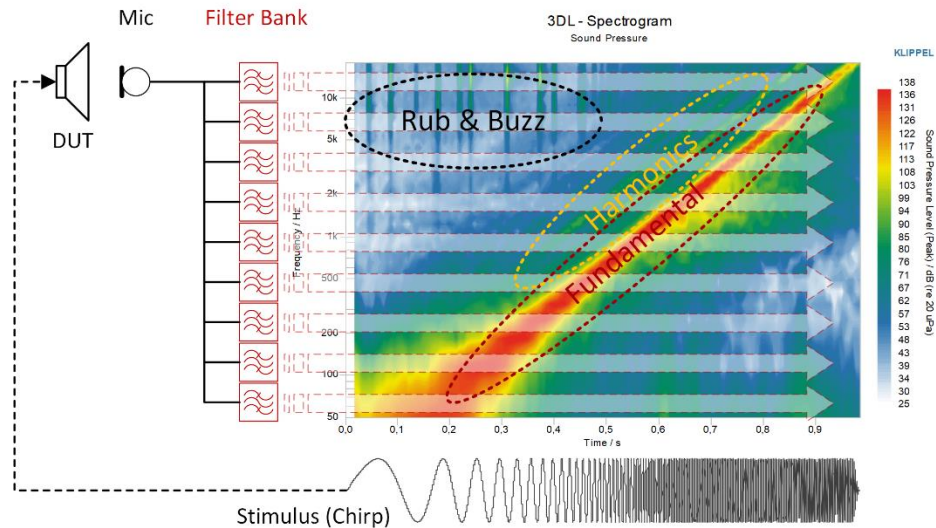
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1 Overview

1.1 Principle

Time-frequency plots (spectrograms) based on *STFT* or *Wavelet* analysis are a common tool in audio analysis and forensics to monitor the spectral information of audio signals over time in an intuitive way.

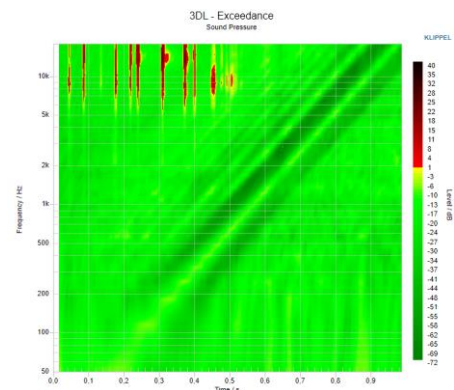
Applied to audio systems testing these methods provide highly valuable diagnostic information about defects or abnormal effects. Particularly when processing responses of sinusoidal test signals such as chirps, the different symptoms in audio reproduction can be identified and separated in the spectrogram as shown below.



The *Spectrogram 3D Limits* brings these benefits to End-Of-Line (EOL) testing by introducing a time-frequency analysis tailored to the specific requirement of quality control. An auditory filter bank (40 filter channels) according to *ITU-R BS1387-1* recommendation is applied to provide high-speed analysis and superior time resolution and for identifying impulsive distortion and other defects with distinctive time patterns. Although the output of each filter channel provides the full sample resolution of the input signal, the time-frequency plot is segmented into blocks to reduce data load using a peak detector to catch impulsive distortion peaks without compromise.

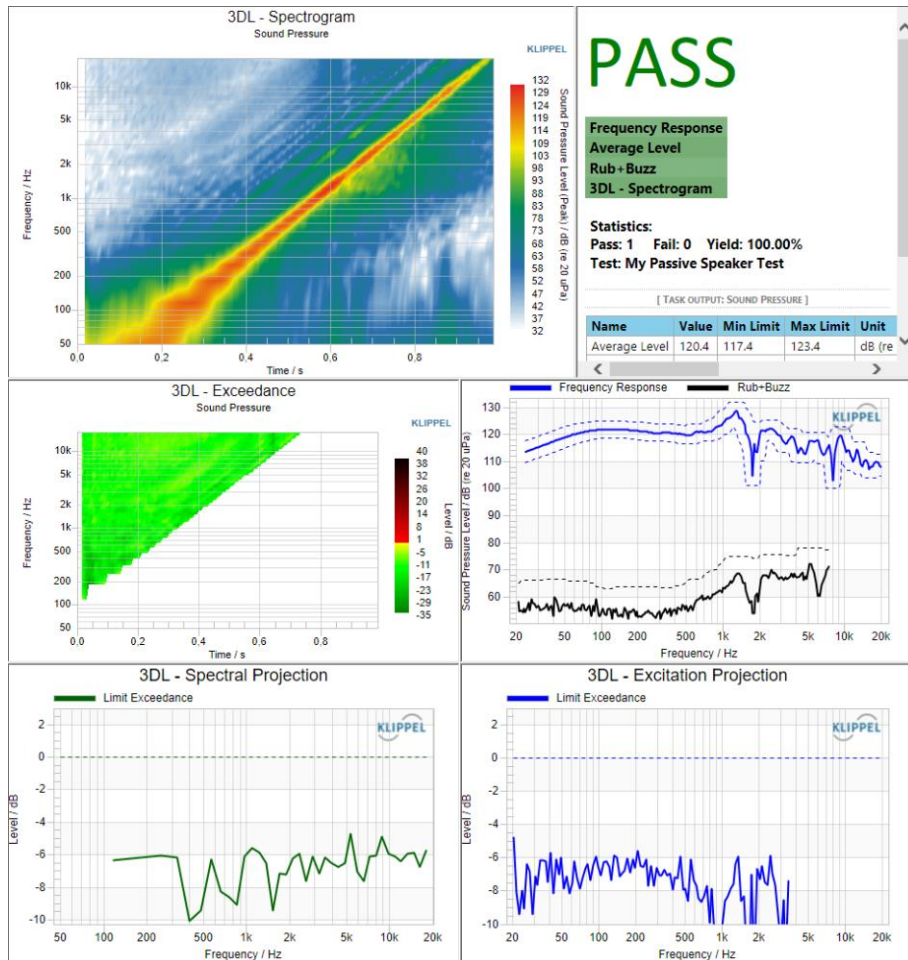
For obtaining automatic PASS/FAIL decision, dedicated limit algorithms help creating spectrogram 3D limits from approved reference DUTs with ease.

The test verdict is based on the so-called *Exceedance* which is simply the difference between the DUT response spectrogram and the limit. This makes it easy to reveal the defect's fingerprints compared to a good unit.



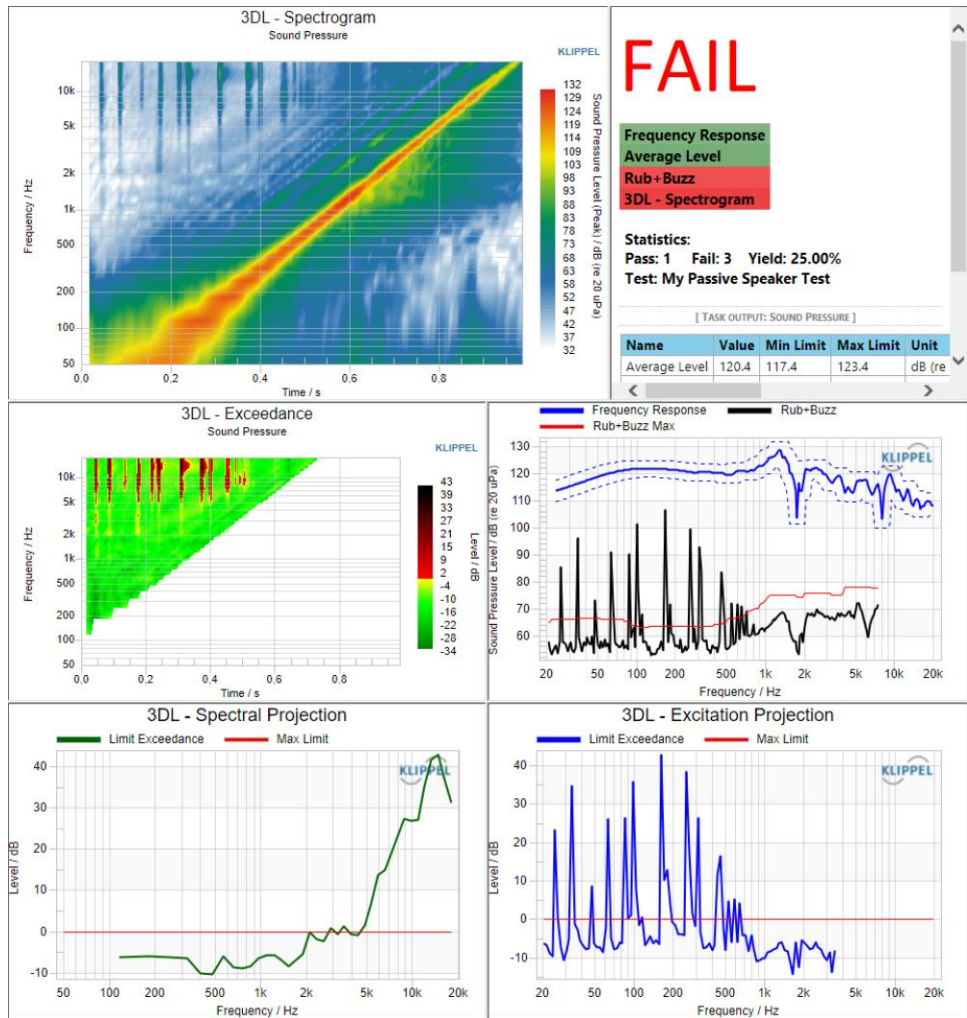
2 Examples

2.1 Example 1: Driver Test PASS Result



Since the measured DUT is free of defects and well within spec, the measurement verdict is PASS. The exceedance plot and the mapped exceedance projections indicate that the SPL is below the spectrogram limit over the full limit time-frequency range.

2.2 Example 2: Driver Test Loose Particle Defect



This DUT exhibits a loose particle defect, which is detected by both the *Rub&Buzz* measurement and the *3DL Spectrogram Exceedance*. The location and impact of single audio signal component is visualized in the *3DL – Exceedance* plot. The derived *Spectral Projection* gives a quick insight in the dominant frequency content of the defect distortion while the *Excitation Projection* indicates the stimulus trigger frequency. This plot corresponds well to the patterns found in *Rub&Buzz* result curve.

3 Requirements

3.1 Hardware

The 3DL can be implemented in various test scenarios ranging from common closed loop EoL testing using KLIPPEL Analyzer devices to open loop test scenarios. See hardware requirements in [C3 - QC Set](#) for more information.

3.2 Software

QC Framework

- KLIPPEL QC Software version 7 or higher
 - *QC Standard* (Item No. 4005-001) or
 - *QC Stand-alone* (Item No. 4005-500)

• *3DL* license

No additional setup is required

R&D Framework	<ul style="list-style-type: none"> • KLIPPEL dB-Lab Release 212.2xx or higher • <i>QC Tasks in R&D</i> license (free) • <i>SPL</i> and <i>3DL</i> license <p><i>No additional setup is required</i></p> <p>Note: KLIPPEL Analyzer 3 (KA3) hardware is required to operate the 3DL in the R&D software framework.</p>
3.3 Acoustics	
Ambient Noise	<p>The 3DL can be operated in any test environment ranging from free air measurements to production testing in dedicated test enclosures.</p> <p>However, since the 3DL is mainly dedicated to testing abnormal sound and distortion at much lower levels than the fundamental response, the typical requirements for <i>Rub&Buzz</i> testing also apply here. Optimum test performance is only ensured when a low acoustical noise floor is provided. Properly shielded test enclosures are highly recommended in loud production environments. This also provides reproducible positioning when testing also the fundamental component.</p> <p>Impulsive ambient noise has the most critical impact on the 3DL test. Therefore, the ambient noise detection feature of the SPL Task based on an additional ambient noise microphone is fully supported by the 3DL. This also applies to the <i>Production Noise Immunity</i> (PNI) add-on for the SPL task which provides auto-repeat and merging in case of noise disturbance, but with restriction. When using 3DL, the PNI only allows full test repetition since merging cannot be applied to the spectrogram without artifacts.</p> <p>Find more information in the specifications C3 - QC Set and S21 QC Production Noise Immunity for more information.</p>

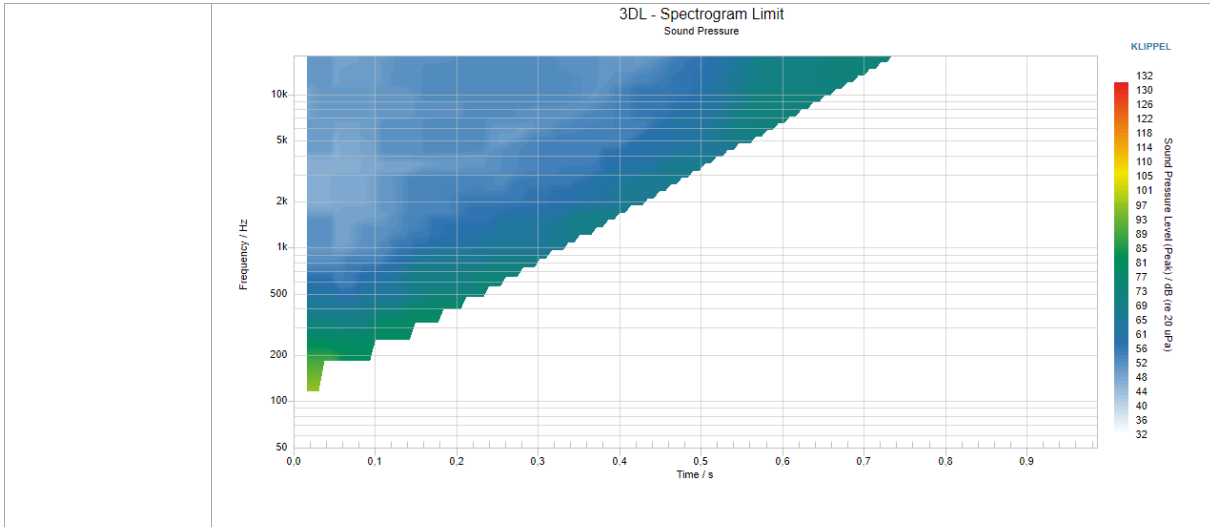
4 Parameters

Tasks Parameters	
Parameter	Comment
Category Results	
3DL – Spectrogram	(On Off) – Activate the spectrogram analysis
Category Display	
3DL – Max. Value Spectrogram	Maximum colormap value of <i>3DL – Spectrogram</i> and <i>3DL – Limit</i> charts in dB
3DL – Dynamic Range Spectrogram	Colormap dynamic range of <i>3DL – Spectrogram</i> and <i>3DL – Limit</i> charts in dB relative to colormap maximum. Spectrogram values out of range are not shown.
3DL – Minimal Value Exceedance	Display floor of chart <i>3DL – Exceedance</i> in dB. Data points below this range are not displayed.
Limit Parameters	
Parameter	Comment
Category 3DL – Spectrogram	
Calculation	<ul style="list-style-type: none"> • Shift (relative limits based on reference DUTs) • Absolute (custom, static limits) • Absolute + Shift
Symptom Frequency	Limit definition over the spectral frequency range of the spectrogram (Y-axis).

Excitation Frequency	Limit definition over the temporal axis range of spectrogram (X-axis), which corresponds to the excitation frequency.		
Harmonic Order	Limit definition according to harmonic order relative to excitation frequency.		
Jitter	Automatic widening algorithm for the limit around peaks and dips.		
Filter Bank Parameters			
Parameter	Value	Unit	Comment
Filter Channels	40	-	number of band-pass filters
Bandwidth	~0.7	Bark	auditory filter bandwidth
Min. Frequency	50	Hz	center frequency of lowest filter channel
Max. Frequency	18	kHz	center frequency of highest filter channel
Time Resolution	7.143 (typ.)	ms	length of analysis time segment (peak hold)

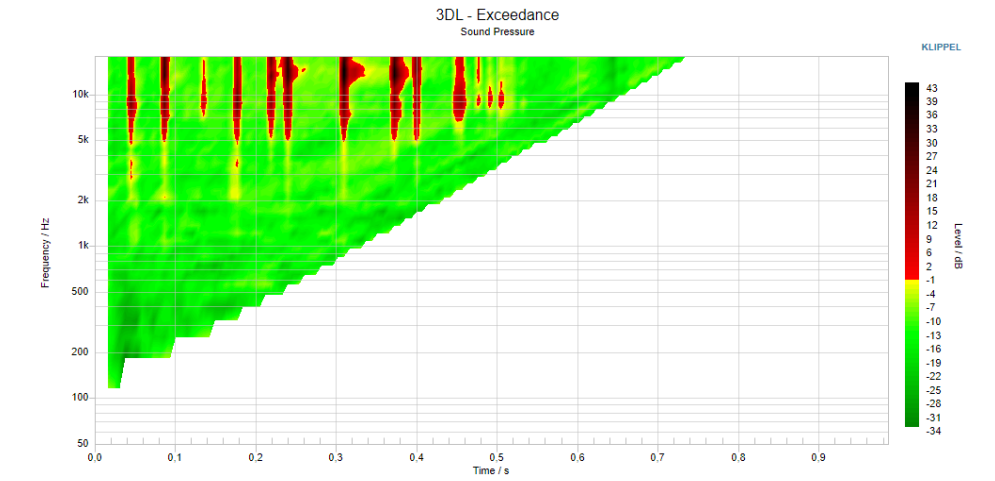
5 Output

Windows	
3DL – Spectrogram	<p>Contour plot displaying level (SPL) over time and frequency, based on the filter bank output.</p> <div style="text-align: center;"> <p>3DL - Spectrogram Sound Pressure</p> </div> <p>In LIMIT CALCULATION MODE it represents the global maximum contour over all selected reference DUT.</p>
3DL – Limit	<p>This chart is closely related to the <i>3DL - Spectrogram</i> window but instead of the measured response it shows the spectrogram limit which is basically the maximum allowed level for a PASS test verdict over time and frequency.</p>



3DL – Exceedance

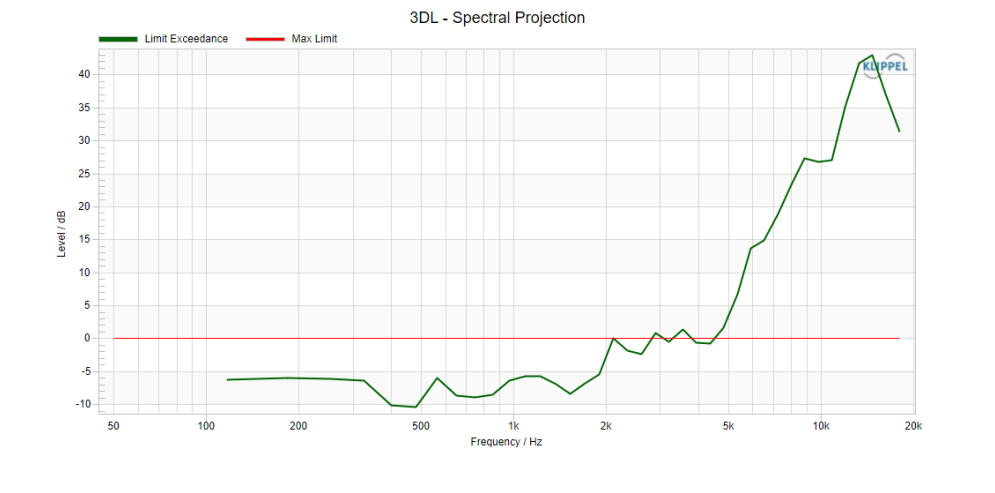
The data shown in exceedance plot is very important for quality control testing since it indicates critical deviation of the tested DUTs response from the reference units that lead to limit violation. It is a result (difference) of the *3DL - Spectrogram* and the *3DL - Limit* highlighting clearly where the limit was exceeded.

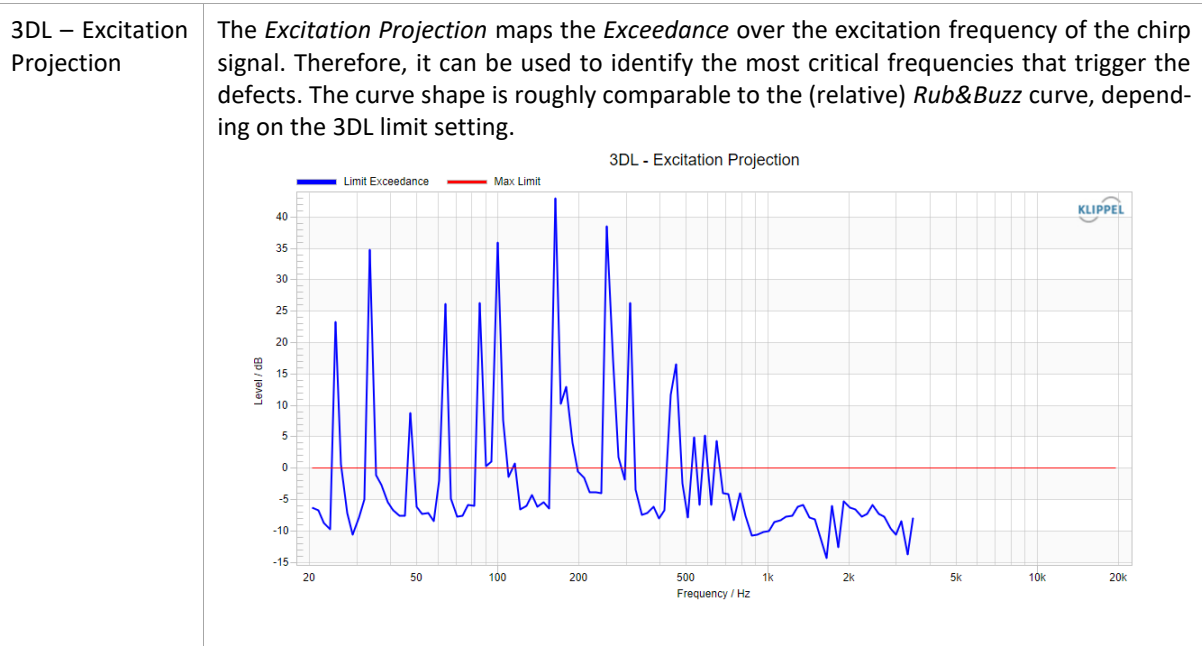


3DL – Spectral Projection

The projections can be regarded as the “shadows” of the *3DL - Exceedance* cast over the two available axes, summarizing the information provided by the full contour plot. The limit curves are always located at 0 dB since the *Exceedance* is a relative plot.

The *Spectral Projection* provides valuable diagnostic information since it shows the dominant frequency content of defect distortion. It is useful to help classifying the defect root cause, adjusting the 3DL limit frequency range or even for optimizing the *Rub&Buzz* band-pass filter settings.





6 References

<p>6.1 Specifications</p>	<ul style="list-style-type: none"> • C3 QC Software • S21 QC Production Noise Immunity • S61 TFA Time-Frequency Analysis
<p>6.2 Manual</p>	<ul style="list-style-type: none"> • 3DL Manual • QC User Manual • PNI Manual
<p>6.3 Standards</p>	<ul style="list-style-type: none"> • Rec. ITU-R BS1387-1 - Method for objective measurements of perceived audio quality

Find explanations for symbols at:

<http://www.klippel.de/know-how/literature.html>

Last updated: March 11, 2022

Designs and specifications are subject to change without notice due to modifications or improvements.

