Acoustical Measurement of Sound System Equipment according IEC 60268-21

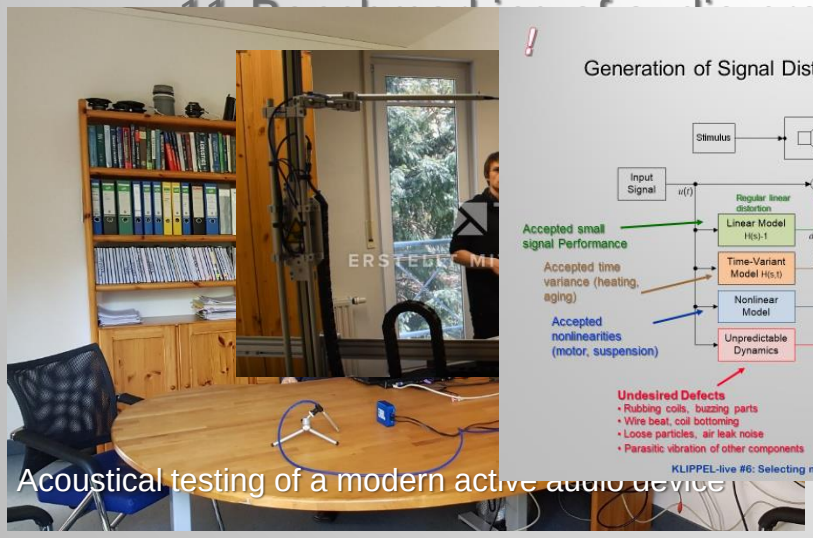
KLIPPEL- live

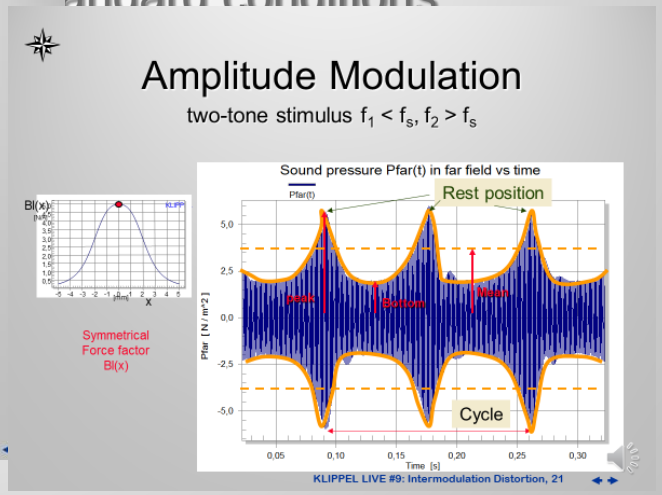
a series of webinars presented by

Wolfgang Klippel

Previous Sessions

1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at an evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects
11. Reproducibility of audio products under standard conditions


Acoustical testing of a modern active audio device



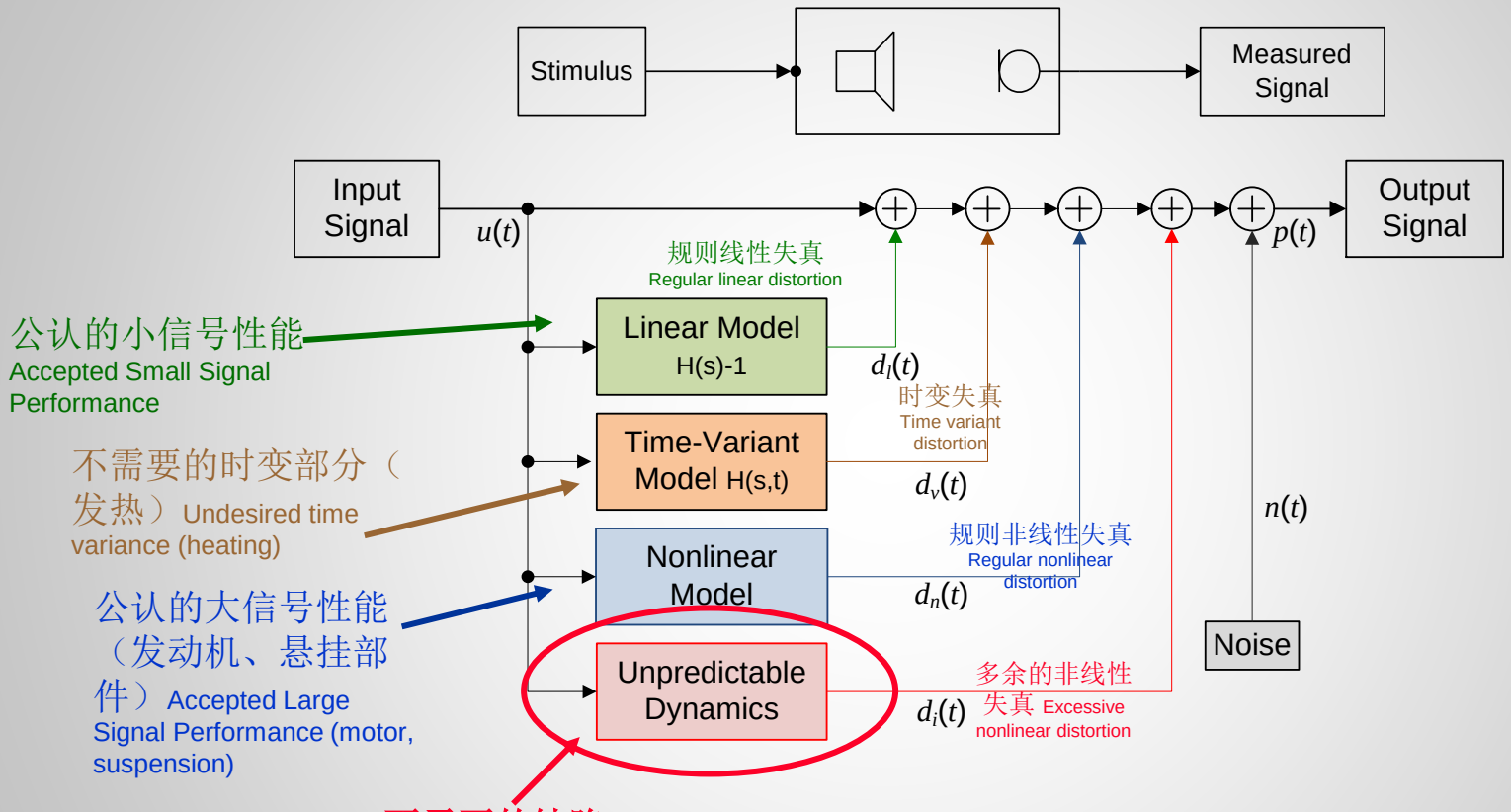
10th KLIPPEL live:
脉冲失真 – 异音、异常行为、缺陷
Impulsive distortion - rub&buzz, abnormal behavior, defects

今日话题 Topics today:

- 音频设备的非常规性能概述 Overview on irregular properties of audio devices
- 符合IEC60268-21标准的测量 Measurements according to IEC Standard 60268-21
- 时域测量脉冲失真 Measurement of impulsive distortion in the time domain
- 结合物理测量和听音 Combining physical measurements and listening

需要和不需要的部分？ Desired and Undesired Components ?

音频系统中信号失真的生成 Generation of Signal Distortion in an Audio System



不需要的缺陷 Undesired Defects

- 擦圈、产生嗡嗡声部件 Rubbing coils , buzzing parts
- 打线、音圈打底 Wire beat, coil bottoming
- 松散颗粒、漏气声 Loose particles, air leak noise
- 其他组件的寄生振动 Parasitic vibration of other components

Poll:

您是如何找出并评估异音和其他非常规失真的?
How do you find and evaluate the rub&buzz and other irregular distortion ?

A. 通过聆听音乐 By listening with music
B. 手动扫描+聆听 Manual sweep + listening
C. Chirp+总谐波失真THD Chirp + Total harmonic distortion (THD)
D. Chirp+高阶谐波 Chirp + Higher-order harmonics
E. Chirp+时域分析（时频分析、脉冲失真分析）
   Chirp + Time domain analysis (Time-Frequency Analysis, impulsive distortion analysis)

搜索关键激励 Searching for a Critical Stimulus
音圈擦圈的可听度 Audibility of Voice Coil Rubbing

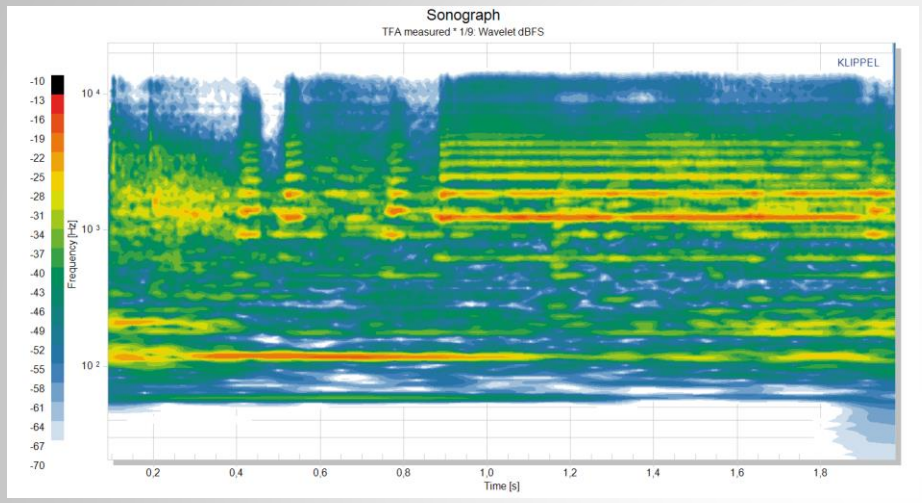
该实验研究激励和输入电压的影响
This Experiment investigates the influence of the stimuli and the input voltage

Signal	Stimulus	Output 1V	Output 2V	Output 3V
Music				
Multi-Tone 20 Hz – 20 kHz				
Multi-Tone 20 Hz – 1 kHz			clear audible	
Sinussoidal Sweep 1 s				

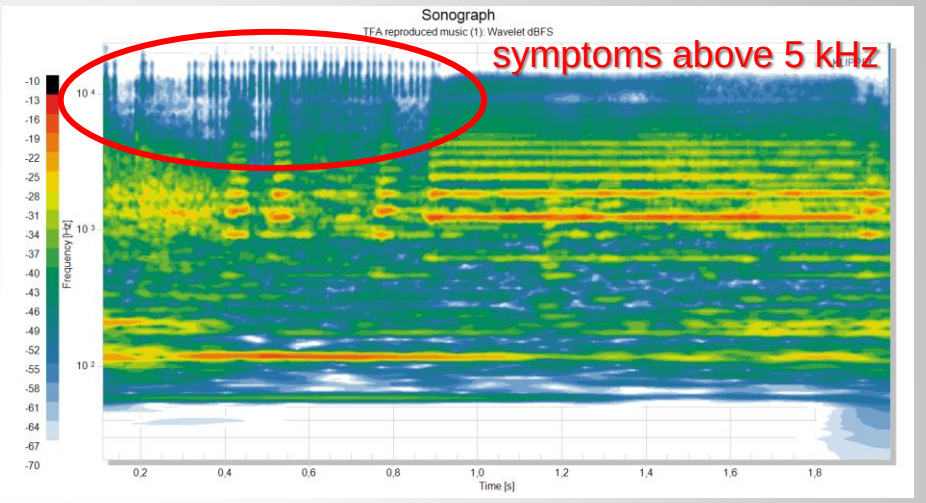
最灵敏的激励 Most sensitive Stimulus

Stimuli less critical for Rub & Buzz

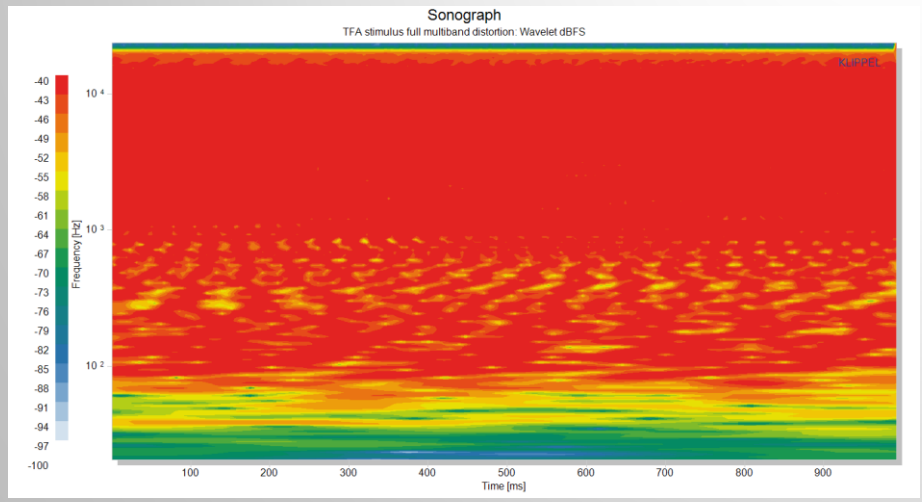
stimulus: music



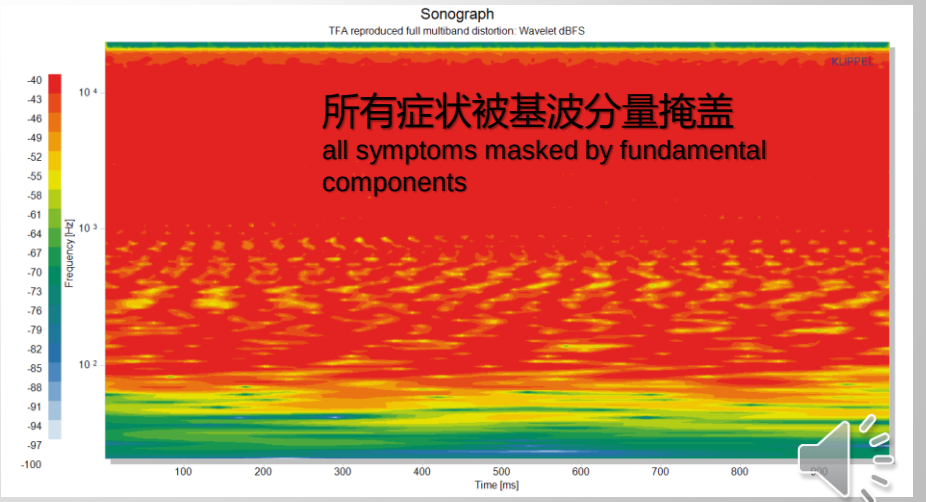
reproduced music at 3 V



stimulus: Full Band Multi-tone complex

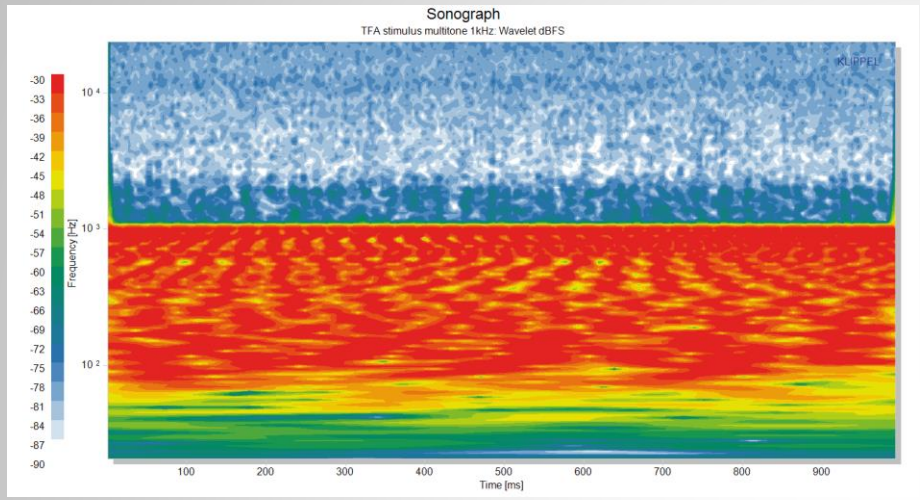


reproduced Full Band Multi-tone complex

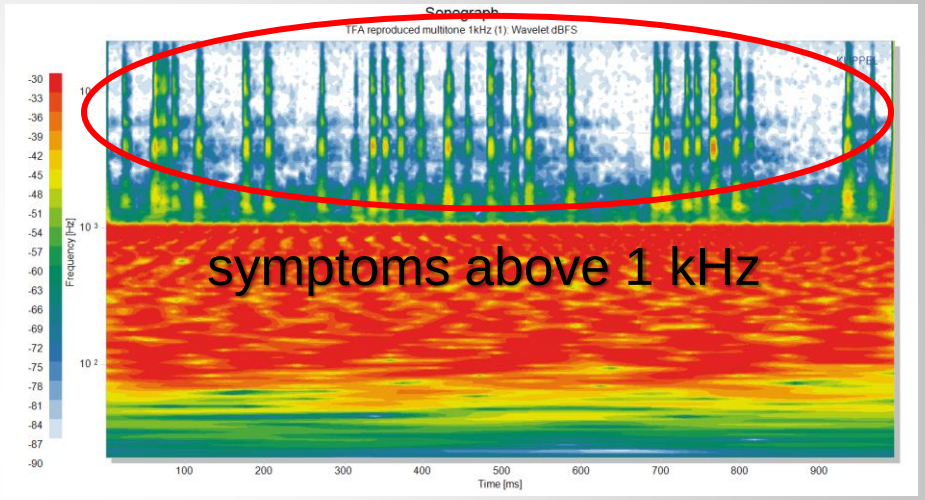


Stimuli critical for Rub & Buzz

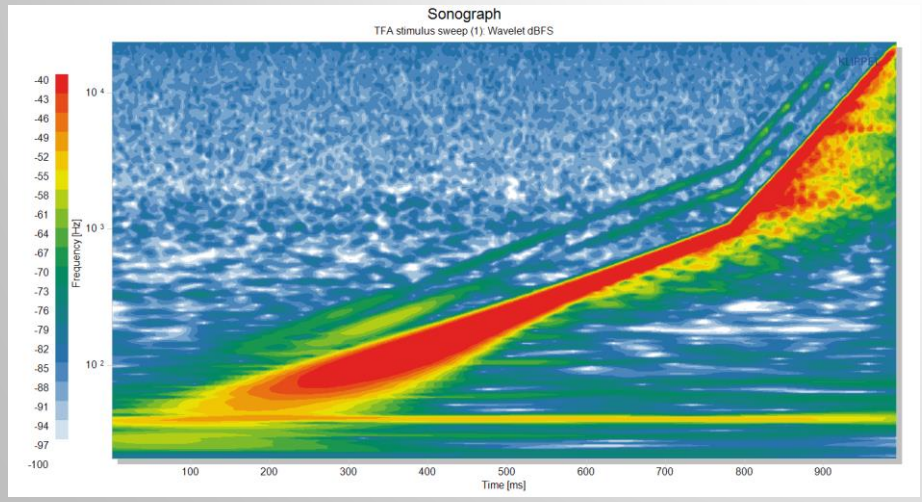
Stimulus: multi-tone distortion low pass 1 kHz



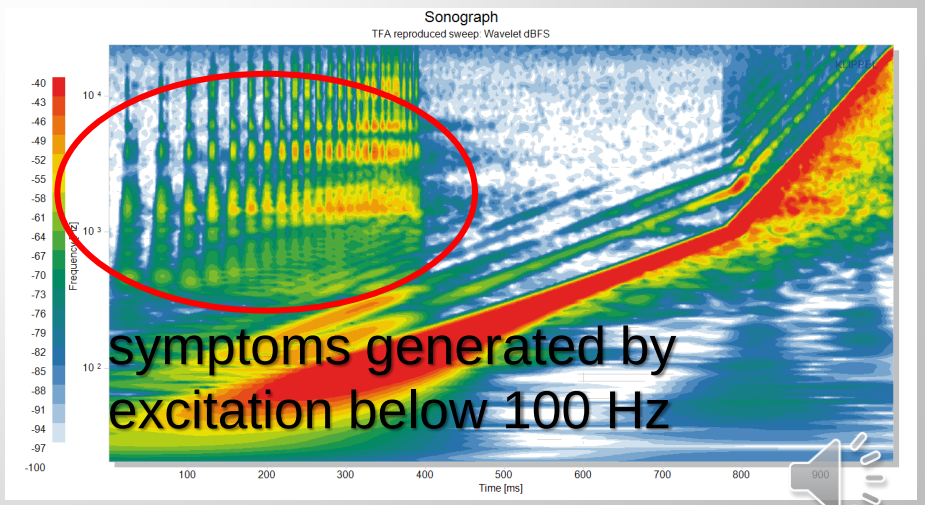
reproduced multi-tone distortion low pass 1 kHz at 3 V



Stimulus: sweep



reproduced sweep at 3 V



Rub&Buzz, Defects, Irregular Behavior

症状 Symptoms

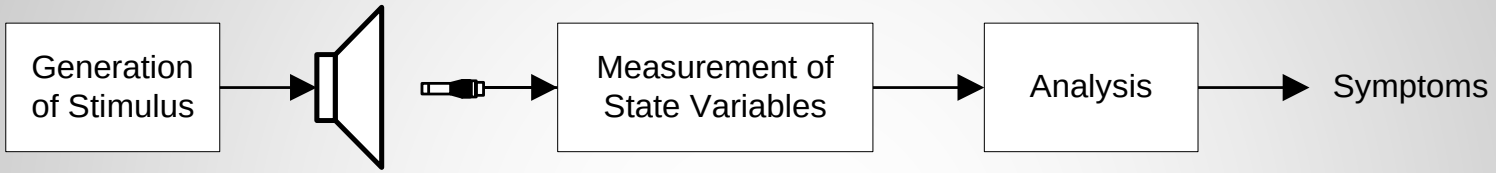
- 咔哒声、脉冲、猝发音、调制噪声 Clicks, impulses, tone burst, modulated noise
- 低能量并且rms值小 Low power and small rms value
- 较高峰值（脉冲性） higher peak value (impulsive)
- 宽带频谱（不仅有谐波） Broad band spectrum (not only harmonics)

需要特殊的测量技术 Special measurement technique required:

- 时频分析（幅度谱不够） Time-frequency analysis (amplitude spectrum not sufficient)
- 精细结构的时域分析 Time domain analysis of the fine structure
- 新失真度量（如IEC60268-21定义的脉冲失真）
  New distortion metrics (e.g. Impulsive Distortion as defined in IEC 60268-21)

检测非常规扬声器缺陷的要求

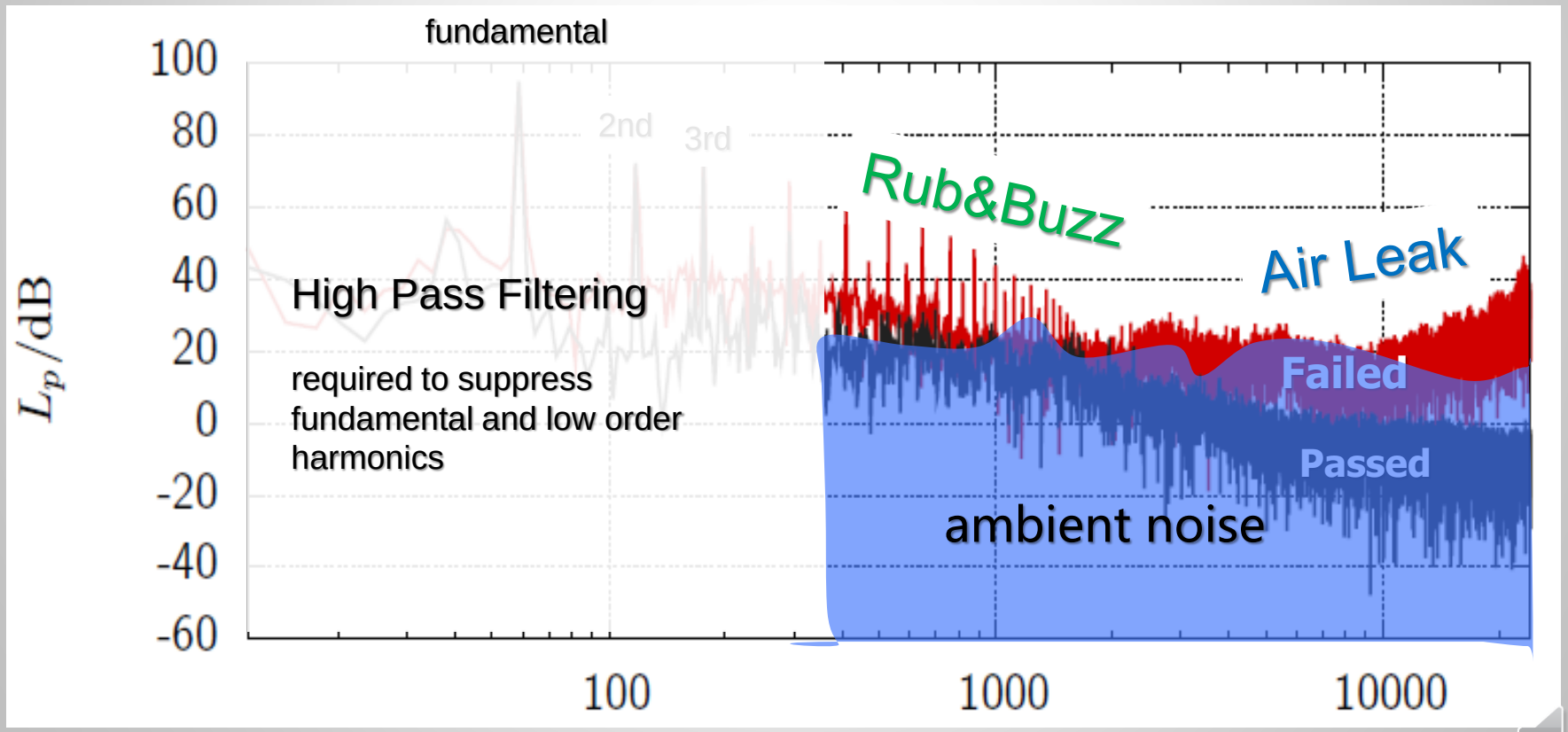
Basic Requirements to detect Irregular Loudspeaker Defects



- 需要高幅值（位移x、速度v、加速度a） → 激励应该激发所有频率
  High amplitude is required (displacement x and/or velocity v and/or acceleration a) → Stimulus shall excite all frequencies
- 大多数缺陷只产生声学症状 → 需要灵敏的麦克风
  Most defects only produce acoustical symptoms → Sensitive microphone required
- 缺陷产生高频分量 → 低通后的激励以及高通后的麦克风信号
  Defects produce high frequency components → Low-pass filtered stimulus and high-pass filtered microphone signal
- 缺陷类似于环境噪声 → 麦克风靠近声源（近场测量）
  Defects are similar to ambient noise → Microphone is located close to the source (near-field measurement)

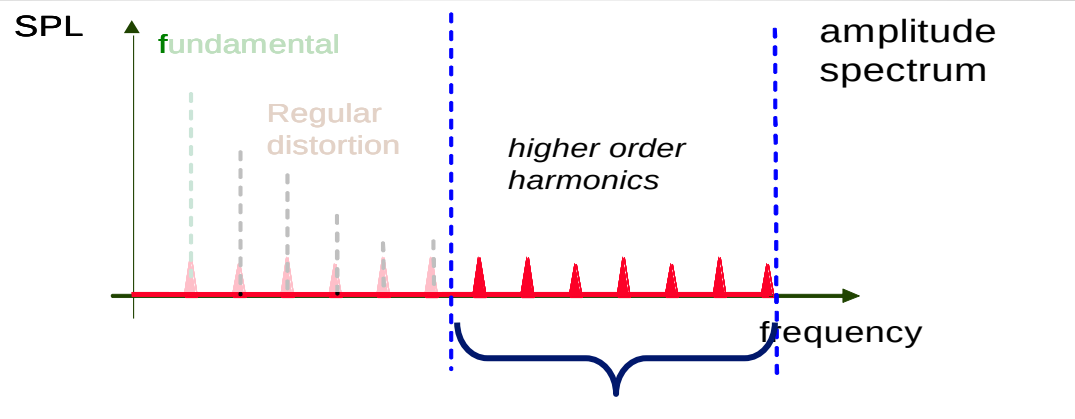
Frequency Domain Analysis

60 Hz Tone reproduced by a good and bad speaker



简单方法Simple Approach

只利用高阶谐波的幅值 exploiting amplitude of higher-order harmonics only



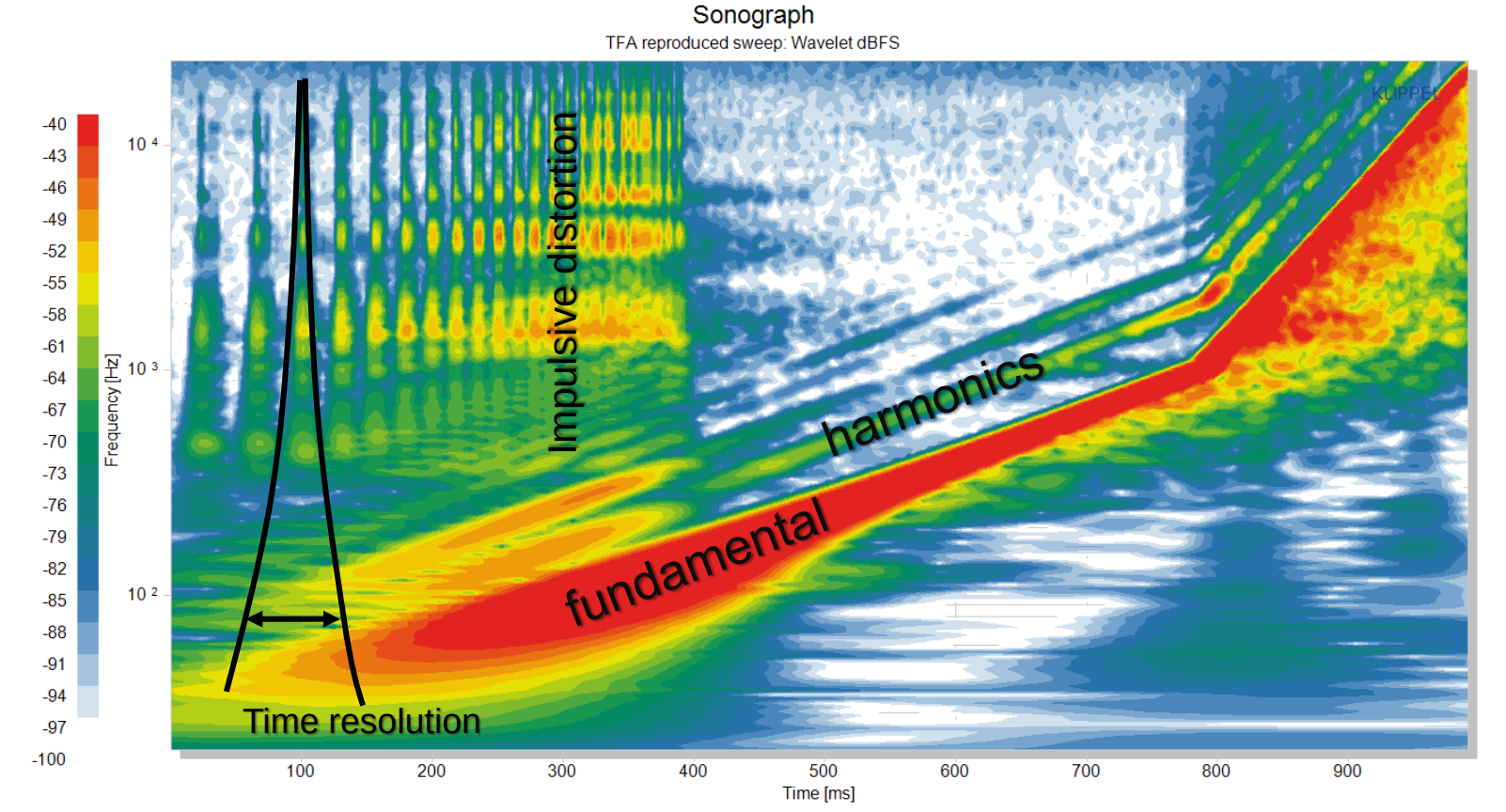
高阶谐波失真已在IEC60268-21中定义
Higher-order harmonic distortion
Are defined in IEC 60268-21

高阶谐波的RMS值
RMS value of Higher-harmonics

问题 PROBLEMS:

- 只对确定性的症状敏感 Sensitive for deterministic symptoms only
- 每个谐波接近于噪声级 each harmonic is close to the noise level
- 对松散微粒和漏气噪声不敏感 insensitive to loose particles and air leakage noise

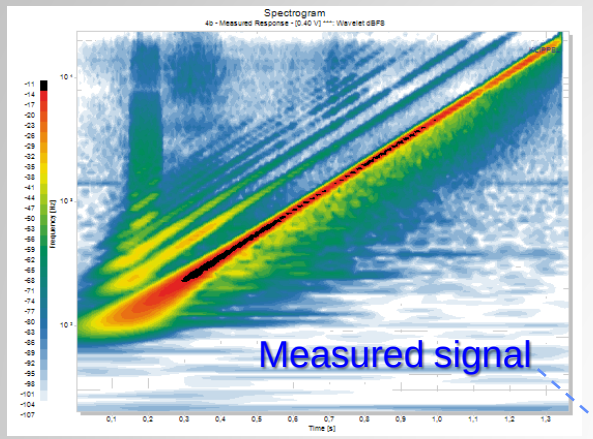
Time Frequency Analysis

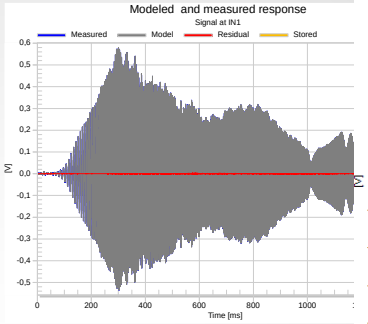


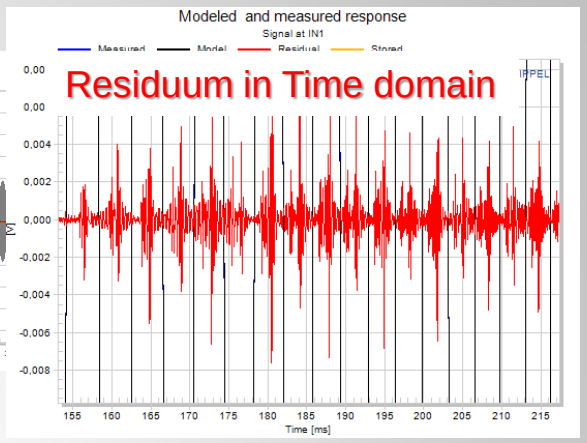
时频分析 TFA Time-Frequency Analysis (TFA)

- 小波变换 Wavelet Transformation
- 频率和时间分辨率之间的最佳折衷 Best compromise between frequency and time resolution
- 能量度量（幅值信息） Energetic metric (amplitude information)
- 未使用相位信息（大多数时域的精细结构丢失） Phase information is not used (Most fine structure in the time domain is lost)

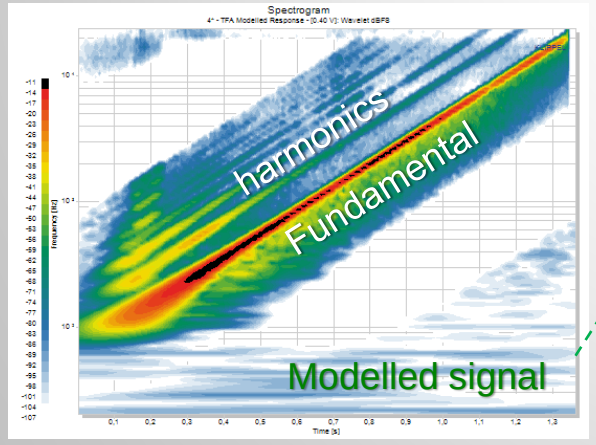
Time Domain Analysis

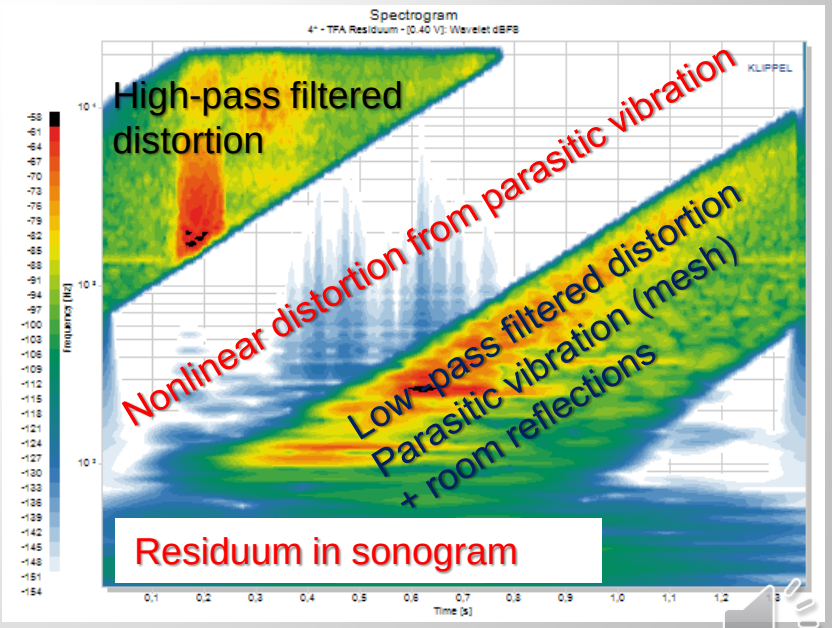




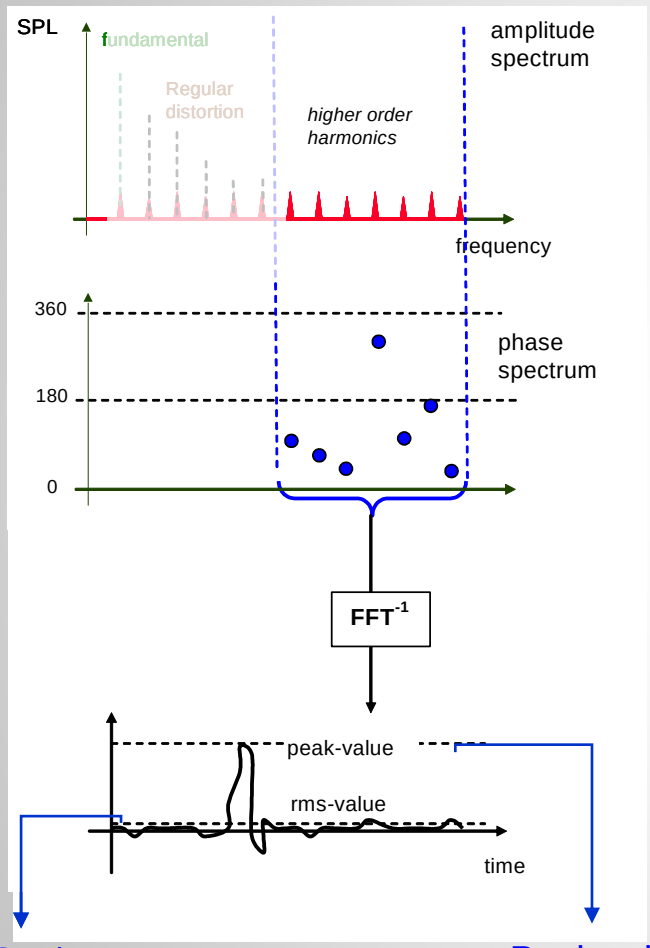


Residuum $p_{res}(t)=p_{meas}(t)-p_{model}(t)$





Time Domain Analysis



分析技术 Analysis Techniques:

- 残余（非线性建模） Residuum (nonlinear modeling)
- 高通滤波 High-pass filtering
- 符合IEC60268-21 According to IEC 60268-21

→ 利用高阶谐波和所有非谐波成分的幅值和相位 Exploiting amplitude and phase of higher-harmonics and all non-harmonic components

→ 峰值揭示了小的瞬变（咔哒声）
Peak value reveals small transients (clicks)

→ 对所有扬声器缺陷都敏感
Sensitive for all loudspeaker defects

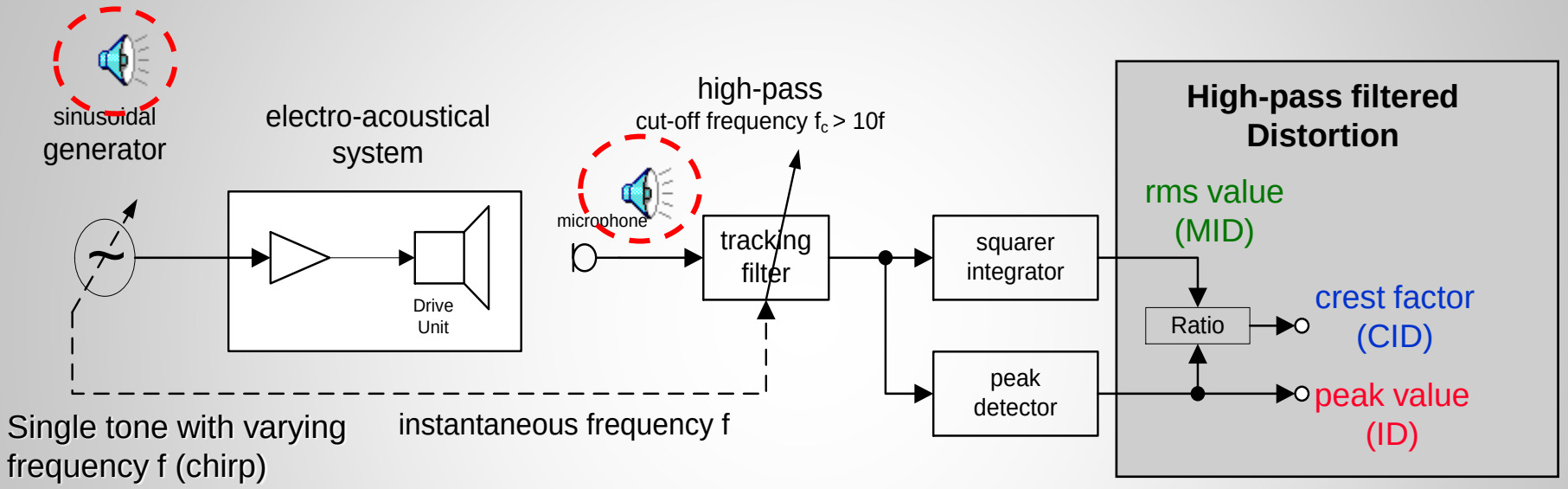
大多数扬声器缺陷产生带有高波峰系数的脉冲失真most loudspeaker defects generate impulsive distortion with high crest factor

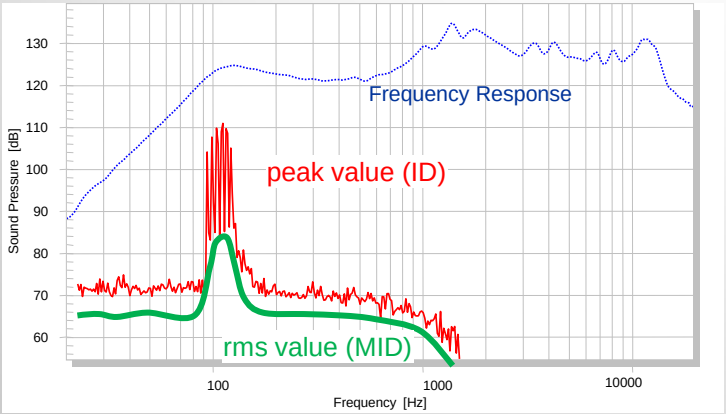
但是 but

常规扬声器失真、电子和麦克风噪声的波峰系数较低
regular loudspeaker distortions, electrical and microphone noise have lower crest factor

Peak value Contra rms-Value

Measurement technique defined in IEC 60268-21





脉冲失真ID对大多数非常规缺陷（如异音"rub and buzz"、松散微粒）来说是一个灵敏的测量项目 *Impulsive Distortion (ID) is a sensitive measure for most irregular defects such as „rub and buzz", loose particles !!*

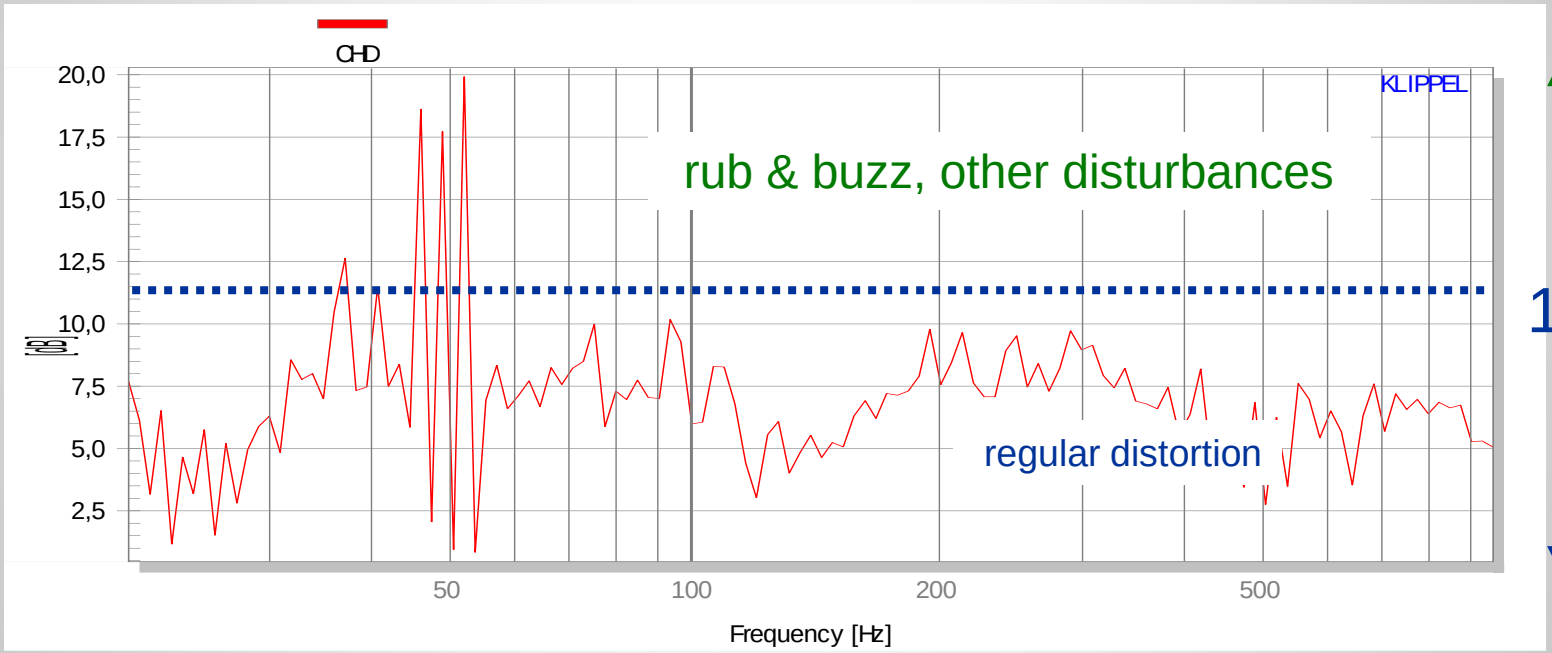
Crest factor of high-pass filtered distortion (CID)

Stimulus: Sinusoidal sweep

$$CID(f) = \frac{ID(f)}{MID(f)}$$

peak-value within one period

Rms-value averaged over one period



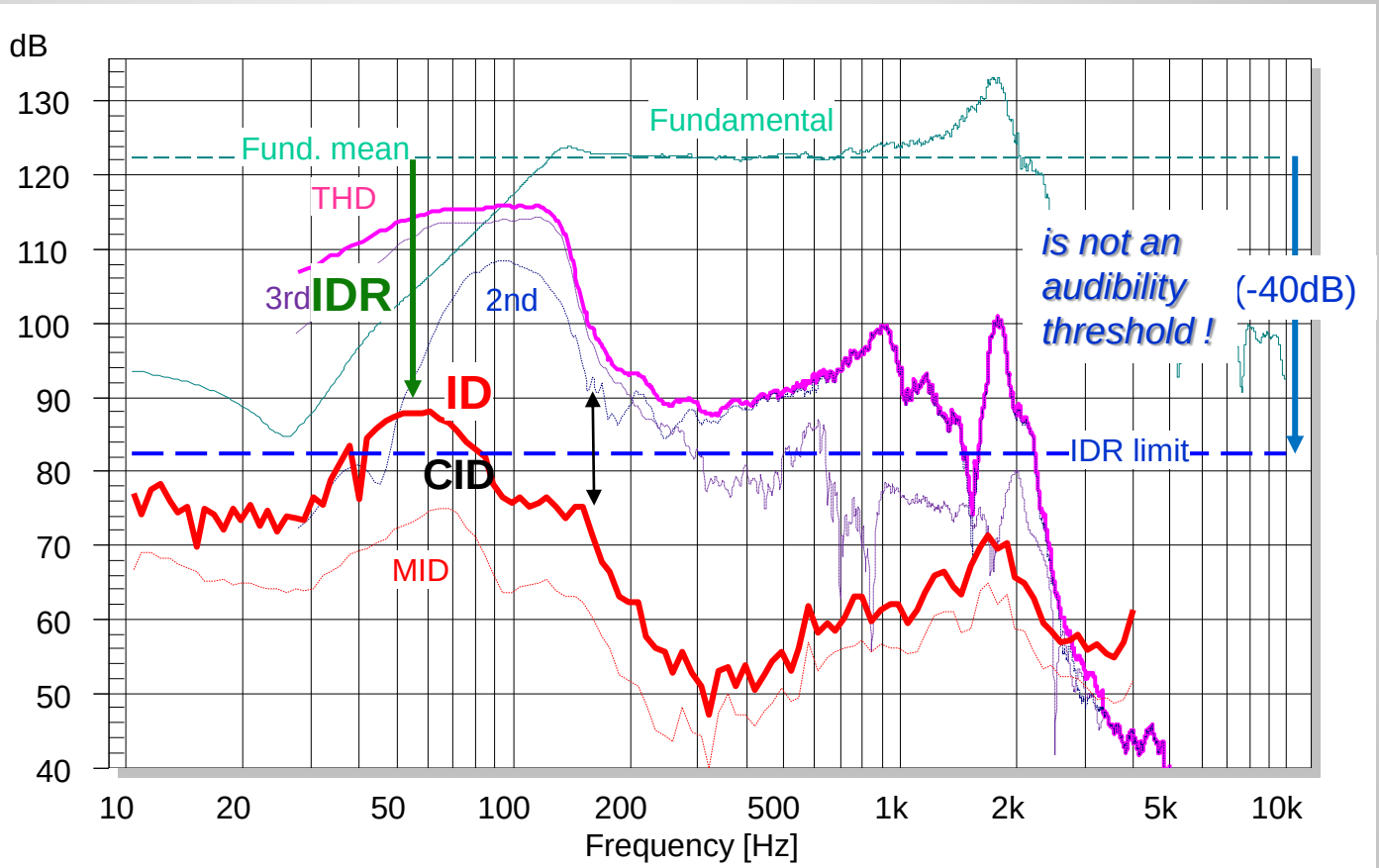
CID可以在绝对度量上解读! CID can be interpreted on an absolute scale !

CID利用所有高频分量的相位信息

CID exploits the phase information of all high frequency components

Loudspeaker Defect or Noise ?

Impulsive distortion ratio (IDR) is defined in IEC 60268-21



显著缺陷的症状 Symptoms of a significant defect:

1. 脉冲失真比 $IDR > -40dB$ Impulsive distortion ratio $IDR > -40dB$

2. 脉冲失真波峰系数 $CID > 12dB$

Crest factor of impulsive distortion $CID > 12dB$

检查符合度 Check for coincidence !

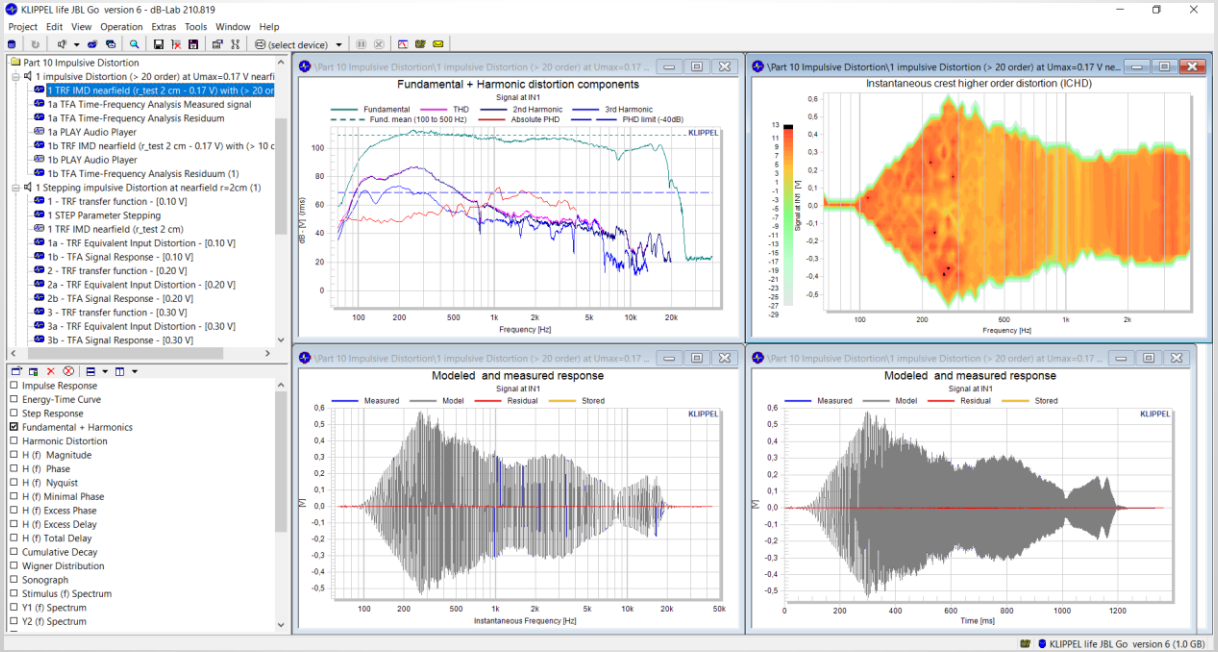
(麦克风噪声不具有脉冲性)

(microphone noise is not impulsive)

Demo

Tools: Using dedicated software modules of the KLIPPEL Analyzer

- TRF PRO (transfer function)



TRF中使用的特征值的交叉参考
Cross Reference for Characteristics used in TRF

IEC60268-21中的特征值 Characteristics in IEC 60268-21		**TEF中的特征值 Characteristics in TRF**	
名称 Name	符号 Symbol	名称 Name	符号 Symbol
脉冲失真 Impulsive Distortion	ID	高阶失真峰值 Peak value of higher- order distortion	PHD
平均脉冲失真级 Mean Impulsive Distortion Level	MID	高阶失真均值 Mean value of higher-order distortion	MHD
脉冲失真波峰系数 Crest factor of Impulsive Distortion	CID	高阶失真波峰系数 Crest factor of higher-order distortion	CHD

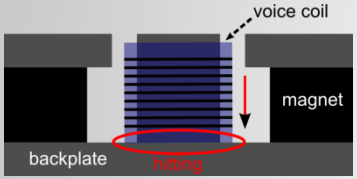
Poll:

您如何确定缺陷以及像异音之类的其他非常规行为?
How do you fix defects or other irregular behavior such as rub&buzz ?

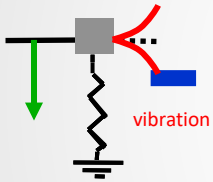
A. 试错 Trial and error
B. 视检（拆卸设备） Visual inspection (dissembling the device)
C. 用修改的激励做更多的测试（变化幅值）
   Further testing with modified stimuli (amplitude variation)
D. 与其他物理特征相关 Correlation with other physical characteristics
E. 其他方法 Other ways

扬声器缺陷的典型特征
Characteristic Features of Loudspeaker Defects

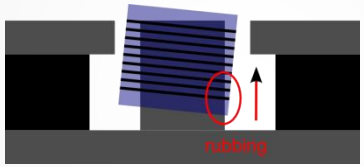
线圈打击底板
Coil hitting backplate



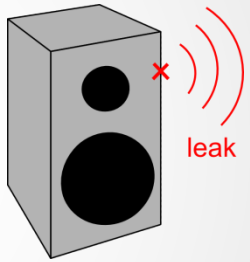
嗡嗡的松动接口
Buzzing loose joint



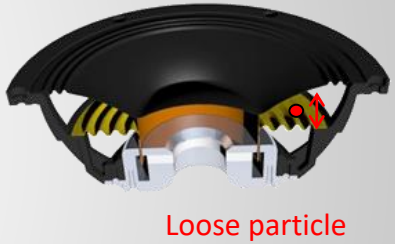
音圈擦圈
Rubbing voice coil



漏气处的流动噪声
Flow noise at air leak



松散微粒打击膜片 Loose particle hitting membrane



确定性的
Deterministic

半随机（混合特征）
Semi-random
(mixed characteristic)

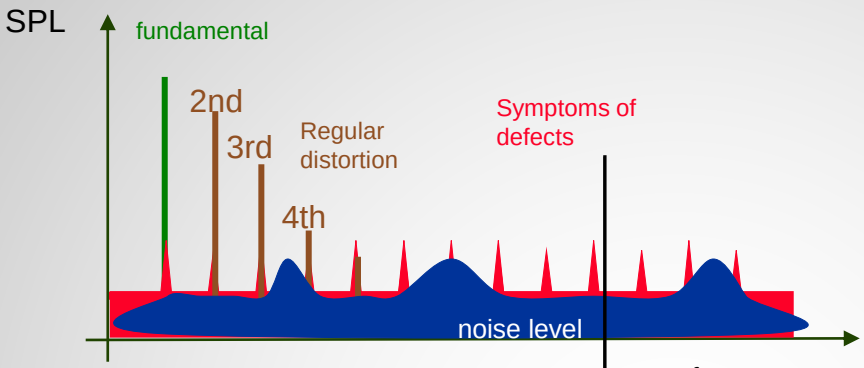
随机
Random

波形可完全重现
Waveform is completely reproducible

包络可重现（波形不行）
Envelope is reproducible (Waveform is not)

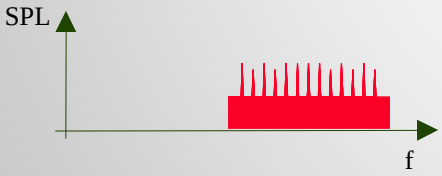
波形不可重现
Waveform is not reproducible

Separating Symptoms of a Defect

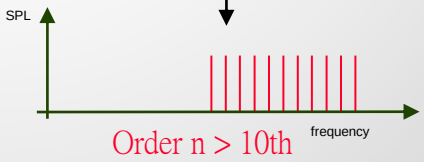


High-pass Filter
cut-off frequency $f_c > 10f$

High-pass filtered symptoms and noise

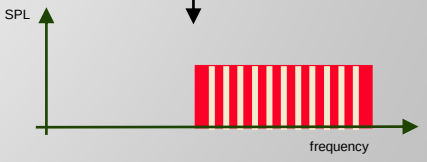


Comb Filter



Deterministic part
(higher-order harmonics)

Inverse Comb Filter



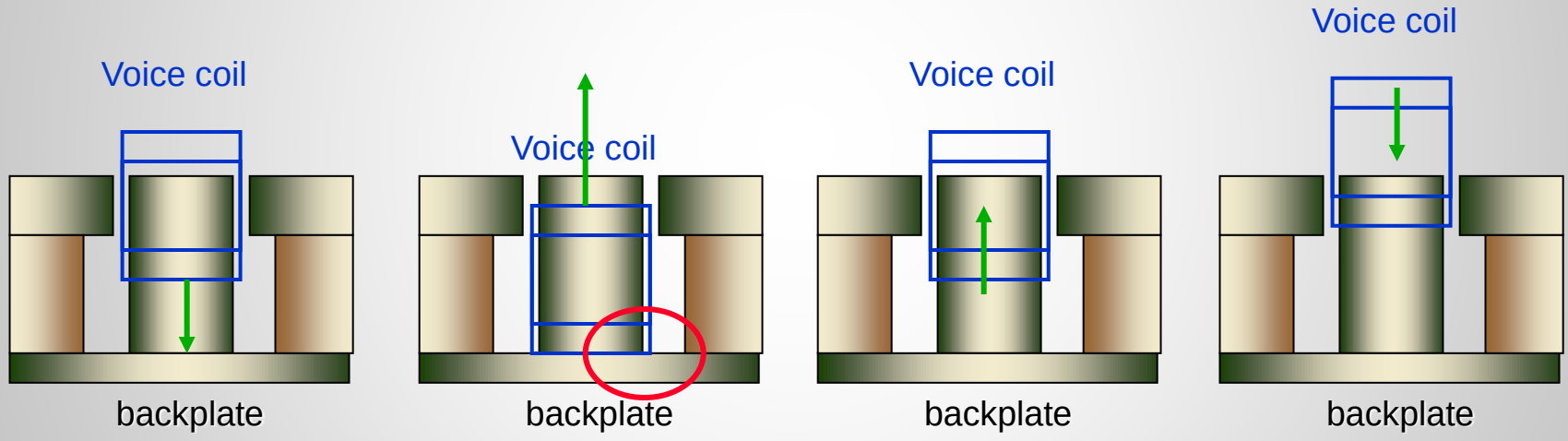
Random part
(non-harmonics)

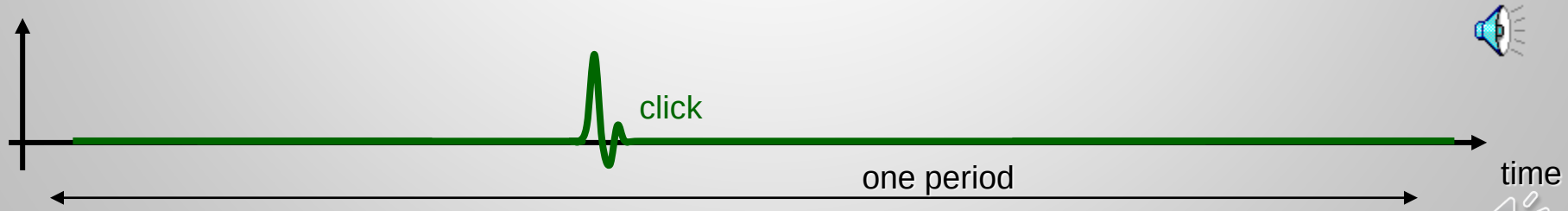
扬声器缺陷：音圈打底
Loudspeaker Defect: Voice Coil Bottoming

根本原因 Root causes:

- 静止位置偏移、DC位移 offset in rest position, DC displacement
- 高音圈行程 high voice coil excursion
- 音圈位移的硬限制 hard limiting of the voice coil displacement

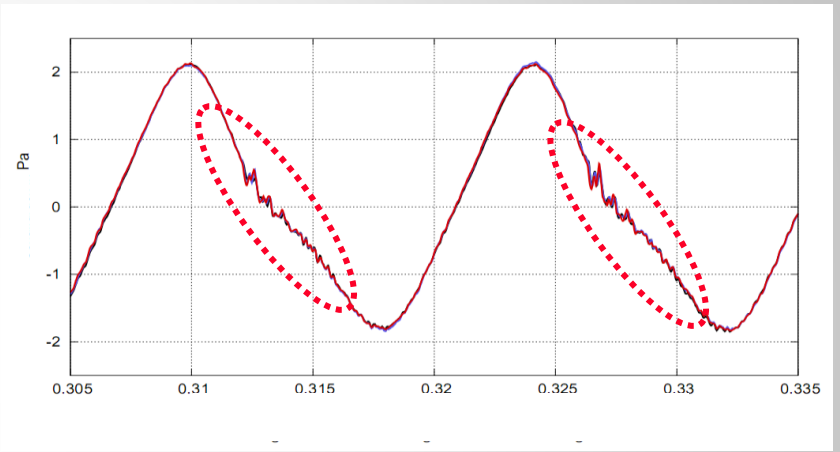
症状Symptoms:
脉冲性、确定性、峰值行程处的咔哒声impulsive, deterministic, click at peak excursion





确定性失真
Deterministic Distortion

Results of three measurements

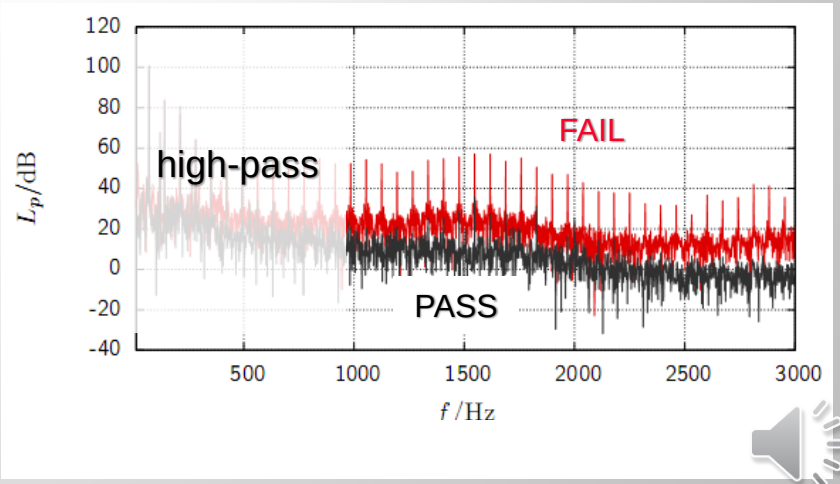


例子 Example:

拉伸击打、打底 tensile slap, bottoming

症状 Symptoms:

- 可重现、可重复 Reproducible, repeatable
- 与激励相关 Related with stimulus
- 脉冲失真 impulsive distortion
- 高阶谐波的确定性幅值和相位
  Deterministic amplitude and phase of higher-order harmonics

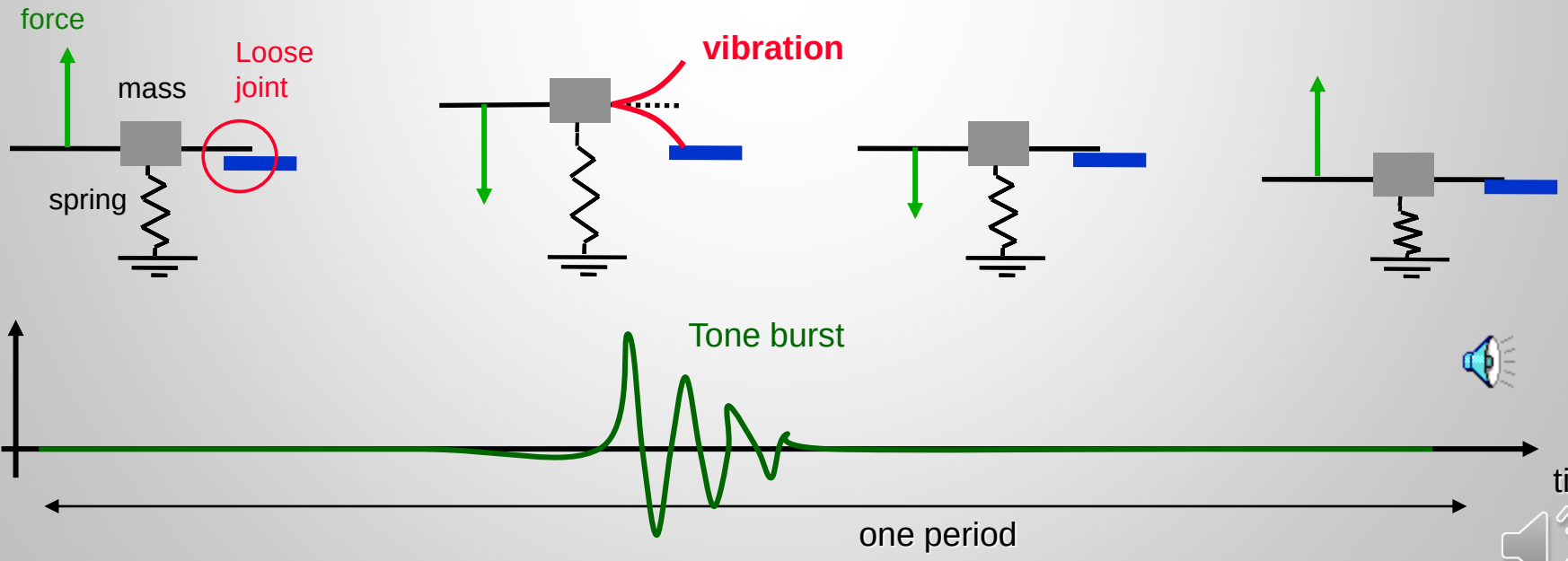


扬声器缺陷：嗡嗡声问题
Loudspeaker Defect: *Buzz problem*

根本原因 Root cause

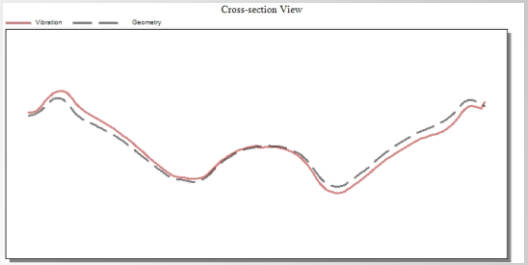
- 松动部分表现为<u>非线性振子</u>
  loose part behaves as a **<u>nonlinear oscillator</u>**
- 由激励驱动和同步
  powered and synchronized by stimulus
- 在临界振幅之上出现
  active above a critical amplitude
- 新的振动模式
  new mode of vibration

症状Symptoms:
特征频率处的短暂猝发音、部分确定性、脉冲性
short tone burst at characteristic frequency, partly deterministic, impulsive



扬声器缺陷：音圈擦圈
Loudspeaker Defect: Voice Coil Rubbing

Cause: rocking mode at 328 Hz

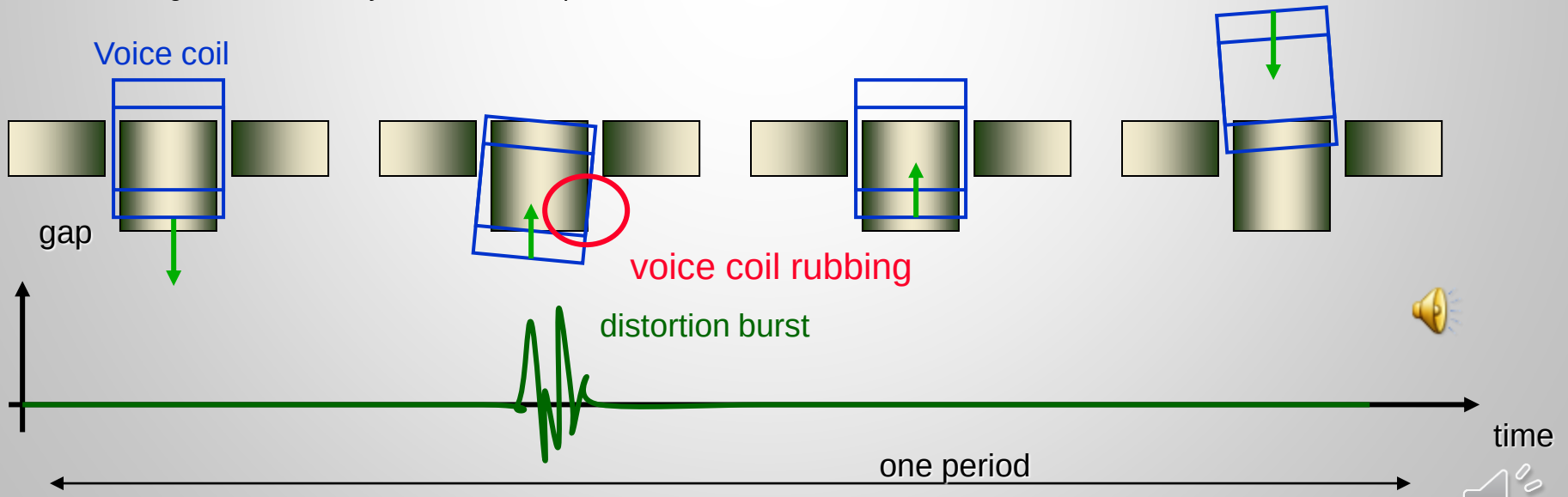


根本原因 Root causes:

- 质量、刚性、BI分布不平衡
  imbalances in mass, stiffness, BI distribution
- 高音圈位移激发摇摆模式
  high coil displacement excites rocking mode
- 在特定位置线圈擦圈 coil rubbing at a certain coil position

症状 Symptoms:

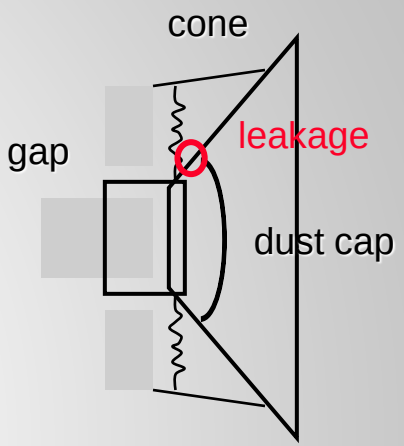
随机信号、被激励调制、脉冲猝发
stochastic signal, modulated by the stimulus, impulsive burst



扬声器缺陷：空气噪声
Loudspeaker Defect: Air Noise

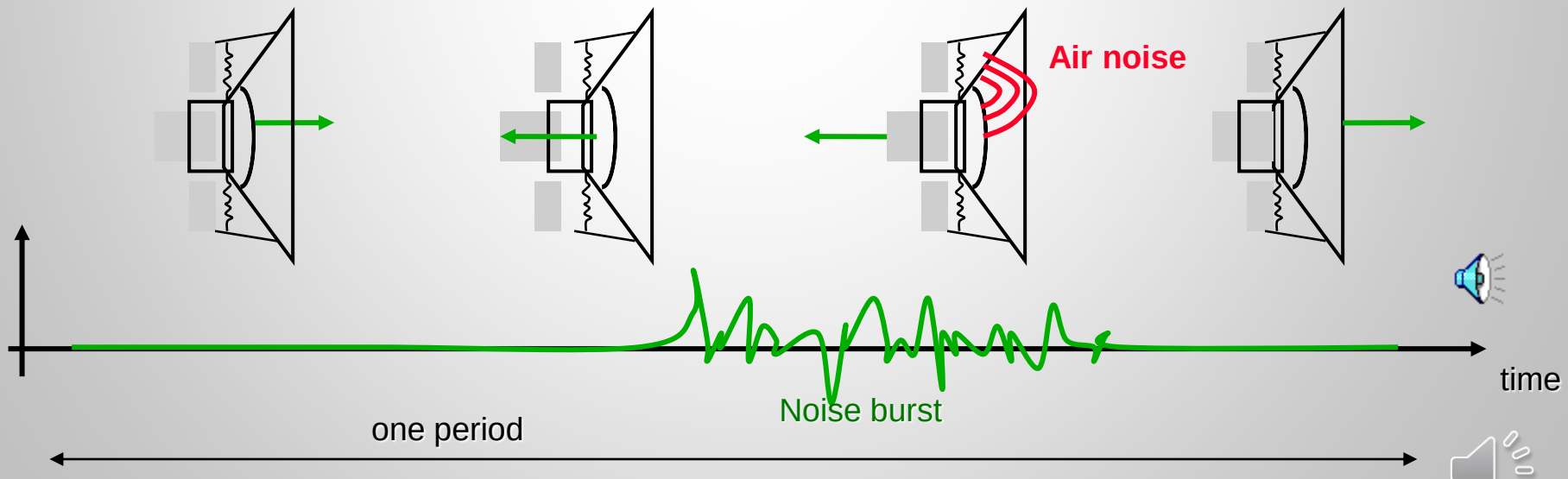
根本原因 Root cause:

- 防尘帽、箱体等泄漏 leakage in dust cap, box, …
- 线圈位移产生空气压力 coil displacement generates air pressure
- 高压引起泄漏处的高空气速度 High pressure causes high air velocity at the leakage
- 周期内湍流产生噪声猝发 Turbulences generate a noise burst in the period



症状 Symptoms:

随机信号、噪声被激励调制、脉冲噪声猝发stochastic signal, noise is modulated by the stimulus, impulsive noise burst



随机失真 Random Distortion

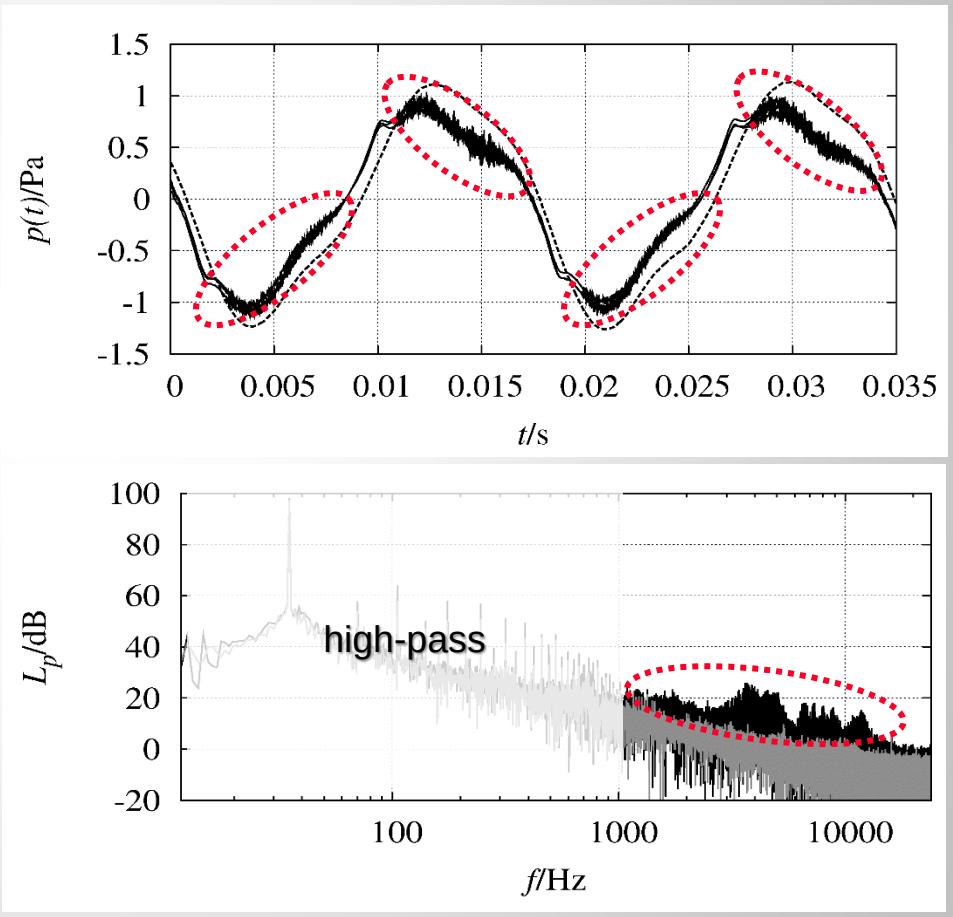
例子 **Example:**

泄漏处的湍流空气噪声、线圈擦圈

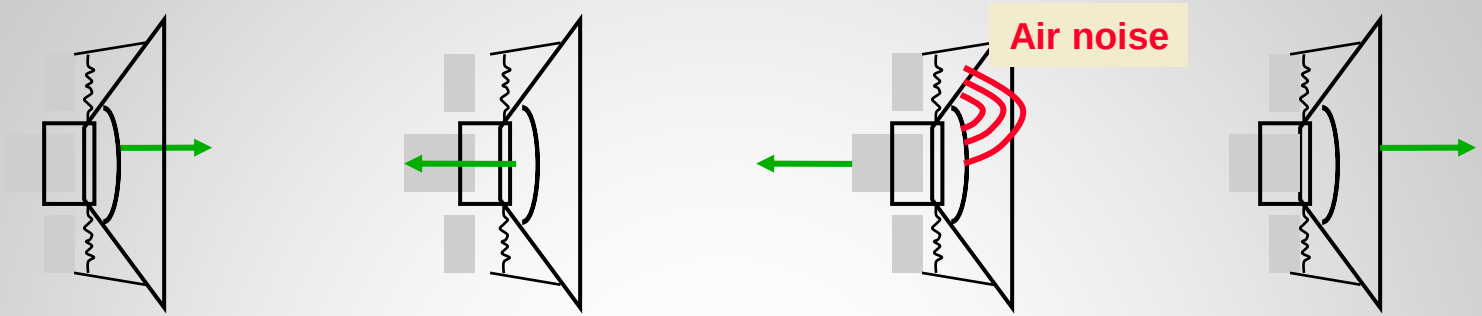
Turbulent air noise generated at leaks, coil rubbing

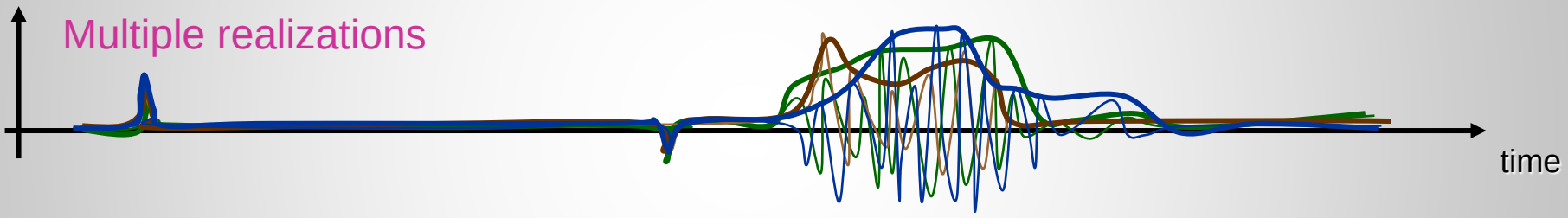
症状 **Symptoms:**

- 失真不能重现
  Distortion are NOT reproducible
- 失真出现在某些时刻
  Distortion occur at particular times
- 密集谱（覆盖音频带及之上）
  Dense spectrum (cover audio band and beyond)

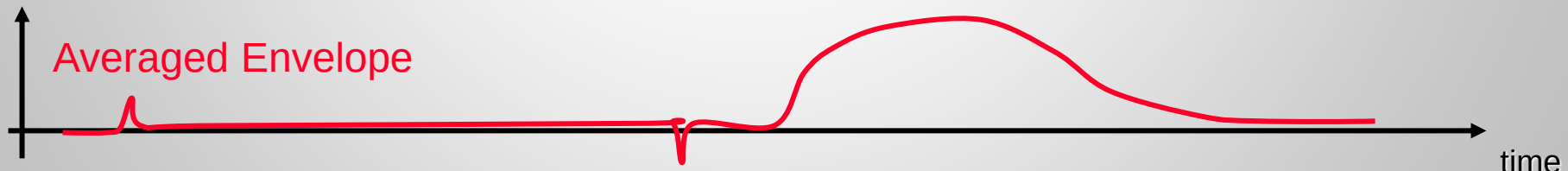


Envelope of the Modulated Noise



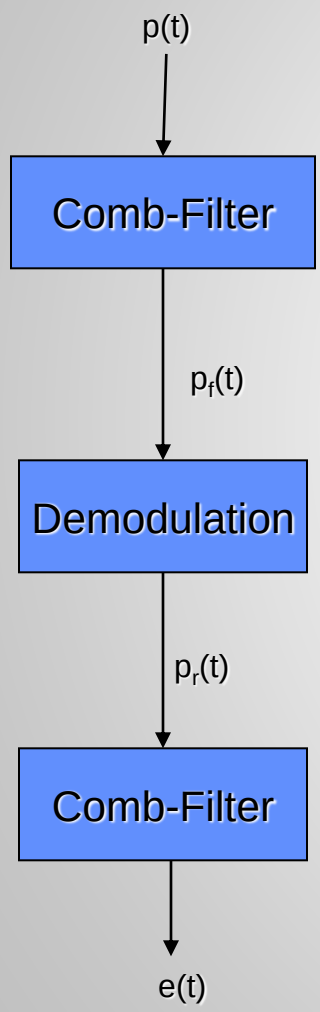


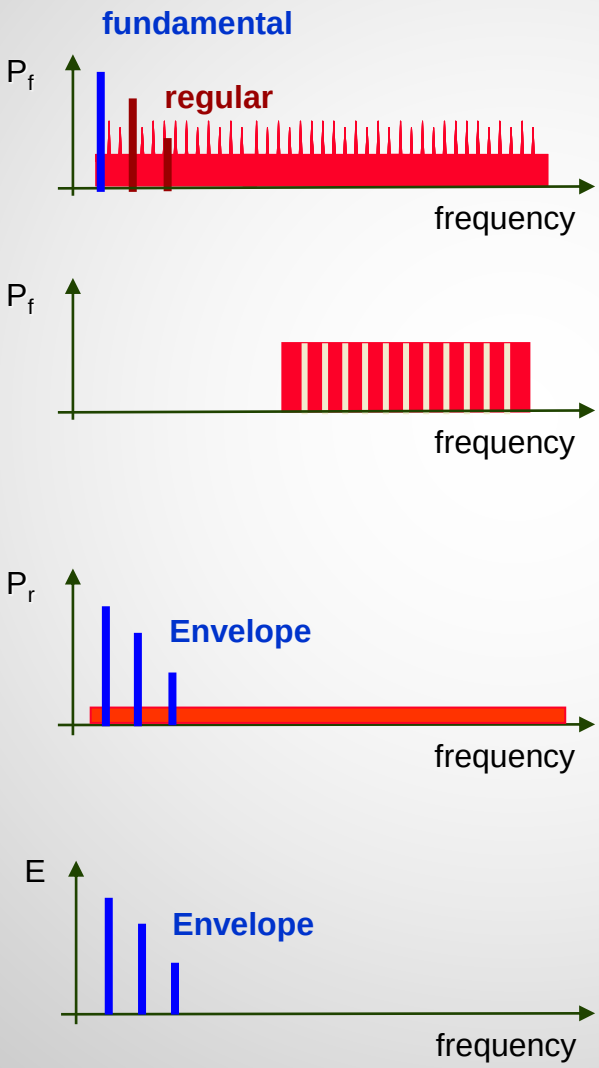
- 调制的噪声包络是确实定性的 Envelope of the modulated noise is deterministic
- 平均包络可提高信噪比 Averaging of the envelope increases signal to noise ratio

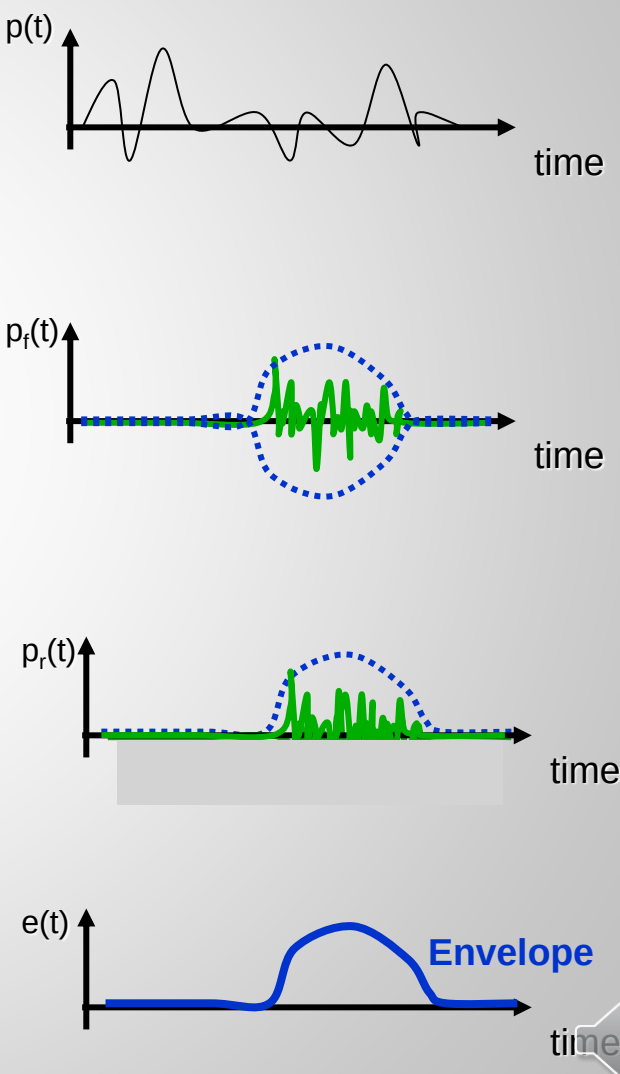


How to Calculate the Envelope ?

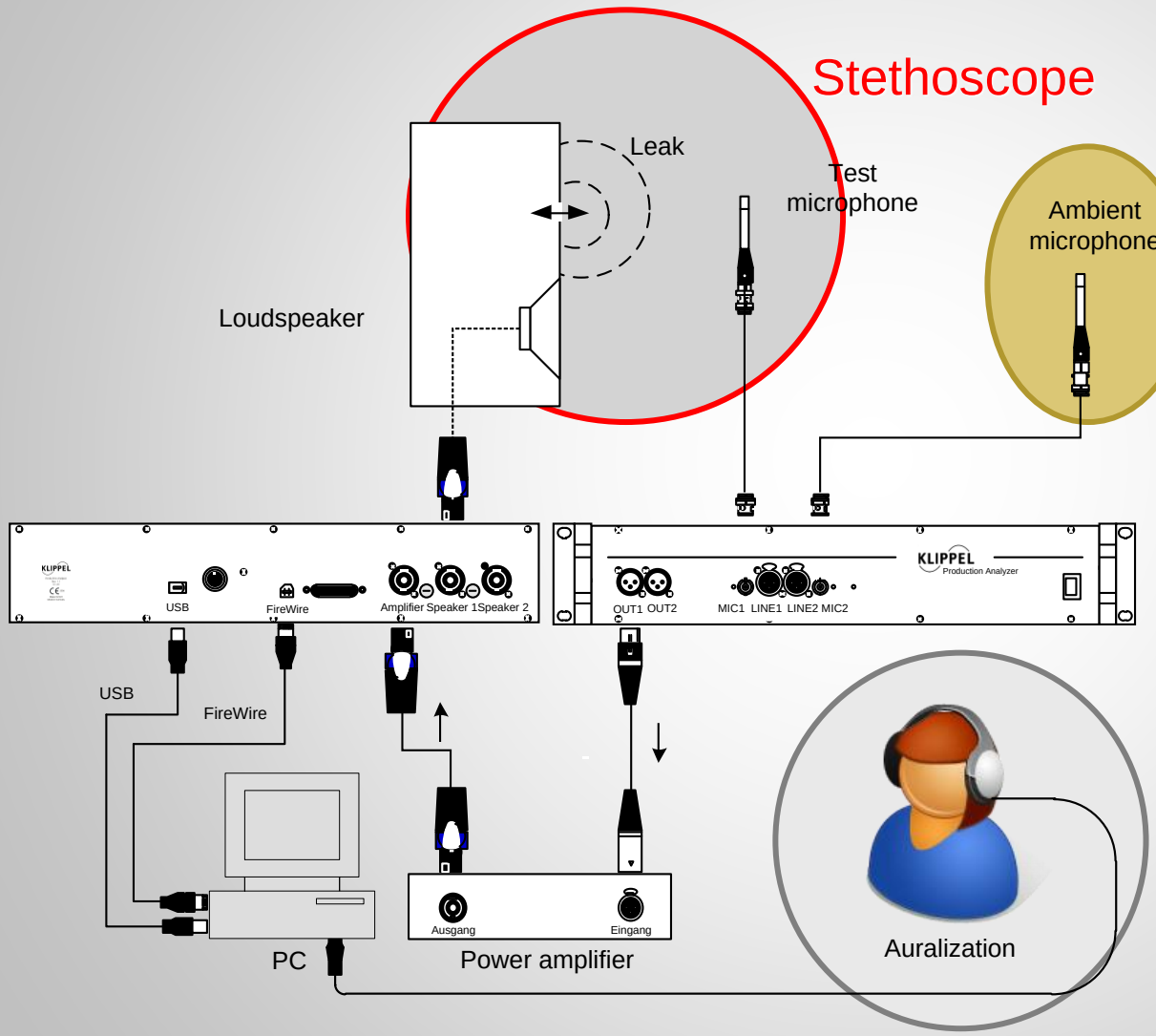
Single tone







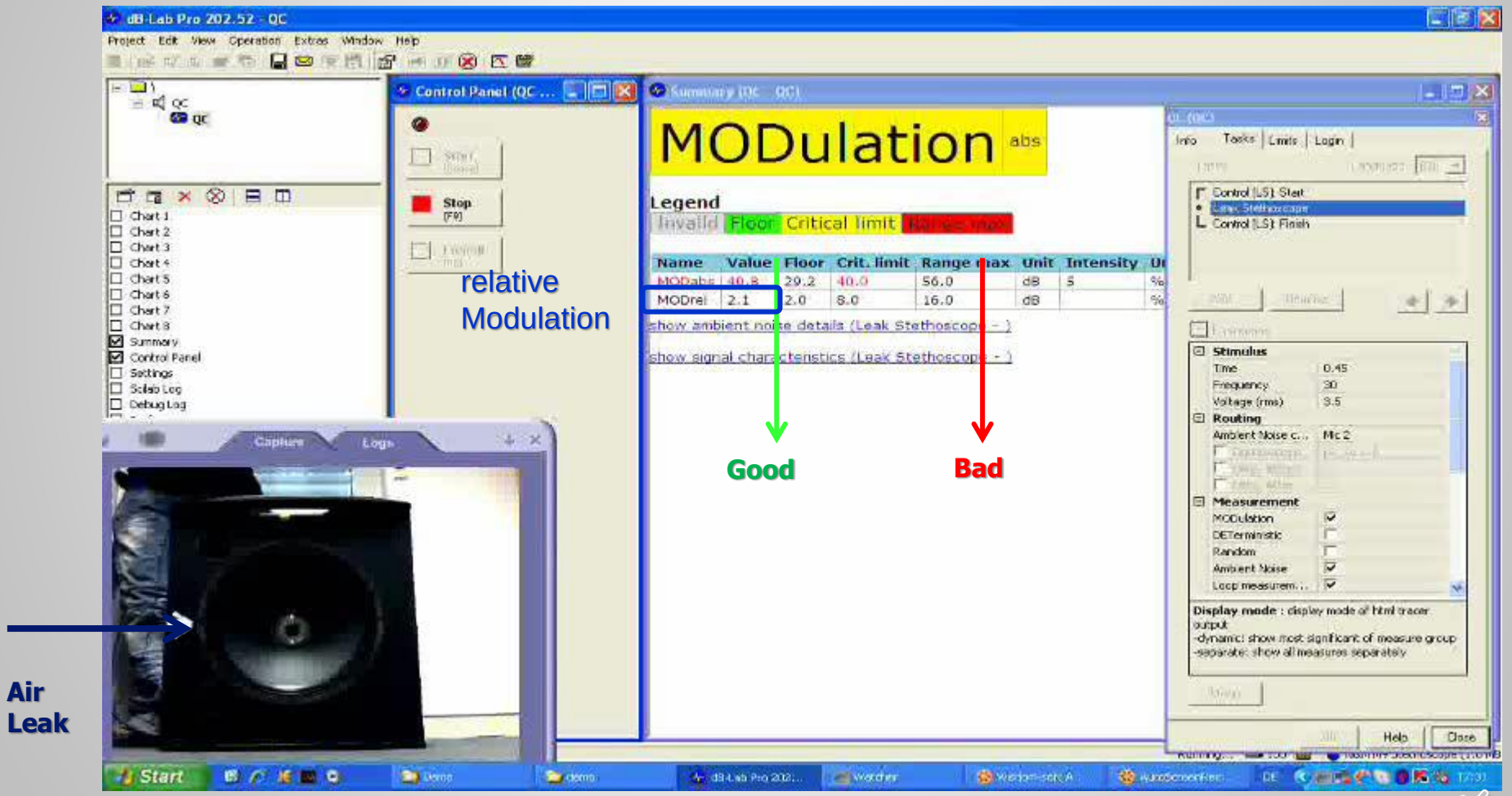
Combining Subjective and Objective Assessment



Objectives:

- Auralization of Irregular Distortion
- Ear Protection
- Signal Transformation
- Defect Localization
- Diagnostics

Localization of Loudspeaker Defects



扬声器缺陷：松散微粒
Loudspeaker Defect: Loose Particles

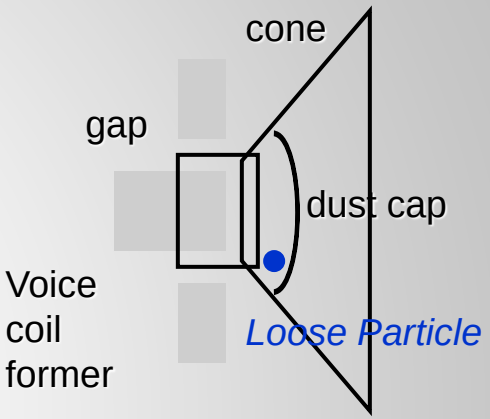
根本原因 Root Cause

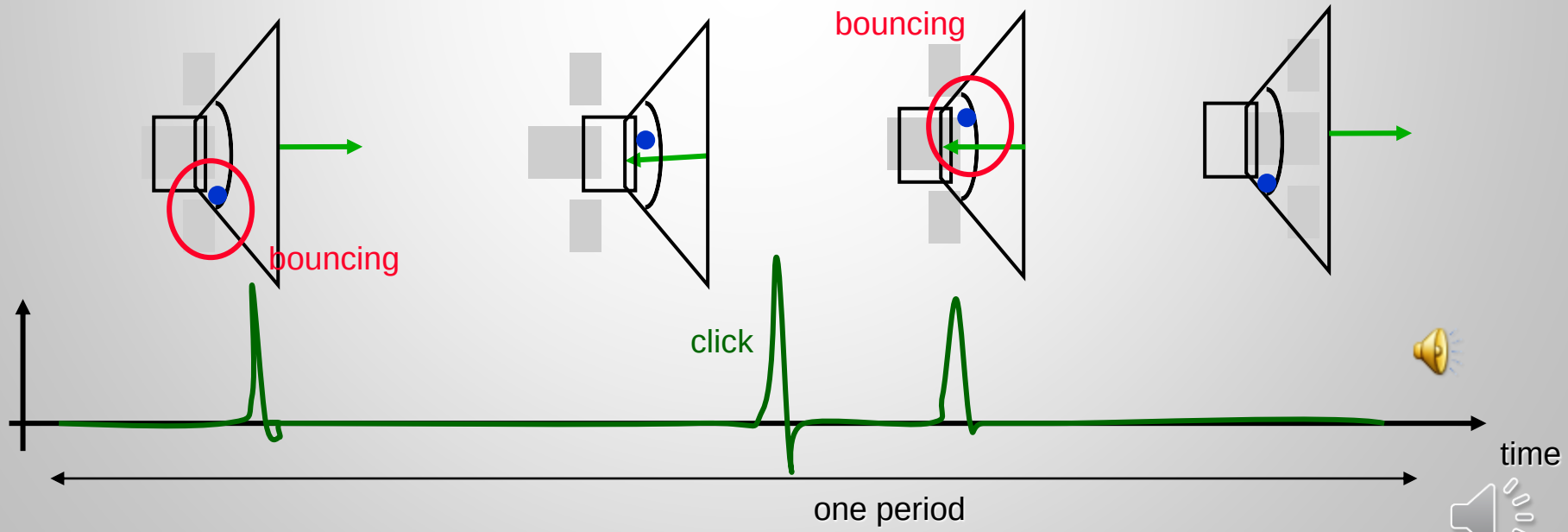
- 微粒被音盆位移加速 particles are accelerated by cone displacement
- 任何时候的弹跳产生小的咔哒声 bouncing generates a short click any time

症状 Symptoms:

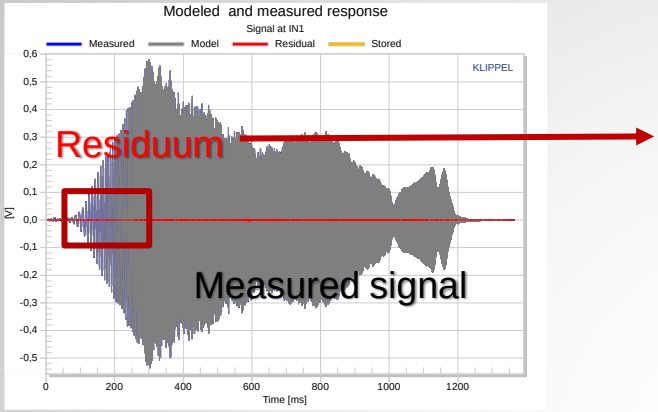
随机、与激励不同步、高峰值SPL但输出能量低、脉冲性

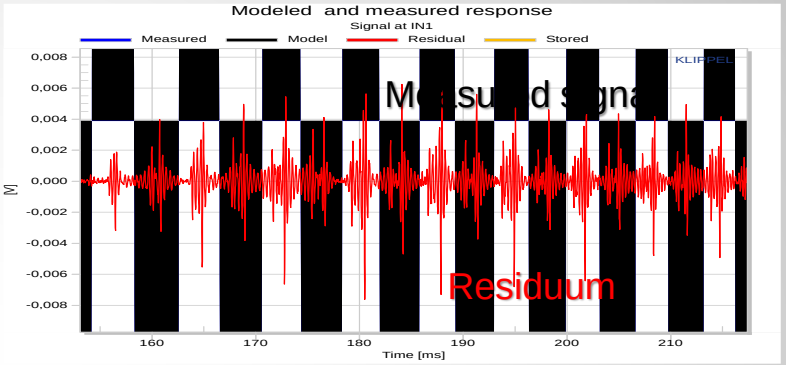
random, not synchronized with stimulus, high peak SPL but low output power, impulsive





Fine Structure Analysis

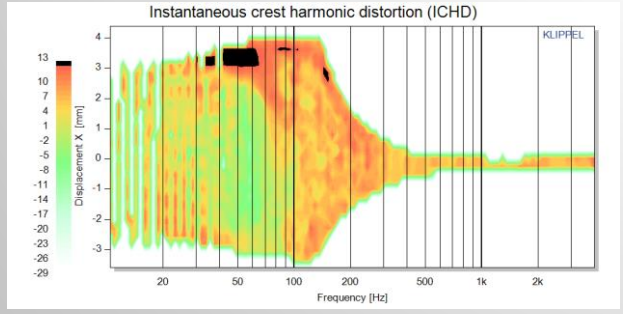




1) 映射残余（瞬时波峰系数ICID）到换能器状态量

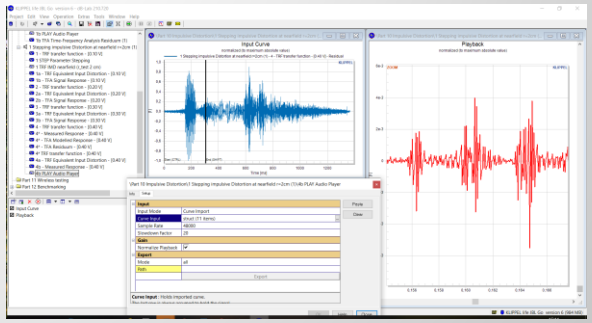
Mapping the residuum (instantaneous crest factor ICID) versus transducer state

- 音圈位移 Voice coil displacement
- 声压（加速度） Sound pressure (acceleration)

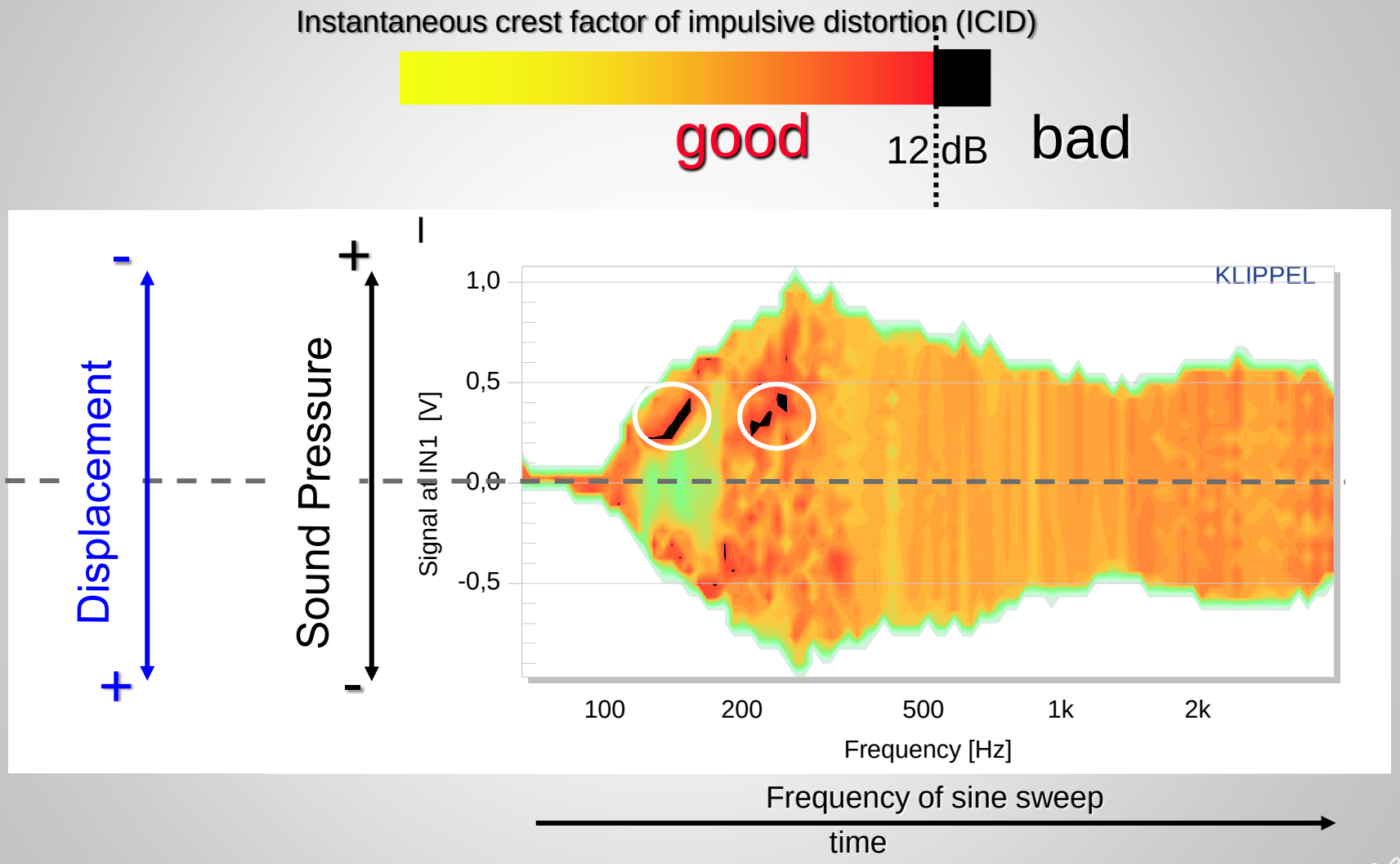


2) 人耳聆听过采样的残余（减速10倍）

Human ear listening to the upsampled residuum (slowdown factor 10)



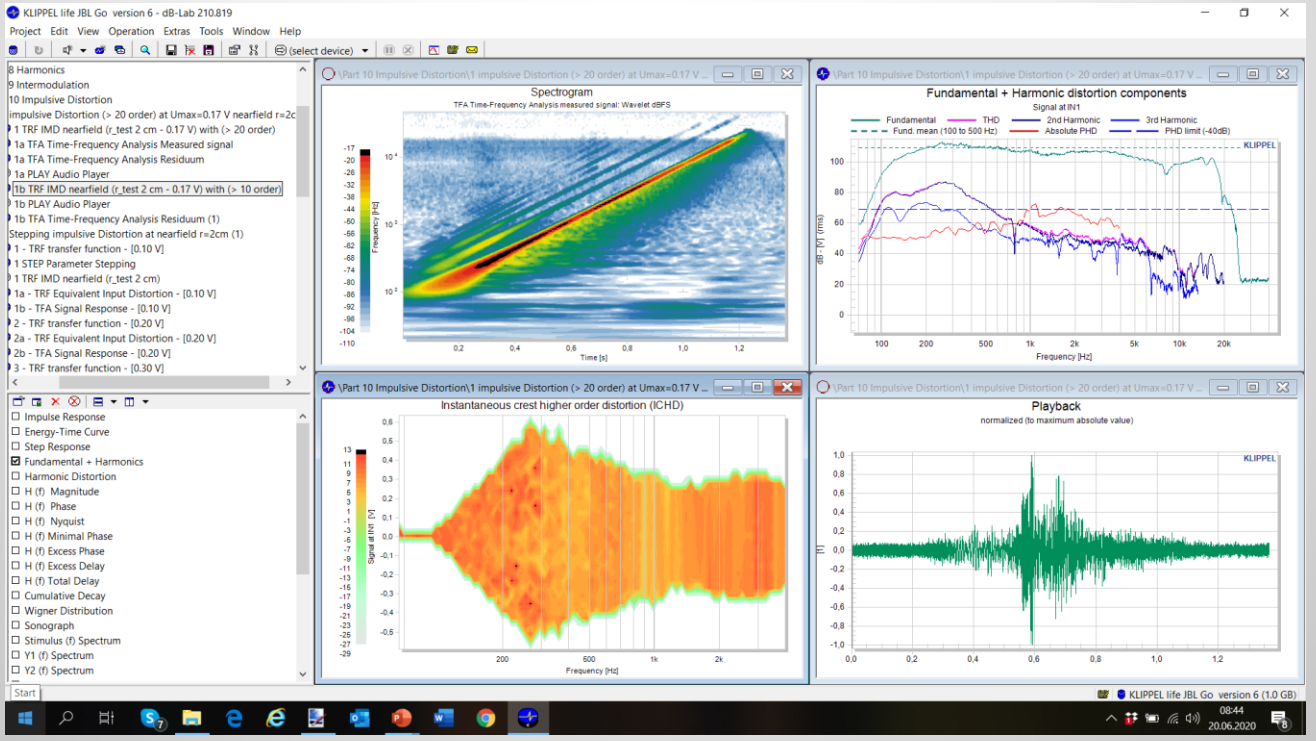
Impulsive Distortion mapped versus State Signal



Demo

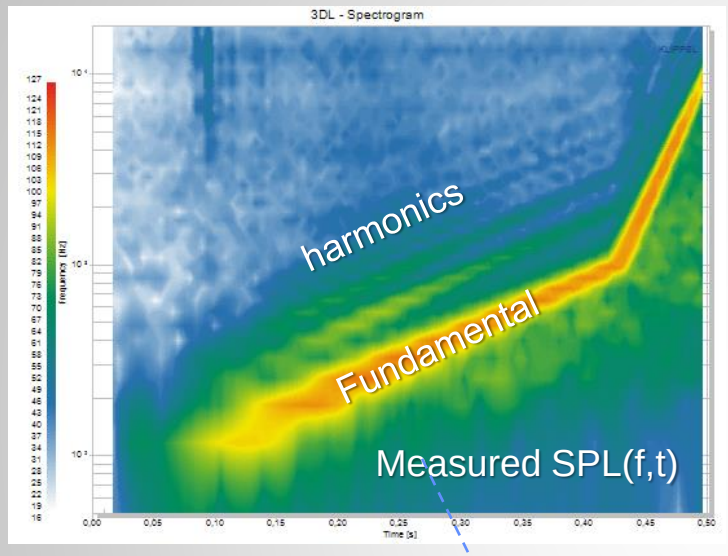
Tools: Using dedicated software modules of the KLIPPEL Analyzer

- TRF PRO (transfer function)
- TRF Stepping
- **TFA (time frequency analysis)**
- **PLAY (audio player for fine structure analysis)**

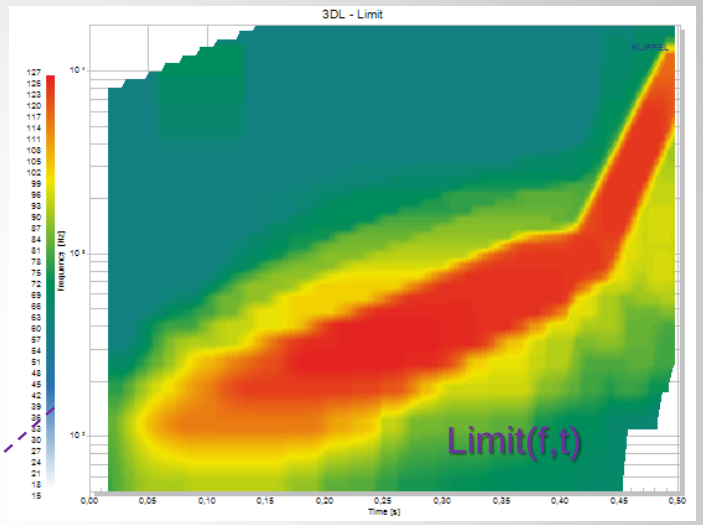


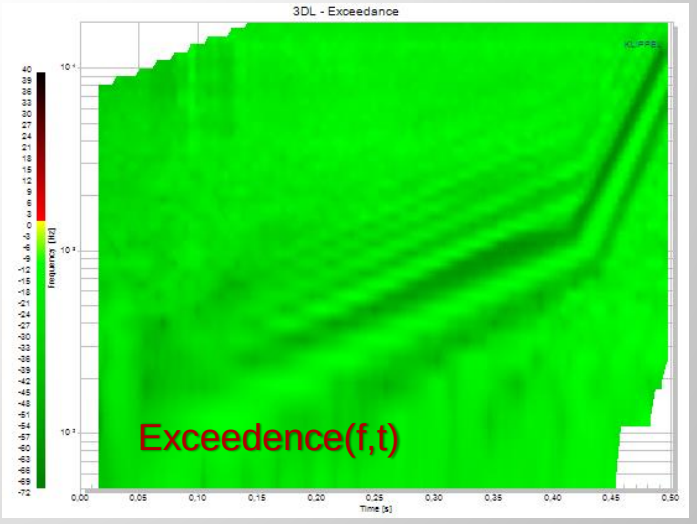
3D Limits in End-of-Line Testing

LIMIT MODE (GOLDEN REFERENCE Devíce)



Limit calculation



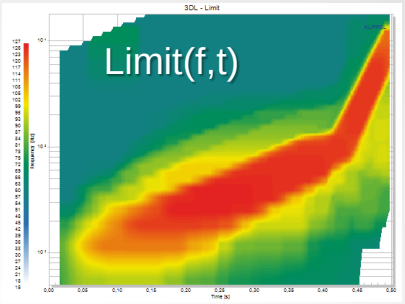


$$Exceedence(f, t) = SPL_{meas}(f,t) - Limit(f,t)$$

Classification:
PASS: negative exceedence value (green)
FAIL: positive Exceedence value (red)

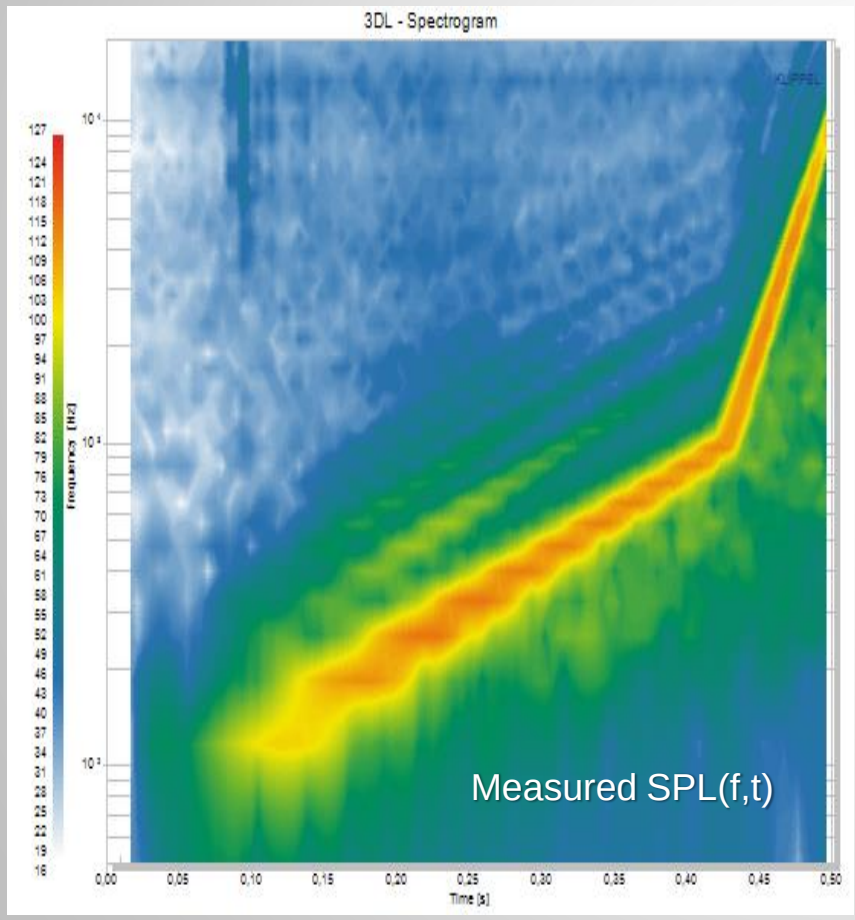
3D Limits in End-of-Line Testing

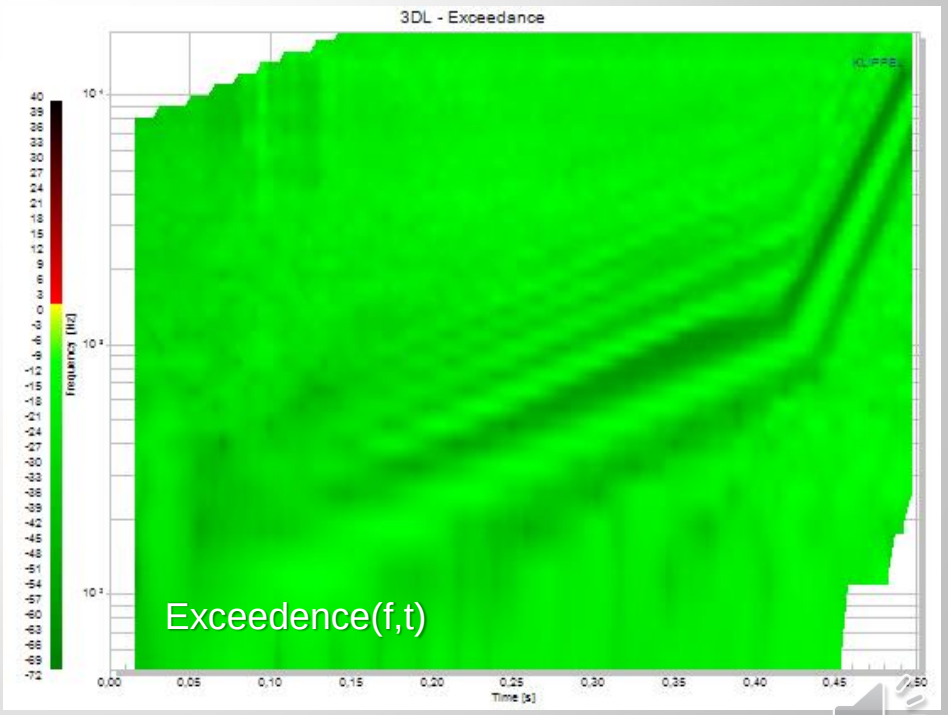
On-Line MODE
(DUT without defect)



PASS

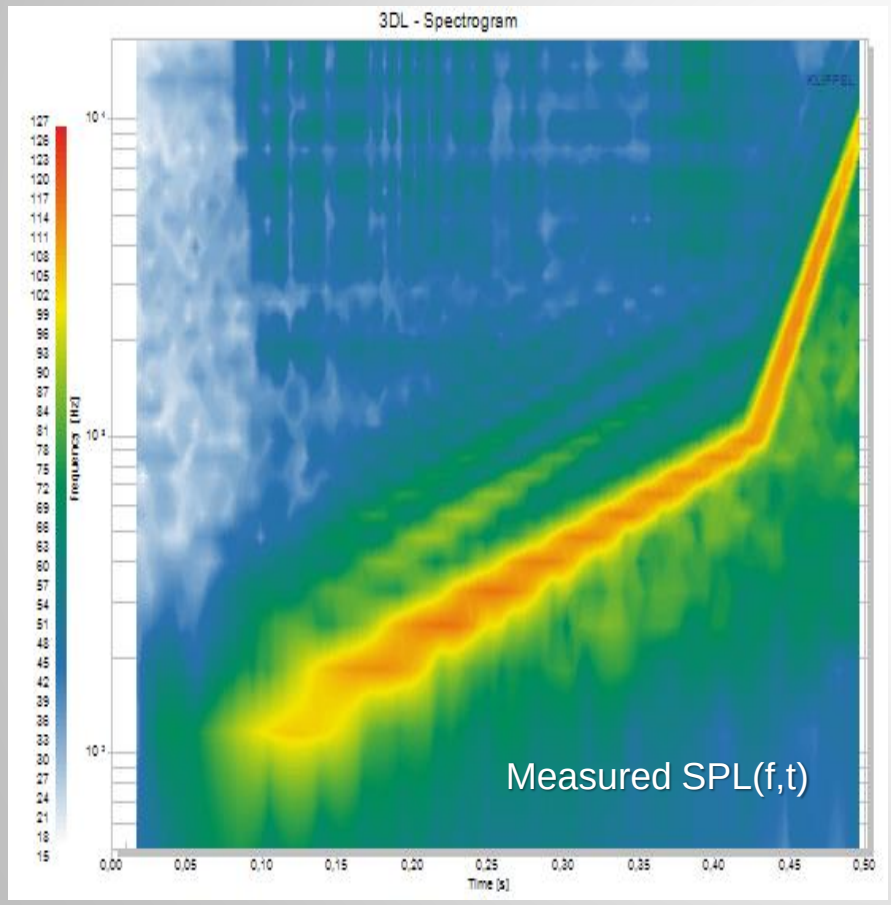
Frequency Response
Average Level
Polarity
THD
2nd Harmonic
3rd Harmonic
Rub+Buzz
3DL - Spectrogram

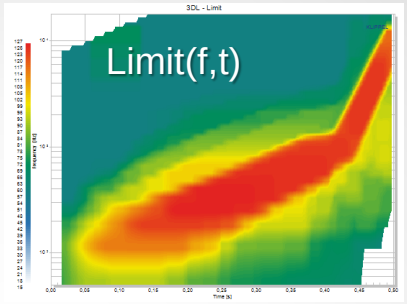




3D Limits in End-of-Line Testing

On-Line MODE
(DUT with defect)

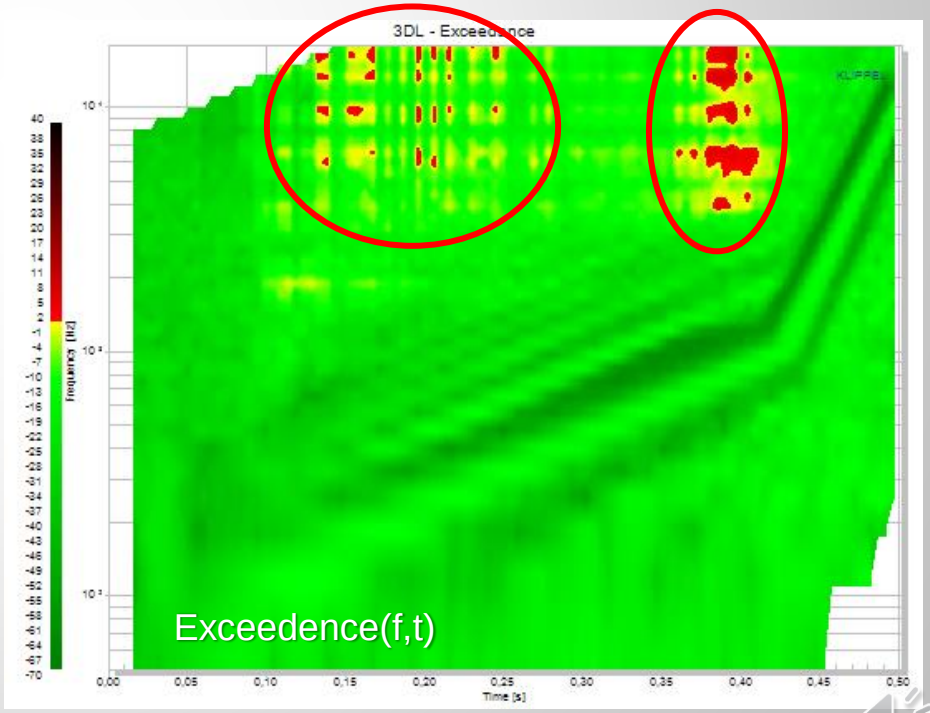




FAIL

Frequency Response
Average Level
Polarity
THD
2nd Harmonic
3rd Harmonic
Rub+Buzz
3DL - Spectrogram

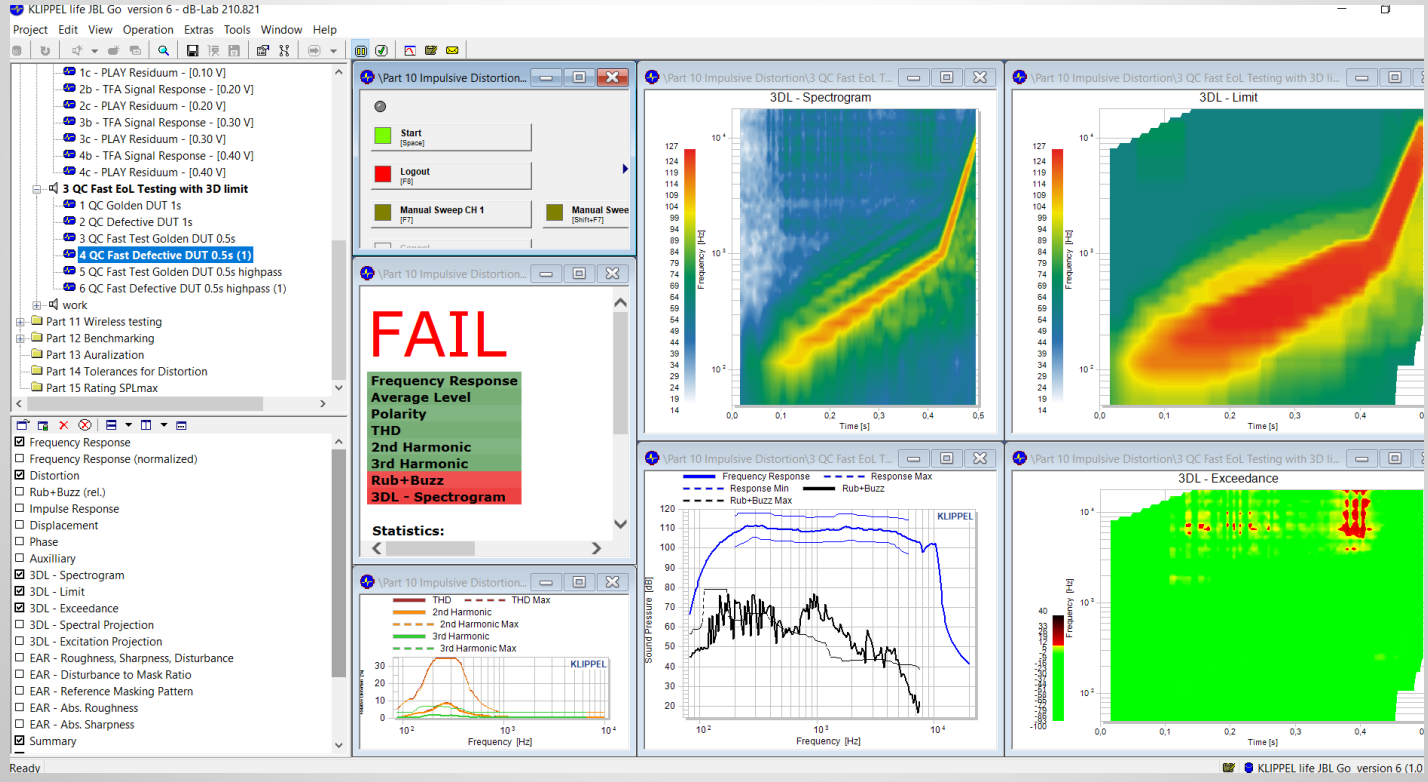
Statistics:



Demo

Tools: Using dedicated software modules of the KLIPPEL Analyzer

- QC Software (SPL Task with 3D limits)



Discussion

Summary

- 正弦信号（chirp）是检测非常规失真非常灵敏的激励
  A sinusoidal signal (chirp) is a very sensitive stimulus for irregular distortion
- 使用灵敏的麦克风并置于近场
  Use a sensitive microphone place in the near field
- 在时域查看失真（残余）
  Inspect the distortion (residuum) in the time domain
- 搜索根本原因并修复它
  Search for the root cause and fix it
- 聆听过采样的失真并查看精细结构
  Listen to the up-sampled distortion signal to inspect the fine structure
- 不要寄送缺陷单元给客户（大多数非常规失真随着时间会变得更糟） Do not ship a defective unit to a customer (most irregular distortion become worse over time) !

Open Questions

到目前为止，我们使用常规的模拟输入通道进行测试。如何测试带有数字甚至无线输入的现代设备呢?

Up to now we have used the conventional analog input channel for testing. How can modern equipment with a digital and even a wireless input be tested ?

第11期网络研讨会主题

The next 11th KLIPPEL live webinar entitled

测试无线音频设备的困难之处

Pitfalls in Testing Wireless Audio Devices (July 22nd)

将讨论 will address the points:

- 新问题概览 Overview on new problems
- 处理长时且可变的时延、采样率漂移、掉线、毛刺
  Coping with long and variable time delay, sample rate drift, dropouts, glitches
- 如何在全息测试和3D声音应用中进行精确的相位测量
  How to perform accurate phase measurements required for holographic testing and 3D sound application
- 简单实用的R&D和QC终端线解决方案
  Simple and practical solutions for R&D and QC end-of-line

Next Section

1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at a single evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects

ASK KLIPPEL TEAM (July 1st)

---- break ---

11. Pitfalls in Testing Wireless Audio Devices (July 22nd)
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. Setting meaningful tolerances for signal distortion
15. Rating the maximum SPL value for product