Acoustical Measurement of Sound System Equipment according IEC 60268-21

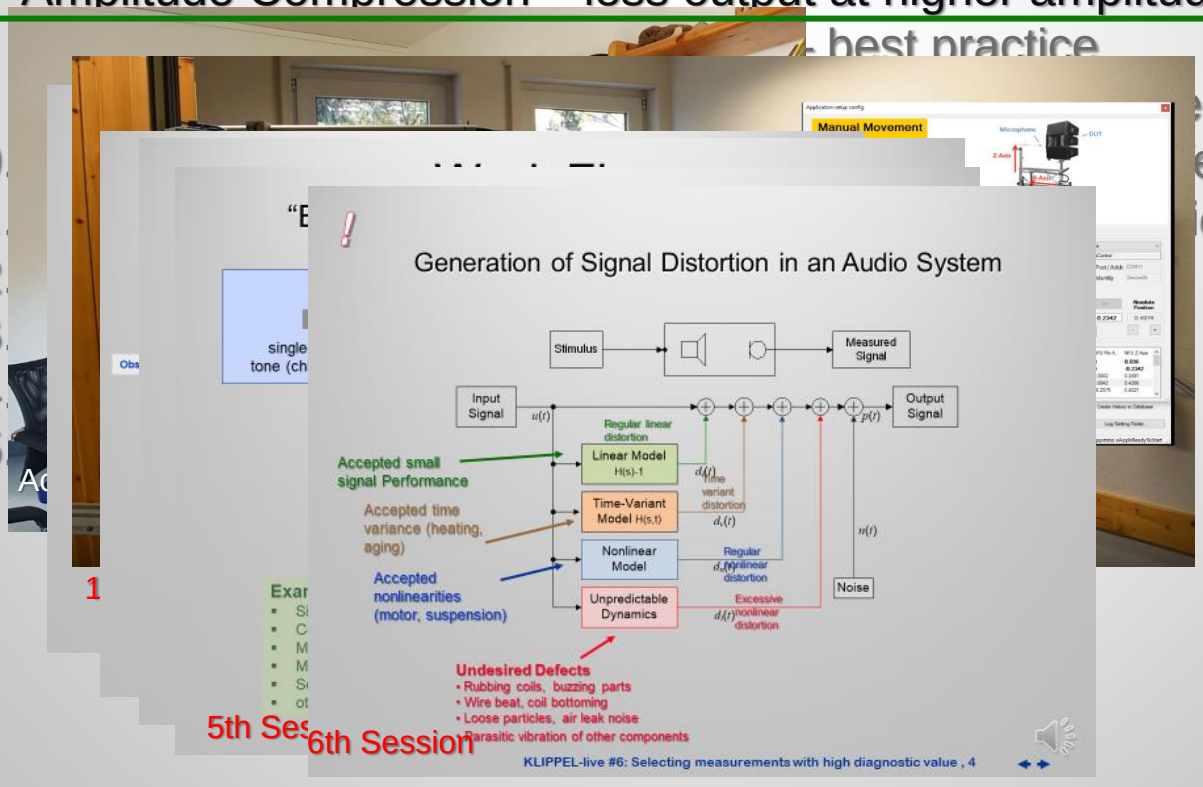
KLIPPEL- live

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. [illegible] best practice
9. [illegible] tone
10. [illegible] ects
11. [illegible] ions
12. [illegible]
13. [illegible]
14. [illegible]
15. [illegible]



Previous Sessions

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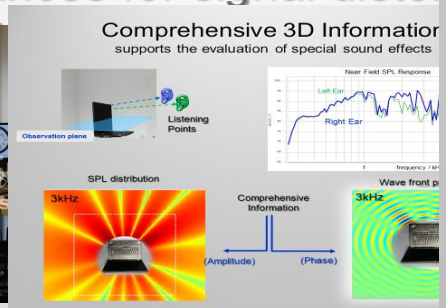
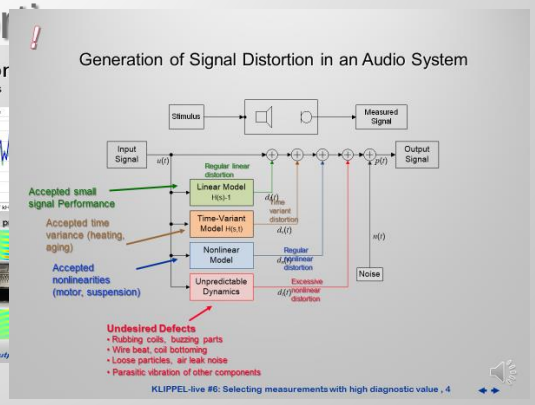
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects
11. Pitfalls in Testing Wireless Audio Devices
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. [illegible] tolerances for signal distor[illegible]
15. [illegible]

2nd Session

6th Session



3rd Session



11th KLIPPEL live:
测试无线音频设备的困难之处
Pitfalls in Testing Wireless Audio Devices

今日话题 Topics today:

- 现代音频设备中的新挑战 New challenges in modern audio devices
- R&D和QC终端线测试的解决方案 Solutions for R&D and QC end-of-line testing
- 普遍问题概述 Overview on common problems
- 确保可靠测试数据的实用建议 Practical tips to ensure reliable test data
- 演示 Demos

Poll:

您更喜欢哪种传输方式来测试有源音频系统?
Which transmission way do you prefer for testing active audio system (if available) ?

A. 模拟线缆 Analog cable

B. 数字线缆（例如Toslink、HDMI、LAN） Digital cable (e.g. Toslink, HDMI, LAN)

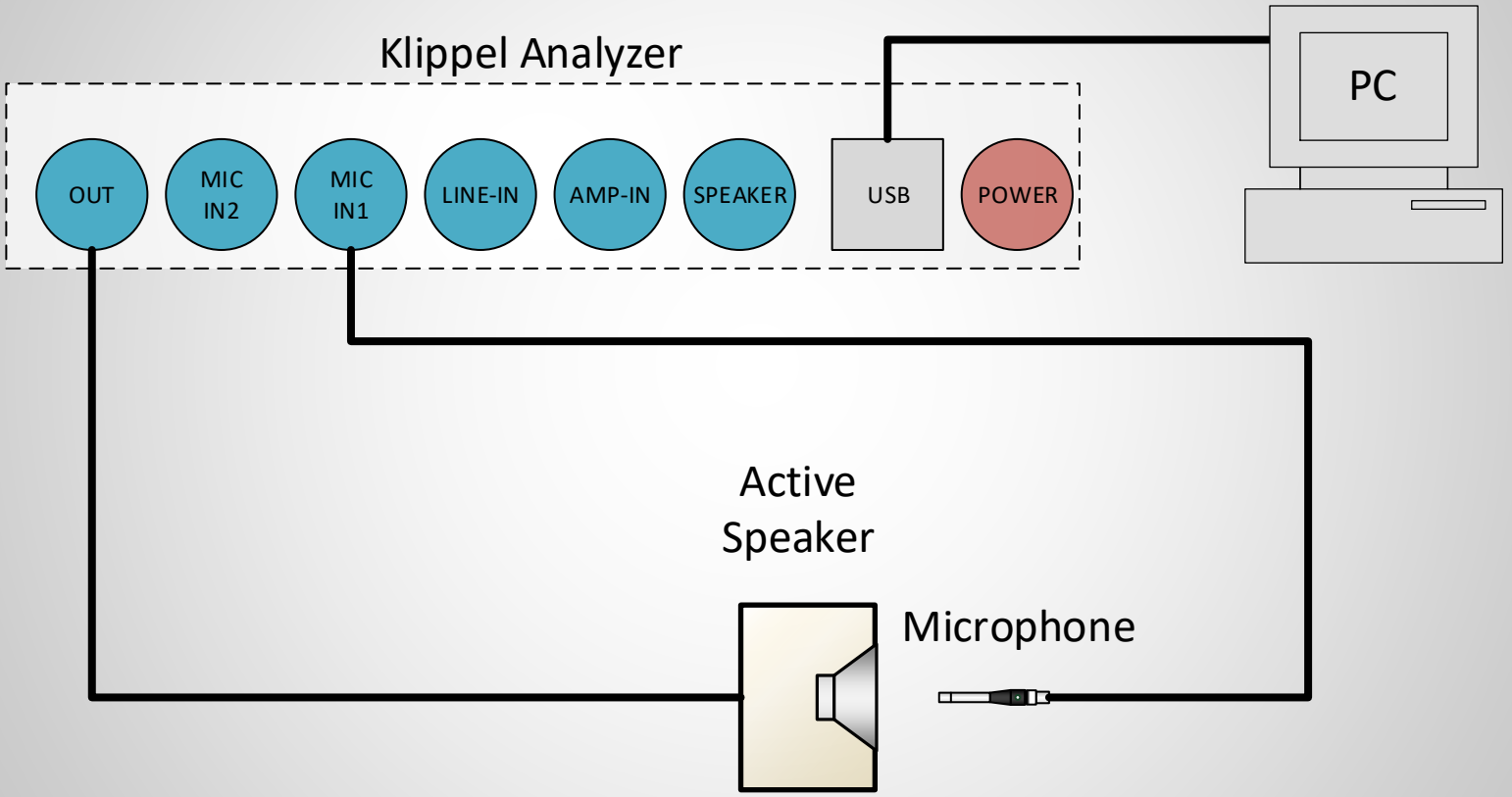
C. 无线（WLAN） Wireless (WLAN)

D. 无线（蓝牙） Wireless (Bluetooth)

E. 异步传输（例如播放和录制音频文件） Asynchronous transmission (e.g. playing and recording an audio file)

F. 其他 others

方案1：闭环测试（模拟）
Scenario 1: Closed-Loop Testing (Analog)



DUT直接连接到分析仪输出端 Analyzer Output Directly Connected to DUT

Bluetooth Technology Overview

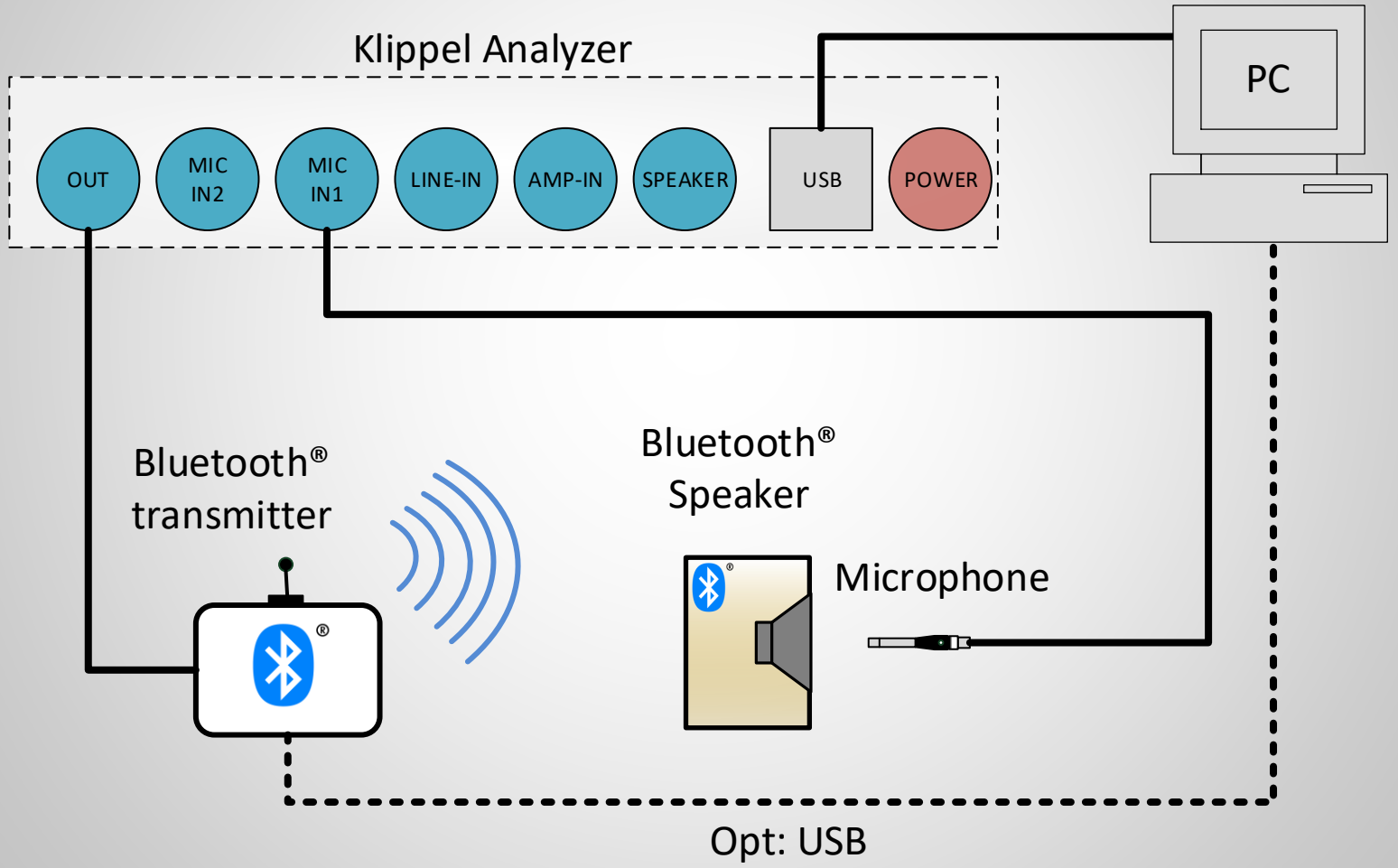
- 短距离通信 Short range communication
- 配对连接 Pairing and connection
- 蓝牙音频 Bluetooth Audio
  - 典型音频 Classic Audio
  - 蓝牙LE音频（低功耗）- 新!
    Bluetooth LE Audio (low energy) – NEW!
- 不同音频配置 Different audio profiles
- 许多专有音频编解码器 Many proprietary audio codecs

AAC · Qualcomm aptX · Qualcomm aptX Low Latency · Qualcomm aptX HD · LDAC · HWA Hi-Res Wireless Audio

方案2：闭环测试（无线）

Scenario 2: Closed-Loop Testing (Wireless)

使用蓝牙传输器（模拟或者USB） Using Bluetooth Transmitter (Analog Input or USB)



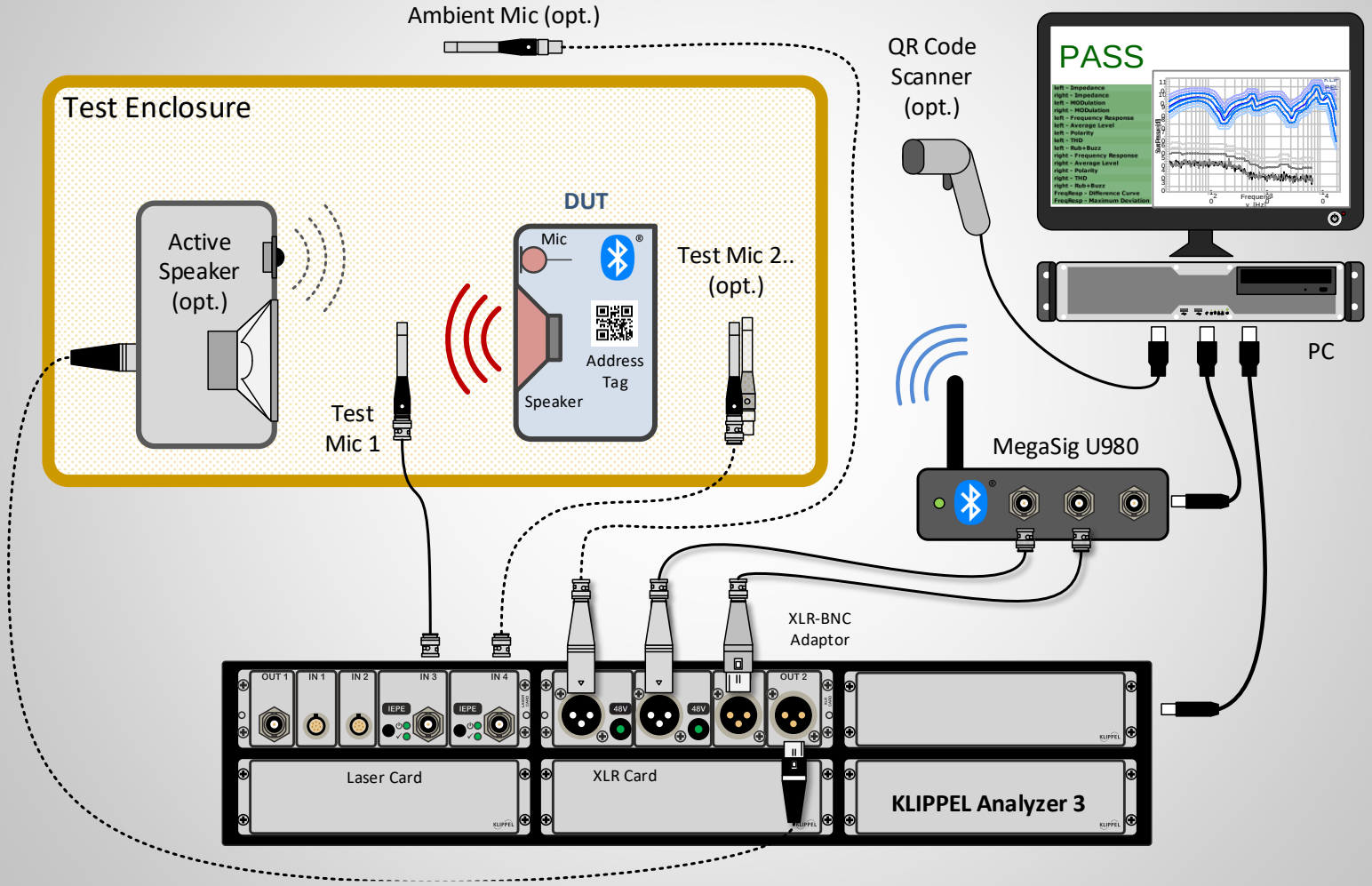
KLIPPEL's solution

Hardware (QC & RnD)

- MegaSig U980
  - 通过USB配置（集成到QC和RnD软件） Configurable over USB (integrated in QC & RnD software)
  - 蓝牙v4.2 Bluetooth v4.2
  - 支持主要的音频配置及codecs Supports major audio profiles & codecs
  - 直接连接到KA3/PA/DA Connects directly to KA3/PA/DA

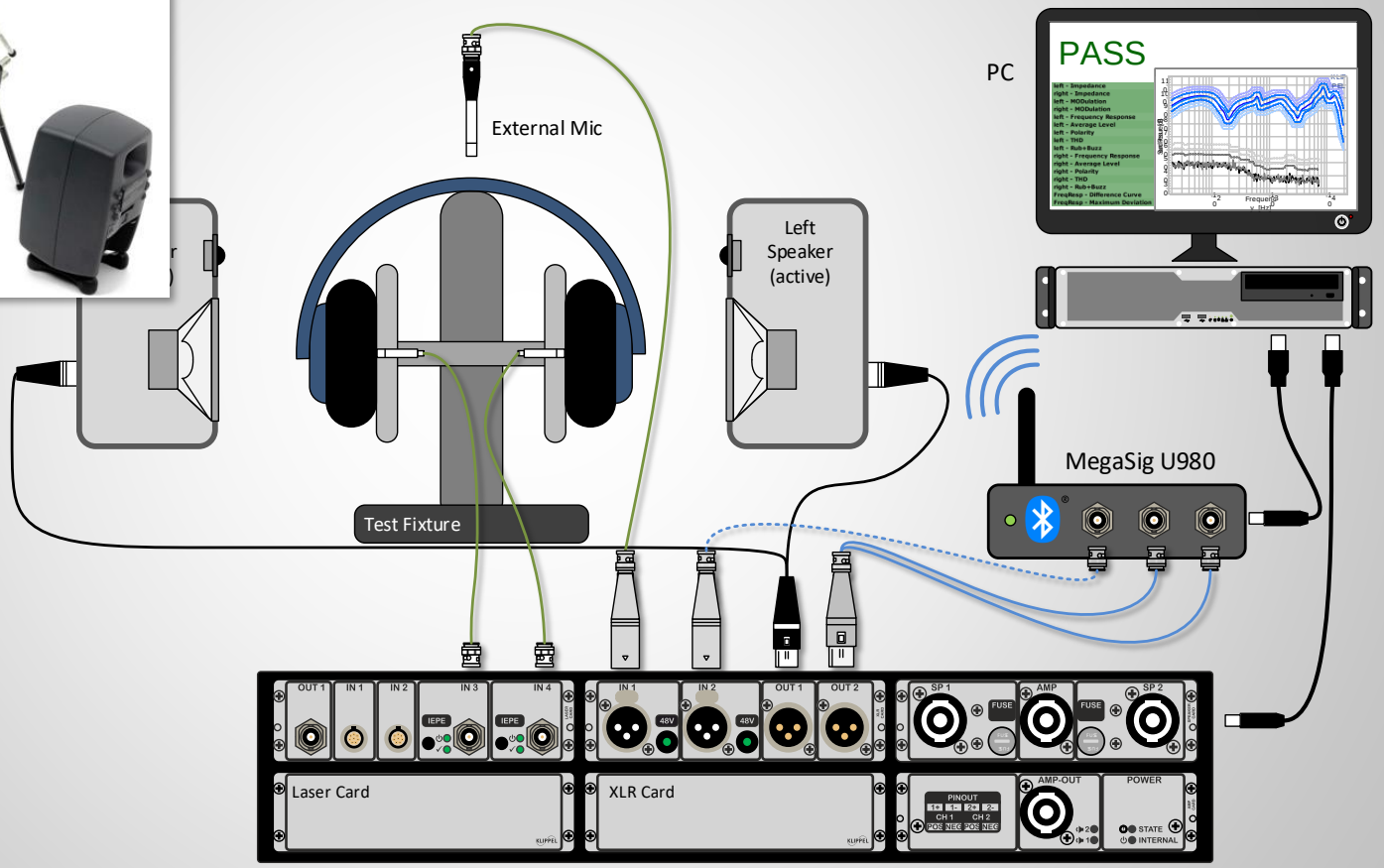
Bluetooth Speaker Test

With Optional Hands-free Microphone Test



Bluetooth Headset Test

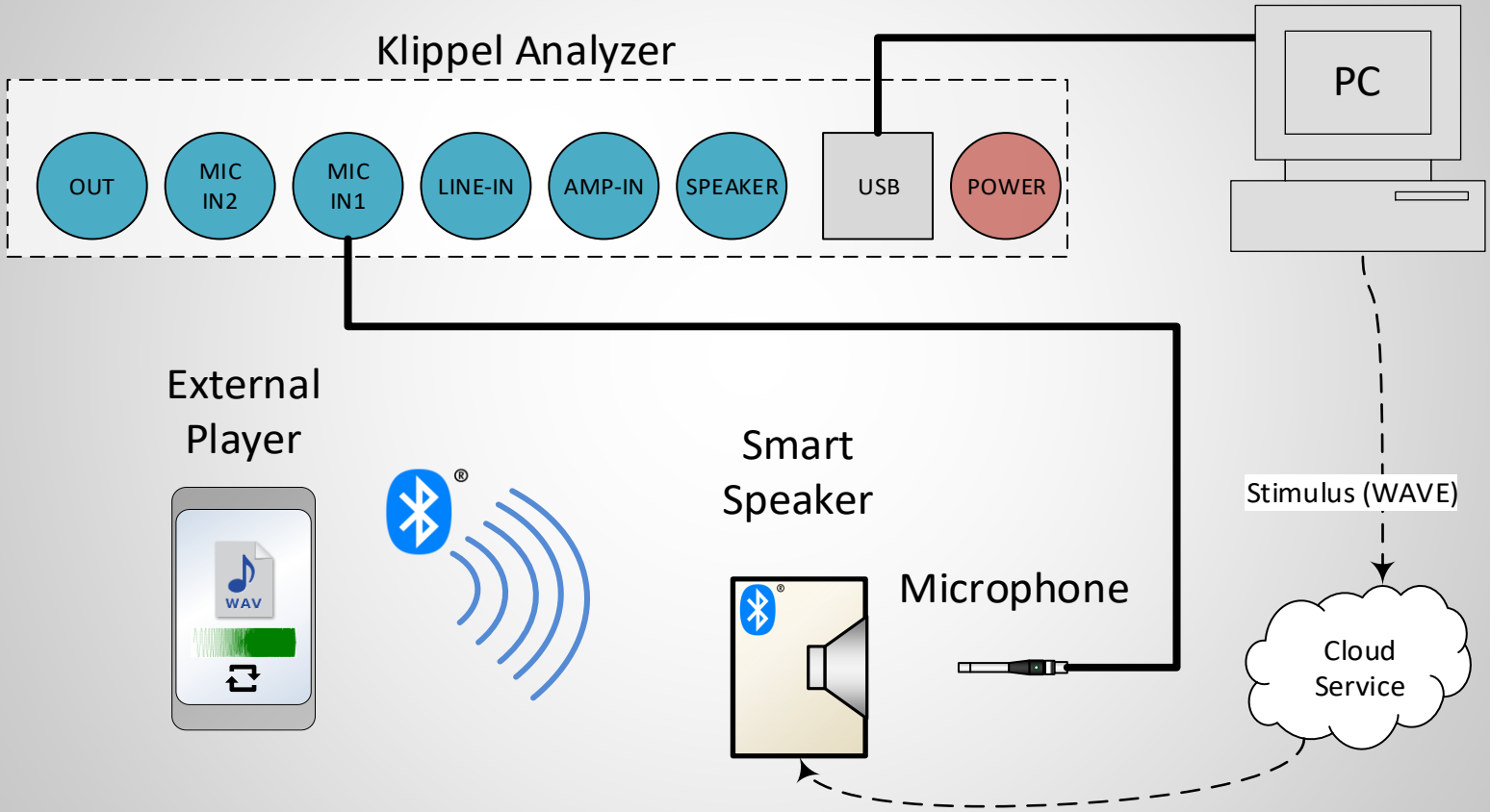
Including ANC Performance Test



方案3：开环测试 Scenario 3: Open-Loop Testing

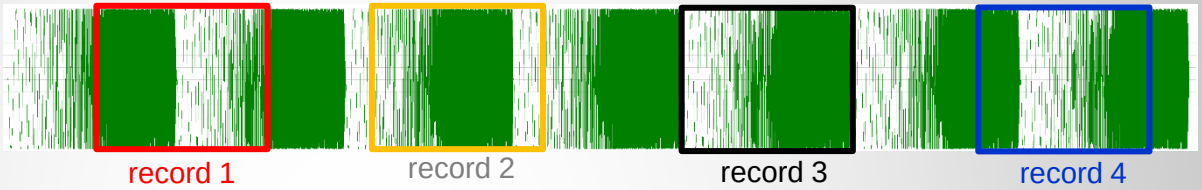
独立播放激励信号（发生器不在链路循环中）

Independent Stimulus Playback (Generator not in Loop)



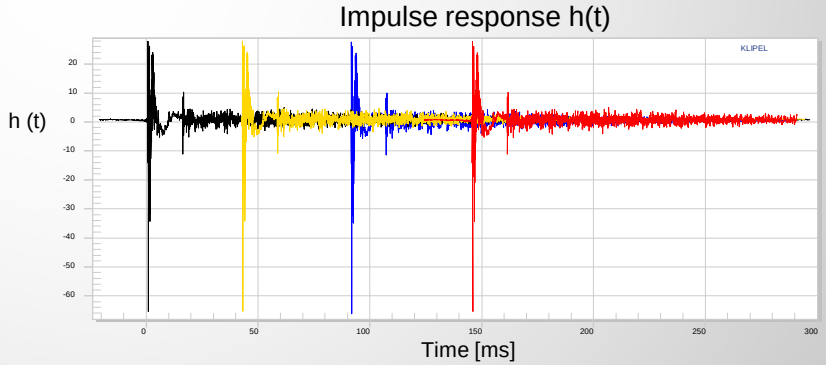
开环测试中的问题
Problem in Open Loop Testing

1) Chirp激励信号 重复循环播放（异步） Chirp stimulus is played again and again (asynchronously)



2) TRF记录波形并计算脉冲响应

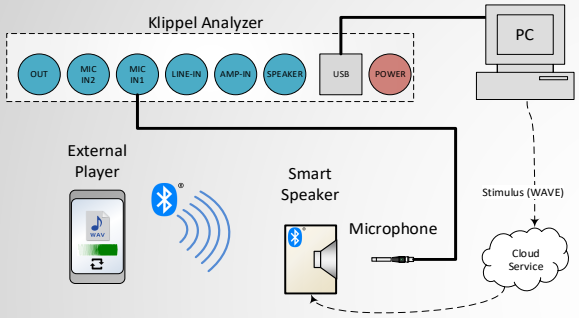
TRF records the waveform and calculates the impulse response



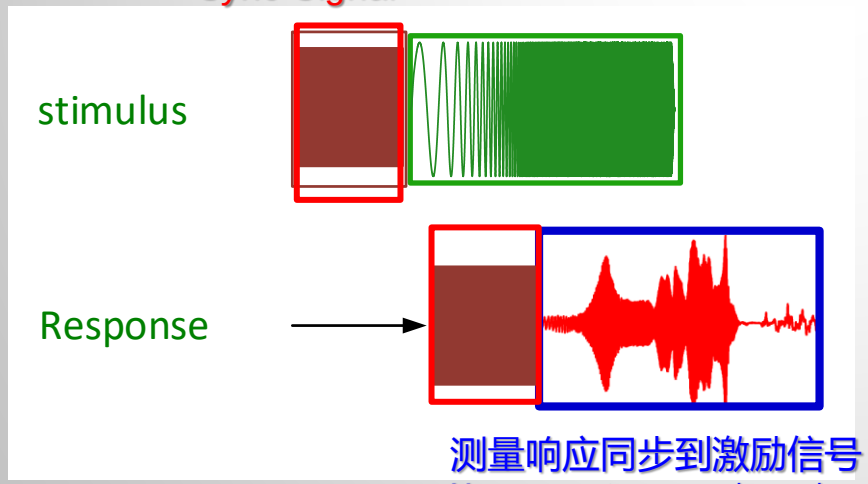
如何检测可变延迟？ How to detect the variable delays ?

开环测试 Open Loop Testing

1) 纯软件方案（外部同步）
Pure Software solution (External Syncronization)



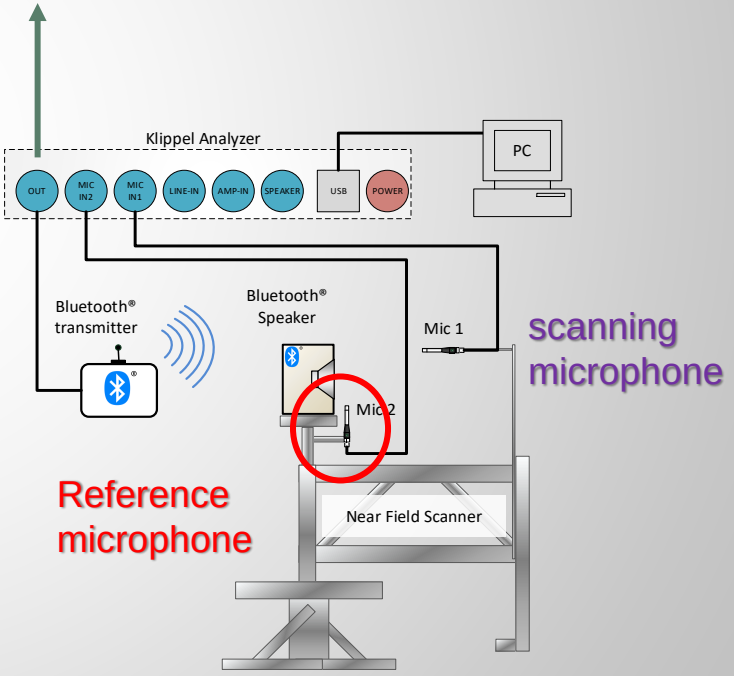
Sync-Signal



测量响应同步到激励信号
Measurement response is synchronized to stimulus

2) 附加硬件方案 Additional Hardware Solution

激励：循环播放chirp信号
Stimulus: Chirp played again and again



scanning microphone

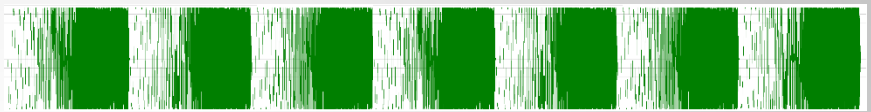
Reference microphone

方案：使用第二支麦克风来同步
Solution: Use a 2nd microphone for synchronization

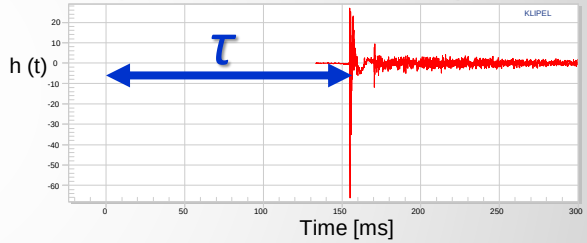
Mic 1:
测量麦克风
measurement microphone

Mic 2:
同步麦克风（固定）microphone for synchronization
(not moved)

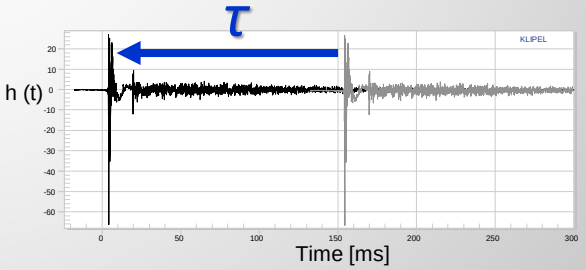
1) 内置音频播放器播放激励
Stimulus is played by an internal wav-player



2) 麦克风2检测时延
Microphone 2 detects time delay



3) 检测到的时延从测量麦克风中移除 Detected delay is removed from the measurement microphone



结果：同步了脉冲响应 Result: Synchronized Impulse Response

NFS：全息方向扫描 Holographic Directivity Scanning

一款智能扬声器的开环测试 Open loop testing of a smart speaker

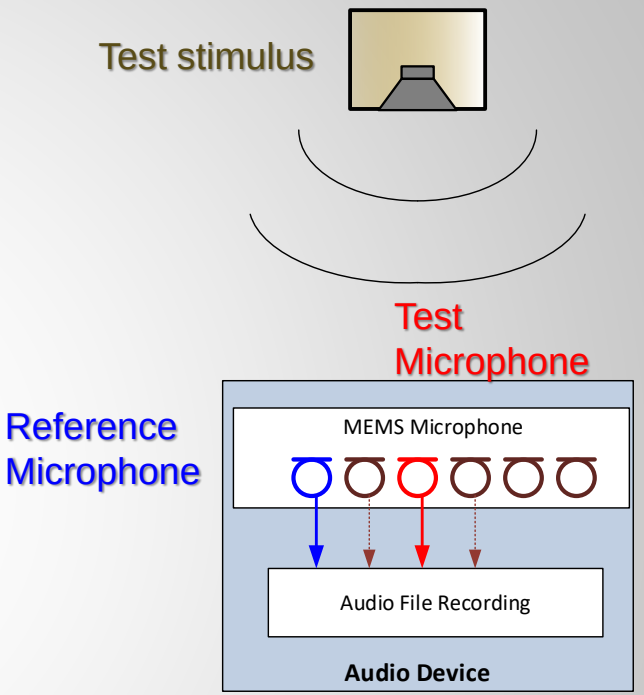
问题 Problems:

- 无模拟输入 No analog input
- 长时延且可变（延迟） Long and varying time delay (latency)
- 外部同步不适用 External synchronization is not applicable

方案：使用固定位置处的第二支麦克风（参考） Solution: 2nd microphone at fixed position (reference)

- 提供测试麦克风的高精度幅值和相位响应 provides high accuracy of amplitude and phase response of the test microphone
- 检测掉线、采样率漂移、环境噪声和其他问题 Detects dropouts, sample rate drift, ambient noise and other problems
- 简单鲁健且高效经济的方案 is a simple, robust and cost-efficient solution

MEMS麦克风的方向性
Directivity of a MEMS Microphone



要求 Requirements

- 绝对传递函数的精度足够高（受设置影响） Sufficient accuracy in the absolute transfer functions (affected by setup)
- （两个麦克风之间）相对幅值和相位响应的精度要高 High accuracy in the relative amplitude and phase response (between mics)

方案 Solution

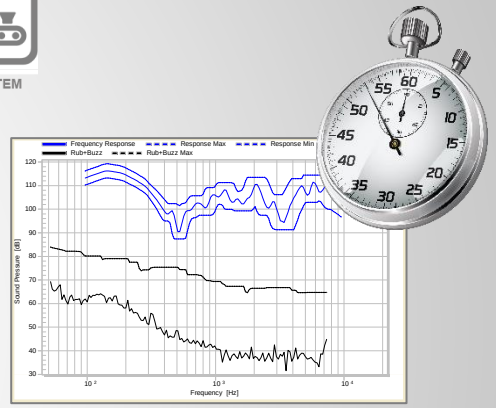
- 使用MEMS中的一个麦克风作为参考 Using one microphone in the MEMS as a reference
- 记录或者传输至少两个信号（测试+参考麦克风） Recording or transmitting at least two signals (test + reference microphone)

Wireless Testing

KLIPPEL Analyzer (R&D modules)

Module	Description	Closed loop setup	Open loop setup
TRF	测量频响、脉冲响应和谐波失真 Measurement of frequency response, impulse response & harmonic distortion	✔	✔
DIS	测量谐波失真和互调失真(稳态) Measurement of harmonic distortion and intermodulation distortion (steady state)	✔	✗
TBM	猝发音测量(瞬时)最大SPL峰值、谐波失真 Tone Burst Measurement (transient) maximum peak SPL, harmonic distortion	✔	✗
MTON	多音测量多音失真、压缩、最大连续SPL Multi-Tone Measurement multi-tone distortion, compression, maximum continuous SPL	✔	(✗)
NFS	扬声器的3D方向性(近场+远场)测量（适用于非消声室） 3D directivity (near + far field) measurement of loudspeakers (applicable in non-anechoic room)	✔	✔
POL	扬声器和麦克风的2D方向性（气球图）(需要消声室) 2D directivity (balloon) of loudspeakers and microphones (anechoic room needed)	✔	✔

产线上的无线设备测试 Wireless Device Testing in Production



产线终端测试的要求 Requirements in End-of-Line Testing

- 快速全面的测试 Fast and comprehensive testing
- 检测缺陷的高灵敏度 high sensitivity for defects
- 使用简便 Simple to use

关键问题 Critical Issues:

- 自动配对 Automatic Pairing
- 流畅的蓝牙设置 Smooth Bluetooth Setup
- 同步（延迟检测和补偿） Synchronization
  (Delay detection and compensation)

Wireless Testing

KLIPPEL Analyzer (QC modules)

QC Base Version, QC Standard or QC Stand-alone (v6.3)

Task	Description	Closed loop setup	Open loop setup
SPL	测量频响、脉冲响应、谐波和脉冲失真 Measurement of frequency response, impulse response, harmonics & impulsive distortion	✔	✔
ALD	空气泄漏检测 Air Leak Detection	✔	✔
SAN	频谱分析 Spectrum Analysis	✔	✔
EQA	均衡&对齐 Equalization & Alignment	✔	✔

Poll:

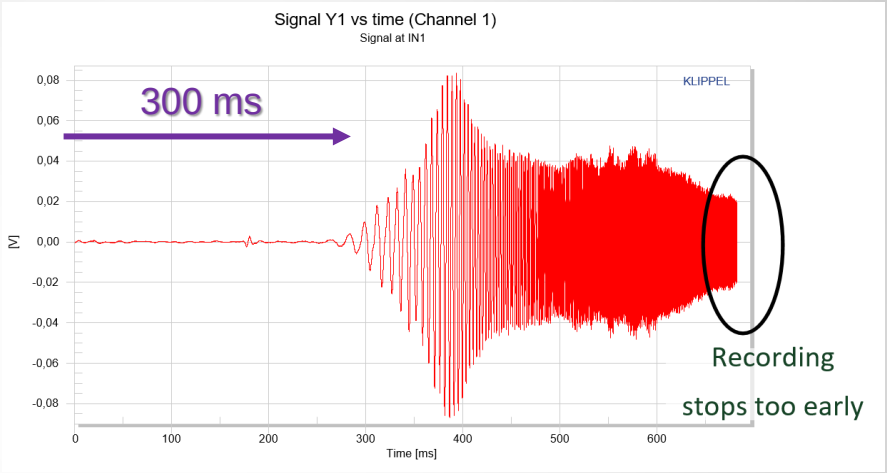
使用数字/无线测试通道时您发现了什么问题?
Which problems do you see using digital/wireless transmission channels ?

A. 无 None
B. 高延迟 Large latency (delay)
C. 可变延迟（相对于时间） Varying latency (versus time)
D. 抖动、时钟漂移、采样率不匹配 Jitter, Clock Drift, Sampling Rate Mismatch
E. 掉线、插值样本 Drop-outs, interpolated samples
F. 其他 others

High Latency

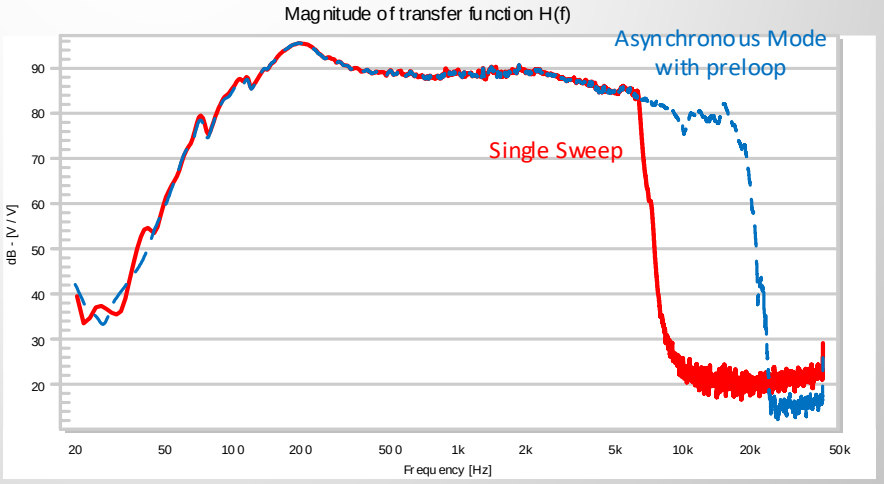
Problem in Bluetooth Devices

典型蓝牙扬声器延迟在30至400ms之间！ The delay of a Bluetooth® speaker is typically between 30 and 400 ms !



单次扫描测试中缺少后期响应
Missing late response in a single sweep test

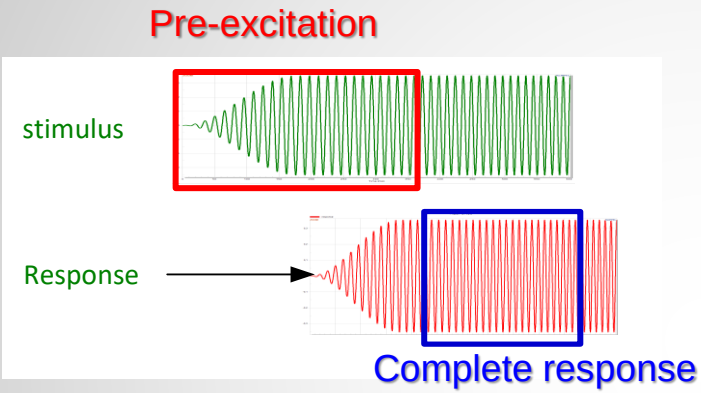
结论 Conclusion:
多次循环播放激励信号
Play multiple loops of the stimulus



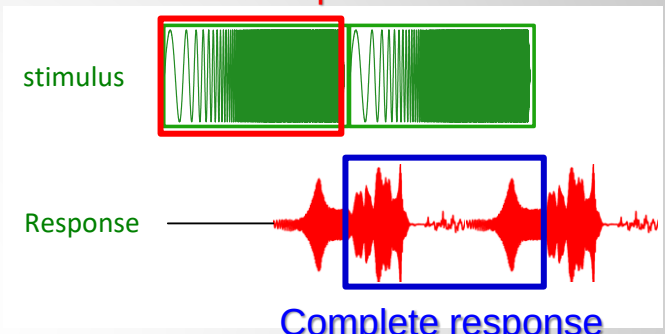
第一个方案：额外激励 1st Solution: Additional Excitation

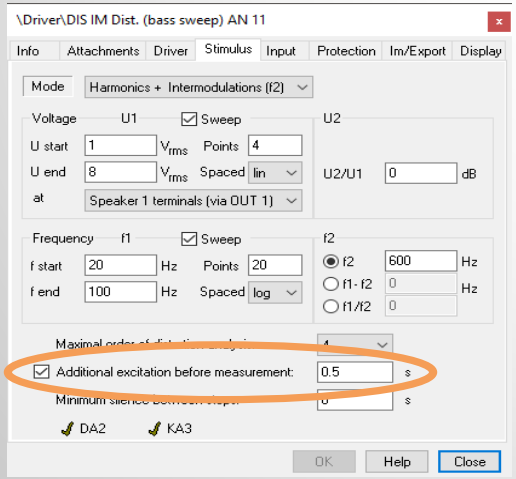
应对高延迟 Coping with High Latency

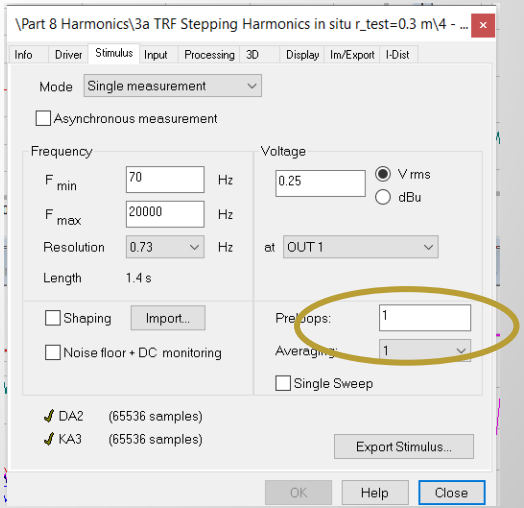
in DIS 3D Distortion Measurement



in TRF Transfer Function Module

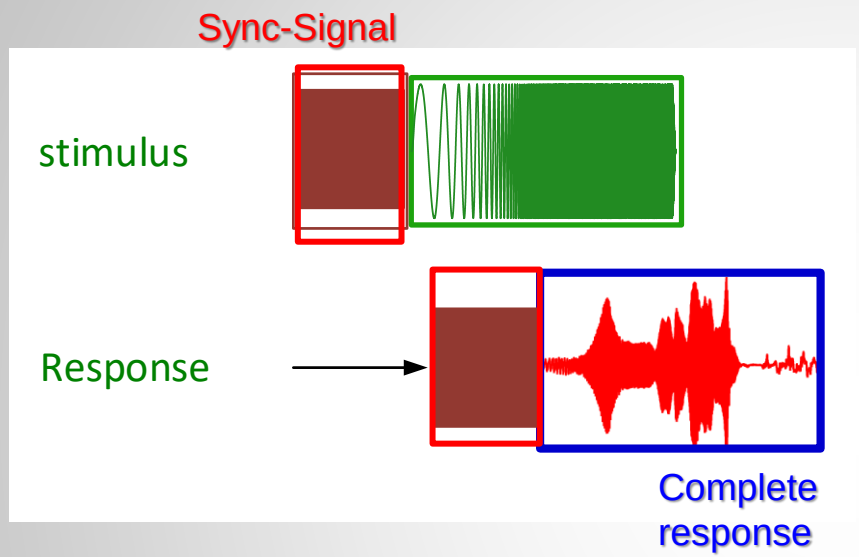






第二个方案：外部同步 2nd Solution: External Synchronization

应对高延迟 Coping with High Latency



External Synchronization (SYN) in the QC system in KLIPPEL Analyzer System

同步信号 Sync-Signal:

- 宽带信号 Broadband signal
- 短同步信号（200ms） Short sync signal (200ms)
- 标识符编码 Identifier encoded
- 伪随机特性 pseudo-random properties

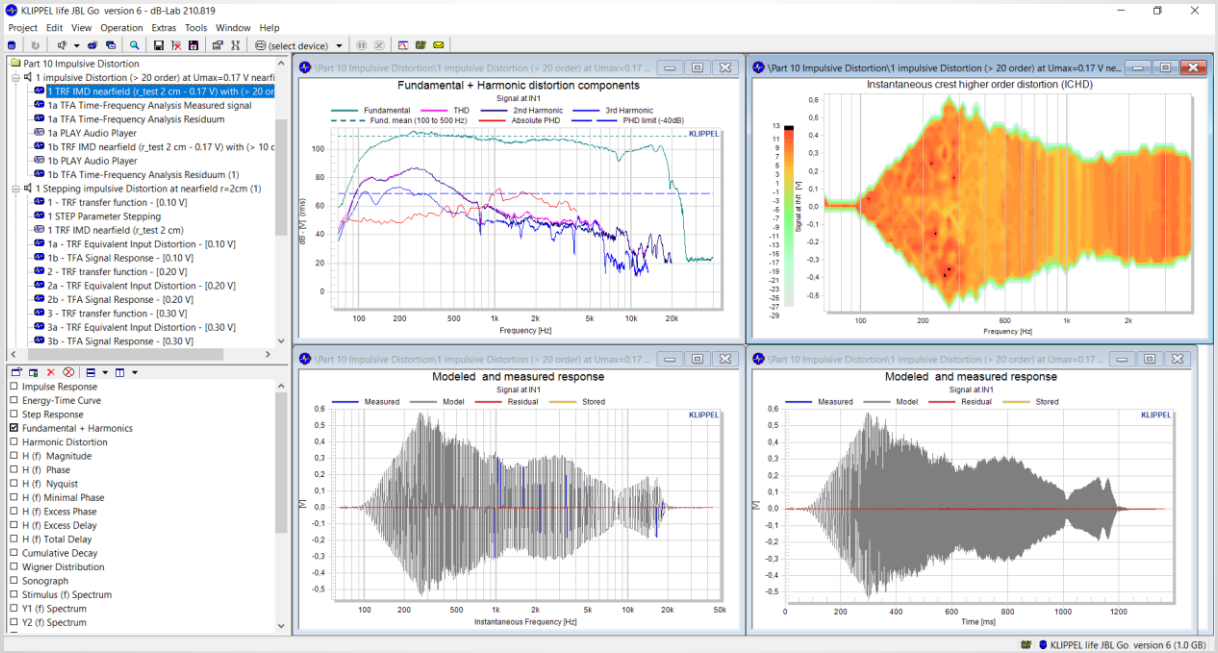
益处 Benefits:

- 延迟无限制 No limitation with of the latency
- 最适合开环测试 Best for open loop testing
- 快速产线终端测试 Fast EoL-testing
- 激励信号识别 Identification of the stimulus
- 链接激励和分析 Linking stimulus and analysis
- 检测采样率不匹配 Detection of sample rate mismatch

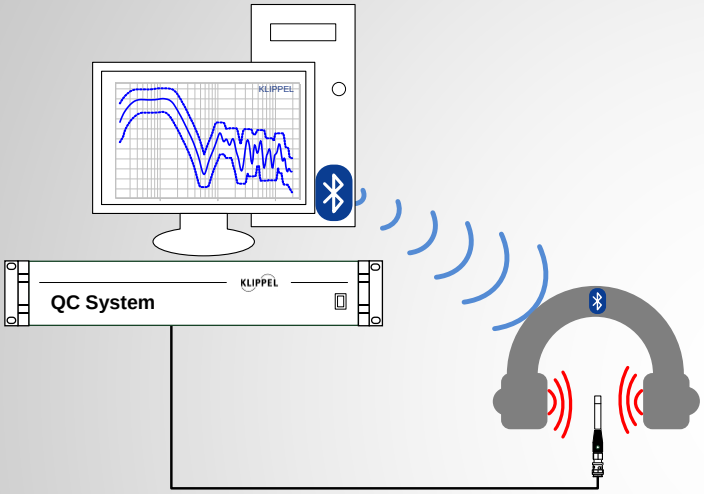
Demo

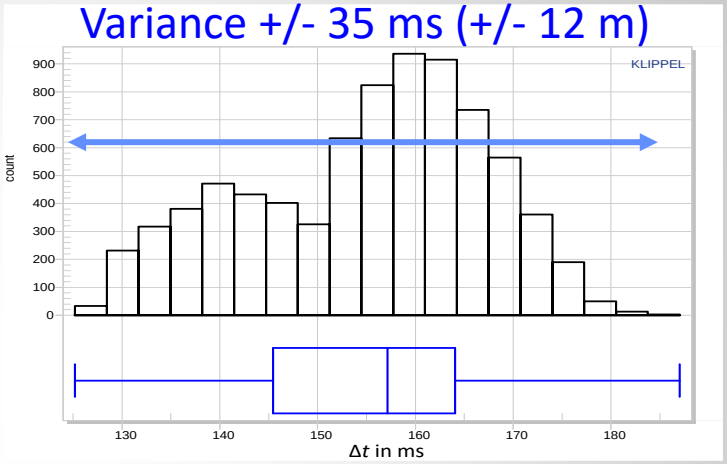
Tools: Using dedicated software modules of the KLIPPEL Analyzer

- QC End-of-Line Testing (External synchronization)



可变延迟 Varying Latency
蓝牙设备中的问题 Problem in Bluetooth Devices





Mean delay ≈155 ms
(≈53 m distance)

后果 Consequences:

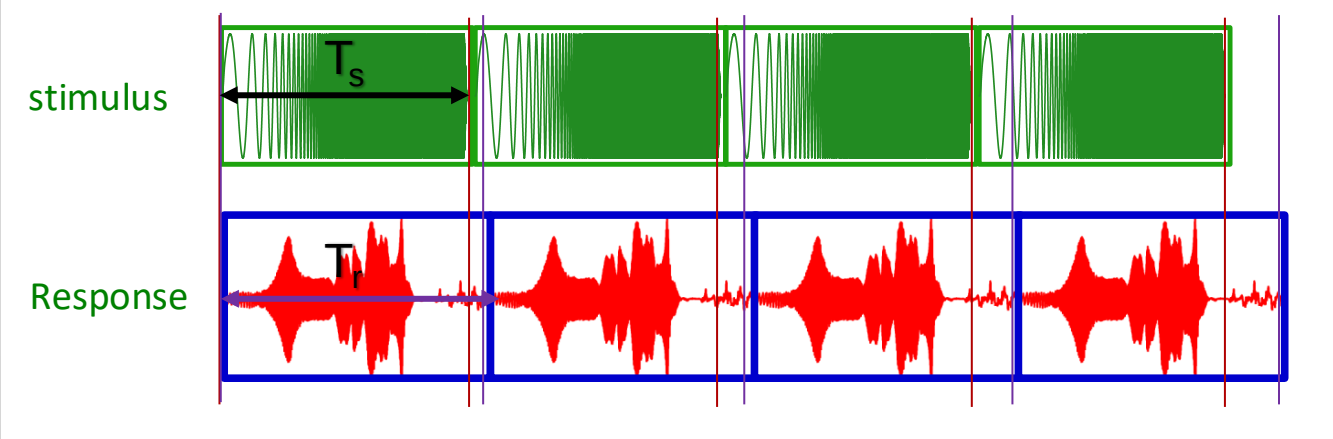
- 影响相位响应（在全息近场扫描中非常关键） Affects phase response (very critical in holographic near field scanning)
- 与其他问题相关（掉线、采样率漂移等） Related to other problems (drop outs, sample rate drift, …)

方案 Solution:

- 参考测量（近场中使用第二支麦克风）获取相干扫描数据 Reference measurements (second microphone in the near field) for coherent scanning data

抖动、时钟漂移、采样率不匹配
Jitter, Clock Drift, Sampling Rate Mismatch
蓝牙设备中的问题 Problem in Bluetooth Devices

根本原因：播放和捕获转换器中的晶体不同！
Root Cause: Crystals of Playback and Capture converters are different!



症状 Symptom:
激励和响应的长度不同
Stimulus and response have a different length

$T_s \neq T_r$

对传输行为的影响 Impact on the transfer behavior:

- 频率转换 Frequency transformation
- 输入和输出之间的非线性关系（不相干） Nonlinear (non-coherent) relationship between input and output
- 随着时间延迟会变得更糟糕 Delay becomes worse over time
- 重采样或者样本校正可以改善（掉线、插值） Resampling or sample correction (dropouts, interpolation) can help

采样率漂移的后果 Consequences of Sample Rate Drift

漂移会降低以下精度 Drift degrades accuracy in

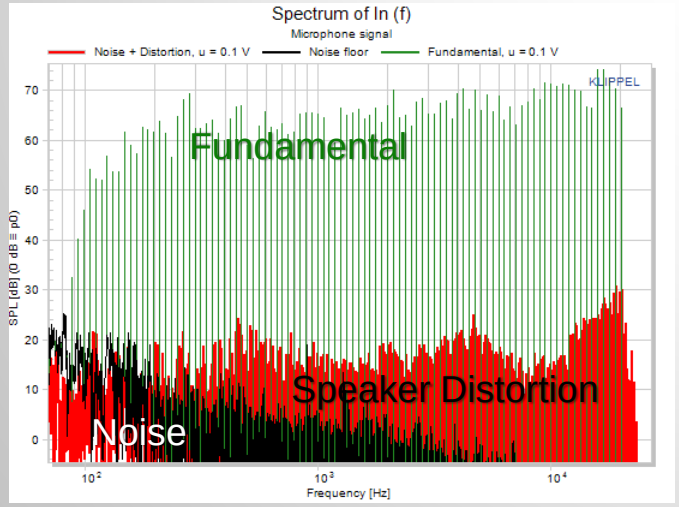
- 频率检测 Frequency detection
- 基波和失真的分离 Separation of distortion and fundamentals
- 失真测量 Distortion measurements
- 相位测量 Phase measurements

建议：避免（如果可以） Tips: Avoid (if you can)

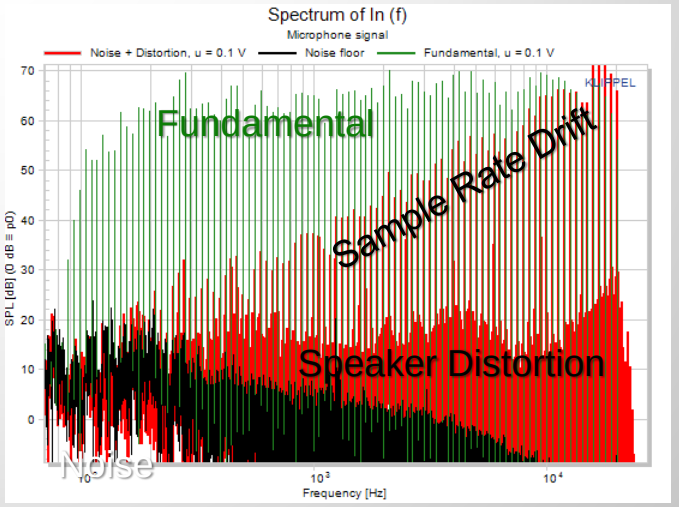
- 长测量（以得到高的频率分辨率） Long Measurements (to get high frequency resolution)
- 长平均 Long averaging
- 将记录的时间信号包裹到FFT中 Wrapping recorded time signal in an FFT

Example: Bluetooth speaker

Multi-tone distortion (analog input)



Multi-tone distortion (bluetooth input)

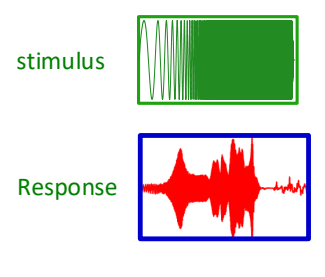


40 dB more distortion

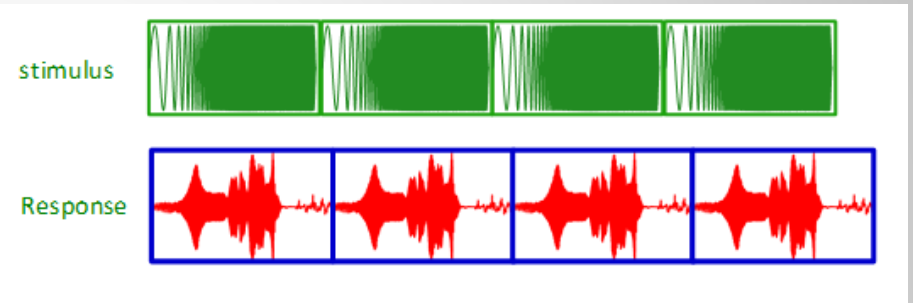
避免长平均 Avoid Long Averaging !

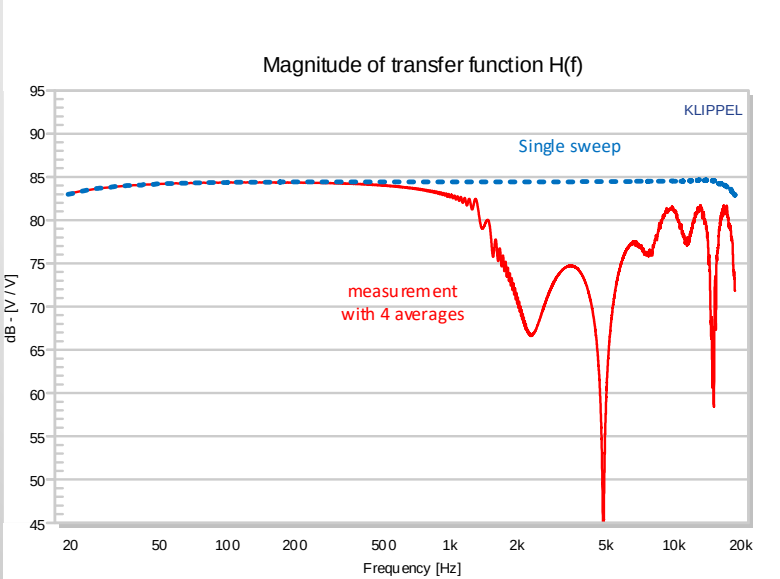
应对采样率漂移 Coping with Sample Rate Drift

Single Sweep



Chirp with 4 Averages

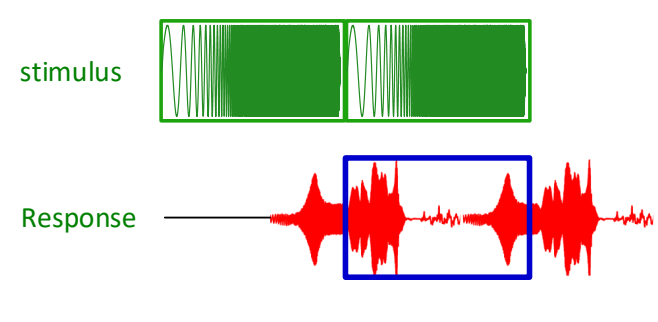




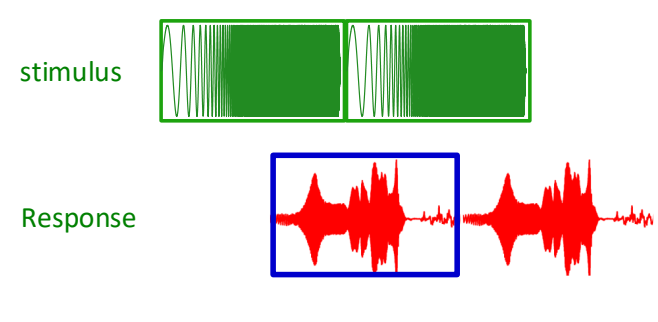
采样率漂移会抵消高频分量！ Sample rate drift generates a cancelation of high frequency components !

使用chirp信号的精确测试
Accurate Testing with a Chirp Signal
应对采样率漂移 Coping with Sample Rate Drift

在音频带中包裹（在音频带的中间）Wrapping in the audio band (in the middle of the audio band)

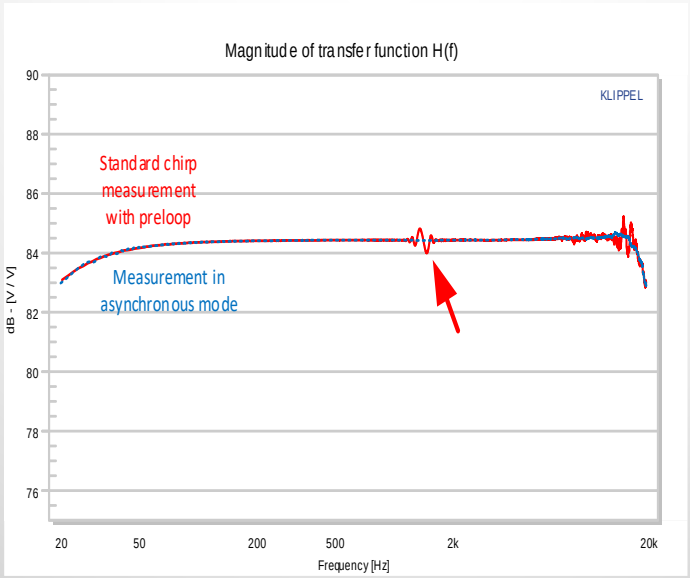


在时间信号的零点处包裹（chirp信号的开始和结尾）Wrapping at zero time signal (begin and end of the chirp)



PRO:
- 简单的标准测量 Simple standard measurement

CONS:
- 幅度响应中有显著错误 Significant error in magnitude response
- 产生咔哒抖动 Click generated
- 不适用于产线终端测试 Not applicable for EoL testing

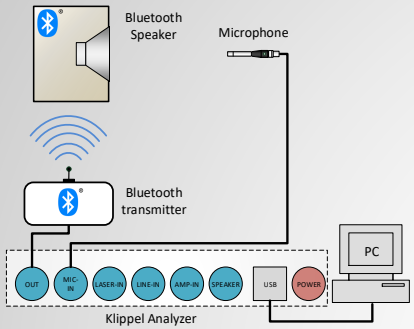


PRO:
- 精度高 Good accuracy
- 无脉冲伪值 no impulsive artifacts
- 用于异音测量 required for rub and buzz

CONS:
- 异步处理 Asynchronous processing
- （两个chirp）(2 chirps)

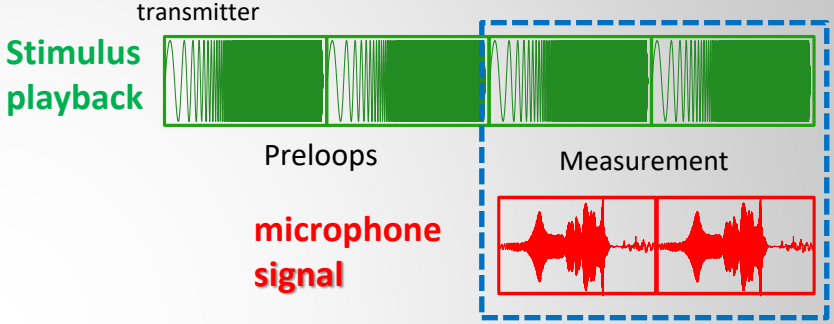
TRF模组中的自动处理方案 Automatic Solution in TRF Module

应对采样率漂移 Coping with Sample Rate Drift

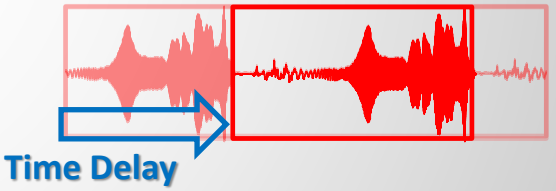


工作原理 How it works?

1) 通过蓝牙传输器发送激励信号 Send Stimulus via Bluetooth transmitter

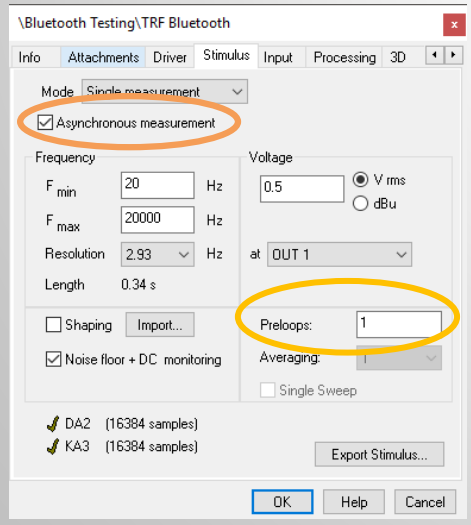


2) 检测延迟并给麦克风信号加窗 Detect Delay and window microphone signal



TRF传递函数模组的属性页面 Property page TRF Transfer Function Module:

- 设置preloop > 1 Set preloop > 1
- 激活异步模式 Activate asynchronous mode



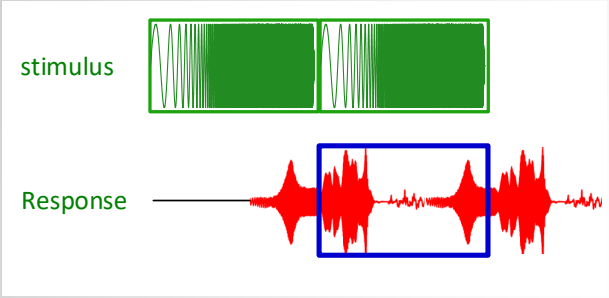
益处 Benefits:

- 最优加窗处理避免任何伪值（咔哒声）
  Optimal windowing avoids any artifacts (clicks)
- 用于测量脉冲失真（异音） Required for measurement of impulsive distortion (rub&buzz)

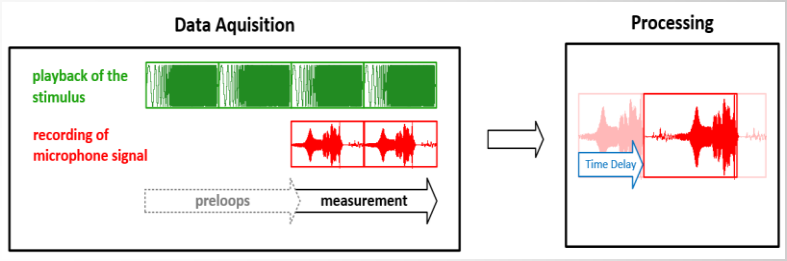
Impact on Impulsive Distortion Testing

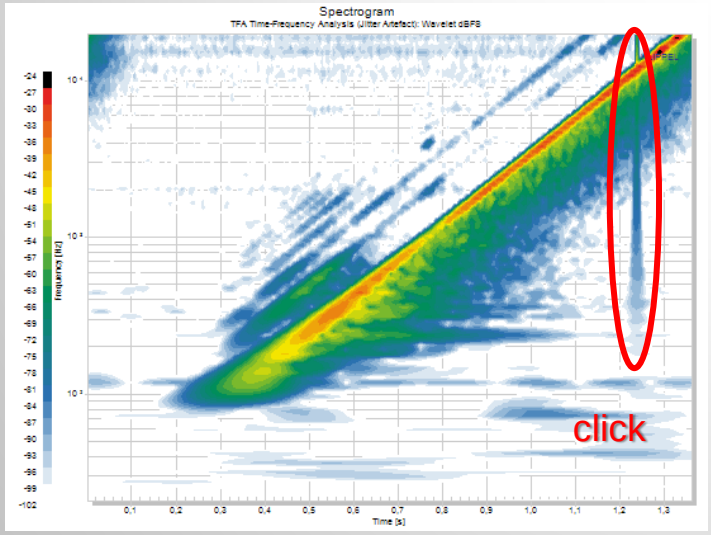
TRF copes with Sample Rate Drift

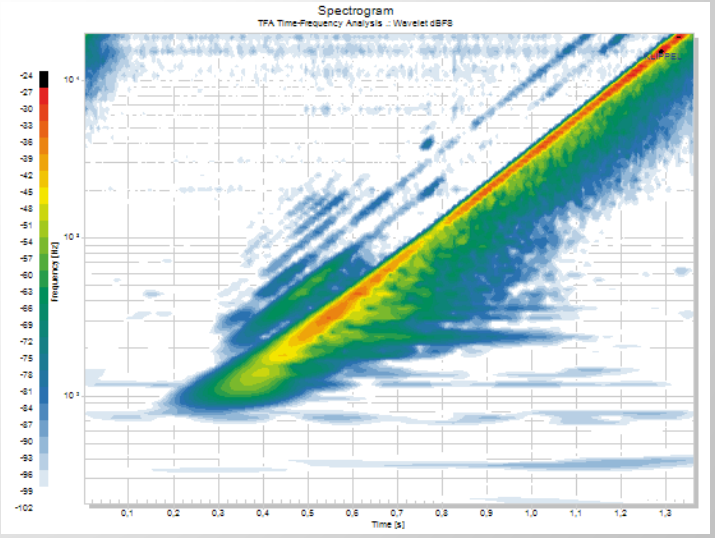
TRF in normal mode



TRF in asynchroneous mode

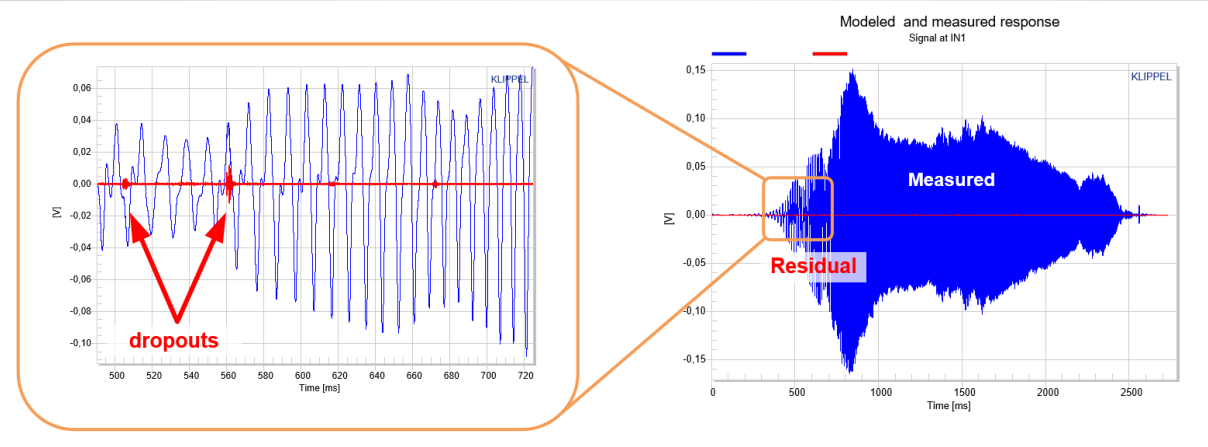






Problems

Dropouts, Glitches, Interpolation Artifacts



根本原因 Root Cause:

- 应对采样率漂移的简单算法会产生脉冲失真 Simple algorithms for coping with sample rate drift can generate impulsive distortion

后果 Consequences:

- 随机伪值（不能重复、不可预测） Those artifacts are random (not repeatable, predictable)
- 可能会和换能单元缺陷混合，在产线终端测试中很关键 Maybe mixed with transducer defects critical for end-of-line testing

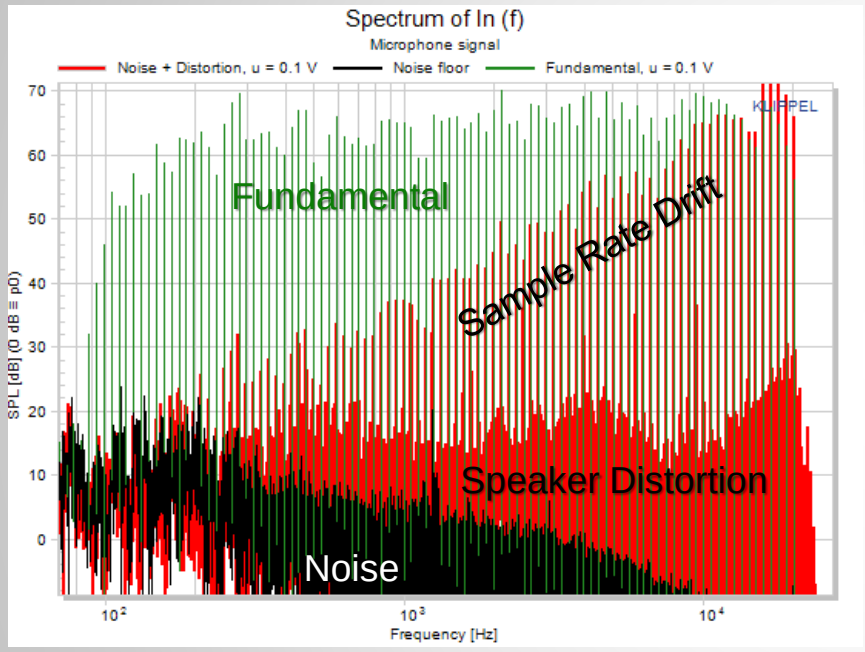
方案 Solution:

- 重复测量并比较结果 Repeat the measurement and compare the results
- 使用开环测量来分离随机换能单元问题（如松散微粒） Use open-loop measurement to separate random transducer problems (e.g. loose particles)

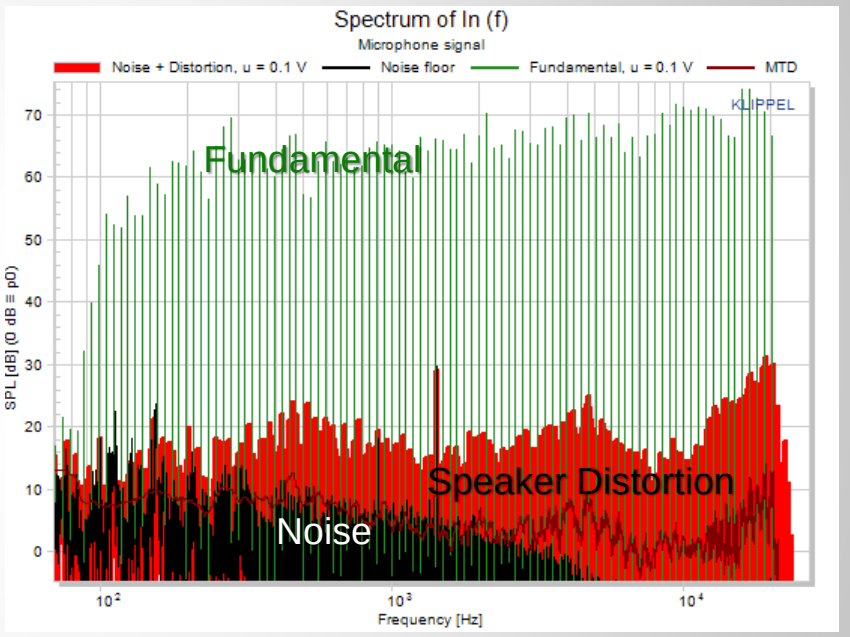
Corrected Multi-Tone Distortion

Coping with Sample Rate Drift

MTON in normal mode



MTON with drift compensation



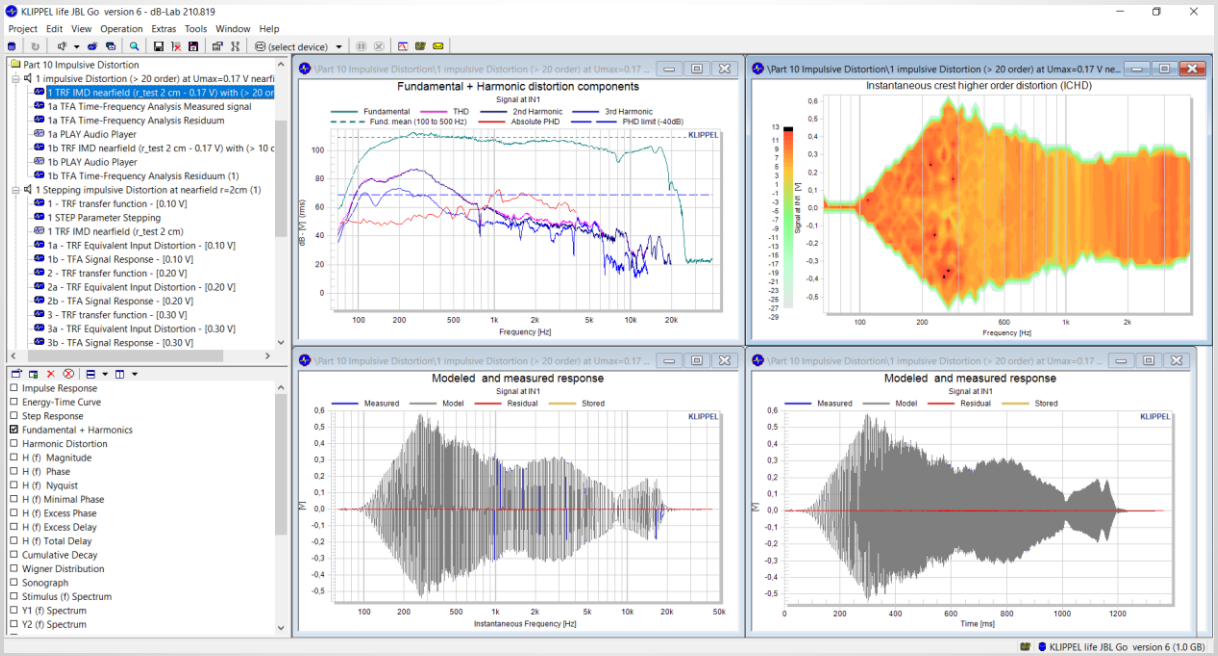
方法 Method

1) 检测以百分比表示的激励和测量信号之间的采样率漂移 Detection of the sample rate drift between stimulus and measured signal in percent
2) 执行频谱分析之前激活补偿 Active compensation before performing spectral analysis

Demo

Tools: Using dedicated software modules of the KLIPPEL Analyzer

- TRF (transfer function)
- MTON Multi-tone Distortion Measurement



Discussion

Summary

- 音频信号的无线/数字传输并不是完美的!
  Wireless/digital transmission of the audio signal is not perfect!
- 存在非线性、时变和随机机制，会产生额外失真
  There are nonlinear, time-variant and random mechanisms which generate additional distortion
- 准确测试需要特殊的预防措施 Accurate testing requires special precaution
- 现代测试设备能提供解决方案 Modern test instruments provides solutions

Open Questions

我们已经讨论了IEC 60268-21定义的标准条件下的物理测试方法
We have discussed physical test methods defined in IEC 60268-21 for standard condition

第12期网络研讨会主题 The next 12th KLIPPEL live webinar entitled
标准条件下音频产品的基准测试
Benchmarking of audio products under standard conditions
将讨论 will address the points:

- 哪些指标很重要? Which criteria are important ?
- 如何选择测量条件? How to choose the measurement conditions ?
- 如何比较测量结果? How to compare the measurement results ?
- 如何得出有意义的结论? How to draw meaningful conclusions ?
- 如何使用标准来简化基准测试? How to use standards to simplify benchmarking ?

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
11. Pitfalls in Testing Wireless Audio Devices
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