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 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

11th KLIPPEL live:
Pitfalls in Testing Wireless Audio Devices

Topics today:

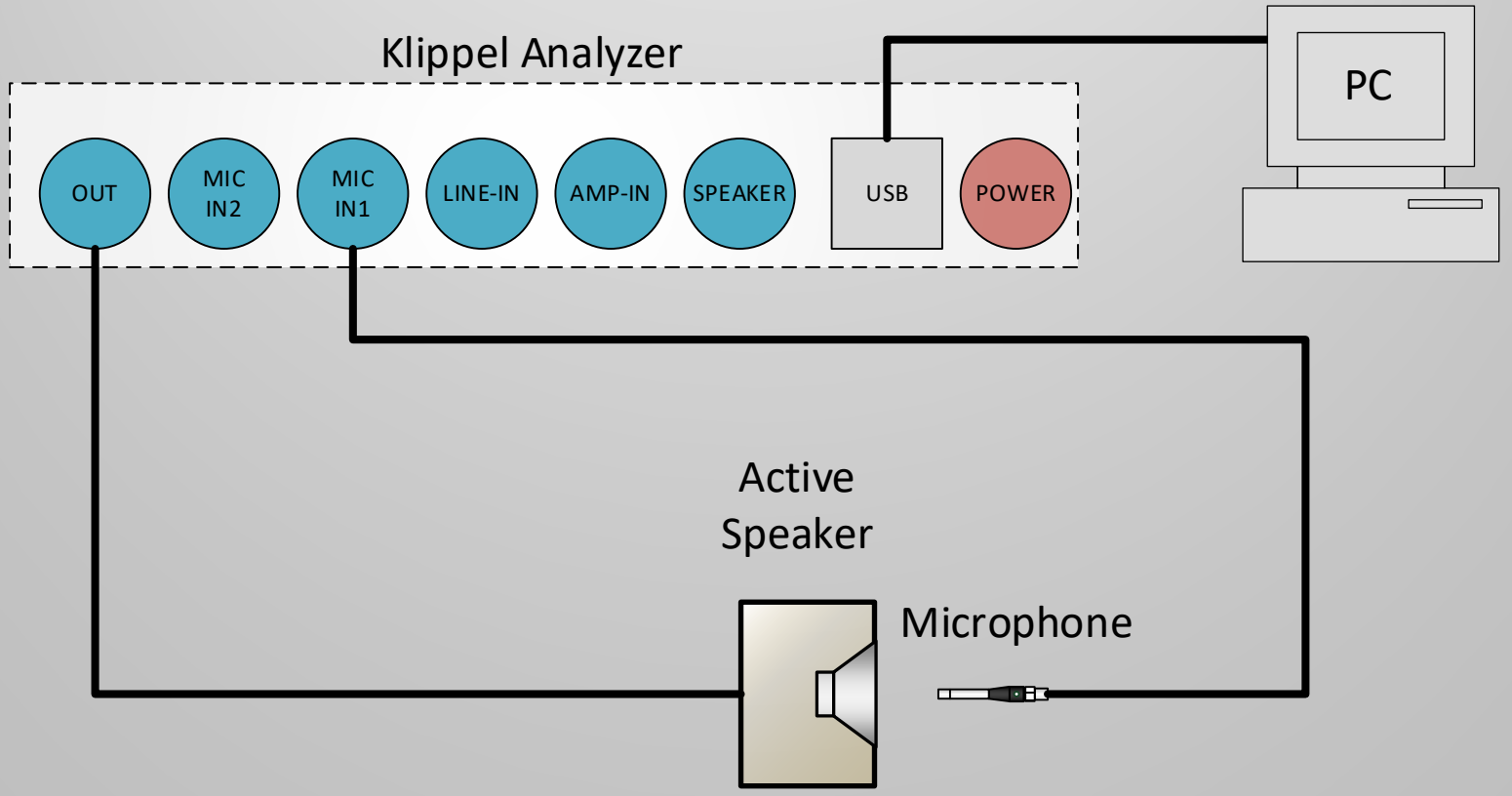
- New challenges in modern audio devices
- Solutions for R&D and QC end-of-line testing
- Overview on common problems
- Practical tips to ensure reliable test data
- Demos

Poll:

Which transmission way do you prefer for testing active audio system (if available) ?

A. Analog cable 71%
B. Digital cable (e.g. Toslink, HDMI, LAN) 52%
C. Wireless (WLAN) 5%
D. Wireless (Bluetooth) 10%
E. Asynchronous transmission (e.g. playing and recording an audio file) 10%
F. Others 0%

Scenario 1: Closed-Loop Testing (Analog)



Analyzer Output Directly Connected to DUT

Bluetooth Technology Overview

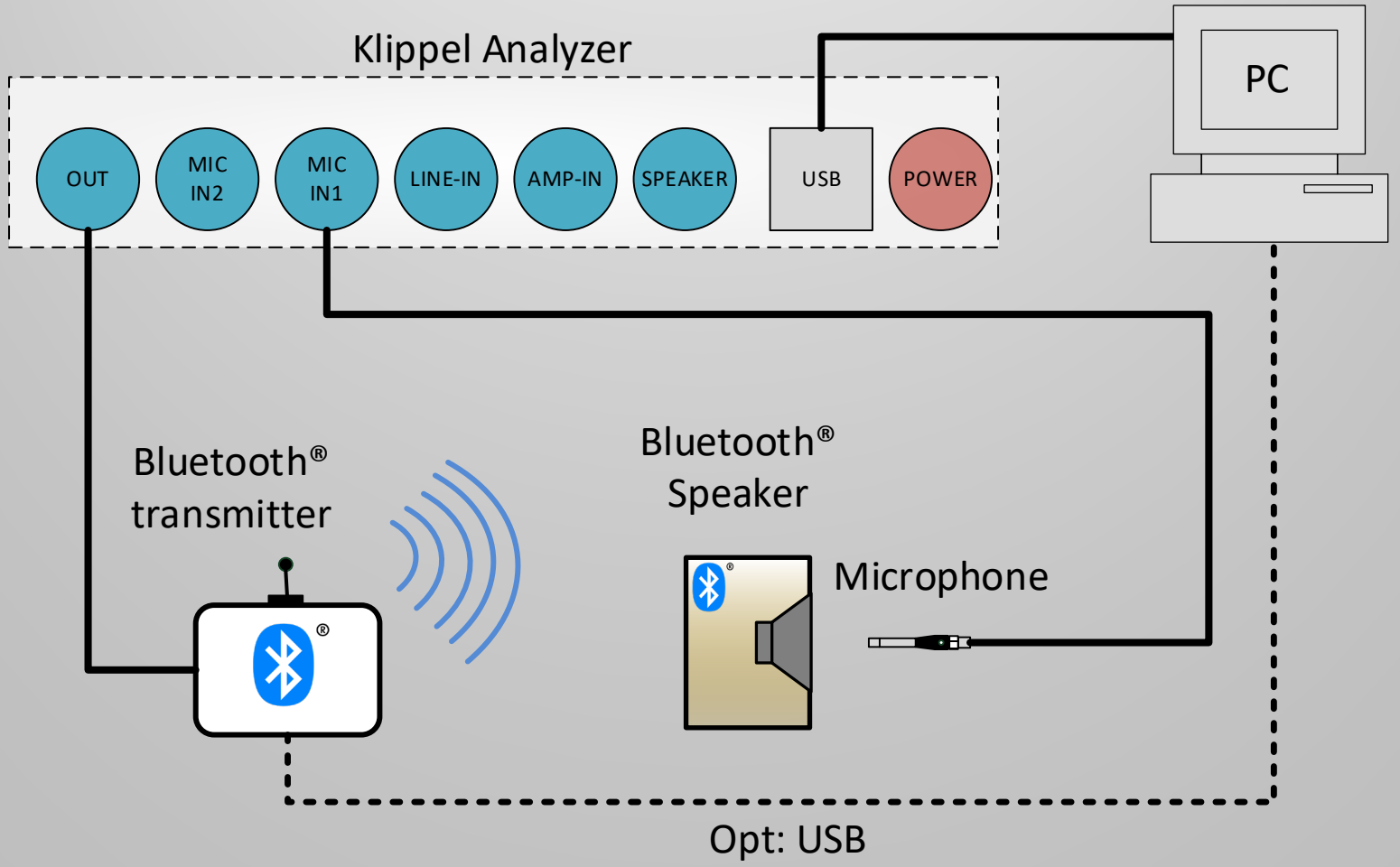
- Short range communication
- Pairing and connection
- Bluetooth Audio
  - Classic Audio
  - Bluetooth LE Audio (low energy) – NEW!
- Different audio profiles
- Many proprietary audio codecs



AAC ✕ Qualcomm® aptX™ ✕ Qualcomm® aptX™ Low Latency ✕ Qualcomm® aptX™ HD LDAC HWA Hi-Res Wireless Audio

Scenario 2: Closed-Loop Testing (Wireless)

Using Bluetooth Transmitter (Analog Input or USB)



KLIPPEL's solution

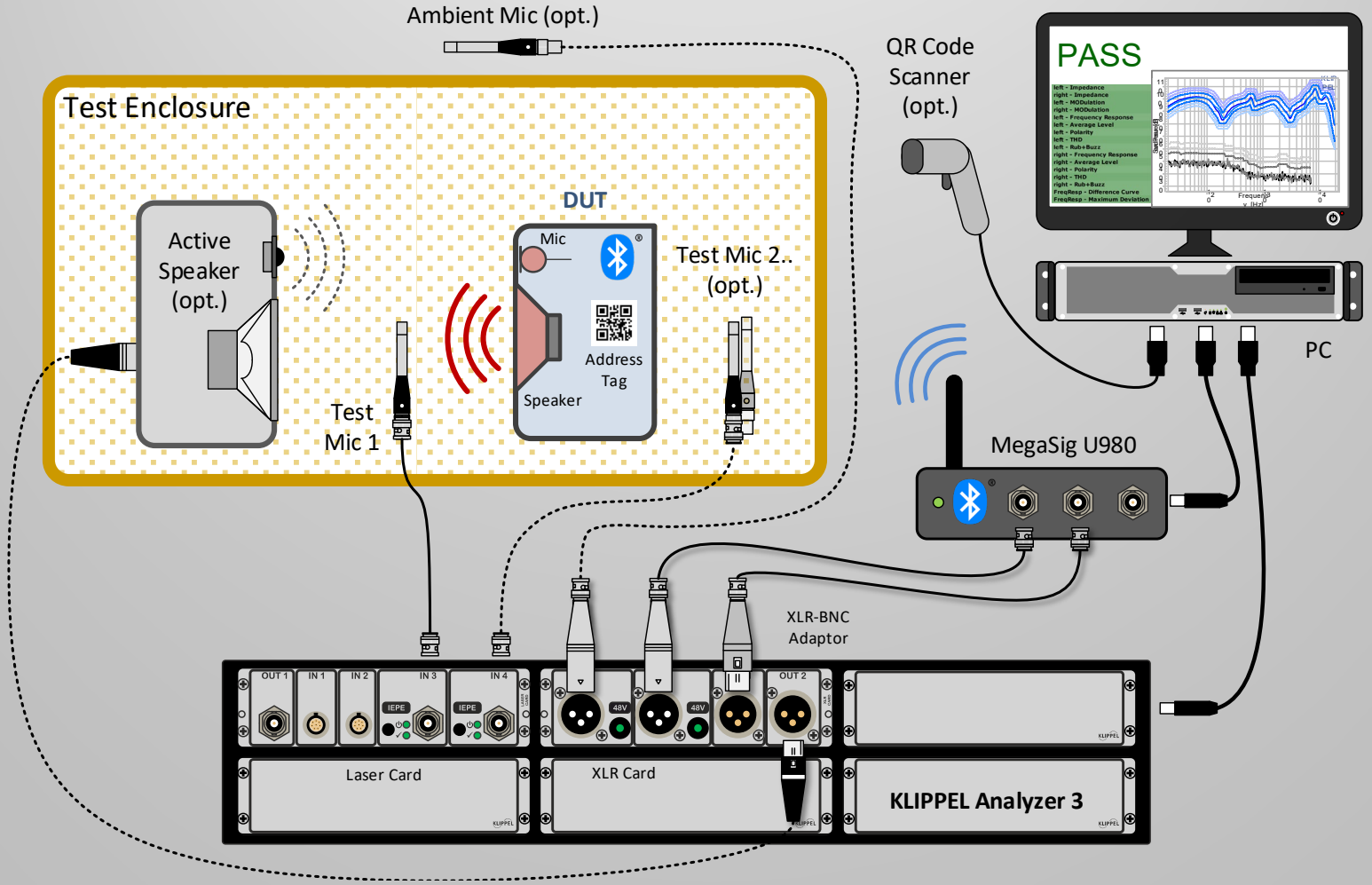
Hardware (QC & RnD)

- MegaSig U980
  - Configurable over USB (integrated in QC & RnD software)
  - Bluetooth v4.2
  - Supports major audio profiles & codecs
  - Connects directly to KA3/PA/DA



Bluetooth Speaker Test

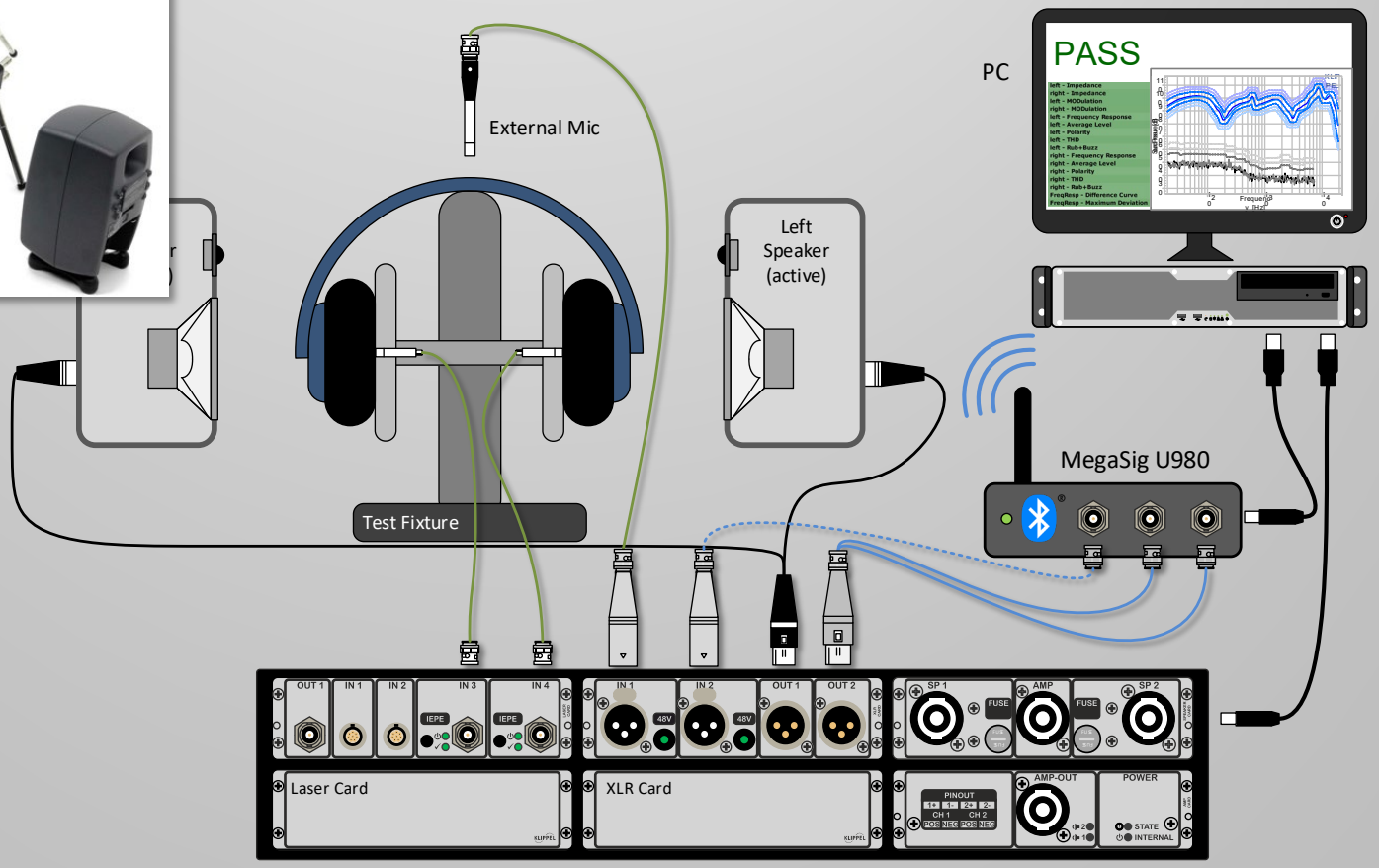
With Optional Hands-free Microphone Test



Bluetooth Headset Test

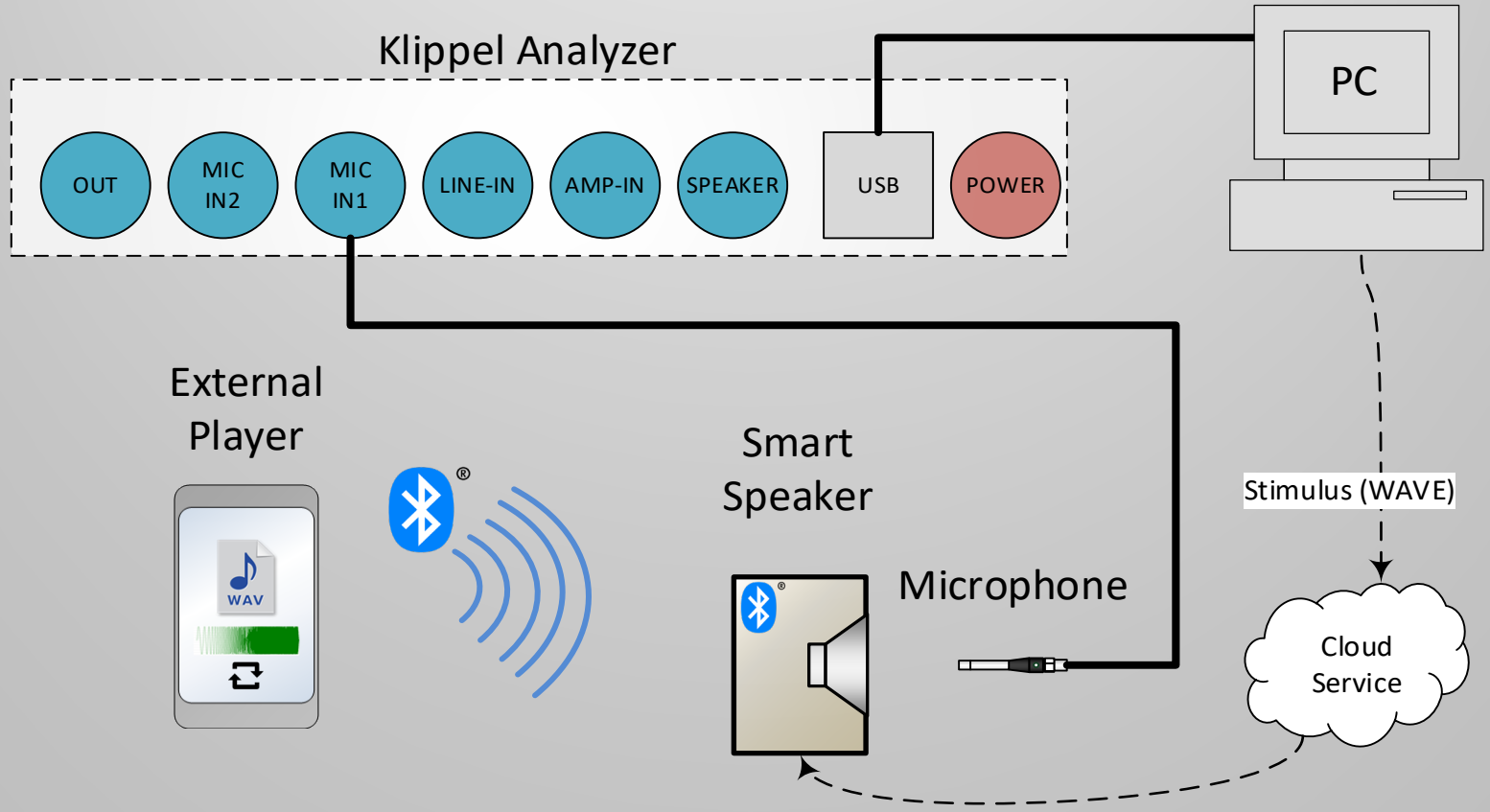
Including ANC Performance Test





Scenario 3: Open-Loop Testing

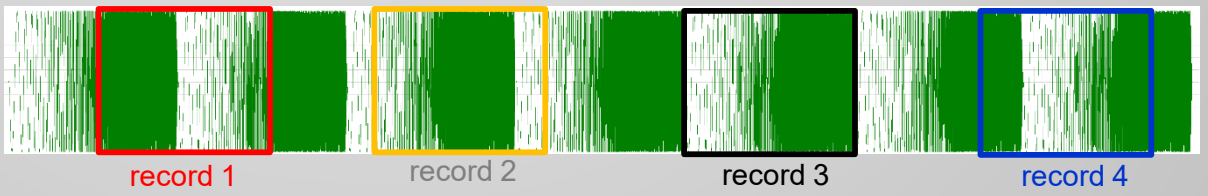
Independent Stimulus Playback (Generator not in Loop)



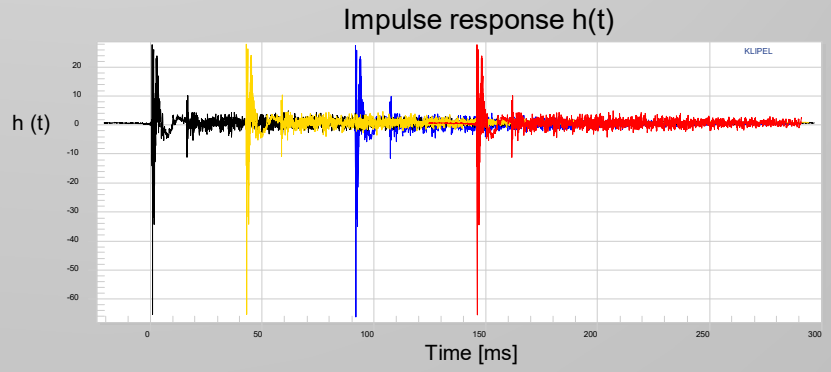
Problem in Open Loop Testing

1) Chirp stimulus is played again and again (asynchronously)





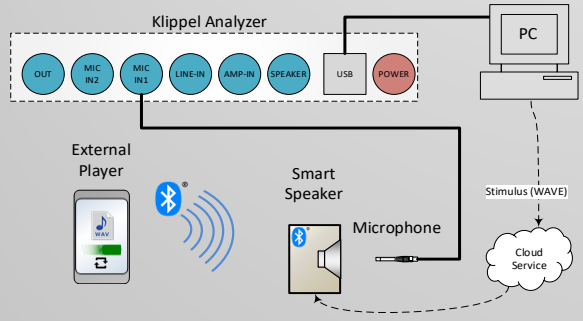
2) TRF records the waveform and calculates the impulse response



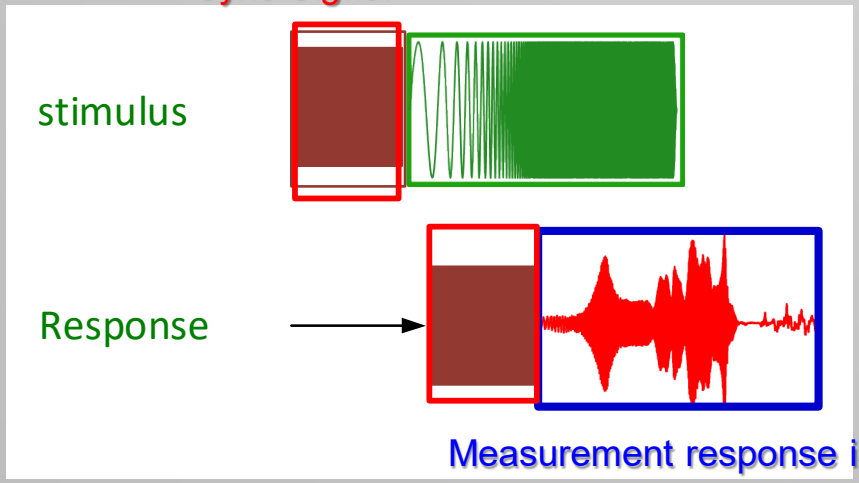
How to detect the variable delays ?

Open Loop Testing

1) Pure Software solution (External Syncronization)



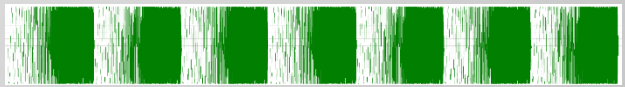
Sync-Signal

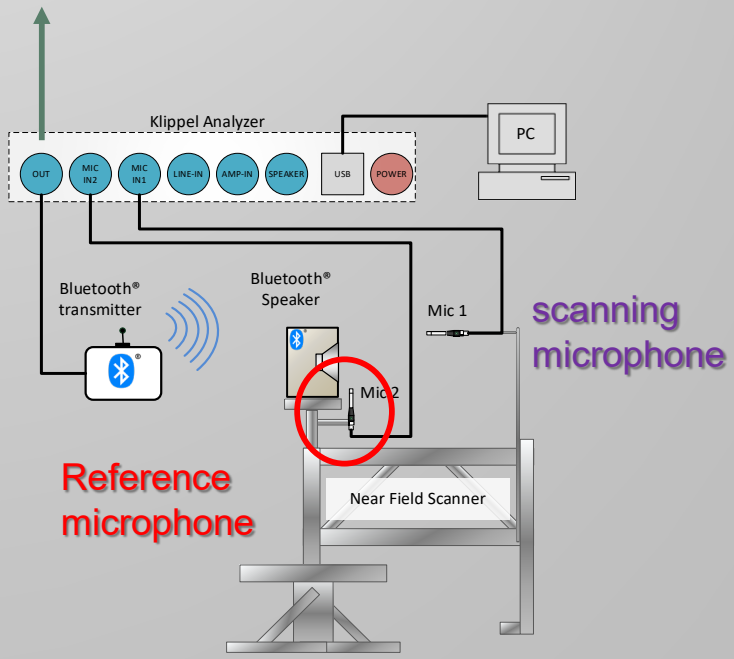


Measurement response is synchronized to stimulus

2) Additional Hardware Solution

Stimulus: Chirp played again and again





scanning microphone

Reference microphone

Solution: Use a 2nd microphone for synchronization

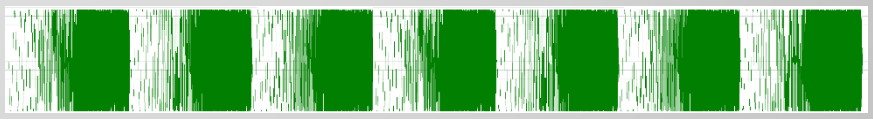


Mic 1: measurement microphone

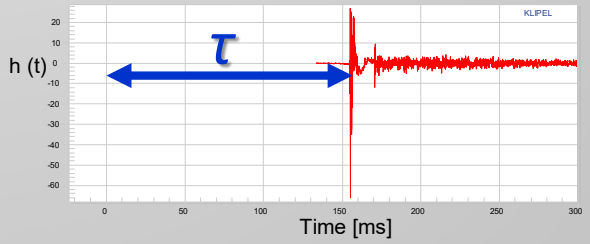
Mic 2: microphone for synchronization (not moved)

measurement surface

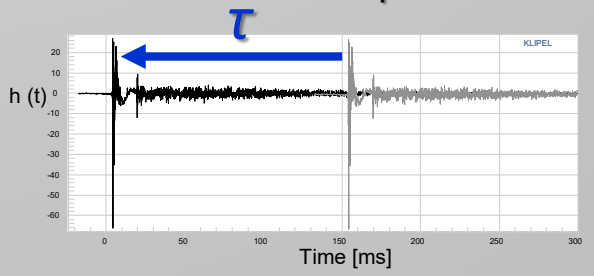
1) Stimulus is played by an internal wav-player



2) Microphone 2 detects time delay



3) Detected delay is removed from the measurement microphone



Result: Synchronized Impulse Response

NFS: Holographic Directivity Scanning

Open loop testing of a smart speaker



Problems:

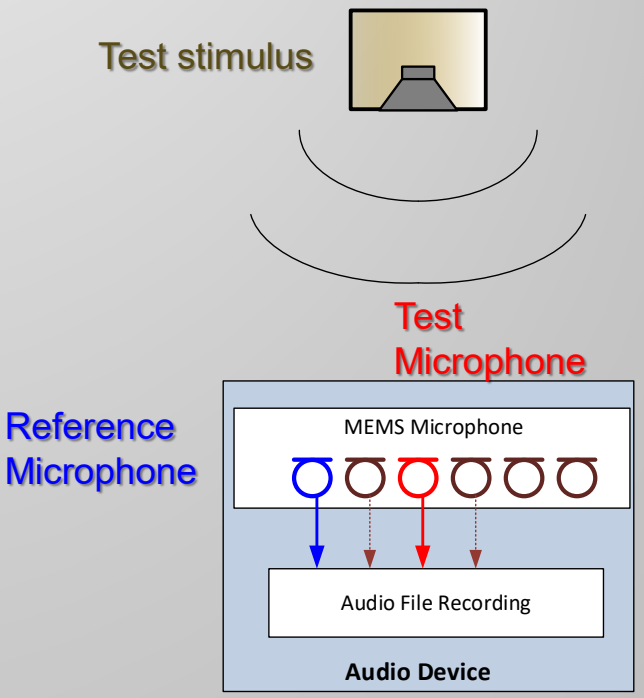
- No analog input
- Long and varying time delay (latency)
- External synchronization is not applicable

Solution: 2nd microphone at fixed position (reference)

- provides high accuracy of amplitude and phase response of the test microphone
- Detects dropouts, sample rate drift, ambient noise and other problems
- is a simple, robust and cost-efficient solution

Directivity of a MEMS Microphone





Requirements

- Sufficient accuracy in the absolute transfer functions (affected by setup)
- High accuracy in the relative amplitude and phase response (between mics)

Solution

- Using one microphone in the MEMS as a reference
- Recording or transmitting at least two signals (test + reference microphone)

Wireless Testing

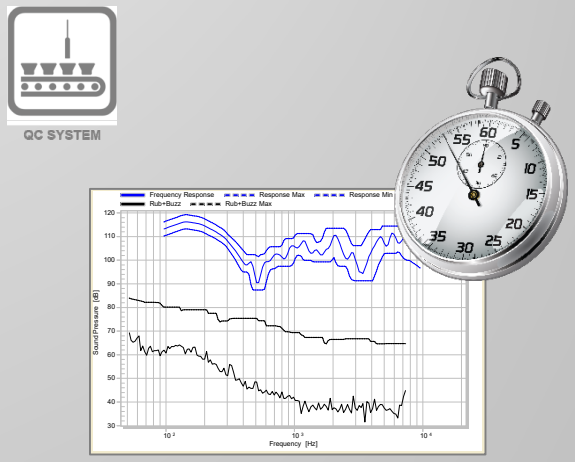
KLIPPEL Analyzer (R&D modules)

Module	Description	Closed loop setup	Open loop setup
TRF	Measurement of frequency response, impulse response & harmonic distortion	✓	✓
DIS	Measurement of harmonic distortion and intermodulation distortion (steady state)	✓	✗
TBM	Tone Burst Measurement (transient) maximum peak SPL, harmonic distortion	✓	✗
MTON	Multi-Tone Measurement multi-tone distortion, compression, maximum continuous SPL	✓	✗
NFS	3D directivity (near + far field) measurement of loudspeakers (applicable in non-anechoic room)	✓	✓
POL	2D directivity (balloon) of loudspeakers and microphones (anechoic room needed)	✓	✓

Wireless Device Testing in Production

Requirements in End-of-Line Testing

- Fast and comprehensive testing
- high sensitivity for defects
- Simple to use



Critical Issues:

- Automatic Pairing
- Smooth Bluetooth Setup
- 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	Measurement of frequency response, impulse response, harmonics & impulsive distortion	✓	✓
ALD	Air Leak Detection	✓	✓
SAN	Spectrum Analysis	✓	✓
EQA	Equalization & Alignment	✓	✓

Poll:

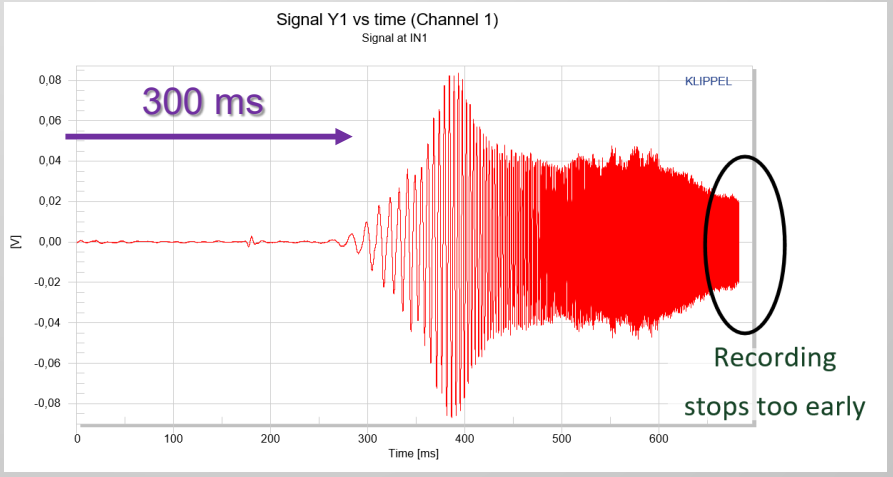
Which problems do you see using digital/wireless transmission channels ?

A. None 5%
B. Large latency (delay) 21%
C. Varying latency (versus time) 37%
D. Jitter, Clock Drift, Sampling Rate Mismatch 11%
E. Drop-outs, interpolated samples 21%
F. Others 5%

High Latency

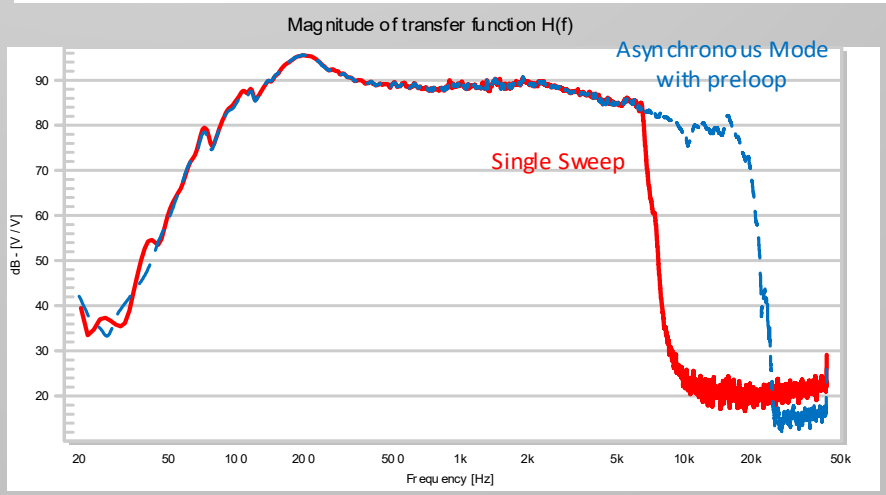
Problem in Bluetooth Devices

The delay of a Bluetooth® speaker is typically between 30 and 400 ms !



Missing late response in a single sweep test

Conclusion:
Play multiple loops of the stimulus

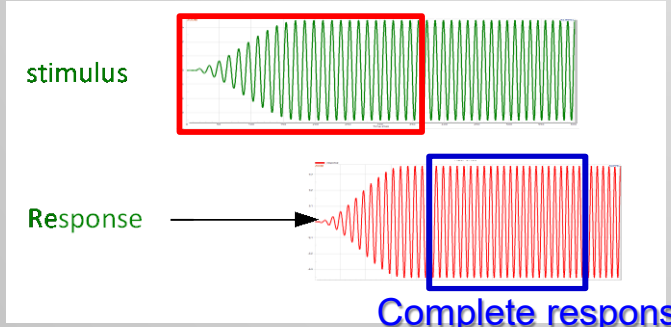


1st Solution: Additional Excitation

Coping with High Latency

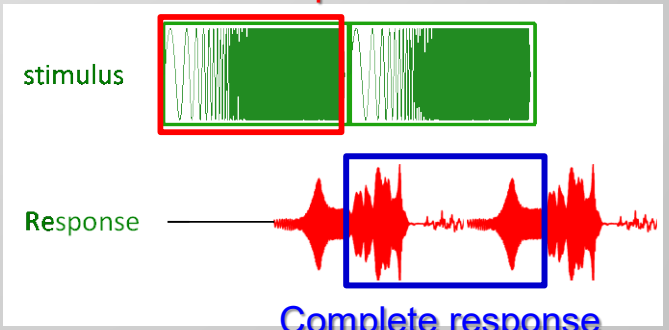
in DIS 3D Distortion Measurement

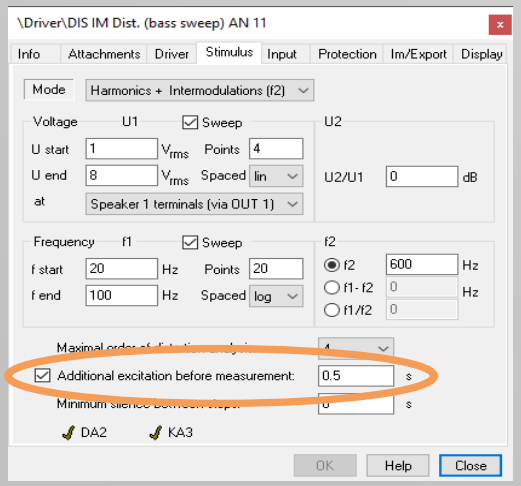
Pre-excitation

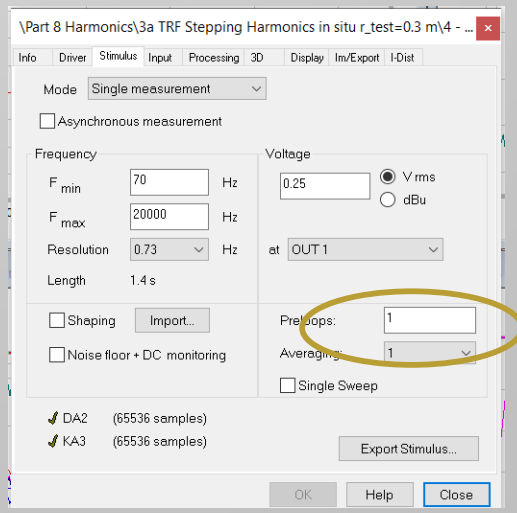


in TRF Transfer Function Module

Pre-loop

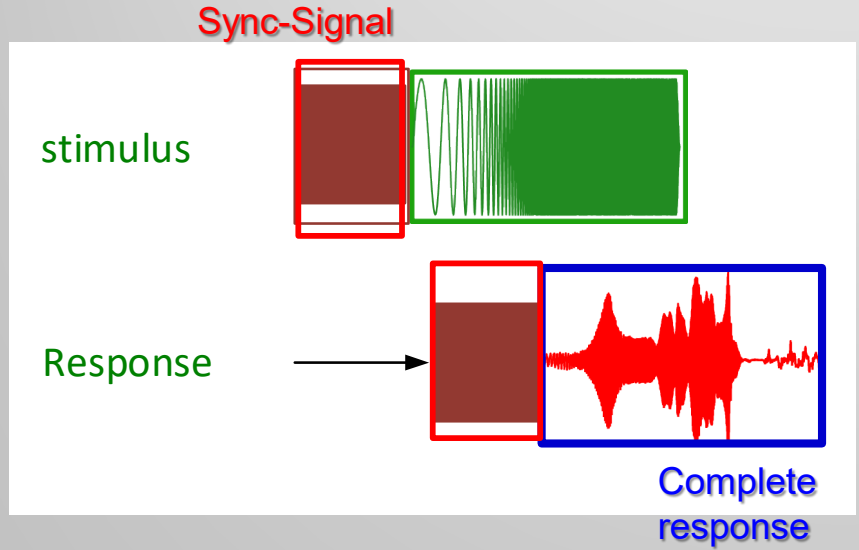






2nd Solution: External Synchronization

Coping with High Latency



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

Sync-Signal:

- Broadband signal
- Short sync signal (200ms)
- Identifier encoded
- pseudo-random properties

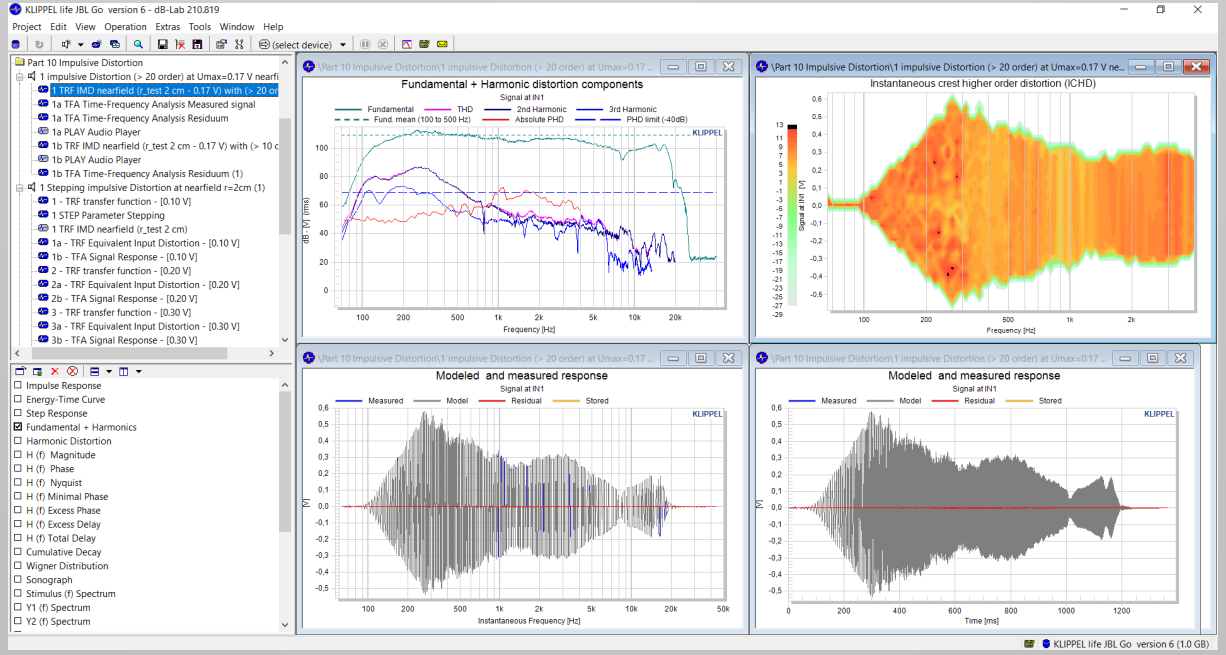
Benefits:

- No limitation with of the latency
- Best for open loop testing
- Fast EoL-testing
- Identification of the stimulus
- Linking stimulus and analysis
- Detection of sample rate mismatch

Demo

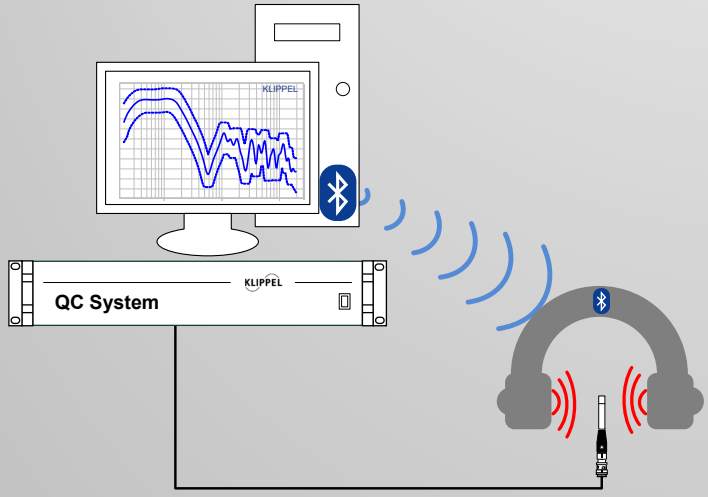
Tools: Using dedicated software modules of the KLIPPEL Analyzer

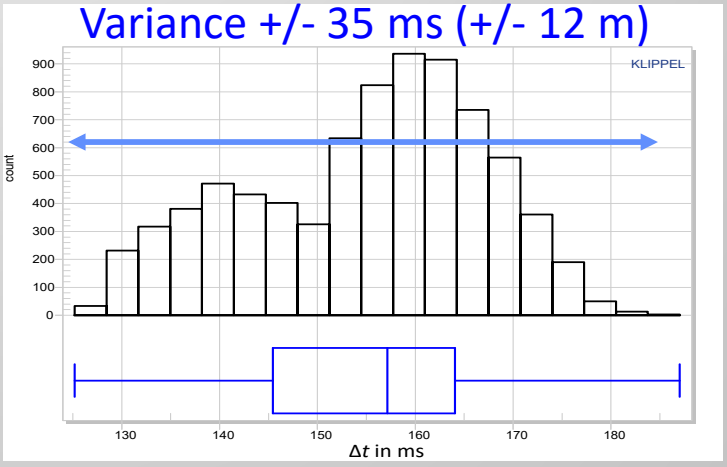
- QC End-of-Line Testing (External Synchronization SYN)



Varying Latency

Problem in Bluetooth Devices





Mean delay ≈155 ms
(≈53 m distance)

Consequences:

- Affects phase response (very critical in holographic near field scanning)
- Related to other problems (drop outs, sample rate drift, …)

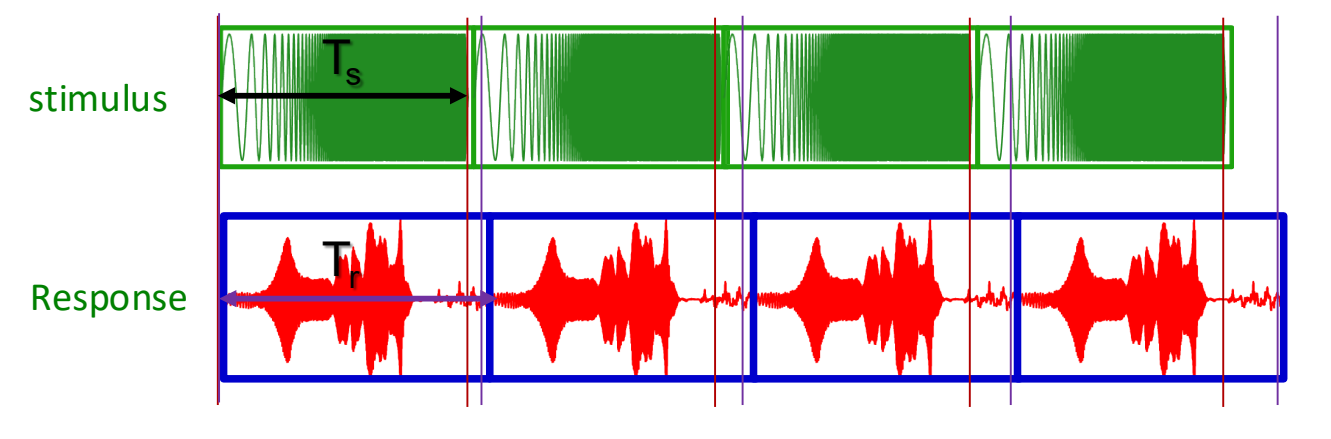
Solution:

- Reference measurements (second microphone in the near field) for coherent scanning data

Jitter, Clock Drift, Sampling Rate Mismatch

Problem in Bluetooth Devices

Root Cause: Crystals of Playback and Capture converters are different!



Symptom:
Stimulus and response have a different length

$T_s \neq T_r$

Impact on the transfer behavior:

- Frequency transformation
- Nonlinear (non-coherent) relationship between input and output
- Delay becomes worse over time
- Resampling or sample correction (dropouts, interpolation) required

Consequences of Sample Rate Drift

Drift degrades accuracy in

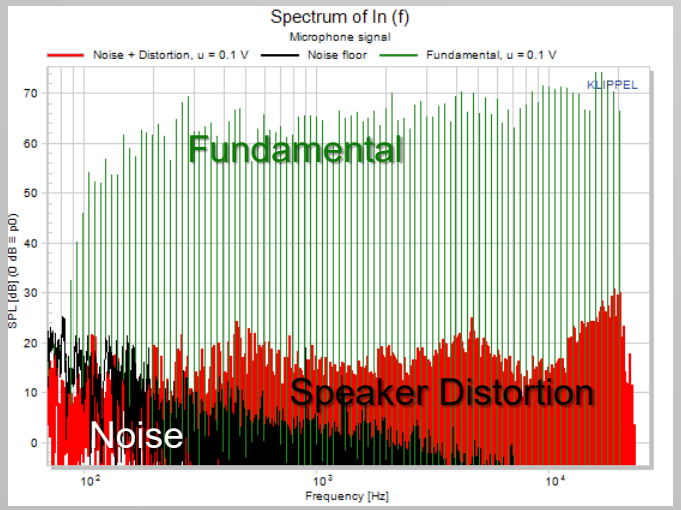
- Frequency detection
- Separation of distortion and fundamentals
- Distortion measurements
- Phase measurements

Tips: Avoid (if you can)

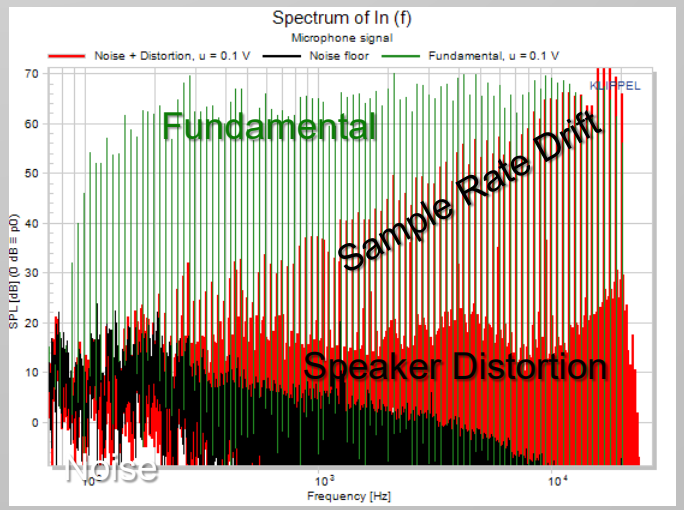
- Long Measurements (to get high frequency resolution)
- Long averaging
- Wrapping recorded time signal in an FFT

Example: Bluetooth speaker

Multi-tone distortion (analog input)



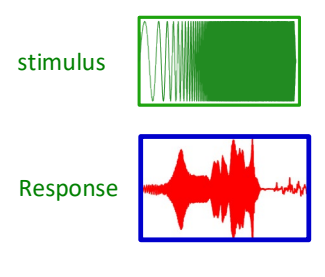
Multi-tone distortion (bluetooth input)



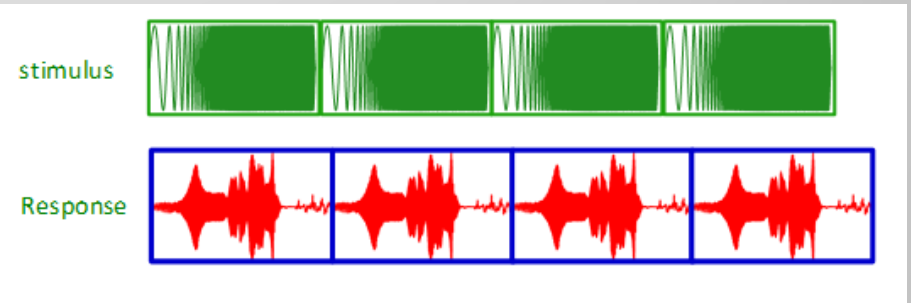
Avoid Long Averaging !

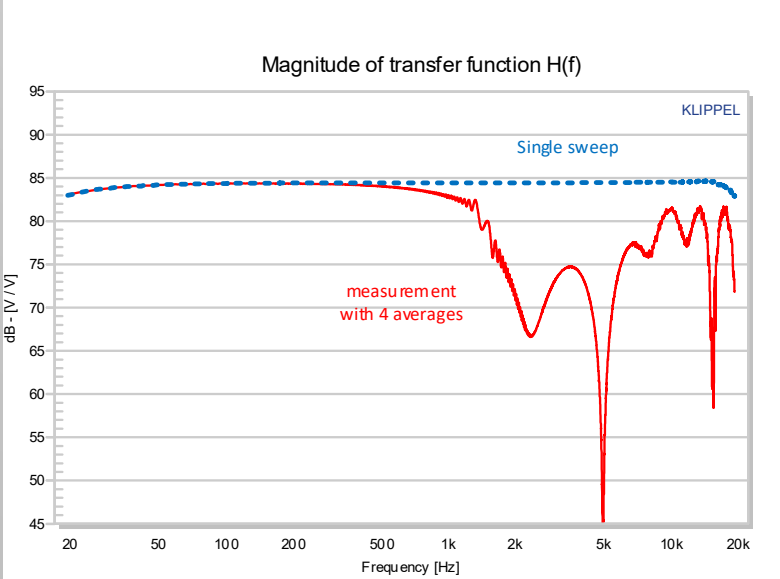
Coping with Sample Rate Drift

Single Sweep



Chirp with 4 Averages



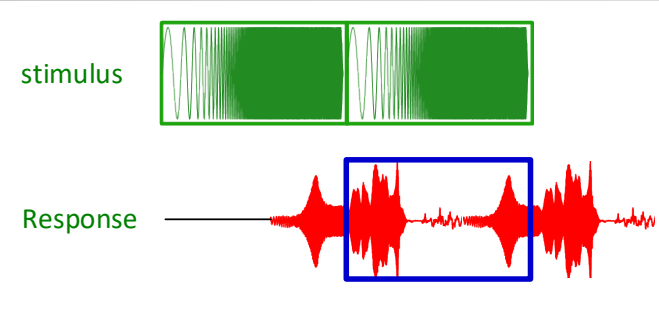


Sample rate drift generates a cancelation of high frequency components !

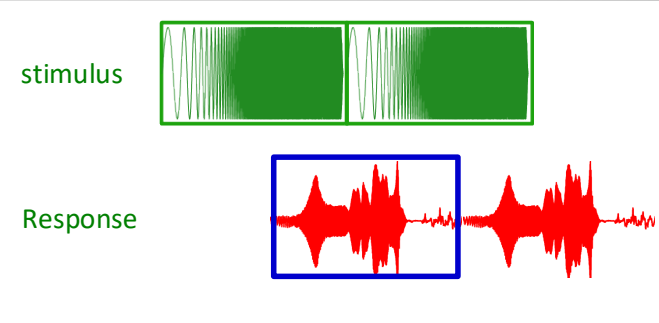
Accurate Testing with a Chirp Signal

Coping with Sample Rate Drift

Wrapping in the audio band (in the middle of the audio band)



Wrapping at zero time signal (begin and end of the chirp)

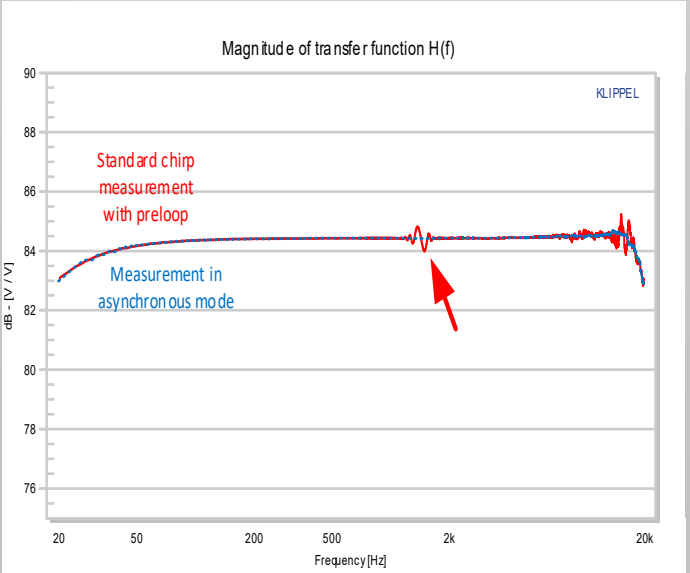


PRO:

- Simple standard measurement

CONS:

- Significant error in magnitude response
- Click generated
- Not applicable for EoL testing



PRO:

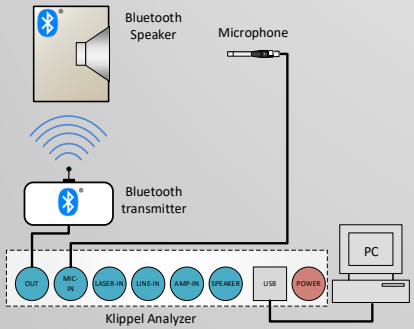
- Good accuracy
- no impulsive artifacts
- required for rub and buzz

CONS:

- Asynchronous processing
- (2 chirps)

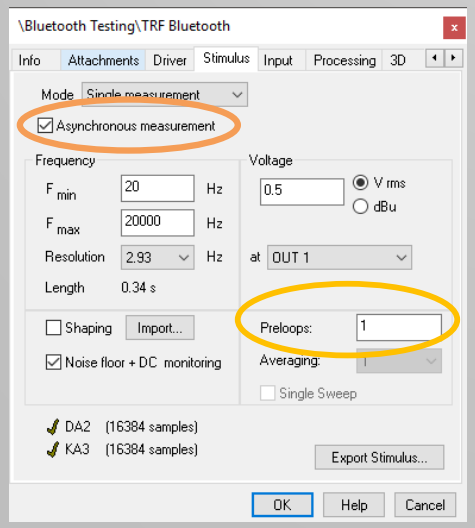
Automatic Solution in TRF Module

Coping with Sample Rate Drift



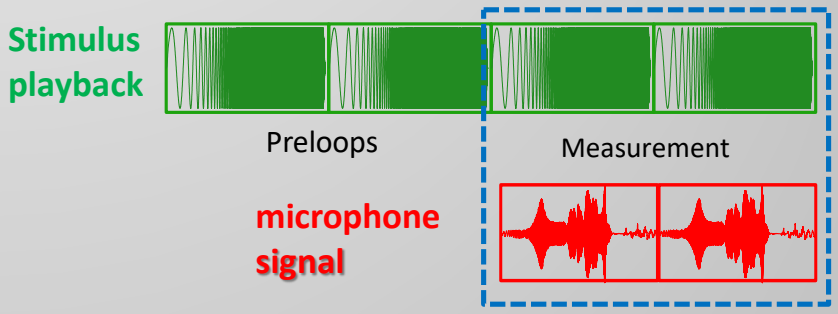
Property page TRF Transfer Function Module:

- Set preloop > 1
- Activate asynchronous mode

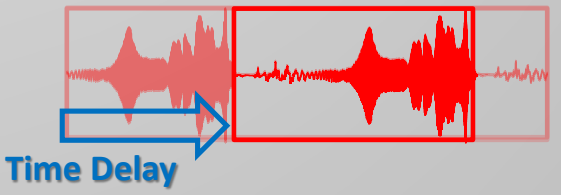


How it works?

1) Send Stimulus via Bluetooth transmitter



2) Detect Delay and window microphone signal



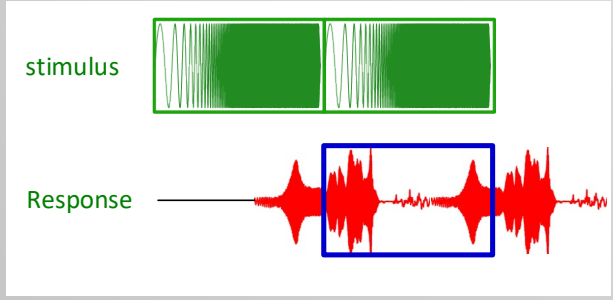
Benefits:

- Optimal windowing avoids any artifacts (clicks)
- Required for measurement of impulsive distortion (rub&buzz)

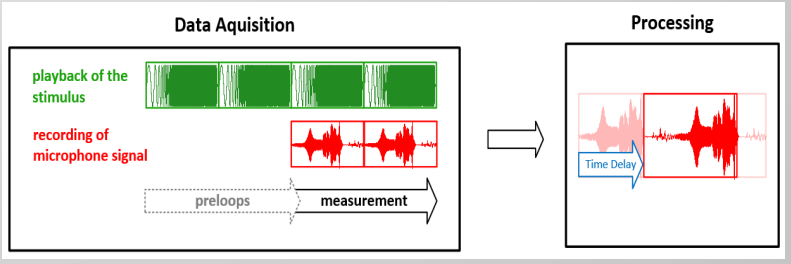
Impact on Impulsive Distortion Testing

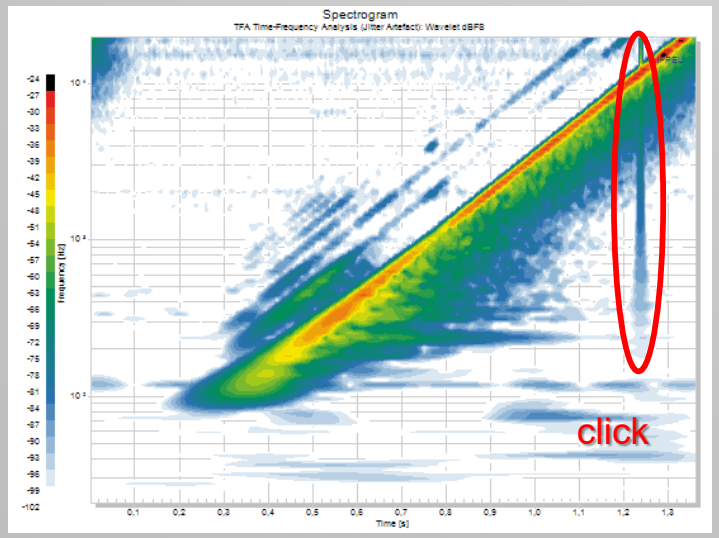
TRF copes with Sample Rate Drift

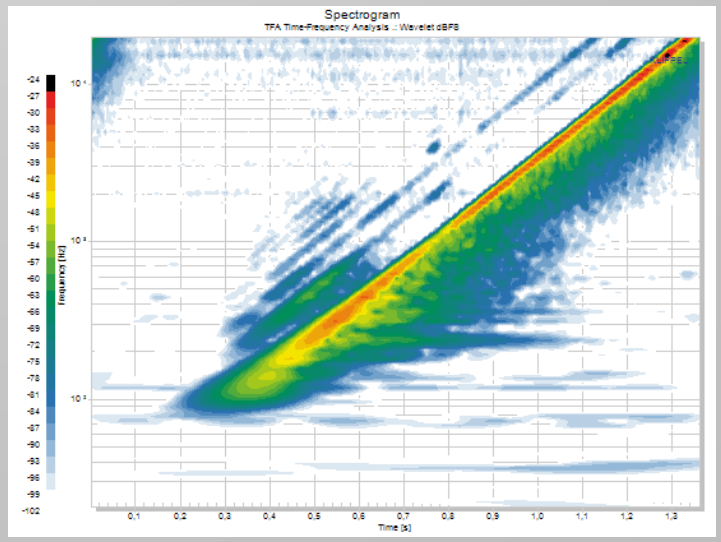
TRF in normal mode



TRF in asynchroneous mode

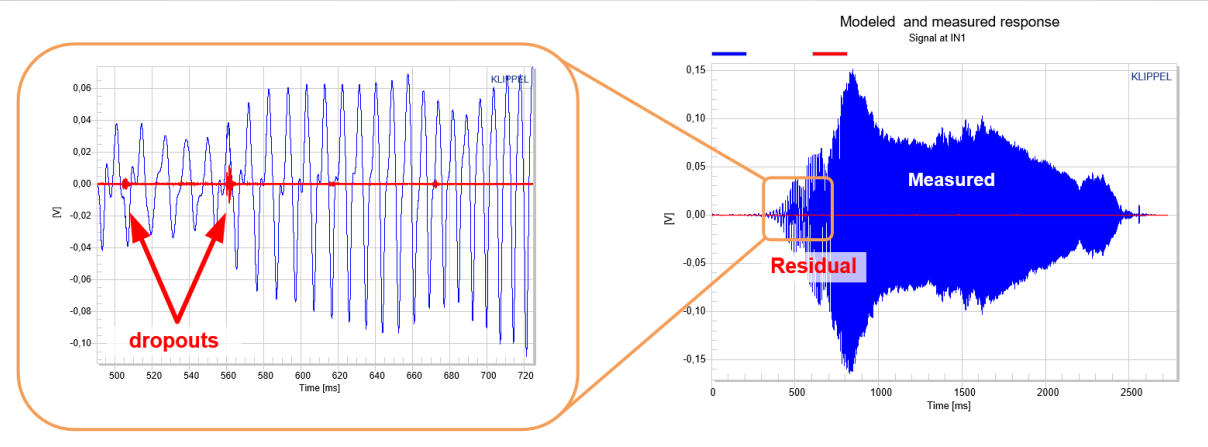






Problems

Dropouts, Glitches, Interpolation Artifacts



Root Cause:

- Simple algorithms for coping with sample rate drift can generate impulsive distortion

Consequences:

- Those artifacts are random (not repeatable, predictable)
- Maybe mixed with transducer defects critical for end-of-line testing

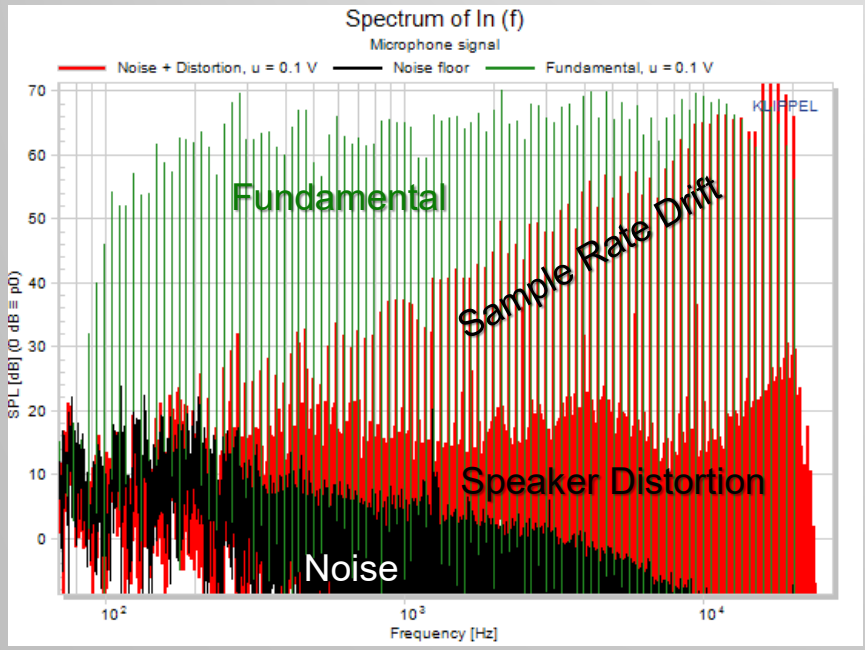
Solution:

- Repeat the measurement and compare the results
- Use open-loop measurement to separate random transducer problems (e.g. loose particles)

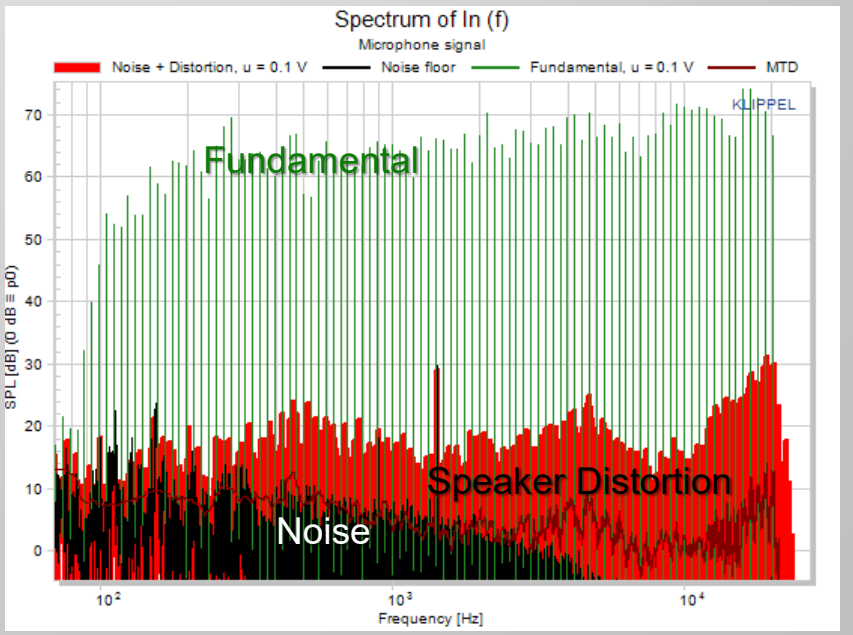
Corrected Multi-Tone Distortion

Coping with Sample Rate Drift

MTON in normal mode



MTON with drift compensation



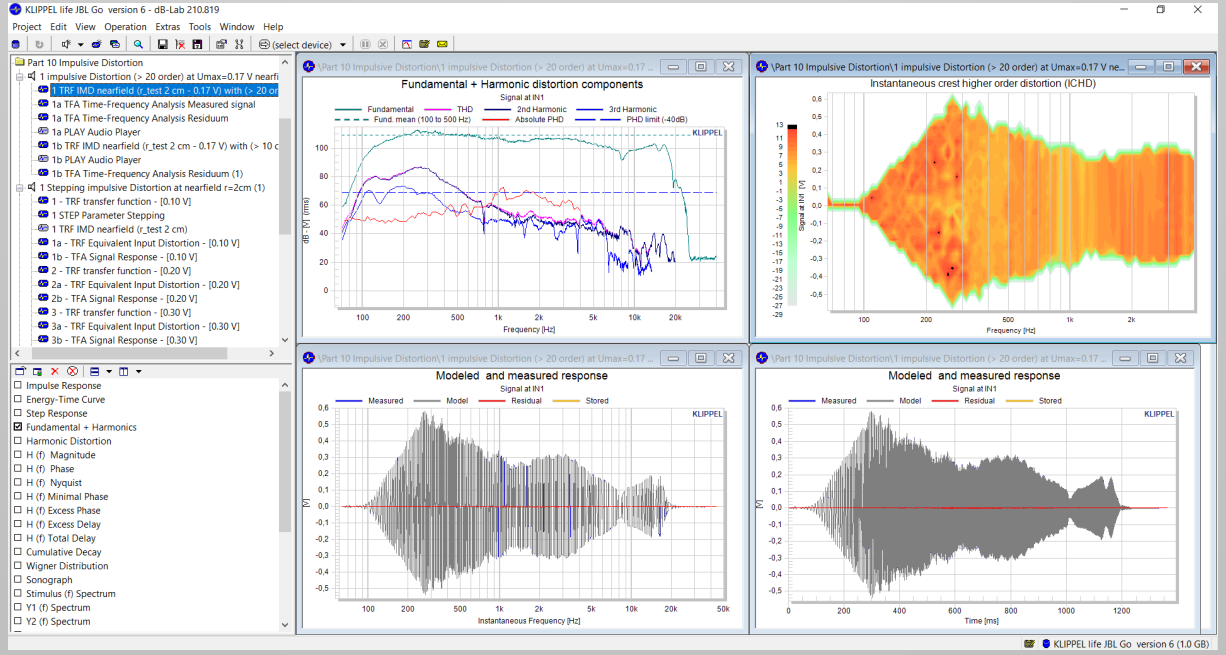
Method

1) Detection of the sample rate drift between stimulus and measured signal in percent
2) Active compensation before performing spectral analysis

Demo

Tools: Using dedicated software modules of the KLIPPEL Analyzer

- Transfer Function Measurement (TRF)
- Multi-Tone Measurement (MTON)



Discussion

Summary

- Wireless/digital transmission of the audio signal is not perfect!
- There are nonlinear, time-variant and random mechanisms which generate additional distortion
- Accurate testing requires special precaution
- Modern test instruments provides solutions

Open Questions

We have discussed physical test methods defined in IEC 60268-21 for standard condition

The next 12th KLIPPEL live webinar entitled
Benchmarking of audio products under standard conditions
will address the points:

- Which criteria are important ?
- How to choose the measurement conditions ?
- How to compare the measurement results ?
- How to draw meaningful conclusions ?
- 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