Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL-live
a series of webinars presented by
Wolfgang Klippel
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. Benchmarking of audio products under standard conditions
12. Auralization of signal distortion – perceptual evaluation
13. Setting meaningful tolerances for signal distortion
14. Rating the maximum SPL value for a product
15. Smart speaker testing with wireless audio input

Previous Sessions

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KLIPPEL LIVE #11: Testing with Wireless Audio Input
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
B. Digital cable (e.g. Toslink, HDMI, LAN)
C. Wireless (WLAN)
D. Wireless (Bluetooth)
E. Asynchronous transmission (e.g. playing and recording an audio file)
F. others
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
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

Test Enclosure

Active Speaker (opt.)
Test Mic 1

DUT
Mic
Address Tag
Test Mic 2.. (opt.)

Ambient Mic (opt.)

QR Code Scanner (opt.)

PASS

MegaSig U980

PC

XLR-BNC Adaptor

Active Speaker (opt.)

XLR Card

KLIPPEL Analyzer 3

Laser Card

KLIPPEL LIVE #11: Testing with Wireless Audio Input, 11
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)

- Stimulus: Chirp played again and again

2) Additional Hardware Solution

- Measurement response is synchronized to stimulus
Solution: Use a 2\textsuperscript{nd} microphone for synchronization

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

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

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

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
<th>Closed loop setup</th>
<th>Open loop setup</th>
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<tbody>
<tr>
<td><strong>TRF</strong></td>
<td>Measurement of frequency response, impulse response &amp; harmonic distortion</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>DIS</strong></td>
<td>Measurement of harmonic distortion and intermodulation distortion (steady state)</td>
<td>✔️</td>
<td>✗</td>
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<tr>
<td><strong>TBM</strong></td>
<td>Tone Burst Measurement (transient) maximum peak SPL, harmonic distortion</td>
<td>✔️</td>
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<tr>
<td><strong>MTON</strong></td>
<td>Multi-Tone Measurement multi-tone distortion, compression, maximum continuous SPL</td>
<td>✔️</td>
<td>✗</td>
</tr>
<tr>
<td><strong>NFS</strong></td>
<td>3D directivity (near + far field) measurement of loudspeakers (applicable in non-anechoic room)</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td><strong>POL</strong></td>
<td>2D directivity (balloon) of loudspeakers and microphones (anechoic room needed)</td>
<td>✔️</td>
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</tr>
</tbody>
</table>
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)**

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<td>SPL</td>
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<tr>
<td>ALD</td>
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<td>SAN</td>
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<tr>
<td>EQA</td>
<td>Equalization &amp; Alignment</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>
Poll:

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

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

Signal Y1 vs time (Channel 1)

Magnitude of transfer function $H(f)$

Asynchronous Mode
with preloop

Single Sweep
1st Solution: Additional Excitation
Coping with High Latency

in DIS 3D Distortion Measurement

Pre-excitation

stimulus
Response
Complete response

in TRF Transfer Function Module

Pre-loop

stimulus
Response
Complete response
2nd Solution: External Synchronization
Coping with High Latency

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

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

Sync-Signal

stimulus

Response

Complete response
Demo

Tools: Using dedicated software modules of the KLIPPEL Analyzer
- QC End-of-Line Testing (External synchronization)
Varying Latency
Problem in Bluetooth Devices

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

Variance +/- 35 ms (+/- 12 m)
Mean delay \(\approx 155\) ms
\((\approx 53\) m distance\)
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)

40 dB more distortion
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

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)

Property page TRF Transfer Function Module:
• Set preloop > 1
• Activate asynchronous mode
Impact on Impulsive Distortion Testing

TRF copes with Sample Rate Drift

TRF in normal mode

TRF in asynchroneous mode

stimulus

Response

Data Acquisition

Processing

Time Delay

stimulus

Response

click
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

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

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