Testing wireless audio devices with Klippel R&D System AN72

KLIPPEL ANALYZER SYSTEM (Document Revision 1.15)

FEATURES

- Measurement of audio devices with long and variable delay
- Open-loop tests (no signal input)
- Measurement with DA2 or KA3 hardware
- Frequency response, Harmonic Distortion, Rub & Buzz, Intermodulation Distortion

APPLICATIONS

- Smart speakers
- Bluetooth® audio devices
- Wireless speakers and headsets
- Smart Phones

DESCRIPTION

The worldwide demand for wireless audio has risen dramatically in the last few years. Measuring these Smart Speakers, headsets and other multimedia devices are introducing specific problems like variable and long delays or dropouts in the signal transmission. In many cases, no direct audio input is provided, resulting in an open-loop test scenario.

This application note shows how to measure audio devices with Bluetooth® or other wireless technologies using the Distortion Analyzer 2 (DA2) or the Klippel Analyzer 3 (KA3) hardware. Limitations and particularities are discussed.

Using the KA3 hardware, these personal audio devices can also be measured with the QC and the External Synchronization (SYN) add-on, which compensates for the delay using a fast synchronization technique [3], also in lab environment.

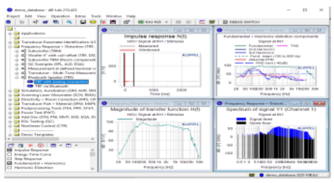
CONTENT

1 Requirements

1.1 Hardware

Klippel Analyzer (KA3 or DA2)	Hardware platform for the measurement modules performing the signal generation, acquisition and digital signal processing in real time. [10]	
Analog Bluetooth® Transmitter	3rd party Bluetooth® transmitter with an analog input (e.g., BNC) or digital input (e.g., SPDIF). Common consumer product can be used, but a professional interfaces like the MegaSig U980 (2800-407) is recommended. This interface gives better transmission stability and control of pairing (e.g., by name or address), codec and sample rate. Note: When selecting the transmitter, make sure the audio codec used is supported by the DUT. Different codecs can be used for different applications (HD vs. low latency). For further information about the Bluetooth® transmitter please see the specification A6.	
Microphone	Any measurement microphone [4]	

1.2 Software

dB-Lab version 210.478 or higher	Frame software of the Klippel Analyzer system	
RnD Modules for wireless testing		

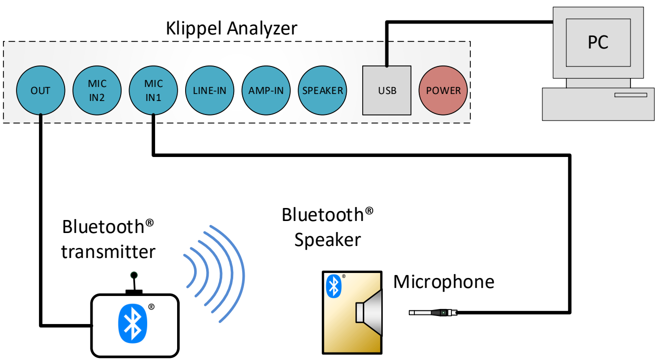
Module	Description	Closed loop setup	Open loop setup
TRF	Measurement of frequency response, impulse response & harmonic distortion	✓	✓
DIS	Measurement of harmonic distortion and intermodulation distortion (steady state)	✓	✗
TBM	Tone Burst Measurement (transient) maximum peak SPL, harmonic distortion	✓	✗
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)	✓	✓

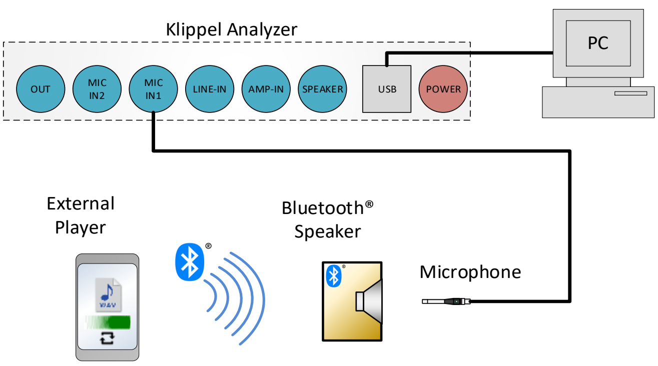
2 Measurement Setup

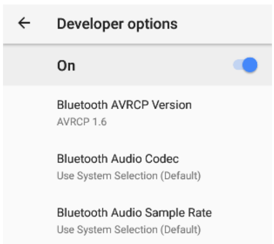
2.1 Device under Test (DUT)

Bluetooth® speaker	This application note is focused on the measurement of a Bluetooth® loudspeaker. Other wireless devices (e.g., Wi-Fi) can be measured in a similar way.

2.2 Hardware Setups

<table>
<tr><td>Setup 1: Closed loop measure-ment with Bluetooth® transmitter</td><td>

The analog output of the Klippel Analyzer (DA2/KA3) is connected to a Bluetooth® transmitter, which sends the signal to the device under test (DUT).
This setup can be used for the following modules: TRF, DIS, TBM, MTON, NFS, POL
In case of the MegaSig Bluetooth® transmitter, please connect the BNC output of the Klippel Analyzer hardware with one of the “Speaker” inputs at the MegaSig device. If a headset should be tested, then the BNC connector “Mic” at the MegaSig device should be connected to the input of the Klippel Analyzer hardware as well. </td></tr>
<tr><td>Setup 2: Open Loop Testing with Bluetooth® transmitter</td><td>

The stimulus is played as a looped wav-file with an external player or directly on the device under test.
The following sections show how the test signal can be exported as a wav file.
This setup can be used for TRF, NFS, MTON, POL
Note:
An Android smartphone can be used as a player. Most phones support several codecs and sample rates, which can be easily controlled by activating Developer options (depending on the Android version).

</td></tr>
<tr><td>KA3 Signal Configuration</td><td> In case you are using a KA3, please also check that the Signal Configuration is correct.

Select the XLR-Card or Laser-Card as the output. For the Input, select either Laser Card IN3 for a BNC-microphone or XLR Card IN1 for a XLR-microphone. (For more information see [10].) </td></tr>
</table>

2.3 Bluetooth® Pairing

Pairing process of Bluetooth connection

Check of connection

Pair the device with the transmitter.
It is recommended to check the wireless connection before starting the measurement. For example, this can be done with music played by an audio player that is connected to the analog input of the transmitter.

Listen to the music carefully and check that the connection is stable and there are no audible dropouts. When everything is okay, connect the Analyzer to the transmitter.

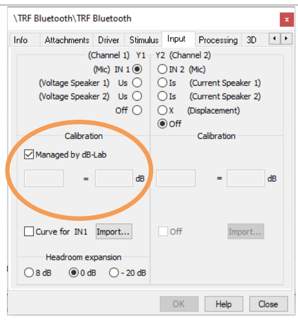
Using the MegaSig U980 Bluetooth® Interface, the pairing can be controlled directly from the dB-Lab Software using the IO-Input Output Module. For more details see section 3.1.

2.4 Sensor Setup

Microphone Calibration

To perform a calibrated sound pressure measurement, go to the ***Input*** Tab. Sensors can be defined globally (Managed by dB-Lab) or individually by operation. See manual dB-Lab for details on sensor handling.

Note: The user interface for the sensor setup depends on the used module, it is shown here for TRF module. The property page tab is labeled Input (TF, DIS, MTON) or Setup (TBM)



3 Transfer function measurement – TRF

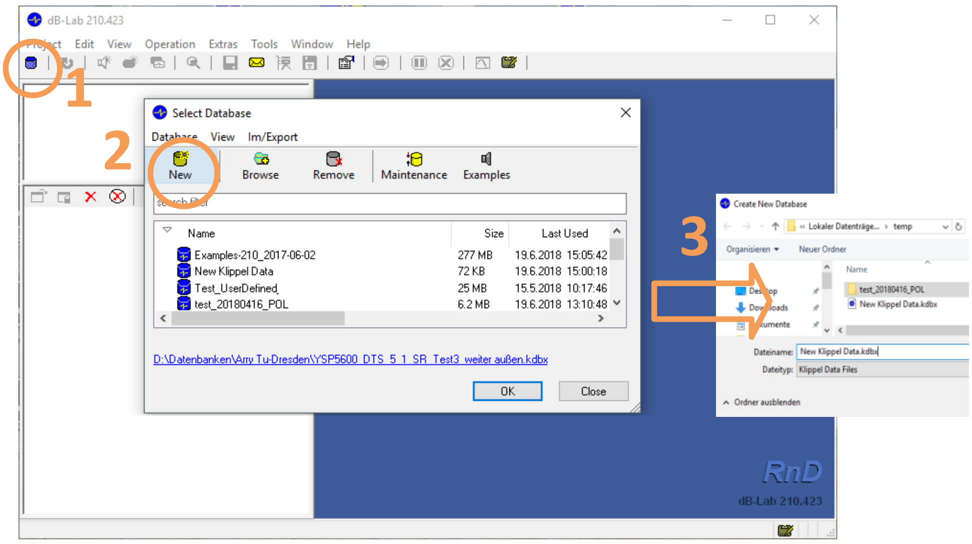
Measurement Targets

- Frequency Response
- Harmonic Distortion (THD)
- Impulsive Distortion (ID)

Open dB-Lab and Create new Database

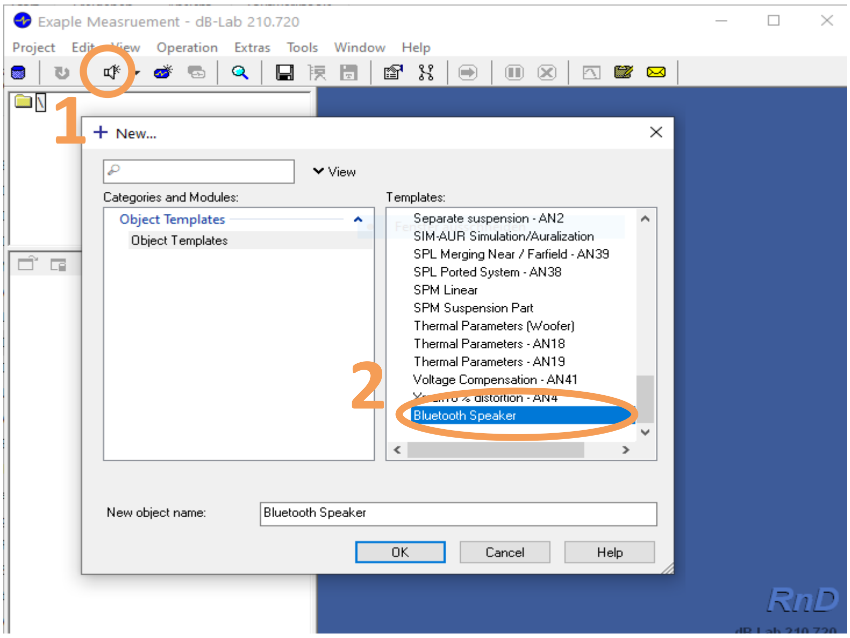
Open dB-Lab and create a new database.

1) Click in the right upper corner Select Database
2) Select New
3) Choose a location for the database on your PC



Select Object Template "Bluetooth Speaker"

1) Click New Object
2) Select the template called ***Bluetooth Speaker***



After confirming with Ok, a new Driver Object is created. This Driver includes an IO Input Output operation for Bluetooth® pairing using the MegaSig980 Interface and a TRF Transfer function module.

Bluetooth Speaker
- 1 IO Bluetooth Pairing (MegaSig U980)
- 2 TRF Bluetooth

3.1 IO – Bluetooth® Pairing

IO- Bluetooth Settings

Using the MegaSig U980 Bluetooth Interface, the pairing can be controlled from dB-Lab. Open the Property Page of the ***IO Bluetooth Pairing*** operation and select the ***Bluetooth®*** tab.

Codec Settings

The U980 provides a control of the A2DP-settings. The following parameters can be defined:

- Codecs
- Volume
- Sample Rate
- Audio Channels (SBC only)

Settings	
Interface	MegaSig U980
Select COM Port	Automatic
A2DP-Codec	SBC
• Volume	15.00
• Sample Rate	Automatic
• Audio Channels (SBC)	Automatic

Bluetooth Pairing

The IO can be set to automatically pair to the next available device as well as pairing:

- pairing by friendly name
- by Bluetooth address
- or Scanning and Selection

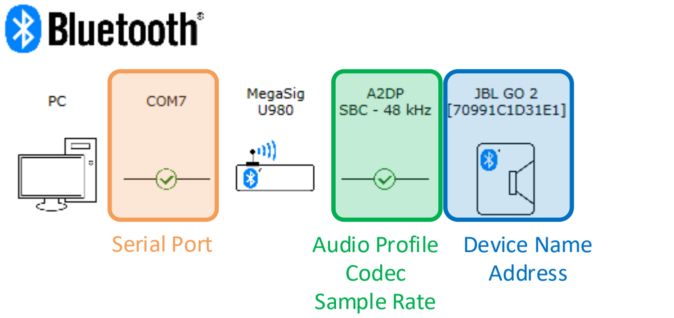
Pairing	
Pair Device	Select Device
	Scan Devices
• Select Device	MEE audio Matrix3
• Friendly Name	MEE audio Matrix3
• Address	E807BF0F6E31
• Timeout	10

Profiles

The U980 provides the A2DP and the HFP (Hands-free) profile for audio streaming and the AVRCP (Audio/Video Remote Control Profile) for volume setting.

Profiles	
Select Audio Profile	◉ A2DP (Audio Sink) ○ HFP (Hands-free)
Activate Other Profiles	
• HFP (Hands-free)	☑
• AVRCP	☑

<table>
<tr>
<td>IO – Bluetooth Results</td>
<td>After running the operation, the characteristics of the Bluetooth connection are shown in the Bluetooth® result window.



Connected Device
<table>
<tr><th>Parameter</th><th>Value</th><th>Description</th></tr>
<tr><td>Connected to</td><td></td><td></td></tr>
<tr><td>Device</td><td>MEE audio Matrix3</td><td>Name of the connected Bluetooth device</td></tr>
<tr><td>Address</td><td>E807BF0F6E31</td><td>Blueooth-Address of the connected Bluetooth device</td></tr>
<tr><td>Class</td><td>240404</td><td>Class of the connected Bluetooth device</td></tr>
<tr><td>Codec</td><td>SBC</td><td>Codec used for audio streaming</td></tr>
<tr><td>Sample Rate</td><td>48 kHz</td><td>Sample Rate used for audio streaming</td></tr>
<tr><td>Audio Profile</td><td>A2DP</td><td>Profile used for audio streaming</td></tr>
<tr><td>RSSI</td><td>-54 dBm</td><td>RSSI (Received Signal Strength Indication) of the Bluetoo
(>-70dBm - Good | >-80dBm - Fair | >-90dBm - Poor)</td></tr>
</table>
</td>
</tr>
</table>

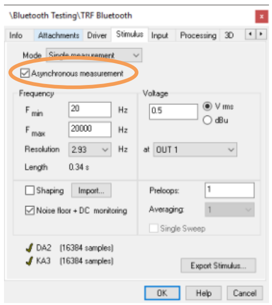
3.2 TRF – Settings

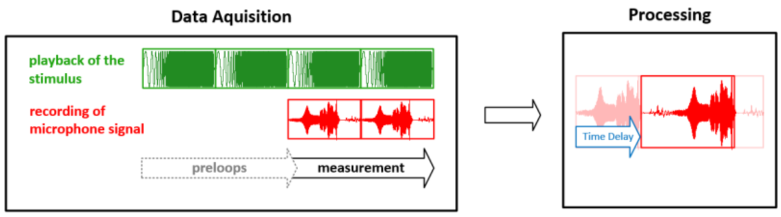
Stimulus Settings

Open the ***Property Page*** of the TRF Operation and select the ***Stimulus*** Tab.

1) ACTIVATE ASYNCHRONOUS MEASUREMENT

To measure a wireless speaker (e.g., Bluetooth®), the ***Asynchronous measurement*** mode must be activated. In this mode, the stimulus is doubled. The time delay is automatically detected and the recorded microphone signal is cut at the detected delay. This is important for avoiding artifacts from the drift of the different digital clocks. (for more information see section 7)





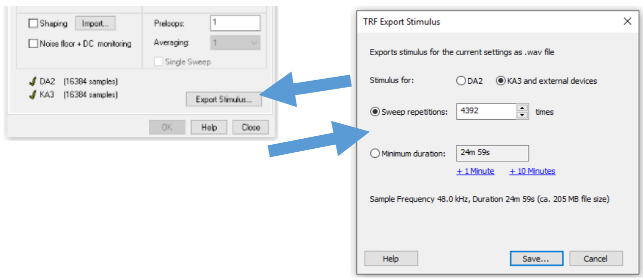
2) ADD RECORDING DELAYS

Wireless connections often have long delays (Bluetooth® typical 30 – 400 ms) which must be considered by adding a recording delay. The preloop feature can be used for this purpose. Because the stimulus has twice the length in the Asynchronous mode, one preloop can compensate a delay that is twice the stimulus length. For example:

Stimulus length	Number of preloops	Measurement time total	Maximum time delay (preloop time)
340 ms	1	1.4 s	680 ms
340 ms	2	2.1 s	1.4 s
680 ms	1	2.7 s	1.4 s
680 ms	2	4 s	2.7 s

3) EXPORT STIMULUS (FOR OPEN LOOP TESTING)

Click ***Export Stimulus*** to save the test signal as a wav-file. It is recommended to select sufficient sweep repetitions that give you time to 1st start the playback and 2nd the recording. A standard auto repeat of an audio player usually cannot be used because it isn't accurate by sample.



⚠ **After exporting stimulus do not change the stimulus settings in the TRF module.**

Run Measurement

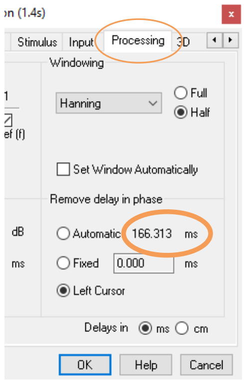
After finishing the configuration, press the green arrow to ***run*** the operation.

Note: For Open loop testing, start the playback of the stimulus first.

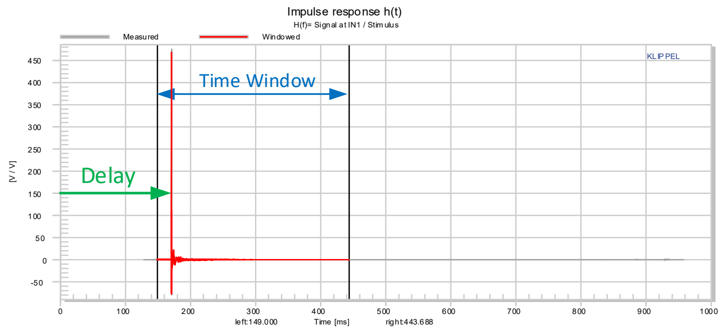
3.3 TRF – Results and Post Processing

Impulse Response

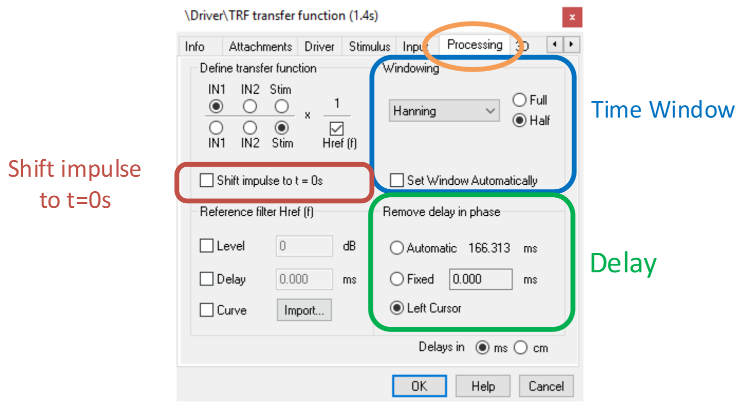
Open the ***Impulse Response*** Window. The curve shows a delay of about 170 ms for the example measurement. You can find the accurate value of the measured delay in the ***Property page*** under ***Processing*** - *Remove delay in phase – Automatic*



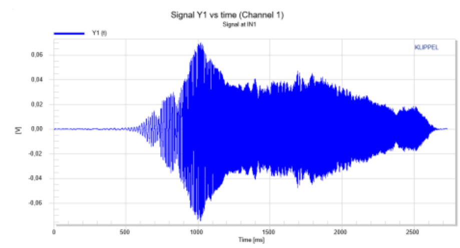
Check the position of the ***Time Window.*** You can easily modify it by shifting the left and right cursor (left click on the cursor and drag).

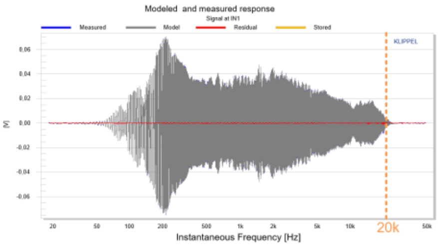


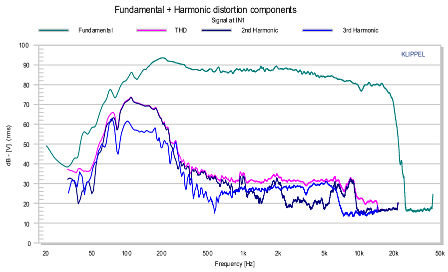
More window settings can be defined in the ***Property Page*** under ***Processing*** – ***Window.***

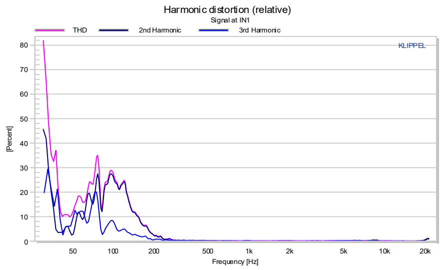


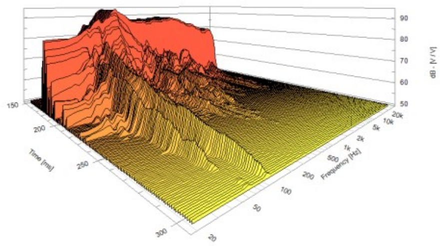
The Impulse Response can also be automatically shifted to t=0 s. This is usefully to set a user defined window relative to the main impulse.

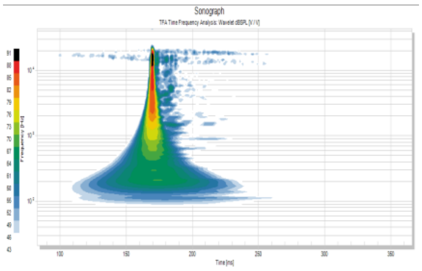
<table>
<tr><td>Microphone signal Y1 (t)</td><td>The Y1(t) window shows the measured time signal of the microphone. This window is a good indicator for checking if the microphone has recorded the complete response of the speaker. (More details about possible problem see section 7)




In TRF Pro, the frequency-time-mapping of the microphone signal can also be checked in the window Modeled Response.</td></tr>
<tr><td>Data analysis and post processing</td><td>For the detailed analysis of the measurement, all features of the TRF module can be used, like windowing, smoothing, adding reference curves, etc. For example, the frequency response and the harmonic distortion can be checked in the result window Fundamental + Harmonics and in the result window Harmonic Distortion.


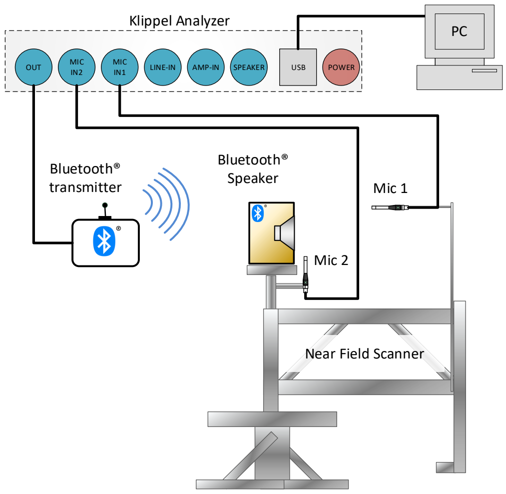


Also, the waterfall spectrum can be analyzed in the TRF.


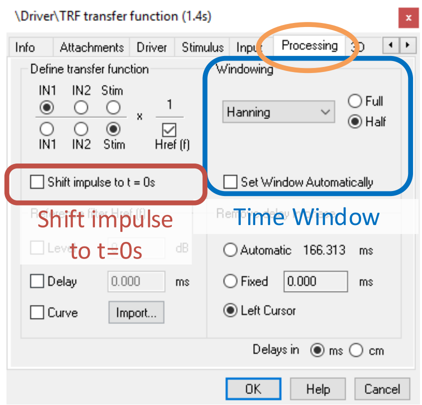


In addition, the data can be post processed, e.g., by the Time-Frequency-Analysis (TFA).</td></tr>
</table>

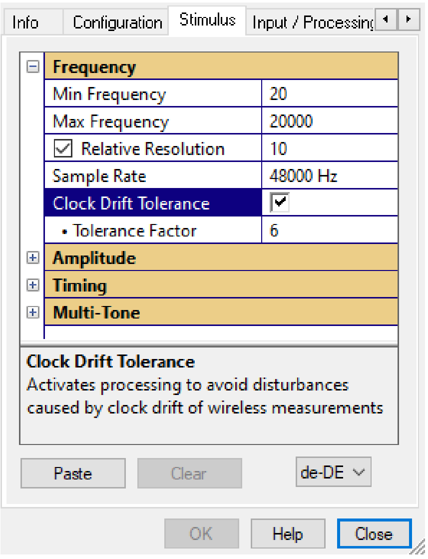
4 Near Field Scanner 3D – NFS

Performing directivity measurements of wireless loudspeakers generates additional challenges. To ensure valid phase information, all of the individual measurements (>1000) need to be synchronized. Thus, the variable delay from the wireless transmission needs to be compensated while keeping the small differences of the acoustical propagation time of the sound wave. In addition, a disturbed measurement, e.g., caused by dropout, needs to be detected and remeasured automatically.	
Asynchronous Measurement Mode	The Near Field Scanner has a special measurement mode for wireless speakers to fulfill these complex requirements. This mode uses a second microphone at a fixed position (Mic 2) to synchronize the main measurement microphone (Mic 1) that scans the sound field of the device under test. The Near Field Scanner supports **open loop and closed loop** setups. For further information, see the Near Field Scanner Software Manual: Tutorial-Part 3: Asynchronous and Open Loop Testing [12]. 

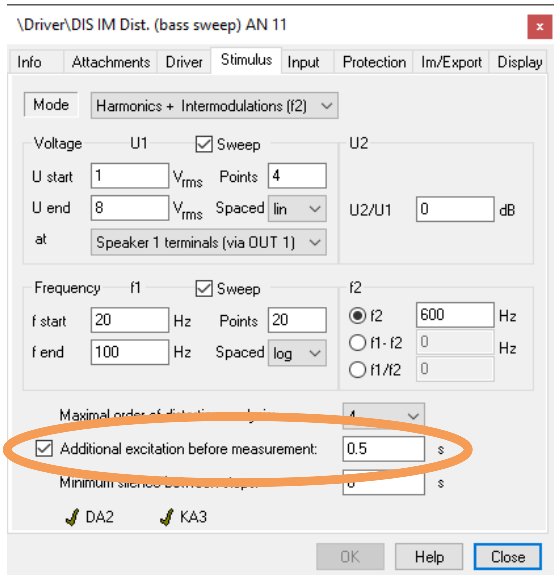
5 Polar Far-Field Measurement - POL

Measurement Setup	For POL (traditional far field directivity) measurements both, open and closed loop testing are supported. See section 3.1 for Bluetooth® connection. As well as the Near Field Scanner (NFS), POL uses the TRF Transfer function module, which needs to be set to the **Asynchronous Measurement** mode (see Section 3.2).
Bluetooth Setup	Most convenient is the automatic Bluetooth configuration using the MegaSig interface. Use the operation template *IO Bluetooth (MegaSig U980)* of the *IO Input Output* module. Note, that this needs to be done just once before starting the actual POL measurement.
TRF Setup	In order to use Time Windowing of the impulse response, it's recommended to activate the **Shift Impulse to t=0s** checkbox in the Processing tab of the Property Page. This will ensure that variable delays will be removed and time windowing will be applied correctly. 

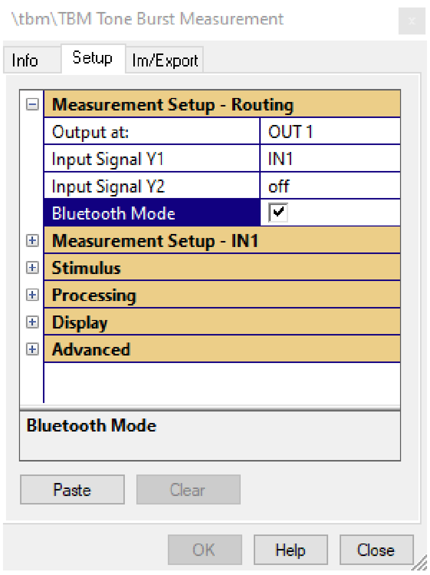
6 Multi-Tone Measurement - MTON

Measurement Setup	For MTON both, open and closed loop testing are supported. See section 3.1 for Bluetooth® connection. A template *MTON Wireless Measurement AN16* is provided. Please refer also to application note AN16 for more details and examples as well as particularities on wireless testing using MTON module.
Bluetooth Setup	Most convenient is the automatic Bluetooth configuration using the MegaSig interface. Use the operation template *IO Bluetooth (MegaSig U980)* of the *IO Input Output* module.
Stimulus Settings	The clock drift caused by the Bluetooth® technology distributes the energy of the excited signal frequencies into the adjacent (non-excited) frequencies, which leads to a massively wrong assessment of multi-tone distortion and / or fundamental response. The Clock Drift Tolerance processing identifies the fundamental components and compensates this effect as well as the long delay of the Bluetooth® transmission.  Averaging shall not be used (set to 1) to avoid artefacts from Bluetooth® connection. For detailed information please refer to the paper *Mastering Wireless Multi-Tone Testing* [18] and the Application Note 16: *Multi-Tone Distortion Measurement* [15].
Closed loop testing	Use hardware setup 1 in this mode. Multiple step measurements can be performed. This offers an automatic test sequence to obtain the operation limits of the DUT related to mechanical and thermal compression as well as multi-tone distortion. Flexible thresholds and stimulus configurations allow the MTON module to pinpoint the SPL_{max} according to IEC 60268-21 as well as the continuous max SPL (ANSI/CEA-2010-B and ANSI/CEA-2034) among other standard measurements.
Open loop testing	Use hardware setup 2 in this mode. Single measurements are available in this mode only. Navigate to the property page *Export* to export the stimulus. The wave file sample rate depends on the stimulus setup. See the MTON manual for details. The multi-tone response shall be recorded gapless, make sure, the stimulus includes sufficient repetitions when exporting. There is no synchronization required between playback and captured signal.
Results	Phase measurement is not available due to an unknown and unstable delay of the Bluetooth connection. Transfer function and fundamental response, compression, and multi-tone distortion are the key results. Influences by clock jitter and drift are compensated. See also AN16 [15] for more details on clock jitter and MTON results.

7 3D Distortion measurement - DIS

Measurement Setup	For DIS, it is required to use Setup 1 and measure with an external Bluetooth® transmitter. See section 3.1 for Bluetooth® connection. Closed loop testing is supported only.
Stimulus Settings	To compensate for the long delay of the Bluetooth transmission, it's required to add ***Additional excitation before the measurement***. This value should be larger than the Bluetooth delay. 

8 Tone Burst Measurement - TBM

Measurement Setup	For TBM, it is required to use Setup 1 and measure with an external Bluetooth® transmitter. See section 3.1 for Bluetooth® connection. Closed loop testing is supported only.
Stimulus Settings	The Bluetooth Mode has to be activated to compensate for the long delay of the Bluetooth transmission. 
Closed loop testing	Multiple step measurements can be performed. This offers an automatic test sequence to obtain the operation limits of the DUT related to mechanical and thermal compression as well as harmonic distortion. Flexible thresholds and stimulus configurations allow the TBM module to assess the SPL_{max} according to IEC 60268-21 as well as the ANSI/CEA-2010-A/B and ANSI/CEA-2034 among other standard measurements.

9 Problems and Particularities

This section will discuss common problems when measuring Bluetooth® or other wireless devices. This should aid in the interpretation of the measurement results and finding root causes of problems. Depending on the quality of the transmission and the codec used, these problems may or may not arise.

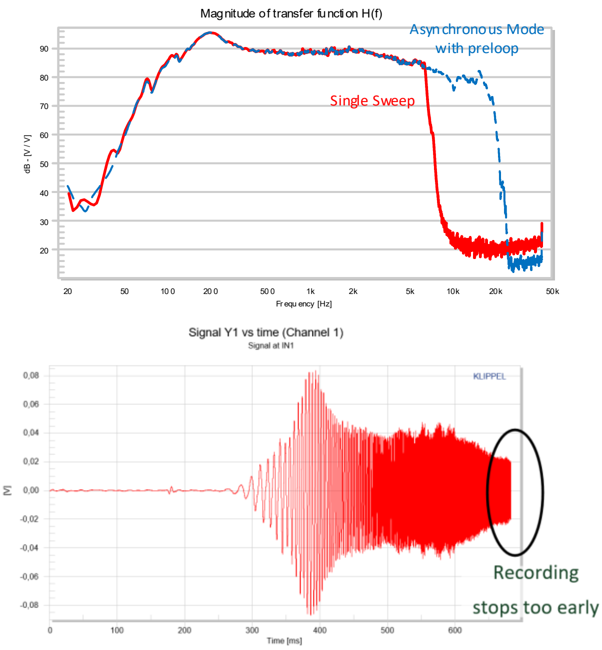
9.1 Verification using Cable or alternative Connection

If possible, it is highly recommended to verify measurement results with cable-based measurements. In many cases, devices have multiple input options that may be used. Clearly processing may be different but basic properties may be checked for plausibility.

9.2 Long Delays

An important particularity for wireless measurement is the transmission delay. The delay of a Bluetooth® speaker is typically between 30 and 400 ms, which includes the wireless transmission plus the latency of internal signal processing within the device.

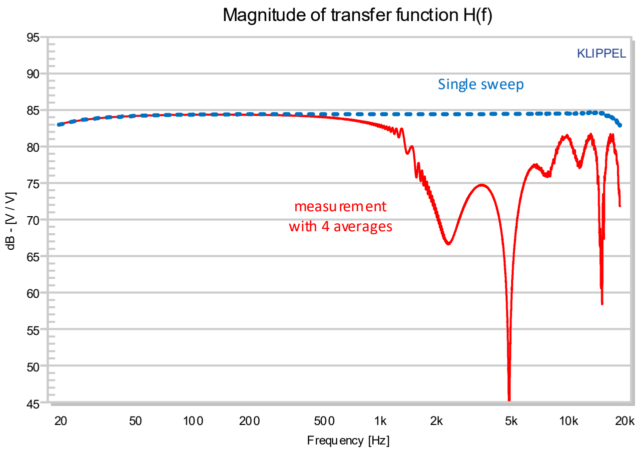
The following example shows how a wrong setup can affect the measurement results for the TRF module. The red solid curve shows the transfer function measured with a single sweep of 680 ms length. Asynchronous mode is deactivated. As shown in the picture, the high frequencies (f>8 kHz) are missing. The analysis of the microphone signal ***Y1(t)*** shows that high frequencies were not recorded because of the long transmission delay.



To solve this problem, the stimulus is at least doubled (equivalent t0 adding a pre-loop). As seen in the frequency response (dashed blue curve), the complete pass band of the DUT was measured correctly. In TRF this extension of the stimulus is done automatically when activating the *Asynchronous Mode.*

9.3 Avoid averaging

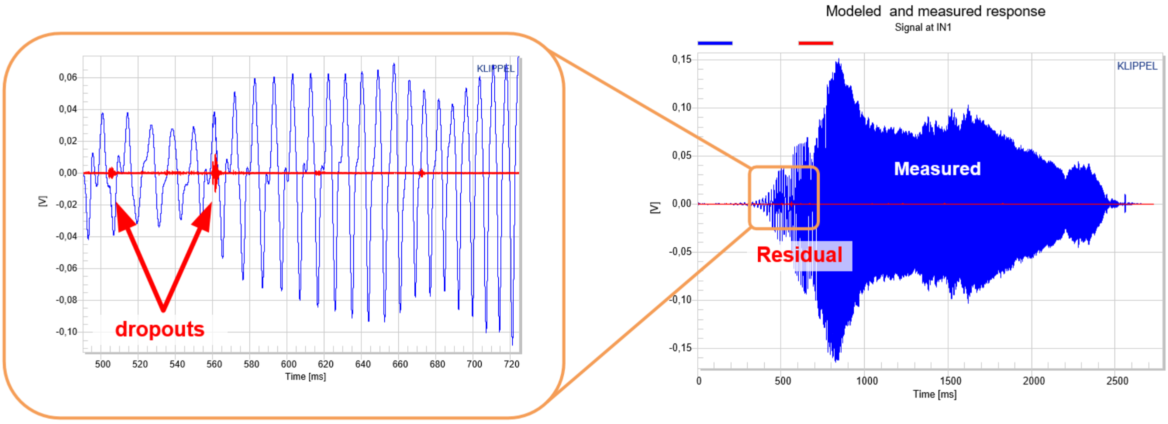
The clock drift makes measurements with averaging almost impossible for Bluetooth® devices. While repeating and averaging the measurements, the sample rate and therefore the phase response may change slightly for every loop. This can cause cancellation effects.

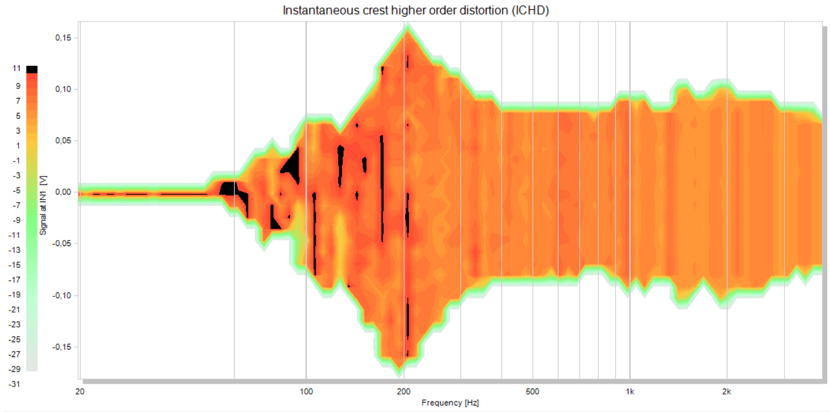


The example shows that the averaged measurement (solid red line) causes dramatic cancellations, especially at high frequencies (f>1 kHz). In this example, the difference is more than 20 dB compared to the single sweep measurement (dashed blue line).

9.4 Dropouts

Please keep in mind that Bluetooth® is sensitive to disturbances in the wireless connection. Disturbances can lead to dropouts, meaning some small parts of the signal are not received properly. This is normally uncritical for measuring the fundamental response because the small dropouts do not have much energy, but for Rub & Buzz analysis, it is one of the most critical problems. The dropout produces symptoms similar to Rub & Buzz of the loudspeaker. To do reliable Rub & Buzz measurements with the Bluetooth® device, you should first check your Bluetooth® transmission and also repeat the measurement to verify the result.





The example shows a measurement with a bad Bluetooth® transmission where some dropouts happened during the measurement. The Residual of TRF Pro analysis (window ***y(f) Modeled Response Waveform***) very clearly shows the click in the signal, and also the ***Instantaneous Distortion 3D*** shows black spots at this position.

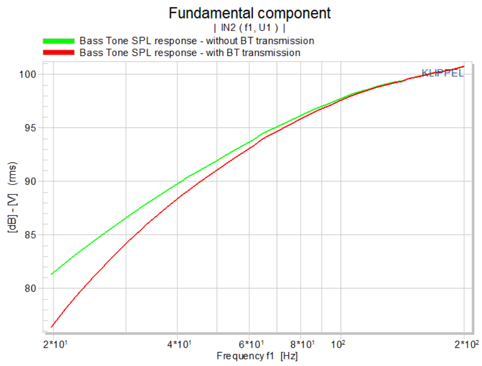
9.5 Low frequency performance of Bluetooth transmitters

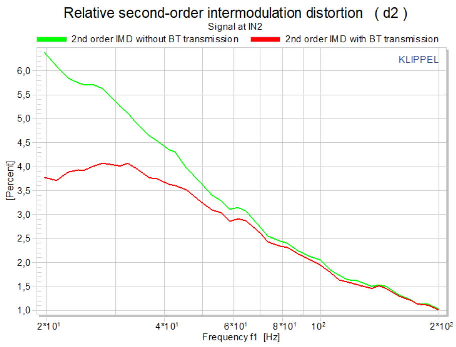
Especially when measuring intermodulation distortion with traditional two-tone methods (DIS) like Voice Sweep or Bass Sweep, you should consider that the analog input of Bluetooth transmitters is most likely AC coupled. This may cause a high-pass characteristics, which influences the measurement results:

BASS SWEEP

By using a Bass Sweep with fixed high frequency Voice Tone and variable low frequency Bass Tone, the influence of the high pass is visible in the fundamental response of the Bass Tone.

Compared to a direct measurement, the measurement with Bluetooth® is showing less output at low frequencies. The low frequency reduction of the fundamental response explains the reduction of the Intermodulation Distortion components, which are about 2% less at 20Hz.

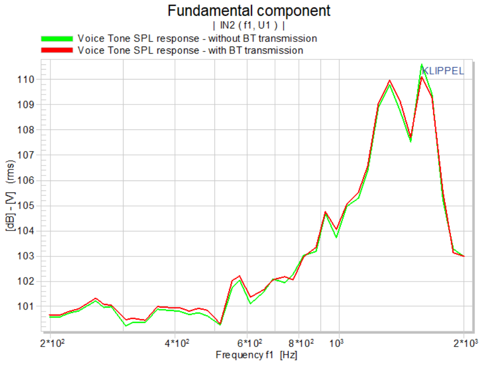


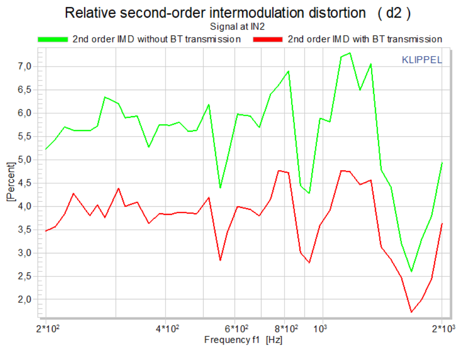


VOICE SWEEP

Using a Voice Sweep with fixed low frequency Bass Tone and variable high frequency Voice Tone shows that the Bluetooth® transmission doesn't affect the fundamental response of the Voice Tone.

However, a constantly lower Intermodulation Distortion is measured due to the damping of the Bass Tone.





To avoid these mistakes, it's recommended to check the excitation of the speaker, e.g., by measuring the displacement with a Laser.

10 References

10.1 Related Modules	[1] S7 - TRF –Transfer Function (TRF) [2] S8 - TRF –Transfer Function Pro (TRF-Pro) [3] S32 - QC External Synchronization (SYN) [4] A4 - Microphones [5] A6 - Accessories [6] S4 - Distortion Measurement (DIS) [7] S44 - Tone Burst Measurement (TBM) [8] S64 - Multi-Tone Measurement (MTON)
10.2 Manuals	[9] Manual - TRF Transfer Function (included in dB-Lab setup) [10] Manual - Hardware [11] Manual - DIS Distortion Measurement (included in dB-Lab setup) [12] Manual - NFS Near Field Scanner (included in dB-Lab setup) [13] Manual - TBM Tone Burst Measurement (included in dB-Lab setup) [14] Manual - MTON Multi-Tone Measurement (included in dB-Lab setup)
10.3 Application Notes	[15] AN16 – Multi-Tone Distortion Measurements [16] AN76 QC Testing of Wireless Audio Devices
10.4 Publications	[17] Marian Liebig: *Challenges of testing mobile devices and mobile testing*, Voice Coil February 2017 [18] Andrew Taylor: *Mastering Wireless Multi-Tone Testing*

Find explanations for symbols at:
http://www.klippel.de/know-how/literature.html
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Designs and specifications are subject to change without notice due to modifications or improvements.

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