Testing wireless audio devices with Klippel R&D System AN72

KLIPPEL ANALYZER SYSTEM (Document Revision 1.12)

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 of wireless audio has risen dramatically in the last few years. Measuring these Smart Speakers, headsets and other multimedia devices is 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 will be discussed.

ALTERNATIVES

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

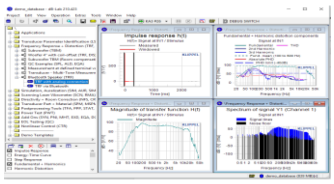
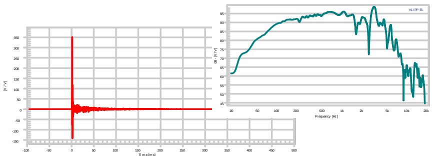
CONTENT

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. [8]	
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).	
Microphone	Measurement microphone [4]	

1.2 Software

dB-Lab version 210.478 or higher	Frame software of the Klippel Analyzer system	
Transfer Function Module TRF/ TRF Pro	The Transfer Function Module (TRF) is a dedicated software module for the measurement of the transfer behavior of a loudspeaker or system. [1]	

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)	✓	✓

Measurement Setup

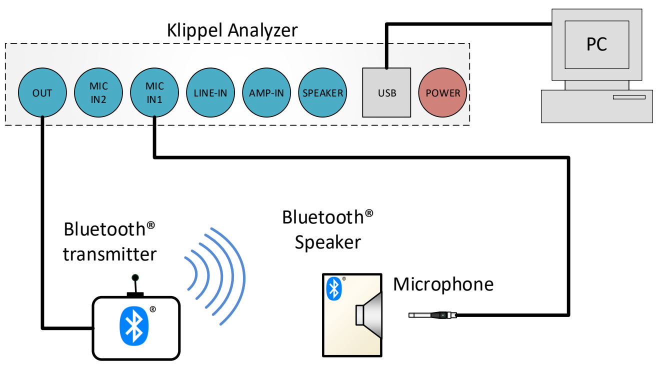
2.1 Device under Test (DUT)

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

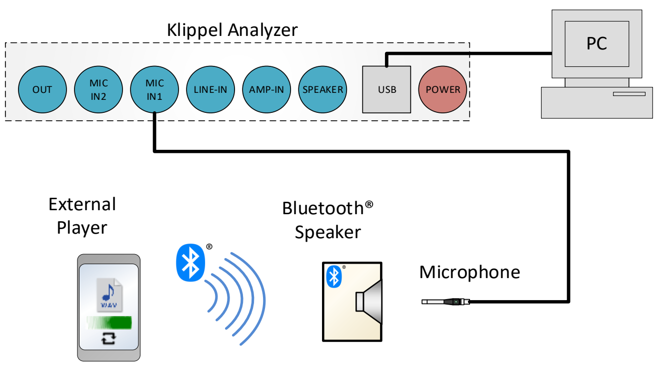
Setup 1: Measurement with Bluetooth® transmitter



The analog output of the Klippel Analyzer (DA2/KA3) is connected to a Bluetooth® transmitter, which sends the signal to the device under test.

This setup can be used for the following modules: TRF, DIS, TBM, MTON, NFS, POL

Setup 2: Open Loop Testing



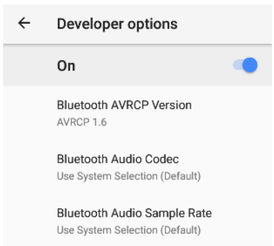
The stimulus is played as a looped wav-file with an external player or directly on the device under test.

The following sections show how the test signal can be exported as a wav file.

This setup can be used for TRF, NFS, POL

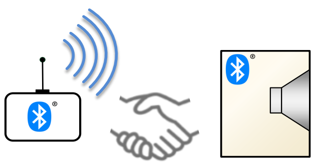
Note:

An Android smartphone can be used as the player. Most phones support several codecs and sample rates, which can be easily controlled by activating the Developer options (depending on Android version).



Pair speaker and transmitter and check 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.

3 Transfer function measurement – TRF

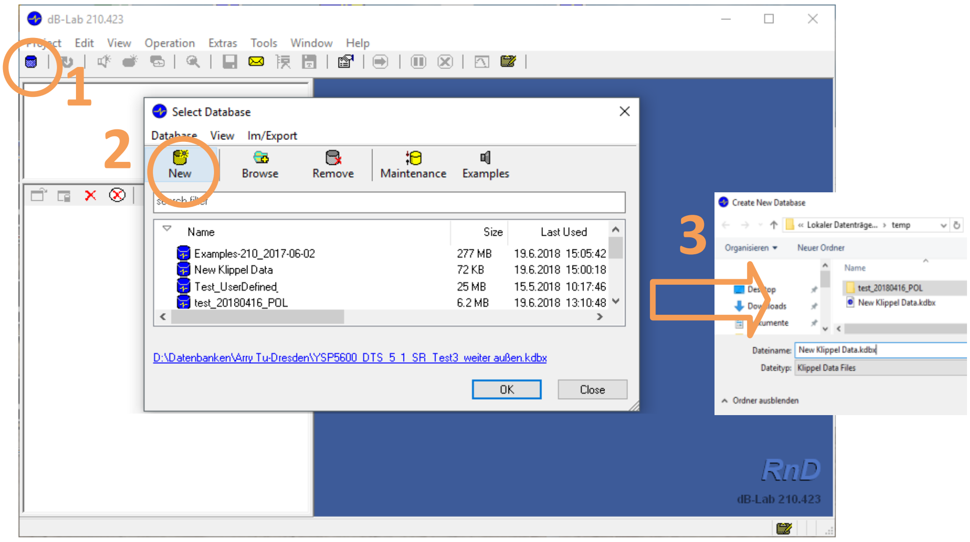
Measurement Targets

- Frequency Response
- Harmonic Distortion (THD)

Open dB-Lab and Create new Database

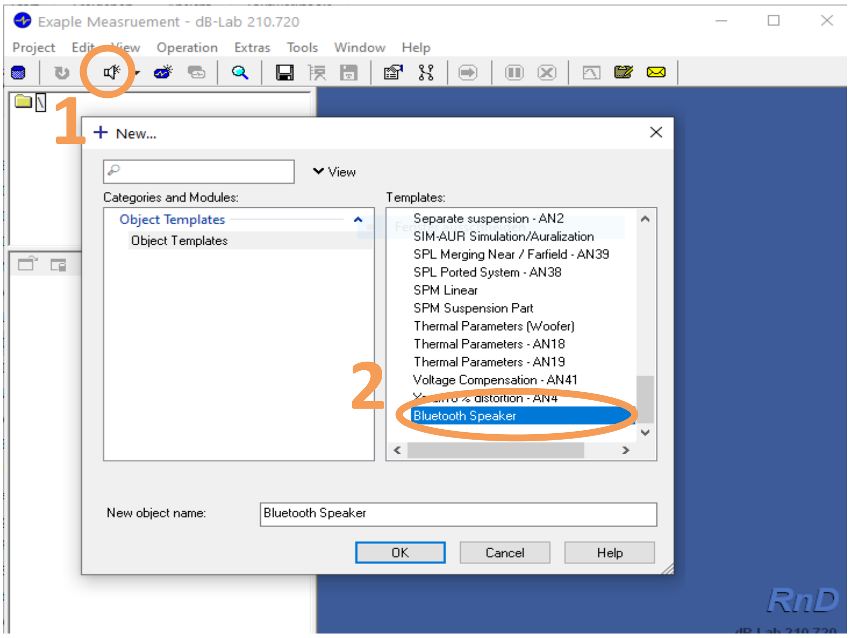
Open dB-Lab and create a new database.

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

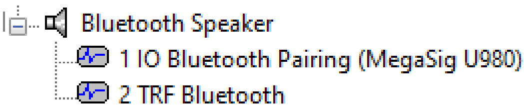


Select Object Template "Bluetooth Speaker"

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.



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 Paring*** 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

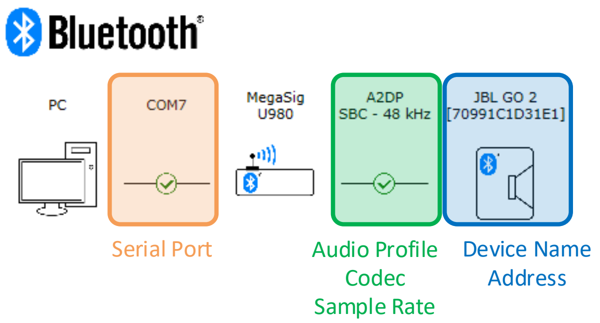
Profiles

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

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

IO – Bluetooth Results

After running the operation, the characteristics of the Bluetooth connection are shown in the Bluetooth® result window.



Connected Device

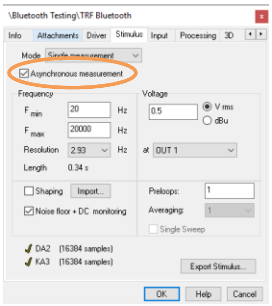
Parameter	Value	Description
Connected to		
Device	MEE audio Matrix3	Name of the connected Bluetooth device
Address	E807BF0F6E31	Blueooth-Address of the connected Bluetooth device
Class	240404	Class of the connected Bluetooth device
Codec	SBC	Codec used for audio streaming
Sample Rate	48 kHz	Sample Rate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

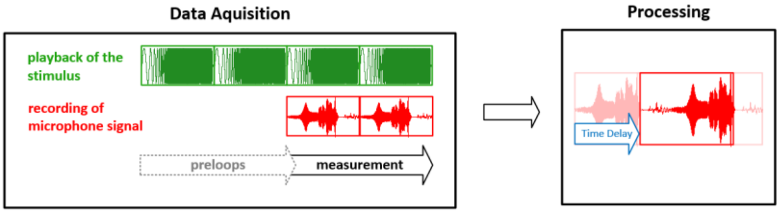
3.2 TRF - Settings

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 6)





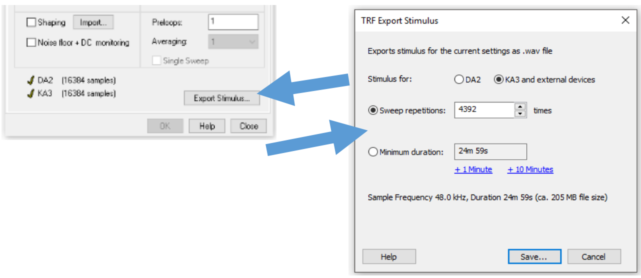
2) ADD RECORDING DELAYS

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:

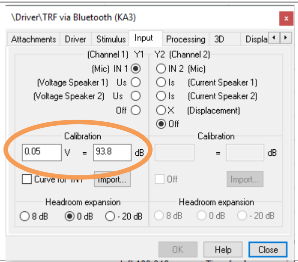
Stimulus length	Number of preloops	Measurement time total	Maximum time delay (preloop time)
340 ms	1	1.4 s	680 ms
340 ms	2	2.1 s	1.4 s
680 ms	1	2.7 s	1.4 s
680 ms	2	4 s	2.7 s

3) EXPORT STIMULUS (FOR OPEN LOOP TESTING)

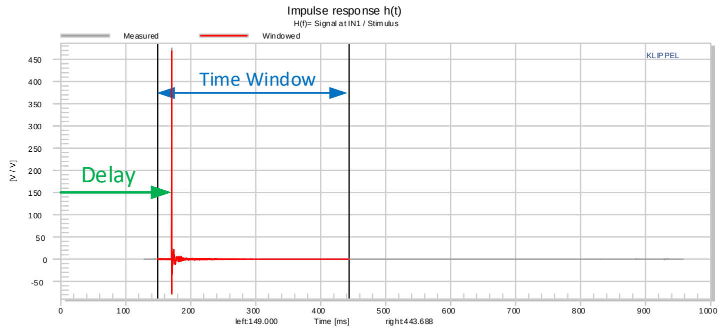
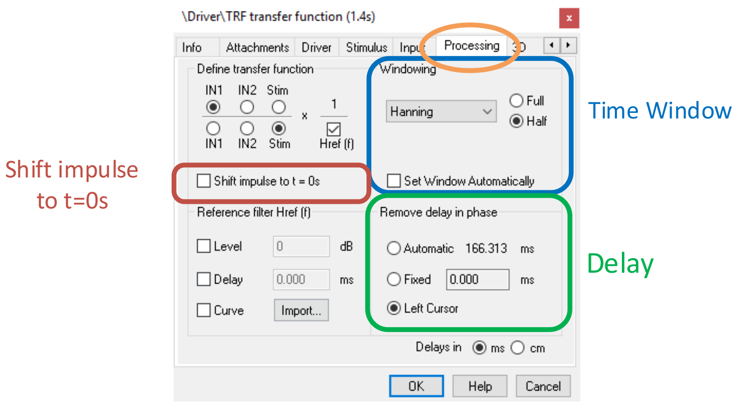
Click ***Export Stimulus*** to save the test signal as a wav-file. It is recommended to select sufficient sweep repetitions that give you time to 1st start the playback and 2nd the recording. A standard auto repeat of an audio player usually cannot be used because it isn't accurate by sample.

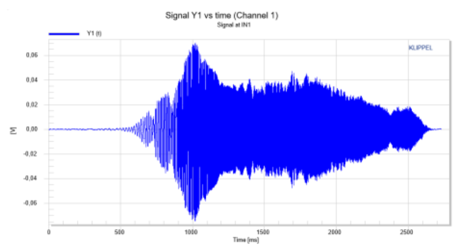


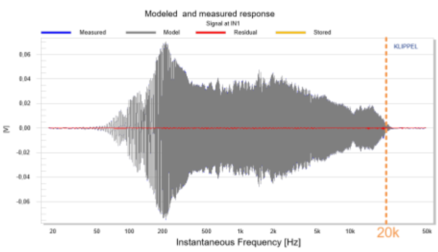
⚠ **After exporting stimulus do not change the stimulus settings in the TRF module.**

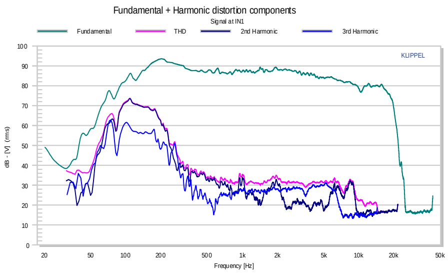
Microphone Calibration	To perform a calibrated sound pressure measurement, select the ***Input*** Tab to define the sensitivity of the microphone. 
KA3 Signal Configuration	In case you are using a KA3, please also check that the ***Signal Configuration*** is correct.  Select the ***XLR-Card*** or ***Laser-Card*** 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 [8].)
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.

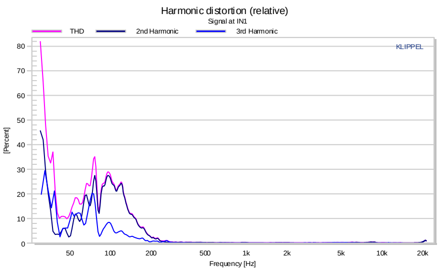
3.3 TRF – Results and Post Processing

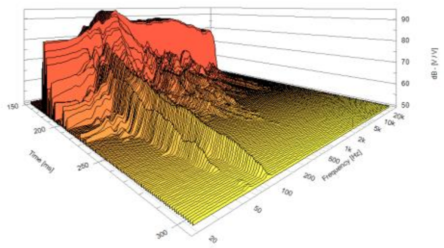
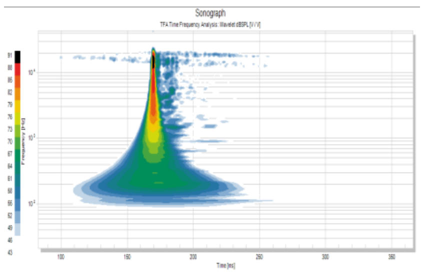
Impulse Response	Open the ***Impulse Response*** Window. The curve shows a delay of about 170 ms for the example measurement. You can find the accurate value of the measured delay in the ***Property page*** under ***Processing*** - ***Constant Time Delay***  Check the position of the ***Time Window.*** 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.
Microphone signal Y1 (t)	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 6)

<table>
<tr>
<td></td>
<td>




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 by the Time-Frequency-Analysis (TFA), performing a Wavelet-Transform of the impulse response.
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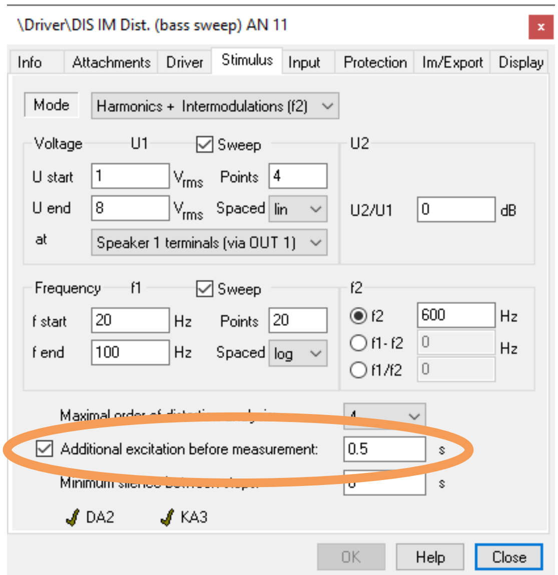
</tr>
</table>

4 3D Distortion measurement - DIS

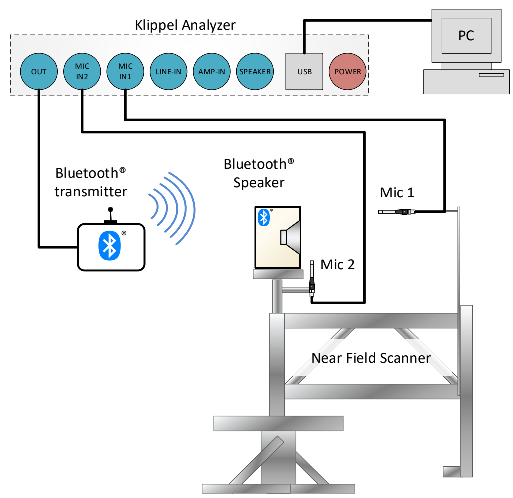
<table>
<tr><td>Measurement Setup</td><td>For DIS, it is required to use Setup 1 and measure with an external Bluetooth® transmitter. (See 2.2)</td></tr>
<tr><td>Stimulus Settings</td><td>To compensate for the long delay of the Bluetooth transmission, it’s required to add Additional excitation before the measurement. This value should be larger than the Bluetooth delay.



</td></tr>
</table>

5 Near Field Scanner 3D – NFS

<table>
<tr><td colspan="2">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.</td></tr>
<tr><td>Asynchronous Measurement Mode</td><td>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 [10].</td></tr>
</table>

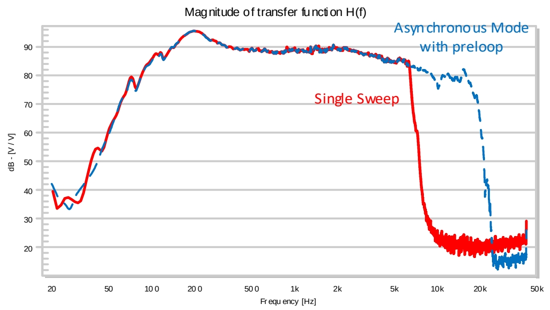
6 Problems and Particularities

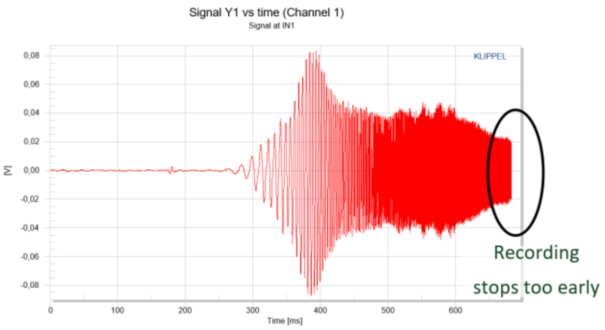
This section will discuss common problems when measuring Bluetooth® or other wireless devices. This should aid in the interpretation of the measurement results and finding root causes of problems. Depending on the quality of the transmission and the codec used, these problems may or may not arise.

6.1 Long Delays

An important particularity for the measurement with the TRF module 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. The red solid curve shows the transfer function measured with 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.





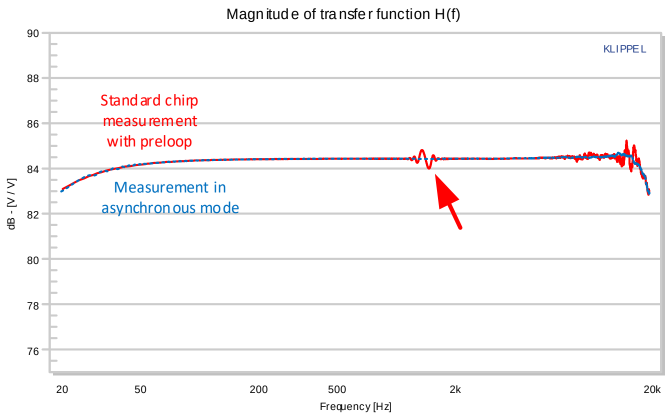
To solve this problem, the measurement was repeated in the Asynchronous mode, which automatically adds a preloop. As seen in the frequency response (dashed blue curve), the complete pass band of the DUT was measured correctly.

6.2 Preloops

To cope with long delays and latencies in active systems, adding a preloop is a common solution. For Bluetooth® measurements, this technique usually shouldn't be used because often it produces artifacts. The problem is the jitter of the Bluetooth® clock, which can cause a slight mismatch in the sampling frequency. In the transfer function, this mismatch can produce artifacts at a specific frequency.

The asynchronous measurement mode avoids these effects by automatically picking the best part of measured signal depending on the delay.

The following example compares a standard measurement with a preloop (red solid line) and a measurement in the asynchronous measurement mode (blue dashed line). At 1.5 kHz, the standard measurement shows a distinct glitch of about ±1 dB.

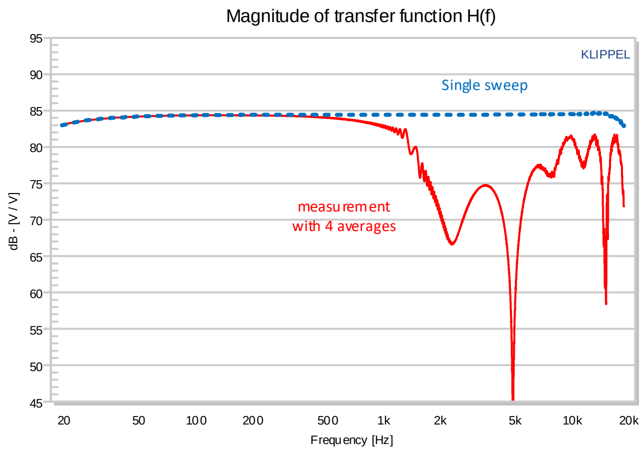


Mathematical background:

The Fourier Transform assumes a periodic signal. That means the beginning and the end of the recorded microphone signal are merged together when calculating the frequency response. When the two separate digital clocks jitter, there can be a jump in phase and magnitude at this position, which finally causes the glitches in the frequency response.

6.3 Avoid averaging

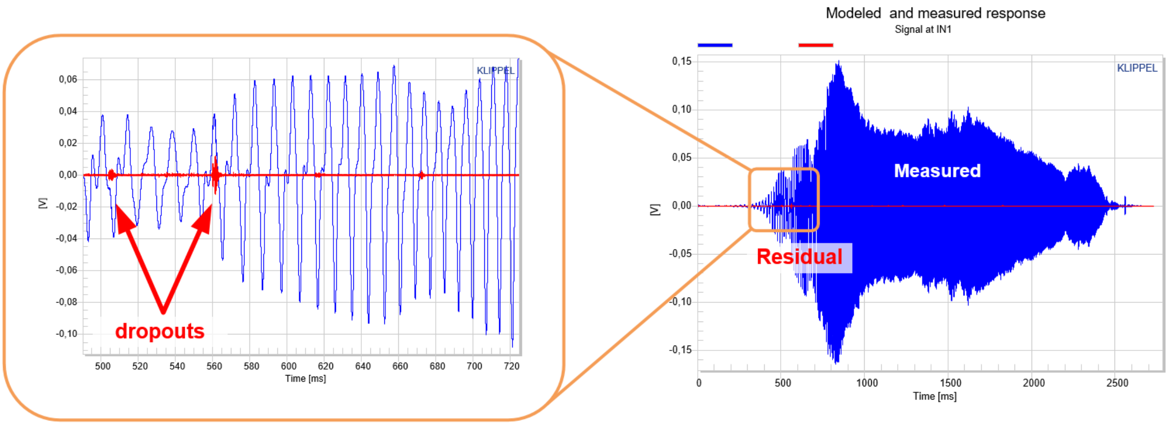
The clock drift makes measurements with averaging almost impossible for Bluetooth® devices. While repeating and averaging the measurements, the phase response may change slightly for every loop. This can cause cancellation effects.

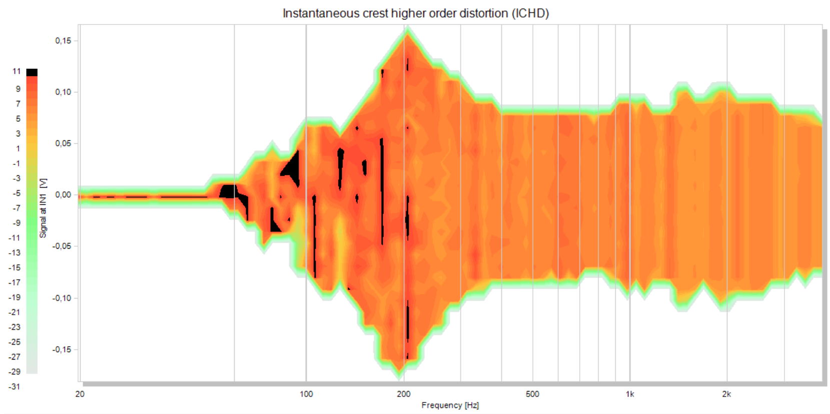


The example shows that the averaged measurement (solid red line) causes dramatic cancellations, especially at high frequencies (f>1 kHz). In this example, the difference is more than 20 dB compared to the single sweep measurement (dashed blue line).

6.4 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 ***Modeled Response***) very clearly shows the click in the signal, and also the ***Instantaneous Crest Higher Order Distortion (ICHD)*** shows black spots at this position.

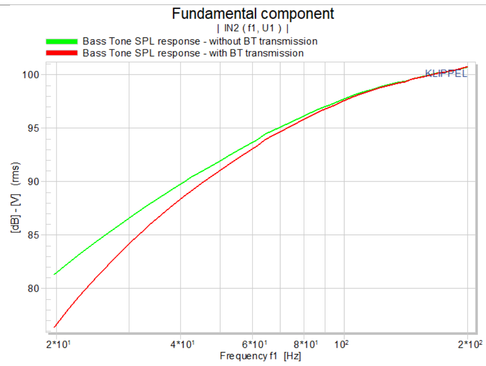
6.5 Intermodulation measurement (for DIS)

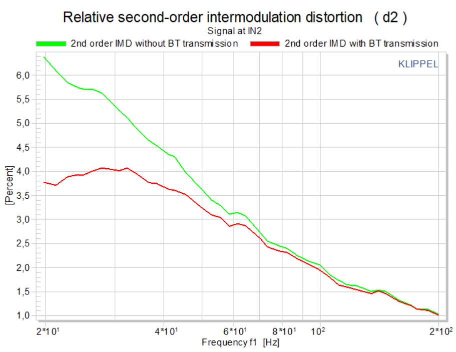
When measuring intermodulation distortion with traditional two tone methods like Voice Sweep or Bass Sweep, you should consider that the analog input of Bluetooth transmitters can be AC coupled. This can cause a high pass characteristics, which could influence the measurement results.

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.

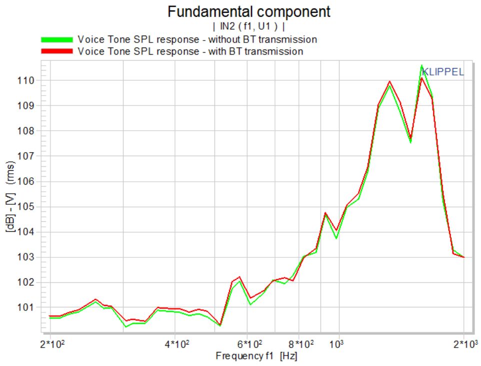


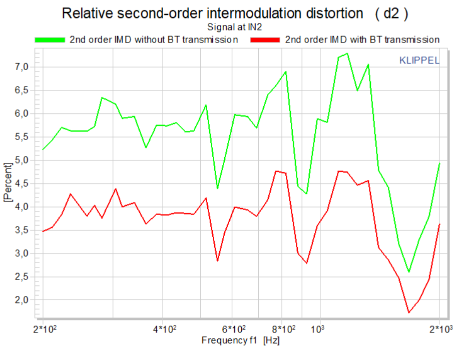


VOICE SWEEP

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.

7 References

7.1 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)
7.2 Manuals	[7] Manual - TRF Transfer Function (included in dB-Lab setup) [8] Manual - Hardware [9] Manual - DIS Distortion Measurement (included in dB-Lab setup) [10] Manual – NFS Near Field Scanner (included in dB-Lab setup)
7.3 Publications	[11] Marian Liebig: *Challenges of testing mobile devices and mobile testing,* Voice Coil February 2017

Last updated: May 19, 2021

Find explanations for symbols at:

http://www.klippel.de/know-how/literature.html