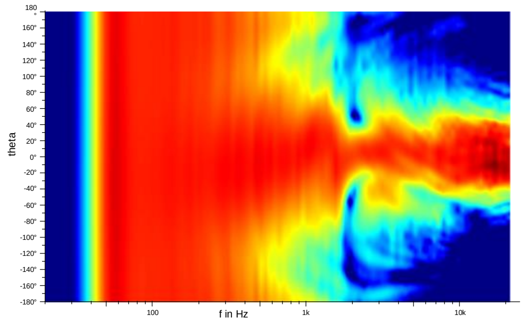
Far Field Measurement using Microphone Arrays

AN 69

Application Note to the KLIPPEL R&D and QC SYSTEM (Document Revision 1.1)

FEATURES

- Polar measurement in far field
- Microphone multiplexing
- Fast, automatic measurement
- Turntable control
- Integrated in Klippel measurement system



DESCRIPTION

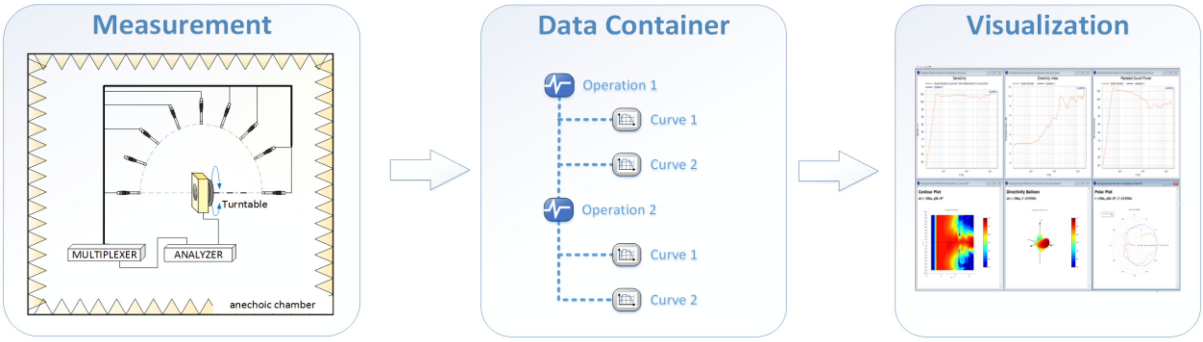
Measuring the directivity of audio devices high amounts of data need to be determined. To collect these data automatically, usually one or two turntables are used to rotate the loudspeaker. As an alternative to rotating the loudspeaker, the radiation pattern can be measured using microphone arrays in combination with a multiplexer.

This application note shows how to perform a directivity measurement using the POL and TRF Modules of the Klippel R&D System in combination with microphone multiplexing. It gives detailed instructions about the complete measurement process from the data acquisition to the visualization of the directivity data.

CONTENT

1 Overview

1.1 Principle



1 - Measurement/ Data acquisition

The 1st step is an automatic measurement. During the scanning process, the full automatic measurement system is switching the multiplexers, moving turntable and performing TRF operation at each measurement point.

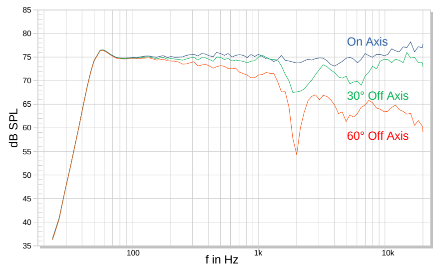
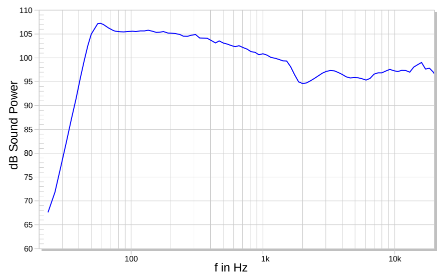
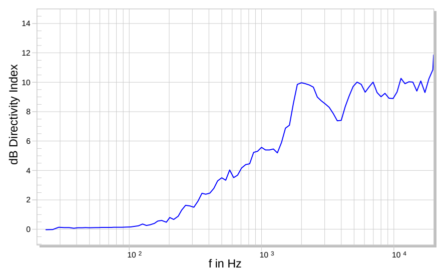
2 – Data Container

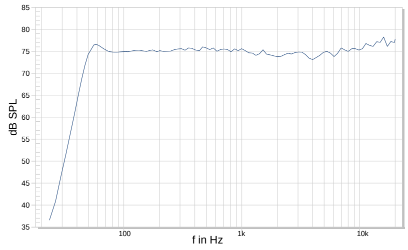
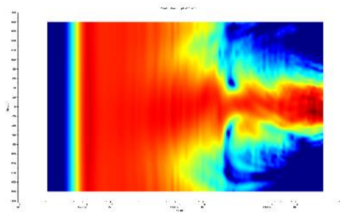
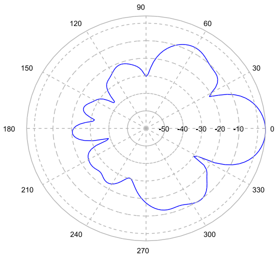
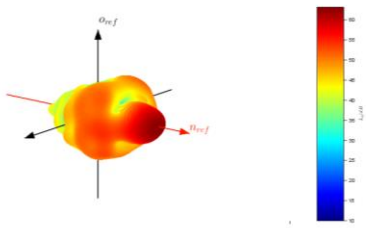
After the measurement, all curves are saved in the database. The extracted data is saved with the coordinates in a data container. In addition each performed TRF operation can be stored in the database as well.

3 – Visualization

In the visualization module the directivity of the DUT can be analyzed. The module provides common far field characteristics like sound power, balloon plot, polar plot, contour plot etc.

1.2 Measurement Results

SOUND PRESSURE LEVEL		*Sound pressure level* over frequency at all measurement positions.
SOUND POWER		Total radiated *Sound Power* of the device under test. *Sound power* characterizes the integrated sound pressure level over all radiation angles.
DIRECTIVITY INDEX		The *Directivity Index* summarizes the relation between the sound pressure levels of all radiation angles compared to the On-Axis sound pressure level. An omnidirectional source has a directivity index of 0.

SENSITIVITY		On-Axis sound pressure level referenced to 1m distance and 1W electrical input power (2.83V for 8Ω)
CONTOUR PLOT		The contour plot visualizes the radiation behavior over frequency and the polar angle theta. The color scale indicates the Sound Pressure Level.
POLAR PLOT		Polar plots visualize the radiation pattern over the polar angle theta for a specific frequency
DIRECTIVITY BALLOON		The balloon plot shows the radiation behaviour over phi and theta for a specific frequency

2 Requirements

2.1 Hardware

DA2		Distortion Analyzer 2 is the hardware platform for the measurement modules performing the generation, acquisition and digital signal processing in real time [3]	H1
Multiplexer (BNC)		8 channel multiplexing hardware that is directly controlled by the Klippel Software. [2]	A8
Microphones		Free field microphone with omnidirectional directivity characteristic over the desired measurement bandwidth.	A4
Amplifier		Amplifier with a flat frequency response over the desired measurement bandwidth	
Turntable (optional)		Turntable to rotate the device under test for a two-dimensional scan. (e.g. LinearX LT360) [9]	

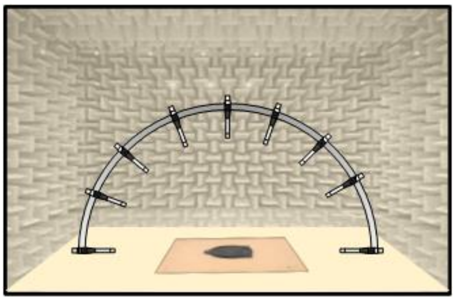
2.2 Software

TRF MODULE (S7)	The Transfer function (TRF) is a dedicated PC software module for measurement of the transfer behavior of a loudspeaker. [1]
KLIPPEL ROBOTICS	The Robotics Software manages the data acquisition. That means it moves the turntables Hardware, switches the multiplexers and performs the measurements.

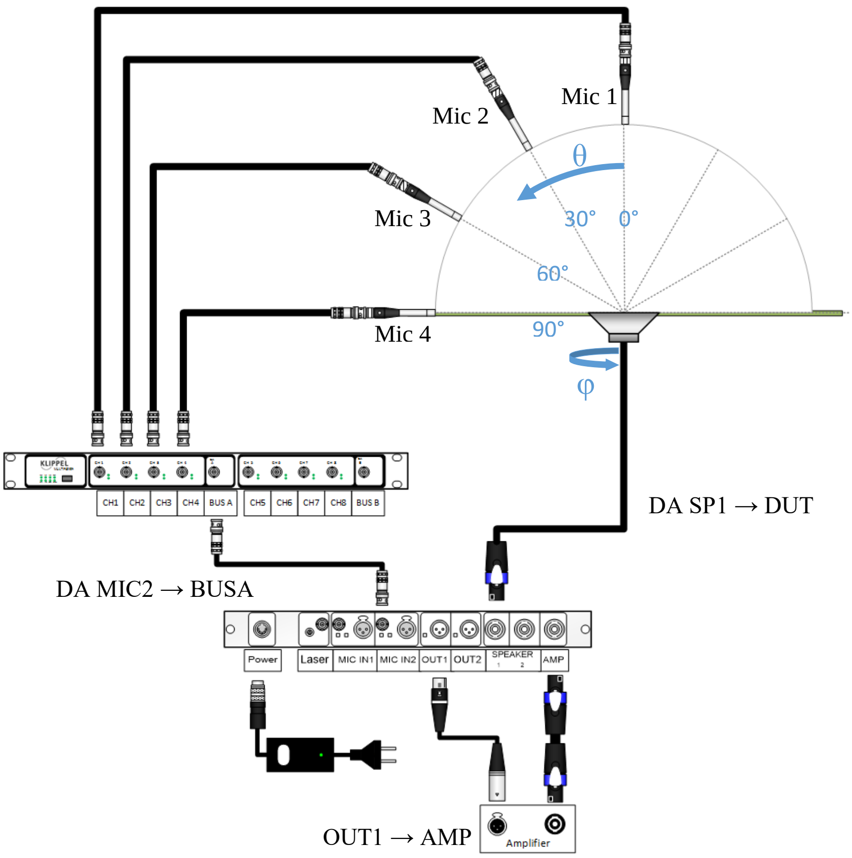
VISUALIZATION SOFTWARE	Software module that visualizes the directivity data e.g. contour plot, sound power, polar plot, etc. [4]

3 Performing a measurement

3.1 Introduction

Target	The example measurement shows how to setup a POL measurement using a microphone array. In the following example a measurement with 4 microphones is done to show the basic configuration. The number of multiplexers and thus the number of microphones is not limited. Please also see the ***Documentation window*** in the software for further information	
Device under test	The device under test is a transducer mounted in the floor of a half anechoic chamber.	

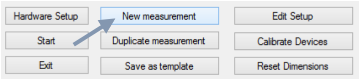
3.2 Measurement Setup



3.3 Start Klippel Robotics and create a new measurement

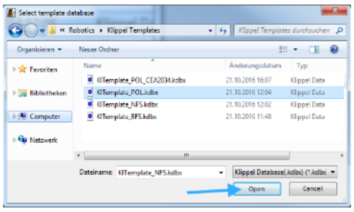
1) Start Klippel Robotics:

Open Robotics Software and click: “***New Measurement***”



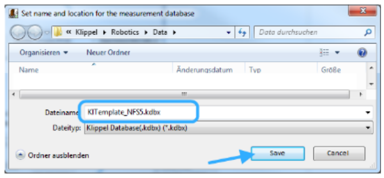
2) Select Template:

Choose “KlTemplate_POL.kdbx“.



3) Select Results Path:

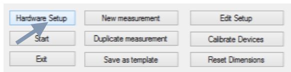
Select a folder and a name for the measurement database.



3.4 Hardware Setup

1) Open Hardware Setup:

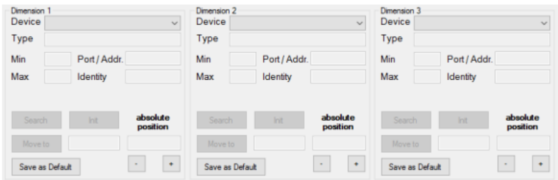
Click: “***Hardware Setup***“ to open the hardware dialog window.



2) Configure Hardware

A - Microphone-Array

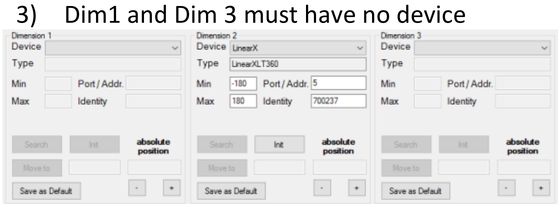
1) No additional hardware is required.
2) Make sure that no device is selected



Dim 1: no Device Dim 2: no Device Dim 3: no Device

B - Microphone-Array + Turntable

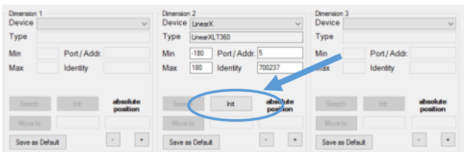
1) Position the Mic-Array over the theta angle
2) Select for Dim 2 the turntable (e.g. LinearX,ET250)
3) Dim1 and Dim 3 must have no device



Dim 1: no Device Dim 2: Turntable (phi) Dim 3: no Device

3) Initialize Turntable (only for Turntable usage)

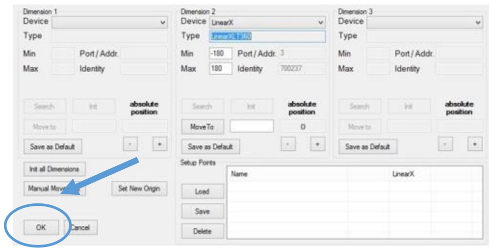
Click the “Init”-Button of this dimension.



In case the Initializing has failed, please check the Trouble Shooting below.

4) Close Hardware Dialog

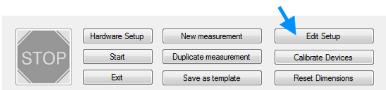
Click “OK“ to confirm your Settings



3.5 Measurement Operation – TRF Transfer function

1) Open Database:

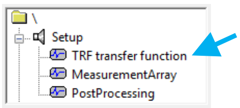
Click “***Edit Setup***“ to open the data-base.



2) Select operation

Select the operation:

“***TRF transfer function*** ”



3) Property Page

Open ***Property Page*** to configure the measurement operation.

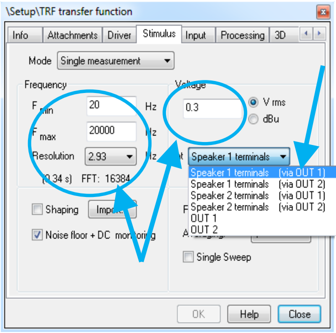
4) Configure Stimulus

Select the "***Stimulus***" tab and define:

- "***Speaker 1 (via OUT1)***"

Configure Parameters:

- Frequency Range (f_{min}, f_{max})
- Frequency ***Resolution***
- Input ***Voltage***

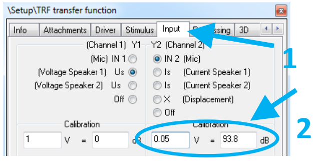


5) Define Channels and H(f)

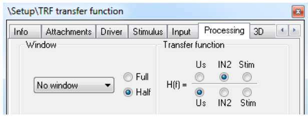
1) Select the "***Input***" tab and define:

- ***Channel 1 – (Voltage Speaker 1) Us***
- ***Channel 2 - IN 2 (Mic)***

2) Insert the **calibration factor** of the mic



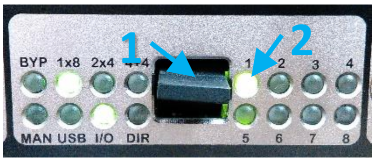
3) Select the "***Processing*** „Tab and define: ***H(f)= IN2 / Us***

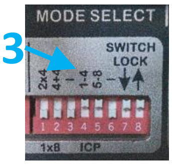


In case the sensitivity values of the different microphones have huge differences, it is recommended using for each microphone a separate TRF Operation with a calbration factor or curve

6) Switch Multiplexer and Run Operation

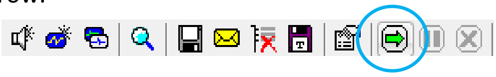
1) Click the manual switch button of the MUX.
2) Route "***BUS A***" to "***CH 1***" to connect Mic1.
3) If required, turn ***IEPE***-Supply on by using the switches on the rear side





For mode selection and IEPE DIP-switching, the MUX must be in ***I/O Mode***. If it is not, reconnect the power supply[2].

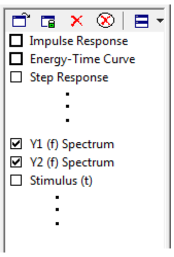
Run the TRF operation by clicking on the green arrow.

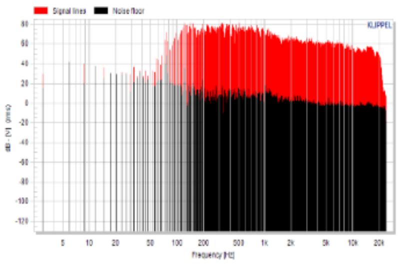


7) Check SNR

Open the Result Windows "***Y1(f) Spectrum***" and "***Y2(f) Spectrum***".

And check if the microphone signal has at least 20dB Signal to Noise Ratio (SNR) in the passband.





If the SNR is less, increase the voltage of the Stimulus or apply averaging.

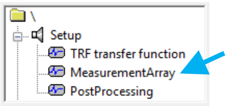
Repeat the same check for the other microphones ("***BUS A***" to "***CH 2-4*** ")

3.6 Measurement Array

1) Select Operation

Select the operation:

"***MeasurementArray*** "

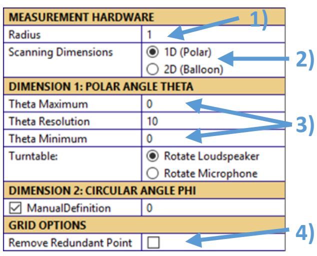


and open the Property Page.

2) Grid Configuration

1D – Scan (no turntable)

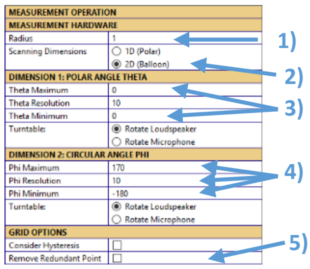
1) Define the measurement ***Radius***
2) Set Scanning Dimension: ***1D(Polar)***
3) Set ***Theta Minimum*** and ***Maximum*** to the same value e.g. ***0***
4) Uncheck ***Remove Redundant Points***



MEASUREMENT HARDWARE	
Radius	1
Scanning Dimensions	◉ 1D (Polar) ○ 2D (Balloon)
DIMENSION 1: POLAR ANGLE THETA	
Theta Maximum	0
Theta Resolution	10
Theta Minimum	0
Turntable:	◉ Rotate Loudspeaker ○ Rotate Microphone
DIMENSION 2: CIRCULAR ANGLE PHI	
☑ ManualDefinition	0
GRID OPTIONS	
Remove Redundant Point	☐

2D – Scan with Phi turntable

1) Define the measurement ***Radius***
2) Set Scanning Dimension:***2D(Balloon)***
3) Set ***Theta Minimum*** and ***Maximum*** to the same value e.g. ***0***
4) Set movement of ***Phi turntable*** (e.g. min= -180°, res=10°, max=170°)
5) Uncheck ***Remove Redundant Points***

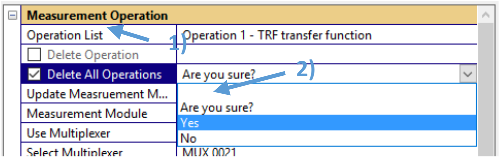


MEASUREMENT OPERATION	
MEASUREMENT HARDWARE	
Radius	1
Scanning Dimensions	○ 1D (Polar) ◉ 2D (Balloon)
DIMENSION 1: POLAR ANGLE THETA	
Theta Maximum	0
Theta Resolution	10
Theta Minimum	0
Turntable:	◉ Rotate Loudspeaker ○ Rotate Microphone
DIMENSION 2: CIRCULAR ANGLE PHI	
Phi Maximum	170
Phi Resolution	10
Phi Minimum	-180
Turntable:	◉ Rotate Loudspeaker ○ Rotate Microphone
GRID OPTIONS	
Consider Hysteresis	☐
Remove Redundant Point	☐

3) Measurement Operation and Multiplexer settings

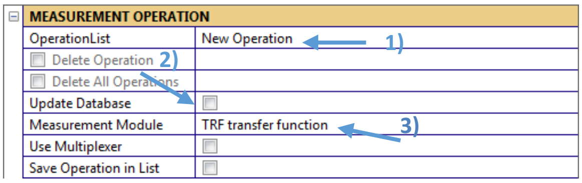
Step 1: Reset Configuration

1) Open the Category ***Measurement Operation***
2) Click ***Delete all Operations*** to reset the Operation List



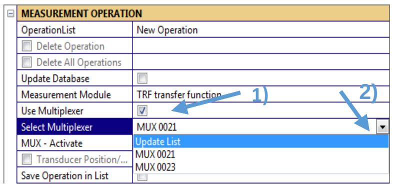
Step 2: Select Measurement Module

1) Select "***New Operation***" in the *Operation List*
2) Click Update Database to refresh the list of ***Measurement Modules***
3) Select the Module for the measurement e.g. "***TRF transfer function***"

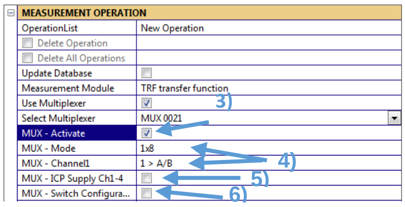


Step 3: Configure Multiplexer Settings

1) To add a switching configuration of a MUX click ***Use Multiplexer***
2) Select in the list the MUX that should be switched or ***Update List*** to see all available Multiplexer

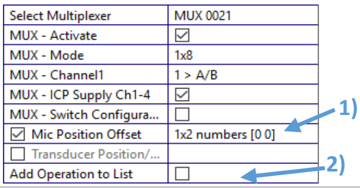


3) Click ***MUX-Activate*** to activate the multiplexer.
4) Adjust the switching configuration. For the Mic1 set: Mode: ***1x8*** ,Ch.: ***1 to A/B***
5) If required, activate ***MUX IEPE-Supply***
6) Click ***Switch Configuration*** to switch the MUX



Step 4: Microphone Position + Save Configuration

1) Specify the microphone position using the Parameter ***Mic Position Offset***. It defines the angle offset of phi and theta. Mic1 is On-Axis so the Offset is [0 0]
   (Example.: mic at θ=45°, φ=10° → offset = [45 10])
2) Click Save in Operation List to store the current Setup



Setup for other Microphones

Repeat step 2-4 for the other microphones

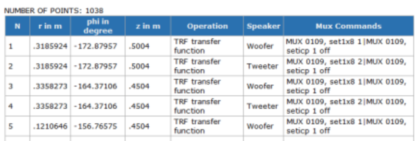
Use the following Settings:

	Mic. 2	Mic. 3	Mic. 4
MUX - Mode	1x8	1x8	1x8
MUX - Ch.	2 > A/B	3 > A/B	4 > A/B
Mic Position	[30 0]	[60 0]	[90 0]

3) Run Operation

Run the ***Measurement Array*** operation by clicking on the green arrow.

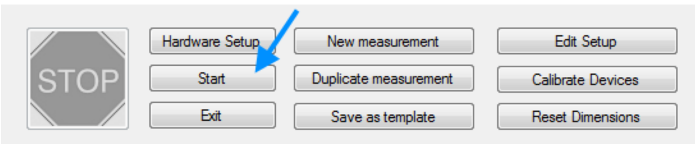
After running the Script the measurement points and the multiplexer settings are shown in a table in the Result window ***Measurement Coordinates***.


NUMBER OF POINTS: 1038

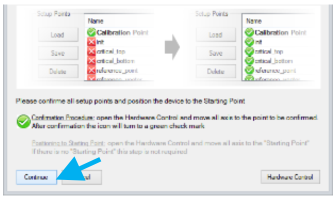
N	r in m	phi in degree	z in m	Operation	Speaker	Mux Commands
1	.3185924	-172.87957	.5004	TRF transfer function	Woofer	MUX 0109, set1x8 1|MUX 0109, seticp 1 off
2	.3185924	-172.87957	.5004	TRF transfer function	Tweeter	MUX 0109, set1x8 2|MUX 0109, seticp 1 off
3	.3358273	-164.37106	.4504	TRF transfer function	Woofer	MUX 0109, set1x8 1|MUX 0109, seticp 1 off
4	.3358273	-164.37106	.4504	TRF transfer function	Tweeter	MUX 0109, set1x8 2|MUX 0109, seticp 1 off
5	.1210646	-156.76575	.4504	TRF transfer function	Woofer	MUX 0109, set1x8 1|MUX 0109, seticp 1 off

3.7 Start Measurement

Close the database to get back to the Robotics and Press "***Start***"



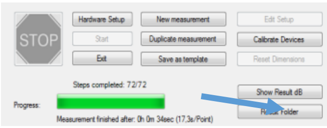
Press "***Continue***" to Start the measurement.



4 Data Processing

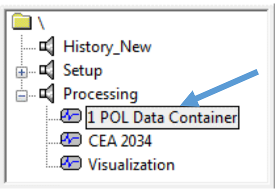
1) Open Database

After the measurement is finished, open the database by clicking "***Show Result dB***".



2) Select Data Container

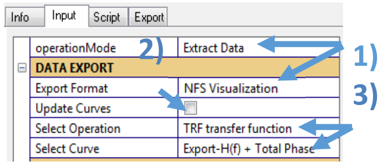
Select the operation:
"***POL Data Container*** "



and open the Property Page.

3) Export Data

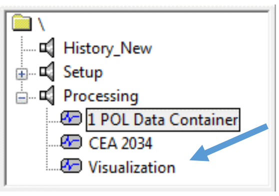
1) Select the Operation Mode "***Extract Data***" and the Export Format "***NFS Visualization***".
2) Click "***Update Curves***"
3) Select the Measurement Operation and Curve that should be analyzed. E.g. "***H(f) + Total Phase***"



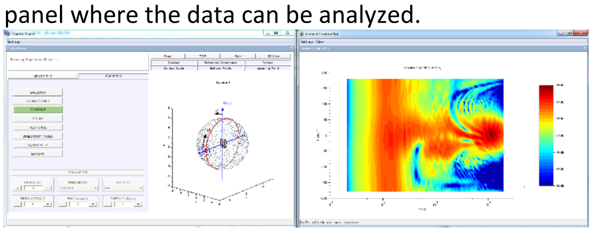
Start the operation. 

4) Visualization module

Select the operation: "Visualization" and press the green arrow 



Running the script will open an interactive control panel where the data can be analyzed.

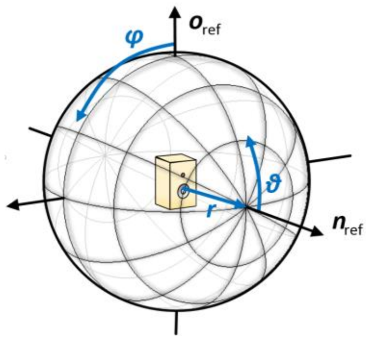


5 Coordinate System

The POL measurement module is based on a spherical coordinates system, that is defined by the radius of the sphere r and the two angles, theta ϑ (off axis angle) and the phi φ (circular angle).

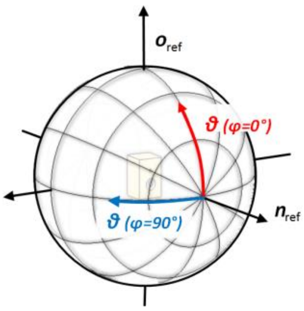
The orientation of the DUT is specified conform to IEC 60268-21. The reference Axis n_{ref} at ϑ=0° defines the main radiation axis.

The orientation vector o_{ref} at φ=0° defines the orientation of the device under test. It usually points to the top the loudspeaker.



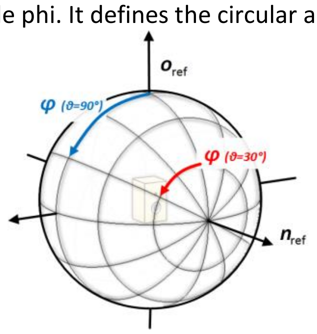
Dimension 1: Polar Angle Theta

The dimension of the 1st turntable is specified as the polar angle theta. It defines the off axis angle.



Dimension 2: Circular Angle Phi

The dimension of the 2nd turntable is specified as the azimuth angle phi. It defines the circular angle.



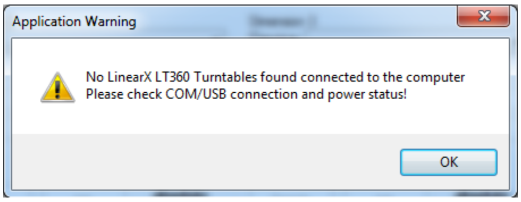
6 References

6.1 Related Modules	[1] *Transfer function (TRF)*, Specification S7, 2016 Klippel GmbH, www.klippel.de [2] *Multiplexer*, Specification A8, 2016 Klippel GmbH, www.klippel.de [3] *Distortion Analyzer 2,* Specification H1, 2016 Klippel GmbH, www.klippel.de [4] *Near Field Scanner 3D (NFS)*, Specification C8, 2016 Klippel GmbH, www.klippel.de
6.2 Manuals	[5] User Manual TRF Transfer function, included in dB-Lab Software installation
6.3 Standards	[6] IEC (E) 60268-21: *Acoustical (Output based) Measurements*, 2015 International Electrotechnical Commission [7] IEC 62777 Ed.1: *Quality Evaluation Method for the Sound Field of Directional Loud-speaker Array System*, 2014 International Electrotechnical Commission [8] CEA-2034: *Standard Method of Measurement for In-Home Loudspeakers*, 2013 Consumer Electronics Association
6.4 Other	[9] LinearX: *LT 360 Precision Turntable*, 2007 LinearX Systems Inc.

7 Trouble Shooting

7.1 Problems with LinearX Turntable - Error during Initialization

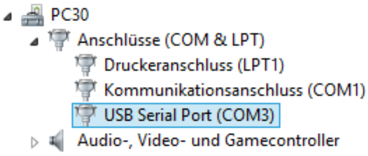
1) Linear is not connected



What to do?

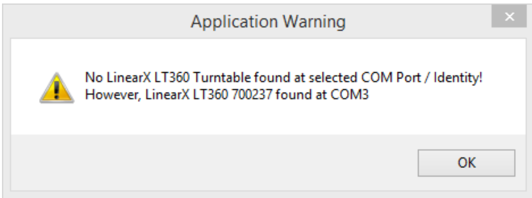
1) Check power connection of LinearX Turntable
2) Check COM-connection of the Turntable
   a. Check if the cable is correct connected to the Turntable

   b. Check in the device manager if COM connector is available



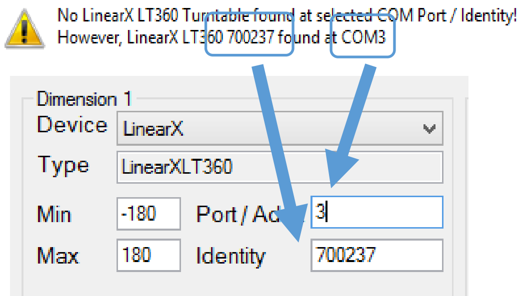
LinearX turntable must be connected via the COM connector. The direct USB is not supported.

2) Linear is connected to another port



What to do?

1) Read the port and the Serial number from the message box.
2) Insert the correct Port and Serial number into the Hardware Setup



Find explanations for symbols at:

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

Last updated: January 26, 2017