Far Field Measurement using Microphone Arrays

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.

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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

<table>
<thead>
<tr>
<th>SOUND PRESSURE LEVEL</th>
<th>Sound pressure level over frequency at all measurement positions.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Sound Pressure Level Graph" /></td>
<td></td>
</tr>
</tbody>
</table>

| SOUND POWER |
|-------------|---------------------------------------------------------------|
| ![Sound Power Graph](image2.png) |

| DIRECTIVITY INDEX |
|-------------------|---------------------------------------------------------------|
| ![Directivity Index Graph](image3.png) |

Sound power characterizes the integrated sound pressure level over all radiation angles.

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.
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]

Multiplexer (BNC)
8 channel multiplexing hardware that is directly controlled by the Klippel Software. [2]

Microphones
Free field microphone with omnidirectional directivity characteristic over the desired measurement bandwidth.

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.
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 “KITemplate_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

   **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

3) **Initialize Turntable (only for Turntable usage)**
   
   Click the “Init”-Button of this dimension.

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 database.

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 \( (f_{\text{min}}, f_{\text{max}}) \)
- 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: \( H(f) = \frac{\text{IN}2}{\text{Us}} \)

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 calibration 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.

Run the TRF operation by clicking on the green arrow.

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

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
2) Grid Configuration
Select the operation: “MeasurementArray”
and open the Property Page.

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

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
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3) Measurement Operation and Multiplexer settings

Step 1: Reset Configuration
1) Open the Category Measure 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

3) Run Operation
Run the Measurement Array operation by clicking on the green arrow.

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"

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 \( \theta \) (off axis angle) and the phi \( \varphi \) (circular angle).

The orientation of the DUT is specified conform to IEC 60268-21. The reference Axis \( n_{ref} \) at \( \theta = 0^\circ \) defines the main radiation axis.

The orientation vector \( o_{ref} \) at \( \varphi = 0^\circ \) 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.
## References

### 6.1 Related Modules


### 6.2 Manuals

5. User Manual TRF Transfer function, included in dB-Lab Software installation

### 6.3 Standards


### 6.4 Other

7 Troubleshooting

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 correctly connected to the Turntable
   b. Check in the device manager if the 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