Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL LIVE

a series of webinars presented by

Wolfgang Klippel

Webinar Series

"Acoustical Measurements"

Previous Sessions

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

Acoustical testing of a modern active audio device

3rd KLIPPEL LIVE:
Drawing meaningful conclusions from 3D output measurement

Topics today:

1. Standard Measurement Techniques
2. Far field directivity (e.g. professional application)
3. Mean value at selected angles (spin-o-rama) (e.g. consumer-home application)
4. Mean value of a listening zone in 3D space (e.g. personal audio devices)
5. Accurate complex data for beam steering (e.g. loudspeaker panels)

Poll:

Is loudspeaker directivity relevant for your work?

- Always
- Depends on the particular application
- Not really

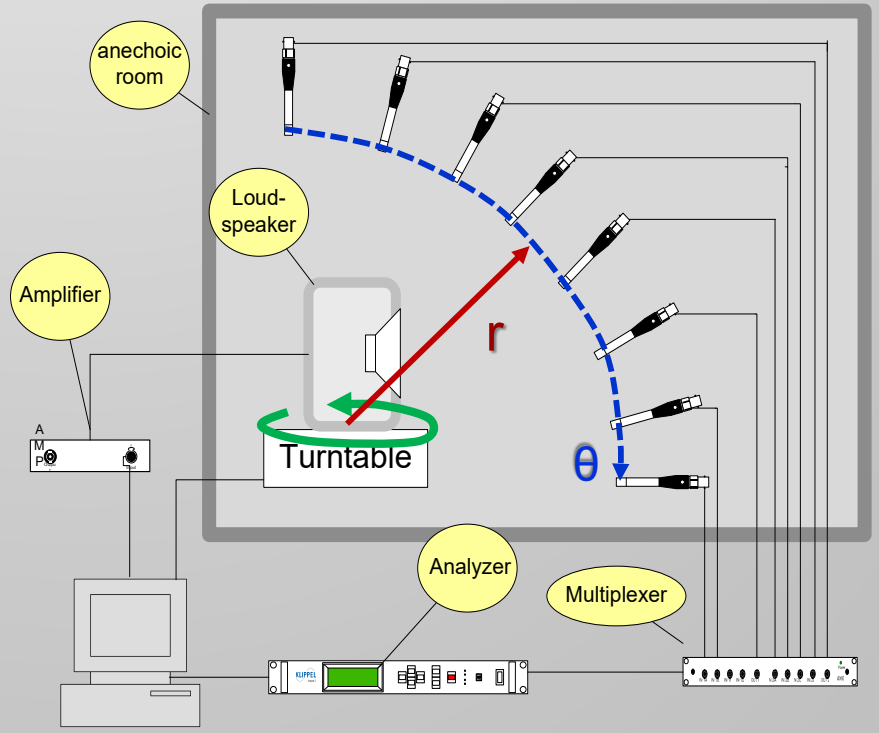
Conventional Directivity Measurement

The sound pressure is measured at multiple measurement points in the far field located on a sphere with radius r.

Angular Resolution depends on the number of measurement points placed in the far field.

5 degree → 2592 points
2 degree → 16200 points
1 degree → 64800 points

Not practical



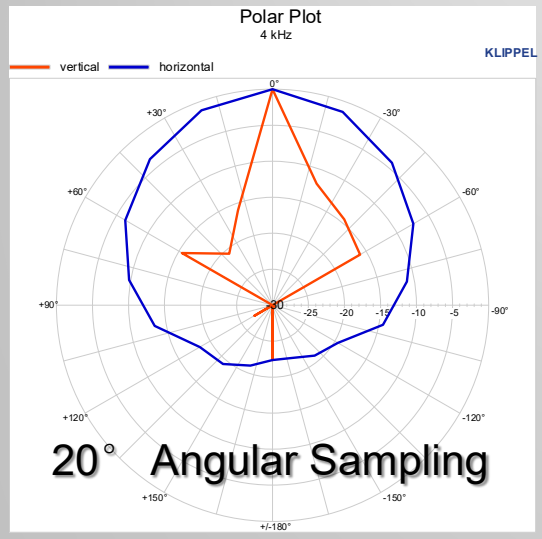
Question:

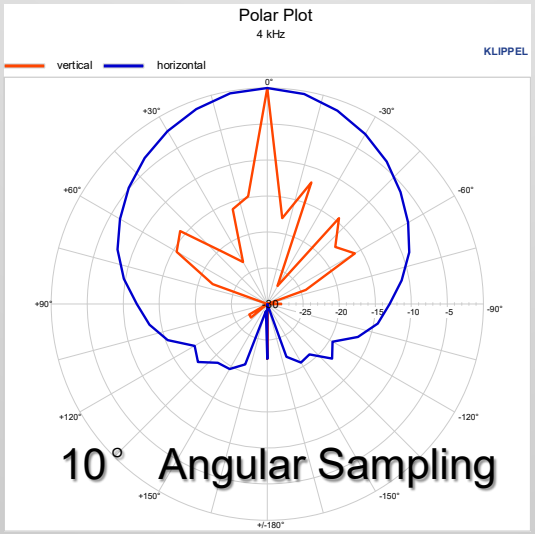
How much angular resolution would you like to see in the measured directivity?

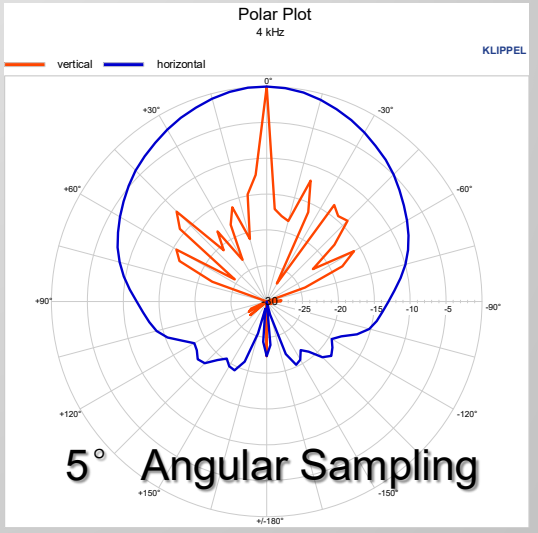
A. Only on-axis data
B. A few measurement point at selected angles (e.g. 30 degree) off-axis
C. Vertical and horizontal polar plots
D. Balloon data with at least 5 degree resolution
E. Balloon data with more than 5 degree resolution

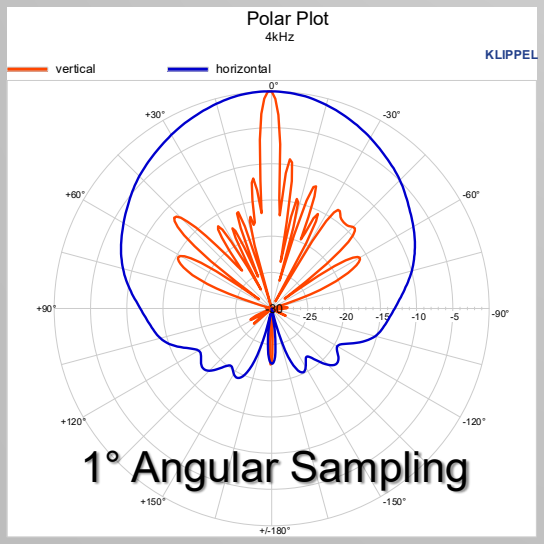
Linear Interpolation between Points

Conventional Directivity Measurement









Vertical direction

Horizontal direction

Linear (complex) interpolation can generate a significant (aliasing) error if the angular sampling can not describe the complexity of the directivity pattern

Holographic Measurement

Near Field Scanning + Wave Expansion

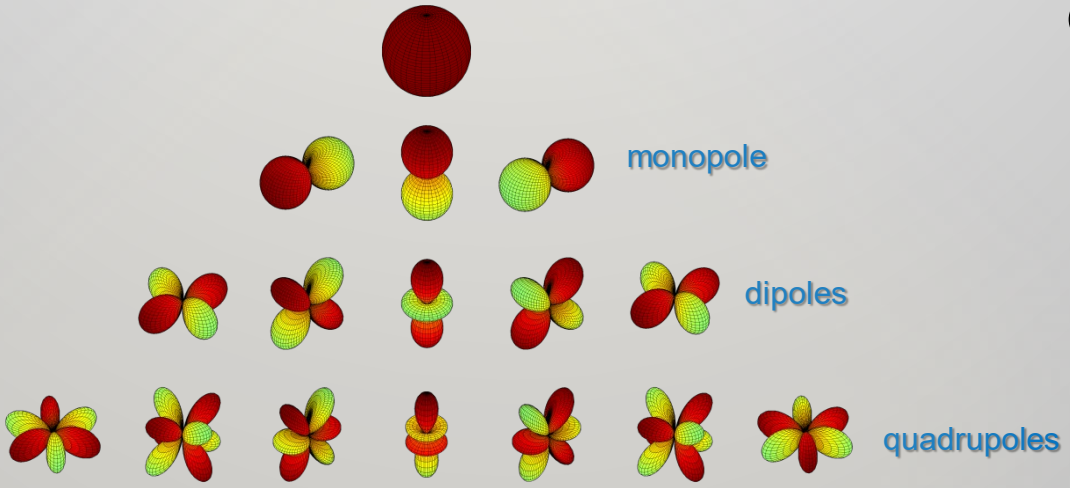
NEAR FIELD DATA

$\underline{H}(f,\mathbf{r})$

+

BASIC FUNCTIONS

$\mathbf{B}(f,\mathbf{r})$



Total Fitting Error

$TFE(f)$

COEFFICIENTS

$\mathbf{C}(f)$

Results

Direct Sound Extrapolation

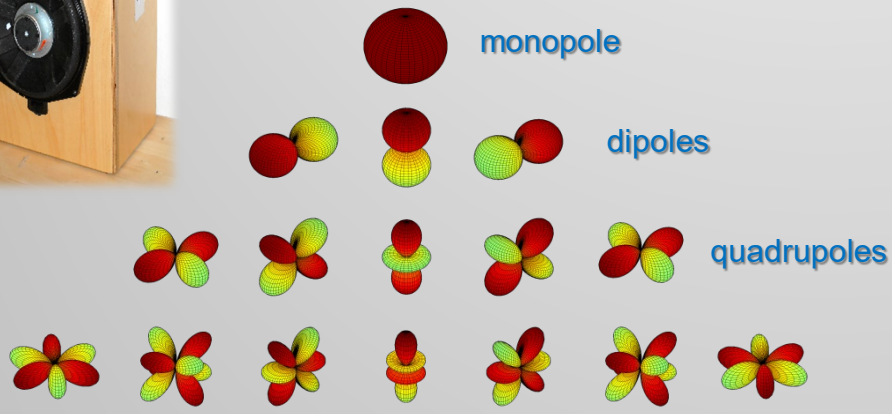
Scanning

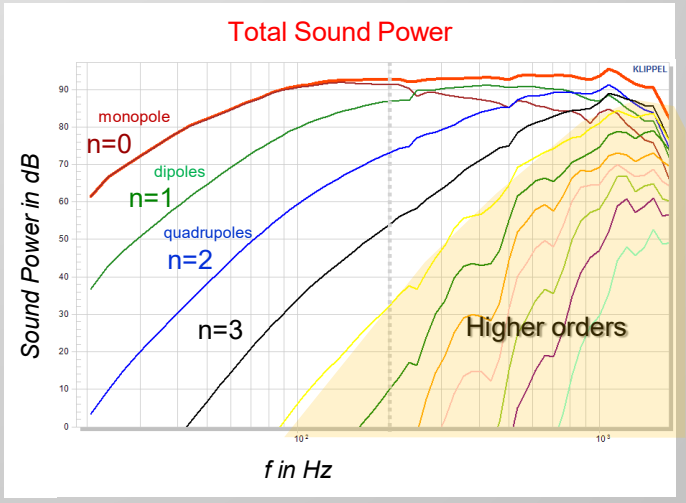
General solutions of the wave equation are used as basic functions in the expansion

Total number of coefficients = $(N+1)^2$

Holographic Measurement

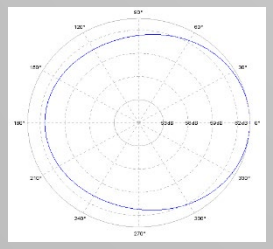
Example: Wave Expansion of a Woofer



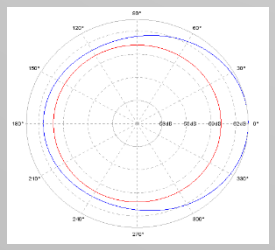


Directivity patterns at 200 Hz:

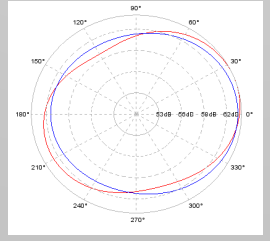
Target



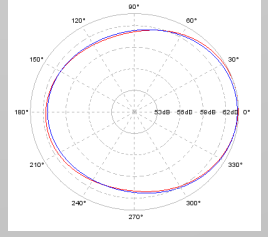
N=0



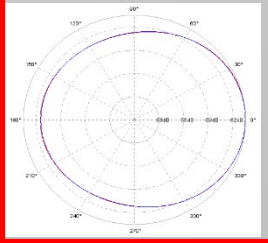
N=1



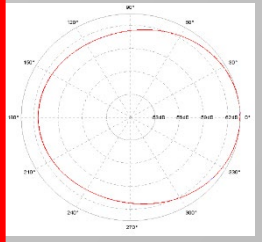
N=2



N=3



N=10

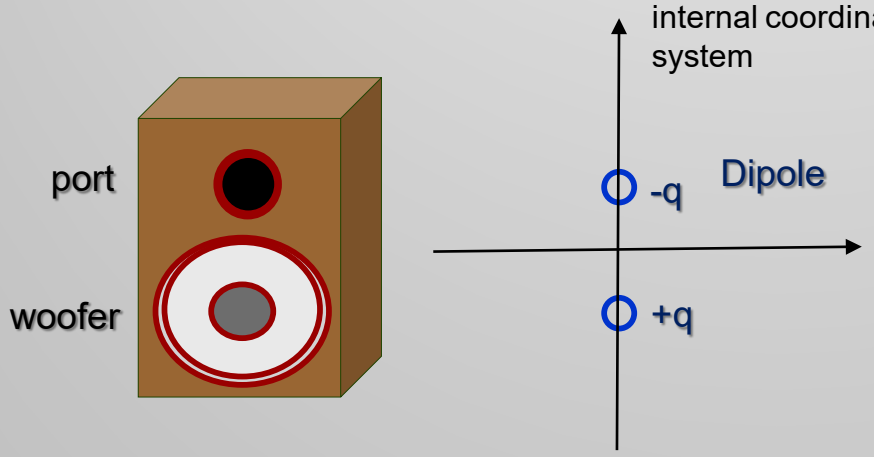


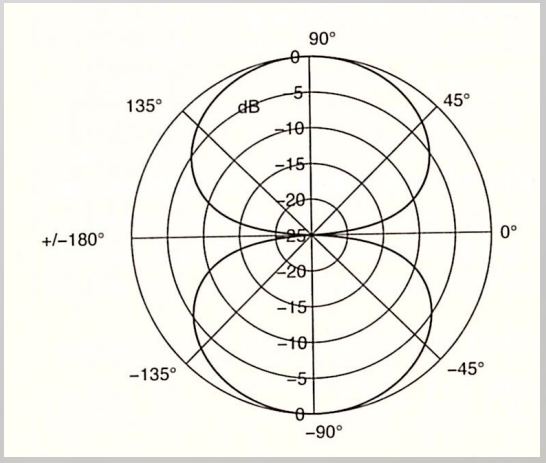
sound field is completely described by order N=3 (16 Coefficients)

can be estimated by a few scanning points (M > 16)

Order of the Expansion Depends on the Loudspeaker Properties

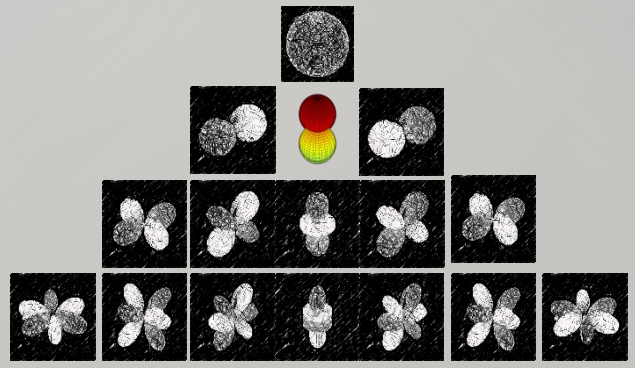
Example: Woofer in a Vented Box far below port resoance





The directivity can be modeled by single coefficients and a single scanning would be required if

- the expansion point is in the acoustical center
- the dipole axis is aligned with the coordinate system



Angular resolution is much higher than the sampling on the scanning grid

Holographic Measurement

Extrapolation of the Direct Sound

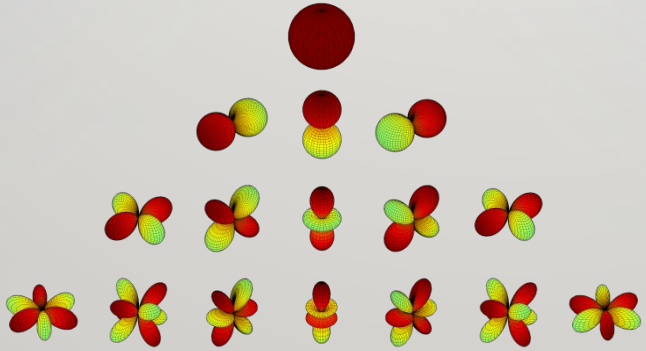
COEFFICIENTS

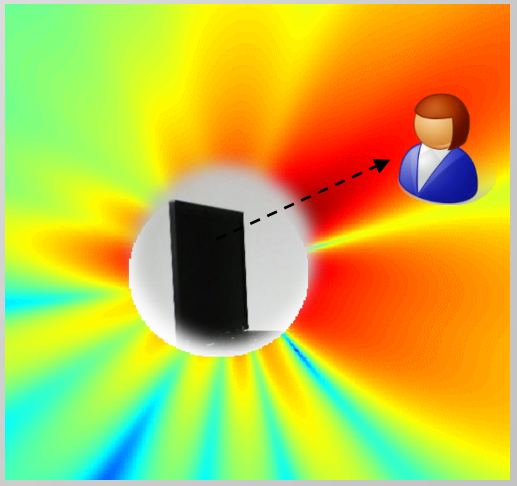
$$\mathbf{C}(f)$$

+

BASIC FUNCTIONS

$$\mathbf{B}(f,\mathbf{r})$$

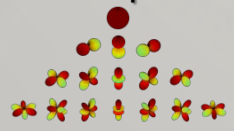




Results

General solutions of the wave equation

Wave Expansion



Scanning

Sound pressure distribution (3kHz) generated by a laptop outside the scanning surface

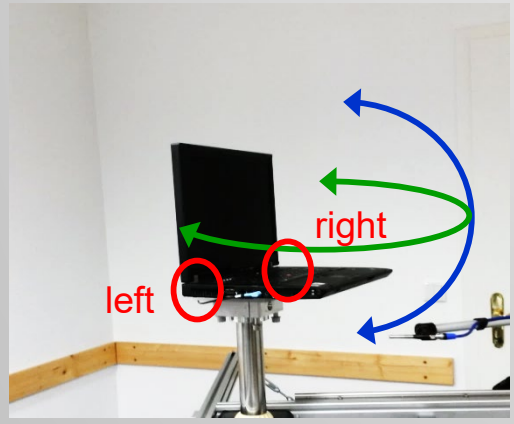
Comparison of the Standard Methods

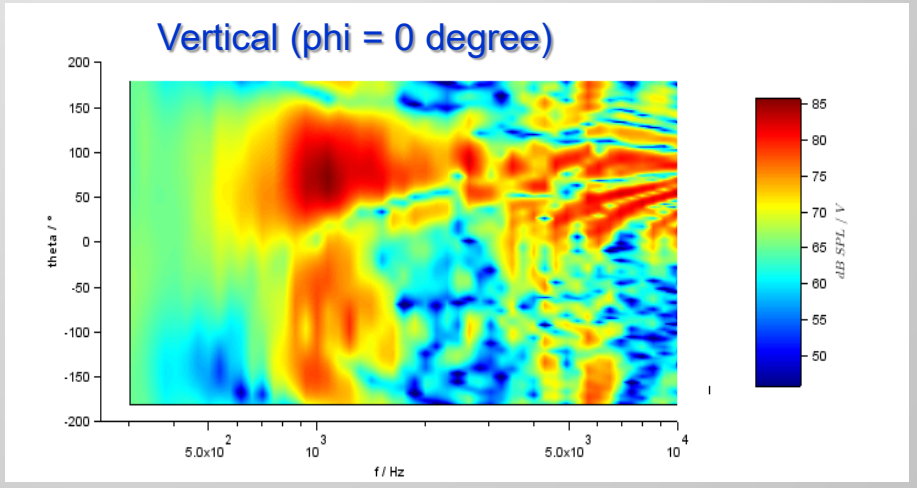
according IEC 60268-21

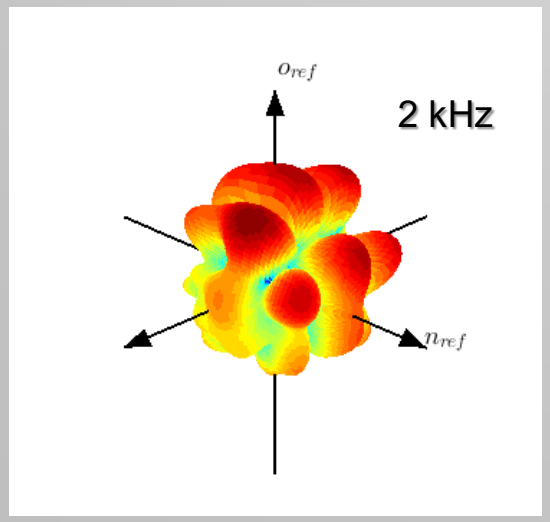
	Conventional Measurement	Holographic Measurement
Sound pressure measurement	direct far field measurement (turntable)	near field scanning (robotics)
Simulated Free Field Condition	Windowing restricted to higher frequencies	• direct sound separation at lower frequencies • Windowing applied at higher frequencies
Model	not required	(spherical) wave model
Results	sound pressure depending on angles and distance r	• sound pressure depending on point **r** in 3D space • model parameters C
Angular resolution	Limited by number and placing of measurement point	Higher than scanning grid (interpolation based on spherical wave modeling)
Extrapolation	within far-field (1/r law is valid)	near and far field (outside scanning surface)
Self-test	not possible	based on total fitting error

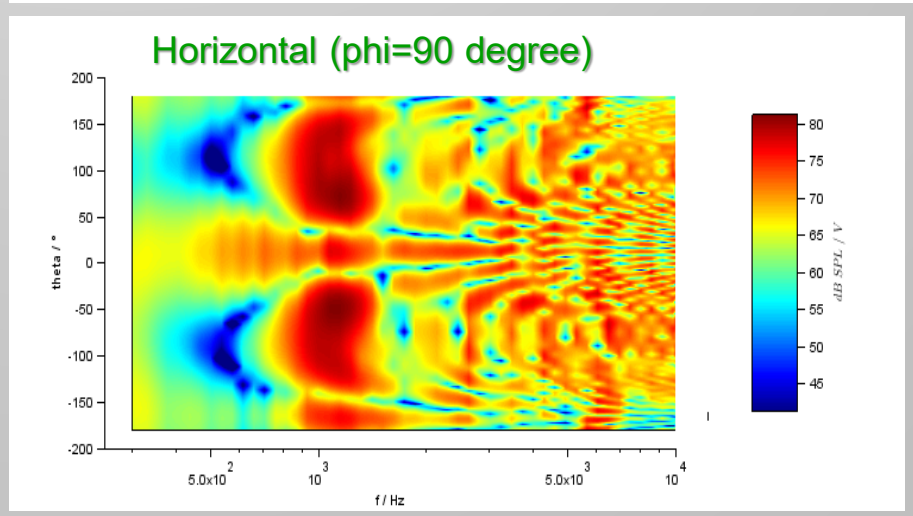
Far field Directivity

Example Laptop r=1m







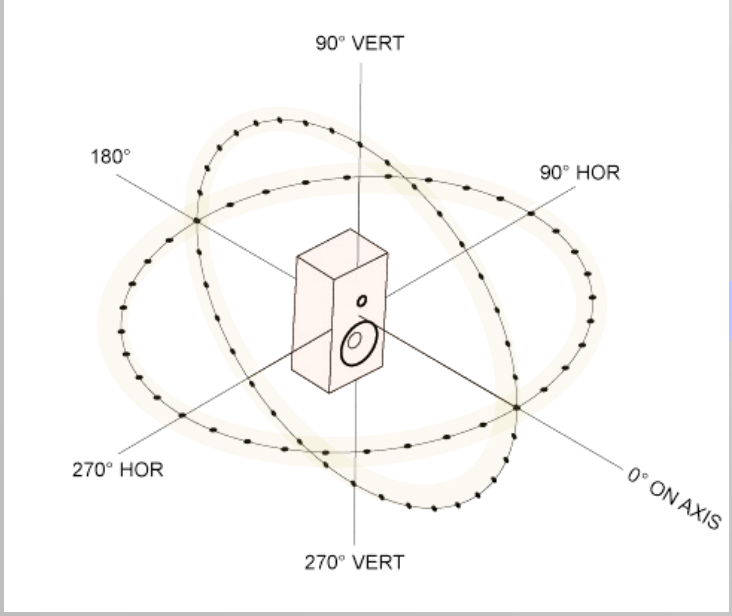


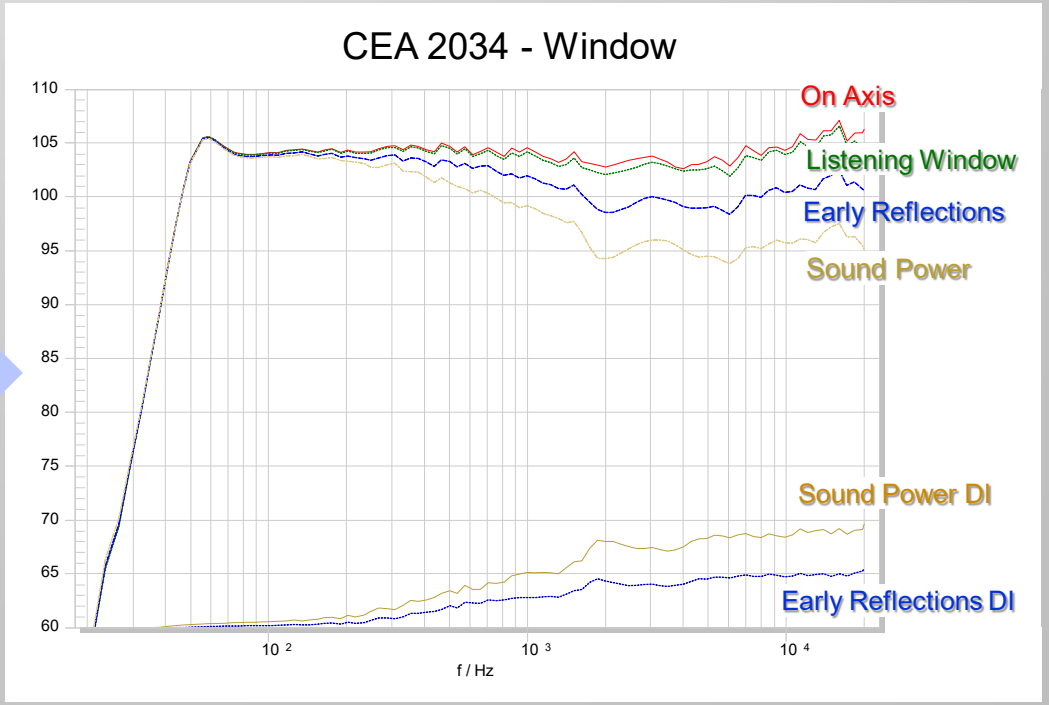
The left and right speaker generate a complex directivity pattern !

CEA 2034 Standard

using Spino-a-rama

Application : Home audio devices, Hifi-Loudspeaker





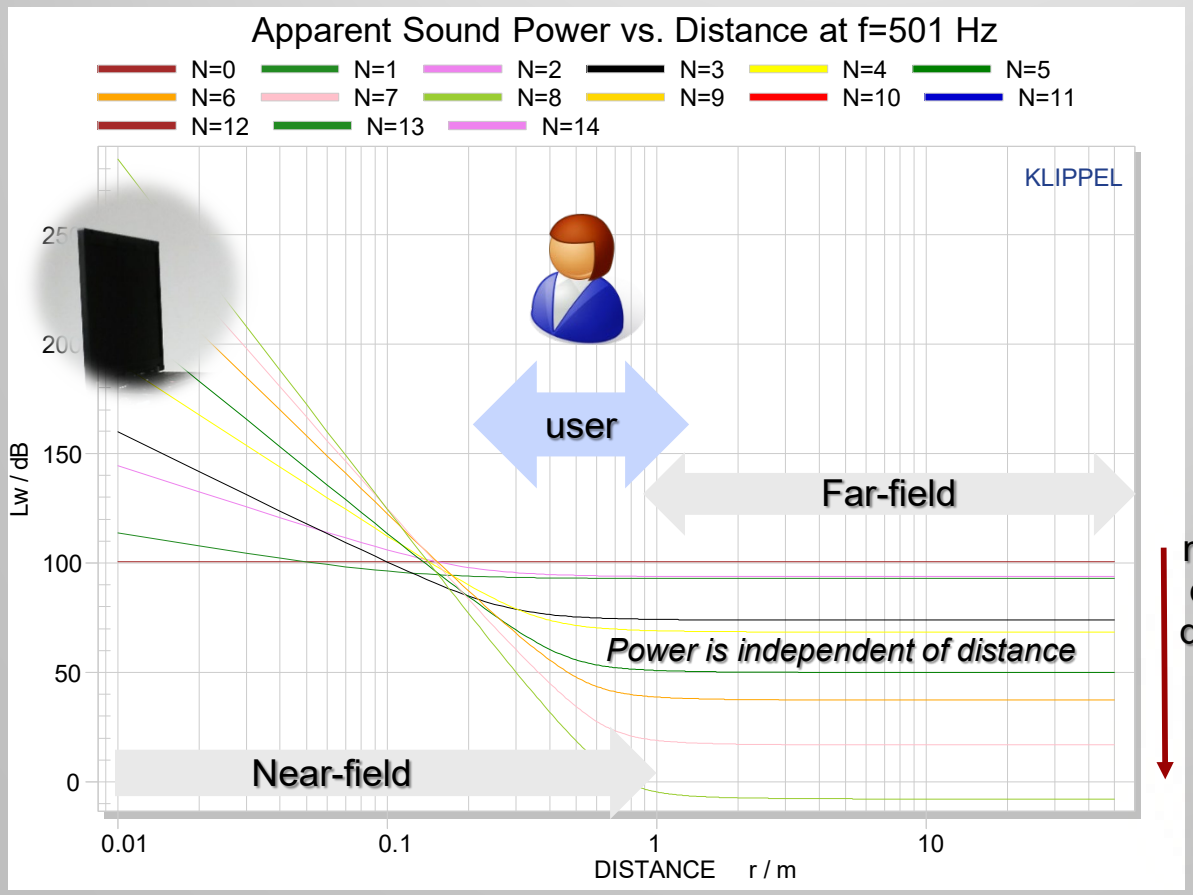
POLL:

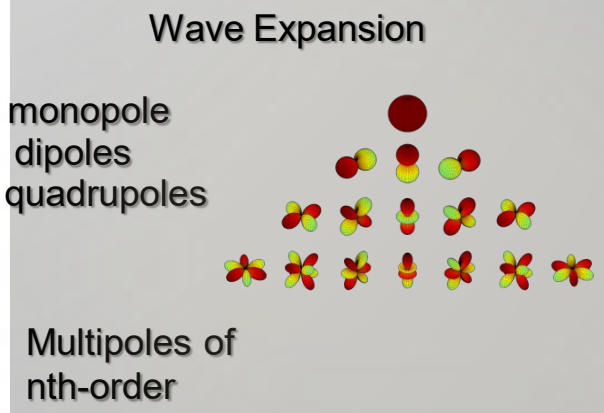
Which intergral values based on CEA 2034 do you use for your work?

(multiple answers)

- None
- Sound power
- Directivity index
- Listening window
- Early reflections

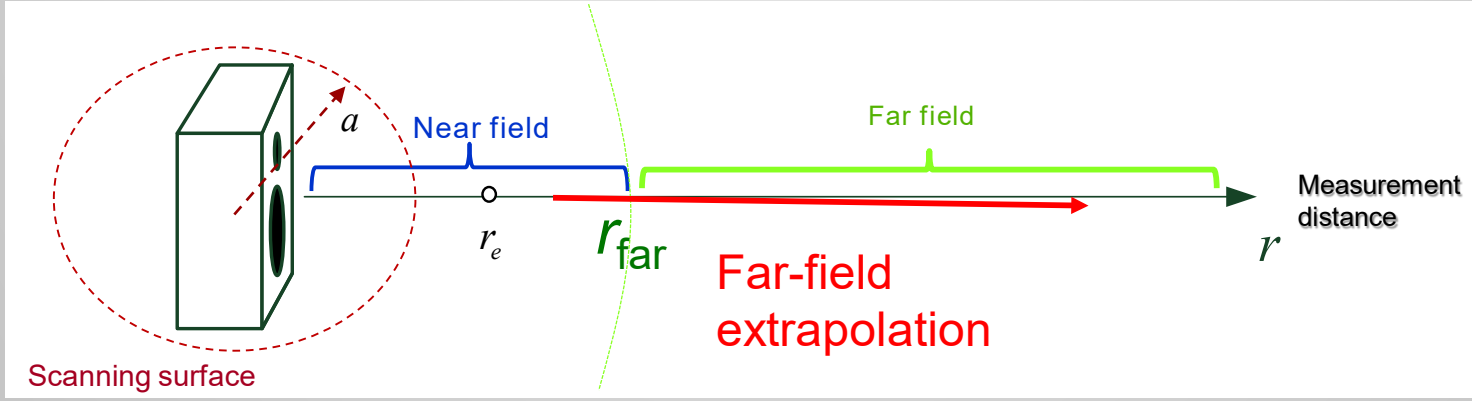
Near-Field or Far-Field?





Determining the location of the near and far-fields is important for personal and handheld audio devices !!

Evaluation Point in the Near Field



Problem:

- Large Speaker
- Reference distance $r_e > r_{far}$ (far field distance)

Solutions:

a) True near-field SPL $L(r_e)$ measured at the evaluation distance r_e ($1/r$ Law is not applicable)

b) Assumed far-field SPL $L_{far}(r_e)$ referenced to evaluation distance r_e (discrepancy to reality, extrapolation into far field is possible)

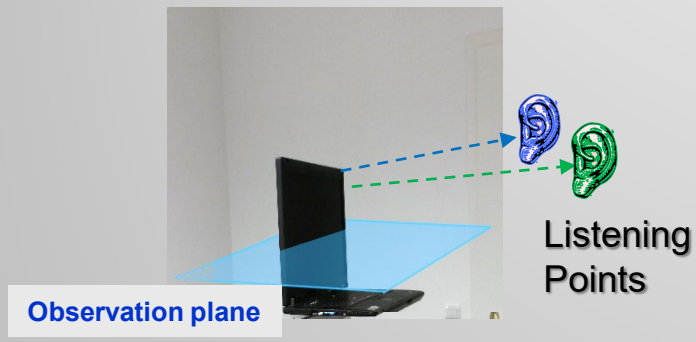
POLL:

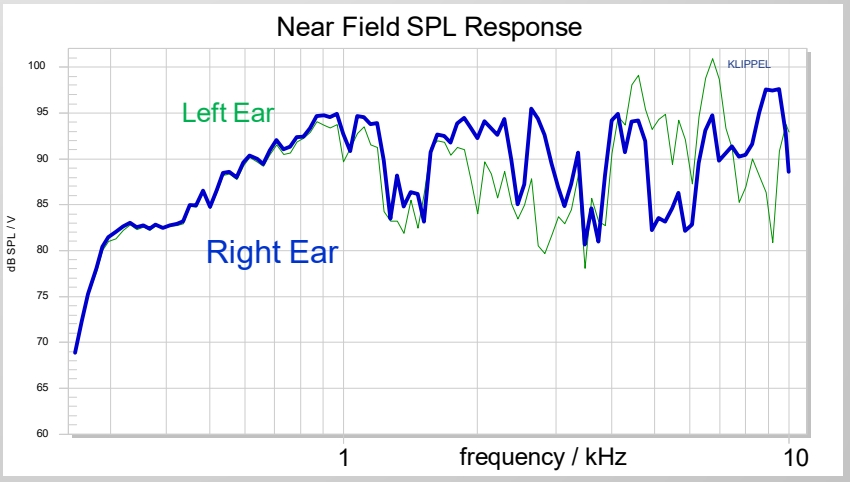
Are the near field properties relevant for your work?

- No
- Yes, the listening zone is in the near field (personal, mobile audio devices, studio monitors)
- Yes, the loudspeaker size (professional equipment, sound bars, sound panels) is too large for my anechoic room
- Yes, other reasons

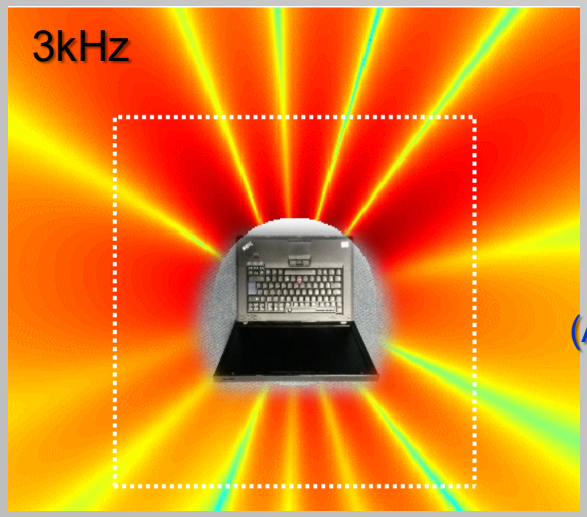
Comprehensive 3D Information

supports the evaluation of special sound effects





SPL distribution



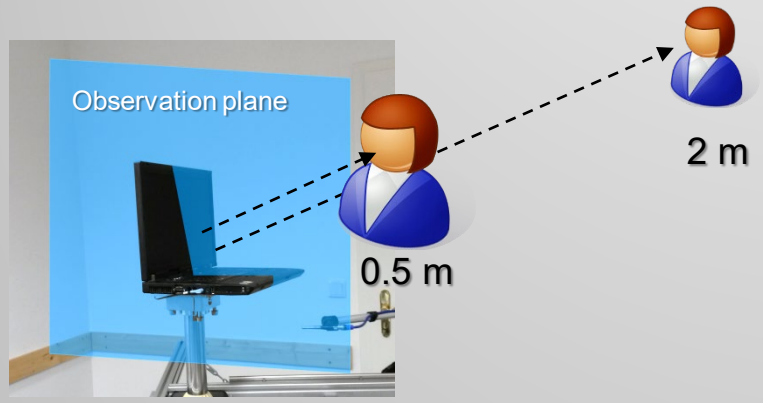
Comprehensive Information

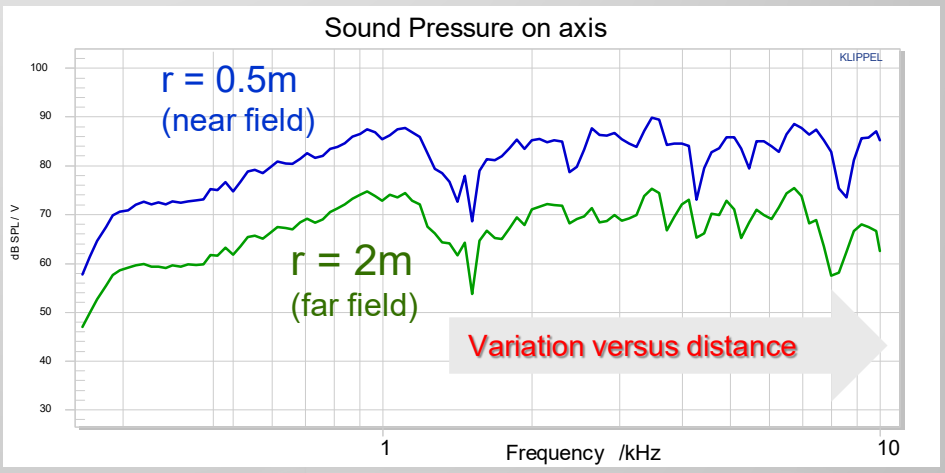
(Amplitude) (Phase)

Wave front propagation

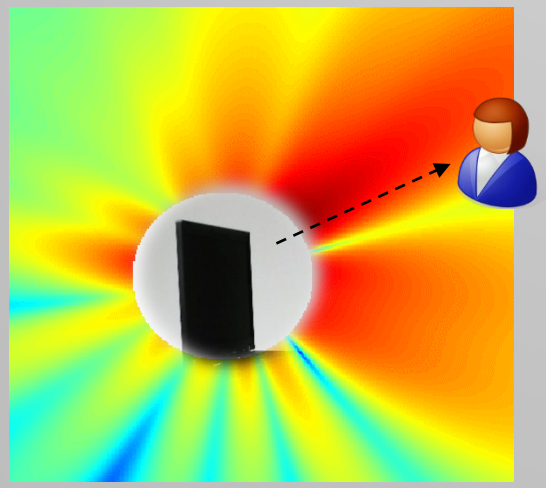
Near-field Information

is important for 3D sound effects





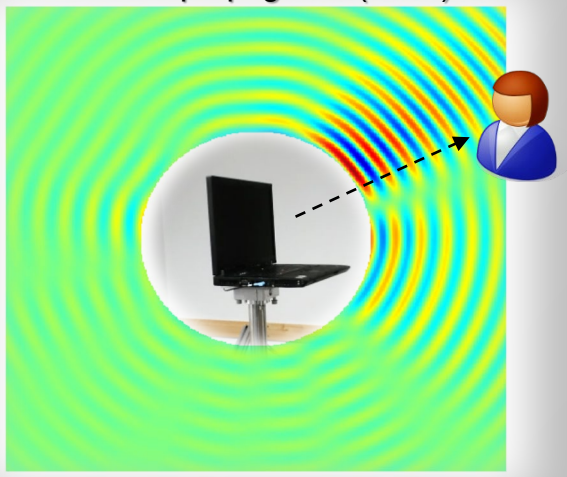
Sound pressure distribution (3kHz)



Comprehensive Information

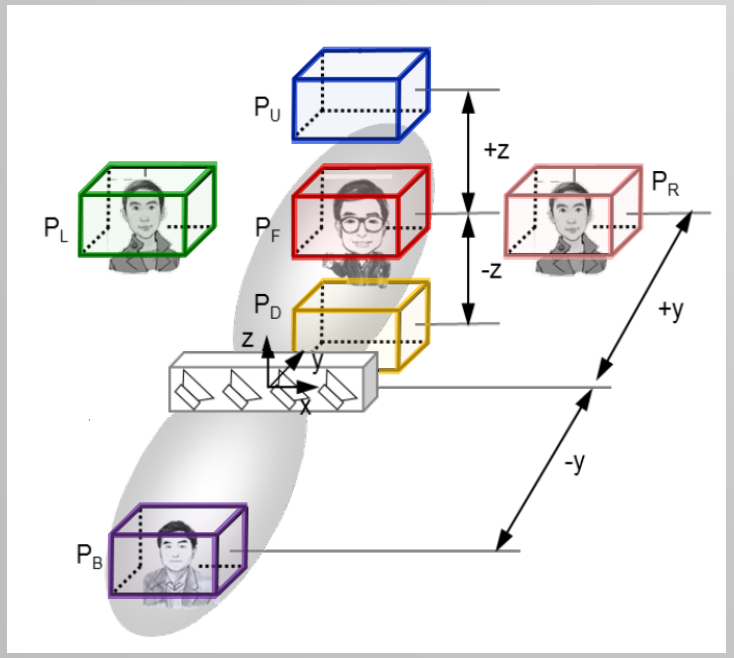
(Amplitude) (Phase)

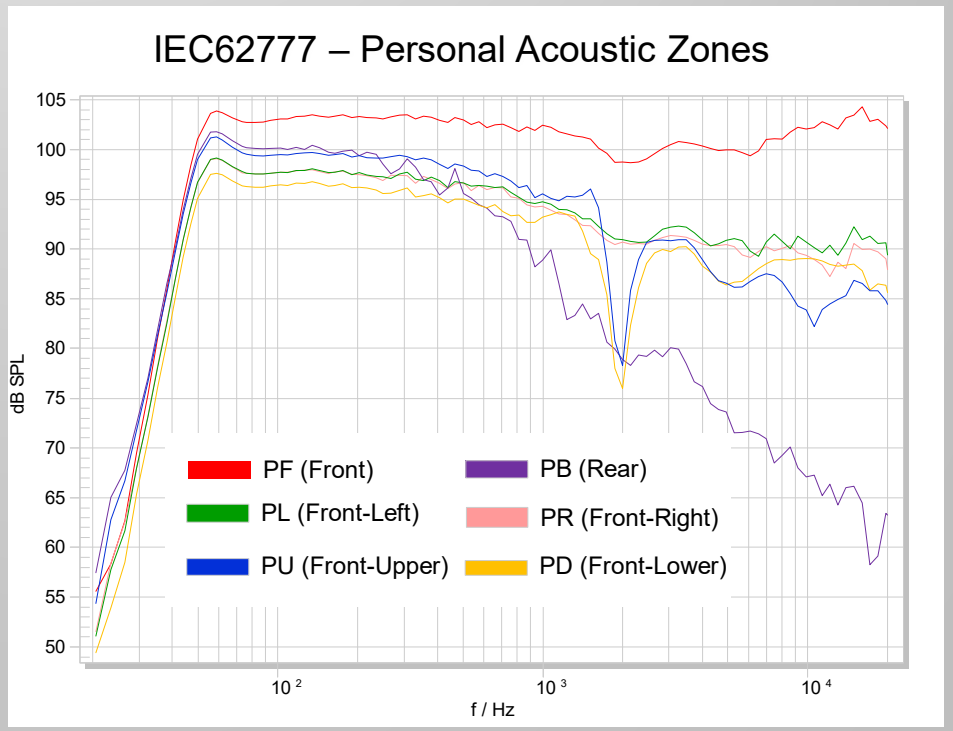
Wave front propagation (3kHz)



IEC 62777 Standard
using Listening Zone

Application: Personal audio devices, Laptops, Tablets, etc.





POLL:

Do you use DSP for generating a desired directivity pattern of your speaker?

(multiple answers possible)

- No
- For two transducers (woofer, tweeter) at the crossover region
- For stereo system
- For active beam forming and beam steering

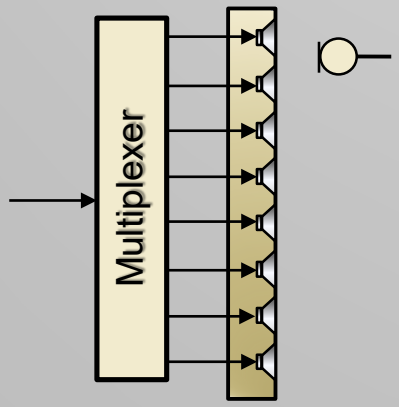
Measurement of line sources
(sound bars, line array)

Particularities:
- Large dimensions
- Multiple tweeter
- Wide spread
  near field (r>>d)

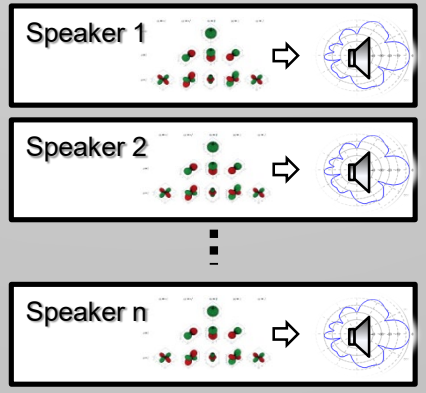
Problems:
- Sound field has high complexity
- Fitting for high Frequencies (>5kHz)
  requires high order N>50
- Many measurement points,
  long measurement time

Solution:

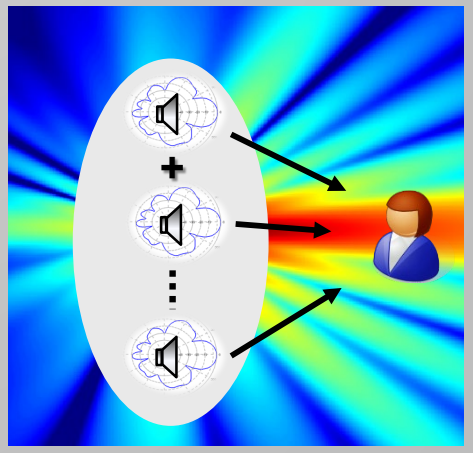
1) Measure each loudspeaker separately by using a multiplexer



2) Wave expansion of each loudspeaker



3) Super positioning of the multipoles

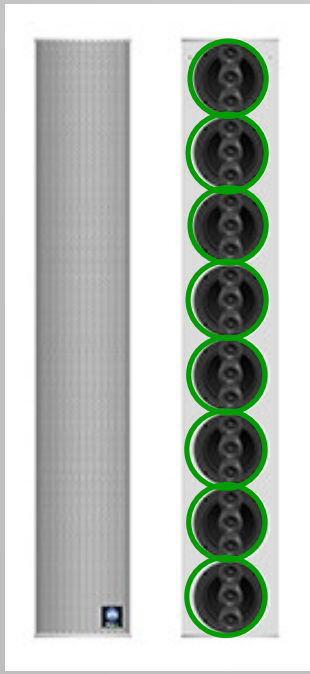


Measurement of line sources (2)

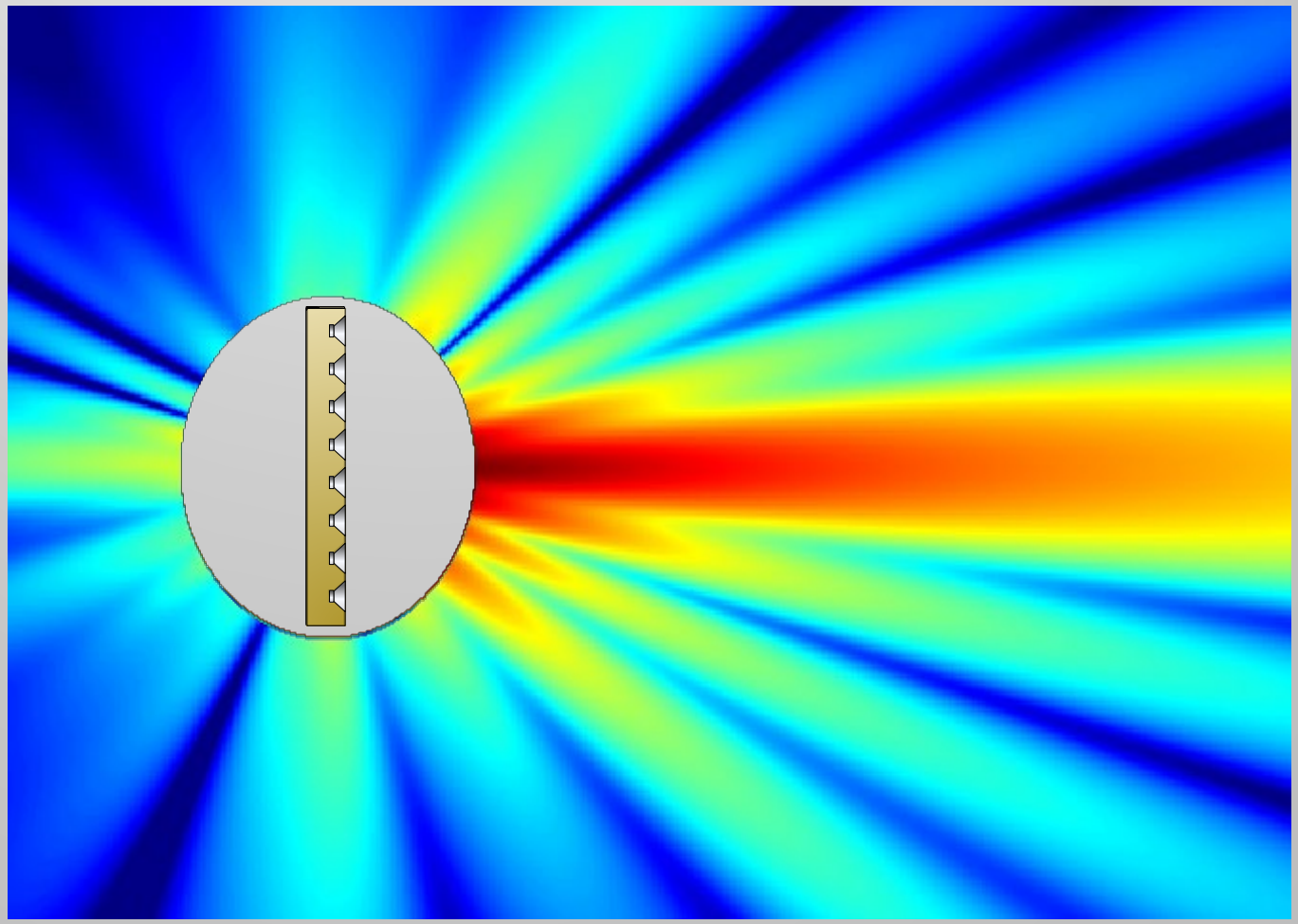
Super positioning of the multiple measurements

Line Array:

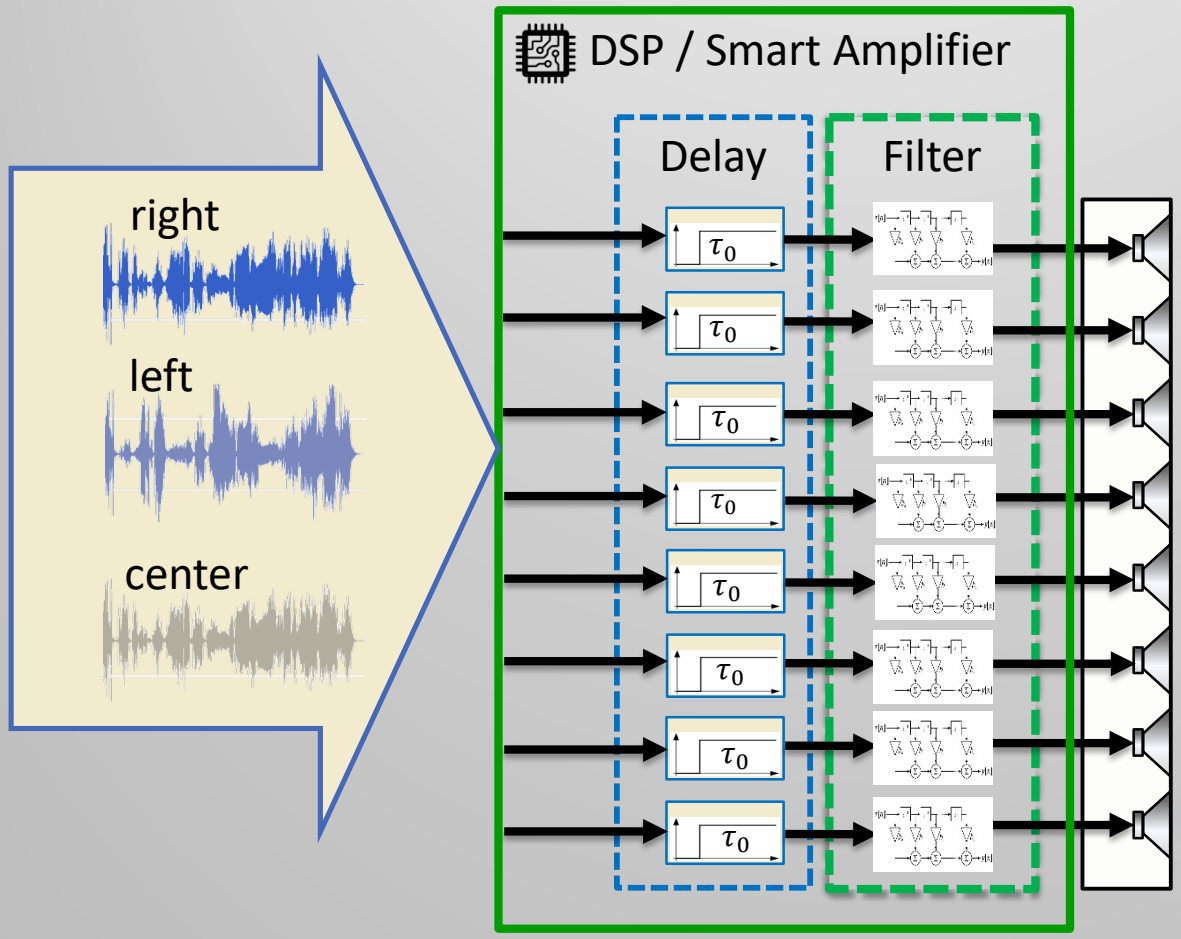
- 8 coaxial speakers
- 24 tweeter
- Super position of 8 multipoles



2kHz



Controlled directivity



Summary

- IEC 60268-21 defines conventional directivity measurements and new techniques for assessing the complete 3D sound output
- A holographic measurement models the sound pressure distribution outside of a scanning surface placed in the near-field of the speakers
- A spherical wave model is well suited for loudspeakers giving maximum resolution using a few parameters
- A holographic measurement performs a self-check and gives maximum accuracy for a minimum number of scanning points
- Traditional characteristics (e.g. spin-o-rama) simplify the interpretation
- Mean values, variances can be calculated for sound zones for the particular application
- Reliable complex 3D output data for each transducer can be provided for beam steering and other DSP processing

Open Questions

However, most measurements (e.g. distortion, equalization) can be performed at a single evaluation point!

Can we perform our daily standard measurements at high accuracy outside the anechoic room?

The 4th KLIPPEL live webinar will address:

- Simulation of free-field and far-field condition according IEC 60268-21
- How to compensate for room influence, different positioning and distance
- Can we use a fixed room compensation functions for different types of speakers?

Next Section

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