Acoustical Measurement of Sound System Equipment according IEC 60268-21

根据IEC 60268-21 标准音响系统设备的声学测试

KLIPPEL LIVE

a series of webinars presented by

Wolfgang Klippel

网络研讨会系列 Webinar Series

“声学测量” “Acoustical Measurements”

之前的课程 Previous Sessions

1. 现代音频设备需要基于输出的测试 Modern audio equipment needs output based testing
2. 普通房间中进行标准声学测试 Standard acoustical tests performed in normal rooms
3. 从3D输出测量中获取有意义的结论 Drawing meaningful conclusions from 3D output measurement

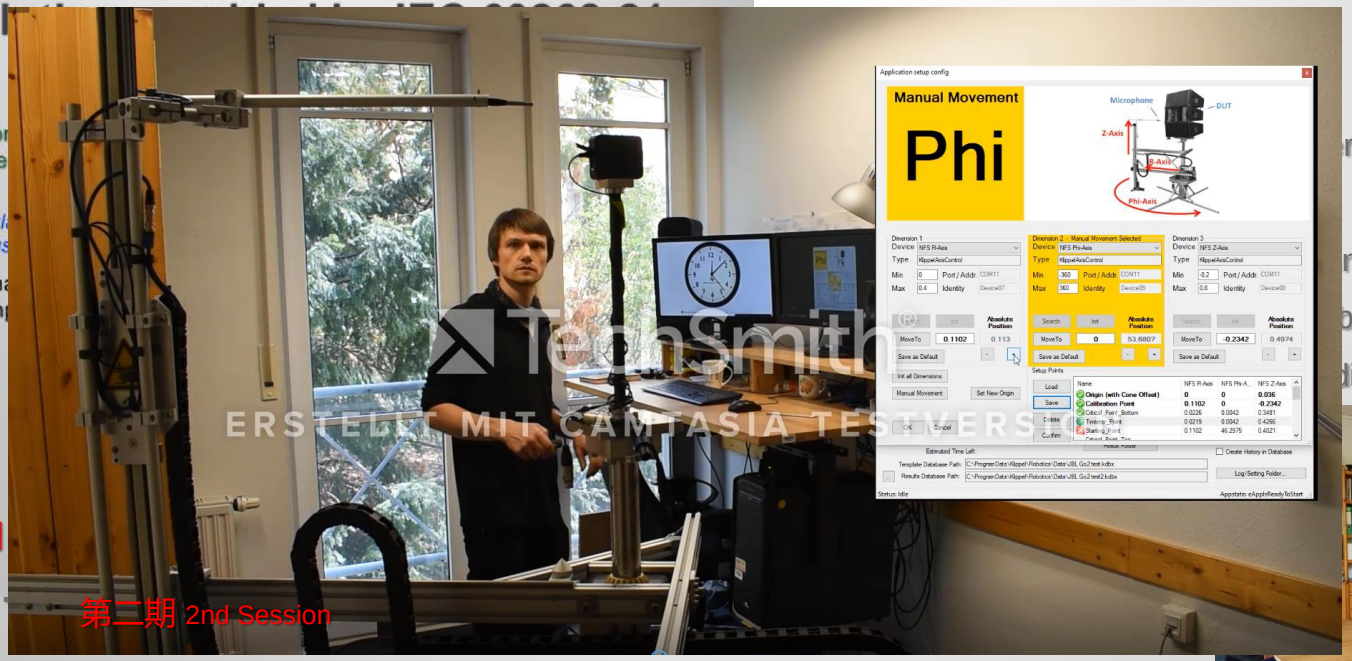
dard condition at an evaluation point

r amplitudes

n a single tone

behavior, defects

ditions



第一期

第二期 2nd Session

现代有源音频设备的声学测试
Acoustical testing of a modern active audio device

3rd KLIPPEL LIVE:

第三期KLIPPEL LIVE：

Drawing meaningful conclusions from 3D output measurement

从3D输出测量得出有意义的结论

Topics today:

今日话题

1. Standard Measurement Techniques
   标准测量技术
2. Far field directivity (e.g. professional application)
   远场方向性（例如专业应用）
3. Mean value at selected angles (spin-o-rama) (e.g. consumer-home application)
   选定角度上的均值（spin-o-rama）（例如家用消费级应用）
4. Mean value of a listening zone in 3D space (e.g. personal audio devices)
   3D空间中听音区的均值（例如个人音频设备）
5. Accurate complex data for beam steering (e.g. loudspeaker panels)
   波束成形的准确复杂数据（例如扬声器面板）

Poll:

投票:

Is loudspeaker directivity relevant for your work?

扬声器指向性与您的工作紧密相关吗?

- Always
  总是
- Depends on the particular application
  取决于特定的应用
- Not really
  并不是

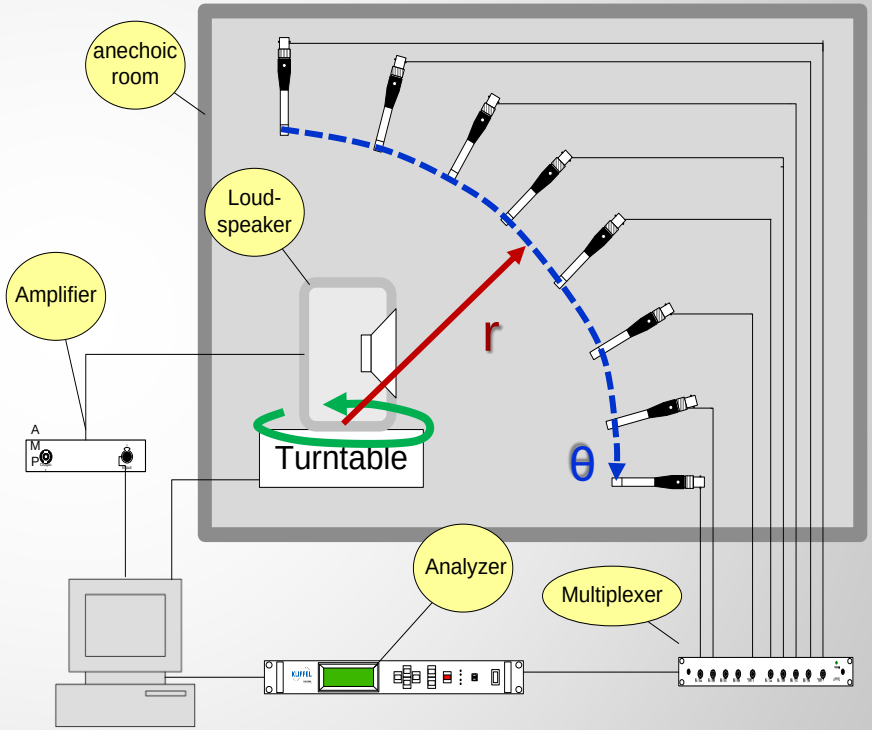
Conventional Directivity Measurement
常规指向性测量

The sound pressure is measured at multiple measurement points in the far field located on a sphere with radius r.
在远场半径为r的球面上的多个测量点处测量声压。

Angular Resolution depends on the number of measurement points placed in the far field.
角分辨率取决于远场中测量点的数量。

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

Not practical
不切实际



Question:

问题:

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

您希望测得的方向性的角度分辨率有多少?

A. Only on-axis data

仅轴上数据

B. A few measurement point at selected angles (e.g. 30 degree) off-axis

选定角度（例如30度）的离轴上几个测量点

C. Vertical and horizontal polar plots

垂直和水平极坐标图

D. Balloon data with less 5 degree resolution

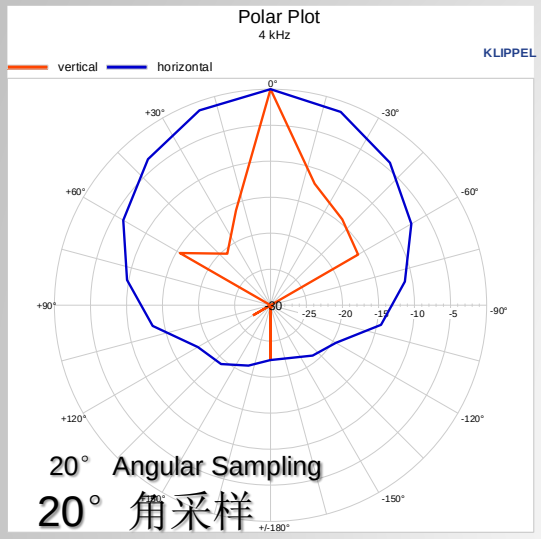
少于5度分辨率的气球图数据

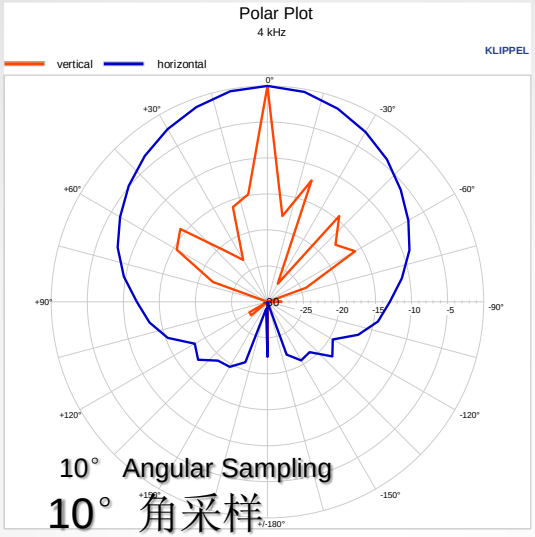
E. Balloon data with more than 5 degree resolution

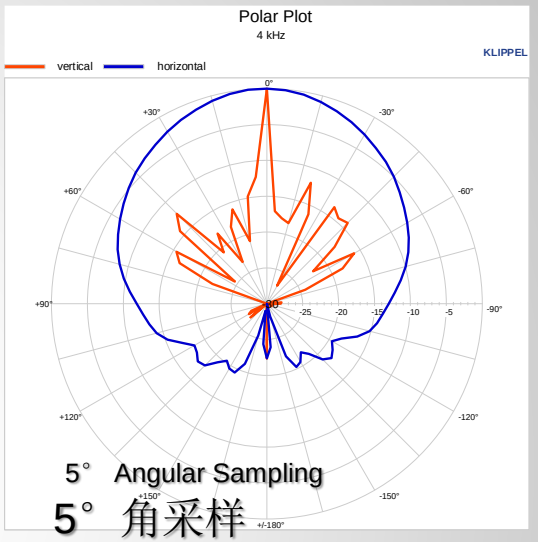
5度以上分辨率的气球图数据

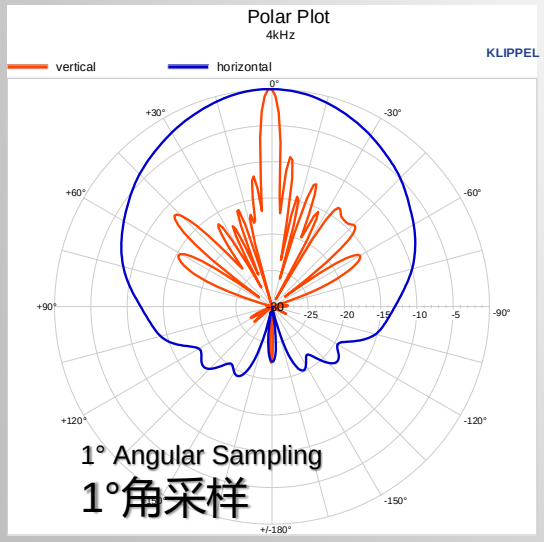
Linear Interpolation between Points 点之间的线性插值

Conventional Directivity Measurement 常规方向性测量









Vertical direction 垂直方向

Horizontal direction 水平方向

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

如果角度采样不能描述方向模式的复杂度，则线性（复）插值会产生明显的（混叠）误差。

Holographic Measurement 全息测量

Near Field Scanning + Wave Expansion 近场扫描 + 波形展开

NEAR FIELD DATA
近场数据

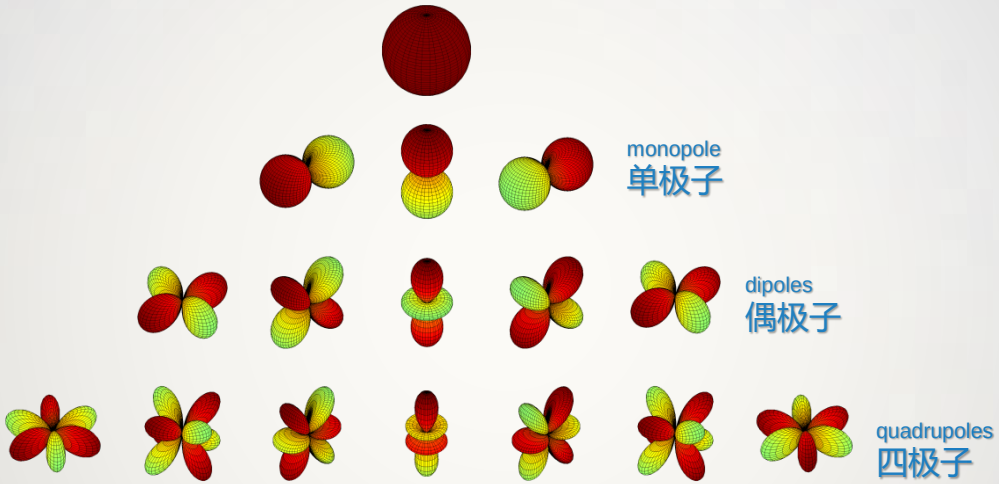
$\underline{H}(f,\mathbf{r})$

Scanning
扫描

+

BASIC FUNCTIONS
基本函数

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



Total Fitting Error
总拟合误差

$TFE(f)$

COEFFICIENTS 系数

$\mathbf{C}(f)$

Results
结果

Direct Sound
Extrapolation
直达声外推

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

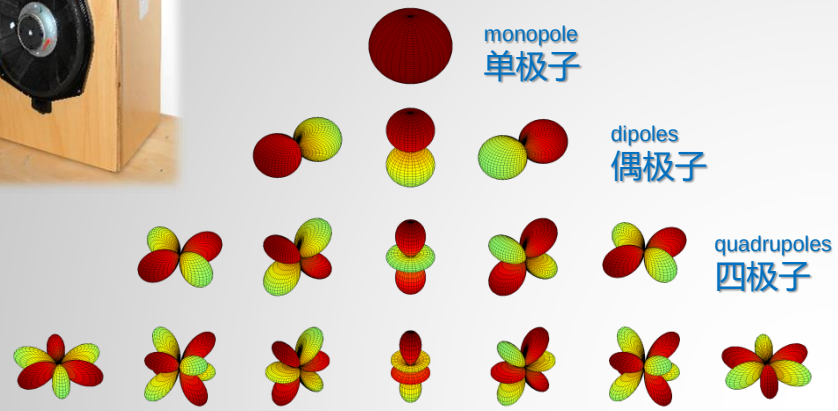
波动方程的一般解用作展开的基本函数

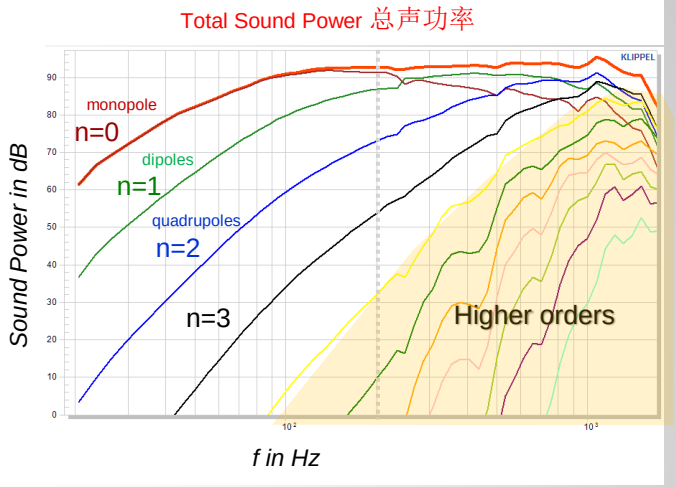
Total number of coefficients = $(N+1)^2$

系数总数 = $(N+1)^2$

Holographic Measurement 全息测量

Example: Wave Expansion of a Woofer 示例：低音扬声器的波展开

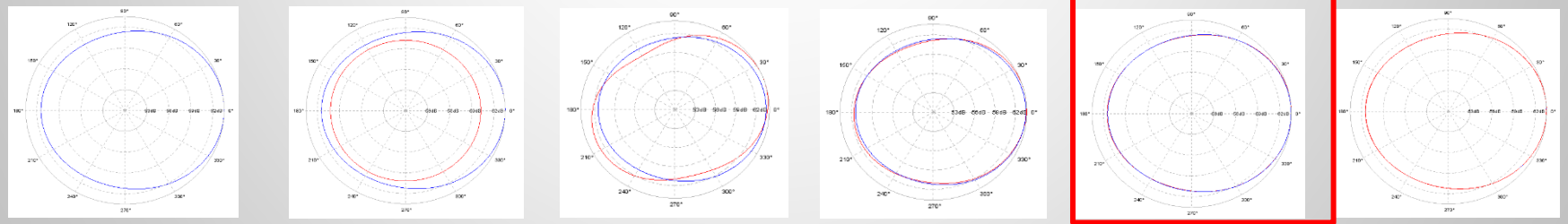




Directivity patterns at 200 Hz:

200 Hz时的方向性图：

Target 目标 | N=0 | N=1 | N=2 | N=3 | N=10



sound field is completely described by order N=3 (16 Coefficients) ***声场完全由 N = 3（16个系数）表示***

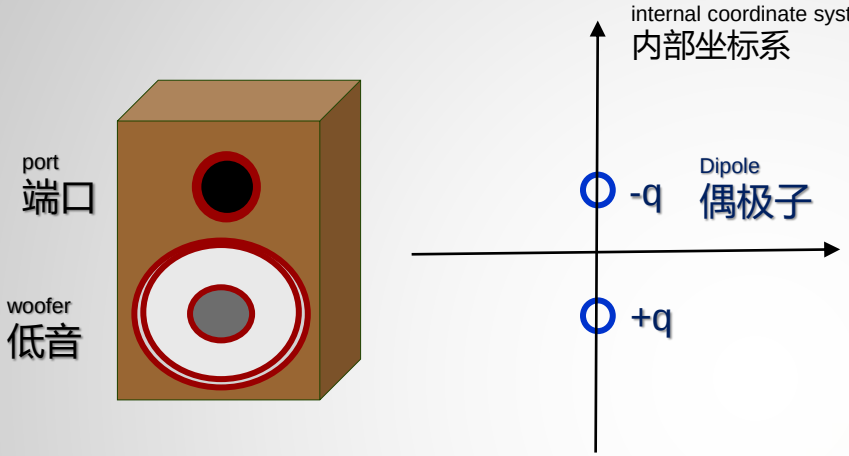
can be estimated by a few scanning points (M > 16) 可以通过几个扫描点来估计（M> 16）

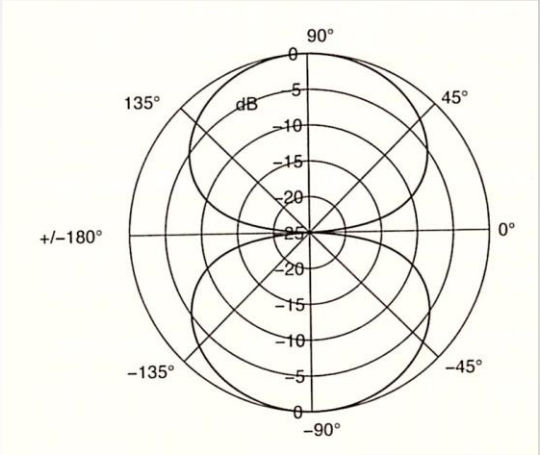
Order of the Expansion Depends on the Loudspeaker Properties

展开阶数取决于扬声器的属性

Example: Woofer in a Vented Box far below port resoance

示例：开口箱中远低于端口谐振的低音单元

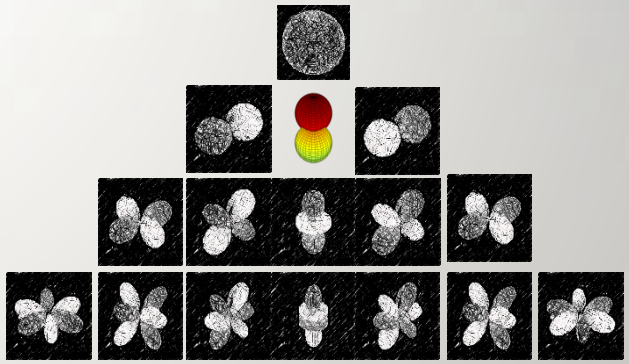




The directivity can be modeled by single coefficients and a single scanning would be required if

其指向性可以通过单个系数建模，且只需要单次扫描，如果：

- the expansion point is in the acoustical center
  扩展点在声学中心
- the dipole axis is aligned with the coordinate system
  偶极轴与坐标系对齐



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

角分辨率远高于扫描网格上的采样

Holographic Measurement 全息测量

Extrapolation of the Direct Sound 直达声的外推

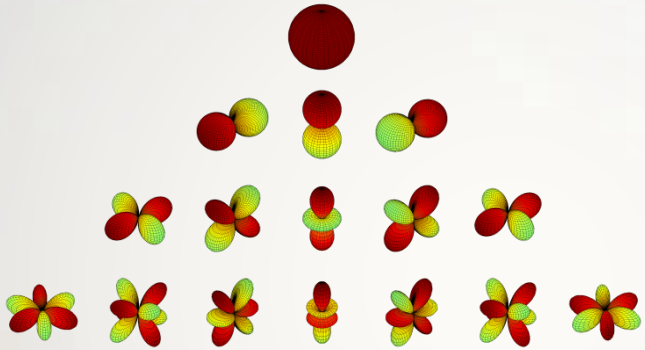
系数
COEFFICIENTS

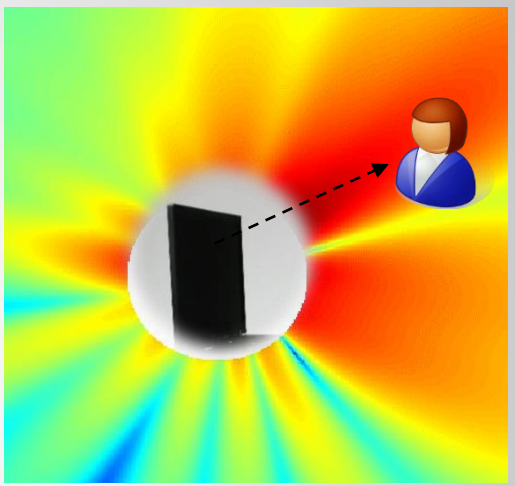
$$C(f)$$

+

基本函数
BASIC FUNCTIONS

$$B(f, r)$$

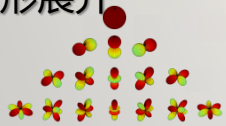




结果
Results

General solutions of the wave equation
波动方程的一般解

Wave Expansion
波形展开



扫描 Scanning

Sound pressure distribution (3kHz) generated by a laptop outside the scanning surface
笔记本电脑在扫描面外产生的声压分布（3kHz）

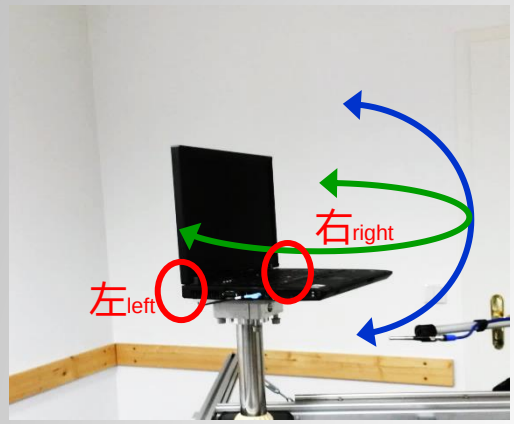
Comparison of the Standard Methods 标准方法比较

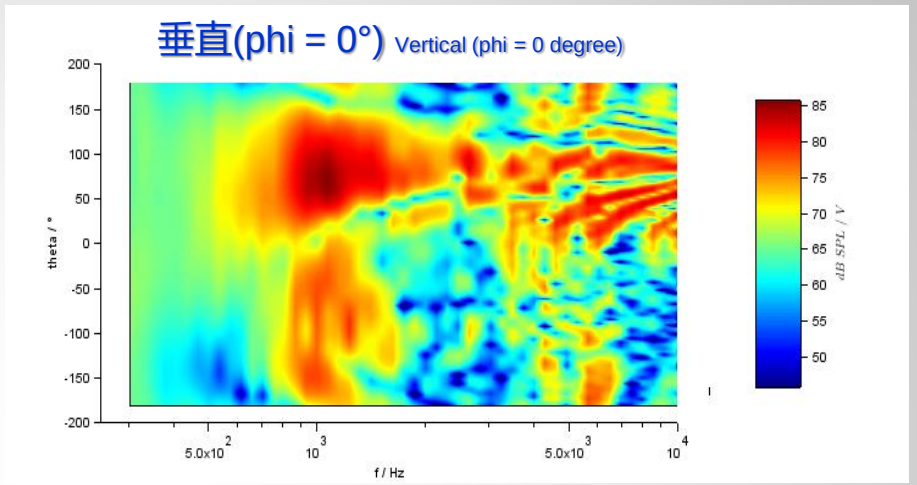
according IEC 60268-21 根据IEC 60268-21

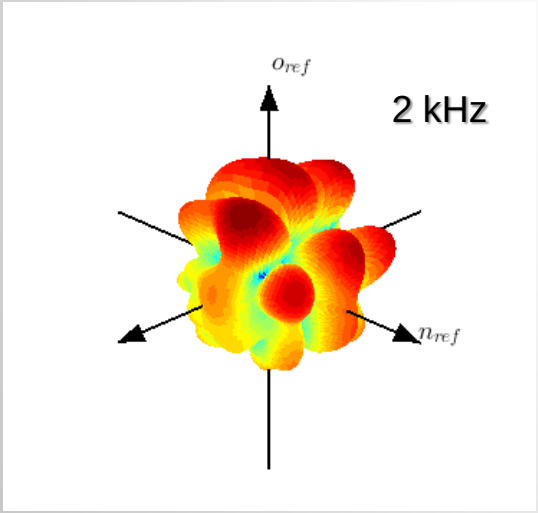
	Conventional Measurement 常规测量	Holographic Measurement 全息测量
Sound pressure measurement 声压测量	direct far field measurement (turntable) 直接远场测量（转台）	near field scanning (robotics) 近场扫描（机器人技术）
Simulated Free Field Condition 模拟自由场条件	Windowing restricted to higher frequencies 限于高频的加窗处理	• direct sound separation at lower frequencies 低频直达声分离 • Windowing applied at higher frequencies 高频应用加窗处理
Model 模型	not required 不需要	(spherical) wave model （球面）波模型
Results 结果	sound pressure depending on angles and distance r 声压取决于角度和距离r	• sound pressure depending on point **r** in 3D space 声压取决于3D空间中的点**r** • model parameters C 模型参数C
Angular resolution 角分辨率	Limited by number and placing of measurement point 受限于测量点的数量和位置	Higher than scanning grid (interpolation based on spherical wave modeling) 高于扫描网格（基于球面波建模的插值）
Extrapolation 外推	within far-field (1/r law is valid) 远场内（1/r法则有效）	near and far field (outside scanning surface) 近场和远场（扫描面以外）
Self-test 自检	not possible 不可以	based on total fitting error 基于总拟合误差

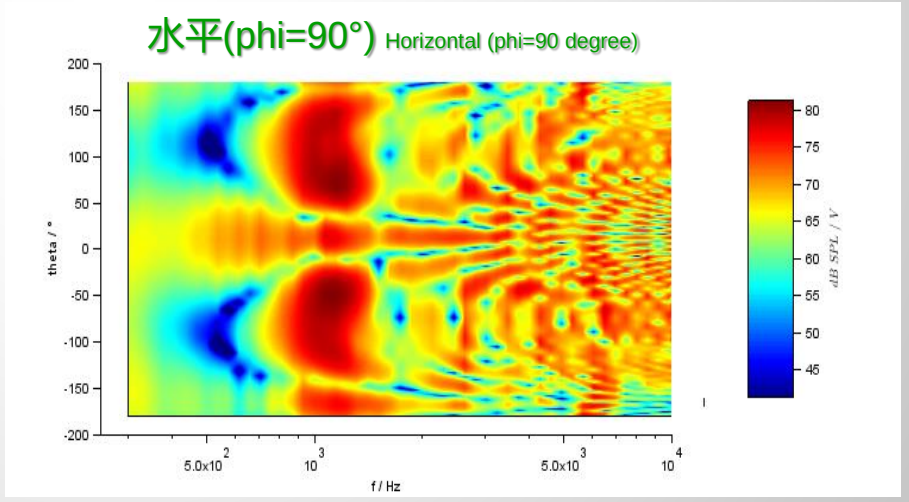
Far field Directivity 远场指向性

Example Laptop r=1m 示例：r=1m处的笔记本









The left and right speaker generate a complex directivity pattern !

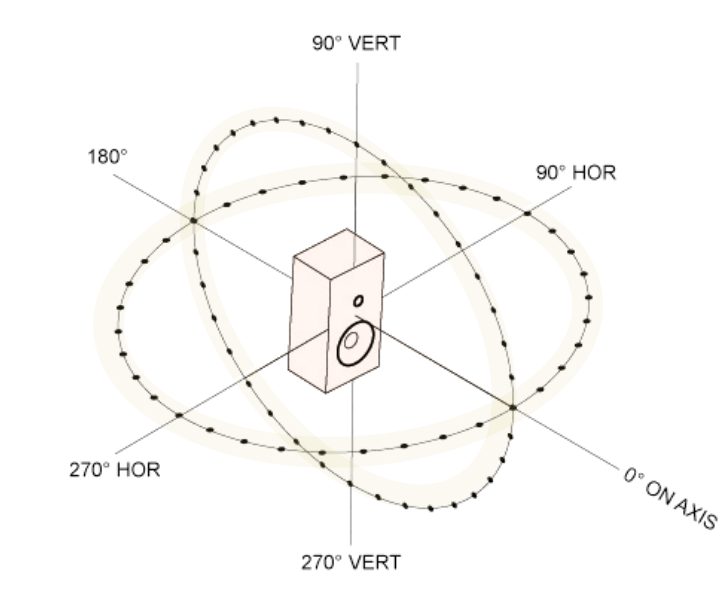
左右扬声器产生复杂的指向性模式!

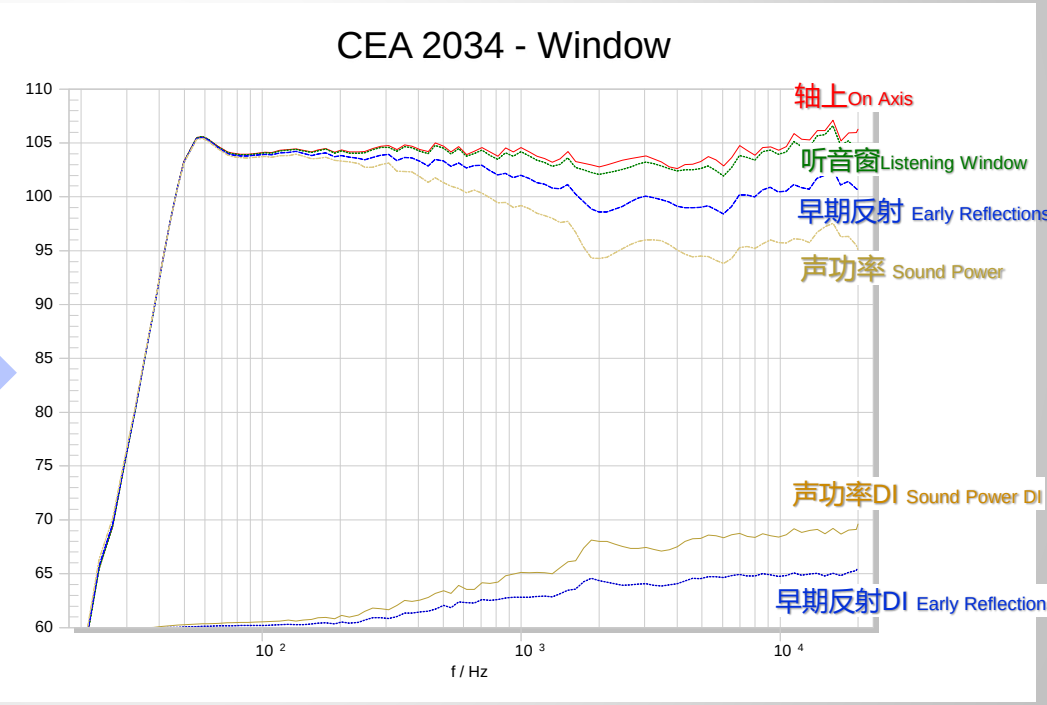
CEA 2034 Standard CEA 2034 标准

using Spino-a-rama 使用Spino-a-rama

Application : Home audio devices, Hifi-Loudspeaker

应用：家用音频设备，高保真扬声器





POLL:

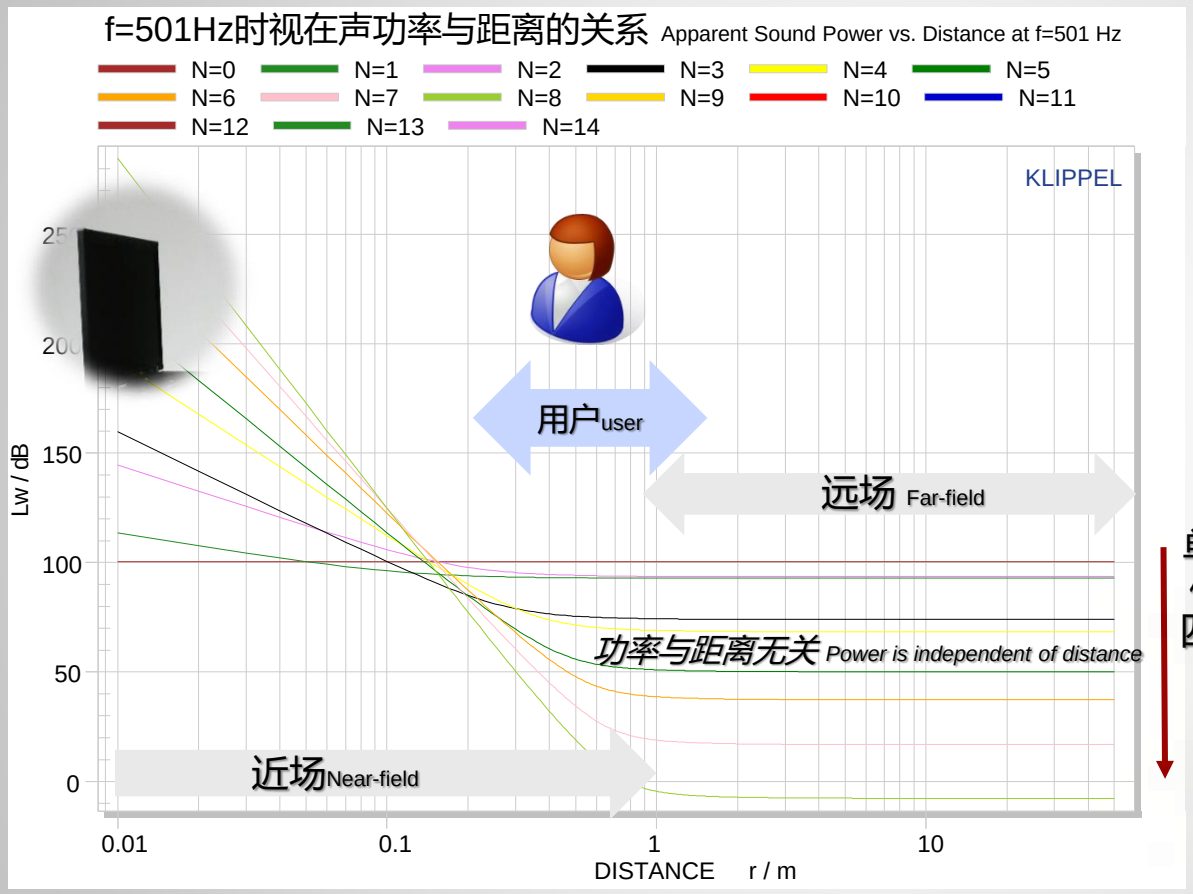
投票：

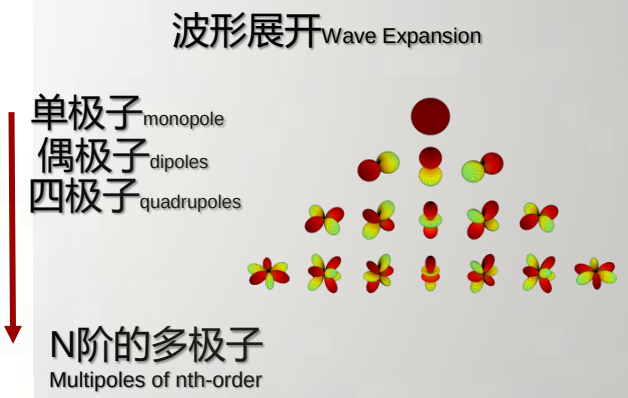
Which intergral values based on CEA 2034 do you use for your work? (multiple answers)

您在工作中使用基于CEA 2034的哪些综合值？ （多选）

- None
  没有
- Sound power
  声功率
- Directivity index
  方向指数
- Listening window
  听音窗
- Early reflections
  早期反射

Near-Field or Far-Field?
近场还是远场?

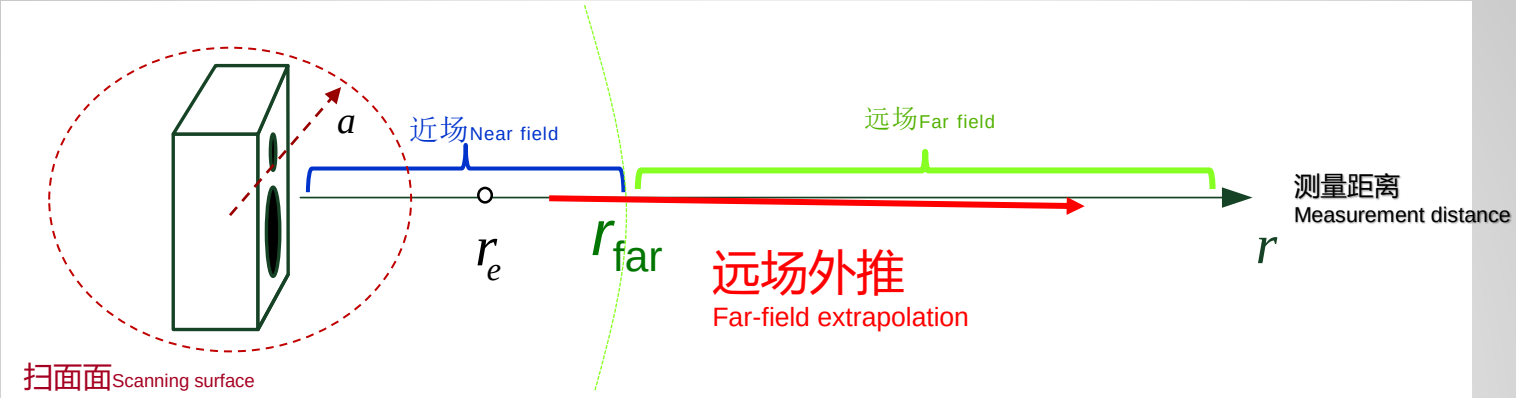




Determining the location of the near and far-fields is important for personal and handheld audio devices !!

确定近场和远场的位置对于个人和手持音频设备很重要!

Evaluation Point in the Near Field
近场评估点



问题： Problem:

- Using a common evaluation distance (r_e =1 m) to compare different speakers but the evaluation point is in the near field ($r_e < r_{far}$)
  使用公用评估距离（r_e =1 m）比较不同的扬声器，但评估点在近场中（$r_e < r_{far}$）

解决 Solutions:

a) True near-field SPL $L(r_e)$ measured at the evaluation distance r_e (1/r Law is not applicable)
在评估距离r_e（1/r法则不适用）下测得真实近场SPL $L(r_e)$

b) Assumed far-field SPL $L_{far}(r_e)$ referenced to evaluation distance r_e (discrepancy to reality, extrapolation into far field is possible)
参考评估距离r_e得出假定远场SPL $L_{far}(r_e)$（与实际情况有差异，可以外推到远场）

POLL:

投票：

Are the near field properties relevant for your work?

近场属性对您的工作重要吗?

- No

  不重要
- Yes, the listening zone is in the near field (personal, mobile audio devices, studio monitors)

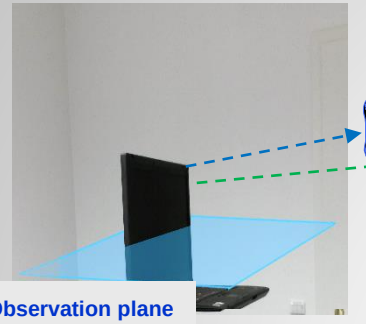
  是的，聆听区域位于近场（个人移动音频设备、演播室监听音箱）
- Yes, the loudspeaker size (professional equipment, sound bars, sound panels) is too large for my anechoic room

  是的，对于我的消声室来说，扬声器的尺寸（专业设备、条形音箱、平板扬声器）太大
- Yes, other reasons

  是的，其他原因

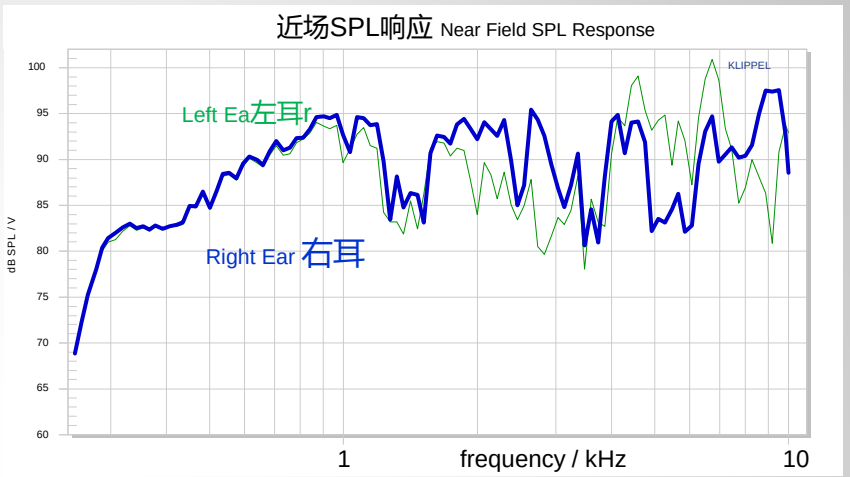
Comprehensive 3D Information 全面的3D信息

supports the evaluation of special sound effects 支持特殊音效的评估

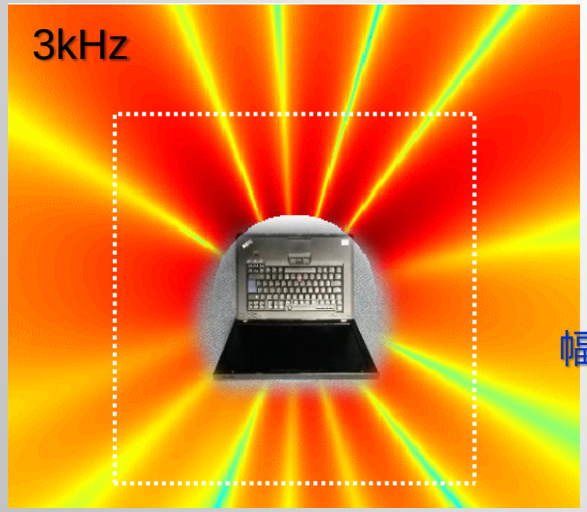


观察平面 Observation plane

聆听点
Listening
Points



SPL分布 SPL distribution



全面信息
Comprehensive
Information

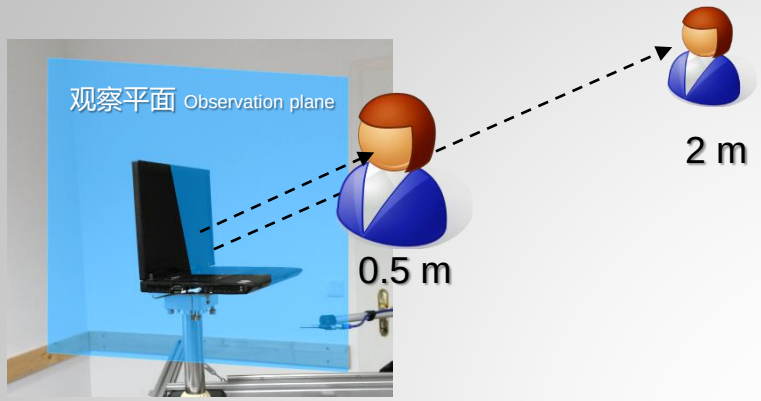
幅度(Amplitude)

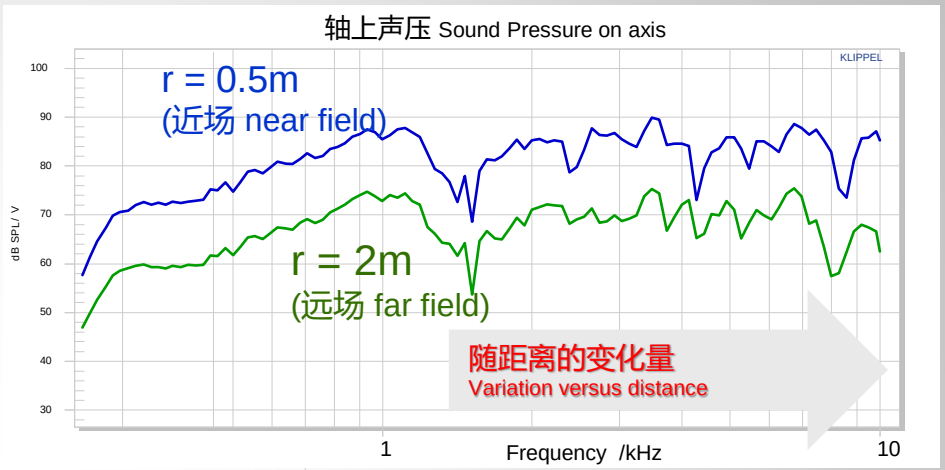
相位 (Phase)

波前传播 Wave front propagation

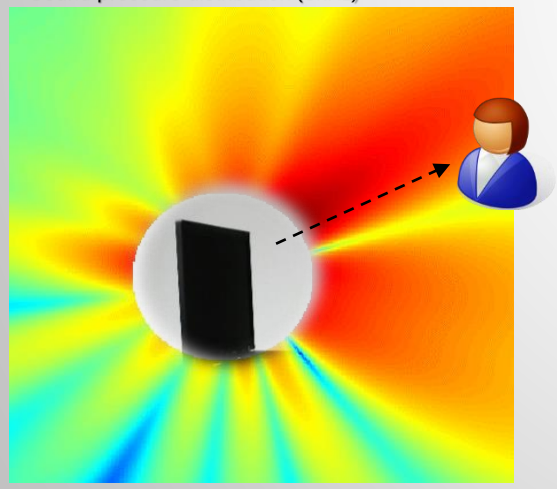
Near-field Information 近场信息

is important for 3D sound effects 对于3D音效很重要





声压分布(3kHz)
Sound pressure distribution (3kHz)



全面信息
Comprehensive Information

幅值 (Amplitude)

相位 (Phase)

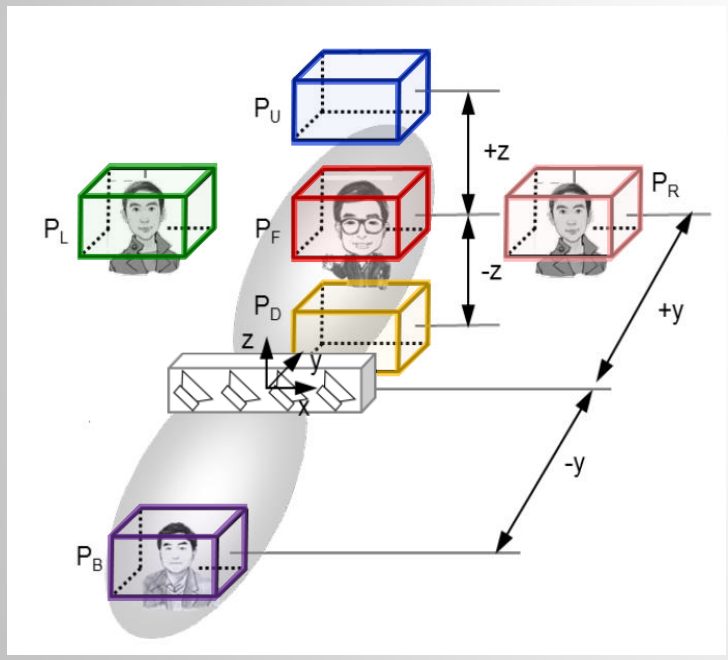
波前传播(3kHz) Wave front propagation (3kHz)

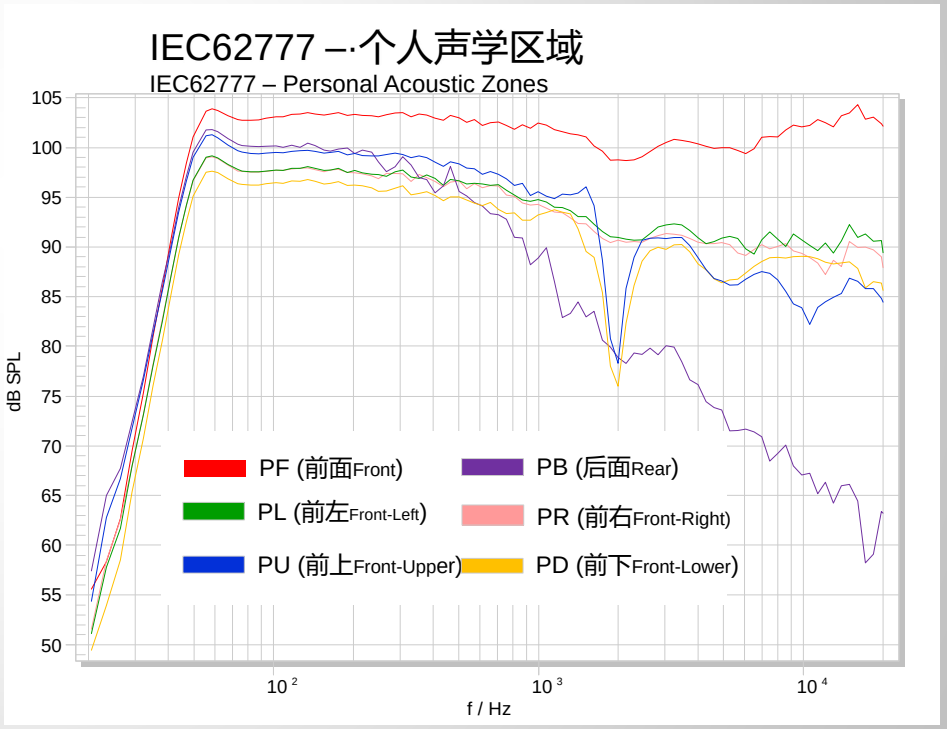
IEC 62777 Standard IEC 62777标准

using Listening Zone 使用聆听区域

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

应用范围：个人音频设备、笔记本电脑、平板电脑等。





POLL:

投票：

Do you use DSP for generating a desired directivity pattern of your speaker? (multiple answers possible)

您是否使用DSP生成所需扬声器指向性模式？（可有多个选项）

- No
  不使用
- For two transducers (woofer, tweeter) at the crossover region
  用于分频区域的两个换能器（低音扬声器，高音扬声器）
- For stereo system
  用于立体声系统
- For active beam forming and beam steering
  用于主动波束成形和波束控制

Measurement of line sources 线源的测量

(sound bars, line array) (条形音箱、线阵列)

特点 Particularities:

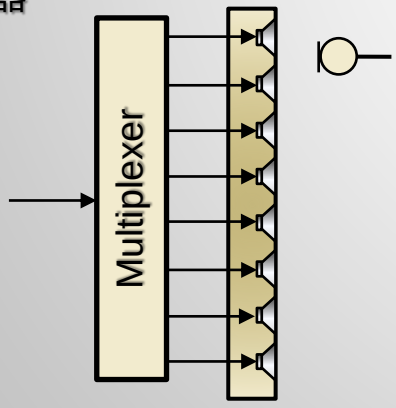
- 大尺寸 Large dimensions
- 多个高音单元 Multiple tweeter
- 传播广 Wide spread
  近场(r>>d) near field (r>>d)

问题 Problems:

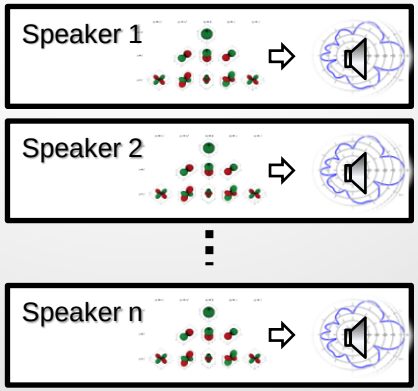
- 声场复杂 Sound field has high complexity
- 拟合高频率(>5kHz)需要高阶次N>50 Fitting for high Frequencies (>5kHz) requires high order N>50
- 测量点多、测量时间长 Many measurement points, long measurement time

解决方案 Solution:

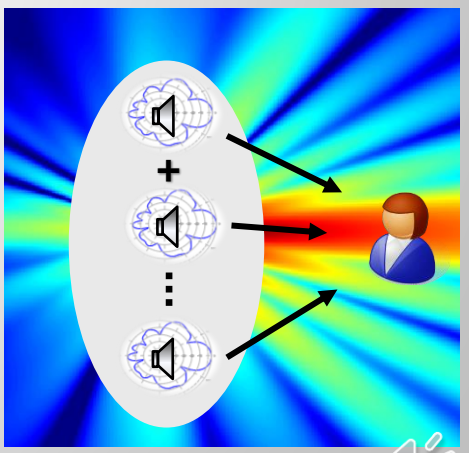
1) Measure each loudspeaker separately by using a multiplexer
使用多路复用器分别测量每个扬声器



2) Wave expansion of each loudspeaker
每个扬声器进行波展开



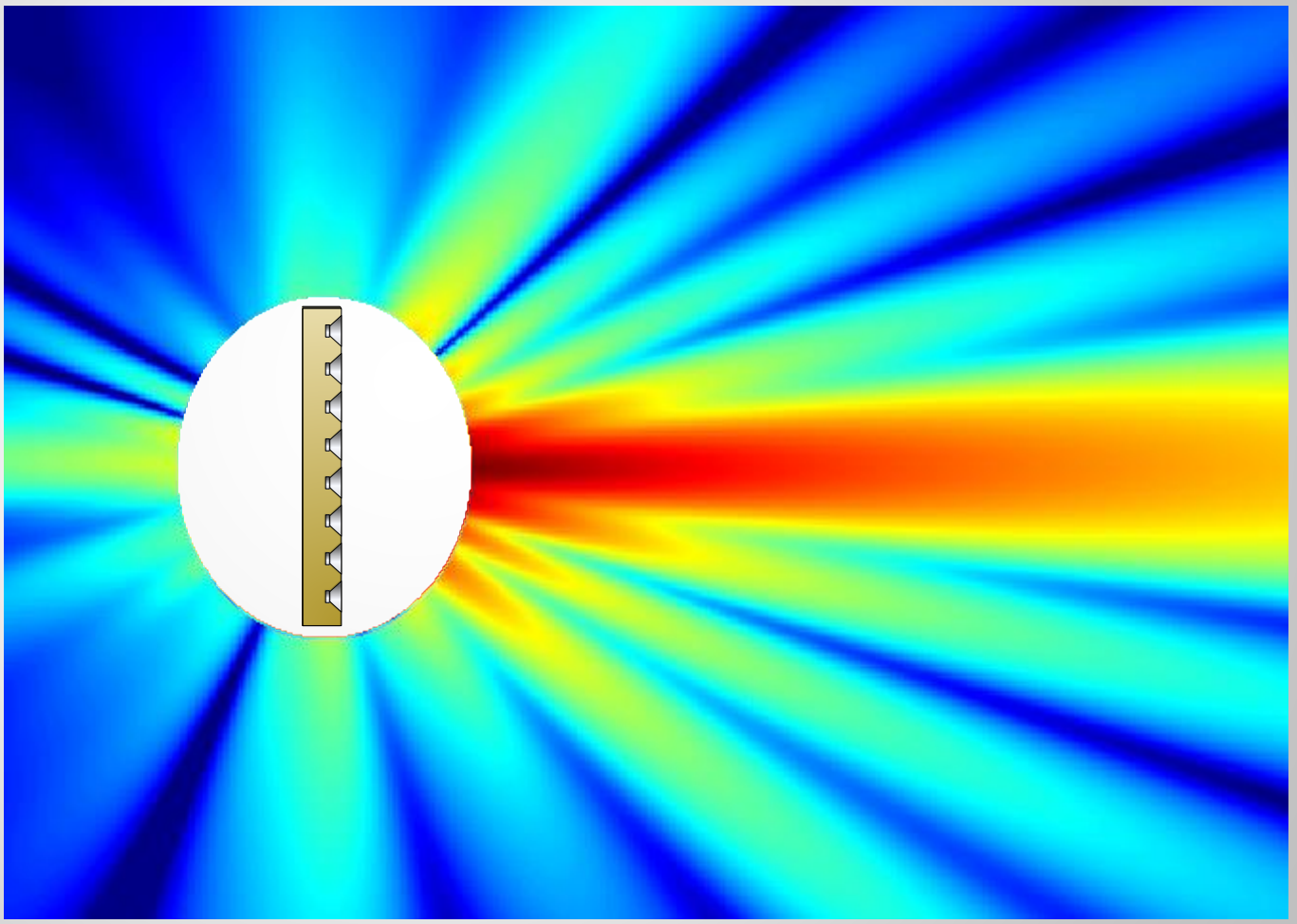
3) Super positioning of the multipoles
多源的叠加



Measurement of line sources 测量线源

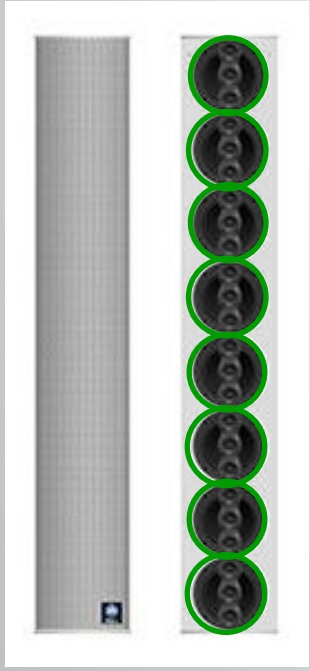
Super positioning of the multiple measurements 多个测量的叠加

2kHz

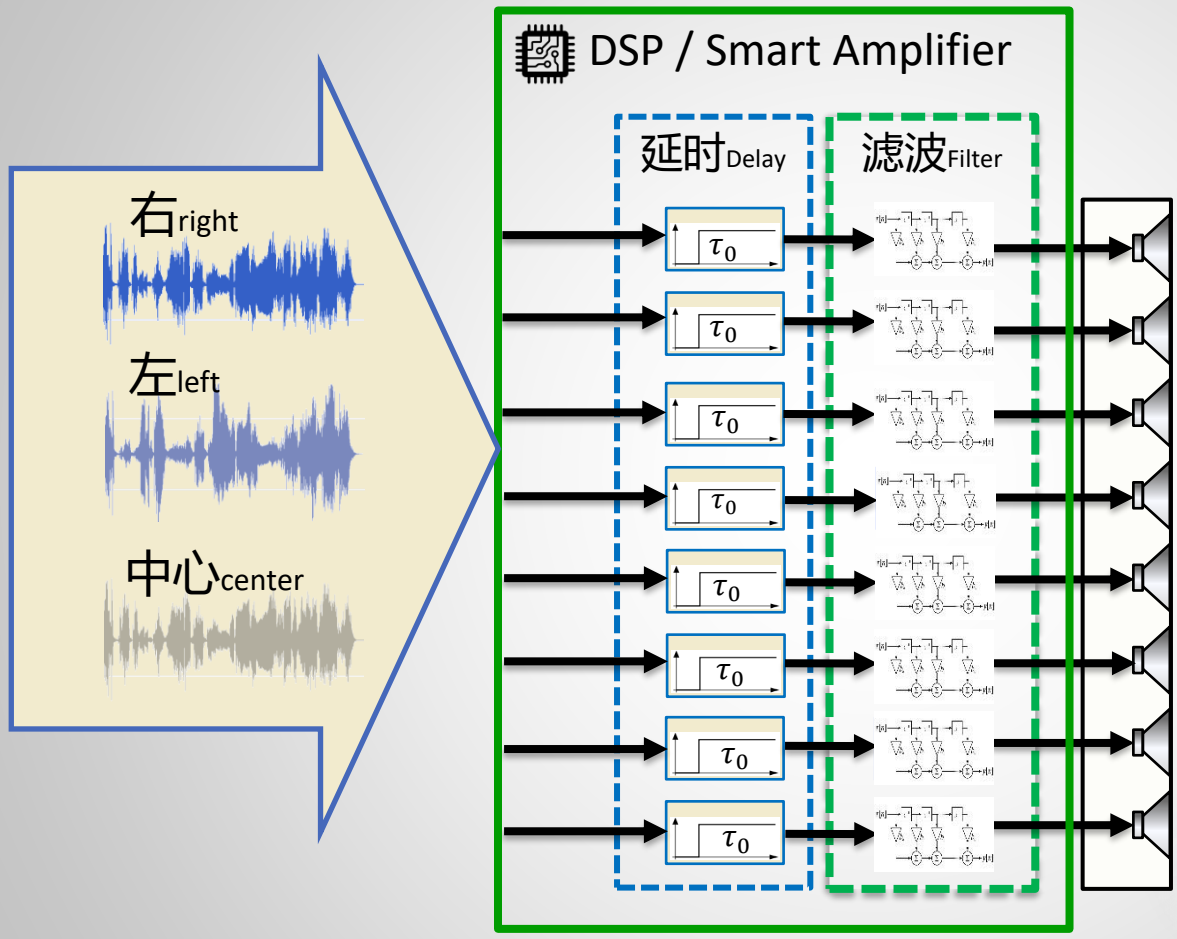


线阵列 Line Array:

- 8个同轴扬声器
  8 coaxial speakers
- 24个高音
  24 tweeter
- 8个多源的叠加
  Super position of 8 multipoles



Controlled directivity 受控指向性



总结 Summary

- IEC 60268-21 defines conventional directivity measurements and new techniques for assessing the complete 3D sound output

  IEC 60268-21定义了常规方向性测量和用于评估完整3D声音输出的新技术
- A holographic measurement models the sound pressure distribution outside of a scanning surface placed in the near-field of the speakers

  全息测量可模拟近场扬声器扫描面以外的声压分布
- A spherical wave model is well suited for loudspeakers giving maximum resolution using a few parameters

  球面波模型非常适用于扬声器，使用一些参数即可提供最高分辨率
- A holographic measurement performs a self-check and gives maximum accuracy for a minimum number of scanning points

  全息测量可进行自检，用最少扫描点数提供最高准确性
- Traditional characteristics (e.g. spin-o-rama) simplify the interpretation

  传统特征（例如spin-o-rama）简化了解读
- Mean values, variances can be calculated for sound zones for the particular application

  可为特定应用的声音区域计算均值和方差
- Reliable complex 3D output data for each transducer can be provided for beam steering and other DSP processing

  可为每个换能单元提供可靠的复杂3D输出数据，以进行光束控制和其他DSP处理

Open Questions 开放性问题

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

但是，大多数测量（例如失真、均衡）都可以在单个评估点进行!

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

我们可以在消声室外进行高精度的日常标准测量吗?

The 4th KLIPPEL live webinar will address:

第四期KLIPPEL在线研讨会将讨论：

- Simulation of free-field and far-field condition according IEC 60268-21
  根据IEC 60268-21的自由场和远场条件模拟
- How to compensate for room influence, different positioning and distance
  如何补偿房间、不同位置和距离的影响
- Can we use a fixed room compensation function for different types of speakers?
  我们可以为不同类型的扬声器使用固定的房间补偿函数吗?

Next Section

下一期内容

1. 现代音频设备需要基于输出的测试 Modern audio equipment needs output based testing
2. 普通房间中进行标准声学测试 Standard acoustical tests performed in normal rooms
3. 从3D输出测量中获取有意义的结论 Drawing meaningful conclusions from 3D output measurement
4. **评估点处的模拟标准条件 Simulated standard condition at an evaluation point**
5. 最大SPL – 赋予该值意义 Maximum SPL – giving this value meaning
6. 选择具有高诊断意义得测量 Selecting measurements with high diagnostic value
7. 幅值压缩 – 输入更高但输出更低 Amplitude Compression – less output at higher amplitudes
8. 谐波失真测量 – 最佳实践 Harmonic Distortion Measurements – best practice
9. 互调失真 – 音乐比单音信号更多 Intermodulation Distortion – music is more than a single tone
10. 脉冲失真 – 异音、异常行为、缺陷 Impulsive distortion - rub&buzz, abnormal behavior, defects
11. 标准条件下音频产品的基准 Benchmarking of audio products under standard conditions
12. 信号失真的可听化 – 感知评估 Auralization of signal distortion – perceptual evaluation
13. 为信号失真设定有意义的公差 Setting meaningful tolerances for signal distortion
14. 评定产品的最大SPL值 Rating the maximum SPL value for a product
15. 带无线音频输入的智能音箱测试 Smart speaker testing with wireless audio input