如何规定扬声器系统的品质？
How to Specify Sound Quality of Loudspeaker Systems ?

by Prof. Wolfgang Klippel,
Institute of Acoustics and Speech Communication
TU Dresden

Nov. 11 Wednesday. 14.00 p.m. Part 1:
•Definition of the Target Performance
•Active and Passive Loudspeaker Systems

Nov. 12 Thursday 8.30 a.m. Part 2:
• Loudspeaker Drive Units, Transducer
• Spiders, Cones, Surrrounds

“小扬声器发大声音”研讨会邀请函“

讲者： Wolfgang Klippel 科力普教授

声学与语言通讯学院/德累斯顿技术大学

Klippel 科力普有限公司

时间： 2009 年11 月16 日

地点： 北京市西城区复兴门外大街真武庙路1 号

北京市中国职工之家饭店

联系电话：+86-010-68576699

网址：http://www.zgzgzj.com/index.php?Locale=zh-cn

时间： 上午9 点-12 点

语言： 英文/中文

费用： 免费

内容： 现代扬声器设计与测量设计的研讨会与演讲（见下面摘要）

目标听众：扬声器研发，生技，品管工程师

电声相关专业如电机，机械，声学，物理，材料，工程专业的学生

邀请函

“在线终端测试应用中仪器和人耳可以相比吗?”

presented by

Prof. Dr. Wolfgang Klippel

Institute of Acoustics and Speech Communication/ University of Technology Dresden, KLIPPEL GmbH

日期: 2009年11 月16 日

地点: 地址：北京市西城区复兴门外大街真武庙路1 号

中国职工之家 电话：86-010-68576699

时间: 02:00 – 05:00 pm

英文: 英文/ 中文

费用: 免费

参与人员: 音频声学设备的设计和开发, 生产线品质控制工程师等.

注册: 音频技术(香港)有限公司 李汉文 先生
Apmanli@biznetvigator.com, or ManLi88@Hotmail.com or

Abstract:

This seminar focuses on the definition of technical specifications and measurement techniques used by suppliers, manufacturers and customers to assess the properties of loudspeaker parts, transducers and complete systems. The most important criterion for defining the target performance of a product, developing the first prototype and ensuring quality during end-of-line testing is the impact on the perceived sound quality. However, subjective evaluation performed in a special listening room or in a production environment is more time consuming and less reliable than objective measurements. A good loudspeaker engineer needs not only a sensitive ear but also a theoretical and practical knowledge in loudspeaker modeling and measurement to find the physical cause of the signal distortion. The seminar gives an overview on characteristics and measurement techniques as defined by international standards and new research projects to develop more comprehensive testing in R&D and QC application.

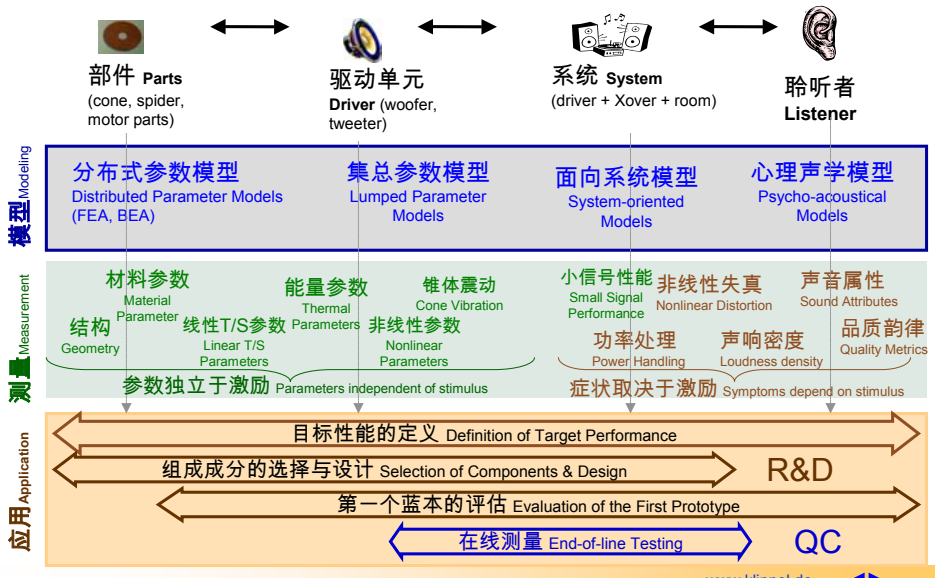
概要:

该研讨会主要讨论关于 技术规格的定义，供应商、制造商和客户使用的测量技术来评估扬声器部件、换能器和完整系统的性能。定义一个产品的目标性能、开发第一个样品和确保终端测试品质的最重要准则是对感受到的声音品质的作用。然而，与客观的测量相比，在特定的测试房里或生产线环境下的主观评价非常耗时且可靠性低。训练有素的扬声器工程师需要的不仅仅是灵敏的耳朵，而且还需要有扬声器模型及测量方面扎实的理论和丰富的实践知识，来查找出信号失真产生的物理原因。该研讨会对国际标准规定的规格和测量技术进行一个概述，同时研究一种新开发的、用于设计和开发以及品质控制的更加全面的测试方法。

研讨会提出的问题
Questions Raised in the Seminar

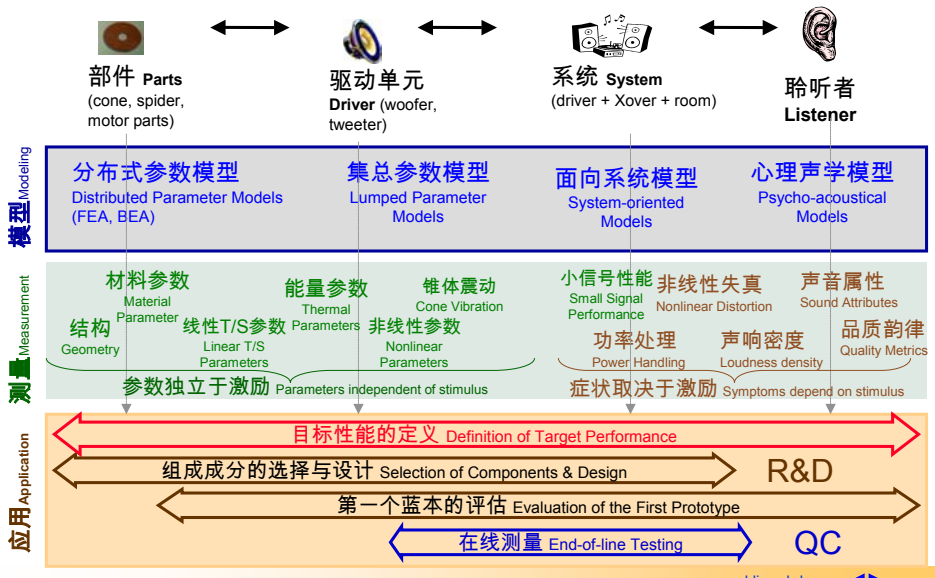
- 对客户、制造商和供应商来讲，哪个特性是最重要的?
  Which characteristics are important for customer, manufacturer and supplier ?
- 如何来定义目标性能特性?
  How to define the target performance ?
- „不良品“和“良品“如何定义?
  What is a „bad“ and a „good“ product ?
- 如何来寻找对特别的系统来讲最佳的换能器?
  How to find a transducer which is optimal for the particular system ?
- 如何来测量有源单元? How to measure an active system ?
- 如何连接R&D系统与在线测试系统的结果?
  How to link R&D with end-of-line testing ?

如何规定扬声器系统的品质?
How to Specify Sound Quality of Loudspeaker Systems ?



如何规定扬声器系统的品质？

How to Specify Sound Quality of Loudspeaker Systems ?



现代扬声器诉求

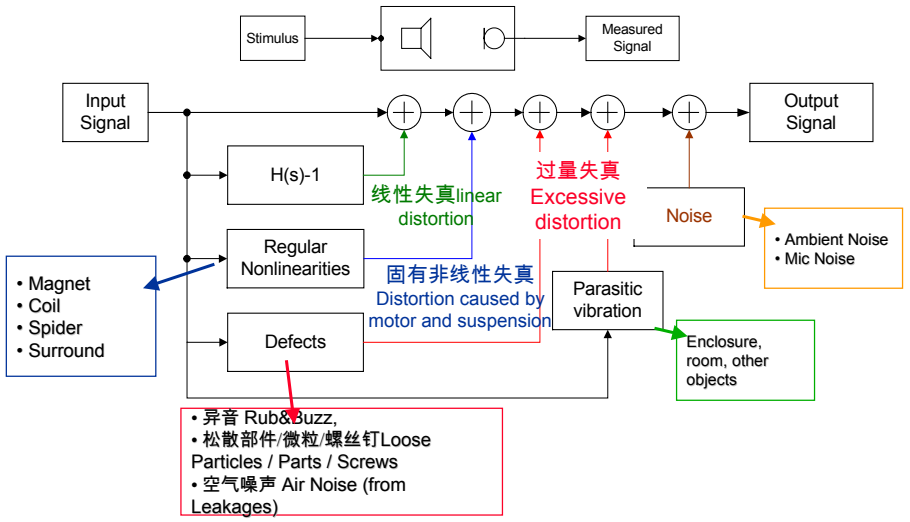
Requirements on Modern Loudspeakers

- 小体积 Small dimensions
- 轻重量 Low weight
- 少成本 Low cost
- 低失真大输出 High output at low distortion
- 最大效率 Maximal efficiency

→及再大声一些 “Loud“speakers are required

扬声器信号失真的产生

Generation of Signal Distortion in Loudspeakers



复制系统的关键点是什么?

What is the Critical Part In the Reproduction System ?

规格 Specifications

1. 小信号性能 Small Signal Performance
   - 幅度响应的平坦度
   - Flatness of amplitude response
   - 直射声音与散射声音的比率
   - Ratio of direct and diffuse sound
   - 响应精度
   - Impulse accuracy

2. 大信号性能 Large Signal Performance
   - 最大声学输出(SPL,POWER)
   - Maximal acoustical output (SPL, power)
   - 常规非线性失真
   - Distortion of regular nonlinearities (THD, IMD)
   - 非常规非线性失真
   - Distortion of irregular nonlinearities (rub &buzz)
   - 耐性,老化度,可靠性
   - Durability, ageing, reliability

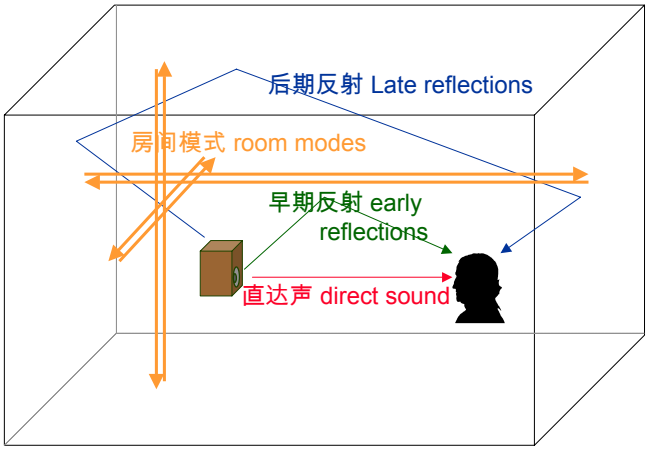
Influence of the Components

房间, 驱动单元,系统
room, driver,system
房间, 驱动单元,系统
room, driver,system
房间, 系统,驱动单元
room, system,driver

驱动单元,房间,系统
driver, room, system
驱动单元,系统
driver, system
驱动单元,系统
driver, system
驱动单元,系统
driver, system

与房间的交互作用范围

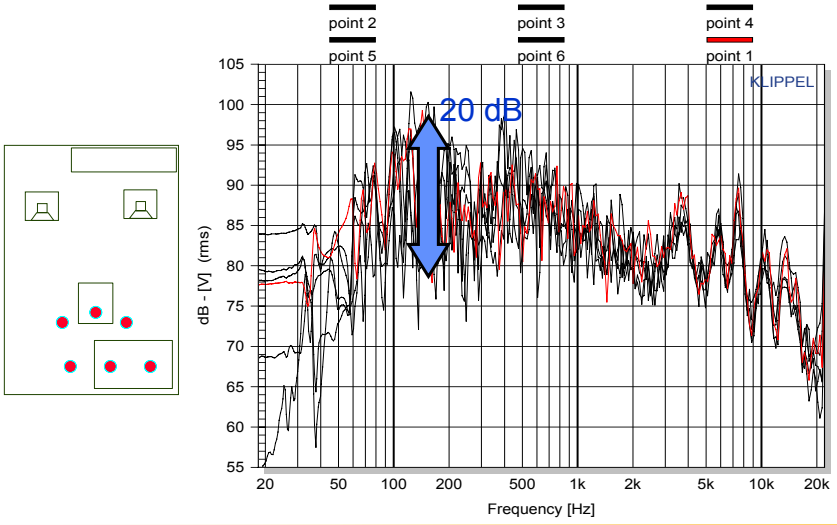
Interaction with the room



扬声器的哪些特性对此非常重要 Which loudspeaker properties are important for this ?

在住房中正常聆听范围内的声压级响应变化

Variation of SPL response within normal listening area in a living room



扬声器的设计始于声学目标环境的定义

Loudspeaker design starts with the definition of the acoustical target environment !

- **扬声器可以被使用在特定环境下吗? Is Loudspeaker used in a particular room ?**
  → 带中间性能或特殊喇叭的通用扬声器 universal loudspeakers with neutral properties or special speaker
- **原声源的数量及位置 Number and position of original sound sources**
  → 单声道或多声道系统 Single-channel or multi-channel system
- **原声源的指向性 Directivity of original sound source ?**
  → 直达声源 (歌手) 或扩散声源 (乐团) directed source (singer) or diffuse source (orchestra)
- **扬声器在房间里的位置 Position of the loudspeaker in room ?**
  → 固定安装在最佳位置或便携式使用 fixed installation at optimal position or portable use
- **聆听距离 Listening distance**
  → 固定在车内,多媒体或可变像便利产品上 fixed as in cars, multi-media or variable as in convenience products

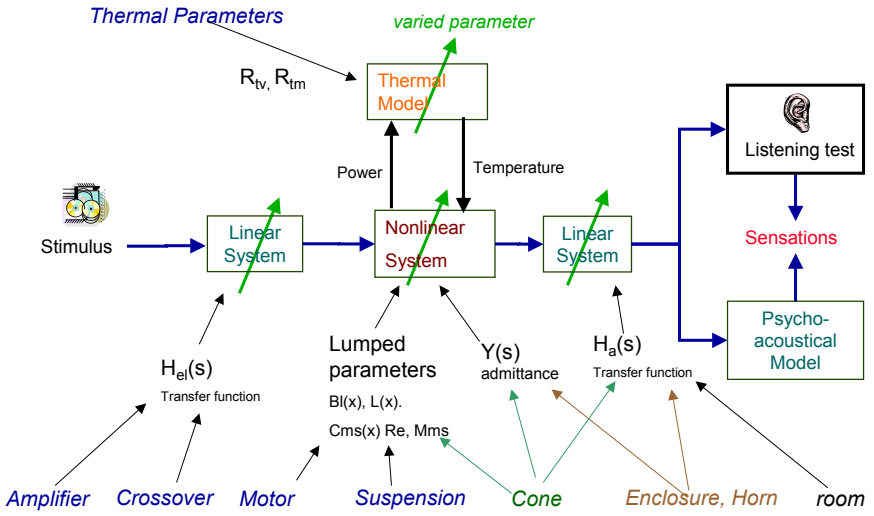
如何定义目标性能?

How to Define the Target Performance ?

1. 先前的开发经验及客户反映 Experience from previous development and customer response
2. 市场上有竞争力产品的评价 Assessment on competitive products in the market
3. 用数字扬声器模型在设计选择上用系统的聆听测试
   Systematic listening tests on design choices using digital loudspeaker modeling (auralization)

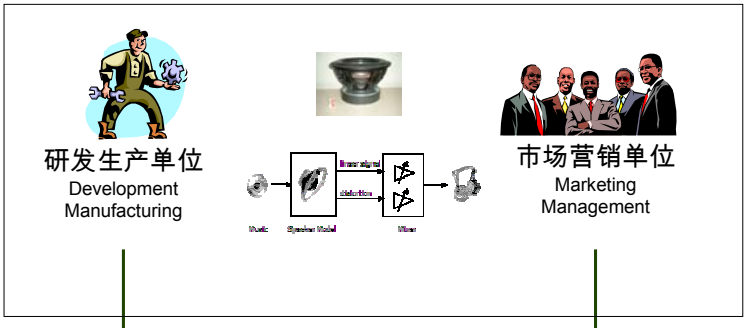
系统的聆听测试使用模拟和分解技术

Auralization – Systematic Listening Tests using Simulation and Decomposition Techniques



扬声器之主观及客观评价

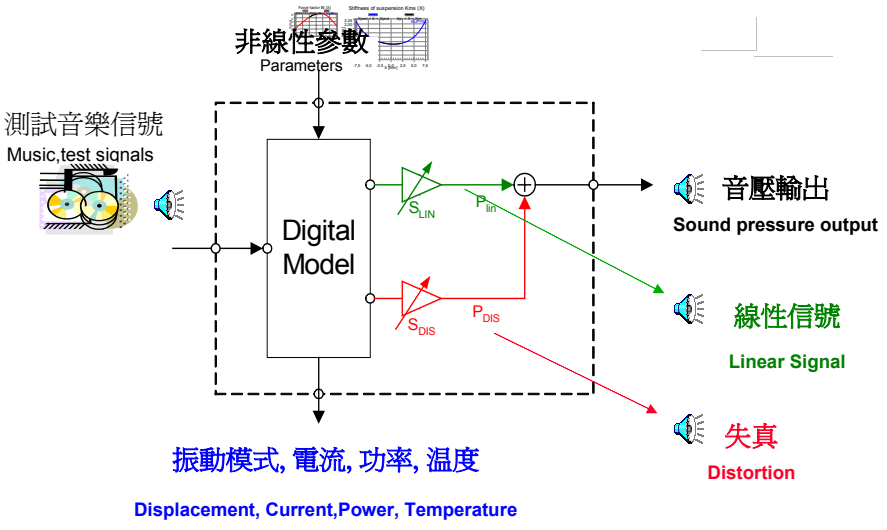
Auralization in Loudspeaker Development



客观评价 Objective Evaluation
- 失真, 最大输出 Distortion, Maximal Output
- 振动模式, 温升模式 Displacement, Temperature
- 设计选择的评估 Evaluation of Design Choices
- 指出改进方向 Indications for Improvements

主观评价 Subjective Evaluation
- 个人印象 Personal Impression
- 足够的音质 Sufficient Sound Quality
- 针对目标市场调适 Tuning to the target market
- 性价比(效益及成本比) Performance/Cost Ratio

聆聽分析失真信號
Listening into a Digital Model

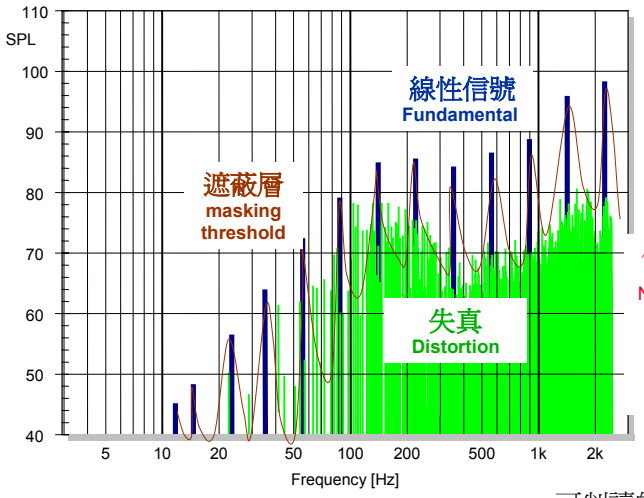


輸出範圍
Measurement of Safety Headroom

	S_{lin}	S_{DIS}	Example
理想揚聲器 Ideal Speaerk	0 dB	-100 dB	
	0 dB	-12 dB	
失真減少 Distortion decreased	0 dB	-9 dB	
	0 dB	-6 dB	
	0 dB	-3 dB	
實際揚聲器 Real Speaker	0 dB	0 dB	
	0 dB	3 dB	
可判讀層 threshold of audibility	0 dB	6 dB	
失真增大 Distortion increased	0 dB	9 dB	
	0 dB	12 dB	

輸出範圍相當於增大失真可判讀比
Safety Headroom = Increase of S_{DIS} to make distortion audible

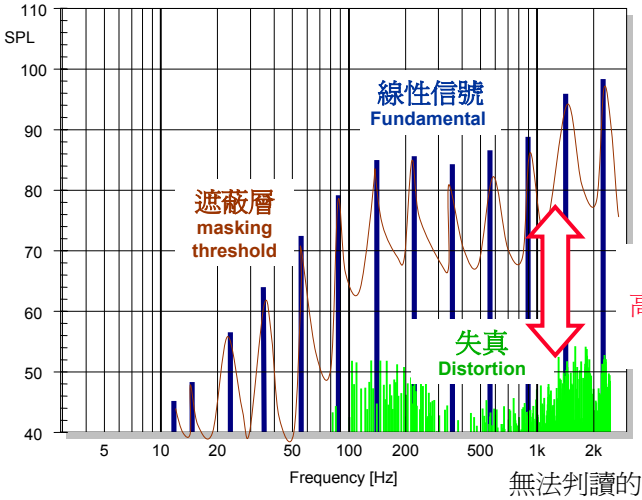
低品質揚聲器之輸出
Output of an Low-Quality loudspeaker



低輸出比範圍
No safety headroom

可判讀的失真信號

高品質揚聲器之輸出
Output of a High-Quality loudspeaker

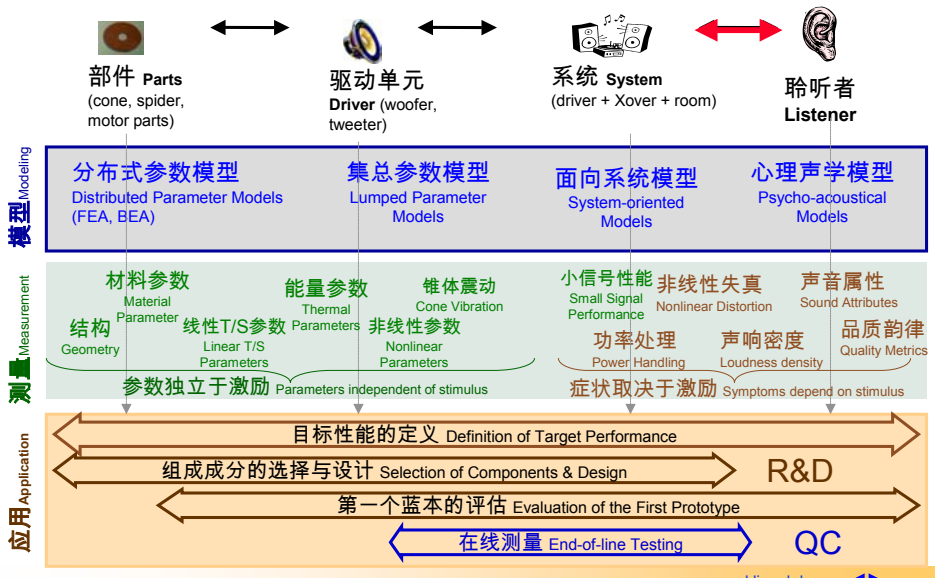


高輸出比範圍
High safety
headroom

無法判讀的失真信號

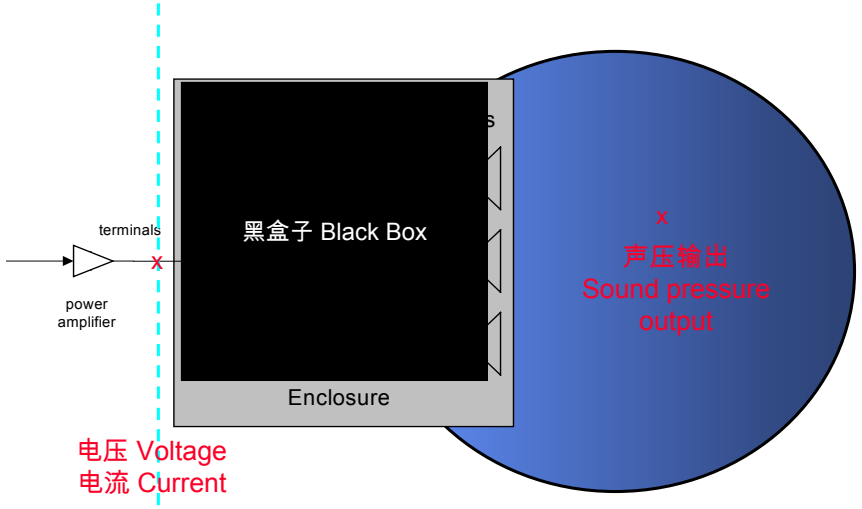
如何规定扬声器系统的品质？

How to Specify Sound Quality of Loudspeaker Systems ?

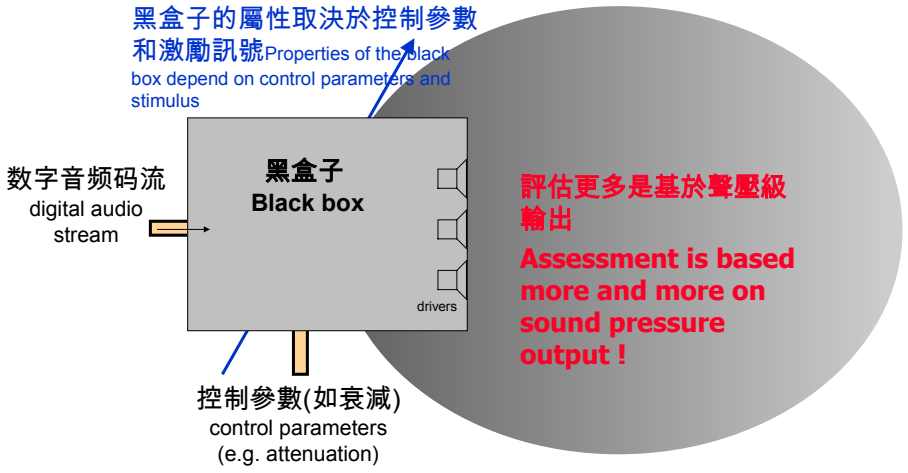


评估无源扬声器系统

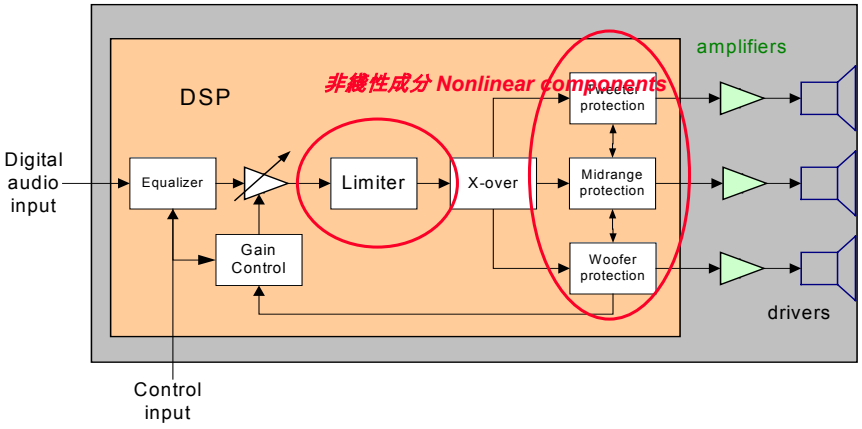
Assessing a Passive Loudspeaker System



有源扬声器系统
Active Loudspeaker Systems



有源揚聲器系統
Active Loudspeaker Systems



在訊號處理，功率放大因數與電聲訊號轉換之間整合
Integration between signal processing, power amplification and electro-acoustical conversion

IEC 60268-5規定的特性參數
Characteristics defined by IEC 60268-5

1. 阻抗 Impedance (rated value, Z(f)-curve, Qts, Vas)
2. 輸入電壓 Input voltage (rated noise, short + long term maximal)
3. 輸入功率 Input power (rated noise, short + long term maximal)
4. 頻率特徵 Frequency characteristics (rated range, fs, fvent)
5. 正頻帶內的SPL 1W的靈敏度 SPL in stated band, Sensitivity for 1 W
6. SPL響應 SPL response for voltage, H(f), effec. freq. range
7. 聲學輸出功率 效率 Output (acoustic) power, efficiency
8. 指向性 Directivity (pattern, rad. angle, index, coverage)
9. 幅度非綫性 Amplitude nonlinearity (THD, IMD)

IEC 60268-5規定的特性參數

Characteristics defined by IEC 60268-5

可以應用，需要修改，對有源喇叭系統是不適用的

can be applied, *need modification*, are not applicable to Active Loudspeaker Systems

1. 阻抗 Impedance (rated value, Z(f)-curve, Qts, Vas)
2. 輸入電壓 Input voltage (rated noise, short + long term maximal)
3. 輸入功率 Input power (rated noise, short + long term maximal)
4. 頻率特性 Frequency characteristics (fs, fvent)
5. *正頻帶內的SPL 1W的靈敏度 SPL in stated band,* Sensitivity for 1 W
6. *輸入電壓的聲學響應 SPL response* for voltage input, *H(f),* **effec. freq. range,**
7. *輸出聲功率 Output (acoustic) power,* efficiency
8. *指向性 Directivity (pattern,* **rad. angle, index, coverage**)
9. *幅度非綫性 Amplitude nonlinearity (THD, IMD)*

扬声器系统的评估

Evaluation of the Loudspeaker System

首个蓝本,竞争产品,最终产品 First Prototype, Competitive Product, Final Product

新的要求New Requirements:

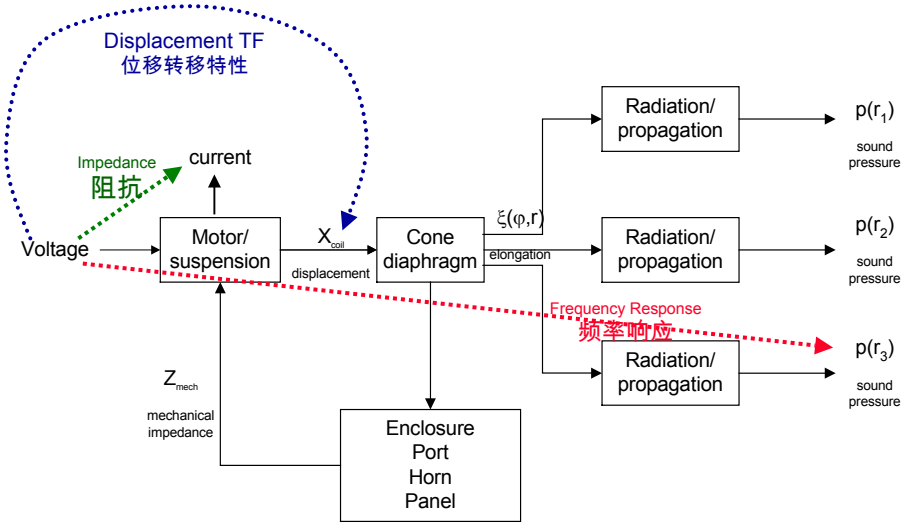
- 有源系统和无源系统 For active and passive systems
- 考虑与房间的交互作用 Consideration of room-interaction
- 最大声学输出的确定 Assessment of maximal acoustical output
- 不规则的扬声器缺陷 Irregular loudspeaker defects (rub, buzz, leakage, particles, loose conections)
- 全面的数据 Comprehensive (orthogonal) set of data
- 便于解释 Easy interpretation
- 将QC与R&D连接 Bridging QC and R&D

→ AES和IEC标准中关于“有源扬声器系统的测量”

→ Standard activities in AES and IEC about a „Measurement of Active Loudspeaker Systems“

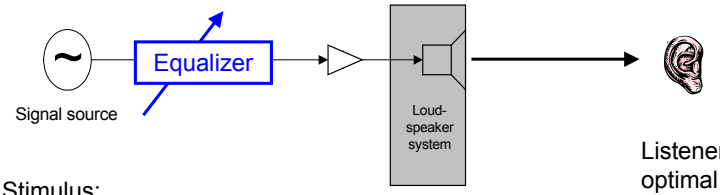
一个好主意: (线性的)转移特性

A good idea: (Linear) Transfer Functions



总声压级响应平滑度的试听测试之设置

Set-up of Listening Test on Smoothness of Total SPL Response



Optimal Stimulus:
Pink noise
最佳驱动：
粉红噪音

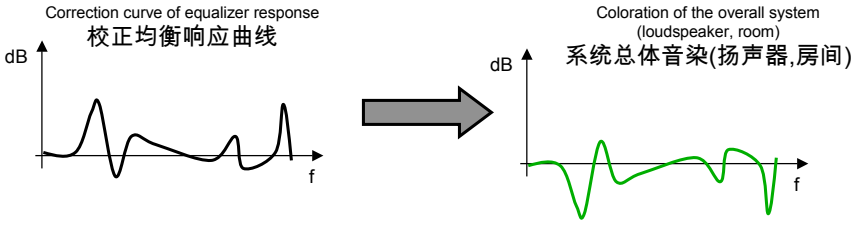
Compensate for coloration by adjusting the equalizer
通过调整均衡器以补偿音染

Listener at optimal position
聆听者在最佳位置

Subjective Criterion 主观标准:
• Spectral coloration 谱音染.

总声压级响应平滑度上试听测试的解读

Interpretation of Listening Tests on Smoothness of Total SPL Response



•System Alignment 系统定位 (woofer enclosure低音箱) → about fs (< 100 Hz) 共振频率 fs < 100 Hz

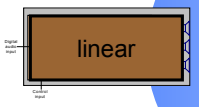
•Room modes 房间模式 → (below 500 Hz 低于500赫兹)

•crossover 交叉模式 → (above 500 Hz 高于500赫兹)

•Break up modes and radiation problems 分裂模式及辐射问题 → (above 500 Hz 高于500赫兹).

特性 哪一个是可以直接应用到有源扬声器系统的？

Characteristics which can directly be applied to active loudspeaker systems



所有相关的特性，不依赖于幅度，如：
All relative characteristics, which are independent of amplitude, such as

- 定向指数 directivity index
- 覆盖角度 coverage angle
- 辐射角 radiation angle
- 有效频率范围 effective frequency range
- 响应的平滑度 smoothness of the response

条件 Conditions:

- 仅仅基于声压输出 based on sound pressure output only
- 考虑声学输出信号的比率 ratio of acoustical output signals is considered
- 小信号模式下测量(限制器，保护，非线性等无效状态)
  measurement in small signal domain (limiter, protection, nonlinearities not active)
- 不依赖于一维的信号处理(均衡器)
  independent of one-dimensional signal processing (equalizer)

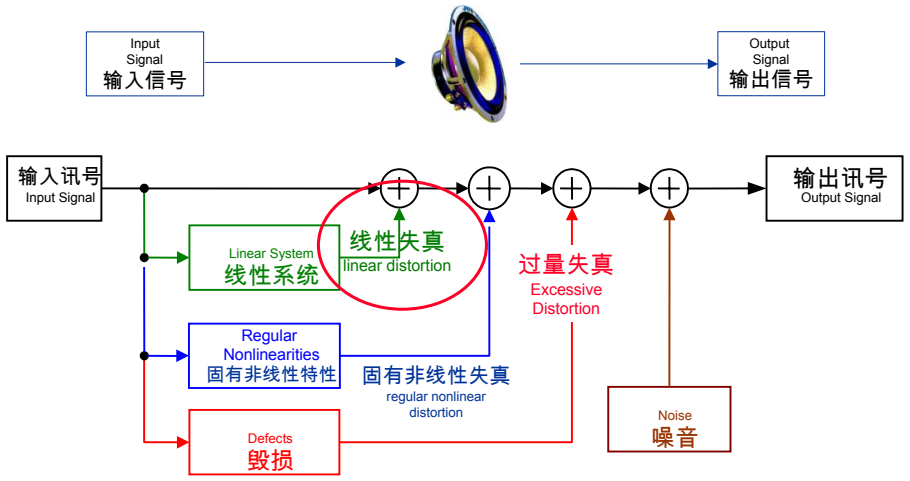
规格：小讯号性能

Specification: Small Signal Performance
有源和无源扬声器系统
Active and passive Loudspeaker System

- SPL沿轴方向的幅度响应 SPL on-axis amplitude response
  → 在无反射条件下 under anechoic conditions (IEC 60268-5)
- 指向性 Directivity
  → 定向指数 Directivity index $D_i(f)$
  → 声功率响应 or sound power response $P_a(f)$ (IEC 60268-5 Sec. 22.1)
- 群延迟 Group delay
  → 等待 latency
  → 变化与频率的关系 variation vs. Frequency,
  → 通道之间的变化 variation between channels

扬声器信号失真的产生

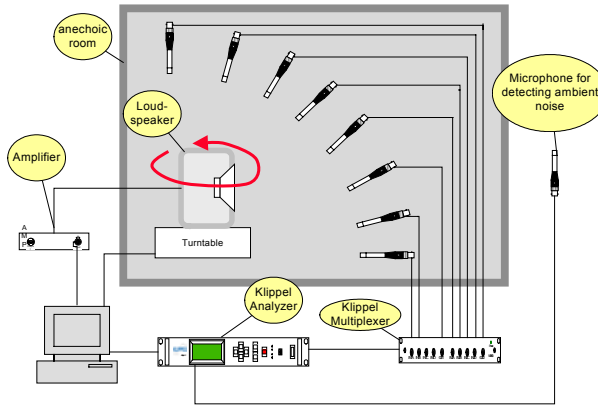
Generation of Signal Distortion in Loudspeakers



指向性测量設置

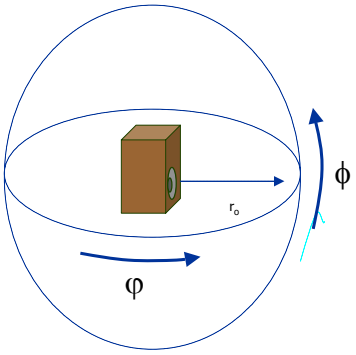
使用一個可調的和8+1麥克風

Setup of the Directivity Measurement using one turntable and 8+1 Microphones



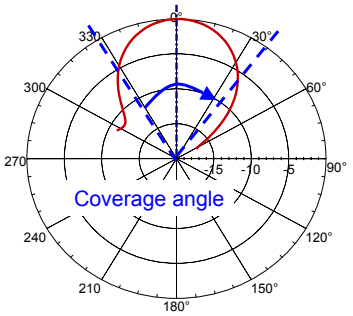
相對指向性特性

Relative Directional Characteristics



- 發散角 Radiation angle
- 定向指數 Directivity index
- 象場角 Coverage angle

  → 可以應用於有源系統 can be applied to Active Systems

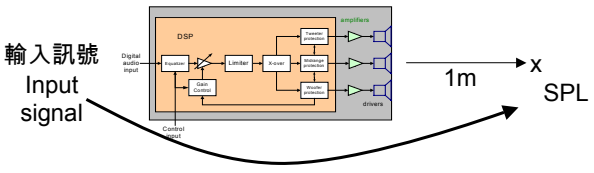


1 kHz

現存的可用標準 Existing standards can be used:
→AES 5id –1997 (1998),
→IEC 60268-5 Paragraphs 23.2, 23.3. 23.4

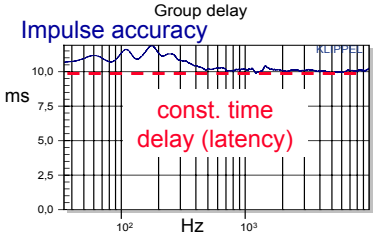
傳遞函數的相關信息(小訊號模式)

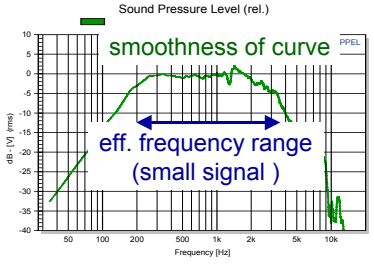
Relevant information of the Transfer Function H(f)
(small signal domain)



相位響應 Phase response
群延遲 Group delay

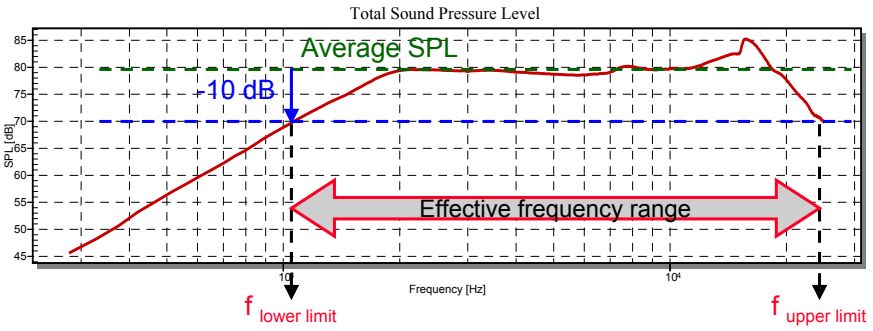
Rel. Amplitude response





有效频率范围

Effective Frequency Range



IEC 标准60268-5段落21.2可以应用到有源扬声器系统。
IEC Standard 60268-5 Paragraph 21.2 can be applied to Active Loudspeaker Systems

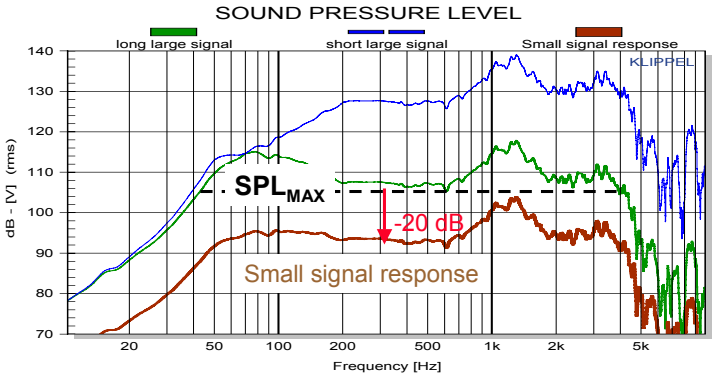
小信号响应

Small Signal Response

用IEC60268-5标准24.2部分作小量修改后测量
is measured by IEC 60268-5 section 24.2 with a minor modification:

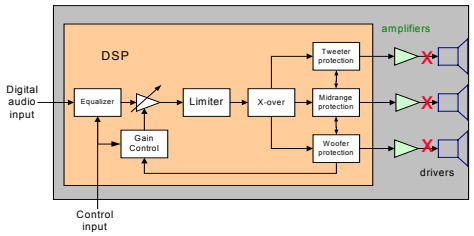
激励讯号校准到声压输出比最大输出SPLmax小-20dB.

the stimulus U is adjusted to give an output which is smaller than SPL_{MAX} -20 dB for $f_{lower,I} < f < f_{upper,I}$



不能用于有源扬声器系统的特性

Characteristics which can not be applied to Active Loudspeaker Systems

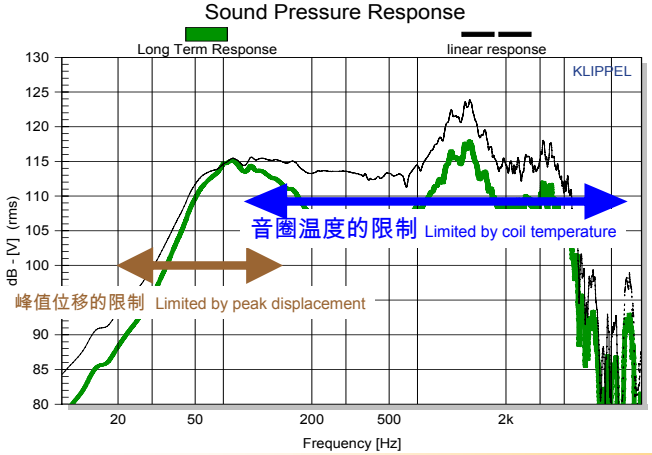


不能连接到扬声器端
no access to terminals of the transducers

- 电压,电流→功率→效率→灵敏度
- voltage, current → power → efficiency → sensitivity
- 阻抗 impedance
- 线性参数 linear parameters (Re, fs, Qts, fbox, Vas)
- 非线性参数 nonlinear Parameters (Bl(x), Kms(x), ...)
- 热量特性 thermal characteristics (Tv, resistances, time constants)

最大声压级

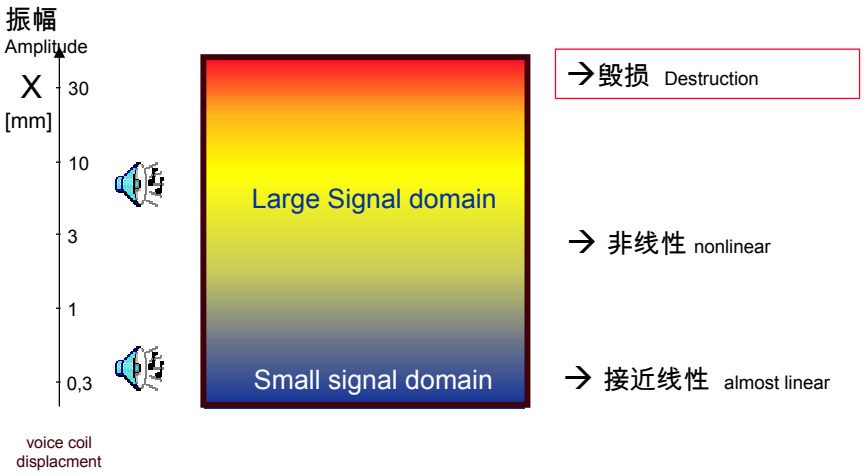
Maximal Sound Pressure Level
长时间的响应影响的因数
factors limiting long term response



长时间响应是用步进正弦信号来测量

Long term response was measured by using a stepped sine wave (1 min on/1 min off cycle)

扬声器的工作效益
Performance of Loudspeakers



受因数限制的最大输出
Factors limiting maximal output

峰值位移 Peak displacement
- 换能器非线性 →失真,压缩
  Transducer nonlinearities → distortion, compression
- 机械保护系统→基本信号的衰减
  Mechanical protection system→ attenuation of bass signal

加快 Acceleration
- 锥体,线圈→机械部分的损坏
- Cone, coil → Damage of the mechanical parts

线圈温度 Coil temperature
- Re的增加→功率压缩→热损伤
  Increase of Re → Power compression → thermal damage
- 热保护系统→总信号的衰减
  Thermal protection system → attenuation of total signal

放大器的输出电压峰值 Peak voltage at amplifier output
- 放大器削波→强大的失真
  Amplifier clipping → impulsive distortion
- 限制,增益控制,保护 Limiter, gain control, protection

规格：大信号性能表现

Specification: Large Signal Performance

有源和无源扬声器系统

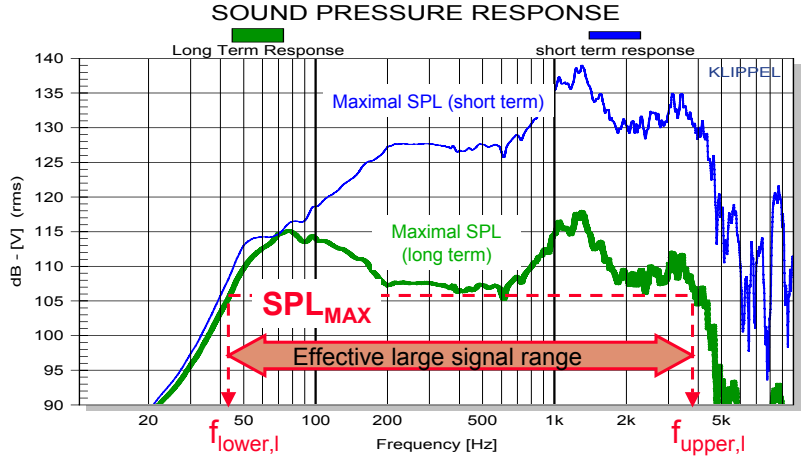
Active and passive Loudspeaker System

- **最大SPLmax ,** 频率范围内，无反射条件下，轴向距离1m
  Maximal SPL_{max} at 1 m, on-axis anechoic conditions, in frequency range
- 有效频率范围(上限和下限)
  Effective frequency range (Upper and lower limits $f_{lower,l} < f < f_{upper,l}$)
- 轴向上响应的平坦度(轴向上SPL响应与平均值的最大偏离)
  Flatness of on-axis response (maximal deviation of SPL on-axis response from mean SPL)
- 谐波失真(等效的输入失真)
  Harmonic distortion (Equivalent input distortion)
- 互调失真(声音和低音扫描)
  Intermodulation distortion (voice and bass sweep)
- 激烈的失真(峰值)表征rub&buzz,松散微粒
  Impulsive distortion (peak, crest) indicating rub&buzz, loose particles
- 调制噪声(MOD)表征空气泄漏
  Modulated noise (MOD) indicating air leakage
- 在加速寿命测试中验证耐久性
  Durability verified in accelerated life test

定义声学输出 SPLmax

最大有效信号范围内的

Defining the Acoustical Output SPL_{MAX} in the effective large signal range $f_{lower,l} < f < f_{upper,l}$



新的输出特性

New Output-Based Characteristics:

定义:SPLmax 在有效的大讯号范围内长时间SPL响应的最低能量值，轴向1m距离处无反射条件下测量。

Definition: SPL_{MAX} is the minimum of the long-term SPL response in the effective large signal range
$f_{lower,l} < f < f_{upper,l}$, measured on-axis in 1m distance under anechoic conditions.

制造商规定的样例 Example as specified by a manufacturer:

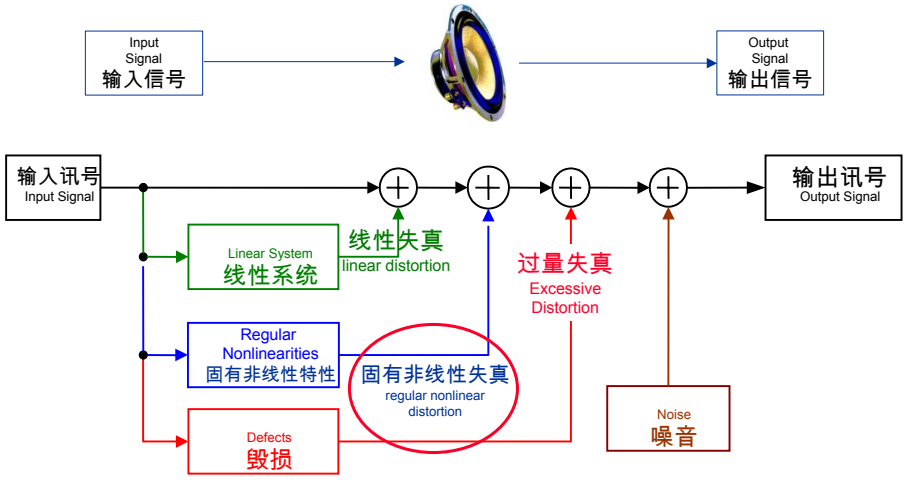
$SPL_{MAX,}$ *=120 dB for 70 Hz < f < 5kHz*

注意 Note:

- **使用小的频率范围SPLMAX 有可能增加。**
  SPL_{MAX} may be increased by using a smaller frequency range
- **SPL_{MAX}考虑的是基本成分的非线性和能量压缩而不是非线性失真**
  SPL_{MAX} considers nonlinear and thermal compression of the fundamental but NOT nonlinear distortion

扬声器信号失真的产生

Generation of Signal Distortion in Loudspeakers

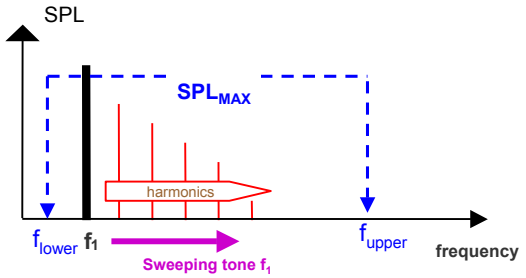


谐波失真 THD @ SPL_{MAX}

Harmonic Distortion for example THD @ SPL_{MAX}

根据IEC60268-5 24.2部分的描述作微量修改来测量：
is measured by IEC 60268-5 section 24.2 with a minor modification:

- 激励信号U校准到产生的输出SPL(f)>= SPL_{MAX}
  the stimulus U is adjusted to give an output SPL(f) ≥ SPL_{MAX} for $f_{lower,I}$ < f < $f_{upper,I}$

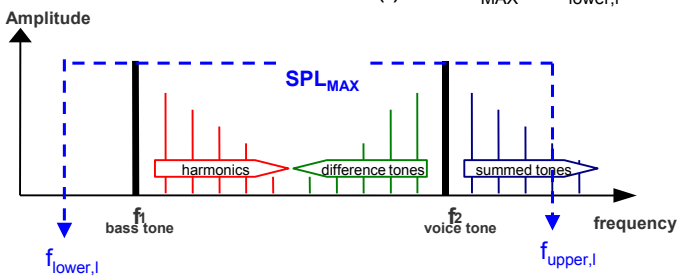


互调失真 IMD @ SPL_{MAX}

Intermodulation Distortion IMD @ SPL_{MAX}

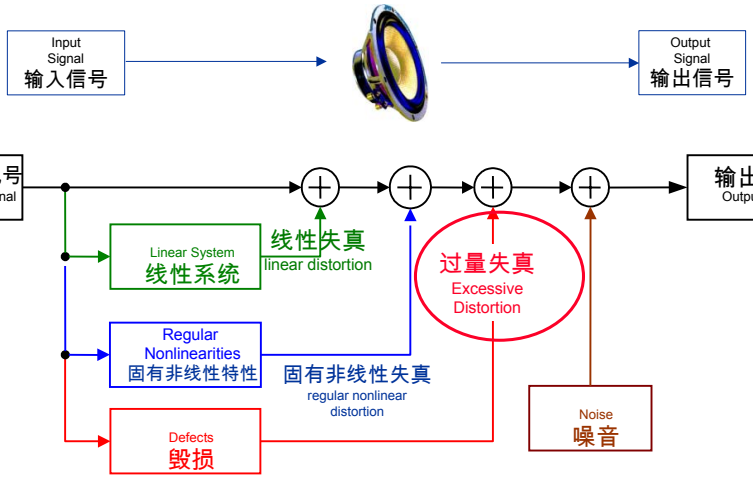
根据IEC 60268-5 24.5部分描述作少量修改来测量：
is measured by IEC 60268-5 section 24.5 with a minor modification:

激励信号U校准到声压级输出SPL(f)>=SPL(max)
the stimulus U is adjusted in such a way that the sound pressure level of the fundamentals SPL(f) ≥ SPL_{MAX} for $f_{lower,I}$ < f < $f_{upper,I}$



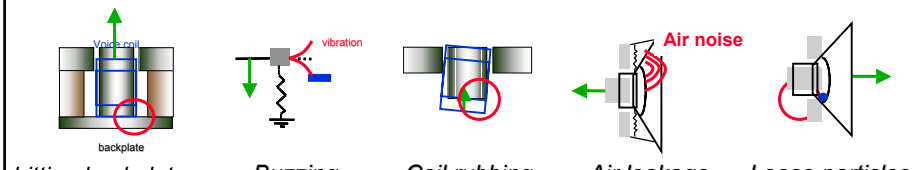
扬声器信号失真的产生

Generation of Signal Distortion in Loudspeakers



扬声器缺陷的模型

Modeling of Loudspeaker Defects



确定的过程
Deterministic Process

半随机过程
Semi-Random Process

随机过程
Random Process

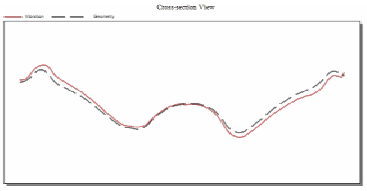
可重现的
reproducible

确定性和随机过程的调制
Deterministic Modulation of a random process

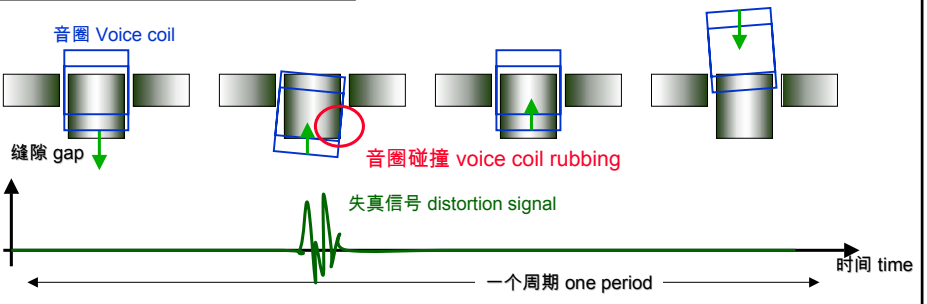
不可预知的
Not predictable

扬声器缺陷:音圈碰撞

Loudspeaker Defect: *voice coil rubbing*



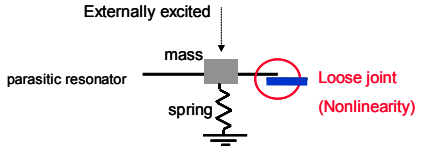
在328 Hz 处可能产生摇摆
Rocking mode may cause at 328 Hz

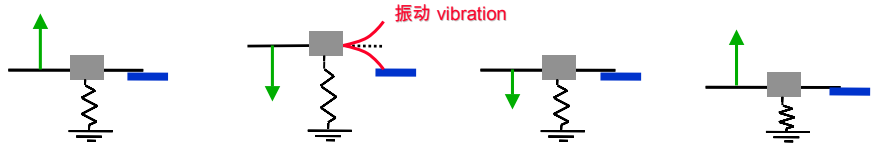


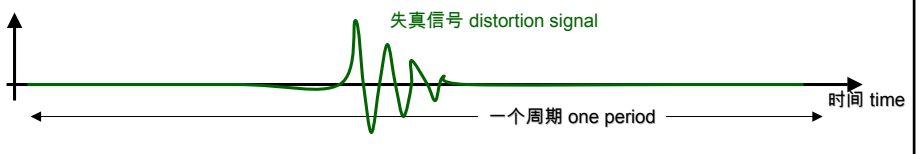
扬声器缺陷: 嗡嗡声问题

Loudspeaker Defect: *Buzz problem*

大多数缺陷表现为非线性振荡器
Most defects behave as a **nonlinear oscillator**
- 在一定的幅度以上起效用
  active above a critical amplitude
- 新的振动模式
  new mode of vibration
- 由激励信号驱动并同步
  powered and synchronized by stimulus
- 恒定的输出功率
  constant output power

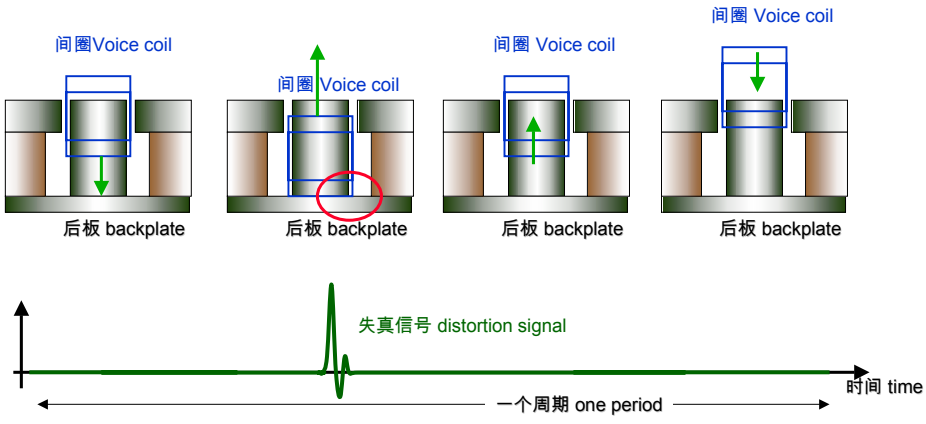






扬声器缺陷: 音圈撞击后板

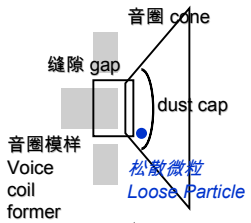
Loudspeaker Defect: *voice coil hits the backplate*

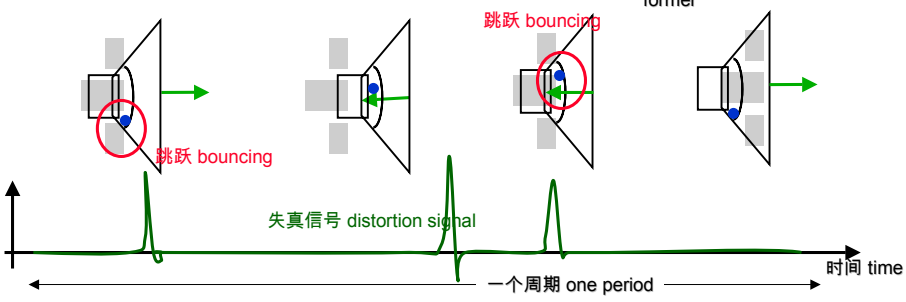


扬声器缺陷: 松散微粒

Loudspeaker Defect: *Loose Particles*

- 随机过程 stochastic process
- 微粒由音圈的位移控制加速 particles are accelerated by cone displacement
- 与激励信号不同步 not synchronized with stimulus
- 恒定的输出功率 constant output power





寻找一个最佳的激励信号

Searching for an optimal Stimulus
可闻的音圈撞击声
Audibility of Voice Coil Rubbing

Signal	Stimulus	Output 1V	Output 2V	Output 3V
Music				
Multi-Tone 20 Hz – 20 kHz				
Multi-Tone 20 Hz – 1 kHz				
Sinussoidal Sweep 1 s				

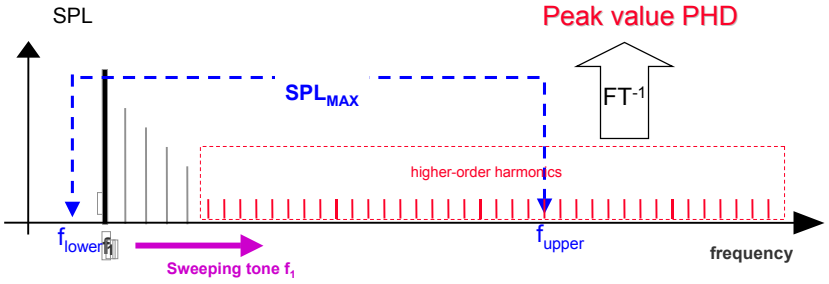
Most sensitive Stimulus

脉冲失真测量 PHD(f) @ SPL_{MAX}

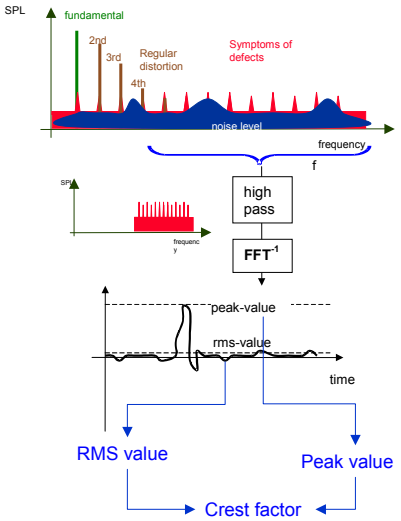
Impulsive Distortion Measurement PHD(f) @ SPL_{MAX}

校准激励信号U，产生输出SPL(f)>=SPLmax,在时域上测量的高次谐波(n>20)失真的峰值

The peak value PHD of the higher-order harmonics (n> 20) measured in the time domain while adjusting the stimulus U to produce an output $SPL(f) \geq SPL_{MAX}$ for $f_{lower} < f < f_{upper}$



时域分析
Time Domain Analysis



解决方法:返回到时域

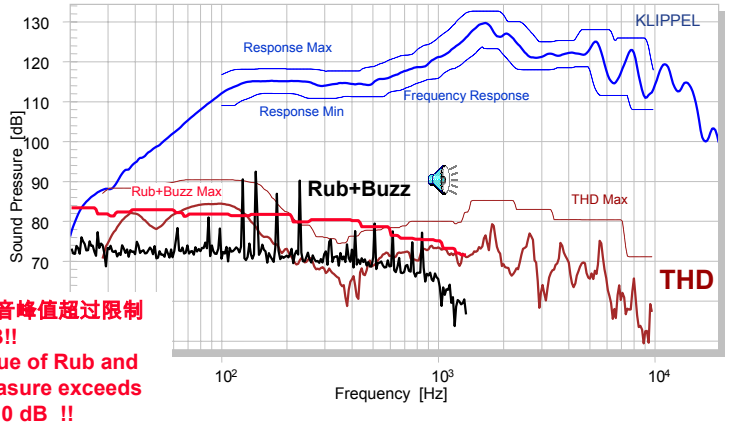
Solution: back to the time domain

- → 高次谐波的峰值振幅和相位
  Peak exploits amplitude and phase of higher-harmonics
- → 峰值揭示短暂的瞬间 peak value reveals small transients (clicks)
- → 峰值和有效值的比值给出失真的波峰因数 Ratio between peak and rms value gives crest factor of distortion
- → 常规失真产生很低的波峰因数 regular distortion generates low crest factor
- → 大多数缺陷产生很高波峰因数的征兆 most defects generate symptoms with high crest factor

非常小的松散微粒
Very Small Loose Particle

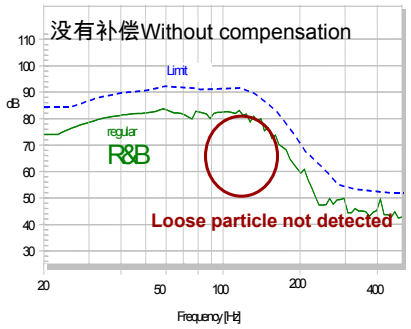
些许细盐 one grain of fine salt

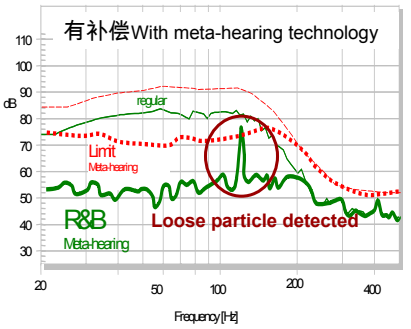
正弦激励
Sinusoidal
Stimulus



测量的异音峰值超过限制条件10dB!!
Peak Value of Rub and Buzz measure exceeds limit by 10 dB !!

目标: 可靠的测量 Target: Reliable Measurement
超听力技术的好处 Benefits of Meta-hearing Technology:



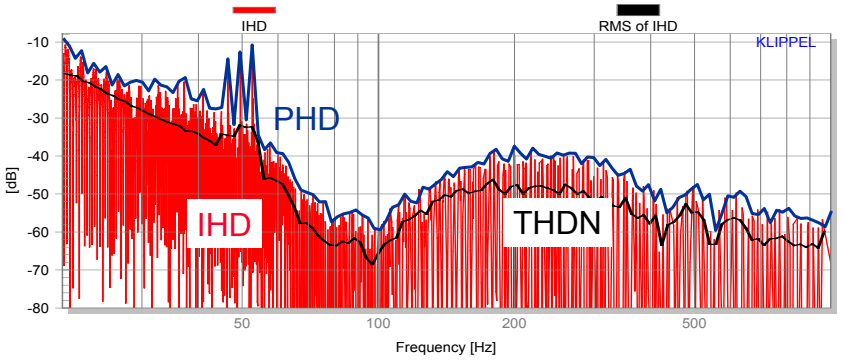


→ 简单地定义PASS/FAIL极限 Simple definition of PASS / FAIL thresholds

→在听力极限下测量 Measurement below the hearing threshold

谐波失真
Harmonic Distortion

驱动信号: 正弦扫频 Stimulus: Sinusoidal sweep



瞬时谐波失真 Instantaneous harmonic distortion

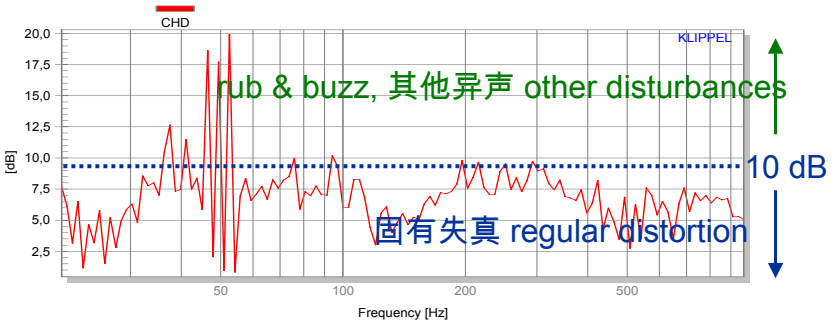
谐波失真的平均值 Mean value of harmonic distortion

峰值谐波失真 Peak harmonic distortion

谐波失真的峰值因子

Crest factor of harmonic distortion (CHD)

驱动信号: 正弦扫频 Stimulus: Sinusoidal sweep

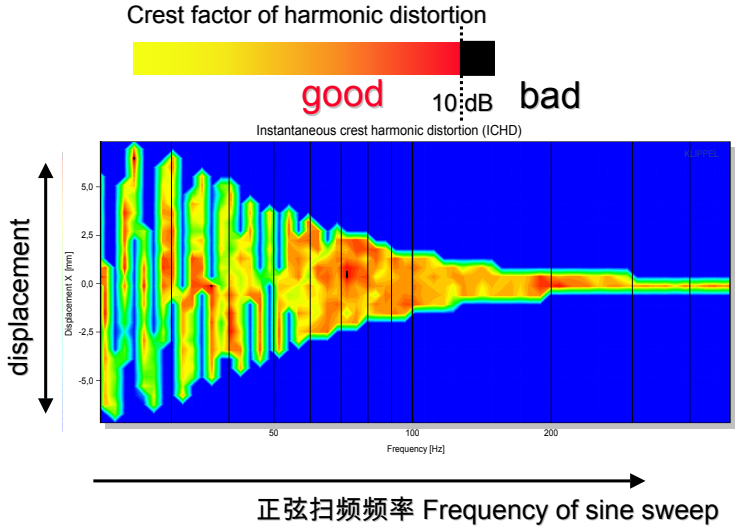


谐波失真峰值因子可以在绝对标度上被解释！

CHD can be interpreted on an absolute scale ！

检查: 谐波失真的峰值因子

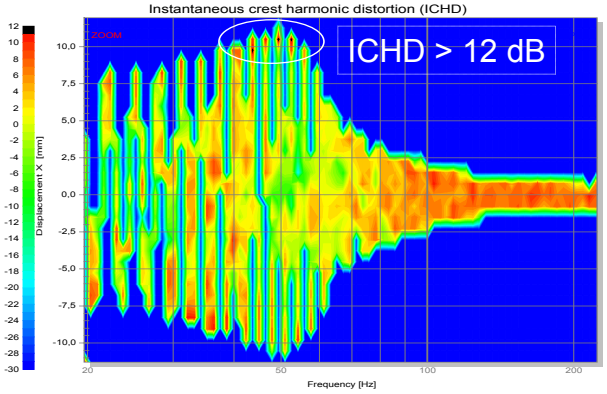
Check: crest factor of harmonic distortion



瞬时峰值谐波失真

Instantaneous crest harmonic distortion ICHD(f,x)

案例A: 毁损单体接线敲打 Case A: „beating wire of a defect driver“



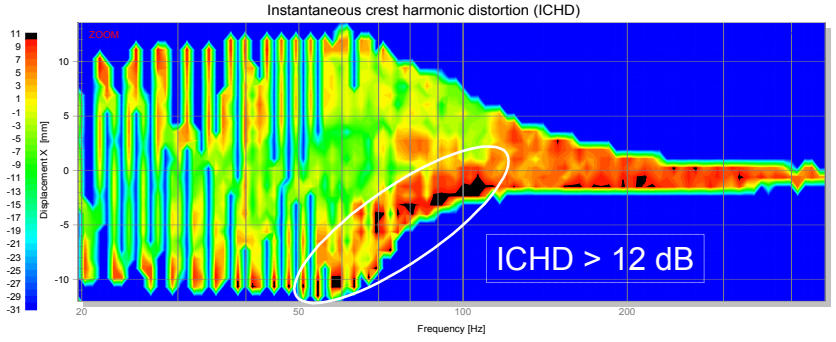
毁损出现在50赫兹 + 10 mm 位移处

Defect occurs at + 10 mm displacement at 50 Hz

瞬时峰值谐波失真

Instantaneous crest harmonic distortion ICHD(f,x)

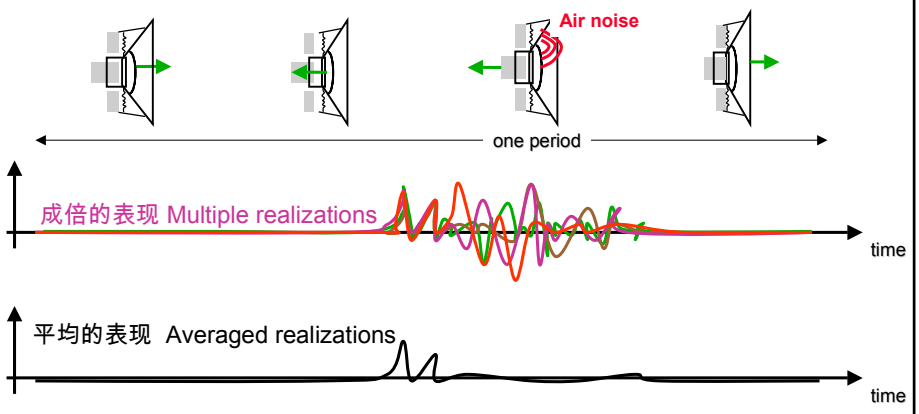
案例B: 毁损单体音圈摩擦 Case B: „rubbing voice coil of a defect driver“



初始摩擦条件 Conditions initiating rubbing:

- 负转折点的音圈偏移 Negative turning point of voice coil excursion
- 共振频率之上 (质量主导) → 音圈倾斜
  Above resonance frequency (mass dominant) → Tilting of voice coil former

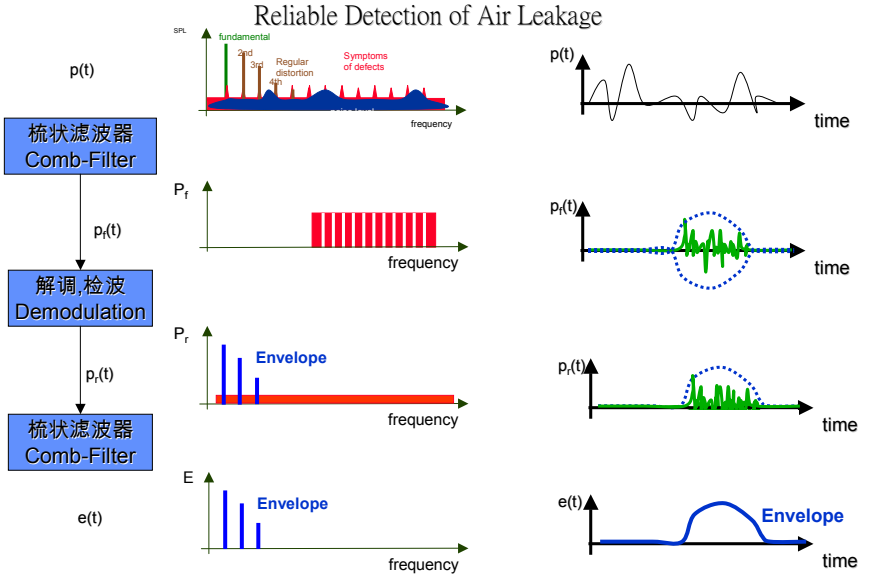
随机噪声是个有价值的征兆
Random Noise is a valuable Symptom



→ 平均方法来抑制随机成分 Averaging suppresses the random component

空气泄漏的可靠检测

Reliable Detection of Air Leakage



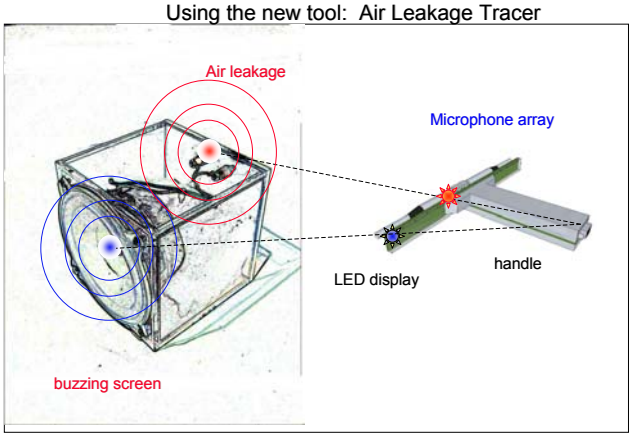
→可以使用大功率的调制噪声信号 Full power of the modulated noise can be used

DEMO

Vented box system with air leakage

空气泄漏的定位
Localization of Air Leakage

使用新的工具: 空气泄漏跟踪器
Using the new tool: Air Leakage Tracer



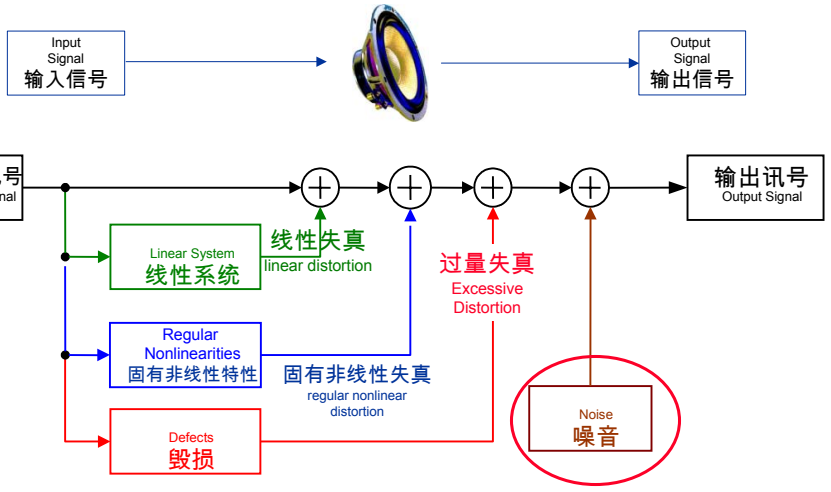
•两通道解调技术来估算麦克风信号之间的时间延迟

Time delay between the microphone signal is estimaten by Two-Channel demodulation technique

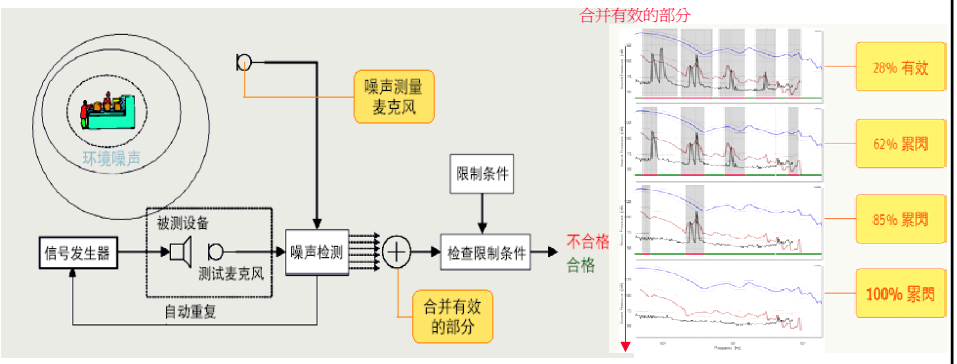
•LED显示空气泄漏的角落
LED display shows the angle of the incident sound

•少数测量显示确定的和随机的声源
A few measurements shows the source of deterministic and random sound

扬声器信号失真的产生
Generation of Signal Distortion in Loudspeakers



环境噪声免疫 - Noise Immunity

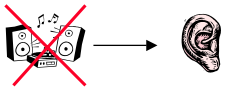


生产线上的环境噪声可以由置于远场的第二个麦克风来监测。被环境噪声干扰的测量结果会自动重复测量，每个测量结果都会保存并整合，最后提供有效的测量结果。尽管每个单一的测量都被环境噪声干扰，也确保了完全的生产线环境噪声免疫

什麼是不良的揚聲器系統？

What is a Bad Loudspeaker System ?

特性不能為人們所接受 Properties which are not acceptable – k.o. criteria



- 由不規則的非綫性(rub,buzz,鬆散微粒，鬆動的電氣連接)產生的激烈的失真

  Impulsive distortion generated by irregular nonlinearities (rub, buzz, loose particles, loose electrical connection)
- 密閉体的空氣洩漏或鬆動的防塵蓋產生重大的空氣噪聲

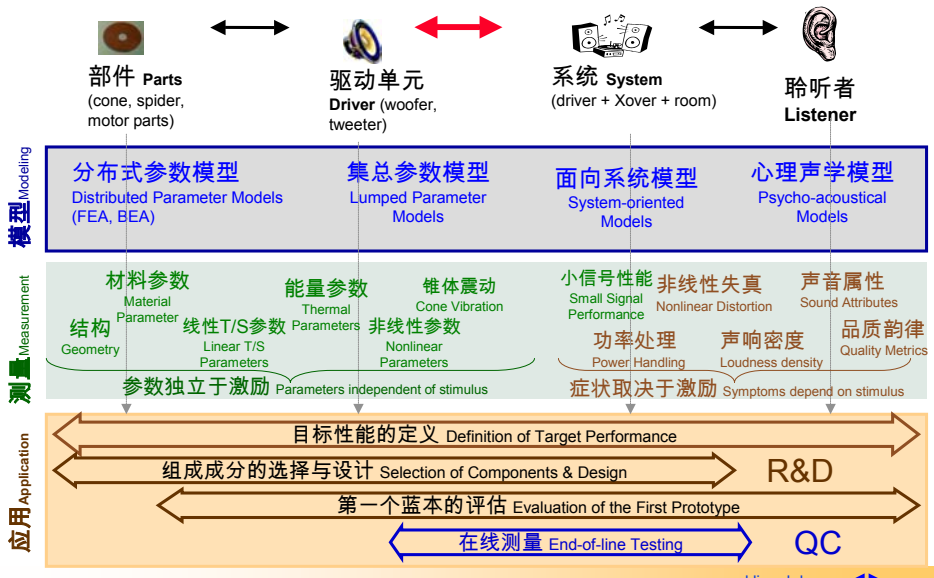
  Significant air noise caused by a leakage in the enclosure or a loose dust cap
- 驅動不穩定和嚴重的不對稱產生過量的非綫性失真

  Excessive nonlinear distortion caused by motor instability and severe asymmetries
- 左右通道之間的時間延遲有很大不同

  Significant differences in time delay between left and right channel

如何规定扬声器系统的品质?

How to Specify Sound Quality of Loudspeaker Systems ?



如何來指定最佳的換能器 ?

How to Specify the Optimal Transducer ?

參數給出全面的數據
Parameters give a comprehensive set of data !!

1. 參數(獨立于激勵訊號)Parameters (independent of stimuli)
   - 聲學轉移函數 Acoustical transfer functions
   - 機械轉移函數 Mechanical transfer functions
   - 小訊號參數 Small signal parameter T/S
   - 大訊號參數 Large signal parameters (thermal, nonlinear)

轉換成參數
Should be transformed into parameters

2. 基於激勵訊號的特性 Stimulus-based Characteristics
   - 最大SPL Maximal SPL
   - 非線性失真(THD，IMD，XDC) Nonlinear distortion (THD, IMD, XDC)
   - 不規則缺陷的症狀 Symptoms of irregular defects (rub, buzz, leakage,...)
   - 線圈溫度，壓縮，Pmax Coil temperature, compression, Pmax

換能器的參數不依賴激勵訊號

Parameters of the Transducer independent of stimulus

1. 驅動和懸邊的線性集總參數 Linear lumped parameters of Motor and Suspension
   → T/S parameters (Re, Mms, Rms, ...), lambda ()
2. 驅動和懸邊的非綫性集総參數 Nonlinear lumped parameters of motor and suspension
   → Bl(x), Le(x), Kms(x), Le(i)
3. 能量參數 Thermal parameters
   → thermal resistances Rtv, Rtm and capacities Ctv, Ctm
4. 綫性分佈的機械參數 Linear distributed mechanical parameters
   → mechanical transfer function $H_x(r_c,j\omega)$, cone geometry z(r), AAL response
5. 遠場的聲壓響應 Sound pressure far field response (transducer in infinite baffle)
   → acoustical transfer function $H_c(r_a,j\omega)$, on-axis SPL response, directivity
6. 機械或聲學負載 Mechanical or acoustical load
   → Mechanical Admittance $Y(j\omega)$ of the coil

什么是良好单元？

What is a good drive unit ?

一般而言 In General:

- 扬声器非线性低不对称度产生低直流位移，同时让线圈保持在磁隙中
  Low asymmetries of loudspeaker nonlinearities generates low dc displacement and keeps coil in the gap
- 低的爬升因子把劲度保持在低频处，保持直流位移最小
  Low creep factor maintains stiffness at low frequencies to keep dc-displacement minimal
- 耦合系数非线性与感应系数非线性是相互平衡的
  Force factor nonlinearity is balanced with inductance nonlinearity
- 足够的劲度和Bl稳定性来确保驱动单元的稳定性
  Enough stiffness and Bl plateau to ensure motor stability
- 在Xmax处不规则非线性不会产生冲动的失真成分
  No impulsive distortion generated by irregular nonlinearities below Xmax
- 能量压缩与机械压缩是相互平衡的
  Thermal compression is balanced with mechanical compression

揚聲器系統設計

Loudspeaker System Design

1，目標性能以及系統參數的定義

Definition of target performance and constraints

2，各個組成成分(DSP,放大機,換能器)之間的接口的定義

Defining the interface between the components (DSP, amplifier, transducers)

3，各個組成成分的規格 Specification of the components

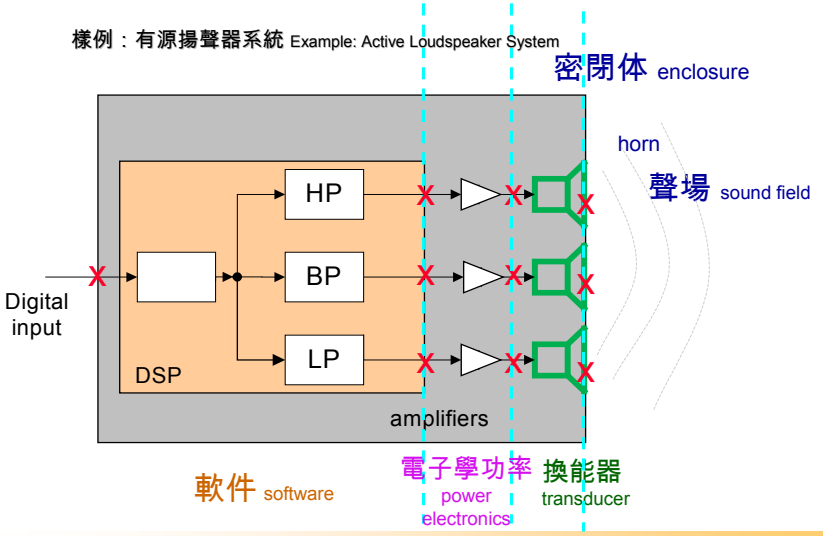
4，組成成分的選擇 Selecting the components

5，組建第一個原型 Building the first prototype

6，性能的確認 Verification of the performance

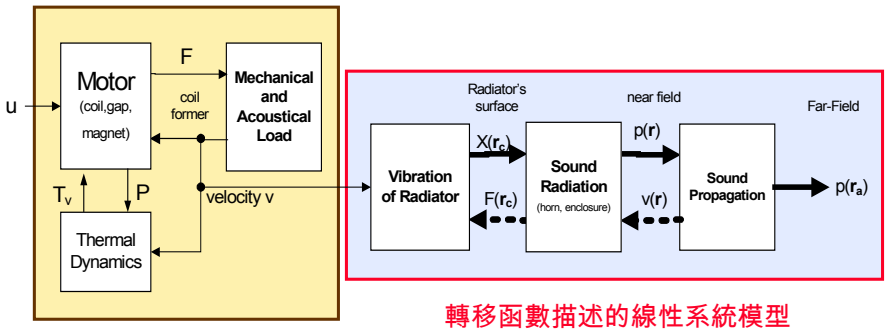
切入点 在信號處理，電子的，換能器，聲學環境之間

Interfaces between Signal Processing, Electronics, Transducer, Acoustical Environment



換能器的訊號流程圖

Signal Flow Chart of the Transducer



轉移函數描述的線性系統模型

Linear system modeled described by transfer function $H(f,r_a)$

集總參數模型描述的非線性系統

Nonlinear system described by lumped parameter model

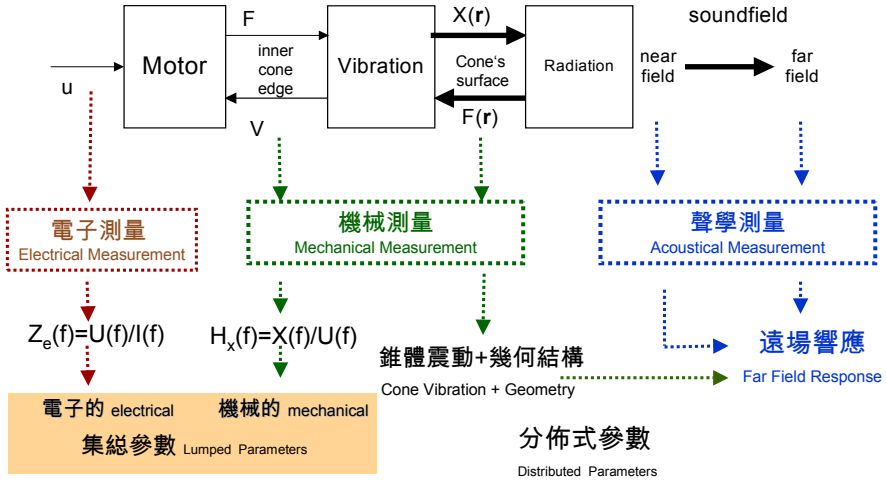
線性參數 Linear Parameter (T/S)

非線性參數 Nonlinear Parameters (Bl(x), Kms(x))

能量參數 Thermal Parameters

測量 是揚聲器診斷的基礎

Measurements are the basis for loudspeaker diagnostics



Cone Scanning Techniques振膜掃描技術

Amplitude振幅

Amplitude+ phase
振幅+相位

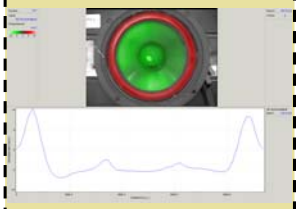
Amplitude振幅
+ phase 相位
+ geometry 幾何形狀

Olson, 1950

Frankort 1978

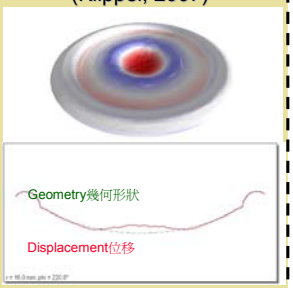
Intensity強度

Doppler Interferometry
杜普勒干涉激光掃描
(Polytech, 1995)

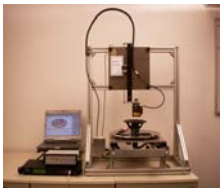


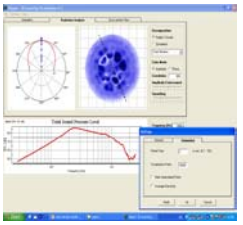
Velocity destribution on the cone
錐體速率分布

Triangulation Laser Scanner
三角測量激光掃描儀
(Klippel, 2007)



扬声器设计的新工具
New Tools for Loudspeaker Design





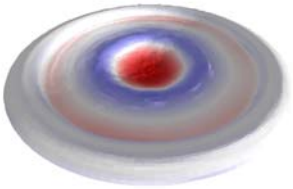
扫描设备 Scanner Hardware

- 致力于扬声器设计 Dedicated to loudspeakers
- 经济的价格 Price effective
- 扫描几何形状Scanning geometry
- 更多其它的应用 Many other applications

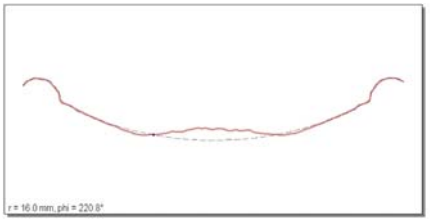
软件分析 Analyzer Software

- 振膜振动运动可视化 Visualization of cone vibration
- 输出声压的预测 Prediction of sound pressure output
- 指向性 Directivity
- 可分解 Decomposition

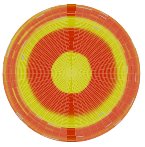
振动数据可视化
Visualization of Vibration Data



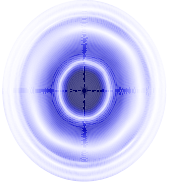
三维动画 3D Animation



横断面削减 Cross-sectional Cut

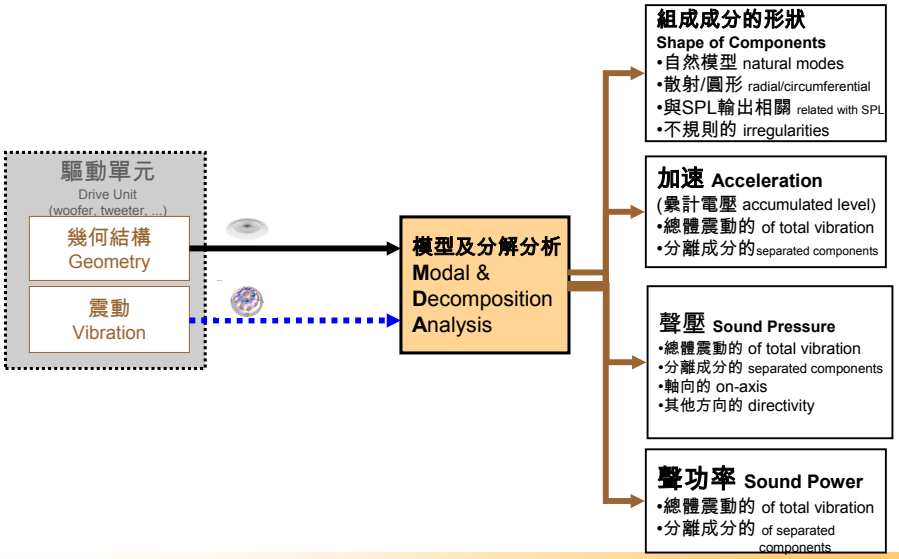


相位分布 Phase Distribution

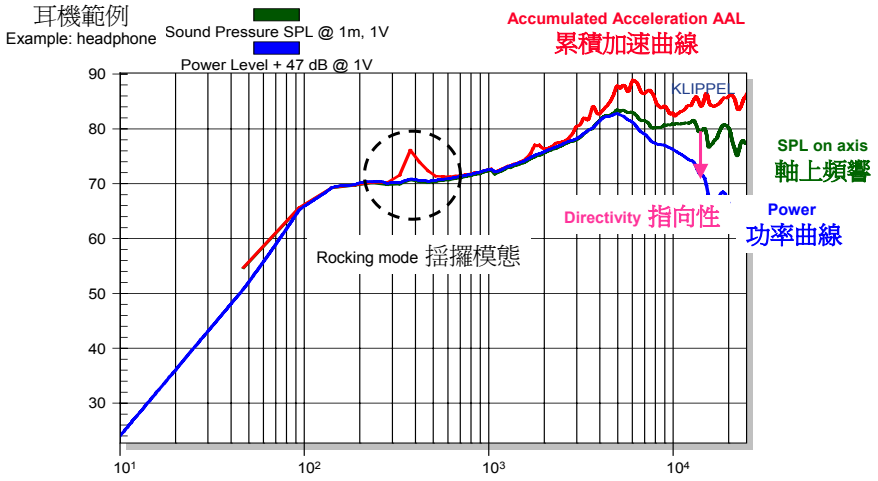


振幅分布 Amplitude Distribution

依掃瞄資料作振動及輻射診斷
Vibration and Radiation Diagnostics based on Scanning Data



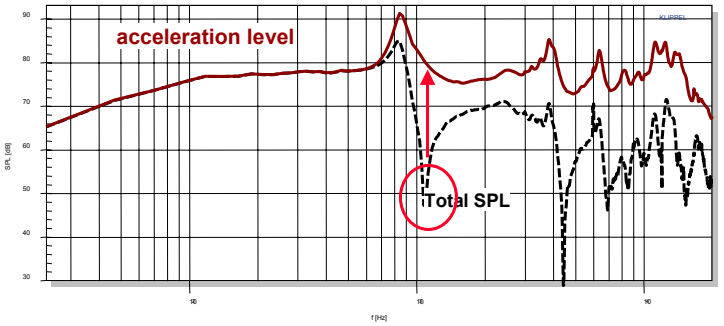
重要結論
Most important Results



爲何產生頻響上的低谷?
What causes the dips in SPL ?
Woofer C with flat radiator

→纍積加速與SPL的比較

Compare Accumulated Acceleration (AAL) with sound pressure (SPL)



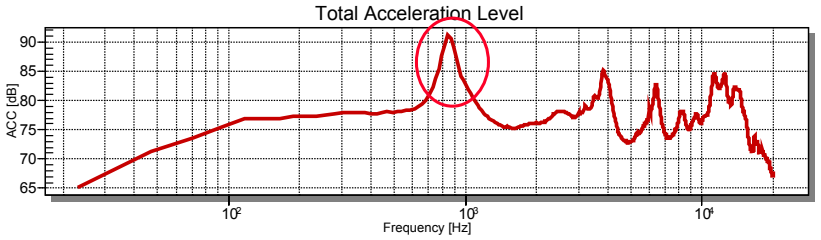
錐體上有足夠的震動！！→ 發射問題

There is enough vibration on the cone !! → Radiation Problem

材質有足夠的阻尼嗎?

Sufficient Damping of the Material ?

Woofer C with flat radiator



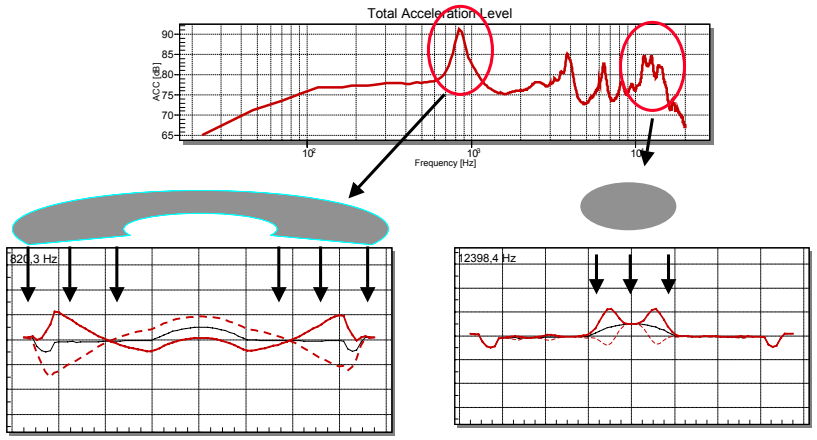
Read 3dB bandwidth in AAL

$$\eta_i = \frac{f_{i+} - f_{i-}}{f_i} = \frac{80}{840} \approx 0.1$$ →增加材料的損耗阻尼 Increase loss factor of material

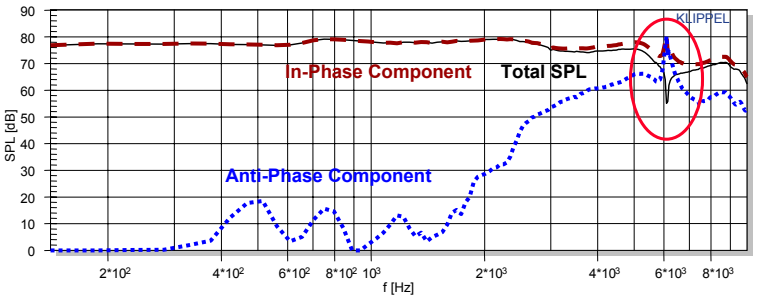
在何處增加阻尼?

Where to apply additional damping ?

woofer C with flat radiator

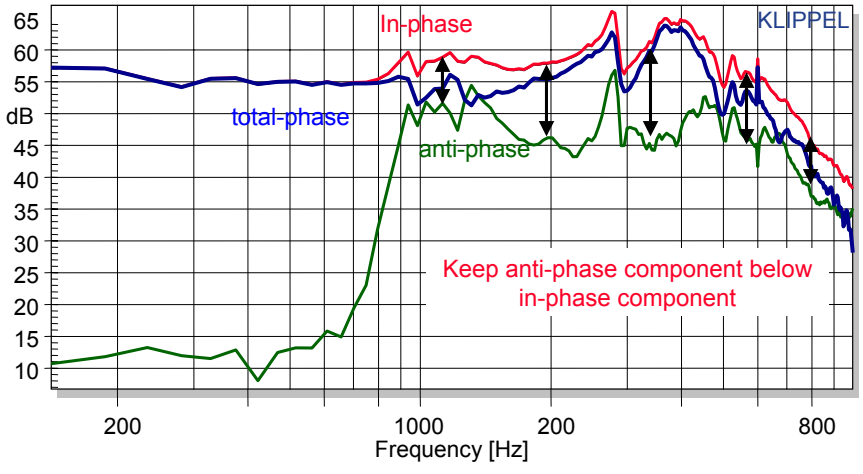


Acoustical Cancellation



IF the in-phase component equals the SPL of anti-phase component then a dip in the total SPL response is generated !!

How to Avoid Dips in the Total SPL Response



如何产生SPLmax？

How to Generate SPL_{MAX} ?

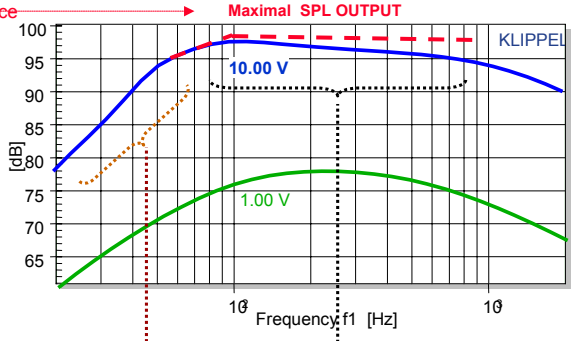
基本SPL 1min Fundamental SPL 1 min

目标性能Target performance

Maximal SPL OUTPUT

系统参数Constraints:

- 放大器供应的最大峰值电压和电流Maximal peak voltage and current provided by amplifier
- 有效发散区域 Effective radiation area



换能器和密闭体的要求
Transducer and enclosure requirements

- 最大音圈峰值位移 Maximal voice coil peak displacement Xmax
- 密闭体，排成直线，调整盒子 Enclosure, alignment, box tuning

- 通带灵敏度 Pass band sensitivity
- 电子输入功率 Electrical input power
- 允许的能量压缩 Permissable thermal compressio
- 最大音圈温度Maximal voice coil temperature

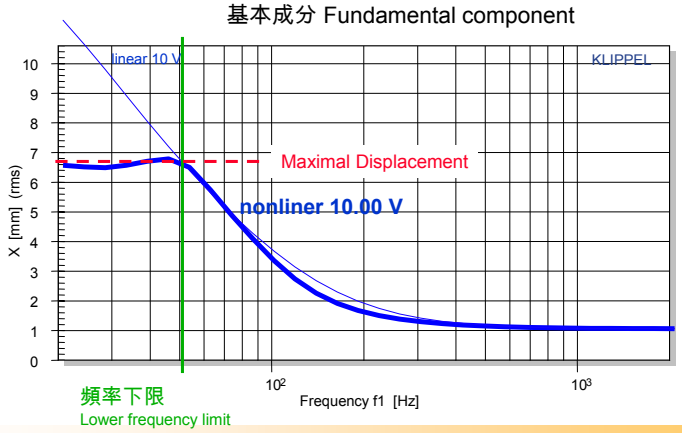
需要多大的峰值位移?

How Much Peak Displacement is Required ?

頻率下限點 軸向1m Upeak=10V時產生SPLmax=92dB SPLgenerating

SPL_{MAX}=92 dB SPL of lower frequency limit at 1 m for U_{peak}=10 V

基本成分 Fundamental component

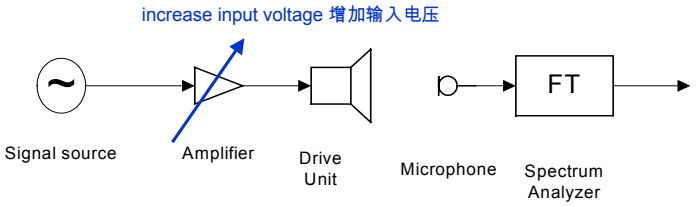


頻率下限
Lower frequency limit

Simple

设置: 测试非线性压缩

Setup: Testing Nonlinear Compression



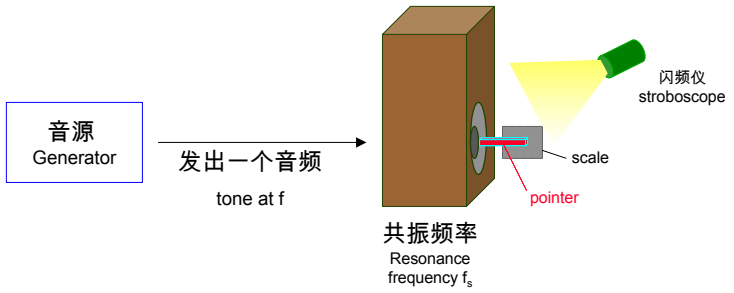
最佳驱动Optimal Stimulus：
Single Tone below resonance
(f = 0.5 fs) 单音，低于共振频率 (f = 0.5 fs)

要求Requirement :
ALMA 测试CD 或 音频发生器
ALMA Test CD or tone generator

对比在高水平下的电压和基本声压级的比率
Compare ratio of voltage and fundamental SPL at high levels
(e.g. 1 ,2 ,4 ,8 ,16 V).

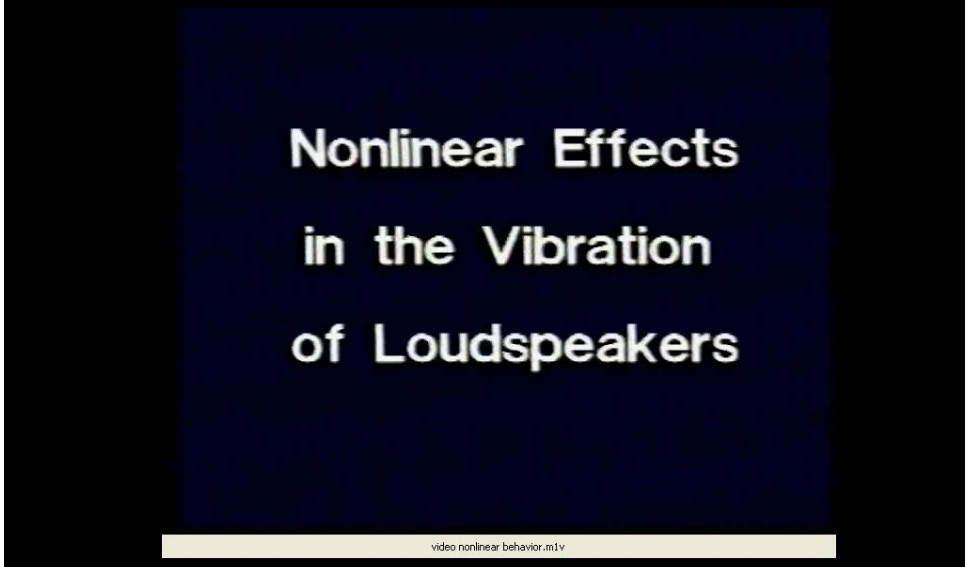
由闪频仪来观看振动模式

Stroboscopic View on the Vibration Behavior



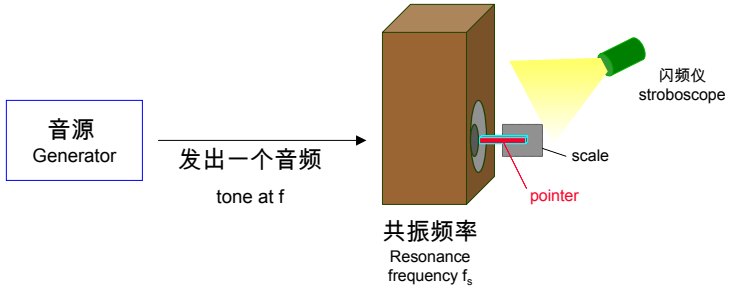
观察频率小于共振频率点	观察频率相当于共振频率点	观察频率大于共振频率点
1. Experiment	2. Experiment	3. Experiment
$f < f_s$	$f \approx f_s$	$f > f_s$

振动行为



由闪频仪来观看振动模式

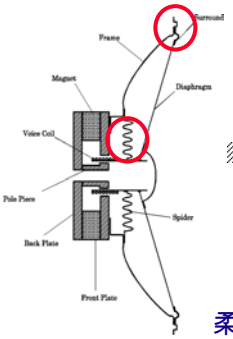
Stroboscopic View on the Vibration Behavior

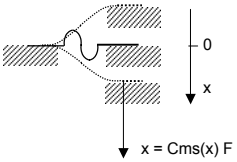


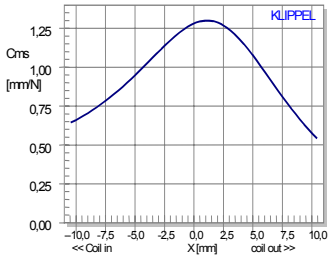
观察频率小于共振频率点	观察频率相当于共振频率点	观察频率大于共振频率点
1. Experiment	2. Experiment	3. Experiment
$f < f_s$	$f \approx f_s$	$f > f_s$
Amplitude Compression	Resonance changes	DC Offset in Displacement

柔顺性

Compliance $C_{ms}(x)$





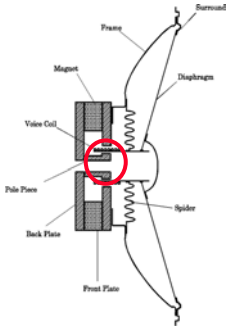


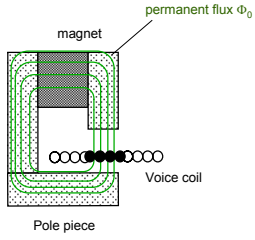
柔顺性改变原因 Variation of Cms(x)

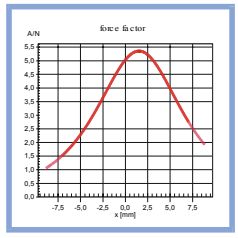
- 弹波及悬边不对称 asymmetry caused by spider and surround
- 运动量, 最大机械负载 moving capabilities, maximal mechanical load
- 调整弹波及悬边 adjustment of spider and surround

磁力强度

Force Factor Bl(x)





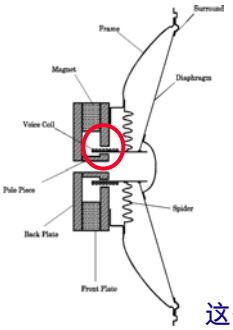


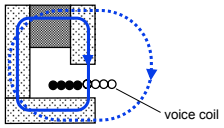
磁力强度改变原因 Variation of Bl(x) caused by

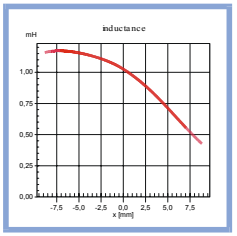
- 磁场改变 Magnetic field
- 线圈高度 Height and overhang of the coil
- 最佳音圈位置 Optimal voice coil position

音圈电感量

Voice Coil Inductance $L_e(x)$







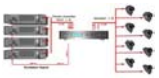
这个参数表示 This parameter shows

- 电感的对称性 asymmetry of inductance
- 最佳磁回位置optimal size and position of short cut ring

Full Dynamic Measurement

Suspension Part Measurement (SPM)

Large Signal Identification (LSI)



Long-term Power Testing (PWT)

Motor-Suspension Check QC (MSC)

Advantages:

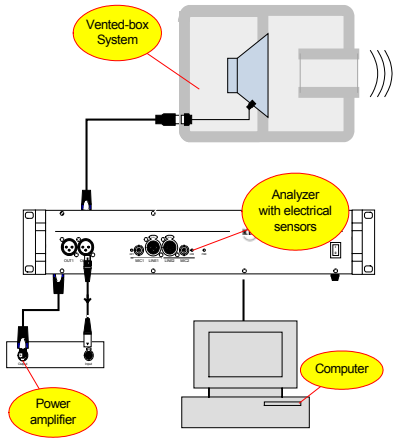
- Loudspeaker under normal working conditions
- Audio-like stimulus
- On-line measurement

Disadvantage:

- Large Signal Idenification (LSI) requires nonlinear signal processing

不需要额外的感应器

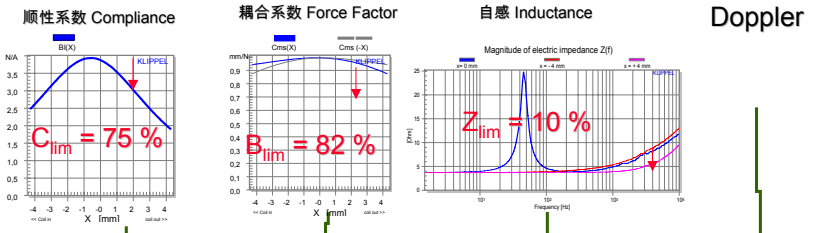
No Additional Sensor Required



- 在连接端仅仅测量电压和电流
  Only voltage and current is monitored at the terminals
- 换能器安装好了也能够检测出驱动和悬边Motor and suspension can be checked when the transducer is mounted in enclosure
- 可以通过长线材测量Measurement via long cables possible
- 对环境噪声的免疫
  Full immunity against ambient noise

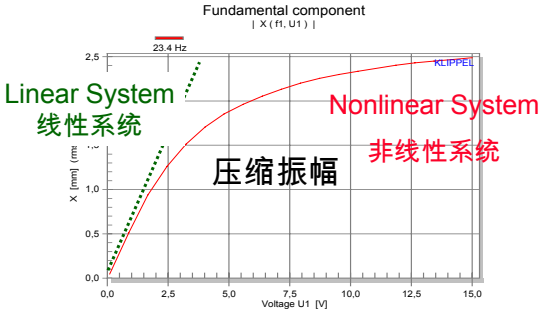
Xmax和其他位移限制

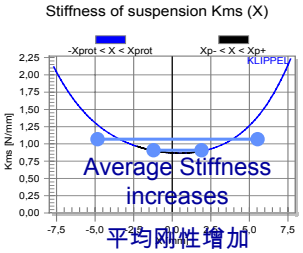
Xmax and other Displacement Limits

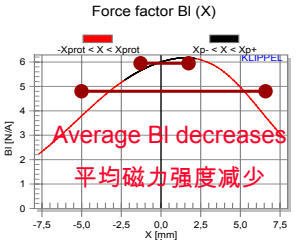


解读：非线性对基波分量有影响

Interpretation: The fundamental component is affected by nonlinearities





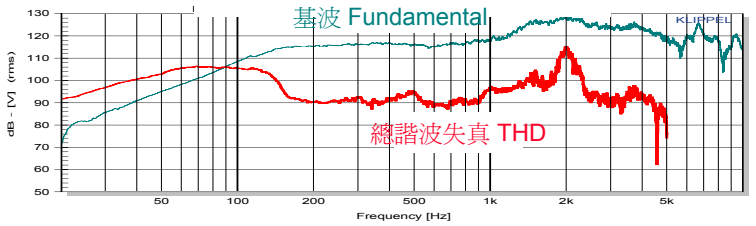


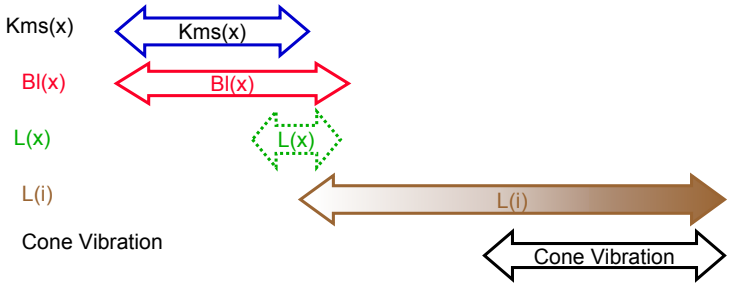
Mechanism 机理:

- Sensitivity changes due to larger Displacement
  由于较大位移从而引起灵敏度变化

諧波失真的原因

The causes of harmonic distortion



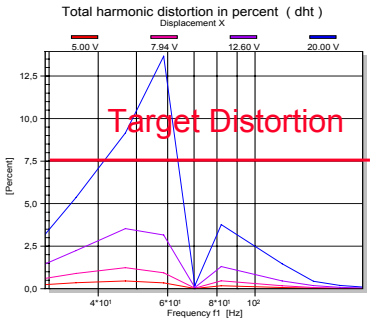


症狀到參數的轉換

Transformation of Symptoms into Parameters

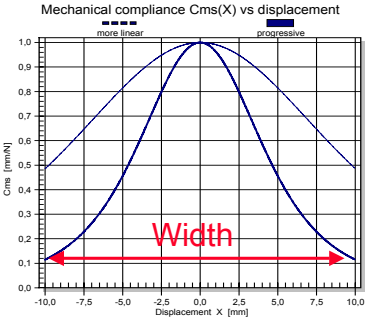
總諧波失真THD@SPLmax → 柔順性Cms(x)的形狀

Total Harmonics THD @ SPL_{MAX} → Shape of Compliance Cms(x)



檢查 Check:

- 頻率共振點處的THD THD at resonance frequency fs
- 基本成分的壓縮 Compression of Fundamental for f < fs
- 位移限制 Displacement limit Xc



單音激勵 Single tone Stimulus → 揚聲器模型 Loudspeaker Model (SIM Module) → 諧波失真 Harmonic Distortion

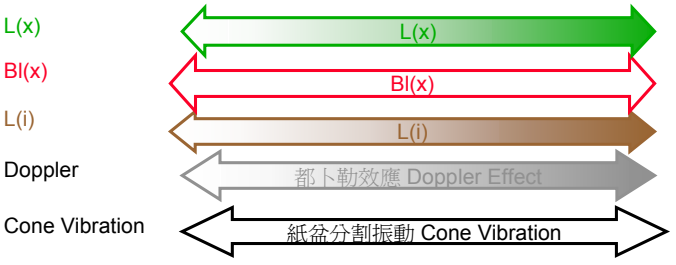
在Bl(x)曲線的非線性曲線編輯器裏改變WIDTH

change WIDTH in nonlinear curve editor of Bl(x) curve

互調失真的原因

the causes of intermodulation distortion

人聲掃頻技術 voice sweep technique

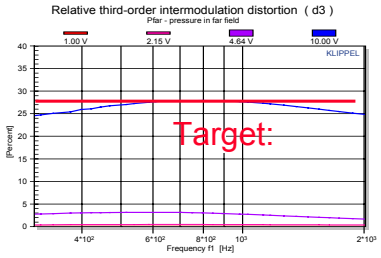


症狀到參數的轉換

Transformation of Symptoms into Parameters

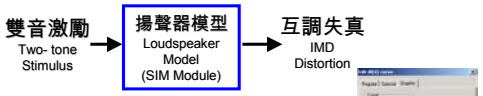
SPLmax處的互調失真 → 耦合係數Bl(x)

Intermodulation distortion IMD @ SPL_{MAX} → force factor BL(x)



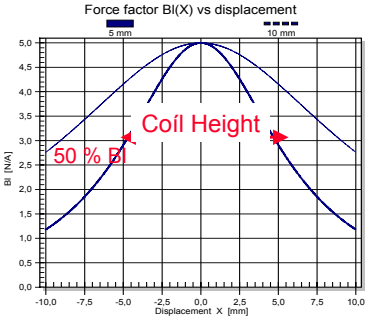
檢查 Check

- SPLmax處的三次諧波失真 使用雙音訊號f2>>fs,f1>fs
  3rd order IMD @ SPL_{MAX} using two-tone signal f_2 >> fs and f_1 < fs
- 位移限制 XBl Displacement limit X_{Bl}



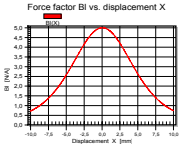
在Bl(x)曲線的非線性曲線編輯器裏改變WIDTH

change WIDTH in nonlinear curve editor of Bl(x) curve



对称非线性失真

Distortion of a Symmetrical Nonlinearity



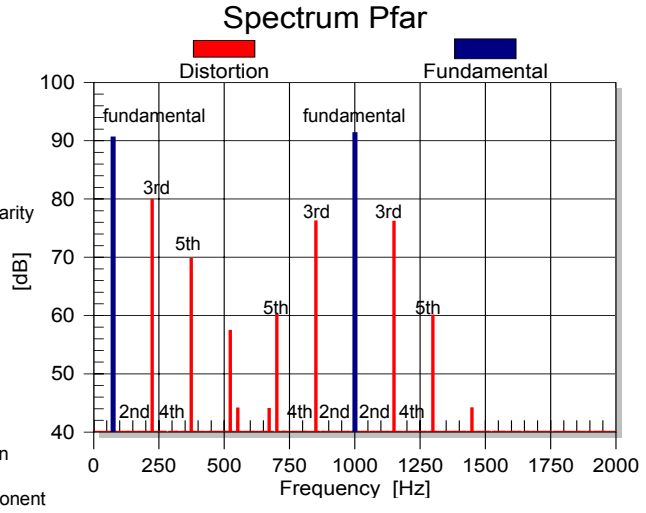
Symmetrical nonlinearity

对称非线性

odd-order distortion

奇数次失真

3rd,5th,7th-order component

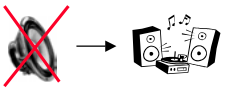


什么是不良的驱动单元？

What is a Bad Drive Unit ?

特性不能被接受的

Properties which are not acceptable – k.o. criteria



- 直流位移大于交流位移的幅度

  Dc displacement is larger than amplitude of ac displacement
- 在共振频率处有分歧和跳动影响

  Bifurcation and jumping effect at the resonance frequency
- 低于Xmax处有音圈撞击，硬碰撞和有摩擦声

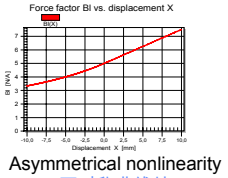
  Voice coil rubbing, hard limiting and buzzing sound below Xmax
- 重大的摆动特点

  Significant rocking mode ($AAL_{circular} > AAL_{total}$)
- 声学功能作废

  Acoustical Cancelation ($SPL_{anti\text{-}phase} \approx SPL_{in\text{-}phase}$)

不对称非线性失真

Distortion of a Asymmetrical Nonlinearity



Asymmetrical nonlinearity

不对称非线性

even-order distortion

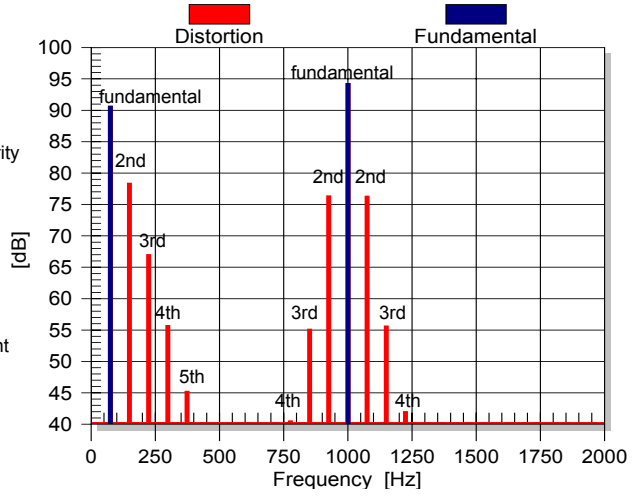
偶数次失真

2nd,4th,6th-order component

odd-order distortion

奇数次失真

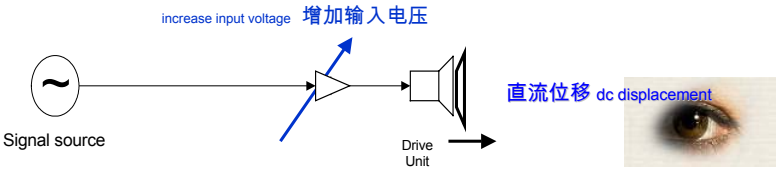
3rd,5th,7th-order component



Simple

设置：测试悬边的对称性

Setup: Testing Symmetry of Suspension



Optimal Stimulus 最佳驱动:

Single Tone just above resonance (f = fs)

单音，位于共振频率处(f = fs)

Requirement 要求:

ALMA Test CD or tone generator

ALMA 测试CD 或 音频发生器

Watch for significant dc component in the voice coil displacement at higher amplitudes.

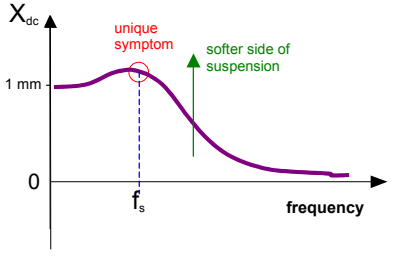
观察较高振幅处音圈位移产生的较大的直流分量

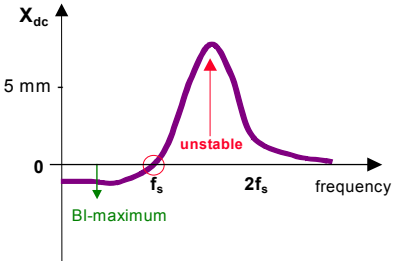
检查:直流位移

Check: dc Displacement

由劲度系数导致的 Caused by Kms(x)

由耦合系数导致的Caused by Bl(x)

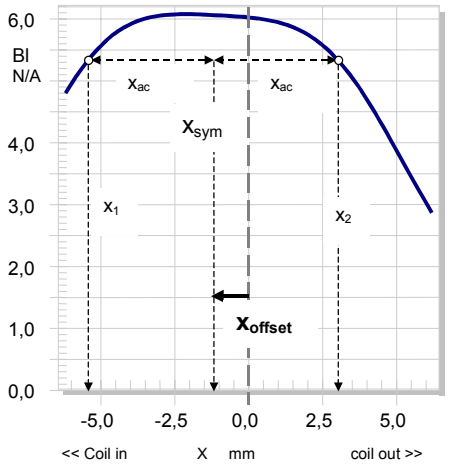




音圈偏移X_{offset}

Voice Coil Offset x_{offset} defined according IEC standard 62458

根据IEC 62458标准定义

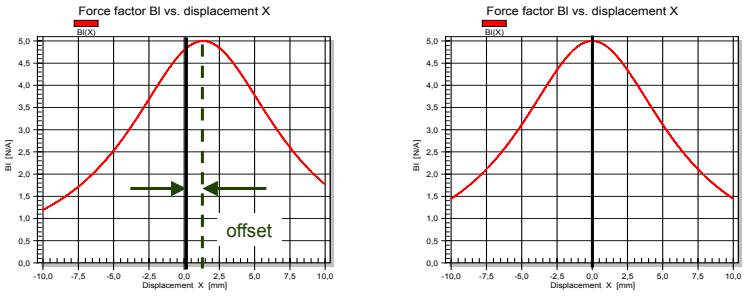


步骤 Steps:

1. 在大信号模式下激励换能器
   Operate transducer in large signal domain
2. 在最大峰值位移xac处读取对称点Xsym
   Read symmetry point X_{sym} at maximal peak displacement x_{ac}
3. $X_{offset}=x_{sym}$ if $X_{ac} > X_B$

校正音圈的靜態位置

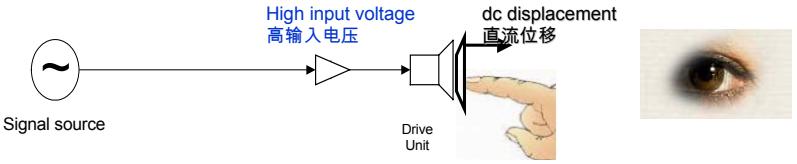
Adjusting Coil's Rest Position



Simple

设置: 测试驱动的稳定性

Setup: Testing Motor Stability



Optimal Stimulus 最佳驱动:

Single Tone just above resonance (f > 1.5fs)

单音，高于共振频率(f > 1.5fs)

Requirement 要求:

ALMA Test CD, tone generator

ALMA测试CD，音频发生器

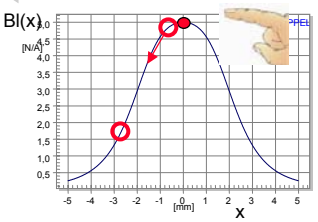
Kick cone inwards and outwards and watch for significant dc component in the voice coil displacement

向内向外敲击纸盆并观察在音圈位移上较大的直流分量

解读: 测试驱动的稳定性

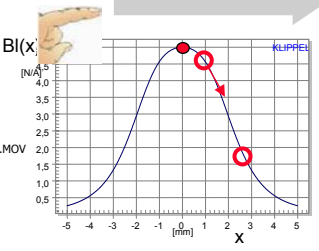
Interpretation: Testing Motor Stability

负直流位移 negative dc displacement



bifurcation caused by motor.MOV

正直流位移 positive dc displacement



Causes 成因:

→Bifurcation into two states

分支为2个状态

→ rest position is unstable

静止位不稳定

Remedies 补救方法:

→应用带高原区的磁力强度侧面图Use Bl profile with a plateau region

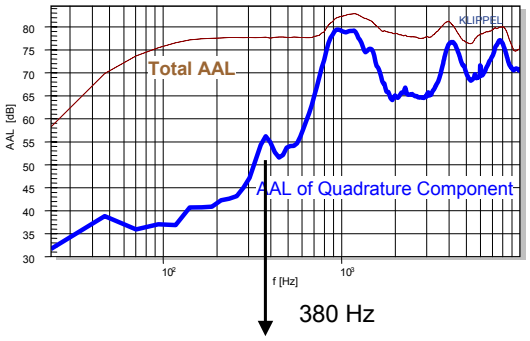
→增加线圈悬垂高度Increase coil overhang or underhang

→增加悬边刚性 increase stiffness of suspension

如何找出摇摆模态

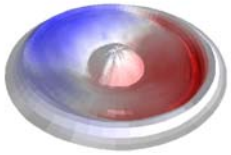
How to find rocking modes ?

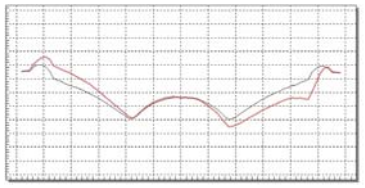
Woofer A with paper cone



在低频处寻找最大的正交成分

Search for maximum in quadrature component in AAL at low frequencies



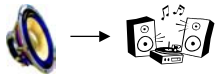


如何指定驱动单元

How to Specify the Drive Unit

哪一個才是實際應用的最佳選擇？

which is optimal for my application ?



根據實際應用的規格 Specifications according to application

- 通带灵敏度 SPL 1m 1W 输出
  Pass-band Sensitivity SPL in 1 m for 1 W
- 轴向幅度响应的平坦度
  Flatness of amplitude response on-axis
- 指定频率范围内的指向性
  Directivity in specified frequency range
- 峰值位移 Peak displacement Xmax
- 根据常规失真的XBl，XC，XL限制的位移
  Displacement limits XBl, XC, XL according to regular distortion
- 能量参数 (时间常数，阻抗，对流冷却)
  Thermal Parameters (time constants, resistances, convection cooling)

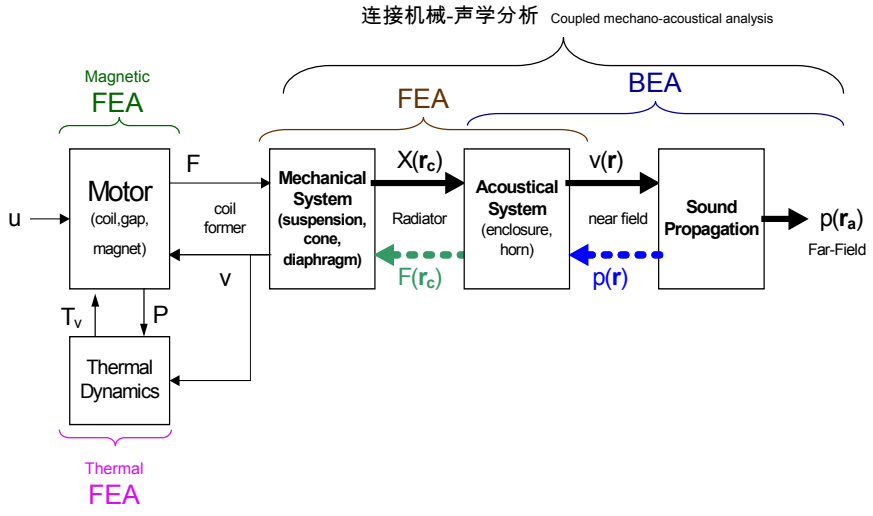
换能器设计的步骤

Steps in Transducer Design

1. 定义目标性能 Definition of target performance
2. 将基于激励信号的特性转换为参数(如果还没有完成)
   Transforming stimulus-based characteristics into parameters (if not already made)
3. 选择适合的材料 Selecting the proper materials
4. 寻找最佳的几何结构 Finding the optimal geometry
5. 考虑制造中的系统规定参数 Considering constraints from manufacturing
6. 制作第一个蓝本 Building the first prototype
7. 性能的确认 Verification of the performance

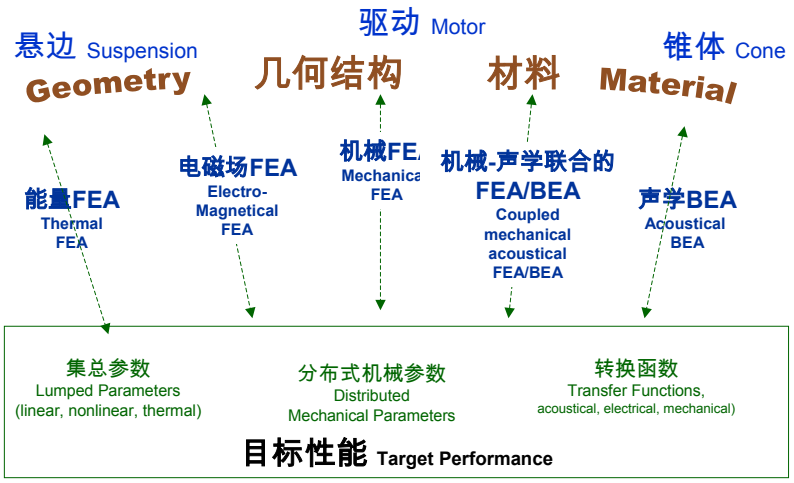
换能器的设计

Design of the Transducer



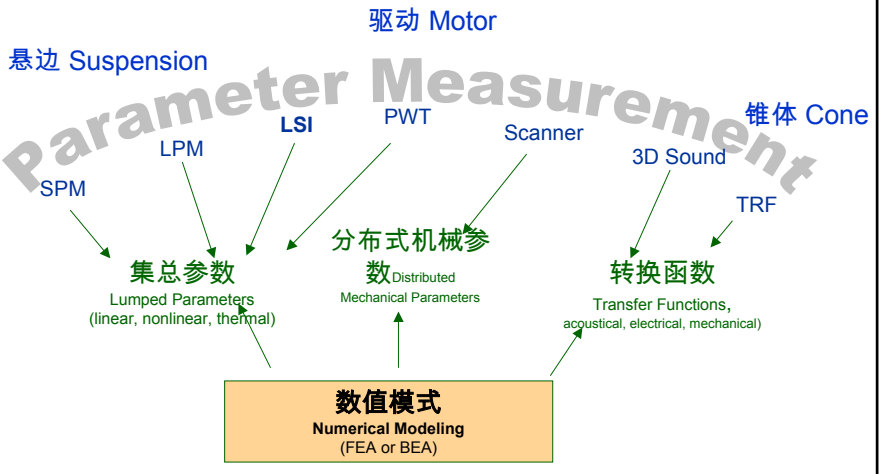
寻找最佳的设计选择

Finding the Optimal Design Choice



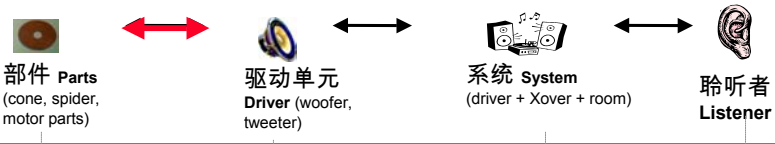
设计选择的证明比较测试的结果与预期的参数

Verification of Design Choice by comparing measured and predicted parameters



如何规定扬声器系统的品质？

How to Specify Sound Quality of Loudspeaker Systems ?



部件 **Parts** (cone, spider, motor parts)

驱动单元 **Driver** (woofer, tweeter)

系统 **System** (driver + Xover + room)

聆听者 **Listener**

模型 Modeling

分布式参数模型 Distributed Parameter Models (FEA, BEA)

集总参数模型 Lumped Parameter Models

面向系统模型 System-oriented Models

心理声学模型 Psycho-acoustical Models

测量 Measurement

材料参数 Material Parameter

结构 Geometry

线性T/S参数 Linear T/S Parameters

能量参数 Thermal Parameters

锥体震动 Cone Vibration

非线性参数 Nonlinear Parameters

参数独立于激励 Parameters independent of stimulus

小信号性能 Small Signal Performance

非线性失真 Nonlinear Distortion

声音属性 Sound Attributes

功率处理 Power Handling

声响密度 Loudness density

品质韵律 Quality Metrics

症状取决于激励 Symptoms depend on stimulus

应用 Application

目标性能的定义 Definition of Target Performance

组成成分的选择与设计 Selection of Components & Design

R&D

第一个蓝本的评估 Evaluation of the First Prototype

在线测量 End-of-line Testing

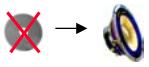
QC

什么是不良的悬边部件？

What is a Bad Suspension Part ?

属性特点不能被接受的

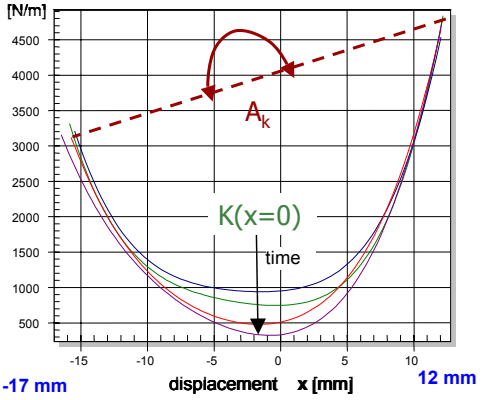
Properties which are not acceptable – k.o. criteria



劲度系数不对称

Ak>20%

Stiffness asymmetry A_k (> 20 %) measured at high excursion



重要的劲度K(x=0,t)损耗(>30%)对时间的关系

Significant loss (> 30 %) of stiffness K(x=0,t) versus time after break-in

劲度系数不对称动态地产生重要的直流位移

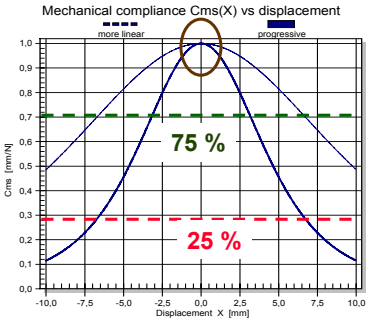
Significant dc displacement generated dynamically by stiffness asymmetry

悬边特性用来描述特别应用中的最佳属性特点

Suspension Characteristics for describing optimal properties in the particular application

静态位置(x=0)的柔顺性Xc(x=0)

Compliance $X_C(x=0)$ at rest position which is important for resonance frequency fs



位移限制Xc产生10%的失真

Displacement limit X_C generating 10 % harmonics

最大远离Xmech，对机械保护来说是非常重要的

Maximal Excursion X_{mech} which is important for mechanical protection

注意：悬边的对称非线性是非常有用的

Note: Symmetrical nonlinearities of the suspenion are usually beneficial

如何指定悬边部件

How to Specify the Suspension Part

R&D测量(SPM模块)

R&D Measurement (e.g. SPM module)

- 垂直操作 Vertical operation
- 钳位与实际应用相似 Clamping similar to final application
- 动态测量 Dynamic measurements
- 小讯号和大讯号模式 Small and large signal domain
- 长时间测量(老化，疲倦)Long-term Measurement (ageing, fatigue)

在线测量 (QC系统)

End-of-line Testing (QC System)

- 水平操作 Horizontal operation
- 最小的箝位 Minimal clamping
- 动态测量 Dynamical Measurement
- 小信号模式 Small Signal Domain
- 快速测量 Fast measurement (< 1s)

重要的特性 Important Characteristics

QC

- 小幅度下测量的动态劲度系数 K Dynamic stiffness K(x=0) measured at small amplitudes

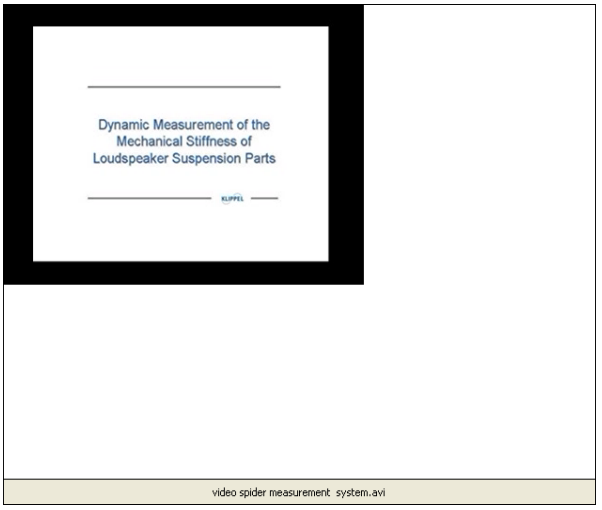
R&D

- 劲度系数对时间t的损耗 Loss of stiffness K(x=0,t) versus time t
- 在高偏离状态下测量的劲度不对称度 Stiffness asymmetry A_k measured at high excursion
- 动态产生的直流位移 DC-displacement generated dynamically
- 最大峰值位移使柔顺性下降到75% Maximal peak displacement X_c giving decay of compliance to 75 %

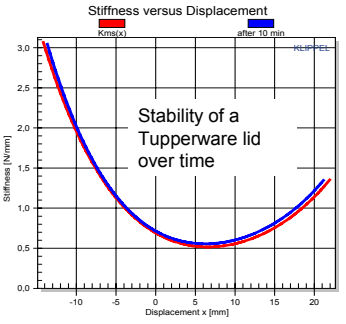
IEC标准62458和62459有更多信息

More details in IEC Standard 62458 and 62459

Dynamic Measurement of the Mechanical Stiffness of Suspension Parts



支架-扬声器最脆弱的部件
Spider - Weakest Part of the Loudspeaker



Tupperware® gives lifetime warranty

研究工作 Research activity:
新材料的重要构造的代替
Replacement of impragnated fabric by new materials

概要 Summary

- 音频系统的信号失真的评估需要电子的，机械的，声学的，心理声学的模型

  Assessment of signal distortion in audio system requires electronical, mechanical, acoustical and psycho-acoustical modeling
- 基于特性的参数独立于激励信号，对评估不规则失真非常

  Parameter-based characteristics are independent of the stimulus and important for assessing regular nonlinearities
- 基于参数的特性是FEA-BEA和数字信号处理非常重要的切入点

  Parameter-based characteristics are an important interface for FEA-BEA and digital signal processing
- 基于激励信号的评估对聆听测试非常重要，检查喇叭耐久性和老化度，查找不规则喇叭缺陷是基于声压输出的

  Stimulus-based assessment are important for listening tests, checking durability and aging and for finding irregular loudspeaker defects is based on sound pressure output

Get a Handout of the Seminar

Contact me under klippel@klippel.de to get a electronic copy of the presentation

Or contact our distributors for the

R&D System

QC System

AP Technology