与KLIPPEL一起学习扬声器的诊断
Learning Loudspeaker Diagnostics with KLIPPEL

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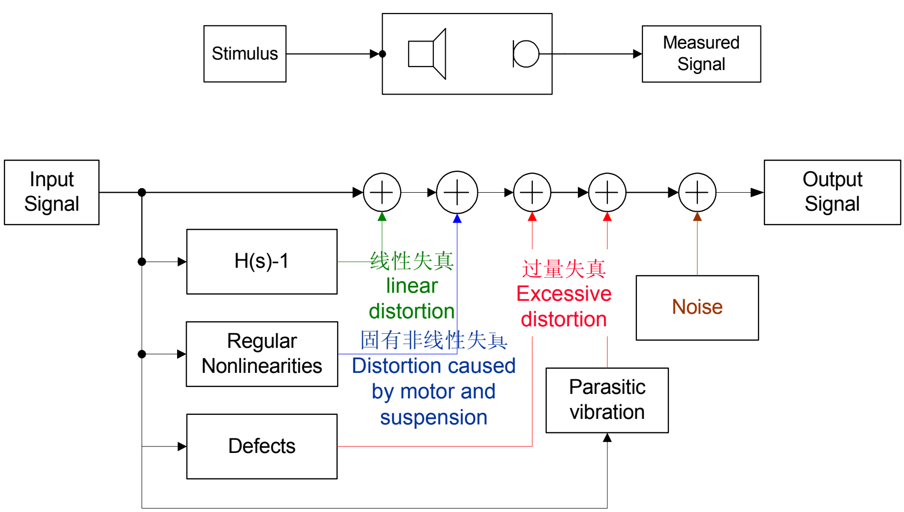
Abstract

This workshop teaches engineers and operators to perform comprehensive measurements on loudspeakers, to interpret the results and to find the physical causes. Practical case studies show typical failure in design and manufacturing. The workshop gives valuable tips and tricks for using the KLIPPEL Analyzer system. The participants can bring their own loudspeaker samples along and can operate the equipment by themselves to learn by doing.

今日议程
Agenda today

1. 哪些测量是必需的？ Which measurements are required ?
2. 如何解释结果？ How to interprete the results ?
3. 什么是好什么是坏？What is good and what is bad ?
4. 怎样改进扬声器？How to improve the speaker ?
5. 让我们在具体的实例中进行练习！ Let‘s practice this on some examples !

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



诊断
Diagnostics

1. 参数基于(模型要求) Parameter based (model required)
- 线性传递函数 Linear transfer functions
- 小信号参数T/S Small signal parameter T/S
- 大信号参数 (热学的，非线性的) Large signal parameters (thermal, nonlinear)

2. 性能基于(取决于驱动信号) Performance-based (depend on stimulus)
- 非线性征兆 Nonlinear symptoms (THD, IMD, XDC)
- 音圈温度，压缩，最大功率 Coil temperature, compression, Pmax

线性参数 + 传递函数
Linear Parameters + Transfer Functions

1. 电输入阻抗的测量 Z(f) **Measurement of Electrical Input Impedance** Z(f)
   - 小信号参数 Small Signal Parameters (Re,Bl,Mms,Le, fs, Kms, Qts +T/S, Zmin)
2. 声学输出的测量 **Measurement of Acoustical Output**
   - 轴敏感性 Sensitivity on-axis, → IEC 60268-5 Sec. 20.6
   - 有效频率范围的限幅 Limits of effective frequency range → IEC 60268-5 Sec. 21.2
   - 平坦性 Flatness (maximal deviation from mean value) →
   - 声功率响应 sound power response $P_a(f)$ → IEC 60268-5 Sec. 22.1
   - 指向性因数 Directivity index $D_i(f)$ → IEC 60268-5 Sec. 22.1
   - 平均效率 Mean Efficiency → IEC 60268-5 Sec. 22.4 Sec
3. 振膜振动测量, 几何形状 **Measurement of Cone Vibration, Geometry**
   - 声学输出预测 (轴声压级, 功率, 指向性) Prediction of acoustical output (SPL on-axis, power, directivity)
   - 隔声罩+房间的考虑 consideration of enclosure+room (→ BEA)

在小信号范围的判定标准
Criteria in the small signal domain

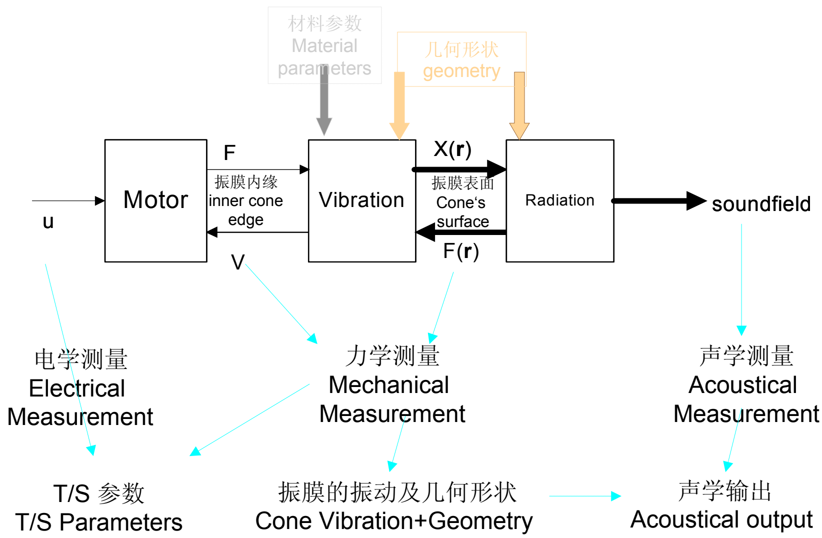
- 带宽 (低于和高于限幅) Bandwidth (lower and upper limits)
- 敏感性 (效率) **Sensitivity** (efficiency)
- 声压级响应的平坦性 (轴上) **Flatness** of SPL response (on-axis)
- 指向性 (功率响应) **Directivity** (power response)

驱动系统里存在的问题
Problems in the motor

- Mms 和 Kms 决定 fs → 带宽
  Mms and Kms determines fs → bandwidth
- Re, Bl^2, Rms 决定 Qts → 平坦性
  Re, Bl^2, Rms determines Qts → flatness
- Bl, Re, Mms → 活塞(刚体)运动模式里的敏感性
  Bl, Re, Mms → sensitivity in piston mode
- L 和 Mcoil → 带宽 bandwidth
  L and Mcoil → bandwidth
- 蠕动因子 → 稳定性 (直流位移)
  Creep factor → stability (dc displacement)

小信号范围内的诊断

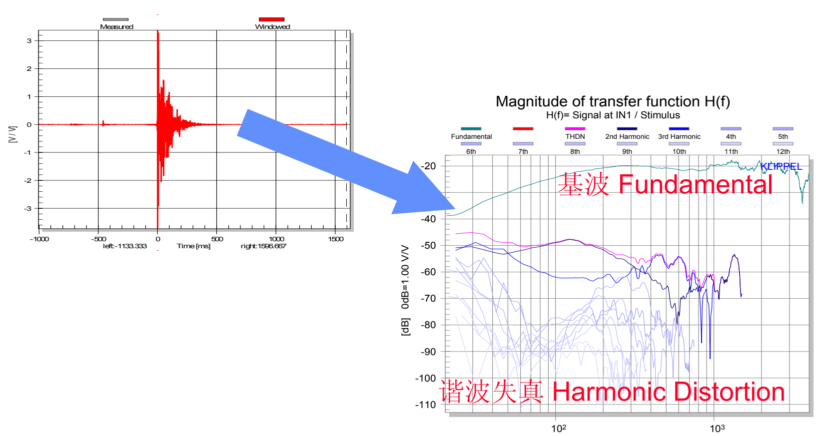
Diagnosis in the Small-Signal Domain



通过传递函数以描述线性行为 TRF

Describing the linear behavior by Transfer functions

脉冲响应 Impulse response



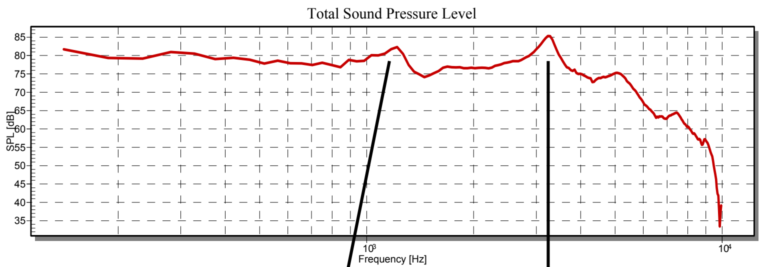
检查振膜的振动
Checking Cone Vibration

- 我们拥有足够的振动振幅了吗？Do we have enough vibrational amplitude ?
- 在振膜的哪一个部分最先出现分裂模式？On which cone part first break-up modes occur ?
- 分裂模式是否逐步取代活塞(刚体)运动模式？Does the break-up modes gradually replace the piston mode ?
- 我们有膜片振动模式和弯曲模式了吗？Do we have membran or bending modes ?

检查辐射问题
Checking radiation problems

- 我们拥有足够的对消效应了吗？ Do we have a strong cancellation effect?
- 对消效应是不是发生在轴点之外？ Does the cancellation affect out-off axis points ?
- 振膜的哪一个部分辐射音压？ Which cone part radiates sound ?
- 辐射面积是不是在逐渐减小？ Does the size of radiating area decreases gradually ？

什么导致了明显的峰值
What causes significant peaks ?



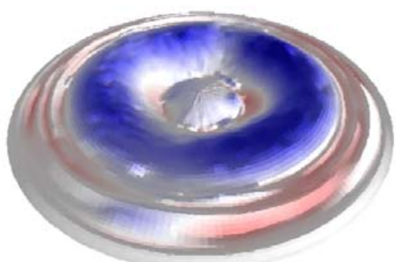
通常是好
Usually ok

第一个振膜环反共振 (弯曲模式) First ring anti-resonance (bending mode)

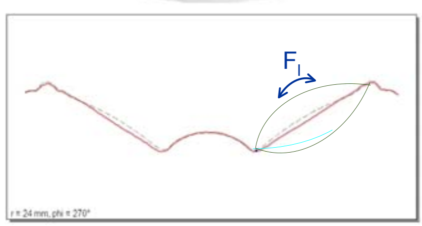
~~纵向共振 (膜片振动模式) Longitudinal resonance (membrane mode)~~

通常是坏
Usually bad

什么是膜片振动模式
What is a Membrane mode ?



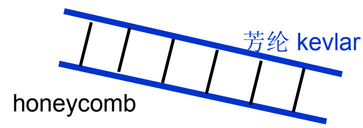
- 纵向刚度产生恢复力 F_l longitudinal stiffness generates the restoring force F_l
- 弯曲内力小 bending forces are small

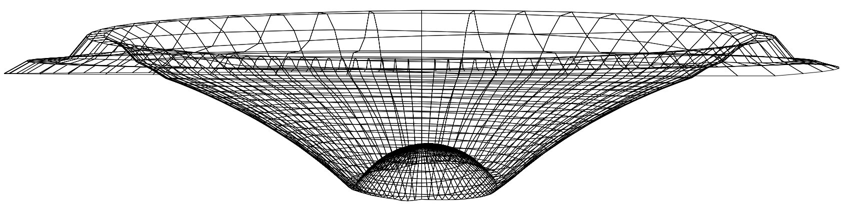


→ 膜片振动模式占用了很大的振膜面积 A membrane mode occupies a large area of the cone

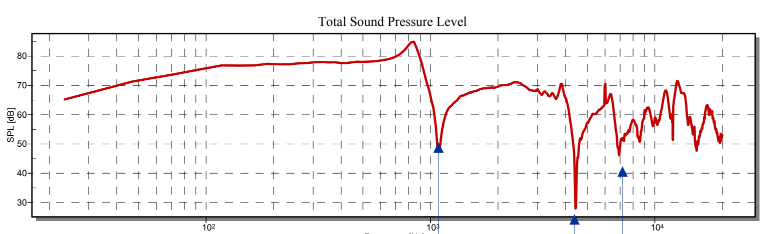
什么在支持膜片振动模式？
What supports membrane modes ?

- 平坦的振膜几何形状 flat cone geometry
- 低纵向刚度 low longitudinal stiffness
- 高弯曲刚度 high bending stiffness





什么导致了明显的谷值？
What causes significant dips ?



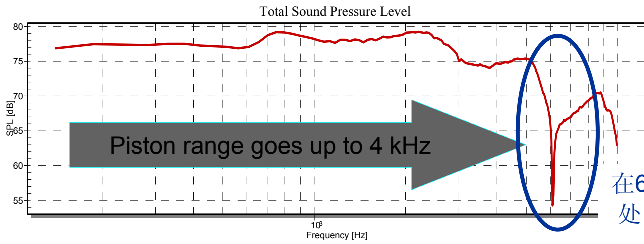
声学对消效应 Acoustical cancellation effect

Causes

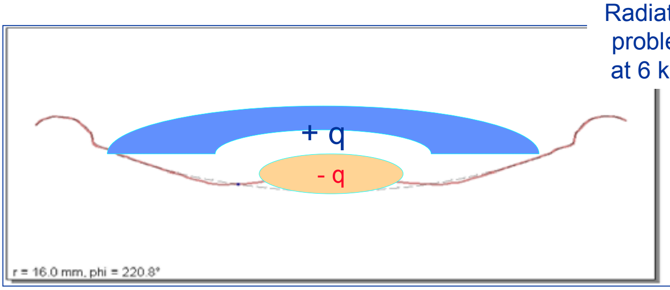
- 振膜的几何形状 Geometry of The cone
- 振膜上的弯曲模式定位 Location of bending modes on the cone
- 膜片振动模式 membrane modes

把纸盆做得越硬越好

Making the cone as stiff as possible



在6千赫兹处的辐射问题 Radiation problem at 6 kHz



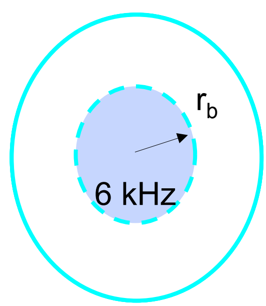
振膜分裂成2个部分来生成相同量级下正向的及反向的体积流速 Cone breaks-up in two areas producing positive and negative volume velocity of equal magnitude

→ 对消效应 Cancellation effect

提示:减少纸盆有效面积

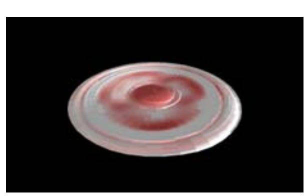
TIP: Reduction of effective cone area

- 分裂始于外部 Breakup starts outside
- 外环面积不能辐射明显的音压 Outer ring area does not radiate significant sound
- 内部应辐射音压 (同相分量) Inner part should radiate sound (in-phase component)

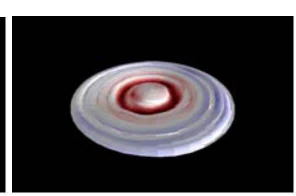


500 Hz

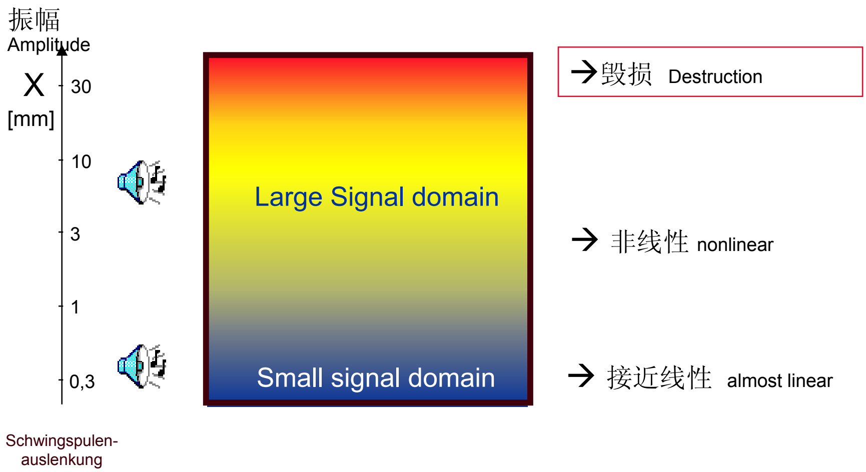
3 kHz



7 kHz



扬声器的工作效益
Performance of Loudspeakers



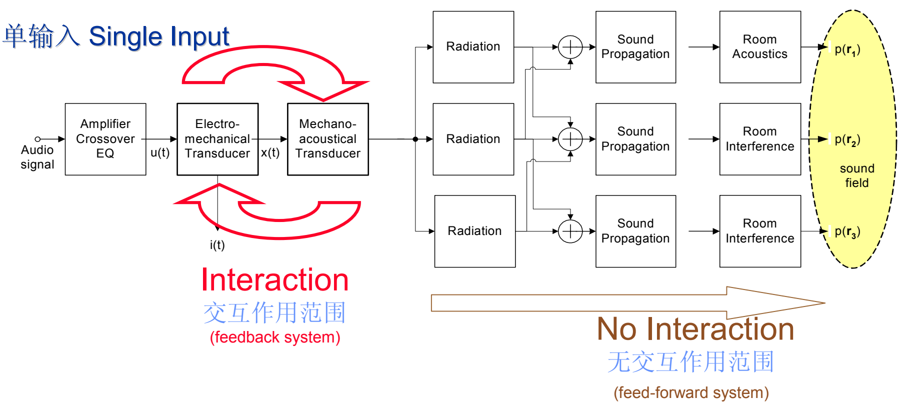
让你的生活更轻松!
Make your life easier !

- 了解信号失真的物理成因 Understand the physical causes of signal distortion
- 使用物理模型 Use a physical model
- 测量大信号参数 Measure large signal parameters

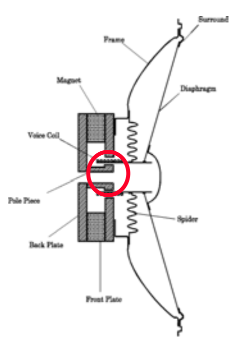
基本扬声器模式
Basic Transducer Modeling

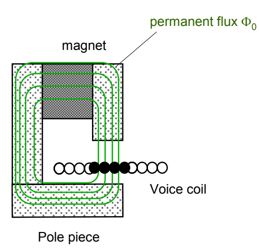
多输出 Multiple Outputs

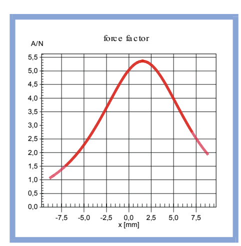
单输入 Single Input



磁力强度
Force Factor Bl(x)





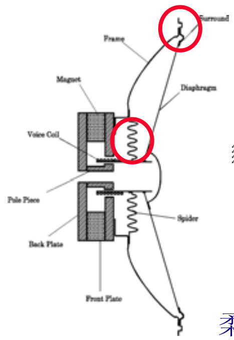


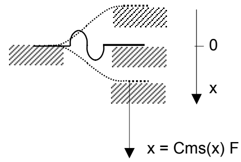
磁力强度改变原因 Variation of Bl(x) caused by

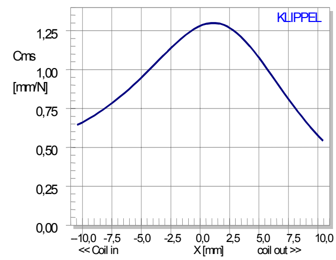
- 磁场改变 Magnetic field
- 音圈高度 Height and overhang of the coil
- 最佳音圈位置 Optimal voice coil position

柔顺性

Compliance $C_{ms}(x)$





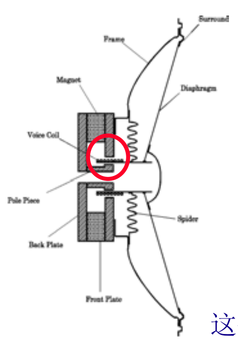


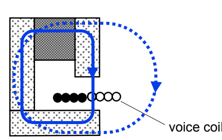
柔顺性改变原因 Variation of Cms(x)

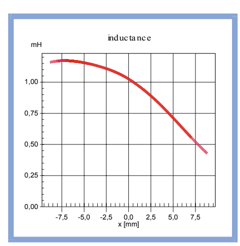
- 定心支片和折环不对称 asymmetry caused by spider and surround
- 运动量, 最大机械负载 moving capabilities, maximal mechanical load
- 调整定心支片和折环 adjustment of spider and surround

音圈电感

Voice Coil Inductance $L_e(x)$





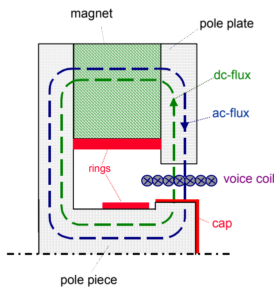


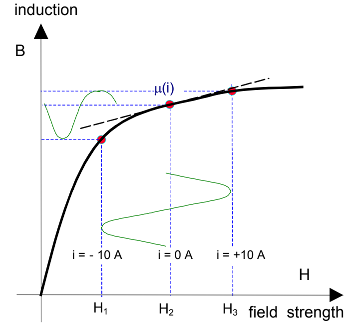
这个参数表示 This parameter shows

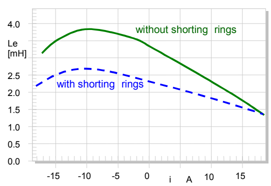
- 电感的对称性 asymmetry of inductance
- 最佳短路环形状与位置 optimal size and position of short cut ring

电感与电流

Inductance $L_e(i)$ versus current







电感的变动量取决于 Variation of $L_e(i)$ depends on

- 材料 (导磁率) material (permeability)
- 导磁路的几何形状 geometry of iron path
- 音圈卷宽 voice coil height windings
- 电流 current

动态参数测量模组总览

Overview on Modules

for Dynamical Parameter Measurement

LPM
线性参数测量
Linear parameters

LSI
大信号鉴定
Nondestructive,
Full protection
Linear, nonlinear and thermal

LSI Woofer 低音
Fs < 600 Hz

LSI Tweeter高音
Fs < 4kHz

LSI Box音箱系统
Fs < 600 Hz
Driver
+ enclosure

SPM
悬吊系统测试
Suspenion part

PWT
功率测试
Power test
with any signal (music !!)
No protection
Linear, nonlinear

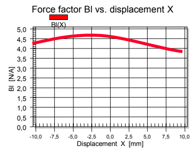
解读大信号参数
Interpretation of the Large Signal Parameters

1) 非线性曲线的形状 The shape of the nonlinear curve
2) 曲线及物理成因的关连 Relationship between curve and physical cause
3) 曲线及信号失真的关连 Relationship between curve and signal distortion
4) 高品质及低品质的扬声器 What is a good and what is a bad speaker ?

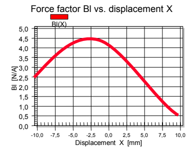
非线性曲线的特性
Properties of the Nonlinear Curve

1) 是常数或者是随着位移或电流而变化 Constant or varying with displacement or current
2) 曲线形状对称或不对称 Symmetrical or asymmetrical shape
3) 软限幅或硬限幅 Soft or hard limiting

弱非线性或强非线性?
Weak or Strong Nonlinearity ?



参数几乎恒定
Parameter almost constant

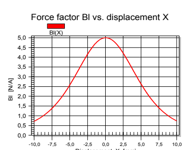


参数变化大
Parameter large variation

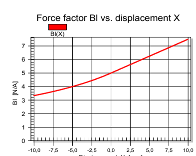
低信号失真
LOW Signal Distortion (THD, IMD)

高信号失真
HIGH Signal Distortion (THD, IMD)

对称性或不对称性
Symmetry or Asymmetry ?



Symmetrical nonlinearity
对称非线性



Asymmetrical nonlinearity
不对称非线性

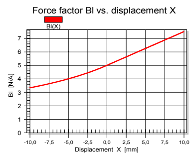
- 与尺寸，重量，价格，效率及最大输出有关 related with size, weight, price, efficiency, maximal output

有好有坏 Good and bad

- 由几何形状的不对称，音圈偏移等引起 Caused by asymmetry in geometry, voice coil offset, ...

通常是坏 usually bad

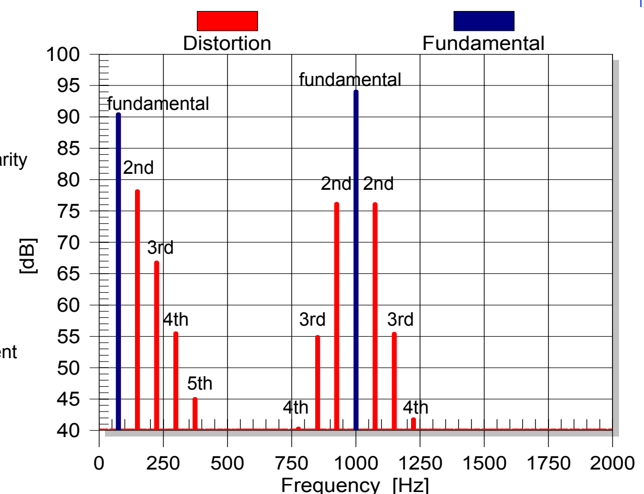
不对称非线性失真
Distortion of a Asymmetrical Nonlinearity



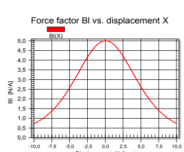
Asymmetrical nonlinearity
不对称非线性

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

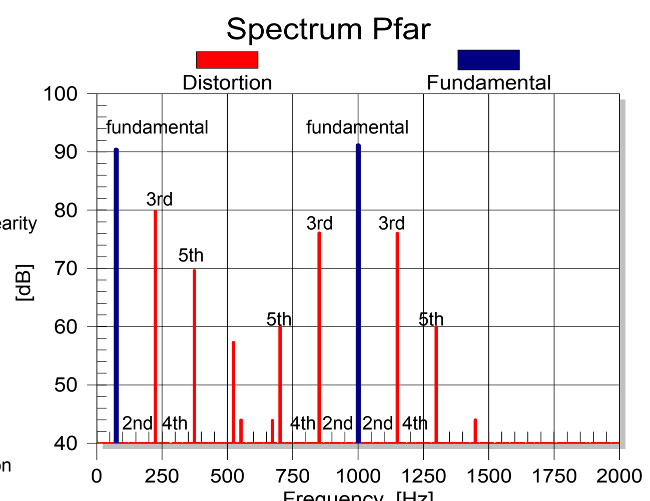


对称非线性失真
Distortion of a Symmetrical Nonlinearity

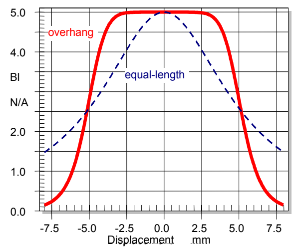


Symmetrical nonlinearity
对称非线性

odd-order distortion
奇数次失真
3rd,5th,7th-order component



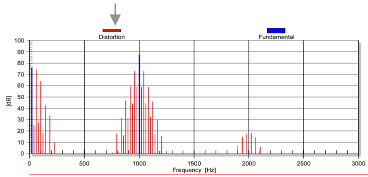
硬限幅或软限幅非线性频谱
Spektrum of hard or soft limiting nonlinearity



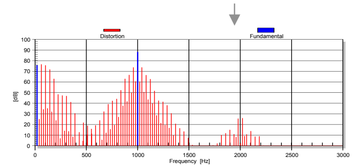
软限幅非线性
soft limiting nonlinearity

硬限幅非线性
hard limiting nonlinearity

声压信号频谱 Spectrum of sound pressure signal (two-tone stimulus):

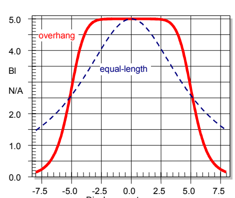


high 2nd- and 3rd order distortion

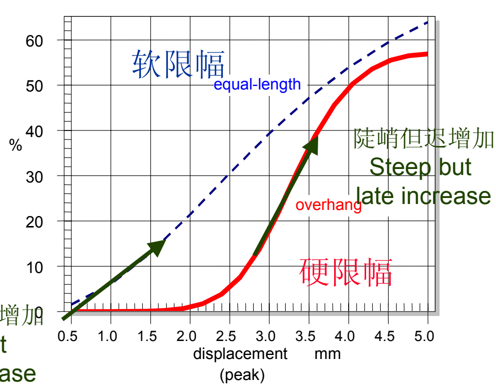


Large amplitude of all components

由硬限幅或软限幅非线性引起的总失真
Total Distortion
generated by hard or soft limiting nonlinearity



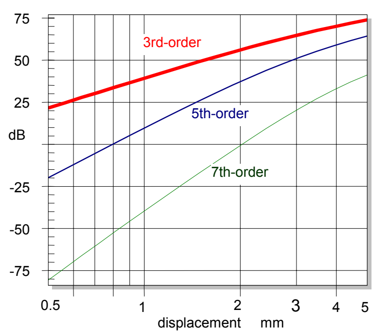
总谐波失真
Total harmonic distortion (*THD*)
in percent



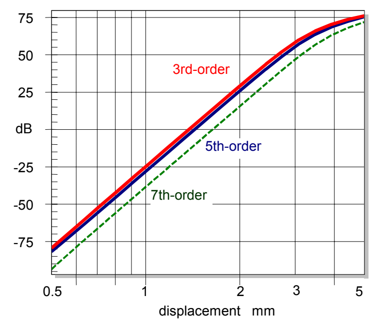
提早但缓慢增加
early but
slow increase

由硬限幅或软限幅非线性引起的失真分量
Distortion Component generated by hard or soft limiting nonlinearity

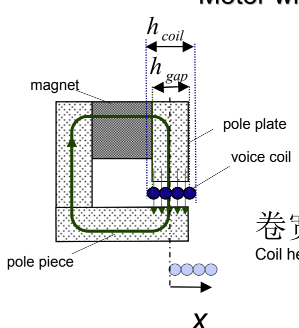
软限幅非线性
soft limiting nonlinearity



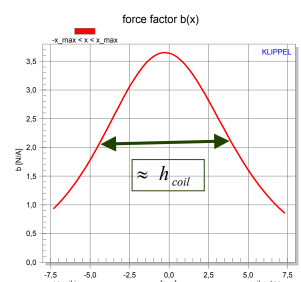
硬限幅非线性
hard limiting nonlinearity



等长磁回系统
Motor with Equal-length Configuration



卷宽 ≈ 磁间隙高
Coil height $h_{coil} \approx$ gap height h_{gap}



使用特性 Properties:

坏 BAD

- 对音圈偏移敏感 Sensitive to offset in rest position
- 高于 Fo 的频率范围运作不稳定 Sensitive to instabilities $f>f_s$

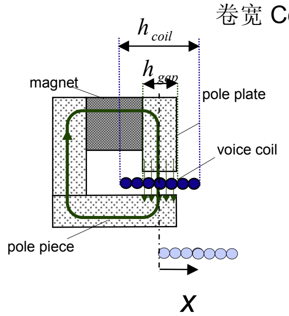
好 GOOD

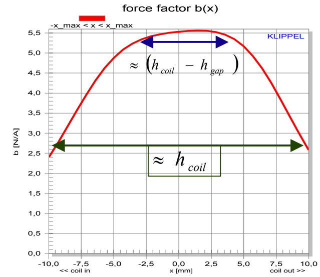
- 小振幅时低阶失真输出 Low order distortion at low amplitudes
- 低电感及磁场调变 low inductance and flux modulation

长音圈的磁回系统

Motor with Overhang Coil

卷宽 Coil height h_{coil} >磁间隙高 gap height h_{gap}





好 GOOD

- 对音圈偏移较不敏感 Insensitive to offset in rest position
- $x < (h_{coil}-h_{gap})$ 时低失真 Low distortion for $x < (h_{coil}-h_{gap})$
- $x > (h_{coil}-h_{gap})$ 时高阶失真 High order distortion for $x > (h_{coil}-h_{gap})$

坏 BAD

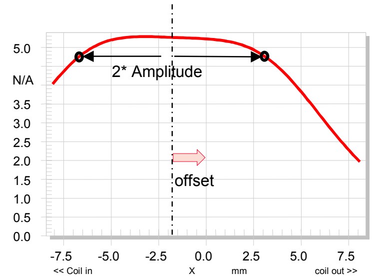
- 高音圈电感 High voice coil inductance
- 对磁场调变敏感 Sensitive to flux modulation

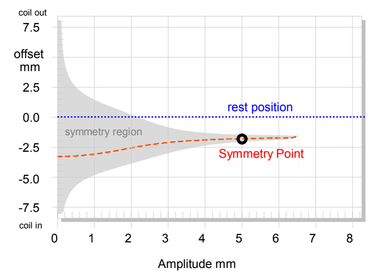
导致磁力强度不对称的两个原因

The two causes for Bl(x)-Asymmetry

1. 音圈偏移 Voice coil Offset
   - 悬吊系统，制造工艺 caused by suspension, manufacturing
   - 音圈移位 Can be fixed by shifting the coil
2. 磁场不对称 Asymmetry of the magnetic field
   - 磁隙的几何形状 caused by gap geometry
   - 要求磁回形状调整 Requires optimal motor design
   - 可用音圈抵消一部分 Can be partly compensated by coil offset

分析磁力强度的不对称曲线
Assessing the Asymmetry of the Bl(x)-curve





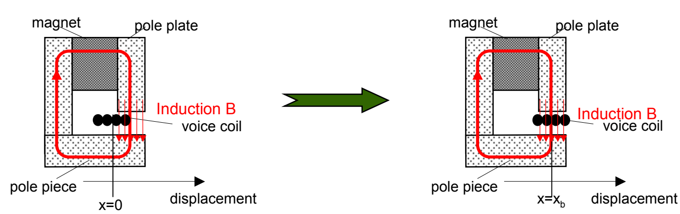
Target 设计目标：

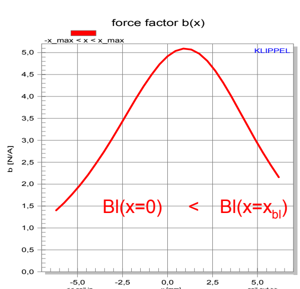
Keep rest position in symmetry region ! 保持静止位置在对称的范围内！

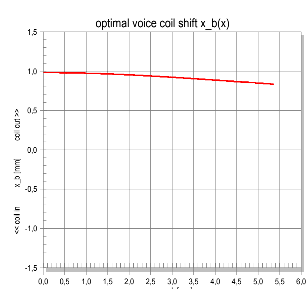
Remedy 修正方法：

If symmetry point is independent of amplitude then offset can be compensated by a voice coil shift ! 调整音圈的位置至振幅的对称点！

调整音圈的位置
Adjusting voice coil position

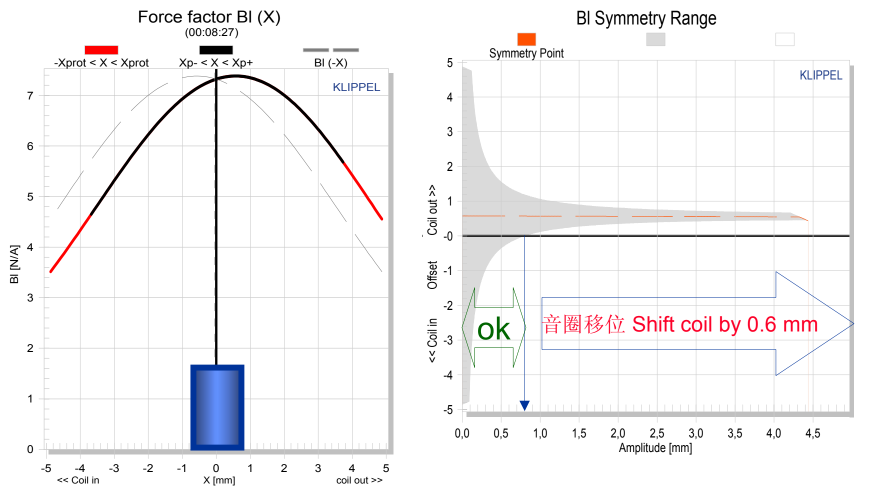






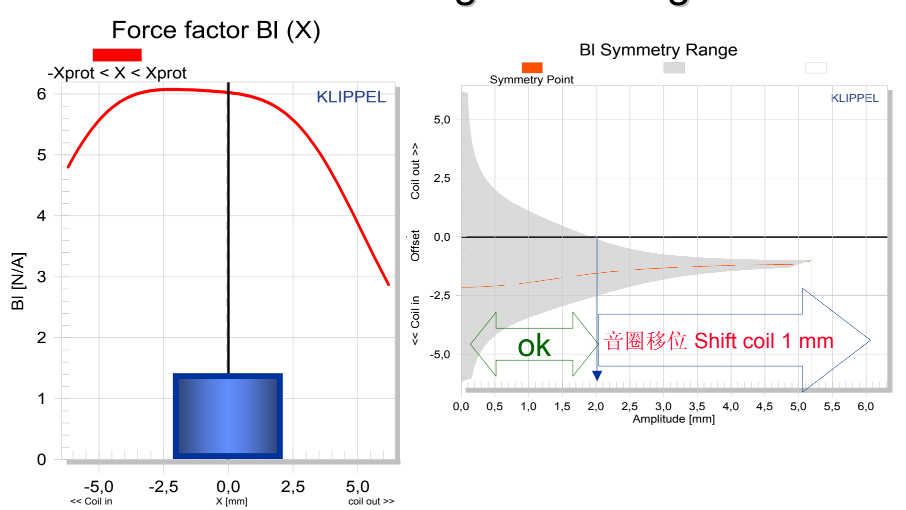
小排线长音圈的磁回系统

Motor with small coil overhang

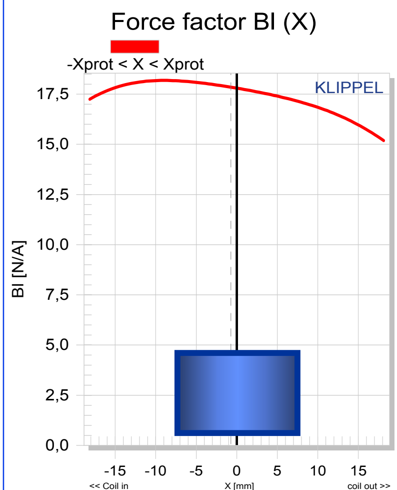


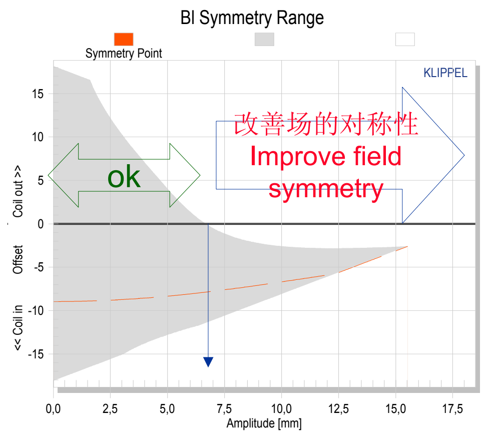
大排线长音圈

Coil with large overhang



音圈偏移或场的不对称性?
Coil offset or Field Asymmetry ?





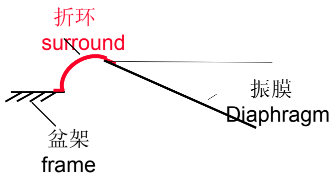
改善磁力强度
Remedies for Bl(x)

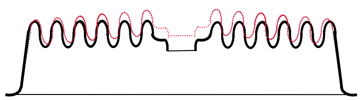
1. 使磁力强度固定不变 Make Bl(x)=constant
   - 增加长音圈 by increasing voice coil overhang
   - 增加短音圈 by increasing voice coil underhang
2. 减少磁力强度的不对称性 Reduce Bl(x) asymmetries
   - 将线圈移至最佳位置 by placing coil at optimal rest position
   - 在磁隙中使用对称的磁场 by using a symmetrical B-field in the gap

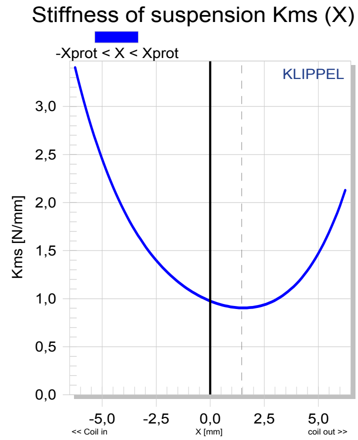
避免刚性特性的不对称性！！

Avoid asymmetries in your Kms(x) characteristic !!

由几何形态引起
Caused by geometry







你的悬吊系统不好的话你的扬声器也不会好

Your Speaker is not better than your suspension

问题是由刚性的不对称造成的: Problems caused by Kms(x) asymmetry:

- 位移的整流 Rectification of the displacement
- 动态系统产生了直流位移 dc displacement is generated dynamically
- → 音圈偏移 Offset in voice coil position
- 磁力强度产生了过多的失真 Bl(x) produces excessive distortion
- 磁回不稳定 Motor may become unstable

保持悬吊系统的非线性
Keep the suspension nonlinear !

使用对称刚性的好处 Benefits of using a symmetrical Kms(x):

- 大振幅时软限幅 Soft limiting at high displacement
- 音圈的自然保护 Natural protection of the coil
- 磁回具有更多的稳定性 More stability of the motor
- 刚性失真增强了低音感受 Kms(x)-distortion enhances bass sensation (aggressive bass)

改善刚性
Remedies for Kms(x)

1. 移走不对称性 Remove asymmetry in Kms(x) by
   - 使用对称的几何形状 using symmetrical geometry
   - 使用较软折环 using a soft surround (spider dominant)
   - 通过定心支片的不对称性来平衡折环 compensate surround by spider asymmetries

2. 减少对称限幅 Reduce symmetrical limiting by
   - 增加定心支片波纹的数量 increasing number of rolls
   - 增加定心支片波纹的大小 increasing size of rolls

3. 避免在初始状态处无刚性 Avoid loss of stiffness at x=0 by
   使用低粘弹性的材料 using material with low visco elasticity

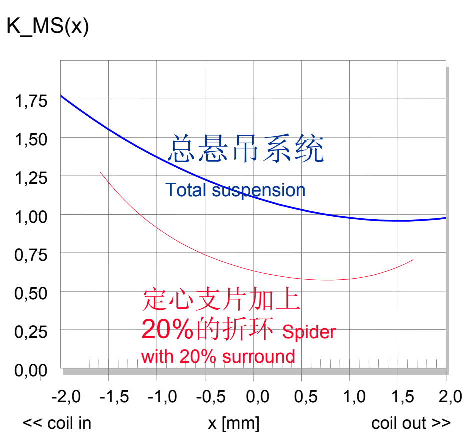
4. 使用小的密闭的箱子 Use small sealed box → 空气刚性起主要作用 dominant air stiffness

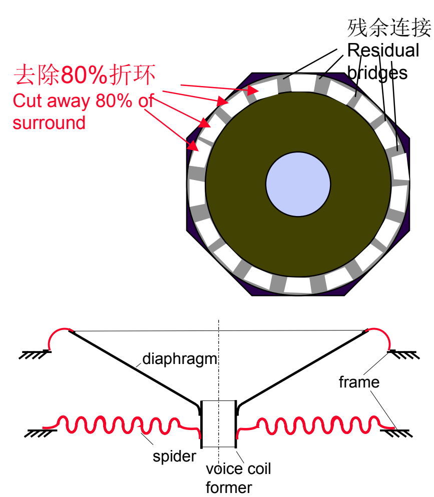
改善电磁场
Remedies for Le(i)

1. 减小交流电磁场 Reduce magnetic ac flux
   - 使用少圈数的小(排线)音圈 by using a smaller coil with less windings
   - 增加音圈电阻 by increasing the voice coil resistance
   - 使用短路材料 using shorting material

2. 在高饱和状态下使用磁路 Operate iron path at higher saturation

定心支片和折环的分离刚性
Separate Stiffness of spider and surround





长音圈并不总是好的
A long coil is not always good !

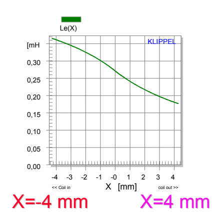
1. 增大音圈卷宽促进了磁力强度的线性 Larger voice coil height improves linearity of Bl(x)
2. 线圈中的电流导致交流电磁场的增加 Increases the magnetic ac field generated by current in coil
3. 增加电感非线性效应 Increases effect of nonlinear inductance (L(x) versus displacement)
4. 产生磁场调变 Causes flux modulation (L(i) and Bl(i))

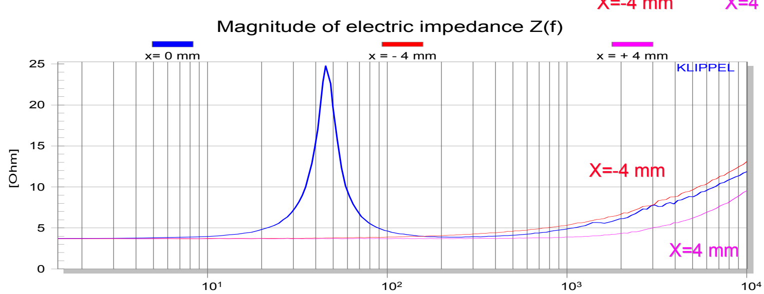
非线性电感的效应
Effect of nonlinear inductance L(x)

引起电感非线性的成因 Le(x) nonlinearity causes

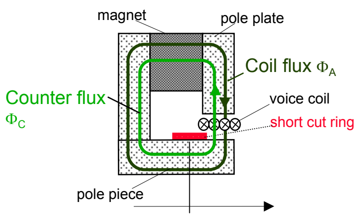
• 输入电阻抗的变化 variation of electrical input impedance

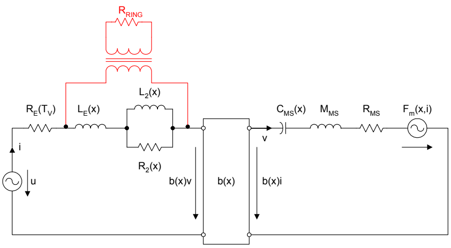
• 低音和声音之间的互调 intermodulation between bass tone and voice tone



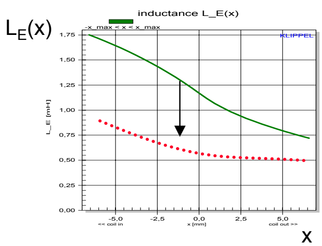


维持电感线性
Linearizing Inductance





电机等效电路 Electro-mechanical Equivalent Circuit



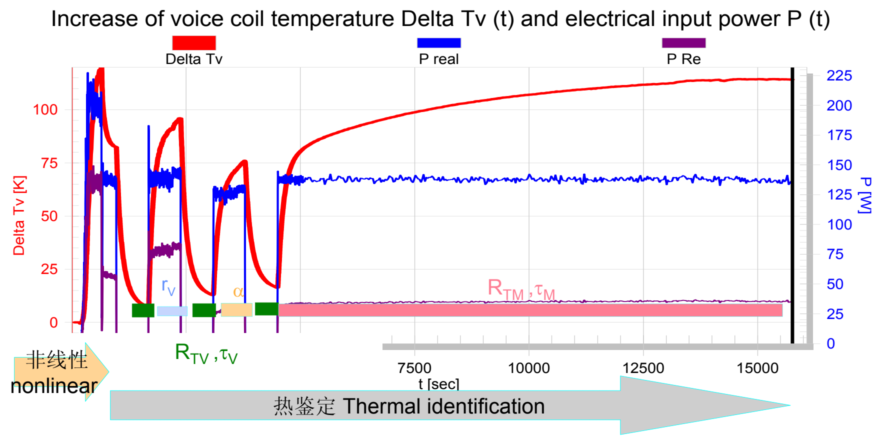
优化设计 Optimal Design:

- 几何形状 Geometry (环或杯 Ring or Cap)
- 材质 Material (铝或铜 Aluminum or Copper)
- 尺寸及位置 Size and position

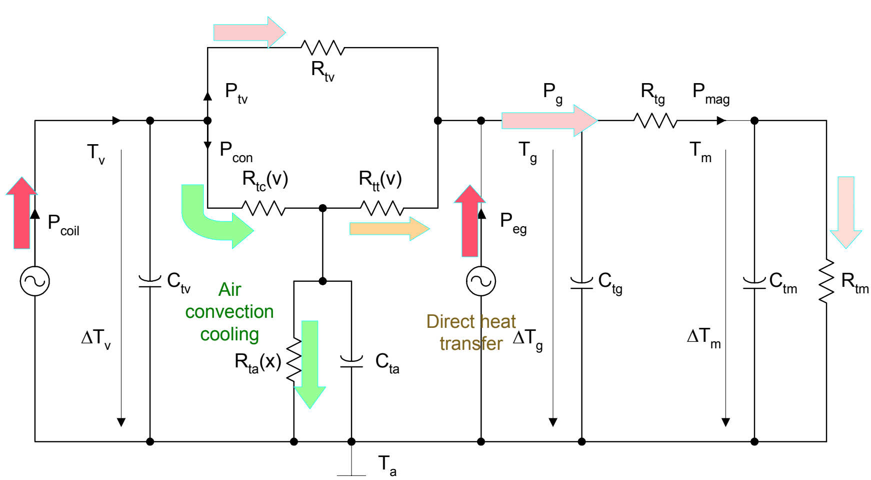
改善电感强度
Remedies for Le(x)

1. 减少交流磁通量 Reduce magnetic ac flux
   - 使用少绕组的小排线音圈 by using a smaller coil with less windings
   - 增加音圈电阻 by increasing the voice coil resistance
   - 使用短路材料 using shorting material
2. 使电感量固定不变 Make Le(x)=constant
   - 在最佳位置安放短路材料 By placing shorting material at optimal position

热学参数的测量
Measurement of thermal Parameters



检查: 热流量
Check: Thermal Heat Flow



非线性热学模型 Nonlinear Thermal Model

原型样品的评价
Evaluation of the Prototype

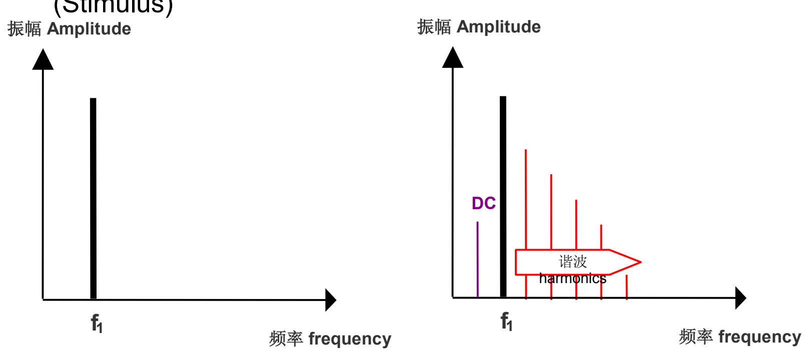
1. 参数基于(模型要求) Parameter based (model required)
- 线性传递函数　Linear transfer functions
- 小信号参数 T/S　Small signal parameter T/S
- 大信号参数 (热学的，非线性的)　Large signal parameters (thermal, nonlinear)

2. 性能基于 (取决于驱动信号) Performance-based (depend on stimulus)
- 非线性征兆　Nonlinear symptoms (THD, IMD, XDC)
- Rub & Buzz征兆　Symptoms of Rub & Buzz
- 音圈温度,压缩,最大功率　Coil temperature, compression, Pmax

1.　征兆一: 谐波失真
Symptom: Harmonic Distortion

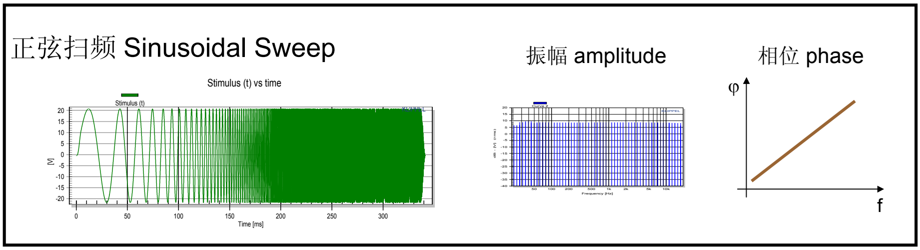
单音
Single tone
(Stimulus)

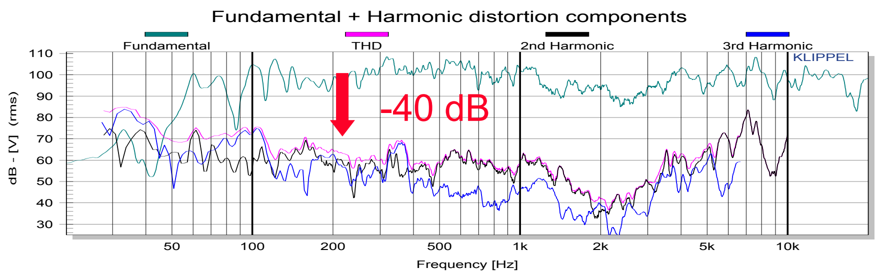
响应
Response



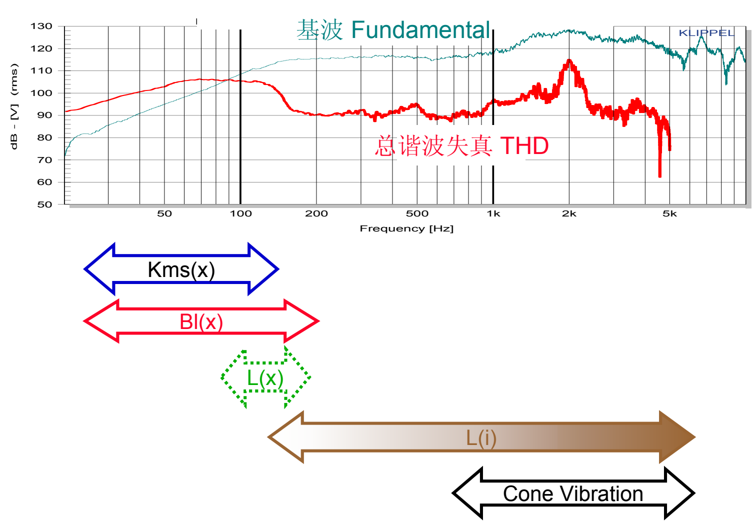
单音信号产生谐波及直流分量 (位移) A single tone generates harmonics and a DC component (in displacement)

测量谐波失真
Harmonic distortion Measurement





谐波失真的成因
The causes of harmonic distortion

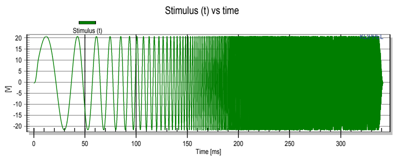


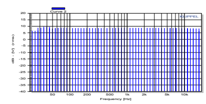
变换驱动信号的相位
Changing the phase of the stimulus

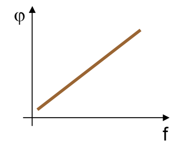
正弦扫频 Sinusoidal Sweep

振幅 amplitude

相位 phase



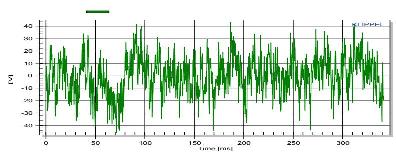


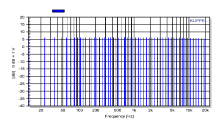


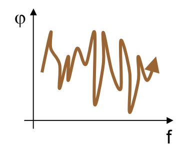
多频音 Multi-tone stimulus

振幅 amplitude

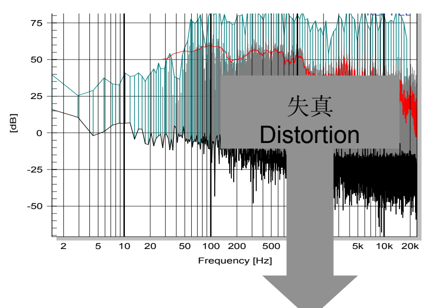
相位 phase







由多频音信号引发的失真分量
Distortion Components generated by a multi-tone stimulus



指纹„Fingerprint“
(对质量监测有益
good for quality control)

Multi-tone Stimulus

?

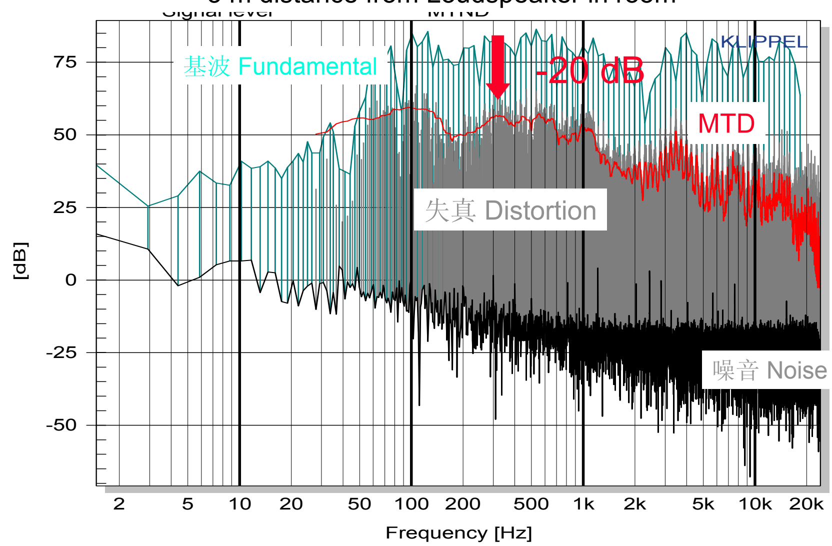
- 在基波频率处失真 distortion at fundamental frequencies
- 谐波分量 harmonic components
- 音差分量 difference-tone components
- 合音分量 summed tone components

} Intermodulation 互調失真

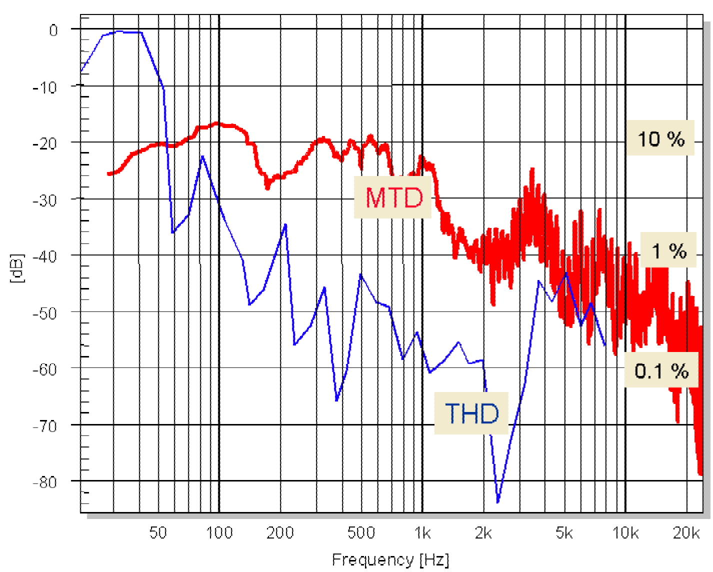
多频音失真不会在细节上展示生成过程
MTD don‘t show the generation process in detail

测试多频音信号失真
Multi-tone Distortion Measurement

3 m distance from Loudspeaker in room



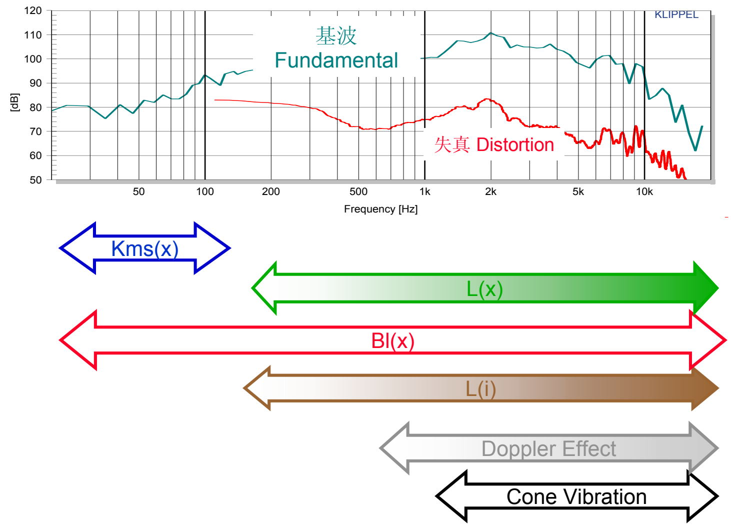
多频音失真对比总谐波失真
Multi-tone Distortion contra THD



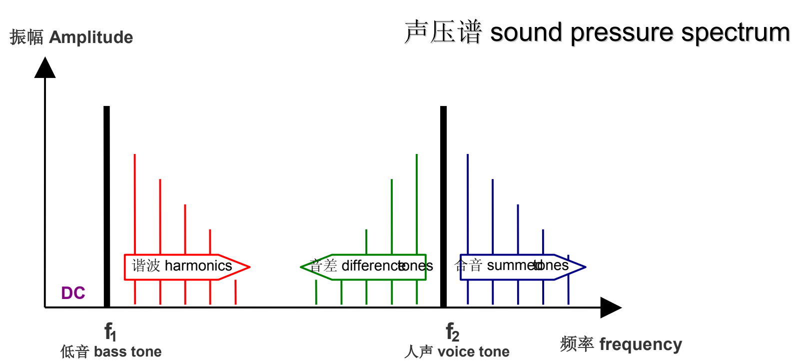
驱动信号 Stimulus:
总谐波失真 THD:
扫频 sweep @
15V

多频音失真MTD:
多频音Multitone @
15V

多频音失真的成因
The causes of multi-tone distortion



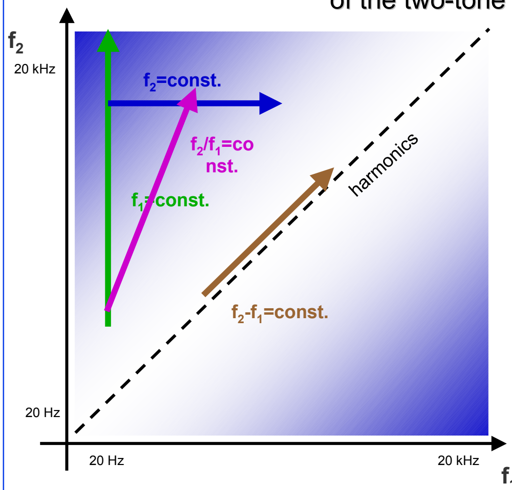
互调的测量
Measurement of Intermodulation
双音驱动 Two-tone Stimulus

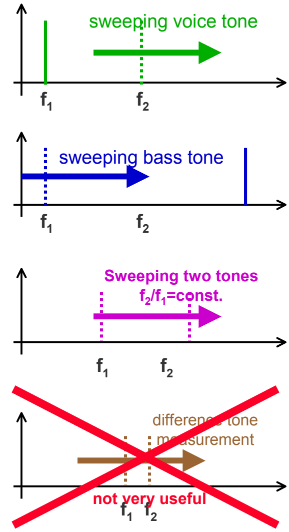


怎样选择频率

How to choose the frequencies

of the two-tone stimulus

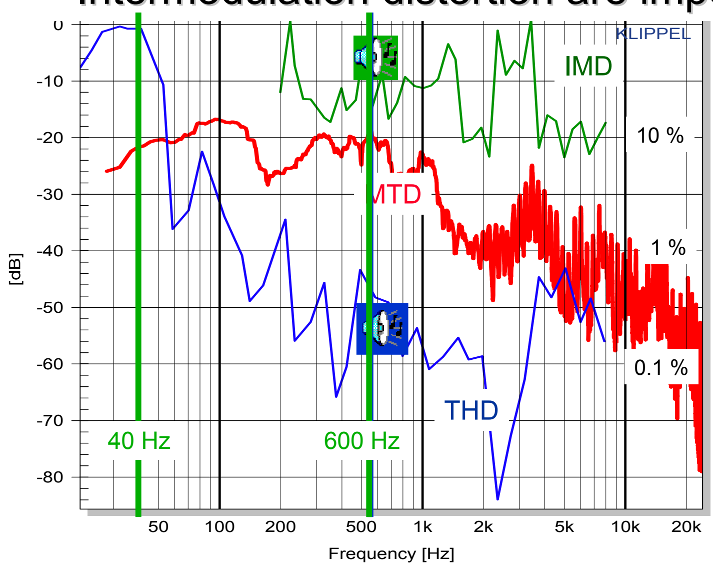




Exploit information for $f_2 \neq f_1$!!!

互调失真是非常重要的！

Intermodulation distortion are important !

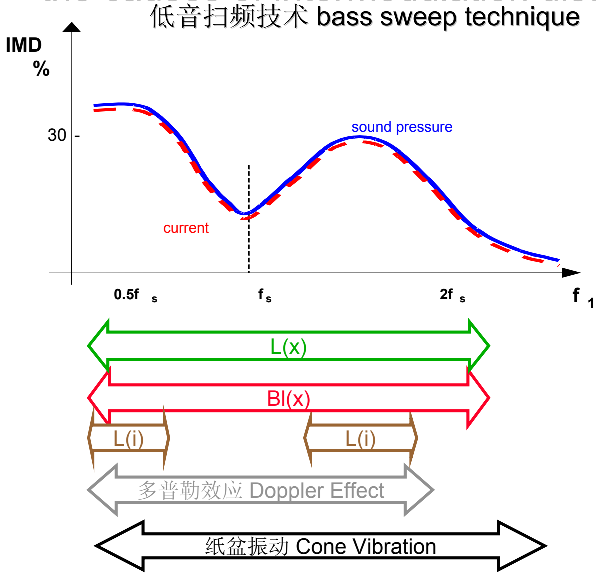


互调失真 IMD:
f1 = 50 Hz @15 V
+ sweep @ 3V

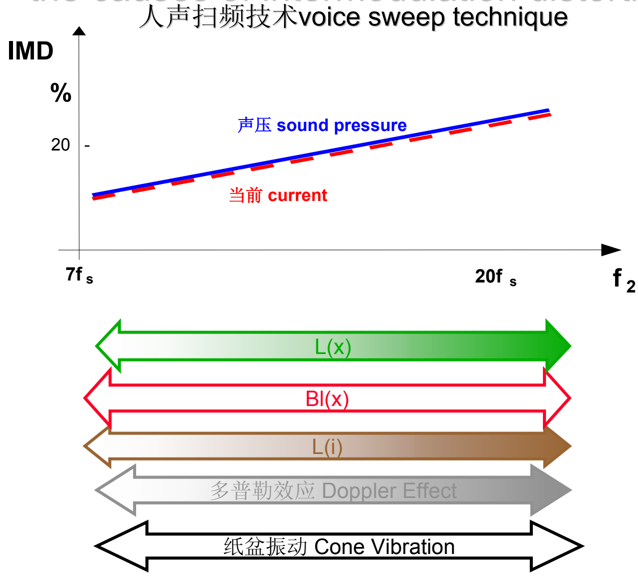
多频音失真 MTD:
Multitone @ 15V

总谐波失真 THD:
sweep @ 15 V

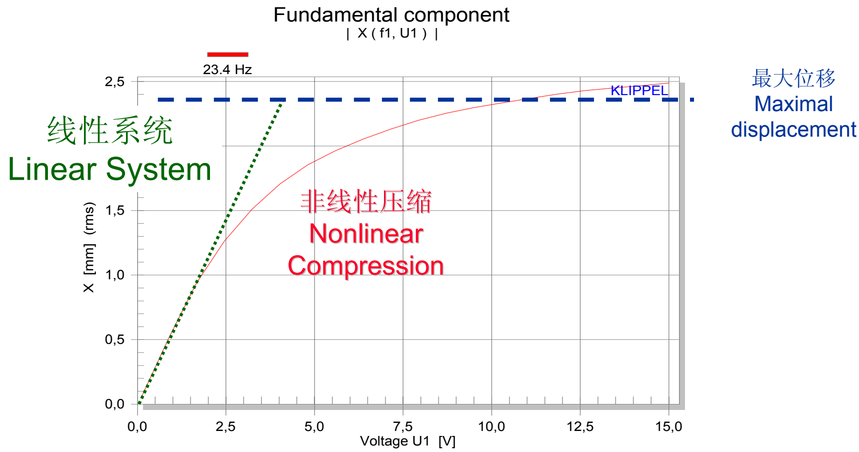
互调失真的成因
the causes of intermodulation distortion
低音扫频技术 bass sweep technique



互调失真的成因
the causes of intermodulation distortion
人声扫频技术voice sweep technique

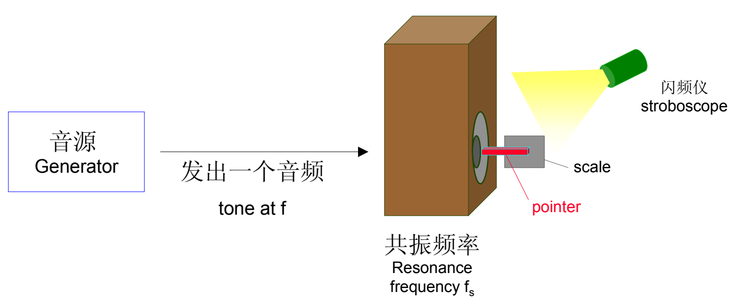


检查:基波的压缩
Check: Compression of fundamental



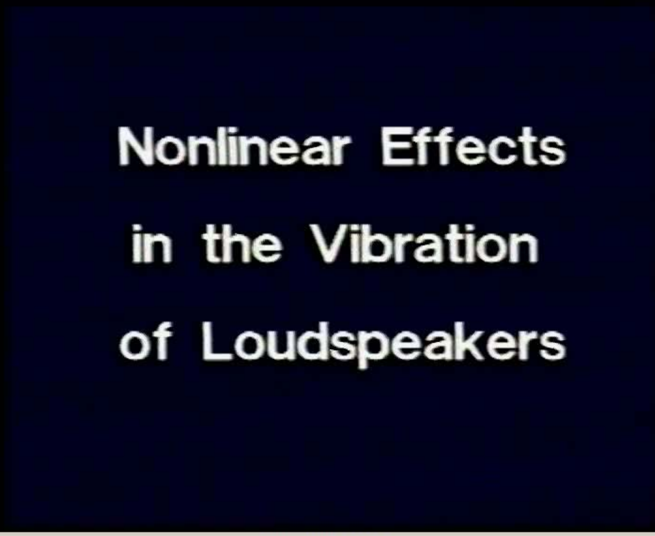
基波分量受非线性的影响 The fundamental component is affected by nonlinearities

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

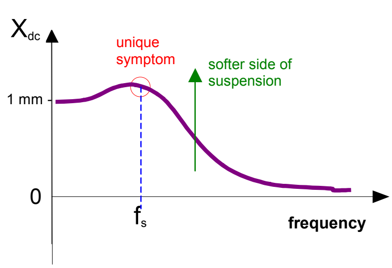


video nonlinear behavior.m1v

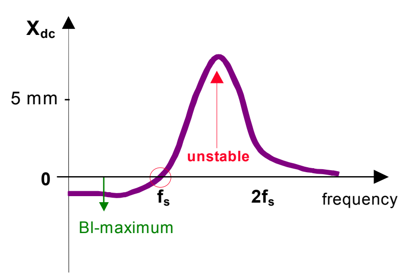
Klippel GmbH

检查:直流位移
Check: dc Displacement

Caused by Kms(x)

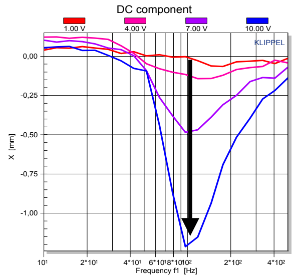


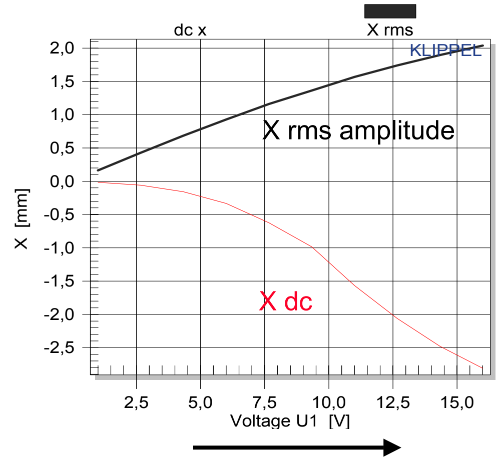
Caused by Bl(x)



www.klippel.de

检查:驱动系统的稳定性
Check: Motor Stability





测试临界频率
Test at critical frequency f ≈1.5 fs

扬声器的不稳定性
Unstable Loudspeakers

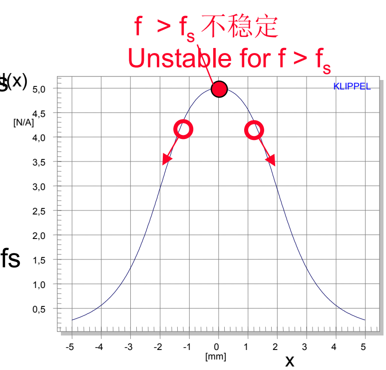
实验 Experiment:

-单体具有较软线性悬吊系统 Driver has soft linear suspension

-等长结构 Equal-length configuration

(磁力强度非线性 Bl(x) nonlinearity)

-正弦驱动信号 Sinusoidal stimulus f > fs




bifurcation caused by motor.MOV

→ 分叉成两个振动稳定状态 Bifurcation into two stable states of vibration

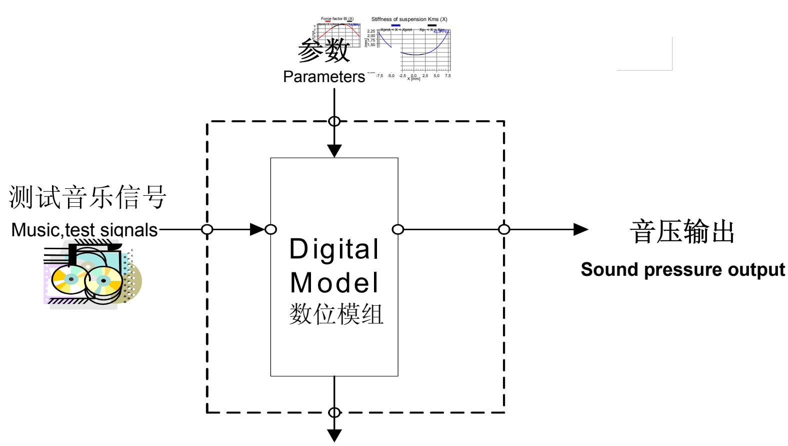
如何应付非线性

How to cope with nonlinearities

- 在近场处测量非线性失真 → 确保足够的信噪比
  Measure nonlinear distortion in the near field → ensure sufficient SNR
- 将失真转换为扬声器的输入 → 等效输入失真概念
  Transform distortion to the loudspeaker input → concept of equivalent input distortion
- 了解非线性之间的关联 → Kms(x), Bl(x), L(x) 之间没有互相抵消
  Be aware of interactions between nonlinearities → no compensation of Kms(x), Bl(x), L(x)
- 检查直流位移 → 不稳定性 Check for dc-displacement → instability
- 使用数字模拟工具 → 观察 THD, X_{max}, SPL_{max}, IMD, P_{max} ,T
  Use numerical simulation tool → see impact on THD, X_{max}, SPL_{max}, IMD, P_{max} ,T
- 从不规则毁损中分离固有非线性 →测量失真的峰值因子
  Separate regular nonlinearities from irregular defects → measure Crest Factor of Distortion

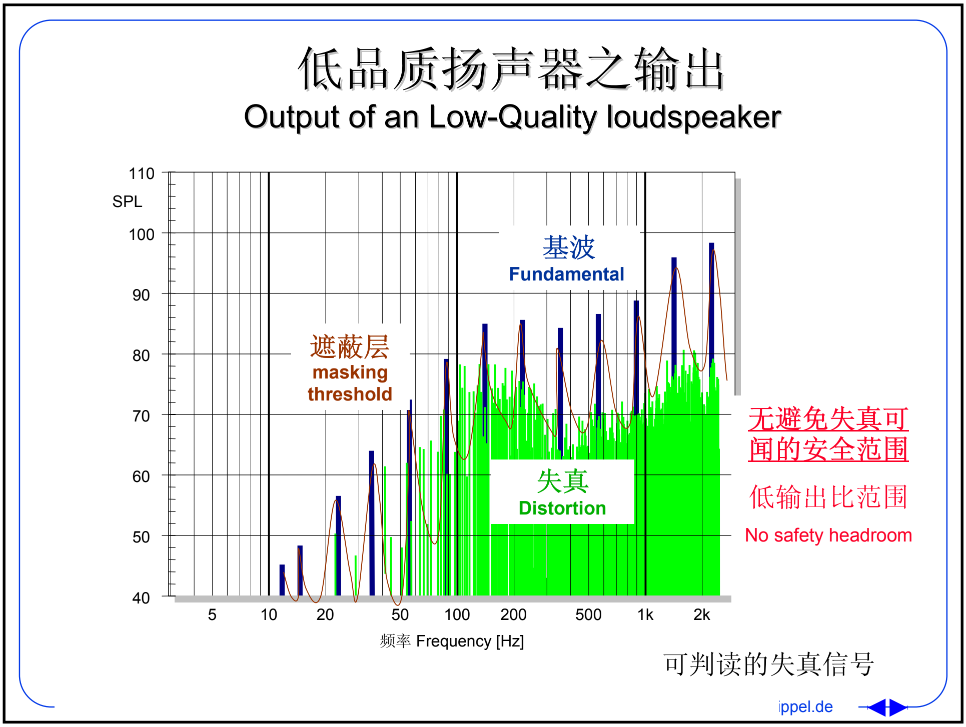
模拟扬声器工作效益

Simulation of Loudspeaker Performance

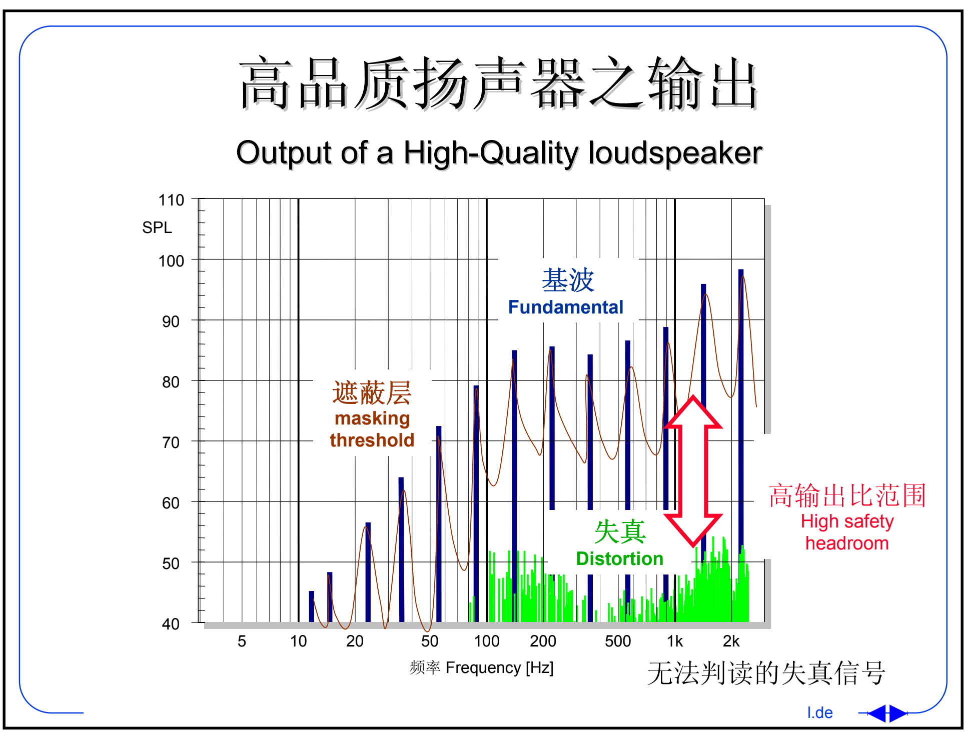


位移, 电流, 功率, 温度

Displacement, Current,Power, Temperature



低品质扬声器之输出
Output of an Low-Quality loudspeaker
110
SPL
100
90
80
70
60
50
40
5
10
20
50
100
200
500
1k
2k
频率 Frequency [Hz]
基波
Fundamental
遮蔽层
masking
threshold
失真
Distortion
无避免失真可
闻的安全范围
低输出比范围
No safety headroom
可判读的失真信号
ippel.de



高品质扬声器之输出
Output of a High-Quality loudspeaker
110
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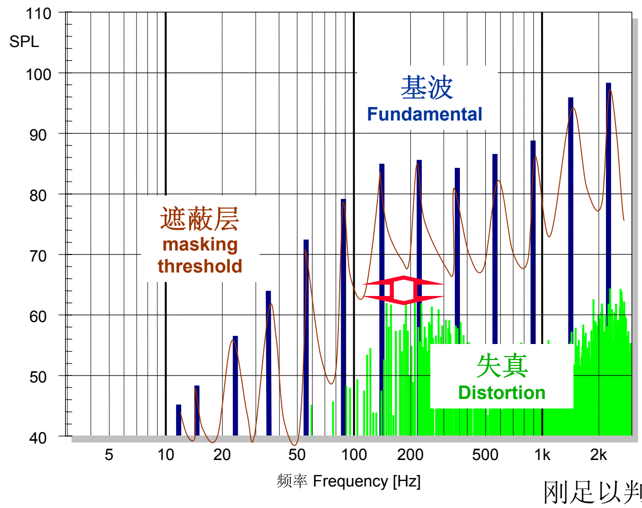
Distortion
高输出比范围
High safety
headroom
无法判读的失真信号
l.de

顶级扬声器之输出

Output of an optimal Loudspeaker



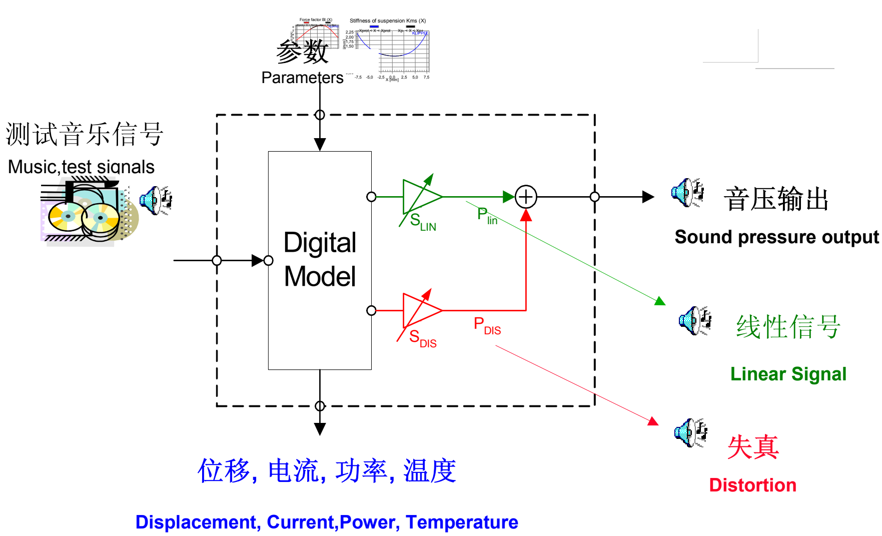
足够的输出比范围

Sufficient safety headroom

刚足以判读的失真信号

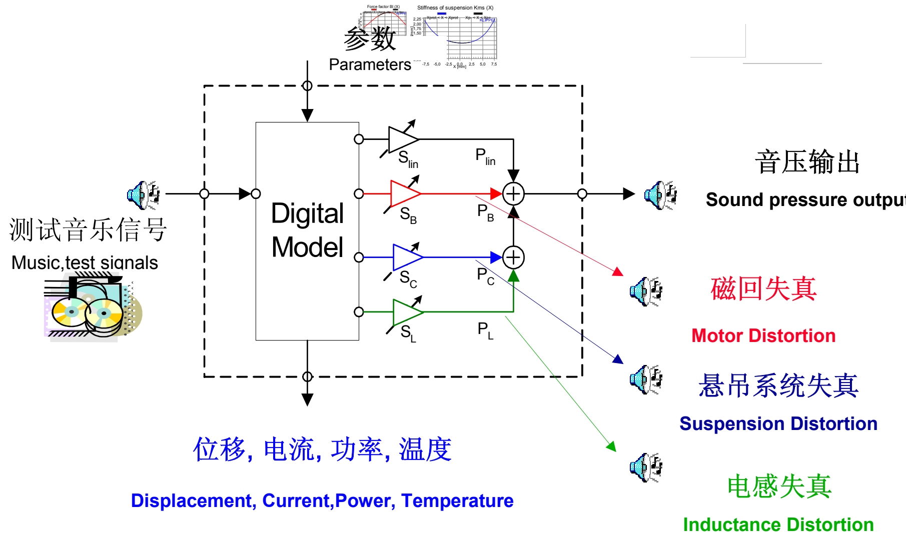
聆听分析失真信号

Listening into a Digital Model



各种失真模式之聆听测试

Listening into a Digital Model



输出范围

Measurement of Safety Headroom

	S_{lin}	S_{DIS}	Example
理想扬声器 Ideal Speaerk	0 dB	-100 dB	
	0 dB	-12 dB	
失真减少 Distortion decreased	0 dB	-9 dB	
	0 dB	-6 dB	
	0 dB	-3 dB	
实际扬声器 Real Speaker	0 dB	0 dB	
	0 dB	3 dB	
可判读层 threshold of audibility	0 dB	6 dB	
失真增大 Distortion increased	0 dB	9 dB	
	0 dB	12 dB	

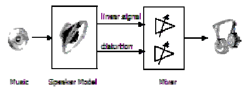
输出范围相当于增大失真可判读比

Safety Headroom = Increase of S_{DIS} to make distortion audible

扬声器之主观及客观评价

Auralization in Loudspeaker Development

研发生产单位
Development
Manufacturing



市场营销单位
Marketing
Management

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

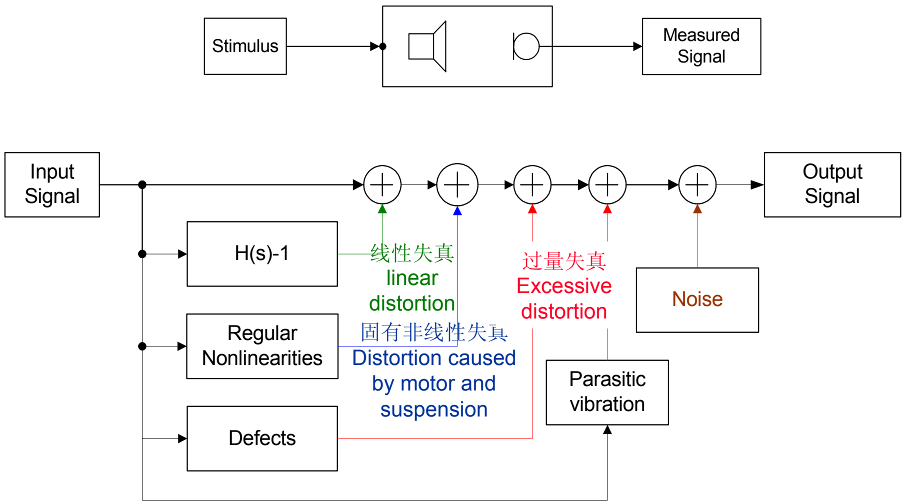
- 个人印象 Personal Impression
- 足够的音质 Sufficient Sound Quality
- 针对目标市场调适 Tuning to the target market
- 性价比(效益及成本比) Performance/Cost Ratio

结论

Conclusion

- "大声" 扬声器总是非线性的
  „Loud"speakers are always nonlinear
- 我们可以建立其非线性模型
  We can model their nonlinearities
- 我们需要大信号参数
  We need large signal parameters
- 失真是征兆而非原因
  Distortions are only symptoms not the cause
- 改善功能效益需要用大信号来分析
  Improving performance requires large signal analysis

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

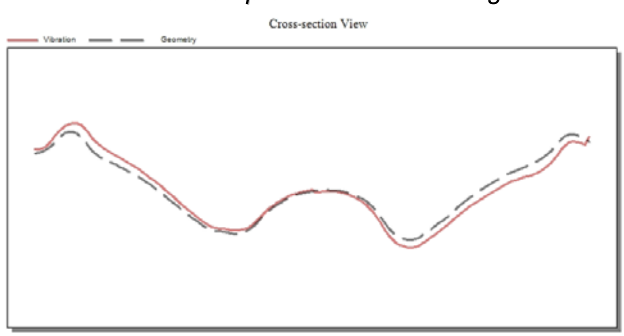


物理学的一个不规则缺损
Physics of a Irregular Defect

第一个例子:音圈摩擦

1st Example: voice coil rubbing

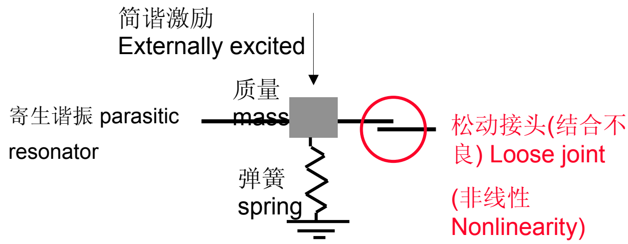
328 Hz



→ 摇摆模式可能导致音圈摩擦 Rocking mode may cause voice coil rubbing

物理学的一个不规则缺损
Physics of a Irregular Defect

第二个例子: 粘胶问题 *2nd Example: Glue problem*

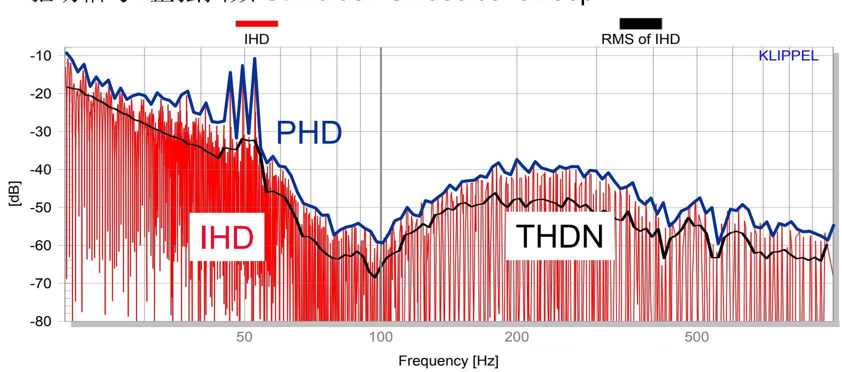


不良的非线性行为模式 Most defects behave as a **nonlinear oscillator**

- 超出限定放大范围 active above a critical amplitude
- 振动新模式 new mode of vibration
- 驱动和同步由驱动信号完成 powered and synchronized by stimulus
- 输出功率稳定 constant output power

谐波失真
Harmonic Distortion

驱动信号: 正弦扫频 Stimulus: Sinusoidal sweep



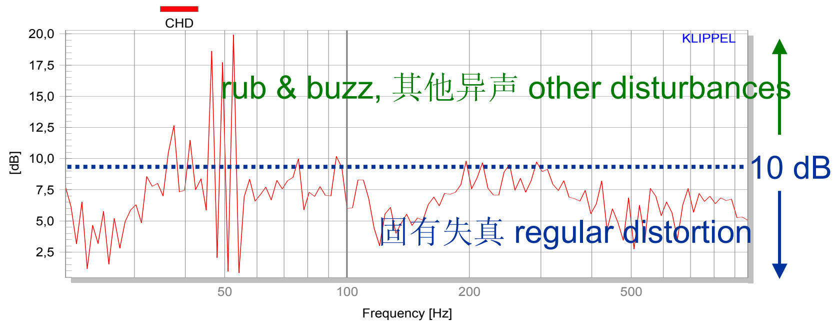
瞬时谐波失真 Instantaneous harmonic distortion

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

峰值谐波失真 Peak harmonic distortion

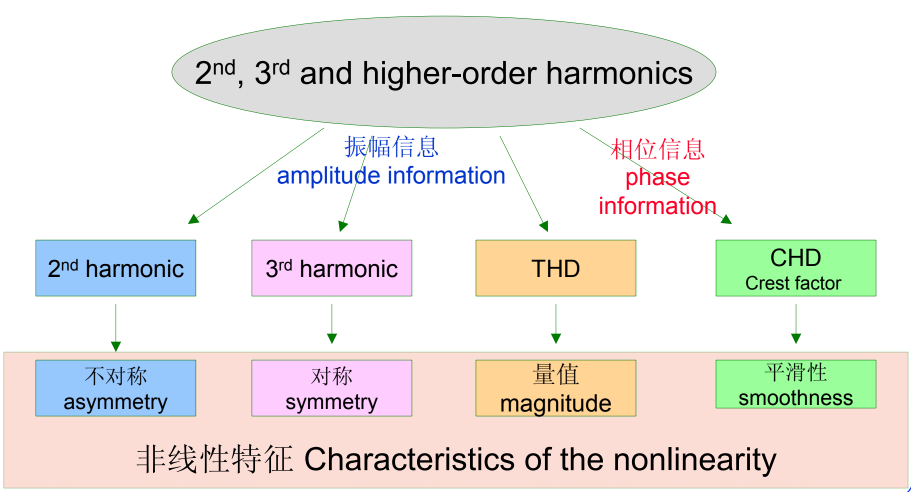
谐波失真的峰值因子
Crest factor of harmonic distortion (CHD)

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 ！

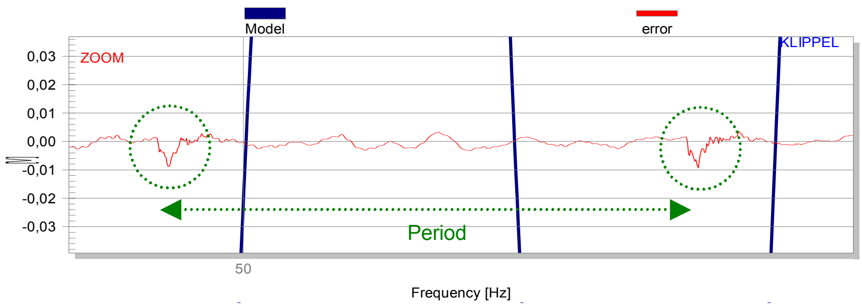
谐波失真测量的结果
Results of the Harmonic Distortion Measurement



时域信号失真的细节

Detail of the distortion time signal

案例 A:Case A: „beating wire of a defect driver“

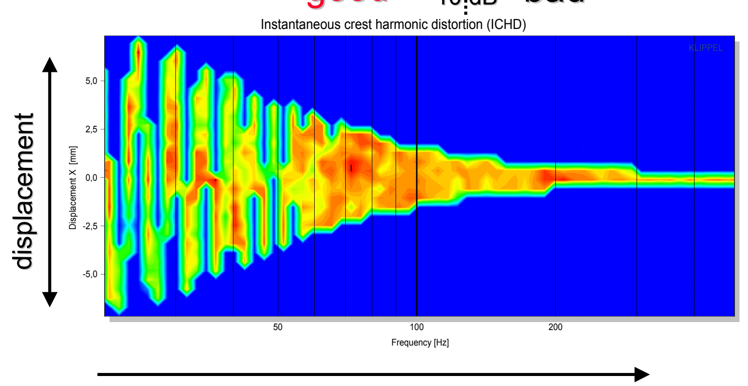


• 固有失真具有高能级 Regular distortion have high energy
• 异声具有低能级 Disturbances have low energy
• 异声是集中在一小部分周期里的 Disturbances are concentrated at a fraction of a period
→ 峰值失真 (大峰值因子) peaky distortion (high crest factor)
→ 有源补偿是有益的 Active compensation is useful

检查: 谐波失真的峰值因子

Check: crest factor of harmonic distortion

Crest factor of harmonic distortion

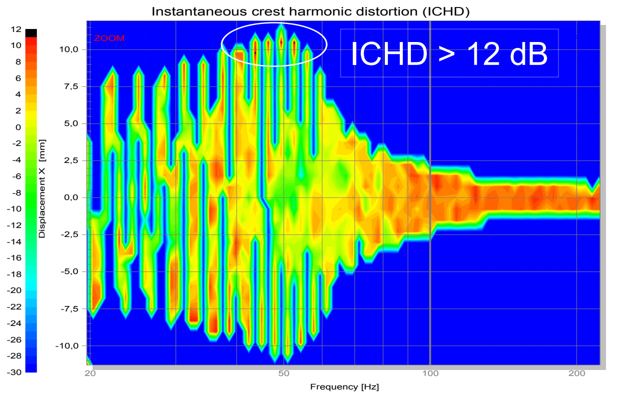


正弦扫频频率 Frequency of sine sweep

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“



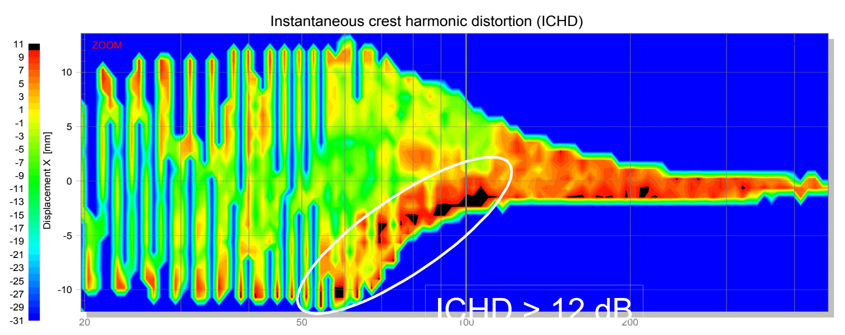
毁损出现在50赫兹 + 10 mm 位移处

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“

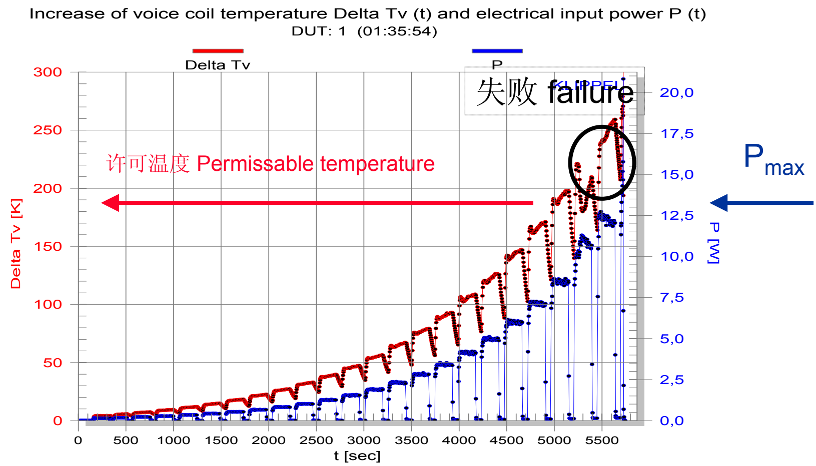


初始摩擦条件 Conditions initiating rubbing:

- 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

评估可承受功率 PWT

Assessing Power Handling

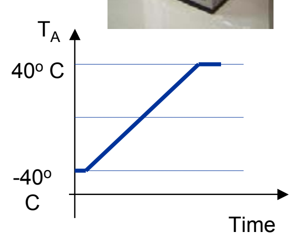


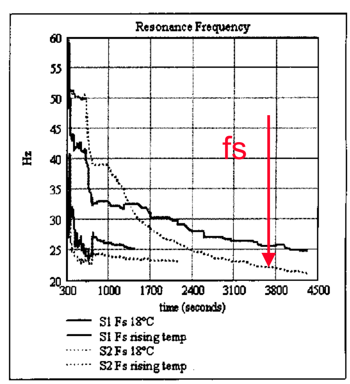
参数变化 Parameter Variation - PWT

研究环境温湿度变化对参数的影响

Investigate the Influence of Ambience Conditions

恒温恒湿箱
chamber

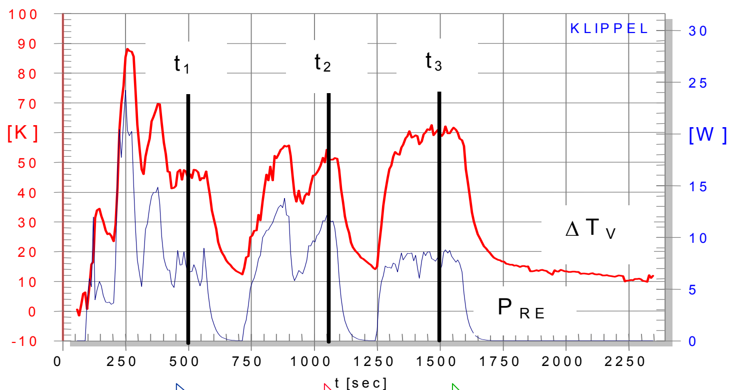




→ S. Hutt: Ambient Temperature Influences on OEM Automotive Loudspeakers, AES preprint 5507

检查:音圈温度

Check: Voice Coil Temperature



音乐 Music:	古典乐 Classic	流行乐 Pop	声乐 Vocal
$\Delta T_V/P_{re}$=	6,8 K/W	4,6 K/W	7,5 K/W

热阻并非恒定!
Thermal resistance is not constant !!