

Using Simple Tools to Design Small Speakers with High Output

使用简单工具设计带高输出的小扬声器

ALMA Symposium Shenzhen 2008

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Schedule Today

今日议程

- Small and Large Signal Diagnostics
小信号和大信号诊断
- Use simple tools
使用简单工具
- How to optimize large signal behaviour
如何优化大信号行为
- Drive units only
仅驱动单元



Simple Tools 简单工具

- Sine generators 正弦信号发生器
- Microphone 麦克风
- Resistor 电阻器
- Spectrum Analyzer 频谱分析仪
- Eye (Optical Check) “眼睛”（位移传感器）



扬声器应用

Loudspeakers are everywhere

- 车用 Cars
- 手机 Cellular phones
- 多媒体, 电脑 Multimedia, Computers
- 助听 Hearing aids
- 家用再生音响 Home hifi reproduction
- 专业音响 Professional audio
- 噪音控制 Active noise control
- ...



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



感知声质再现

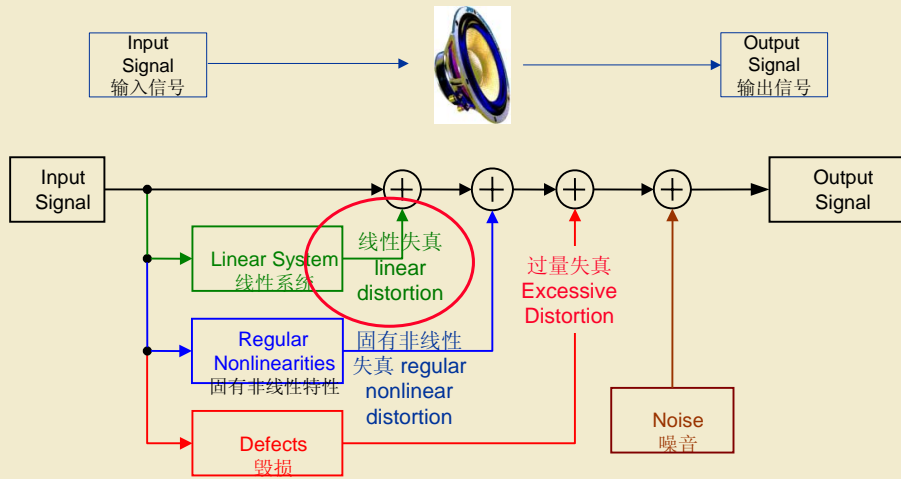
Perceived Quality of Sound Reproduction

取决于 Depends on

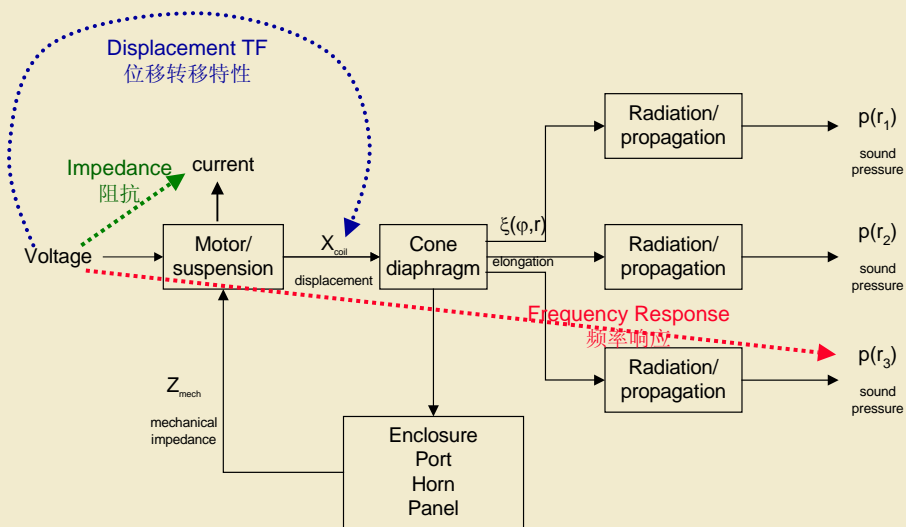
- 驱动信号 Stimulus (music, speech)
- 声学环境 acoustical environment (room)
- 听, 训练, 聆听者的期望
Hearing, training, expectation of the listener
- 电声学单体 Electro-acoustical transducer



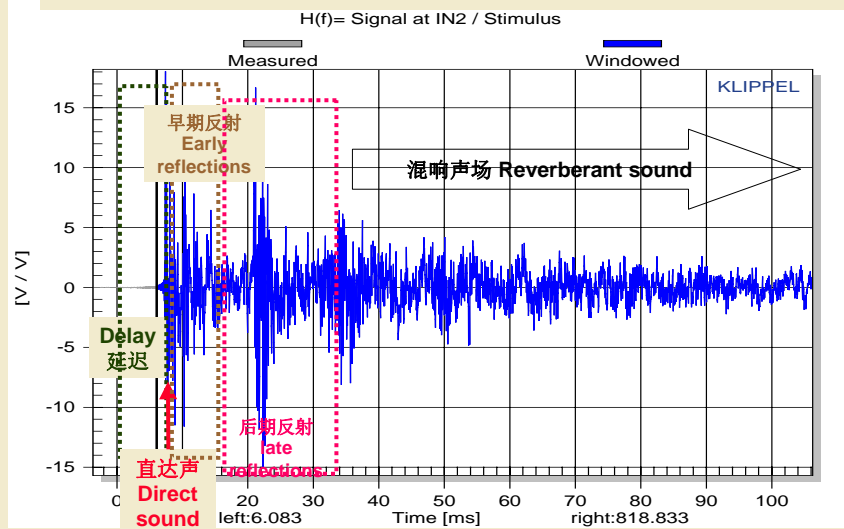
扬声器信号失真的产生 Generation of Signal Distortion in Loudspeakers



A good idea: (Linear) Transfer Functions 一个好主意: (线性的)转移特性

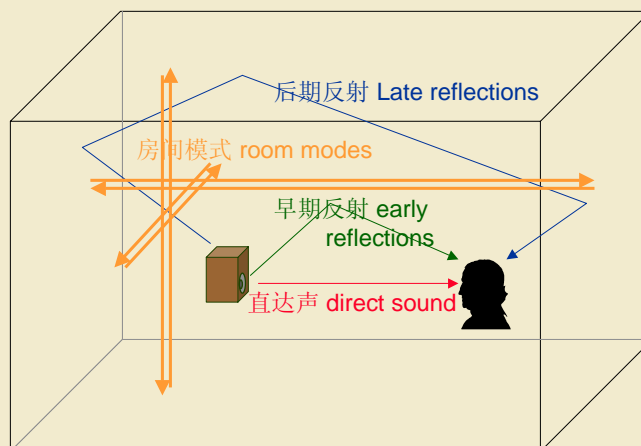


脉冲响应 Impulse Response (扬声器在室内 loudspeaker in room)



Klippel, ALMA China 2008, Simple Tools, 11

与房间的交互作用范围 Interaction with the room

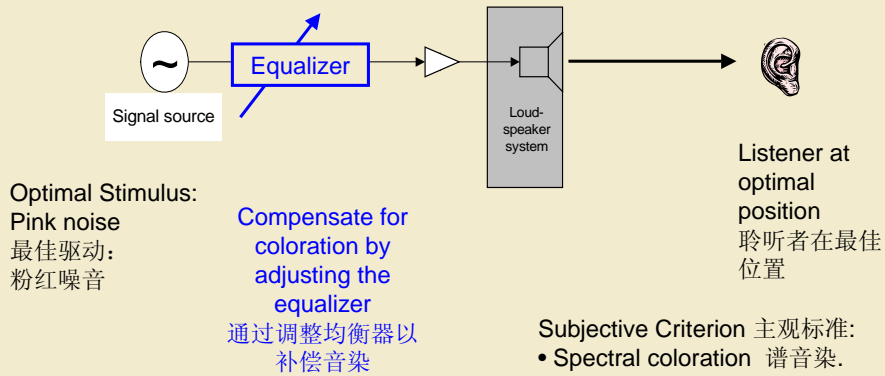


扬声器的哪些特性对此非常重要 Which loudspeaker properties are important for this ?

Klippel, ALMA China 2008, Simple Tools, 12

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

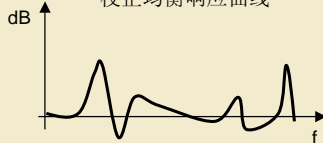
总声压级响应平滑度的试听测试之设置



Interpretation of Listening Tests on Smoothness of Total SPL Response

总声压级响应平滑度上试听测试的解读

Correction curve of equalizer response
校正均衡响应曲线

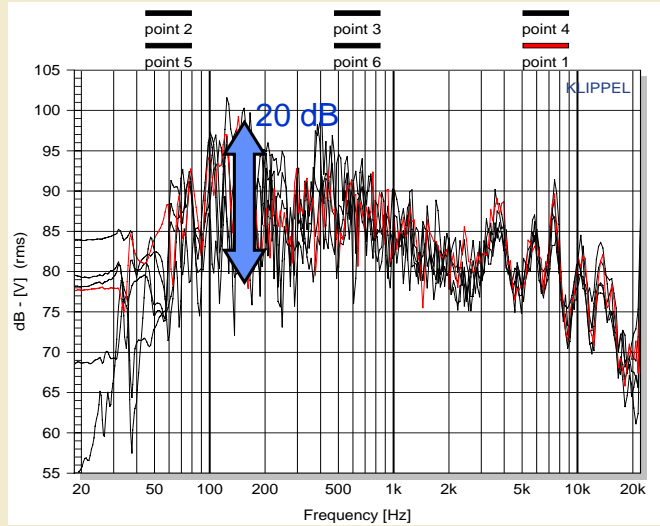
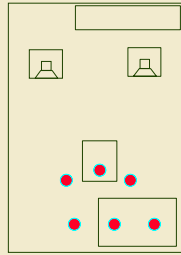


Coloration of the overall system
(loudspeaker, room)
系统总体音染(扬声器,房间)



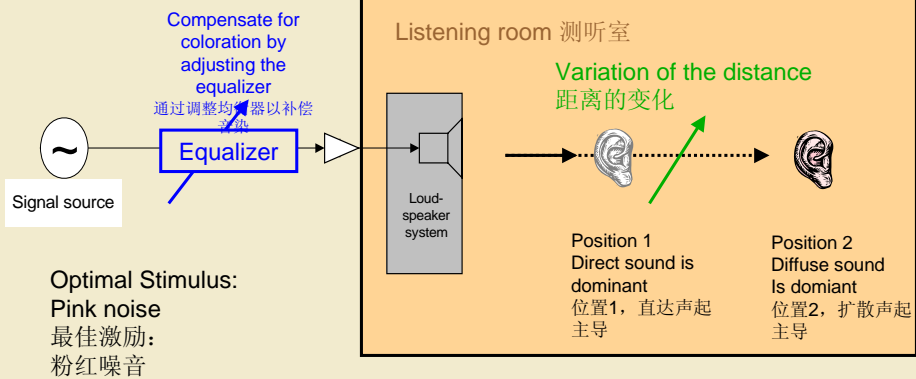
- System Alignment 系统定位 (woofer enclosure 低音箱) → about f_s (< 100 Hz) 共振频率 f_s < 100 Hz
- Room modes 房间模式 → (below 500 Hz 低于500赫兹)
- crossover 交叉模式 → (above 500 Hz 高于500赫兹)
- Break up modes and radiation problems 分裂模式及辐射问题 → (above 500 Hz 高于500赫兹).

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



Klippel, ALMA China 2008, Simple Tools, 15

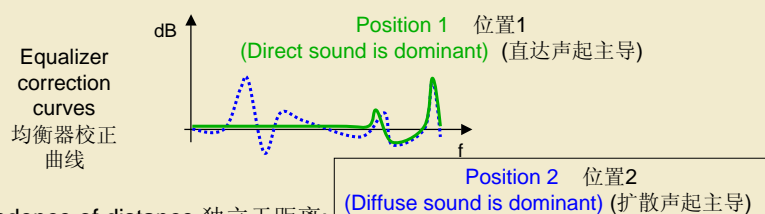
Set-up of Listening Test
on coloration caused by diffuse or direct sound
由扩散声或直达声引起的音染方面试听测试的设置



Test Criterion 测试标准:
• Spectral coloration 谱音染

Klippel, ALMA China 2008, Simple Tools, 16

由扩散声或直达声引起的音染方面试听测试的解读 Interpretation of Listening Tests on coloration caused by diffuse or direct sound



Independence of distance 独立于距离:

- System alignment (woofer + enclosure) 系统定位 (低音+闭箱)
- crossover problems 交叉问题
- Break up modes 分裂模式

only in diffuse sound 仅存在于扩散声

- Room modes 房间模式

Dependence on distance 依赖于距离

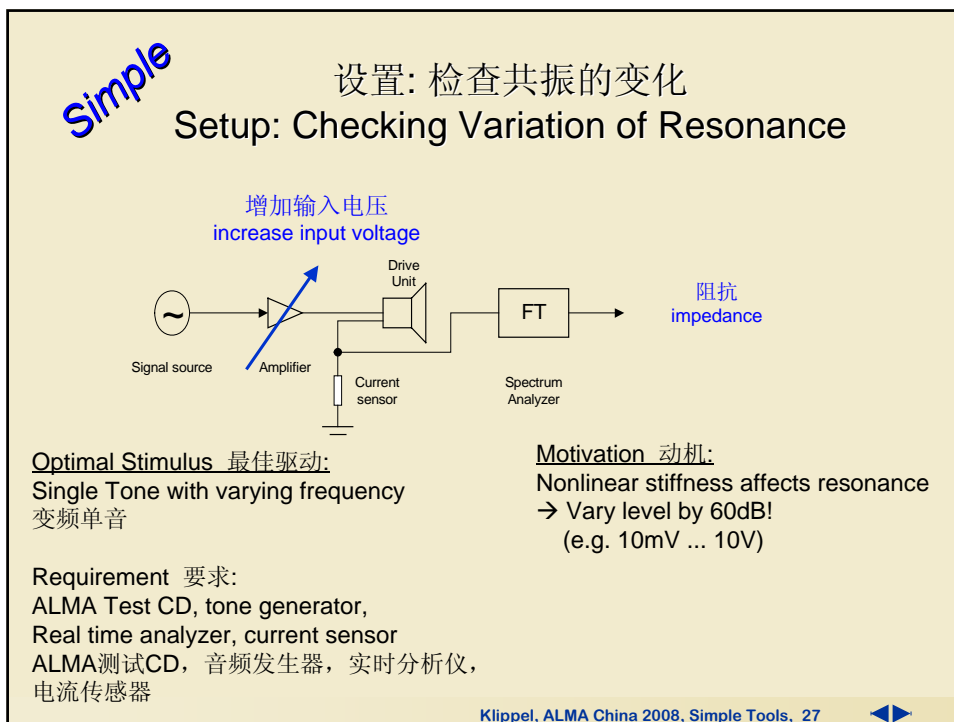
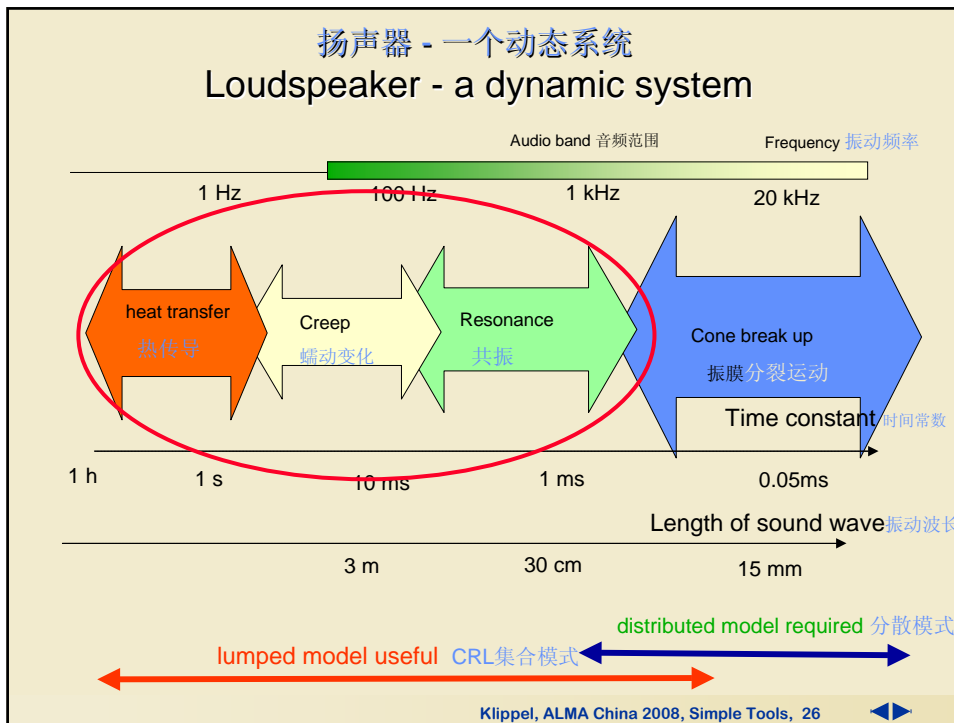
- radiation problems 辐射问题



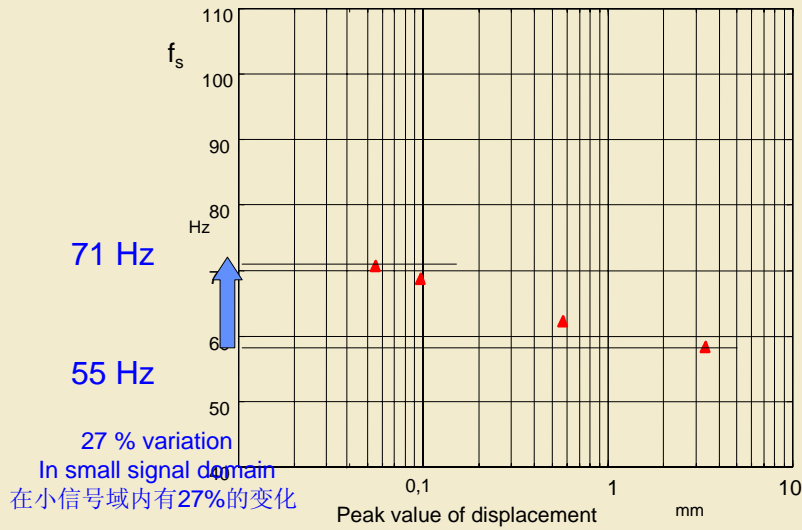
扬声器的设计始于声学目标环境的定义 Loudspeaker design starts with the definition of the acoustical target environment !

- **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

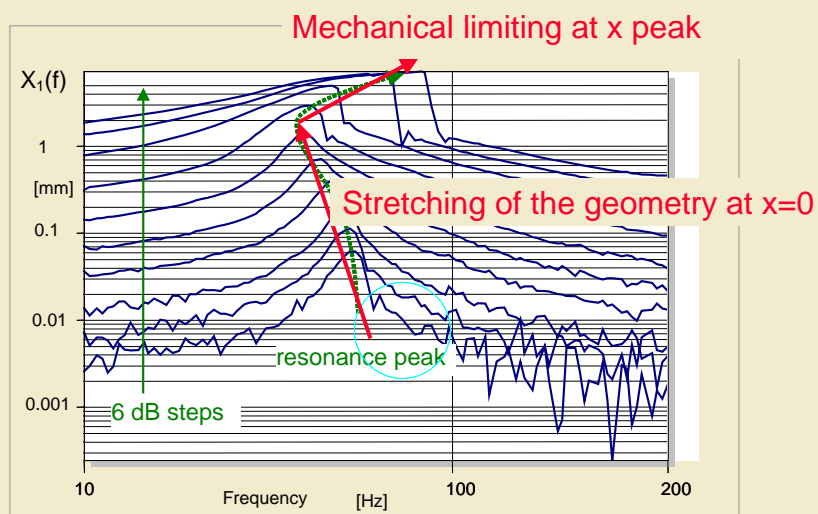




Resonance Frequency f_s versus Amplitude 共振频率 f_s - 振幅



Resonance depends on Amplitude 共振频率依赖于振幅



Linear Lumped Parameters 线性集合参数

Important
重要

Basic parameters 基本参数:

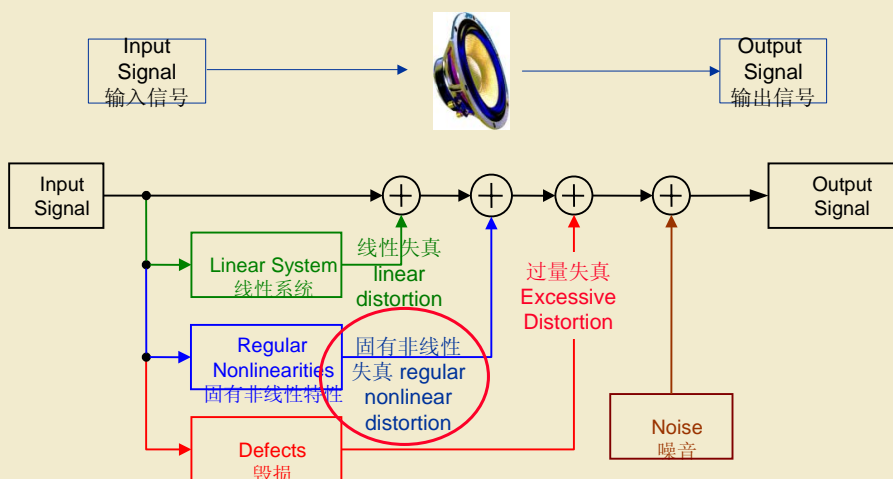
- **dc resistance R_e** 直流电阻 R_e
- Voice coil Inductance L_e (+ additional parameters describing impedance at higher frequencies)
音圈电感 L_e (+附加参数描述在高频率处的阻抗)
- **Moving mass M_{ms} (including air load)** 移动质量 M_{ms} (包括空气动力载荷)
- **Force factor Bl** 磁力强度 Bl
- Mechanical resistance R_{ms} 机械阻力 R_{ms}
- **Stiffness K_{ms} of the suspension at f_s** 在 f_s 处的悬边的刚性 K_{ms}
- Viscous-elastic stiffness parameters („creep factor“) 粘弹性刚性参数(“蠕变因子“)

Derived Parameters (Thiele/Small):

- **Resonance frequency** 共振频率 f_s
- **Electrical Q-factor Q_{es}** 电的Q因子
- **Mechanical Q factor Q_{ms}** 机械的Q因子
- **Total Q-factor Q_{ts}** 总的Q因子
- **Equivalent box volume V_{as} of mechanical stiffness** 机械刚性的等效箱体积
- **Pass-band sensitivity** 通带灵敏度

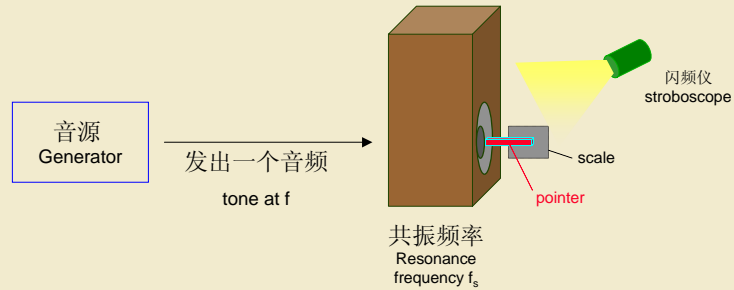
Time varying
时变

扬声器信号失真的生成 Generation of Signal Distortion in Loudspeakers



由闪频仪来看振动模式

Stroboscopic View on the Vibration Behavior



观察频率小于
共振频率点

1. Experiment

$$f < f_s$$

观察频率相当于
共振频率点

2. Experiment

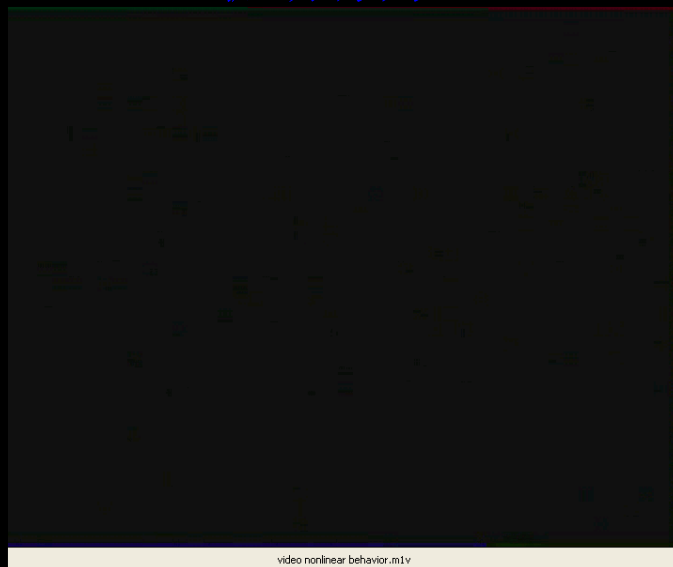
$$f \approx f_s$$

观察频率大于
共振频率点

3. Experiment

$$f > f_s$$

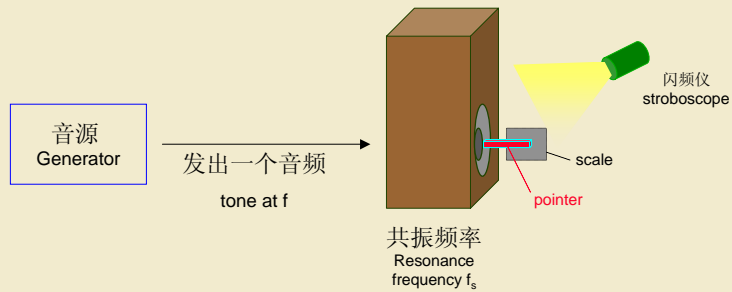
振动行为



video nonlinear behavior.m1v

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

1. Experiment

$$f < f_s$$

Amplitude Compression

观察频率相当于共振频率点

2. Experiment

$$f \approx f_s$$

Resonance changes

观察频率大于共振频率点

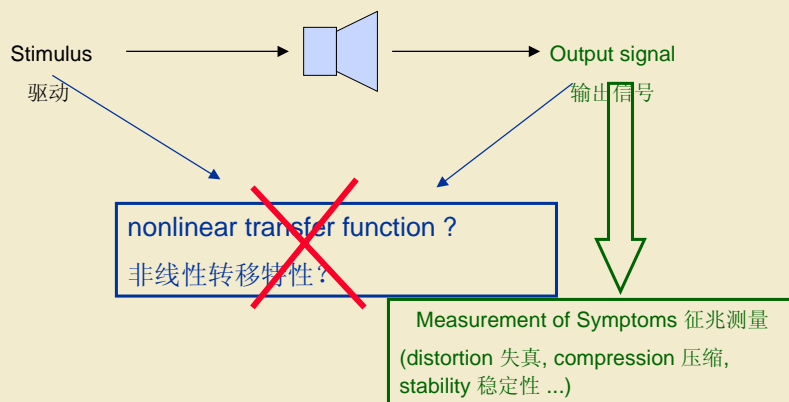
3. Experiment

$$f > f_s$$

DC Offset in Displacement

Assessing Loudspeakers in the Large Signal Domain

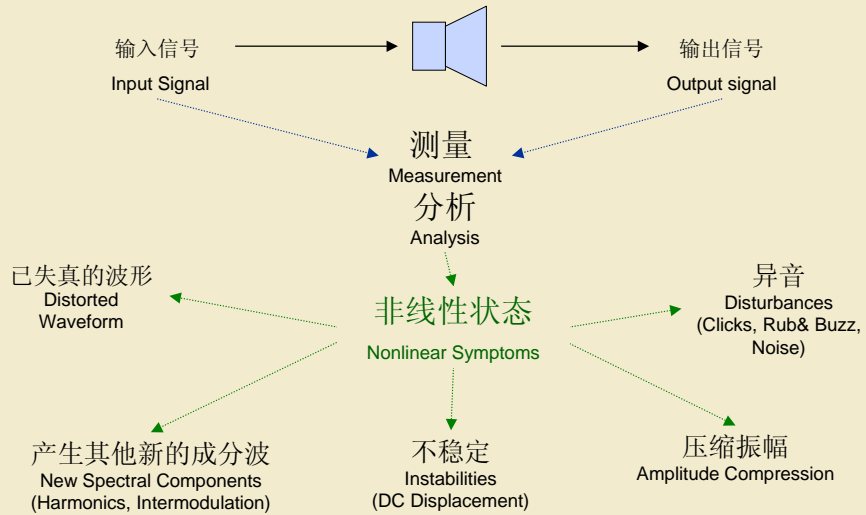
在大信号域内评估扬声器



„SYMPTOMS“ are not parameters of a nonlinear system because they highly depend on the stimulus!
“征兆”不是非线性系统的参数，因为它们强烈取决于驱动信号！

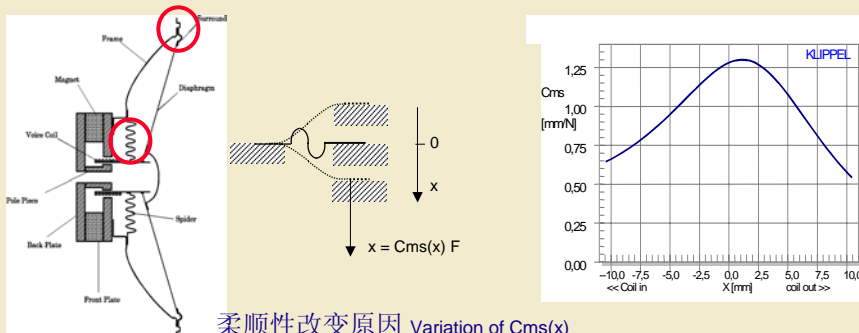
取得大信号振动模式

Assessing the Large Signal Behavior



柔顺性

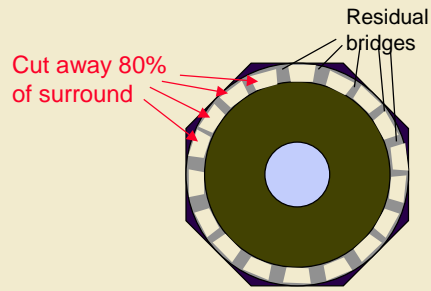
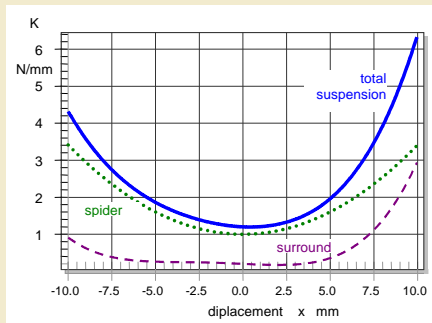
Compliance $C_{ms}(x)$



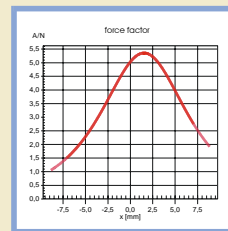
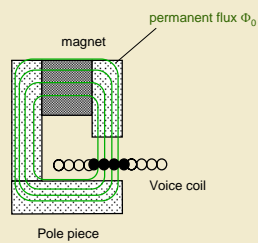
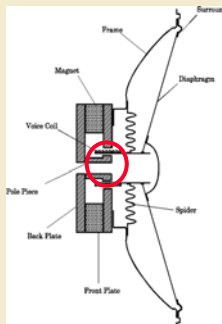
柔顺性改变原因 Variation of $C_{ms}(x)$

- 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

Stiffness of contributed by spider and surround 由弹波和悬边贡献的刚性



磁力强度 Force Factor $Bl(x)$

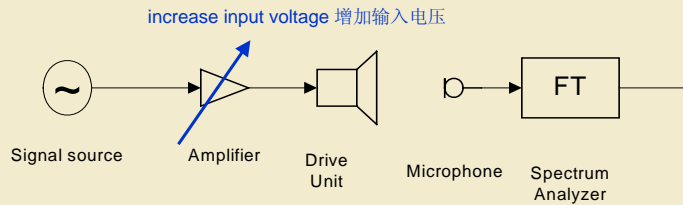


磁力强度改变原因 Variation of $Bl(x)$ caused by

- 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

Simple

Setup: Testing Nonlinear Compression 设置: 测试非线性压缩



Optimal Stimulus 最佳驱动:

Single Tone below resonance
($f = 0.5$ fs) 单音, 低于共振频率 ($f = 0.5$ fs)

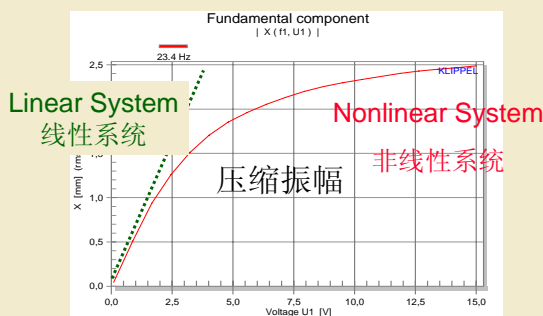
Requirement 要求:

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

Compare ratio of voltage and
fundamental SPL at high levels
(e.g. 1, 2, 4, 8, 16 V).

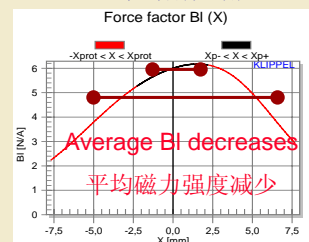
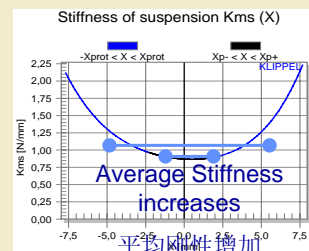
对比在高水平下的电压和基本
声压级的比率

解读: 非线性对基波分量有影响 Interpretation: The fundamental component is affected by nonlinearities



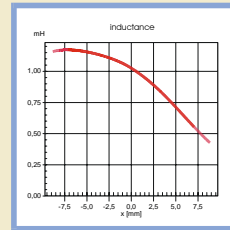
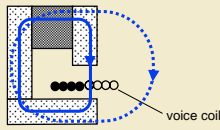
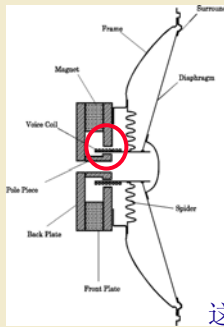
Mechanism 机理:

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



音圈电感量

Voice Coil Inductance $L_e(x)$



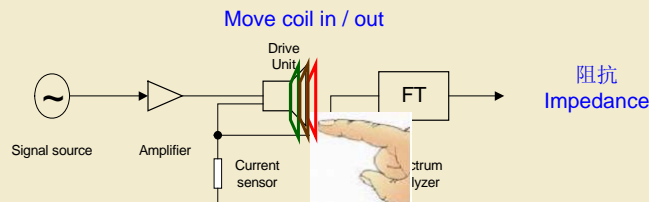
这个参数表示 This parameter shows

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

Simple

设置: 检查非线性电感

Setup: Checking Nonlinear Inductance



Optimal Stimulus 最佳驱动:

Noise or full band sweep
Displace coil manually

Requirement 要求:

ALMA Test CD, tone generator,
Real time analyzer, current sensor
ALMA测试CD, 音频发生器, 实时分析仪,
电流传感器

Motivation 动机:

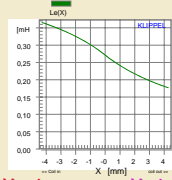
Nonlinear inductance affects input impedance 非线性电感影响输入阻抗
→ Check when coil is

- inside,
- at rest position and
- outside

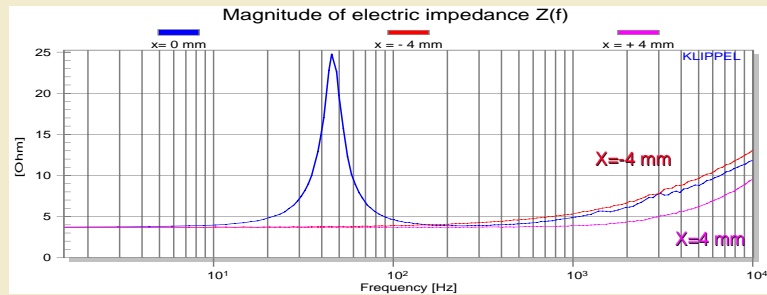
非线性电感的效应 Effect of nonlinear inductance $L(x)$

引起电感非线性的成因 $L_e(x)$ 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

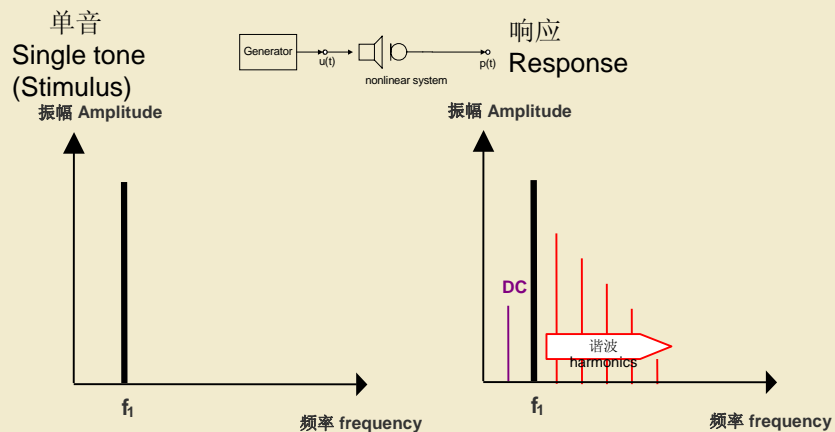


$x = -4 \text{ mm}$ $x = 4 \text{ mm}$



Klippel, ALMA China 2008, Simple Tools, 45

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

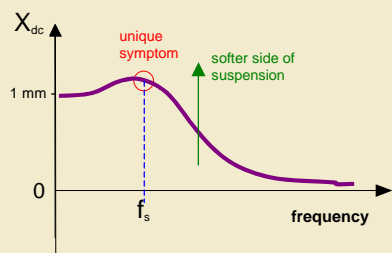


单音信号产生谐波及直流分量 (位移) A single tone generates harmonics and a DC component (in displacement)

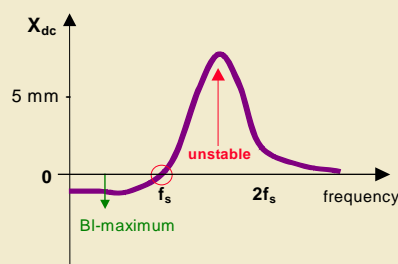
Klippel, ALMA China 2008, Simple Tools, 49

检查:直流位移 Check: dc Displacement

Caused by $K_{ms}(x)$

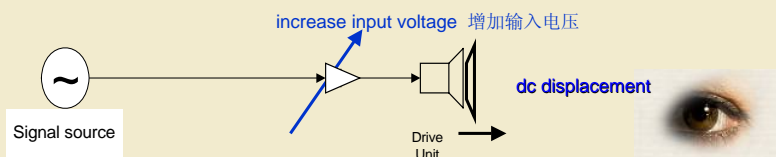


Caused by $Bl(x)$



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Setup: Testing Symmetry of Suspension 设置: 测试悬边的对称性



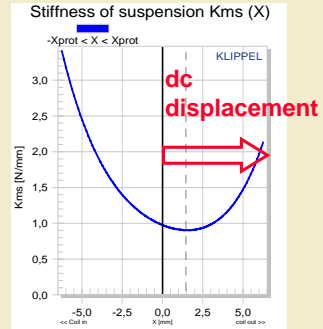
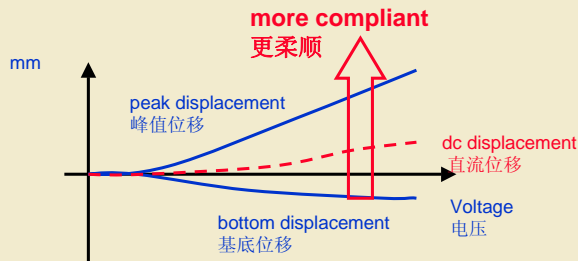
Optimal Stimulus 最佳驱动:
Single Tone just above resonance
($f = f_s$) 单音, 位于共振频率处($f = f_s$)

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

Interpretation: Symmetry Check of Suspension 解读：悬边对称性检测



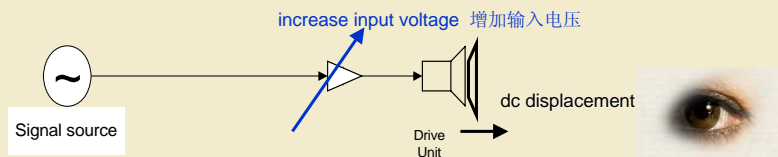
Asymmetry in $K_{ms}(x)$ curve causes rectification of the ac signal

(moves coil always to the side where the suspension is more compliant)

刚性曲线 $K_{ms}(x)$ 的不对称性引起直流信号的整流(将音圈总是移到悬边柔顺性更强的一边)

Simple

Setup: Testing Symmetry of Force Factor 设置：测试磁力强度的对称性



Optimal Stimulus 最佳驱动:

Single Tone just above resonance
($f > 1.5f_s$)

单音，高于共振频率($f > 1.5f_s$)

Requirement 要求:

ALMA Test CD, tone generator

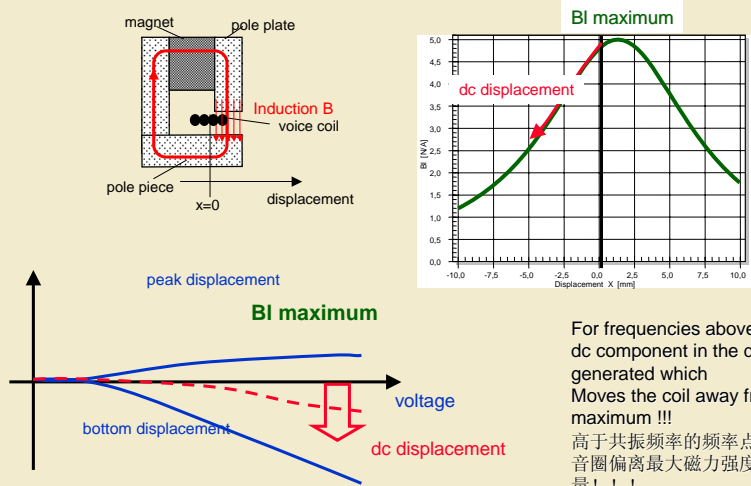
ALMA测试CD, 音频发生器

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

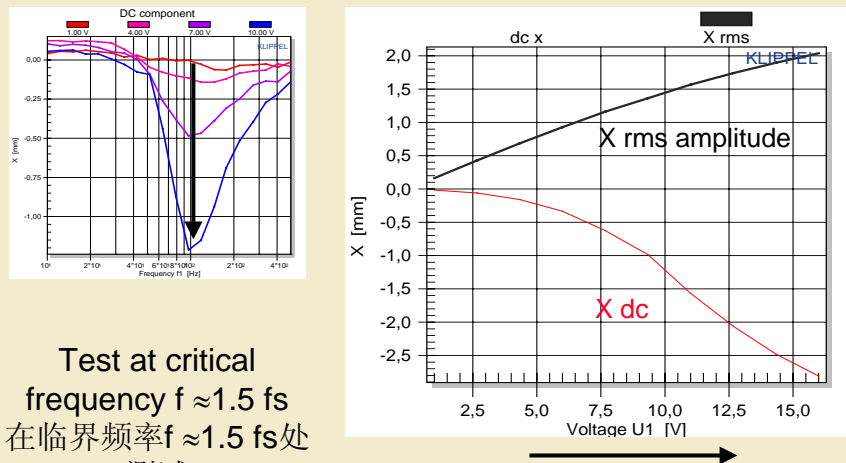
Interpretation: Symmetry Check of $BI(x)$

解读：磁力强度的对称性检测



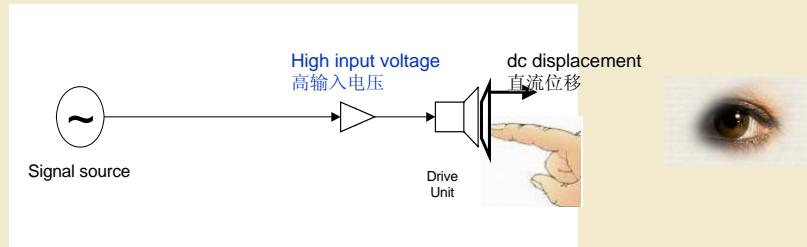
DC displacement due to $BI(x)$ asymmetry

由于磁力强度 $BI(x)$ 的不对称性产生直流位移



Simple

Setup: Testing Motor Stability 设置: 测试驱动的稳定性的

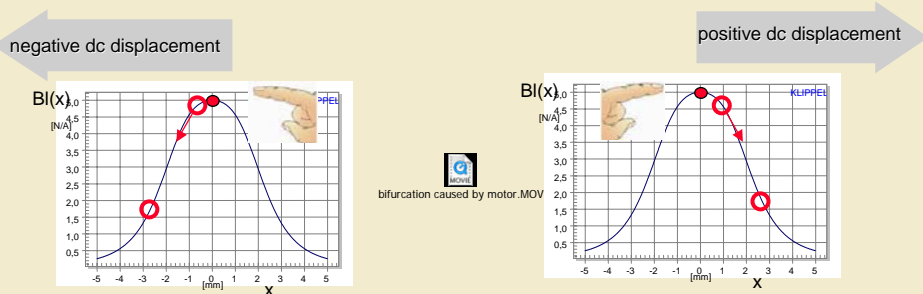


Optimal Stimulus 最佳驱动:
 Single Tone just above resonance
 ($f > 1.5f_s$) 单音, 高于共振频率 ($f > 1.5f_s$)

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

Interpretation: Testing Motor Stability 解读: 测试驱动的稳定性的

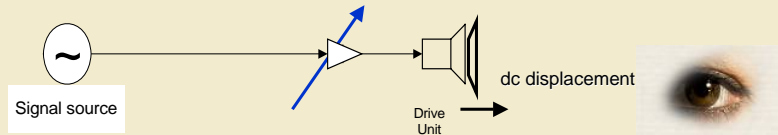


Causes 成因:
 → Bifurcation into two states
 分支为2个状态
 → rest position is unstable
 静止位不稳定

Remedies 补救方法:
 → Use BI profile with a plateau region
 应用带高原区的磁力强度侧面图
 → Increase coil overhang or underhang
 增加线圈垂悬高度
 → increase stiffness of suspension
 增加悬边刚度

Simple

Asymmetry of Inductance Curve $L(x)$ 电感曲线 $L(x)$ 的不对称性



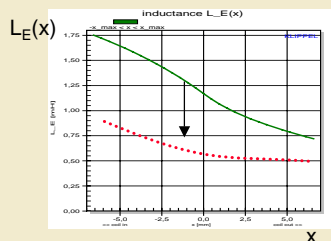
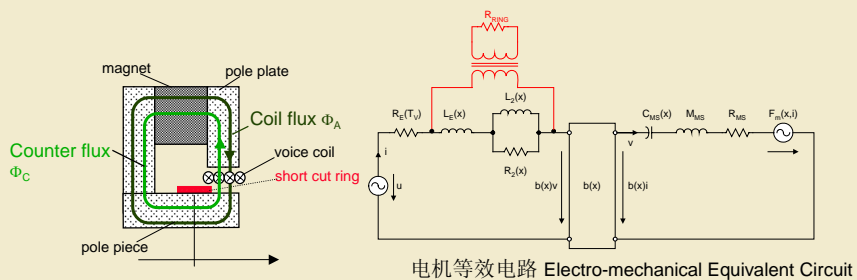
Optimal Stimulus 最佳驱动:
Single Tone above resonance
($f > 3f_s$)
单音, 高于共振频率($f > 3f_s$)

Requirement 要求:
ALMA Test CD, tone generator
ALMA测试CD, 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

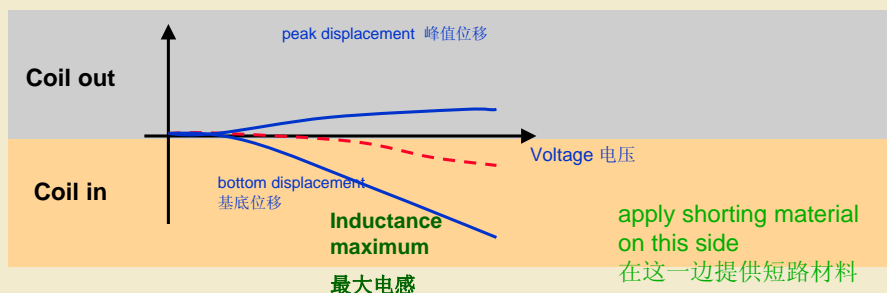
维持电感线性 Linearizing Inductance



优化设计 Optimal Design:

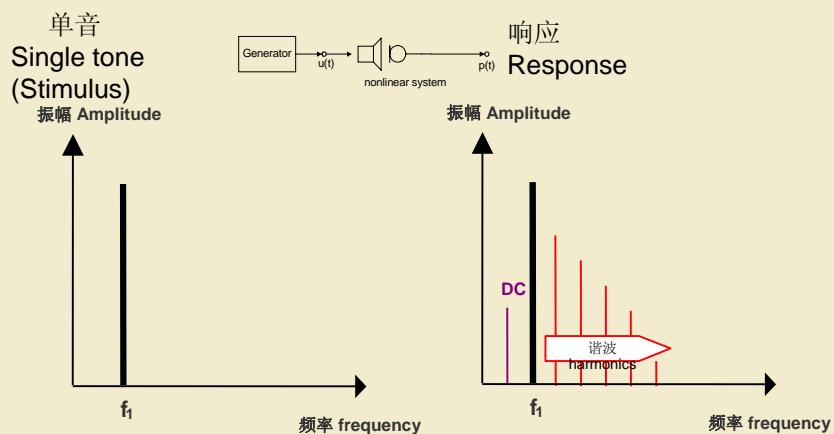
- 几何形状 Geometry (环或杯 Ring or Cap)
- 材质 Material (铝或铜 Aluminum or Copper)
- 尺寸及位置 Size and position

Remedy: Optimal position of shorting ring 补救方法:短路环的最佳位置



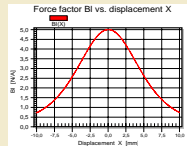
DC component is directed to the inductance maximum
 → Apply more conductive material on this side
 直流分量直指最大电感
 → 在这一边应提供更具导电性的材料

征兆一: 谐波失真 Symptom: Harmonic Distortion



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)

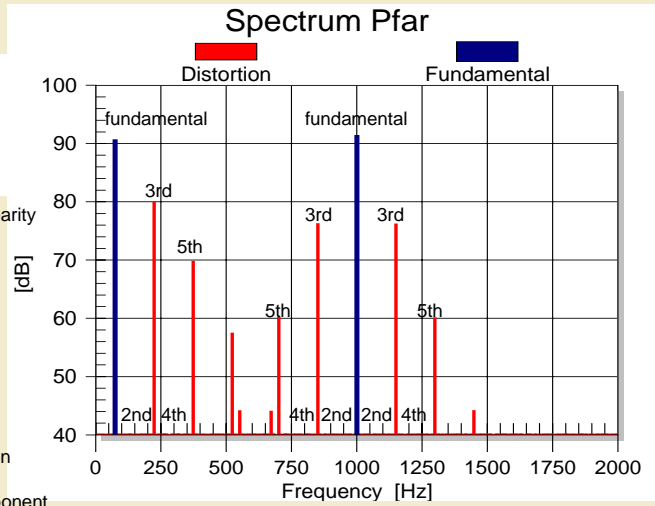
对称非线性失真 Distortion of a Symmetrical Nonlinearity



Symmetrical nonlinearity
对称非线性

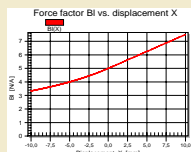


odd-order distortion
奇数次失真
3rd, 5th, 7th-order component



Klippel, ALMA China 2008, Simple Tools, 62

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



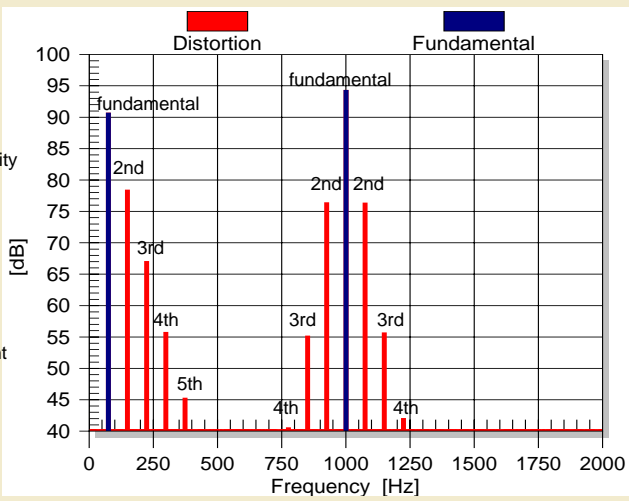
Asymmetrical nonlinearity
不对称非线性



even-order distortion
偶数次失真
2nd, 4th, 6th-order component



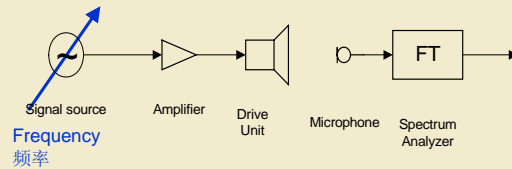
odd-order distortion
奇数次失真
3rd, 5th, 7th-order component



Klippel, ALMA China 2008, Simple Tools, 63

Simple

Harmonic Distortion in Sound Pressure 声压上的谐波失真



Amplitude response
versus frequency:
振幅响应-频率

2nd-order HD 2次谐波失真
3rd-order HD 3次谐波失真
Total HD 总谐波失真

Optimal Stimulus 最佳驱动:

Single Tone with varying frequency
变频单音

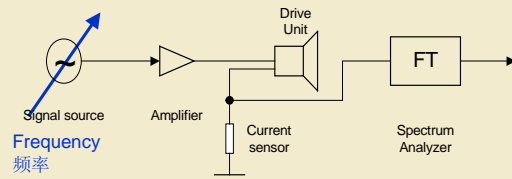
Requirement 要求:

ALMA Test CD, tone generator,
Real time analyzer
ALMA测试CD, 音频发生器, 实时分析仪

Defined by IEC standard
60268-5

Simple

Harmonic Distortion in Current 电流中的谐波失真



Amplitude response
versus frequency:
振幅响应-频率

2nd-order HD
3rd-order HD
Total HD

Optimal Stimulus 最佳驱动:

Single Tone with varying frequency
above 2 x fs
变频单音

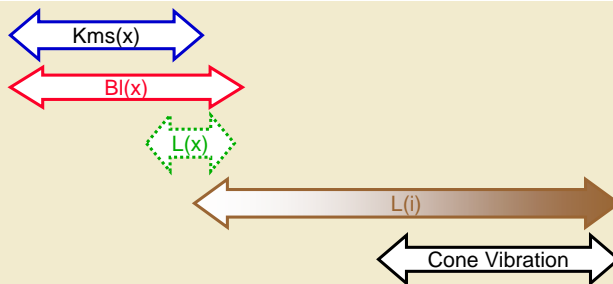
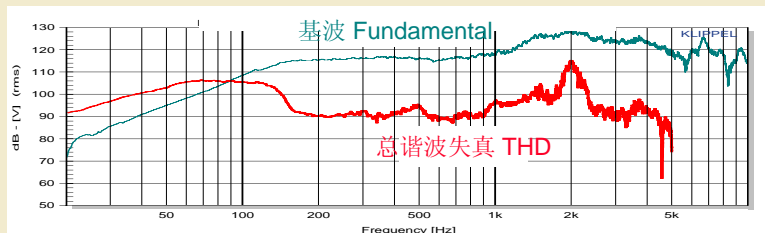
Requirement 要求:

ALMA Test CD, tone generator,
Real time analyzer, current sensor
ALMA测试CD, 音频发生器, 实时分析仪,
电流传感器

Motivation 动机:

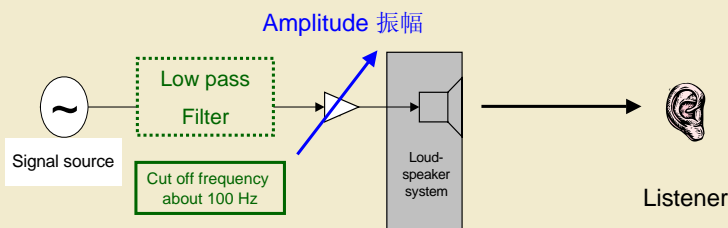
Nonlinear inductance affects input
impedance 非线性电感影响输入阻抗
→ Generates high distortion in input
current 在输入电流中产生较大的失真

谐波失真的成因 The causes of harmonic distortion



Klippel, ALMA China 2008, Simple Tools, 66

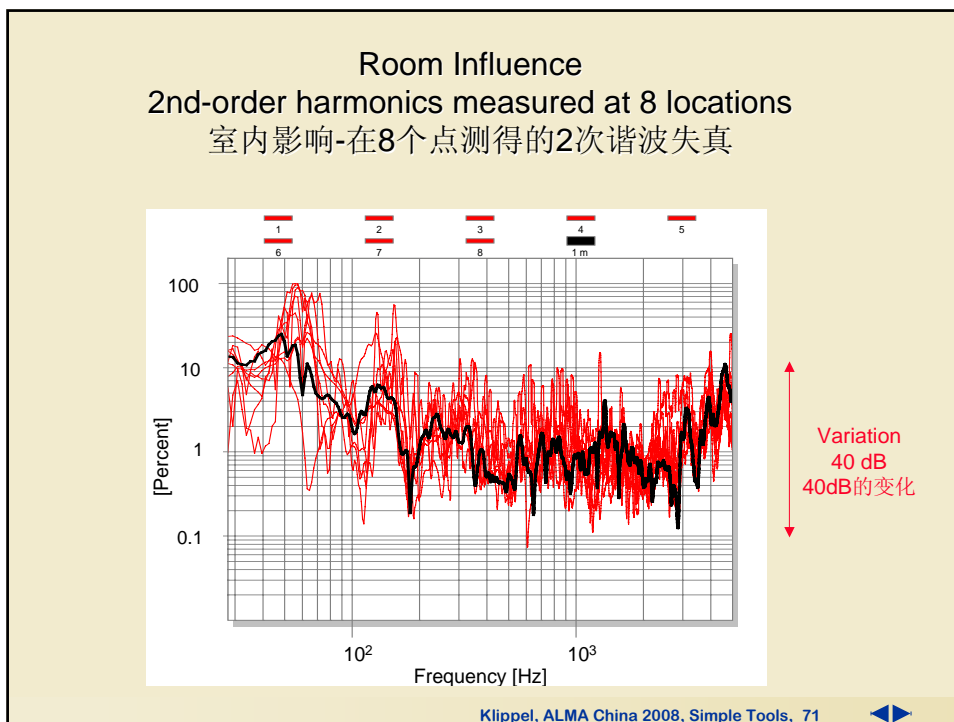
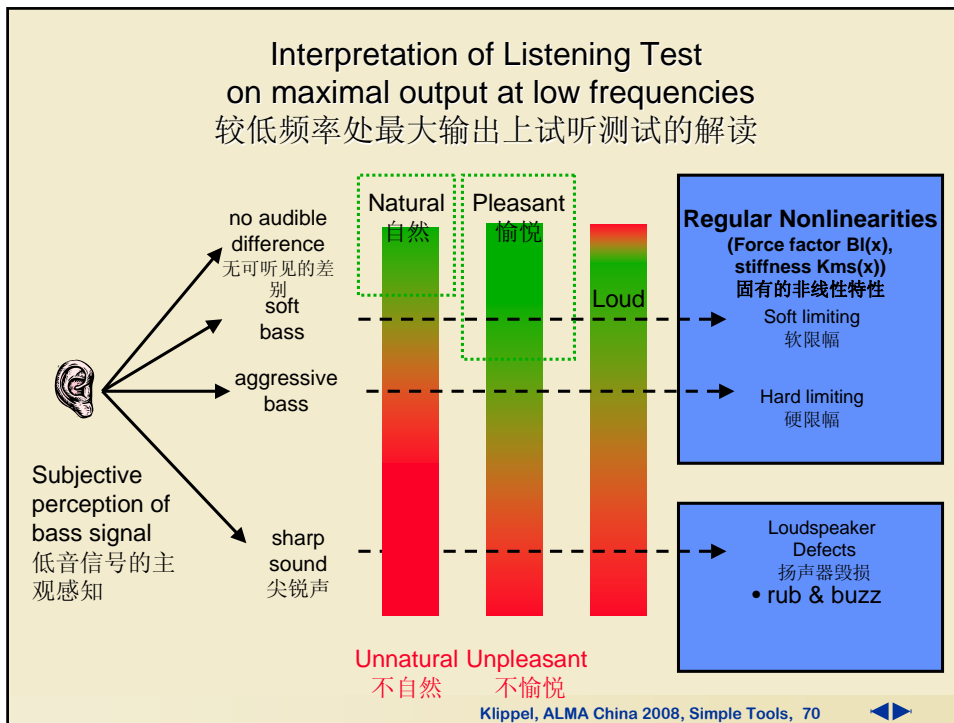
Set-up of Listening Test on maximal output at low frequencies 较低频率处最大输出上试听测试的设置



- Optimal Stimulus 最佳驱动:**
- Music with sufficient bass (drum, guitar, organ, double bass)
带足够低音的音乐
 - Single tone 单音

- Test Criteria 测试标准:**
- Maximal loudness of bass ? 低音足够大声?
 - Softness and hardness of bass ?
低音的柔软性和硬度?
 - Sharpness of sound ? 声音的尖锐度?
 - Naturalness, pleasantness ? 自然, 愉快?

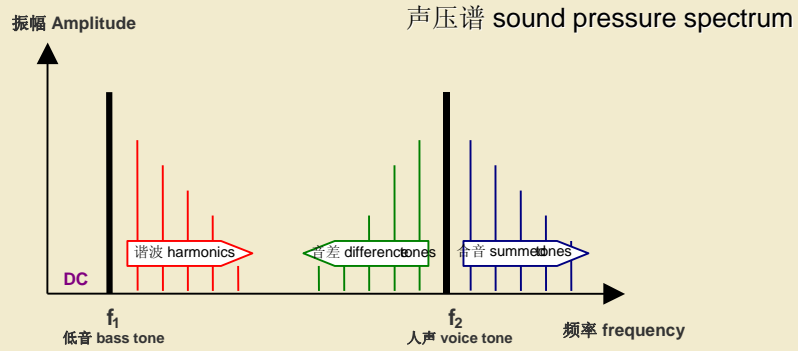
Klippel, ALMA China 2008, Simple Tools, 69



互调的测量

Measurement of Intermodulation

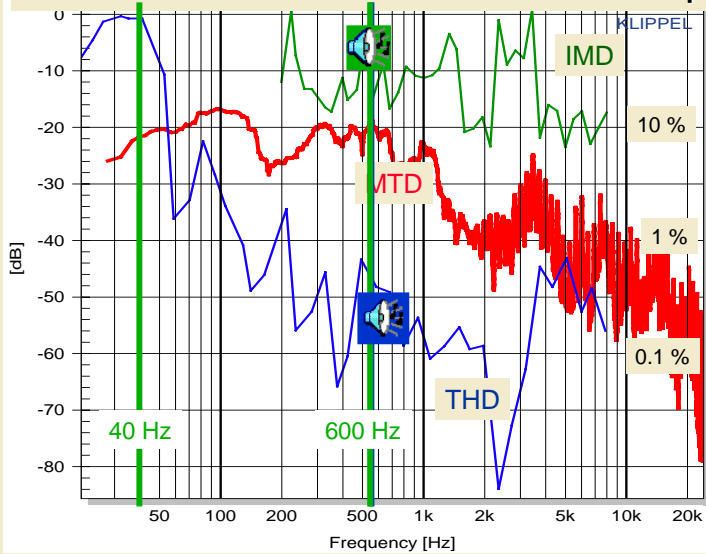
双音驱动 Two-tone Stimulus



Klippel, ALMA China 2008, Simple Tools, 72

互调失真是非常重要的！

Intermodulation distortion are important !



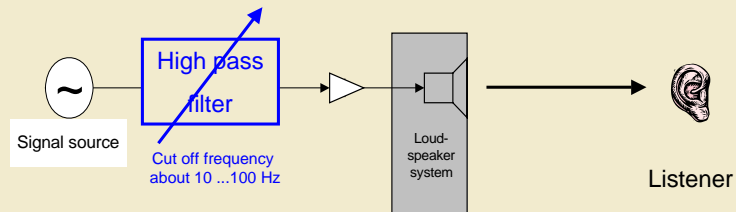
互调失真 IMD:
 $f_1 = 40 \text{ Hz @ } 15 \text{ V}$
+ sweep @ 3V

多频音失真 MTD:
Multitone @ 15V

总谐波失真 THD:
sweep @ 15 V

Klippel, ALMA China 2008, Simple Tools, 73

Set-up of Listening Test on modulation distortion at high amplitudes 较高振幅处调制失真的试听测试的设置



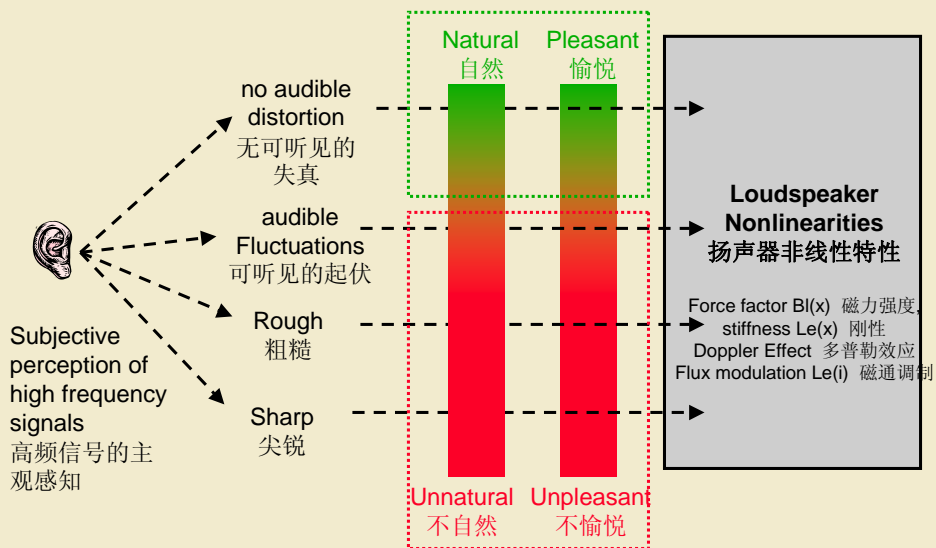
Optimal Stimulus 最佳驱动:

- Music with sufficient bass (double bass+ singer) 带足够低音的音乐
- Two-tone 双音
- Multi-tone complex 复杂的多频音

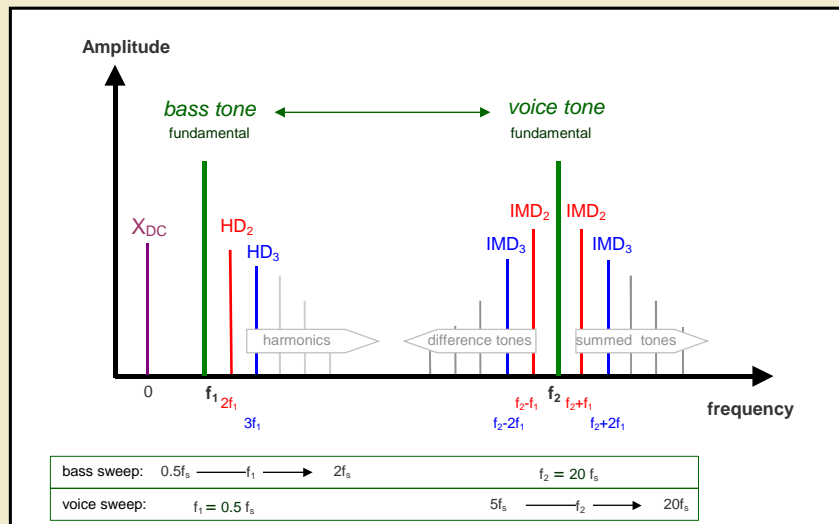
Test Criteria 测试标准:

- High frequency component impaired by bass signal ? 高频分量会被低音信号损坏吗?
- Roughness of sound ? 声音的粗糙度?
- Sharpness of sound ? 声音的尖锐度?
- naturalness, pleasantness ? 自然, 愉悦?

Interpretation of Listening Test on modulation distortion at high amplitudes 较高振幅处调制失真的试听测试的解读



Optimal Two-tone Stimulus
Loudspeaker Systems and Drive Units
最佳双音驱动
扬声器系统和驱动单元



Klippel, ALMA China 2008, Simple Tools, 77

Intermodulation Measurement
using a Two-Tone Stimulus

互调失真测量
使用双音驱动

Advantages 优势:

- Simple generation (by using two sinusoidal generators) 简单生成(通过使用2个正弦波发生器)
- Separation of noise and distortion 分离噪音和失真
- Easy to interpret 易于解读
- Good for loudspeaker diagnostics 适于扬声器诊断
- Sensitive stimulus also for listening tests 灵敏的驱动同样可用于聆听测试

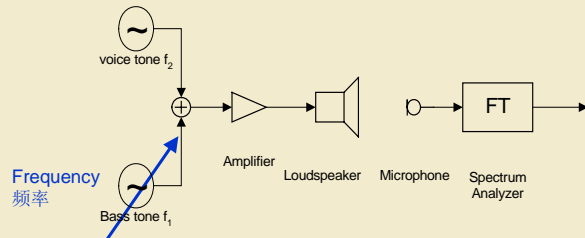
Disadvantages 缺点:

- Frequency of excitation tones have to be set carefully 激励音的频率需要很小心地设置

Klippel, ALMA China 2008, Simple Tools, 78

Setup for IMD in Sound Pressure

bass sweep technique
在声压上设置互调失真
低音扫频技术



Amplitude response
versus frequency f_1 :
振幅响应-频率 f_1

2nd-order IMD 2次互调失真
3rd-order IMD 3次互调失真

Optimal Stimulus 最佳驱动:

Two-Tone stimulus 双音驱动

Varying frequency of bass tone about resonance $0.5f_s < f_1 < 2f_s$
在 $0.5f_s < f_1 < 2f_s$ 内, 低音的变频

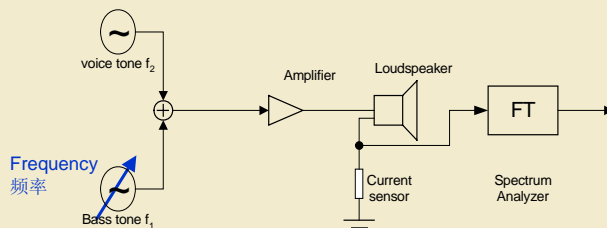
Constant frequency of voice tone above resonance $f_2 = 7f_s$
高于共振频率, $f_2 = 7f_s$, 人声的恒定频率

Requirement 要求:

2 sinusoidal generators, Spectrum analyzer
2个正弦波发生器, 频谱分析仪

Setup IMD in Input Current

bass sweep technique
在输入电流上设置互调失真
低音扫频技术



Amplitude response
versus frequency f_1 :
振幅响应-频率 f_1

2nd-order IMD 2次互调失真
3rd-order IMD 3次互调失真

Optimal Stimulus 最佳驱动:

Two-Tone stimulus 双音驱动

Varying frequency of bass tone about resonance $0.5f_s < f_1 < 2f_s$
在 $0.5f_s < f_1 < 2f_s$ 内, 低音的变频

Constant frequency of voice tone above resonance $f_2 = 7f_s$
高于共振频率, $f_2 = 7f_s$, 人声的恒定频率

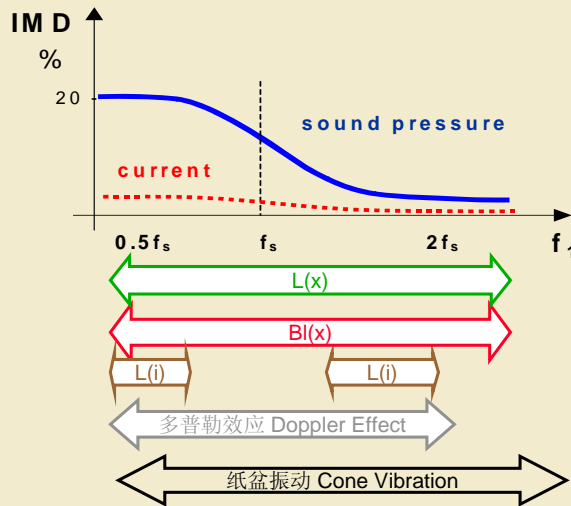
Requirement 要求:

2 sinusoidal generators, Spectrum analyzer, current sensor
2个正弦波发生器, 频谱分析仪, 电流传感器

互调失真的成因

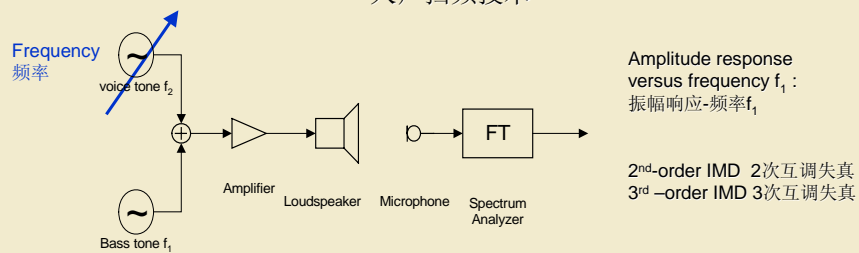
the causes of intermodulation distortion

低音扫频技术 bass sweep technique



Measurement of IMD in Sound Pressure

voice sweep technique
声压上互调失真的测量
人声扫频技术



Optimal Stimulus 最佳驱动:

Two-Tone stimulus 双音驱动

Varying frequency of voice tone above resonance $5f_s < f_2 < 20f_s$

在 $5f_s < f_2 < 20f_s$ 内, 人声的变频

Constant frequency of bass tone below resonance $f_1 = 0.5f_s$

低于共振频率, $f_1 = 0.5f_s$, 低音的恒定频率

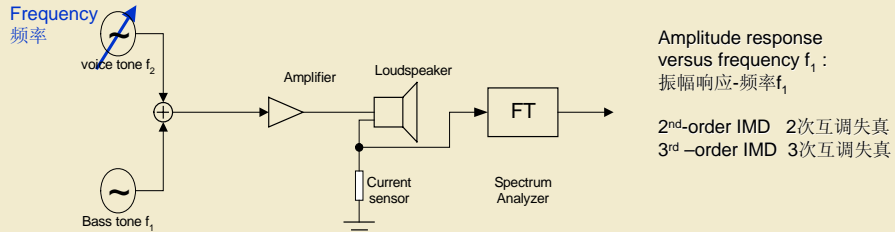
Requirement 要求:

ALMA Test CD, 2 tone generators, Spectrum analyzer, Microphone

ALMA测试CD, 双音发生器, 频谱分析仪, 麦克风

Measurement of IMD in Input Current

voice sweep technique
输入电流上互调失真的测量
人声扫频技术



Optimal Stimulus 最佳驱动:

Two-Tone stimulus 双音驱动

Varying frequency of voice tone above resonance $5f_s < f_2 < 20f_s$

在 $5f_s < f_2 < 20f_s$ 内, 人声的变频

Constant frequency of bass tone below resonance $f_1 = 0.5f_s$

低于共振频率 $f_1 = 0.5f_s$, 低音的恒定频率

Requirement 要求:

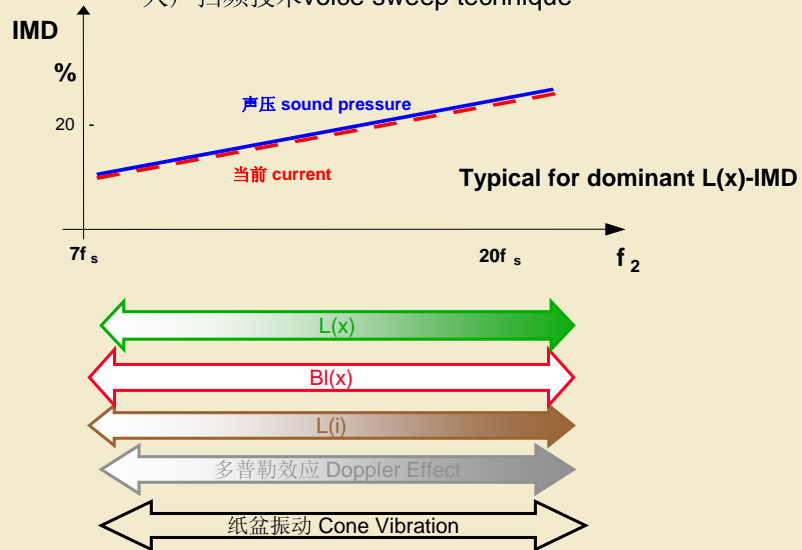
ALMA Test CD, 2 tone generators, Spectrum analyzer, current sensor

ALMA测试CD, 双音发生器, 频谱分析仪, 电流传感器

互调失真的成因

the causes of intermodulation distortion

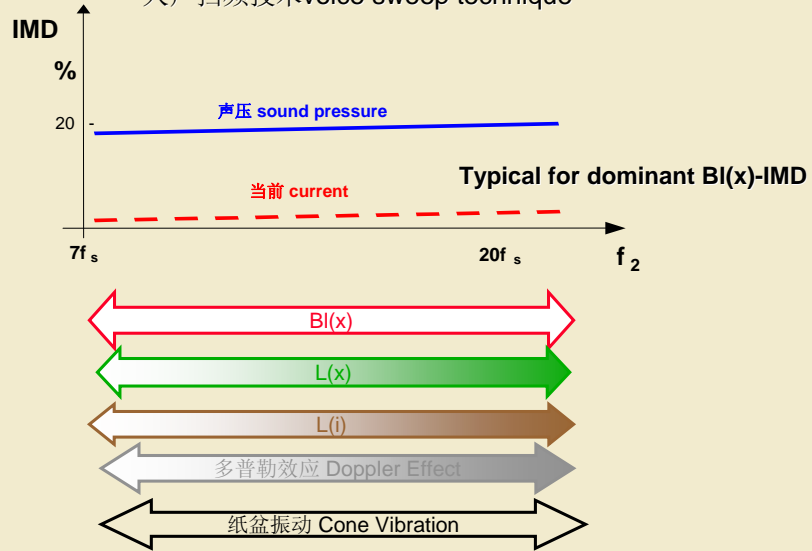
人声扫频技术 voice sweep technique



互调失真的成因

the causes of intermodulation distortion

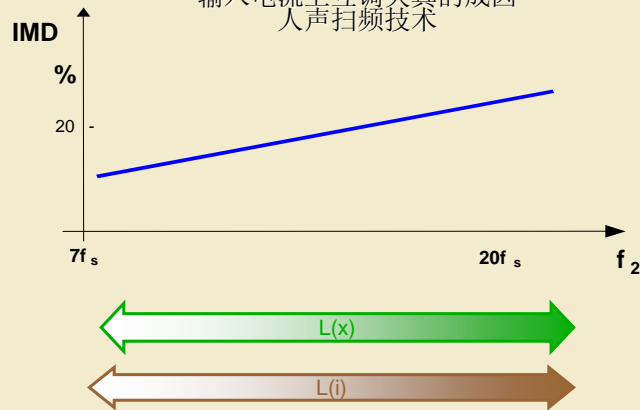
人声扫频技术 voice sweep technique



Causes for IMD in Input Current

voice sweep technique

输入电流上互调失真的成因
人声扫频技术



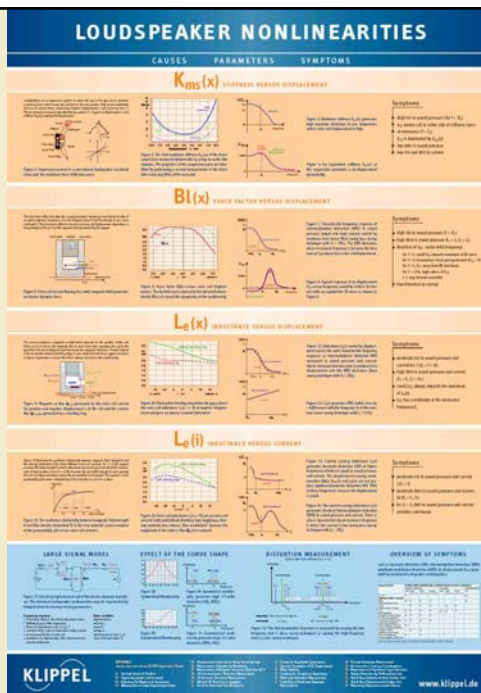
IMD found in input current will also appear in sound pressure output
 → Unique indicator for inductance nonlinearities
 在输入电流上发现的互调失真也同样出现在声压输出上
 → 电感非线性特性的独特指标

非线性及失真的关联

Relationship between Nonlinearity and Distortion

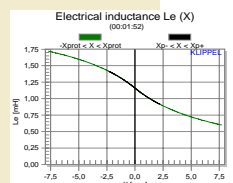
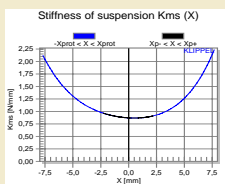
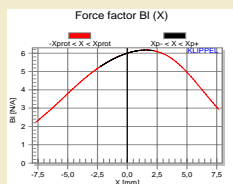
- Detailed discussion on practical examples in the Journal of Audio Eng. Soc., Oct. 2006.

- Get a free poster for your workshop



Klippel, ALMA China 2008, Simple Tools, 88

Large Signal Identification LSI-Module of the KLIPPEL Analyzer 大信号识别

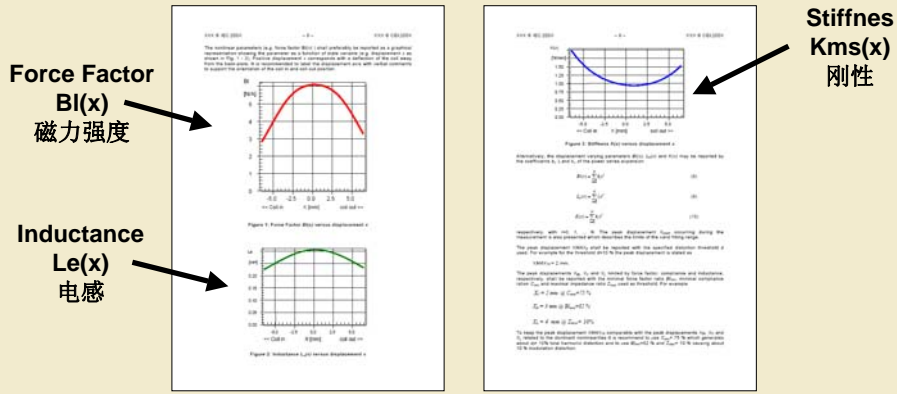


Results 结果:

- Nonlinear Parameter 非线性参数
- Displacement Limits 位移极限
- Thermal Parameter 热力参数

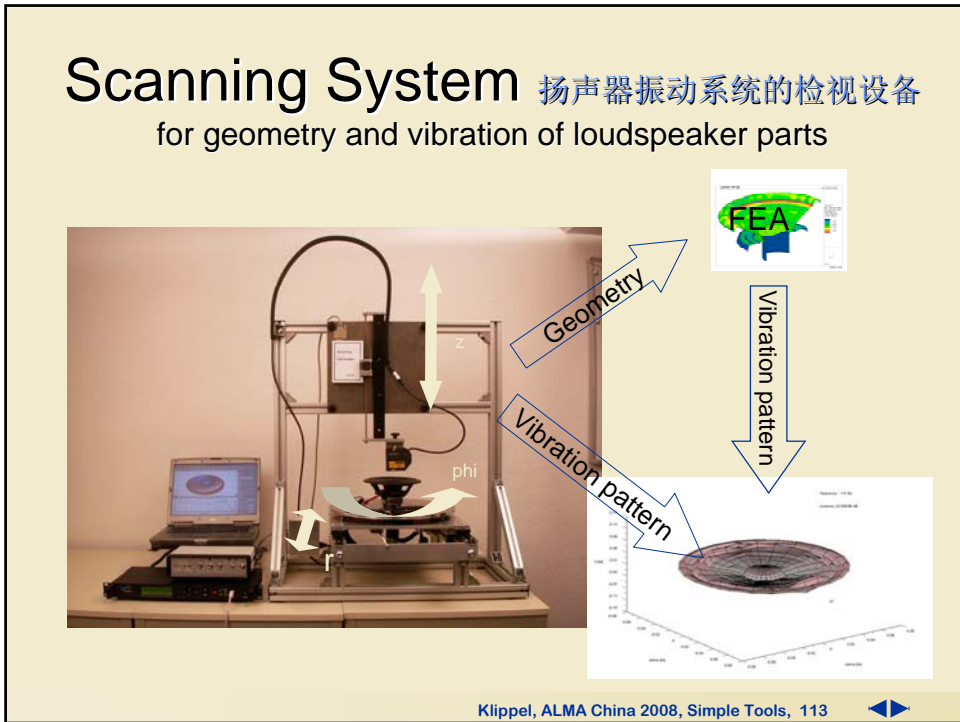
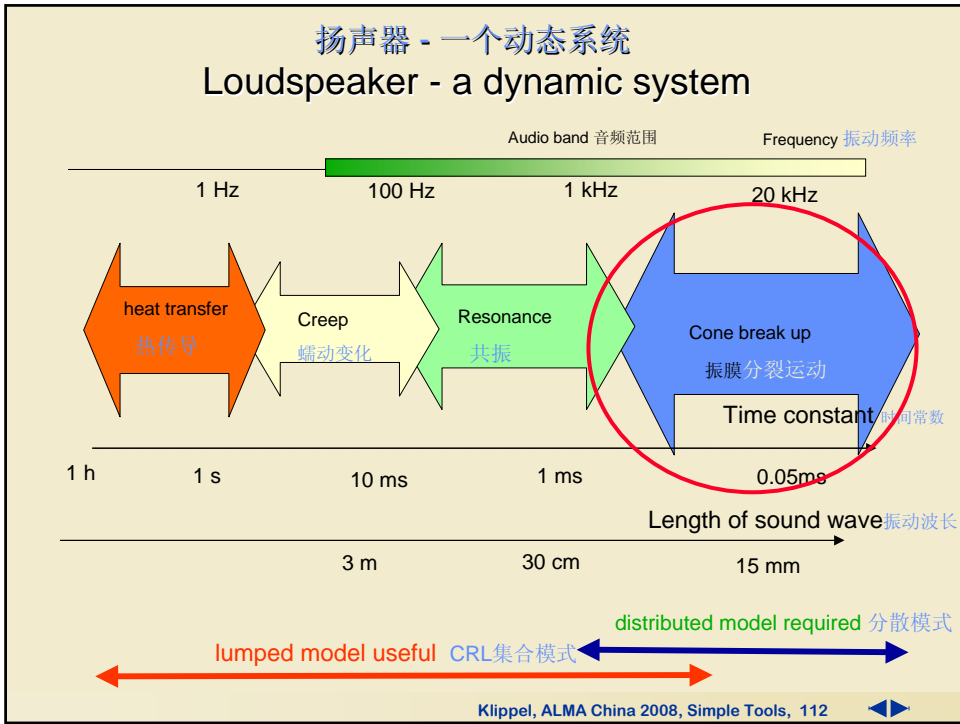
Klippel, ALMA China 2008, Simple Tools, 98

IEC-Standard: PAS62458: 2006



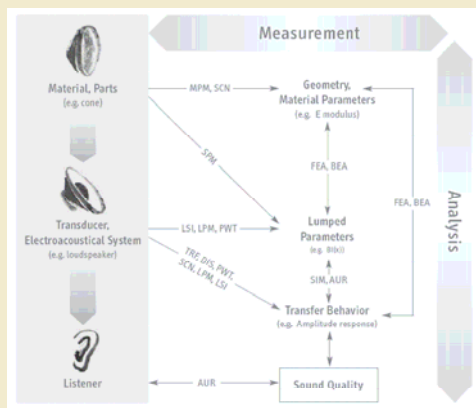
Driver Diagnosis in Voice Coil Magazine

The figure shows the cover of the 'VOICE COIL' magazine, 'THE PERIODICAL FOR THE LOUDSPEAKER INDUSTRY'. It includes several diagnostic graphs for drivers, such as Force Factor $BI(x)$ and Inductance $Le(x)$ versus displacement x . The graphs are arranged in a grid and include descriptive text in Chinese.

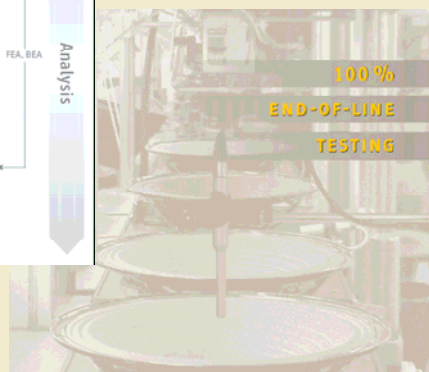


KLIPPEL Analyzer System KLIPPEL分析仪系统

Tools for development



and manufacturing



Klippel, ALMA China 2008, Simple Tools, 115

結論

Conclusion

- “大聲”揚聲器總是非線性的
„Loud“speakers are always nonlinear
- 我們需要大信號參數
We need large signal parameters
- 失真是特徵而非原因
Distortions are only symptoms not the cause
- 改善功能效益需要用大信號來分析
Improving performance requires large signal analysis

Klippel, ALMA China 2008, Simple Tools, 116

www.klippel.de

- **Know-How** (get applications notes, papers, ...)
知道如何得到应用手册，论文资料等
- **Getting Help** (email or phone)
寻求帮助 (电邮或电话)
- **Providing Suggestions, Ideas, Wishes**
提供 建议，想法，愿望
- **Planning Customized Solutions** (integration, extentions)
设计定制的解决方法 (集中，扩展)
- **Download Free Viewer Software**
下载 Free Viewer Software

Thank you!
谢谢!

