大聲壓輸出的小型揚聲器
Big Sound from Small Speakers
Part 2

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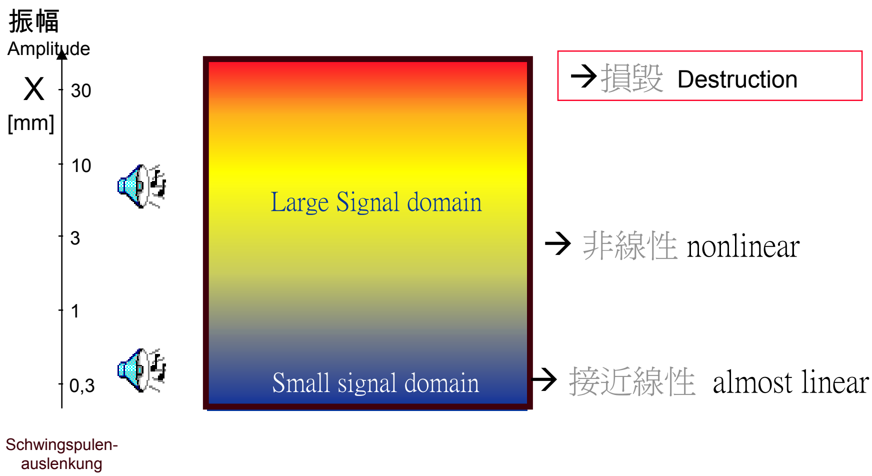
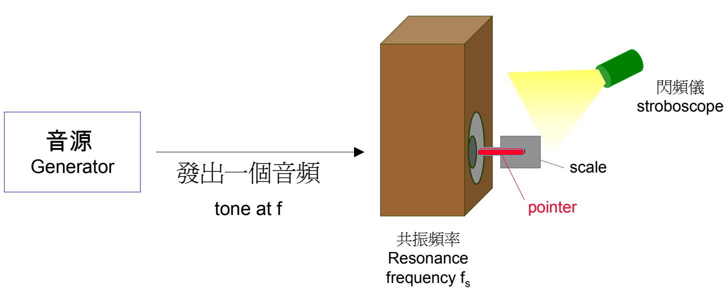
Topics addressed in this section:
本節概要

- Overview on Dominant Nonlinearities in Loudspeaker
  揚聲器裡非線性的優勢概述
- Limitation of the Acoustical Output
  聲學產生的限制
- Generation of Nonlinear Distortion, Impact on Sound Quality
  非線性變形的產生對聲音品質有所影響
- Design of Small Speakers with Optimal Performance
  有最佳效果的小型揚聲器設計
- Particularities of Microspeakers
  Microspeakers的特殊性

Performance of Loudspeakers
揚聲器的工作效益

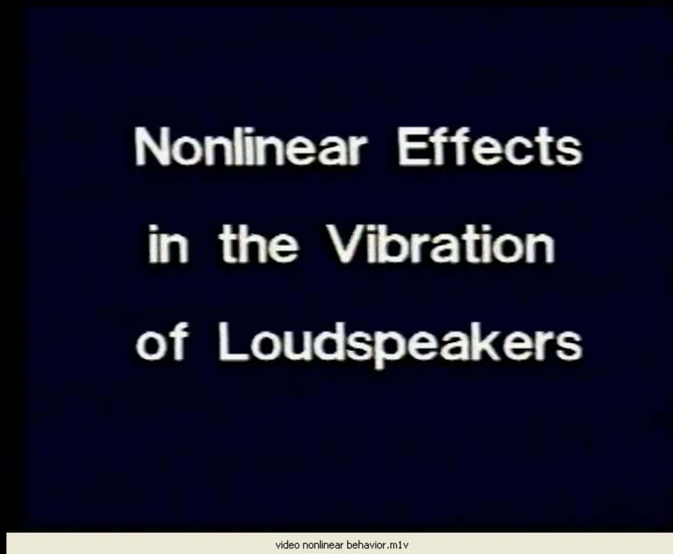


Stroboscopic View on the Vibration Behavior
由閃頻儀來觀看振動模式



觀察頻率小於 共振頻率點	觀察頻率相當於 共振頻率點	觀察頻率大於 共振頻率點
1. Experiment	2. Experiment	3. Experiment
f < fs	f ≈ fs	f > fs

振动行为



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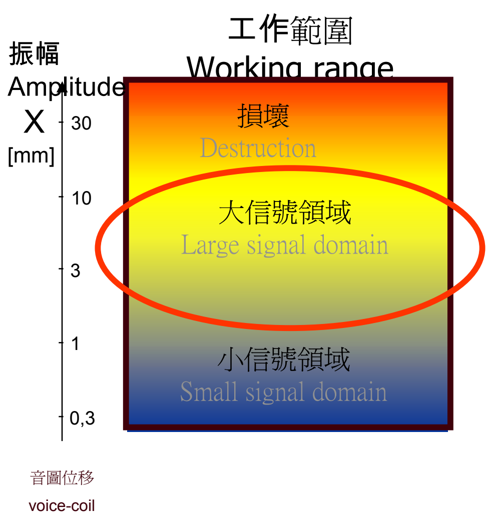
Large Signal Synthesis
大信號合成

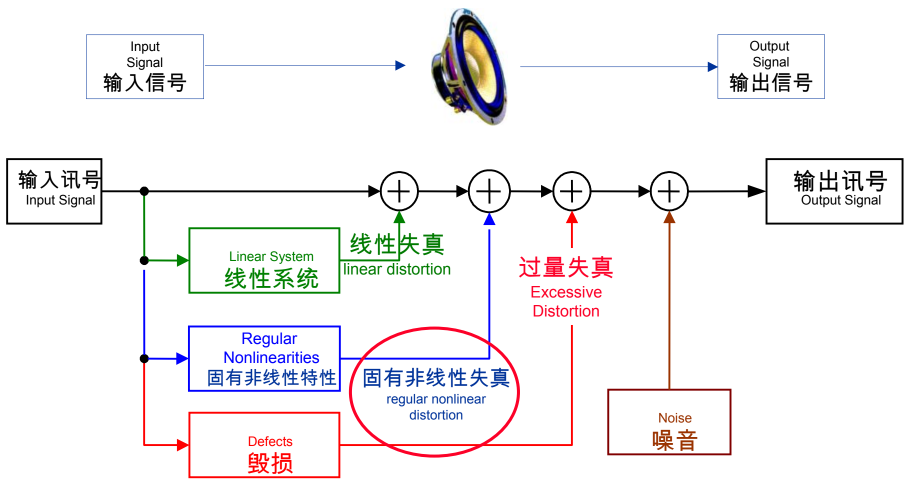


- Maximal Output最大輸出
- Distortion失真
- Power Handling功率處理
- Stability穩定性

Related to size,
weight, cost !!!
與尺寸,重量,成本有關

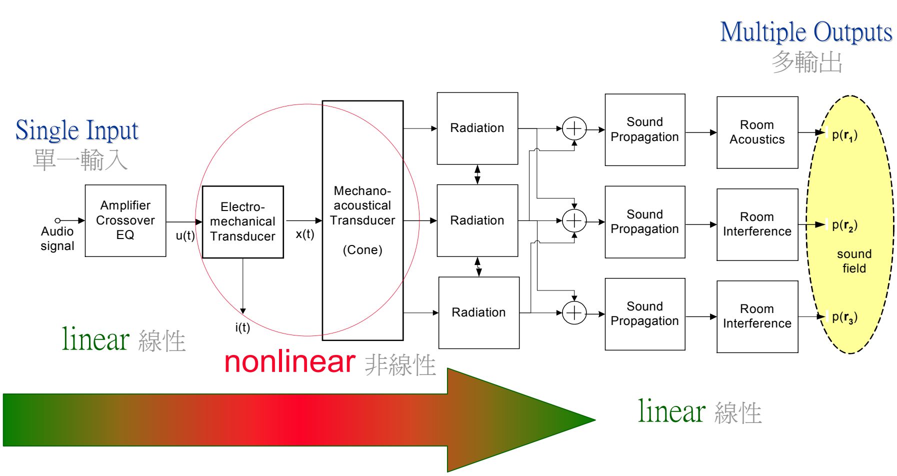
扬声器信号失真的产生

Generation of Signal Distortion in Loudspeakers

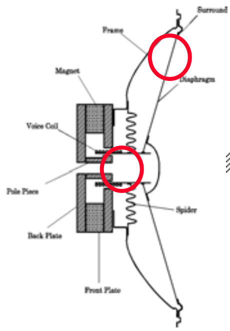


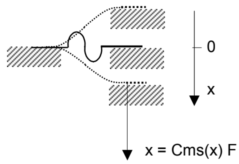
Nonlinearities in Loudspeakers

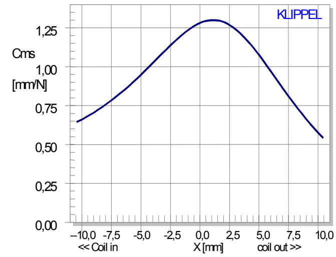
揚聲器裡的非線性



Compliance Cms(x)
柔順性







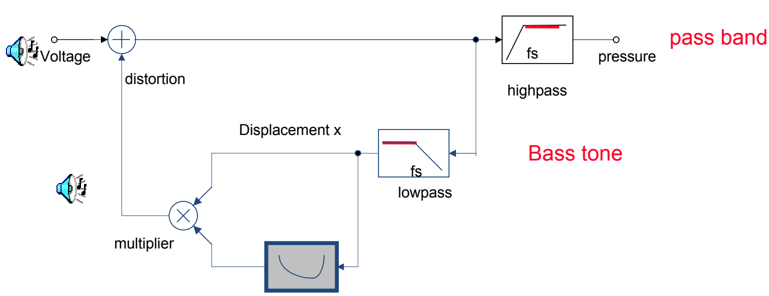
Variation of Cms(x)柔順性改變原因

asymmetry caused by spider and surround定心支片和折環不對稱

moving capabilities, maximal mechanical load運動量, 最大機械負載

adjustment of spider and surround調整定心支片和折環

Problem: Distortion due to Kms(x)
問題:因Kms(X)失真



- Multiplication of x with power of x
  隨著功率增加X

改善剛性
Remedies for Kms(x)

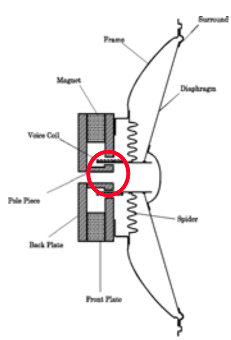
1. 移走不對稱性 Remove asymmetry in Kms(x) by
   - 使用對稱的幾何形狀 using symmetrical geometry
   - 使用較軟懸邊 using a soft surround (spider dominant)
   - 利用彈波的不對稱性來平衡懸邊 compensate surround by spider asymmetries

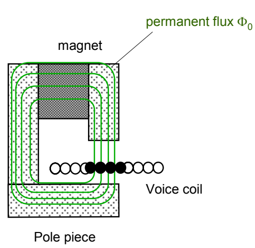
2. 減少對稱限幅 Reduce symmetrical limiting by
   - 增加彈波波紋的數量 increasing number of rolls
   - 增加彈波波紋的大小 increasing size of rolls

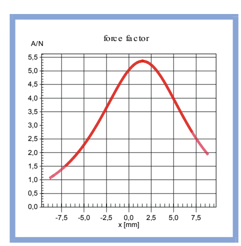
3. 避免使用低黏彈性的材料所造成的剛性損失在x=0時 Avoid loss of stiffness at x=0 by using material with low visco elasticity

4. 使用較小的密閉箱子 Use small sealed box → 空氣的剛性起主要做用 dominant air stiffness

Force Factor Bl(x)
磁力強度







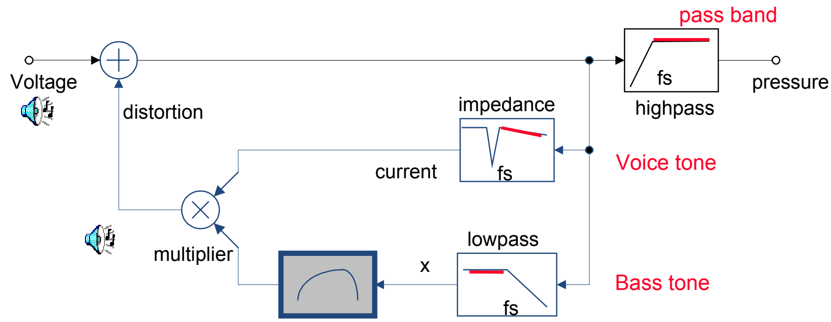
Variation of Bl(x) caused by磁力強度改變原因

Magnetic field磁場改變

Height and overhang of the coil音圈高度

Optimal voice coil position最佳音圈位置

Problem: Distortion of Bl(x)
問題:因B1(X)失真

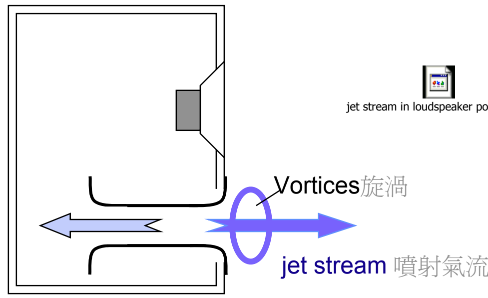


1. Motor force F=Bl(x)*I馬力F= Bl(x)*I
2. Multiplication of x and I增加X及I
3. High distortion (f1 ≦ fs, f2 > fs)

改善磁力轉換因子
Remedies for Bl(x)

1. 使磁力轉換因子爲常數 Make Bl(x)=constant
   - 使用長音圈 by increasing voice coil overhang
   - 使用短音圈 by increasing voice coil underhang
2. 減少磁力轉換因子的不對稱性 Reduce Bl(x) asymmetries
   - 將音圈位置最佳化 by placing coil at optimal rest position
   - 在磁隙中使用對稱的磁力場 by using a symmetrical B-field in the gap

Nonlinearities at Loudspeaker Ports
在揚聲器端口的非線性

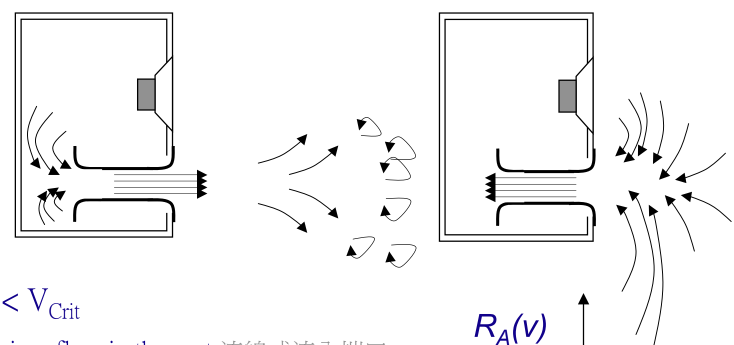


jet stream in loudspeaker ports .MOV

- Flow resistance depends on particle velocity $R_A(v)$ 流動抵抗取決於粒子速度
  - Turbulences generate broad-band noise 紊流產生寬帶噪音
  - Asymmetric flow generates a DC pressure in the enclosure

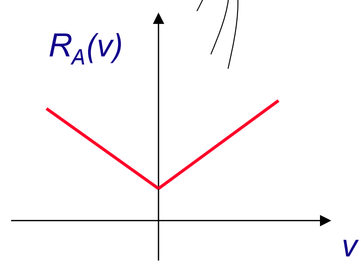
    不對稱流動 圈內產生DC電壓

Flow Resistance $R_A(v)$ at Medium Amplitudes
流動阻力媒介振幅

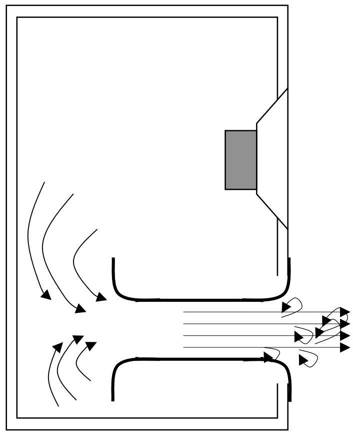


- $V < V_{Crit}$
- laminar flow in the port 流線式流入端口
- energy dissipated in the far field

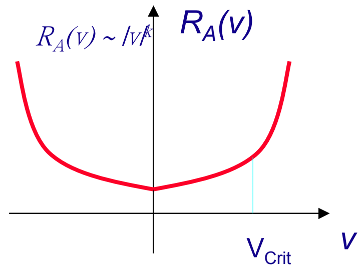
  能量在遠的區域消散
- Harmonics at low frequencies低頻聲學
- $R_A(v) \sim |v|^*m$



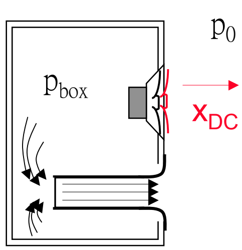
Flow Resistance $R_A(v)$ at High Amplitudes
在高幅度流動阻力

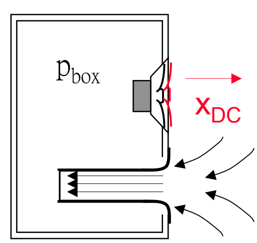


- $V > V_{Crit}$
- turbulent flow in the port
  在端口的混亂流動
- Energy also dissipated in the port
  能量也在端口消失
- White noise
- $R_A(v) \sim |v|^k$

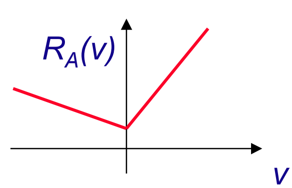


Asymmetrical Flow Resistance $R_A(v)$
不對稱流動阻力





- $R_A(v_0) > R_A(-v_0)$
- DC component in pressure p_{box}
- dynamical voice coil offset x

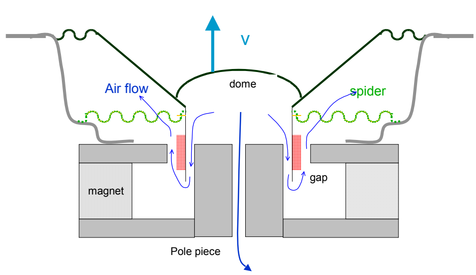


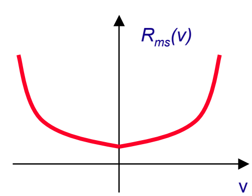
Vented Box System

Symptoms:
- Q-factor of port decreases with amplitude (port closes !!)
- Harmonics (not critical !!)
- Generates modulated air noise (critical !!)
- dc component in sound pressure in enclosure and a dynamic offest in voice coil working point (critical !!)

Remedies:
- Keep velocity in port low (< 10 m/s)
- Keep port geometry symmetrical !!

Nonlinear Mechanical Resistance Rms(v)





$R_{ms}(v)$ depends on velocity v of the coil due to air flow and turbulences at vents and porous material (spider, diaphragm)

Remedies for Nonlinear Mechanical Damping

Problem:

Air Flow in vents, holes, leakages or porous material in enclosures

Dissipation depends on velocity (turbulences, energy is moved into the far field)

Occurs in:

Microspeaker, Headphones, Tweeter

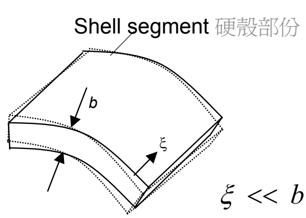
Horn compression driver

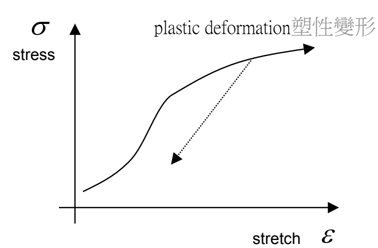
Remedy:

Increase electrical damping by increasing Bl or decreasing Re

better sealing of the enclosure

Partial Vibrations in the Diaphragm
在隔板內的部份振動





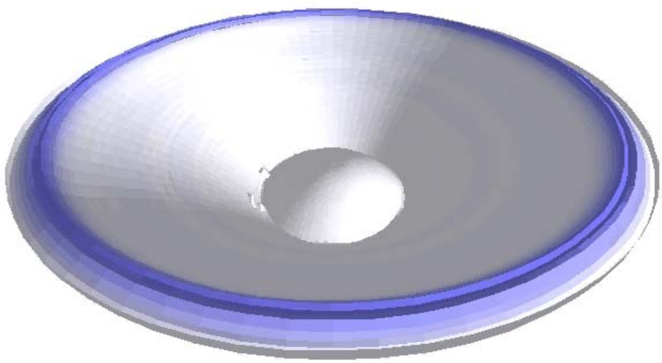
deformation of the shell geometry

硬殼幾何學變形

εσ

18 “ woofer at 300 Hz radial vibration component

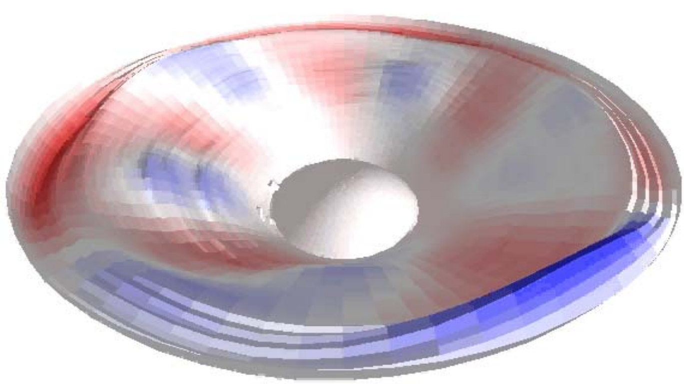
放射振動組成部分



axial-symmetrical FEA neglects circular modes

18 “ woofer at 300 Hz total vibration component

總振動組合部份

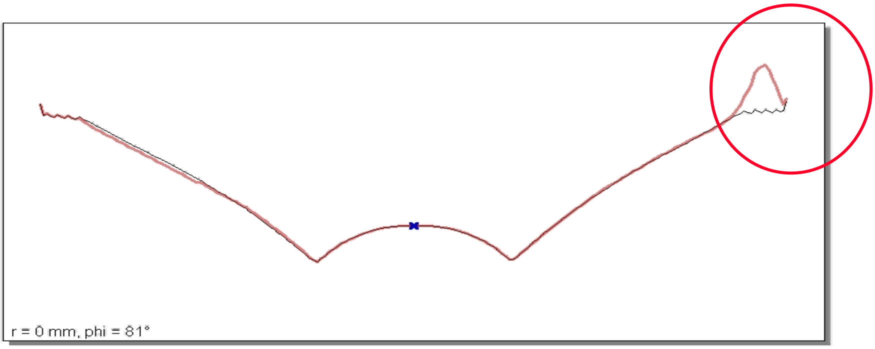


Scanning reveals significant circular modes

Geometrical Nonlinearities Generate Harmonics

Cone Profile at 300 Hz

幾何非線性產生諧波圓錐外形



單體的非線性表

Ranking List of transducer Nonlinearities

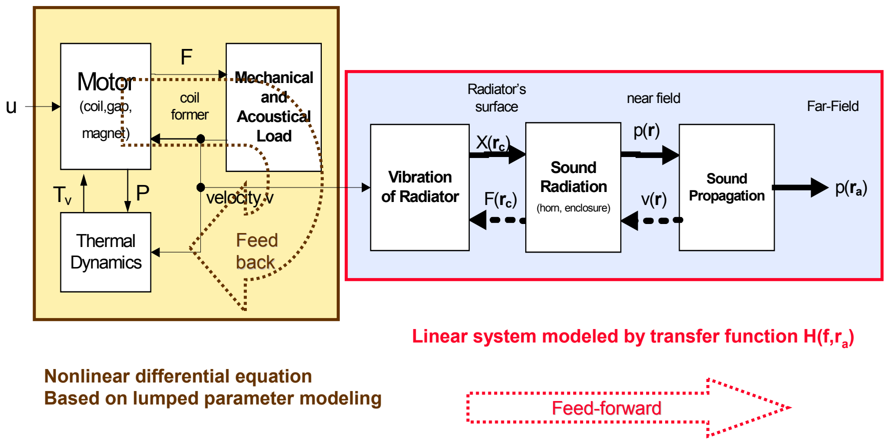
1. 磁力強度 Force Factor Bl(x) microspeaker
2. 柔順性Compliance Cms(x)
3. Rms(v) Nonlinear Mechanical Losses Rms(v)
4. 風管的非線性 Port Nonlinearity RA(v)
5. 電感量 Inductance Le(x)
6. 非線性聲音傳播 Nonlinear Sound Propagation c(p)
7. 電磁場模組Flux Modulation Le(i)
8. 多普勒失真Doppler Distortion (x)
9. 非線性振膜振Nonlinear Cone Vibration
10. 及其他many others ...

→低音揚聲器 →woofers

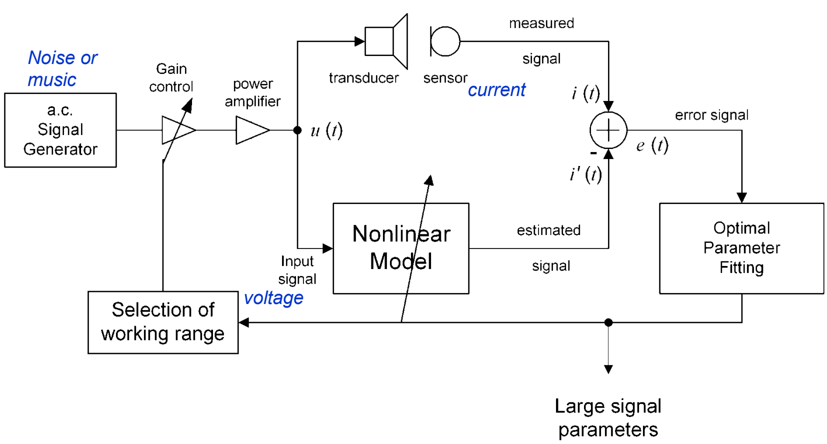
→號筒揚聲器 →horns

Signal Flow Chart of the Transducer

simplified by assuming a linear impedance for the mechanical load



Full Dynamic Measurement



described in IEC Standard PAS 62458:2008

Full Dynamic Measurement

Suspension Part Measurement (SPM)

Large Signal Identification (LSI)

Long-term Power Testing (PWT)

Motor-Suspension Check QC (MSC)

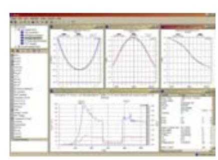
Advantages:

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

Disadvantage:

- Large Signal Idenification (LSI) requires nonlinear signal processing

Model used in LSI

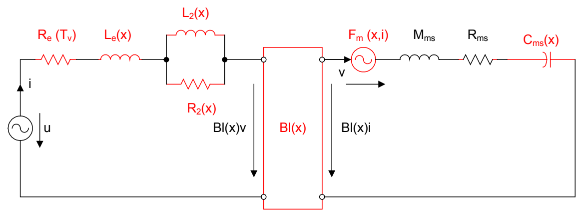


Assumptions:

- Electro-dynamical transducer
- Mechanical resonator (2nd-order system LSI Woofer and LSI Tweeter)
- Additional resonator (4th-order system in LSI Woofer Box)
- Linear damping Rms(x,v) = const. (or Qes < Qms)
- Four nonlinearities: Bl(x), L(x), Kms(x), L(i)
- L(i)+L(x) represents impedance Z(f,i,x)
- Bl(x) also reflects influence of magnetic ac-flux

LSI of Tweeter Drive Units

Model used in LSI Tweeter (current version 202)



Assumptions:

- Electro-dynamical transducer with f_s > 100 Hz
- Application to headphones, tweeter, microspeaker, microphones
- Mechanical resonator (2nd-order system)
- Three nonlinearities: Bl(x), L(x), K_{ms} (x)
- Linear damping R_{ms} (x,v) = const. (if Q_{es} > Q_{ms}, then measurement in vacuum recommended)
- No creep considered

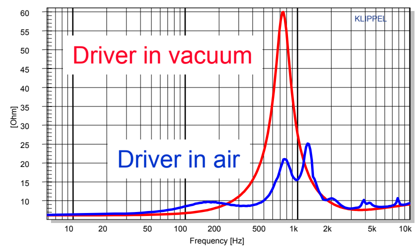
Influence of the Acoustics

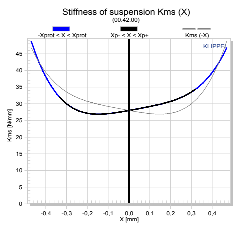
1. Acoustical load causes additional resonances
   → Compression driver, Headphones, Microphones
2. Damping Rms(v) depends on velocity
   → Microspeaker, Headphones, Microphones

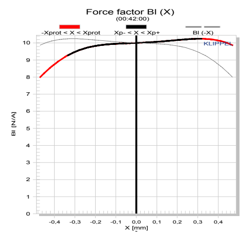
→ Perform measurement of drivers in vacuum

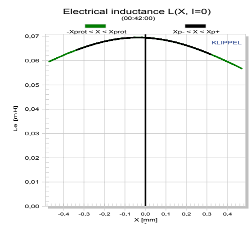
Suppress the acoustics

Example: LSI of Horn Compression Drivers in Vacuum



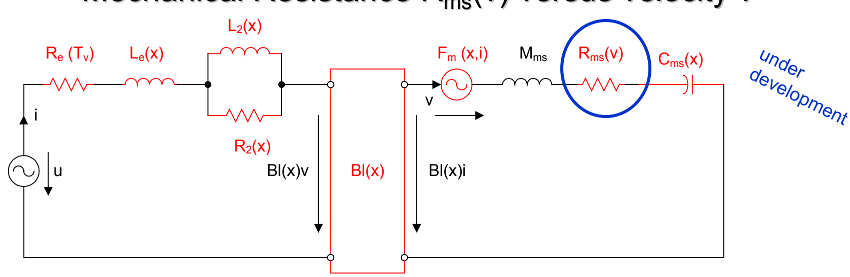






Measurement of Nonlinear Damping

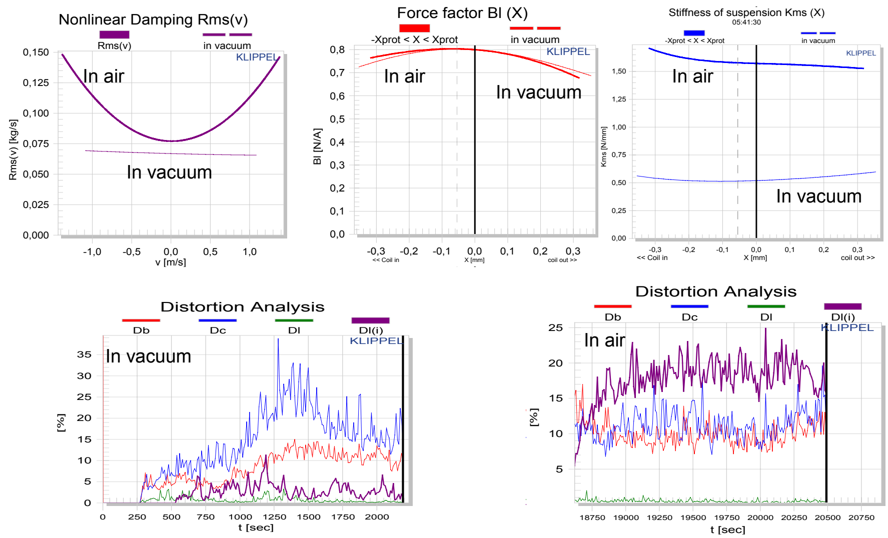
Mechanical Resistance $R_{ms}(v)$ versus velocity v



- Mechanical losses dominate electrical damping in microspeakers, headphones, microphones
- Mechanical Resistance $R_{ms}(v)$ varies with velocity v and is the dominant source of nonlinear distortion in microspeakers
- Only a dynamic measurement technique can be used
- LSI Tweeter (version 204) will also reveal this nonlinearity

Results of the Extended LSI Tweeter

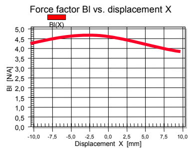
Microspeaker



非線性曲線的屬性
Properties of the Nonlinear Curve

1) 常數或者隨位移或電流變化
   Constant or varying with displacement or current
2) 形狀對稱或非對稱
   Symmetrical or asymmetrical shape
3) 軟限制或硬限制
   Soft or hard limiting

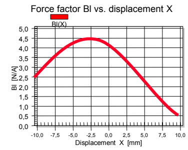
弱非線性或強非線性?
Weak or Strong Nonlinearity ?



參數幾乎恆定
Parameter is almost constant

↓

低信號失真
LOW Signal Distortion (THD, IMD)



參數變化大
Parameter varies significantly

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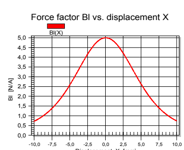
高信號失真
HIGH Signal Distortion (THD, IMD)

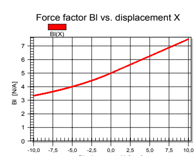
對稱或非對稱
Symmetry or Asymmetry ?



Symmetrical nonlinearity
對稱非線性

- 與尺寸、重量、價格、效率及最大輸出有關 related with size, weight, price, efficiency, maximal output

有好有壞 Good and bad

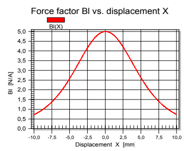


Asymmetrical nonlinearity
不對稱非線性

- 由幾何形狀的不對稱，音圈偏移所引起 Caused by asymmetry in geometry, voice coil offset, ...

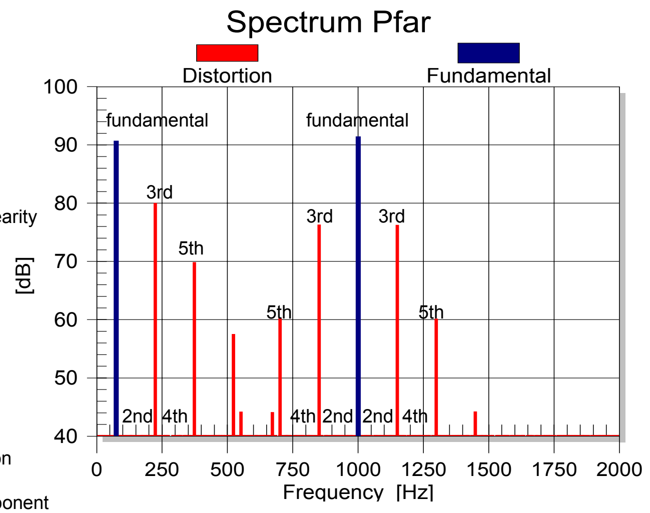
通常是壞 usually bad

對稱非線性失真
Distortion of a Symmetrical Nonlinearity

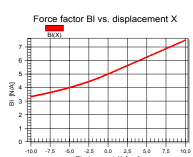


Symmetrical nonlinearity
對稱非線性

odd-order distortion
奇次諧波失真
3rd,5th,7th-order component



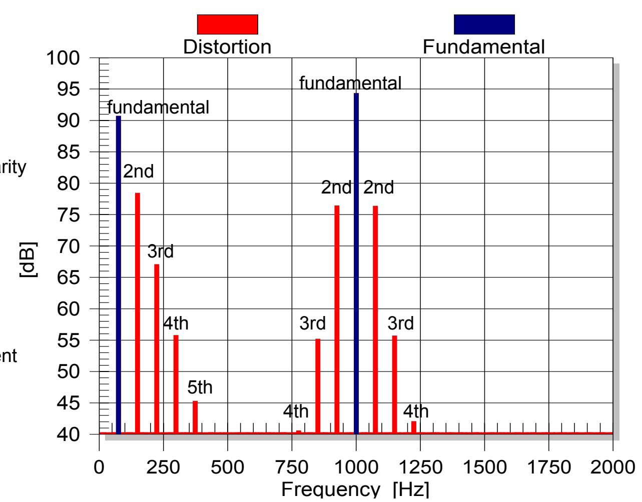
不對稱非線性失真
Distortion of a Asymmetrical Nonlinearity



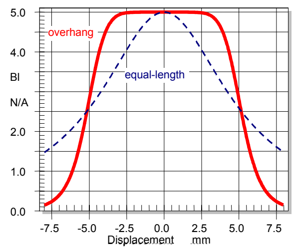
Asymmetrical nonlinearity
不對稱非線性

even-order distortion
偶次諧波失真
2nd,4th,6th-order component

odd-order distortion
奇次諧波失真
3rd,5th,7th-order component



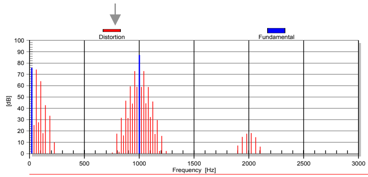
硬限幅或軟限幅的非線性頻譜
Spectrum of hard or soft limiting nonlinearity



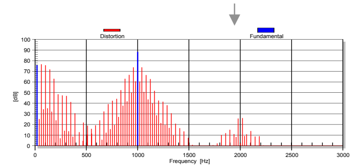
軟限幅非線性
soft limiting nonlinearity

硬限幅非線性
hard limiting nonlinearity

聲壓信號頻譜 Spectrum of sound pressure signal (two-tone stimulus):

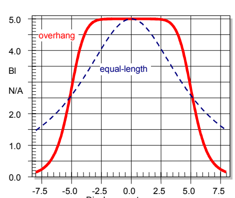


high 2nd- and 3rd order distortion

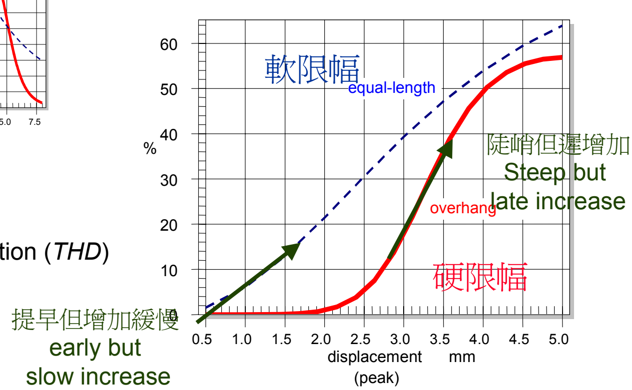


Large amplitude of all components

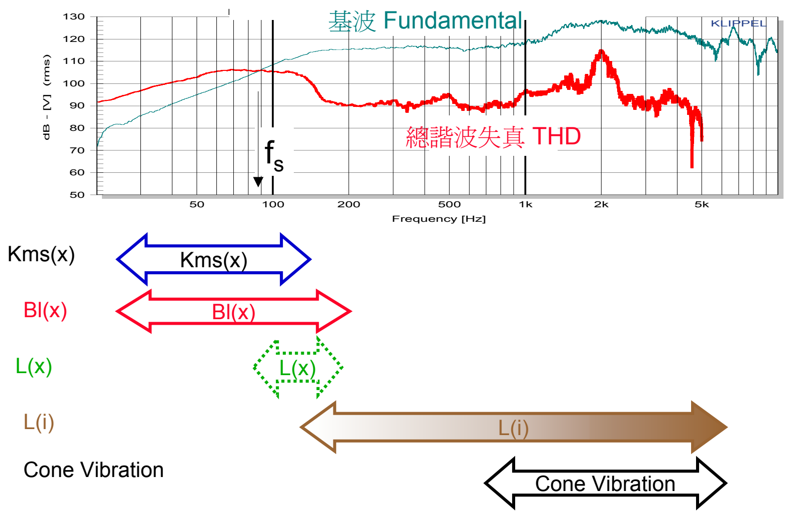
由硬限幅或軟限幅所造成的THD
Total Distortion
generated by hard or soft limiting nonlinearity



總諧波失真
Total harmonic distortion (*THD*)
in percent

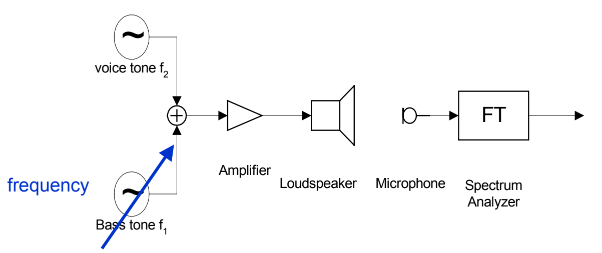


諧波失真的原因
The causes of harmonic distortion



Setup for IMD in Sound Pressure

bass sweep technique

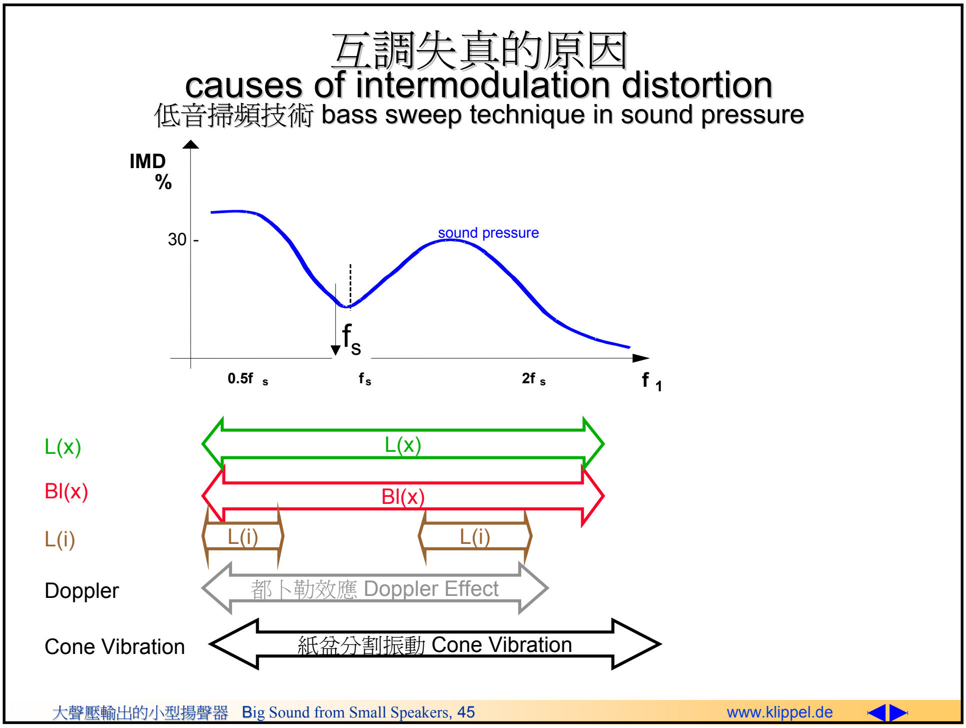


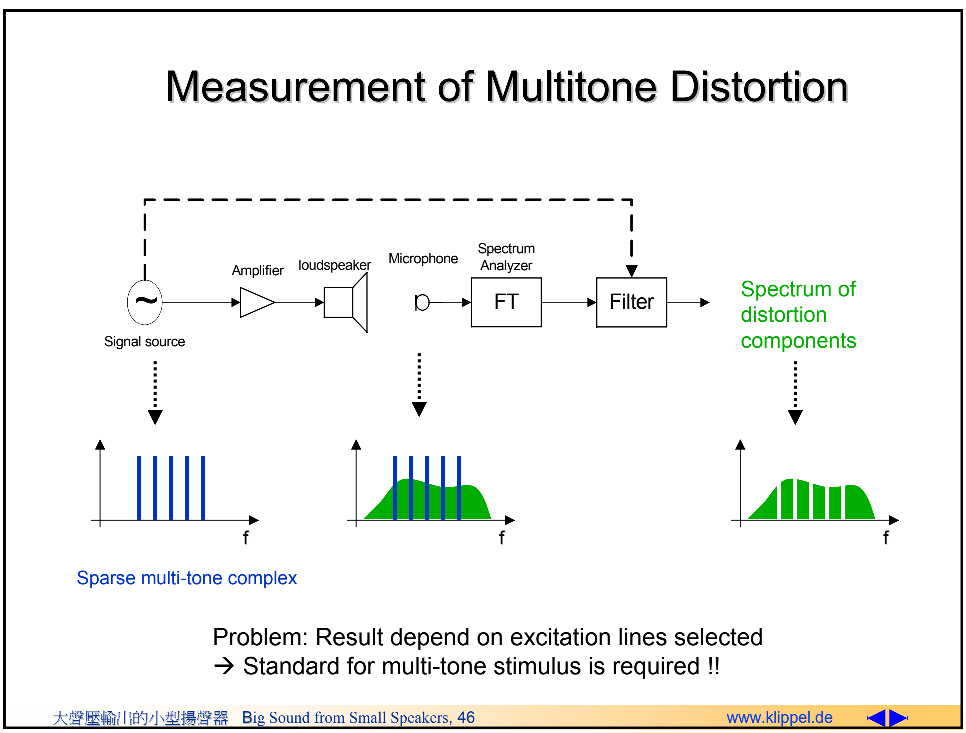
Amplitude response versus frequency f_1 :

2^{nd}-order IMD
3^{rd} –order IMD

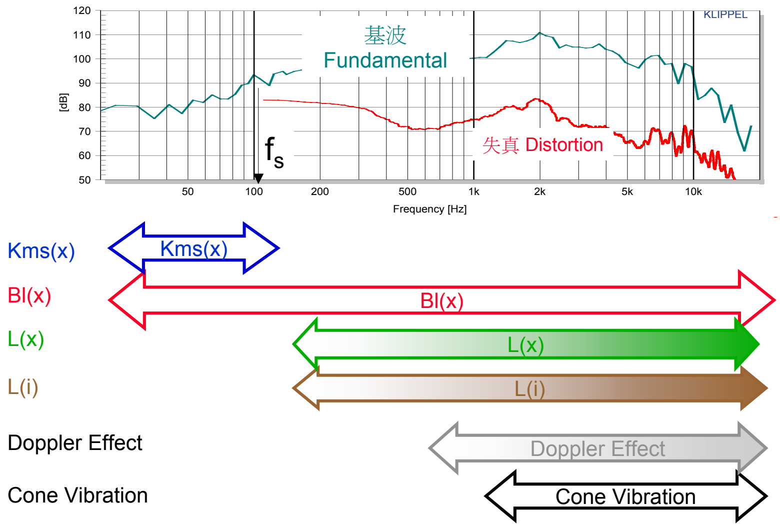
<u>Optimal Stimulus:</u>
Two-Tone stimulus
Varying frequency of bass tone about resonance $0.5f_s < f_1 < 2f_s$
Constant frequency of voice tone above resonance $f_2 = 7f_s$

<u>Requirement:</u>
2 sinusoidal generators, Spectrum analyzer


互調失真的原因
causes of intermodulation distortion
低音掃頻技術 bass sweep technique in sound pressure
IMD
%
30
sound pressure
f_s
0.5f s
f s
2f s
f 1
L(x)
Bl(x)
L(i)
Doppler
Cone Vibration
L(x)
Bl(x)
L(i)
L(i)
都卜勒效應 Doppler Effect
紙盆分割振動 Cone Vibration
大聲壓輸出的小型揚聲器 Big Sound from Small Speakers, 45
www.klippel.de

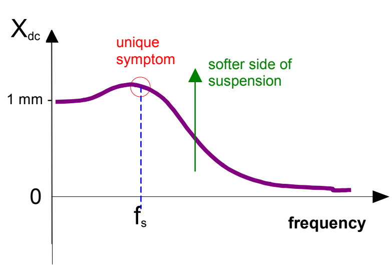

Measurement of Multitone Distortion
Amplifier
loudspeaker
Microphone
Spectrum Analyzer
FT
Filter
Signal source
Spectrum of distortion components
f
f
f
Sparse multi-tone complex
Problem: Result depend on excitation lines selected
→ Standard for multi-tone stimulus is required !!
大聲壓輸出的小型揚聲器 Big Sound from Small Speakers, 46
www.klippel.de

多頻音失真主因
The causes of multi-tone distortion

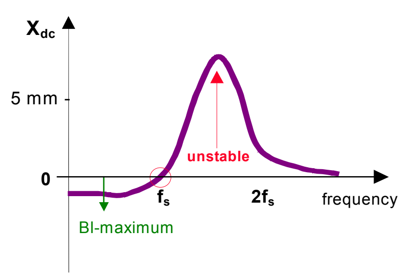


檢查：直流位移
Check: dc Displacement

Caused by Kms(x)

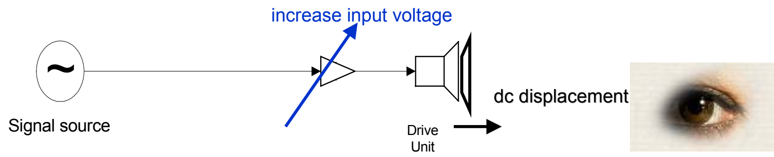


Caused by Bl(x)



Simple

Setup: Testing Symmetry of Suspension

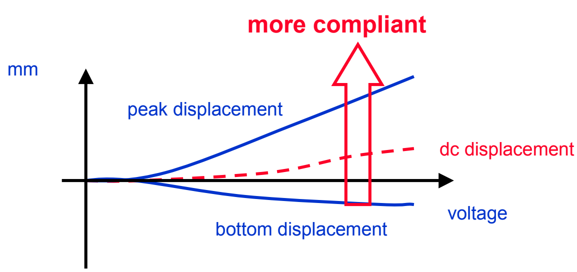


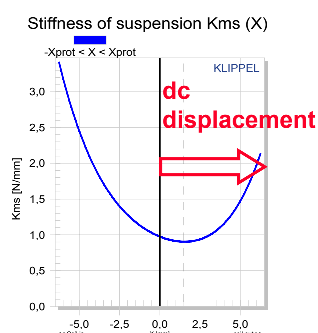
Optimal Stimulus:
Single Tone just at resonance
(f = fs)

Requirement:
ALMA Test CD or tone generator

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

Interpretation: Symmetry Check of Suspension

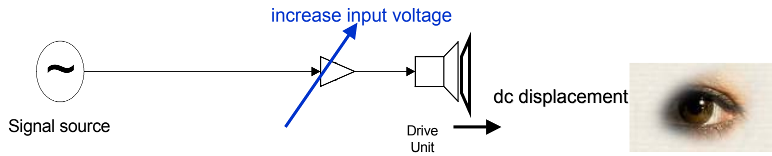




Asymmetry in Kms(x) curve causes rectification of the ac signal (moves coil always to the side where the suspension is more compliant)

Simple

Setup: Testing Symmetry of Force Factor

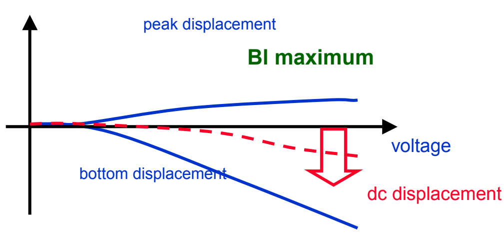


<u>Optimal Stimulus:</u>
Single Tone just <u>above</u> resonance
(f > 1.5fs)

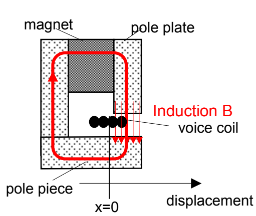
Requirement:
ALMA Test CD, tone generator

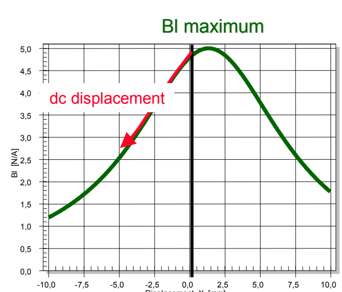
Watch for significant dc component in the voice coil displacement at higher amplitudes.

Interpretation: Symmetry Check of Bl(x)



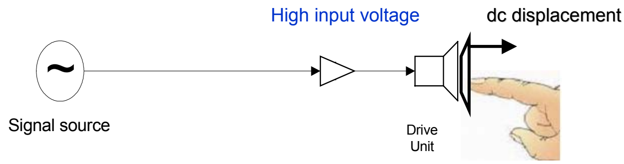
For frequencies above resonance a dc component in the displacement is generated which Moves the coil away from the Bl maximum !!!





Simple

Setup: Testing Motor Stability



Optimal Stimulus:
Single Tone just above resonance
(f > 1.5fs)

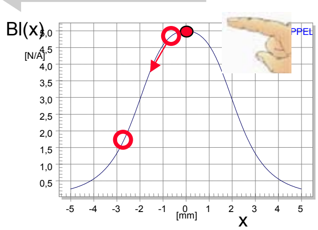
Requirement:
ALMA Test CD, tone generator

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

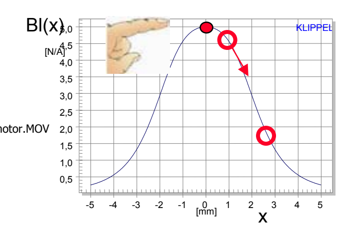
Interpretation: Testing Motor Stability

negative dc displacement

positive dc displacement



bifurcation caused by motor.MOV



Causes:

→Bifurcation into two states

→ rest position is unstable

Remedies:

→Use Bl profile with a plateau region

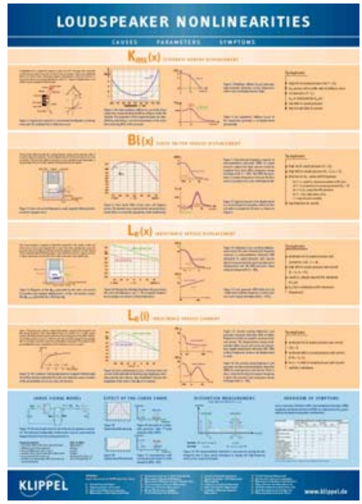
→Increase coil overhang or underhang

→ increase stiffness of suspension

Loudspeaker Nonlinearities – Causes, Parameters, Symptoms

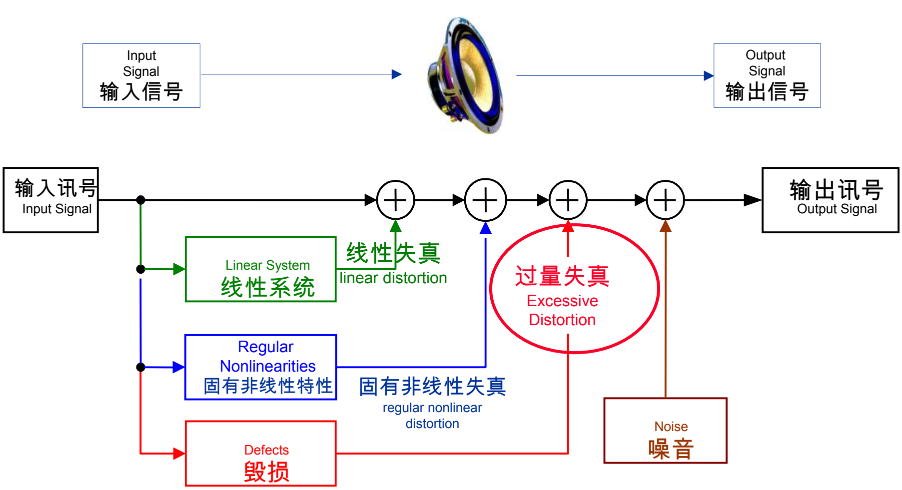
- Detailed discussion on practical examples in the Journal of Audio Eng. Soc., Oct. 2006.

- Get a free poster for your workshop

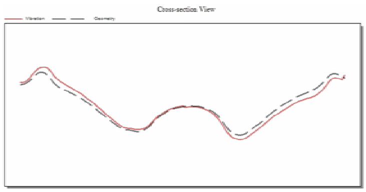


扬声器信号失真的产生

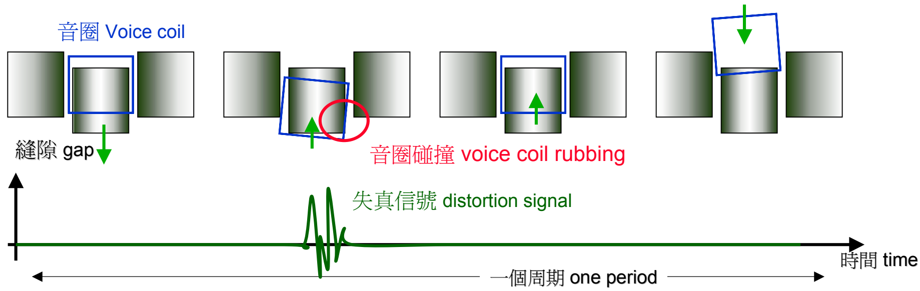
Generation of Signal Distortion in Loudspeakers



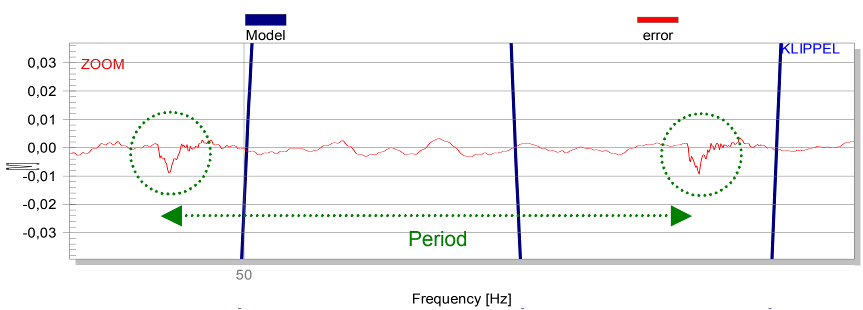
揚聲器缺陷:音圈碰撞
Loudspeaker Defect: voice coil rubbing



在328 Hz 處可能產生搖擺
Rocking mode may cause at 328 Hz



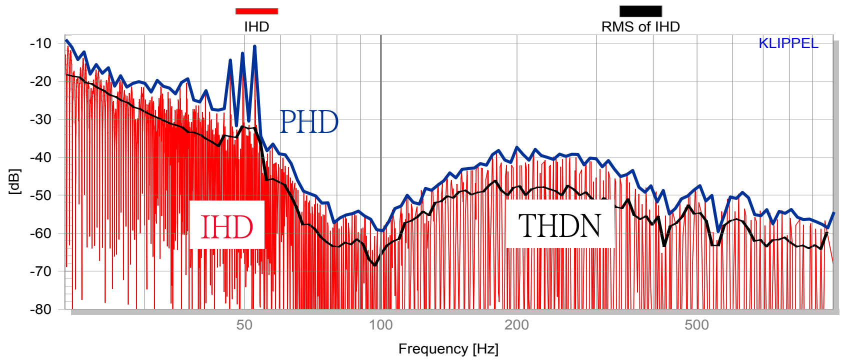
時域信號失真的細節
Detail of the distortion time signal
案例 A:Case A: „beating wire of a defect driver“



- 固有失真具有高能級 Regular distortion have high energy
- 異聲具有低能級 Disturbances have low energy
- 異聲是集中在一小部分週期裡的 Disturbances are concentrated at a fraction of a period
- 峰値失真 (大峰値因子) peaky distortion (high crest factor)
- 有源補償是有益的 Active compensation is useful

諧波失真
Harmonic Distortion

驅動信號: 正弦掃頻 Stimulus: Sinusoidal sweep



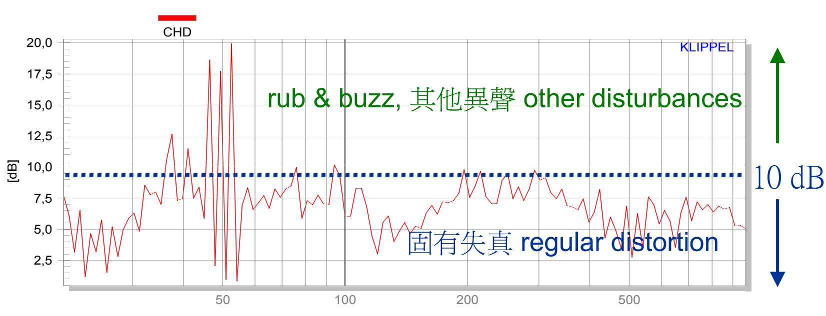
瞬時諧波失真 Instantaneous harmonic distortion

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

峰值諧波失真 Peak harmonic distortion

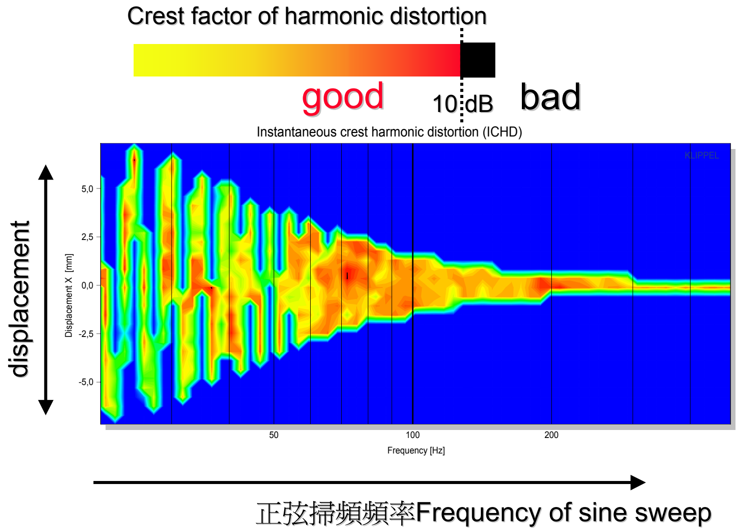
諧波失真的峰值因子
Crest factor of harmonic distortion (CHD)

驅動信號: 正弦掃頻 Stimulus: Sinusoidal sweep

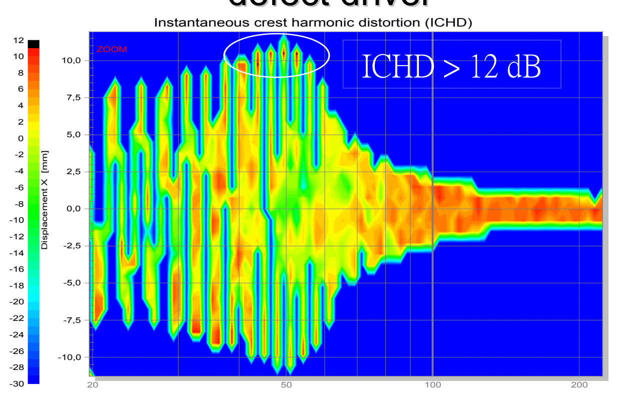


諧波失真峰值因子可以在絕對標度上被解釋!
CHD can be interpreted on an absolute scale ！

檢查: 諧波失真的峰值因數
Check: crest factor of harmonic distortion

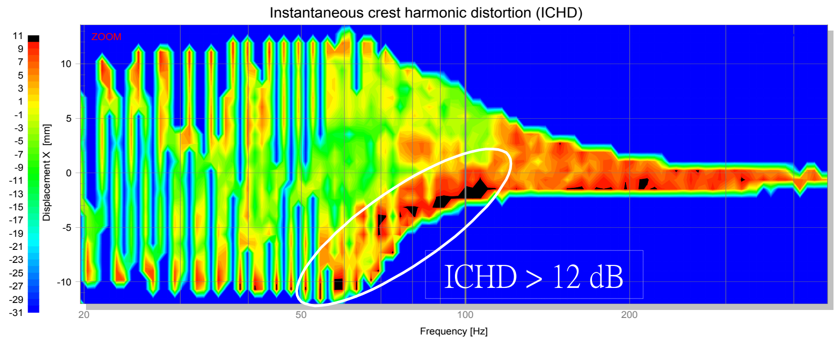


瞬時峰值諧波失真
Instantaneous crest harmonic distortion ICHD(f,x)
案例A: 毀損單體接線敲打 Case A: „beating wire of a defect driver“



毀損出現下50赫茲 + 10 mm 位移處
Defect occurs at + 10 mm displacement at 50 Hz

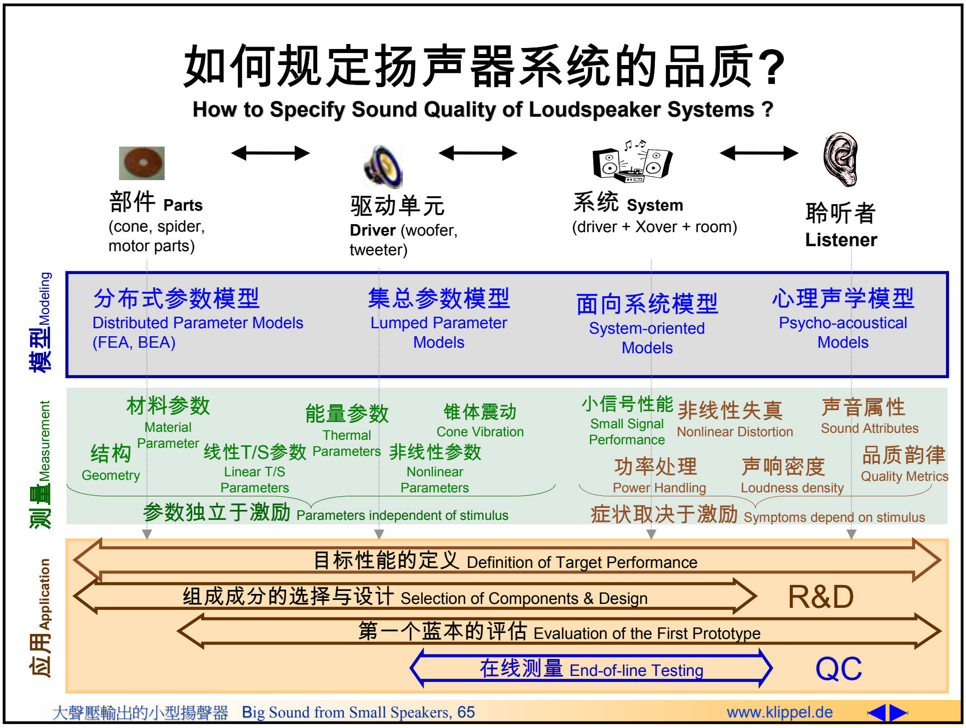
瞬時峰值諧波失真
Instantaneous crest harmonic distortion ICHD(f,x)
案例B: 毀損單體音圈摩擦 Case B: „rubbing voice coil of a defect driver“



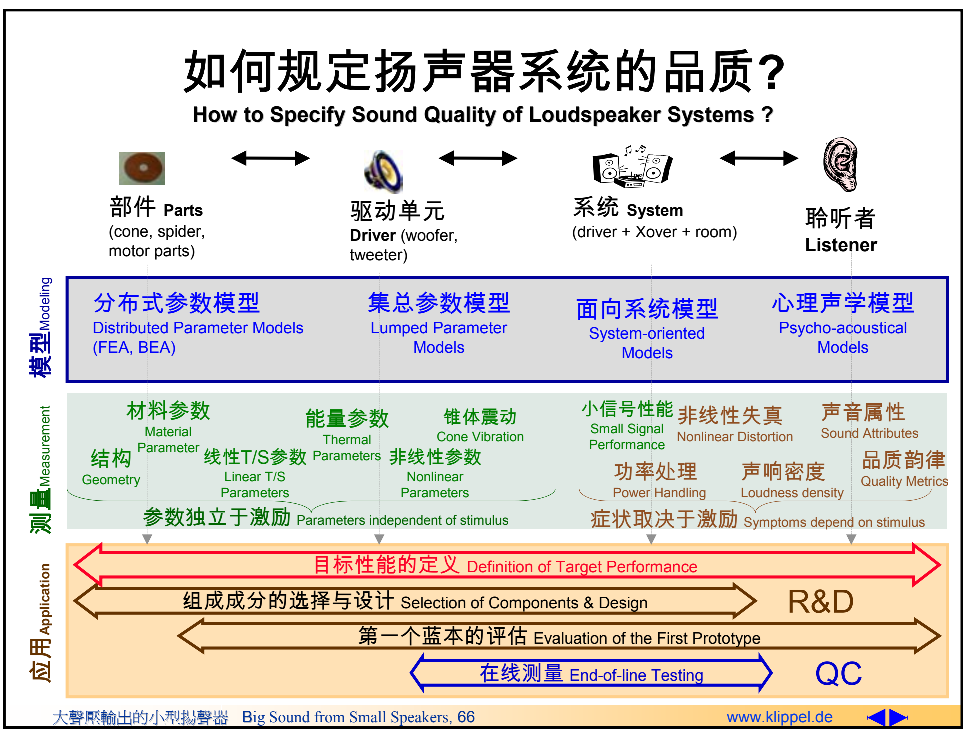
初始摩擦條件 Conditions initiating rubbing:
負轉折點的音圈偏移
Negative turning point of voice coil excursion
共振頻率之上 (質量主導) □ 音圈傾斜
Above resonance frequency (mass dominant) □

How to cope with nonlinearities

- Measure nonlinear distortion in the near field
  → ensure sufficient SNR
- Transform distortion to the loudspeaker input
  → concept of equivalent input distortion
- Be aware of interactions between nonlinearities
  → no compensation of Kms(x), Bl(x), L(x)
- Check for dc-displacement
  → instability
- Use numerical simulation tool
  → see impact on THD, X_{max}, SPL_{max}, IMD, P_{max} ,T
- Separate regular nonlinearities from irregular defects
  → measure Crest Factor of Distortion



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
能量参数
Thermal Parameters
锥体震动
Cone Vibration
线性T/S参数
Linear T/S Parameters
非线性参数
Nonlinear Parameters
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
参数独立于激励 Parameters independent of stimulus
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
大聲壓輸出的小型揚聲器 Big Sound from Small Speakers, 65
www.klippel.de



如何规定扬声器系统的品质?
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非线性参数
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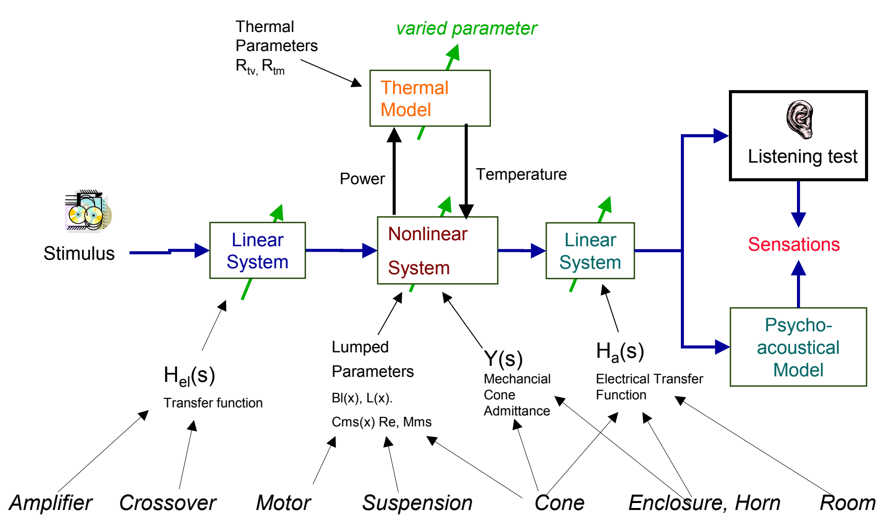
www.klippel.de

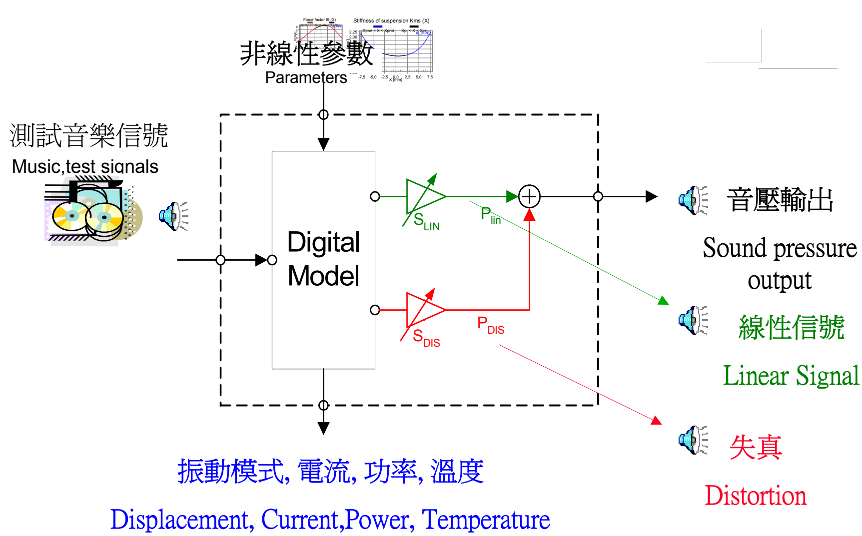
系统的聆听测试使用模拟和分解技术

Auralization – Systematic Listening Tests using Simulation and Decomposition Techniques



Listening into a Digital Model

聆聽分析失真信號



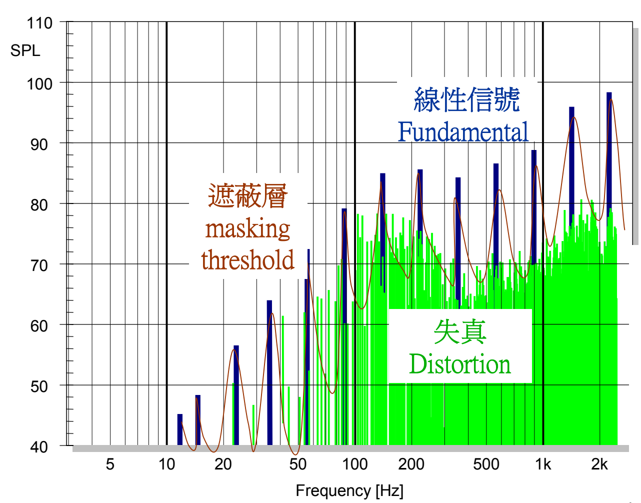
Measurement of Safety Headroom
輸出範圍

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

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



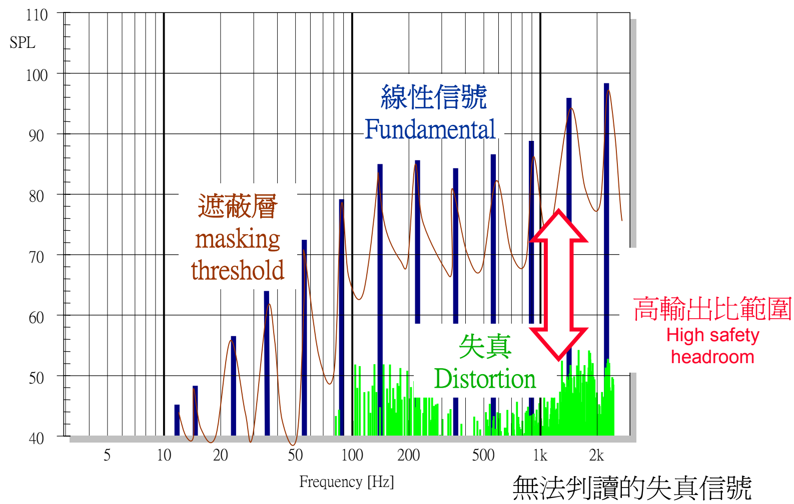
低輸出比範圍

No safety headroom

可判讀的失真信號

Output of a High-Quality loudspeaker

高品質揚聲器之輸出



無法判讀的失真信號

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

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

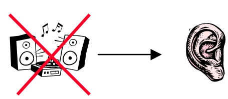
→ AES和IEC标准中关于"有源扬声器系统的测量"

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

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

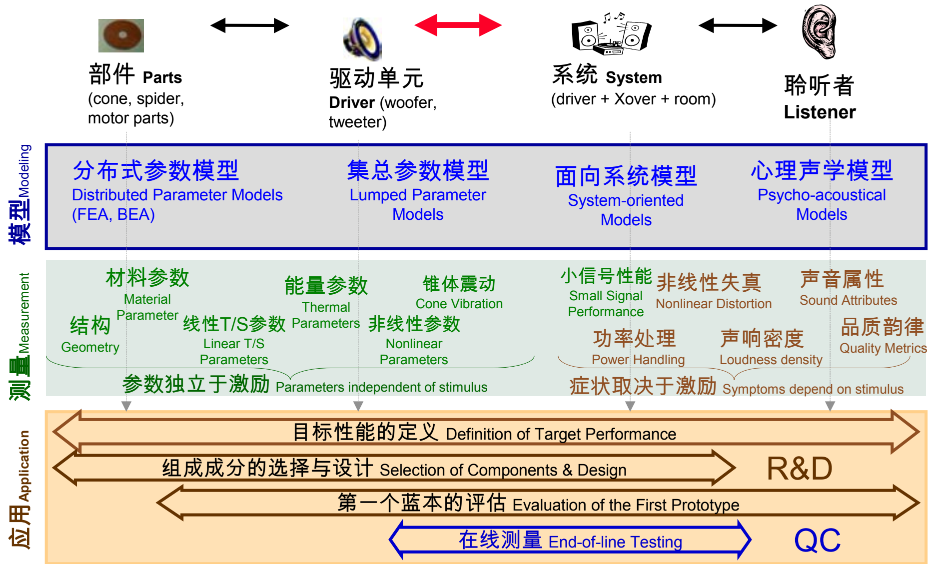
  Significant air noise caused by a leakage in the enclosure or a loose dust cap
- 驅動不穩定和嚴重的不對稱產生過量的非綫性失真

  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 ?



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

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 !!

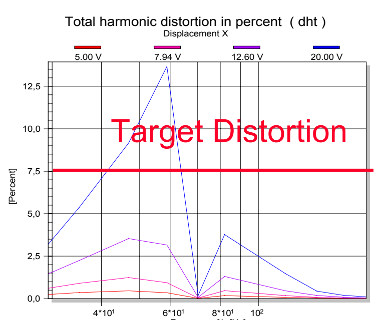
1. 參數(獨立于激勵訊號)Parameters (independent of stimuli)
- 聲學轉移函數 Acoustical transfer functions
- 機械轉移函數 Mechanical transfer functions
- 小訊號參數 Small signal parameter T/S
- 大訊號參數 Large signal parameters (thermal, nonlinear)

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

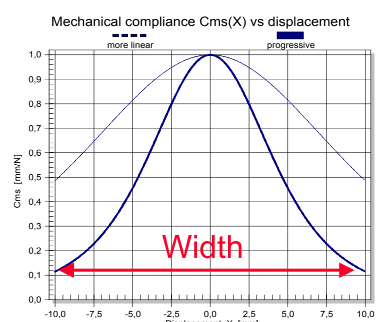
轉換成參數
Should be transformed into parameters

Transformation of Symptoms into Parameters

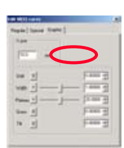
Total Harmonics THD @ SPL_{MAX} → Shape of Compliance Cms(x)



Check:
- THD at resonance frequency fs
- Compression of Fundamental for f < fs
- Displacement limit Xc

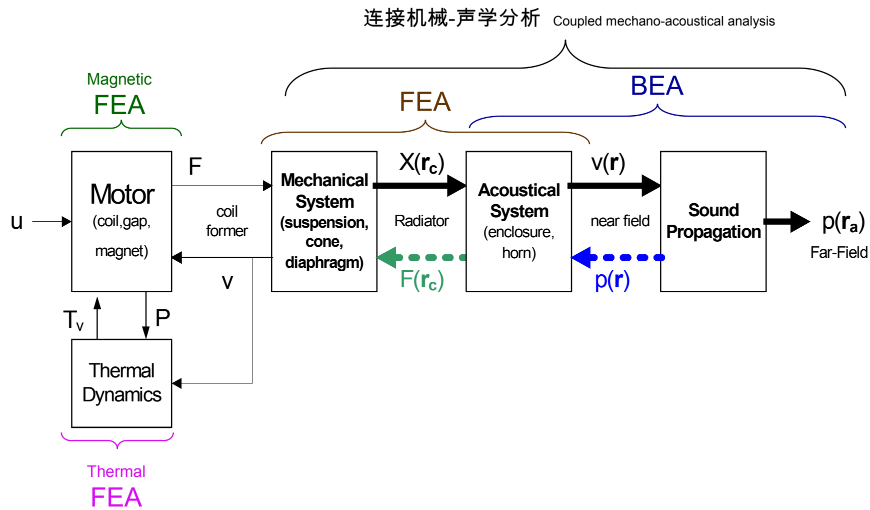


Single tone Stimulus → Loudspeaker Model (SIM Module) → Harmonic Distortion

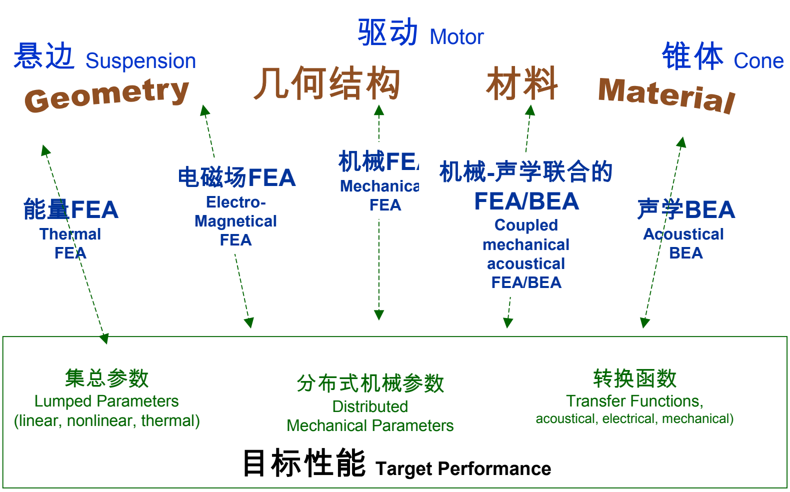


change WIDTH in nonlinear curve editor of Bl(x) curve

换能器的设计
Design of the Transducer

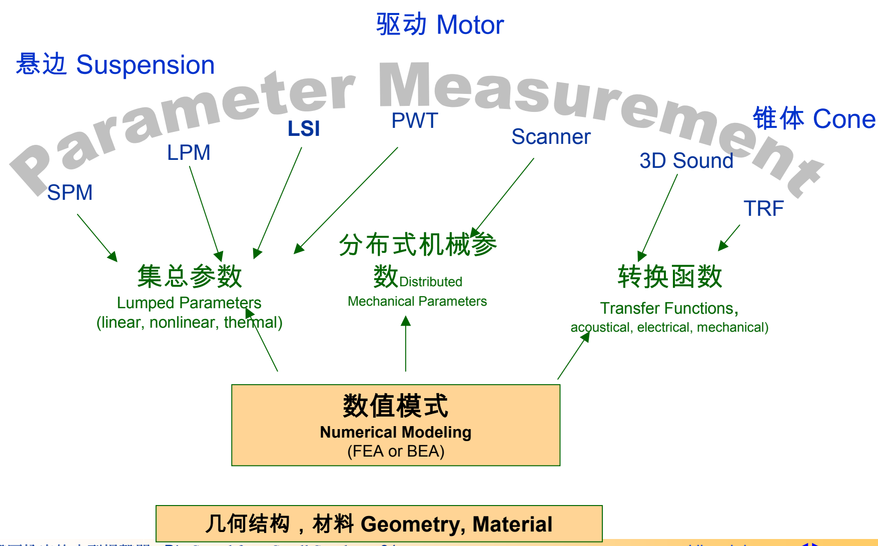


寻找最佳的设计选择
Finding the Optimal Design Choice



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

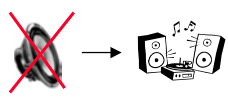


什么是不良的驱动单元？

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

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

联系方式 Contact

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