Acoustical Distortion Measurements

Parts 6-10 of the KLIPPEL- live webinar

Acoustical Measurement of Sound System Equipment

according IEC 60268-21

presented by

Wolfgang Klippel

Sessions of KLIPPEL- live Webinar

根據 IEC 60268-21 對音響系統設備進行聲學測量

Acoustical Measurement of Sound System Equipment according IEC 60268-21

1. 現代音頻設備需要輸出基本的測試 Modern audio equipment needs output based testing
2. 在普通房間進行的聲學標準測試 Acoustical standard tests performed in normal rooms
3. 從 3D 輸出測量中得出有意義的結論 Drawing meaningful conclusions from 3D output measurement
4. 在單個評估點模擬標準條件 Simulated standard condition at a single evaluation point
5. 最大聲壓級– 數字變得很重要 Maximum SPL – a number becomes important
6. 信號失真–強大的揚聲器診斷概念 Signal distortion – a powerful concept for loudspeaker diagnostics
7. 幅度壓縮–在較高幅度下輸出較少 Amplitude Compression – less output at higher amplitudes
8. 諧波失真測量 - 最佳實踐 Harmonic Distortion Measurements – best practice
9. 互調失真 - 音頻不僅僅是一個音調 Intermodulation Distortion – audio is more than a single tone
10. 脈衝失真 – 異音、異常行為、不良 Impulsive distortion - rub&buzz, abnormal behavior, defects
11. 具有無線音頻輸入的智能揚聲器測試 Smart speaker testing with wireless audio input
12. 在標準條件下對音頻產品進行基準測試 Benchmarking of audio products under standard conditions
13. 信號失真的可聽化——感知評估 Auralization of signal distortion – perceptual evaluation
14. 為信號失真設置有意義的容差 Setting meaningful tolerances for signal distortion
15. 評定產品的最大 SPL 值 Rating the maximum SPL value for product

Previous Sessions

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6. 選擇具有高診斷價值的測量 Selecting measurements with high diagnostic value
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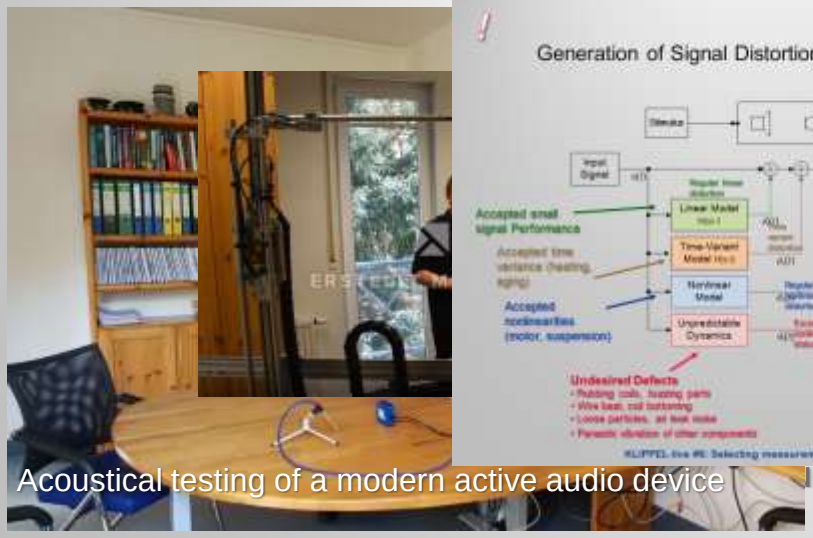
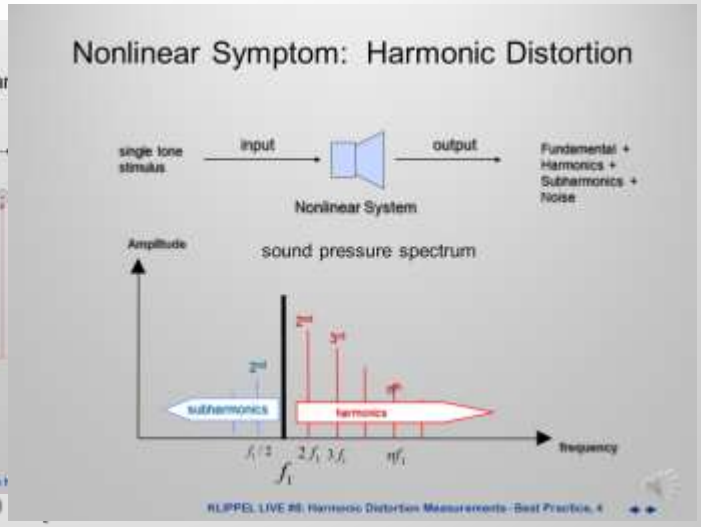
8. 諧波失真測量 - 最佳實踐 Harmonic Distortion Measurements – best practice



Acoustical testing of a modern active audio device



9th KLIPPEL LIVE:
Intermodulation Distortion – music is more than a single tone

今日主題 Topics today:

- 互調失真的物理原因 Physical causes for intermodulation distortion
- 根據 IEC 標準 20268-21 進行測量 Measurements according to IEC Standard 20268-21
- 用two-tone激發測試 Testing with a two-tone stimulus
- 使用multi-tone進行測試Testing with a multi-tone complex
- 解釋結果 Interpretation of the results
- 實際示範 Practical demos

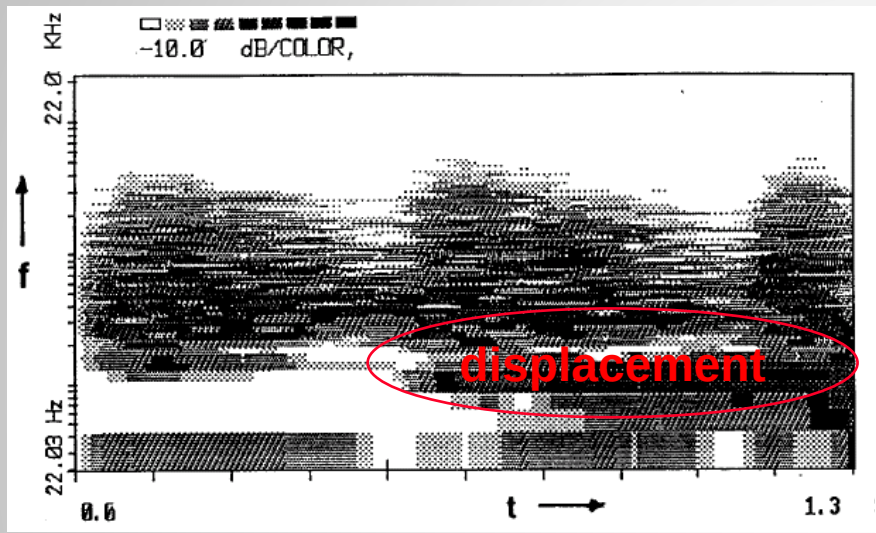
投票 Poll:

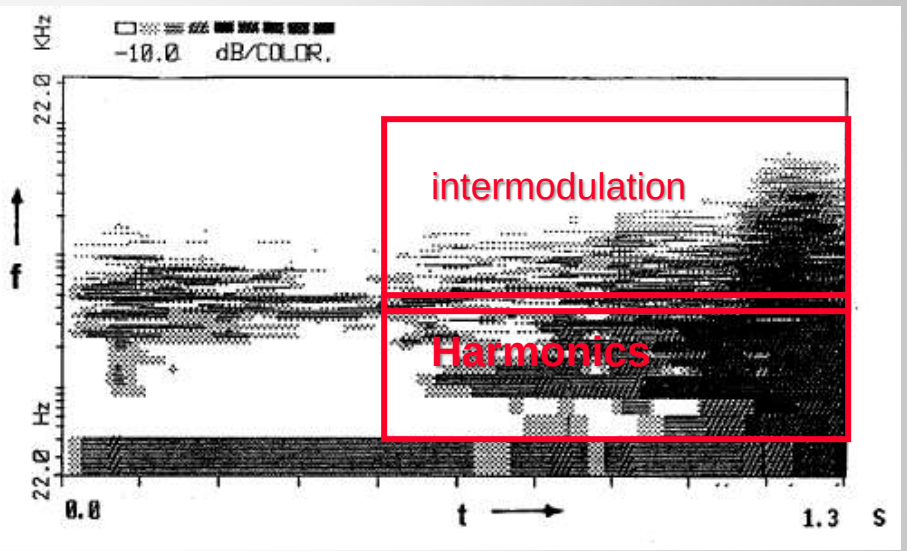
你評估互調失真嗎？

Do you evaluate the intermodulation distortion ?

A. 不會 No
B. 會，透過聽音樂 Yes, by listening to music
C. 會，使用雙音激發 Yes, by using a two tone stimulus
D. 會，使用multi-tone Yes, by using a multi-tone complex
E. 會，透過其他方式 Yes, by other ways

音樂中的失真
Bl-Distortion in Music





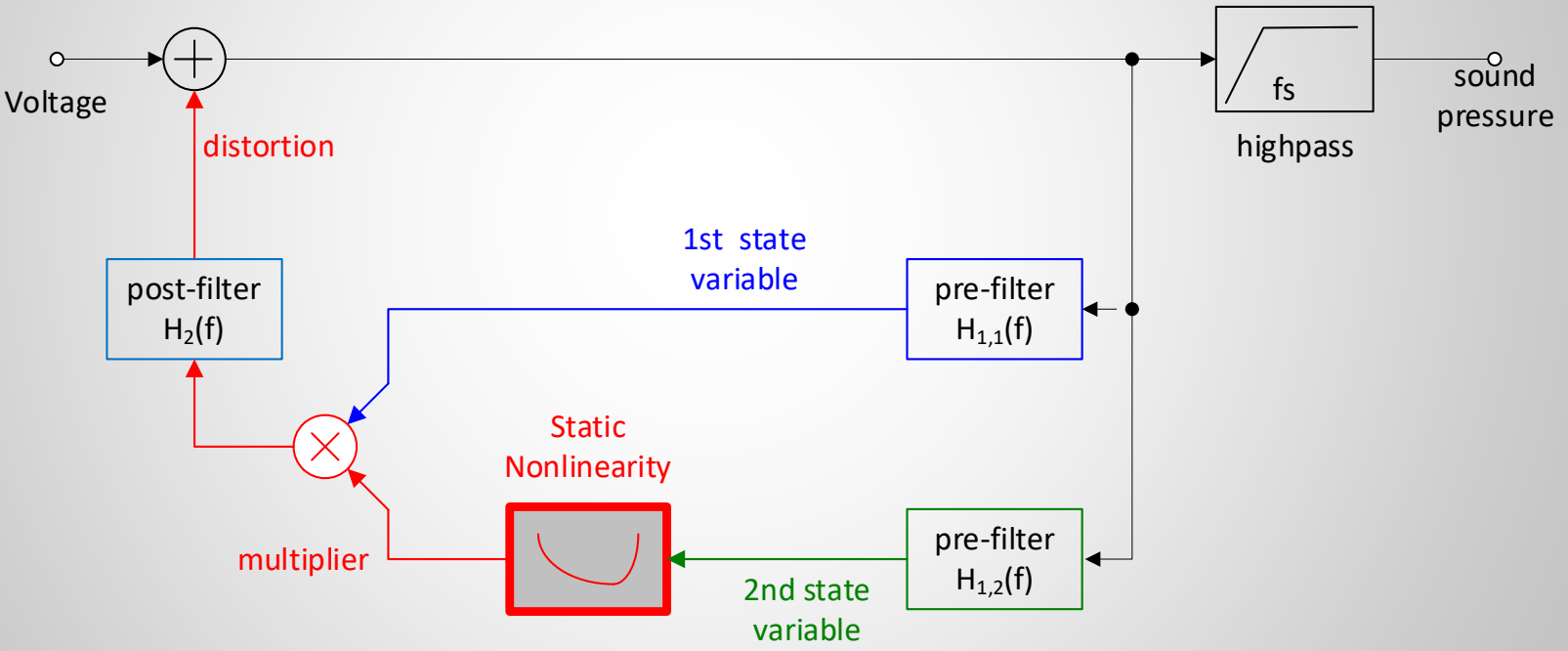
Undistorted music signal

Distortion generated by Bl(x) only

需要高位移 → 低於 fs 的信號 → 低音信號
High displacement required → signal below fs → bass signal
當 fs < 100 Hz 時，與音頻帶中的信號互調會產生雜訊
Intermodulation with signal in audioband generate roughness when fs < 100 Hz
對音質影響大
High impact on sound quality

什麼導致IM失真？
What causes the IM Distortion ?

Generalized Signal Flow Model
describing a separated nonlinearity



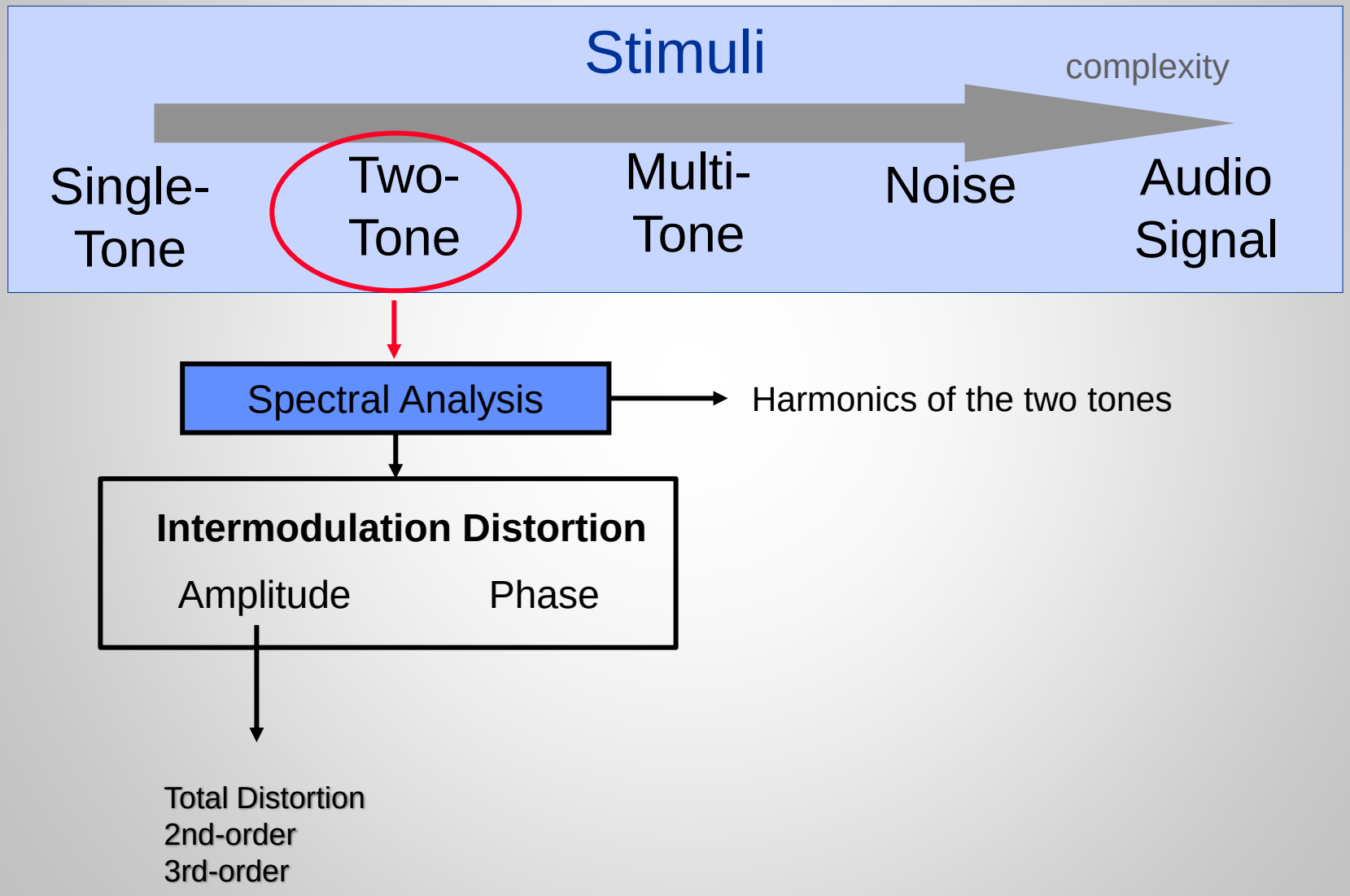
The multiplication of two different state variables generates unique intermodulation distortion !

高 IM 失真的原因
Causes for high IM-Distortion

NONLINEARITY	INTERPRETATION	PRE-FILTER $H_{1,1}(f)$ (output)	PRE-FILTER $H_{1,2}(f)$ (output)	
Stiffness $K_{ms}(x)$ of the suspension	restoring force	Low-pass (displacement x)	Low-pass (displacement x)	
Force factor Bl(x)	electro-dynamical force	Band-stop (current i)	Low-pass (displacement x)	Negligible THD $f > 2f_s$
	nonlinear damping	Band-pass (velocity v)	Low-pass (displacement x)	
Inductance $L_e(x)$	self-induced voltage	Band-stop (current i)	Low-pass (displacement x)	Negligible THD
	reluctance force	Band-stop (current i)	Band-stop (current i)	
Inductance $L_e(i)$	varying permeability	Band-stop (current i)	Band-stop (current i)	
Mechanical resistance $R_{ms}(v)$	nonlinear damping	Band-pass (velocity v)	Band-pass (velocity v)	
Young's modulus $E(\varepsilon)$ of the material	cone vibration	Band-pass (strain ε)	Band-pass (strain ε)	
Speed of sound c(p)	nonlinear sound propagation (wave steepening)	High-pass (sound pressure p)	High-pass (sound pressure p)	
Time delay $\tau(x)$	nonlinear sound radiation (Doppler effect)	High-pass (sound pressure p)	Low-pass (displacement x)	Negligible THD

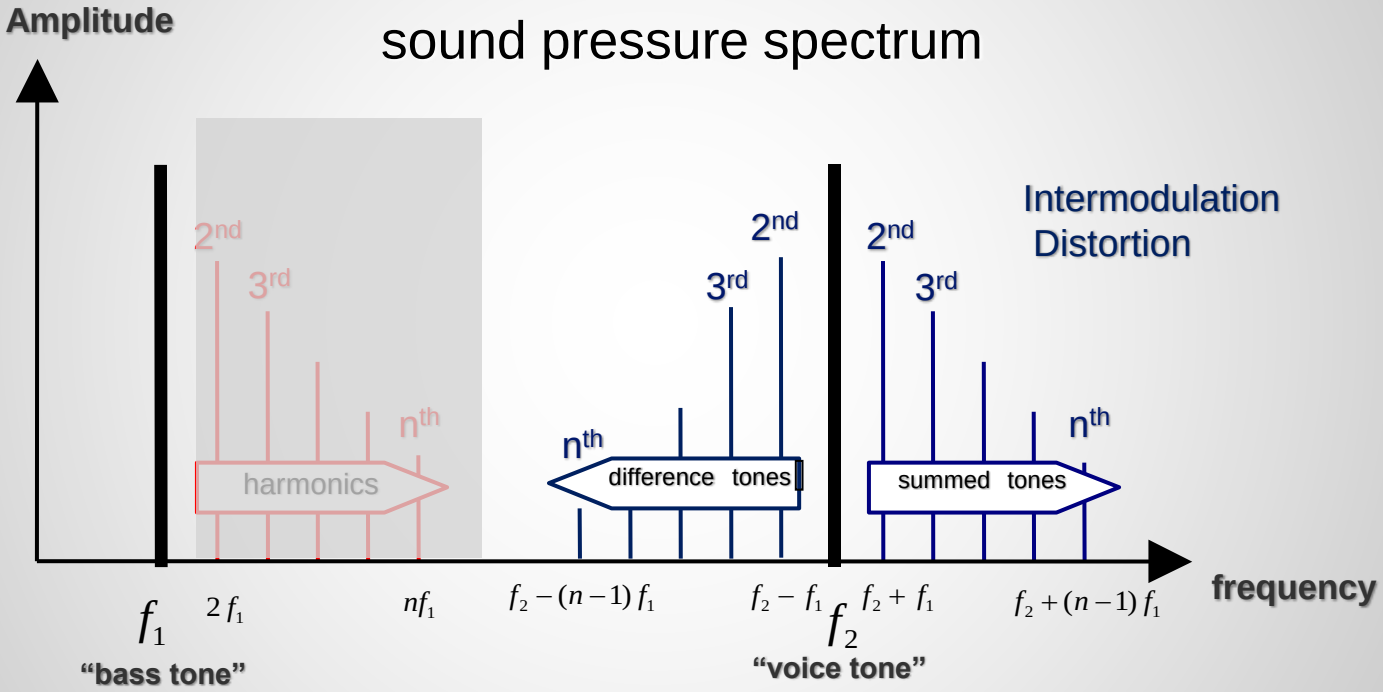
Measurements of Intermodulation Distortion is important !

稀疏但全面的激發
Sparse but Comprehensive Stimulus



互調失真 Intermodulation distortion

generated by Two-tone Stimulus



To simplify the identification of the components:

- Keep large distance between the exciting tones f_1 and f_2

IM-Distortion (two-tone signal)

Definitions according IEC 60268-21

Second-order Modulation

(FM + AM)

$$L_{2IMD} = 20\lg\left(\frac{\tilde{p}(f_2 - f_1) + \tilde{p}(f_2 + f_1)}{\tilde{p}(f_2)}\right)$$

Third-order Modulation

(FM + AM)

$$L_{3IMD} = 20\lg\left(\frac{\tilde{p}(f_2 - 2f_1) + \tilde{p}(f_2 + 2f_1)}{\tilde{p}(f_2)}\right)$$

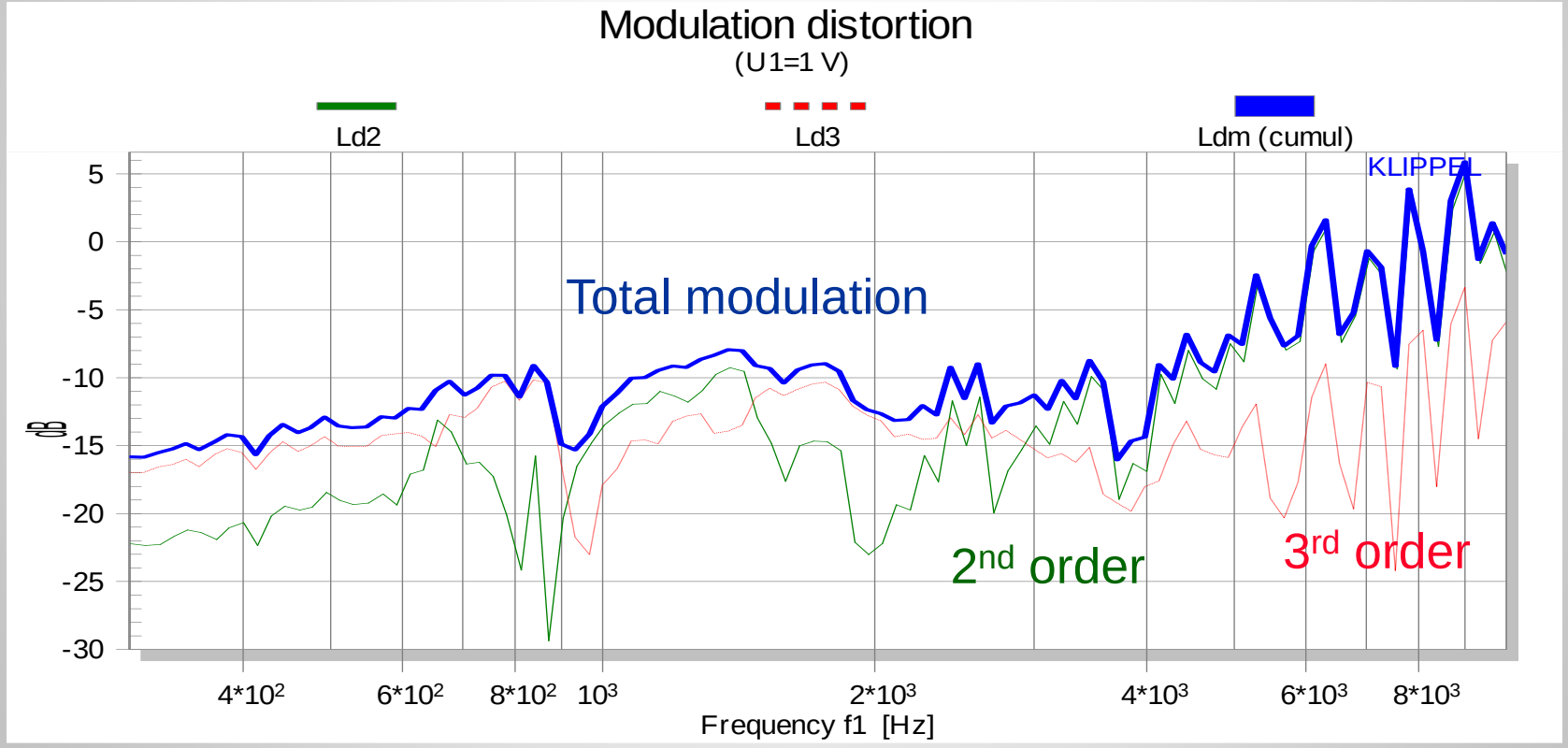
Total Modulation Distortion

(FM+ AM)

$$L_{TIMD}(f_1, f_2) = 20\lg\left(\frac{\sum_{k=1}^{2} \tilde{p}(f_2 - kf_1) + \tilde{p}(f_2 + kf_1)}{\tilde{p}(f_2)}\right)$$

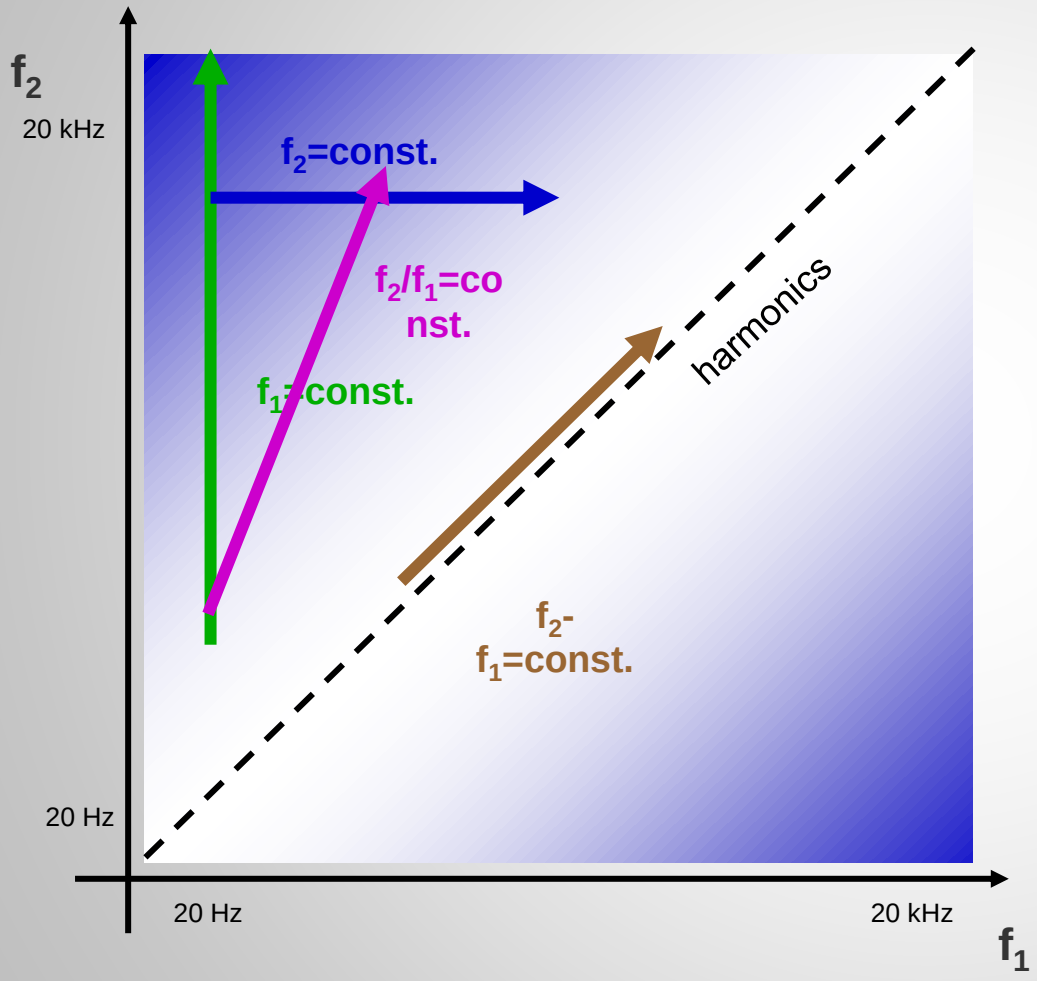
The IEC 60268-21 uses relative measures (IMD component divided by carrier)
The relative IMD are similar to the equivalent input distortion because the frequency distance $|f_2-f_1| << f_2$
→ Near field measurement can be used to improve SNR

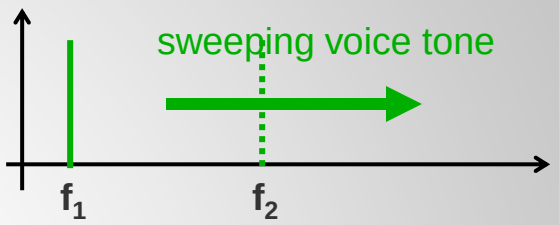
二階和三階分量對總互調失真的貢獻
Contribution of 2nd and 3rd-order Components to the total intermodulation distortion

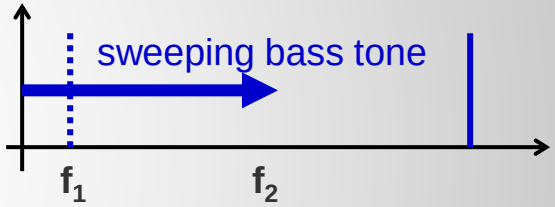


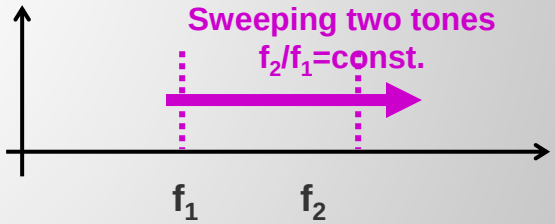
掃描雙音信號
Sweeping the Two-Tone Signal

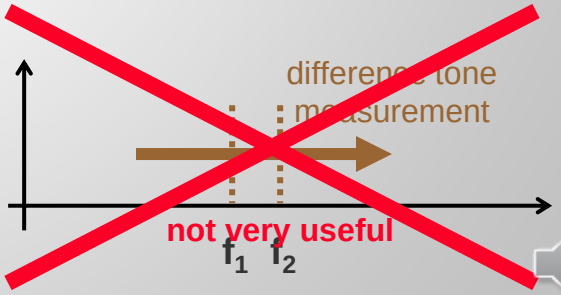
How to choose the frequencies ?











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

投票 Poll:

您如何設置測試激發中兩種音調的頻率？

How do you set the frequencies of the two tones in the stimulus for the testing ?

A. 沒有 None

B. 固定兩個音調（f1 > f2）Fixed setting two tones ($f_1 > f_2$)

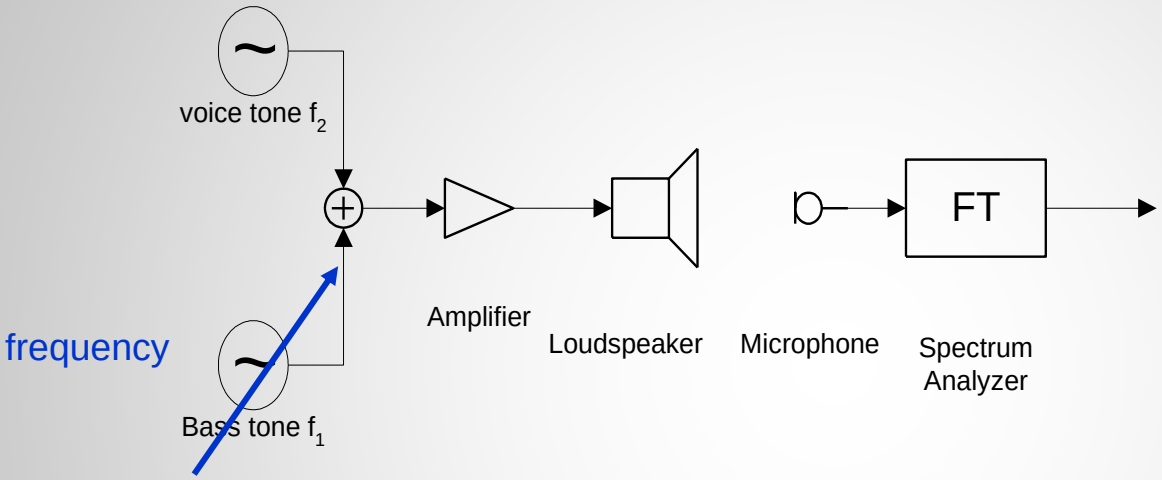
C. 掃低音 f1（固定 f2 > 可變 f1）Sweeping the Bass tone f_1 (fixed f_2 > variable f_1)

D. 掃音調 f2（固定 f1 < 可變 f2）Sweeping the voice tone f_2 (fixed f_1 < variable f_2)

E. 以恆定頻率比 f2/f1=const 進行雙音掃頻 Sweeping two tone sweep with constant frequency ratio f_2/f_1=const

F. 其他 Other

聲壓中 IMD 的設置
Setup for IMD in Sound Pressure
bass sweep technique



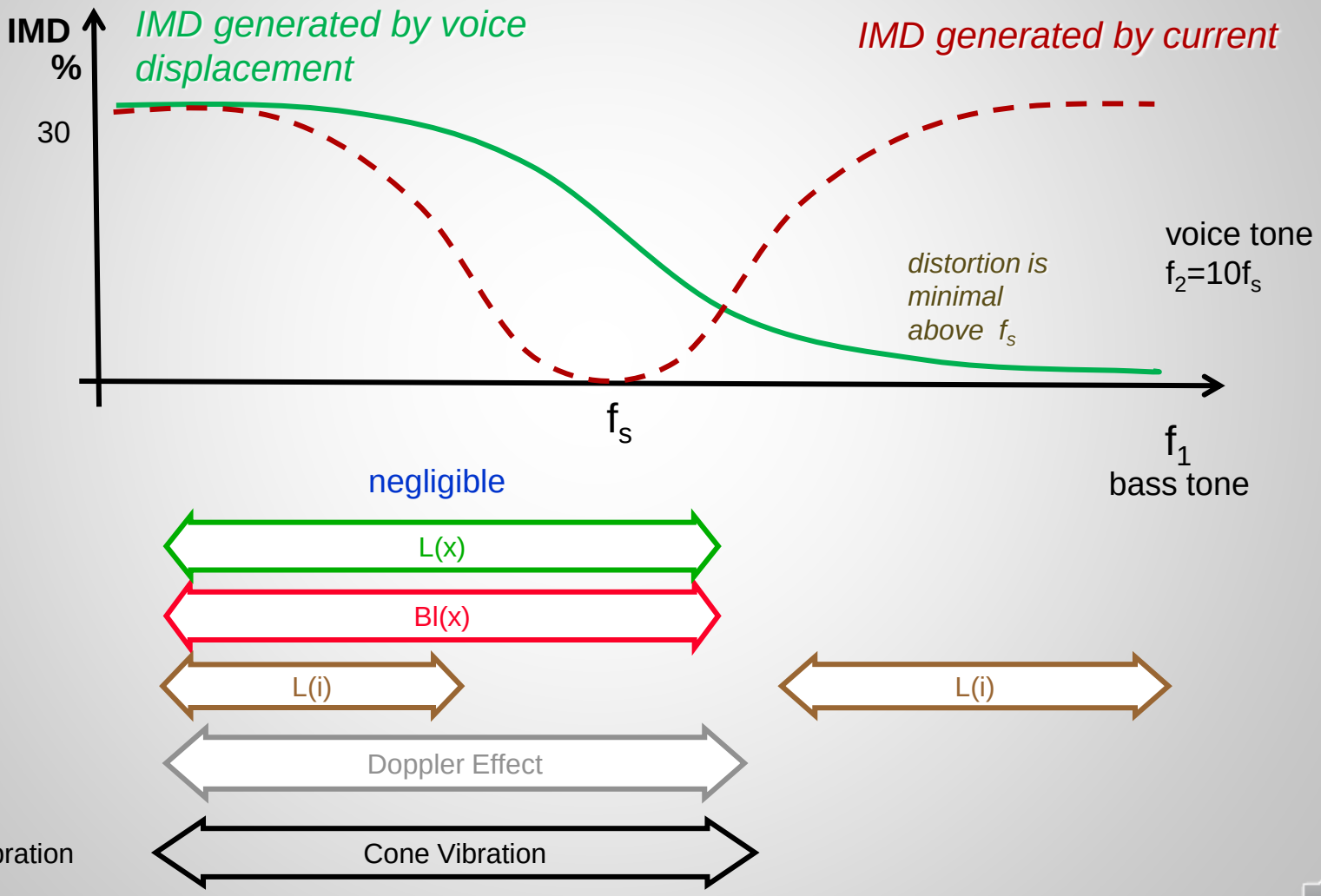
Amplitude response versus frequency f_1 :

2^{nd}-order IMD
3^{rd} –order IMD

<u>最佳激發 Optimal Stimulus:</u>
雙音激發 Two-Tone stimulus
關於共振的低音頻率變化 0.5fs < f1 < 2fs
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>要求 Requirement:</u>
2 個正弦波產生器，頻譜分析儀 2 sinusoidal generators, Spectrum analyzer

聲壓輸出中 IMD 的原因
Causes of IMD in Sound Pressure Output
using bass sweep technique

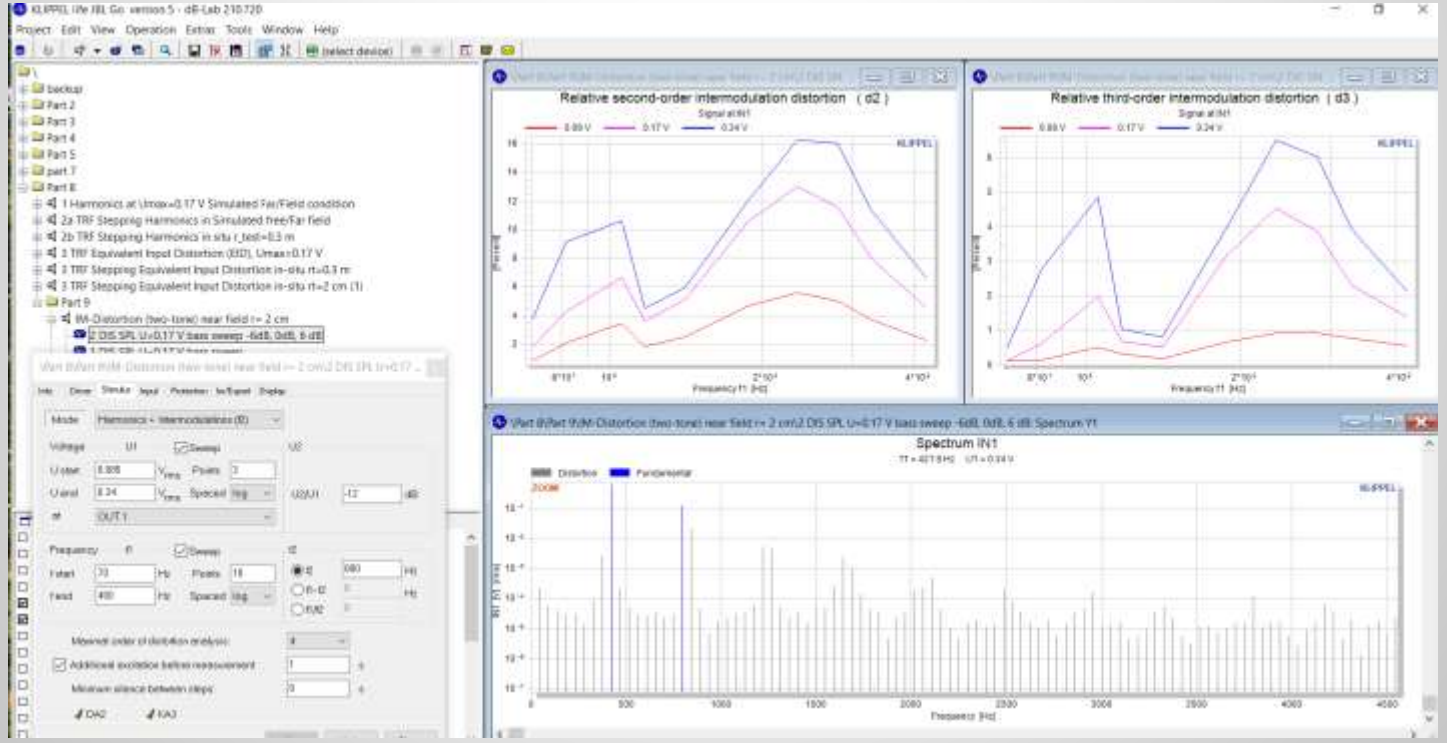


示範 Demo: Intermodulation Distortion

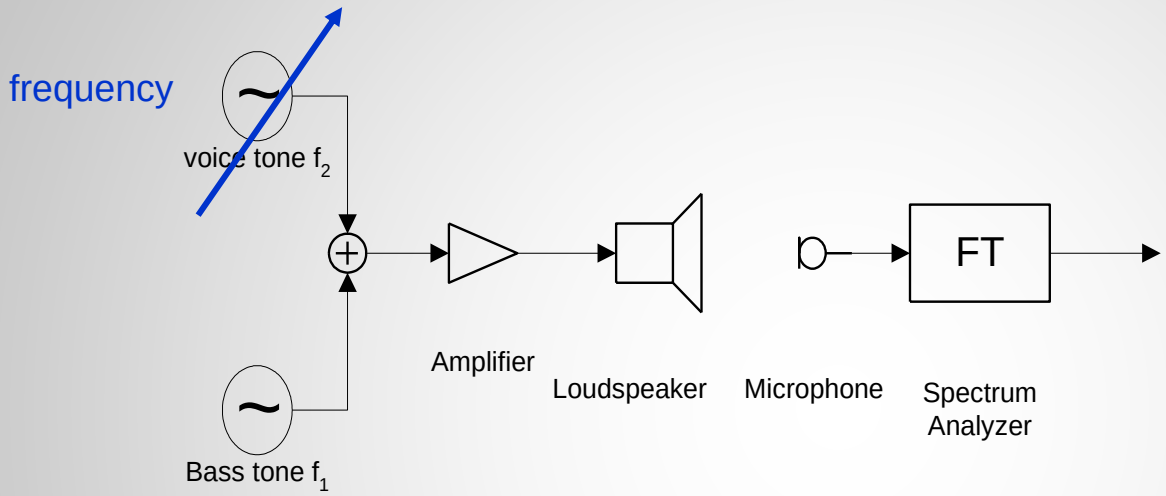
2 tone stimulus with bass sweep

Tools of the KLIPPEL Analyzer:

- 3D Distortion Measurement (DIS)



聲壓中 IMD 的測量
Measurement of IMD in Sound Pressure
voice sweep technique



Amplitude response versus frequency f_1 :

2^{nd}-order IMD
3^{rd} –order IMD

最佳刺激Optimal Stimulus:

雙音激發 Two-Tone stimulus
共振以上的音調變化頻率 5fs < f2 < 20fs
Varying frequency of voice tone above resonance $5f_s < f_2 < 20f_s$
低於共振頻率的低音恆定頻率 f1 < 0.5fs
Constant frequency of bass tone below resonance $f_1 < 0.5f_s$

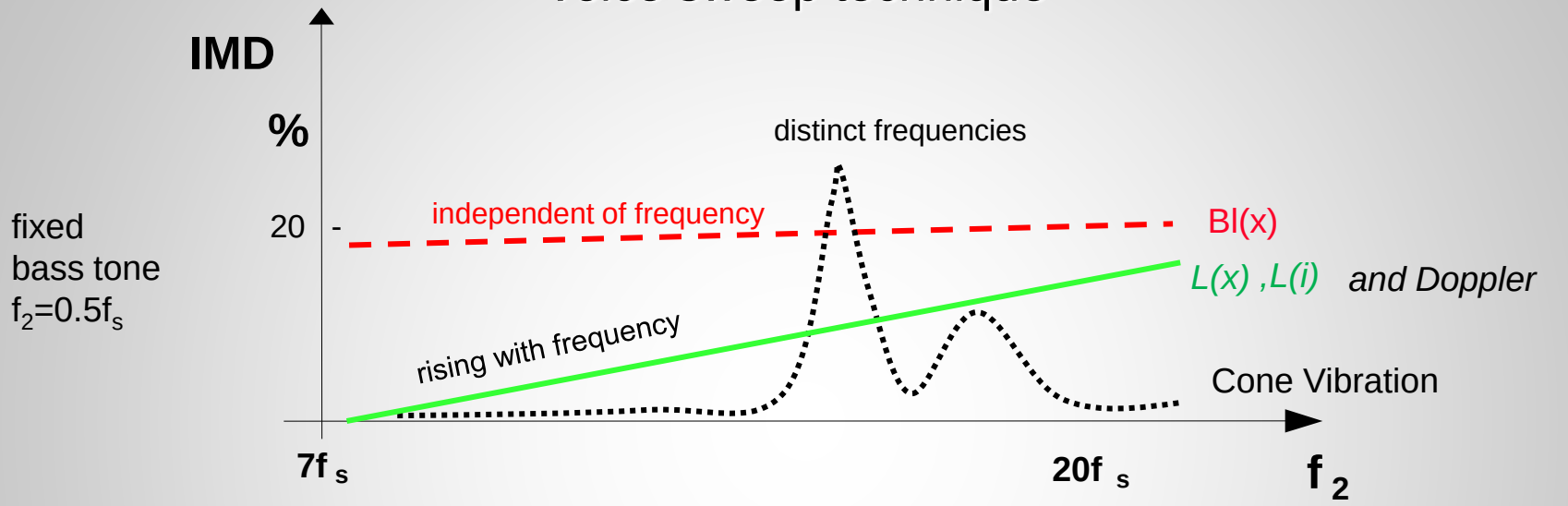
要求 Requirement:

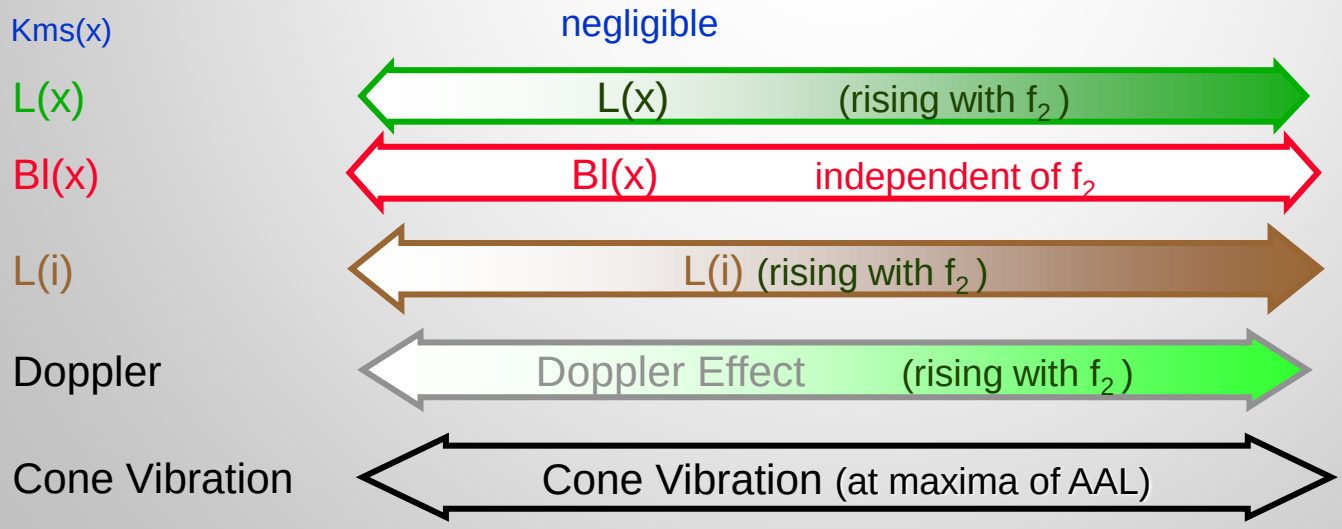
ALMA 測試 CD、2 個音調發生器、頻譜分析儀、麥克風
ALMA Test CD, 2 tone generators, Spectrum analyzer, Microphone

聲壓輸出中IMD的成因

The Causes of IMD in Sound Pressure Output

voice sweep technique



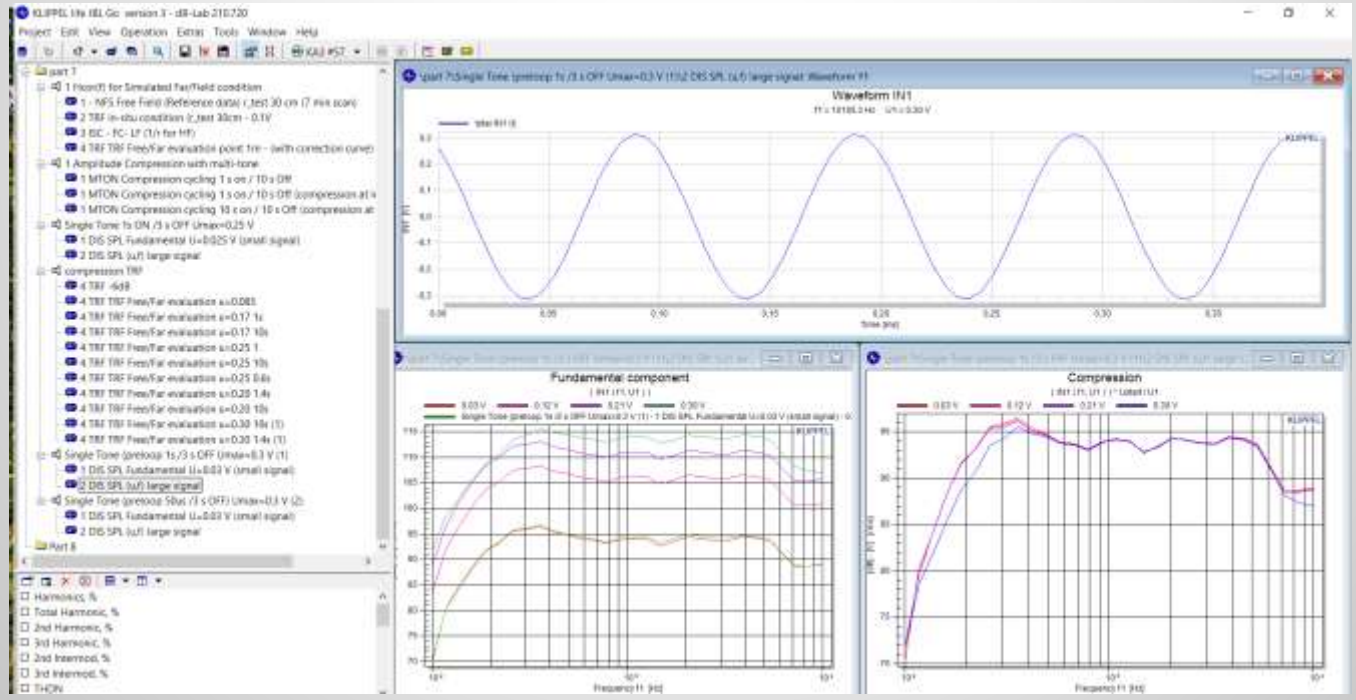


示範 Demo: Intermodulation Distortion

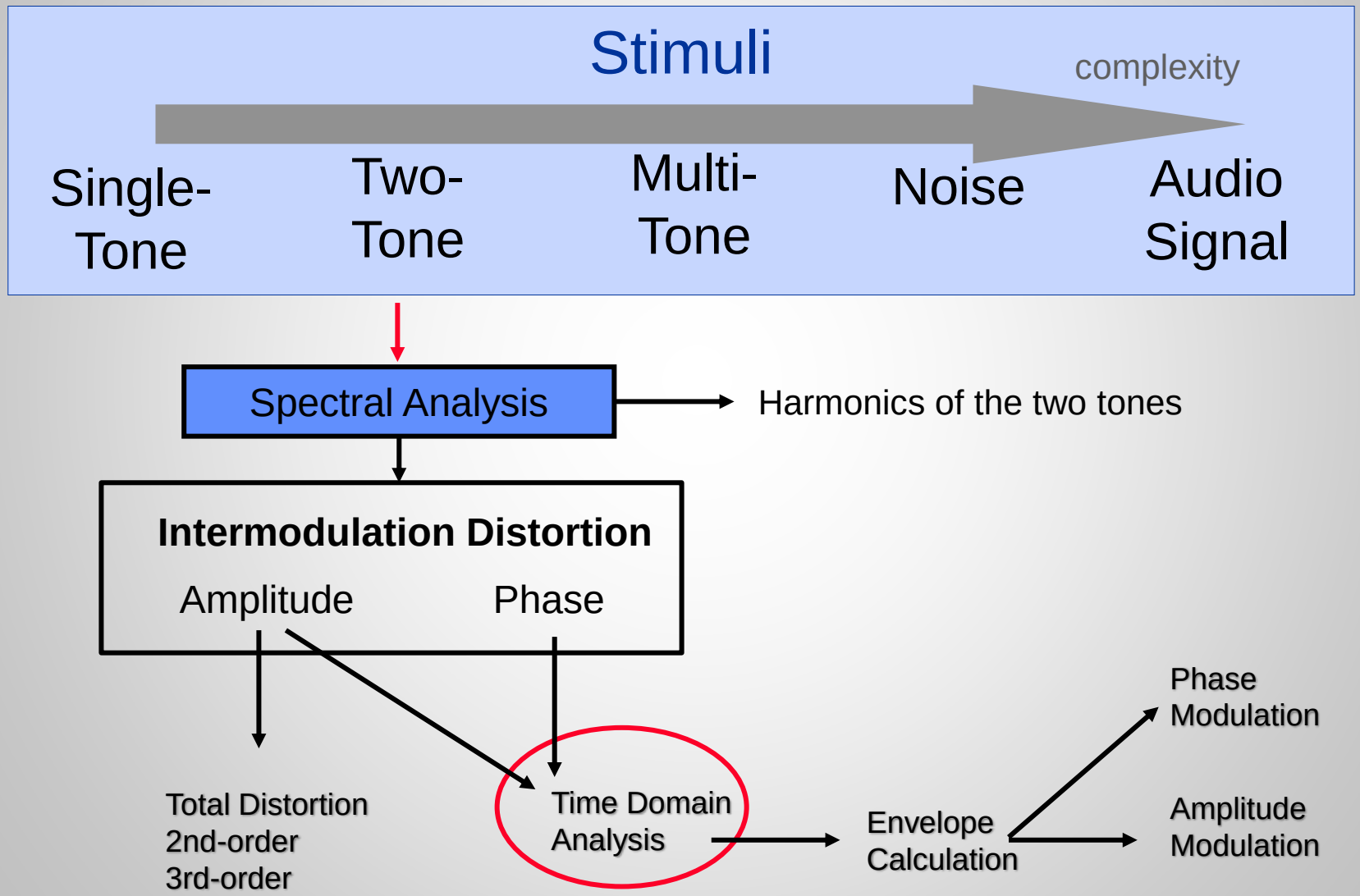
2 tone stimulus with voice sweep

Tools of the KLIPPEL Analyzer:

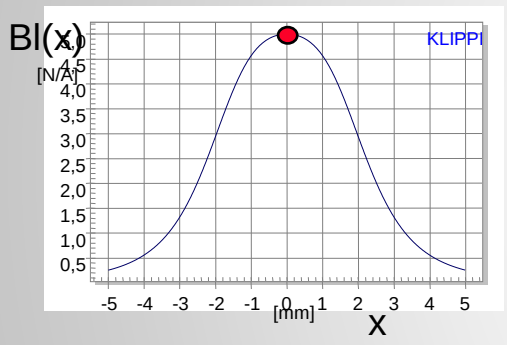
- 3D Distortion Measurement (DIS)



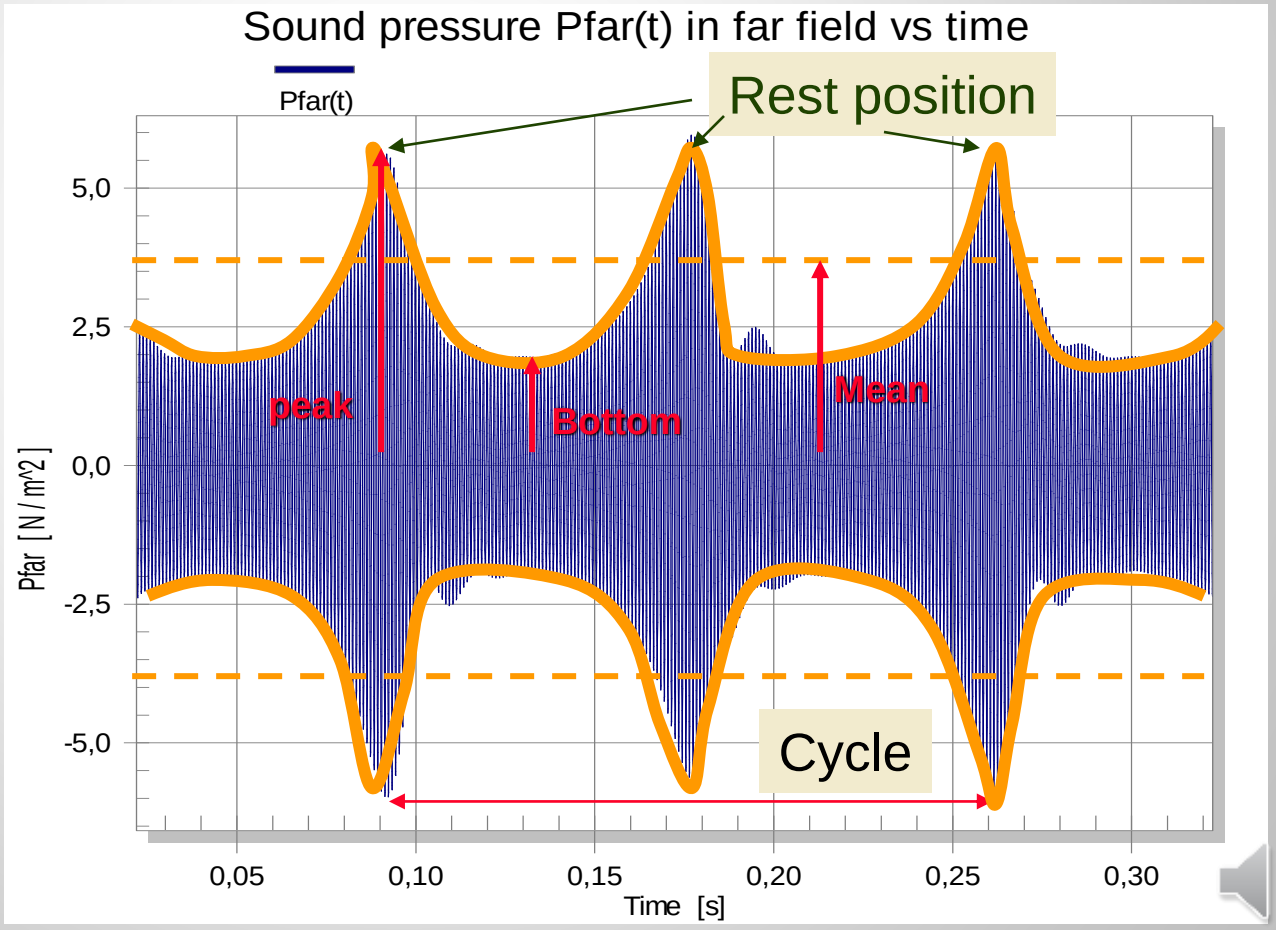
稀疏但全面的刺激
Sparse but Comprehensive Stimulus



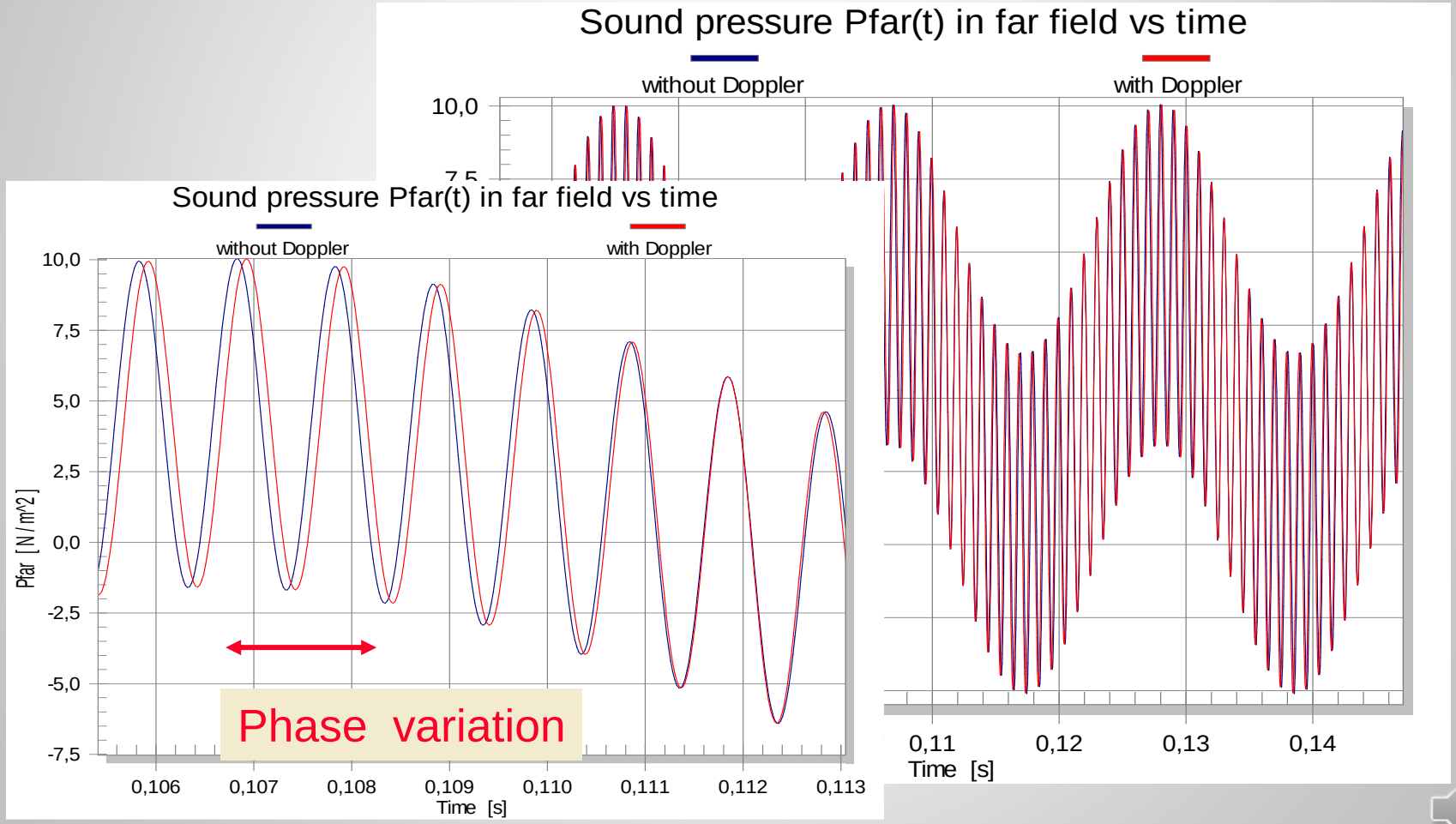
調幅
Amplitude Modulation
two-tone stimulus $f_1 < f_s$, $f_2 > f_s$



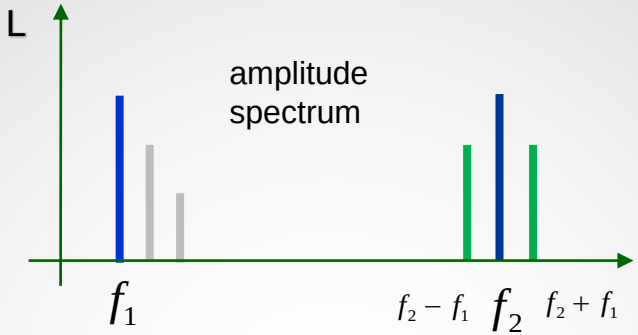
Symmetrical
Force factor
Bl(x)



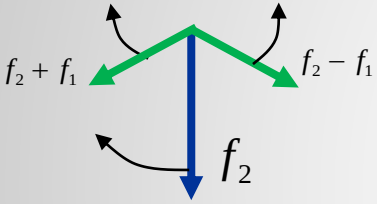
相位
Phase (Frequency) Modulation
caused by Doppler Effect

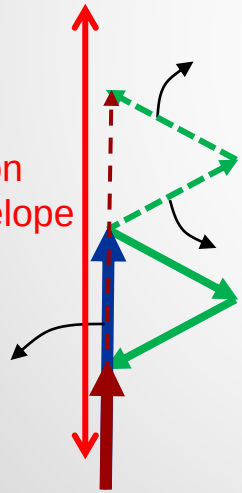


互調失真相位
Phase of Intermodulation Distortion

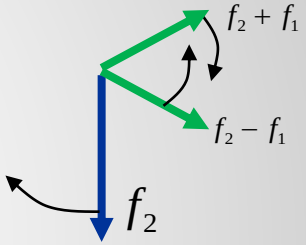


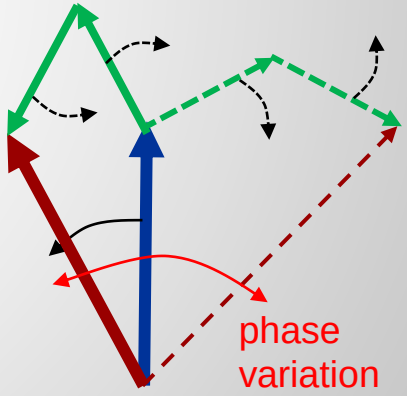
in-phase





90 degree phase shift





Amplitude **M**odulation

Frequency **M**odulation

(Phase Modulation)

互調失真的可聽度
Audibility of Intermodulation Distortion

臨界條件 Critical condition:

- “低音”的調製頻率足夠低 (fB < 30 Hz)

modulation frequency of the „bass tone“ is sufficiently low (f_B < 30 Hz)

- 語音音調的載波頻率為 1 kHz 音調 (80 dB SPL)

Carrier frequency of the voice tone is at 1 kHz tone (80 dB SPL)

簡短的摘要 Short summary

→ **AM 調製（例如力因數失真）在 3 % 時可聽到並被感知為噪聲**

AM modulation (e.g. force factor distortion) are audible at 3 % and perceived as roughness

→ FM 調製的閾值在 30 % 時變得可聽

Threshold of **FM modulation** become audible at 30 %

Zwicker, Fastl, 1999

→ **多普勒失真並不重要**

Doppler distortion are not critical

More in section #14: Setting meaningful tolerances for Signal Distortion (August 12th)

IM-失真（雙音信號）
IM-Distortion (two-tone signal)
Definitions according IEC 60268-21

Second-order Modulation

(FM + AM)

$$L_{2IMD} = 20\lg\left(\frac{\tilde{p}(f_2 - f_1) + \tilde{p}(f_2 + f_1)}{\tilde{p}(f_2)}\right)$$

Third-order Modulation

(FM + AM)

$$L_{3IMD} = 20\lg\left(\frac{\tilde{p}(f_2 - 2f_1) + \tilde{p}(f_2 + 2f_1)}{\tilde{p}(f_2)}\right)$$

Total Modulation Distortion

(FM+ AM)

$$L_{TIMD}(f_1, f_2) = 20\lg\left(\frac{\sum_{k=1}^{2} \tilde{p}(f_2 - kf_1) + \tilde{p}(f_2 + kf_1)}{\tilde{p}(f_2)}\right)$$

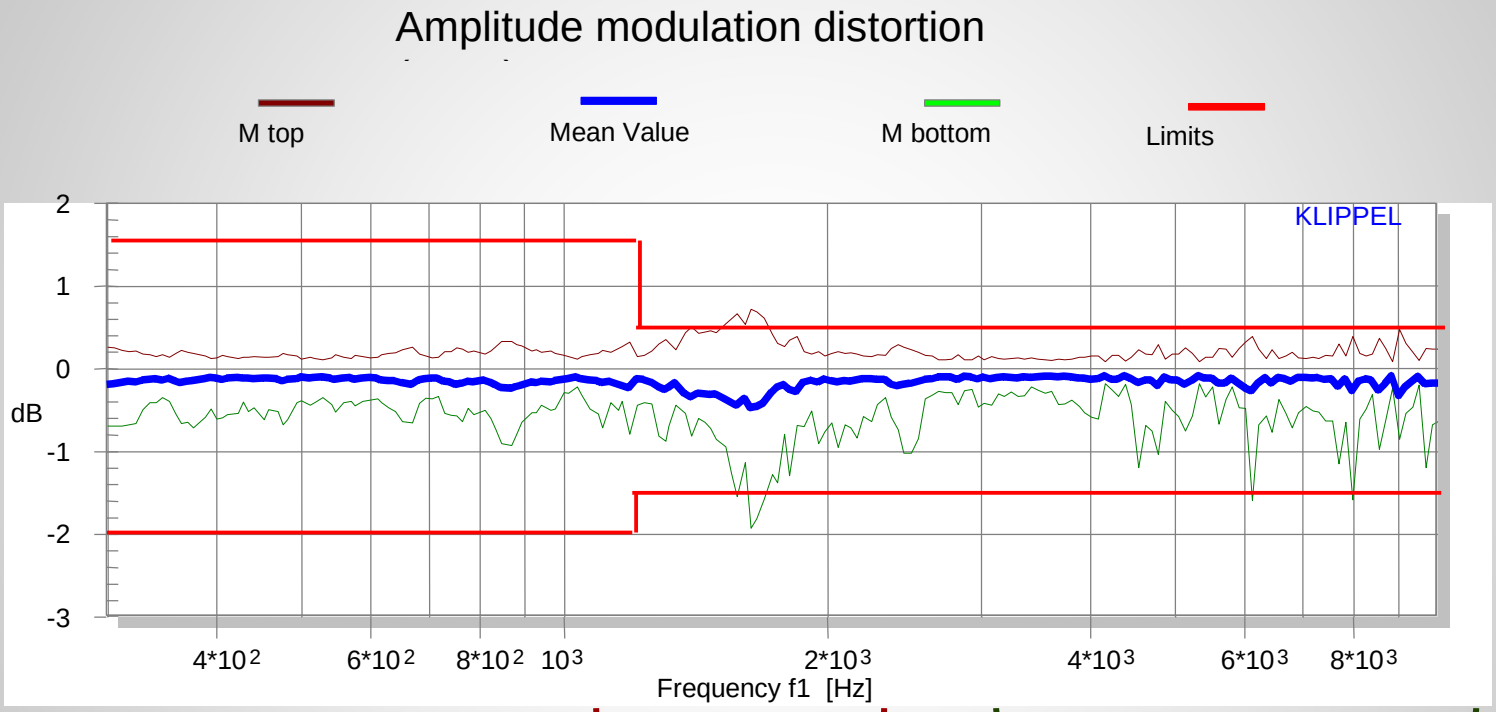
Amplitude Modulation

(AM only)

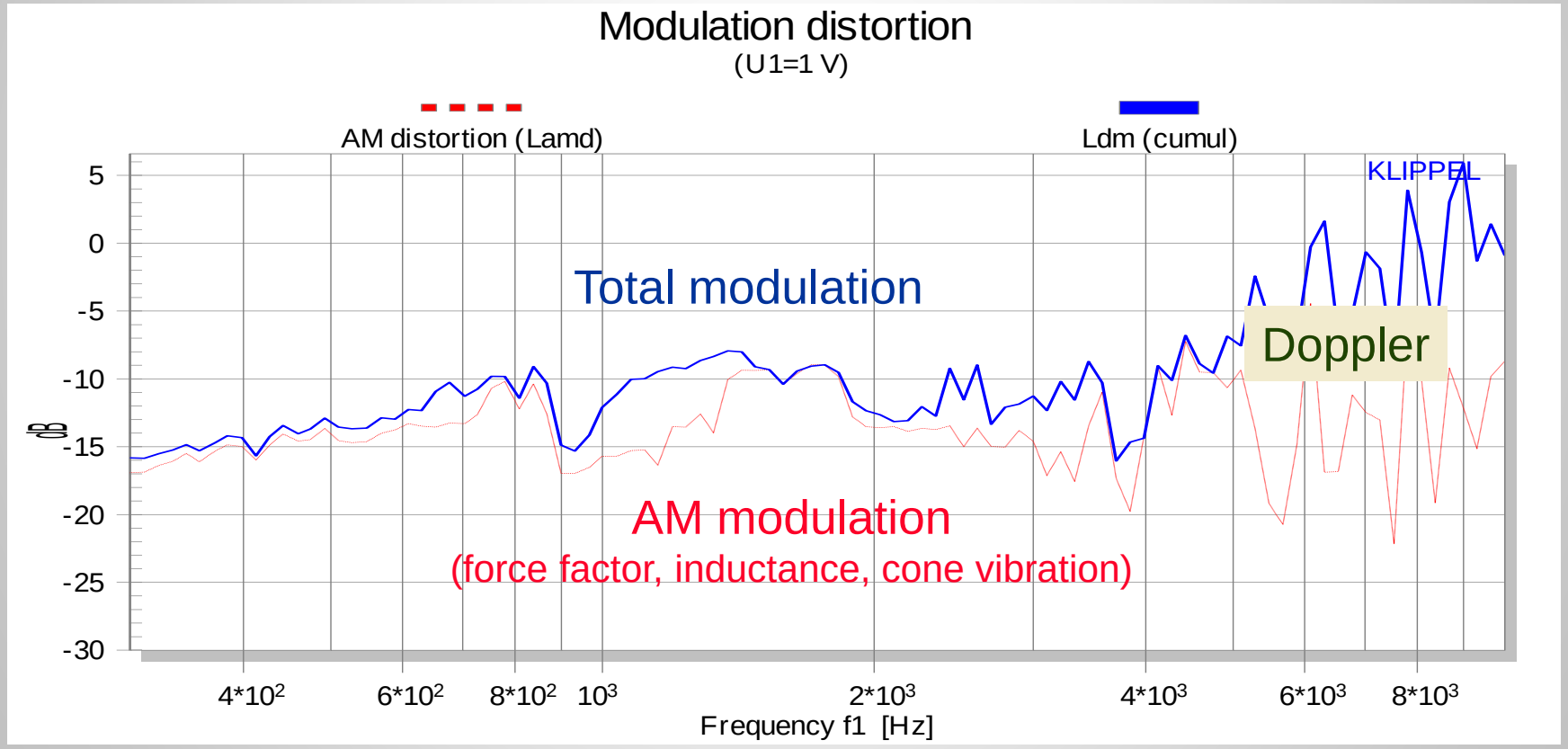
$$d_{AMD} = \frac{\sqrt{\frac{2}{K}\sum_{k=1}^{K}\left(E[k] - \overline{E}\right)^2}}{\overline{E}} * 100\% \qquad L_{AMD} = 20\lg\left(\frac{d_{AMD}}{100}\right)$$

$$\overline{E} = \frac{1}{K}\sum_{k=1}^{K} E[k]$$

Interpretation of the Envelope



調幅的貢獻
Contribution of Amplitude Modulation
to the total intermodulation distortion

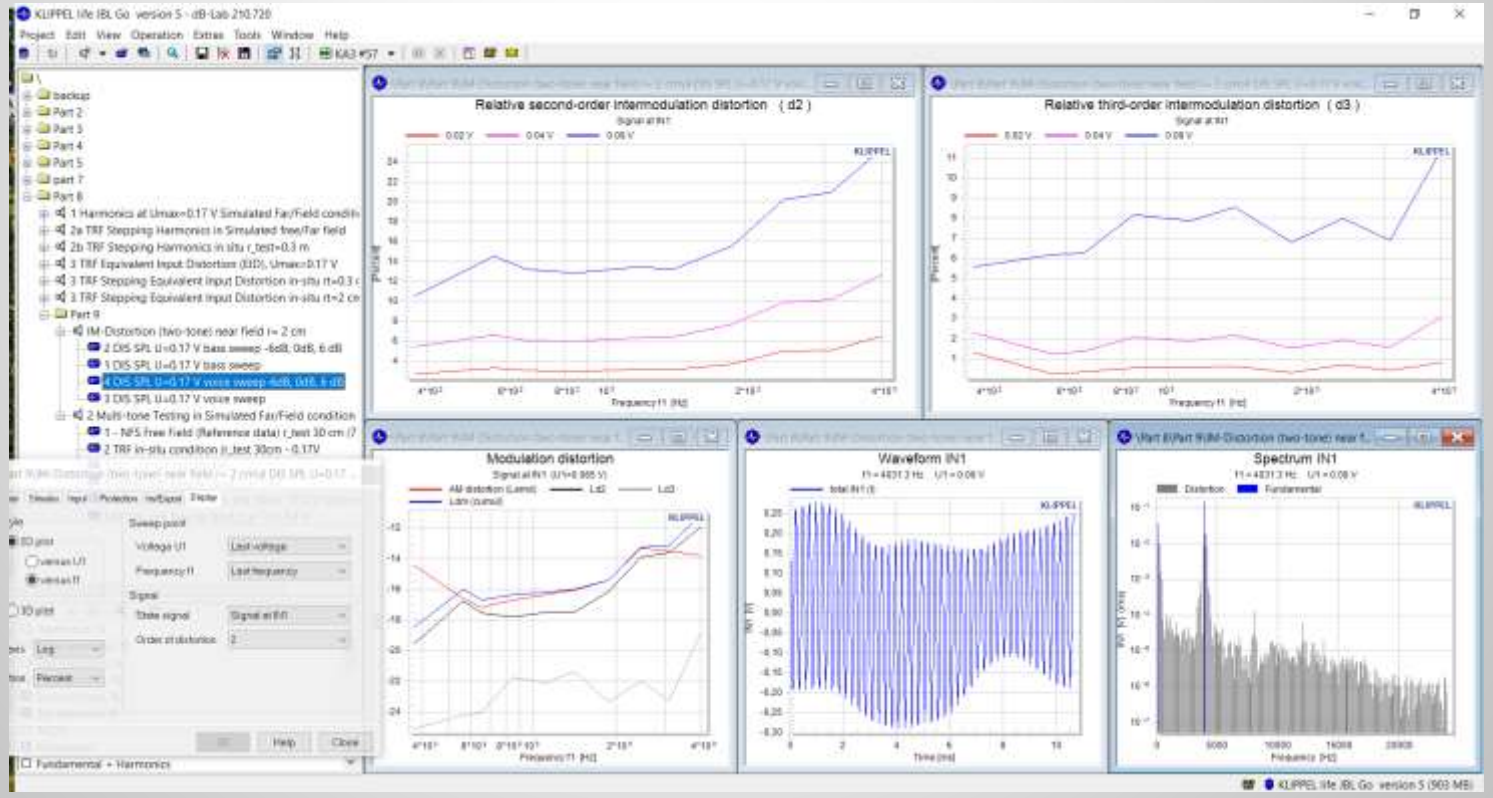


示範 Demo: Amplitude Modulation

2 tone stimulus with voice sweep

Tools of the KLIPPEL Analyzer:

- 3D Distortion Measurement (DIS)



互調測量
Intermodulation Measurement

using a Two-Tone Stimulus

優點 Advantages:

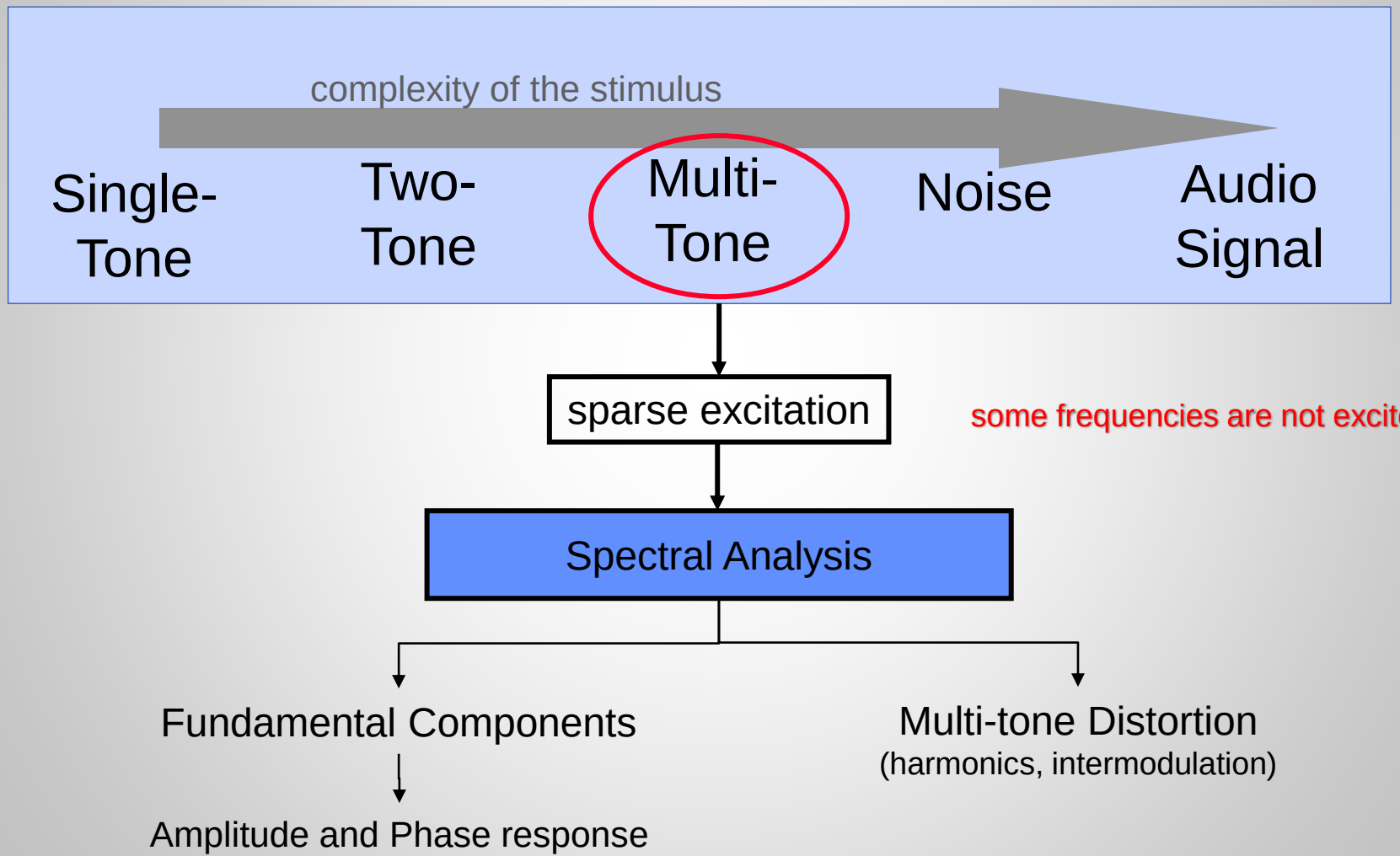
- 簡單生成（使用兩個正弦產生器）Simple generation (by using two sinusoidal generators)
- 噪聲和失真的分離Separation of noise and distortion
- 易於解釋 Easy to interpret
- 適用於研發中的揚聲器診斷 Good for loudspeaker diagnostics in R&D
- 靈敏的激發也適用於聽力測試 Sensitive stimulus also for listening tests

缺點 Disadvantages:

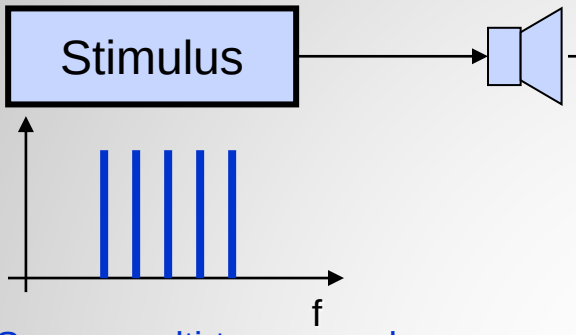
- 必須仔細設置激發音的頻率

Frequency of excitation tones have to be set carefully

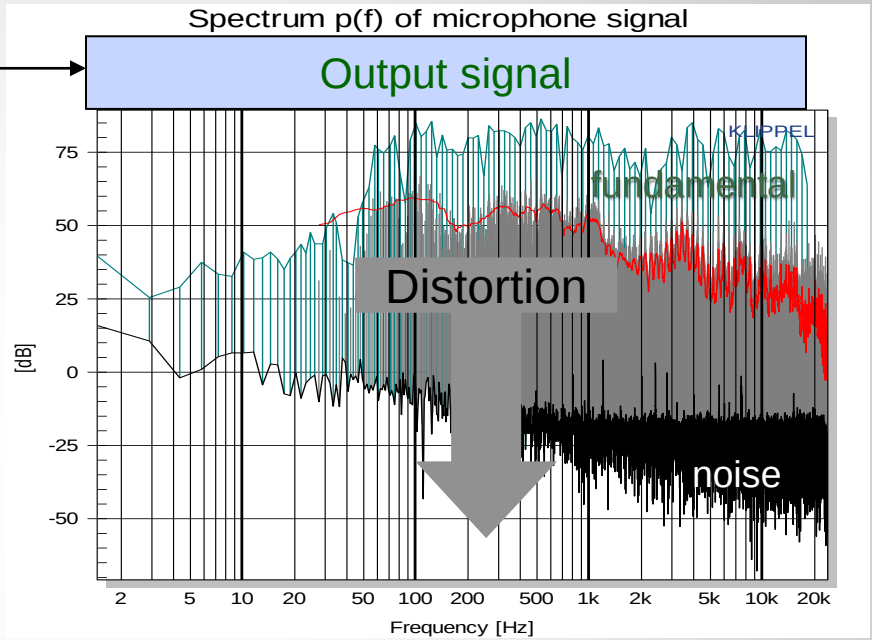
通用的激發
Universal Stimulus
complex, steady-state, like an organ tone



多音失真 (MTD)
Multi-Tone Distortion (MTD)



Sparse multi-tone complex



- Can represents the (typical) audio signal
- Activates all loudspeaker nonlinearities
- Allows fast testing (good for EoL)
- Can be used for long term testing (thermal, endurance, climate, reliability)

- harmonic components
- difference-tone intermodulation
- summed tone intermoduluation

- Consideres all nonlinear distortions
- Can be easily separted from noise
- Simplifies root cause analysis
- Good basis for perceptual interpretation

投票 Poll:

您是否評估多音刺激產生的失真？

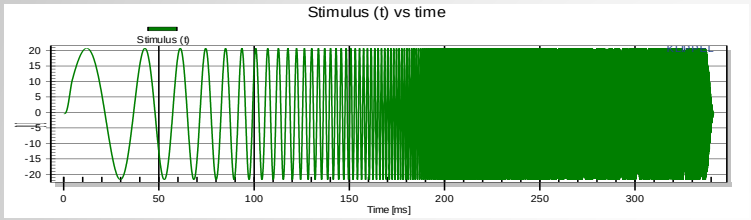
Do you evaluate the distortion generated by a multi-tone stimulus ?

A. 是的 Yes

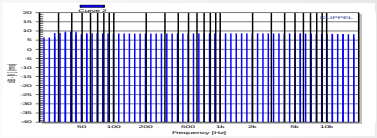
B. 不 No

激發音的相位很重要
Phase of the Excitation Tones is important !!

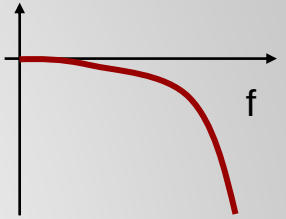
Time signal (logarithmic sweep)



Amplitude spectrum



Phase spectrum

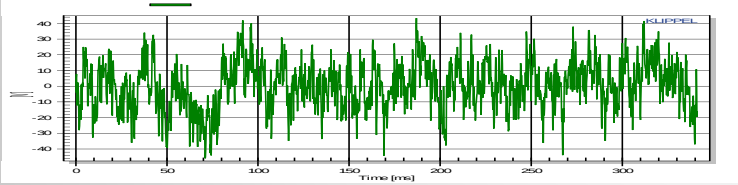


At one time there is only one frequency component !!!

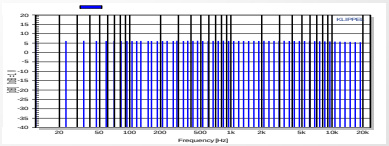
→

Harmonics only

Time Signal (Multi-tone complex)



Amplitude spectrum



Phase spectrum

At any time there are multiple frequency components interacting !!!

→

Intermodulation + Harmonics

多音刺激的定義屬性
Defined Properties of Multi-tone Stimulus
according IEC 60268-21

客觀條件 Objective:

- 確保不同儀器測量結果的可比性 ensure comparability of the results measured by different instruments
- 確保不同儀器測量結果的可比性 easy to generate (by software implementation)
- 應該可以修改刺激（帶寬，分辨率 R） Modification of the stimulus should be possible (bandwidth , resolution R)

Amplitude spectrum

$$x(t) = \sum_{i=1}^{N} U(f_i)\cos(2\pi f_i t + \varphi_i)$$

Frequencies of the sparse line spectrum logarithmically spaced

$$f_i = \frac{1}{T}\mathrm{int}\left(T \cdot f_{start} \cdot 2^{i/R}\right) \quad with\ i = 1,\ldots,N$$

resolution

Duration (periodicity)

Starting frequency

Max. Number of frequencies

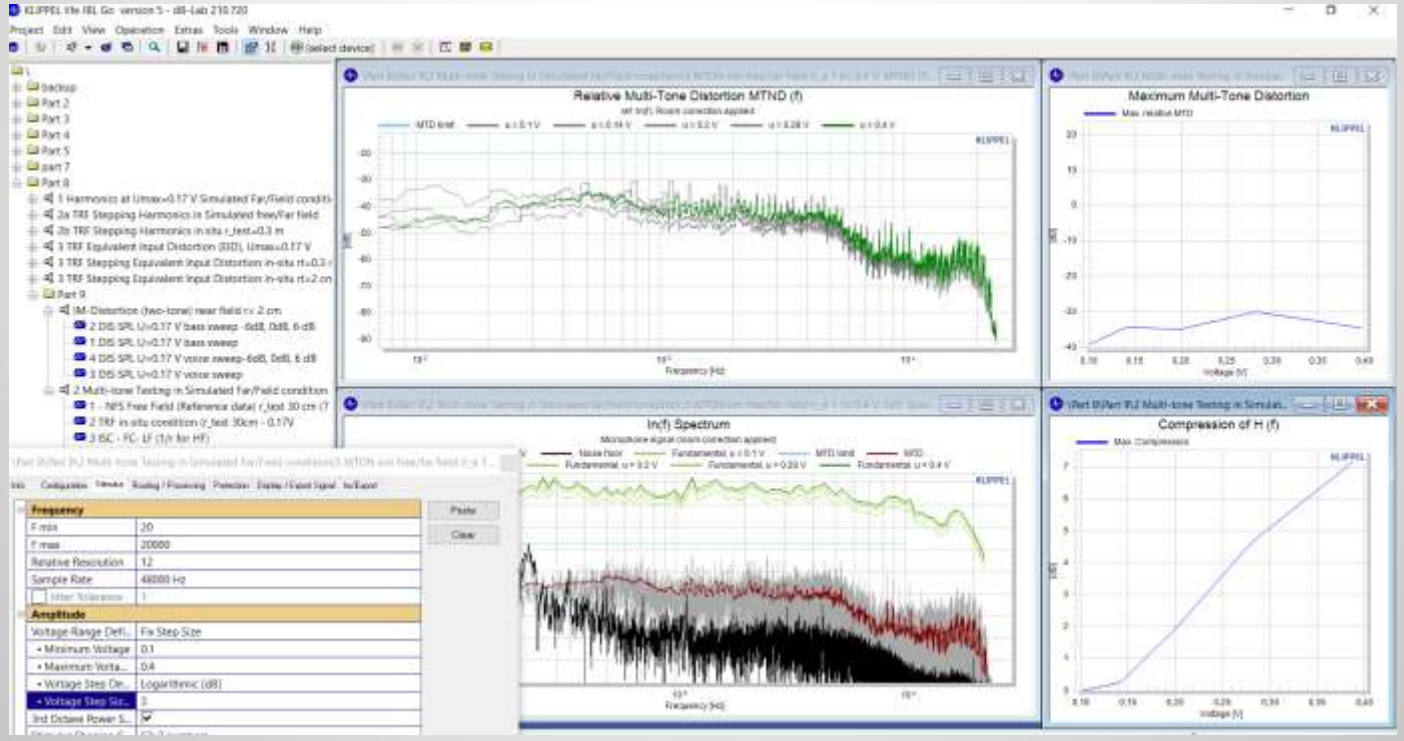
Pseudo-random phase

$$\varphi_{i+1} = \frac{2\pi}{m}\left[\left(\frac{a\varphi_i * m}{2\pi}\right)\mathrm{mod}_m\right]$$

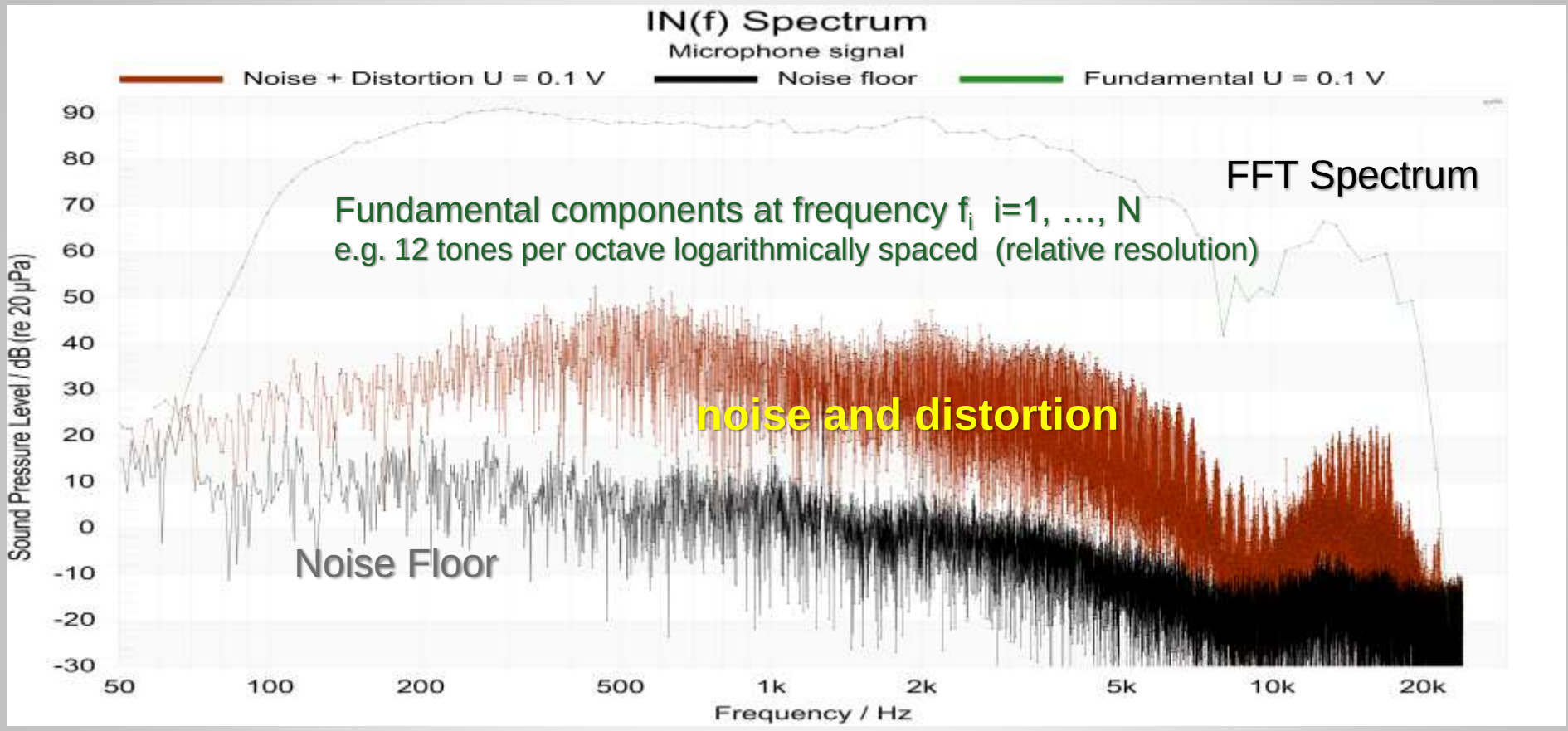
Seeds (a=48271, m=2^{31}-1 and φ_1=1)

示範 Demo 1a: Generation of a Multi-tone Stimulus

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer



Sound Pressure Spectrum

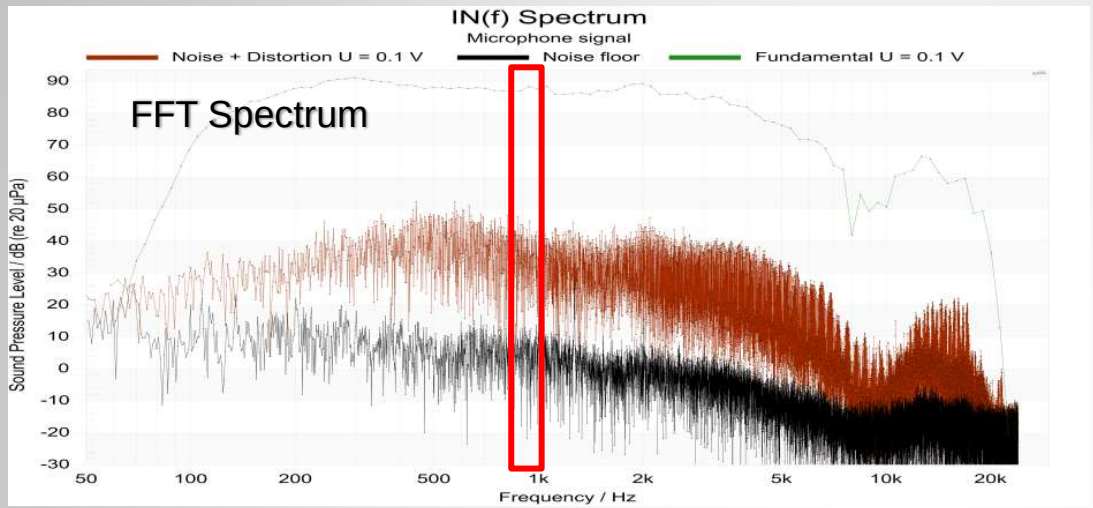


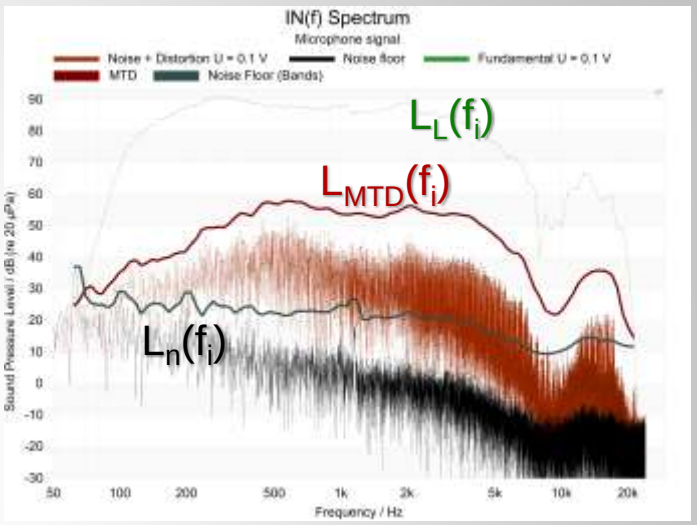
Separation of the distortion and noise from fundamentals

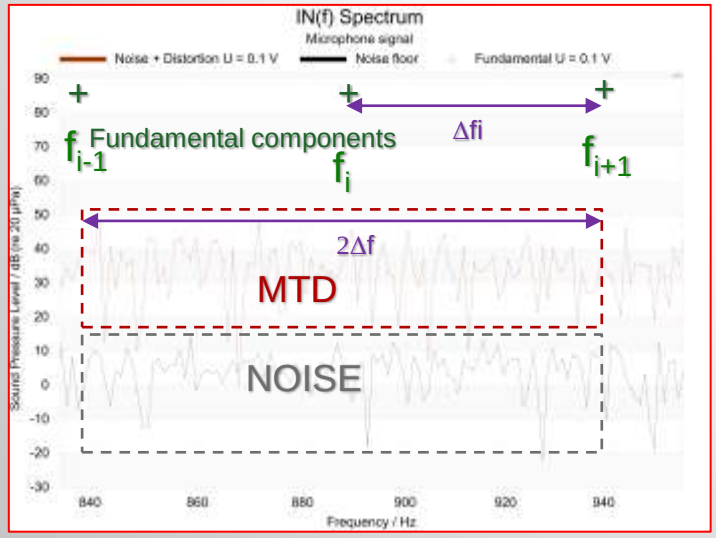
$$\underline{P}_{MD}(f, \mathbf{r}_{near}) = \begin{Bmatrix} 0 & for\ f = f_i \\ \underline{P}(f, \mathbf{r}_{near}) & for\ f \neq f_i \end{Bmatrix} \quad i = 1, \ldots, N$$

Noise floor has been measured without excitation of the loudspeaker

Integrated MTD Spectrum





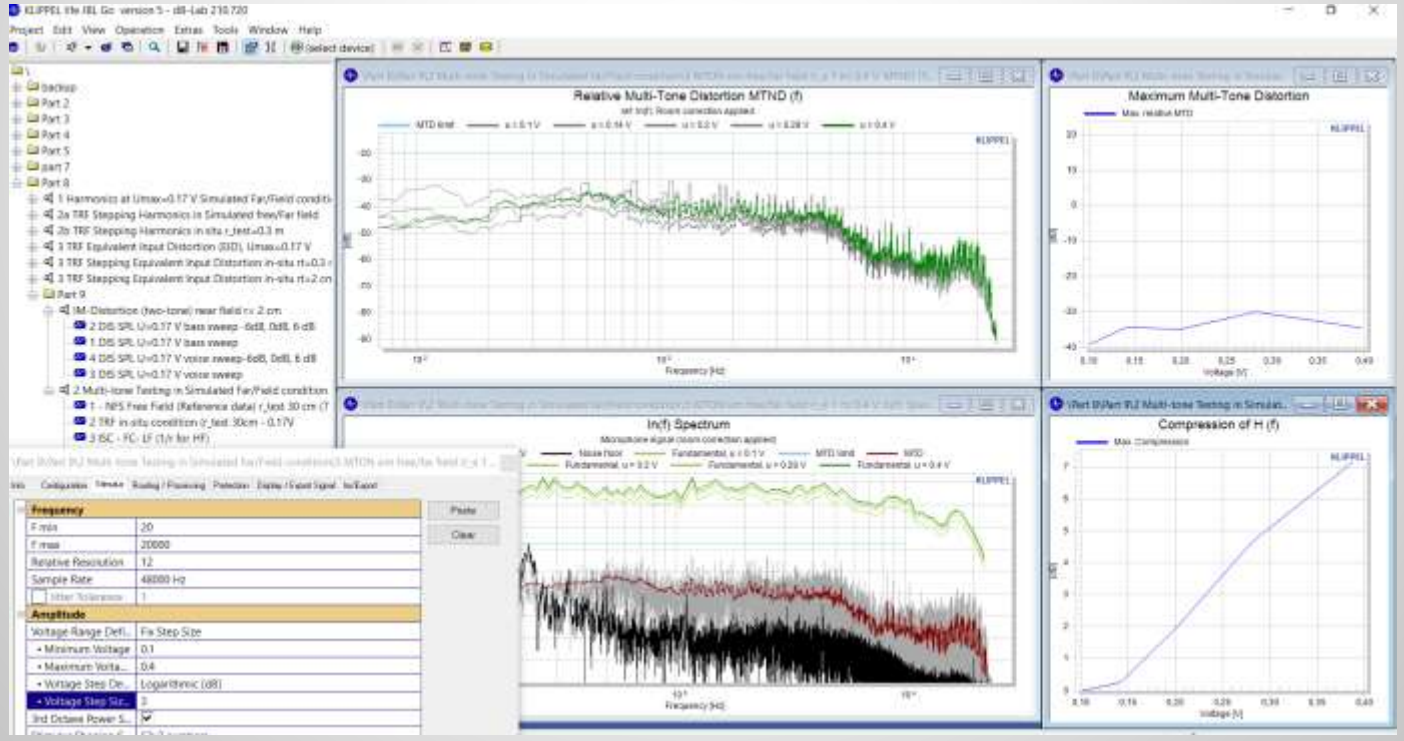


INTEGRATION and SPL calculation

$$L_{\mathrm{MTD}}(f_i) = 10\lg\left(\frac{\int_{f_{i-1}}^{f_{i+1}} \left|P_{MD}(f,\mathbf{r}_{\mathrm{near}})\right|^2 df}{2p_0^2}\right)\mathrm{dB} \qquad i = 2,\ldots,N-1$$

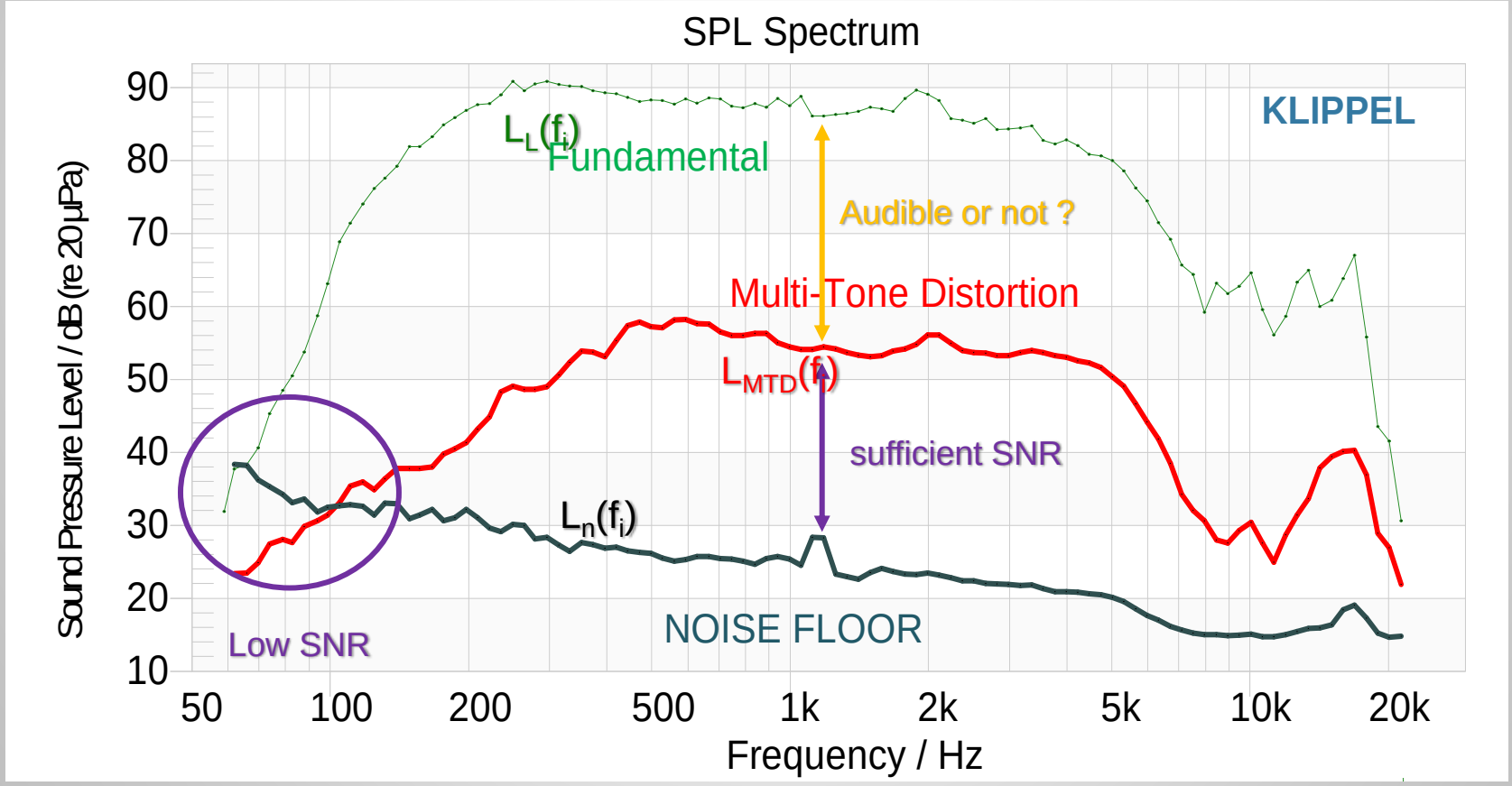
示範 Demo 1b: SPL Distortion Spectrum

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer

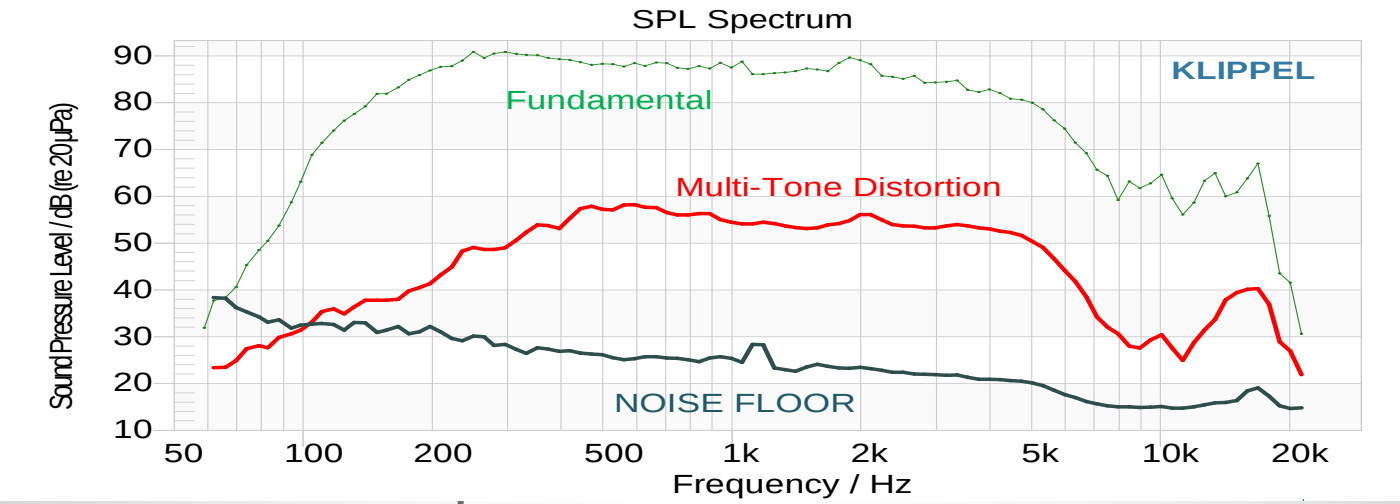


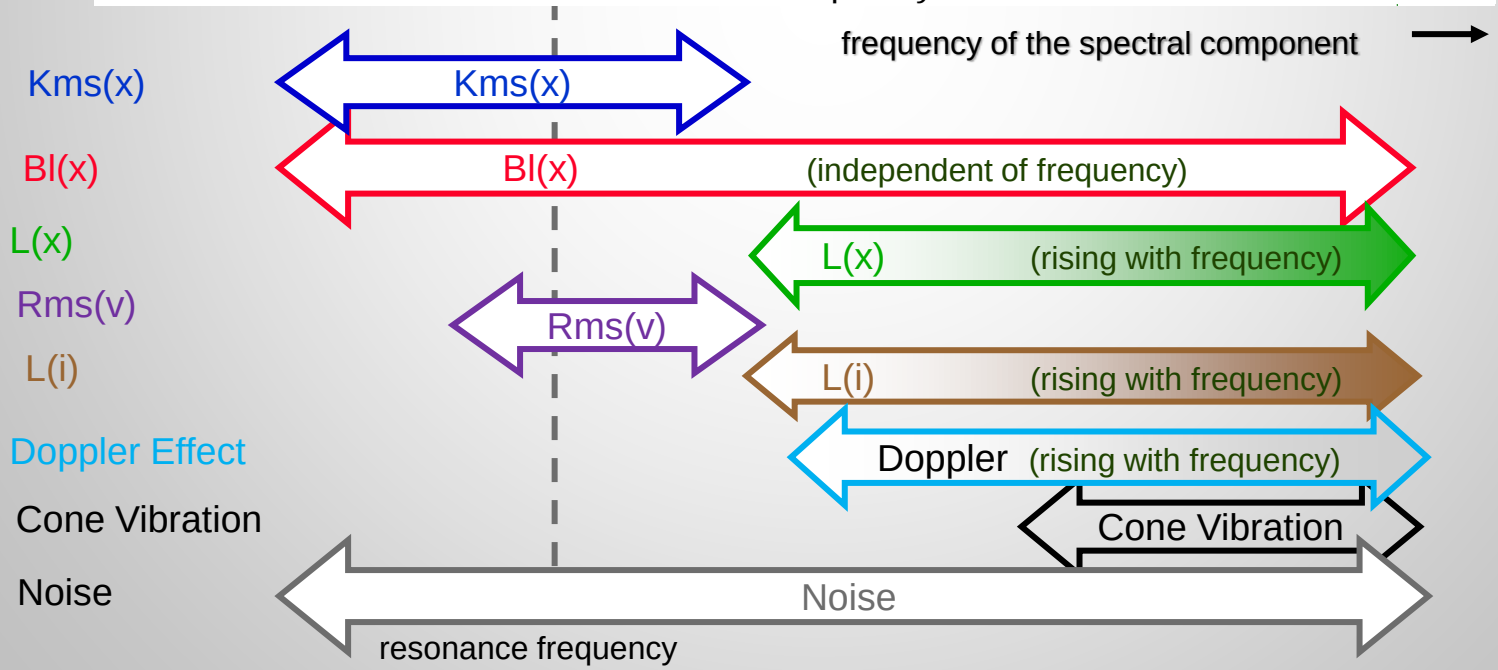
Comparable SPL Spectra

SPL of fundamental, MTD and noise are measured in the same frequency bands with a relative resolution depending on the stimulus !



多音失真的原因
The Causes of Multi-Tone Distortion
MTD SPL spectrum (absolute presentation)

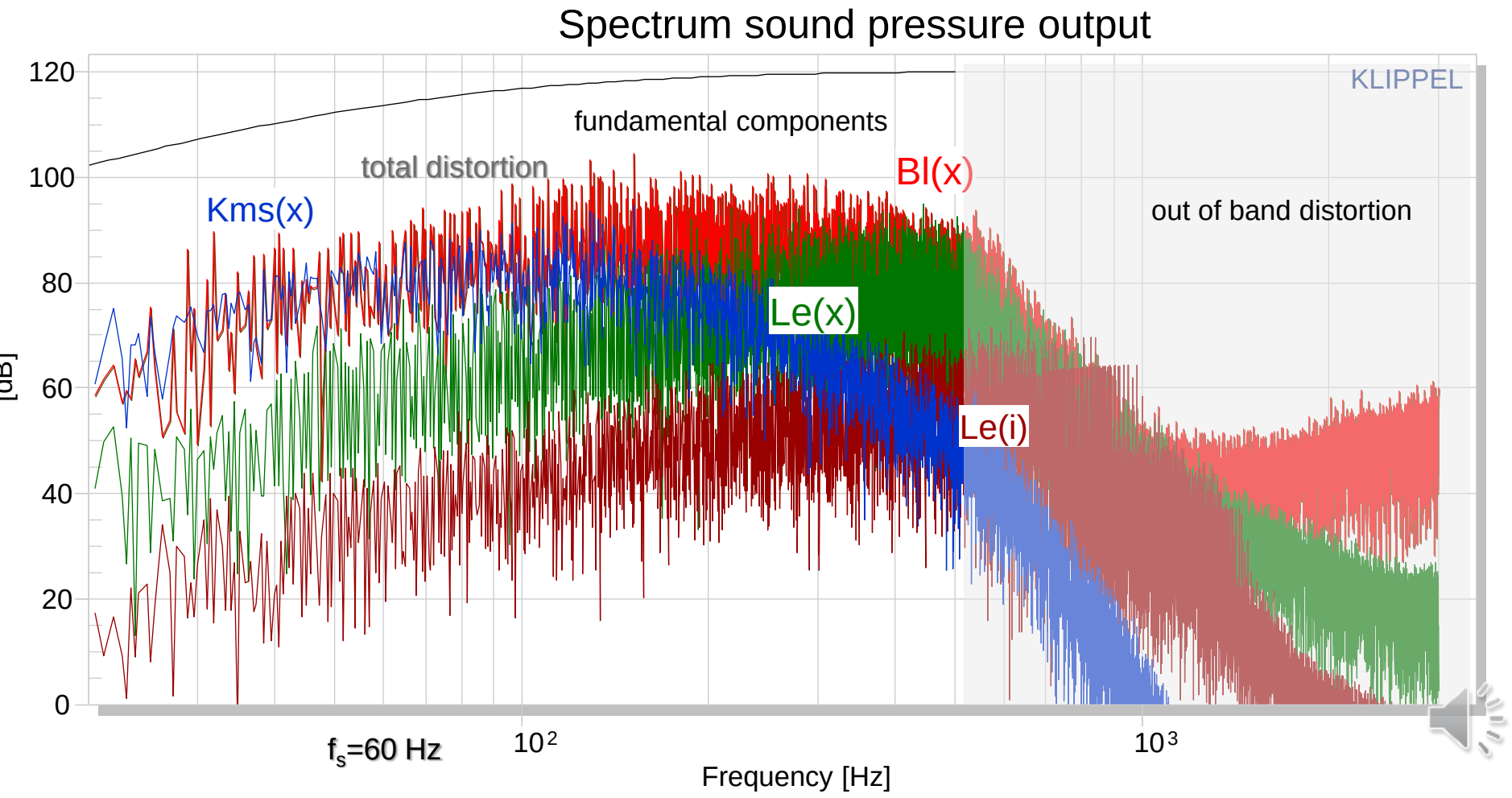




練習 Exercise: 低音單體 Woofer

Analysis of Multi-tone Distortion

causes: Le(x) Kms(x) Bl(x) Rms(v) Le(i) Doppler Effect Cone Vibration

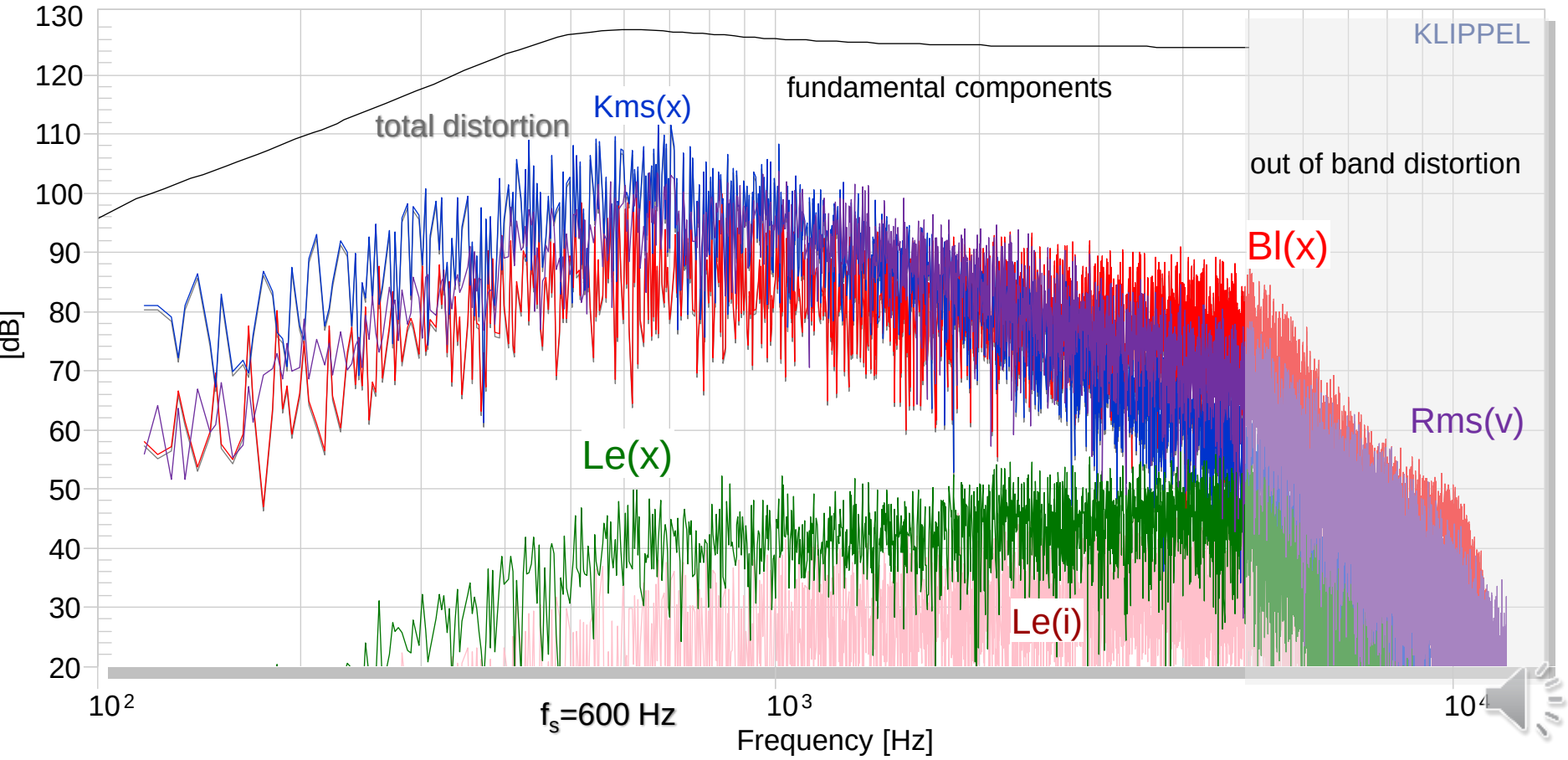


練習Exercise: 微型單體 Microspeaker

Analysis of Multi-tone Distortion

causes: Le(x) Kms(x) Bl(x) Rms(v) Le(i) Doppler Effect Cone Vibration

Distortion Components

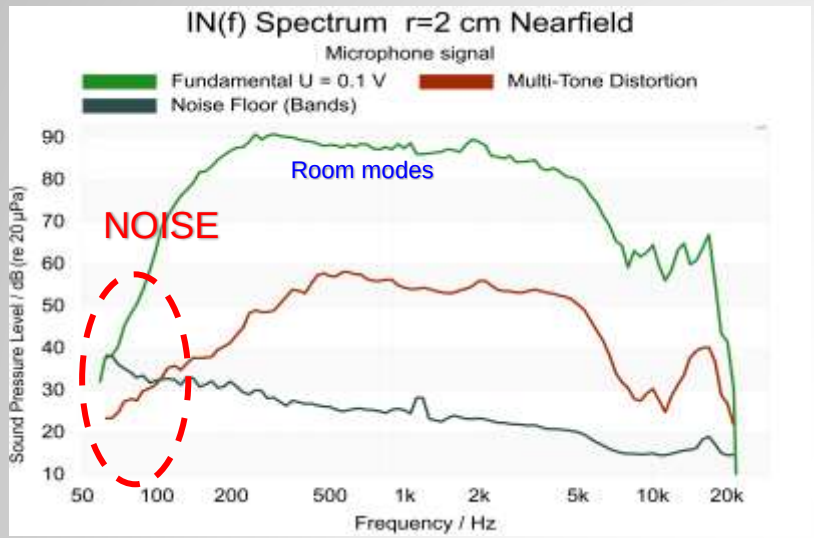


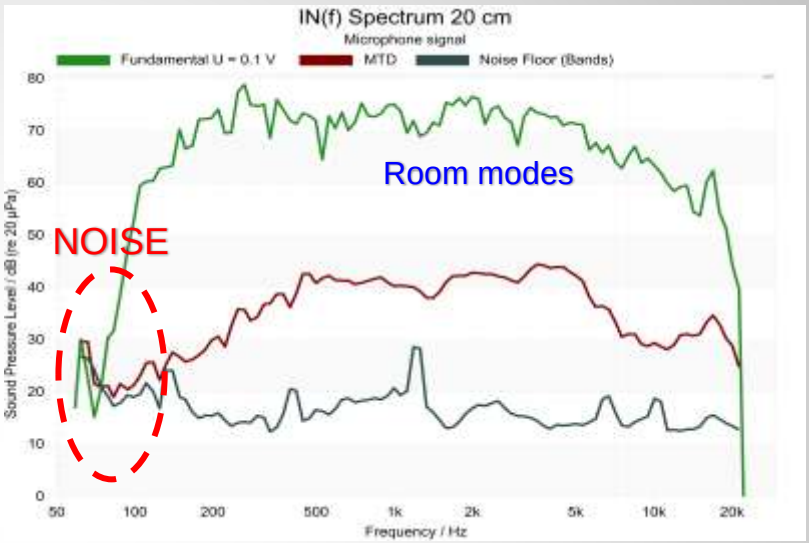
示範 Demo 2: Room Influence

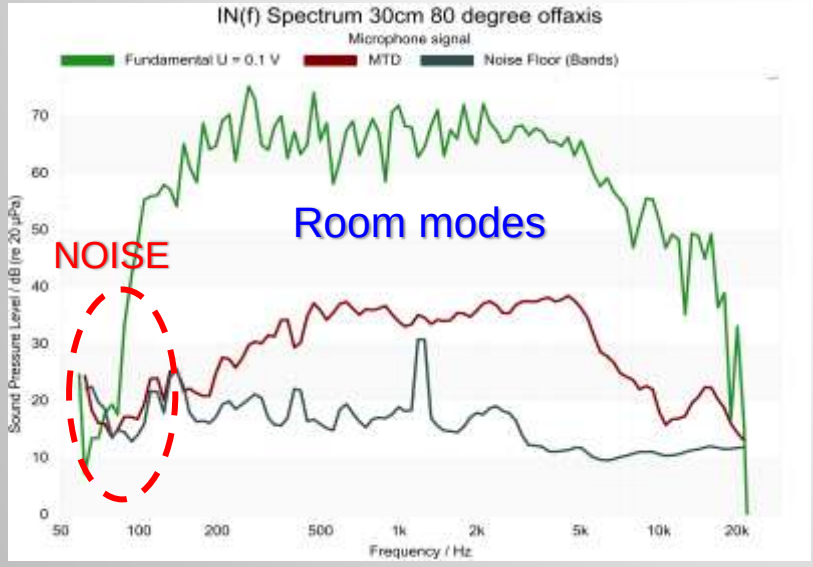
Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer

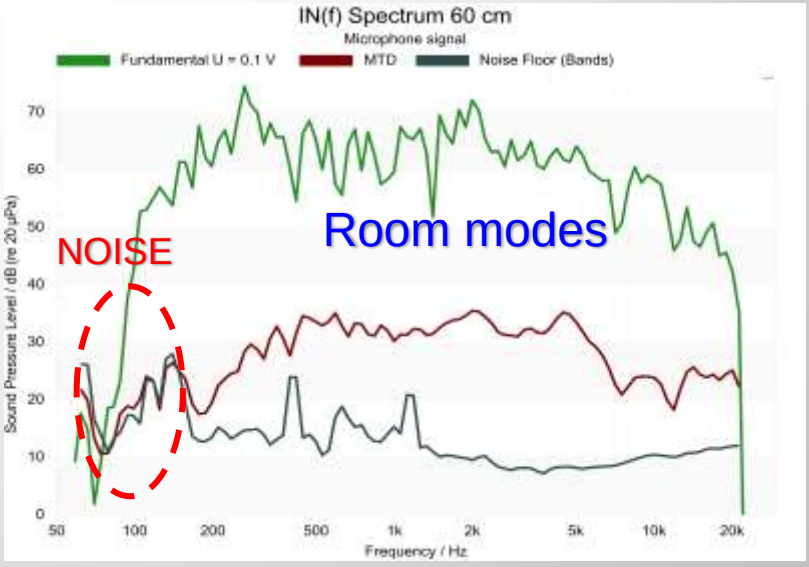
Room Influence

MDS SPL Spectrum (absolute)



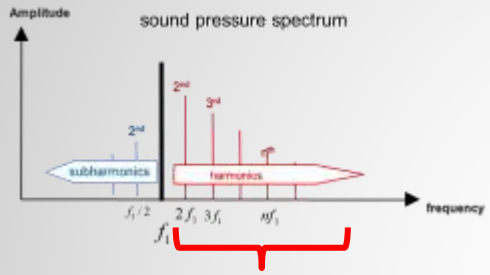


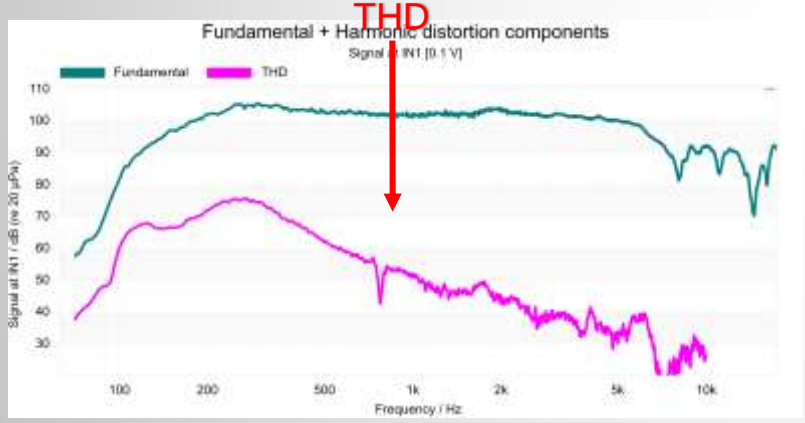




THD contra MTD (absolute SPL)

Total Harmonic Distortion

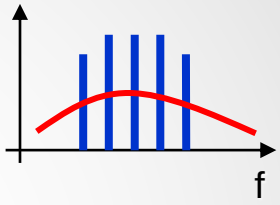




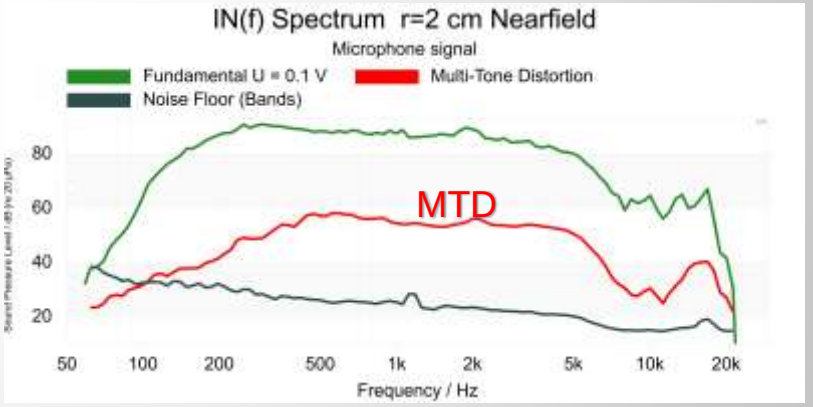
excitation frequency f_i →

Multi-tone Distortion

Sound pressure spectrum



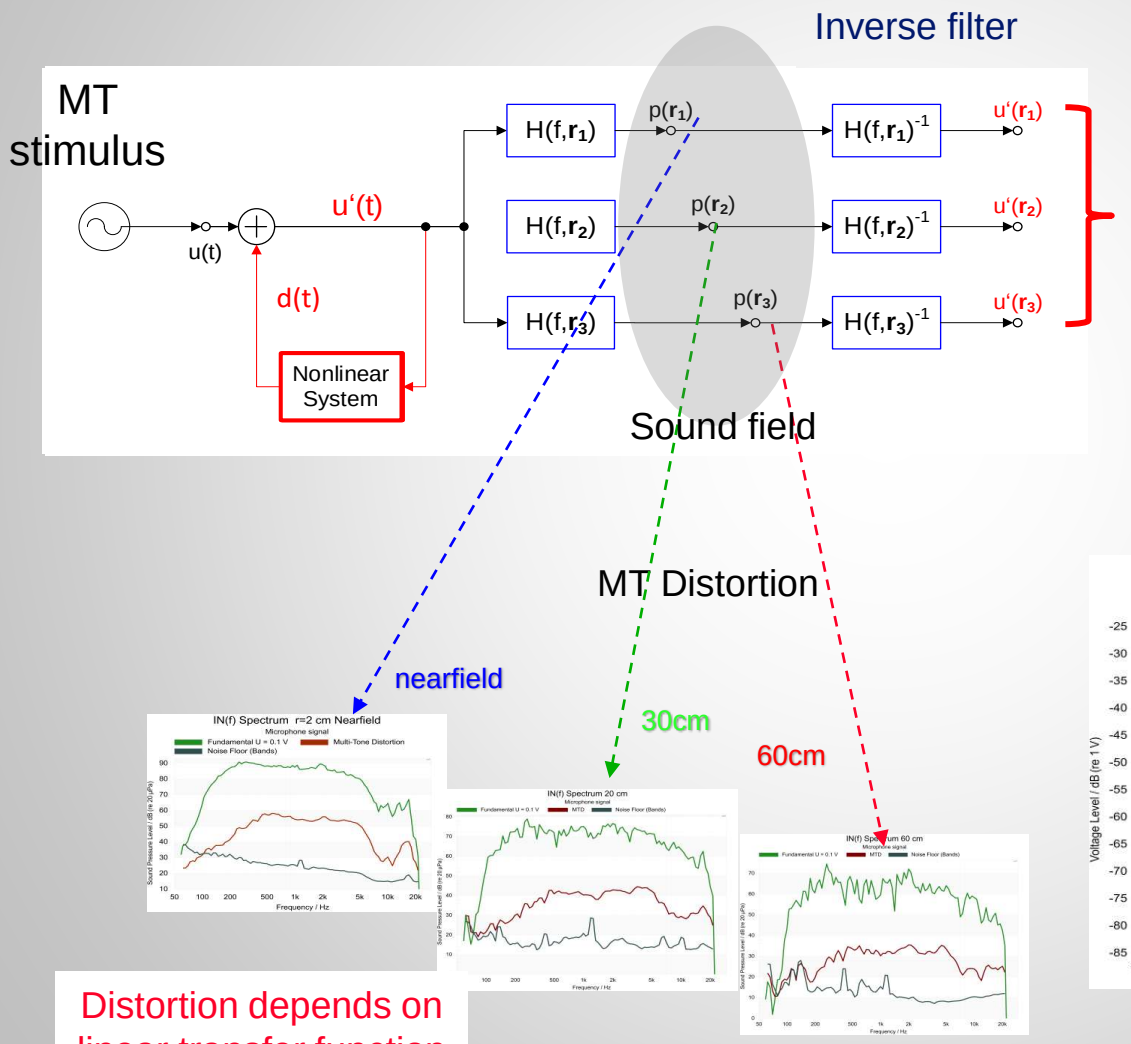
Sparse multi-tone complex



spectral frequency f →

Which measurement is more meaningful ?

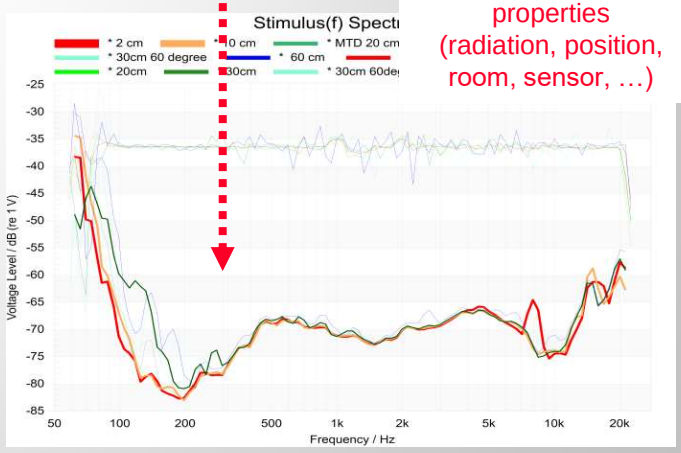
Equivalent MT Input Distortion
Determine the distortion at the source



Distorted input signal

$u'(\mathbf{r}_1) \approx u'(\mathbf{r}_2) \approx u'(\mathbf{r}_3) \approx u'(t)$

Equivalent MT input distortion

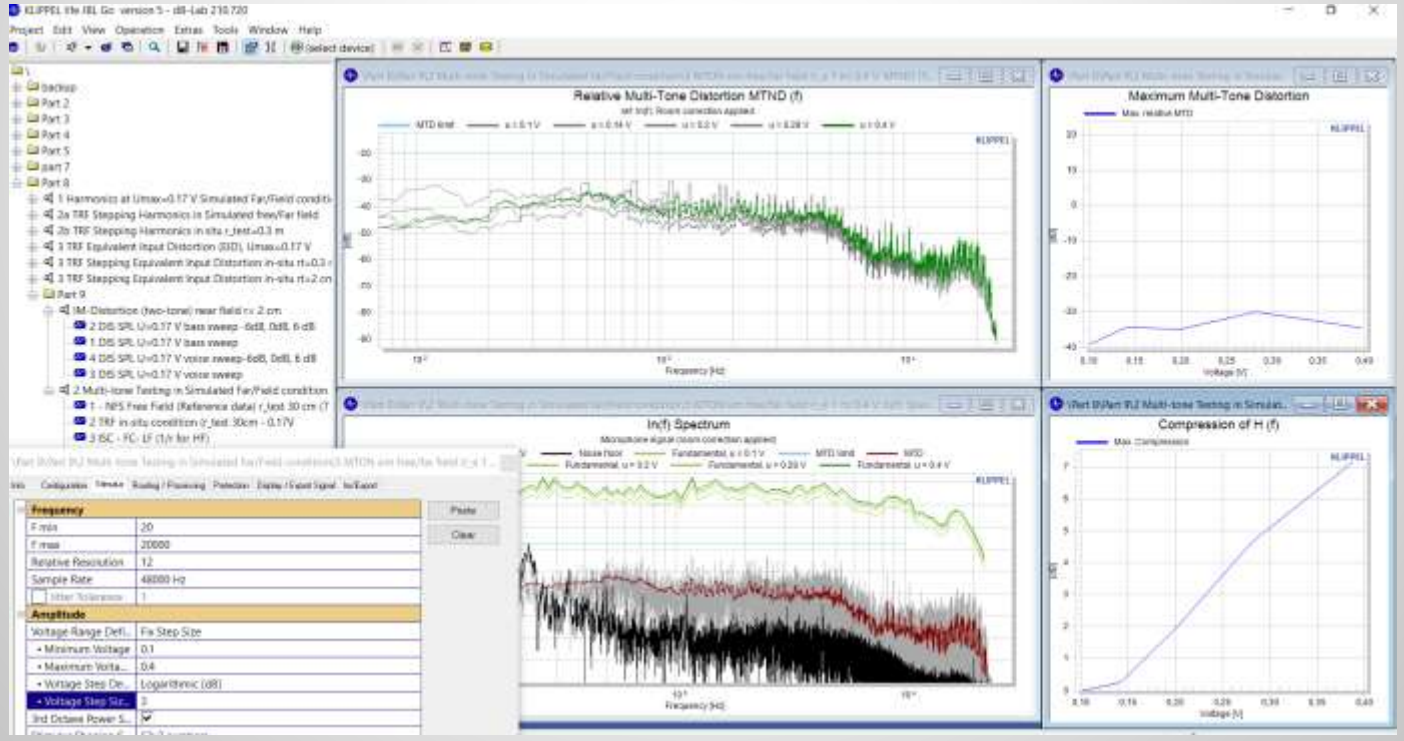


Independent of linear properties (radiation, position, room, sensor, …)

Distortion depends on linear transfer function

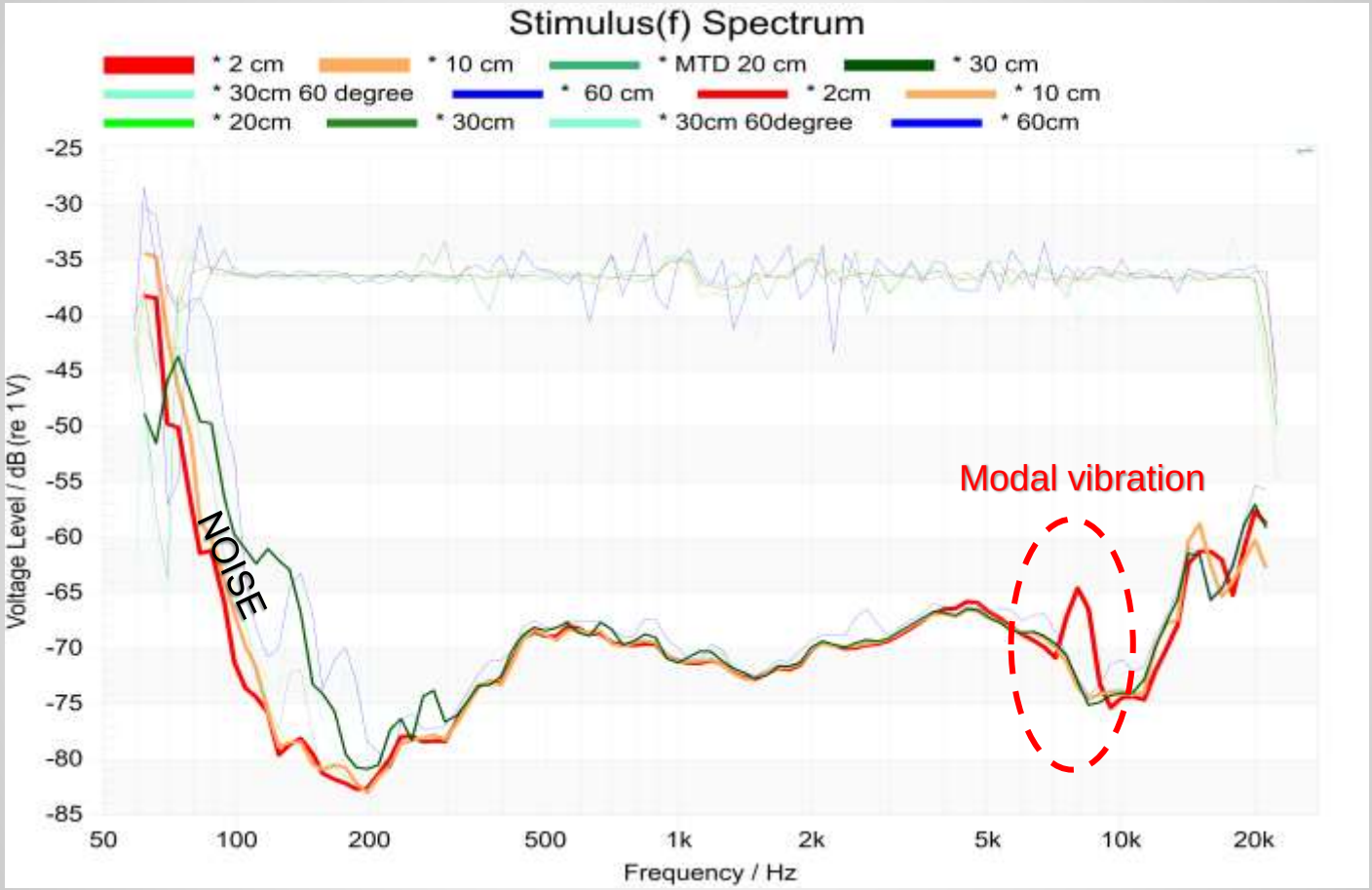
示範 Demo 3: Equivalent input MTD

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer



Equivalent Input Distortion

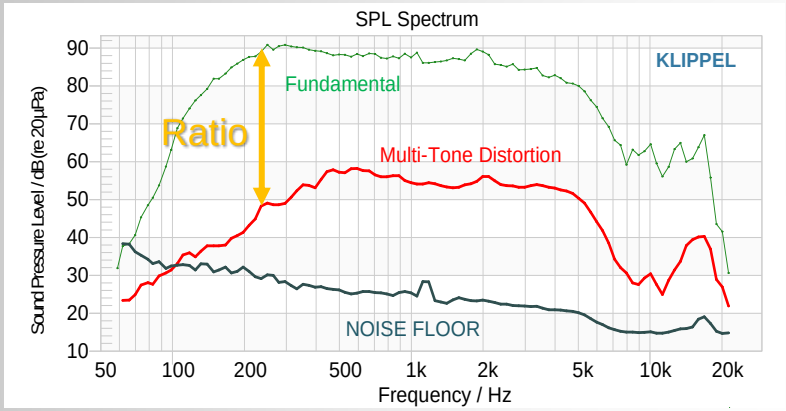
absolute voltage signal



Equivalent input MTD are almost independent of the microphone position

Relative Metrics of MTD

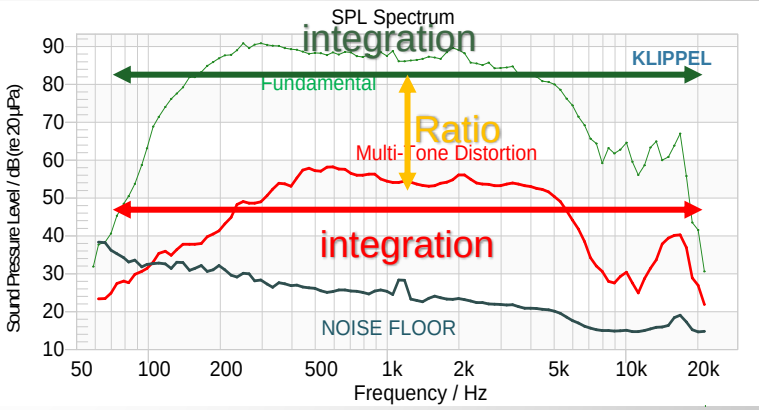
Spectral Multi-Tone Distortion Ratio



$$R_{\mathrm{SMTD}}(f_i) = 10\lg\left(\frac{\int_{f_{i-1}}^{f_{i+1}} |P_{MD}(f, \mathbf{r}_{\mathrm{near}})|^2 df}{2|P(f_i, \mathbf{r}_{\mathrm{near}})|^2}\right)\mathrm{dB} \qquad i = 2,\ldots,N-1$$

Interpretation: Distance between fundamental $L_{fun}(f_i)$ and $L_{MTD}(f_i)$

Total Multi-Tone Distortion Ratio

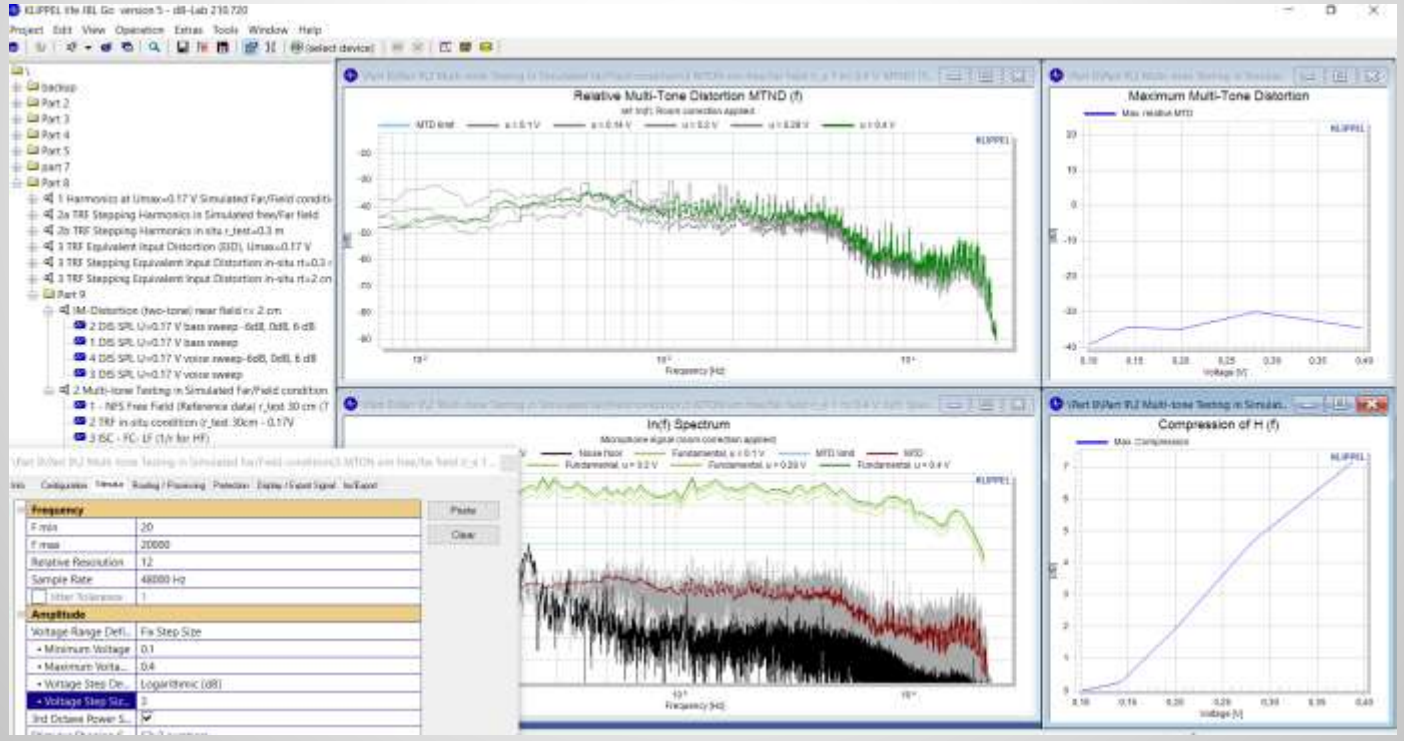


$$R_{TMTD}(\mathbf{r}_{\mathrm{near}}) = 10\log_{10}\left(\frac{\int |P_{\mathrm{MD}}(f, \mathbf{r}_{\mathrm{near}})|^2 df}{\int |P(f, \mathbf{r}_{\mathrm{near}})|^2 df}\right) dB$$

Interpretation: Energy ratio of the total distortion and total fundamental signal

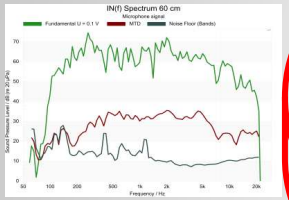
示範 Demo 1c: Relative Metrics for MTD

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer

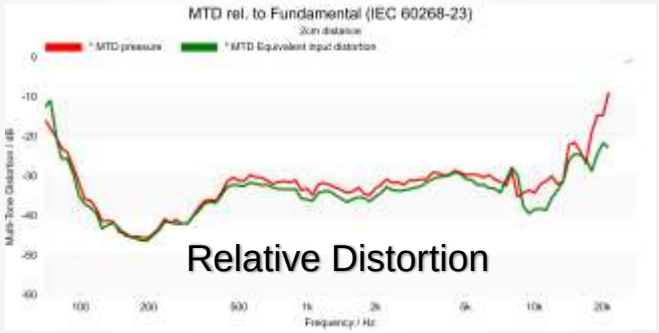


Properties of the Relative Metrics

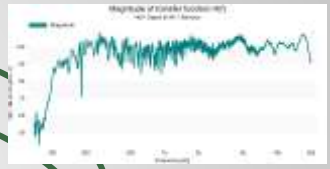
SPL MTD Distortion Spectrum



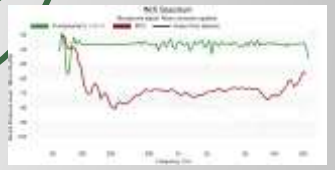
Multitone Measurement
at any point in the sound field



Inverse filtering



Equivalent input distortion



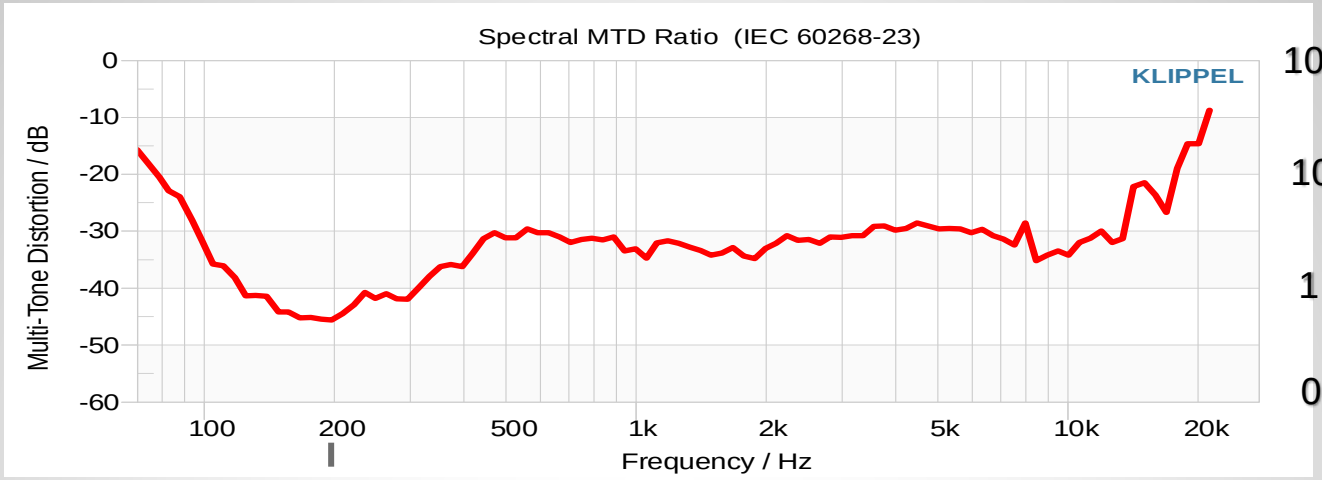
Spectral MTD Ratio in sound pressure

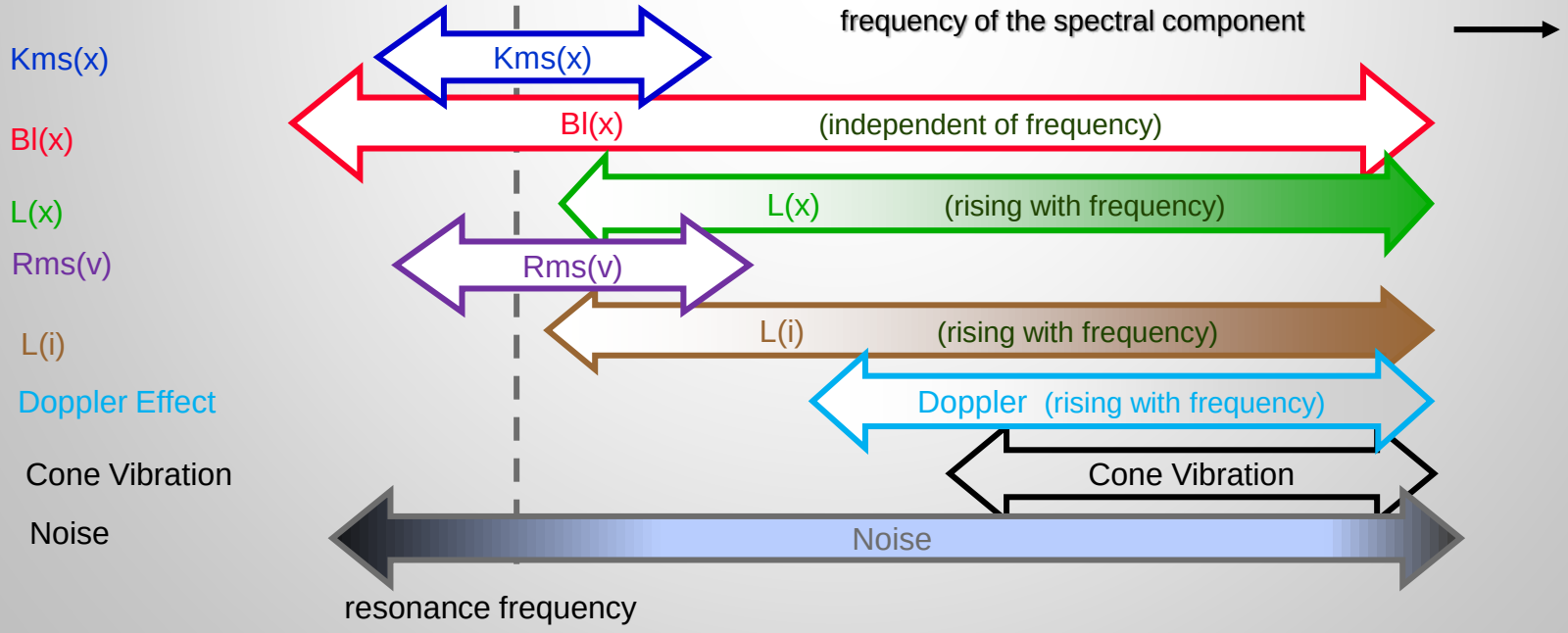
Conclusion:

- Relative equivalent input distortion and the spectral MTD ratio are identical
- One measurement in the near field is sufficient to describe the Multi-tone distortion
- Near-field measurement gives best SNR (to avoid noise problems)

The Causes of Multi-Tone Distortion

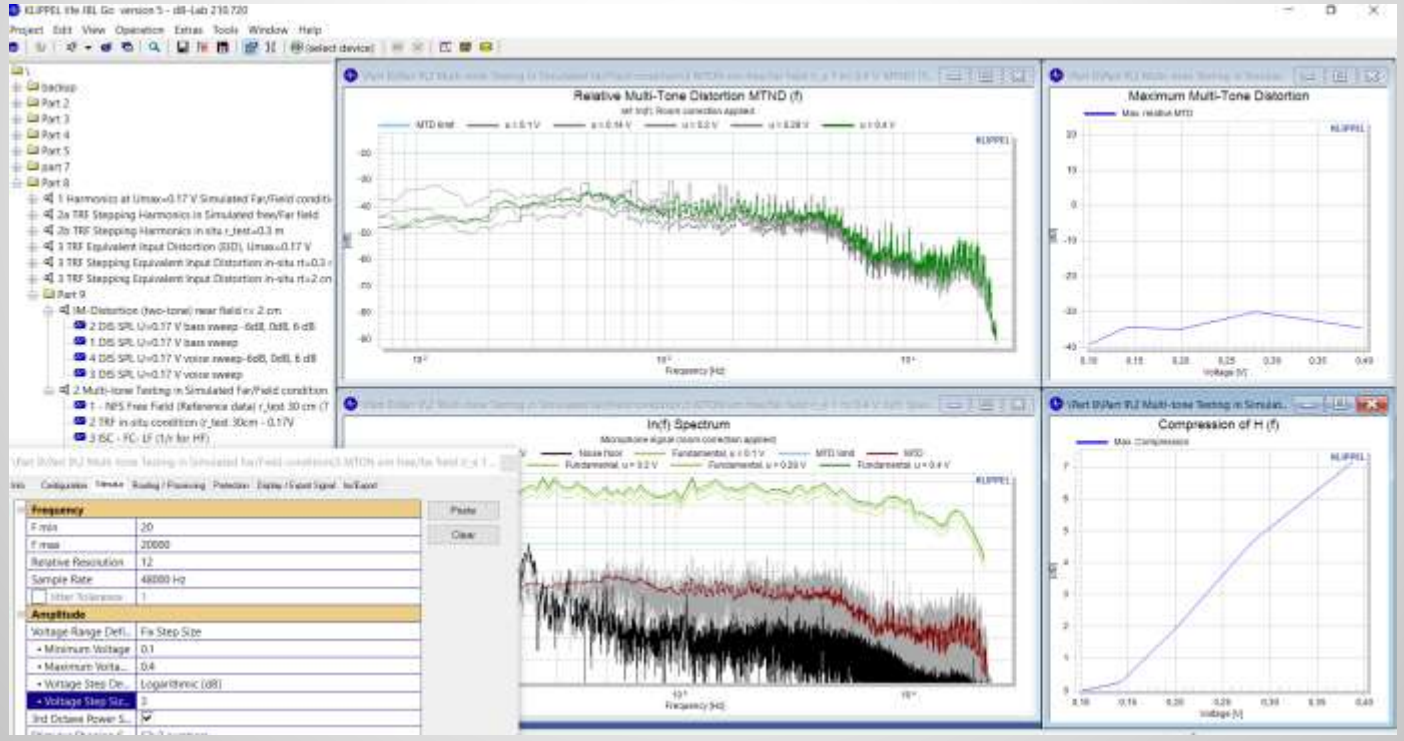
spectral MTD ratio (relative representation)





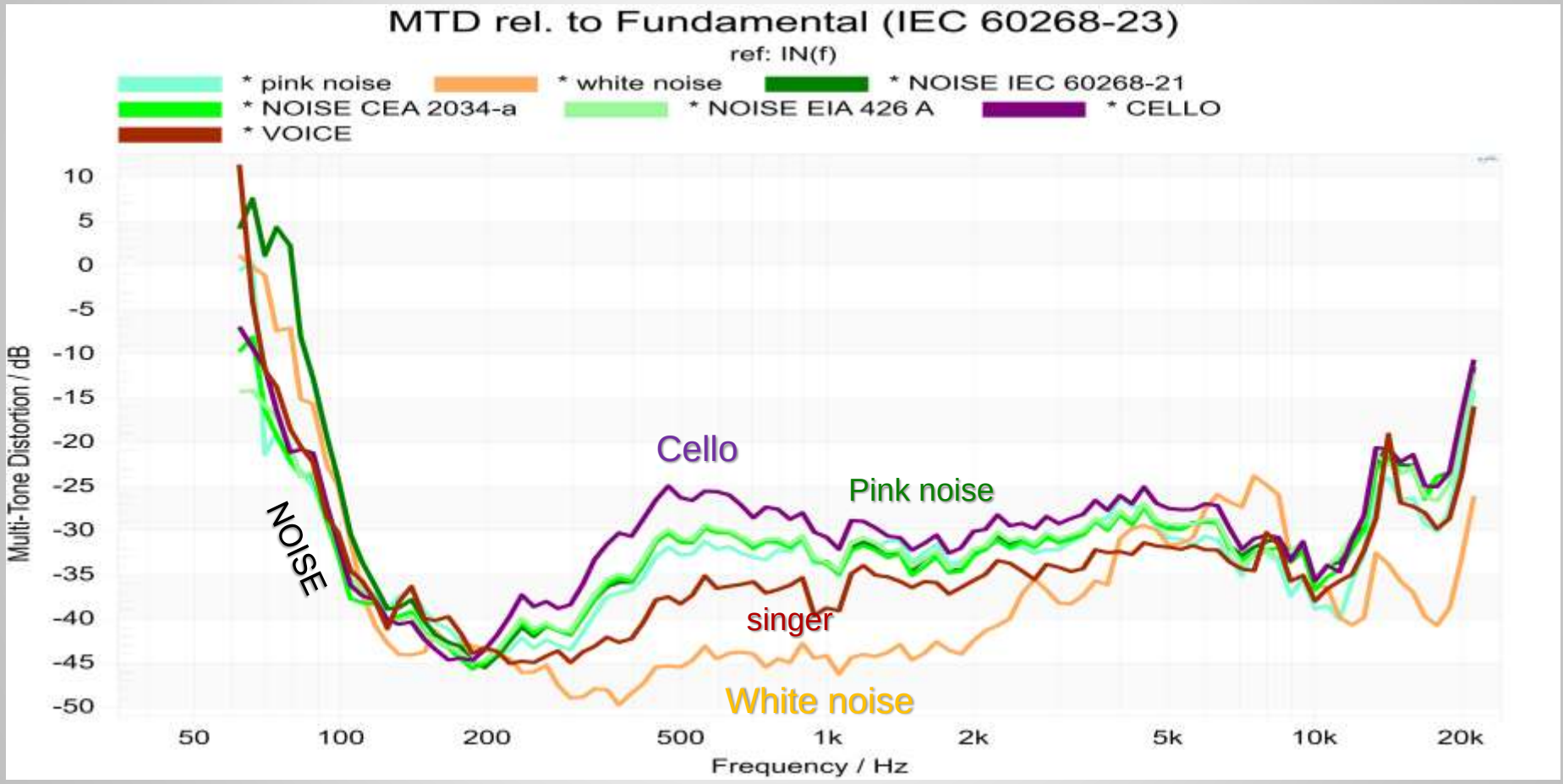
示範 Demo 4: Influence of the Stimulus Spectrum (amplitude Shaping)

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer



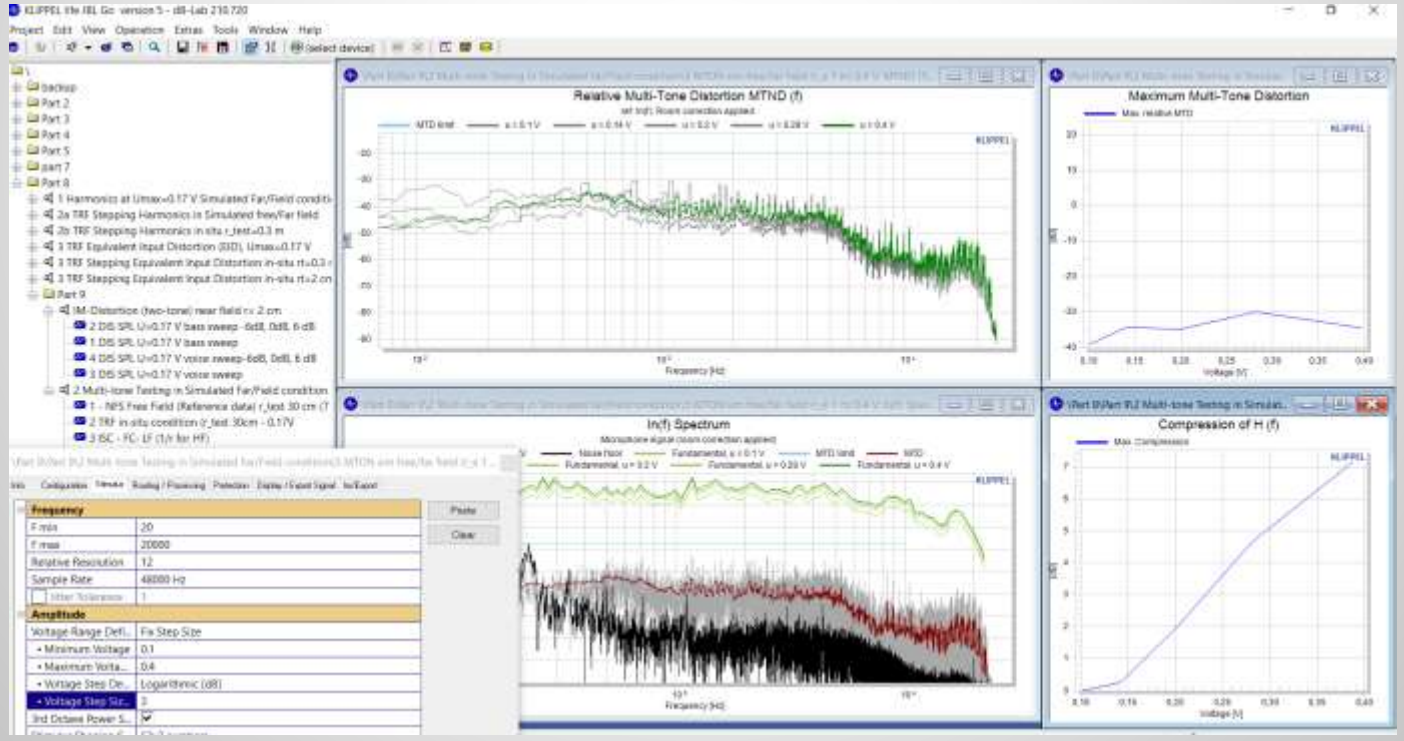
Influence of the Stimulus

(shaping amplitude spectrum)



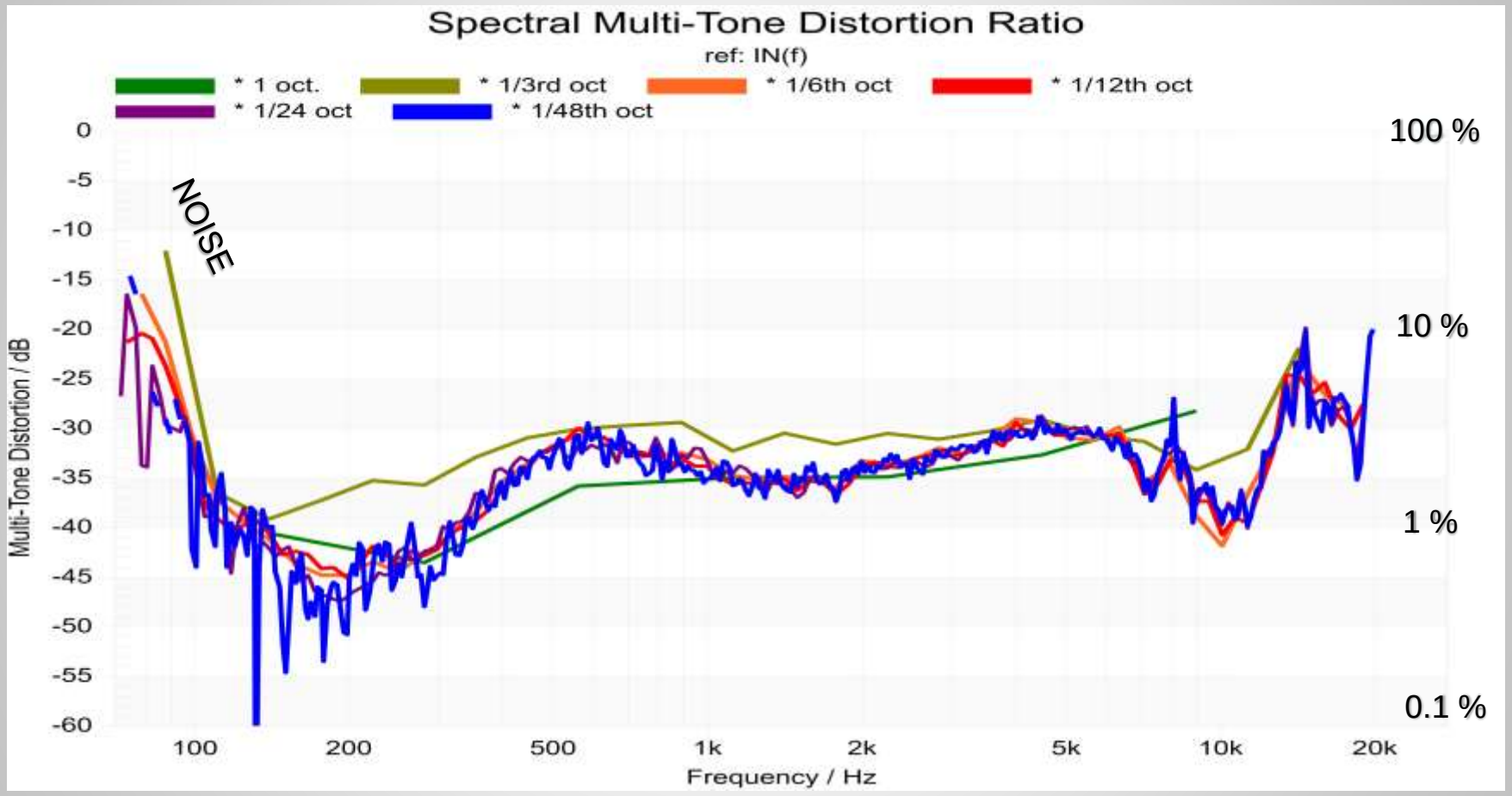
示範 Demo 5: Influence of the Stimulus Resolution (number of tones per octave)

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer



Influence of the Stimulus

(Resolution of the Multi-Tone)

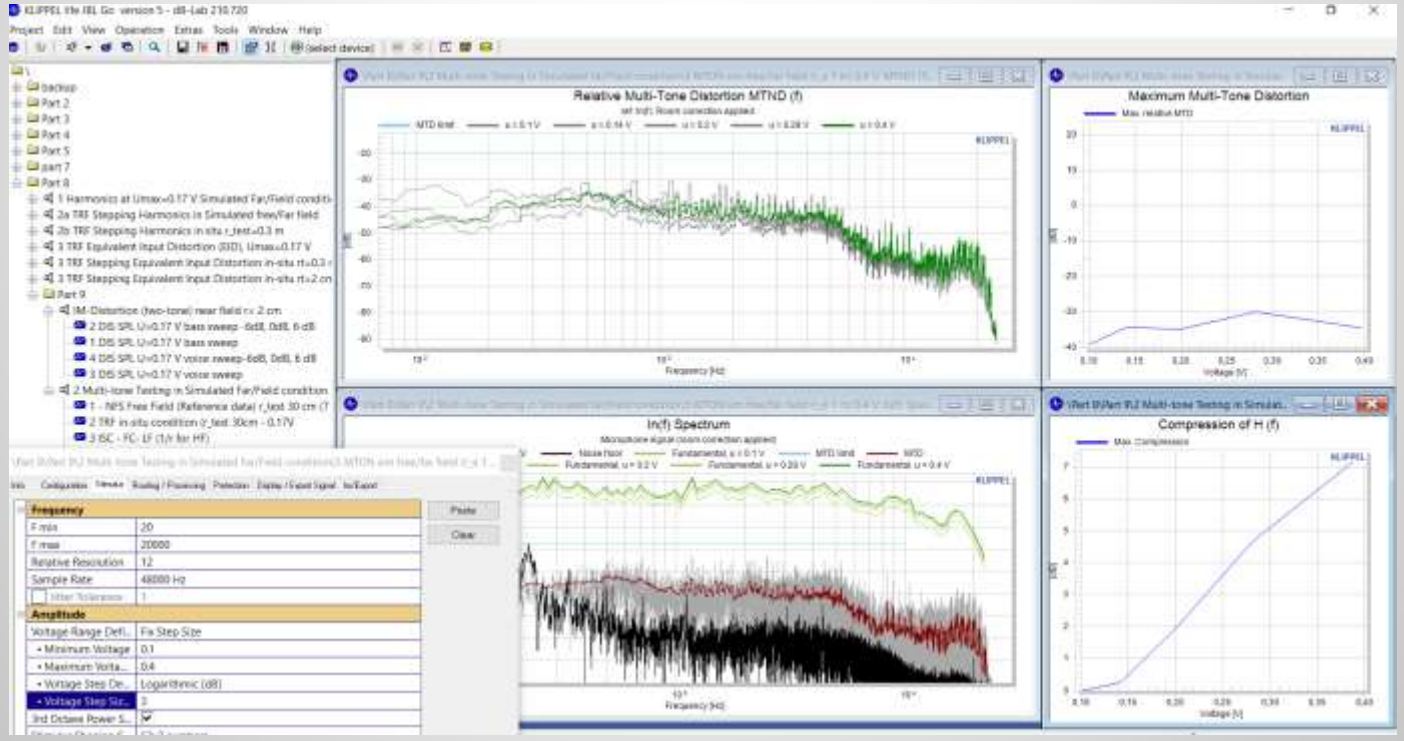


Resolution has a minor influence

(12 tones per octave is recommended)

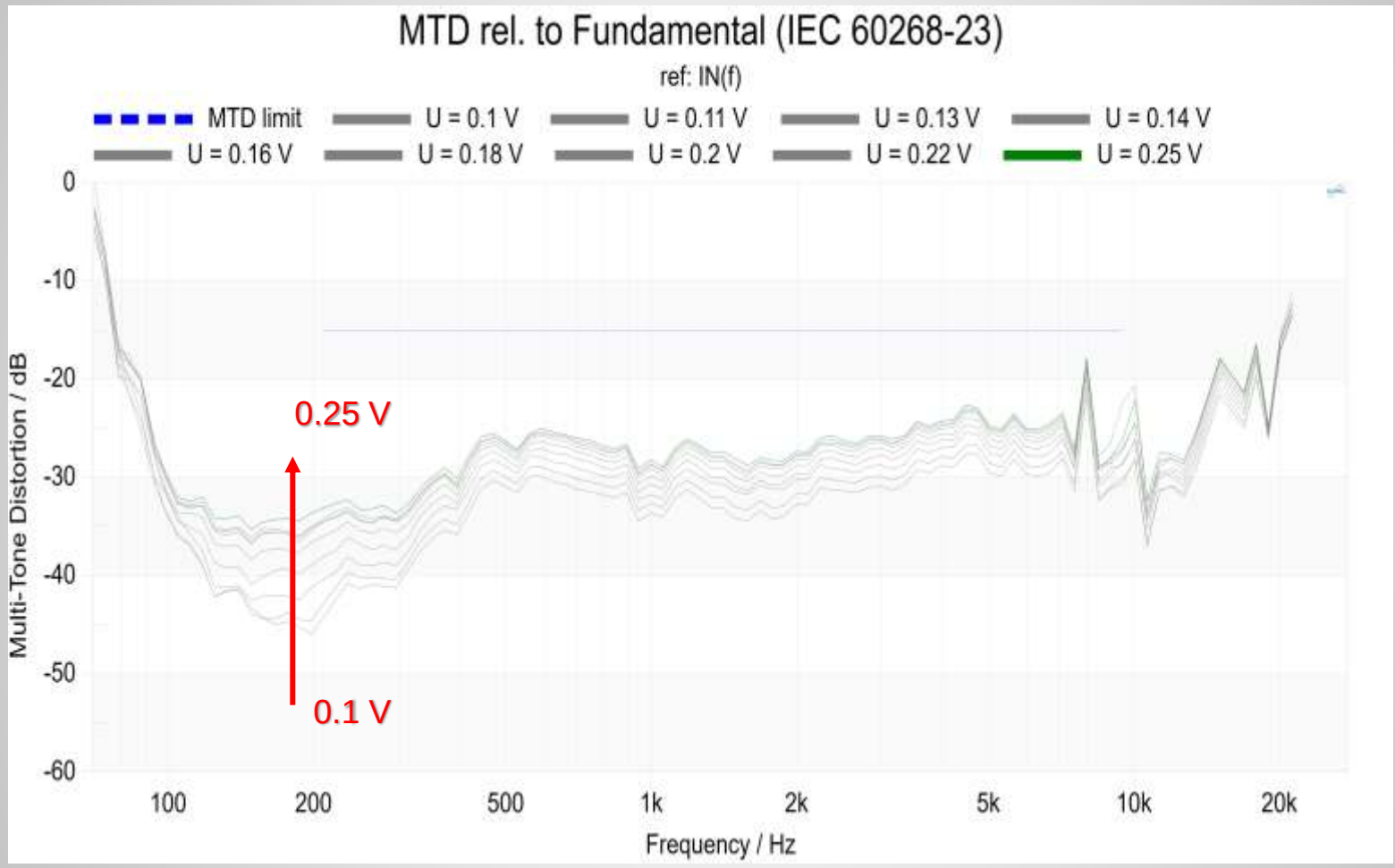
示範 Demo 6: Influence of the Stimulus Amplitude (voltage stepping)

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer



Influence of the Stimulus

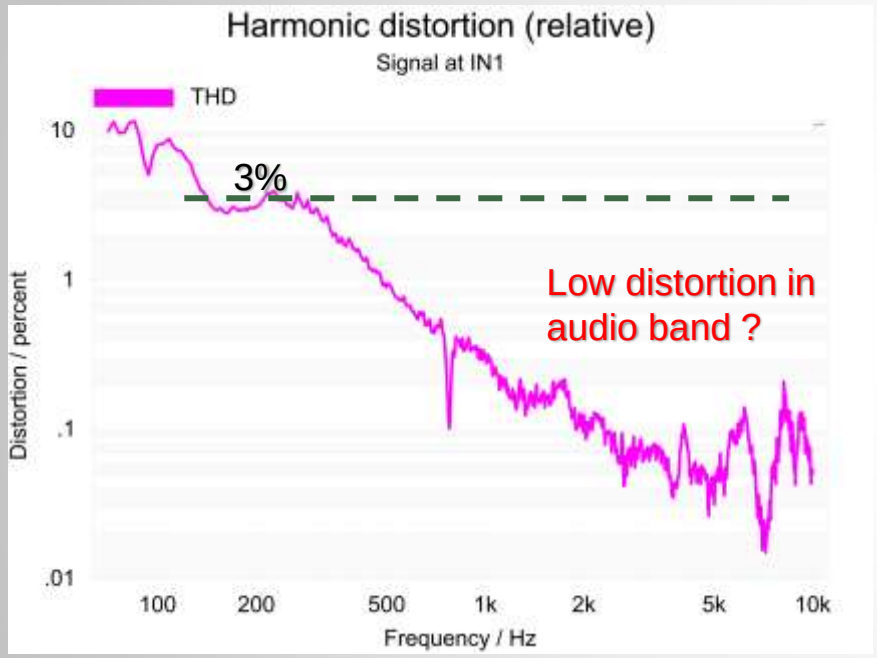
(AMPLITUDE of the Multi-Tone)

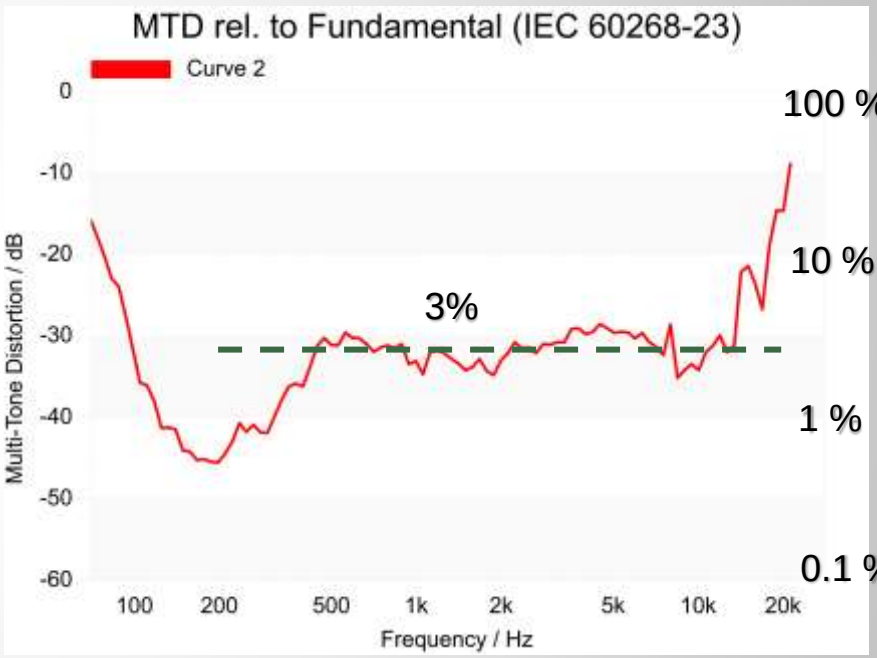


THD contra MTD (relative metrics)

Total Harmonic Distortion
(referred to fundamental)

Multi-tone Distortion ratio





excitation frequency f_i →

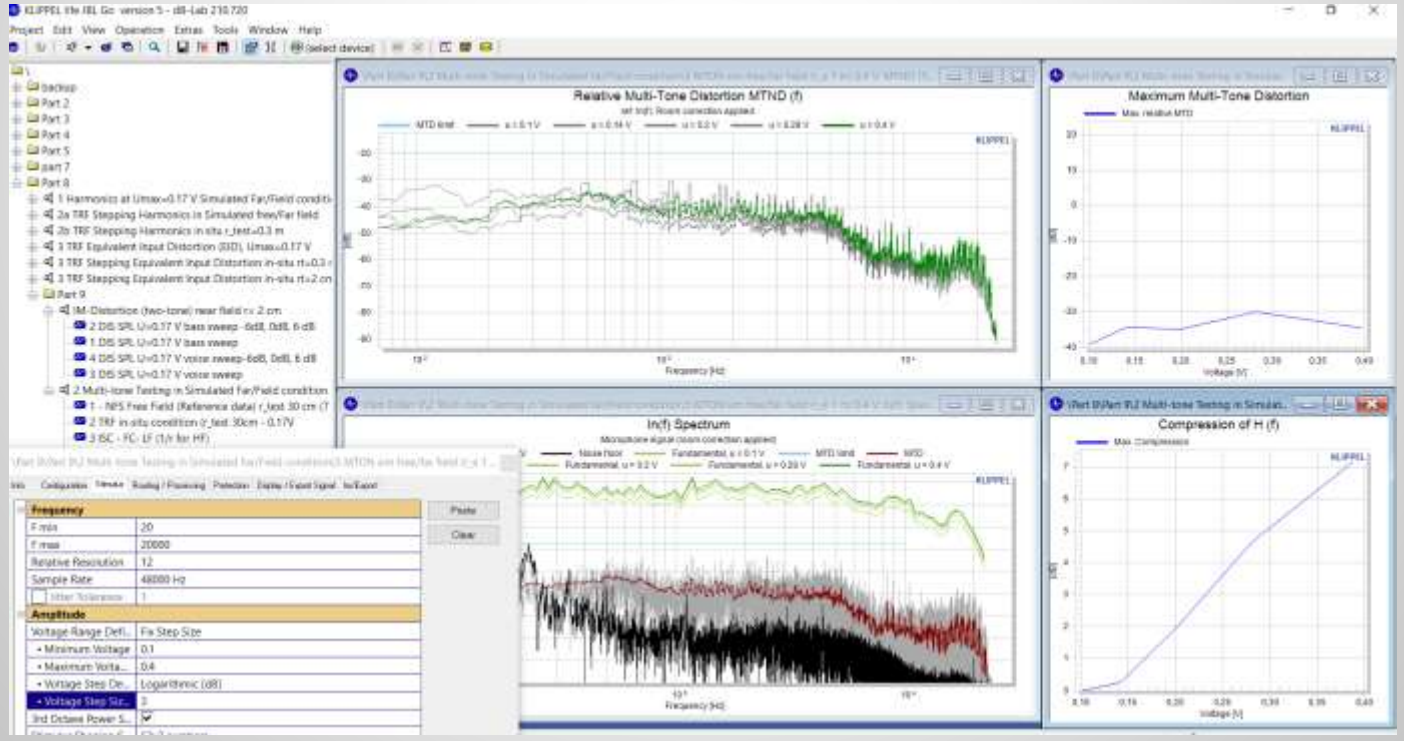
spectral frequency f →

Which measurement is more meaningful ?

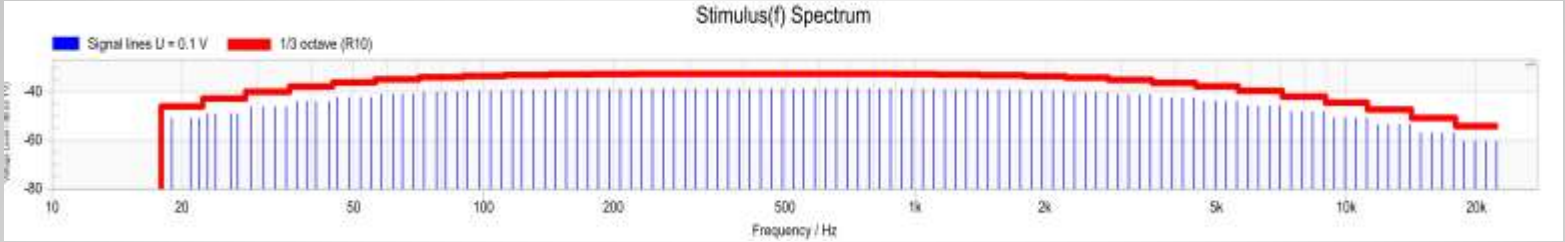
Harmonic distortion meausurement (THD) can not explain
distortion generated by a normal audio signal (music) !!

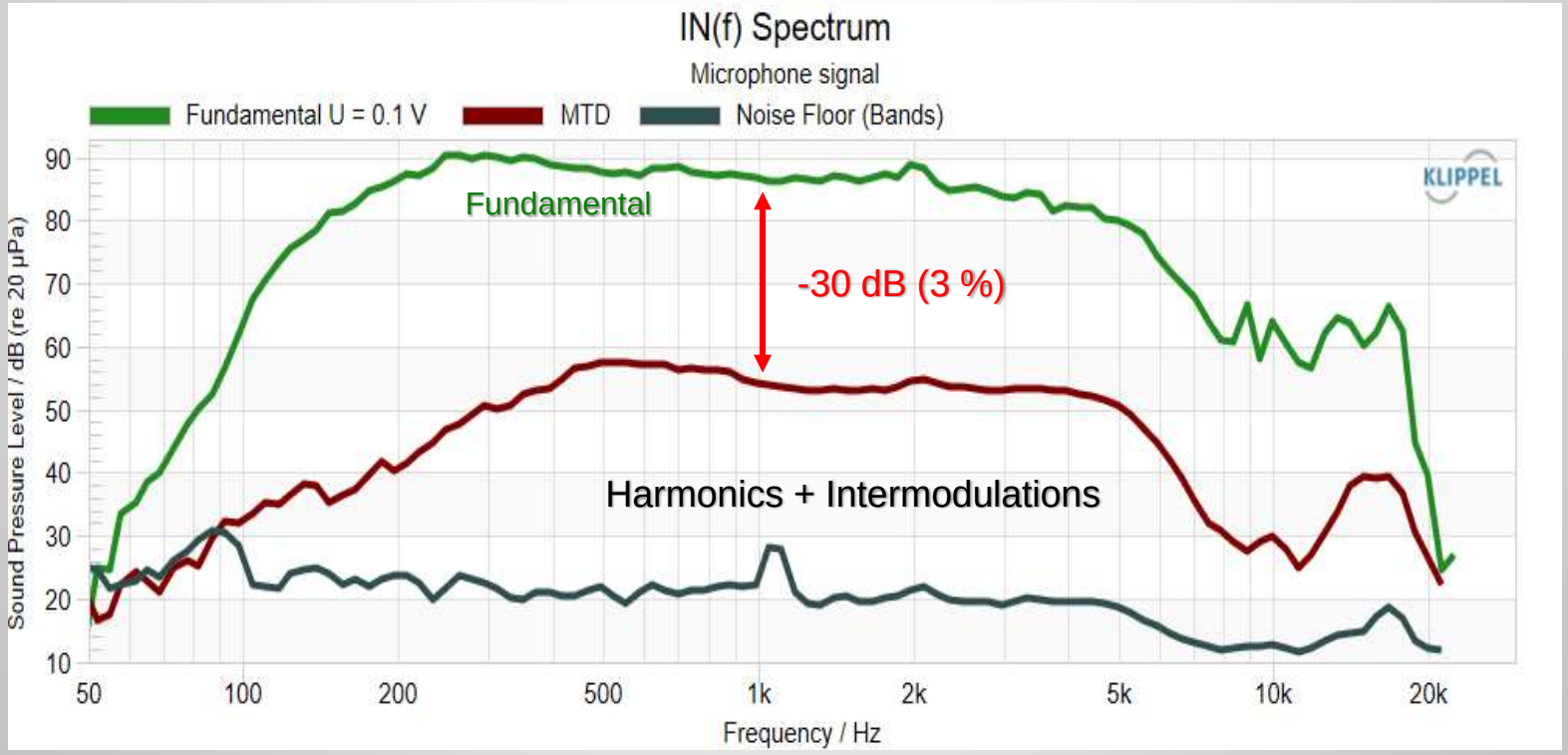
示範 Demo 5: Influence of the Stimulus Bandwidth (narrow band contra full audio band)

Tool: Using a dedicated software module MTON (multi-tone) of the KLIPPEL Analyzer

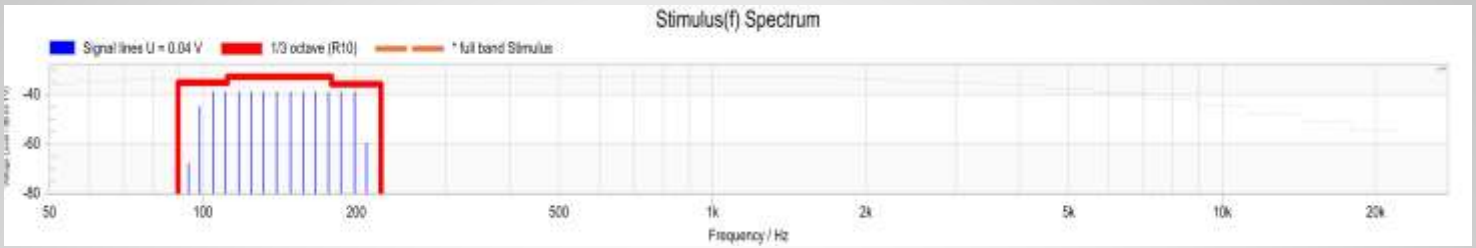


Full Band Excitation

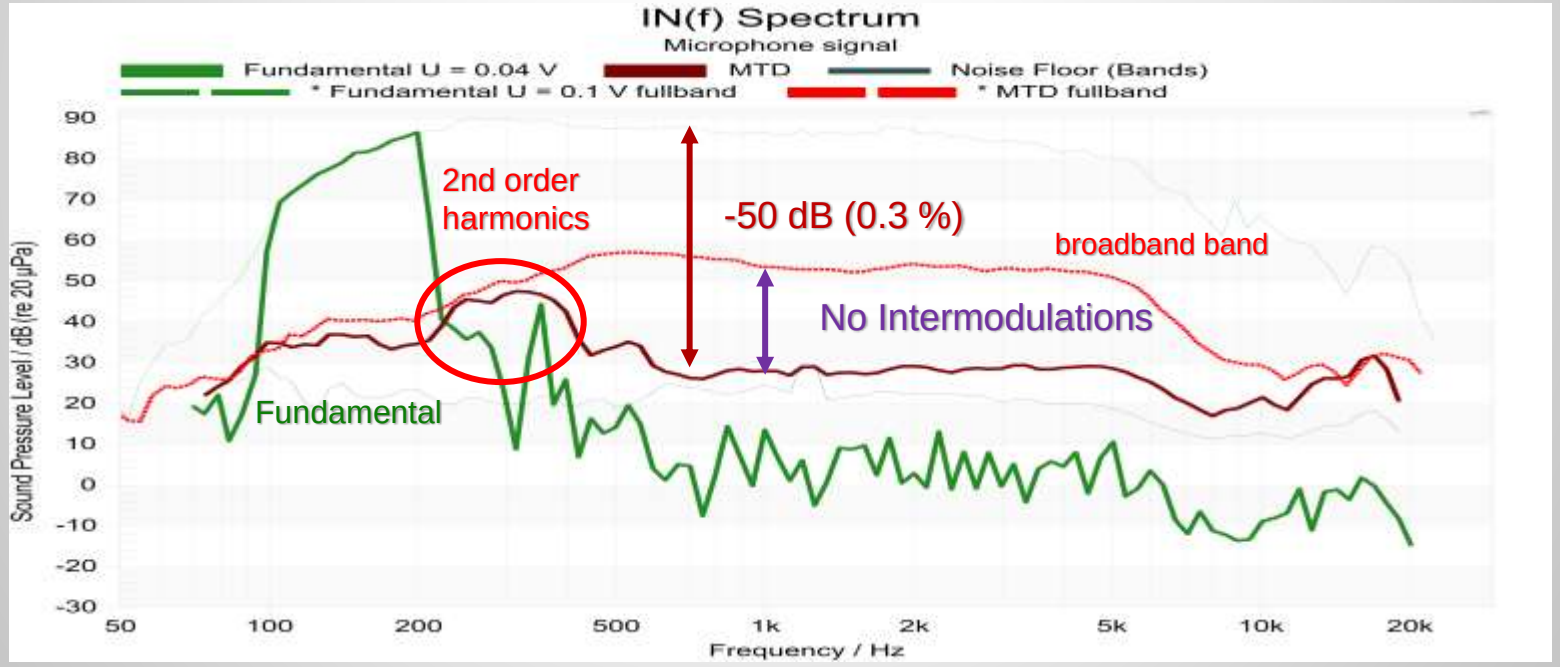




Low Frequency Excitation

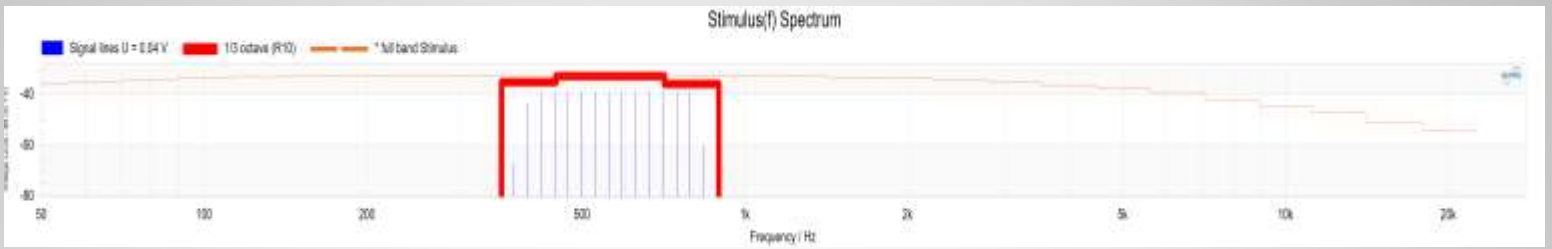


Low frequeny band generates the voice coil displacement that activates the loudspeaker nonlinearities

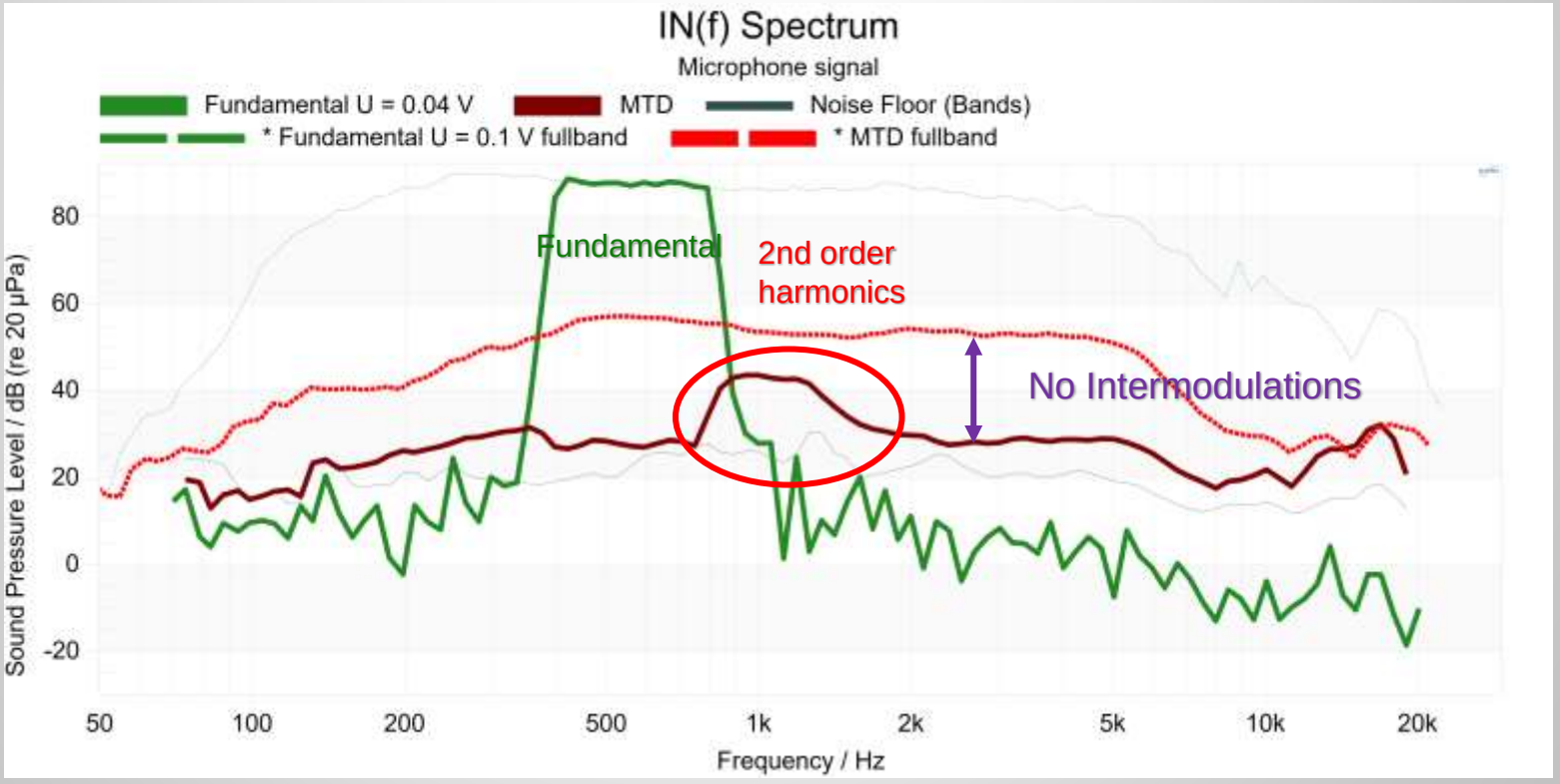


The intermodulation generates 20 dB more distortion in the audio band !!

High Frequency Excitation

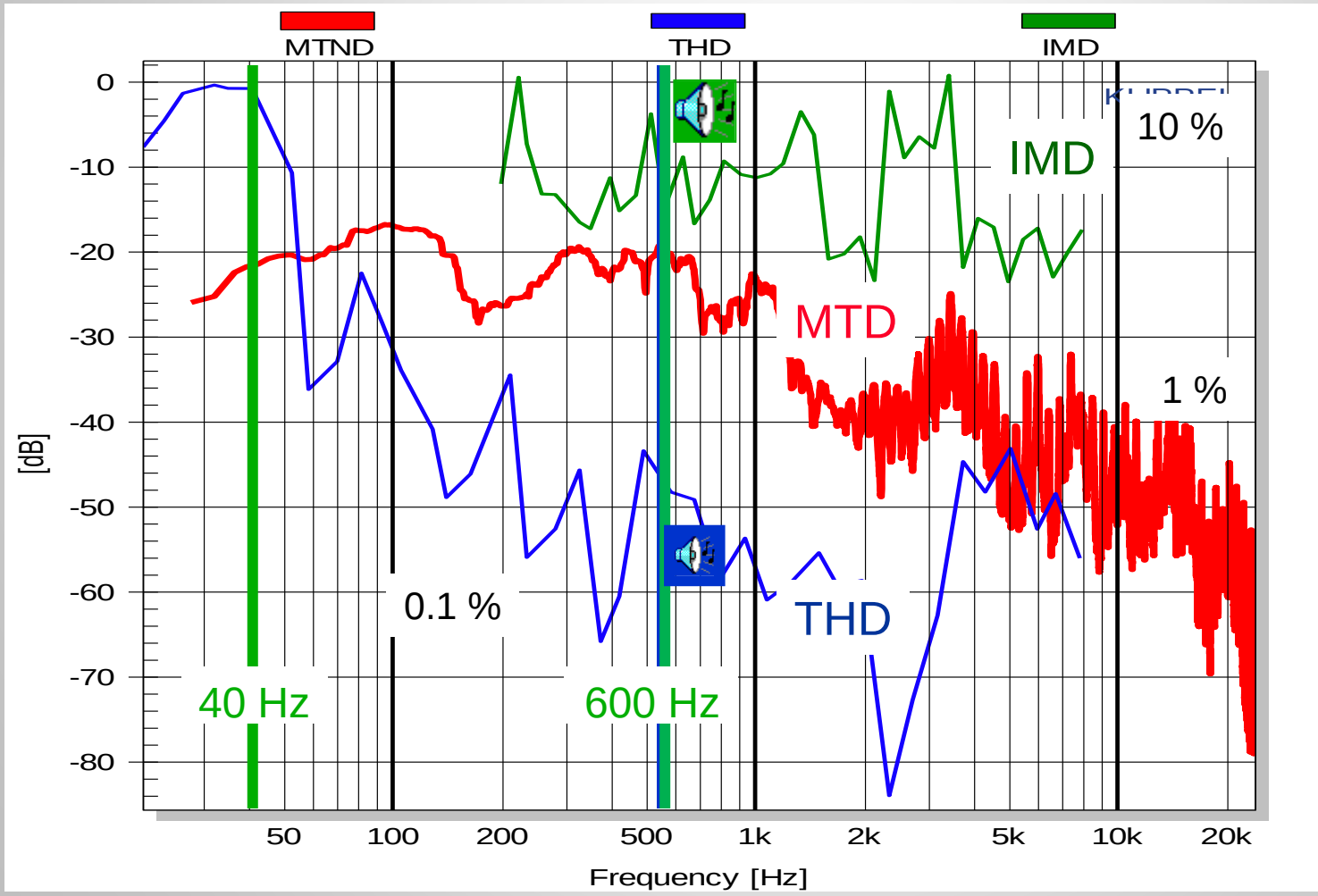


High frequeny band generates low voice coil displacement



The displacement varying loudspeaker nonlinearities are not activated !

多音失真測量
Multi-tone Distortion Measurement
compared with traditional THD, IMD



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

MTD:
Multitone @ 15V

THD:
sweep @ 15 V

多音失真的測量
Measurement of Multi-Tone Distortion

優點 Advantages:

- 考慮互調分量 Considers intermodulation components
- 類音頻信號 Audio-like signal
- 噪聲和失真的分離 Separation of noise and distortion
- 快速（非常適合質量控制）fast (perfect for quality control)

缺點 Disadvantages:

- 激發的幅度和相位必須由標準定義 Amplitude and phase of stimulus have to be defined by standard
- 沒有分離奇數和偶數階失真分量 no separation of odd- and even-order distortion components
- 沒有顯示非線性的不對稱性does not reveal the asymmetry of the nonlinearities
- 沒有分離諧波和互調 no separation of harmonics and intermodulation
- 基本成分也被扭曲 fundamental components are also distorted

This measurement is very powerful in loudspeaker diagnostics !

討論 Discussion

結論 Summary

- IM-Distortion 提供諧波無法提供的有價值的診斷信息

IM-Distortion give valuable diagnostic information not provided by harmonics

- IM 失真是 L(x) 非線性的唯一症狀（通過短路環減少）

IM-Distortion is the only symptom for L(x) nonlinearity (reduced by shorting rings)

- 多音測量提供所有非線性失真分量的綜合指紋

Multi-tone measurements gives a comprehensive fingerprint of all nonlinear distortion components

- 多音測試顯示項目材料的影響

Multi-tone testing shows the impact of the program material

- 雙音激發提供更詳細的訊息，是聽力最關鍵的信號

Two-tone stimulus gives more detailed information and is the most critical signal for listening

開放問題 Open Questions

How to evaluate the irregular properties of the audio device ?

The next 10th KLIPPEL live webinar entitled
Impulsive distortion - rub&buzz, abnormal behavior, defects
will address the points:

- 需要比人耳更靈敏的特殊測量 Need for special measurements more sensitive than the human ear
- 時頻分析顯示什麼 What the Time-Frequency analysis shows
- 在時域中檢查脈衝失真的精細結構 Inspecting the fine-structure of impulsive distortion in the time domain
- 如何找到不良行為的根本原因How to find the root cause of the irregular behavior
- IEC 60268-21 提供的新解決方案 New solutions provided by IEC 60268-21

高振幅測量
Measurements at High Amplitudes
Series presented summer 2021

1. 現代音頻設備需要輸出基本的測試 Modern audio equipment needs output based testing
2. 在普通房間進行的聲學標準測試 Acoustical standard tests performed in normal rooms
3. 從 3D 輸出測量中得出有意義的結論 Drawing meaningful conclusions from 3D output measurement
4. 在單個評估點模擬標準條件 Simulated standard condition at a single evaluation point
5. 最大聲壓級– 數字變得很重要 Maximum SPL – a number becomes important
6. 信號失真–強大的揚聲器診斷概念 Signal distortion – a powerful concept for loudspeaker diagnostics
7. 幅度壓縮–在較高幅度下輸出較少 Amplitude Compression – less output at higher amplitudes
8. 諧波失真測量 - 最佳實踐 Harmonic Distortion Measurements – best practice
9. 互調失真 - 音頻不僅僅是一個音調 Intermodulation Distortion – audio is more than a single tone
10. 脈衝失真 – 異音、異常行為、不良 Impulsive distortion - rub&buzz, abnormal behavior, defects

Next section

11. 具有無線音頻輸入的智能揚聲器測試 Smart speaker testing with wireless audio input
12. 在標準條件下對音頻產品進行基準測試 Benchmarking of audio products under standard conditions
13. 信號失真的可聽化——感知評估 Auralization of signal distortion – perceptual evaluation
14. 為信號失真設置有意義的容差 Setting meaningful tolerances for signal distortion
15. 評定產品的最大 SPL 值 Rating the maximum SPL value for product