Acoustical Measurement of Sound System Equipment according IEC 60268-21

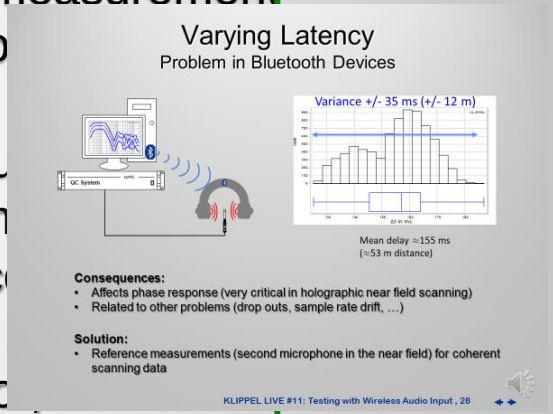
KLIPPEL- live

a series of webinars presented by

Wolfgang Klippel

Previous Sessions

1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at a single evaluatio
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic valu
7. Amplitude Compression – less output at higher an
8. Harmonic Distortion Measurements – best practic
9. Intermodulation Distortion – music is more than a
10. Impulsive distortion - rub&buzz, abnormal behavic
11. Pitfalls in Testing Wireless Audio Devices
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. Setting meaningful tolerances for signal distortion
15. Rating the maximum SPL value for product



12th KLIPPEL live:
标准条件下音频产品的基准测试
Benchmarking of audio products under standard conditions

今日话题 Topics today:

- 在高低幅值处选择基本的物理特征
  Selecting essential physical characteristics at low and high amplitudes
- 根据供应商规格书进行基准测试
  Benchmarking based on supplier specification
- 以客户定义的相同最大SPL进行基准测试
  Benchmarking at the same maxSPL defined by customer
- 通过定义的性能界限值评定最大SPL，进行基准测试
  Simple benchmarking by rating maxSPL based on defined performance limits
- 这些方法在两款蓝牙音箱上的实际应用
  Practical application of the methods to two Bluetooth speakers

投票 Poll:

您是如何对音频产品进行基准测试的？ （多选）
How do you benchmark your audio products? (multiple choices)

A. 从没做过 I have never done it.

B. 同制造商提供的规格书进行比较
Comparing technical specification provided by manufacturer

C. 对设备进行物理测量并比较结果
Performing physical measurements on the device(s) and comparing the results

D. 聆听产品重现最喜欢的音频样本
Listening to the products reproducing my favorite audio samples

音频设备的性能指标
Performance Metrics for Audio Devices

- 成本 cost
- 尺寸、体积、形状、重量 size, volume, shape, weight
- 最大输出(最大SPL、最大功率$P_{a,max}$) maximum output (max. SPL, max. power $P_{a,max}$)
- 效率（功耗、发热、电池供电设备的续航时间）
  efficiency (power consumption P_E, heating, mobile operation time in battery powered devices)
- 感知的音质（频谱和空间特性、失真）
  perceptual audio quality (spectral and spatial properties, distortion)
- 可靠性（故障概率） reliability (probability of failure)
- 外压（过载、环境）的耐久性 endurance of external stress (overload, environment)
- 艺术产品设计和人体工程学 artistic product design and ergonomics
- 技术故事 technical story
- 品牌声誉、用产品彰显个人身份 reputation of the brand, personal identification with the product
- 娱乐或享乐偏好 enjoyment or hedonistic preference

今日主题：特定物理测量（标准条件下）
Our topic today: Special physical Measurement (under standard condition)

投票 Poll:

哪些对您的基准测试重要？ (多选)
What is important for your bench marking ? (multiple choices)

A. 最大输出（最大SPL、最大功率$P_{a,max}$）
maximum output (max. SPL, max. power $P_{a,max}$)

B. 效率（功耗、发热、电池供电设备的续航时间）
efficiency (power consumption P_E, heating, mobile operation time in battery powered devices)

C. 感知的音质（频谱和空间特性、失真）
perceptual audio quality (spectral and spatial properties, distortion)

D. 可靠性（故障概率） reliability (probability of failure)

E. 外压(过载、环境)的耐久性
endurance of external stress (overload, environment)

降低复杂度!
Reduce complexity !

音频产品的基准测试可以通过以下方式简化:
The benchmarking of audio products can be simplified in the following way:

- 比较同类产品（例如耳机） Comparing similar products (e.g. headphones)
- 专为明确定义的最终用户群体（例如青少年）设计
  Designed for a clear defined group of end-users (e.g. teenager)
- 指定终端应用条件（例如入耳式）
  Specify final application condition (e.g. in-ear)
- 选择最少的指标来评估重要属性
  Select a minimum of metrics evaluating the important properties
- 使用明确定义的指标（例如标准）
  Use metrics which are clearly defined (e.g. standards)
- 定义评估条件（例如输入电平）
  Define the evaluation condition (e.g. input level)

重要标准特征
Important Standard Characteristics

Characteristics	output based testing
On-axis fundamental transfer response	*
3D output, directivity[3]	*
Electrical impedance[5]	-
Lumped parameters (linear, nonlinear,thermal)[5]	-
Amplitude compression[3]	*
DC-displacement X_{DC}[4]	(*)
Harmonic distortion (THD, 2nd, 3rd-order)[3]	*
Multi-tone distortion(HD +IMD)[3]	*
Distortion in reproduced audio signal	*
Modulated noise	*
Impulsive distortion (rub & buzz)[3]	*
Destructive test	*
Maximum displacement X_{MAX}[4]	(*)
Maximum SPL_{MAX} or input voltage U_{MAX}[3]	*
100h-long-term test[3]	*
Accelerated life test[5]	*
Environmental test[5]	*

[3]performed according **IEC 60268-21**
[4]measured according IEC 62458
[5]measured according IEC 60268-22 CDV

模型参数（与激励无关）
Parameters of a model (independent of the stimulus)

使用定义的测试信号测量到的症状 Symptoms measured with a defined test signal

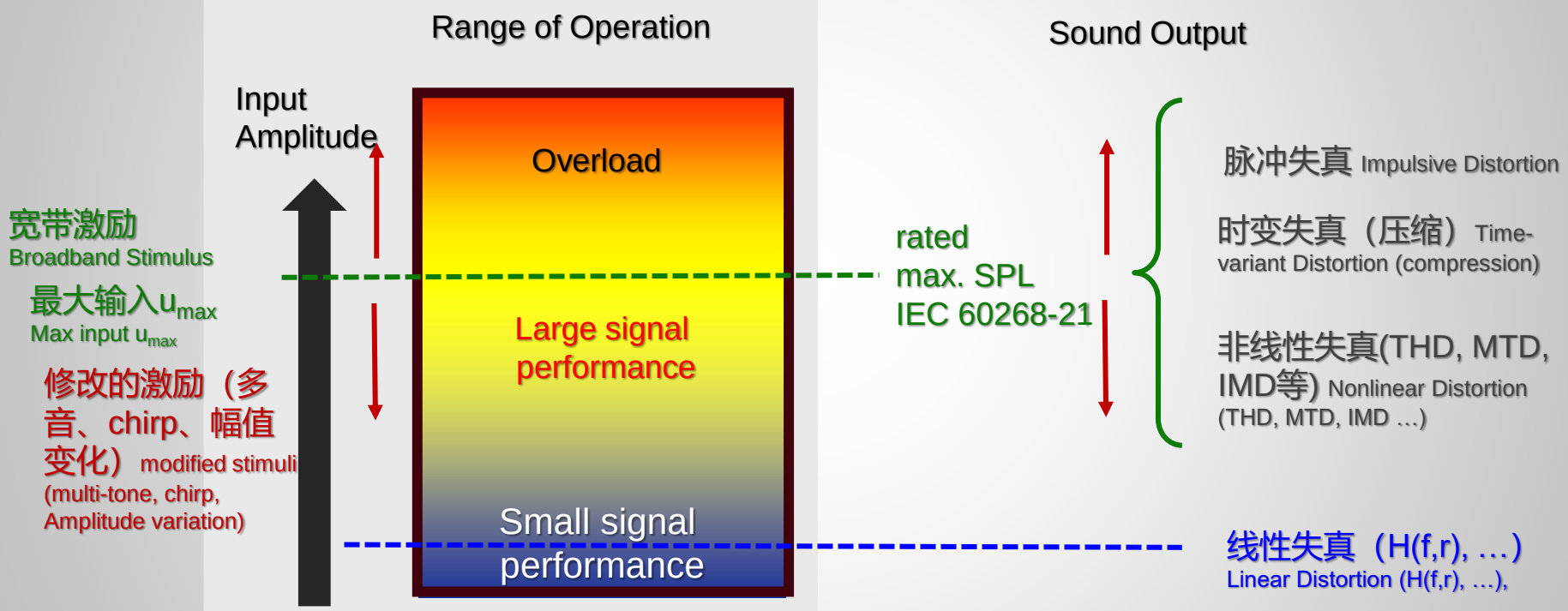
考虑特定应用的额定特征
Rated characteristics considering the particular application

使用代表程序材料的激励进行长时测试 Long term testing with stimulus representing program material

对基准测试重要 Important for benchmarking

评估条件
Evaluation Condition

测试激励的幅度对音频系统的性能有很大影响!
The magnitude of the test stimulus has a high impact on performance of the audio system !



符合IEC 60268-21的额定最大SPL（最大输入电压u_{max}）简化了基准测试!
The rated maximum SPL (maximum input voltage u_{max}) according to IEC 60268-21 simplifies the benchmarking !

低幅值处的基准测试
Benchmarking at Low Amplitudes

测量条件 Measurement Condition:

- 小信号域（ $u=0.1\ u_{max}$ ） Small Signal Domain ($u=0.1\ u_{max}$)
- 任意宽带激励 Any broadband stimulus
- 远场/自由场条件下的选定点（轴上、听音域）(CEA 2034 标准)
  Selected points (on-axis, listening zone) under far field /free field condition (CEA 2034 Standard)

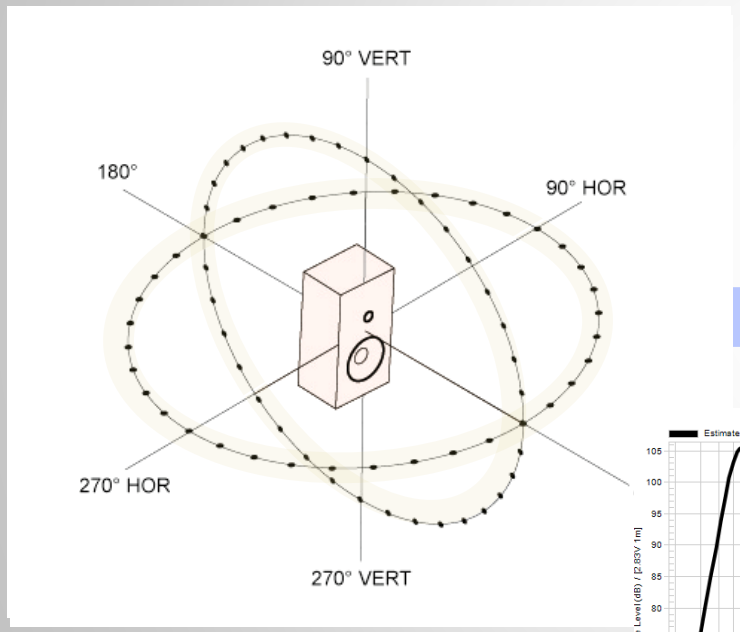
线性失真的重要指标： Important Metrics for Linear Distortion:

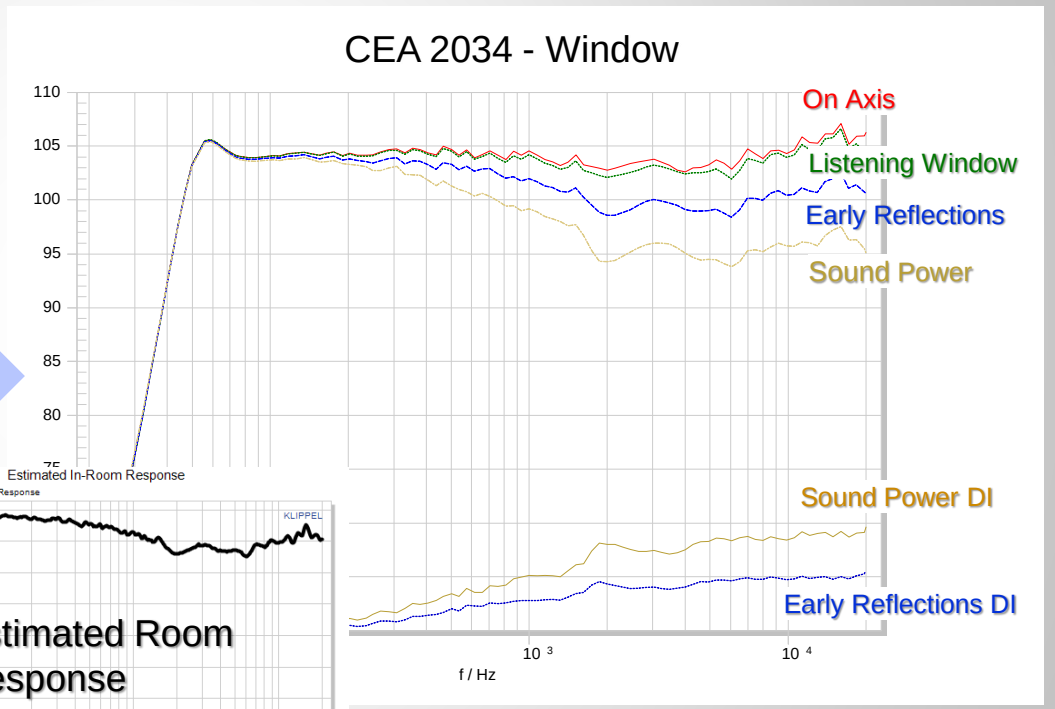
1. 有效频率范围的上限和下限（IEC 60268-21 ）
   Upper and lower limits of the effective frequency range (IEC 60268-21)
2. SPL响应（如估计的房间响应CEA 2034标准）以1/3倍频程平滑 SPL response (e.g. estimated room response CEA 2034 Standard) smoothed with 1/3rd octave
3. 与目标响应（新IEC项目电视、监听音箱）的平均偏差
   Mean deviation from a target response (new IEC project TV, monitor)

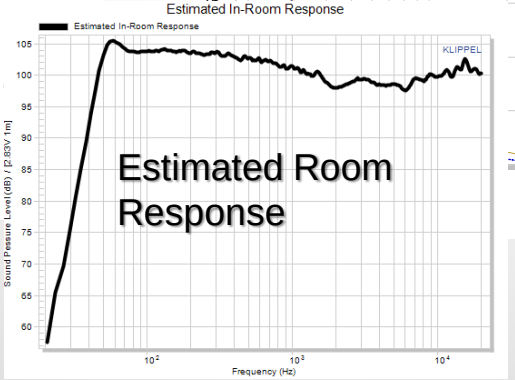
CEA 2034 Standard

using Spino-a-rama

Application : Home audio devices, Hifi-Loudspeaker







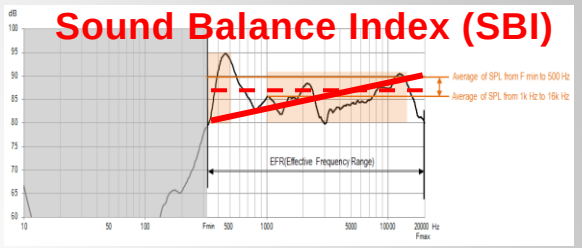
线性失真的新指标 New Metrics for Linear Distortion

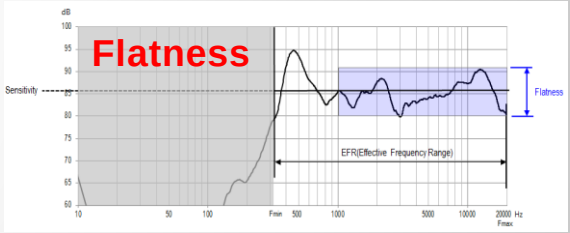
用于TV和监听音箱音频系统的测量方法

Measurement methods for TV and monitor audio systems

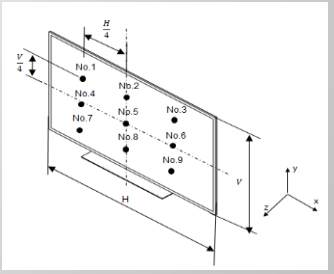
New IEC Project: PT 100-31

Measuring metric	Unit	Definition
Sound Balance Index (SBI)	**dB**	**不同频段之间的SPL差异 The difference of SPL between different frequency band**
Flatness	**dB**	**不同频段之间SPL的标准差 Standard deviation of SPL in the different frequency band**
SPL uniformity	%	屏幕9点和扬声器轴上SPL的一致性 Uniformity of SPL at screen 9 points and speaker on axis
Effective Frequency Range (EFR)	Hz	扬声器能在每个位置播放的频段 Frequency band which the speaker can play at each location
Sensitivity	dB	EFR之间的SPL均值 Average of SPL between EFR
Total Harmonic Distortion (THD)	%	输出信号量与输入信号量的比较 Amount of output signal compared to input signal
Directivity index	dB	下面两个SPL值的比值 The ratio of the following two SPL values
Radiation angle	Degree	低于轴上SPL10dB的角度 Angle of less than 10 dB below the SPL on axis
Coverage angle	Degree	各方向之间少于最大SPL6dB的角度 Angle between direction 6 dB less than maximum SPL





SPL uniformity

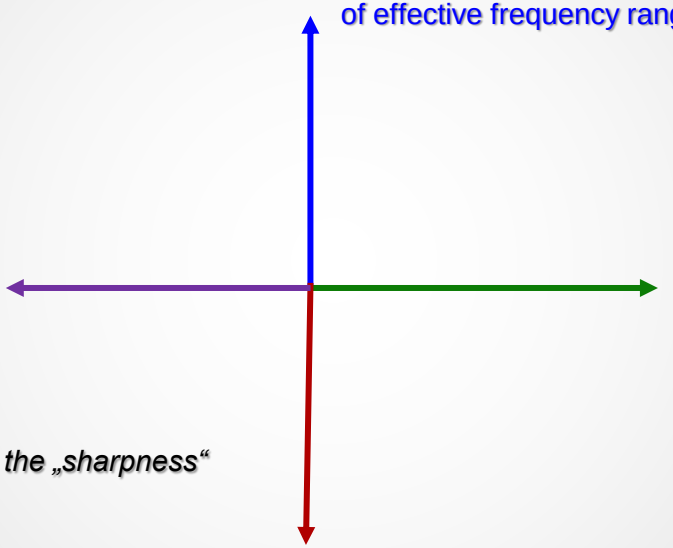


符合IEC标准的基本指标
Essential Metrics according IEC Standards
评估小信号性能 for Assesing Small Signal Performance

影响"低频性能" affects the „Low bass performance"

有效频率范围下限 Lower limit of effective frequency range

有效频率范围上限Upper limit of effective frequency range



SPL响应随频率变化量（对比平坦度） variance of SPL response versus frequency (contra flatness)

对"清晰度"的贡献 Contributes to the „sharpness"

→ 感知为"声染色"
Perceived as „sound coloration"

声平衡指数 Sound Balance Index

各种标准中还定义了其他重要指标：There are other important metrics defined in various standards:

- *声功率方向指数 IEC 60268-21 Sound Power Directional Index IEC 60268-21*
- *延迟 IEC 60268-21 Latency IEC 60268-21*

高幅值处的基准测试
Benchmarking at High Amplitudes

想法：使用额定最大SPL作为大信号测量的基础
IDEA: Using Rated MAXIMUM SPL as the basis for the Large Signal Measurement

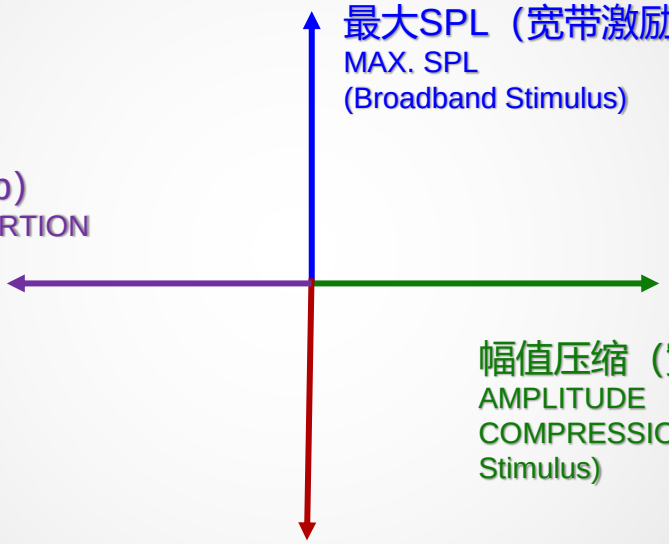
有三种有趣的方式： There are three interesting ways:

1. 对供应商评定的每个DUT使用单独的maxSPL值进行测试
   Testing using individual maxSPL values for each DUTs rated by supplier
2. 以客户定义的maxSPL目标值进行测试（产品要求）
   Testing at maxSPL target value defined by customer (product requirement)
3. 比较客户额定的maxSPL Comparing maxSPL rated by customer

符合IEC 60268-21的基本指标

Essential Metrics according IEC 60268-21

评估大信号性能 for Assesing Large Signal Performance



最大输出
Maximum Output

最大SPL（宽带激励）
MAX. SPL
(Broadband Stimulus)

脉冲失真（chirp）
IMPULSIVE DISTORTION
(Chirp)

时变特性 Time-variant properties

非常规性能（异常音）Irregular properties (rub&buzz)

对音质影响小，但对可靠性影响大
Low impact on audio quality but
High impact on reliability

幅值压缩（宽带激励）
AMPLITUDE
COMPRESSION (Broadband Stimulus)

对音质和可靠性有很大影响 High impact on audio quality and reliability

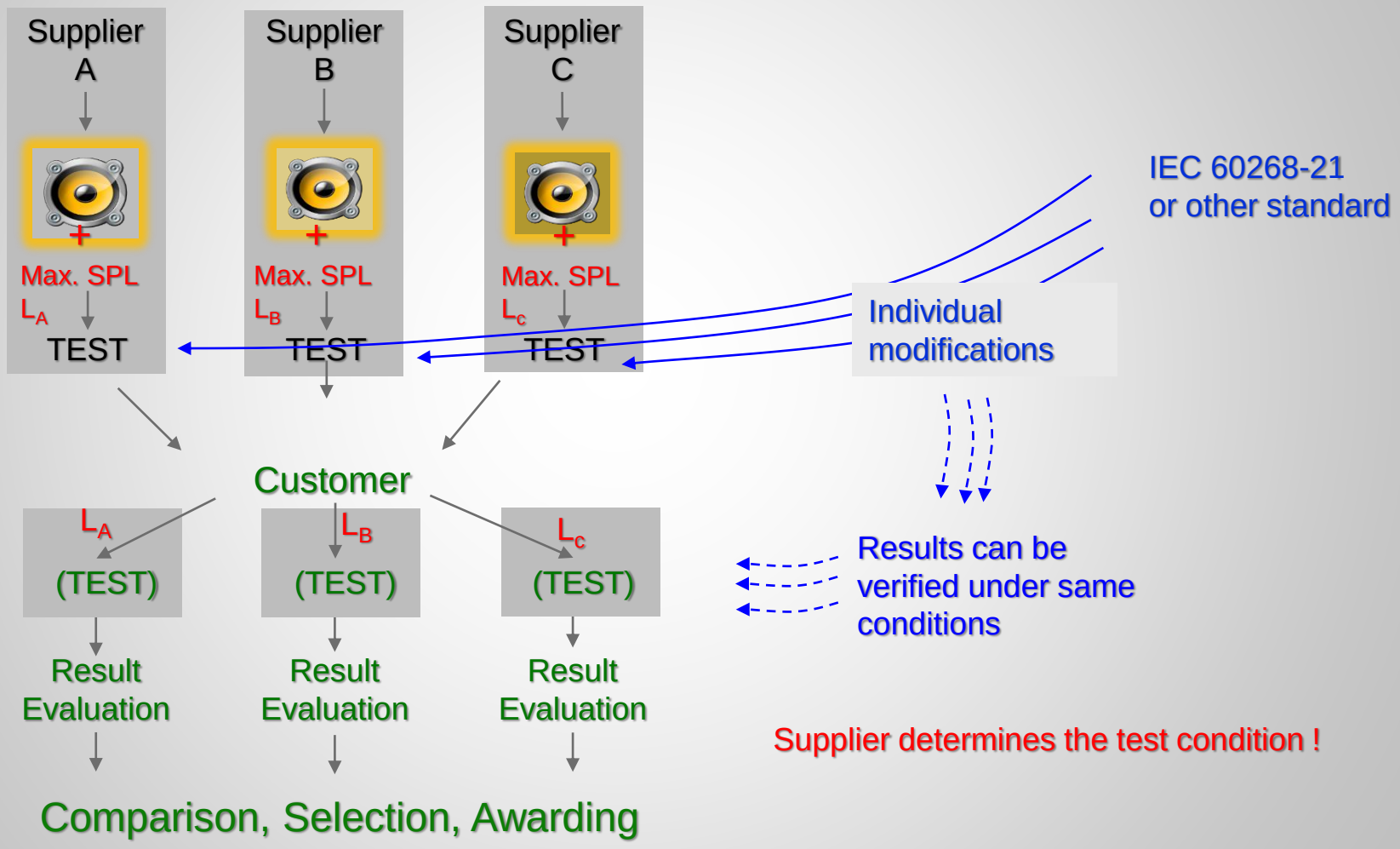
多音失真（宽带激励）MULTI-TONE
DISTORTION (Broadband Stimulus)

常规非线性（设计接受）
Regular Nonlinearities (accepted by design)

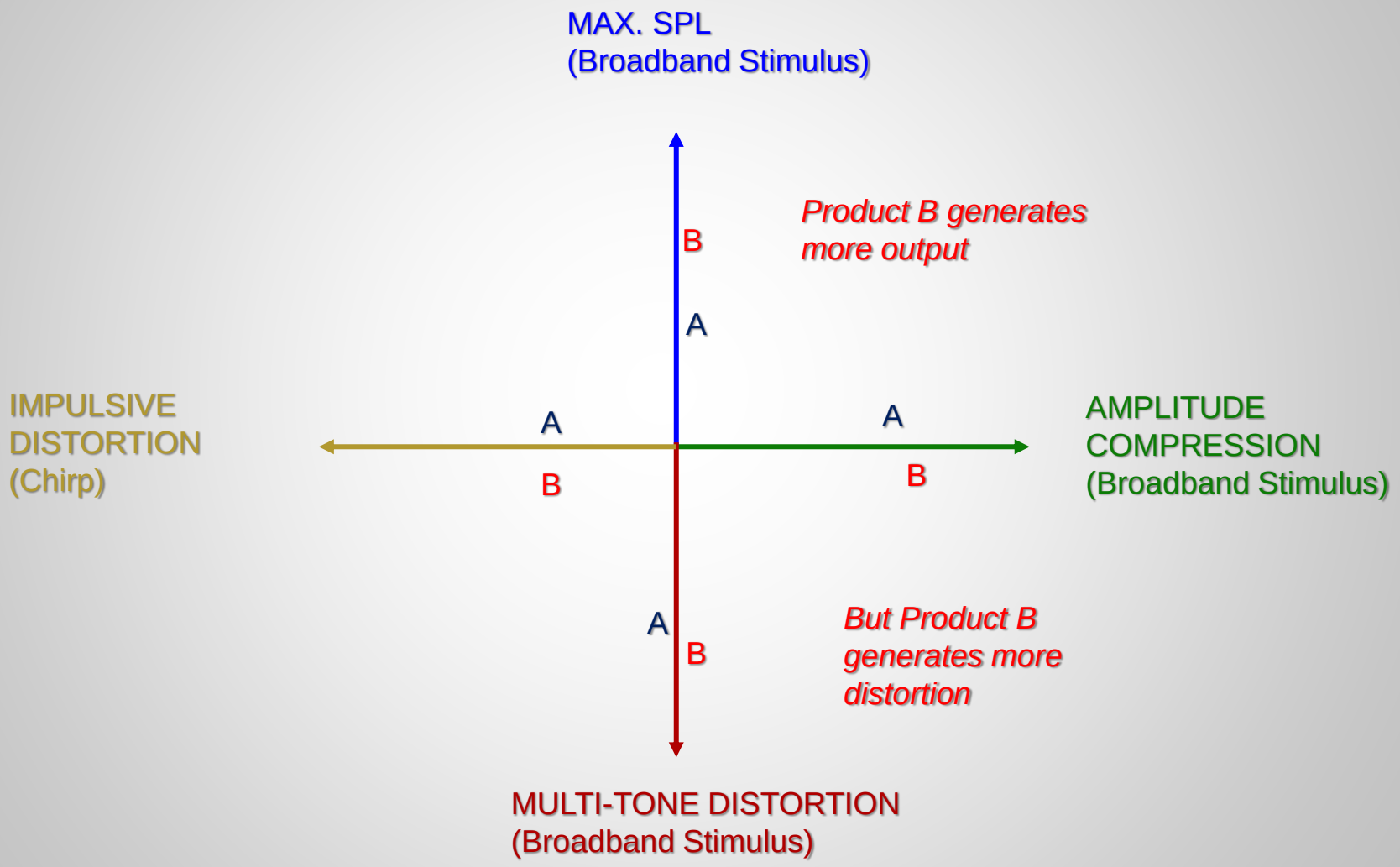
对音质影响大 High impact on audio quality

方法1：单独最大SPL处的基准测试

1st Method: Benchmarking at Individual Max. SPL



单独最大SPL处两款产品A和B的基准测试
Benchmarking of Two Products (A,B) at Individual Max. SPL



单独最大SPL处的基准测试
Benchmarking at Individual Max. SPL

想法：最大SPL和音频性能的最佳匹配
IDEA: Best matching of Max. SPL and Audio Performance

优点 Benefits:

- 供应商基于背景信息额定最大SPL
  Supplier rates Max. SPL based on background information
- 基于已有产品进行基准测试 Benchmarking based on existing products
- 不需要同供应商沟通 No communication with supplier required
- 最小化客户的测试工作量 Minimum test effort for customer

缺点 Drawbacks:

- DUT有不同的最大SPL值和失真值，比较起来更复杂 Comparison of DUTs with different Max. SPL values and distortion values is more complicated

应用： Application:

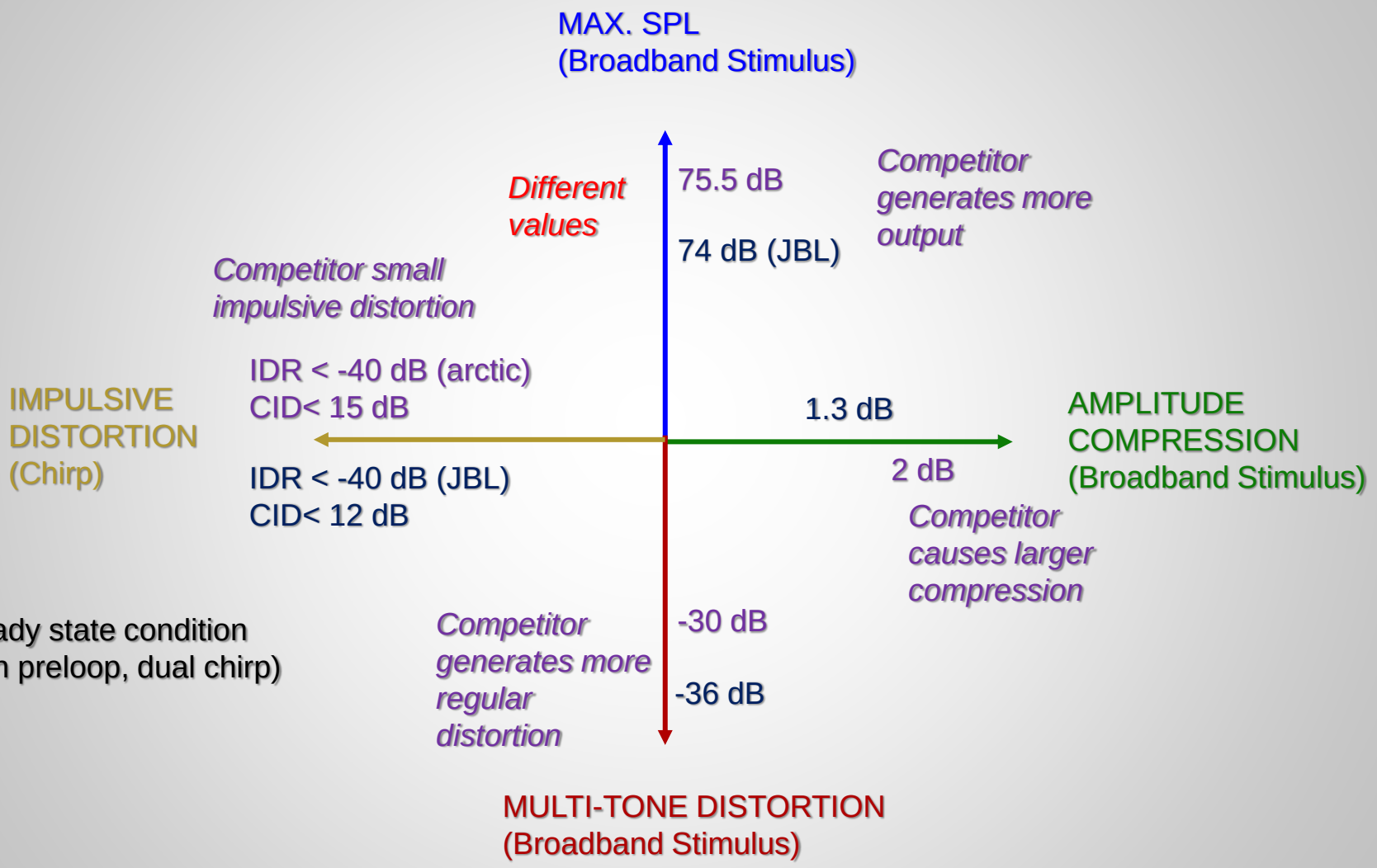
- 根据供应商发布的数据表进行基准测试 Benchmarking based on datasheet published by supplier

Demo: Benchmarking at Individual Max. SPL

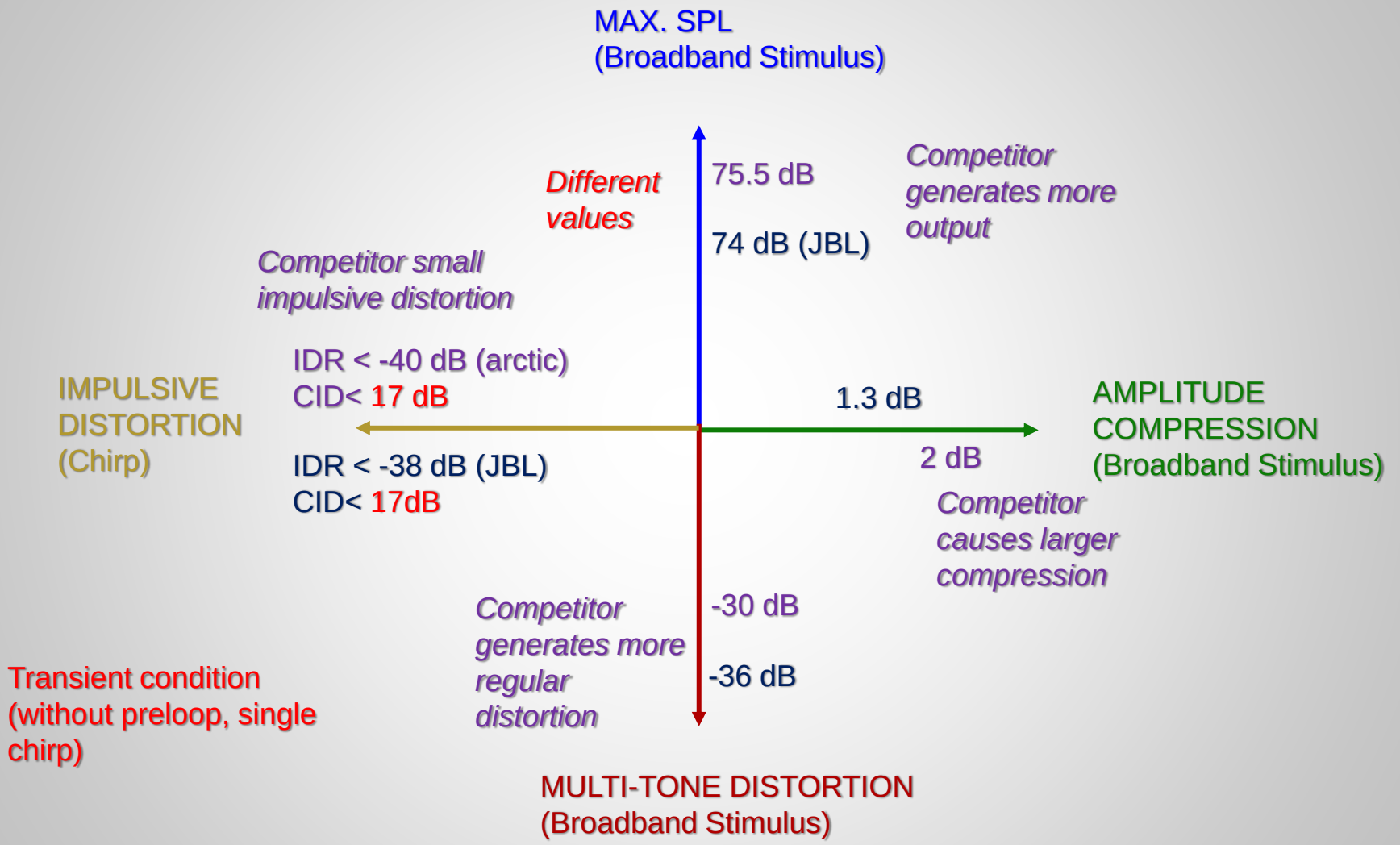
Tools: Using dedicated software modules of the KLIPPEL Analyzer

- NFS Near field scanning
- ISC Insitu Room Compensation
- TRF PRO (transfer function)
- TRF Stepping
- MTON Multi-tone Measurement

Benchmarking of the two Bluetooth Speakers at Individual Max. SPL

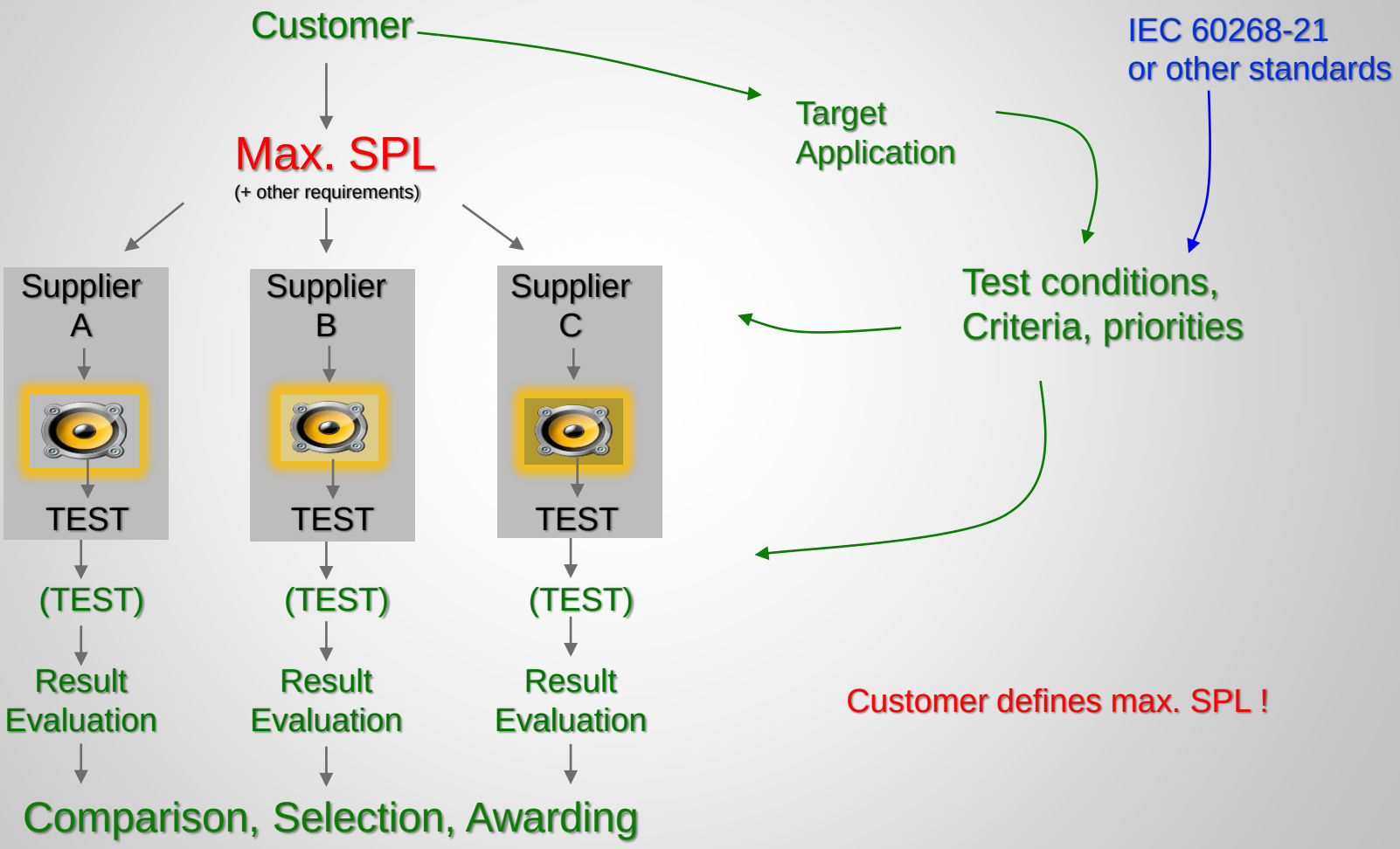


Benchmarking of the two Bluetooth Speakers at Individual Max. SPL



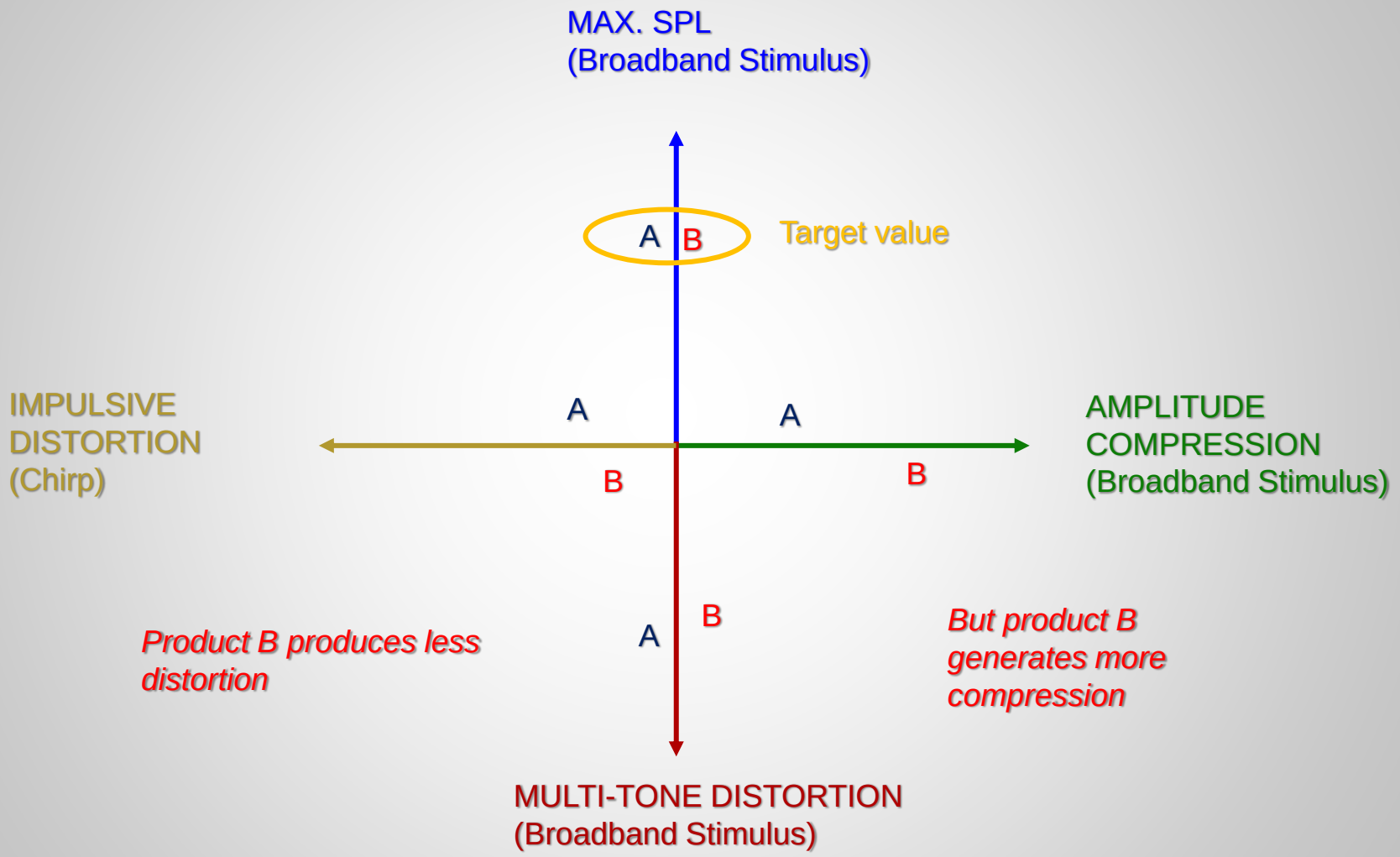
方法2：最大SPL目标值处的基准测试

2nd Method: Benchmarking at Target Max. SPL



Benchmarking at Target Value

Essential Metrics according IEC 60268-21



目标值处的基准测试
Benchmarking at Target Value

想法：针对给定最大SPL的最佳音频性能
IDEA: Best Audio Performance for given Max. SPL

优点： Benefits:
- 客户定义最大SPL值（目标要求） Customer defines Max. SPL value (target requirement)
- 客户和供应商定义测量条件 Customer and supplier define measurement condition
- 简化客户与供应商之间的沟通 Simplifies communication between customer and supplier
- 供应商可以将所有测试结果提供给客户 Supplier can provide all test results to customer
- 最小化客户的测试工作量 Minimum test effort for customer
- DUT的测试结果具有可比性 Test results of the DUTs are comparable

缺点 Drawbacks:
- 产品开发开始之前就定义好了最大SPL Max. SPL is defined before product development begins

应用 Application:
- 换能单元制造商 – 系统集成商（OEM业务） Transducer Manufacturer – System Integrator (OEM business)

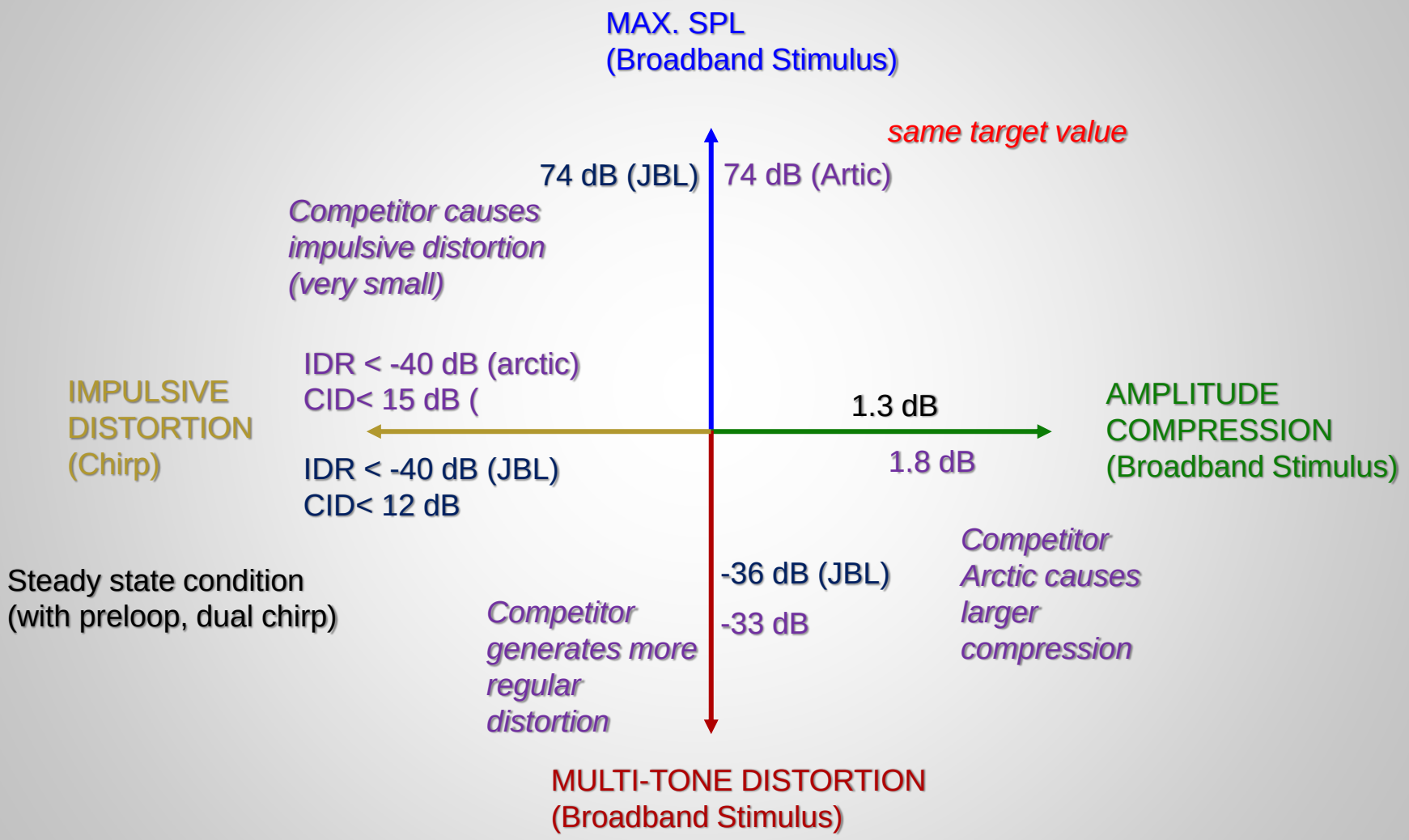
Demo

Benchmarking at Target Value

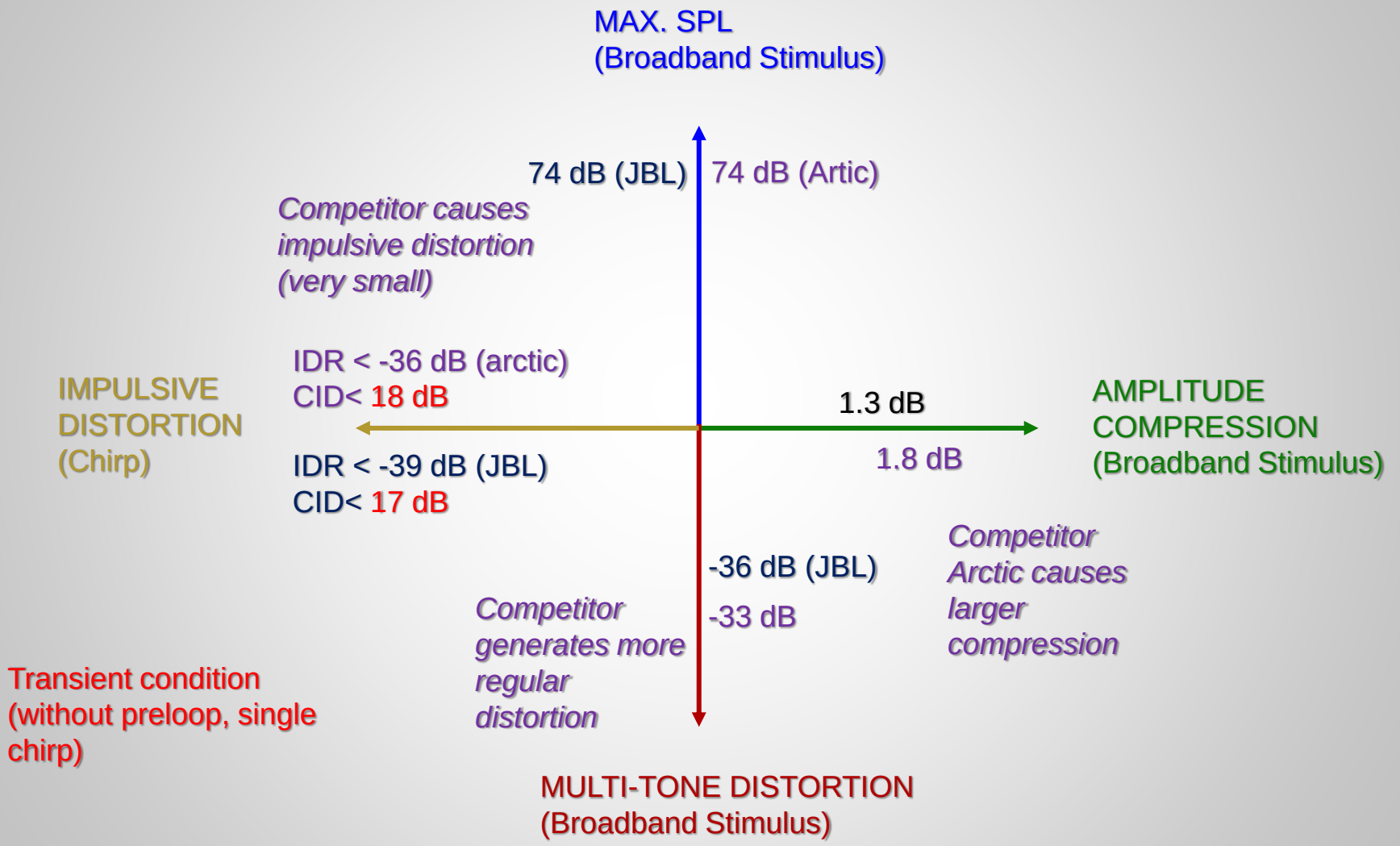
Tools: Using dedicated software modules of the KLIPPEL Analyzer

- NFS Near field scanning
- ISC Insitu Room Compensation
- TRF PRO (transfer function)
- TRF Stepping
- MTON Multi-tone Measurement

Benchmarking of the two Bluetooth Speakers at Target Max. SPL

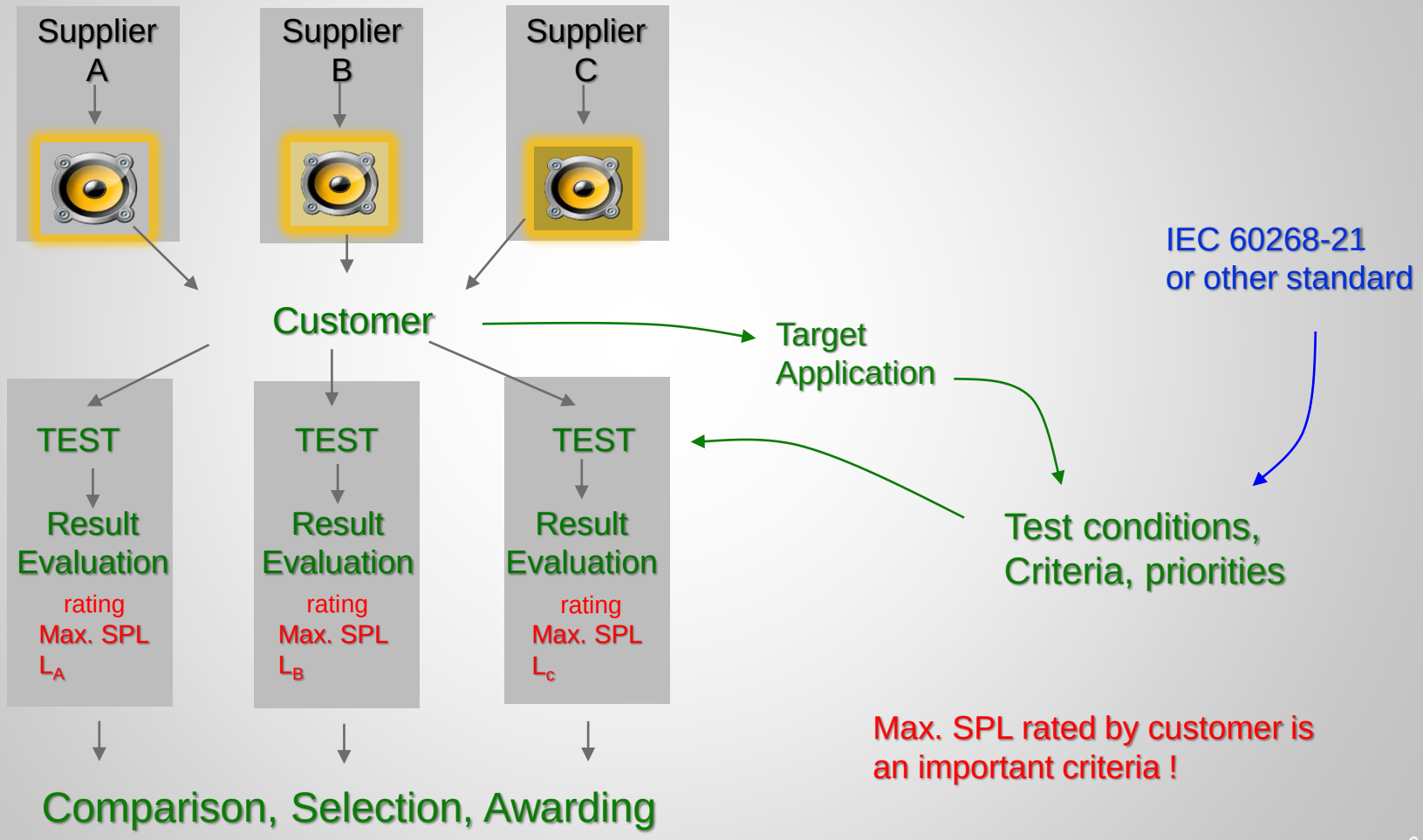


Benchmarking of the two Bluetooth Speakers at Target Max. SPL



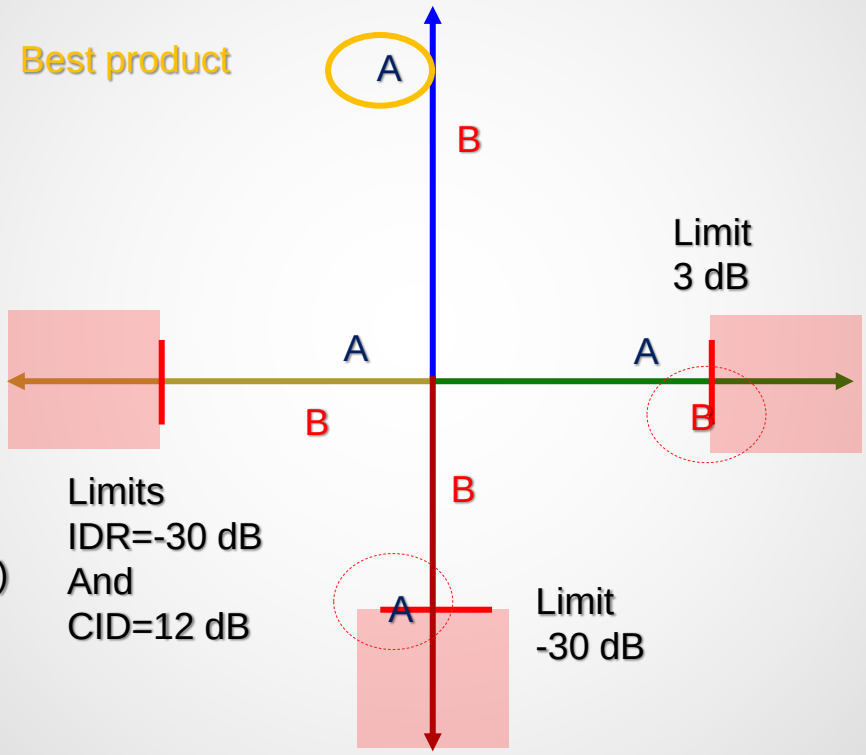
方法3：通过客户在相同条件下额定的最大SPL进行基准测试

3rd Method: Benchmarking by maxSPL rated by customer under same condition



Benchmarking by maxSPL rated by customer

Essential Metrics according IEC 60268-21



通过客户额定的最大SPL进行基准测试
Benchmarking by maxSPL rated by customer

想法：针对给定音频性能的最高最大SPL
IDEA: Highest Max. SPL for given Audio Performance

优点 Benefits:
- 可以应用于任何产品 Can be applied to any product
- 客户定义测试条件（IEC 60268-21） Customer defines test condition (IEC 60268-21)
- 足够的音频性能 Sufficient Audio Performance
- 简化基准测试决策 Simplified decision in benchmarking

缺点 Drawbacks:
- 客户方的测试工作 Test effort on customer side
- 对于音频性能比最大SPL更重要的应用不太有用 Less useful for applications where audio performance is more important than Max. SPL

应用 Application:
- 需要较大最大SPL的专业设备、小型便携式个人音频设备 Professional equipment, small portable-personal audio equipment where larger Max. SPL is desired

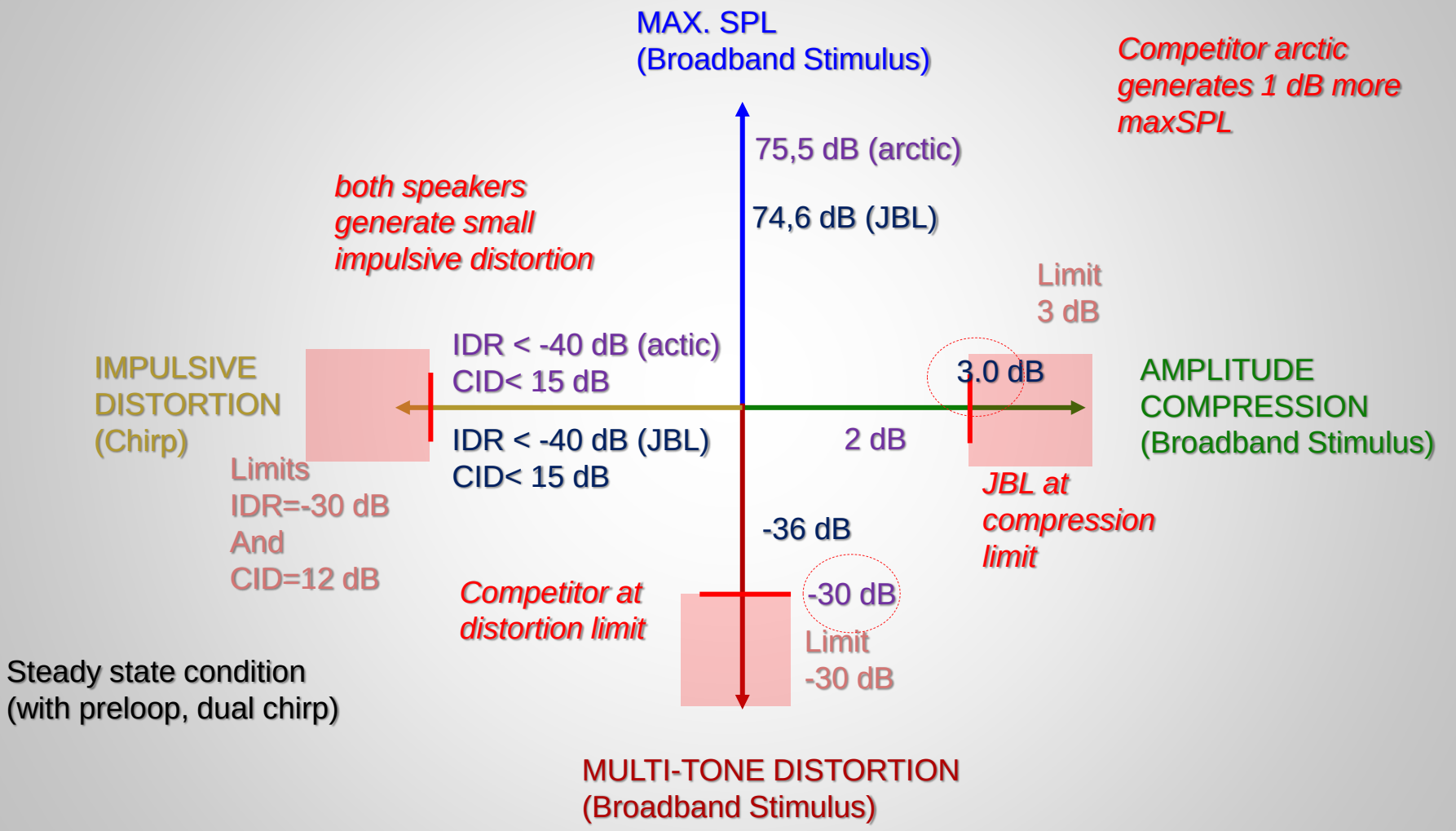
Demo

Benchmarking: Rating maxSPL by customer

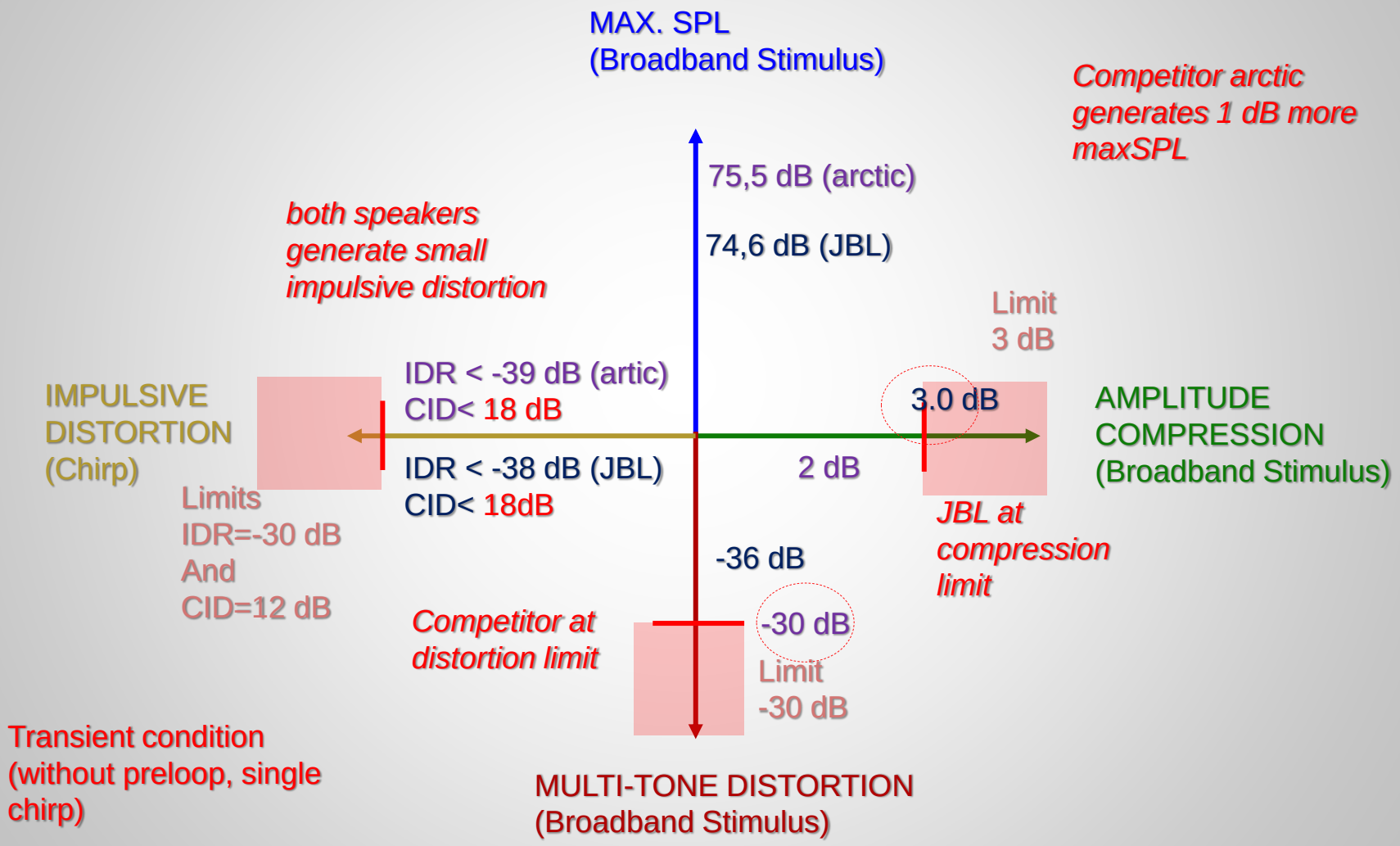
Tools: Using dedicated software modules of the KLIPPEL Analyzer

- NFS Near field scanning
- ISC In-situ Room Compensation
- TRF PRO (transfer function)
- TRF Stepping
- MTON Multi-tone Measurement

Benchmarking of the two Bluetooth Speakers by customer using same limits



Benchmarking of the two Bluetooth Speakers by customer using same limits



Summary

- IEC 60268-21为基准音频产品提供了有用的方法和有意义的特征 IEC 60268-21 provides useful methods and meaningful characteristics for benchmarking audio products
- 额定maxSPL是测试和基准测试的重要特征
  Rated maxSPL is an important characteristic for testing and benchmarking
- 有效频率范围和与目标响应的平均偏差是重要的小信号特征Effective frequency range and the mean deviation from target response are important small signal characteristics
- 幅度压缩、多音失真和脉冲失真为评估大信号性能提供了必要信息
  Amplitude compression, multi-tone distortion and impulsive distortion give essential information of assessing the large signal performance
- 考虑到特定的目标应用，必须为每个度量标准定义界限值和允许的公差 Limits and permissible tolerance have to be defined for each metric considering the particular target application

Open Questions

IEC 60268-21的范围仅限于物理测量。标准测试如何与感知评估联系起来? The scope of IEC 60268-21 is limited to physical measurements. How can standard tests be linked to perceptual evaluation ?

第13期KLIPPEL网络研讨会主题 The next 13th KLIPPEL live webinar entitled

信号失真的可听化 – 感知评估

Auralization of signal distortion – perceptual evaluation

将讨论 will address the points:

- 如何用普通的音频激励信号（音乐、语音）测试音频系统
  How to test audio systems with ordinary audio stimuli (music, speech)
- 如何分离密集频谱激励中的线性、时变和非线性失真
  How to separate linear, time-variant and nonlinear distortion in stimuli with a dense spectrum
- 如何结合物理和感知测试 How to combine physical and perceptual testing
- 如何评估信号失真的掩蔽效应 How to evaluate the masking of signal distortion

Next Section

1. Modern audio equipment needs output based testing
2. Standard acoustical tests performed in normal rooms
3. Drawing meaningful conclusions from 3D output measurement
4. Simulated standard condition at a single evaluation point
5. Maximum SPL – giving this value meaning
6. Selecting measurements with high diagnostic value
7. Amplitude Compression – less output at higher amplitudes
8. Harmonic Distortion Measurements – best practice
9. Intermodulation Distortion – music is more than a single tone
10. Impulsive distortion - rub&buzz, abnormal behavior, defects
11. Pitfalls in Testing Wireless Audio Devices
12. Benchmarking of audio products under standard conditions
13. Auralization of signal distortion – perceptual evaluation
14. Setting meaningful tolerances for signal distortion
15. Rating the maximum SPL value for product