Acoustical Measurement of Sound System Equipment according IEC 60268-21

KLIPPEL LIVE

a series of webinars presented by

Wolfgang Klippel

Targets of the Webinar

- Apply the new IEC standard 60268-21 in practice (e.g. testing an active speaker)
- Perform the acoustical measurement in normal rooms by generating simulated free field conditions
- Speed up directivity measurement and investigate speaker-room interaction
- Comprehensively test the signal distortion generated by artificial test stimuli and common audio signals
- Interpret measurement results, avoid pitfalls, other tips
- Linking the physical and perceptual evaluation of audio systems
- Discuss open question

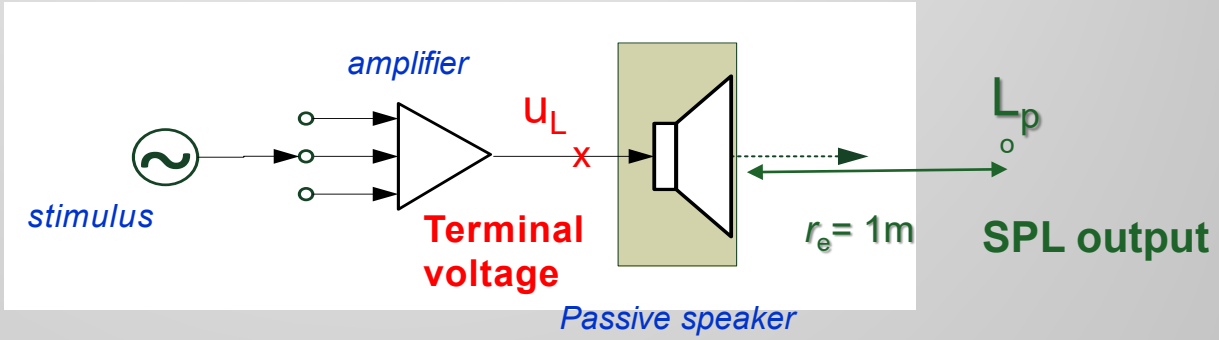
1st Section

ACOUSTICAL (OUTPUT BASED) MEASUREMENTS

Agenda today

1. Problems in testing of modern devices
2. Solutions provided by IEC Standard 60268-21
3. Standard measurement condition
4. Freedom, flexibility for the particular application
5. Consequences for the practical work
6. Questions, Discussion

Testing of Passive Loudspeaker Systems

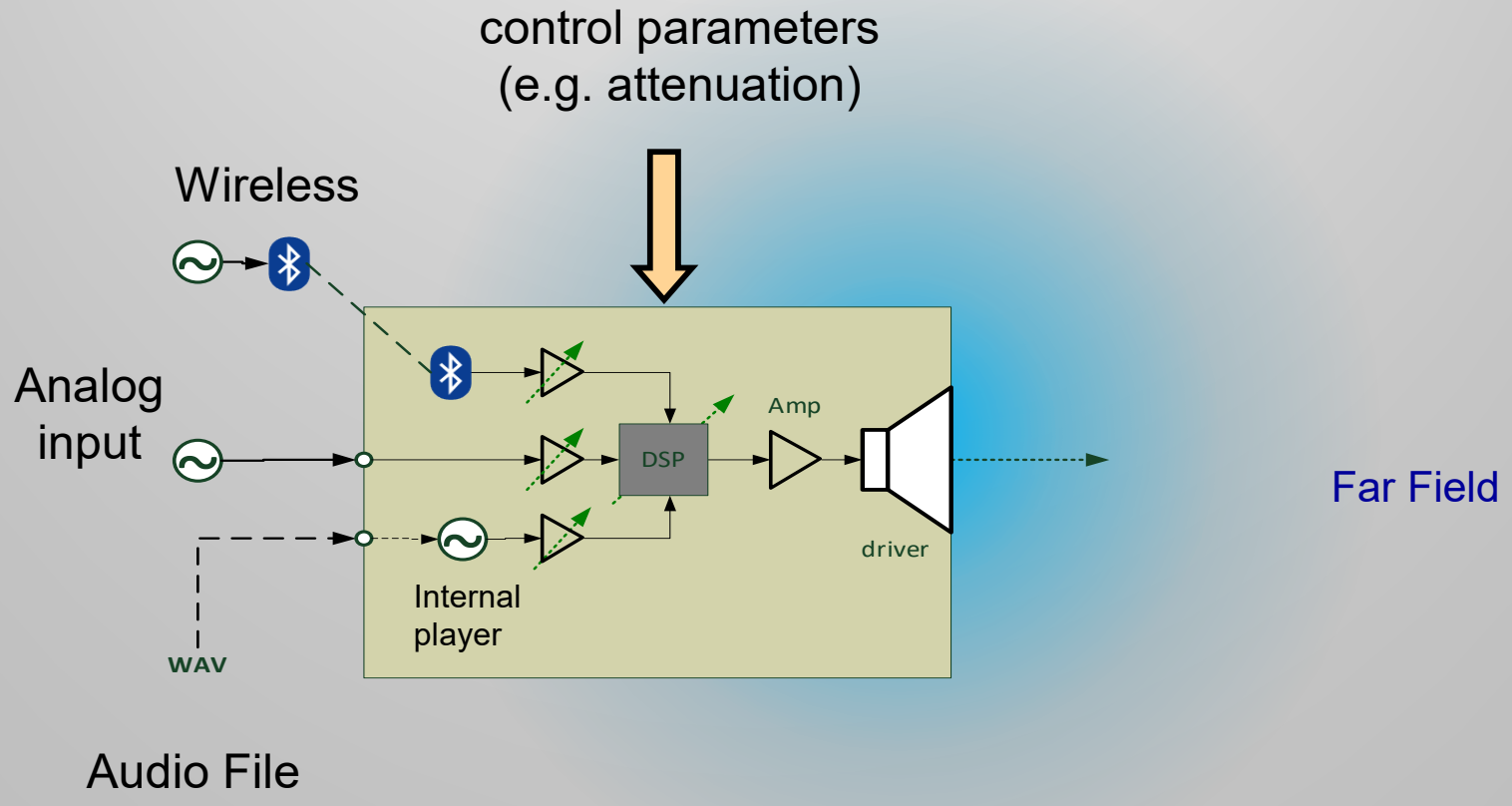


Defining the terminal voltage u_L (corresponding to an nominal input power P_N) of the amplified stimulus was the simple and convenient basis for testing transducers and passive loudspeaker systems (see IEC 60268-5).

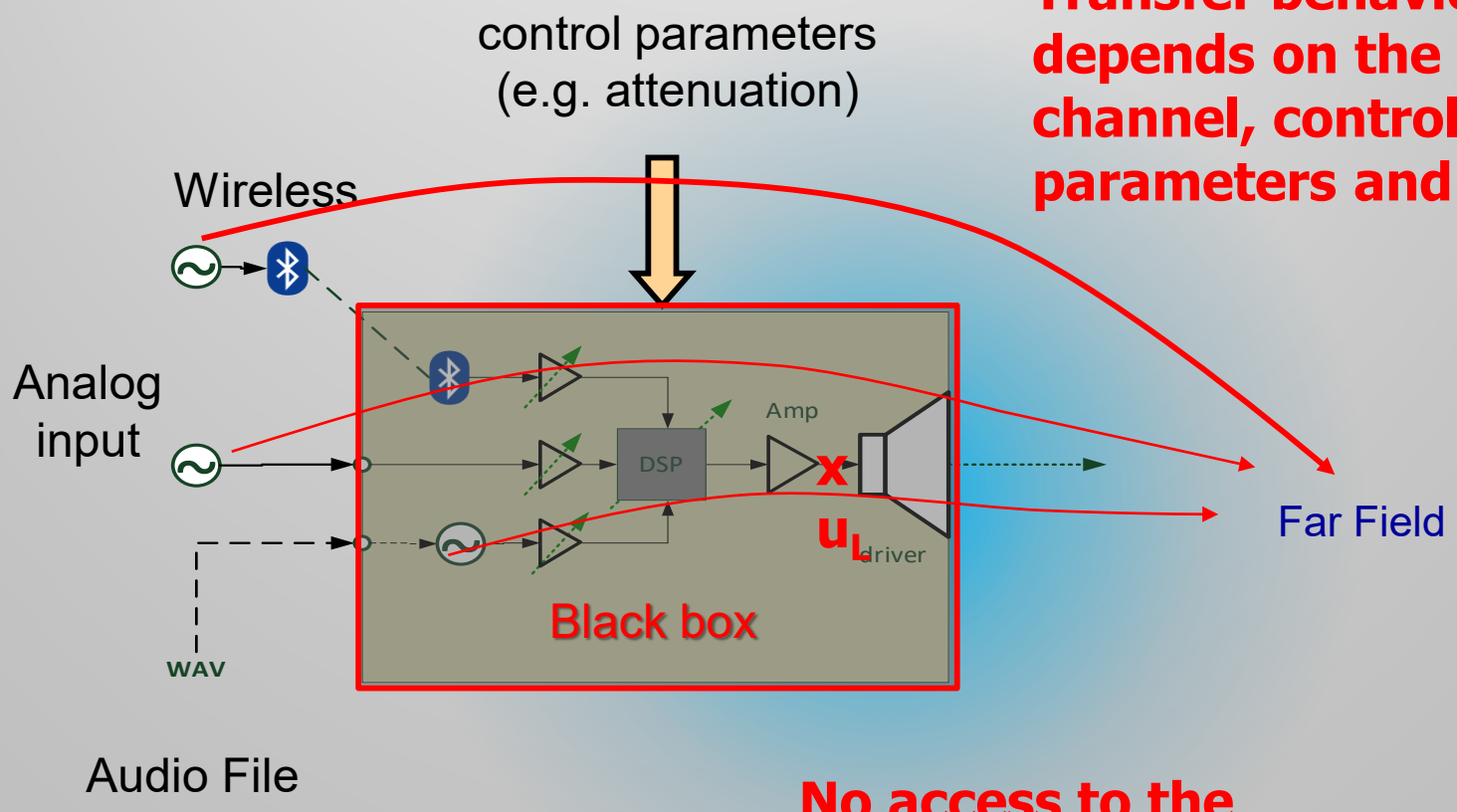
For example, the sensitivity of a passive loudspeaker can be expressed as

$$L_p = 70 \text{ dB @ 1m, 2.8 V (1 W)}$$

Modern Audio Device



Consequences for Testing



Transfer behaviour depends on the input channel, control parameters and DSP

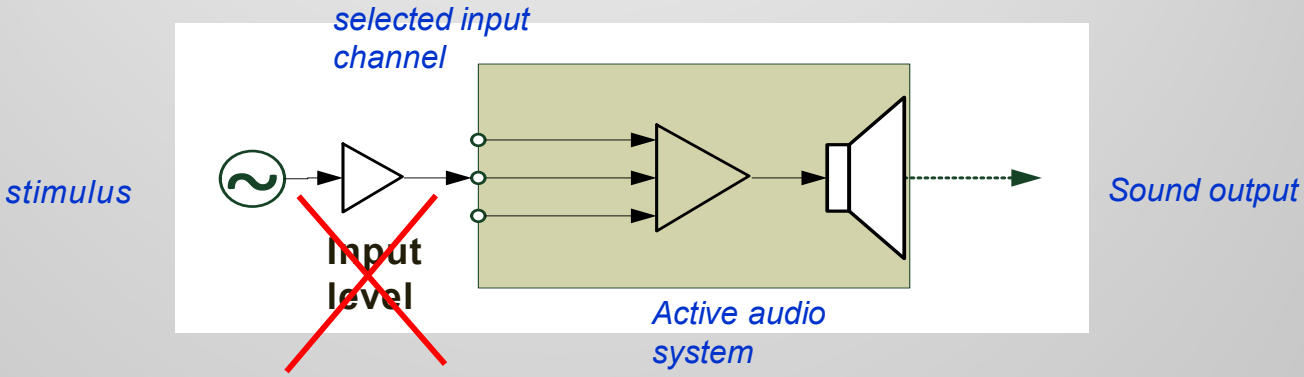
No access to the transducer voltage u_L

Poll:

Do you measure the sensitivity of active audio systems?

- No
- Yes

Problems for Testing Active Audio Systems

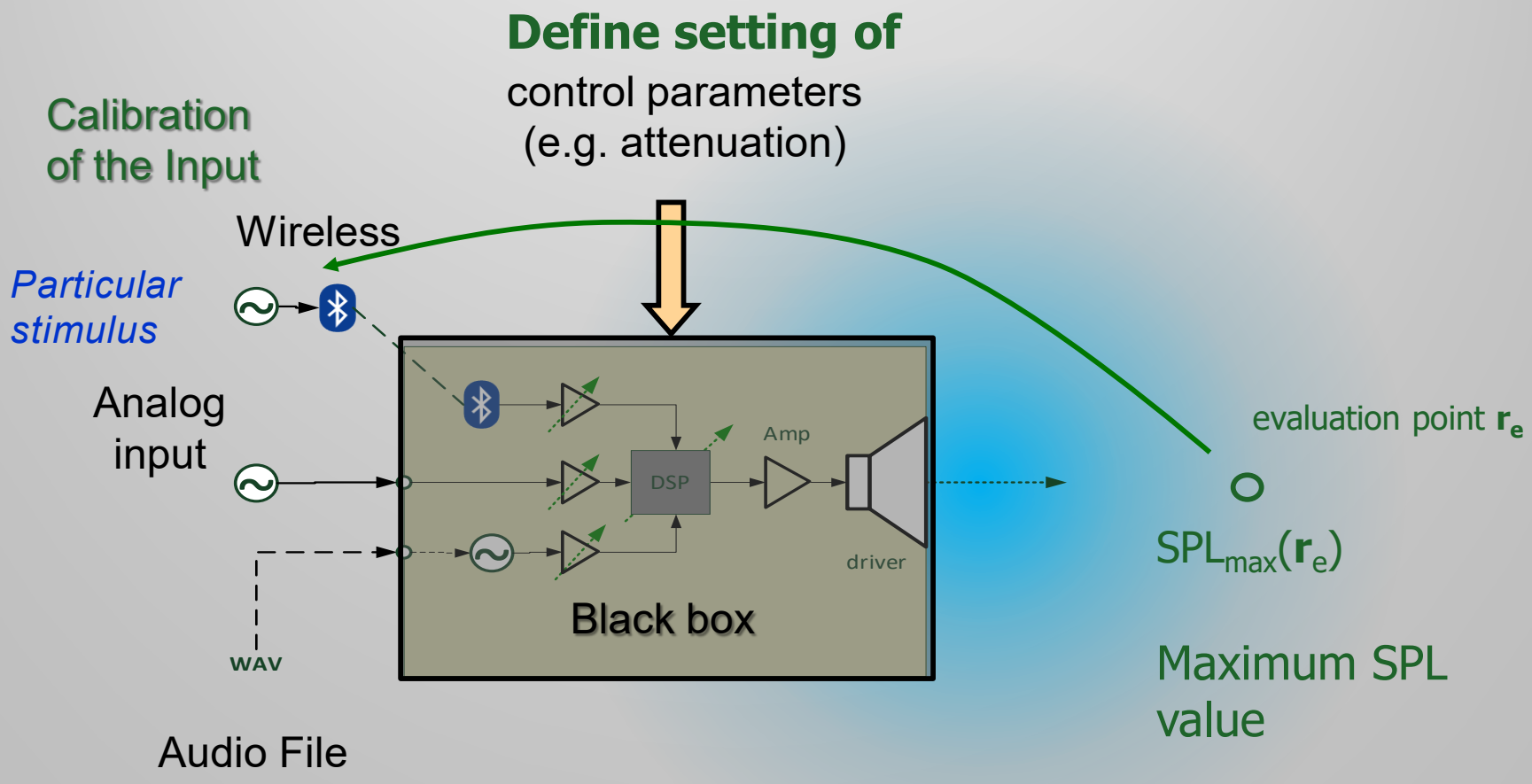


Input level, voltage, electrical input power become less useful for defining the test condition!

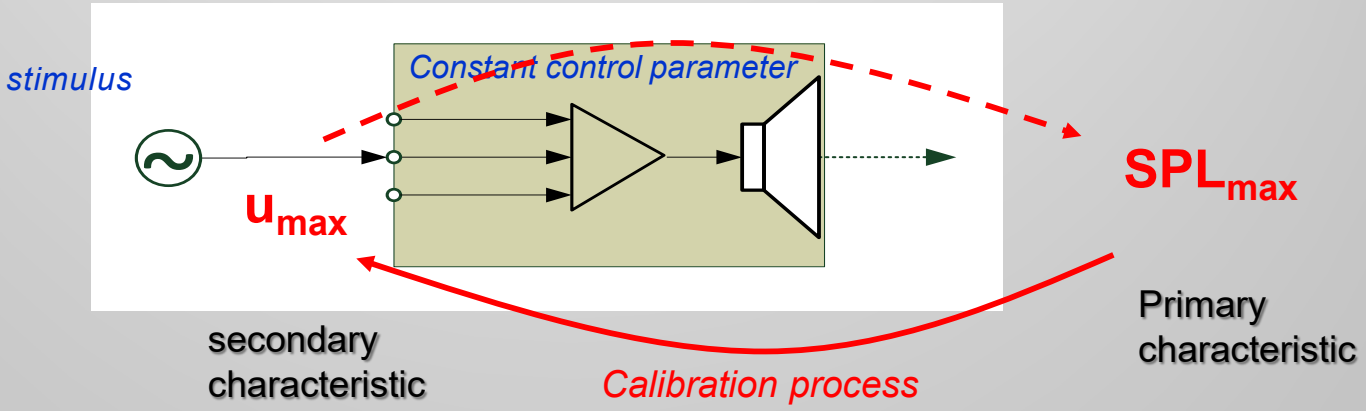
Issues of how to:

- specify the amplitude of the stimulus?
- benchmark different devices having different input channels?
- ensure repeatability and reproducibility of those test?
- avoid an overload of the device under test?
- define small signal measurements?
- find a simple and practical solution?

Solution provided by IEC 60268-21



Maximum Input and Output Value



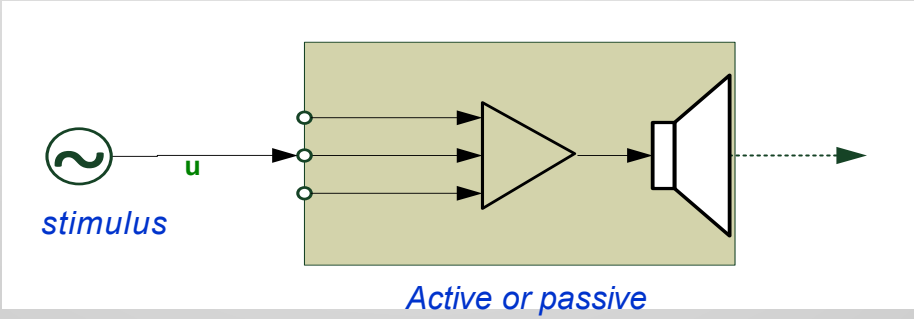
Rated maximum input voltage u_{max}

- Good for (passive) systems with a single input and constant transfer function between input and output
- Depends on the input channel
- Depends on the control parameter

Rated maximum (output) SPL_{max}

- Universal approach for passive and active systems
- Can be applied to any input channel
- Can cope with gain controllers, equalizers, limiters, protection systems, ect.

Who determines the maximum SPL value ?



$SPL_{max}(r_e)$

Definition by IEC 60268-21

- Manufacturer rates the measurement condition (e.g. stimulus, position, environment)
- Manufacturer rates SPL_{max} based on information from design, practical measurements and the target application

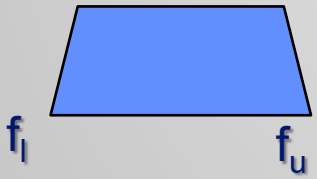
Requirement

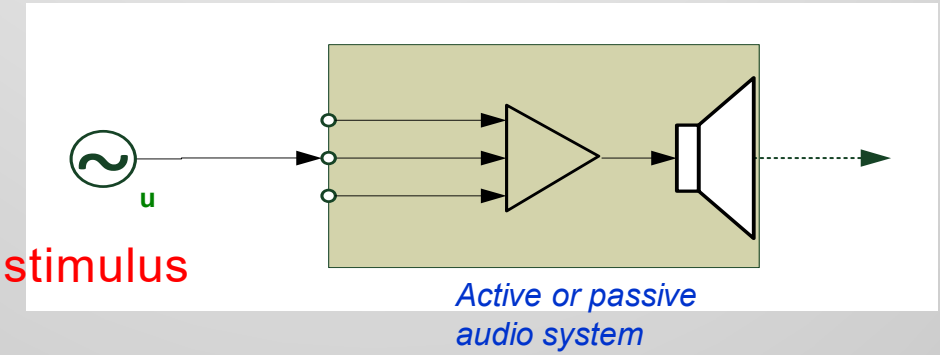
- DUT can reproduce a defined test stimulus at rated maximum SPL
- DUT will **not be damaged** by the test stimulus during 100h power test

Benefit

- Maximum SPL value is meaningful for engineering, marketing, final user

Rated Conditions: Test Stimulus





$SPL_{max}(r_e)$

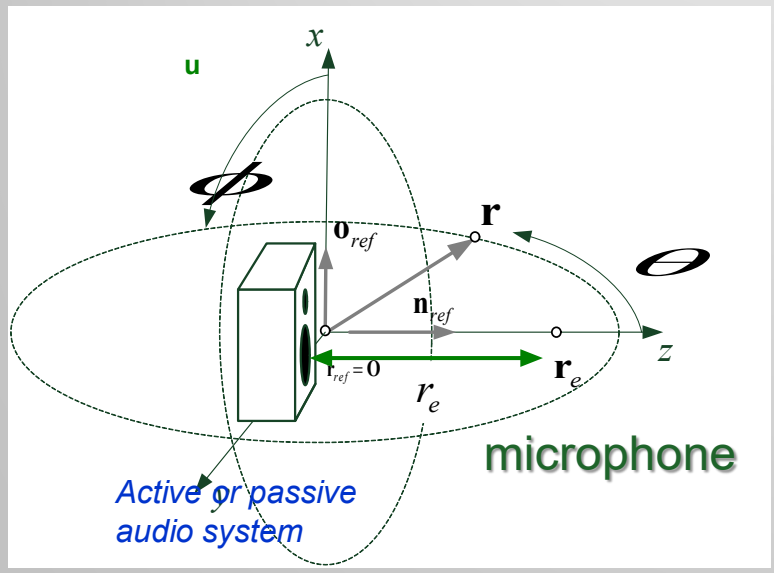
Stimulus Properties (IEC 60268-21) stated by the manufacturer:

- Broadband (pink or white noise, dense or sparse multi-tone complex)
- Lower and upper limits f_l and f_u of the rated frequency band
- Shaping of the power spectrum (e.g. typical program material IEC 60268-1)
- Crest factor (Kurtosis)

Benefit

- The test stimulus represents the typical program material in the final application

Evaluation Point r_e



Manufacturer states the geometrical conditions (IEC 60268-21)

Position of the audio system (DUT)

- Reference point $\mathbf{r}_{ref}$ (e.g. cone center)
- Reference axis (e.g. perpendicular to cone surface)
- Orientation vector $\mathbf{o}_{ref}$ (e.g. upright position)

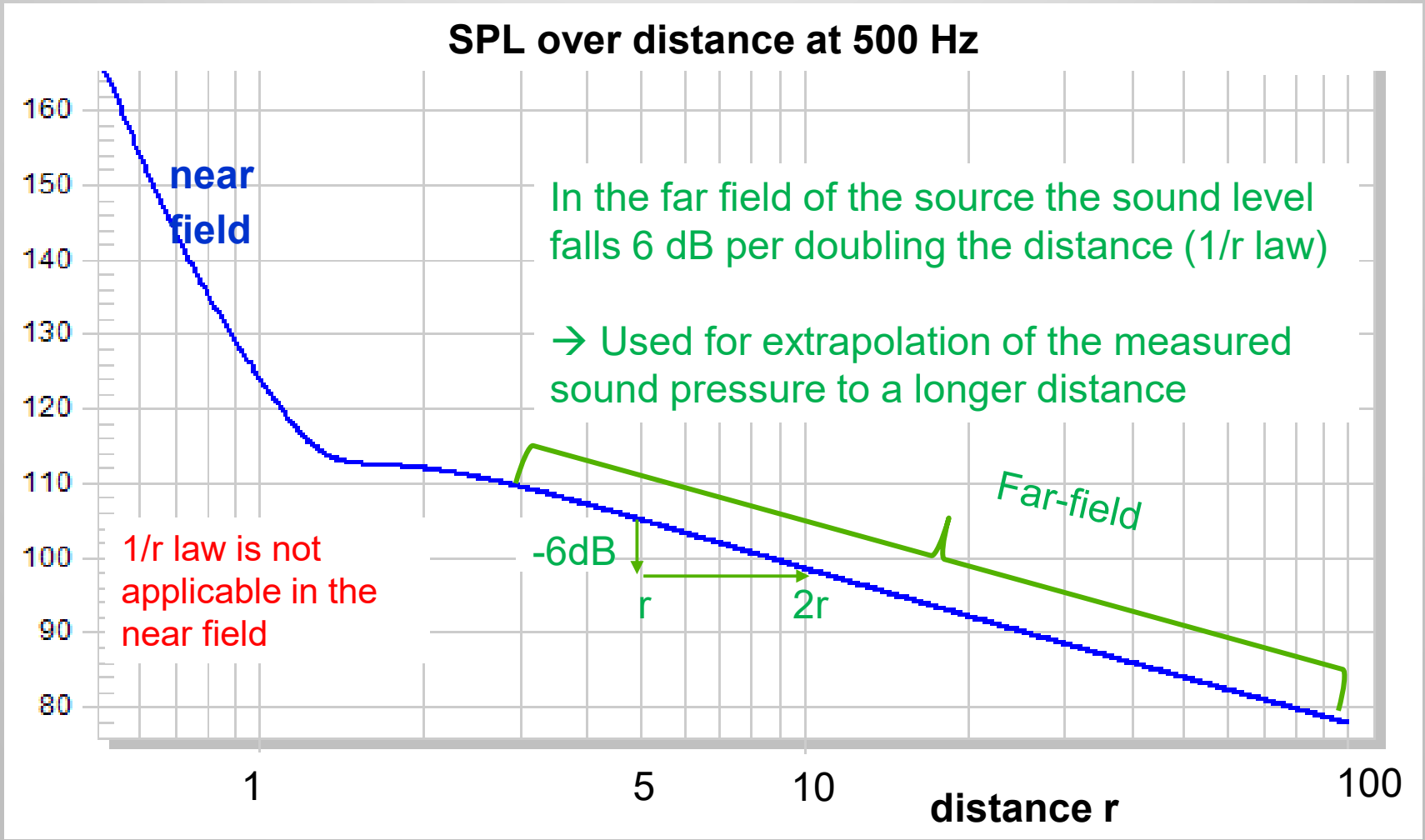
For example:
1 m distance on-axis

Is the evaluation point in the near or in the far field ?

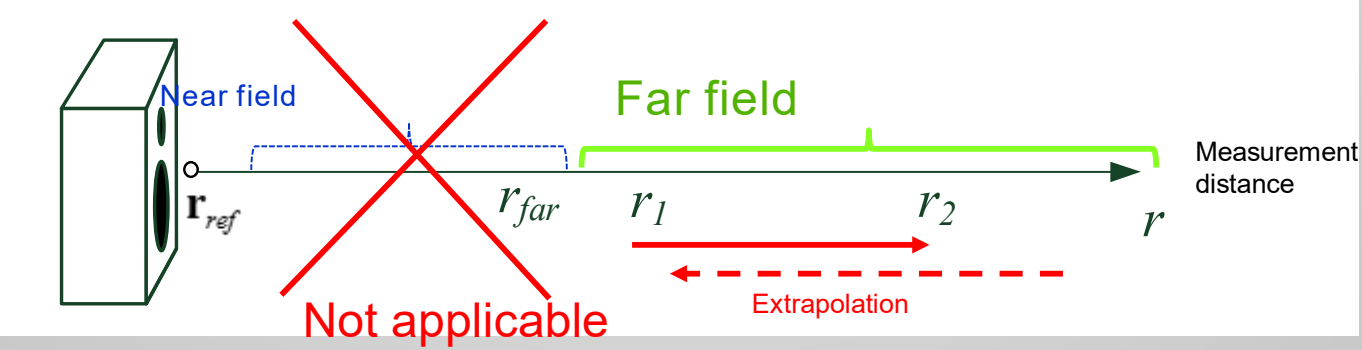
Position of the microphone

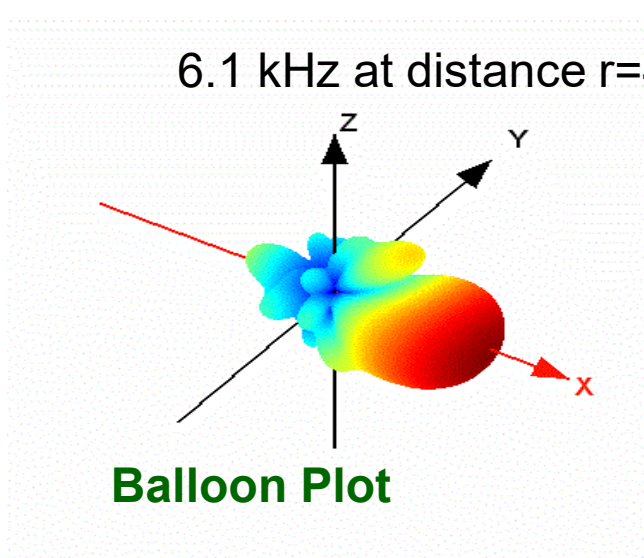
- Evaluation point $\mathbf{r}_e$ (usually on the reference axis)
- evaluation distance r_e between reference point $\mathbf{r}_{ref}$ and evaluation point $\mathbf{r}_e$

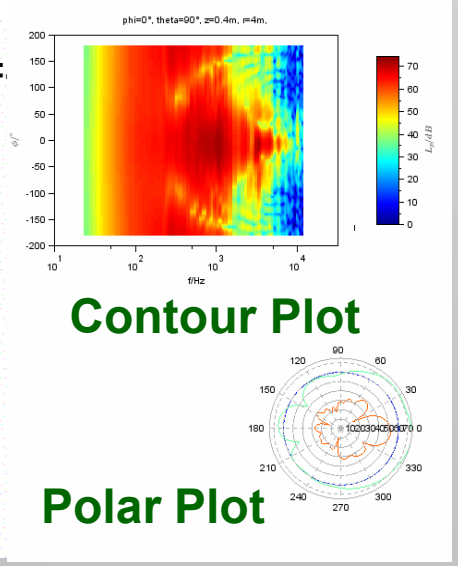
Why are Far-Field Conditions Used ?



Extrapolation of Far Field data







$$\underline{H}(f, r_2, \theta, \phi) = \underline{H}(f, r_1, \theta, \phi) \frac{r_1}{r_2} e^{-jk(r_2 - r_1)}$$

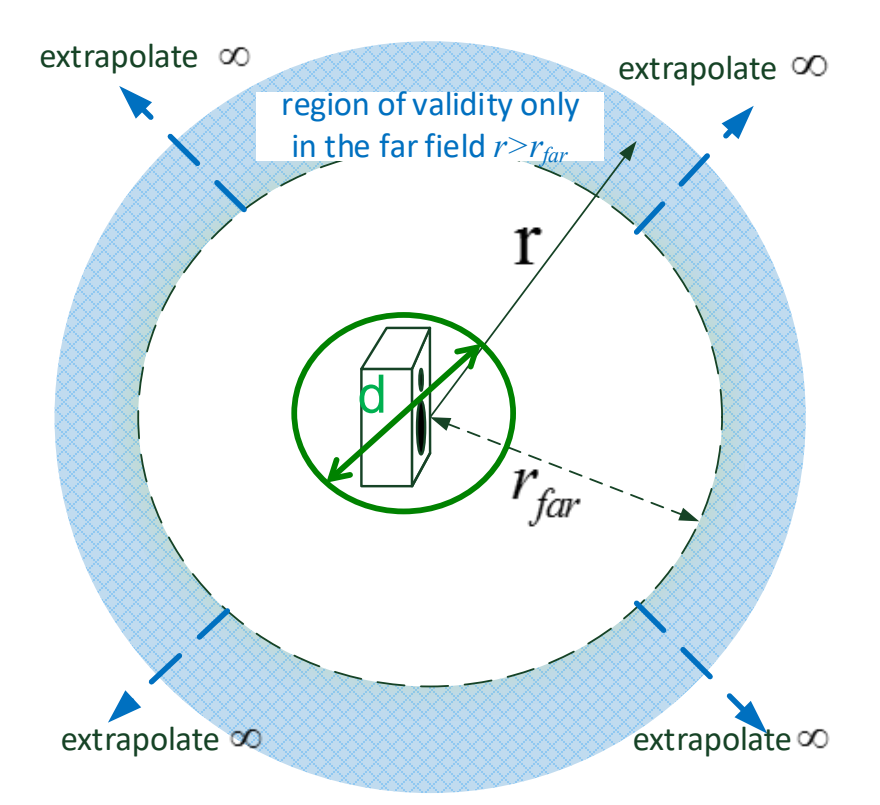
Requirements:

- free field condition (direct sound)
- *far field condition*
- same direction ($\phi_2 = \phi_1$, $\theta_2 = \theta_1$)

How to Ensure Far-Field Conditions ?

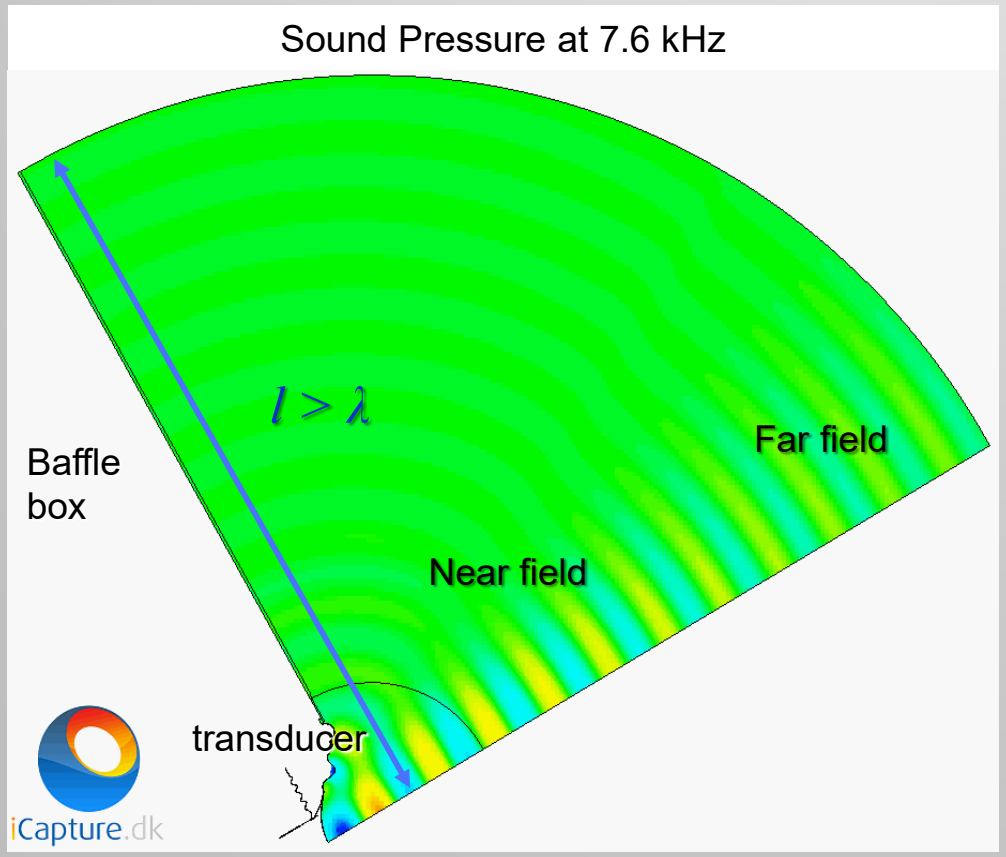
Requirements:

- *Distance $r_{far} >> d$*
  (critical for large geometrical dimension d, e.g. line array)
- *Distance $r_{far} >> \lambda$*
  (critical at long wavelength λ, e.g. subwoofer)
- *ratio $r_{far}/d >> d/\lambda$*
  (critical at short wavelength λ and large radiator dimension d, e.g. panel speaker)



→ Large loudspeaker systems require large anechoic rooms ! (e.g. line arrays)

Relevance of Near-Field Characteristics



1. **Sound source has large dimensions** (e.g. line array)

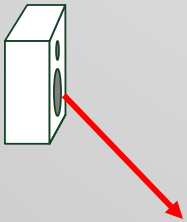
→ anechoic room is too small
→ measurement point not in the far field

2. The listener is close to the source (e.g. personal audio equipment, car, multimedia, studio monitor, home equipment)

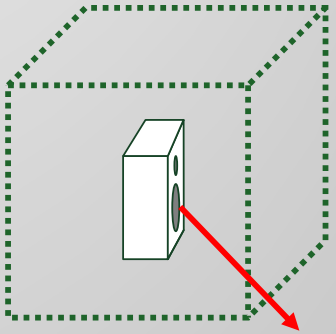
→ far field data are less meaningful

Acoustical Test Environment

Free-field condition

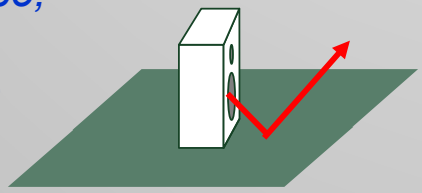


Simulated free-field condition

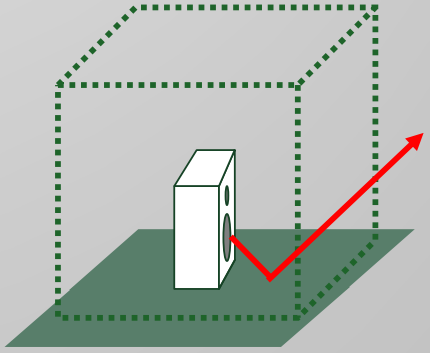


Transparent boundaries

Half-space, free-field condition

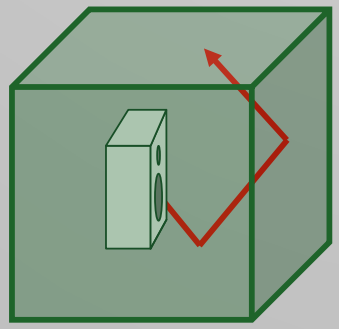


Simulated half-space, free-field condition

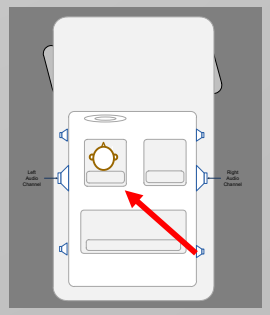


reflecting boundaries

Diffuse sound condition



Target application condition



Free-field Condition according IEC 60268-21

Problems:

- **Anechoic rooms are not perfect!** Insufficient absorption generates wall reflections and standing waves at low frequencies.
- **Finite size of the half space!** Edges generate sound reflections.
- **Gating techniques are limited at low frequencies!** Insufficient distance to the boundaries (ground, walls, furniture) generates reflections which can not be separated by windowing of the impulse response.

Consequences:

Error in the measurement of the direct sound radiated from the DUT.

IEC Requirement:

State the limits of the valid frequency range where the measurement errors in the sound pressure exceed ±0.5 dB in amplitude and ±10° in phase.

Practical Solution:

Near field measurement with separation of outgoing and incoming waves.

Other Test Conditions

IEC 60268-21: Sound System Equipment, Part 21 Acoustical (output based) Measurements describes in detail:

- Climatic Test Condition
- Preconditioning of the Device
- Mounting of the Device under test
- Additional information required (e.g. type description, design data)

Summary of the 1st section

- A single value SPL_{max} is the basis for acoustical testing of modern audio systems
- The manufacturer shall rate this value SPL_{max} according to IEC requirements.
- The manufacturers assures that the device can generate the SPL_{max} at the rated condition without damage.
- The manufacture determines the physical and perceptual audio performance at the rated SPL_{max} according the particular application.

Discussion

Open Questions

How to

- perform standard measurements in a normal room?
- generate SIMULATED free-field conditions according IEC 60268-21?

Open Questions

How to:

- perform standard measurements in a normal room?
- generate SIMULATED free-field conditions according IEC 60268-21?

The upcoming 2nd webinar will address:

- Practical limits of windowing direct sound in the impulse response
- Near field scanning and holographic processing
- Direct sound separation by modeling the wave propagation

Next KLIPPEL LIVE in one week!

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 an 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. Benchmarking of audio products under standard conditions
12. Auralization of signal distortion – perceptual evaluation
13. Setting meaningful tolerances for signal distortion
14. Rating the maximum SPL value for a product
15. Smart speaker testing with wireless audio input