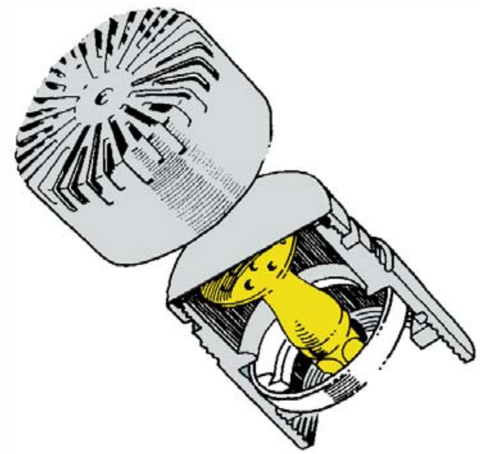
Fundamentals of Measuring Sound

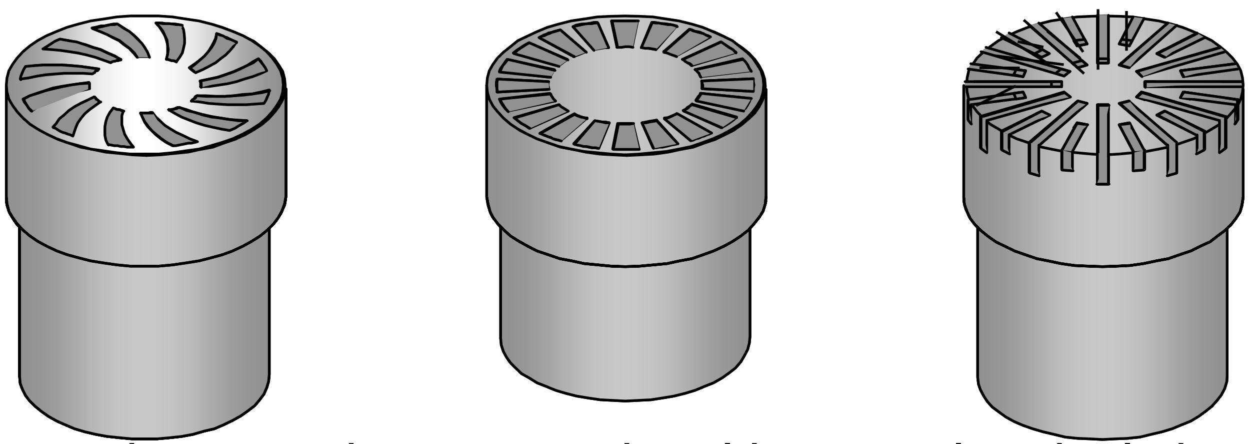
Contents:

Measuring Microphones (*Transducer*)



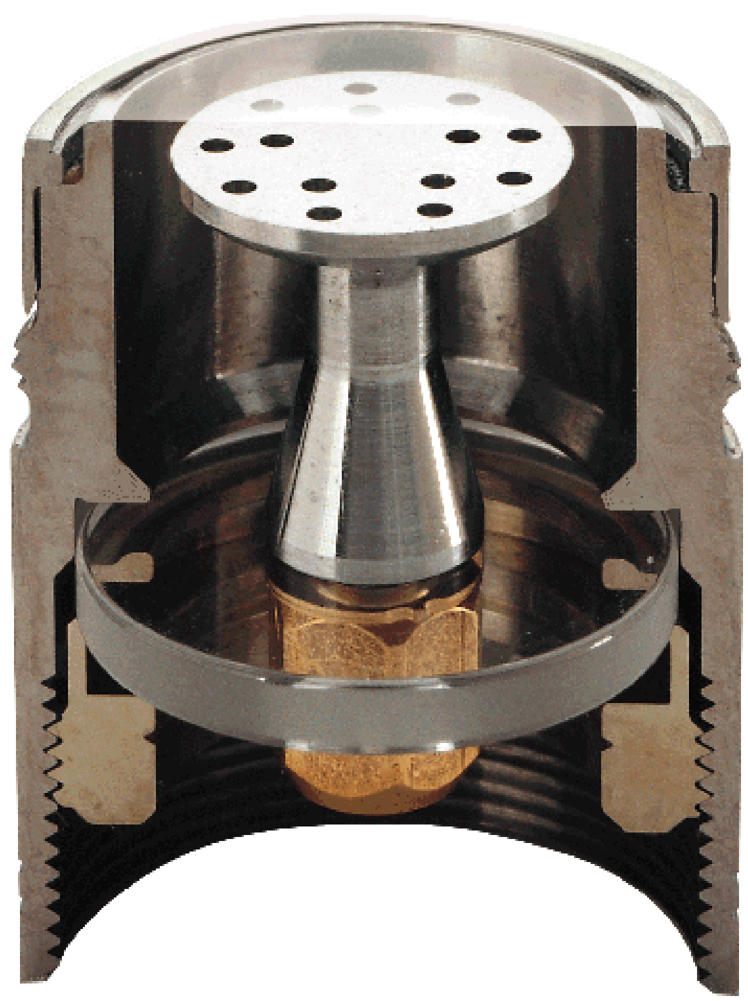
Features:

- Wide Frequency Range
- Flat Frequency Response
- Wide Dynamic Range
- Low Distortion
- Robust, long term stability
- Simple design
- …….



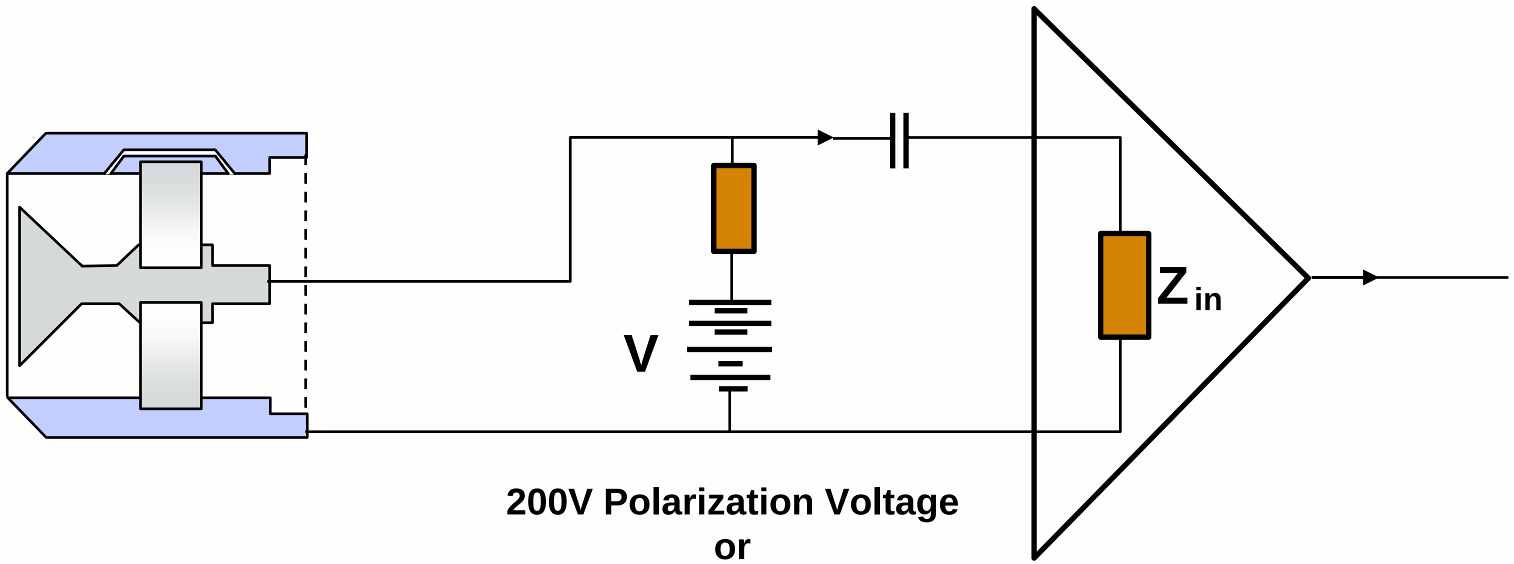
Converting sound pressure signal into an electrical signal

The Condenser Microphone



The Polarised Condenser Microphone

Principle of Operation



200V Polarization Voltage
or
prepolarized

$$\left.\begin{array}{l} Q = CV \\ C = \varepsilon \dfrac{A}{d} \end{array}\right\} \Rightarrow V = \frac{Q}{C} = \frac{Q}{\varepsilon A} d \Rightarrow \Delta V = \frac{Q}{\varepsilon A} \Delta d$$

How much does the diaphragm move ?

$$\frac{\Delta V}{V} = \frac{\Delta d}{d}$$

For typical measurement microphone:

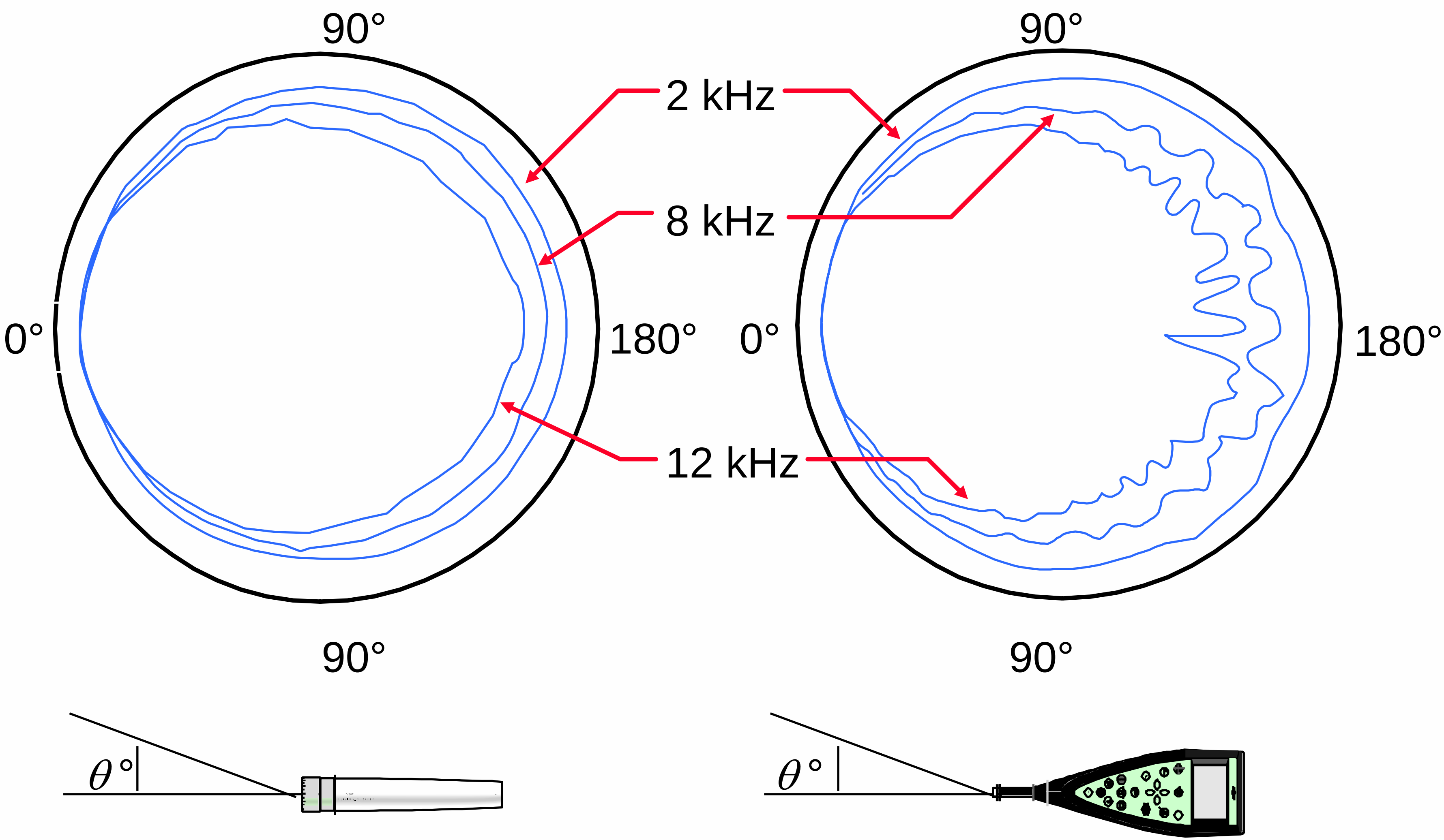
- diameter 12.5 mm
- thickness of diaphragm 5 µm
- distance between diaphragm and backplate 20 µm
- polarisation voltage 200 V
- sensitivity 50 mV/Pa

For 94 dB = 1 Pa the diaphragm moves

$$\Delta d = \frac{\Delta V \times d}{V} = \frac{50\text{ mV} \times 20\ \mu\text{m}}{200\text{ V}}$$
$$= 5\text{ nm}$$

Diameter of diaphragm	Pressure (level re 20µPa	Diaphragm's movement
12.5mm	1Pa (94dB)	5nm (5×10^{-9} m)
12.5mm	0.02Pa (60dB)	1 Å (10^{-10} m)
12500km (thickness of diaphragm 5km)	0.02Pa (60dB) 0.0002Pa (20dB)	0.1m (10^{-1} m) 0.001m (10^{-3} m)

Directional Characteristics



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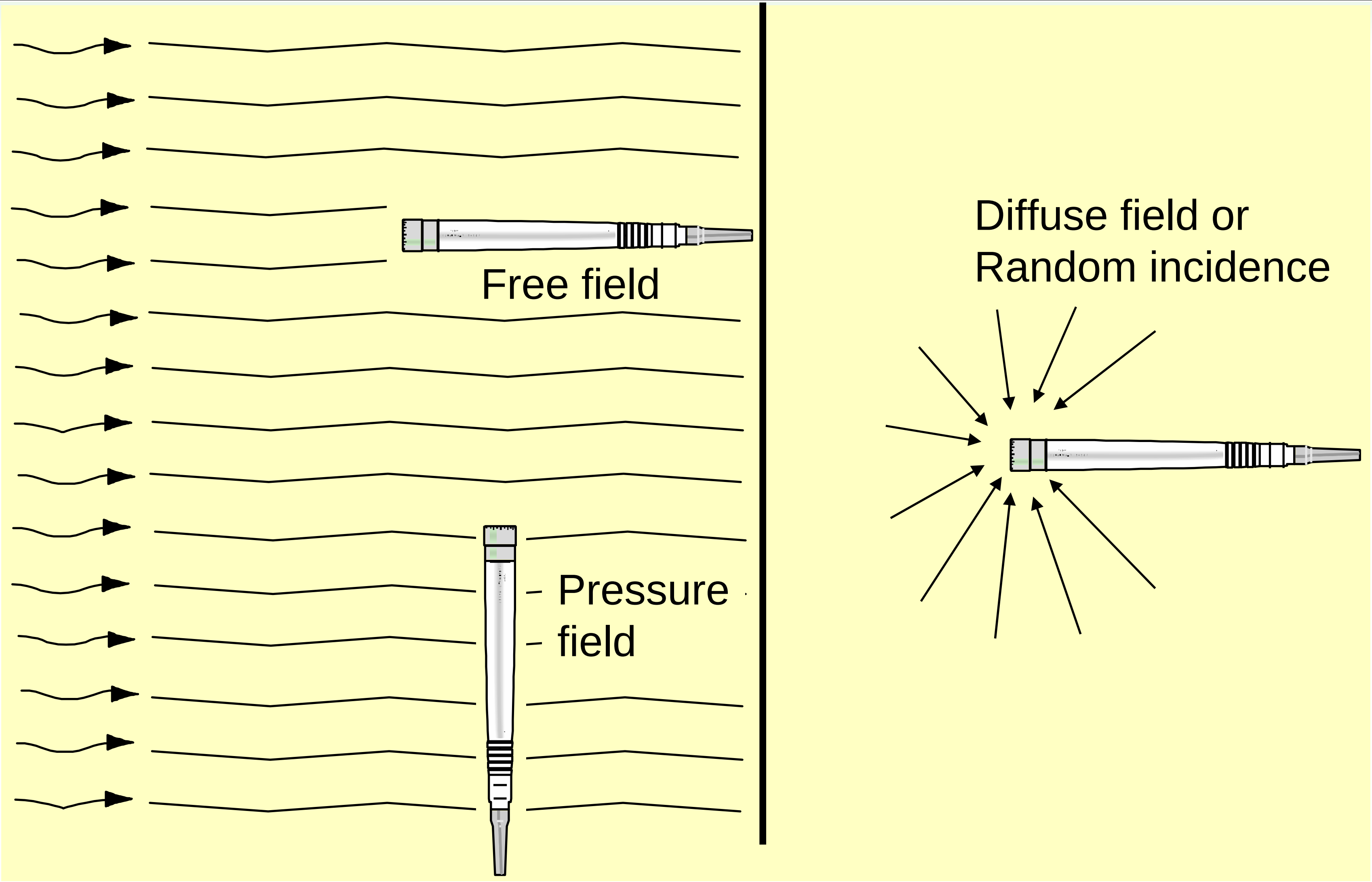
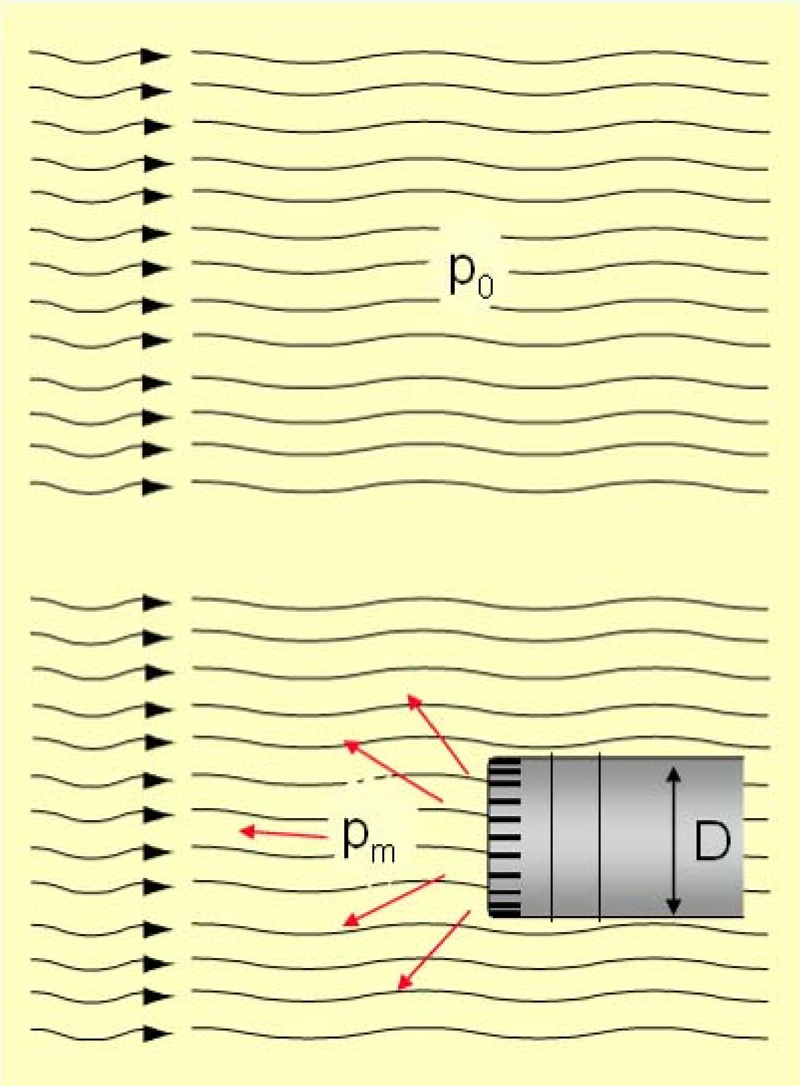
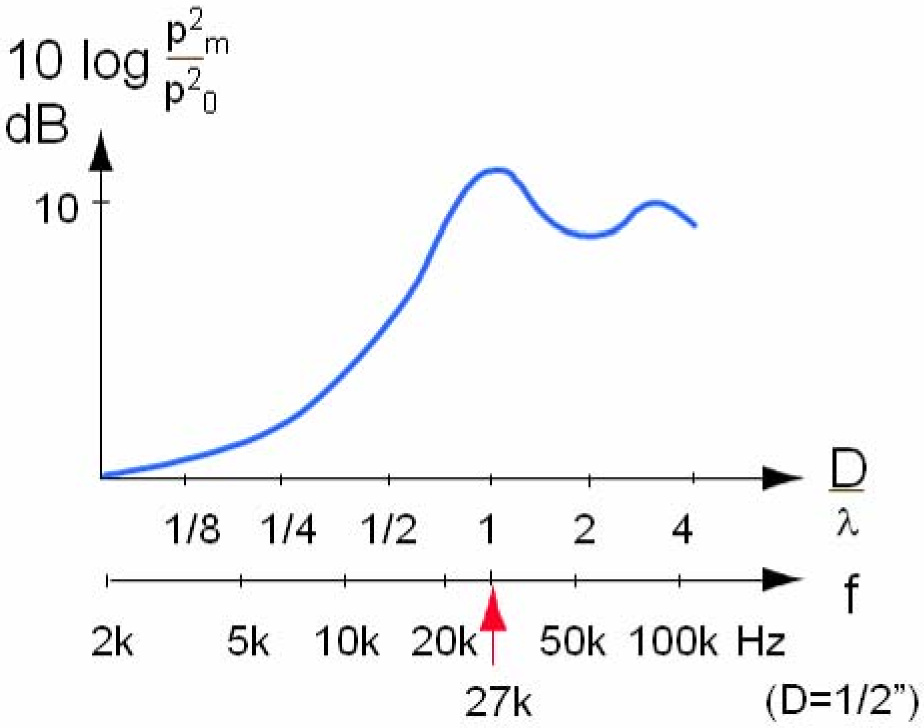
Types of Microphones



Free Field Correction





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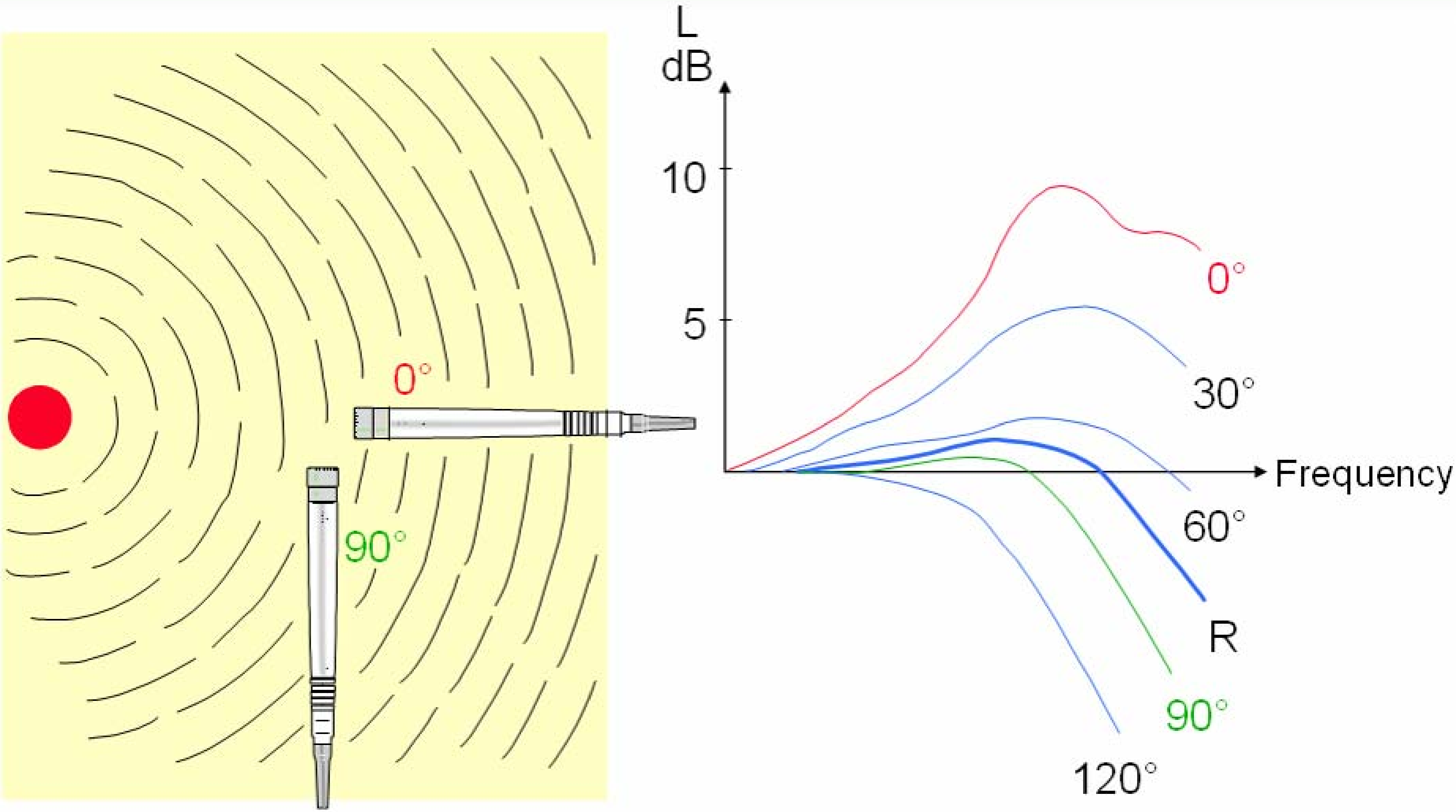
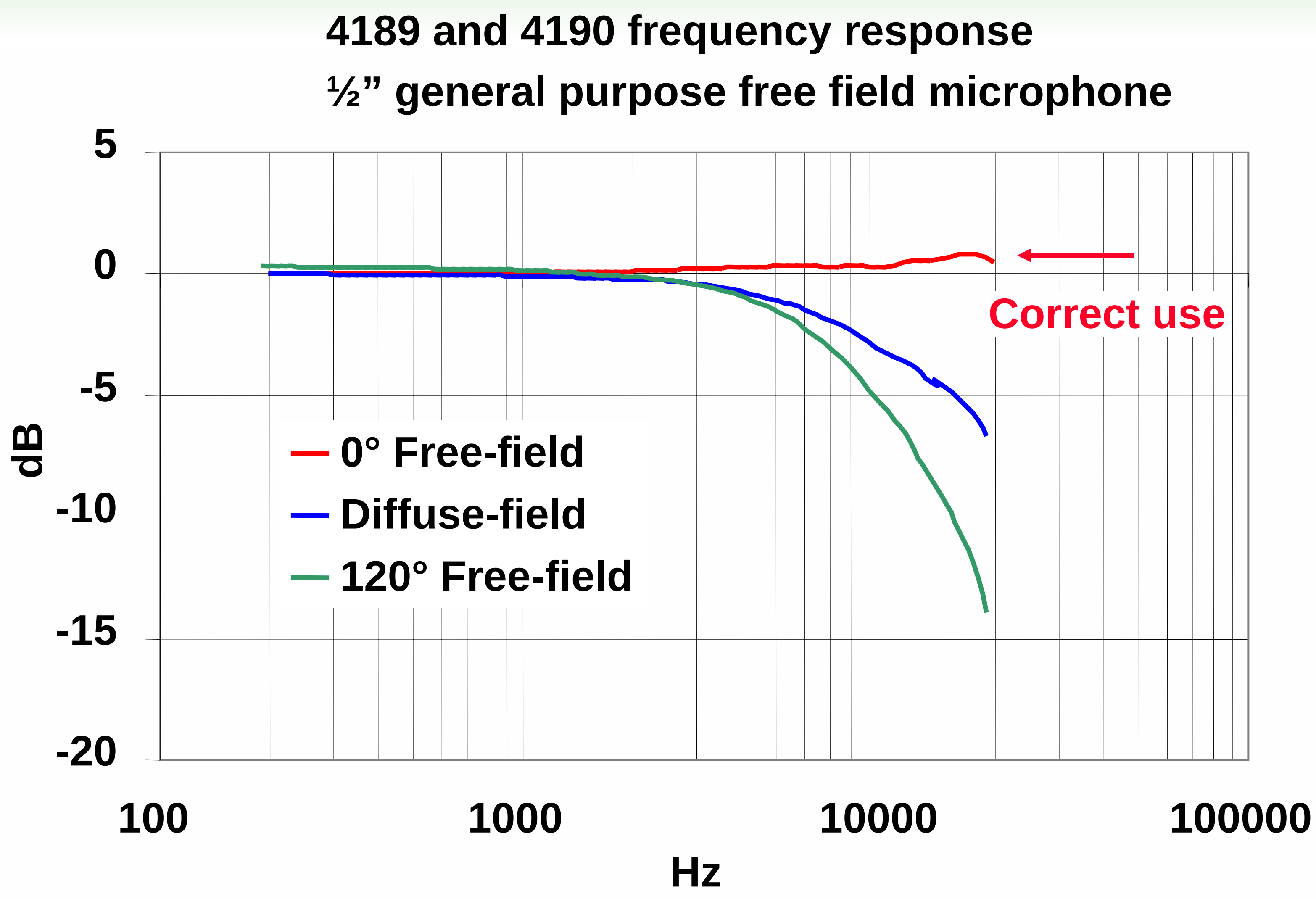
Free Field Correction

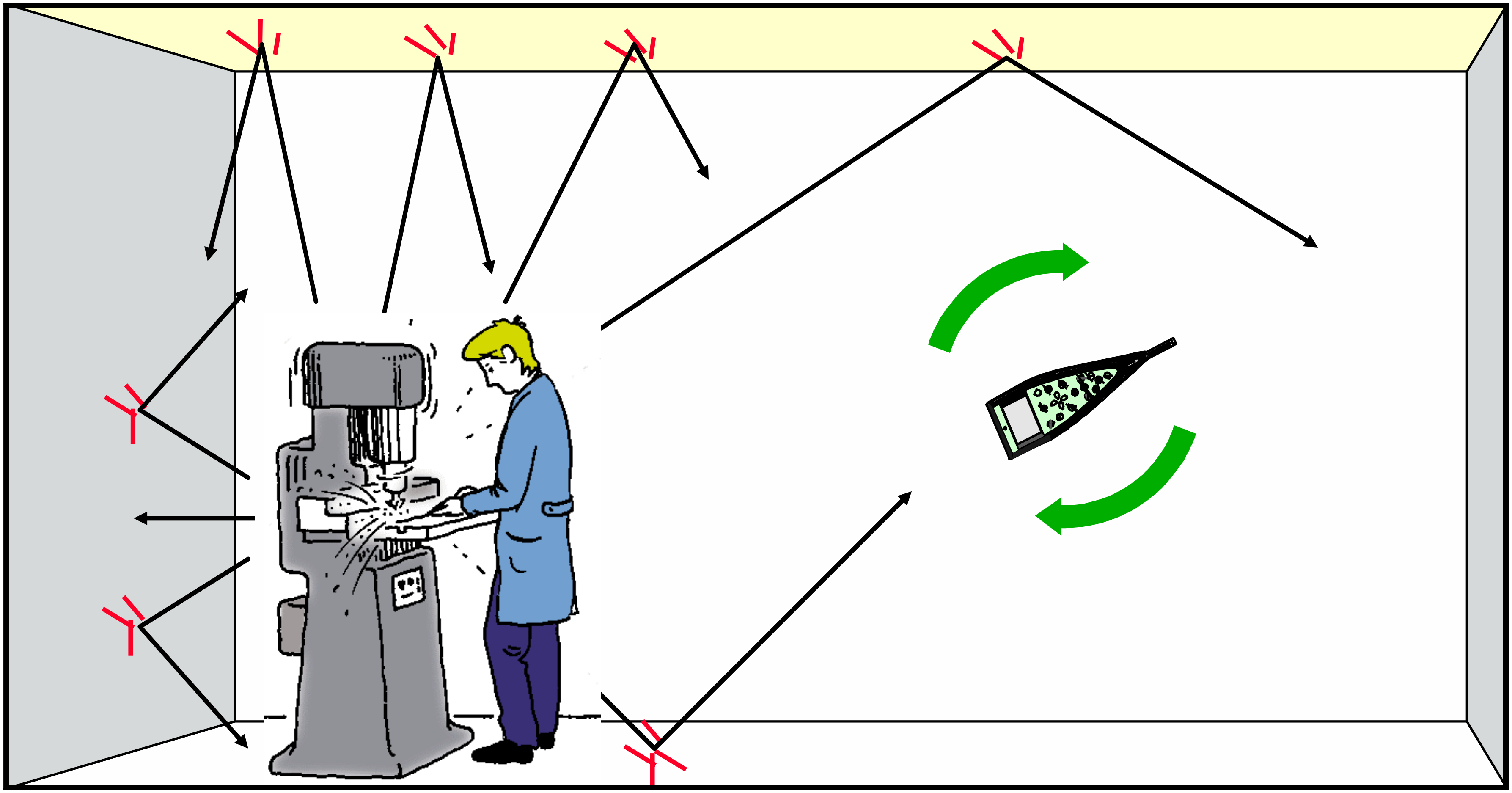


Use of Free Field Microphones

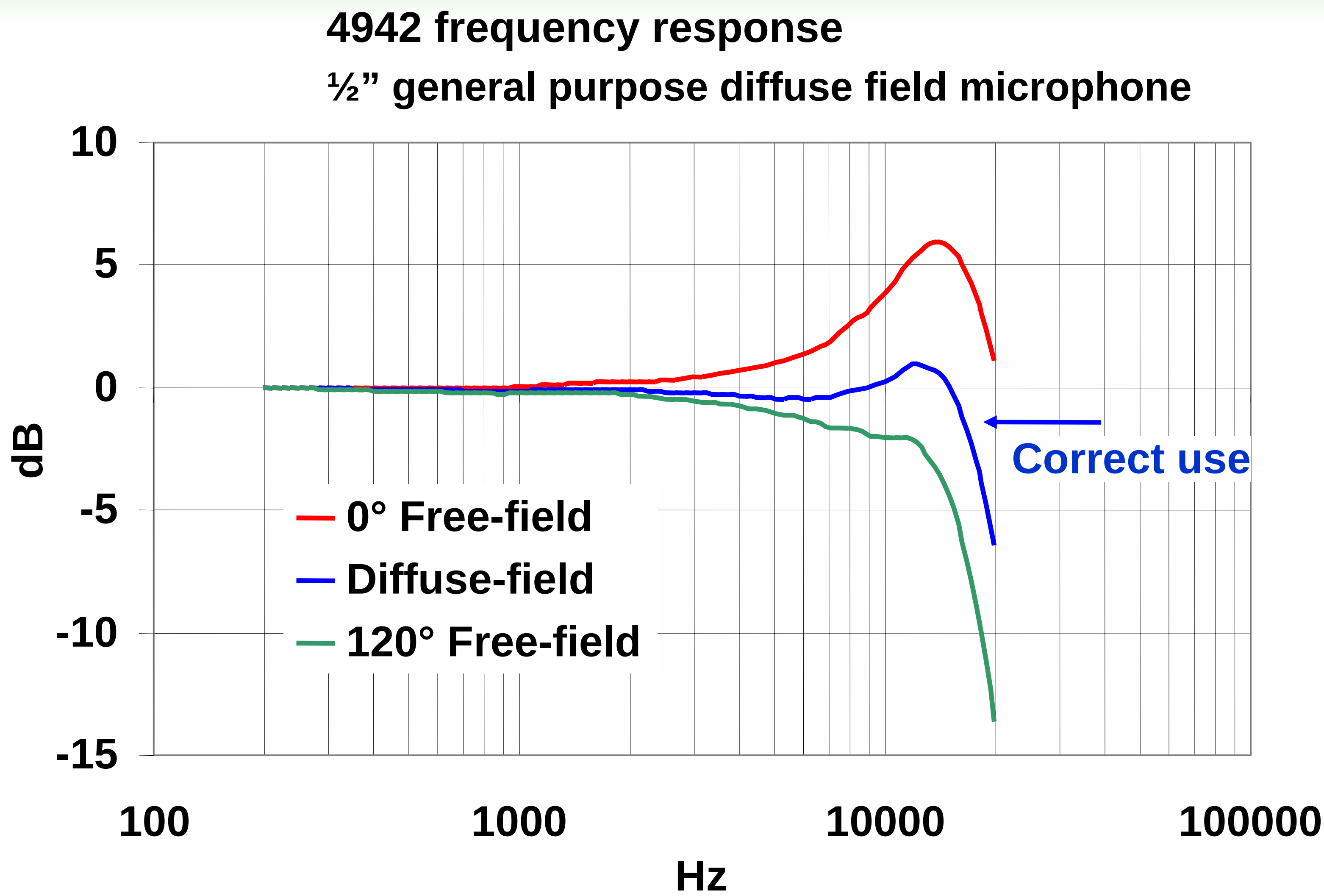
Free-field microphones - *One noise source*



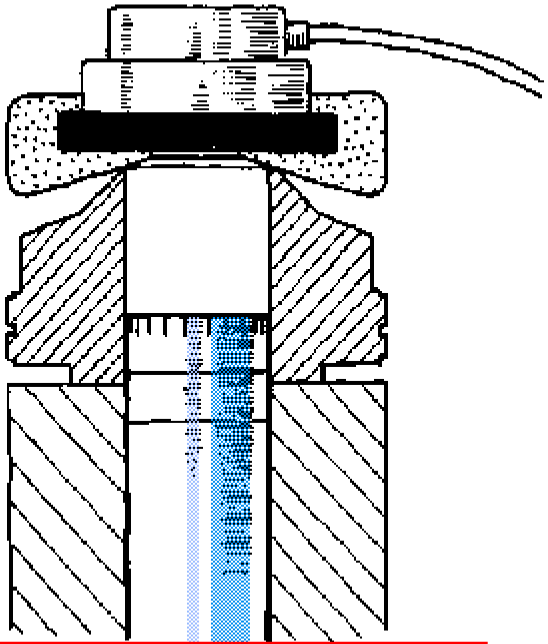
Use of Random Incidence Microphones



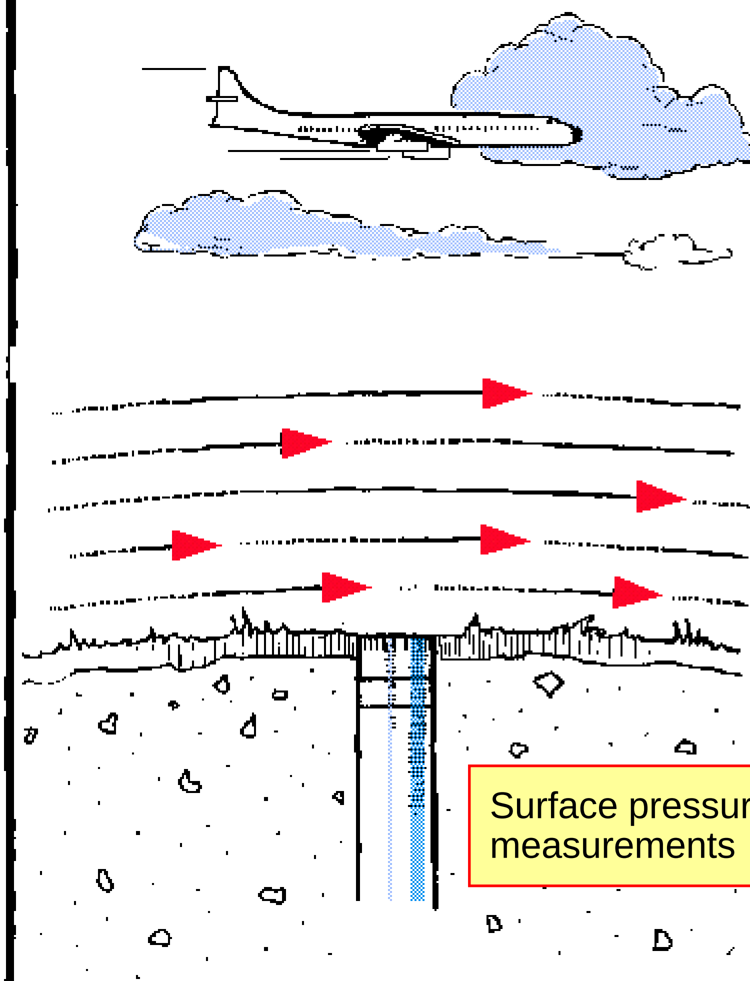
Diffuse-field microphones - *Interior noise*



Use of Pressure Field Microphones



Small enclosures as couplers and artificial ears.



Surface pressure measurements

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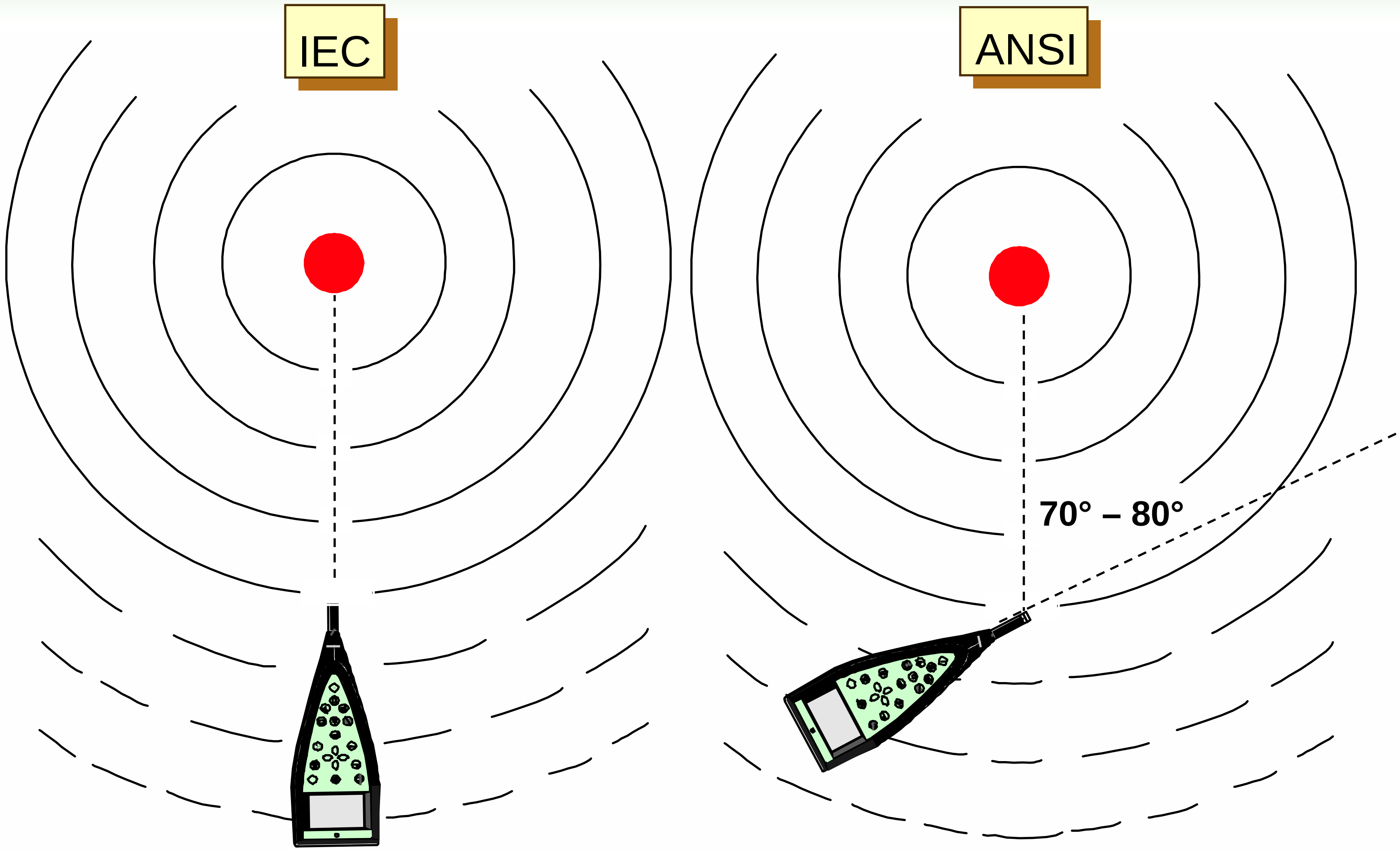
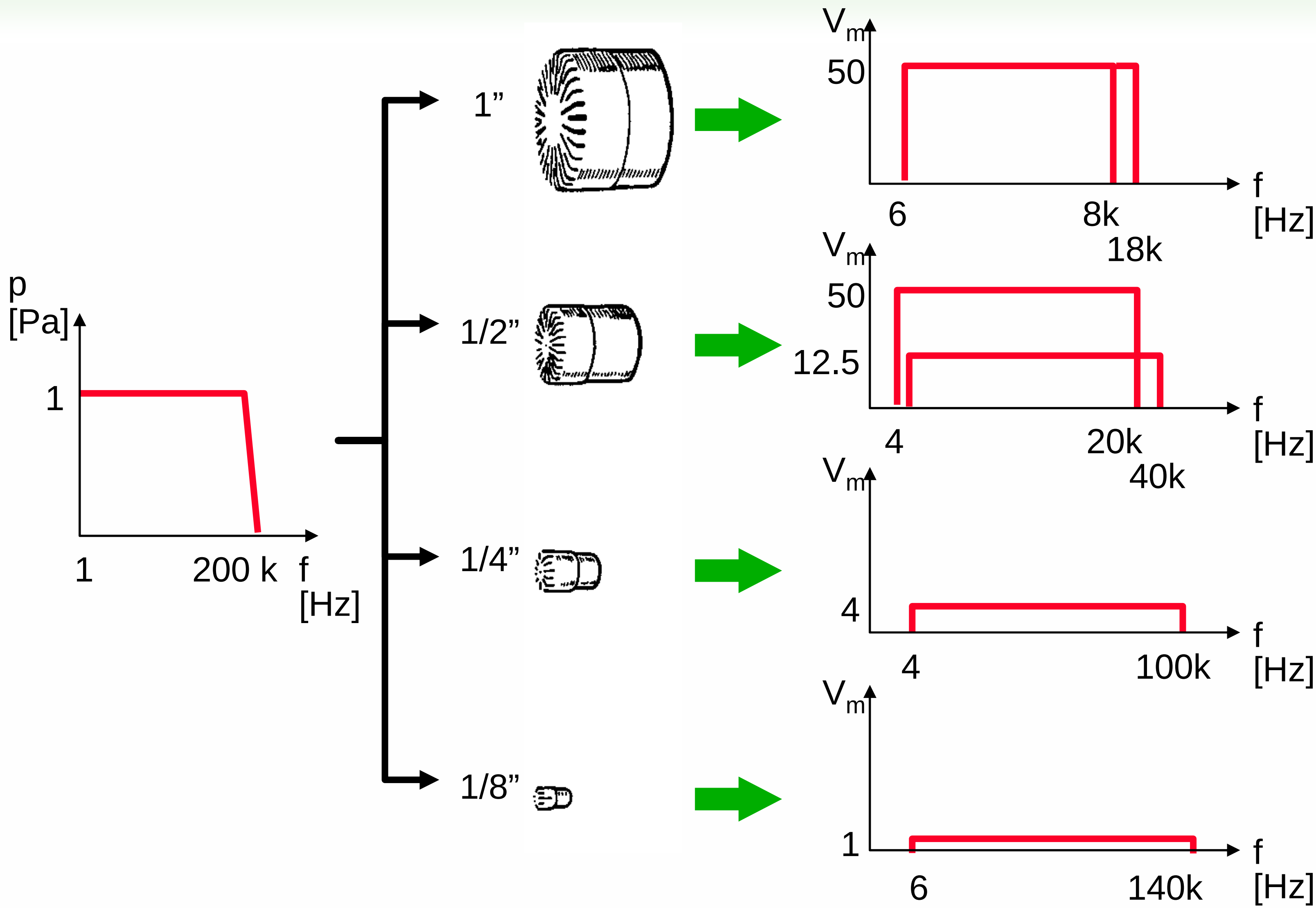
Measuring in Accordance with Standards:



Free Field Microphone

Random Incidence Microphone

Frequency Range and Sensitivity



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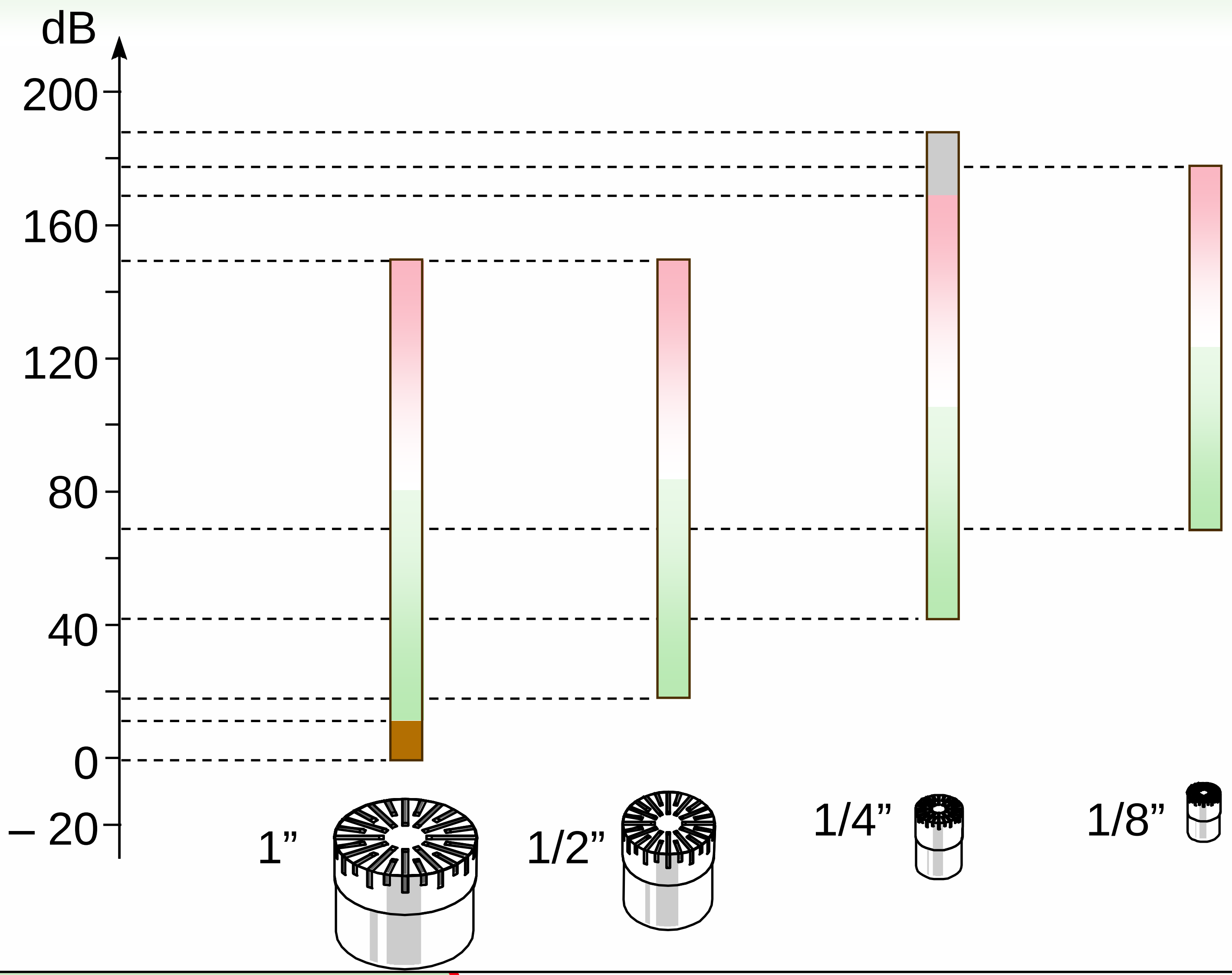
Dynamic Range



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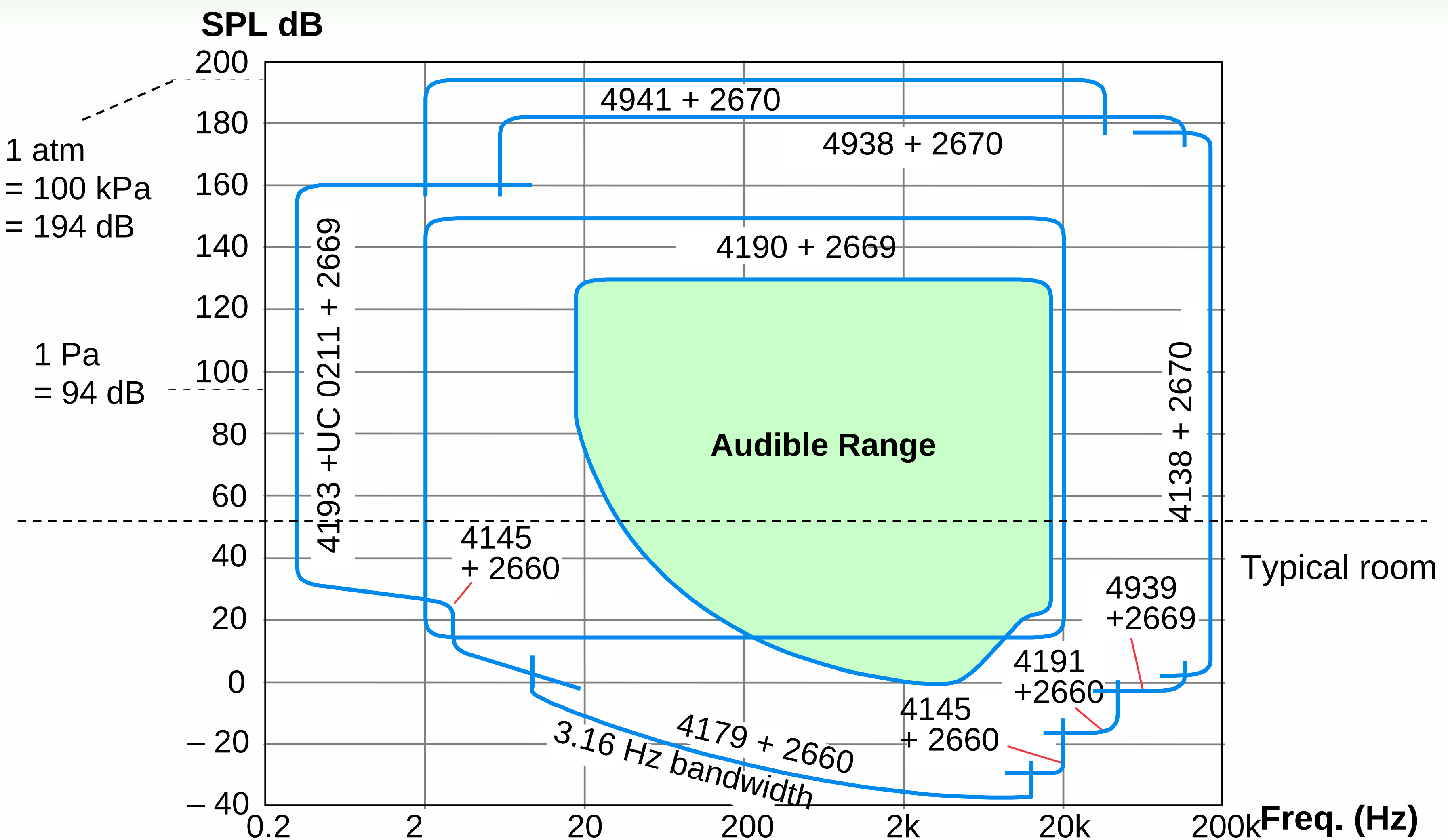
Much More Than Sound – B&K Microphones Measurable Range



Fundamentals of Measuring Sound

Contents:

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- Measuring Sound in Practice

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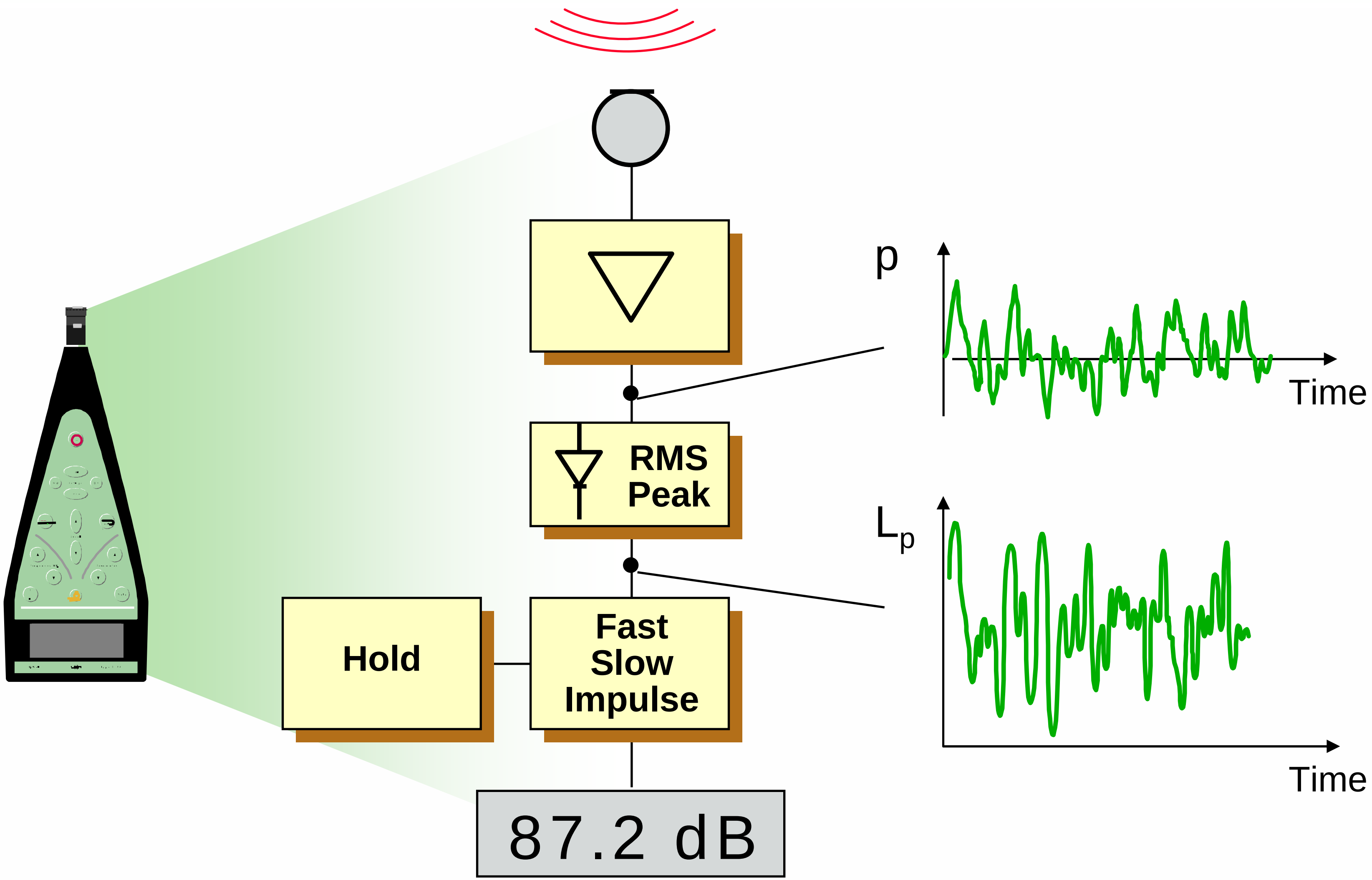
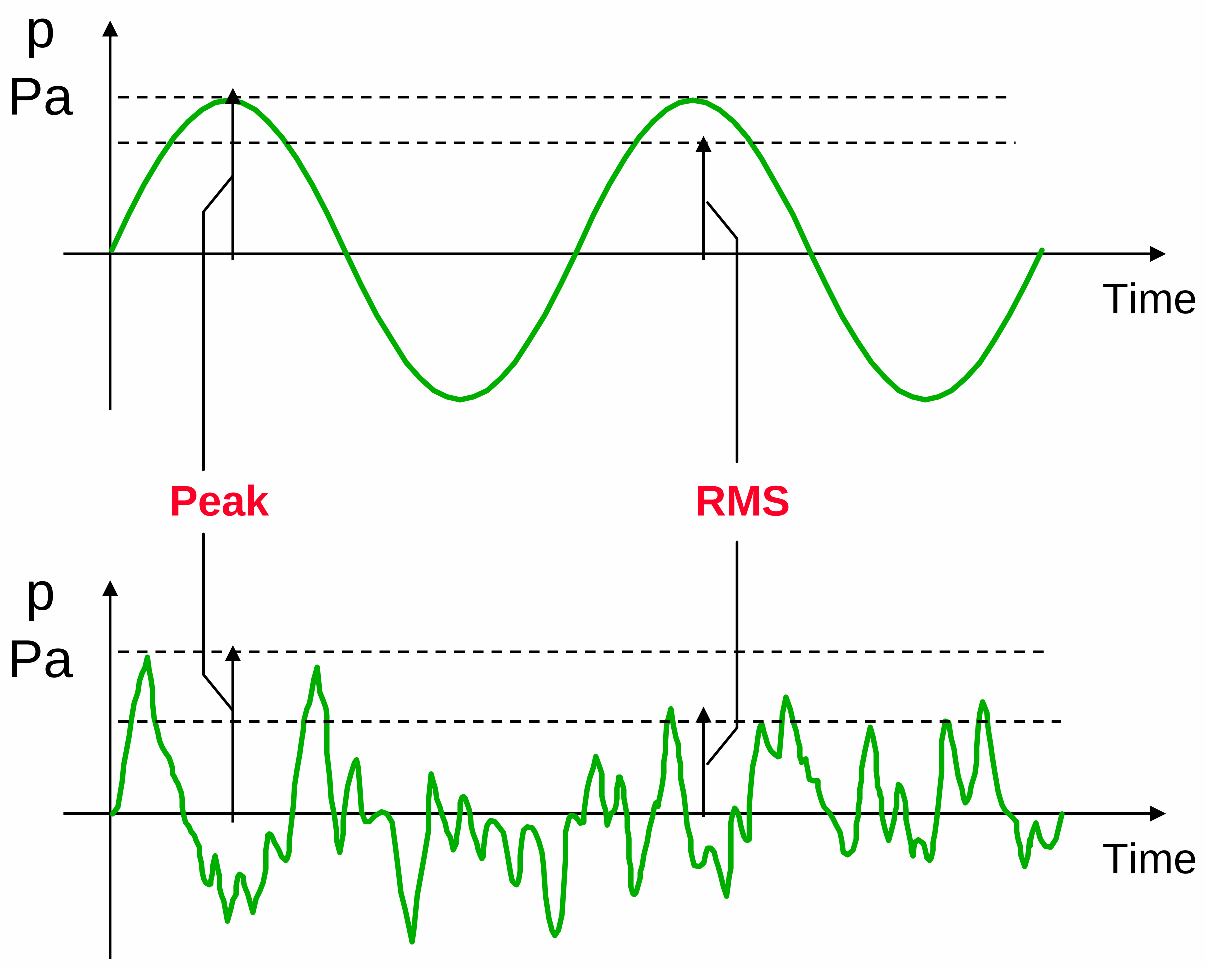
The Sound Level Meter *(Voltmeter - Overall Analyzer)*



Basic Sound Level Parameters



$$\textbf{RMS} = \sqrt{\frac{1}{T}\int_0^T x^2(t)dt}$$

(Root Mean Square)

Peak

$$\textbf{Crest factor} = \frac{\textbf{Peak}}{\textbf{RMS}}$$

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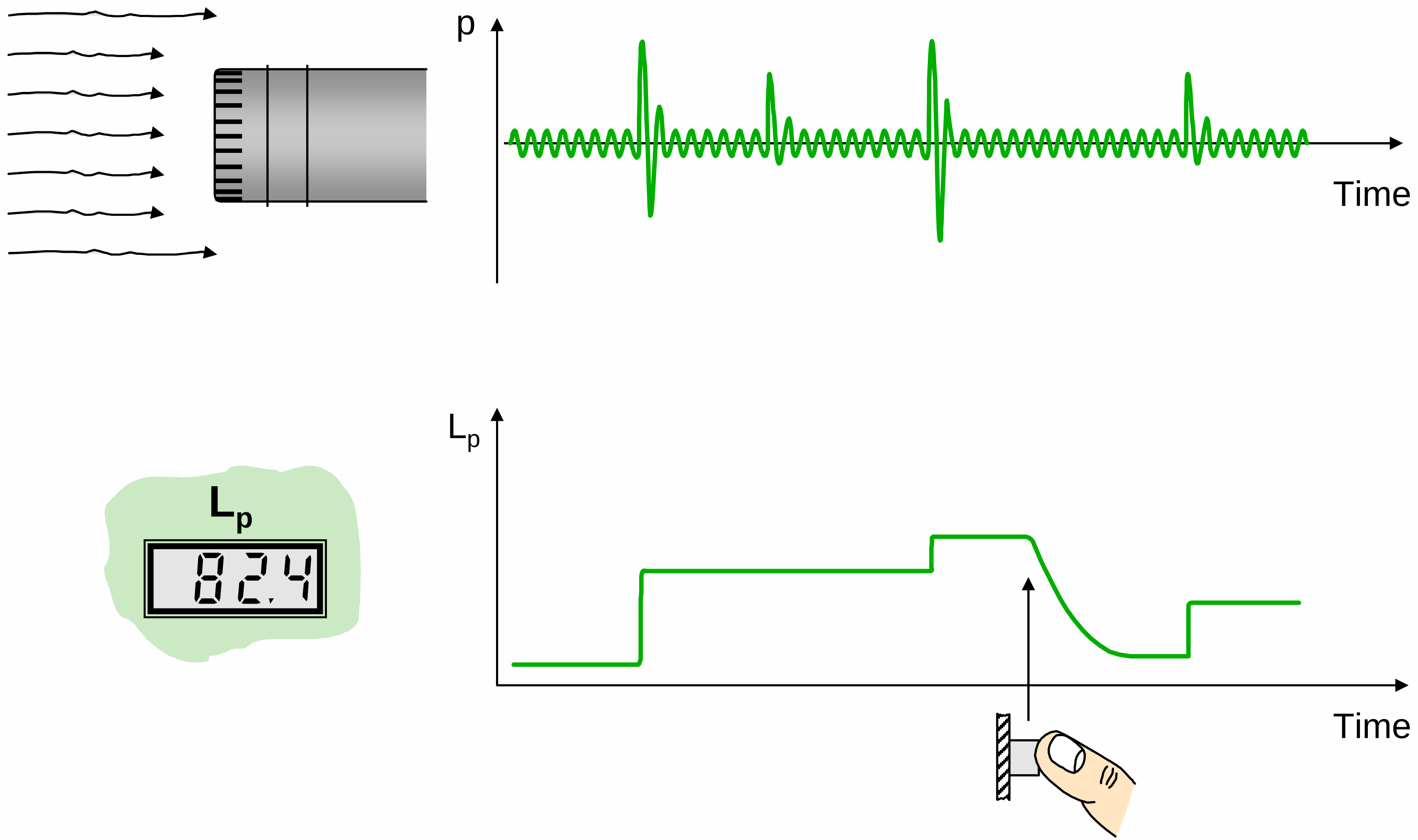
Peak Hold *(Peak Detector)*



D

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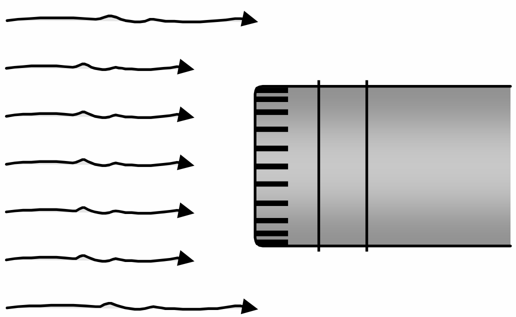
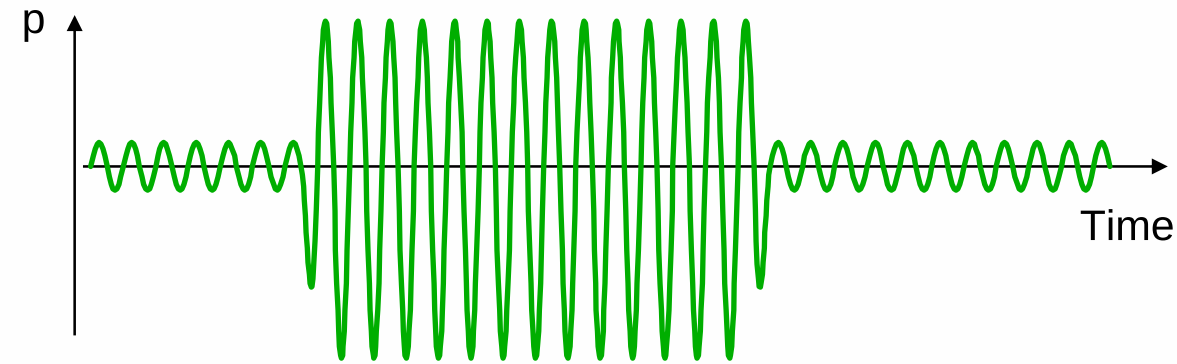
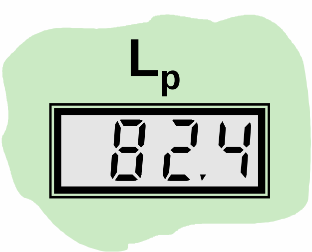
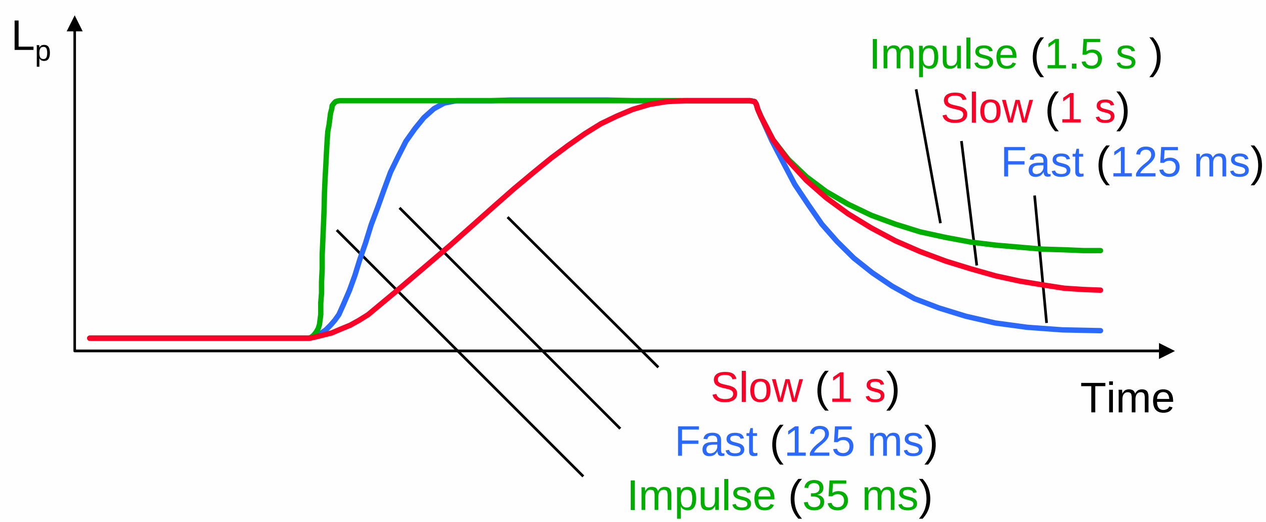
Demonstration Equipment

Time Weighting *(RMS detector)*

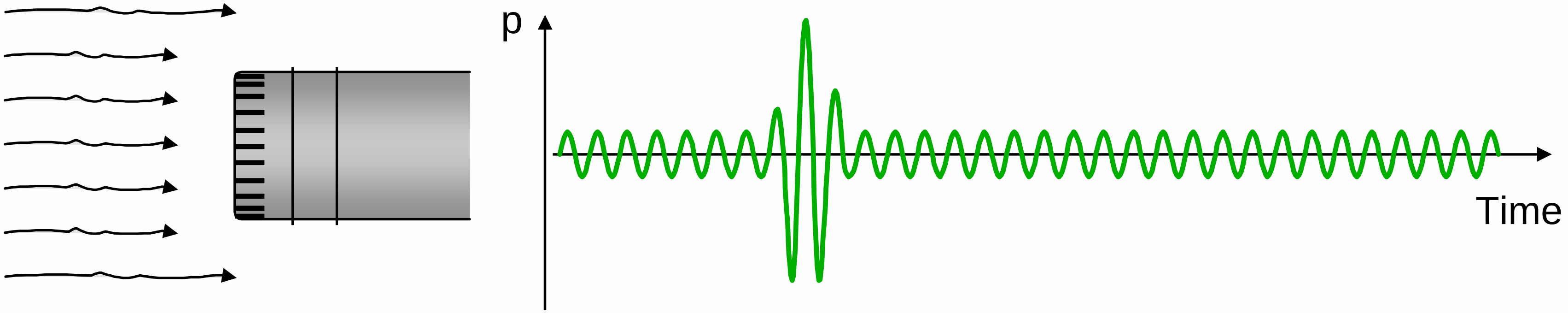




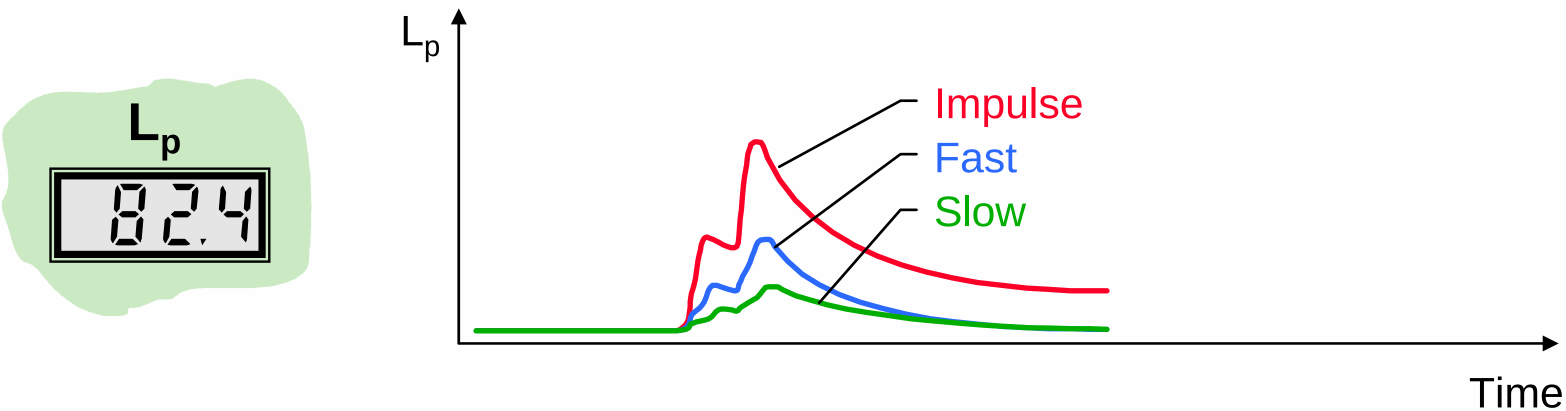




Time Weighting *(RMS detector)*



- Squaring & Exp. Averaging:



- Track or smooth time variations depending on choice of τ

D

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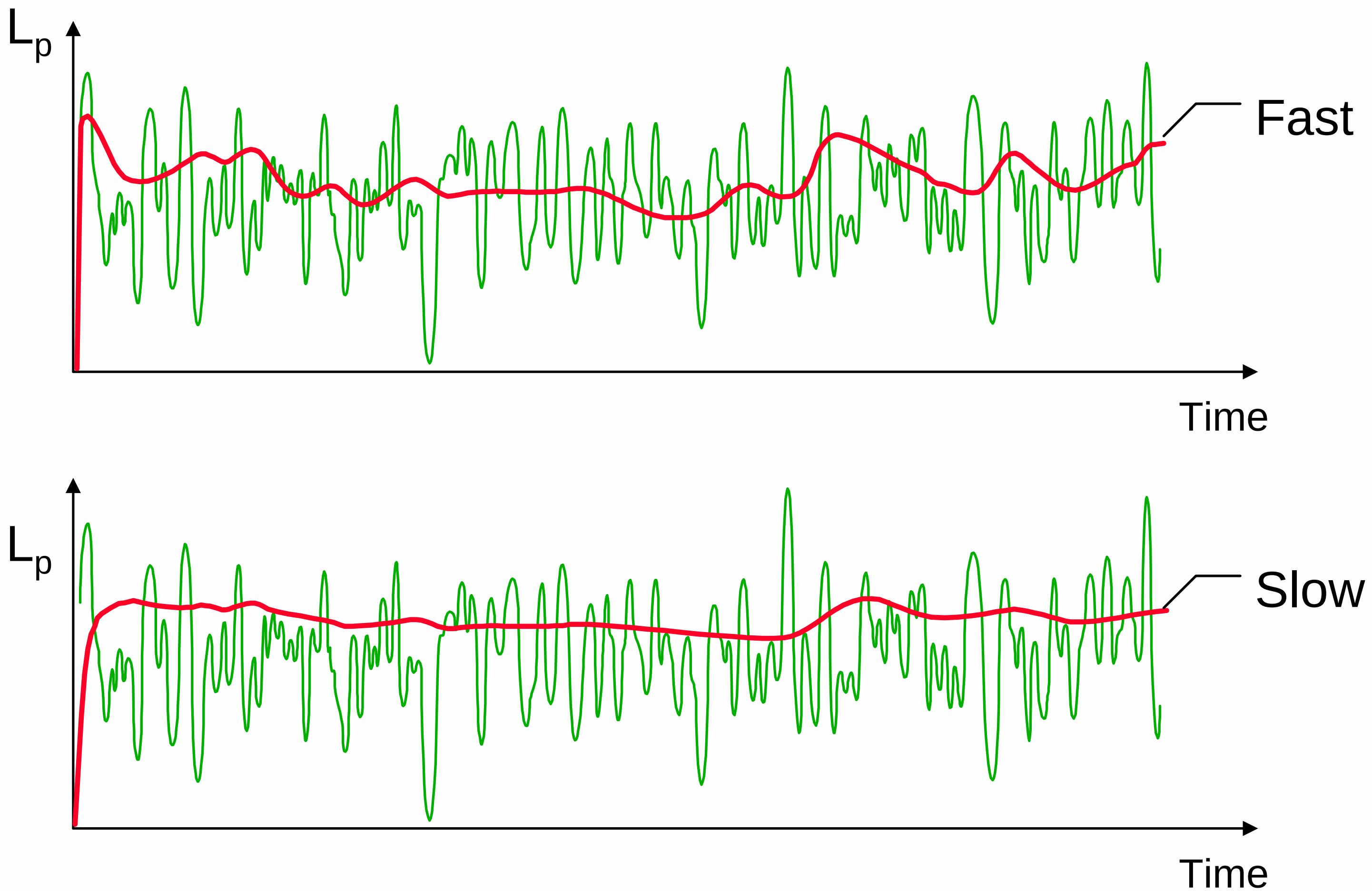
Time Weighting



- Track or smooth time variations depending on choice of τ

D

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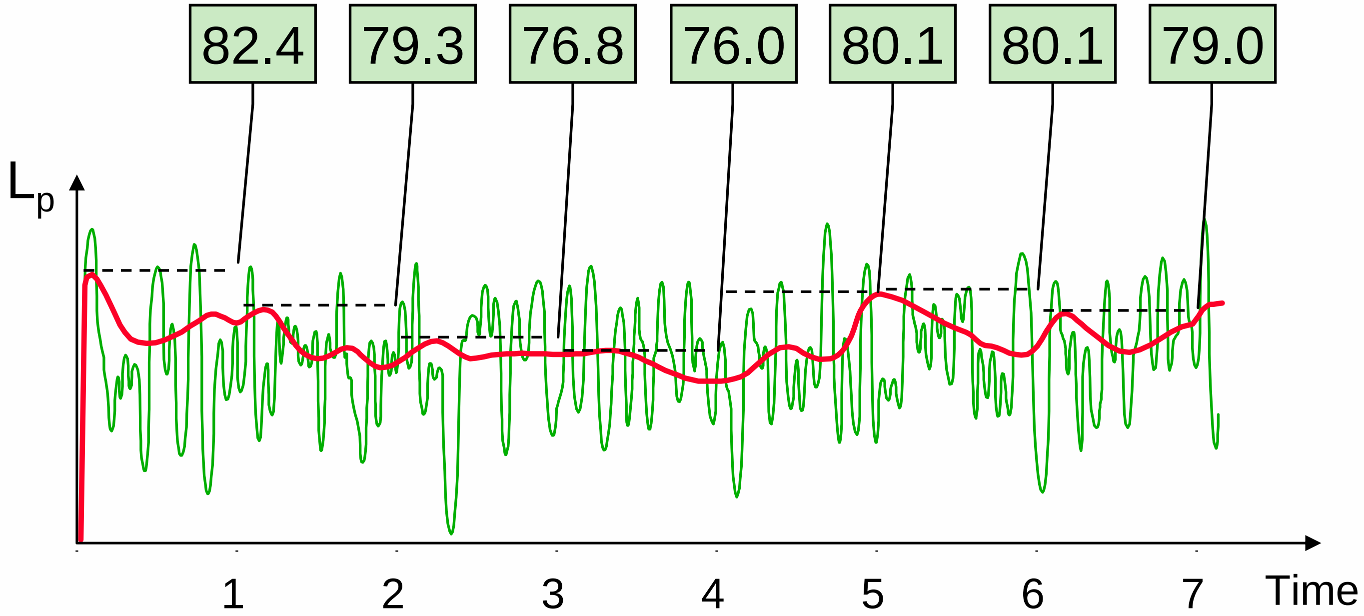
The Digital Display



Fundamentals of Measuring Sound

Contents:

- The Microphone
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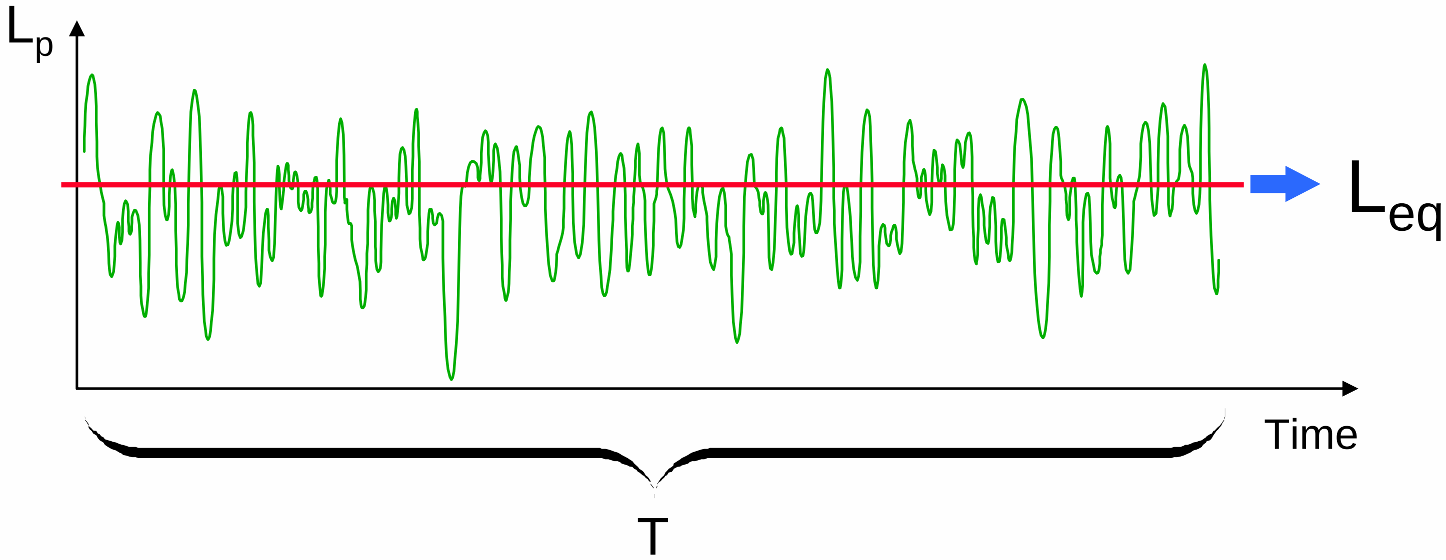
- L_{eq}
- Noise Dose
- Measuring Sound in Practice

Equivalent Level, L_{eq} , (*Linear Averaging*)

$$L_{eq} = 10 \log_{10} \frac{1}{T} \int_0^T \left(\frac{p(t)}{p_0} \right)^2 dt$$

- Integrating Sound Level Meters
- The L_{eq} is the energetic average of the noise



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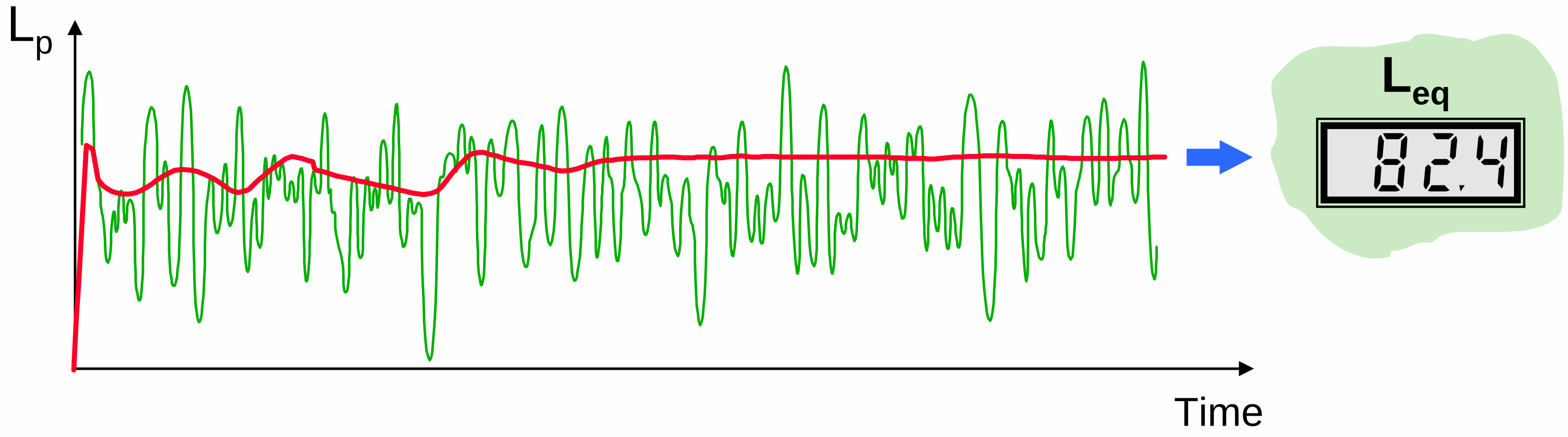
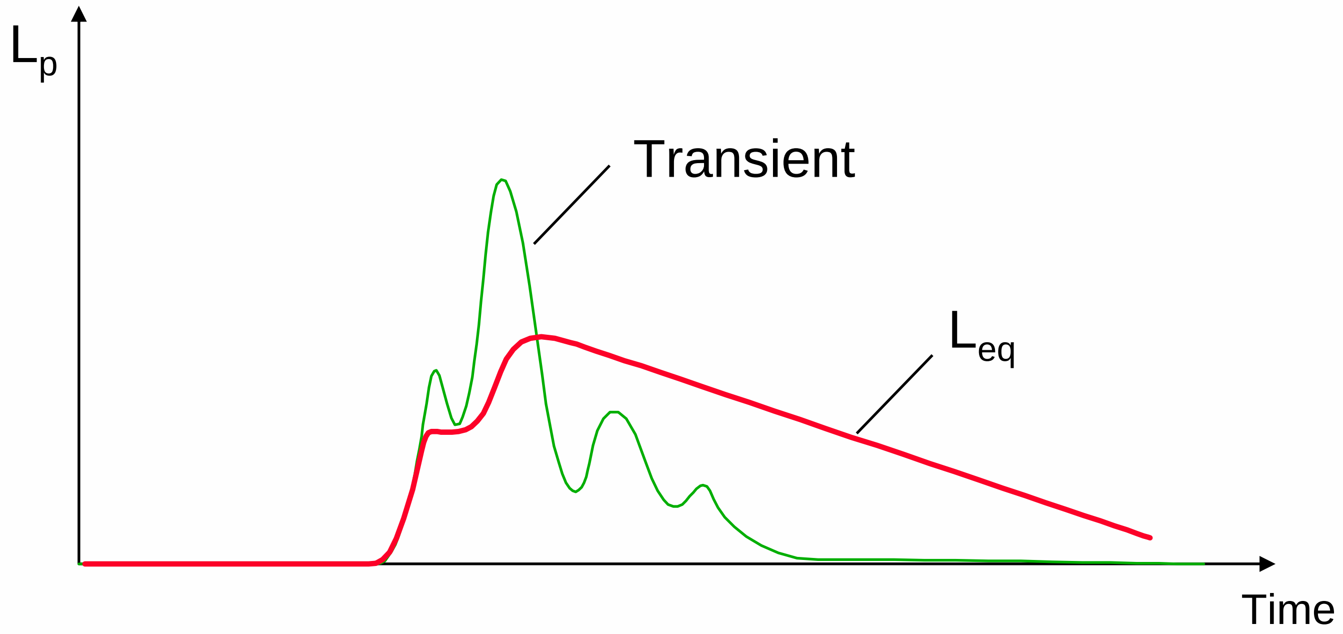
Measuring L_{eq} , *(Linear Averaging)*



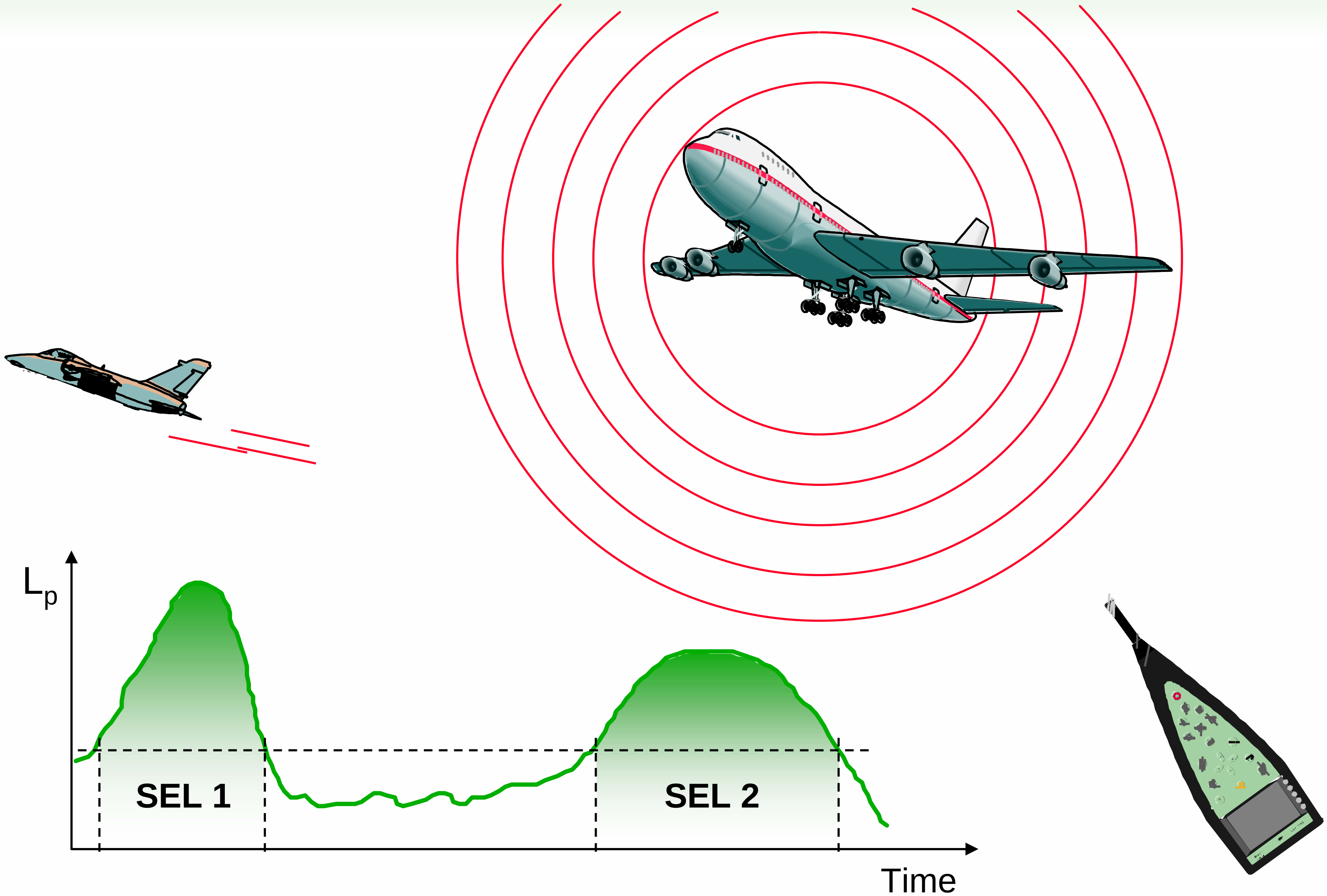
- Smooth (or track) time variations depending on choice of T (and mode)

D

L_{eq} for Transient Noise



Sound Exposure Level and its Origin



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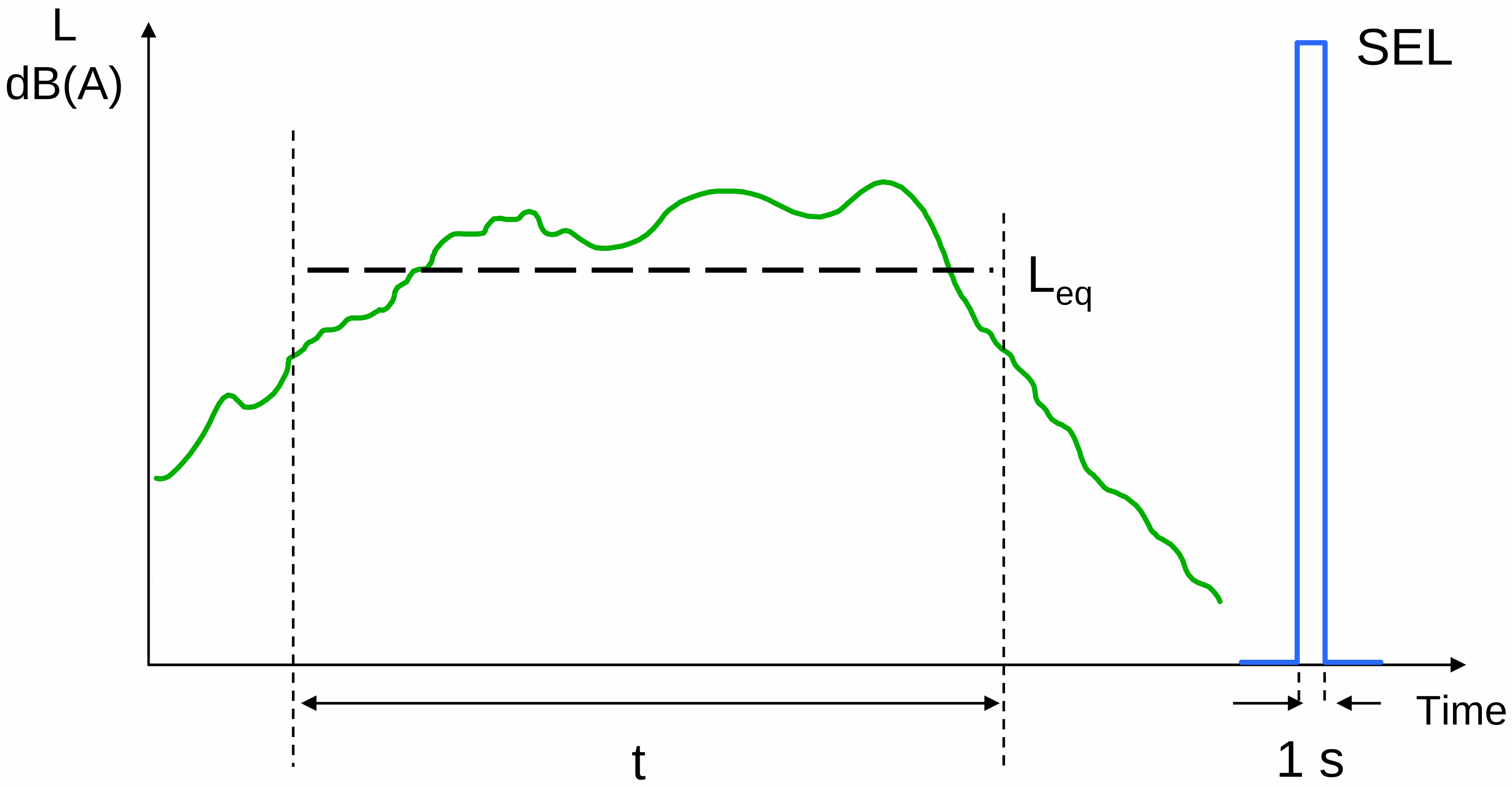
Sound Exposure Level, SEL, *(Energy)*

$$SEL = L_{eq} + 10\log\left(\frac{t}{1s}\right)$$



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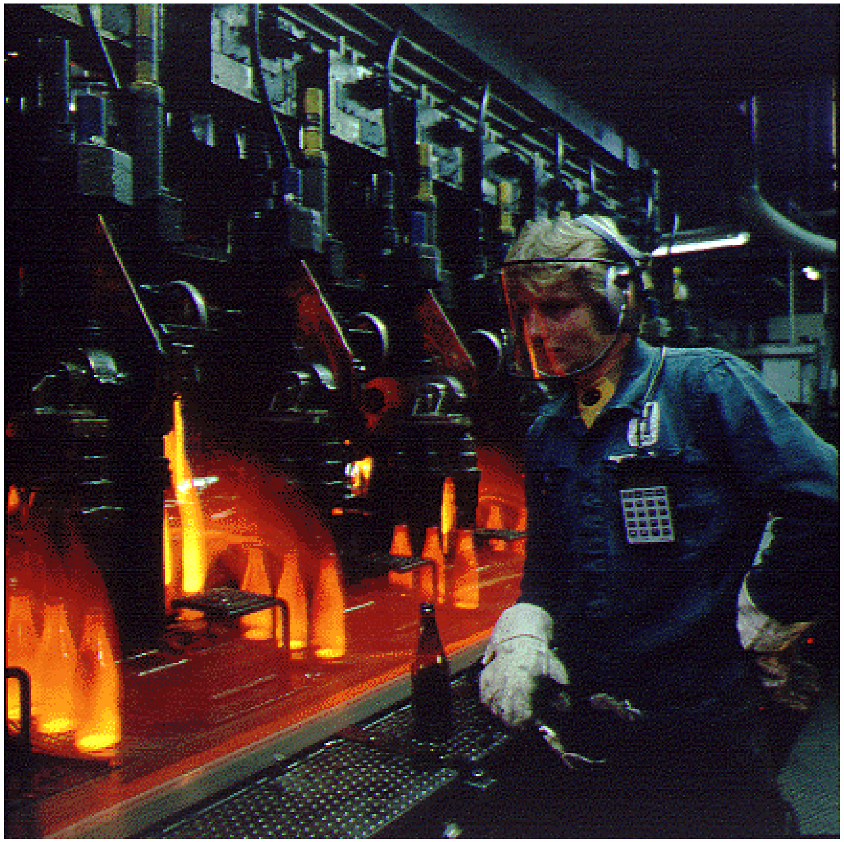
Noise Dose Measurement in Practice



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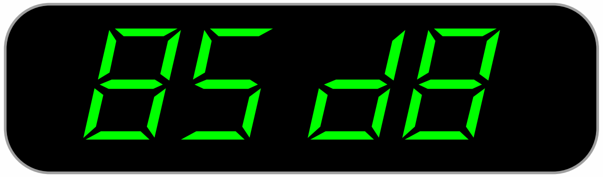
Definition of Noise Dose

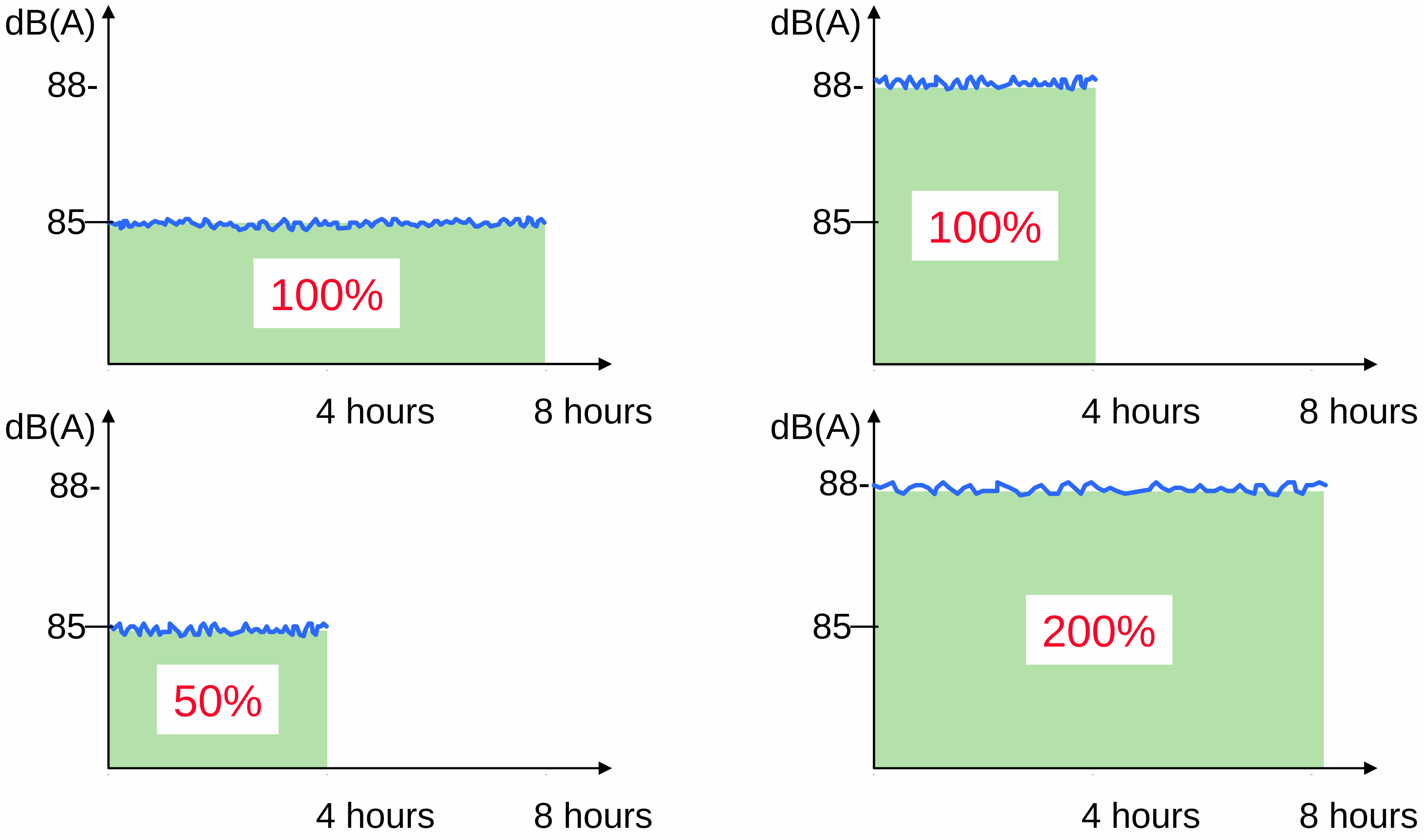


in

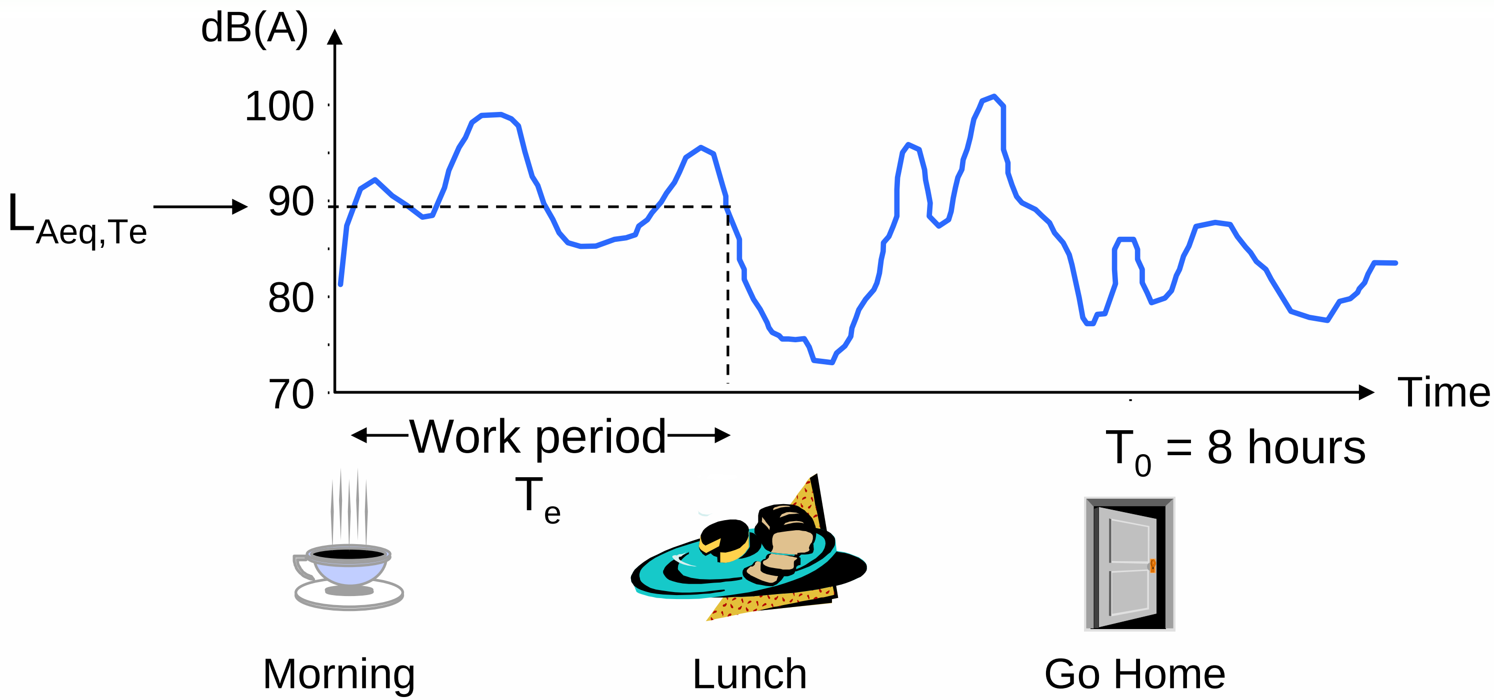
= 100 % Noise Dose

The actual dB level depends on National Legislations. In some countries the level is 80 dB

Noise Dose Examples



Daily Personal Noise Exposure, $L_{EP,d}$



$$L_{EP,d} = L_{Aeq,Te} + 10\log_{10}\frac{T_e}{T_0}$$

Example:

$L_{Aeq,Te}$ = 89.2 dB and T_e = 4 hours

$$L_{EP,d} = 89.2 + 10\log_{10}\frac{4}{8} = 89.2 - 3 = \underline{\underline{86.2\,\text{dB}}}$$

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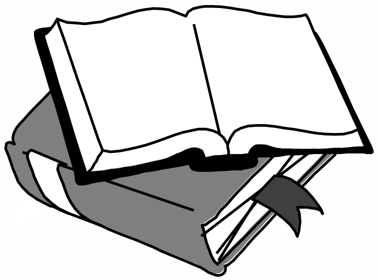
Standards



- ISO 9612

  Guidelines for the measurement and assessment of exposure to noise in a working environment

International

- ISO 1999

  Determination of occupational noise exposure and estimation of noise-induced hearing impairment

International

- IEEC Directive EEC/86/188

  The protection of workers from the risk related to the exposure to noise at work

The European Union

- OSHA

  Occupational Safety and Health Act

USA and others

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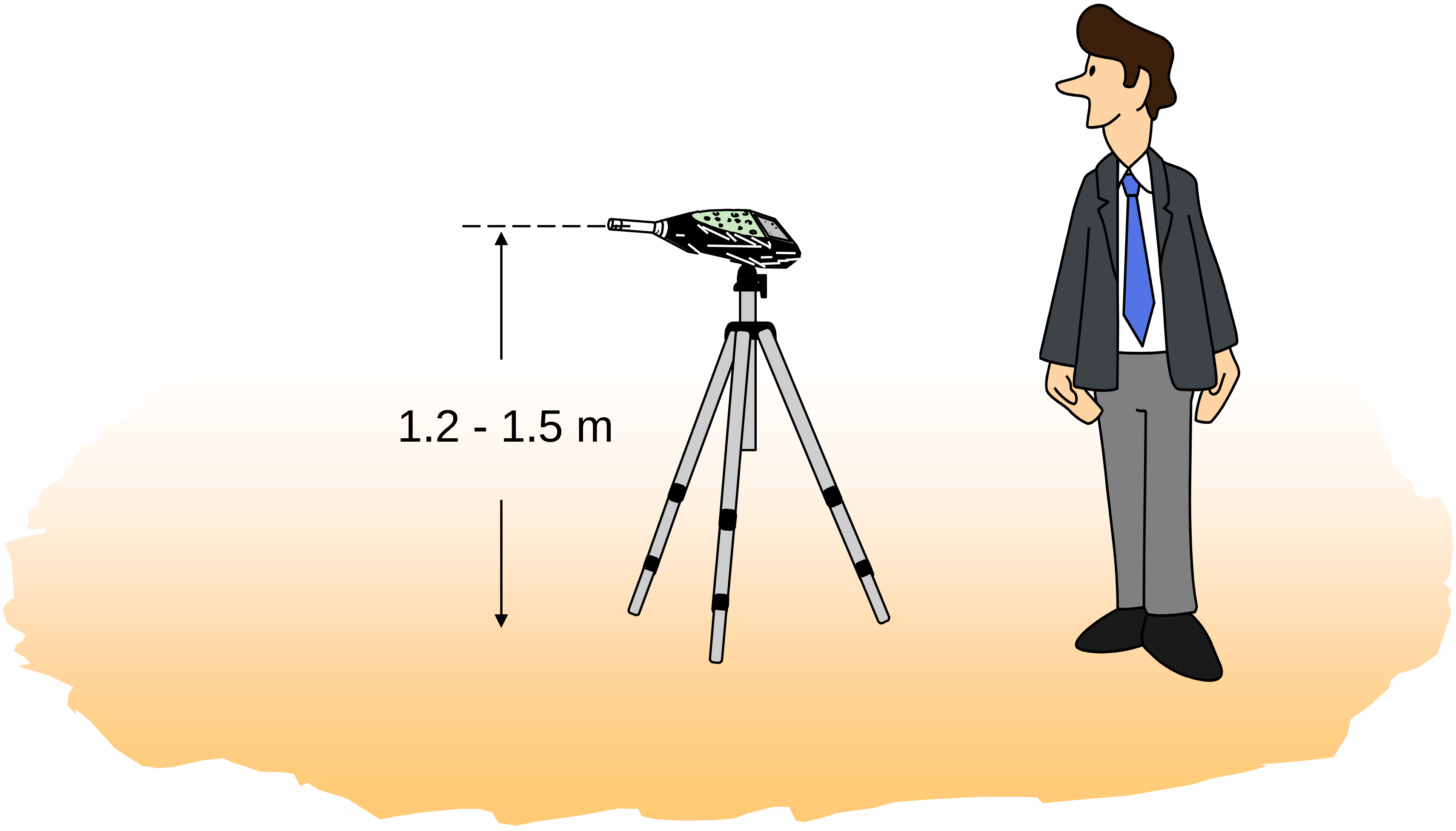
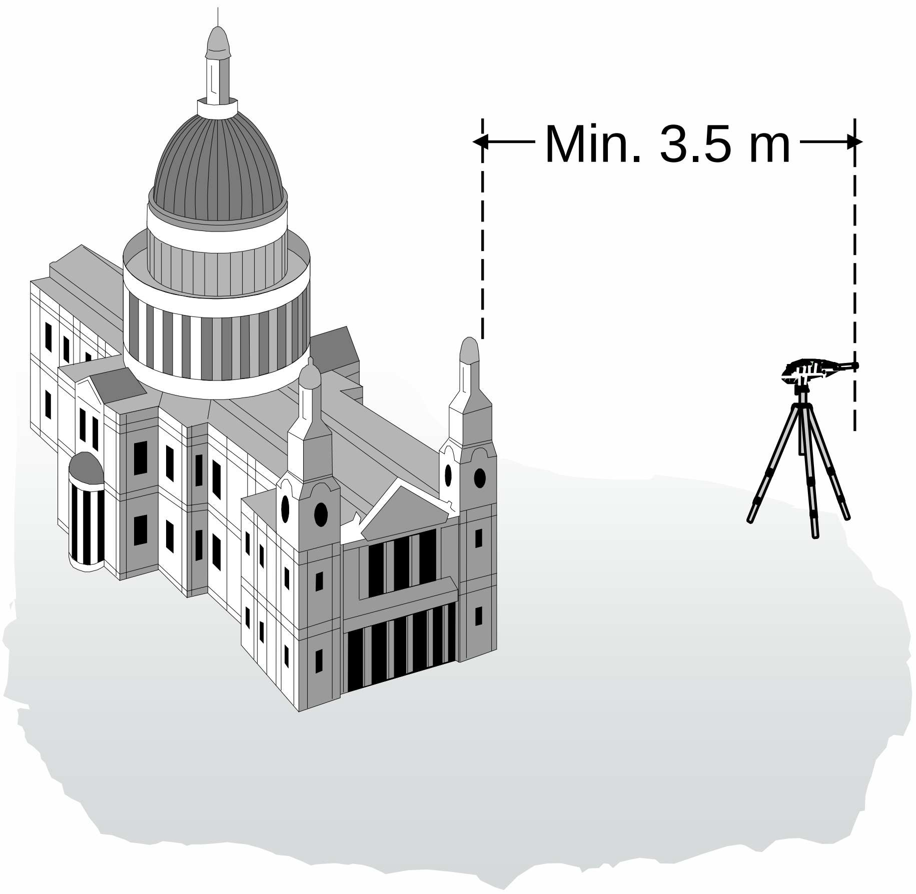
Microphone Position above the Ground

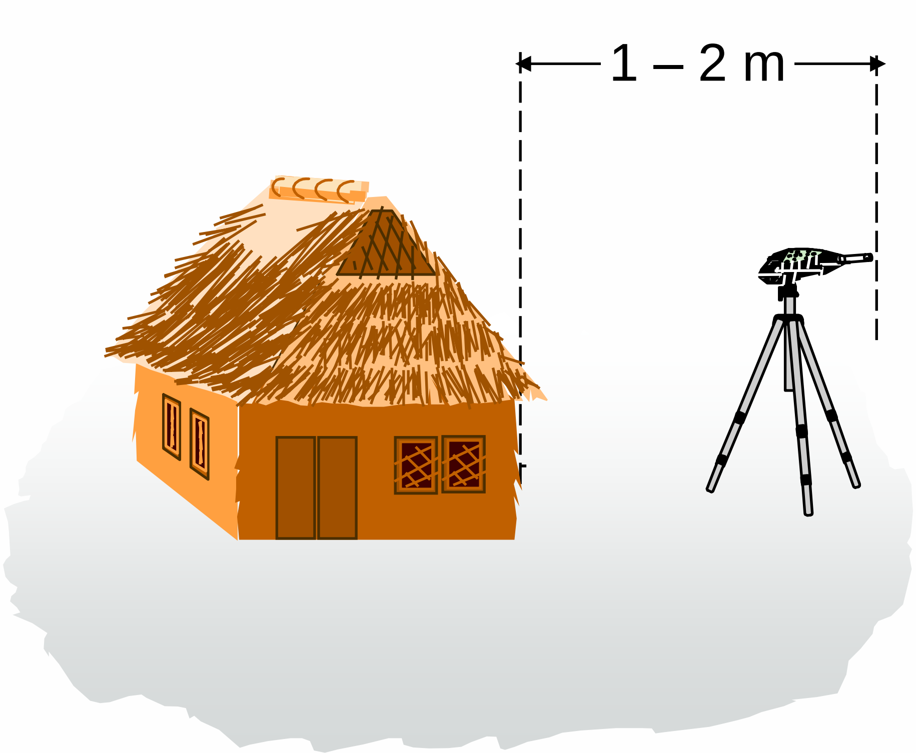


Microphone Position outdoors

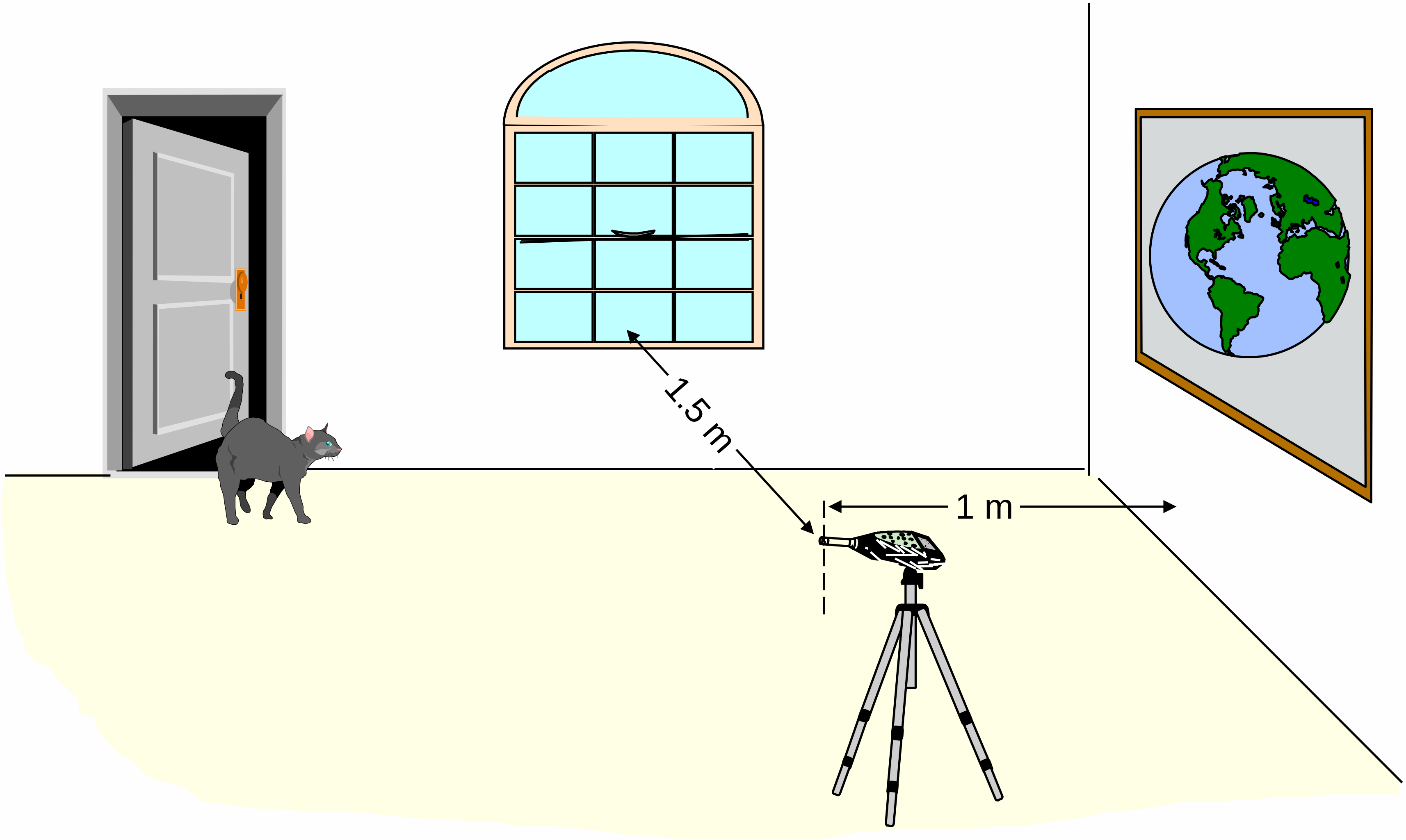
To minimize the influence
of reflections



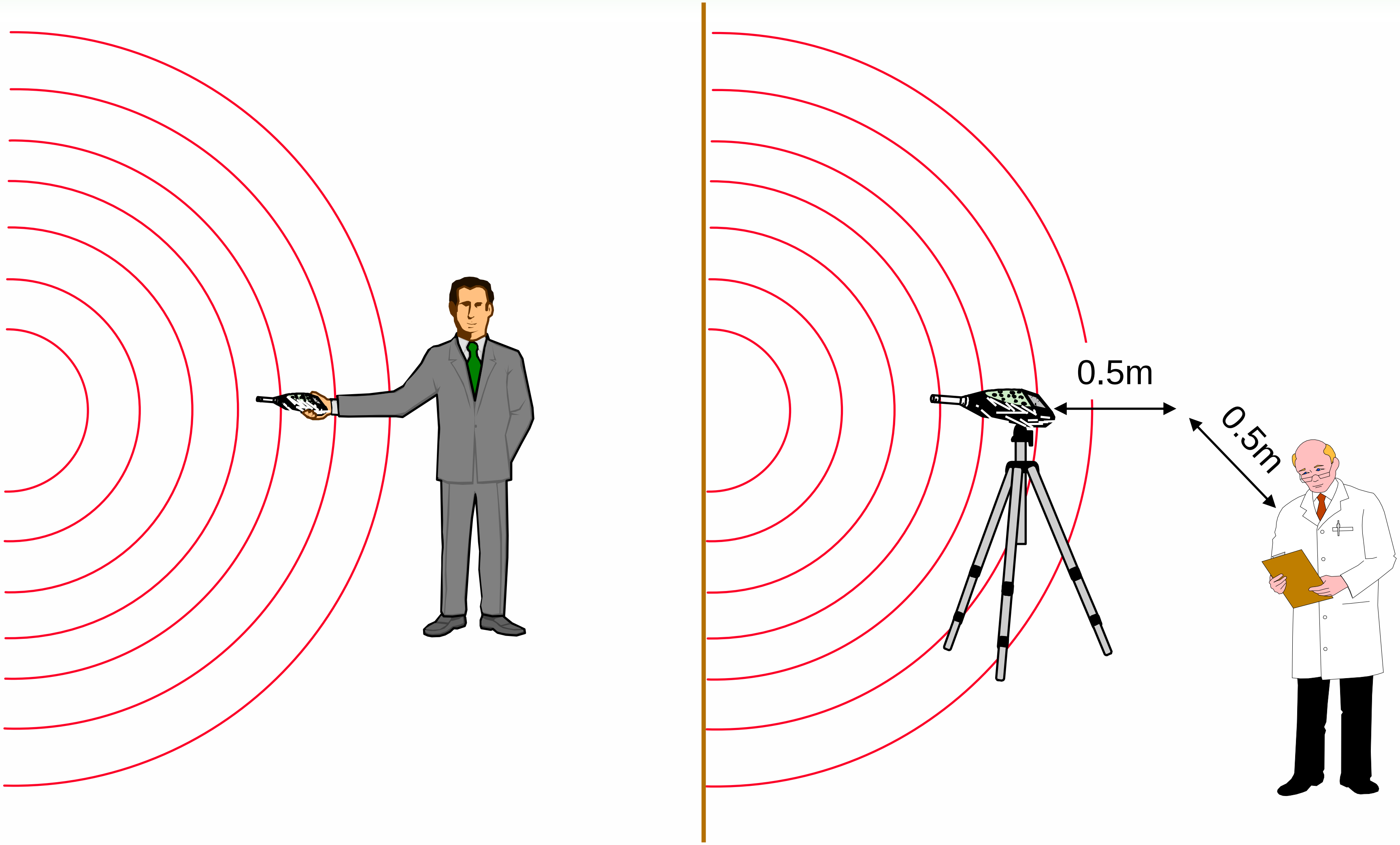
In front of facades



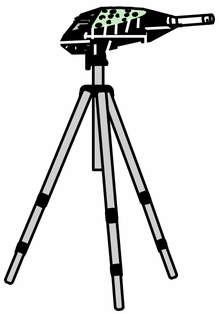
Microphone Position indoors

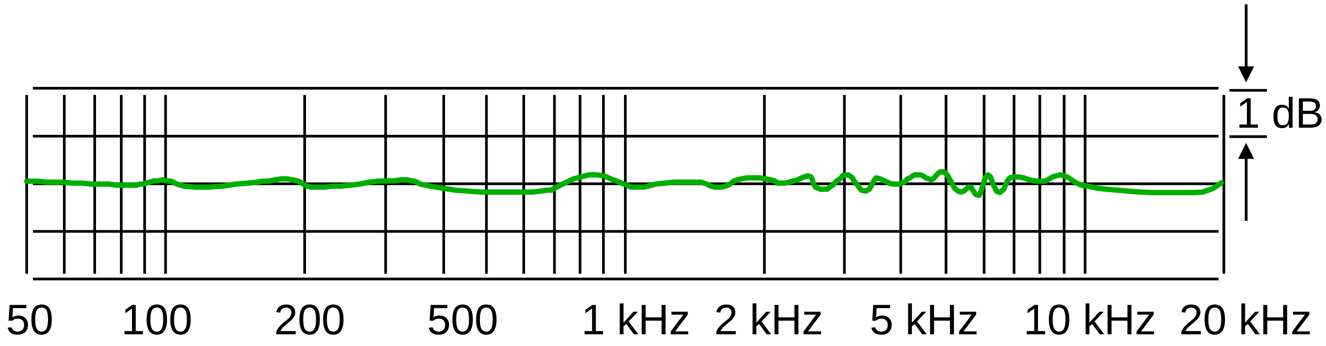


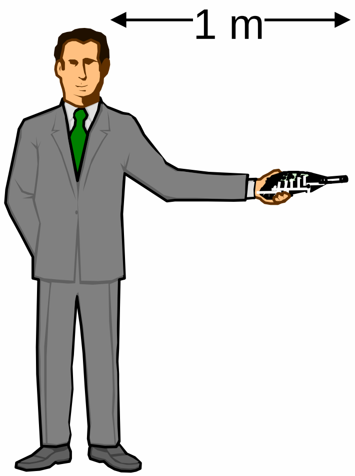
Operator Positioning

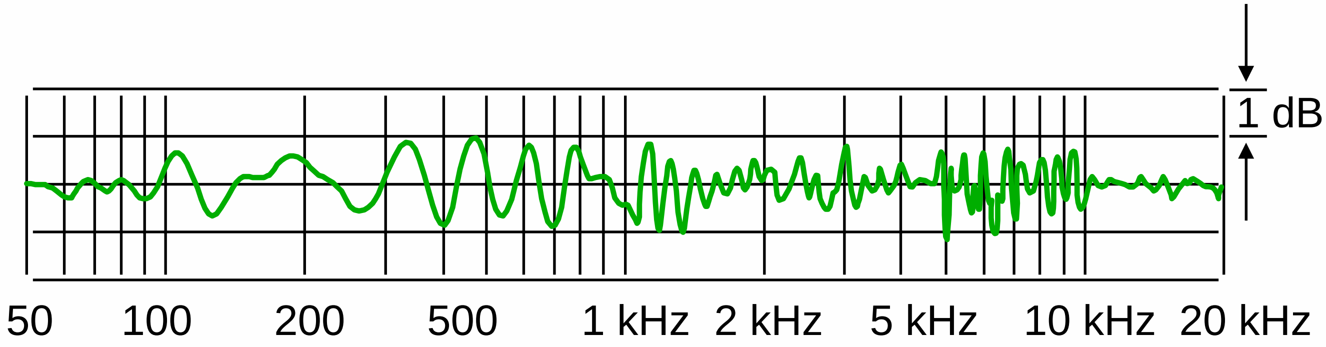


Influence from Sound Level Meter and Operator

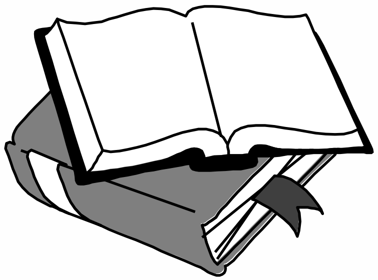








Standards



Standards for Sound Level Meters

- IEC 61672 – International
- ANSI S 1.43 – America

Standards for Measurement Procedures

- ISO 1996

  Description and measurement of environmental noise

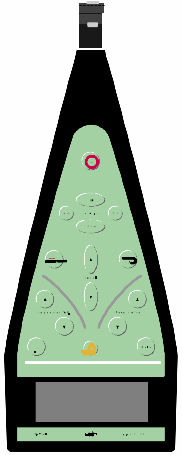
- ISO 9612

  Guidelines for the measurement and assessment of exposure to noise in a working environment

Accuracies for Sound Level Meters

Four levels of accuracy for Sound Level Meters

- Type/Class 0: Laboratory Standard
- Type/Class 1: Precision (Field and Laboratory)
- Type/Class 2: General Purpose (Field)
- Type/Class 3: Survey (Field)



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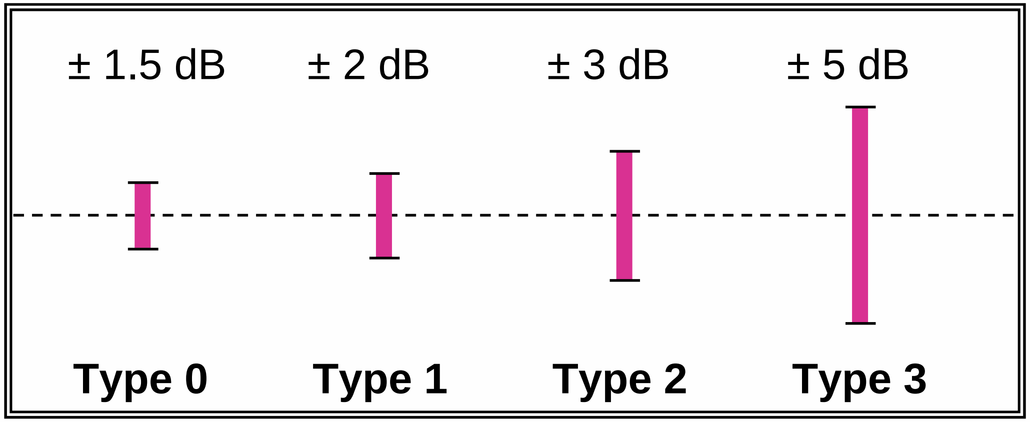
Accuracies of Sound Level Meters

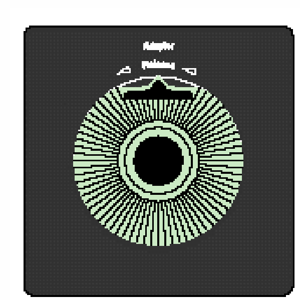
- Practical accuracies (Non reference conditions) calculated from allowed tolerances for
  - warm-up
  - directional effects
  - frequency weightings
  - range control
  - time weighting
  - ambient pressure
  - humidity
  - temperature
  - calibrator
  - operator influence

Practical Accuracies



Acoustic Calibration

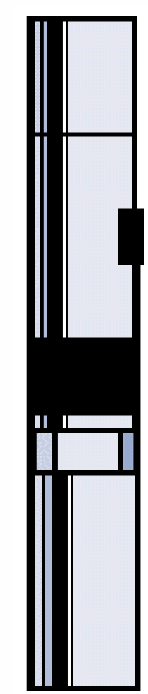
Acoustical Calibrator



94 dB

114 dB

Pistonphone

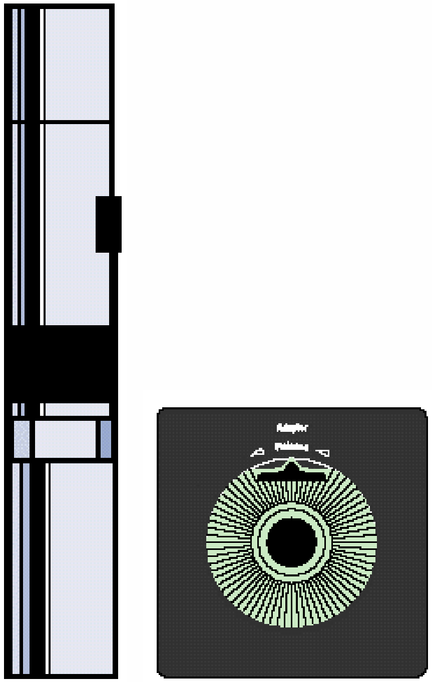


124 dB

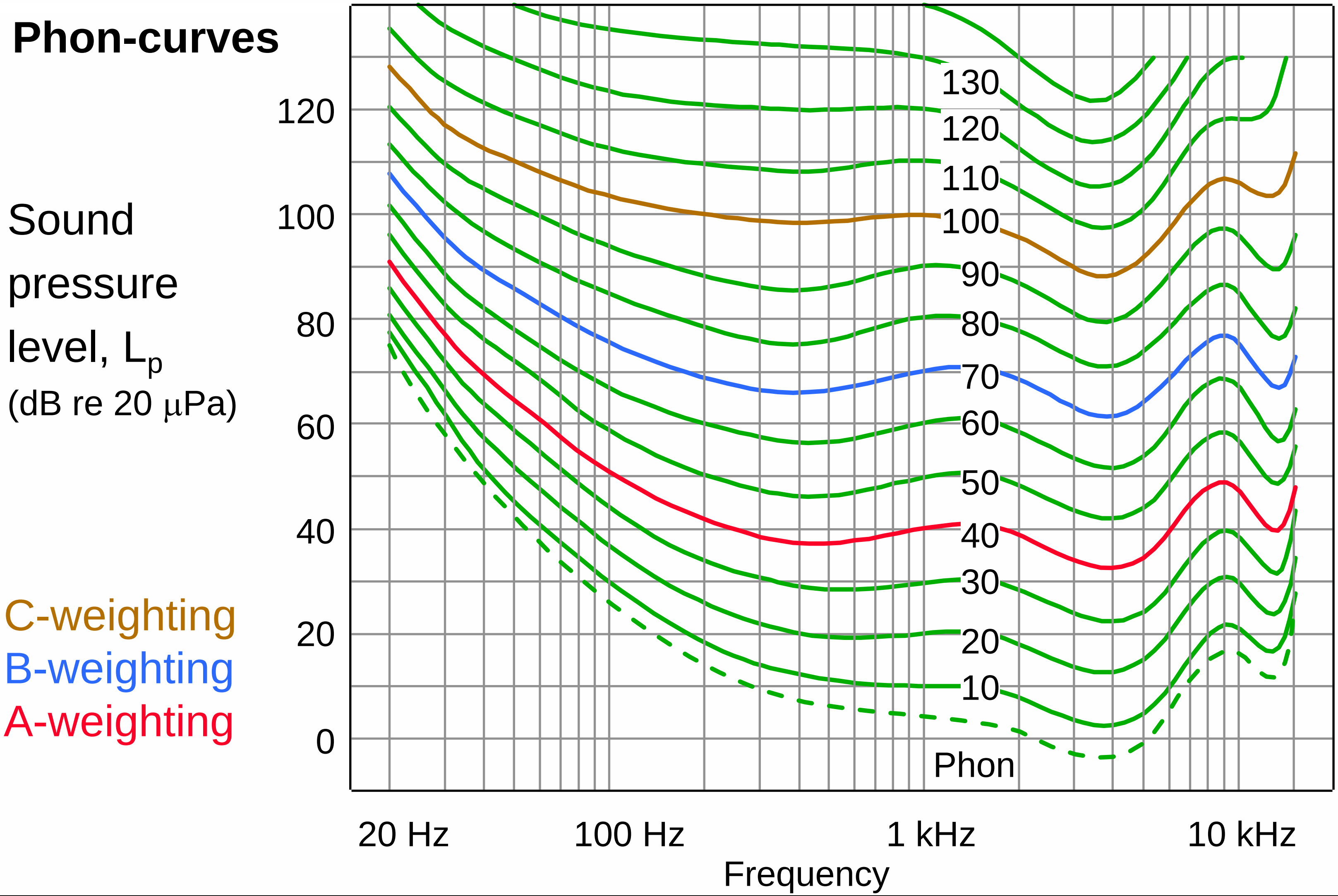
Calibration according to ISO 1996

- Before and after each series of measurements:
  - use a Sound Level Calibrator or a Pistonphone
  - record the results of calibration

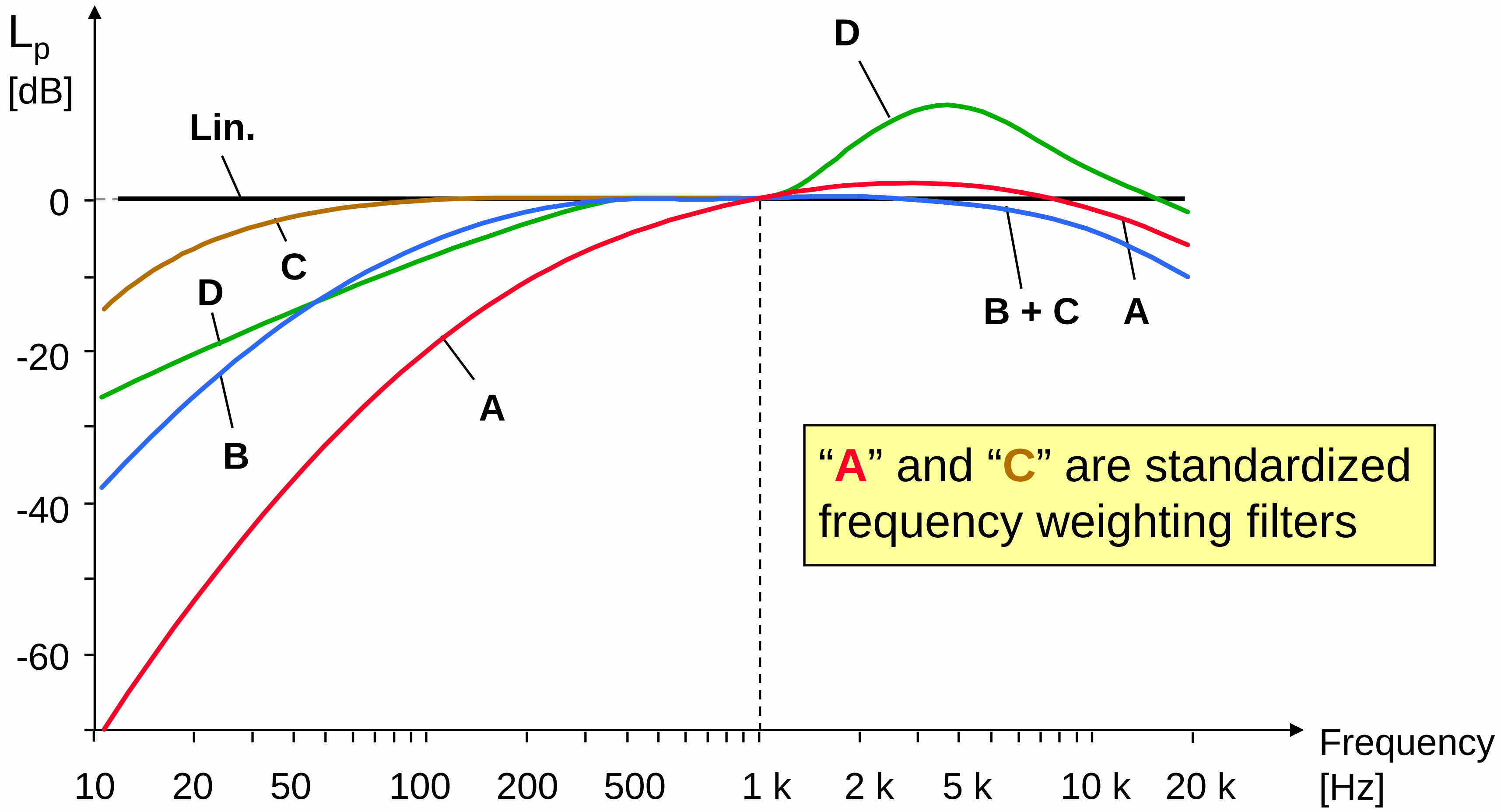
- In addition, if measurements are made over a prolonged period, verify the calibration at least twice daily using:
  - either the method described above
  - or by using an integral calibration system



Equal Loudness Contours for Pure Tones



Frequency Weighting Curves



"**A**" and "**C**" are standardized frequency weighting filters

Conclusion 1

- The sensitivity of a microphone depends on the direction of the noise - that is why there are free-field and diffuse-field microphones
- Sound level meters are integrating measurement equipment with standardized time weightings and measurement parameters (fast, slow, impulse)
- The L_{eq} is the energetic average of the noise over a period of time and is one of the most important noise measurement parameters
- The Noise Dose and Daily Personal Noise Exposure ($L_{EP,d}$) are ways of showing how much noise exposure a person has received in relation to legal limits

Conclusion 2

- Your measurement position should, in general, be far enough away from reflecting surfaces such as the ground, walls and the operator
- For most practical purposes, a type (class) 1 sound level meter is the most versatile
- You should calibrate your sound level meter before and after each measurement
- Human perception of sound and background for A,B,C and D-weighting

Summary

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Lecture material

- A link to a copy of the presentation will be sent to all participants by e-mail within a few days

Want to know more?

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