SPAU332
Hearing Aids I

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Electroacoustic performance & measurement of hearing instruments

Aim of today's lecture: Understand and perform basic electroacoustic analysis of hearing aid performance in a coupler.

Key learning outcomes

1

Describe couplers and ear simulators for testing hearing aids.

2

Identify a hearing instrument test box and its components.

3

Understand the range electroacoustic tests used to evaluate hearing aid performance and their importance.

4

Demonstrate awareness of two international hearing aid test standards.

Measurements in couplers and ear simulators

We cannot know how a HA performs unless we measure its response.

Standard couplers and ear simulators exist to enable standardised measurements which are highly repeatable.

Standard couplers are used for comparison of hearing aid characteristics to those provided by the hearing aid manufacturer.

Coupler

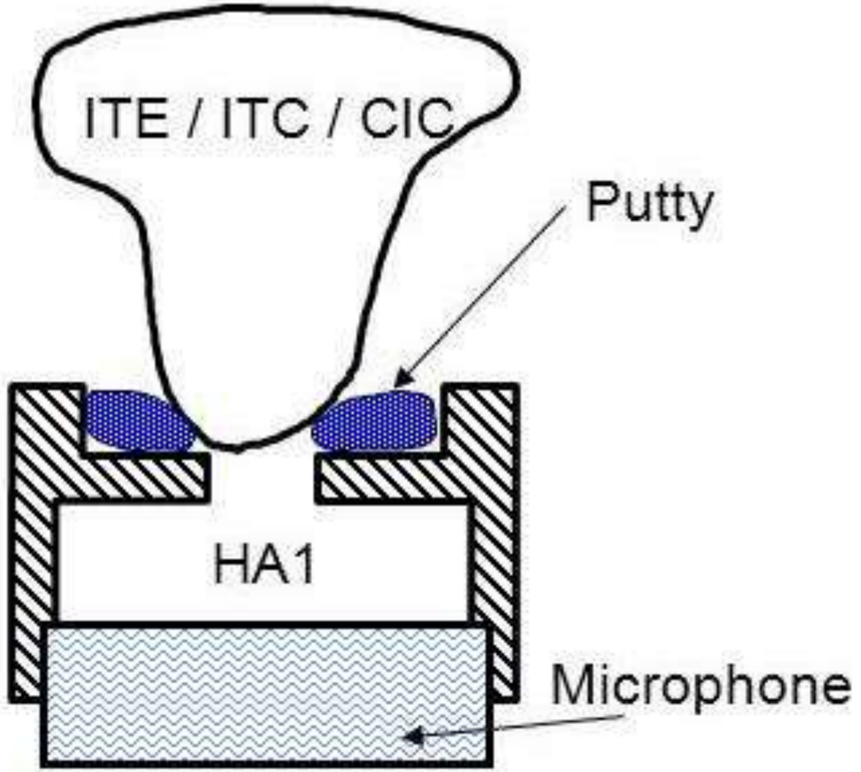
- Coupler = cavity
- One end connected to a HA, other end connected to a microphone.
- Standard coupler has a volume of 2 cubic centimeters, trying to represent the volume of an adult ear canal past the earmould (residual ear canal volume).
- Not a good approximation of the average adult ear canal volume and acoustic impedance of the ear at high frequencies.

Coupler

- Couplers need to be connected to any type of hearing aid, and this is achieved by having a range of adapters available.
- HA1 - For ITE, ITC aids. Has no ear mould simulator. Use putty to connect to coupler
- HA2 – BTE’s. Has earmould simulator, connected to BTE via tubing

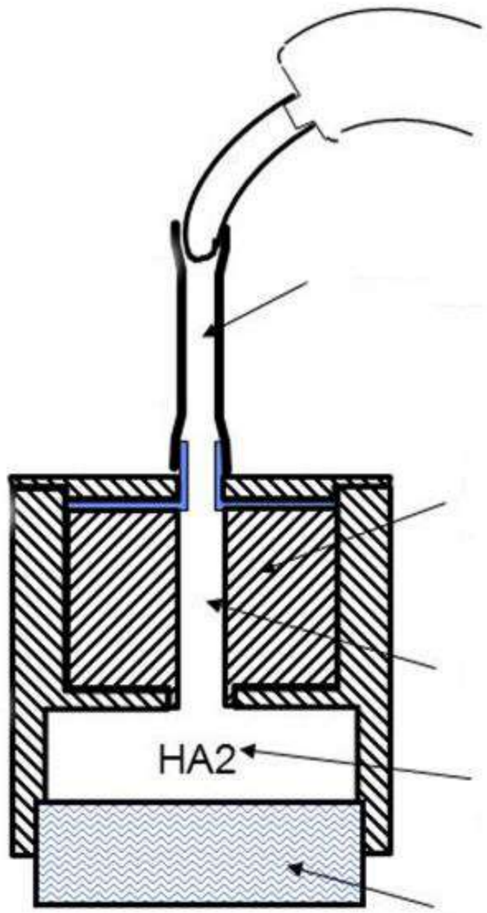
HA-1 Coupler

- Used to measure acoustic pressure generated by an ITE hearing aid.
- Most ITC and CIC hearing aids can also be measured using this coupler.
- Hearing aid held in place and sealed with putty.



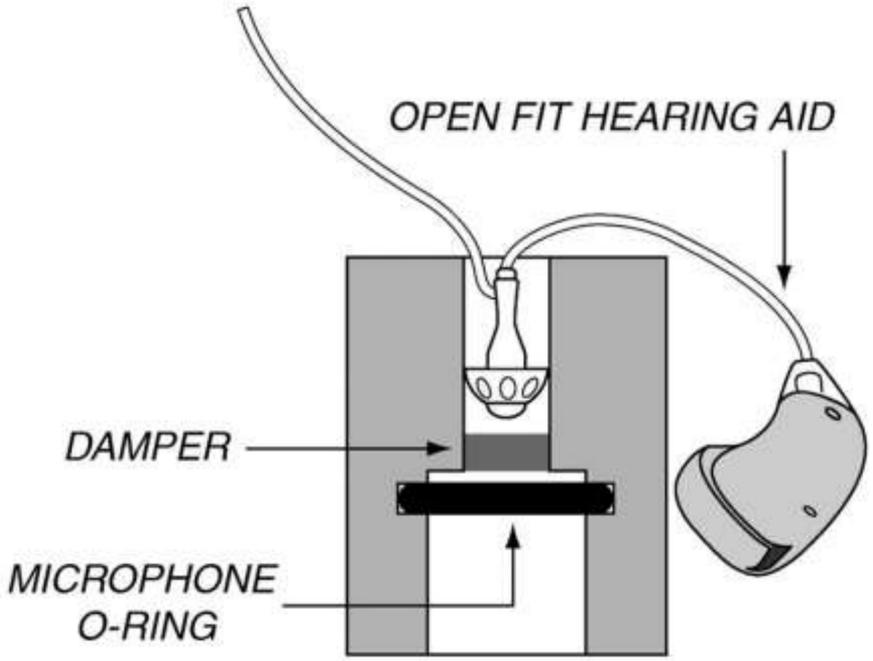
HA-2 Coupler

- Used to measure acoustic pressure generated by BTE hearing aids.
- Hearing aid is attached directly to the tubing.



Open-fit Coupler

- Not a standard 2cc coupler.
- Work on standardization in progress.
- Also used for RIC hearing aids.
- Can also use adaptor on HA-1 coupler.



Limitations of 2cc couplers

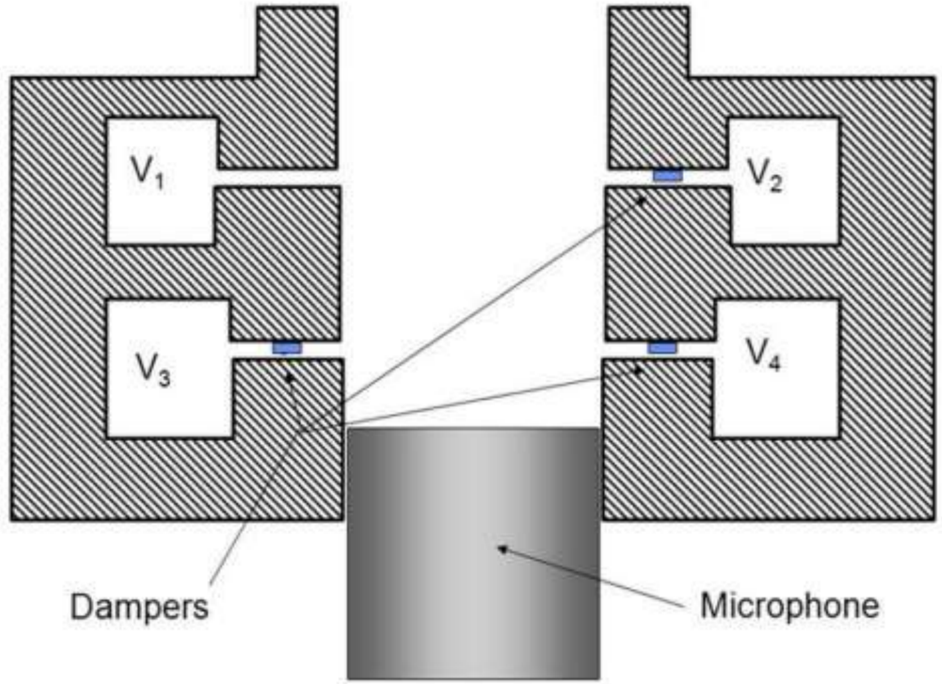
- The volume of the coupler is, on average, too large compared with the residual ear canal volume of a typical hearing aid fitting.
- The impedance characteristics of the human ear canal and middle ear are not well represented.
- The plumbing (e.g. the earmould) alterations are not accurately represented by the hard-walled cavity.

Real-ear simulators

- Try to better mimic the impedance of a real ear canal.
- More accurate than 2cc coupler, but still cannot show the SPL present in the individual's ear.
- Two standardised real-ear couplers are currently used around the world.
  - Zwislock coupler
  - IEC711 real-ear simulator

Zwislocki coupler

- Has several cavities.
- Typically more expensive than 2cc couplers.
- As the frequency rises, the impedance of the tubes rise, they effectively close off, therefore causing the effective total volume to gradually fall.
- Little connecting tubes can become easily blocked.



IEC711 real-ear simulator

- Similar to Zwislocki coupler but with only two cavities.
- 711 will become dominant ear simulator as Zwislocki coupler is no longer being manufactured or supported by any company.

KEMAR

- Knowles electronics manikin for acoustic research.
- IEC 711 coupler placed in head.
- More realistic measure of the head, body and torso effect on acoustic stimuli.

Correction Factors

- Hearing aid fitting is dependent on calculations which convert measures obtained in a 2cc coupler to:
  - Gain in the real ear, or
  - Absolute ear canal SPL, or
  - In some cases, convert hearing thresholds in dB HL to 2cc coupler or ear canal SPL

Correction Factors

- Reference equivalent threshold in SPL (RETSPL)
  - Difference in dB between HL and the reference coupler used for calibrating earphones
  - Earphone specific
  - **Not** patient specific – RETSPLs have nothing to do with actual patients
  - With prescriptive methods the RETSPL is used:
    - To convert HL values to 2cc coupler values
    - With the real-ear to coupler difference (RECD) to convert HL values to ear canal SPL values and fitting targets to ear canal SPL

Correction Factors

- Real-ear to dial difference (REDD)
  - Differences between dB HL (e.g. the patient's hearing threshold) and the output in SPL in the ear canal
  - Can be measured directly or calculated by adding the RECD and the RETSPL
  - With prescriptive methods the REDD is
    - Added to the dB HL audiogram and the LDLs to obtain ear canal SPL values that are displayed on the fitting screen
    - Added to the prescriptive target values to obtain targets expressed in ear canal SPL

Hearing aid test box

- Sound treated box
- Main components:
  - Tone or noise generator
  - Amplifier
  - Loud speaker (sound source)
  - 2cc coupler (HA1, HA2)
  - Reference microphone (control microphone)
  - Measurement microphone

Hearing aid test box

A. Reference microphone
B. BTE adapter tube
C. The coupler assembly
D. Battery simulator
E. Cable groove
F. Elevation plate
G. Coupler microphone sockets
H. Sound absorbing foam lining
I. Main loudspeaker
J. Rear loudspeaker
K. The AURICAL HIT lid

Functions of a test box

- To generate and present sounds of a required SPL to the microphone of the hearing aid.
- To attenuate ambient noise
  - The lid seals well to the box so excluding external noise
  - Possesses solid dense walls
  - The internal absorbent material decreases internal sound reflections so that most of the sound reaching the microphone comes directly from the speaker
  - The reduction in reflected sound waves makes it easier for the control microphone to achieve the desired SPL at the hearing aid input.

Reference microphone

- Monitors the SPL reaching the HA from the loudspeaker.
- If the sound is higher/lower than it should be, the control mic system turns the volume up/down to ensure the correct level of sound is delivered to the HA.

Measurement signals

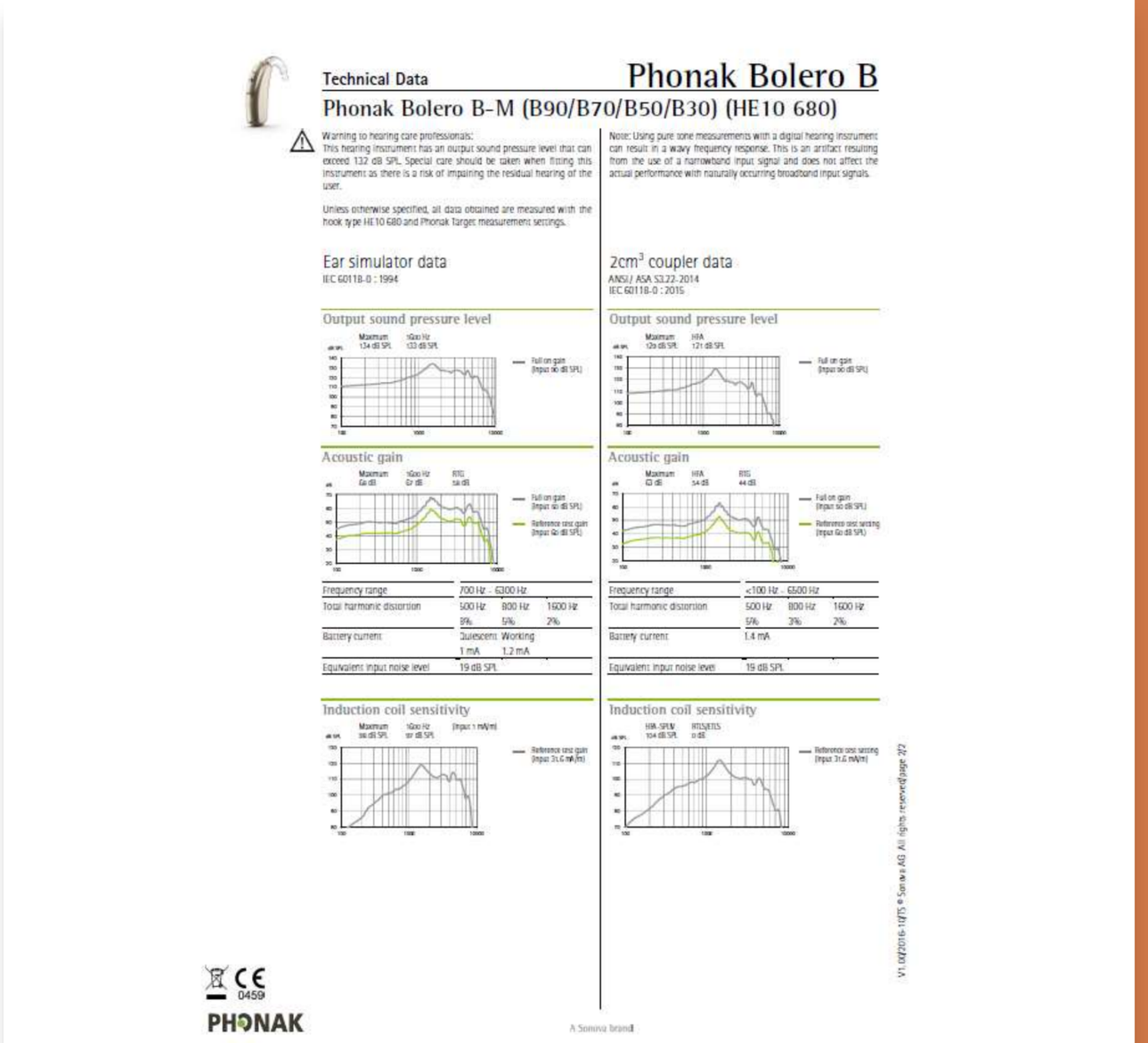
- Test boxes generally use two different types of measurement signals
- Pure tones
  - Automatically sweeps in frequency across the desired range (typically 125 Hz to 10 kHz)
- Broadband noise like signals
  - All frequencies are presented simultaneously

International hearing aid test standard

- Several standards specifying how hearing aids should be tested have been published by:
  - American National Standards Institute (ANSI)
  - International Electrotechnical Commission (IEC)
- ANSI S3.22 (2014)
- IEC 60118-0 (2015)
- Both specify consistent methods to measure and verify the performance of systems and devices

Hearing aid data sheet

- Gives information about functioning of the hearing aid in specific test conditions.



Technical Data

Phonak Bolero B

Phonak Bolero B-M (B90/B70/B50/B30) (HE10 680)

Warning to hearing care professionals:
This hearing instrument has an output sound pressure level that can exceed 132 dB SPL. Special care should be taken when fitting this instrument as there is a risk of impairing the residual hearing of the user.

Unless otherwise specified, all data obtained are measured with the hook type HE10 680 and Phonak Target measurement settings.

Note: Using pure tone measurements with a digital hearing instrument can result in a wavy frequency response. This is an artifact resulting from the use of a narrowband input signal and does not affect the actual performance with naturally occurring broadband input signals.

Ear simulator data
IEC 60118-0 : 1994

2cm³ coupler data
ANSI/ ASA S3.22-2014
IEC 60118-0 : 2015

Output sound pressure level

Acoustic gain

Frequency range	700 Hz – 6300 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	6%	5%	2%
Battery current	Quiescent	Working	
	1 mA	1.2 mA	
Equivalent input noise level	19 dB SPL		

Frequency range	<100 Hz – 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	6%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

Induction coil sensitivity

PHONAK

A Sonova brand

Main parameters of interest

- Output sounds pressure level with 90 dB input (OSPL90)
- Acoustic gain measures
- Frequency response

Other parameters of interest

- Harmonic distortion
- Equivalent input noise level
- Battery current drain
- Telecoil response

OSPL90

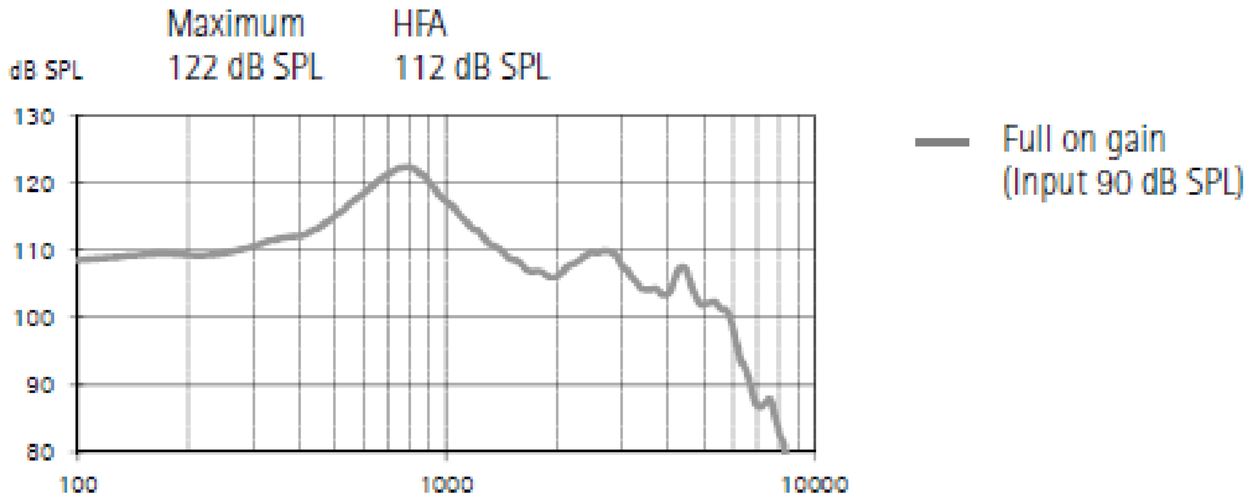
- The sound pressure level produced in the 2cc coupler or ear simulator with an input sound pressure level of 90 dB SPL at a specified frequency or frequencies, the gain control is in the full-on position and the other controls are set for maximum gain and output.

OSPL90

- Input of 90 dB SPL
- Output in dB SPL
  - Typically maximum output of the hearing aid
- Varies with frequency
- Plotted as a function of frequency
- Tolerance: 3 dB for OSPL90, +/- 4 dB for HFA-OSPL90

OSPL90

Output sound pressure level



Acoustic gain measures

- Full on gain
  - Measured with and input of 50 dB SPL.
  - Volume control set at maximum.
  - The value should not deviate from the value provided by the manufacturer by more than +/- 5 dB

Acoustic gain measures

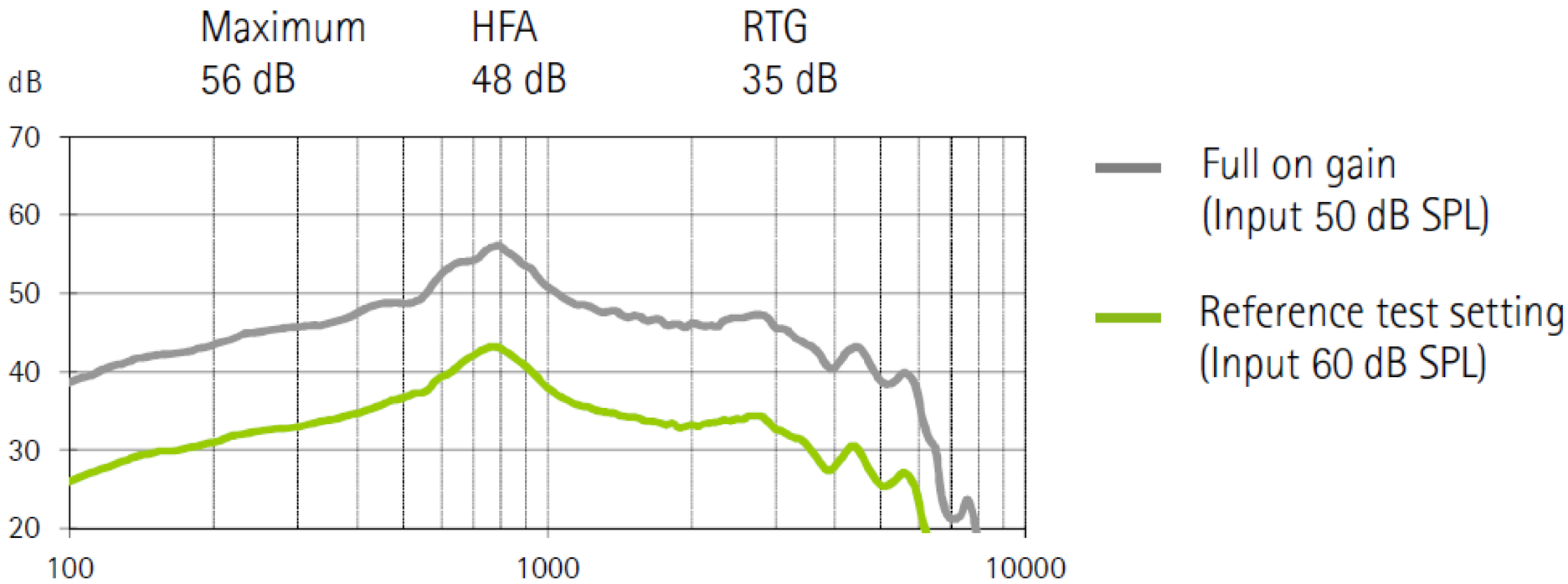
- Reference test gain
  - Measured with and input of 60 dB SPL.
  - Amount of gain measured with a hearing aid depends on where the volume control and other features are set.
  - If the volume is full-on – full on gain measured.
  - But may not want to measure settings when hearing aid saturated for mid-level input signals, so use reference test gain.
  - RTG is stated for information only and therefore no tolerance information is required.

Frequency response

- Input of 50/60 dB SPL
- Output in dB SPL
- Varies with frequency
- Plotted as a function of frequency

Acoustic gain and frequency response measures

Acoustic gain

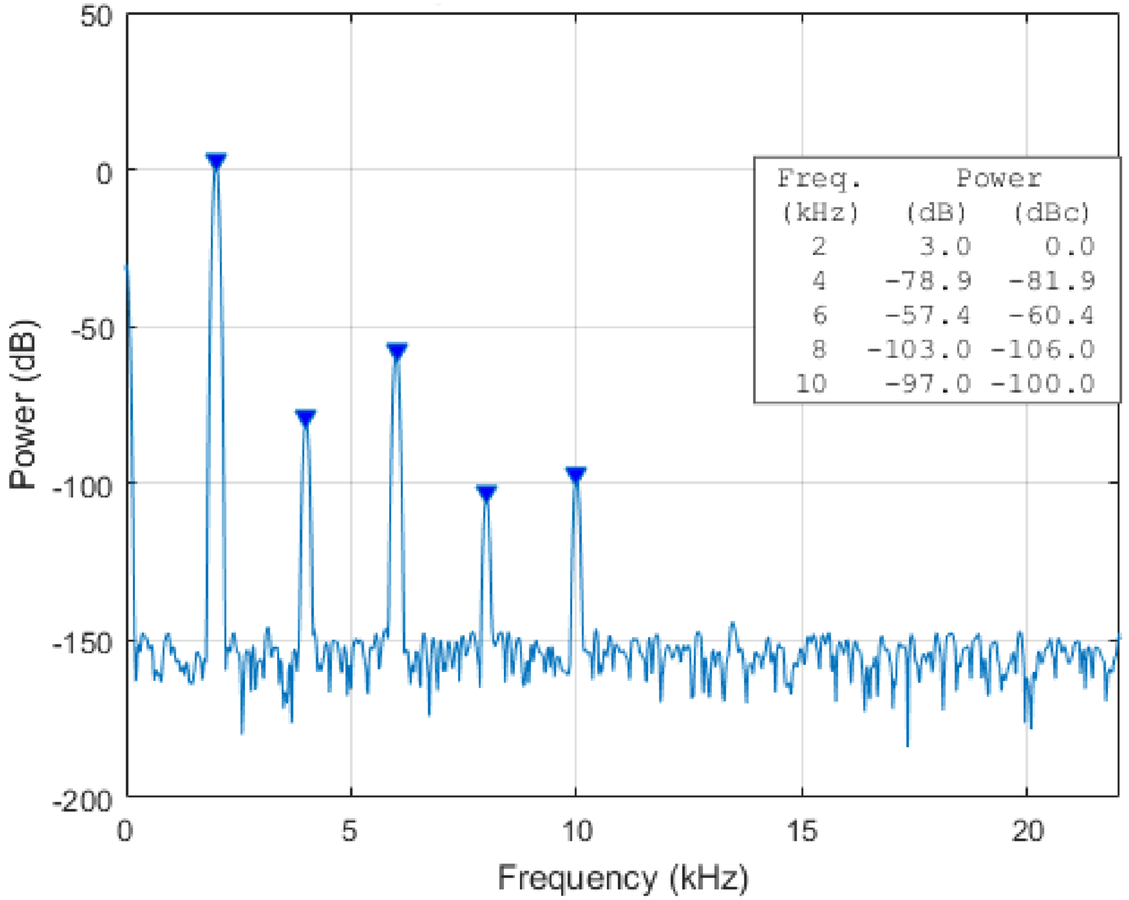


Harmonic distortion

- An ideal hearing aid would produce an output identical to the input signal, only amplified
- Hearing aids are not capable of doing this and invariably the output is also a slightly distorted version of the original input signal
- The term distortion is used to describe unwanted non-linearity. Hearing aids should produce as little unwanted distortion as possible

Harmonic distortion

- Harmonics are multiples of the original frequency
- Take a pure tone of 2 kHz
  - Original tone or fundamental frequency
    = 2 kHz
  - First harmonic
    = 1 x 2 kHz = 2 kHz
  - Second harmonic
    = 2 x 2 kHz = 4 kHz
  - Third harmonic
    = 3 x 2 kHz = 6 kHz



Harmonic distortion

- Harmonic distortion is measured by filtering out the fundamental frequency from the output signal and measuring the remaining harmonic content.
- Measurements usually only consider the second and third harmonics. These can be considered separately or together in terms of ‘total harmonic distortion’.
- Harmonic distortion should not exceed the value provided by the manufacturer plus 3%.

Harmonic distortion

Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

Battery current drain

- Battery life is affected by a number of variables:
  - Battery capacity in mAh (battery rating)
  - Hearing aid factors such as gain control, signal intensity, sound input, and discharge voltage level.
  - Other factors such as temperature and humidity, dry-aid kit usage, and other environmental factors.
- Higher than expected battery drain usually indicates impending mechanical failure of device.

Battery current drain

Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

Equivalent input noise level

- Hearing aids generate their own internal random noise that must be minimised to prevent the masking of important quieter sounds.
- Internal noise is usually analysed in one-third octave bands and is expressed as an equivalent input noise level.
- Should not exceed the maximum value specified by the manufacturer plus 3 dB.

Equivalent input noise level

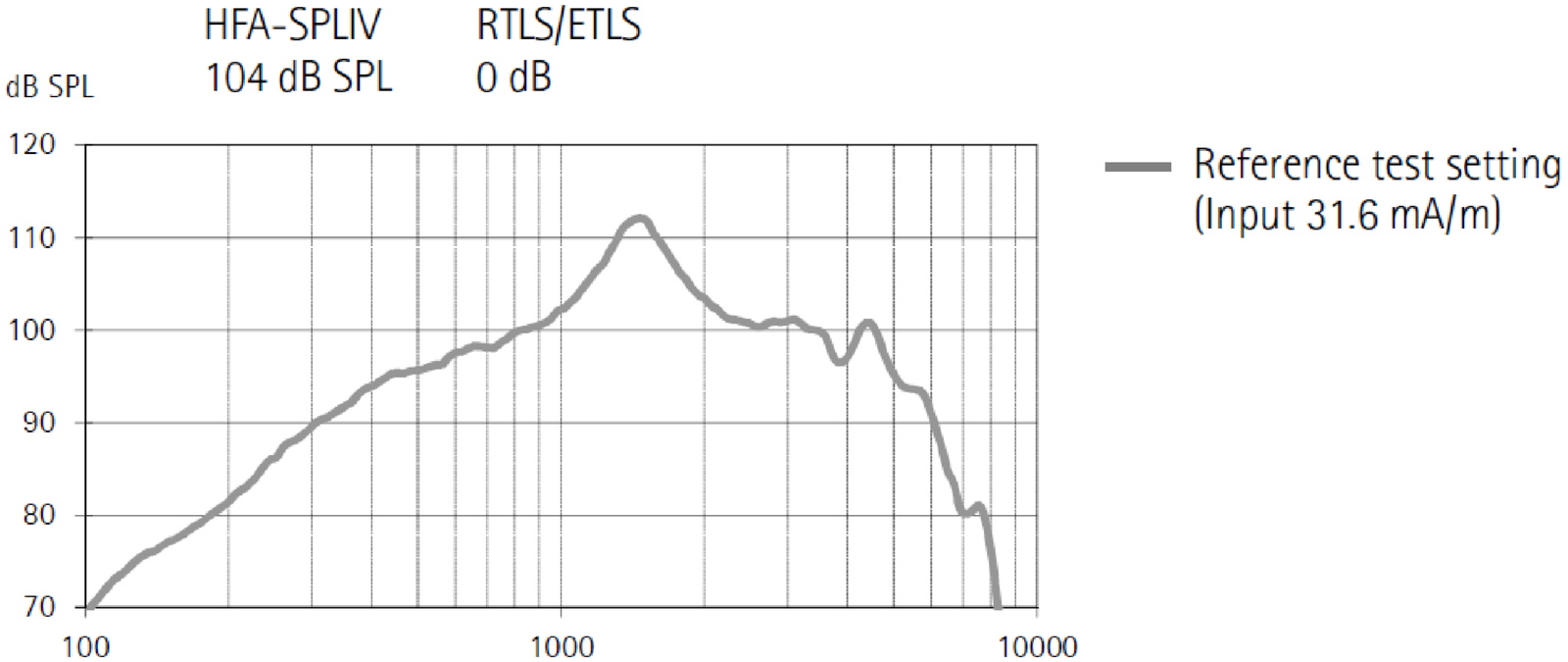
Frequency range	<100 Hz - 6500 Hz		
Total harmonic distortion	500 Hz	800 Hz	1600 Hz
	5%	3%	2%
Battery current	1.4 mA		
Equivalent input noise level	19 dB SPL		

Telecoil response

- A strong magnetic field is generated in the test box and the gain control on the hearing aid is set to the reference test position or full-on position.
- The magnetic response is displayed as a graph of output SPL against frequency. A frequency response curve can be recorded between 200 & 5000Hz.
- Values should be within +/- 6 dB of the manufacturer’s values.

Telecoil response

Induction coil sensitivity



Coupler-based verification

- Substitute for PMMs
- Can run the same tests as you would for PMMs in a coupler