Music in the view of a hearing aid manufacturer

Volker Kühnel PhD
Director of Hearing Performance
Sonova AG, Stäfa, Switzerland

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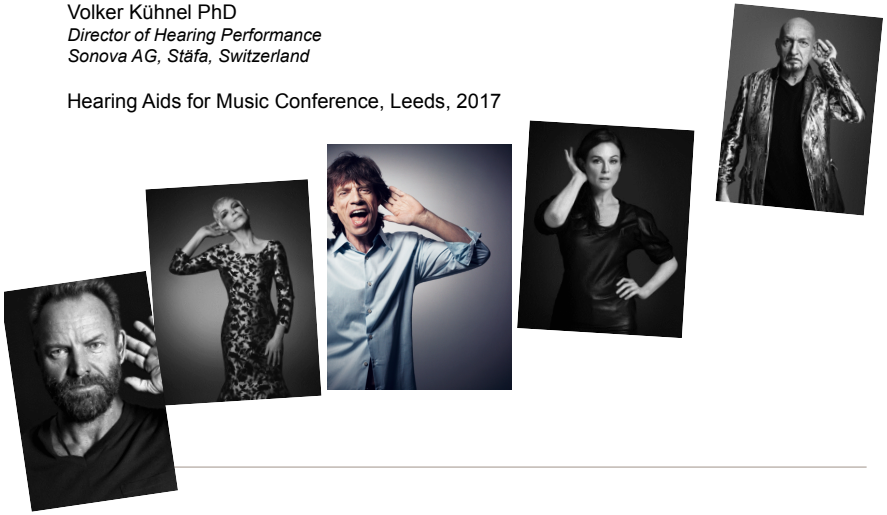


Music and hearing aids

– Music is important! This is true as music enhances the quality of a person's life, not only in terms of enjoyment, but also as a medium that models social structures and provides a medium for human interaction (Cross, 2006).

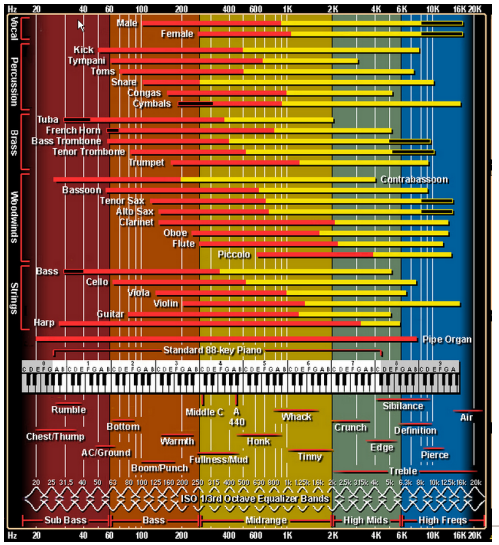
– High frequency hearing loss is by far the most common audiometric configuration found in individuals fitted with hearing aids and affects speech comprehension but also music perception adversely as music and lyrics can't be detected or identified easily with only limited access to information located in the high frequencies (Glista & McDermott, 2008).

Music and hearing aids

Sound quality is important to enjoy music
Optimized speech intelligibility, currently major focus of hearing devices
Interest on topic *Hearing aids & music* increases (not complete):

– "Hearing Aids and Music" (Chasin & Russo 2004)
– "Music as an Input to a Hearing Aid" (Chasin 2007)
– "Six ways to improve the listening of music through hearing aids" (Chasin, 2010)
– "Hearing instruments to enjoy live music" (Hockley et al. 2010)
– "Hearing Matters: Aided Mapping for Music Lovers: Addressing the Basic Issues" (Colucci 2013)
– "The Influence of Non-Linear Frequency Compression on the Perception of Timbre and Melody by Adults with a Moderate to Severe Hearing Loss" (Uys et a. 2013)
– "Music Preferences With Hearing Aids: Effects of Signal Properties, Compression Settings and Listener Characteristics" (Croghan et al. 2014)
– "Back to Basics: Music Listening and Hearing Aids. Are All Approaches the Same? Stop and Listen" (Chasin, 2017)

Frequency range and dynamic range of music



20 Hz – 20 kHz

Very large dynamic range:

40 up to >110 dB SPL

Important factors:

Rhythm

Harmonic structures

Timbre

Modulations

Consequences of sensorineural hearing loss

– reduced dynamic range -> soft sounds become inaudible
– reduced frequency bandwidth -> loss of high frequencies
– reduced frequency resolution -> poorer pitch detection
– Degraded binaural processing -> poorer spatial resolution

– > Difficulties to resolve complex music with a damaged auditory system
– Perceived distortions may result from altered auditory function

– Key for a good music experience:
  – present the relevant cues of music appropriate to the residiual hearing capabilities
– But: what are the most important cues?

Important perceptual properties for music are affected

What is «natural sound quality»?

It depends on
  – the hearing loss:
    – Mild to moderate Hearing loss vs. Severe to profound loss
  – Familiarity:
    – For inexperienced hearing aid users:
      – acoustic transparency – ie a flat frequency response, no compression
    – For experienced users:
      – Familiarity to the used devices -> switch from Analog to Digital devices
  – Needs and expectations:
    – Active musicians vs non-musician

– Do we have a common vocabulary to describe attributes / factors contributing to sound quality?
  – Musicians vs. naiive listeners vs clinicians? -> find a common language

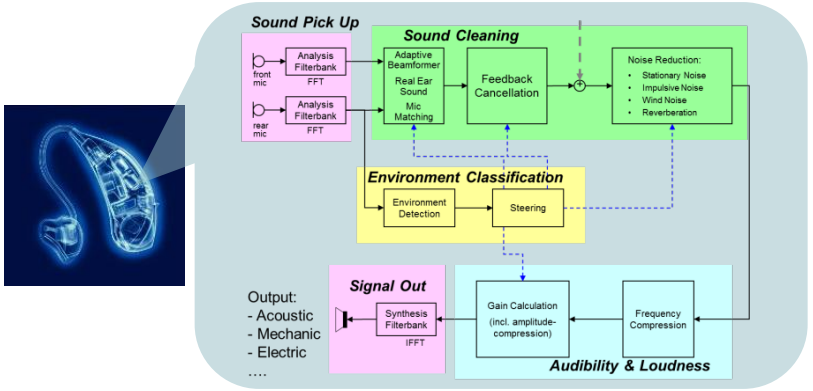
There is not one solution for all

Main factors influencing music perception with hearing aids – technical view

– Dynamic range
  – possible distortions at very high input levels
– Limitations of the Loudspeaker (Receiver)
– Gain control: AGC, WDRC, MPO
– Impact of sound processing algorithms like
  – Directional microphones, Feedback cancellation, noise reduction etc.

A modern hearing system

– An overview over features and possible impact on music perception

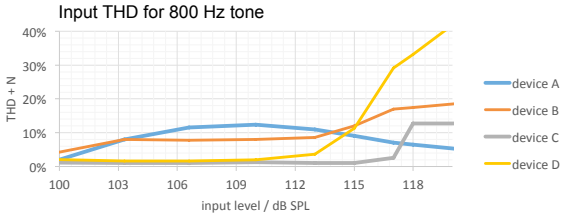


Hearing aids - electroacoustic of the Input stage

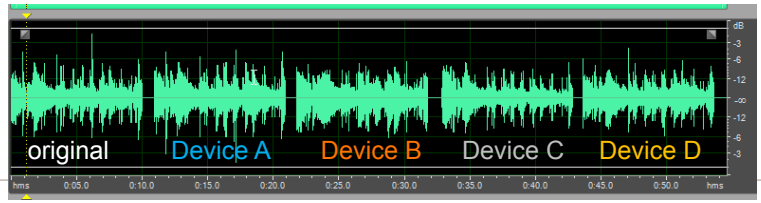
– Dynamic range of current HI microphones + AD-converter:
  25 dBA - 115 dBSPL
– Covers most inputs without distortions

– Omni-directional vs directional:
  – ITE/ CIC: omni for most natural spatial perception
  – RIC/ BTE: RealEarSound -> restauration of the Pinna effect, omni gives more «room» and reverberations

Typical input distortions for 4 current digital HI



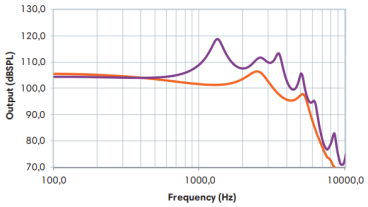
Music sample: 107 dB SPL, 118 dB Peak level



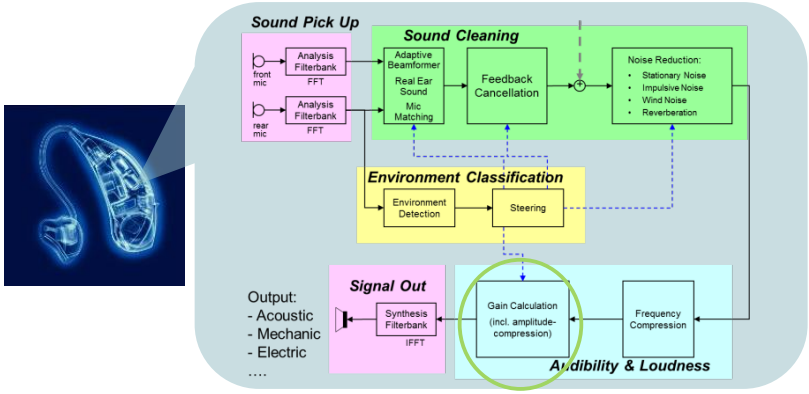
The Loudspeaker / Receiver

Amplifier outputstage:
typically > 100dB dynamic range

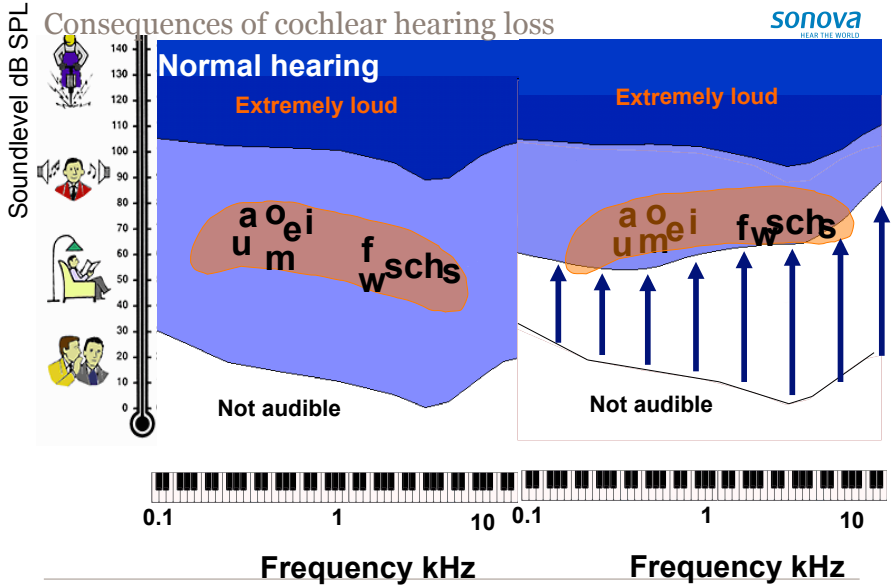
– Receiver technology:
  – Balanced armature receiver is optimized for high efficiency
    – limitited frequency response at high frequencies
    – smoothness of frequency response?
    – can be compensated with DSP filtering to some extent
  – High level distortions of the receiver
    – relevant for very high output levels



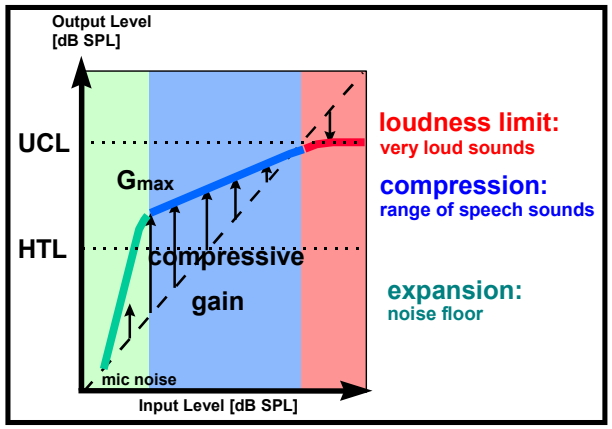
Gain processing



Consequences of cochlear hearing loss



Hearing aid compression



Fast or slow Gain processing?

- Different manufacturers have different philosophies for hearing loss compensation
- Fast actings syllabic compression (WDRC):
  - Optimized for speech intelligibility
  - Aims at making all sounds audible again
  - Compensates for cochlear compression loss
- Drawback:
  - Reduces temporal and spectral contrast -> «blurred»
  - Reduces binaural cues -> «narrow» sound image, less spatial separation

Fast or slow Gain processing?

- Slow compression (Automatic Volume Control):
  - Tries to restore average loudness perception
  - Can preserve dynamics of the signal (speech)
  - Can preserve spatial cues
- Drawback:
  - Sudden loud sounds may be perceived too loud
  - Soft sounds following loud input may get inaudible

- For music slow or combined fast/ slow systems seem to be preferred

MPO – maximum power output limiting

–An important function in hearing aids to avoid excessive SPL and discomfort for very loud inputs
–Helps to avoid distortions of the output stage or the loudspeaker/ receiver
–Drawback:
  – Too low MPO settings reduce the signal dynamic range
  – Multi band limiters also may reduce spectral contrast of the signal

–Ideally the MPO is only rarely activated for music

Gain expansion – «soft squelch»

–Is used to reduce system noise (microphones, preamplifier) or low level background noise
–It is optimized for speech input
–Drawback:
  – The device may be preceived as «dead» in quiet environments or for very soft music passages
  – It may create unwanted fluctuations when activated and deactivated
–For Music:
  – If possible deactivate the expansion or set the expansion TK very low

– With improved technology soft squelch is less important

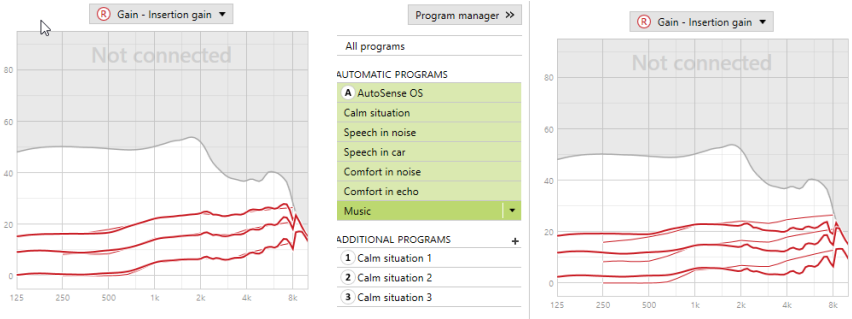
Frequency response

– Typically hearing aid amplification emphasise the main speech region (500-3000 Hz) and reduce low frequencies
– This results in improved speech intelligbility at same loudness perception compared to a flat frequency response

– Impact on music perception:
  – Reduced low frequencies: Music is not perceived as full
  – >Increase low frequencies (below 1 kHz) to achieve fuller sound

Frequency response - example

– Flat 50 dB hearing loss, NAL NL2 target



default program

Phonak music program

Frequency lowering

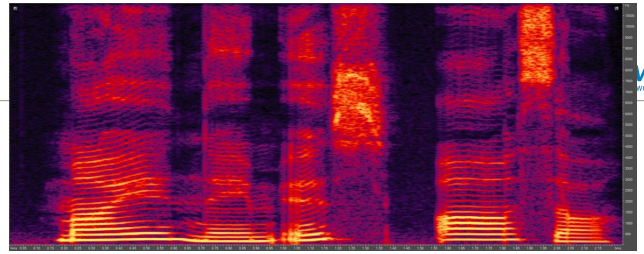
Idea:

– Make high frequency fricatives eg «s» «sh» «th» «f» audible again for severe to Profound hearing impaired

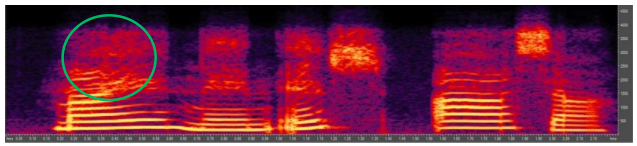
–Depending on the algorithm it can affect the harmonic structure of sounds

–Is designed mainly for speech

– original

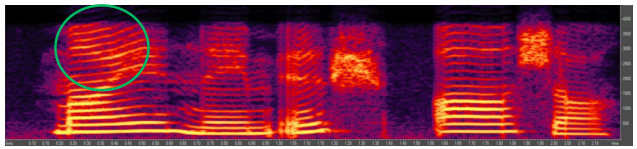


– SoundRecover 1



My name I s A s a

– SoundRecover 2



Frequency lowering

–Adaptive Frequency lowering (SR2) better preserves music sounds than static frequency lowering

–For Music: either disable or set high Cutoff frequency (> 2kHz)

Feedback cancelling

–Maintains acoustic stability with high gain

–Up to 20 dB over critical gain is possible with phase cancellation algorithms and frequency shifting (eg 10 Hz)

–Works great for speech input

But:

– Frequency shift can be preceived as mistuned pitch (out of tune)
– Adaptiv FB-canceler modulates tonal periodic signals

For music:

– disable Feedback canceller if possible or use a less agressive settings
– Reduce gain if needed

Programm automatic

If a fully automatic hearing device is desired
- For music the device should behave consistent and predictable:
  - No fading between different sound processing schemes
  - Reaction time is rather slow – 10-15 sec

Accessories – streaming music

- Bluetooth technology enables direct streaming from smartphone / TV/ MP3 player to the hearing aids.
- No direct sound avaliable
  - It has to be delivered from the HI- receiver
- If possible choose a larger Receiver for RIC devices
  - Results in more headroom in the lows -> fuller sound

Finally: my hints for improving music experience with Hearing aids

- Turn off fancy adaptive features like:
  - Noise reduction, reverberation reduction, Adaptive beamforming, feedback cancellation
- Try to achieve a smooth and flat frequency response
- Choose the largest acceptable receiver for RIC devices to have more bass and dynamics. Eg. xP instead of xS receiver with Phonak products
- A more linear setting is preferred in most cases (slow or dual compression) + (increased MPO)
- Increase the low frequencies, but avoid clipping/ saturation
- Use either a manual music program or a dedicated program in the automatic mode