Possible Pitfalls of InSitu Measurements
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Background

Deviations between NAL-NL1 target and REM gain during InSitu verification of First Fit were reported.

- Bad shape of curve between 1.5 and 3kHz
- “2kHz dip”
- Peaks at higher frequencies

- Observed especially in UK and Australia
- Observed for various hearing instruments
- Observed for various test systems

- Individual characteristics
Background

A project was started to

- Investigate the reproducibility of the reported observations
- If applicable: find reasons for the deviations
- If applicable: perform fix and validate the fix

The actual presentation gives an overview about the investigations and actions performed within this project.
Agenda of actual presentation

- Outcomes of investigations (reproducible impact factors)
  - Connexx model
  - Test setup
  - Individual anatomy
- Actions based on these findings
- Validation
- Further Recommendations

- Questions and discussion at the end of each section
Investigated issues

- Impact of hearing instrument setting / Connexx model
  - Internal clocking / Connexx Model
  - Input compression (AGCi)
  - Output limiting (AGCo)

- Impact of test setup and protocol
  - Stimulus
  - Sound source position
  - Probe tube Position
  - Room acoustics
  - Measurement system

- Impact of individual anatomy
  - Inter-individual variation of OEG and RECD
  - HI tube length
  - Volume of ear canal
  - Diffractions of sound signal caused by head and shoulder
Impact of hearing instrument setting / Connexx model

Wireless applications and standard on the ASIC make a 5% overclocking of the chip necessary. However, all correction curves of the electro-acoustic elements stored in Connexx 5.3 are still based on the original clocking. The effect on the gain curve differs depending on the shape of the curve and is hardly predictable. In general, stronger effects can be expected for moderately sloping curves. Amount: about 2dB less gain for f<5kHz.

(Acuris S, First Fit Cluster3, pure tone stimulus)
An impact of sub-optimal AGCi settings (level meter) can be observed across the whole frequency range. Amount: up to 3dB @ 2kHz

(Acuris S, First Fit Cluster3, LTASS stimulus)
The impact of AGCo (intended behavior) may cause large deviations from the Connexx simulation of LE90 curve, if modulated noise is used as stimulus. Direct impact cannot be excluded for modulated stimuli and higher amplification levels. In fact, a reduction of about 6dB was observed for this study for 15dB linear gain with AGCo limiting while using the Aurins stimulus. When output liming was set to PC, correct gain curves were observed.

(Acuris S, FOG curve for IEC-2 noise)
Impact of hearing instrument setting

- Impact of Connexx model and chip clocking
  - 5% over-clocking was not accounted for in the Connexx model
    => mis-shaping of curve especially between 1 and 2kHz, about 2dB less gain for f<5kHz
  - AGCi parameters / level meters were sub-optimal
    => up to 3dB less gain than expected
  - AGCo may influence measurement in some cases
    => up to 6dB less gain was observed
Impact of test setup and protocol

If two different stimuli are used for measurement, gain may be falsely estimated by Unity1 using the 16bit software.

Example: If Aurins is used for the measurement of insertion response and pink noise for the measurement of open ear response, the gain calculated by Unity1 will be over-estimated in the frequency range around 1kHz.
If AURINS noise is used for the IG measurement, the measured curves must not be compared to the target curves displayed in the Unity, because the latter are NAL targets which are, by definition, based on an LTASS input. The correct targets are shown in Connexx and yield about 6dB less gain for Aurins between 1 and 2.5kHz (Cluster3, typical age related hearing loss).
The position of the reference microphone yields a different sound field compared to the field reference point. If the input level is regulated with respect to the reference microphone, less input than expected is presented to the hearing instrument.
Impact of test setup and protocol

The sound source position at 45deg combined with the different sound field cause a deviation from the standard REUG as assumed by Connexx. This may cause a peak / dip pattern in the aided response between 2.5 and 6kHz.

(Acuris S, First Fit Cluster3, pure tone, KEMAR measurement)
The position of the reference microphone yields a different sound field compared to the field reference point. In addition, the MLE for 45° sound direction differs from the 0° MLE. This leads to a different input to the instrument and, as a consequence, to a different gain curve than expected.
Summed effects of setup and Connexx model

If the impacts of AGCi, clocking, and test setup are regarded isolated from each other, they are all within the tolerance range. However, if they are combined, the total effect rises up to about 6dB.
Example case

The stimulus spectrum was not equalized during the measurement. This caused a prominent dip at 2.5 kHz during the InSitu measurement which cannot be attributed to the instrument. Rather, this is a measurement artifact caused by diffractions at the head and the shoulders of the patient. Expected gain curve: about 20dB flat from 250Hz to 6kHz.
Impact of test setup and protocol

- If two different stimuli (Pink Noise and Aurins) are used for measurement, this may result into an over-estimation of gain at 1kHz with old Unity1 software.

- The position of reference microphone below the ear may cause dip at 1.8kHz of about 3dB.

- The sound source position at 45° causes peaky shape for f>2kHz.

- NAL-NL1 is based on LTASS and does not support the AURINS stimulus, instead Connexx makes a calculation based on the LTASS target. Unity is unable to do this and always shows the LTASS targets.

- For some stimuli (incl. AURINS) only the overall level is equalized during the measurement, but not the spectrum shape. For these stimuli, diffraction at head and shoulders may cause dip at 2.5kHz of 10dB. The amount and shaping of the dip are determined by the individual anatomy of the patient.
Impact of individual anatomy
Length of HI tube

For HI tubes longer than standard, a more peaky shape of the gain curve can be expected for $f>1\text{kHz}$.
Impact of individual anatomy
Volume of ear canal

Less overall gain is measured for identical HI settings in case of larger ear canal volumes (i.e. large ear canal diameter).
Impact of individual anatomy
Individual OEG and RECD: one example

The target gain curve in this figure was 20dB flat from 250 Hz to 4kHz. The statistical OEG and RECD curves lead to deviations below 900Hz (leakage effects) and a dip between 1 and 2 kHz. Importing individual OEGs or RECDs and using tight ear molds led to a satisfactory result in this case.
Impact of individual anatomy
Average individual RECD

Measurements of individual RECDs with 50 subjects at an individual research site yielded an average RECD very much comparable to the standard RECD that is actually used in Connexx (HA2).
Impact of individual anatomy

- Individual factors
  - Longer HI tube may cause dip at 2kHz
  - Larger ear canal volumes may cause less overall gain
  - Diffraction of stimulus at patient’s shoulder may cause dip at 2.5kHz
  - Individual REUG and RECD may have unpredictable influence which may be compensated easily by importing individual curves. However, the standard RECD used by Connexx fits very good to the average individual RECD.
Modifications and fixes
Connexx 5.4

- Compensation of clock trimming: included in Connexx 5.4
- Optimisation of AGCi level meter: included in Connexx 5.4
- Activate PC instead of AGCo during test setting for InSitu and coupler measurements: included in Connexx 5.4
- Adjustment to modified sound field in case of InSitu fitting (reference mic and sound source positions): Connexx 5.4 allows this to be optimised via country specific SiFit.
Modifications and fixes

Unity

- Future versions of Unity software will be able to import the Connexx Auris target curve. Until then
  - Compare to the Connexx targets to be met, not the Unity targets (on-top modus does not work!) or
  - Use Icra1 stimulus for InSitu measurements
Verification of the modified Connexx model
Coupler measurements (UPL)

- LE40
- Deviation at LE40

- typical age related hearing loss
- modulated speech-like stimulus (IEC2)
- Prisma2 Pro

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Verification of the modified Connexx model
Coupler measurements (UPL)

typical age related hearing loss
modulated speech-like stimulus (IEC2)
Prisma2 Pro
Verification of the modified Connexx model
First Fit Accuracy of Prisma2 Pro

Median REM Gain Curves

- LTASS Target
- Prisma2 Pro

Insertion Gain (dB)

Frequency

Median REM insertion gain of 6 subjects
Verification of the modified Connexx model
First Fit Accuracy of Prisma2 Pro P

Median REM Gain Curves

- LTASS Target
- Prisma2 Pro P

Median REM insertion gain of 6 subjects
Verification of the modified Connexx model
First Fit Accuracy of Prisma2 Pro P

Median REM Gain Curves

- Median REM insertion gain of 6 subjects
Summary

- Deviations between target gain and REM gain as reported in the past are the result of various effects. Both instrument settings and measurement artefacts play a role.

- Several impacts of HI setting / Connexx model were corrected for in Connexx 5.4.

- Individual corrections that are needed due to test setup can be implemented in country specific SiFit (e.g. NHSFit).

- The impact of very individual anatomy cannot be excluded. In some cases, it may be useful to import individual curves to Connexx in order to enhance the quality of the fitting. However, this does not always work with Unity1 using the 16bit software => switch to 32bit software recommended.
Recommendations

- **Hearing instrument settings**
  - Switch to test settings or switch off all adaptive parameters manually before REM measurement

- **Test setup**
  - Use the same stimulus for the measurement of unaided and aided responses
  - Use LTASS or ICRA instead of AURINS
  - If other stimuli are used: do not use the NAL-NL1 target displayed in Unity, but compare with target displayed in the fitting software (import of Connexx targets into Unity will be offered soon)
  - Unity32 or Unity1 with 32bit software is recommended

- **Individual factors**
  - For patients with longer HI tubes, 2kHz dips should be expected
  - For patients with large ear canal, less overall gain should be expected
  - For patients with very unusual REURs, import OEG and/or RECD into Connexx (applicable approach for Unity2)