Audiological Bulletin no. 35

Ensuring the correct in-situ gain

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Introduction

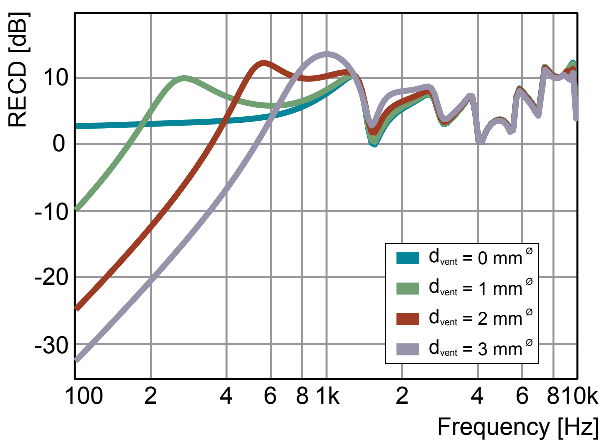
Hearing aids are commonly fitted according to data based on a standard adult ear. This neglects the fact that the acoustic conditions around an individual's outer ear are rarely standard. The difference between standard and individual outer ears can be seen in the RECD.

If we want to be sure to present the correct sound pressure at the eardrum, this difference between average data and real-life individual data must be measured and corrected for in the hearing aid fitting.

To do this, Widex measures the individual hearing threshold with the hearing aid in the ear, the Sensogram, and with the introduction of the Assessment of In-Situ Acoustics concept (AISA) we come one step closer to perfection in fitting precision. Here is where also the individual RECD data comes into the picture.

Individual RECD's compared to average data

Many factors can make the individual RECD differ from the average. The most prominent effect is the vent effect, which can have a large impact in the low frequency area as shown in the figure below.



Other factors could be the dimensions of the tubing connecting the hearing aid with the earmould or the dimensions of the ear canal itself.

How does RECD data influence the hearing aid fitting?

As RECD values have an influence on the amplification, a change in RECD values means a change in the sound perssure level when the sound is produced by the hearing aid. This change will have an effect in all the circumstances where the hearing aid is used as a sound generator. The hearing aid acts as a sound generator in two ways:

- when measuring the in-situ hearing threshold where the hearing aid produces the test tones
- when the hearing aid is in normal use, taking in sound from the environment and amplifiying it

Even more precise threshold measurement

When the RECD is different from what the hearing aid expects, the sound pressure level calculated by the fitting software when making the Sensogram measurement does not correspond 100% to what is presented in the ear canal. Let us have a look at an example:

A hearing aid user has an ear canal that differs from the average ear: His RECD value at 250Hz is 20dB lower than the default average RECD value in the hearing aid due to a vent in the earmould. That means that the hearing aid delivers a sound pressure level that is 20dB lower than what is was originally set to provide. The user's hearing loss tells us that he starts hearing a sound when the sound pressure level at the eardrum is 50dB HL. But as the hearing aid delivers a sound pressure level that is 20dB lower due to the vent, the Sensogram measurement is artificially raised to 70dB HL to produce this 50dB HL real sound pressure level at this individual's eardrum, which is the value at which he starts hearing a sound.

To match the needs of the real individual ear and to measure the correct hearing threshold, this deviation from the average has to be known and corrected for. We can obtain this knowledge from either a vent effect measurement, as this low frequency deviation normally would be explained by a partly open earmould, or by making an individual RECD measurement. When we know the degree of deviation from the average, it is easy to correct the measurement.

In this example we measured the user's hearing threshold to be 70dB HL. We have now estimated the vent effect to be –20dB and therefore know that the sound pressure at the eardrum is 20dB lower than the default hearing aid setting. We can then find the correct threshold by deducting the known deviation from the measured threshold, and the real threshold will be: 70dB HL – 20dB = 50dB HL.

Measurement and gain setting using Sensogram and correcting both gain and threshold.	**What the hearing aid expects**	**How it is in the real world**
RECD	0 dB	-20 dB
Threshold measurement	70 dB HL	50 dB HL
Gain based on a 50dB HL threshold and half gain rule (simplified for the example)	25 dB	5 dB
Corrected gain based on RECD difference	45 dB	25 dB

The correctly measured threshold gives the best starting point for calculating the needed target gain for all input levels.

Correct sound pressure level at all times

The target gain is calculated from the measured threshold using the fitting rationale for the hearing aid. But if the hearing aid delivers less sound pressure due to a vent than the manufacturer has designed it to do, the gain setting in the hearing aid will also be too low.

In the example we know that the presented sound pressure is 20dB lower than planned at 250Hz. To get the correct sound pressure level, we therefore have to add an extra 20dB gain at that frequency. To make the calculation easy, we use a half gain fitting rule in this bulletin, which means that for a hearing loss of 50dB HL, the target gain needs to be half of the 50dB, that is: 25dB. The vent lowers the sound pressure level in the ear canal by 20dB so the real gain with no correction will be 25dB – 20dB = 5dB. That is 20dB too low compared to the target gain, so we set up the hearing aid to provide 25dB + 20dB = 45dB to obtain the real gain of 25dB which was needed originally.

Why does the Sensogram not take this effect into account?

When using an in-situ threshold measurement like the Sensogram, a difference in the RECD value concerns the threshold measurement as well as the actual gain setting.

The example from earlier on using a Sensogram instead of an audiogram but without any corrections:

Measurement and gain setting using Sensogram without corrections.	**What the hearing aid expects**	**How it is in the real world**
RECD	0 dB	-20 dB
Threshold measurement	70 dB HL	50 dB HL
Gain based on a 70dB HL threshold and half gain rule	35 dB	15 dB
Corrected gain based on RECD difference	not corrected	

We see that the hearing threshold measured is 20dB too high. This means that we will set the hearing aid to deliver a higher gain than what we actually would want for the real 50 dB HL hearing loss, which is not known at this time. But as the same 20 dB difference caused by the vent applies to the gain setting (35 dB), the increased gain will again be lowered by the vent effect (35 dB – 20 dB = 15 dB). The result is, as shown, a real gain that is 10dB lower than the target gain of 25 dB.

If the fitting was done based on threshold measurement data from a well calibrated audiometer, the measured threshold showed 50dB HL and we chose to use that as basis for the fitting, the result would be a real gain of 5 dB instead of the target gain of 25 dB, as shown in the table below.

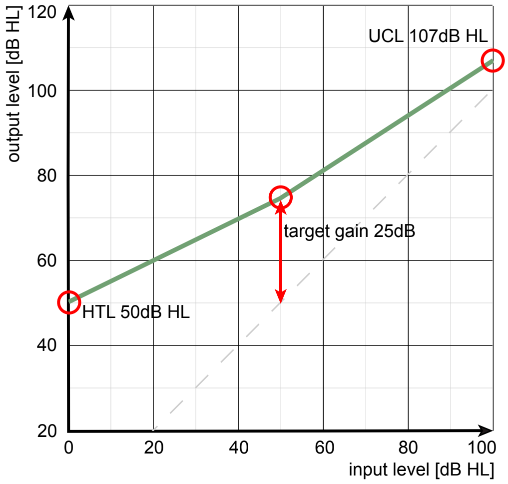
Measurement and gain setting using audiogram with no corrections.	**What the hearing aid expects**	**How it is in the real world**
RECD	0 dB	-20 dB
Threshold measurement	not measured	50 dB HL
Gain based on a 50dB HL threshold and half gain rule	25 dB	5 dB
Corrected gain based on RECD difference	not corrected	

In this example the audiometer calibration fits the user perfectly, so the presented sound pressure in the threshold measurement is exactly as expected. This will almost never be the case in real life even though it should be close. When using an in-situ audiogram measurement and estimating the error either using a vent effect estimate or making an RECD measurement, the audiometry measurement will always be calibrated exactly to the individual user.

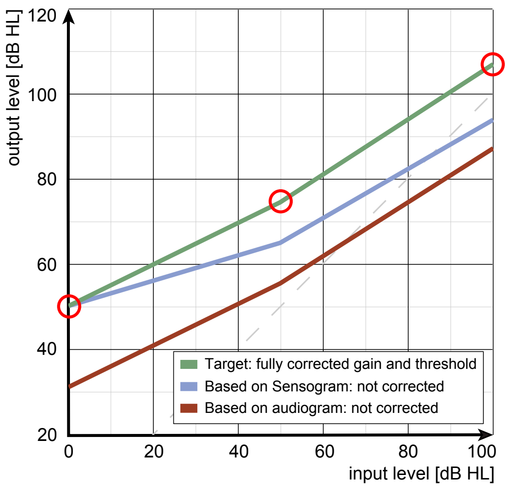
One step further: looking at compression

To explain the principle, we have used the half-gain rule for the example in this bulletin. In non-linear hearing aids, the hearing loss compensation will be tailored according to the input level. For soft input levels, the gain will be high and for loud input levels the gain will be much lower. How will this type of correction affect a fitting with compression hearing aids? How does this compare to just making an in-situ audiogram measurement and get done with it?

In the figure below, the real output level from the hearing aid is shown as a function of the input level when both the gain setting and the threshold measurement are corrected for the vent effect. The graph shows the gain set according to the half-gain fitting rule at a 50dB HL input level, which in this example is the level of normal speech. For 0dB HL input the target is a 100% hearing loss compensation so the output level will be 50dB HL at 0dB HL input level. For loud input levels, the target is defined by the UCL value. The target for loud levels is to play back sound with an input level equal to the normal-hearing person's UCL (about 97dB HL) at an output level equal to the UCL of the hearing aid user. The hearing aid user's UCL is calculated from the user's measured hearing threshold.



By correcting both the hearing threshold and the gain setting, the hearing aid user gets the needed gain at all input levels.



The drawing to the left shows the resulting output for three scenarios.

The blue line shows the result when a Sensogram is measured with no knowledge of the vent effect. At the threshold the gain will correspond perfectly to the target. At normal speech input levels around 50dB HL, the correction for the half gain rule will also be half of the vent effect. For loud inputs, the fitting rule will estimate that the user's UCL is 114dB HL, and as a result of the vent effect, this will be presented as 94 dB HL instead. As it should have been 107, this is an error of 13 dB.

The red line shows the result using an audiogram measurement alone. Using the correct threshold, but not making any corrections for the vent effect, gain will be 20dB too low for all input levels compared to the green target line.

Summary

In most cases there will be a difference between the sound pressure level we want to present in the ear canal of a hearing aid user, and the sound pressure level that the hearing aid really presents.

Using the individual earmould and hearing aid to measure the hearing threshold brings this difference into the equation and thereby brings the end result a lot closer to the wanted target. The only way to get everything correct is to measure the difference and correct for it both in the threshold measurement and the gain setting.

This measurement can be done by making an individual RECD measurement for each user. As the primary factor controlling the RECD for low frequencies is the vent and leakages in the earmould, estimating the vent effect for frequencies below 1kHz could also be sufficient.