

Adaptive Phonak Digital (APD)

Audiological background

At Phonak all basic requirements for hearing aids and a hearing aid fitting are based on the idea of a House of Acoustics. The House of Acoustics is a concept describing the different steps and elements of a hearing aid fitting. It provides three floors: the basement, the first floor and the attic. The floors are corresponding to the different steps of a hearing aid fitting process (Figure 1) which are based on each other and are essential to obtain a stable building. The basis (basement) is the calibration. The hearing aid has to operate exactly as specified. The acoustical parameters of a hearing aid are verified with an artificial ear. The second aspect of the basement requires that a hearing aid can provide acoustical transparency at the ear. Would the client wear the hearing aid with this setting and switch it on, he/she would hear according to his/her own hearing loss. For this purpose, the following parameters have to be considered:

- The individual gain of the auditory canal (REUG or OEG)
- The difference between the acoustical level at the eardrum and the acoustical level at the 2 cc coupler (RECD)
- The Microphone Location Effect (MLE)

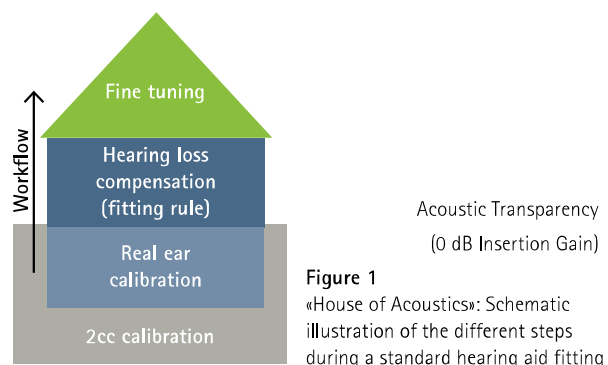
To determine the desired transformations two possibilities exist:

1. Individual measurement
2. Estimation

Basically it has to be considered that the measurements as well as the estimations on feedback measurements are approximations only because the above mentioned transformations are considering levels only; phases are neglected. When the basement is completed, the hearing loss compensation can be initiated. Based on the audiogram and further parameters it has to be decided which of the prescription rules seems most suited for the compensation of the hearing loss.

Based on the selected prescription rule and the entered audiometric data with the fitting software the gain and the compression of the hearing aid will be adjusted.

To provide an optimal fitting of their hearing aid portfolio Phonak invented its own fitting rule – Adaptive Phonak Digital – which is described and discussed in the following: With Adaptive Phonak Digital it can be assumed that an adequate loudness transformation of the input signals into



the usable area of the end user is obtained. Adaptive Phonak Digital comprises of precalculations for different hearing losses. Internally, calculations of the target gain exist for the types of the hearing loss mild, moderate, severe-to-profound, ski-slope hearing loss and reverse slope hearing loss. The precalculations are based on loudness assessments of hearing impaired and normal hearing listeners as function of the presentation levels (16,889 loudness assessments of 290 test subjects). With the applied research method it was possible to specify the loudness functions of the hearing impaired and as well the normal hearing subjects by linear functions. In principle Adaptive Phonak Digital is a prescription rule which maps the hearing impaired loudness function into a normal hearing loudness function. The shift of the loudness function into the direction

Audiological background

of enhancing presentation levels with an increasing hearing loss is compensated by the gain. The compression is calculated according to the increased steepness of the hearing impaired loudness function (recruitment).

For the above mentioned types of hearing losses different corrections of the pure loudness compensation for narrow-band signals have been proven beneficial. Five different basic prescription rules were derived from these corrections. During

the calculation of the target gain with Adaptive Phonak Digital, a weighting is calculated for each of the five hearing loss types based on the audiogram. The five calculations will be combined proportionally following the ratio of the weightings. For typical representatives of the hearing loss types in Figure 2 target gains are shown according to DSL v5 Adult, Adaptive Phonak Digital and NAL-NL2 and for speech signals at 50 dB, 65 dB und 80 dB.

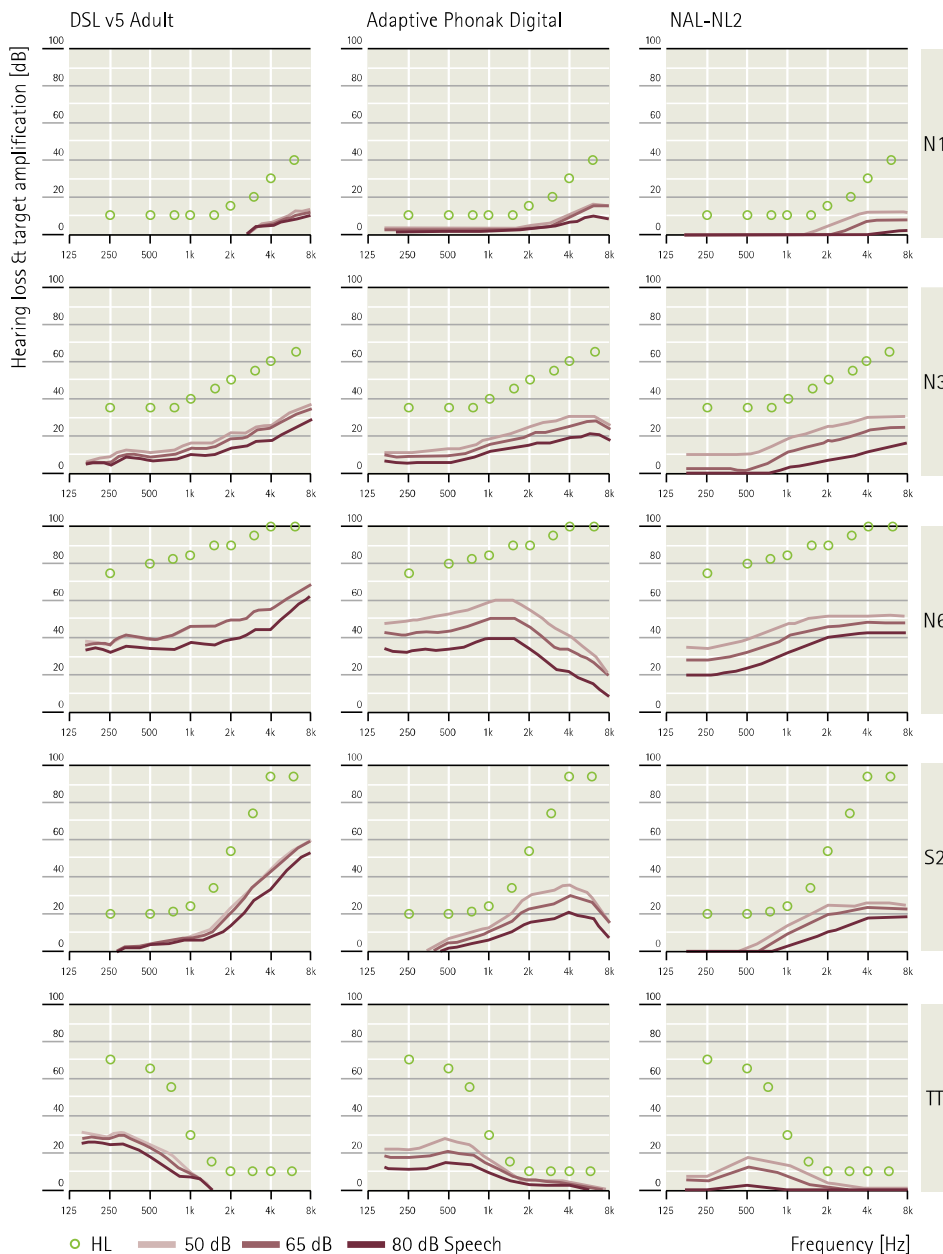


Figure 2 Comparison of target gains for soft, moderate and loud speech for the prescription rules DSL v5 Adult, Adaptive Phonak Digital and NAL-NL2 and for the standard audiograms N1 (mild), N3 (moderate), N6 (severe) and S2 (ski-slope hearing loss) following IEC 60118-15 [1] and a reverse slope hearing loss (TT). The hearing loss is shown as the circles.

Audiological background

In general it can be established that in comparison to DSL v5 Adult, Adaptive Phonak Digital focuses the gain to those ranges in which benefit can be generated while the gain is reduced in those ranges in which benefit can't be achieved. In comparison to NAL-NL2, Adaptive Phonak Digital prescribes more amplification at low frequencies and less compression at speech relevant frequencies.

For mild hearing losses the narrow-band loudness compensation is applied one to one. Typically, a slightly higher gain for soft and moderate high frequency signals results compared to DSL v5 Adult. The target gain is similar to NAL-NL2 with somewhat less compression leading to less amplification for low input levels (top row in Figure 2).

For moderate hearing losses the speech relevant range is slightly enhanced while the highest frequencies are slightly reduced. Typically, a slightly higher gain for soft and moderate signals in the mid-frequency range and a distinct decreased gain at 8 kHz will follow in comparison to DSL v5 Adult. Also for this hearing loss group Adaptive Phonak Digital and NAL-NL2 are quite similar, speech relevant frequencies are emphasized in both approaches. However the prescribed compression of Adaptive Phonak Digital in this frequency region is somewhat lower (second row in Figure 2).

For severe-to-profound hearing losses the speech relevant range is somewhat accentuated. For frequencies above 2.5 kHz, the gain is continuously reduced because it can be supposed that this range is nearly not auditory usable. Therefore the hearing aid output power is concentrated into those ranges which the severe hearing impaired can use reasonably. Typically a slightly higher gain for soft and moderate signals in the low and mid-frequency range and a distinct gain reduction above 3 kHz will follow in comparison to DSL v5 Adult. Compared to NAL-NL2 the amplification at low frequency is significantly higher for Adaptive Phonak Digital in that frequency range where NAL-NL2 normally prescribed only minor amplification due to the strong contribution of those frequencies to the overall loudness perception. At high

frequencies amplification is intensely reduced with Adaptive Phonak Digital adverse to the suggestion of NAL-NL2 (third row in Figure 2).

For ski-slope hearing losses the slope range is slightly boosted, typically the hearing loss range from 40-60 dB HL. Above this range the hearing loss compensation is continuously reduced. A typical result is a slightly higher gain in the slope range and a gain reduction above the slope in comparison to DSL v5 Adult. For this hearing loss group the amplification at low frequencies is significantly reduced using NAL-NL1 but in contrast at high frequency Adaptive Phonak Digital and NAL-NL2 are quite similar. (fourth row in Figure 2) For reverse slope hearing losses the slope range is increased, typically the hearing loss range from 30-50 dB HL. Below this range and below 500 Hz the hearing loss compensation is continuously reduced. In comparison to DSL v5 Adult typically a slightly higher gain in the slope range and a gain reduction below the slope results. For this hearing loss group NAL-NL2 the prescribed gain at low frequencies is much more conservative in comparison to Adaptive Phonak Digital what is also the case for high frequencies. (bottom row in Figure 2).

After the presetting, the first floor is completed. On top of the first floor, the attic has to be built. For that purpose with the House of Acoustics the hearing aid will be adjusted (interactively) corresponding to the individual requirements/expectations/sensations of the hearing impaired. For this reason the individual fine tuning of the gain happens in this floor, e.g. for a comfortable perception of the own voice, but also for activating or deactivating of enhanced hearing aid features (noise control, directional microphone, wind noise control etc.). Individual hearing aid programs and the fine tuning of gain as well as additional functions in specific, mainly problematical listening situations are the main focus of this range of hearing aid fitting and the House of Acoustics. After the gain and all additional functions of the respective hearing aid are individually adjusted, the House of Acoustics is completed.

Clinical evidence

Of course, in most cases a fine tuning (attic) of the precalculated fitting targets is necessary to satisfy hearing impaired with their hearing aids. In an extensive study it was investigated to what extent the presettings of the prescription rule Adaptive Phonak Digital are in accordance with the final expectations of hearing aid clients [1]. 203 hearing aid fittings from six different countries were analyzed. The field study considered the presettings, the results of the first fitting session one-two follow-up sessions and subsequent questionnaires. The primary evaluation parameter was the deviation from the proposed gain. An outcome of the investigated hearing aid fittings, shared the average fine tuning of gain was between 0 and 2 dB in the speech range (Figure 3). With it, Adaptive Phonak Digital has matched the favored loudness and timbre impressions of the hearing impaired very well. The standard deviation (3-7 dB) illustrates that fine tunings were made client specific in different directions. Small deviations to the precalculations indicate also the fine tuning of the saturated sound pressure level (MPO) and the kneepoint control (Figure 4). The fine tuning of the kneepoint control was 1-2 dB. The standard deviation is compared to the gain fine tuning with 2-5 dB lower.

What about the client assessments? Subjective questionnaire results are showing strong correlation. The larger part of the clients (approx. 66%) confirmed the proposed gain setting (Figure 5). For the assessment of timbre generated with Adaptive Phonak Digital, the aspect of „too shrill“, i.e. sharpe sound components was studied. The background is that especially for clients with presbycusis it is difficult to accept gain in the high frequency range. At the same time they need an adequate gain for sound components with high frequencies to achieve a good speech understanding. The results show that for 87% of the respondents a complete acceptance was found.

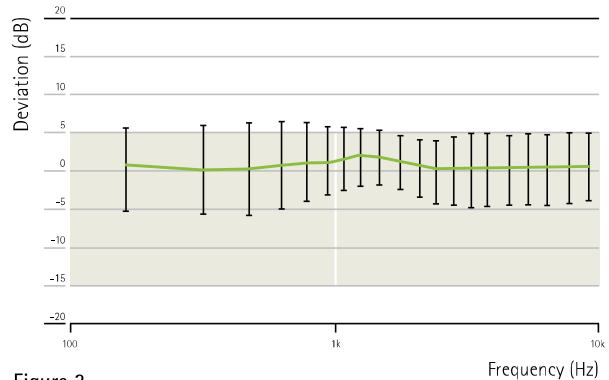


Figure 3
Averaged gain difference between APD presetting and fine tuning.

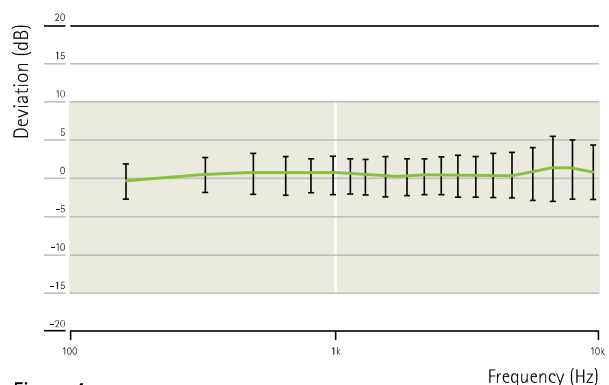


Figure 4
Averaged kneepoint difference between APD presetting and fine tuning.

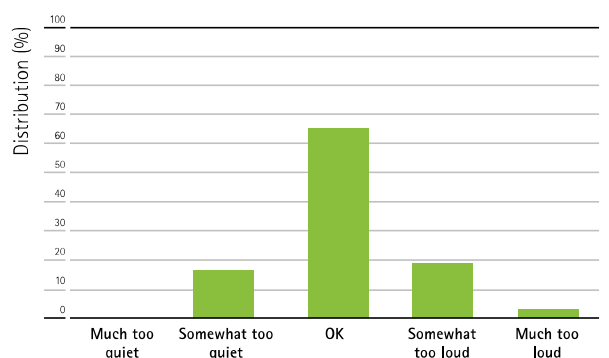


Figure 5
Client ratings of the gain setting of Adaptive Phonak Digital.

Clinical evidence

The same survey was done also for the sound quality in the low frequency range („too dull“). In total, 95% of the clients approved the sound quality in the low frequency range. A total rating of the sound quality shows that 98% of the respondents assessed it positive (Figure 6). Also, a good speech understanding was achieved by the majority of the individuals (Figure 7).

In summary, the precalculation with Adaptive Phonak Digital is on average in very good accordance with the client's expectations. Necessary corrections at the gain, MPO or kneepoint control do not exceed 2 dB. The standard deviations of the fine tunings at these controls (until 7 dB) indicate client-specific fine tunings. The subjective statements of the clients are assessing the fitting performance of Adaptive Phonak Digital mainly positive.

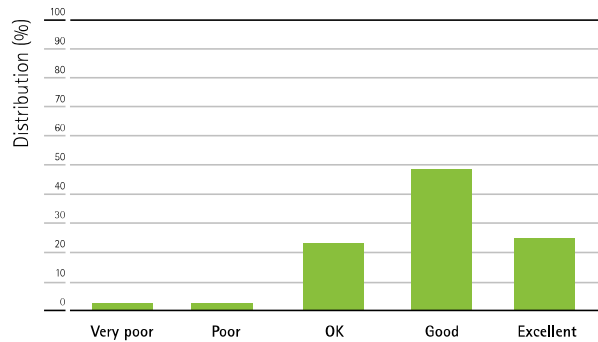


Figure 6
Overall rating of sound quality.

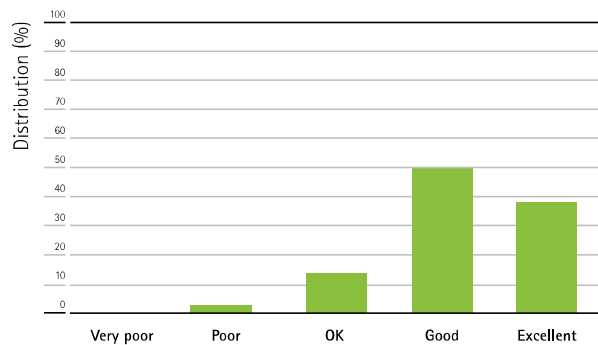


Figure 7
Client ratings for speech understanding.

Software tips

The preparations for a successful application of Adaptive Phonak Digital start with the client data. There you are able to adapt the usage experience and the desired signal processing strategy for the client. The supported usage experience levels are first time user, short time user, experienced user and long term user. The objective for the long term users is to obtain good speech understanding including soft speech while for first time users the focus is rather on a good spontaneous acceptance and avoiding too much unfamiliar high frequency gain. With it the desired acclimatization correction is influenced. With this preconfigured acclimatization level primarily the gain parameters and – if necessary – the setting of the feedback suppression are affected. The automatic adaptation of the acclimatization level is performed only if Adaptive Phonak Digital is used. For all other prescription rules the 100% setting is always preselected. For the preferred signal processing strategy linear and non-linear can be selected. Thereby it is possible to influence the compression without affecting the gain for moderate speech significantly.

If the Phonak Target-Software is used with NOAH, audiometric data existing in NOAH is automatically imported in Phonak Target and considered in the precalculation. If no audiometric data exists or a new input is desired, Phonak Target provides two possibilities: a manual audiogram input and a measurement with AudiogramDirect. For the measurement with AudiogramDirect it is recommended to perform the feedback and real ear test before the AudiogramDirect measurement is performed. The feedback and real ear test can be run via the tab [Client] and the screen [RECD] (Figure 8) or via the tab [Fitting] and the screen [Feedback and real ear test].



Figure 8
Start of feedback and real ear test.

Software tips

After the hearing aid selection it is recommended to specify the required acoustic parameters (tab [Instruments], screen [Acoustic parameters]). As mentioned above this has a direct influence on the accuracy of the presetting. The acoustic parameters can be evaluated or changed every time whereas Phonak Target automatically proposes a recalculation of the presetting.

The resulting presetting you can find below the tab [Fitting] in the screen [Basic tuning] (Figure 9). Beside the input level dependent gains you will find the possibility to influence the target gain in percentage. Your specification in the client data has a direct influence on it. This is also valid for the compression settings. Also the usage experiences can be modified – if wished – to achieve an even more individual setting. You can select between 70–110% of the presetting which corresponds to the setting difference between first time user and long term user. Please check also, if the desired presetting calculation was performed with Adaptive Phonak Digital. It is possible to configure Adaptive Phonak Digital as the standard prescription rule below [Fitting].

In the case of using the NAL-NL2 prescription rule, only for the user experience level first time user the corresponding modification of the NAL-NL2 prescription rule is applied and offered as 100% target gain. All other usage experience levels (short time user, experienced user and long term user) are providing the NAL-NL2 setting for experienced users.



Figure 9
Phonak Target pre-setting screen.

References

- [1] Akustik – Hörgeräte – Teil 15: Methoden zur Charakterisierung der Hörgeräte-Signalverarbeitung, E DIN EN 60 118 – 15: 2009.
- [2] Lützen M.: Analyse von Strategie und Verlauf von Hörgeräteanpassungen in der Praxis. Diplomarbeit, Institut für Hörtechnik und Audiologie, 2005.