WHITEPAPER
2016

Feedback shield LX and Feedback Analyser

Reinventing feedback management for the next generation of hearing aids

ABSTRACT

Why do we need a good anti-feedback system? The answer is obvious – feedback is uncomfortable, preventable, and unwanted by clients and clinicians alike.

Opn is Oticon's new hearing aid, built on the new Velox platform. Feedback Shield LX is the ultimate enabler of OpenSound Navigator, the technology in Opn which allows hearing aid wearers access to more sound in their surroundings while maintaining good speech understanding, recalling more of conversations afterwards, and reducing listening effort. Feedback shield LX safeguards the three pillars of good feedback management: maintaining audibility, preserving sound quality, and eliminating feedback.

This white paper has three important themes: first, the new feedback system is explained in detail. Second, the new fitting software feature, Feedback Analyser, is introduced. Third, a case is made for why the clinician should always run a feedback analysis, so Feedback shield LX can work optimally at all times.

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Feedback shield LX

The new anti-feedback system (AFBS) is built on the three well-known principles of effective feedback suppression: frequency shift, phase inversion, and gain control. There are several ways in which the anti-feedback system on the Velox platform differs from the Inium and Inium Sense platforms. This can be a complex topic, but in the sections below, different aspects of the new anti-feedback system are explained in terms clinicians can relate to from their daily practice.

A dual-microphone anti-feedback system

The most important new characteristic of Feedback shield LX is that it is a dual-microphone anti-feedback system. This means that there are two anti-feedback systems on each hearing aid: one for the front microphone and one for the back microphone. Within each path, the three pillar technologies are integrated (frequency shift, phase inversion, and gain control). Input from the microphones is analysed simultaneously with the processing in the signal path. Figure 1 shows a simplified schematic of the implementation on the Velox platform.

So how does a dual-microphone system enable the advanced sound processing scheme, OpenSound Navigator? In a one-microphone system, the AFBS follows directionality mode changes. Unprovoked feedback can occur when a system follows the directionality system because it is time-consuming to update in sync with directionality patterns. OpenSound Navigator uses an infinite number of possible directionality states and these are essentially irrelevant for feedback limit estimation. Let's say the hearing aid wearer is sitting on his couch watching TV when all of a sudden his wife turns on the vacuum cleaner behind him. The hearing aid has adapted to the change in the environment by balancing sounds differently through the OpenSound Navigator, but the risk of feedback has not changed. This means that the hearing aid unnecessarily makes a new feedback estimate which takes up substantial processing power better used for signal processing in the hearing aid. What we would like the AFBS to do is adapt based on the risk of feedback as the person moves (chews, hugs, yawns) and as tonal sounds come and go.

In a dual-microphone system as seen in figure 1, the link between the AFBS and the OpenSound Navigator is removed and this, very importantly, facilitates the effective and incredibly fast (>100/sec) use of an infinite number of directionality states available in the OpenSound Navigator. In turn, Feedback shield LX can react faster because it does not rely on directionality states in the hearing aid. Updates to the AFBS depend on input to the hearing aid and are adaptive in order to use the least amount of processing power while quickly adapting to changing risk of feedback. Please refer to white paper on the OpenSound Navigator to learn more about the details of this new feature. Another advantage of the dual-microphone system relates to the implementation of the Feedback Analyser in Genie 2. Please see this section for more details.

A single-mode anti-feedback system

On the Inium Sense platform, the AFBS incorporated frequent switches between three modes of updating the AFBS, based on whether or not feedback was

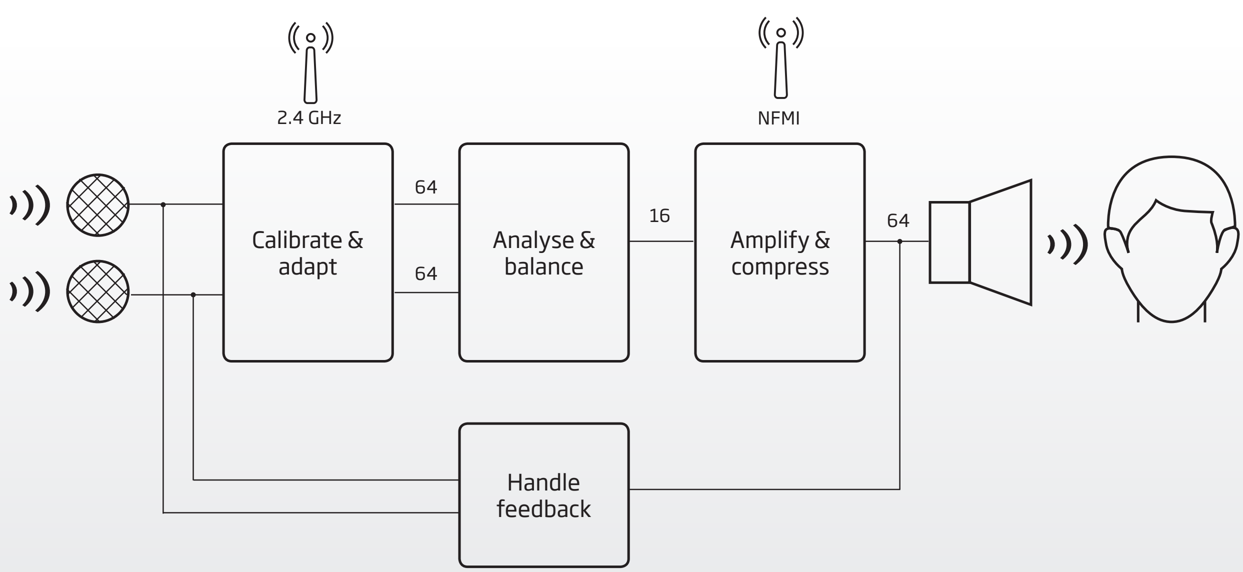

Figure 1: The dual-microphone AFBS on the Velox platform.

detected and whether or not there were tonal sounds in the environment. On the Velox platform, The system does not operate in modes. Briefly put, this means that frequency shift, phase inversion, and gain control are continuously engaged and adapting to changes in the feedback estimate, figure 2. This section explains why a single-mode system is the right choice for the Opn miniRITE and how frequency shift is best used to support the AFBS.

Frequency shifting is not a feedback suppression strategy on its own. It is used as an added "tool" to help the phase inversion part of the AFBS work most efficiently. Phase inversion is done by creating an internal feedback path within the hearing aid. When the internal and external feedback paths match up, the signal portion that is identified as unwanted feedback is cancelled. The advantage is that feedback cancellation can be done without any decrease in gain. The disadvantage is that external prolonged tonal sounds can be mistaken for feedback. A small frequency shift can be introduced to improve the phase inversion process by de-correlating the input from the output. In other words, the hearing aid is able to detect a difference between external sound input and hearing aid feedback because a frequency shift is applied to the hearing aid output. When the output feeds back into the hearing aid, it differs slightly from the external sounds and the two sounds are no longer in phase with each other, preventing the feedback from building to an audible level (Dillon, 2012). Adding to this, the frequency shift means that external tonal sounds are not as "visible" to the phase inversion part of the AFBS and therefore a better estimate of the feedback path is possible.

As with most good things, shifting frequency is associated with a cost. The trade-off lies in the degree of shift: a larger shift in frequency allows a better estimation of what is feedback versus what is external sound. However, a larger shift is also associated with a decrease in perceived sound quality, especially for a tonal input such as music and voices.

This highlights the importance of choosing a degree of shift that does not compromise sound quality. Research gives us good indications in this area. Moore & Hopkins (2007) evaluated how normal-hearing and hearing-impaired persons were able to detect various degrees of shift and at what frequencies a shift was most noticeable. Most importantly, normal-hearing listeners were able to detect a shift far more often than hearing-impaired listeners and thus performed better. A more significant high frequency hearing loss was associated with worse performance in frequency shift detection. Furthermore, testing was carried out using pure-tones, which are easier to detect than complex sounds. As an example, for normal-hearing listeners listening to a harmonic complex centered at 2200 Hz with a 200 Hz fundamental frequency, the shift needed to be at least 16 Hz in order for them to reliably detect an audible difference. As another example, for normal-hearing individuals tested in a controlled environment using pure-tones, it required a 16 Hz shift of the harmonic complex to be detectable above 1600 Hz when the fundamental frequency was 100 Hz.

The tendency for both groups was that high fundamental frequencies were more easily detectable than low fundamental frequencies and the higher the center frequency (frequency where shift occurs), the more difficult it was to detect the shift. This can be used advantageously by the AFBS in hearing aids where the listener will always have a hearing loss and therefore has a higher threshold for hearing a frequency shift, particularly at high frequencies. Feedback shield LX is designed conservatively such that even people with normal hearing could not reliably detect the frequency shift used by the AFBS for a female voice with a 200 Hz fundamental frequency. It follows that frequency shifts on voices with lower fundamental frequencies are even harder to detect.

The result is that on the Velox platform, a permanent 10 Hz frequency shift is implemented starting at 1330 Hz. Raising the shift starting point, compared to the

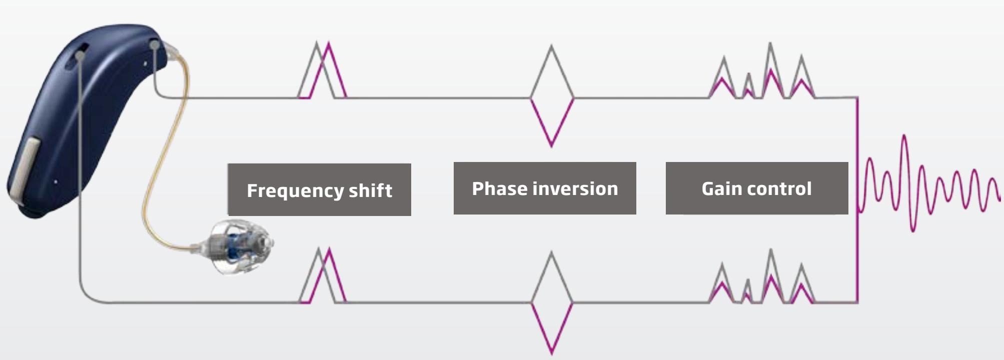

Figure 2. All three feedback strategies are continuously engaged. Here shown for the two separate microphones.

Inium Sense platform 900 Hz starting point, significantly reduces the likelihood of an audible shift and places it in the most beneficial location. This allows the hearing aid to apply the shift permanently and eliminates the need for the AFBS operating in different modes that are input-dependant.

As mentioned, the frequency shift starts at 900 Hz on the Inium Sense platform but the AFBS is active above approximately 2000Hz. This means there is a frequency window where the shift is basically "wasted" by not benefitting the AFBS and only contributing to sound quality degradation. On the Velox platform, the AFBS is fully active above 1560Hz, leaving hardly any room for unnecessary shift.

Better resolution, better margin with Opn

Terminology is important to help understand feedback management and improvements to an anti-feedback system. As a refresher, here are a few common terms:

Full-on insertion gain (FoIG): The highest amount of gain possible for a given hearing aid as measured under ideal technical measurement conditions. This is rarely realised in real-life fitting scenarios but can sometimes come close if hearing loss becomes more severe.

Gain limit: A predicted value or a measured value (using Feedback Analyser). The gain limit is the point where the hearing aid stops adding more gain due to a higher risk of feedback. The clinician can choose to adjust the gain limit higher or lower for a client, based on professional judgement. In Opn, the gain limit is set equal to the estimated or measured feedback limit. This corresponds to the line between the white and red areas in figure 3.

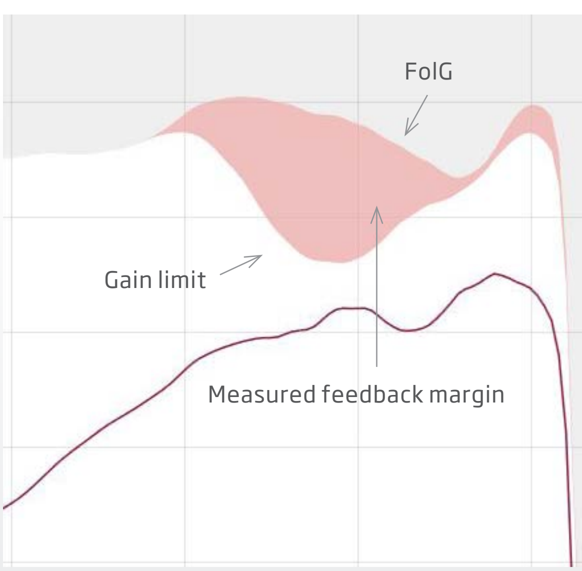

Figure 3. Feedback management terms: gain limit, measured feedback margin and full-on insertion gain (FoIG).

Critical gain: the amount of gain that results in borderline audible feedback. This is also known as the feedback limit. This limit is static and only changes when acoustical conditions change. Not depicted.

Gain margin: The gain margin can be defined as the amount of more gain that can be given before the hearing aid reaches critical gain. The gain margin can be negative, meaning that it can sometimes be necessary to turn down gain to be at the critical gain level. This might occur if a very open fitting is chosen for a person with steeply sloping high frequency hearing loss. Not depicted.

The terms, some shown in figure 3, ease understanding of how Feedback shield LX is effective for feedback management.

As mentioned, the gain limit can be a predicted value, based on the audiogram and the hearing aid acoustic parameters, or it can be a measured value, based on the individual ear acoustics, the audiogram and the hearing aid acoustic parameters. In the design of the system, the manufacturer defines how the gain limit should be set and then prescribes the limit accordingly. If the gain limit is set high, then more gain can be given before the anti-feedback system reduces gain and this increases the risk of unwanted feedback. If the gain limit is set low, then less gain can be given before the anti-feedback system reduces gain. This may cause the hearing aid to be too conservative when estimating the risk of feedback. For Opn, the gain limit is set equal to the feedback limit and this is also known as a 0 dB gain limit. The aim is to find a good balance and with the 0 dB gain limit, the clinician can now give their clients more gain, increasing the gain margin. Allowing the hearing aid processing to operate freely in an area where there could potentially be a higher risk of feedback means that the AFBS must always ensure quick and effective feedback suppression.

This is ensured through the integration of the AFBS with other hearing aid systems. As the risk of feedback rises significantly, precautions are taken. As an example, a hearing aid wearer hugs her spouse tightly, and now the hearing aid reacts quickly to reduce gain in the specific areas of the frequency range at risk of feeding back. Thus, the system remains completely stable, but in high alert. Once the hug is over, the system returns to its regular state of readiness.

What has just been described is the ongoing, adaptive portion of Feedback shield LX and it involves fast, temporary, and targeted gain reduction and gain restoration. The 64 frequency channels on the Velox platform means a finer resolution of the system, which allows a more precise feedback path estimation. This ties into how Feedback shield LX can now provide a wider gain margin than on the previous platform. In simple terms, the clinician can now give more gain with less feedback.

Feedback Analyser in Genie 2

The purpose of Feedback Analyser is to function as a tool for the clinician to evaluate and verify the gain needed for a particular client can be realised within the acoustic parameters chosen. In other words, can the clinician give the client the gain they need with the hearing aid they are wearing? Feedback Analyser replaces the predicted gain margin with a measured and accurate gain margin.

What does Feedback Analyser do? When the clinician runs a feedback analysis, the AFBS is recalibrated to take the individual client's ear into account. The Feedback Analyser establishes the gain margin for a particular ear, based on the client's ear acoustics. If the feedback analysis is not carried out, then the estimated gain margin is determined only by the audiogram and the chosen acoustics. This could result in a feedback margin being either too high or too low. The last section will delve more into different client feedback scenarios and why running Feedback Analyser should always be prioritised.

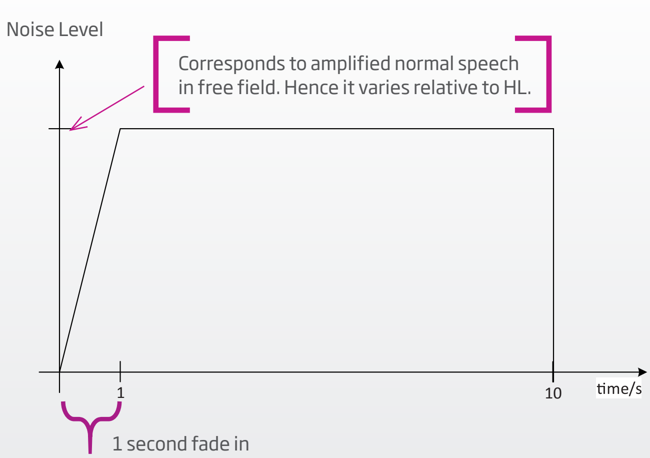

Figure 4. Feedback Analyser fade-in, analysis time and level.

New name & placement

Feedback Analyser in Genie 2 is the new name for Feedback Manager in Genie. This name change signifies a shift from a passive role of the clinician where the fitting software is "managing feedback" to a more active role of the clinician where he/she analyses the risk of feedback to get the best possible fitting outcome for the client. Once analysed, the clinician can make the appropriate decision on what they want in terms of acoustics. Once chosen, the Oticon hearing aid now takes full control of managing feedback by taking the necessary precautions to avoid it. To signify the importance of using Feedback Analyser for every new fitting and every time an acoustic or audiometric change is made, it now has a more prominent position in the left task pane in Genie 2, under the Fitting heading.

Analysis duration and level

As described earlier, the anti-feedback system on the Velox platform is designed as a dual-microphone system. This means a feedback analysis can be performed simultaneously for the front and back microphones and this contributes to reducing the analysis time from 30 seconds previously to 10 seconds on the Velox platform (figure 4). The result is a single, measured gain margin per hearing aid. This gain margin is automatically shown in the Feedback Analysis and Fine-tuning screens.

The level of the feedback analysis has also changed. Some clients found the previous level to be too loud. The level is now hearing loss dependent, corresponding to 65 dB SPL speech in free field.

Noise level indicator

The Noise level indicator is a new feature added to the Feedback Analyser screen in Genie 2. It is designed as a tool to help clinicians run a valid and precise analysis in one try. Background noise affects the analysis in a negative way and it is advisable to reduce environmental sounds as much as possible when performing the analysis. The Noise level indicator allows the clinician to monitor when background noise is at an acceptable level and when it will be advisable to close the door or take other precautions to reduce noise.

Why you should always run Feedback Analyser

Since the launch of the Inium Sense platform at the beginning of 2015, Oticon has recommended running a feedback analysis in the fitting software. Perhaps due to several implementations of our feedback system, this recommendation has not been widely implemented. The purpose of this section is to explain why, now more than ever, it is crucial to perform this analysis at every new fitting and every time the acoustic properties of the hearing aid change (dome type, ear wax) or there is an update to the audiogram. The clinician can also choose to use the Feedback Analyser as a quick verification tool. At each appointment, the clinician runs a quick analysis and it is then displayed side-by-side with the previous analysis. If it is identical, then they can proceed as usual, but if it differs, it could be an indication that the ear canal should be examined and the dome or venting evaluated.

The following six illustrated explanations take the clinician through the logic of running a feedback analysis. In the text, Feedback Analyser is written as FA. Figure 5a, 5b, and 5c show examples of what might happen when the FA is not run. Figure 6a, 6b, and 6c show how Feedback shield LX works in three different scenarios. The graphics are conceptual and do not depict specific fittings but are created to depict how the FA can impact real-life fittings.

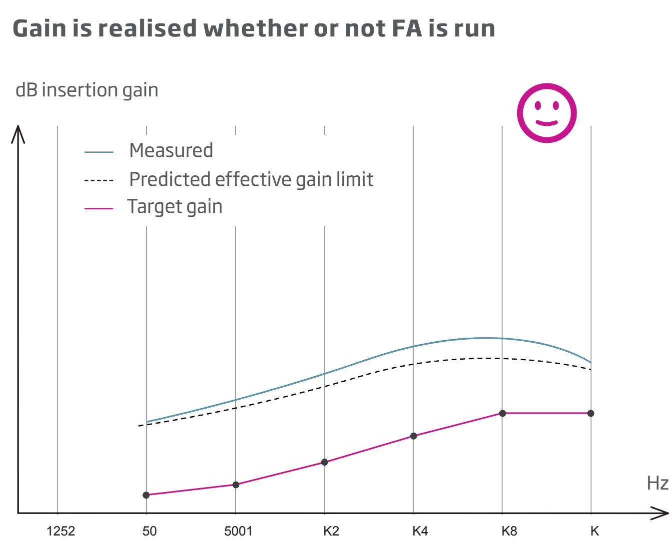

Figure 5a.
This is the ideal scenario for any fitting. The gain desired by the clinician is realised whether or not the FA is run. Here, target insertion gain is depicted by the magenta line. The pre-measurement predicted effective gain limit is shown by a dotted line and the post-measurement measured and actual feedback limit as it would look if clinician ran the FA is shown by the blue line. Both feedback limits are acceptable for the fitting. However, if the clinician did not run the FA, then they would not know that the predicted feedback limit was acceptable. This is a good reason to run the FA, even for low-gain fittings.

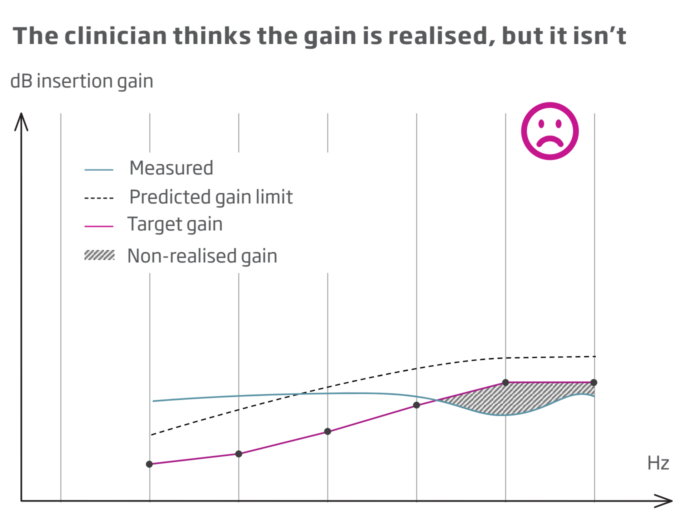

Figure 5b.
The clinician does not run the FA and therefore only sees the dotted line depicting the predicted gain limit. In this scenario, however, the effective gain limit (the actual gain limit when the client wears the hearing aid) is below the predicted gain limit, but also below the target insertion gain. To the clinician, it appears as if the target gain is achieved but in reality, the AFBS is reducing the target gain down to the effective gain limit. If the clinician ran the FA, they would become aware of this problem and have a chance to reevaluate the fit and acoustics.

The AFBS limits gain unnecessarily

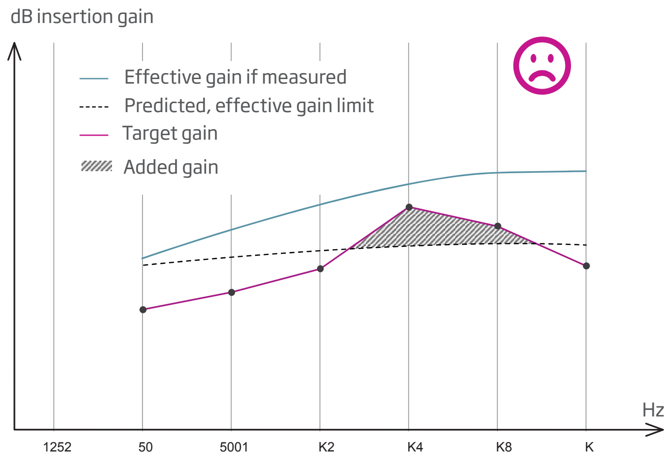

Figure 5c.
The clinician does not run the FA and therefore only sees the dotted line depicting the predicted gain limit. In this scenario, the effective gain limit, if measured, is above the predicted gain limit and the target insertion gain. To the clinician, it appears as if the target gain is not achieved at certain frequencies but in reality, the AFBS is perfectly capable of supporting more gain. Not running the FA, in this case, is limiting the available gain to the predicted gain limit which is, in turn, the effective gain limit. If the clinician ran the FA, they would be able to realise the gain needed for this client. If they rely on the predicted limit, the AFBS now unnecessarily limits the target gain.

In the next three examples, we look at how Feedback Shield LX will react in different scenarios.

Prescribed dome is used and Feedback Analyser is run

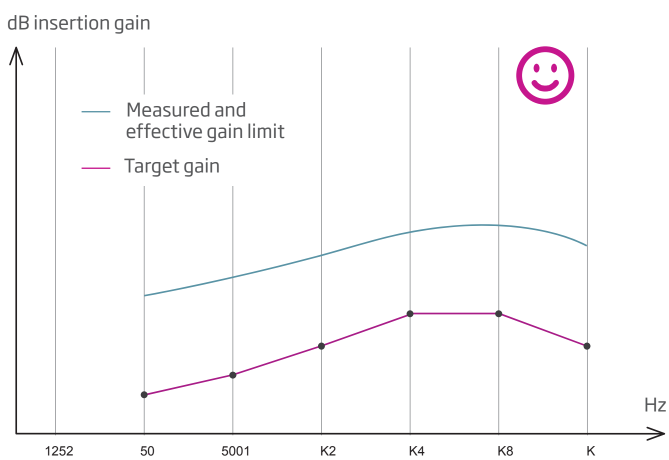

Figure 6a.
In this scenario, the FA is run and the fitting software prescribed dome is used. A good gain margin is available and by running the FA, the AFBS has been calibrated to work optimally. Any system working with measurements rather than predictions is likely to work more accurately without over- or under-compensating.

Setting a new effective gain limit

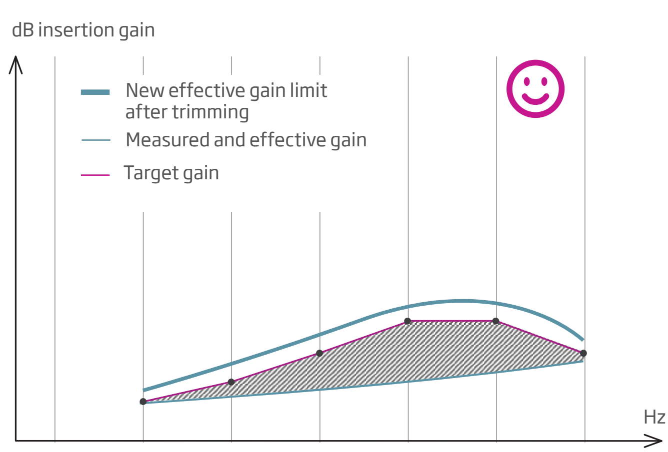

Figure 6b.
In this scenario, the FA is run and the clinician has chosen to use a dome which is more open than the one recommended by the fitting software. While this is a perfectly acceptable solution, it sometimes results in compromises in the amount of realisable gain. In this case, the measured/effective gain limit is below the target gain (bottom blue line). The clinician decides to trim the gain limit above the target gain, in order to achieve desired gain. The fitting software allows the clinician to do this and the clinician is made aware that there may be a higher risk of feedback. The advantage of running the FA is that the AFBS is calibrated and is therefore working with precise limits. The clinician can be sure that the limit seen is the actual limit in the hearing aid.

Prescribed dome used and Feedback Analyser not run

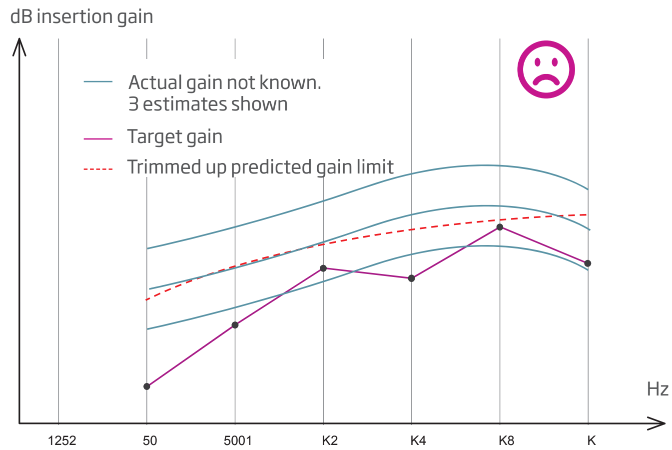

Figure 6c.
This scenario is similar to 2b, except that the FA is not run. The clinician has chosen to use a dome which is more open than the one recommended by the fitting software. The predicted and effective gain limit (not shown) falls below the target gain and the clinician decides to trim up the predicted gain limit in order to meet targets. Because the AFBS is uncalibrated, the actual gain limit very likely differs from the predicted gain limit in use and imprecision is introduced, resulting in the AFBS over- or under-compensating. This leads to a higher risk of feedback and a possible unseen gain limitation. It may also lead to the AFBS having a longer reaction time when suppressing feedback because it makes assumptions based on the limits is has available.

To summarise, the main purpose of Feedback Analyser is to calibrate the AFBS to work optimally. It works more optimally because a system using measured limits is much more accurate than a system using predicted limits. Since the launch of Inium Sense Feedback shield, this has been Oticon's recommendation and it will allow the clinician to make informed decisions about their fittings.

Conclusion

Feedback shield LX is the new anti-feedback system on the Velox platform. This dual-microphone single-mode system allows the clinician to give their client more gain with less risk of feedback. It is the enabler of OpenSound Navigator, which sets the bar high for bringing multiple sound sources to the listener in a balanced and integrated way. Technology that has worked well on the Inium Sense platform continues to play an important role on the Velox platform, but in a way that makes sense on a platform that allows for more flexibility and more precision in how sound is processed. Running the Feedback Analyser in Genie 2 leads to an anti-feedback system that is tailored to the individual hearing aid wearer's acoustics characteristics and it truly allows Feedback shield LX to work optimally at all times.

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21710 / 24.06.2016

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