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Effective feedback control
Inium Sense feedback shield^{SP}

ABSTRACT

An effective feedback management strategy will not only limit feedback but also ensure consistent access to speech with minimal distortion. Oticon Dynamo and Sensei SP effectively control feedback while providing both adults and children with severe-to-profound hearing loss with the amplification they need and continuous access to speech and high sound quality. This is achieved through the combination of high gain and output capabilities, well-fitted ear molds and an effective anti-feedback management system.

The Inium Sense platform and its fast processor deliver efficient feedback management, which in turn has been specifically adapted to the Super Power style of instrument. We call this anti-feedback system **Inium Sense feedback shield^{SP}**. The Inium Sense feedback shield^{SP} is capable of detecting the risk of feedback much faster. This enables the system to prevent feedback more effectively and eliminate it more efficiently if it is about to occur compared to the anti-feedback system in the previous generation of Super Power instruments. All this is done while still maintaining high sound quality.

What this means to your patient is being able to:

- Receive appropriate hearing loss compensation to support effective communication and language development in children
- Give hugs without annoying whistling
- Wear instruments comfortably throughout the day

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Building on three well-known and effective technologies

Inium Sense feedback shield^{SP} builds on the well-known principles of phase inversion or feedback cancellation, but with significant updates and additions introduced in Inium feedback shield[1,2] and further developed for Inium Sense feedback shield[3].

The functionality of phase inversion, frequency shift and gain control is schematically depicted in figure 1. Figure 1a) shows how phase inversion utilizes the principle of destructive interference to cancel out the feedback signal. A signal with the opposite phase of the feedback estimate is superimposed on the input signal, ideally ensuring an intact signal free of feedback. Figure 1b) shows how frequency shift de-correlates the input and output signal. This renders the system less susceptible to tones in the environment and thus make it easier to correctly identify internally generated feedback and not mistakenly try to cancel out external tones instead. In short, frequency shift improves the feedback path estimation and enables a more precise application of phase inversion. Finally, figure 1c) shows how gain control manages sudden feedback conditions in independent channels.

Inium Sense feedback shield^{SP} introduces frequency shift and improved gain control to the Super Power instrument families. Furthermore, the anti-feedback system has been modified to support the high output capabilities of this particularly powerful style of instrument and also the higher demands for gain in the Super Power fitting.

Against this background, two modifications to Inium Sense feedback shield^{SP} are being introduced:

- an extended low-frequency operating range
- a 10 Hz frequency shift

To understand how these modifications support the Super Power instrument in delivering high gain and output with minimal feedback, we first need to recap the dynamic behavior of Inium Sense feedback shield^{SP}, and then get insights into the design choices when developing a Super Power instrument.

The agile anti-feedback scheme

The three technologies are set up in an agile anti-feedback scheme to intelligently control feedback based on the detection of feedback and tonal content from the environment. This is desirable since frequency shift in itself can create audible artifacts for the signal. The larger the frequency shift, the more efficient is the de-correlation or masking of external tones, but at the increased risk of producing audible artifacts. In essence, Inium Sense feedback shield^{SP} is set up so frequency shift is primarily used to control feedback when it is detected and secondarily used only when it is estimated that sound quality is not at risk. The rationale of creating an agile anti-feedback system is to favor sound quality while keeping the signal free from disturbing artifacts and whistling to the benefit of the hearing aid user.

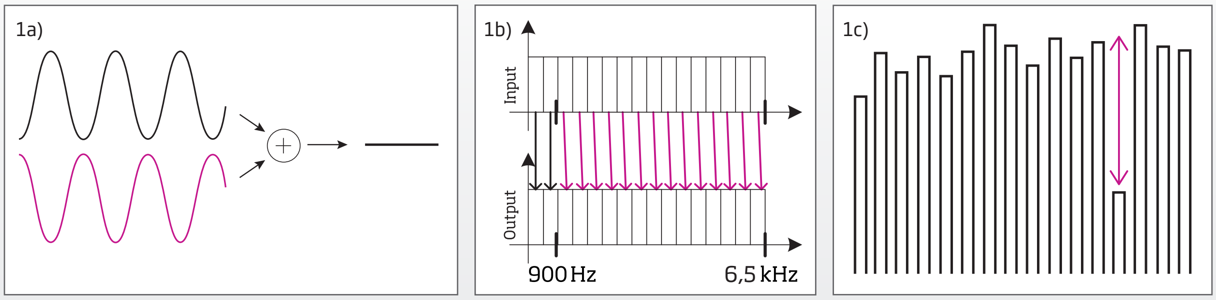

Figure 1. Schematics of the functionality of 1a) phase inversion, 1b) frequency shift, and 1c) gain control.

To ensure optimal sound quality in a given sound environment, input from two detectors, a feedback detector and a tonal detector, guides the use of the anti-feedback technologies. Figure 2 shows the detectors and three different modes of operation. The modes are: fast update phase inversion, sometimes referred to as fast mode, no update of phase inversion and frequent update of phase inversion. What characterizes the three modes is thus the application of phase inversion, and accordingly, the use of frequency shift. The feedback path is constantly estimated by the system. The use of frequency shift to support this estimation is however targeted for when phase inversion is applied. Whenever the phase inversion filter is updated, whether fast or frequently, frequency shift ensures that this is done with the best possible estimate. Finally, gain control is always available regardless of mode, to act as a safe line when sudden and large changes to the feedback path occur. Gain is both quickly reduced in the affected frequency channel and subsequently restored, as the critical feedback situation ceases.

What should be noted is that whenever feedback is detected, i.e. the instrument is either whistling or close to whistling, this will always activate the full force of the anti-feedback system: fast update of the phase inversion filter to effectively cancel the feedback signal and the feedback path estimate is supported by frequency shift.

To learn more about the dynamic properties of the Inium Sense feedback shield^{SP}, and how this supports sound quality, please refer to the section on Inium feedback shield in Nera Audiology[2] or the Inium feedback shield[1] white paper. Also, to learn more about gain control, please refer to the Inium Sense feedback shield[3] whitepaper.

Designing for Super Power

As indicated above, the modifications to the Inium Sense feedback shield^{SP} variant of the Oticon anti-feedback system support the high output capabilities of this style of instrument and the higher demands for gain in the Super Power fitting.

Extended low-frequency operating range

To support the output of the instrument, an extended low-frequency operating range has been implemented. Figure 4a shows a typical output frequency response for the BTE SP, behind-the-ear Super Power instrument (magenta) and the BTE/RITE, receiver-in-the-ear, styles of instrument (grey). The solid grey shaded area and the two hatched areas below the graphs indicate high-risk areas for the occurrence of feedback for the BTE SP and BTE/RITE respectively. It can be observed that the greater the output the higher the risk of feedback, and that for the BTE SP style the high-risk area is broader and extends to lower frequencies than for a traditional BTE/RITE style. This illustrates the high demands placed on the anti-

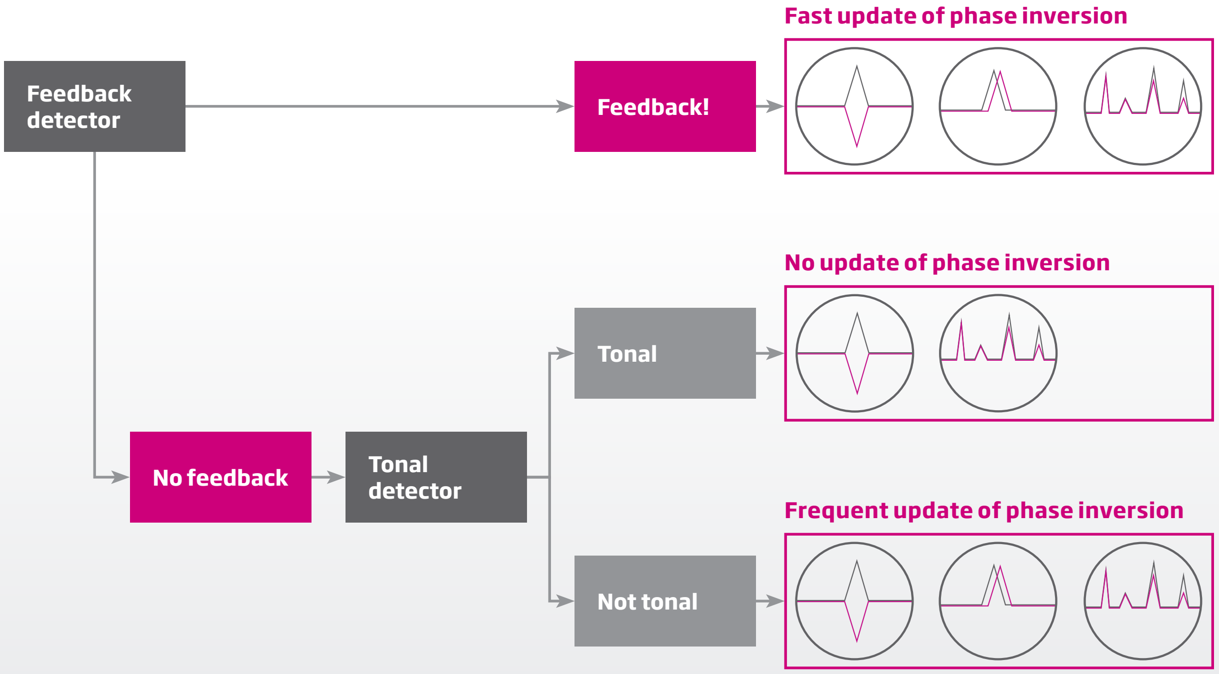

Figure 2. Schematic modes and detectors in feedback shield.

feedback system for the Super Power instrument and the need for an operating range that extends to lower frequencies to cover the entire high-risk area for this style. The operating range for Inium Sense feedback shield^{SP} and Inium Sense feedback shield is indicated by the bars above the curves in figure 4a.

Accessing max gain

To ensure that it is possible to access as much gain as possible, two important design changes are implemented for fitting of the Super Power style of instrument: one influences the gain prescription in Genie and the other the gain capabilities of the instrument.

Oticon Genie fitting software operates with something called *Predicted Feedback Margin* (figure 3). It appear as a grey area on the graph between the Full-on-Insertion-Gain curve and the prescribed gain curves. Genie predicts feedback in order to take the expected effects of selected style and acoustics on the feedback path into account in the gain prescription. The Predicted Feedback Margin is meant as guidance as to where feedback might become a problem and so it is possible to simply increase gain into the grey area. You have the option to run the Feedback Manager in order to further personalize the predicted feedback margin. Most often the measured and predicted feedback limit will not be the same. In some cases measuring the feedback limit may result in a higher gain prescription than the initial prescription. This is when the feedback problems proposed by the predicted feedback limit are greater than what is actually the case and when gain has been limited by this prediction. At the outset of a Super Power fitting, the assumption is that a tight ear mold has been fitted with no leakage and in effect, the influence of the Predicted Feedback Margin is much less. This ensures that potentially unnecessary constraints do not influence the gain prescription. However, this also increases the likelihood of feedback-related issues if the individual feedback limit is not set.

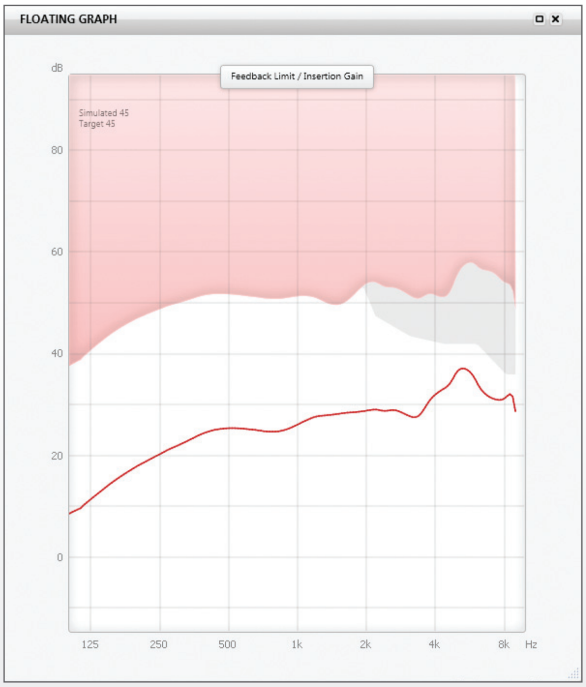

Figure 3. Genie 2015.2 graph from Feedback Manager showing the Predicted Feedback Margin for a RITE instrument as the grey shaded area.

The second design change relates to a value in the instruments called gain margin. The gain margin serves the purpose of keeping gain at a certain distance from the estimated feedback path and thus reducing the risk of feedback. At the same time, the gain margin is a hard limit that cannot be exceeded in the fitting of the instrument. Figures 4b and 4c illustrate a typical Oticon margin optimized for sound quality and a minimal gain margin optimized for maximum gain. The topmost pink line indicates the point when the instrument will start to actually whistle. The graded pink area below this line indicates an area of feedback-related issues such as degraded sound quality and instability of performance. As the feedback path changes, this pink area and the whistling point will move. The gain margin that is optimized for sound quality gives the anti-feedback system time to react long before the instrument starts to whistle and even before sound quality is compromised. When a minimal gain margin has been implemented, the anti-feedback system needs to apply the strongest setting and feedback may not be reduced as quickly when it occurs. On the benefit side, a minimal gain margin ensures access to the full gain capabilities of the instrument. For this reason, the gain margin value in Oticon Super Power instruments is reduced compared to other Oticon instrument styles.

The two described design changes implemented in Super Power instruments ensure that 1) more gain can be prescribed since the Predicted Feedback Margin is designed to be higher and so the effect on gain prescription is reduced and that 2) gain can be prescribed at the edge of the feedback since the gain margin is minimal.

Minding sound quality in Super Power

Providing access to maximum gain is a design goal at Oticon for a Super Power instrument. As described above, this places higher demands on the anti-feedback system, and of course places high demands when fitting the instrument to the patient. The higher demands on Inium Sense feedback shield^SP affect the net behavior of the anti-feedback system. That is, the amount of time spent in fast mode is increased since more gain can be prescribed and the gain margin is minimal, and the system thus needs to apply the strongest setting. In fast mode, phase inversion updates fast, and thus, Inium Sense feedback shield^SP will apply frequency shift more than Inium Sense feedback shield. Since sound quality is also a design goal in Oticon Super Power development, a 10 Hz rather than a 20 Hz frequency shift is used in Inium Sense feedback shield^SP.

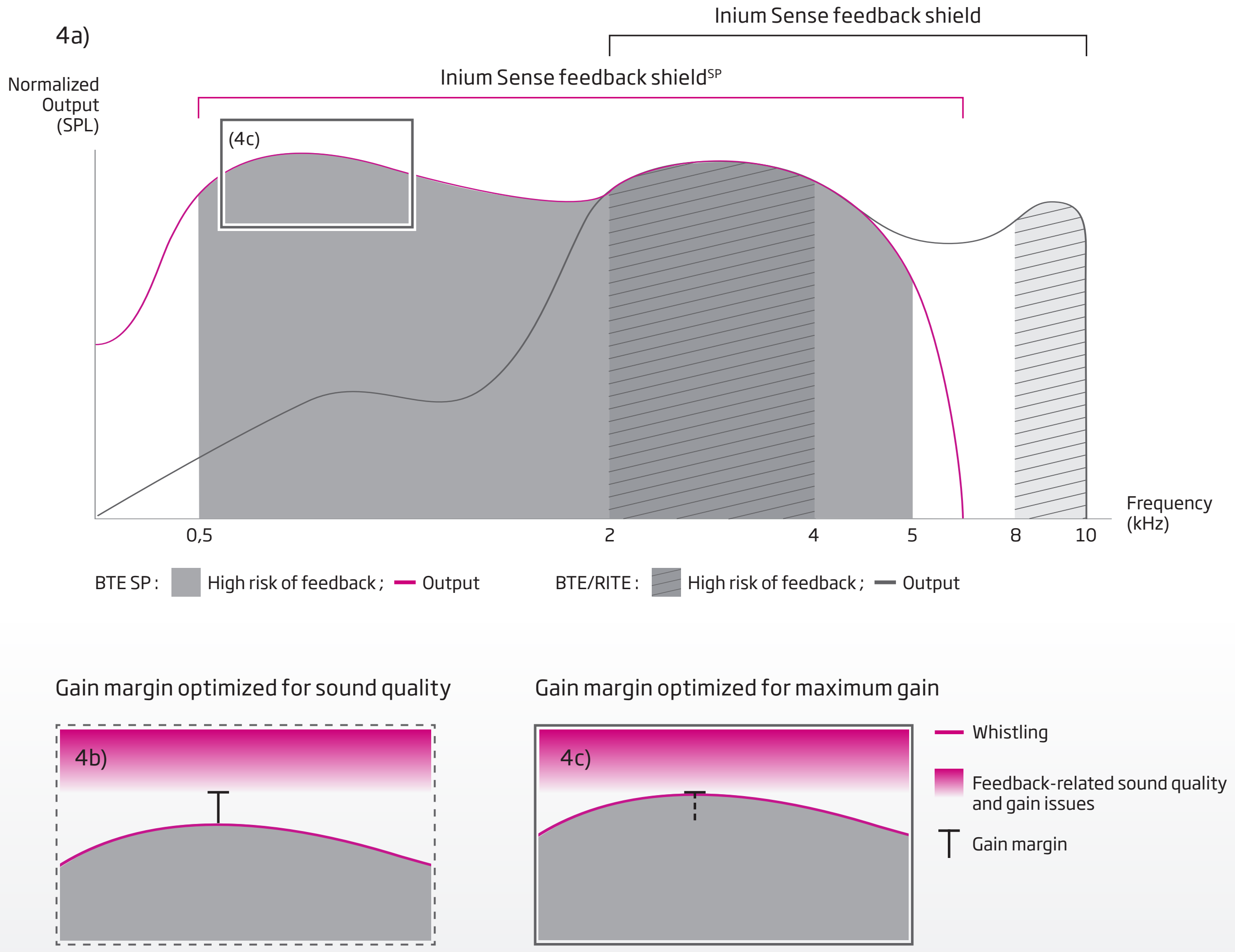

Figure 4a) shows output curves as a function of frequency of a typical BTE SP instrument (pink curve) and a BTE/RITE instrument (grey curve). Below the BTE SP curve is shown a grey area that indicates the frequency range with high risk of feedback. Below the BTE/RITE curve this is shown as two hatched areas. Above the curves, the bars indicate the operating range of Inium Sense feedback shield^SP and Inium Sense feedback shield. 4b) and 4c) illustrates a gain margin optimized for sound quality and for maximum gain respectively.

Relationship between gain margin and feedback limit

You have the option to run Feedback Manager as part of an initial fitting or when your patient or pediatric client receives new ear molds or when the acoustics or gain prescription otherwise change. The Feedback Manager measures the static feedback path for the given fitting and sets a feedback limit accordingly. The feedback limit ensures that gain is not prescribed to be within the pink feedback area shown on figure 4b and 4c. How far below the feedback area gain can be prescribed is set by the gain margin. In the two fittings in figure 4b and 4c, the prescribed gain and the selected acoustics put the instrument at the maximum output that can be provided, i.e. the output curve is at the feedback limit. In a fitting with less gain or a tighter acoustic coupling to the ear, the output might be well below the feedback limit. If on the other hand, more gain was desired or if a more open coupling had been selected, the feedback limit would restrict the prescribed gain to ensure a stable instrument. If feedback limit is not set in this case, this would result in a fitting within the red area, and consequently a very aggressive use of the anti-feedback system.

Effective feedback control

Inium Sense feedback shield^{SP} is capable of detecting the risk of feedback much faster, preventing it more effectively and eliminating it more efficiently if it is about to occur while still maintaining a high sound quality compared to the anti-feedback system in the previous generation of Super Power instruments.

On figure 5, time of day is shown as a function of high-risk of feedback. Anti-feedback performance of the old anti-feedback system is shown to the left while performance with Inium Sense feedback shield^{SP} is shown to the right. For daily situations that will trigger a change in the feedback path, the risk for feedback increases. While these situations previously would lead to whistling instruments, the improvement in the anti-feedback system in Oticon Dynamo and Oticon Sensei SP ensures a more effective feedback control.

This improvement holds the prospect of ensuring that your patient can wear his or her hearing aids comfortably during the day and give hugs without annoying whistling, which is not trivial. In addition, the design of the anti-feedback system also allows maximum and stable access to gain, which in turn supports effective communication and language acquisition.

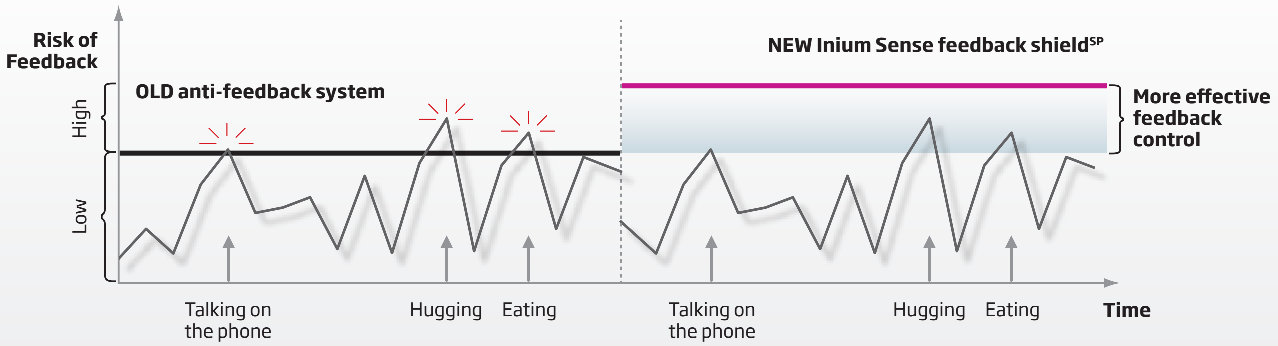

Figure 5. Time is shown as a function of high-risk of feedback. Anti-feedback performance of the old anti-feedback system is shown to the left while performance with Inium Sense feedback shield^{SP} is shown to the right. Similar daily situations that will trigger a change in the feedback path are shown for each system.

References

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