

Supero™ – digital MultiMode Signal Processing

and MPO shaping

Summary

Meeting the needs of people with severe to profound hearing loss places enormous demands on a hearing instrument system. It has to make the most of narrowed residual dynamic range and the hearing instrument needs to accommodate marked individual differences in the optimal amplification strategy for compensating for severe to profound hearing loss. There also must be flexibly adjustable protection against loud sound peaks, that precisely tracks the discomfort threshold.

Supero meets these demands using digital MultiMode Signal processing and an effective system for frequency-dependent output limiting.



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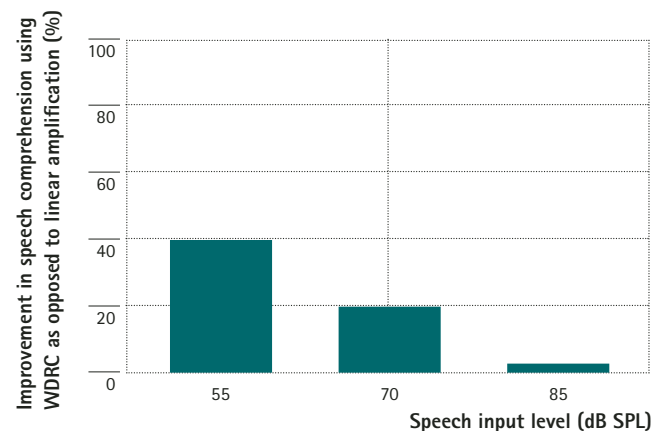
By contrast with pure conductive hearing impairment, sensorineural hearing impairment is characterized by limited residual dynamic range. Although the hearing threshold is higher, there is typically almost no increase in the discomfort threshold. The more pronounced the hearing impairment, the more restricted is the remaining dynamic range that the hearing impaired person can utilize. As hearing loss increases, the hearing instrument has the increasingly difficult task of amplifying incoming signals to lie within the narrow dynamic range available so that the hearing impaired person can comprehend speech adequately. As well as providing the necessary amplification to bring sounds within the audible range, effective limiting of maximum power output is also important to avoid unpleasantly loud or even painful sound levels. Hearing instruments that compress a broad range of incoming sound levels (Wide Dynamic Range Compression – WDRC) attempt to reproduce an acoustic environment's inherently broad dynamic range within the hearing impaired person's narrow "dynamic range window". Low level incoming signals receive considerable amplification to make them audible, while high level sounds receive

reduced amplification to prevent them from becoming too loud. An alternative approach uses linear hearing instruments that amplify incoming sounds equally, regardless of their level and truncates the highest levels (peak clipping) to prevent excessive sound pressure at the eardrum. This however is at the cost of output signal distortion. A compromise between linear and WDRC hearing instruments is to be found in systems that operate in a linear fashion over a wide range of input signals, while compressing sounds that are louder than a certain level (Super Compression – SC).

There is no established rule about which of these processing strategies is best for people with severe to profound hearing loss. What is certain though, is compression's helpfulness for comprehending low-level speech sounds. Souza and Bishop (1999) investigated speech comprehension at input levels of 55, 70 and 85 dB SPL using both linear and compression amplification. The way that compression emphasizes quiet speech components bringing them into the audible range clearly benefitted the test subjects, especially at 55 dB SPL. Yet there were still clear advantages to using compression for 70 dB SPL inputs as well.

Figure 1

People with profound hearing loss benefit from compression amplification, at low input levels in particular (source: Souza and Bishop, 1999).



Other research groups obtained fairly similar results (e.g. Ringdahl et al., 1999, Marriage and Moore, 2000).

Studies of severe to profoundly hearing impaired people also have revealed a subjective preference for compression over linear processing in many situations. However, there is a stronger preference for linear amplification as hearing impairment increases (Baker et al., 2001). One reason for this is the subjects' often longstanding familiarity with their own hearing instruments, since profound hearing loss traditionally has been compensated for using a linear strategy. Such established preferences may hinder the switch to compression considerably, even where this strategy could prove beneficial. Furthermore, the full positive impact of a new amplification strategy often is not achieved immediately, but only after several months' familiarization (Arlinger et al., 1996). Preference and performance differences between individual test subjects also grow more pronounced with increased hearing loss (e.g. Faulkner et al., 1991).

The more profound the hearing loss, the more flexible and individually customizable the provided amplification needs to be. A hearing system therefore must offer a wide choice of options for the hearingcare professional to provide the best possible fitting.

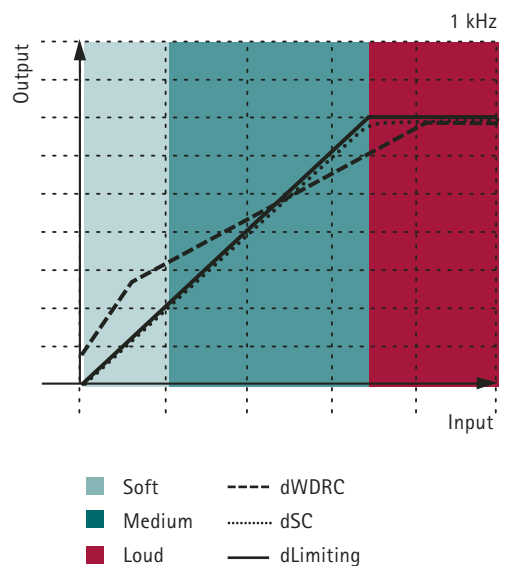
Amplification strategy adapted to the individual

Supero meets the needs of "tailor-made" amplification. With five independently adjustable frequency channels, Supero offers a great deal of fitting flexibility. The digital MultiMode Signal Processing (dMSP) concept offers three distinct amplification strategies:

Figure 2
Manual dMSP selection in the software.



Figure 3
Schematic input/output characteristics for three dMSP strategies.



1. dWDRC

Digital Wide Dynamic Range Compression is performed independently within each of the 5 frequency channels. A compression ratio of from 1:1 to 10:1 is calculated depending on the degree of hearing loss. The compression kneepoint lies at 40–50 dB SPL (depending on the frequency channel), moving upwards if feedback necessitates gain limiting (see Figure 4).

2. dSC

Digital Super Compression: In this approach, the input signal is amplified linearly up to the compression threshold in all 5 frequency channels.

3. dLimiting

Digital Limiting: This strategy uses linear amplification within all 5 frequency channels.

All three signal processing schemes use output limiting compression to limit the output, with differences in time constants applied appropriately for each type of signal processing.

The Supero dMSP strategy initially selected depends on the degree of hearing loss, and may be overridden by the hearingcare professional in the Basic and Custom hearing programs.

The dMSP strategy is chosen depending on the following criteria:

- dLimiting: average hearing loss at 0.5, 1, 2 and 3 kHz ≥ 80 dB, or > 90 dB in at least two of the four frequencies 250 Hz, 500 Hz, 1 kHz and 2 kHz.
- dSC: average hearing loss at 0.5, 1, 2 and 3 kHz ≥ 70 dB.
- dWDRC is chosen when the criteria for dSC or dLimiting are not fulfilled.
- In binaural fitting and cases of asymmetric hearing loss, the strategy appropriate to the less severe hearing loss predominates.

The basic principle is thus to apply more linear amplification with increasing hearing loss. This corresponds with current practice, with the tendency to use linear hearing instruments to compensate for severe to profound loss. Longstanding acclimatization to linear amplification makes it more difficult to become accustomed to compression amplification, nonetheless there are large individual differences within this group of hearing impaired people. The flexible dMSP strategy gives hearingcare professionals maximum fitting freedom to achieve the best possible results.

Figure 4

The compression characteristics within each of the five frequency channels are adjusted if necessary to avoid feedback.

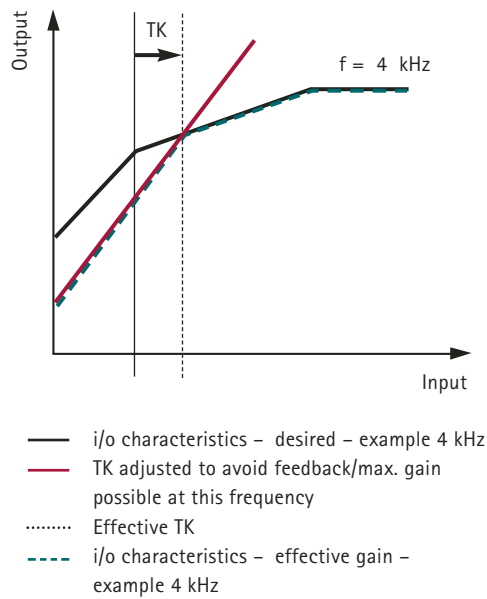
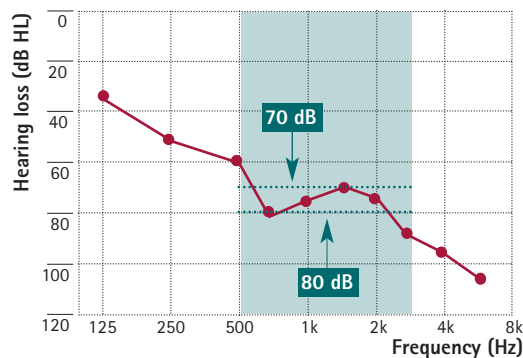


Figure 5

This audiogram shows a median threshold of audibility between 70 and 80 dB over the 0.5–3 kHz frequency range. Consequently, dSC is pre-set as the initial processing strategy.



Individual MPO shaping

With severe to profound hearing loss in particular, it is crucial to make effective use of whatever residual hearing is available. Pre-calculating and adjusting MPO in a broadband, frequency-independent way fails to exploit valuable dynamic range for potential improvement in audibility. If only broadband adjustment is available, MPO must be reduced so as not to exceed the discomfort threshold anywhere within the entire frequency spectrum (see Figure 6, left). This almost invariably wastes valuable dynamic range and audibility potential in other frequency regions, where the output level is restricted more than is necessary. Optimal exploitation of residual dynamic range thus calls for individual, frequency-specific adjustment of maximum power output (MPO). Unless explicitly specified otherwise, the PFG fitting software calculates the discomfort threshold based on the client's audiogram, to determine frequency-specific MPOs for each of the five Supero channels. In addition, hearingcare professionals can fine-tune MPO individually in all five channels for a fitting that is best suited to individual client needs.

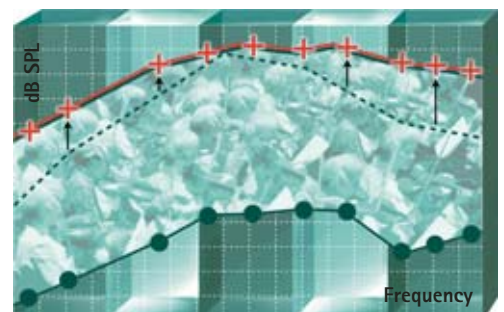
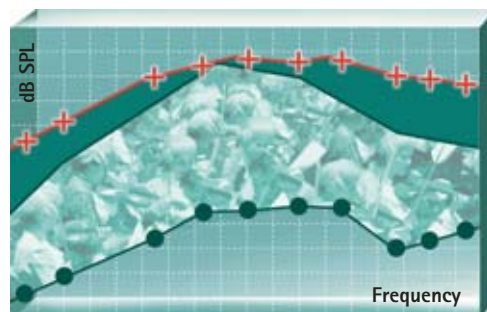
Output limiting

The combination of high gain and modest residual dynamic range makes it important to include effective protection against uncomfortable or even painful output levels for people with severe to profound hearing loss. Supero provides this protection in the form of a three-stage level control that does not impair audibility or user comfort. At the first stage (quiet to loud input signals), linear amplification (dLimiting and to some extent dSC) or compression (dWDRC) are applied. The second stage of control is activated when the individually set MPO is reached in any frequency channel. Here, loud to very loud signals are subjected to very fast, channel-specific compression limiting to ensure continued comfort in noisy situations. Broadband MPO is also assessed as a further means of ensuring that the discomfort threshold is never exceeded. The third stage of control uses instantaneous broadband output limiting to protect against sudden signal peaks. This system operates similarly to peak clipping (truncation of amplitude spikes in excess of a given threshold). The broadband clipper becomes active at a level 10 dB above the broadband MPO, provided the compression limiter has taken control. The Supero output level limiting strategy retains audibility and user comfort while providing effective, individual protection against excessively loud signals.

Figure 6

Residual hearing potential goes unused without frequency-dependent MPO adjustment (left). Frequency-dependent MPO adjustment fully exploits the available dynamic range (right).

- ● ● Hearing threshold
- + + + + Uncomfortable level
- Maximum Power Output (MPO)



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