Designing Hearing Aids for Children with Severe-to-Profound Losses

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Designing a hearing aid for a child with a severe-to-profound hearing loss involves coupling advanced technological developments with the unique needs of children. Many of the advanced technological features that need to be considered when selecting a hearing instrument for a child with severe-to-profound hearing loss reside in the hearing instrument hardware.

In addition to a focus on reliability, the hearing instrument should provide sufficient gain, effective and dynamic feedback management, and a secure and seamless integration of accessories (eg, FM systems). These features ensure that children receive the constant and audible signal required to increase the development of auditory, speech, and language skills.

Hardware features include, but are not limited to, delivery of an audible signal, effective feedback management, availability of more telecoil gain, a small and comfortable shell, high reliability, and secure and reliable accessories integration. How these features are developed and implemented, using the Oticon Sumo family of super-power hearing instrument as an example, is the subject of this article.

Hardware Features

Signal Audibility. For auditory, speech, and language development, children require a clear and audible sound from their hearing instruments. In order to provide audibility, a sufficient amount of maximum power output (MPO) and gain is required.[1] In the past, the current consumption requirements and the mechanical limitations of conventional super-power platforms restricted the ability to reach consistent, high levels of output necessary for these children.

Figure 1. Vented receiver of the SUMO family showing the unique vents receiver and the increased diameter sound outlet.

The recent introduction of Output Optimization Technology (OOT), is designed to allow sufficient output while providing a Battery Management System for the needs of users of super-power hearing instruments. One of the mechanical problems of standard receivers is that the movement of the diaphragm within the receiver is restricted. This limits output, particularly in the low frequencies, because freedom of movement in the diaphragm helps determine available output. A solution to this problem is to add two holes to the backside of the receiver (Figure 1); this provides ventilation which reduces the stiffness of the system thereby allowing an increase in diaphragm movement. To ensure that feedback does not become an issue with the extra sound path through the ventilation holes, the vented receiver is then placed in a “sound-proof” box. With this, the receiver diaphragm has more freedom of movement, increasing available gain and MPO without increasing the risk of feedback.

While ventilating the receiver allows increased gain and MPO, the sound path from a conventional receiver unfortunately restricts this increased sound from exiting the receiver. To overcome this difficulty, the receiver-port size is increased which allows a more direct path for the sound to travel. This ensures that as much sound as possible can exit the hearing instrument and thereby increases the gain and output.

The last part of OOT is a lowering of the receiver impedance which allows a higher overall output. Receivers with low impedance have been used previously in super-power hearing instruments, but often consume too much current. However, a dedicated Battery Management System and output amplifier design has been developed to ensure that the increased current consumption is controlled and MPO is kept as high as possible given any battery condition.

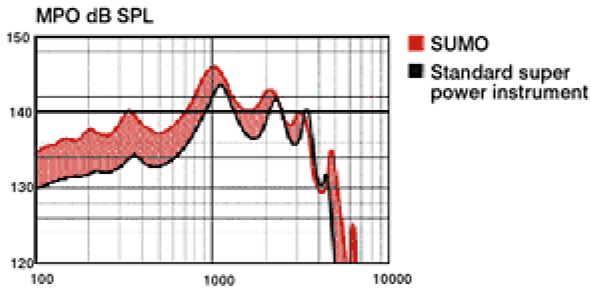

Figure 2. Comparison of the maximum MPO that is available using Output Optimization Technology (OOT) in SUMO XP versus the available MPO in a conventional super-power hearing instrument.

By having an increased MPO, more available gain can be realized—particularly in lower frequencies—allowing greater audibility (Figure 2). The increased low-frequency gain and higher MPO provides children who have severe-to-profound hearing impairment access to voicing cues, manner of articulation, and prosodic cues.[2] This critical information assists in the development of auditory, speech, and language skills.

Effective Feedback Management. Providing effective feedback management is a crucial factor when selecting a hearing instrument for a child with severe-to-profound hearing loss. Feedback is often an issue when providing unrestricted use of the volume control. In order to develop auditory, speech, and language skills, gain and full usage of the volume control is needed for children, as they require full access to auditory input across their residual frequency range.

When ensuring effective feedback management, there are two points to consider: internal feedback in the hearing instrument and external acoustical feedback.

u Internal feedback. There are two types of internal feedback to consider, both involving the vibrations from the receiver itself. The first is mechanical feedback, which occurs in the low frequencies. The vibrations from the receiver can cause the microphone and shell to vibrate, creating internal feedback. To handle internal mechanical feedback, the Sumo family contains a suspension system for the microphone and receiver with a stiff shell designed to decrease the vibrations transferred from the receiver.

Figure 3. The 'mu-metal' casing around the vented receiver.

The second kind of internal feedback is acoustical feedback which primarily occurs in the high frequencies. This occurs when the vibrations from the receiver and the casing around the receiver leaks sound. To help solve this problem, the Sumo receiver is placed in a metal box which closes in the sound. There is also a need to dampen electromagnetic transmission when the telecoil is used. In order to decrease the electromagnetic transmission, "mu-metal," an alloy which shields magnetic-field transmissions, is used to surround the receiver (Figure 3). This shielding allows more gain to be given without audible electromagnetic feedback.

u External acoustical feedback. When handling external acoustical feedback, two methods can be utilized: Dynamic Feedback Cancellation (DFC) and feedback management (static cancellation). The combination of these systems is designed to guarantee effective handling of feedback. DFC (used in Syncro, Adapto, Gaia, and Atlas hearing aids) is a two-stage feedback cancellation system designed to reduce all occurrences of feedback without a reduction in gain or distortion of the signal.[3]

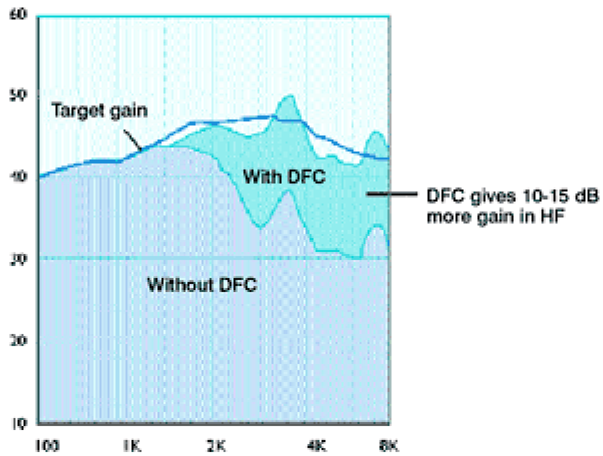

Figure 4. The gain provided with and without the Dynamic Feedback Cancellation System.

The increase in the feedback margin provided by the DFC allows for two solutions, depending on the hearing loss. For a severe hearing loss where there is often useable hearing in the high frequencies, the DFC allows gain targets to be met and full audibility to be achieved across the frequency range (Figure 4). This provides children with access to all speech cues, facilitating auditory, speech, and language development.[4] For profound hearing losses, the practitioner typically focuses on residual hearing in the low-to-middle frequencies. Therefore, high-frequency audibility is not a high priority and the increased feedback margin provided by the DFC decreases the occurrence of feedback during everyday activities, such as when chewing food or using the phone.

While advanced DFC systems are effective in most situations, it is not possible to completely eliminate feedback for the high-gain and MPO requirements of super-power instruments; in these cases, a system to manage and control the feedback is needed. The Feedback Manager in the Genie fitting software is another method of optimizing gain without feedback. It statically decreases the occurrence of acoustic feedback by “locking” the gain in the high frequencies for higher volume control settings. This solution continues to allow an increase in gain for low frequencies while limiting high frequency gain so that the volume is not restricted by the feedback limits of the instrument.

Reliability and Size. Because children’s ears are tiny, a smaller and more comfortable shell set is desired. However, this is a challenge when designing a hearing instrument for children with severe-to-profound hearing loss where more gain is required. To meet this gain requirement a larger 675 battery is needed, which often leads to a larger shell to house the battery. Using digital modeling, many different shapes of hearing instrument shells can be tested prior to production. This modeling allows the creation of shells designed to provide a comfortable, yet small shell package

Tamper resistant options are a successful way of locking the switches, wheels, and doors of a hearing instrument, preventing children from inadvertently switching programs, turning down the volume, or opening the battery drawer. The ability to “lock” these controls is imperative to ensure excellent audibility for a child throughout the day.

As these children lead rough-and-tumble lives and are totally dependent on their hearing instruments for listening, high reliability and secure accessories integration are critical. Their lifestyles demand a reliable hearing instrument. Before releasing a hearing instrument for worldwide production, a stringent series of tests ensure the hearing instrument’s ability to withstand daily life—including temperature changes, moisture, sunlight, static electricity, and impacts (eg, being dropped). After each test, the prototype hearing instrument is assessed to ensure it is still working according to manufacturer specification. The frequency response, total harmonic distortion, electrical consumption, and controls are evaluated to check for any possible damage that might have occurred during testing. If damage has occurred, the damage is taken into consideration and the hearing instrument is redesigned to guarantee reliability.

Figure 5. In the "sweat chamber," instruments are exposed to five cycles of fine salt mist that help to simulate the long-term effects of perspiration.

To meet the needs of children living in different countries with various climactic conditions, Oticon also conducts a number of specific tests to ensure that the hearing instrument functions reliably, irrespective of differing physical environments. To simulate climactic extremes, the hearing instrument is cycled between a salt mist chamber and a drying oven (131°F) (Figure 5). After 5 cycles, the hearing instrument is placed in a warm humid chamber for 7 days (104°F and 93% Relative Humidity) to simulate repeated exposure to sweat. After the 7 days, the hearing instrument is analyzed. Functionality is tested and the frequency response of the hearing aid is recorded to evaluate if there has been any damage to the hearing instrument that needs to be rectified prior to worldwide release for sale.

To simulate a hearing instrument being dropped, Oticon drops a hammer from 59 inches above the hearing instrument. This is completed with the hearing instrument in 6 different orientations. The hammer hitting the hearing instrument is similar in force to the hearing instrument falling on the floor. After each hit, the hearing instrument's frequency response is assessed to ensure it is working properly.

Because children like colors, different colored transparent shell covers are an option. As the shells are transparent, sunlight including infrared radiation can pass through them. This can potentially influence the electronics and mechanics of the hearing instrument. The infrared radiation can have lasting effects and change the physical properties of the shell which may lead to the shell breaking. Therefore, the consequences of repeated exposure to sunlight are taken into account during production and reliability testing. Similarly, when living in dry climates, static electricity can be a problem. To test this, an electrostatic-charge (up to 8 kV) is discharged to the hearing instrument. Following the discharge, the hearing instrument is again assessed to make sure it is working properly.

Accessory Integration. Accessories are an essential part of the hearing instrument for children with severe-to-profound hearing impairment, as they provide consistent access to the targeted speech signal in children's noisy environments. One commonly reported frustration is that personal FM ear-level receivers can be difficult to connect to hearing instruments or even lost during use. Therefore, secure adaptors are required for the FM system to have a reliable connection. One solution is to create an interlocking system of integrating the FM receiver with the hearing instrument. The interlocking system of Sumo secures connectivity between the hearing aid and the FM receiver by a dedicated FM receiver directly connecting into the battery drawer (Figure 6). It is then closed within the hearing instrument making it impossible to inadvertently drop off, while remaining easy for the parents, teachers, and audiologists to use. This ensures consistent input from the FM system.

Figure 6. Interlocking adaptor for hearing instruments.

Talking on the telephone is a critical activity in the life of a child, as it allows them to connect with family and friends and share their thoughts.[5] Many children with severe-to-profound hearing loss have difficulty accessing auditory information on the telephone due to insufficient telecoil gain. To provide a solution, hearing instruments like Sumo provide a boost in gain in the telecoil setting. This is fundamental for this population to be able to communication on the telephone with their family and friends.

Summary

Due to universal newborn hearing screening, children with severe-to-profound hearing impairment are identified and diagnosed at younger ages.[6] Following diagnosis, it is critical to provide appropriate amplification to these children.[7,8]

When selecting a hearing instrument for a child with severe-to-profound hearing impairment, there are many factors that need to be considered. These features are included in the hardware of the hearing instrument and in the fitting software used to fit the instrument. The hardware features focus on meeting the gain and headroom requirements for severe-to-profound hearing loss, as well as providing a clear, audible, and consistent signal. Included in providing sufficient gain and headroom is the optimization of the sound pathway and effective feedback management. The ability to integrate accessories, such as FM, helps to provide a reliable and consistent signal to the child throughout their day.[9]

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