STARKEY INTRODUCES S SERIES™ WITH DRIVE ARCHITECTURE™

In recent years, Starkey has pioneered a progression of technological innovations, beginning with the release of the Destiny™ family of hearing instruments in 2006. With no break in the pace of development, 2007 saw the introduction of the flagship Destiny 1600, with the first ever integration of real-ear measurement into a hearing aid. In 2008 the Zōn™ receiver-in-canal (RIC) device was released and subsequently earned five design and technology awards. These products represented the culmination of years of scientific exploration and evidence-based development, resulting in unprecedented growth for Starkey and hundreds of thousands of satisfied patients. Despite the success, Starkey's ethic of continuous improvement dictates that our engineers and scientists continue to enhance the features of instruments and software alike. The result is a new family of hearing instruments with a high-end feature set that once again sets the standard for performance, comfort and personalization.

Introducing S Series by Starkey

This paper will offer an overview of the capabilities of S Series 11, with an emphasis on the most salient features that make up the product family. Specifically, we will address feedback cancellation with the PureWave Feedback Eliminator, personalized verification with Live Real Ear Measurement and Live Speech Mapping, and a new set of comfort and intelligibility tools collectively called the Acoustic Scene Analyzer.

Controlling Feedback

Drive Architecture – the new digital platform underlying S Series – has given Starkey's researchers the power to redefine clinical expectations for an effective and reliable feedback canceller. The multi-core processing capabilities of Drive Architecture allow PureWave Feedback Eliminator, the new feedback canceller in S Series, to recruit multiple processors, each adapting a sub-band filter for the purpose of signal identification and adaptation at speeds that are near real time without the risk of distortion or decreased sound quality.

Many hearing professionals regard Starkey's Active Feedback Intercept (AFI) as the benchmark that *nearly* eliminated feedback in traditional hearing instrument fittings. However, with the increasing popularity of open canal fittings, professionals are quickly learning that the type of feedback that occurs in open canal fittings differs from that occurring in occluded fittings. The difference lies in the acoustic characteristics of feedback paths in occluded and open canal fittings. In a traditional occluded fitting, the feedback path is typically restricted, resulting in feedback across a narrow range of frequencies and amplitudes. The constrained characteristics of the acoustic feedback simplify the task of cancellation. In contrast, the acoustic characteristics of the feedback path in open canal fittings are more complex and inherently more difficult to control and ultimately eliminate.

The difficulty of managing open canal feedback is substantiated by the fact that some leading hearing aid manufacturers artificially restrict available gain in open canal fittings, perhaps compromising access to prescriptively appropriate signal audibility for the sake of avoiding feedback. It is Starkey's development philosophy that an effective feedback canceller should provide added stable gain in any fitting configuration, ensuring speech audibility for all patients.

AFI has led the field of feedback cancellers for the past three years (Banerjee et al., 2006; Merks et al., 2006). Now PureWave Feedback Eliminator replaces AFI as the industry-leading solution for feedback cancellation, offering up to 25dB of added stable gain (ASG) in an open canal fitting. The performance improvements found in PureWave Feedback Eliminator are expected to be most noteworthy in open canal fittings that present the most challenging, complex forms of feedback. A systematic comparison of PureWave and AFI was performed to quantify the differences between the two systems, the results of this comparison are shown in Figure 1. In this figure, the difference in peak added stable gain when comparing AFI and PureWave is plotted as a function of Frequency. In regions of complex feedback that may have restricted the peformance of AFI, PureWave has shown improvements in peak ASG of up to 15dB. The mean data show a performance improvement of 20% over AFI. These improvements have been achieved while also significantly improving the system's sound quality in the presence of complex tones.

To compare performance of feedback cancellers across competitive hearing instruments, the S Series RIC was tested along with a group of four of the most recently released RIC products. Ten patients were fit with each hearing instrument in an open canal configuration. To eliminate variability in occlusion due to different ear tip designs, the hearing aid outputs were delivered to the ear without any earbuds (or domes or eartips).

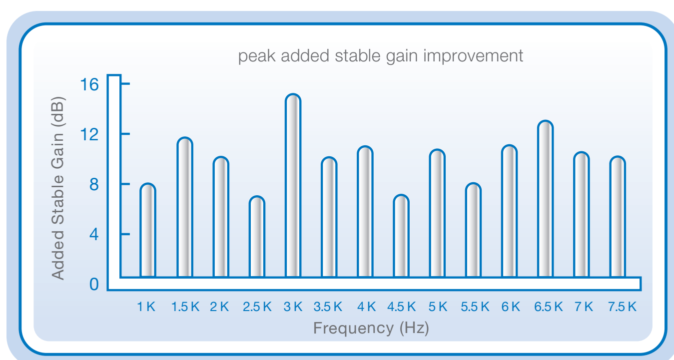

Figure 1. Peak Added Stable Gain Improvement

Maximum Stable Gain (MSG), defined as the highest programmed hearing aid gain just below the point of feedback, was compared (Figure 2). Results show the maximum stable real-ear insertion gain for S Series and the top competitive RIC devices as a function of frequency. S Series maintains a clear lead over the closest competitor with a mean gain margin of 7dB and peak margins of 10dB and 17dB at 3.0 and 7.0 kHz, respectively. These measures establish the S Series RIC as a class leader on measures of MSG.

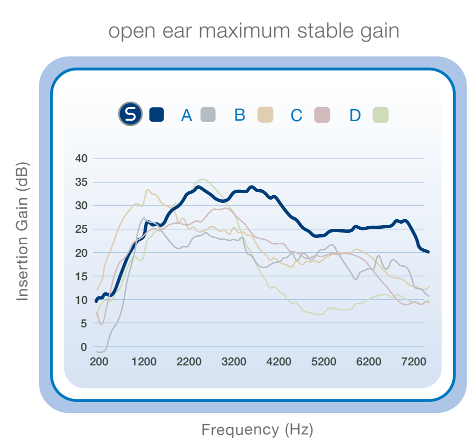

Figure 2. Open Ear Maximum Stable Gain

Starkey has proudly led the way in the research and design of effective feedback cancellation, a fundamental feature defining quality and success of advanced technology. Now PureWave Feedback Eliminator sets a new stage, allowing hearing professionals to offer more patients levels of audibility and comfort never obtained before.

Guaranteeing Fitting Accuracy with Live Real Ear Measurement

Although it is well accepted that acoustic verification with probe tube microphones is an essential part of the professional fitting of hearing instruments, the use of real-ear measurement is less common than we might expect (Kirkwood, 2006; Strom, 2007). Practitioners cite time constraints and equipment cost as deterrents to the regular use of real-ear systems.

Live Real Ear Measurement in S Series takes a direct measure of the patients Aided Real-Ear Response and uses these data throughout the fitting process (Figure 3). A probe tube attached to the hearing aid microphone measures the SPL in the ear canal in response to a speech-shaped noise. The system then uses this information to adjust hearing aid gain to achieve a precise match to the prescriptive target. This entire process is integrated into the Best Fit procedure in Inspire® 2009 to measure and match to target in a matter of seconds.

At this point the measured SPL data are stored in the hearing instrument. At subsequent patient visits for fine-tuning adjustments, this information provides an accurately calibrated SPL display on the software screen.

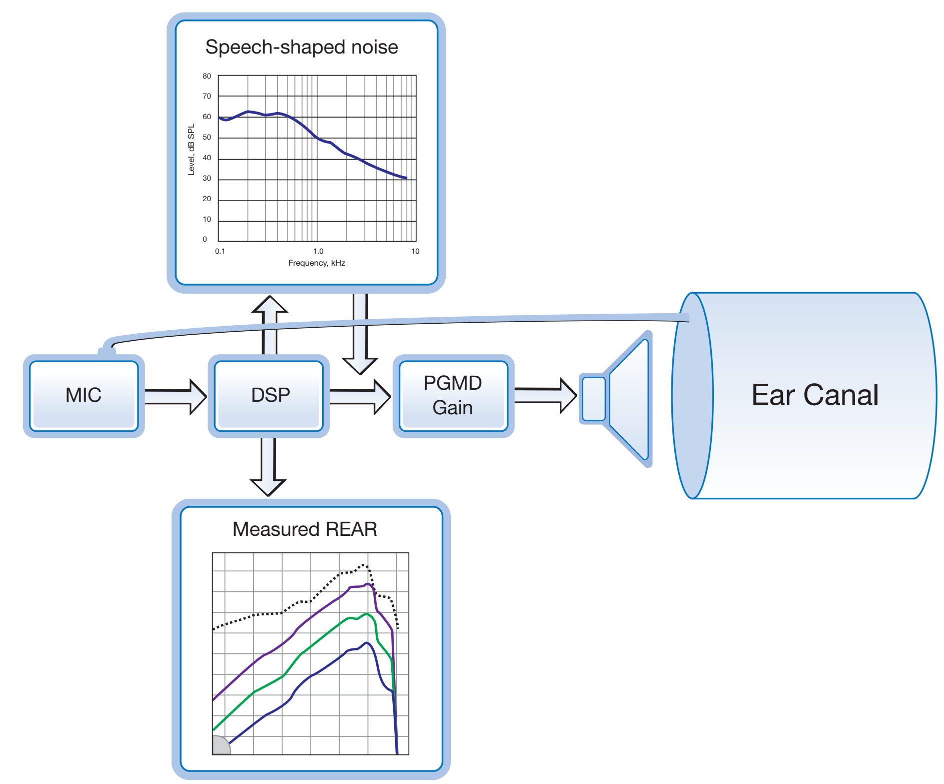

Figure 3. Diagrammed data collection and analysis for Live Real Ear Measurement

Summarizing the Live Real Ear Measurement procedure:

1. The DSP adjusts the response parameters to calculate an initial match to the selected prescriptive target based on average ear canal acoustics.
2. The DSP generates an electrical speech-shaped noise. Programmed gain is applied to this signal before going to the receiver.
3. The hearing aid microphone measures the SPL as a function of frequency in the ear canal through a probe tube and sends that response back to the DSP.
4. The DSP measures the difference between predicted and measured response and adjusts the hearing aid parameters by that amount. At that point the display on the software screen reflects actual ear canal SPL.
5. The measured SPL data are stored in the hearing aid and the Inspire software record to guarantee accuracy in subsequent fine-tuning adjustments.

No other hearing instrument or software package in the marketplace has the capabilities offered by Live Real Ear Measurement in S Series. It guarantees the personalized, custom fit of every hearing aid to every patient's ear and hearing loss needs.

Verification and Counseling with Live Speech Mapping

Speech Mapping has gained importance for many hearing professionals, serving as a tool for both verification and counseling (Cunningham et al, 2002; Moore, 2007). The use of speech in verifying and demonstrating hearing aid performance not only provides a real-world verification signal, but also offers greater validity to patients and families who are attempting to understand the effects of hearing loss and the benefits of amplification.

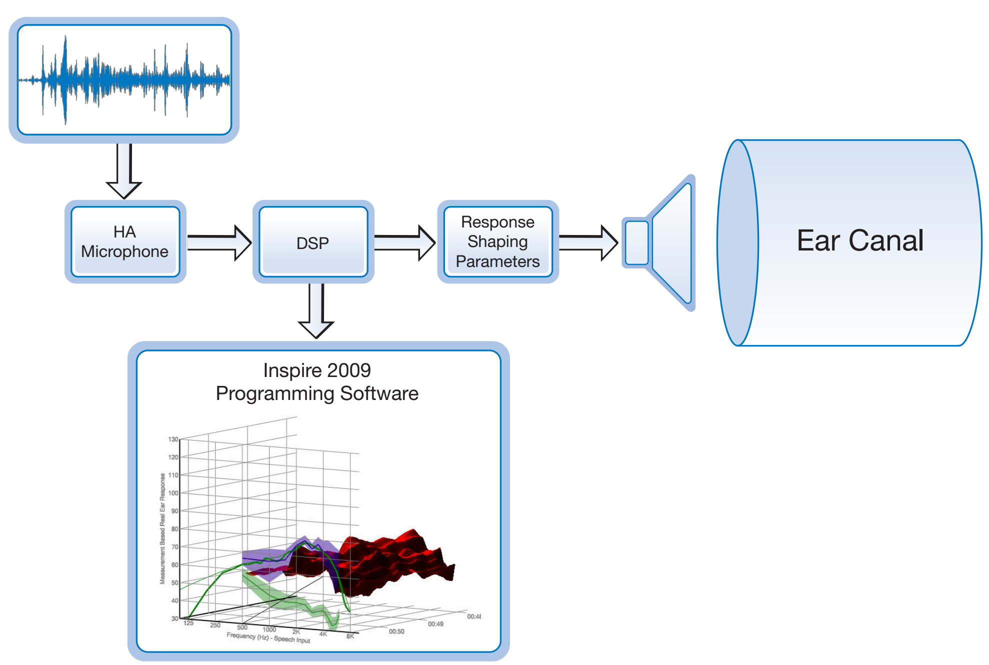

Figure 4. Diagrammed data collection and display for 3D speech mapping

The goal of speech mapping is to display the output of a hearing instrument in the patient's ear canal in response to any acoustic input. The Live Speech Mapping feature in S Series instruments offers the benefits of speech mapping without the need for a conventional probe tube system.

The Live Speech Mapping routine is shown in Figure 4. An acoustic signal, live or recorded, enters the hearing instrument microphone. The DSP receives this input and presents on the software screen a display of the output of the hearing instrument in the patient's ear. Integrating the SPL data from the Live Real Ear Measurement system, it shows a real-time response calibrated to each individual patient and each individual hearing instrument.

The Live Speech Map displays either a two- or three-dimensional display of the hearing instrument output. The software allows the operator to capture and freeze any sound or voice and print the result or save it in the patient file in the database.

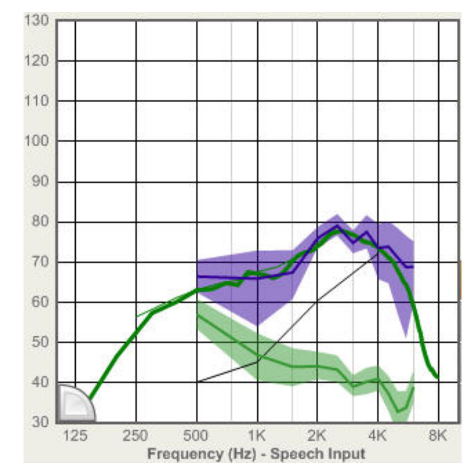

Figure 5a. Example of 2D Speech Mapping from Inspire 2009

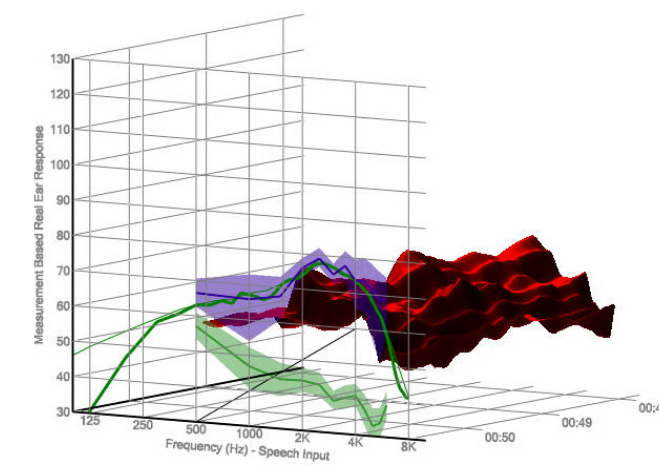

Figure 5b. Example of Live 3D Speech Mapping from Inspire 2009

Two Live Speech Mapping display options are shown in Figure 5. Both displays show a captured 10-second sample of an S Series hearing instrument response to live speech. The green curve shows the input to the hearing instrument and the purple curve the output. The thin black line represents the patient's thresholds in dB SPL. The two-dimensional graph in Figure 5a displays the captured average output by frequency over a 10-second interval.

The red, contoured shape in the three-dimensional plot in Figure 5b displays the dynamic changes in speech over time. When viewed as a live running record, it can demonstrate to patients the complex, changing nature of the speech signal. It also enables the hearing professional to scroll back in time to examine the effects of programming changes or specific acoustic events captured on the record.

Figure 5 shows an appealing and straightforward demonstration that can be used with a hearing aid patient. Using the spouse's voice as the input, capture a 10-second sample and demonstrate how the input and output curves displayed on the speech mapping screen relate to the audiometric information. We see here that the voice at the input (green shaded region) falls below threshold above about 1500 Hz, while the output of the aid (purple shaded region) is above threshold over a much wider range. No other hearing instrument on the market can perform speech mapping integrated into the hearing aid without relying on commercial real-ear equipment.

Handling an Acoustically Complex World

One of the biggest challenges for hearing aid wearers is accommodating the wide range of acoustic conditions that the world presents to them. S Series addresses this challenge with the Acoustic Scene Analyzer, a system that includes four subcategories: AudioScape, InVision Directionality, Automatic Telephone Solutions and T^2.

This new system for managing noise and preserving speech intelligibility uses a complex classification and decision-making process. Incoming signals are analyzed, identified and classified every six milliseconds to adapt the hearing instrument for comfort and clarity in as many situations as possible. The Acoustic Scene Analyzer can seamlessly select and implement the most appropriate algorithms individually or collectively.

Maintaining Comfort. Digital hearing instruments in recent years have offered ever-improving tools to control noise and improve comfort. S Series uses a set of algorithms, called AudioScape, to categorize acoustic inputs into meaningful groups and then apply adaptive processing to optimize comfort in all situations. The nature of the adaptation in AudioScape depends on a number of factors – overall input level, input level in each channel, statistical categorization of inputs and a patented algorithm for estimating signal-to-noise ratio. In addition to these decision criteria and dynamic adjustments, the operator can select up to five levels of adaptation for each noise category.

Figure 6. AudioScape icons showing activation of each of the five adaptive algorithms and speech

Personalizing Comfort. Research on acceptable noise levels suggests that patients differ in their ability to tolerate noise (Nabelek et al., 2006). With an eye to personalizing the instrument to individual patient preferences, S Series uses Comfort Control to set the signal-to-noise ratio at which the adaptive algorithm engages.

Some hearing aid wearers, who are highly sensitive to noise, might prefer to begin adapting to noise when its acoustic impact is relatively small. Other patients, who can tolerate higher levels of noise or poorer SNRs, may prefer to maintain gain levels for speech, even in the presence of noise. Comfort Control accommodates this range of individual needs.

T^2 Acoustic Remote Control. S Series offers a remote control that won't be lost. Most touch-tone and mobile phones around the world respond to a key press with a standardized tone for each number on the keypad. T^2, a breakthrough technology from Starkey, uses these touch-tones to control hearing instruments using any cell phone or other touch-tone phone. No longer dependent on manual adjustments or a remote control, patients can adjust their hearing aids with a device that many already carry in their pockets.

Final Word

The multi-core Drive Architecture platform in S Series has allowed Starkey to introduce a series of hearing instruments that continue to meet the needs of hard-of-hearing people.

This article has described several important features:

- PureWave Feedback Eliminator demonstrates superior performance. It not only increases stable gain to unprecedented levels, but also adapts quickly to changes in the feedback path without artifacts or signal degradation.
- Live Real Ear Measurement is a verification system built into the hearing instrument, which not only automates the initial fitting but also retains the data for any future adjustments.
- Acoustic Scene Analyzer identifies and adapts to a wide variety of acoustic conditions, prioritizing speech intelligibility or comfort as the listening demands.
- T^2 is a new take on the remote control, allowing patients to control their hearing aids with touch-tone phones.

S Series and its supporting software, Inspire 2009, offer additional features and benefits that will be best experienced when hearing professionals and patients begin using this state-of-the-art technology. For more information on benchmarking methodology, please visit www.starkeyevidence.com.

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Starkey Laboratories, Inc.
6700 Washington Avenue South
Eden Prairie, MN 55344-3476
800.328.8602

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