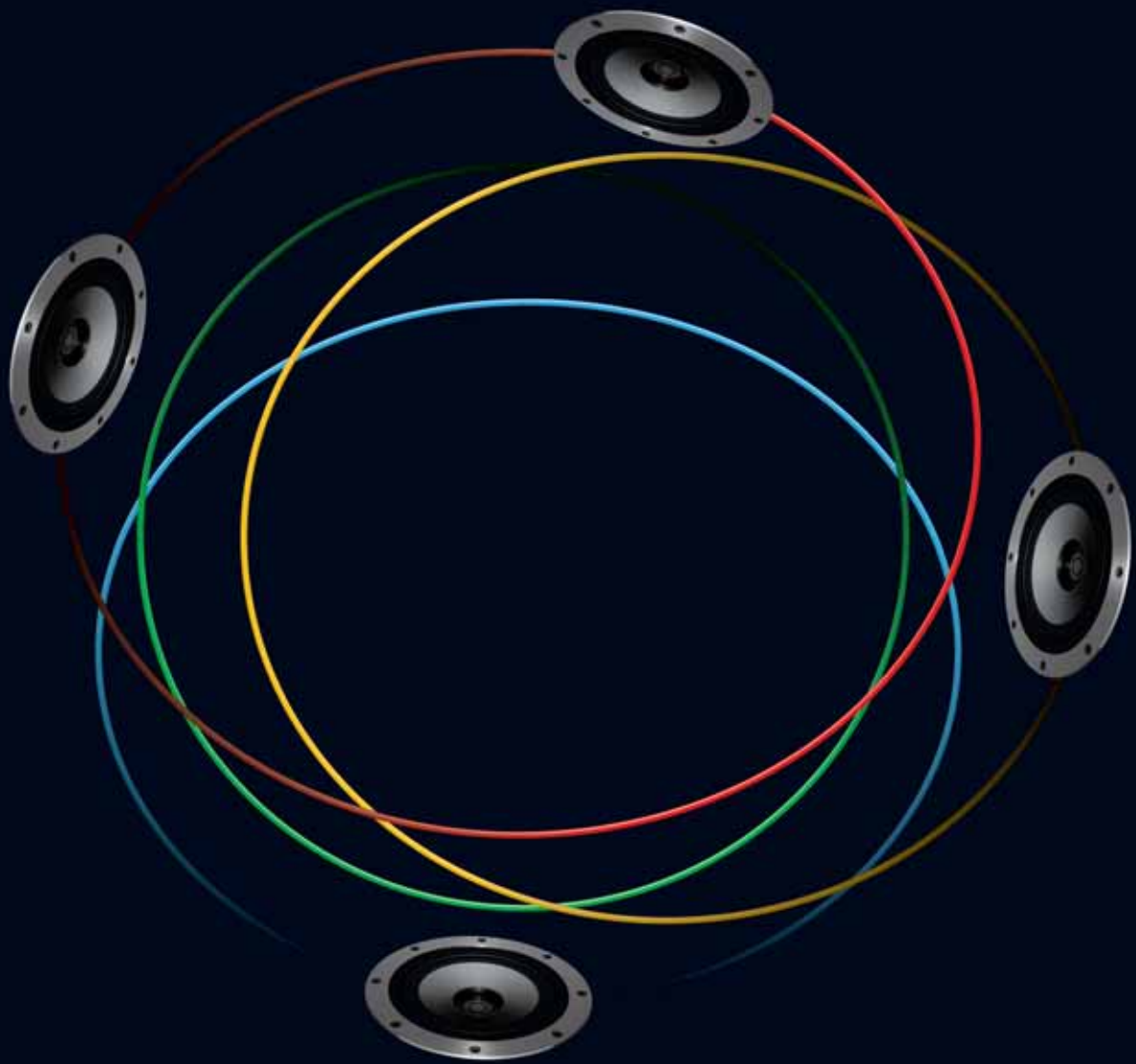


# Surround sound by ReSound

## Audiology background



An advertisement for a brand of cassette tapes once posed the question, “Is it live or is it Memorex?” In the context of today’s sophisticated surround sound audio systems, the thought of a cassette tape providing a sound experience which could be confused with the real thing seems quaint. Just as surround sound technologies have placed movie-goers, music lovers and gamers into the center of the action, surround sound by ReSound takes hearing instrument wearers to a new level of auditory awareness and natural sound perception. Thanks to the ReSound surround sound processing, which restores directivity patterns similar to the open ear and eliminates drawbacks of traditional directionality, wearers can enjoy enhanced awareness of their sound environments, fully detailed sound quality, and ease of understanding speech in the most challenging surroundings. Additional advancements such as extended high frequency bandwidth and improved feedback management technology complement the ReSound surround sound processor to provide the most natural sound quality with this exceptional hearing instrument.

## HEARING “BETTER” IS JUST NOT GOOD ENOUGH

It is universally acknowledged that the primary complaint of hearing instrument users is hearing in noise. Rehabilitation as well as hearing instrument design focus on improving the hearing impaired individual’s ability to understand speech in noisy conditions. The assumption is that resolution of this primary issue will lead to success and satisfaction with hearing instruments. Advances in hearing instrument technology such as multichannel wide dynamic range compression and directionality have indeed been shown to provide benefit in this area as defined by conventional laboratory and self-report measures. And yet, market surveys indicate continued dissatisfaction with various aspects of hearing instrument performance, and reports such as the following are everyday fare for hearing care practitioners:

*“I am definitely hearing more. Sounds are crisp and I am able to follow meetings better. But sometimes it’s kind of like an out-of-body experience where things seem surreal. I can hear the cat crunching her cat food in the kitchen from two rooms away. At work I hear people typing on their keyboards and it sounds like it’s in my head. If I hear a horn honking or siren when I’m driving, I can’t figure out where to look.”*

Howard, 62 year-old new hearing instrument user

Like Howard, hearing instrument users may experience their surroundings as sounding unnatural or even disorienting in spite of demonstrating what is considered to be benefit of amplification. In Howard’s case, his speech recognition scores improved with

amplification, but he continued to indicate dissatisfaction with the devices in numerous daily listening environments. It can be difficult to reconcile evidence that the hearing instruments are beneficial with reports that they are unappreciated in many situations. However, hearing instrument wearers' overall satisfaction is closely tied to the number of their daily listening environments in which they can function satisfactorily (Kochkin, 2005) rather than benefit determined under controlled and predictable conditions. It was estimated that hearing instruments would need to be of use to wearers in at least 70% of the listening situations encountered in order for them to assign a high overall satisfaction rating.

## AUDIBILITY AND ENVIRONMENTAL AWARENESS = NATURAL SOUND

The philosophy behind surround sound by ReSound was to recreate natural perception of sound environments in addition to providing benefit in the traditional sense. This involves putting the individual wearers back in touch with as many of their wide-ranging listening situations as possible. The list of situations in which an individual experiences hearing difficulties might include talking in small groups and at parties, communicating at meetings, using the phone, hearing the instructor at a fitness class, hearing announcements over PA systems, orientation in traffic, speaking with small children, and many others. While it is typical to distill such a list to "problems hearing in noise" or "problems hearing in challenging situations", this captures neither the dynamics of these real situations nor the actual nature of the listener's issues. Reverberation, background noise level and composition, distance and positioning of the listener relative to the talkers, access to visual cues, listener's intent, listener's knowledge of context, and the listener's ability to shift and focus attention are but a few of the many extrinsic and intrinsic factors which would contribute to an individual's functioning in any particular real environment.

While hearing instruments can give hearing impaired listeners access to acoustic information, listening to, interpreting and using that information to communicate in their surroundings are activities which occur in the brain. Recognizing that no artificial decision-making can replace the specialized sound processing of the human auditory system, ReSound researchers explored how best to apply hearing instrument technology to take advantage of this ability. The result is the surround sound by ReSound, which extends proven Sound by ReSound technologies with the ReSound surround sound processor. The combination of these technologies facilitates the auditory system's ability to parse the incoming stream of sound and make sense of the auditory environment

by providing audibility, improved signal-to-noise ratio when possible, and by preserving localization cues. This latter fact is crucial not only for spatial hearing but also in creating the natural sound quality reported by wearers.

## THE SURROUND SOUND EXPERIENCE

“Surround sound” is a term to which many people can easily relate. Surround sound plays back recorded sound using sound enhancing techniques and encircling the listener with multiple speakers to create a virtual three dimensional sound environment. It recreates a realistic, full sound picture and gives the listener a sense of actually being in the situation. Likewise, the ReSound surround sound processor preserves and conveys acoustic information in such a way that wearers’ surroundings sound natural rather than “surreal” as described by Howard in the quote above. However, rather than recreating sound environments, the ReSound surround sound processor helps wearers reconnect with their actual environments. This is accomplished by channeling higher frequency sounds through advanced directional processing, while preserving the natural between-ear phase differences for lower frequency sounds.

The ReSound surround sound processor represents a revolution in directionality. It solves byproducts of this type of processing that have been shortcomings of even the most advanced adaptive directional systems. Research has shown that hearing instrument users tend not to change directionality mode even when they are able to identify situations in which directionality might be beneficial (Cord, 2002). Why? Any of the known issues with directional processing may be relevant to the individual hearing instrument wearer. These include:

### **1. Noise as a result of equalizing for inherent low-frequency roll-off**

Directionality is achieved by applying a delay to sounds entering the rear microphone port and subtracting this signal from the sound entering the front microphone port. This results in a reduction of output for sounds coming from the rear. However, this effect is frequency dependent. Since low frequency sound has longer wavelengths, the phase relationships between the signals sampled from the front and rear microphone ports will be more similar, resulting in less low frequency output regardless of the direction of arrival of the sound. For the hearing-instrument wearer, this means less volume, less fullness of sound, and less audibility when in directional mode. It is common practice to compensate for this effect by boosting low frequency amplification.

Unfortunately, this has the undesired effect of amplifying the noise floor to the point where it may be audible and objectionable to the wearer (Ricketts & Henry, 2002).

## **2. Distortion of near-field signals, such as wind blowing across the microphones**

Wind noise is caused by turbulent air flow over the hearing instrument microphones. The resulting pressure changes are picked up by the microphones and amplified, causing annoying loud noise which can also mask sounds the listener wants to hear. Wind noise is worse when directionality is active due to the fact that directional microphones are more sensitive to sounds occurring near them than sounds from sources farther away (Thompson, 2003).

## **3. Phase distortions to the incoming signal that can disrupt localization cues**

The most basic auditory localization cues are differences in time and level of sound arriving at the two ears. These interaural time and level differences (ITD and ILD, respectively), are salient depending on frequency. ITD is resolvable in lower frequencies and dominates localization (Wightman & Kistler, 1992). Current directional technology introduces phase distortions to the incoming signal, inherent in its filter processing, that can disrupt localization cues.

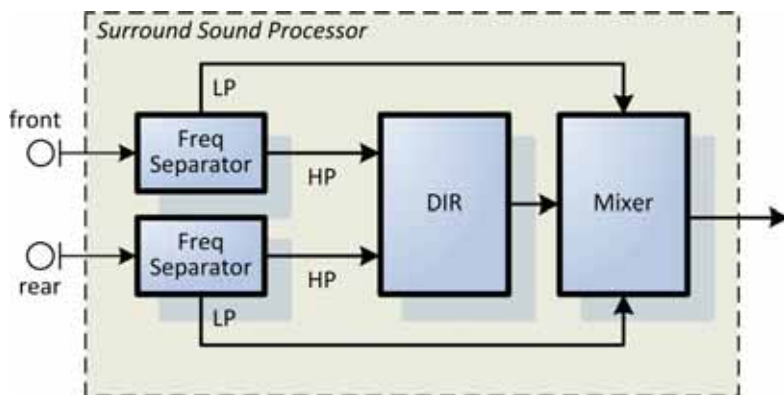
## **4. Microphone placement for behind-the-ear (BTE) instruments resulting in disproportionate response patterns.**

BTE hearing instruments have enjoyed a surge in popularity due at least in part to the emergence of tiny, cosmetically-discreet devices. A disadvantage of this style of instrument is the loss of spectral cues provided by the pinna, resulting in less directivity for BTE devices than for those with microphone placement in the concha (Fortune, 1997) and translating to reduced speech recognition in noise performance compared to ITE devices (Ricketts et al, 2001).

## THE SURROUND SOUND PROCESSOR – THE NEXT BEST THING TO THE UNAIDED EAR

Each of these issues is solved by the surround sound by ReSound. This unique technology combines information about the individual's audiometric data with form factor specific information to calculate a personalized mix of directional and omnidirectional processing. As illustrated in Figure 1, incoming sound will be preprocessed, with higher frequency components delivered to the directional system while an omnidirectional response is maintained in low frequencies. This processing strategy replicates directionality patterns of the unaided ear

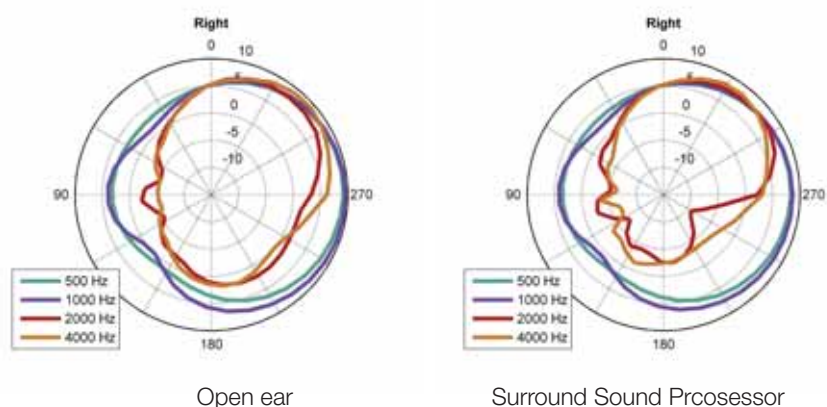
even for BTE microphone placement, contributing to natural perception of sound for the user.



**Figure 1:**

The ReSound surround sound processor separates the incoming sound into high and low frequencies, processes them separately, and then remixes them before passing the signal on through the amplification system. Directionality is applied at frequencies above an individually determined blending point.

Figure 2 illustrates how the ReSound surround sound processor preserves open ear directional characteristics. The left panel shows the open ear directional response for 4 frequencies measured on KEMAR. Note how the response is omnidirectional with only subtle asymmetries for the 2 lower frequencies while in the higher frequencies there is relatively more amplification for frontal incident sound than for sound coming from other directions. The right panel presents the same measurement performed with surround sound by ReSound. The processor ensures that the directional characteristics with the hearing instrument in situ are a good match to those of the open ear.



**Figure 2:**

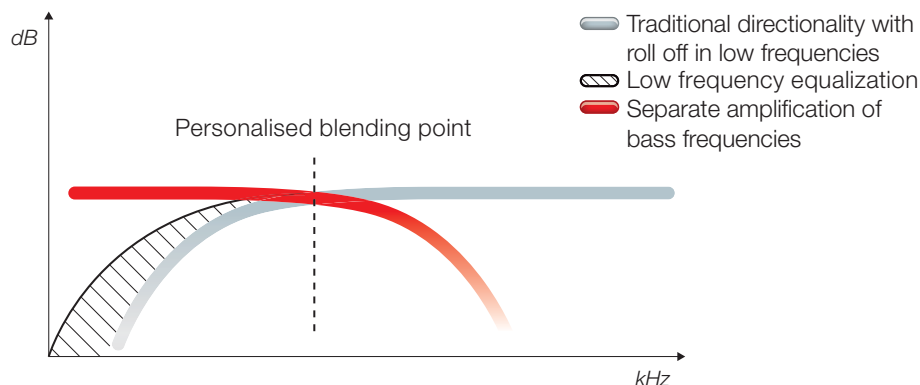
The directional characteristics of the ReSound surround sound processor are similar to the open ear. The response is omnidirectional at lower frequencies and directional at higher frequencies.

Directional systems in hearing instruments create artificial directional responses, such as cardioid or hypercardioid, based on mathematical constructs. While they can provide some directional advantage, it is at the cost of environmental awareness, which is a component of users' strong preferences for omnidirectional microphone mode (Walden et al., 2004; Walden et al., 2007). In contrast, the ReSound surround sound processor provides a directional pattern closer to a person's own,

thereby striking a natural balance between environmental awareness and directional advantage. The result is sound closer to the way hearing instrument wearers remember their acoustic world – what they describe as “natural” sounding.

**Figure 3:**

*An individually determined blending point (dotted line) defines the extent of directional processing. Surround sound processing eliminates the need to compensate for the low frequency roll-off associated with traditional directionality. Thus there is no need to compromise between audibility and added noise.*



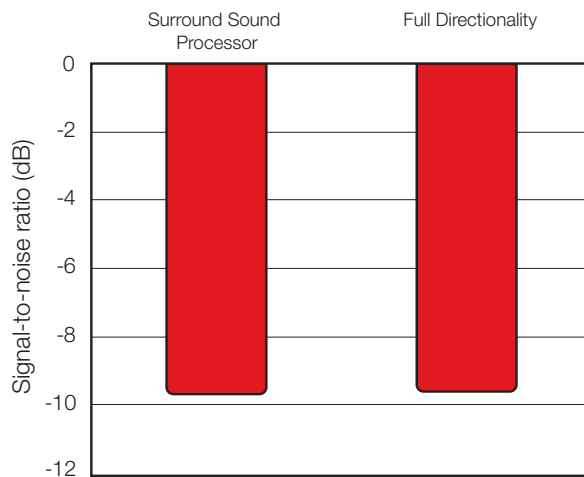
### **Personalized, seamless, noise-free directional blend**

In-house investigations revealed that the optimum mix of directional and omnidirectional processing depends both on the amplification needs of the listener as well as the particular device being fit. Those with more severe hearing losses generally require better signal-to-noise ratios than those with less severe hearing losses and are more likely to be fit with occluding devices where directionality can be achieved at lower frequencies. This means a higher directional mix – more low frequency directionality – for such clients. In contrast, those with milder high frequency losses would be prescribed a lower directional mix with no low frequency directionality. Device specific characteristics, such as microphone spacing, affect low frequency roll-off of directionality and sound quality if this roll-off is to be compensated. These various factors are incorporated to determine the ideal blending point for each individual fitting.

## BETTER SPEECH RECOGNITION IN SURROUND SOUND

Given that directionality is the only proven technology to improve speech understanding in noise (Bentler, 2005) the “more-is-better” approach of maximizing directionality across frequencies might lead one to expect better speech recognition in noise performance with full directionality than with ReSound surround sound processor. On the other hand, articulation index theory would predict a negligible difference between the two types of processing, as added audibility in the lower frequencies should represent only a modest contribution to intelligibility (Kryter, 1962). Figure 4 shows results from a clinical investigation in which 18 participants were fit with devices in which they could switch between an omnidirectional, a full directional, and mixed

directional response. Both full directionality and the mixed directional response provided equivalent directional benefit as predicted by the directional enhancement of speech important frequencies for both types of processing. These results support the notion that the lack of directionality in the low frequencies has virtually no impact on directional benefit. Because of the ReSound surround sound processor, all wearers can be provided directional benefit with no trade-off between audibility of low frequencies and noisiness.



**Figure 4:**

*Results of the Hagerman speech in noise test (Wagener et al, 2003) with 18 test subjects. Participants wore either BTE or RIE instruments fit with custom earmolds or occluding eartips. Directional benefit with the ReSound surround sound processor was equivalent to that obtained with full directionality.*

## SPEECH RECOGNITION VERSUS SOUND QUALITY

It is typical to see speech intelligibility with hearing instruments discussed separately from sound quality. And yet it is unlikely that hearing instrument wearers perceive varying aspects of listening with their devices in such a compartmentalized fashion. What does seem likely is that “natural” sound quality relates to the holistic experience of hearing and perceiving sound, encompassing fidelity and perceptual dimensions such as “fullness”, “brightness” and “loudness” (Gabrielsen et al, 1974) as well as hearing and processing speech. When sound is experienced as natural, the listener can effortlessly segregate and group the continuous stream of sound in the environment. A hearing instrument achieves good sound quality by preserving spectral, dynamic, and temporal aspects of the input sound to an extent that higher level auditory and cognitive processing can interpret these physical attributes and construct auditory environments. For example, in a busy office environment, hearing instruments with good sound quality would allow the wearer not only to hear that people were talking and that others were typing, but also to perceive the spatial relationships among these sound sources and shift attention from one to another. Not only would this give the user a natural perception of the environment, it would also aid in speech intelligibility. Freyman et al (2001) found that the improved intelligibility observed when the speech and interfering sound are spatially separated was attributable

to the perceived locations of the signal of interest and noise. In other words, knowing where to direct one's attention makes it easier to listen to the desired signal. It is not just that the sound sources are spatially separated, but that the listener perceives them as such.

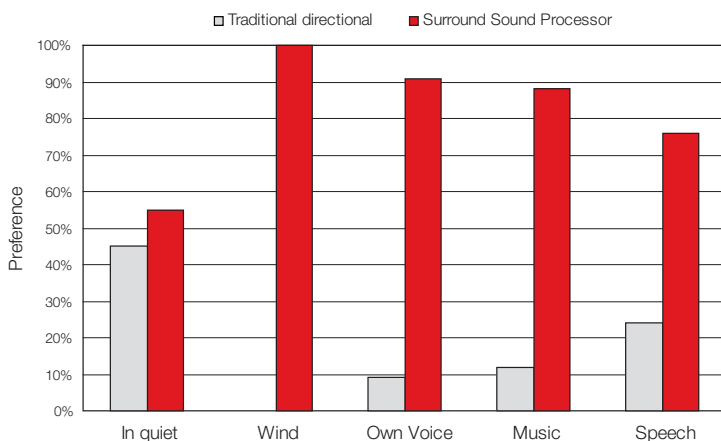
## SURROUND SOUND QUALITY

Sound quality as applied to hearing instruments seems difficult to pin down. While sound quality in other audio applications refers to the fidelity of the reproduced sound compared to the original, hearing instrument hardware limitations and fitting methodologies have been fundamentally at odds with this concept. Not surprisingly, "better sound quality" was reported to be consumers' second most desired improvement in hearing instruments (Kochkin, 2002). Furthermore, hearing instrument wearers appreciate and judge sound quality similar to normal-hearing listeners. Killion (2004) found that hearing-impaired and normal-hearing listeners' ratings of sound fidelity when listening to music recorded through hearing aids and in a KEMAR open ear were virtually identical. In addition, this study reported that the highest ratings of fidelity and the best performance on a speech-in-noise recognition test were obtained with the amplified open ear recordings.

The idea behind surround sound by ReSound is to promote good speech intelligibility and natural sound quality by emulating the acoustic characteristics of the open ear, and the results of Killion (2004) support this approach. Wearers can enjoy the advantages of directionality without compromising on sound quality. An internal investigation designed to prove the concept that the ReSound surround sound processor would enhance sound quality relative to directionality across all amplified frequencies was carried out with normal-hearing listeners. In a double-blind design, listeners judged sound quality of 200 paired samples of speech material recorded simultaneously by right and left dual microphone in-the-canal (ITC) instruments fit on KEMAR. The comparative conditions included full directionality and varying degrees of directional mix. The winning conditions were those where the blending point for directionality was above 1500 Hz, thereby providing an overall response similar to the open ear. In a clinical follow-up trial 25 hearing impaired listeners wearing directional BTE, ITC or receiver-in-the-ear (RIE) instruments rated sound quality when listening with full directionality versus the ReSound surround sound processor. Nine of the 25 preferred the ReSound surround sound processor condition while 16 had no preference. The 9 listeners who preferred the ReSound surround sound processor had milder hearing losses and explained that their choice was based on clearer, less noisy sound with this type of processing. The remaining participants had more severe hearing losses

and were all fitted with BTE and RIE instruments, which have wider microphone spacing than dual microphone ITC instruments. Thus, the degree of noise would have been less, and their more severe hearing losses would mean reduced audibility for any noise.

To further investigate how the total sound experience with the ReSound surround sound processor compares to traditional directionality, Heymans et al (2009) conducted a double blind study in which 20 hearing-impaired listeners expressed a preference for either the surround sound processor or full directionality in response to recordings of various listening situations and when sitting near a fan to simulate wind. As seen in Figure 5, listeners had an overwhelming preference for the ReSound surround sound processor in situations where overamplification of sounds near the hearing instruments, like wind and own voice, would be problematic for traditional directionality. The effect of the surround sound processor more natural sound quality was also evident in the associated strong preferences for music and speech. Similar to the in-house clinical investigation previously discussed, there was no strong preference for either type of processing in quiet, which was probably attributable to severity of hearing loss and lack of audibility of the noise floor for many of the participants.



**Figure 5:**

*The vast majority of hearing-impaired listeners preferred the ReSound surround sound processor to traditional full directionality. These results reflect how the surround sound processor eliminates drawbacks of traditional directionality Heymans et al, 2009.*

## MAKING THE CONNECTION WITH STATE-OF-THE-ART DIRECTIONAL OPTIONS

Surround sound by ReSound offers a multitude of advanced directionality modes that work with the ReSound surround sound processor to improve speech understanding in noisy situations while maintaining natural sound quality for enhanced spatial hearing in all environments.

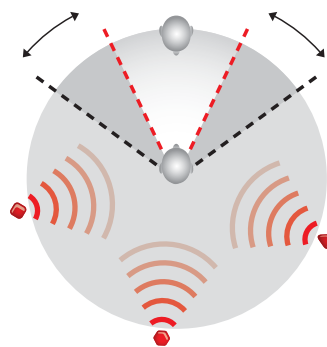
### **AutoScope Adaptive Directionality™**

AutoScope is the most advanced adaptive directional algorithm available. This system analyzes the inputs to the two microphones to

determine the direction of arrival of sounds and to estimate whether directionality is likely to be of benefit. If the environment is quiet or if the signal-to-noise ratio is very favorable (approximately 8 dB or greater), an omnidirectional response will be applied. If the ongoing analysis indicates a change in the environment that would favor a directional response, this is automatically provided within seconds. The transition between directional and omnidirectional responses is seamless and unnoticeable to the user due to the effect of the ReSound surround sound processor. If desired instead, a slow transition between omnidirectional and directional processing can be affected by activating SoftSwitching. Like its predecessor, MultiScope directionality, AutoScope adaptively cancels the strongest noise source behind the user, and can simultaneously act on noise occurring at different locations when the frequency content of the noise sources differs. In addition, AutoScope monitors the relative levels of the sounds entering the front and rear microphones to automatically adjust the width of the directional beam. The stronger the signal coming from the front, the more narrow the beamwidth will be adjusted. Conversely, as the level at the front microphone decreases, the beamwidth is widened to catch more of the surrounding sounds. This effect is like zooming in on a single talker located in front of the hearing instrument wearer and zooming out when others off to the sides are speaking, as illustrated in Figure 6.

**Figure 6:**

*AutoScope directionality automatically narrows the width of the directional beam to focus on a speaker in front, and expands the beam when speakers are not directly in front of the user or when there is no background noise.*




### **Natural Directionality™ II**

Surround sound by ReSound also enhances the unique asymmetrical fitting strategy introduced by ReSound. An asymmetric fitting is one in which a hearing instrument with directionality is fit on one ear, the “focus” ear, and a hearing instrument with an omnidirectional response is fit on the other, the “monitor” ear. This fitting approach is based on the idea that information presented to the two ears that differs in signal-to-noise ratio and audibility will be perceived as a unified binaural image based on which ear has the better representation of the signal of interest. This allows the wearer to take advantage of the improved signal-to-noise ratio benefit of directionality without

significantly decreasing audibility for sounds arriving from behind. No manual switching of directional mode is required, which eases demands on the wearer to be able to analyze the environment, understand when directionality might be advantageous, and physically select the appropriate response. Also, no automatic switching of directional mode takes place, which ensures that one of the devices will always be in the preferred microphone mode regardless of the listening situation. Asymmetric fittings have been shown to provide directional benefit equivalent to bilateral directional fittings under laboratory conditions (Bentler et al, 2004; Cord et al, 2007), and increased ease of listening compared to bilateral directional fittings (Cord et al, 2007). This supports that Natural Directionality™ II is an excellent way for users to effortlessly derive benefit from directional technology while maintaining full awareness of their surroundings.

	Bass	Treble
Focus ear:	Omni	Fixed directionality
Monitor ear:	Omni	Synchronised omni



**Figure 7:**

*The time delays between the monitor ear and focus ear are synchronized to create a more natural, balanced perception for wearers of surround sound by ReSound.*

Although an asymmetric fitting can be done with other hearing instruments which offer both omnidirectional and directional microphone modes, they will be prone to the same disadvantages listed earlier, including noisiness and overamplification of nearby sounds. In addition, adaptive directional processing can negate the ease of listening advantage of the asymmetric fitting, as the constantly shifting directional patterns preclude adaptation to the acoustic cues. An additional issue specific to advanced directional systems currently available is that the processing delay between the instrument in directional mode will be longer than that of the instrument in omnidirectional mode. The resulting asynchrony of the cues provided to the two ears disrupts spatial hearing and awareness. As discussed, this negatively impacts the holistic impression of the auditory environment and perceived sound quality.

### **Optimum environmental awareness and sound quality**

The ReSound surround sound processor eliminates the overall drawbacks of directionality regardless of whether AutoScope Adaptive Directionality™ or Natural Directionality™ II is selected for the individual. To maximize environmental awareness and sound quality Natural Directionality™ II, an invariable directional pattern optimized to the human head – rather than the instrument in free field – is applied. Another unique characteristic of surround sound by ReSound is that the processing in the monitor ear is synchronized to match that of the focus ear in order to preserve temporal cues to the two ears. (Figure 7) This also represents

an important contribution to spatial hearing and natural sound quality. Finally, the ideal ear to be fit as the focus ear is selected automatically by the Aventa fitting software based on hearing thresholds, speech importance weighting and, if available, speech-in-noise testing results.

## FULL-BODIED SOUND QUALITY

As a pioneer in hearing loss compensation, ReSound broke new ground as the first to introduce Wide Dynamic Range Compression in hearing instruments and the first to base amplification on an accurate model of cochlear frequency analysis through frequency warping. While most digital frequency techniques for frequency analysis yield constant bandwidth with uniform spacing of the bands, the Warp17 compression system efficiently resolves frequencies into 17 smoothly overlapping frequency bands corresponding to the auditory Bark scale (Smith & Abel, 1999). The Bark scale incorporates the human auditory system critical bandwidth as the scale unit (Zwicker et al, 1957). With low processing delay and nearly immeasurable distortion, this system provides the foundation of the surround sound by ReSound superior sound quality.

As a further enhancement of the natural-sounding surround sound experience, the bandwidth is extended in the upper range. Aside from the obvious advantage of better audibility and enjoyment of high frequency content of music and environmental sounds, this extended response also contributes to more complete spatial hearing. Although stability of lower frequency ITD is paramount for localization of individual sounds heard in isolation, the availability of additional high frequency information can enhance perceptual separation of simultaneously occurring auditory objects in real world environments (Darwin, 2008). The ability to group auditory objects and make sense of the sounds in one's environment are important factors in easing listening effort, improving speech intelligibility, and providing a natural sound experience. Together, the surround sound by ReSound and extended high frequency amplification set the stage for optimum spatial hearing and speech intelligibility.

## SOUND QUALITY – ALSO WHAT YOU DON'T HEAR

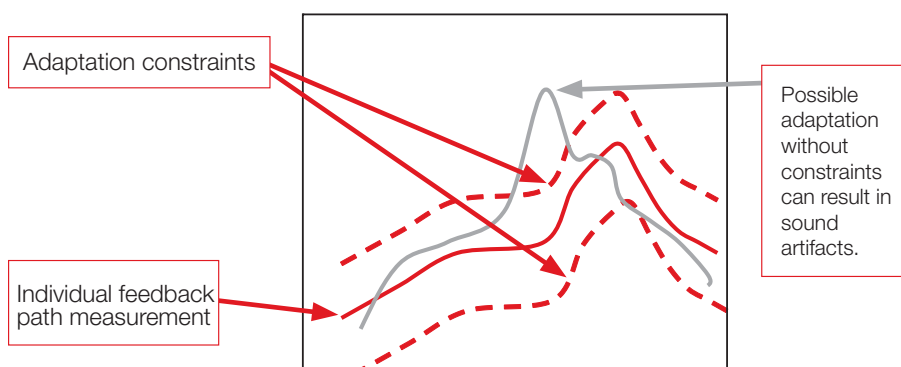
A common grievance of hearing instrument wearers is acoustic feedback. This annoying whistling is not only uncomfortable and embarrassing, it may necessitate changes to the fitting which reduce audibility, degrade sound quality and decrease physical comfort. Despite improved overall ratings of satisfaction with digital versus older technology, there is still much room for improvement in terms of

occurrence of acoustic feedback. Only 50% of hearing instrument users expressed satisfaction on this aspect of device performance (Kochkin, 2005).

Cancellation of feedback by use of phase-inverting filters is the only technique for reducing feedback which does not involve altering other aspects of the fitting, such as venting or frequency response. While such techniques were introduced more than a decade ago and are currently offered in products from many manufacturers, performance differences exist. Feedback cancellation works by analyzing the pathways by which amplified sound returns to the hearing aid microphones, constructing a model representing these pathways, and subtracting the model from the actual input signal. Although the concept of feedback cancellation is simple, modeling feedback pathways involves much complexity. Adding to the complexity is the fact that these pathways are ever-changing as the hearing instrument is worn, and the model must constantly be updated to reflect these changes. Furthermore, feedback cancellers have difficulty distinguishing between feedback and some environmental sounds and may try to cancel these sounds. The result can be unpleasant chirping or ringing artifacts, which degrade sound quality and interfere with audibility.

### **DFS: Leading edge feedback cancellation technology**

Like the preceding generations of ReSound feedback cancellation systems, ReSound Dual Stabilizer® II DFS identifies acoustic feedback and uses two cancellation filters to eliminate feedback without reducing gain. A static filter is calibrated during the fitting to characterize the stable elements of the fitting such as earmold acoustics and responses of the transducers. During use of the hearing instrument, an adaptive cancellation filter supplements the static one to account for dynamics of the feedback path. An advantage of having the static filter as a reference point is that it is possible to constrain the adaptive filter to only cancel sounds which are likely to be feedback. These adaptation constraints make the system more immune to the sound degrading artifacts which occur when tones, beeps or music sounds



**Figure 8:**

*The Dual Stabilizer® II DFS system determines a model of the feedback path, and imposes constraints on how far away from this model the system can adapt. This prevents the system from attempting to cancel sounds which probably are not feedback, like beeps or music sounds.*

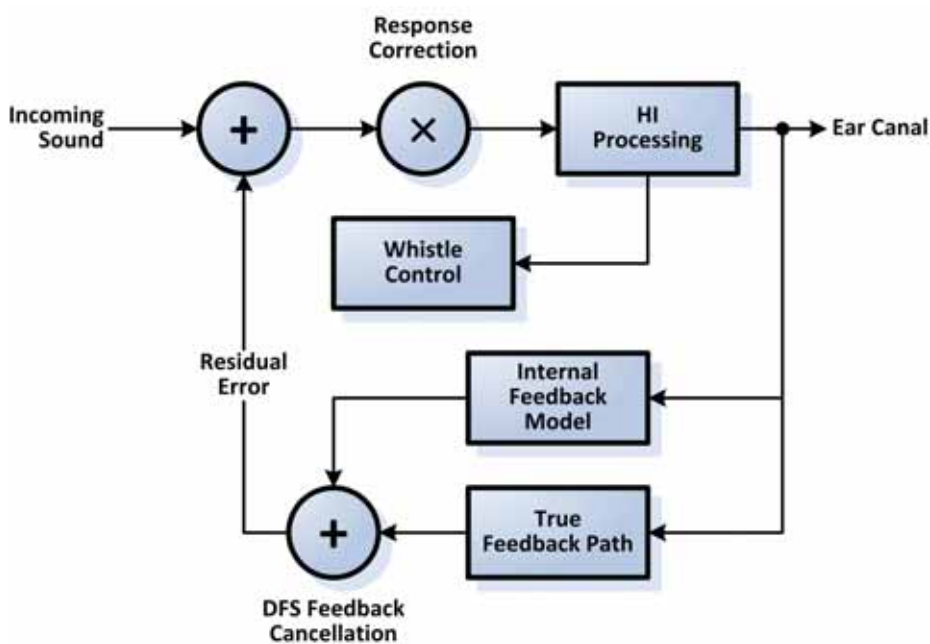
are erroneously attacked by the system as feedback (Figure 8). The Dual Stabilizer® II DFS can provide 10 to 15 dB more stable gain for a particular fitting. Finally, because surround sound by ReSound devices also feature frequency specific adaptive dual microphone directionality, feedback cancellation must work independently for each of the microphones. The Dual Stabilizer® II DFS uniquely incorporates separate cancellation filters to account for the different feedback paths to each microphone.

## WHEN GOOD FEEDBACK CANCELLATION GOES BAD – A SOLUTION

Feedback cancellation would appear to be the ultimate solution to acoustic feedback. If it can completely cancel feedback without introducing sound quality artifacts, then acoustic limitations to available gain would no longer be an issue. Unfortunately, no hearing instrument manufacturer has yet mastered perfect modeling of the feedback path, and the inconsistency between the model and the actual feedback signal can reintroduce and even worsen the whistling and chirping that the processing is intended to eliminate. ReSound technology leads the field in immunity to such processing artifacts with its use of two cancellation filters, adaptive filter constraints and separate cancellation filters for dual microphone instruments, making the Dual Stabilizer® II DFS the most effective and best-sounding available. However, even this exceptional system can break down under certain conditions. According to Kates (2008), adaptive feedback cancellation systems are limited in their ability to account for reverberation in the hearing instruments wearer's real world environments. Because room reverberation times are much longer than the impulse responses of hearing instrument components and acoustic feedback path elements, it would require much more complex processing to effectively model these. An additional limitation discussed by Kates is the nonlinear nature of hearing instrument components under some operating conditions. Since feedback cancellation processing is based on linear models, their accuracy can fail in the presence of nonlinearities.

WhistleControl™ serves as an effective “emergency brake” in situations where the Dual Stabilizer® II DFS processing cannot accurately model and cancel feedback. For example, an individual wearing open fit hearing instruments might experience feedback when holding a hand or telephone near the ear. In such a case, WhistleControl™ would adjust the high frequency response just enough to eliminate feedback until the hand is moved away, upon which the prescribed output would be restored. Unlike gain reduction systems which wait for feedback to occur before acting on gain, WhistleControl™ carries on an ongoing

analysis of the actual output power of the amplification system to determine how the compressor output corresponds to what is expected if the feedback path model is accurate. This is an indirect way of verifying that the true feedback path is close to the model. If this is not found to be the case, correction to the response is applied to align the actual output with the demands imposed by the existing conditions. Figure 9 illustrates how WhistleControl™ combines information from the output of the amplifier and the model of the feedback path to predict when feedback will occur and adjust the response accordingly to prevent it.



**Figure 9:** WhistleControl™ combines analysis of the amplifier output with the feedback path model to predict when feedback cancellation processing will be overloaded, and applies situational adjustment of the hearing instrument response to preserve sound quality for the user.

WhistleControl™ can be adjusted to varying levels of “aggressiveness” via the Aventa fitting software. The most conservative setting of WhistleControl™ will correct the hearing instrument response only when the mismatch between the feedback model and actual feedback path is very large, while the stronger settings may make adjustments even in occasional situations when the Dual Stabilizer® II DFS would have effectively eliminated feedback without sound quality degradation. A recommended setting is automatically applied depending on how the gain for the individual fitting is set relative to the estimated static feedback path. Regardless of the setting, the degree to which the response is adjusted is dependent on the situation. Only enough correction to prevent feedback will be applied in any situation where WhistleControl™ is active. For the user, the result is uninterrupted preservation of feedback-free sound quality.

## SUMMARY

Surround sound by ReSound provides a natural-sounding listening experience to wearers. It can be likened to going from listening to stereo speakers to a sophisticated surround sound audio system, and translates to increased and effortless awareness and orientation in listening environments. Surround sound provides a more full and detailed sound quality and delivers important acoustic cues for localizing sounds, which facilitates speech understanding even in challenging situations. The surround sound processor is a ground breaking technology that creates a personalized blend of frequency dependent directionality to restore a response similar to that of the unaided ear. Extended high frequency bandwidth of the warp-based amplification system adds to environmental awareness as well as sound enjoyment, while WhistleControl™ ensures pleasant, feedback-free hearing instrument use in all situations. Finally, surround sound by ReSound carries forward proven sound quality enhancing technologies such as NoiseTracker and Environmental Optimizer for the ultimate surround sound experience.

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**Worldwide headquarters**

GN ReSound A/S  
Lautrupbjerg 7  
DK-2750 Ballerup  
Denmark  
Tel.: +45 45 75 11 11  
Fax: +45 45 75 11 19  
[www.resound.com](http://www.resound.com)

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