SONIC Spotlight

Radian Noise Management

Intelligent and integrated systems on the Sonic Extend technology platform deliver a new approach to natural sound, speech understanding in noise and listening comfort in digital hearing aids.

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Following the successful launches of Speech Variable Processing in 2011 and SoundDNA in 2017, we now introduce Extend, the latest technology platform from Sonic. With considerably greater processing power and memory, Extend provides new noise management and compression technologies – streamlined for improved sound quality, speech intelligibility and listening comfort.

Introduction

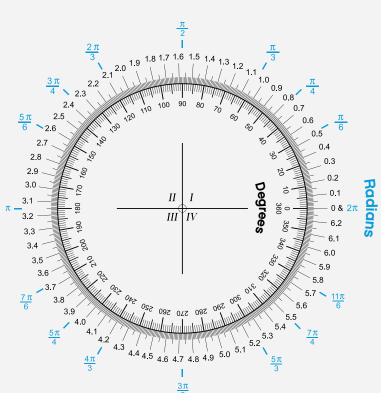
The increased capabilities of the **Extend** platform allow the upgrading of two fundamental systems within the digital signal processing (DSP) that support the natural sound quality of our latest hearing products. This paper describes the new noise management system; ***a separate paper examines the new compression system***. Taken together, they comprise our new core DSP – designed to actively **find, filter** and **fine-tune** sound with precision – in order to provide optimal hearing for the listener. Read on to learn how **Radian Noise Management** does its part to find and filter sound, to help advance the user experience in noise.

Background

Many hearing aid technologies exist to address the paradox of amplifying certain sounds while reducing others at the same time. Yet, speech understanding in noise continues to remain an issue for many listeners, year after year (Glyde et al., 2011). Considering this predicament, Sonic is determined to present a more beneficial hearing solution. It all starts with Radian Noise Management (RNM). This system consists of two premier features:

1. *Radian Directionality* – a high-performance directional microphone system
2. *Radian Noise Reduction* – a high-performance digital noise reduction algorithm

The following sections explain key details of each in further detail.



The term **'Radian'** might sound familiar to you – it is a unit of angular measure that we often learn about in mathematics. Radians can represent a full 360° of a sphere or any angle in between (Fig. 1). Like radians, both meaningful sounds and distracting noise can arise from any direction, at any time. Radian–*technologies* are poised to perform rapidly, responding to speech and noise where and when they emerge in the listening landscape—for a better sound experience.

Figure 1: Radian example

Directionality overview

As the point of entry for all input signals in a hearing system, the microphones on a hearing aid act as the gatekeeper for the resulting auditory experience of the listener. As we'll learn, Radian Directionality is an adaptive beamforming microphone system. As such, it recognizes the benefits of both omnidirectionality and focused directionality depending on the listening scenario, and automatically adapts itself according to the signal types, to capture the optimum angle of sound. A short review follows.

Omnidirectionality

A hearing aid with this microphone pattern aims to be equally sensitive to sounds from all directions. This is advantageous in many situations, such as: when listening to music; when outside in the wind; when listening to soft sounds behind or to the side; when driving a car and talking to a passenger; or when walking together with someone along a street. In the last two examples with speech, it's not possible to look at the conversational partner constantly, therefore a microphone pattern with sensitivity to all angles is optimal.

Directionality

In other situations, the importance of directionality cannot be overstated. Persons with hearing loss have more difficulty hearing in noise, as background noise can mask speech cues in certain frequency regions (Dillon, 2012). Directionality optimizes the microphones to increase the chances that noise will be removed. Directional microphones help in situations where noise and speech are separated in different directions, by becoming less sensitive to sound coming from an alternate location (Ricketts, 2000). The point where the directional microphone is least sensitive is the null direction.

The directional setting can be fixed or adaptive. Knowing how fixed directional microphones operate is necessary before explaining adaptive processing. Fixed directionality improves speech understanding in background noise by improving the signal-to-noise ratio (SNR) for a signal coming from the front of a listener, compared to sounds from other directions. For example, in a free-field situation where speech arrives from the front and background noise arrives from the side or back, omnidirectionality will receive all sounds equally and produce an SNR of 0 dB. Directional microphone systems using two or more microphones with a fixed directional polar pattern – e.g., *cardioid, supercardioid, or hypercardioid* – delay the rear microphone signal, and that signal is electronically subtracted from the front microphone signal. For sounds that approach exactly from the side (+90/-90 degrees), their sensitivity will be reduced by 6 dB, 9 dB or 12 dB respectively as indicated below (Figure 2).

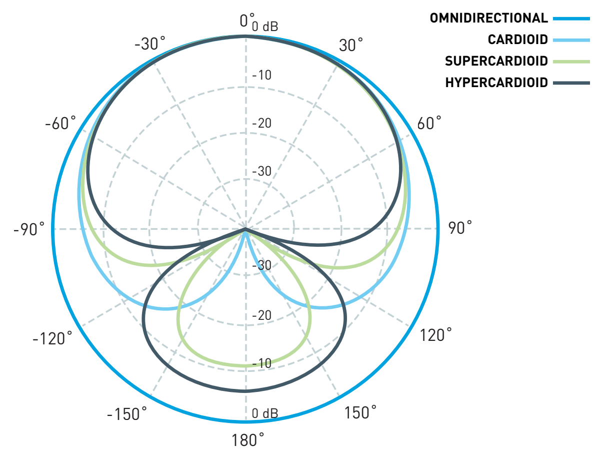


Figure 2: The directional characteristics of various microphone types in a free field. Using polar coordinates, the plots display along the radius how sensitive the various microphones are for sound approaching from all angles.

Fixed polar patterns look different when placed on the head *in situ* compared to measurements taken in the free field. This is due to the head shadow effect as well as a device's microphone placement. With the former, the head physically obstructs high frequency sound from behind and the opposite side, reducing its intensity as it reaches the microphone (Schaub, 2008). With the latter, depending on the style of aid (e.g., BTE, ITE), the microphone placement will alter the expected null location compared to the free field (Anderson and Van Doorn, 2011). As such, polar patterns that react differently in situ should be a factor to consider with hearing aids. Adaptive directionality indeed responds advantageously in comparison, by automatically adjusting the null to the angle where the most noise is detected in the environment. Its ability to steer the point of maximum attenuation towards the specific location of noise where it arises will offer a better SNR improvement compared to a fixed setting (Christensen, 2013).

Radian Directionality: Find

New *Radian Directionality* from Sonic extends the benefits of the microphone modalities described above when placed on the head in many ways. First, *automatic switching* between an omnidirectional state in quiet and an *adaptive* directional setting in noise helps to achieve an SNR improvement with negligible loss of audibility of desirable sounds that originate from the sides and the back, compared to a static setting. This approach helps to overcome dissatisfaction in listening environments where the signal of interest originates from locations other than the front (Walden et al., 2004).

Second, Radian Directionality offers two new sound profiles for its base omnidirectional setting. *True Omni* provides more of a standard fixed omnidirectional response for maximum sensitivity to sound in all directions, while *True Omni Plus* addresses microphone location considerations. It uses a special fixed directional microphone setting in the high frequencies to achieve a microphone behavior similar to the external ear in order to restore lost pinna cues. This type of response allows the instrument to be more sensitive to higher frequencies from the front to aid in speech intelligibility and localization, considering microphone placement above the pinna (Kates, 2008). The better match to the ears' natural response for behind-the-ear hearing aids can provide an improved SNR benefit, compared to the traditional omni mode.

Third, the adaptive component of this system provides an ideal strategy to select the best polar pattern and address head shadow effects at the same time (Oberzut and Olson, 2003). It actively *finds* the desired signals to amplify by locating noise and generating nulls in the necessary direction to attenuate it. This produces a more favorable SNR than other fixed microphone options in environments where speech and noise can arise from unpredictable locations. A high-performance beamforming algorithm constantly scans the environment in 360°, collecting input from the front and rear microphones. The algorithm uses a self-adjustment technique that updates rapidly, allowing it to continuously adjust the null direction to select the polar response with the best SNR. As a result, fluid-like changes in null steering quickly react to movement or changing noise sources, to better suppress noise and preserve the signal of interest, i.e. speech.

Perhaps the greatest single advantage of Radian Directionality is its ability to continuously cancel unwanted noise in more bands than our previous technology allowed. When noise is detected, the system applies diverse polar patterns in various frequency regions to cancel multiple noise sources, provided the signals differ in location and in spectral content. Its robust multiband design consists of 24 discrete frequency bands to separate noise of different frequencies with a fine resolution. As a point of comparison, a system that does not use multiband directionality could only suppress the most intense noise signal in a listening environment, even if other noises are present. Previous directional systems from Sonic operated with either 4 or 16 frequency bands. As such, this design helps Radian Directionality improve the SNR by removing noise with more precision in various directions – and promotes better speech recognition in noise.

Noise reduction overview

Listening to a conversation in background noise, such as rushing water, traffic, fans or group chatter can be more than just a minor distraction for hearing aid users. It can significantly increase their listening effort when trying to focus and follow the dialog (Wendt et al., 2015). Therefore, a hearing aid's ability to effectively reduce competing noise becomes particularly important in the presence of speech.

While the goal of directional microphones is to improve speech recognition in noise, digital noise reduction (DNR) serves an altogether different purpose. These algorithms work to identify non-speech input signals and reduce their gain. The main benefits of removing noise are to improve listening comfort and positively impact ease of listening (Bentler et al., 2008). Several studies verify that DNR can do just that and more. For example, DNR can reduce listening effort (Sarampalis et al., 2009, Desjardins & Doherty, 2014), increase ratings of sound quality (Ricketts & Hornsby, 2005) and improve acceptance of the noise (Lowery & Plyler, 2013). As such, DNR remains a vital element for a successful hearing aid fitting, and a perfect complement to directional microphones in the presence of unwanted environmental noise.

As is often the case, both the desired speech signal and the unwanted noise are present at the same time. A hearing system can use an algorithm that measures modulation parameters to identify speech (highly modulated signals) vs. steady state noise (low modulated signals) to obtain a precise location of noise within specified frequency bands. In this way, a modulation-based noise reduction algorithm designates the difference between the largest and smallest levels over a short time interval and determines the SNR estimate per band.

Once the modulation is determined, the next step involves calculating the desired attenuation. Band signals with lower modulation should receive more attenuation than band signals with higher modulation. As such, the noise reduction algorithm adaptively reduces the level more in bands where the noise potentially causes the most disturbance. The actual amount of applied attenuation will vary, depending on the noise reduction levels offered and selected in the fitting software for a specific hearing aid. Going from a Low to High noise reduction setting will increase the amount of attenuation with the goal to offer more comfort, making it possible to optimize individual patient needs in noise.

Another factor to consider is the speed of the algorithm. With noise reduction, it is possible to look at the signal level and measure an instantaneous modulation value so the system can react quickly, both when modulation increases and decreases (Bentler and Chiou, 2006). The system can then remove attenuation rapidly, at the onset of speech, when modulation increases. Conversely, it can apply attenuation rapidly, at the onset of noise, when the modulation decreases. Fast-acting short time constants can help the system maintain good sound quality as speech and noise signals spontaneously arise in the listening environment (Helbling et al., 2013).

Radian Noise Reduction: Filter

Radian Noise Reduction takes all the above into account. It is our new modulation-based adaptive noise reduction system, designed to filter background noise more effectively and improve listening comfort. As described, this system analyzes the signal modulation in individual frequency bands to measure the SNR and control how it responds. When activated, Radian Noise Reduction progressively attenuates signals showing less modulation. It applies the minimum amount of noise reduction necessary – a strategy that reduces the risk of attenuating speech sounds in the same band, which can happen with more aggressive systems. Notably, whereas our previous DNR algorithm operated in *16 frequency bands* based on the input of *4 SNR estimators,* the current one works more robustly, operating in *24 frequency bands* based on the input of *24 independent SNR estimators*. The expanded design improves the system's accuracy to estimate and reduce noise, providing finer resolution across the frequency spectrum and allowing more effective noise suppression (Figure 3). Its fast-acting time constants respond rapidly to speech and noise fluctuations as they vary. In this way, it is activated only when needed.

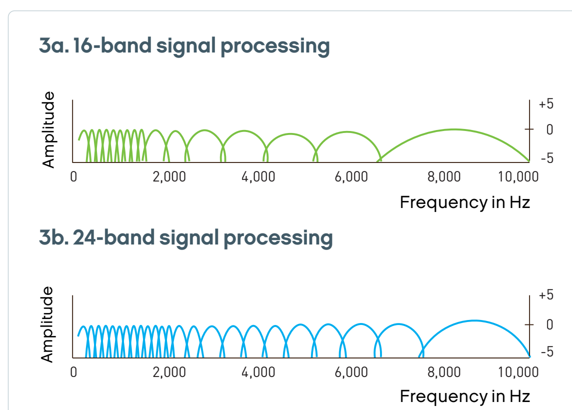


Figure 3: Frequency resolution based on 24 bands (3b) versus 16 bands (3a) allows more frequency-specific information from different signals i.e. noise and speech to be identified.

Radian Noise Reduction improves the hearing aid output SNR up to 4.6 dB SNR, compared to our previous technology. The system's high-performance capabilities are a direct result of the Extend platform's processing power and streamlined interaction with the directional system operating in the same 24 frequency bands. Heightened abilities include: 1) an increased sensitivity to noise detection, and 2) a more accurate calculation of noise attenuation. Together this facilitates an improvement for determining the most beneficial amount of noise reduction to apply for the given environment, whether it is noise only or speech and noise (Figure 4). With greater operational efficiency compared to our previous DNR system, the algorithm can filter noise with more precision, to promote improved listening comfort and preserve speech at the same time.

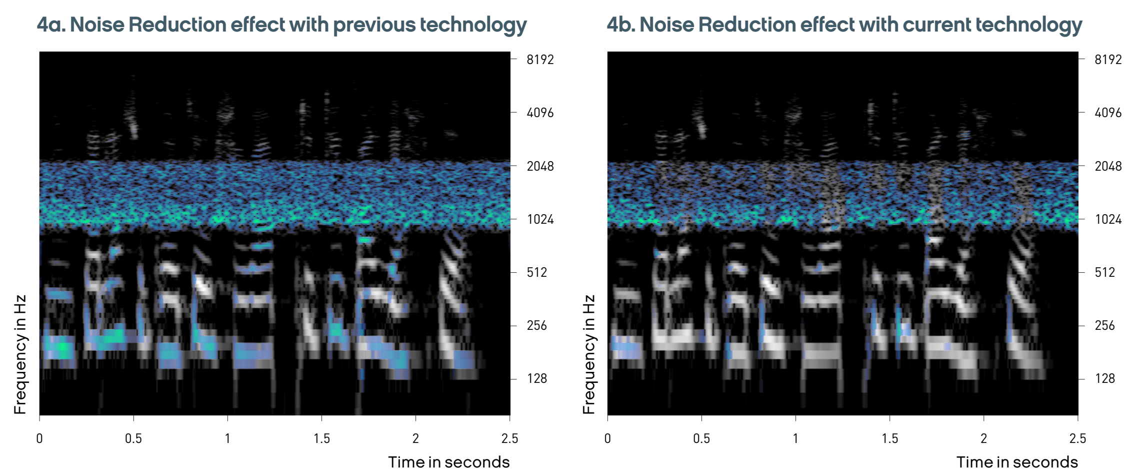


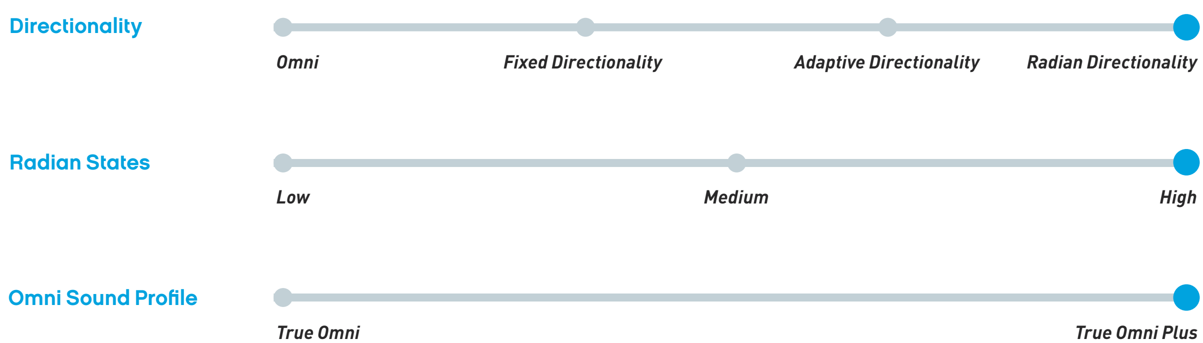
Figure 4: The spec-compare analysis shown above visualizes the effect of signal processing on sound files (Kuriger, 2020). Here it shows the effect of noise reduction implemented in a hearing aid with previous (4a) versus current (4b) technology with a narrowband noise (NBN). The amount of attenuation provided by the algorithm is shown in blue and unchanged speech signal parts in white. Whereas the NBN is correctly attenuated by both algorithms, speech is better preserved with the current technology found in Radian Noise Management.

Software controls

Depending on the product and/or technology level, Radian Noise Management offers up to three control options in the EXPRESS*fit*® Pro fitting software to customize performance, based on user needs and preferences:

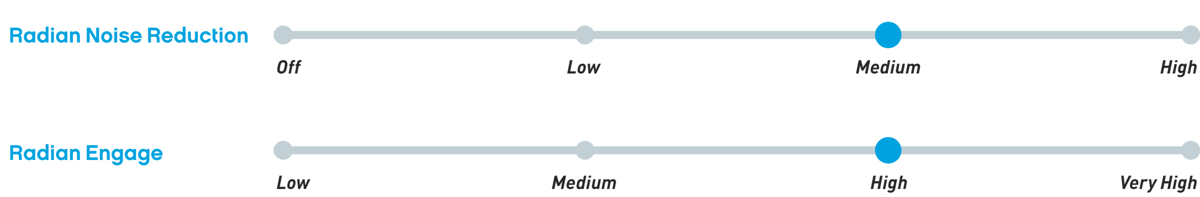
» *Radian Directionality* – To enhance speech understanding in noise, up to three adaptive performance control options are available: **High Performance** provides the most narrow directional response and is ideal for patients who are sensitive to noise; **Medium Performance** offers a narrow directional pattern; and **Low Performance** adjusts to a wider response. Radian Directionality's *Omni* control has two selectable options: **True Omni** for a customary fixed omni response; or **True Omni Plus** with a fixed pinna-style response. *Note: optional microphone settings Adaptive Directionality and Fixed Directionality are not part of RNM.*

Radian Noise Management



» *Radian Noise Reduction* – To enhance listening comfort, select from **Off, Low, Medium and High**. The High setting offers the most amount of attenuation for noise (up to 10 dB); Medium offers a moderate amount (up to 8 dB); and Low provides the least amount of gain reduction for noise (up to 6 dB).*

» *Radian Engage* – To optimize the onset of directionality and noise reduction according to individual preferences for speech-in-noise listening environments, select **Low** or **Medium** to better preserve environmental sounds; alternately choose **High** or **Very High** to quickly put an emphasis on the speech signal at the onset of low-level noise.



*Maximum attenuation values per band for the highest technology level

Summary

This paper describes Radian Noise Management, part of the advanced hearing aid technologies in the Extend platform designed to improve speech intelligibility, listening comfort and sound quality for people with hearing impairment. RNM coordinates adaptive beamforming directionality and high-performance noise reduction in 24 bands to reduce the intrusiveness of noise from various angles in the listening environment.

In particular, the noise management system is responsible for finding speech and filtering out environmental noise. It accurately measures the SNR and precisely attenuates noise with improved efficiency. Subsequently, it supplies the cleaned input signals to the non-linear compression system, ***Radian Speech Processing***, to fine-tune the amplification.

With the goal of enhancing speech while reducing distracting noise, these streamlined systems form the all-new core DSP sound strategy from Sonic. Working together, Radian-*technologies* actively find, filter and fine-tune sound with precision to advance the hearing experience for the listener.

For a demonstration or to learn more, please contact your local Sonic provider.

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