Sonic Spotlight

SPiN Management

Speech in Noise gets special treatment with an effective noise management system

Understanding speech in noise is one of the most challenging listening tasks for a person with hearing loss. Noise reduction systems in hearing aids encompass both directional microphones and noise reduction algorithms. With the **Speech in Noise (SPiN) Management system,** Sonic coordinates these two separate technologies to address speech in noise more effectively. Read on to find out how SPiN Management puts a new 'spin' on speech in noise.

See page 8 for clinical test results.

Importance of the signal-to-noise ratio

Understanding speech in noise is a challenge for everyone, but it is especially problematic for individuals with varying degrees of hearing loss. In fact, hearing-impaired persons need a significantly greater signal-to-noise ratio (SNR) advantage over persons with normal hearing in order to understand an equal amount of speech (Dillon, 2001). Accordingly, the best thing we can do for our patients is improve the SNR, whether they are trying to listen at a party, in a noisy restaurant or anywhere that speech and noise exist together (Gnewikow et al., 2009).

Directional microphones and noise reduction algorithms are the tools we use to improve the SNR and help attenuate background noise. These systems address the problem of noise in different manners and are traditionally uncoordinated. New Speech in Noise (SPiN) Management, found exclusively in the Sonic SoundDNA platform, now coordinates these technologies to better manage speech-in-noise listening environments. Let's take a closer look at these two components to understand the role they play in addressing noisy environments.

Directional systems review – the basics

Being more sensitive to sound in certain directions, directional microphones provide measurable improvements in speech recognition in noise, satisfaction, and benefit when compared with omnidirectional microphones (Ricketts, 2001). However, there are advantages and disadvantages to omnidirectional and directional systems, depending on the listening environment.

It has been established for quite some time that instruments with omnidirectional microphones amplify speech to improve audibility in quiet environments (Walden et al., 2000). A later study by Walden et al. (2004) even found omnidirectionality to be the preferred microphone mode in relatively quiet listening situations. However, that study also explained that the majority of our active listening time is not done in quiet, but rather in the presence of background noise. Unfortunately, omnidirectional microphones fail to provide enough intelligibility for speech when noise is introduced into the listening background. Not surprisingly, Kochkin (2007) revealed that persons with hearing impairment will only be most satisfied with using hearing instruments that are effective in a variety of environments, especially in conditions of noise. Combining these facts, we realize that improving the SNR becomes a top priority in improving patients' overall satisfaction with hearing instruments.

How can this be done? Directional microphones are the gateway to providing the benefit of an improved SNR, by increasing sensitivity to sounds from the front, and decreasing sensitivity to sounds from other directions – something omnidirectional microphones alone cannot achieve.

As shown in Figure 1, directional listening modes on hearing instruments can be divided into two categories: (1) Adaptive Directional modes, which possess polar patterns that continuously track and reduce dominant sounds from the sides and behind the head; and (2) Fixed Directional modes, which incorporate one of several types of polar plots (e.g., cardioid, hypercardioid, supercardioid), but regardless of the one selected, differs from adaptive directionality in that the pattern does not change according to variations in the listening environment. Both types can process signals in separate frequency bands – a 'multiband' design – to further cancel noise sources simultaneously with differing spectral characteristics from different directions.

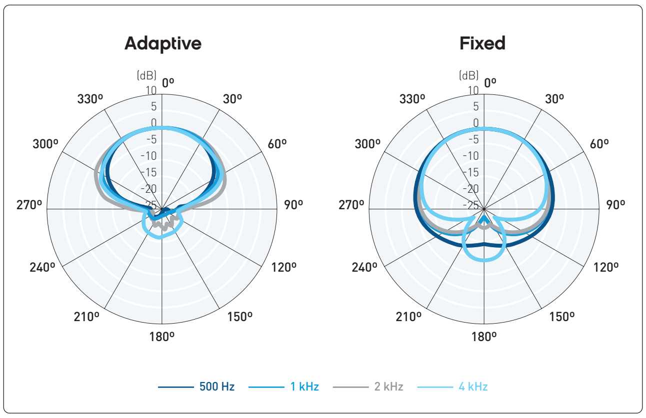

Figure 1: Adaptive (left) and Fixed (right) directional polar plots

However, success with directional microphones is dependent on a number of factors in order to achieve benefit. Directional benefit, whether fixed or adaptive, is influenced by the amount of spatial separation between signal and noise, the distance between the signal and the listener, and the level of room reverberation (Ricketts, 2000). Low-frequency roll off, which is the inevitable drop in frequency response that occurs in directional modes, causes internal microphone noise levels to increase when directionality is engaged (Kates, 2008), as well as noise for other near-field signals, such as wind (Valente, 2002).

These factors begin to explain why exclusively using either omnidirectional or directional microphones still show mixed results of user satisfaction. Some users prefer omnidirectional patterns even in noise, especially when the signal is a far distance from the listener, or when room reverberation is high (Walden et al., 2004). Additionally, some users prefer omnidirectionality for other reasons. For instance, Cord (2004) explains that the lower output level generally seen in the directional mode may reduce the volume of all sounds too much, including signals desired to be heard. Whereas some may perceive this reduction as beneficial, others may feel it is too much attenuation. Even with a low-frequency boost added back into a directional response, some users still want to hear subtle elements in their surrounding environment, which are often removed in directional modes due to the introduction of nulls (angles of maximum attenuation) in the polar plots. Finally, some users fail to benefit from the proper microphone system if they don't manually switch listening programs at the right time.

Many of these issues can be resolved with automatic directionality and a multiband design. With automatic directionality, the hearing aid itself monitors the overall level, plus temporal and spectral characteristics of the environment, then transitions in and out of directionality based on the information it receives. With a multiband design—in addition to the advantage of offering different polar responses to attenuate noise from different locations simultaneously—the hearing aid can preserve low frequencies with omnidirectionality, while activating directionality in higher frequencies. This strategy improves loudness and sound quality in a variety of situations, overcoming the many limitations noted above.

Digital noise reduction review – the basics

On the surface, noise reduction algorithms may seem to be more straightforward than directional microphones – but they really aren't. They are just as complex and thought-provoking for a multitude of reasons. Whereas directional microphones provide measurable improvements in speech recognition in noise, the effect of noise reduction is often more subtle. It is widely accepted that noise reduction can provide listening comfort, but there is not much evidence that shows it can improve speech recognition. Due to the peculiar nature of this technology, it is wise to carefully consider the role it plays in reducing noise for listeners with hearing impairment.

The primary goal of noise reduction is to acoustically analyze the incoming signal and reduce hearing aid output in the presence of noise (Figure 2). The expectation in doing so is that it will reduce the effects of noise on speech perception and sound quality. Noise reduction has evolved over time from simple analog filters to complex digital noise reduction (DNR) algorithms. Today's common modulation-based algorithms differentiate speech versus noise based on temporal characteristics in the signal: high modulations detected over time indicate speech signals; low modulations detected over time indicate noise. On a continual basis, these algorithms determine the SNR by measuring the level of noise in different frequency bands (Levitt, 2001). Frequency bands with a high SNR contain speech and those with a low SNR contain noise. Simply enough, DNR reduces the gain in the bands with a low SNR.

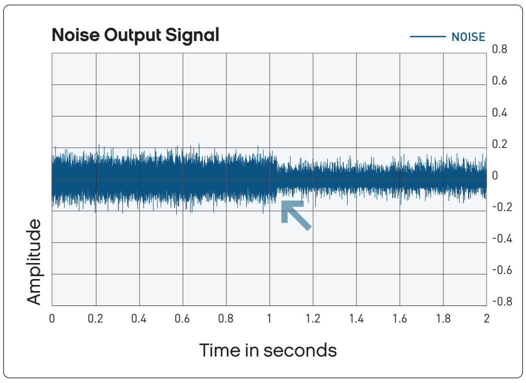

Figure 2: Output of noise signal with noise reduction off vs. on (indicated by arrow)

The question remains, if noise reduction can successfully decrease gain in frequency bands that contain noise, but cannot conclusively improve speech recognition, then why bother to use it? According to a recent literature review, many benefits exist that support the use of DNR (Beck and Behrens, 2016).

Reduced listening effort: Listening effort relates to the cognitive resources necessary for speech understanding (Hicks & Tharpe, 2002). The presence of background noise increases listening effort, meaning that more cognitive resources are required to understand speech. Numerous peer-reviewed studies consistently show that DNR reduces listening effort in noise (Sarampalis et al., 2009; Ng et al., 2013; Ricketts and Hornsby, 2005; Bentler et al., 2008).

Improved SNR: Nonlinear amplification can worsen the SNR of the hearing aid output when compression is applied on noise components of a speech-in-noise signal (Naylor and Johannesson, 2009). However, a hearing aid with DNR can improve the output SNR, providing the listener with amplified sound that is cleaner with less distortion, as reported by Pittman (2013) and Stelmachowicz et al. (2010).

Improved acceptance of noise: A patient's ability to accept background noise is an important key to successful hearing aid fittings (Nabelek, 2005). Two studies completed in 2013 (Lowery and Plyler; Wu and Stangl) conclusively show that DNR improved the ability to accept noise for listeners with sensorineural hearing loss.

Improved speech recall: Background noise can impact one's ability to remember speech that has been heard. However, two relevant studies show that DNR can improve memory for speech in background noise. Rudner and Lunner (2013) reported that while background noise typically reduces memory of speech in noise, hearing aids with DNR improve recall of speech in noise. They explain that DNR may enable a release of cognitive resources, making it easier to listen – and thereby improving memory for speech in noise. Similarly, Ng et al. (2015) studied speech recall in individuals with both high and low working-memory capabilities. It was concluded that DNR improved recall for speech in background noise for all hearing aid users – regardless of their working-memory abilities.

Preservation of speech: DNR has been examined to find if it has a negative impact on speech perception. Research by Desjardins & Doherty (2014) and Pittman (2011) shows that it does not. The former group, using fast-acting modulation-based DNR, found that speech recognition in noise did not change (improve or worsen) with DNR activated – meaning that speech signals were preserved and not degraded. The latter researcher similarly showed that performance on speech perception tasks is maintained when DNR is active.

Preference: Finally, sound quality preferences in regards to DNR have been investigated. Studies by Ricketts and Hornsby (2005) and Bentler et al. (2008), for example, reveal that hearing aid users report preferences for hearing aids with DNR in noisy listening situations, since it provides greater sound comfort. Going one step further, Neher and Wagener (2016) investigated preferred DNR strength among hearing aid users. Their results indicated this is more of an individual trait, and where possible, patients should decide on their preferred DNR strength during the hearing aid fitting.

Speech in Noise (SPiN) Management

For a hearing aid user's speech intelligibility in noise to improve, the SNR must improve. As we have learned above, directional microphones and DNR algorithms help to improve the SNR for individuals with hearing loss by reducing background noise. To maximize the effectiveness of these two features, Sonic has developed an advanced noise management system that coordinates their operation. Made possible by the processing power of the SoundDNA platform, new Speech in Noise (SPiN) Management provides a cohesive framework to support speech-in-noise listening experiences. Three newly-designed 'Speech in Noise features'—**SPiN Directionality, SPiN Noise Reduction, and SPiN Engage**—simultaneously respond to environmental noise in a new automatic, adaptive and multiband design, summarized in Table 1, and described in detail below:

Table 1: SPiN Management features and descriptions

SPiN Management Overview	SPiN Directionality	SPiN Noise Reduction	SPiN Engage
Automatic activation in speech-in-noise	✔	✔	Coordinates onset of directionality and noise reduction in 16 frequency bands
Adaptive control in speech-in-noise	✔	✔	
16-frequency multiband design	✔	✔	

SPiN Directionality

The first component of SPiN Management is SPiN Directionality. As an all-new microphone system, SPiN Directionality automatically activates in response to noise sources. The system shifts direction as needed and applies the optimal directivity response—from fixed omnidirectional to full directional—to improve the SNR for the listener. Without requiring user interaction, automatic directionality offers the greatest chance of providing satisfaction in multiple listening environments (Kochkin, 2007). Here's how it works.

Automatic activation: The automatic component of SPiN Directionality engages the directional microphone when background noise starts and returns to omnidirectional when background noise stops. In other words, the automatic activation turns on the directional microphone only when needed, based on the overall level and temporal and spectral characteristics of the environment.

Adaptivity: SPiN Directionality's adaptive options modernise directivity for enhanced performance in noise. By constantly altering the internal time delay between the front and rear microphones, polar patterns adaptively change in response to spatially dynamic listening environments (i.e., noise sources that are moving relative to the listener). Directed by the level and location of noise, SPiN Directionality uses null-steering to select the polar plot with the best SNR in each frequency band.

Multiband design: SPiN Directionality implements multiple, independent directional systems in sixteen different frequency bands – compared to four bands in the past. This provides fine resolution for isolating and suppressing noise from different directions across the frequency spectrum with accuracy. To maintain both loudness and sound quality, multiband directionality preserves low-frequency input with omnidirectionality, while permitting directional responses in mid and high frequencies.

SPiN Noise Reduction

The second component of SPiN Management, SPiN Noise Reduction removes noise that has not been attenuated by SPiN Directionality. It is a fast-acting modulation based DNR algorithm that detects temporal characteristics of sound. Its speed allows it to preserve speech (signals with high modulation) and reduce noise (signals with low modulation). Here's how it works.

Automatic activation: SPiN Noise Reduction automatically detects the modulation rate and depth of incoming sound. Signals with a high modulation rate are desirable (e.g. speech), whereas signals with a low rate are undesirable (e.g. steady-state background noise). The algorithm analyzes the depth of modulation by continuously monitoring the peaks and troughs of the signal. A large peak-to-trough value signifies a high SNR and a small peak-to-trough value signifies a low SNR. This process estimates the SNR, providing an accurate representation of speech versus noise.

Adaptivity: SPiN Noise Reduction adaptively responds to changing environments, reducing gain only as much as needed when noise presents. For example, if a large amount of noise is present and the SNR is poor, the maximum amount of gain attenuation is applied; if the SNR becomes favorable, the minimum amount of attenuation is applied. The algorithm adapts quickly to provide listening comfort. To optimize accuracy, it uses extremely fast time constants. In this manner, it can efficiently respond to rapid fluctuations in noise, to attenuate noise even between the smallest speech pauses and preserve speech down to the phonemic level.

Multiband design: SPiN Noise Reduction operates in a sixteen frequency multiband design. This high-resolution framework offers precision for 1) identifying noise of varying spectral content and 2) reducing gain in the narrow bands where noise is detected. By working in the same frequency bands as SPiN Directionality, the two systems synergize by simultaneously managing speech and noise across the frequency spectrum, no matter the level or location.

SPiN Engage

The third component of SPiN Management is SPiN Engage. SPiN Engage refers to the SNR threshold level that will activate SPiN Directionality and SPiN Noise Reduction in response to noise. Working within the same multiband design, SPiN Engage coordinates the onset of directionality and noise reduction as the SNR fluctuates in sixteen independent frequency bands.

Since hearing aid users have varying tolerance limits regarding how much noise they are willing to accept, SPiN Engage allows customization based on individual needs and preferences. It offers up to four settings that correspond to the level of help your patient needs—or prefers—in changing listening environments. Therefore, it is beneficial to determine the extent that background noise bothers your patient in daily listening activities.[1]

For example, if your patient is extremely distracted or disturbed in speech-in-noise environments, SPiN Engage can be set with an immediate onset to rapidly put an emphasis on the speech signal (Very High setting). However, if your patient can accept more noise, or prefers to retain auditory awareness of environmental noise, SPiN Engage can be set to have a more gradual onset (High, Medium, Low settings).

[1] Interested readers are encouraged to explore further information and instruction on conducting acceptable noise testing in the clinic (Gordon-Hickey et al., 2012).

The effect of SPiN Management on the input signal

Figure 3a shows a typical speech-in-noise input signal. Notice how the noise surrounds soft speech and fills in the pauses between speech phonemes. Figure 3b shows how effectively SPiN Management treats speech-in-noise signals when activated. With SPiN Management in use, notice how speech is preserved and the amplitude of the noise is reduced. This improves the SNR of the original signal and provides the system with a cleaner signal to amplify.

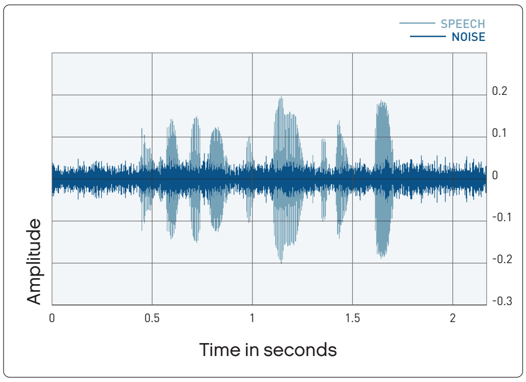

Figure 3a: Speech-in-noise input signal before SPiN Management

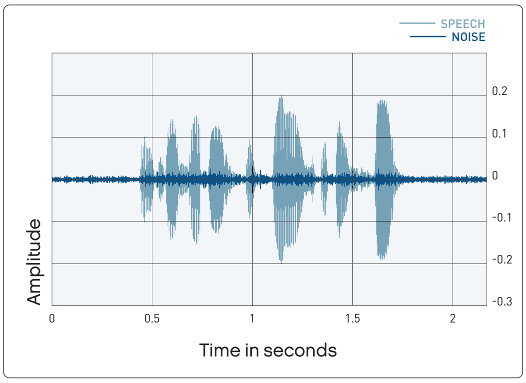

Figure 3b: Speech-in-noise signal after SPiN Management

SPiN Management in EXPRESS*fit*® Pro

The features that comprise SPiN Management are easy to program, and easy to use. In addition, they are flexible and can be customized based on individual needs and preferences. Locate SPiN Management settings under the Features tab in the Feature Selection screen in EXPRESS*fit* Pro.

Optimize each SPiN Management performance setting according to the guidelines below. Options may vary per selected listening program and/or technology level of the product.

SPiN Directionality constantly adapts the null-steering and directional pattern to optimize the SNR of the incoming signal in sixteen frequency bands where noise presents. **High Performance** adjusts the directionality to the narrowest directional pattern available. **Medium Performance** limits the width of the directional pattern, while **Low Performance** provides the widest directional pattern, comparatively.

SPiN Noise Reduction reduces the gain in sixteen frequency bands where noise presents. Where available, select **High, Medium, Low** or **Off** to apply the strength of desired noise attenuation according to patient needs. This adaptive feature attenuates background noise, only as much as needed, to restore listening comfort in noisy conditions.

SPiN Engage coordinates the onset of directionality and noise reduction as the SNR varies. Options include **Very High, High, Medium and Low**. The levels correspond to how soon the noise reduction technologies engage to reduce noise. Very High and High are ideal for patients who are bothered by soft-level noise, or who need a high SNR to hear in noise. Medium and Low are optimal for patients who can tolerate progressively stronger noise levels, or who can accept a lower SNR to hear in noise.

SPiN Management clinical test

SPiN Management supports improved word recognition in noise: A hearing aid trial was conducted to measure SNR improvement with hearing aids in a clinical setting. The objective was to compare the performance of hearing aids with SPiN Management to the previous family of hearing aids without SPiN Management. Thirty experienced users with moderate to severe hearing loss were individually fit with premium-level pairs of devices without SPiN Management and with the new SoundDNA devices with SPiN Management. Both sets were programmed with default settings in the fitting software and the same acoustical options were used for each. The gain was prescribed using NAL-NL2 targets and verified with REM (Verifit Audioscan) equipment.

The test set-up consisted of a speaker array with the hearing aid user seated in the center. Speech was presented directly in front of the listener at 0° azimuth and four noise sources were presented from various points around them ranging from 45° to 135° azimuth. In this configuration, the difference between the unaided and the aided SNR can be measured, as well as the difference between the directional strategies from the former technology to the new technology.

Speech testing was completed in the lab in a simulated environment using the Oldenburg Satztest (OLSA) (Wagener, et al., 1999). The OLSA is an adaptive speech in noise test. For this specific test, the 50% speech intelligibility level was used. This means that the speech will grow louder or softer depending on the responses of the volunteer in order to maintain an understanding of approximately 50% of the speech material. Speech Reception Threshold (SRT) is measured by the level of SNR (in dB) achieved with 50% intelligibility. A low SNR score means a greater benefit. Three test conditions were used: unaided, aided without SPiN Management, and aided with SPiN Management.

Results were analyzed by comparing the difference between the improvements from unaided to both aided conditions and then between both aided conditions. With a mean difference of 3.3 dB SNR ($p < 0.001$), the results revealed an overall improvement of SRTs with amplification, compared to the unaided condition. Furthermore, with a mean difference of 1.4 dB SNR ($p < 0.001$), there was also a significant difference between the SoundDNA devices with SPiN Management and the hearing aids without SPiN Management (Figure 4). Interpreting these results, the scores were better for the SPiN Management condition, meaning that there was a greater benefit between unaided and aided with SPiN Management than without.

More than just a comfort feature that reduces noise for the listener, SPiN Management specially optimizes the SNR to also provide the advantage of improved word recognition in noisy environments, compared to previous technology.

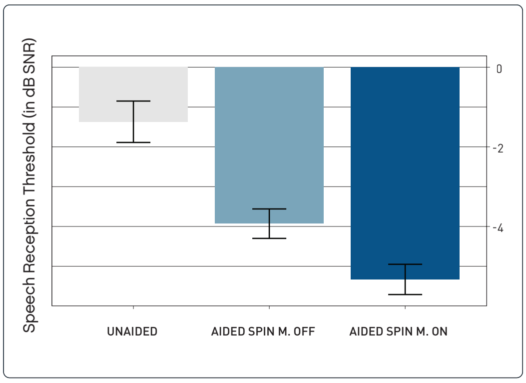

Figure 4: Speech-in-noise performance from the OLSA test expressed in dB SNR for the unaided and aided (without SPiN Management, and with SPiN Management) test conditions.

Benefits

The SPiN Management system from Sonic coordinates noise reduction technology to control speech-in-noise listening environments for individuals with hearing loss. Three features —SPiN Directionality, SPiN Noise Reduction, and SPiN Engage—simultaneously react and respond to environmental noise in a completely automatic, adaptive and multiband design. SPiN Management benefits patients by enhancing listening experiences in noise, personalized for individual needs. Best of all, SPiN Management is easy to program—and easy to use. Both hearing care professional and patient alike can be sure SPiN Management controls noise when it is needed the most. As a key feature within the SoundDNA platform, SPiN Management is available in EXPRESS*fit*® Pro.

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

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