WINDGUARD: BRINGING LISTENING COMFORT TO WINDY CONDITIONS

Tammara Stender and Marcel Hielscher

Abstract

Wind noise can create a frustrating listening experience for hearing aid users. Even at low wind speeds, high levels of turbulent noise can be created at the hearing aid microphones, adding high levels of noise to distort the signal of interest. ReSound's new WindGuard feature uses dual-microphone signal processing to effectively reduce the level of the wind noise in today's hearing devices. In this white paper, WindGuard is described, as well as use cases in which it will be most beneficial to hearing instrument users. Information about how to properly set this new feature in the Aventa software is also provided.

When wind strikes a surface such as the head, the pinna of the ear, or a hearing instrument, turbulence is created (Dillon et al., 1999). This turbulence contains fluctuations in pressure, which are converted to electrical fluctuations by the hearing instrument microphones. Wind noise has a significant impact on the listening experience for hearing instrument users. Whether the individual enjoys a day on the golf course or a relaxing ride on a bicycle, wind noise at the level of the hearing instrument microphones can exceed 80 dB SPL. When this level of turbulent noise enters the microphones, it degrades speech intelligibility and often creates listening discomfort for the user due to the intensity of the wind noise. Figure 1 illustrates the turbulent velocity of wind when the user is wearing a behind-the-ear (BTE) hearing instrument. Red hues indicate the areas of highest turbulent velocity.

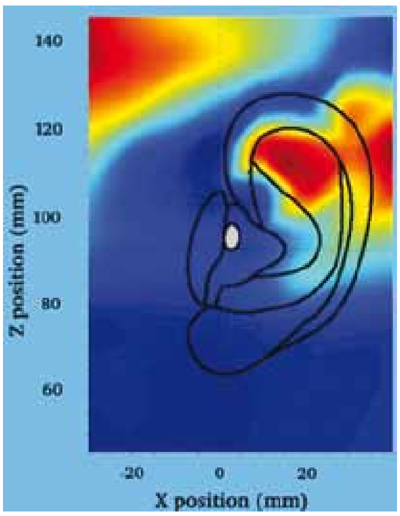

Figure 1. Turbulent velocity of wind for a BTE hearing instrument.

FACTORS INFLUENCING THE SEVERITY OF THE WIND NOISE PROBLEM

Several factors can either increase or diminish the severity of wind noise issues for hearing instrument users. First, the location of the microphone(s) can influence the degree of wind noise. Hearing instruments that have microphone(s) within the concha cymba, such as custom remote microphone (RM) hearing instruments, or at the opening of the ear canal within the concha, such as completely-in-the-canal (CIC) hearing instruments, are less affected by wind noise due to the protection provided by the anatomical features of the external ear. In contrast, BTE hearing instruments typically have the least degree of protection from wind noise by the external ear due to the location of the microphone(s) above or behind the pinna. Figure 2 depicts the wind noise as a function of energy at the microphone location for the RM, CIC and BTE hearing instruments.

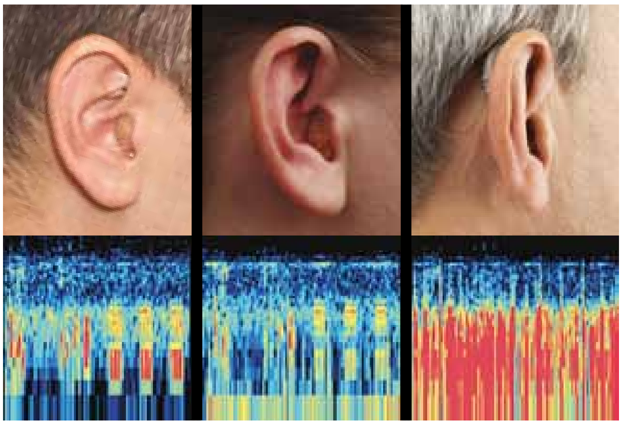

***Figure 2.** Energy spectrum of wind noise at the level of the hearing instrument microphone, for the RM (a), CIC (b) and BTE (c) form factors. Low energy is depicted by blue and high energy is depicted by red.*

The level of the wind noise perceived by a hearing instrument user is dependent on the location of the wind with respect to the hearing instrument. For both custom and BTE hearing instruments, the lowest level of wind flow noise occurs when the hearing instrument microphones are directly facing the flow (Chung et al., 2009, 2010).

The signal processing of the hearing instrument can also contribute to the problem. Wind noise is more problematic for dual-microphone hearing instruments than for those with single microphones (Thompson, 2000; Kates, 2008), because wind noise is spectrally low-frequency and spatially uncorrelated. When wind is present, distinct air vortexes are created at each microphone of the hearing instrument. Since each of these vortexes is unique, so is the signal at each microphone, and the signals are thereby uncorrelated. Combining uncorrelated inputs at the 2 microphones or ports of a directional hearing instrument results in an increase of the signal level. Thus, in a traditional directional hearing instrument with low-frequency equalization, wind noise is amplified. Hearing aid manufacturers have different ways of approaching this dilemma. Most directional hearing instruments today use two omnidirectional microphones, and users have the option to switch microphone modes to omnidirectional when wind noise is problematic (Beard & Nepomuceno, 2001; Thompson & Dillon, 2002; Chung et al., 2009, 2010). Other methods used to control wind noise in hearing instruments include the use of microphones that have lower sensitivity, and high-pass filtering due to the predominant low-frequency characteristics of wind noise (Chung, 2010). ReSound, with its Surround Sound Processor that assigns an omnidirectional response to low frequencies, already alleviates much of the wind noise problem. However, wind noise still remains. For this reason, WindGuard was developed as a second line of defense against wind noise in both directional and omnidirectional microphone modes.

RESOUND WINDGUARD

The new WindGuard feature detects noise at both the front and rear microphones of dual-microphone hearing instruments. The feature works when a directional response is chosen, as well as when the hearing instrument is in an omnidirectional program. When sounds such as speech are present, the signals at both microphones will be roughly equivalent. This occurs because for the most part, the wavelengths of speech sounds are longer than the distance between the microphone ports on the hearing aid. However, when wind occurs, the signals are not equivalent due to its uncorrelated nature. This distinct property of wind noise allows for the system to distinguish and differentiate between wind noise and desired low-frequency sounds in the acoustic environment.

The goal of WindGuard is to apply enough gain reduction in the frequency bands where wind is detected to provide listening comfort for the hearing instrument user, without disrupting the gain levels of the frequency bands that are unaffected by wind. The amount of gain reduction applied varies with the environment and the level of the wind noise, making the reduction as personalized as possible to the situation without sacrificing audibility for other sounds. The end result: the hearing instrument user has a very natural sounding experience, with soft wind noise in the background and preserved audibility for other sounds in the environment.

WindGuard consists of two components: a wind detection module and a wind reduction module. In the detection stage, only sounds below 3000 Hz are considered, since wind noise typically has a spectral peak around 100 Hz at high wind speeds (Larsson & Olsson, 2004). The amount of wind noise with respect to other sounds is calculated across both microphones by correlating the filtered outputs of each microphone. Wind noise is likely to be present when the signals from each microphone are not correlated. This calculation occurs at a very high rate in order to ensure wind noise is quickly detected and reduced. In the final stage of wind detection, the level of wind noise is compared to the level of other sounds in the environment to determine a wind-to-sound ratio, which is used by the wind reduction module to determine by how much to reduce gain.

The second component of WindGuard is the wind reduction module. When the system determines that wind noise is present and greater than 70 dB SPL, gain reduction is applied to specific frequency bands. Figure 3 shows a highly simplified schematic of the 2 modules of WindGuard.

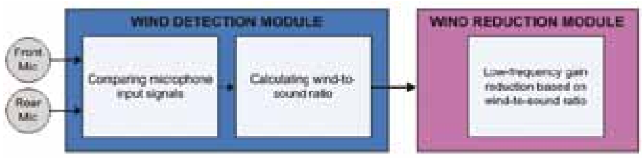

Figure 3. *Simplified schematic of dual-microphone input and WindGuard.*

WINDGUARD'S ADAPTABILITY TO CHANGING WIND CONDITIONS

WindGuard ensures the optimum solution is provided regardless of the environment. Obviously, when no wind noise is detected, no gain reduction is applied. However, the system does continually analyze and store information about the current environment for use in calculating the wind-to-sound ratio. Figure 4 illustrates the three different states of WindGuard processing. In panel *a*, no wind noise is detected. In this situation, the level of environmental sound is continually updated for use in calculating wind-to-sound ratio in case wind noise appears. Panel *b* shows the state where wind noise is detected, but where it is below 70 dB SPL. No gain reduction is applied in this case. Panel *c* illustrates how gain is reduced in low-frequency bands if wind noise is detected and exceeds 70 dB SPL. The amount of gain reduction is based on the wind-to-sound ratio and is intended to bring the level of wind noise to the average sound level of the user's environment. The reaction time of wind noise gain reduction is 250 ms, which means that the amount of reduction could change up to 4 times per second. This reaction time is fast enough to react to changes in the amount of wind noise experienced by the hearing instrument user and slow enough to avoid artifacts or other distortions of the sound.

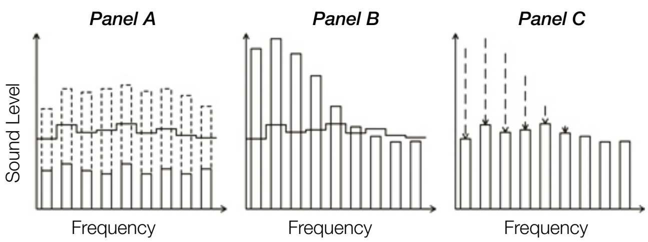

Figure 4. *States of WindGuard processing. Bars depict the power per band. Solid bars indicate the minimum power level within a certain period of time, and dotted bar extensions indicate the maximum power level within that same time period. The horizontal solid jagged line shows the average power level per band of the acoustic sound. The (A) scenario depicts the situation where there is no wind, when the average power level is calculated. Scenario (B) illustrates the presence of wind noise, when wind noise is less than 70 dB SPL. No gain reduction occurs in this scenario since the wind noise is detected at a low level. In Scenario (C), wind noise is detected above 70 dB SPL. Gain reduction, shown as down-arrows, is applied to bring the levels of the wind noise to the average power levels previously stored by the system.*

WindGuard is available in omnidirectional as well as all directional input mode settings. When WindGuard is activated in an omnidirectional program, the rear microphone is enabled for the sole purpose of wind detection. In this case, no signal from the rear microphone is used in signal processing other than for wind noise reduction purposes.

OPTIMAL PARAMETERS AS DEFINED BY SUBJECT TRIAL RESULTS

When developing a new feature such as WindGuard, it is vital to receive input from end-users in their everyday environments. This is important for two reasons: to ensure that benefit is obtained from the new feature as compared to the end users' experiences without the feature, and to verify that parameter settings are appropriate in most situations. As with most features, WindGuard has several possible parameter settings. After the best parameter settings are theorized, it is essential to seek end-user comments and concerns that occurred during their trial period with the feature enabled in trial hearing instruments.

Users in research trials were fitted with the WindGuard feature activated in one of several available ReSound Alera form factors. To ensure that wind noise reduction would be advantageous to end users, questions about the need to communicate in wind noise were asked to trial participants. First, subjects were asked how often they were in windy environments when there was no need for communication. Second, these same subjects were asked how often they encounter environments with wind noise in which they need to communicate. Overall, test subject responses indicated that although they do not always need to communicate in windy environments, there is a distinct need to communicate often in some windy situations.

After ensuring test subjects encountered sufficient wind noise to be able to accurately evaluate the new feature, they were asked about their experiences. When test subject responses were evaluated together after a wear time of four to six weeks, changes to the feature parameters were made to address concerns with WindGuard or wind noise that arose. Feature-development parameters that were changed according to cumulative subject feedback included the amount of gain reduction per band, the attack and release time constants, the wind noise detector threshold setting, and the strength and impact of the different levels of WindGuard ("Mild," "Moderate" and "Strong"). Following these changes, test subjects were asked again to evaluate the hearing performance in windy conditions.

CASE STUDY EXAMPLE

The case of a woman fitted with binaural Alera Fusion Standard BTE hearing instruments helps to illustrate this process. She has a symmetrical, moderate sloping to severe sensorineural hearing loss, and was thus fitted in the closed hearing instrument configuration. Following are her comments about wind noise at the second, third and fourth follow-up visits (Table 1).

Trial Visit	***Wind Noise Experiences and Comments***	***Resolution/Change in WindGuard***
2nd	"Very disturbed by wind noise. Cannot have a conversation with anyone when the wind blows."	Increased setting of WindGuard in the fitting software from "Moderate" to "Strong"
3rd	"Still bothered by the wind noise."	**Refitted the hearing instruments with changes to WindGuard parameters**
4th	"Can now hear a change for the better when wind noise occurs. No longer is bothered by the wind noise. Likes the hearing instruments."	(End of trial)

Table 1. *Case study example from a research trial.*

For this trial subject, changes to the WindGuard parameters resulted in a decrease of wind noise and subsequent alleviation of problems with wind noise in daily use. Results showed that parameter changes to WindGuard based on trial subject comments were helpful in preserving good sound quality and audibility.

FITTING WINDGUARD TO THE HEARING INSTRUMENT USER'S NEEDS

Using the subject trial results as a guideline, default settings were established for the WindGuard feature for each program in the Aventa fitting software. WindGuard is available for all dual-microphone hearing instruments, including BTE devices which typically have the greatest degree of wind noise (see Figure 2) of all form factors, and for dual-microphone in-the-canal (ITC) and in-the-ear (ITE) devices which are larger and more likely to experience turbulent wind noise concerns. WindGuard is not necessary for remote microphone, CIC or mini-canal hearing instruments due to the protection from wind afforded by the pinna and external ear.

Options for fine tuning to the individual patient's preferences depend on the Alera family chosen. For the Alera 9 series, WindGuard setting options in Advanced Features include "Off," "Mild," "Moderate" and "Strong" (Figure 5). Settings differ in the amount of gain reduction that occurs when wind noise is detected. For the Alera 7 series, options include "Off," "Mild" and "Moderate." WindGuard is not available in the Alera 5 series.

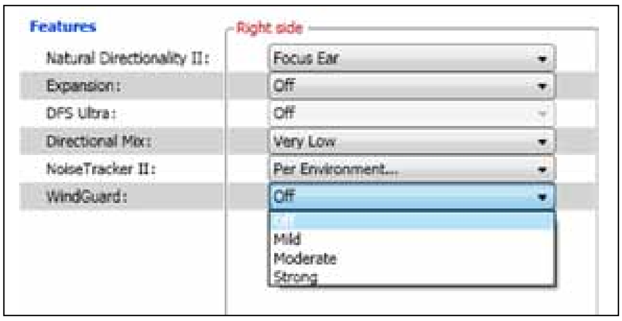

Figure 5. *WindGuard settings for the Alera 9 series.*

To illustrate how the settings affect the amount of wind noise reduction, imagine the hearing device user is a bicyclist on a busy street. The user is currently in a program with WindGuard activated. The non-wind, street noise is 70 dB SPL, which has been calculated to be the average power level by the detector. Suddenly a gust of wind blows past the cyclist at 80 dB SPL. WindGuard will subtract the wind noise from the average power level, and apply an offset based on the "Mild," "Moderate" or "Strong" feature setting. Thus, the amount of gain reduction is dependent on two aspects: the difference between the level of the wind noise and the average level of the environment without wind (wind-to-sound ratio), and the offset that derives from whether WindGuard is set to "Mild," "Moderate" or "Strong." Further, the gain reduction is applied for every band individually; thus, for a multi-band hearing instrument, each band may have a different amount of gain reduction.

WindGuard is an option in the following programs:

- Natural Directionality II
- Basic
- Basic + SoftSwitching
- Music
- Outdoor
- Party
- Restaurant
- Traffic

WindGuard is available in all microphone programs in the Alera 9 and 7 series. The feature is defaulted to "Off" in each of these hearing instrument microphone-based programs, except for the Outdoor program in which the default setting is "Mild." WindGuard is not an option in telecoil (TC), direct audio input (DAI) or streaming programs.

FITTING RECOMMENDATIONS

As the Outdoor program is not a default program, WindGuard will not be activated for most fittings. If during the case history or while conversing with patients they mention problems hearing when outdoors in windy conditions, such as on a golf course or while riding a bicycle, it may be advantageous to either add an Outdoor program to their hearing instruments or to manually activate WindGuard in the most commonly used program for that patient. If the "Mild" setting is not appropriate and wind noise issues persist for an individual patient, the setting can be easily increased in Aventa to "Moderate" or "Strong" for greater reduction of the wind noise. For many patients who find themselves outdoors for occupational or recreational purposes, WindGuard may be very beneficial for the patient's listening comfort and ultimate acceptance of the hearing instruments.

SUMMARY

The frustration and listening discomfort that comes from wind noise in the environment can be very detrimental to the sound quality experienced by hearing instrument users. Wind can detract from the speech in the environment, sacrificing intelligibility even at low wind speeds. For this reason, ReSound developed the WindGuard feature, which reduces the level of the wind noise in dual-microphone hearing instruments. Optimal settings were derived from test subject trials to ensure that real-world end-user benefits could be attained. WindGuard can be easily accessed and fine-tuned for the individual patient through Aventa fitting software.

REFERENCES

1. Beard J, Nepomuceno H. (2001). Wind noise levels for an ITE hearing aid. Knowles Engineering Report, 128, Revision A.
2. Chung K. (2010, April 06). Reducing Noise Interference: Strategies to Enhance Hearing Aid Performance. The ASHA Leader.
3. Chung K, Mongeau L, McKibben N. (2009). Wind noise in hearing aids with directional and omni-directional microphones: polar characteristics of behind-the-ear hearing aids. Journal of Acoustical Society of America, 125(4), 2243–59.
4. Chung K, McKibben N, Mongeau L. (2010). Wind noise in hearing aids with directional and omni-directional microphones: polar characteristics of custom-made hearing aids. Journal of Acoustical Society of America, 127(4), 2529-42.
5. Dillon H, Roe I, Katsch R. (1999). Wind Noise in Hearing Aids. NAL Annual Report.
6. Kates J. (2008). Digital Hearing Aids. San Diego: Plural Publishing.
7. Larsson P, Olsson P. (2004). Detection of wind noise in hearing aids. Masters thesis, Department of Electroscience, Lund Institute of Technology, March, 2004.
8. Thompson SC. (2000). Directional microphone patterns: They also have disadvantages. Audiology Online.
9. Thompson S, Dillon H. (2002). Wind noise in hearing aids. Presented at American Academy of Audiology Convention, Philadelphia, PA.