Vol. 3 No. 5 / 2000

SONIC innovations

Improved Speech Intelligibility in Noise with a Single Microphone Noise Reduction Technique

Michael J. Nilsson
Xiaoling Fang
Robert M. Ghent, Jr.
Patrick Murphy
Victor H. Bray, Jr

Abstract

Reception Threshold for Sentences (RTS) as measured by a modified version of the HINT test [M.J. Nilsson et al., J. Acoust. Soc. Am. 95(2), 1085–1099 (1994)] were collected on 28 hearing-impaired listeners fit binaurally with digital hearing aids incorporating a 9-channel spectral subtraction technique of single-microphone noise reduction. Thresholds were measured in quiet and noise presented at a zero degree azimuth with the subjects listening unaided, aided without noise reduction, and aided with noise reduction and no modification to the gain function when noise reduction was activated. Additional data included soundfield thresholds as a frequency-dependent measure of the impact of the noise reduction algorithm on sensitivity to soft sounds. RTS in noise reveal a significant effect of noise reduction with noise reduction decreasing RTS relative to no noise reduction. RTS in quiet reveal a significant effect of noise reduction with noise reduction increasing RTS relative to no noise reduction. Soundfield thresholds reveal a loss of sensitivity mainly in frequencies below 1000 Hz. The noise reduction algorithm will be reviewed and discussed.

Presented at the Acoustical Society of America 140th Meeting December 3-8, 2000 Newport Beach, California

INTRODUCTION

Spectral subtraction, as a signal processing algorithm, has been used for many years to reduce or eliminate the level of maskers found in mixed, single-channel signals. The level of success with various implementations of spectral subtraction has depended upon the application, as well as the expectations of the user.

In hearing aids, which must provide amplification as well as improvements in signal to noise ratio, spectral subtraction has not yet been able to provide measurable performance benefits in noise. Implementations have been plagued with acoustic artifacts (waterfall effect, pumping, or other distortions), and when these are controlled, the benefits are only seen with respect to self-evaluated improvements in listening comfort1.

A new implementation which combines a modified spectral subtraction technique with a unique signal processing algorithm, has been evaluated to determine if measurable performance improvements can now be identified.

ALGORITHM

All single-microphone noise reduction (NR) algorithms need some method of detecting signal versus noise in a single input. The current system uses a unique nine-channel architecture2 and implements the noise reduction in each of these channels. Signals in each channel are separated into the amplitude envelope and vibrational component (i.e., the vocal cords create the vibration that is modulated in amplitude by the vocal tract). The noise detectors determine the portion of the entire signal that is noise based upon the modulation rate of the envelope. From this, the signal to noise ratio in each channel is calculated which, in turn, determines the specific amount of gain reduction applied.

The test system (currently implemented in the NATURA™ 2 SE and CONFORMA™ 2 SE products) has dual time constants.

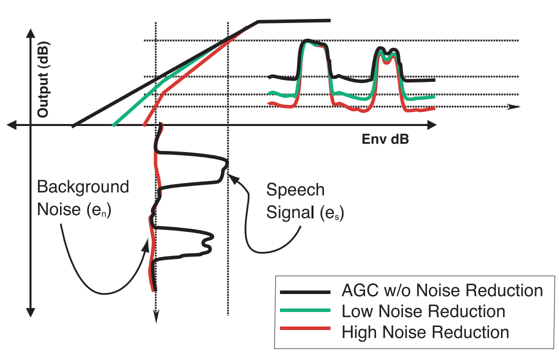

Figure 1. Noise Reduction I/O Operation

The noise detector is characterized by slow attack times (to accumulate sufficient information to accurately identify noise) and fast release times (to shut off quickly when the noise is no longer present). Once engaged, real-time processing with very fast attack and release is implemented to respond to variations in signal-to-noise ratio (Figure 1). The system makes rapid adjustments to the gain based upon short term variations in the signal-to-noise ratio. The change in signal-to-noise ratio caused by the momentary increase in energy of a modulated signal is enough to change the gain applied to the signal. By implementing this processing independently in narrow, half-octave channels, the system becomes transparent to the listener.

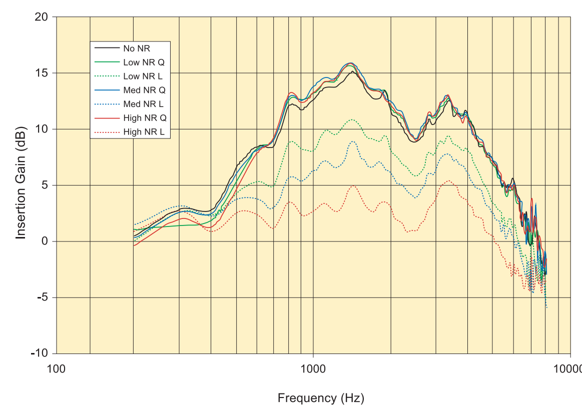

Figure 2. Real-Ear Insertion Response

An example of the real-world impact of this processing is shown in Figure 2. The Real-Ear Insertion Response (REIR) averaged across 14 ears shows the change in gain with different levels of noise reduction. It also demonstrates the system's ability to maintain the prescribed gain when the noise detector is not triggered, as shown in the quick ("Q") measures which overlap the curve without noise reduction. The amount of noise reduction ranges between 5 and 10 dB, depending upon the noise reduction setting.

METHOD

Subjects: Twenty-eight subjects were fit binaurally with CIC, ITC, or ITE devices with the current noise-reduction algorithm. Audiometric data is summarized in Figure 3.

Apparatus: Previous experience with this system3 lead to the creation of a modified set of HINT4 materials. To ensure the noise reduction processing was engaged during the playback of the speech materials, the noise onset was increased to 5 seconds. All subjects were fit using a proprietary audiogram-based fitting algorithm (EXPRESSfit™). Fittings were not altered between noise-reduction and non-noise-reduction settings.

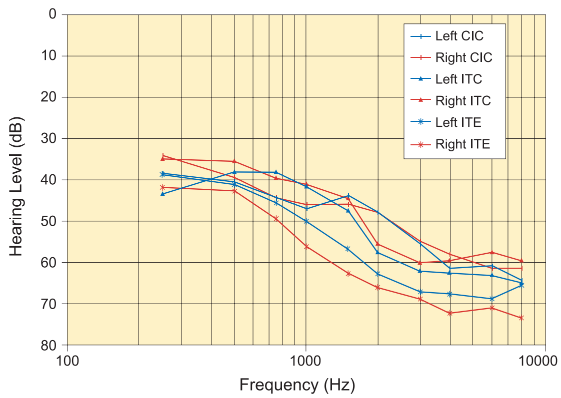

Figure 3. Mean Audiogram by Device Style

Protocol: Subjects were placed in a double-walled sound room facing a single loudspeaker. HINT reception thresholds for sentences (RTS) were measured. The RTS measures the level at which the sentences can be correctly repeated half the time and is expressed in dB A when the sentences are presented in quiet, or signal-to-noise ratio (S/N) relative to the 65 dB A noise. RTS was measured in five conditions: unaided, aided with no NR, low NR, medium NR, and high NR. Lower RTS indicates that the same level of performance can be achieved at a lower presentation level of poorer S/N.

In addition to HINT measures, sound field thresholds were obtained using warble tones from a loudspeaker 1 m in front of the subject.

RESULTS

Mean HINT scores were analyzed separately for the quiet and noise conditions. For data in noise, a main effect of level of noise reduction was found [F(3,75)=21.99, p<.001]. Post-hoc analyses showed significant benefit from amplification, and additional benefit with any level of noise reduction (Figure 4). The performance intensity function of the HINT predicts a 15–20% intelligibility benefit in noise from amplification and an additional 15–20% improvement in noise from the current spectral subtraction system.

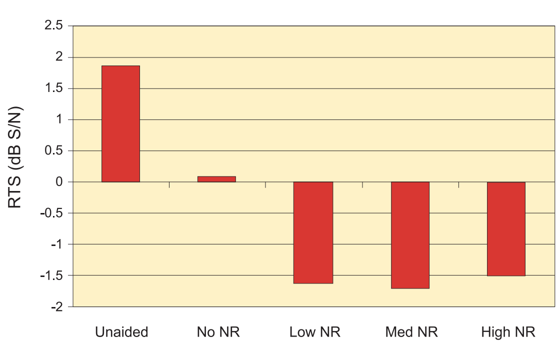

Figure 4. HINT RTS in Noise

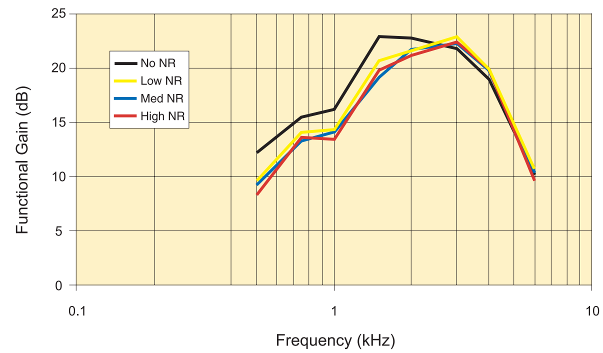

Figure 5. Mean Functional Gain

In an effort to determine if the noise reduction impacted sensitivity, functional gain in the soundfield was measured. Analysis of functional gain found a main effect of noise reduction [F(3,66)=180.53, p<.001] and an interaction between noise reduction and frequency [F(21,462)=40.97, p<.001]. Figure 5 displays the interaction.

Analysis of HINT thresholds in quiet revealed a main effect of noise reduction [F(3,75)=42.50, p<.001]. Amplification provided significant benefit, with a decrease in this benefit when noise reduction was active (see Figure 6).

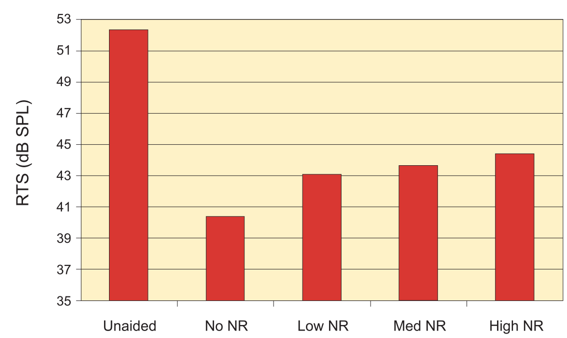

Figure 6. HINT RTS in Quiet

DISCUSSION

Twenty-eight subjects have been fit with a new single-microphone noise reduction algorithm. Data demonstrates the various degrees of noise reduction available (Figure 2), as well as significant improvements in speech performance in noise (Figure 4) relative to unaided as well as aided conditions without noise reduction. The noise reduction algorithm decreases sensitivity to soft, low frequency signals (Figure 5) which would account for the reduced benefit from amplification in quiet with noise reduction active (Figure 6). Because of the system's sensitivity to the signal-to-noise ratio, even a quiet environment (such as a sound booth in the laboratory) will cause some noise reduction to engage. For example, the thermal noise of the microphone or the soft noise of the ventilation system will create estimates of a low signal-to-noise ratio in quiet, producing some gain reduction. This effect in quiet would suggest that optimal implementation of the system should give the user the ability to turn the noise reduction on or off to maximize benefit across various listening conditions.

REFERENCES

1. Ludvigsen, C., Elberling, C., & Keidser, G. (1993). Evaluation of a noise reduction method: Comparison between observed scores and scores predicted from STI. Scand Audiol Suppl, 38, 50–55.
2. Nilsson, M., & Bray, V. (1999). The application of a cochlear model to hearing aid design. Instructional course, AAA 11th Annual Convention, Miami Beach, Florida.
3. Nilsson, M., Fang, X., and Bray, V. (2000). Noise reduction in a 9-channel DSP hearing aid. Presentation, AAA 12th Annual Convention, Chicago, Illinois.
4. Nilsson, M, Soli, S.D., & Sullivan, J.A. (1994). Development of the Hearing-In-Noise test for the measurement of speech reception thresholds in quiet and in noise. J. Acoust. Soc. Am., 95(2), 1085–1099.

Presented at the Acoustical Society of America 140th Meeting
December 3-8, 2000 Newport Beach, California

SONIC innovations