



Noise Reduction in a 9-Channel DSP Hearing Aid

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ABSTRACT

A novel single-microphone noise reduction algorithm has been implemented in a DSP hearing aid platform. This implementation of noise reduction differs from previous algorithms in temporal, spectral, and amplitude characteristics. The assumptions made in this algorithm will be presented. Data comparing the performance of this device to the same platform without noise reduction will also be presented.

INTRODUCTION

Single-microphone noise reduction has been available for several years in digital hearing aids, with reports of subjective benefit (improvements in comfort and ease of use) but no significant improvements in objective measures of speech in noise¹. The underlying methodology of these noise reduction algorithms is to find some characteristic(s) to differentiate speech from noise and manipulate gain when differences are present.

A new implementation of noise reduction in a nine-channel DSP hearing instrument has been tested on 15 subjects. The noise reduction is integrated with a signal processing algorithm based upon a model of outer-hair-cell loss in the cochlea² (Figure 1). The system combines fast, frequency-dependent

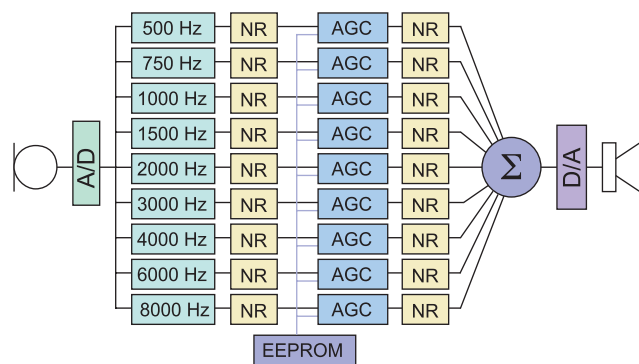


Figure 1. 9-Channel Signal Processor with Noise Reduction

attack and release times with independent compression and noise reduction in narrow channels. The noise reduction is frequency and signal-to-noise ratio dependent. Combined, these features lead to a more natural and clearer listening experience, as reported by patients.

ALGORITHM

All single-microphone noise reduction (NR) algorithms need some method of detecting signal versus noise in a single input. The **SONIC innovations NATURA™ 2 SE** system takes advantage of a nine-channel architecture to implement noise reduction separately in each of the nine channels (Figure 1). Signals in each channel are broken down into the amplitude envelope of the signal and vibration of the signal (similar to the shaping of the signal by the mouth, tongue, and palate versus the vibration of the vocal cords). A noise detector then works with the amplitude envelope information to determine the level of the noise, the portion of the entire signal that is noise, and the approximate signal-to-noise ratio. This information is then used to subtract the spectrum of the noise (thus the commonly used term “spectral subtraction”) which

ends up being a variation on the amount of gain applied in any one channel.

The NATURA 2 SE noise-reduction algorithm is unique in its application of different maximum amounts of noise reduction depending upon the channel (making the noise reduction frequency-dependent) and the signal-to-noise ratio (very difficult situations are difficult even for normal hearing listeners; very easy situations are no problem even for hearing-impaired listeners). The noise detector is unique in its use of slow attack and fast release times, and the function defining the amount of noise reduction is designed to minimize acoustic artifacts that are common to many spectral subtraction algorithms. All of this processing occurs interactively with the Automatic Gain Control (AGC) and is therefore dependent upon the fitting for the individual, making noise reduction customized for each listener. 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 noise is not detected, as shown in the quick (“Q”) measures which overlap the curve without noise reduction. The maximum noise reduction varies between 5 and 10 dB at the maximum gain of the average REIR.

METHOD

SUBJECTS: Fifteen subjects were fit binaurally with CIC, ITC, or ITE devices with the current noise-reduction algorithm. All were experienced users of NATURA hearing aids.

APPARATUS: Subjects evaluated the devices with respect to sound quality (rating their own voice, music, speech, and

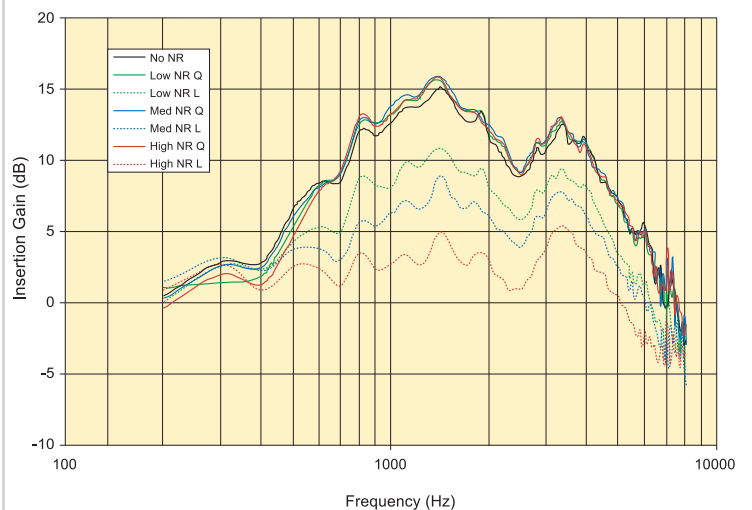


Figure 2. Real-Ear Insertion Response Measured with Composite Noise

environmental sounds on a seven-point scale for naturalness, clarity, ease of understanding, and overall sound quality) and speech understanding (using an unmodified HINT³ in quiet and noise). All subjects were fit using a proprietary audiogram-based fitting algorithm. Fittings were not altered between noise-reduction and non-noise-reduction settings.

PROTOCOL: Subjects were placed in a double-walled sound room facing a 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 signal-to-noise ratio (S/N). RTS was measured in four conditions: no NR, low NR, medium NR, and high NR. Lower RTS in the low and medium NR conditions relative to the no NR condition indicates that the same level of performance can be achieved at a poorer S/N.

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

RESULTS

Mean HINT scores show a trend for improvement in performance in noise for the low and medium NR conditions relative to no NR and high NR conditions. Statistically, the low NR scores are significantly different ($p < .01$) from the high NR scores. The HINT was optimized for clinical efficiency and has a noise onset time of 1 s which does not give the noise reduction algorithm time to fully engage (an estimated 5–7 s). An optimized test condition, where the onset of the noise is long enough to fully engage the noise reduction before the sentence starts, will be tested in a future protocol.

In an effort to determine if the noise reduction impacted sensitivity, sound-field thresholds were measured. Thresholds

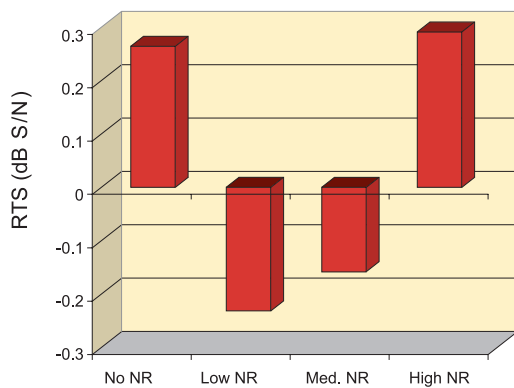


Figure 3. HINT Reception Thresholds for 4 Noise Reduction Conditions

show very little difference between noise reduction settings

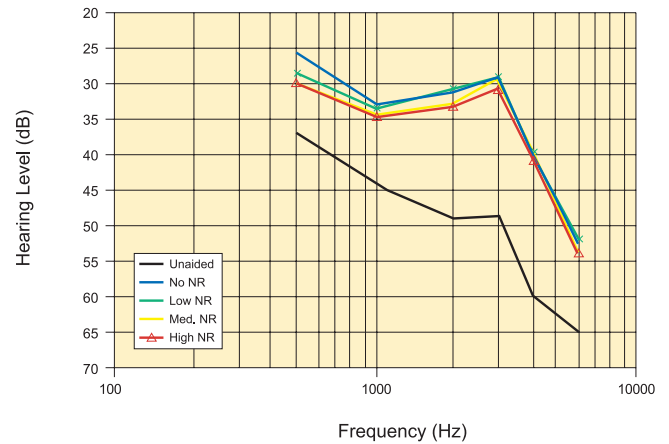


Figure 4. Average Soundfield Thresholds for 15 Subjects

except for the 500 Hz channel. The algorithm is therefore having a minimal impact on sensitivity to soft sounds.

DISCUSSION

Fifteen of an expected total of 32 subjects have been fit with a new single-microphone noise reduction algorithm. Preliminary data show the frequency dependence of the noise reduction (Figure 1), the various degrees of noise reduction available (Figure 2), as well as significantly different speech performance with the various settings (Figure 3). It is important to note that the original design of the HINT materials did not take into account the attack time required for a single-microphone noise reduction circuit; the onset of the noise before the sentence is much shorter than the attack time of the circuit. Therefore, the potential of the circuit is not being displayed. Instead, the impact of noise reduction in more transient environments is being assessed, which is possibly a better indicator of real-world settings. Additional testing is planned with a modified HINT incorporating long enough noise onset times to fully engage the noise reduction before a sentence begins. This is expected to measure the full potential of the NATURA 2 noise reduction algorithm.

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, 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.

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Editor's Note: For further information please see the companion paper "Improved Speech Intelligibility in Noise with a Single Microphone Noise Reduction Technique" by Nilsson et al. (2000).

