New Stimuli for Evaluation of Multichannel Noise Reduction Hearing Aids

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Introduction

Modern digital noise reduction algorithms are designed to provide a fine scale frequency analysis in individual channels and based on the estimated signal to noise ratio within each channel, a decision is made on how much gain reduction is applied within that particular channel. From a signal processing design stand point, the idea sounds excellent. In fact, if a noise reduction algorithm precisely achieves a fine scale noise reduction, then it is reasonable to expect improvement in speech intelligibility. However, from a practical and clinical stand point, there needs to be some questions answered. First, when a noise reduction algorithm applies gain reduction with a certain channel, how are the neighbouring channels (even for that matter, channels farther away) affected? Second, how is the perceived sound quality as a result of noise reduction? Third, how much noise reduction is truly achieved within an individual channel? Do hearing aids from different manufactures perform differently on such a test?

Noise reduction in multichannel hearing instruments is currently quantified by using steady-state signals (e.g. speech spectrum shaped noise) and measuring the overall gain reduction. Bentler and Chiou (2006) evaluated the noise reduction characteristics of hearing aids in response to ICRA noise, clear speech, random noise, and speech babble. Hearing aids from different manufacturers varied in terms of the time constants for activation of noise reduction, degree of gain reduction as a function of frequency, and differences in gain reduction at different presentation levels. A problem with the signals used in previous research to test noise reduction algorithms is that they do not measure noise reduction within individual channels. In this paper, we describe new stimuli and their effectiveness in evaluating multichannel noise reduction circuits more precisely.

The proposed stimuli were created by notch-filtering ICRA noise (Dreschler et al., 2001) and filling-up the notch with steady-state narrowband noise so that the resultant spectrum matched that of the original ICRA noise. Each resultant test stimulus is a broadband ‘speech like’ signal with an embedded narrowband of steady state component (see figures 1-2). If the hearing aid can detect the steady state signal within the ongoing fluctuations, gain should be reduced within that narrowband. Two research questions were addressed in this study. 1) How do digital hearing aids with multichannel noise reduction respond to the proposed stimuli? 2) Is the degree of gain reduction within individual channels (using the proposed stimuli) comparable to the gain reduction to broadband noise?

Methods

Hearing Instruments: Digital behind the ear hearing instruments with multichannel noise reduction from four major manufacturers in the US market were obtained and programmed for flat 65 dB HL using NAL NL1 prescriptive formula. Directionality, digital feedback suppression, and manual volume control (where available) were disabled. At the time of data collection, the selected hearing instruments were advertised as the upper echelon of their technology. The four hearing instruments, in principle, employed similar temporal modulation based digital noise reduction algorithm. However, there were some differences in the manner in which the algorithms were executed – a primary difference between was the number of noise reduction channels. As shown below in the hearing instruments varied from 8-16 noise reduction channels.

Creation of the stimuli: Three different bandwidths of steady-state noise (1/3 oct, 1 oct, 2 oct) were embedded at six different frequencies (0.25, 0.5, 1, 2, 3, and 4 kHz) resulting in 18 new stimuli. In addition, one speech-shaped noise, and one ICRA noise at 0 dB SNR were included in the pool of stimuli creating a total of 20 test stimuli. Each stimulus was 2 minutes in duration that was decided to be long enough for the noise reduction algorithm to get activated. The overall RMS amplitudes of the stimuli were equalized.

Manufacturer A	14-channel digital noise reduction
Manufacturer B	16-channel digital noise reduction
Manufacturer C	8-channel digital noise reduction
Manufacturer D	16-channel digital noise reduction

Table 1 Number of noise reduction channels in the hearing aids tested in this study

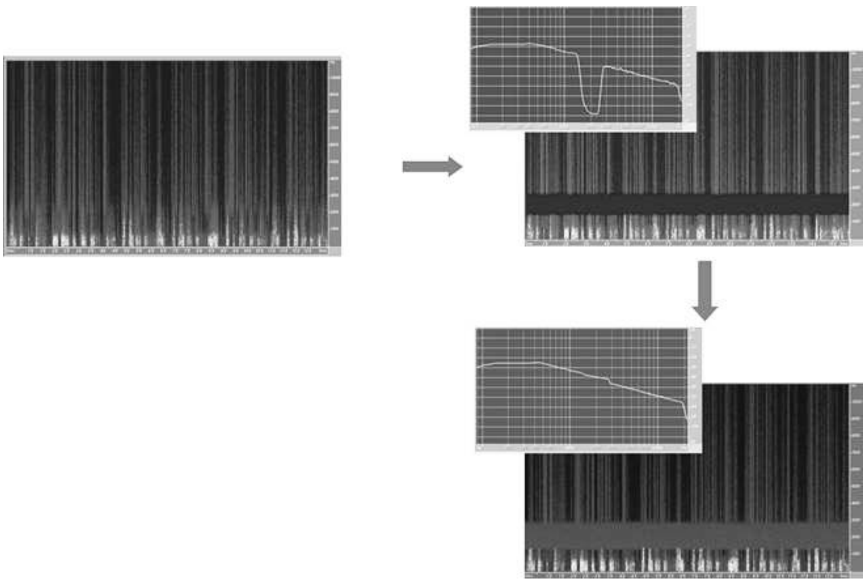

Figure 1. *Spectrogram of ICRA noise (top left). The ICRA noise was notch-filtered shown here with 1-oct wide notch centered around 2000 Hz (top right). The notch was filled with a steady state noise (bottom).*

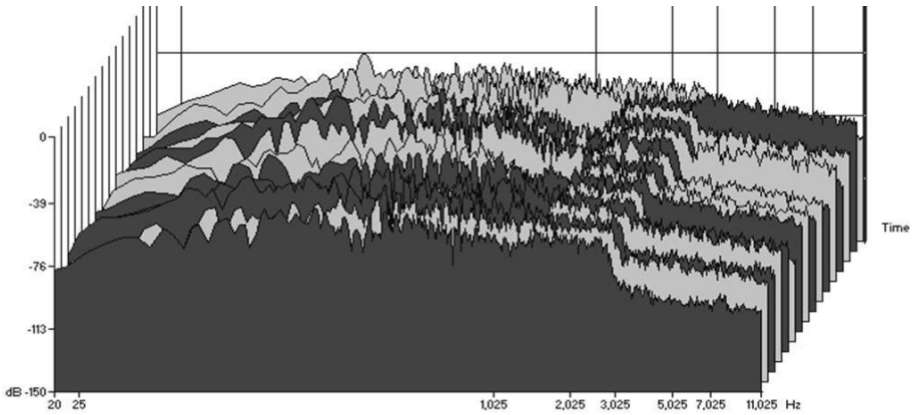

Figure 2*. Time slice spectrogram of the above stimulus. The x-axis represents frequency, y-axis amplitude, and on the z-axis are shown time (16 slices). The 1-oct narrowband steady state signal is embedded at 2000 Hz. Rest of the bandwidth is fluctuating*

Test procedure: The 20 stimuli were recorded on to a compact disc. Instrumentation for signal presentation included a Harman Kardon CD player connected to a GSI-61 clinical audiometer. The output was delivered in the sound field (10'x10' double walled booth) through a loudspeaker. The stimuli were calibrated to 65 dB SPL at the level of KEMAR's ears that was placed at one meter distance from the speaker. Each programmed hearing aid was mounted on KEMAR with a custom earmold and the output of the hearing aids were recorded with a Etymotic Research ER-11 amplifier with a half inch microphone coupled to a Knowles Electronics DB-100 Zwislocki coupler and digitized using a commercially available sound editing program. Special attention was given during the recording process to avoid peak clippings in the recorded samples. The volume setting on the sound card of the recording computer was set at a low level to avoid clipping.

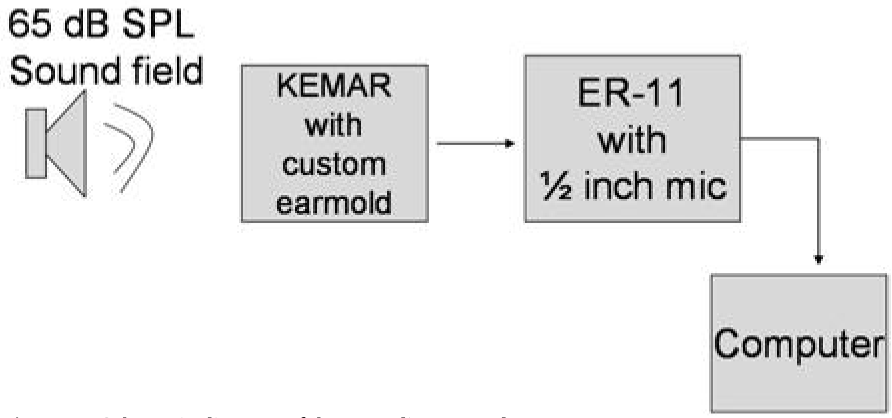

Figure 3. *Schematic diagram of the recording procedure*

Results

The response of the four hearing instruments to different stimuli is shown in figure 4. The left panel figures represent output of the hearings to steady state speech shaped noise at 65 dB SPL. As can be seen from the four left panels hearing aids from manufacturers 'A' and 'D' resulted in greater degree of noise reduction and faster attack times compared to those of manufacturers 'B' and 'C'. The average overall gain reduction in response to speech shaped steady state noise varied from as small as 2.5 dB (manufacturer C) to 13 dB (manufacturer D). The results obtained with the new proposed stimuli provide additional information on the degree of gain reduction at individual octave/mid-octave frequencies. Hearing aids from Manufacturer D resulted in the maximum gain reduction across all frequencies. While manufacturer A provided greater noise reduction at higher frequencies (>2000 Hz), manufacturer B provided greatest noise reduction at lower frequencies (<2000 Hz). Of the tested algorithms, the noise reduction from manufacturer C was comparatively least effective when tested with the proposed stimuli.

Discussion

The results of this study reveal some interesting aspects about digital noise reduction. While nearly every hearing aid manufacturer uses some form of temporal modulation detection at the core of their noise reduction algorithm, the four hearing aids tested so far in this study reveal a wide gap in the performance of the noise reduction algorithm.

The proposed stimuli can adequately assess the degree of noise reduction at different frequencies in multichannel noise reduction hearing aids. As can be seen in Fig 4, the four hearing aids are quite different in the frequency specific noise reduction. As more and more sophisticated noise reduction algorithms are launched, it is important that the performance data is available for the clinicians. Currently we are evaluating noise reduction algorithms from other manufacturers. As a continuation of this project we plan to study the sound quality of the tested noise reduction algorithms.

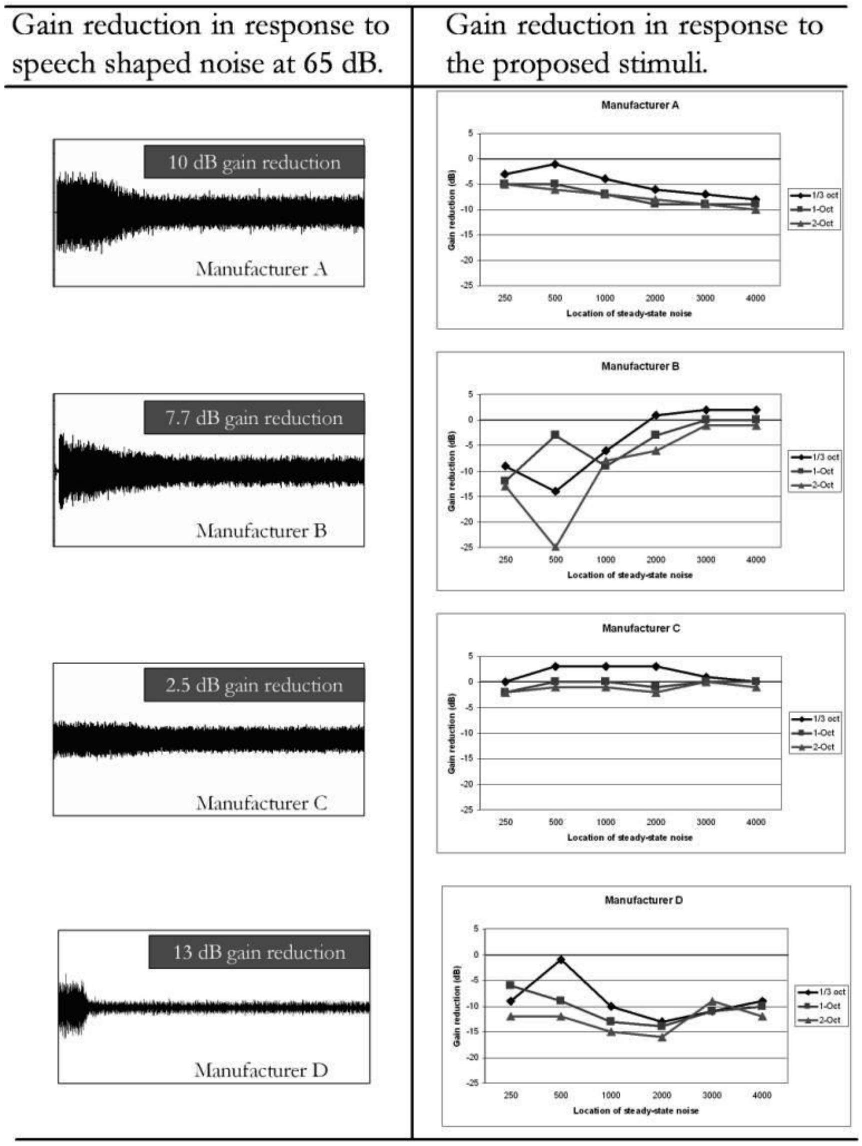

Figure 4*. Left panels show gain reduction in each hearing aid in response to speech shaped noise. The right panels show gain reduction in response to the proposed stimuli. The frequencies plotted on the x-axis represent the location where the steady state noise was embedded. Each line represents a different width of the steady state noise band. Greater negative values refer to more noise reduction.*

List of references

Bentler, RA., and Chiou, L. (2006). Digital Noise Reduction: An Overview. Trends in Amplification, 10(2), 67-82.

Dreschler, W.A., Verschuure, H., Ludvigsen, C., & Westermann, S. (2001). ICRA Noises: Artificial noise signals with speech-like spectral and temporal properties for hearing aid assessment. Audiology, 40, 148-157.

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