Perceptual Effects of Noise Reduction in Hearing Aids

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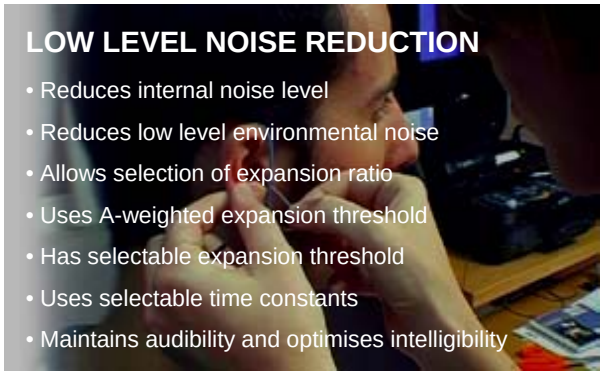

LOW LEVEL NOISE REDUCTION

- Reduces internal noise level
- Reduces low level environmental noise
- Allows selection of expansion ratio
- Uses A-weighted expansion threshold
- Has selectable expansion threshold
- Uses selectable time constants
- Maintains audibility and optimises intelligibility

INTRODUCTION

Hearing aids have several components that generate low levels of internal noise. The most bothersome noises are thermal noise in the microphone and pre-amplifier, and the quantization noise in the analog-to-digital converter (see Figure 1). These low-level noises at the input to the hearing aid are amplified to become higher-level noise at the output. Hearing aids can also amplify low level ambient sound to louder than normal levels. Noise reduction is designed to reduce the perceptual effects of these amplified sounds. This is done by reducing gain when low level noise is detected.

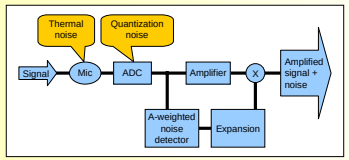

Figure 1. Hearing aid block diagram showing internal noise sources and low-level noise reduction.

THE PERCEPTUAL EFFECTS OF LOW LEVEL NOISE REDUCTION

Modern amplification schemes, such as multi-channel compression (Dillon, Ear & Hearing, 1996) and ADRO™ (Blamey, Martin & Fiket, JAAA, 2004) apply more gain to low level sounds than high level sounds. Higher gains improve audibility for soft sounds and intelligibility for soft speech. However, higher gains also increase the likelihood that listeners will hear the internal noise of the hearing aid. This study investigated the effects of noise reduction on intelligibility and noise intensity.

LOW LEVEL NOISE REDUCTION (LLNR) PROCESSING

The LLNR investigated was a single-channel expansion scheme that was activated when the input sound level dipped below the expansion threshold. An A-weighted filter shaped the sound spectrum prior to measuring its level, resulting in a threshold with constant loudness rather than constant intensity across frequency. The effects of different settings for expansion ratio and expansion threshold (in dB A) were investigated with hearing aid test box measures and listening experiments.

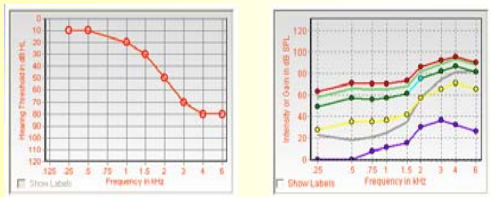

Figure 2: Audiogram and ADRO™ fitting used for the hearing aid test box measures. The fitting parameters are Maximum Output Level (red), Comfort Target (green), Audibility Target (yellow) and Maximum Gain (purple).

HEARING AID TEST BOX MEASURES

A BTE hearing aid was programmed with an ADRO™ fitting for a person with near-normal hearing in the low frequencies as shown in Figure 2. The Long Term Average Speech Spectrum (LTASS) was measured in the Audioscan Verifit VF-1 test box for speech levels from 55 to 75 dB SPL and a range of expansion ratios and thresholds. The Speech Intelligibility Index (SII) was calculated from the LTASS in each condition. The onset time for LLNR was fixed at 200 ms to avoid truncating the ends of soft speech sounds and the offset was set to 20 ms to avoid cutting off the onset of speech sounds.

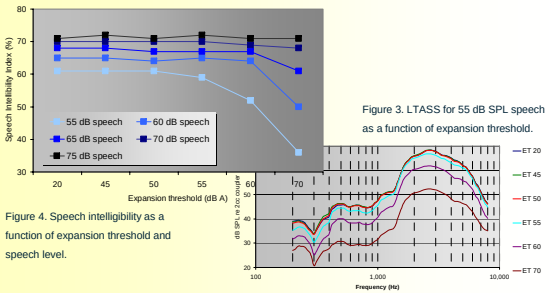

Figure 4. Speech intelligibility as a function of expansion threshold and speech level.

Figure 3. LTASS for 55 dB SPL speech as a function of expansion threshold.

EXPANSION THRESHOLD

Figure 3 shows measurements of the LTASS for a 55 dB SPL speech input with expansion thresholds of 20, 45, 50, 55, 60 and 70 dB A. The expansion ratio was 0.5. Figure 4 shows the SII values calculated from the LTASS measures for speech input levels of 55 to 75 dB SPL. The data show that the intelligibility of soft speech was not compromised by expansion thresholds up to 50 dB A. Thresholds up to 60 dB A can be used without compromising speech intelligibility at 60 dB SPL and above.

EXPANSION RATIO

Figure 5 shows the internal noise spectrum measured at the output of the hearing aid for three different expansion ratios. Figure 6 shows that output levels for soft speech were not affected by any of the expansion ratios. The measures were all made with the expansion threshold set to 45 dB A.

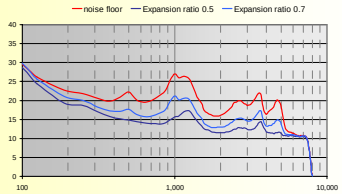

Figure 5. Internal noise spectra at the output of the hearing aid.

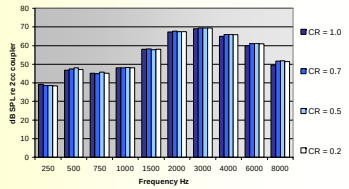

Figure 6. Output levels for amplified 55 dB speech input at selected frequencies and expansion ratios.

CONCLUSIONS

At the end of the study, listeners with normal and impaired hearing described the impact of noise reduction on the sound of the hearing aid. A threshold of 45 dB A significantly reduced the loudness of the internal noise. Most listeners preferred an expansion ratio of 0.7 more than 0.5 because greater modulation of the internal noise produced a noticeable “pumping” effect. Recommended settings are 0.7 for the expansion ratio and 45 dB A for the expansion threshold.

DYNAMIC HEARING