SOUND QUALITY ENHANCEMENT BY INCREASING THE DYNAMIC RANGE OF A HEARING AID

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INTRODUCTION

The overall sound quality of a hearing aid depends on a chain of components, all of which contribute to the sound quality a user will experience. The first component in this chain is the input stage of the hearing aid. Modern digital hearing aids convert analog audio signals into digital audio signals as soon as possible in order to apply a variety of digital signal processing algorithms to the audio signal. The input stage of the hearing aid should ensure a distortion free signal is passed along to the rest of the hearing aid for processing. If an audio signal is distorted while passing through the input stage of the hearing aid, the audio quality will be degraded before any advanced processing can be performed.

Analog to Digital Conversion

When designing the input stage of a hearing aid, it is important to have a high quality analog to digital converter (ADC). The ADC is one key factor in determining the dynamic range of the hearing aid. If this dynamic range is small, then the hearing aid will either not be able to reproduce soft sounds, or will be incapable of converting high input sounds without saturation distortions occurring. By increasing the dynamic range of an ADC, a hearing aid can faithfully reproduce soft sounds while still allowing loud sounds to be converted without saturation distortion.

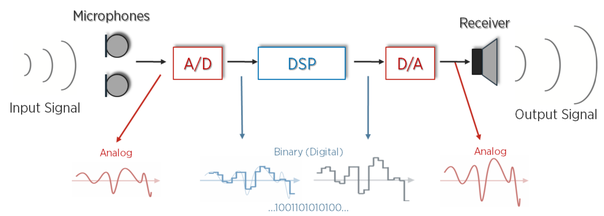

Figure 1. Basic diagram of the processing stages in a digital hearing aid. Acousic sound waves are picked up by the microphones and converted into an analog signal which is then converted to a digital signal for processing. The analog signal is converted to a digital signal by an analog to digital converter (ADC).

Saturation distortion in a hearing aid may occur when the input signal exceeds the upper limit of a hearing aid's ADC dynamic range. When saturation distortion occurs, hearing aid users may describe sounds as having a "crackling" or "raspy" sound quality. Since this distortion occurs in the front end of the hearing aid processing stage, the signal passed along to later hearing aid stages will be degraded. Once a signal has been clipped it is impossible to recover this degraded signal by further processing.

INTRODUCTION (cont.)

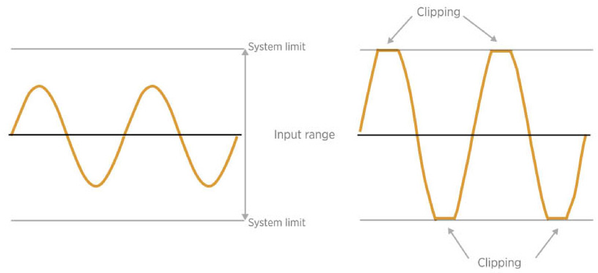

Figure 2. An analog signal without saturation distortion (left) and with saturation distortion (right). If the input signal exceeds the input limit of the ADC, the input signal will be "clipped".

Additionally, saturation distortion may limit the ability of a hearing aid to differentiate between speech signals and noise signals, thus advanced features such as noise reduction algorithms may be negatively impacted. Therefore, saturation distortion must be prevented from occuring if a high sound quality is desired.

METHODS

- Recordings were performed in sound field through KEMAR with two different micro sized behind the ear hearing aids.
- Hearing aid #1 was a modern wireless hearing aid with conventional ADC technology
- Hearing aid #2 was the Widex Dream hearing aid with an improved ADC and a higher maximum input level.

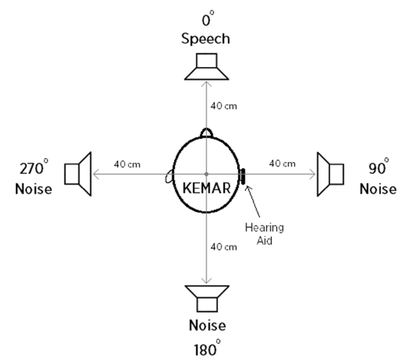

Figure 3. Recording setup for audio recordings comparing the two hearing aids with different ADC technologies. Speech signals were presented from 0 degrees. A speech weighted noise was presented from 90, 180, 270 degrees. The distance of each speaker from KEMAR was 40 cm.

METHODS (cont.)

- Speech weighted noise was presented at 90°, 180°, and 270° at a level of 106 dB SPL.
- Speech [NU-6 word lists] was presented from 0°. The speech was recorded through a hearing aid with two different signal to noise ratios: 0 dB SNR and +3 dB SNR.
- One set of recordings were with each hearing aid programmed with an omni directional microphone and no noise reduction.
- A second set of recordings were made with each hearing aid programmed with an adaptive directional microphone and noise reduction.

ANALYSIS

For the omni-directional, no noise reduction recordings, the hearing aid with the conventional ADC introduced audible distortion to the speech signal at both signal to noise ratios. The conventional ADC did not retain input information for loud levels and appeared to clip the input of loud level sounds compared with the Widex Dream hearing aid [see figures 4 and 5].

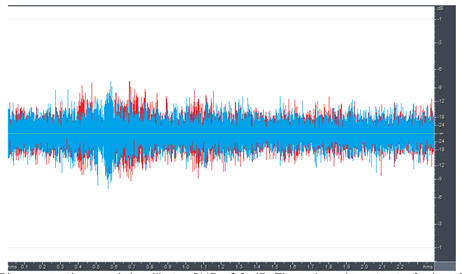

Figure 4. "Please say the word dead" at a SNR of 0 dB. Time-domain output of a hearing aid with a conventional ADC [blue] and a Widex Dream hearing aid [red]. Both hearing aids were programmed with an omni-directional microphone and noise reduction off.

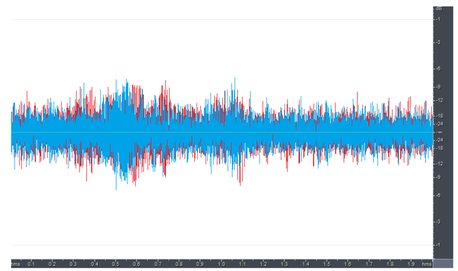

Figure 5. "Please say the word base" at a SNR of 3 dB. Time-domain output of a hearing aid with a conventional ADC [blue] and a Widex Dream hearing aid [red]. Both hearing aids were programmed with an omni-directional microhpone and noise reduction off.

ANALYSIS (Cont.)

For the adaptive directional, noise reduction recordings, the time-domain output signal of the conventional ADC appeared noisier compared with the Widex Dream hearing aid. The loud input portions of the speech signal were more faithfully reproduced by the Widex Dream hearing aid compared with the hearing aid with the conventional ADC.

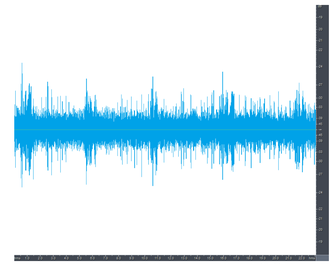

Figure 6. Time domain output of a hearing aid with a conventional ADC programmed with a an adaptive directional microphone and noise reduction at 0 SNR [speech and noise at 106 dB SPL]. NU-6 words from List 1A: "laud", "boat", "pool", "nag", "limb"

Figure 7. Time domain output of the Widex Dream hearing aid programmed with an adaptive directional microphone and noise reduction at 0 SNR [speech and noise at 106 dB SPL]. NU-6 words from List 1A: "laud", "boat", "pool", "nag", "limb"

CONCLUSIONS

Hearing aid users are likely to expereince significantly better sound quality as a result of a higher input dynamic range ADC. Saturation distortions are minimized which helps to retain the naturalness of the sound. Providing an undistorted signal to the digital signal processor of the hearing aid also may allow for the maximum potential of various signal processing algorithms such as noise reduction.

REFERENCES

Baekgaard, L// Knudsen, NO// Arshad, T// Andersen HP. 2013. Designing Hearing Aid Technology to Support Benefits in Demanding Situations, Part 1. Hear Rev, 20(3): 42-50.