# Using spectrograms to visualize frequency lowering systems in hearing aids

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Frequency lowering techniques are a way to improve the ability of the hearing impaired individual to obtain benefits from speech cues that would otherwise be distorted or even imperceptible using traditional amplification. In order to verify these new techniques, there needs to be methods to assess what they do either in situ or in a test box. For example, the Verifit REM system has a test signal where, for each stimulus, the 1/3 octave band levels above 1000 Hz are reduced by 30 dB, except for an isolated 1/3 octave band centered at the frequency indicated e.g. 4000 Hz. This allows testing of a frequency lowering system at specific target frequencies. Is there, however, another way to examine frequency lowering systems without using dedicated measurement signals? A series of measurements were made with a speech signal to generate spectrograms with the frequency lowering feature on and then off. Direct comparisons can then be made, using Matlab, between the two resulting graphs by generating a new spectrogram which can illustrate the differences between the two. This methodology was applied to gain matched hearing aids from four manufacturers with frequency lowering that are commercially available.

## Introduction

Frequency lowering systems are designed to provide high-frequency information to those who can no longer access it via conventional hearing aid technology. Frequency lowering is a general term for any system that moves high-frequency (HF) information to a lower frequency range. The implementation method can vary greatly between manufacturers.
For the clinician who wants to use frequency lowering, it is important to verify its effectiveness. Frequency lowering is designed to improve speech understanding; therefore, a speech test with HF emphasis would be useful, such as the California Consonant Test (Owen & Schubert, 1977) or a logotome speech test e.g. OLLO (Wesker et al., 2005).
Electroacoustic measures can also be used to test frequency lowering systems. Audioscan's Verifit provides filtered signals that are used to verify and adjust frequency lowering technology (Glista et al., 2009; Glista & Scollie, 2013; Kuk, 2013).
Another method of assessing frequency lowering systems is to calculate spectrograms (Kuk, 2013; McDermott, 2011). Although not readily available in the clinical setting, spectrograms are capable of showing the energy transfer over time that the other test methods cannot. The output of frequency lowering systems can be analyzed, which allows for comparisons between the various systems (McDermott, 2011).

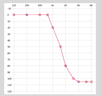
## Purpose

- Provide comparisons between a simulated real-ear measurement (S-REM) and the spectrogram
- Demonstrate a method to subtract spectrograms
- Demonstrate how four frequency lowering systems are functioning in real time

## Methods

Four commercially available BTEs
- 3 BTEs w/earhooks and 1 BTE RITE

Hearing Aid Settings:



- Occluded acoustics, NAL-NL2,
- Gain for 40dB HL flat audiogram
- Frequency lowering set using audiogram on left
- Adaptive features set to off

**Audioscan Verifit Measurements**
Software Version 3.10.2, S-REM Speechmap:
- Speech 6300 65 dB SPL (carrot phrase) freq. lowering off
- Speech 6300 65 dB SPL (carrot phrase) freq. lowering on

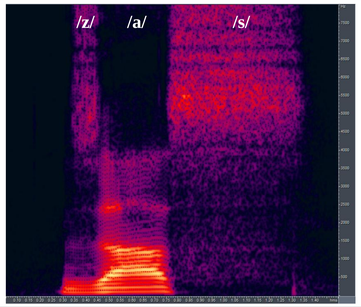
**Test System**
Measurements made using:
- Interacoustics TB S 50 pyramid,
- National Instruments PXI 1044 Board (NI) with analog I/O card with custom designed LabVIEW 2010 SP1 tool
- Signal played at 80 dB SPL

**Spectrogram Calculations**
- MATLAB Version: 7.14.0.739 (R2012a)
- Script available at: http://www.mathworks.ch/matlabcentral/fileexchange/40078-speccompare.

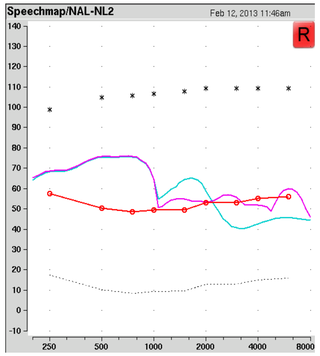
## Results

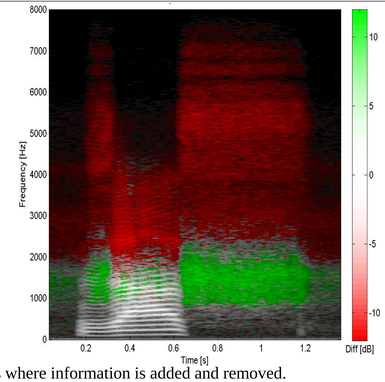
Original Signal, SASS, from the OLLO Corpus, Wesker et al. (2005)
Spectrogram generated with Adobe Audition 1.5.

- Figures, A, B, C, and D represent four different frequency lowering systems.
- Two measurements: S-REM with Verifit and Spectrogram
- Red area on spectrograms=acoustic information removed by frequency lowering.
- Green area on spectrograms=acoustic information added by frequency lowering.



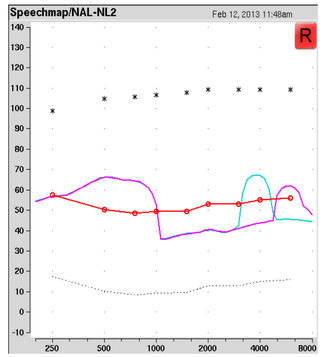

A

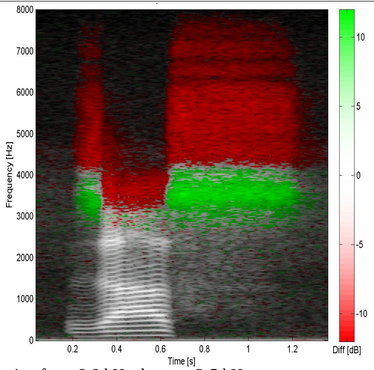



**Left Panel:** Verifit S-REM shows defined points where information is added and removed.
**Right Panel:** Spectrogram shows areas of overlap between added and removed information.

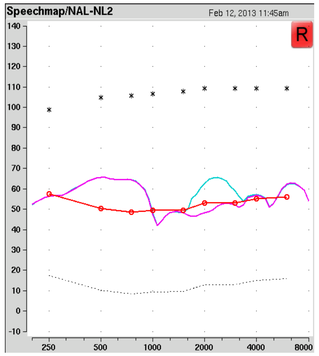
B

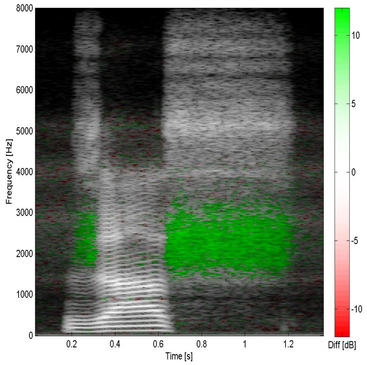



**Left Panel:** Verifit S-REM shows a shift of information from 6-8 kHz down to 3-5 kHz.
**Right Panel:** Spectrogram reveals additional missing information at 3-4 kHz as well.

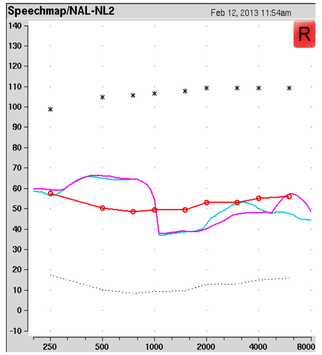
C

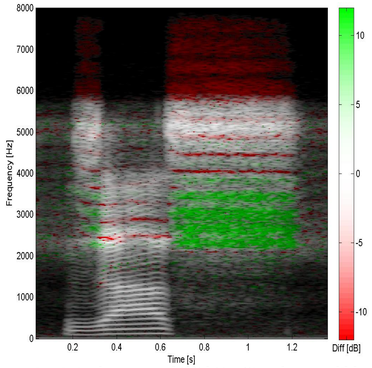



**Left Panel:** Verifit S-REM shows both signals overlap except where the added information is present.
**Right Panel:** Spectrogram confirms the added information and shows no removal of information from original signal.

D




**Left Panel:** Verifit S-REM shows the removed information is in the range of 6-8 kHz. Signal not audible.
**Right Panel:** Spectrogram shows additional missing bands of information starting at 2 kHz.

## Conclusions and Clinical Implications

In this investigation, spectrograms were subtracted to illustrate how frequency lowering systems function in real time. Given these results, it is necessary to look beyond the description that manufacturers offer clinicians and provide a more comprehensive guide for frequency lowering systems so that clinicians can make optimal decisions based on their fitting philosophy.

- Spectrograms with the subtraction method can show more relevant information.
- Subtracted spectrograms show missing information or artifacts with frequency lowering, which can provide important information to the clinician.
- Subtracted spectrograms are able to provide visual verification for the clinician in an easy to understand and quick to read format.

**References**

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