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Optimized Target Matching: Demonstration of an Adaptive Nonlinear DSP System

Victor H. Bray , Jr,.
Richard W. Harris
Jeannette S. Johnson

Abstract

An optimized hearing aid system should meet the requirements of linear and nonlinear prescriptions across multiple hearing loss configurations. Such a system would have multiple frequency-shaping bands, linear and nonlinear input/output functions, and adjustable compression ratios and kneepoints across multiple channels. This paper demonstrates a new DSP-based hearing aid that matches to target for multiple hearing loss configurations using both linear and nonlinear targets.

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INTRODUCTION

A fundamental concept of aural rehabilitation is that amplification must be tailored on a frequency–specific basis to meet the needs of the individual. From this concept came the linear prescriptions of *Berger*, *POGO*, and *NAL*. With the advent of multichannel hearing aids with wide dynamic range compression, the concept has been expanded to require that frequency-specific prescriptions should also specify level-dependent gain. The newer prescriptive recommendations, i.e., *DSL (i/o)*, *FIG6*, and *IHAFF*, all capitalize on the newer high technology hearing aids, recommending varying gain targets with respect to low, mid, and high input levels.

PROCEDURE

Target matching was used to challenge the flexibility of an in-the-canal (ITC) programmable hearing aid that incorporates the new **SONIC innovation**s Multiplicative DSP™ circuit. Hearing aid performance was measured at Brigham Young University using a Fonix 6500 hearing aid test system with HA-1 coupler. Four case study audiograms (see Figure 1) were selected from the textbook *Auditory Disorders* by Jerger & Jerger (1981)[1]. These audiograms represent typical low-frequency hearing impairment (Meniere's Disease), mid – frequency (trauma), sloping high-frequency (noise-induced), and ski-slope high frequency (ototoxicity) hearing losses.

The *NAL*[2] prescription for hearing aid gain was used to create linear targets for each of the four audiograms. *DSL (i/o)*[3] and *FIG6*[4] were employed to create nonlinear targets for the four representative audiograms. In all cases, the targets were 2cc coupler gain for ITCs utilizing average real-ear transfer functions. The *DSL (i/o)* software specifies targets for 50, 65, and 80 dB input levels. For comparison purposes, the *NAL* targets were calculated at the same input levels. The *FIG6* software specifies targets for 40, 65, and 95 dB input levels. To allow for pure-tone data collection with the Fonix system, the *FIG6* data were interpolated to transfer the 40 dB targets to a 50 dB level. The prescriptive targets and measured hearing aid performance are plotted in dB SPL in the HA-1 coupler.

RESULTS

Phenomenally tight matches to prescriptive targets are possible with a hearing aid having 9 programmable compression channels incorporating 9 frequency shaping bands. In this demonstration, most target points are matched to within 1 dB across the frequency range from 500 to 6000 Hz at input levels of 50, 65, 80, and 95 dB SPL.

SUMMARY

Given specific prescriptions for amplification are highly dependent upon the audiometric configuration, there is a distinct audiological need to design hearing aid systems that can meet the diverse requirements of linear and nonlinear prescriptions across multiple hearing loss configurations. An optimized system would have multiple frequency shaping channels, linear and nonlinear input/output functions, adjustable compression ratios, and adjustable compression kneepoints. This experiment demonstrates the power of the new **SONIC innovations** DSP-based hearing aid in readily matching to target for diverse hearing loss configurations using both linear and nonlinear prescriptions.

For a greater understanding of the Multiplicative DSP technology, please see the companion paper "Digital Signal Processing (DSP) Derived from a Nonlinear Auditory Model" by Bray, Chabries, Davis, and Johnson (1998)[5].

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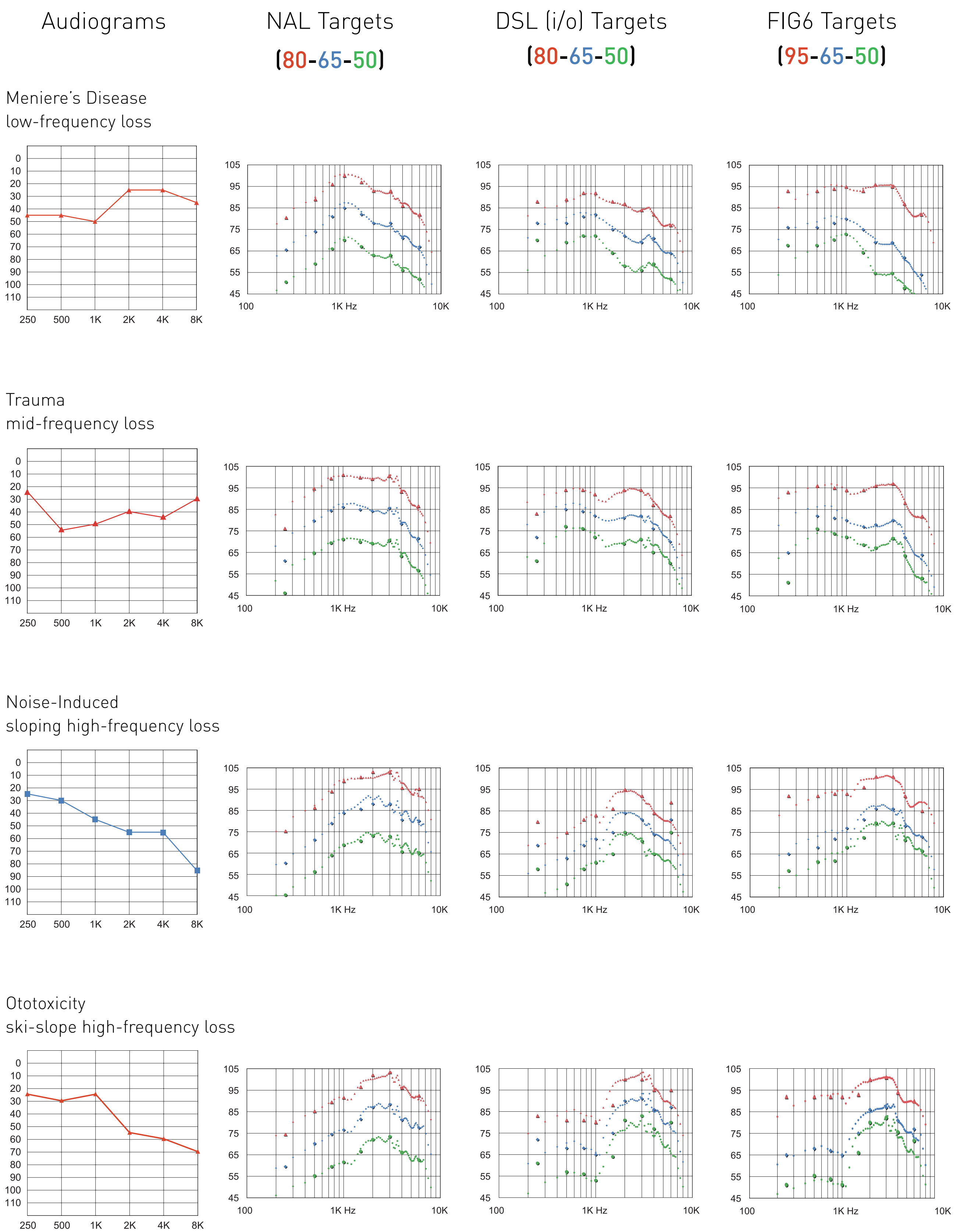
Audiograms
NAL Targets
(80-65-50)
DSL (i/o) Targets
(80-65-50)
FIG6 Targets
(95-65-50)
Meniere's Disease
low-frequency loss
Trauma
mid-frequency loss
Noise-Induced
sloping high-frequency loss
Ototoxicity
ski-slope high-frequency loss
250 500 1K 2K 4K 8K
100 1K Hz 10K

Figure 1

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