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Bench-top SNR Testing of Open vs. Occluded Fittings

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Abstract

The Noise Reduction Index (NRI) is a bench-top estimate of the signal-to-noise ratio (SNR) change of a mixed signal (target plus masker) through an audio system. The NRI makes use of multiple recordings obtained in a test environment consisting of a two-dimensionally-diffuse noise field with target signals presented from 0° azimuth. It has been used to characterize and quantify the SNR change of conventional hearing aids as well as advanced features such as directionality and noise reduction algorithms. In the present study the NRI was measured on an open-ear hearing aid in both a sealed coupler (reference configuration) and an open-type fitting in order to assess the impact on changes to SNR from leakage through an open-tip fitting. Measurements were obtained in an unobstructed sound field and on a KEMAR. It is hypothesized that the low-frequency effects of an open fitting will reduce any SNR advantages the signal processing may introduce in the sealed coupler. Data will be presented showing how much of the change in SNR achieved in the coupler remains in the open-tip condition.

INTRODUCTION

This study looked at the impact of an 'open-tip' fitting relative to the same fitting in an occluded configuration (the reference configuration) in an unobstructed sound field (on a stick), and on a KEMAR with both open (medium dome-tip, Figure 1a) and more occluding ('tulip' tip, Figure 1b) configurations in order to reflect use conditions. The NRI was used to directly evaluate the change in SNR effected by the device under test (DUT) in the various test conditions and with various features enabled.

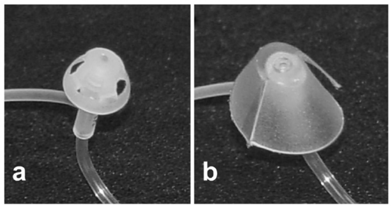

Figure 1

The test devices were two Sonic Innovations Ion open-fit hearing aids with identical programming. Ion hearing aids can be programmed with any combination of omnidirectional, fixed directional, or adaptive (DIRECTIONALfocusTM) directional microphones and digital noise reduction. Combinations of these features were chosen to reflect their incremental benefit and how the fitting configurations may affect that benefit.

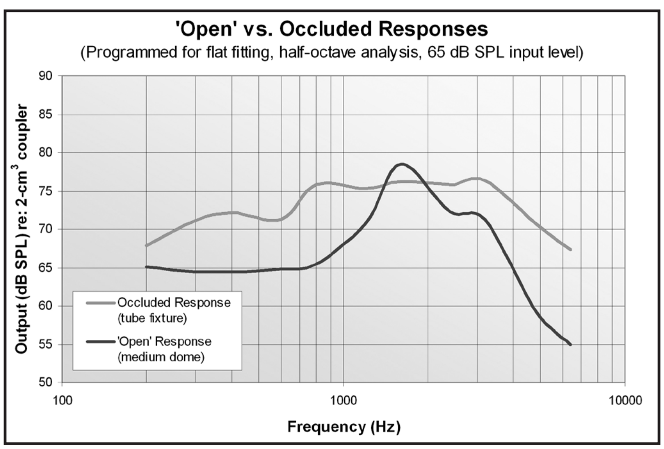

Figure 2

Test fittings were verified in a sealed 2-cm^3 coupler to deliver about 12 dB of linear gain programmed for a relatively flat frequency response. The dome-tip 'open' fittings were verified with ½-octave analysis, comparing frequency response differences between the 'open' and occluded fittings (Figure 2).

METHODS

All measurements were obtained in a two-dimensionally-diffuse (2DD) sound field[1,2] with the devices mounted on a stick as well as worn by a KEMAR. Measurements were averaged across the two hearing aids. KEMAR measurements were made using an ER-11 ½-inch microphone/preamplifier system coupled to a Zwislocki occluded ear simulator mounted on the right ear (Figure 3), with the manikin's head centered in the sound field. Stick measurements were made using a 2-cm^3 coupler and B&K 4144 1-inch microphone. Audio signals were sent to a sound card on a Windows-based computer running Adobe Audition (ver. 1.5) for recording. This same software was used to edit and process the recordings, and calculate the NRI.

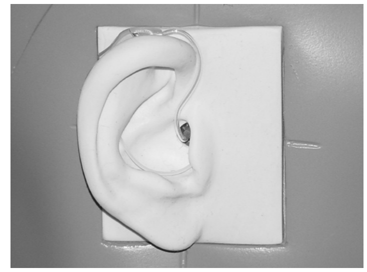
Figure 3

The NRI is obtained by simultaneously delivering a speech signal (concatenated HINT[3] sentences) and noise (four uncorrelated sources of HINT masking noise) into a 2DD sound field per Figure 4, calibrated to achieve 65 dB SPL with a 0 dB SNR. Two recordings of this mixed signal are made through the DUT, one with the noise signals 180° out of phase. The sum/2 and difference/2 of the two recordings yield, respectively, estimates of the average rms power of the speech and noise remaining in the mixed signal at the output of the DUT. The difference between these two estimates is the NRI. More detail about the derivation and use of the NRI have been described previously[4,5].

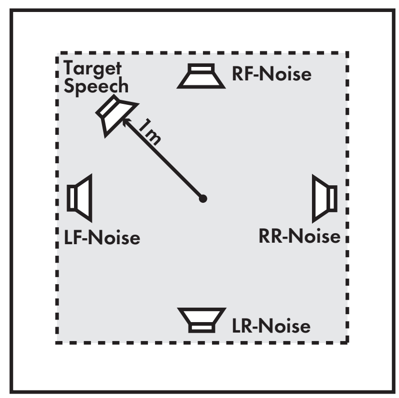

Figure 4

RESULTS

Unobstructed Sound Field vs. KEMAR: The unaided KEMAR introduces an NRI degradation of -2.3 dB in this test environment by virtue of the head, torso, and pinna interacting with the spatial orientation of the target speech (0° azimuth) relative to the noise, with energy arriving from all azimuths, especially from the side where no shadow is created. This finding is consistent with data reported by Shaw[6] and Burkhard & Sachs[7]. When the KEMAR is aided with an over-the-ear hearing aid, additional degradation to the NRI is realized due to the position of the microphone.

Figure 5 depicts the impact of the KEMAR on aided measurements, relative to the unobstructed sound field, collapsed across programmed features (transducer selection

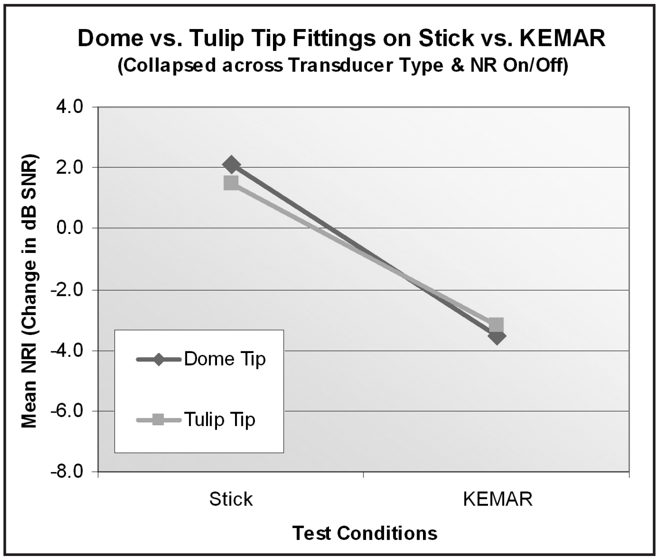

Figure 5

and digital noise reduction on and off). The NRI goes from a positive value of about 2 dB when measured in the unobstructed sound field to as low as -3.5 dB when measured on the KEMAR (higher NRI values are better). The KEMAR accounts for over 40% of the 5.5 dB SNR degradation measured in this test environment. The balance is due to disturbances introduced by microphone placement.

Dome Tip vs. Tulip Tip and Impact on Features: NRI measurements made on the stick are valid and informative, but they do not yield data that are typical of what would be obtained in real-world use. Therefore, knowing the impact of the head, torso, and pinna on NRI measurements in this test environment, the measurements were repeated on the KEMAR with the dome and tulip tips, representing the typical 'open' and more occluding fittings, respectively.

Figure 6 demonstrates that, as expected, the NRI appears to be better for the tulip tip relative to the dome tip, but the difference is only about 1 dB regardless of which combination

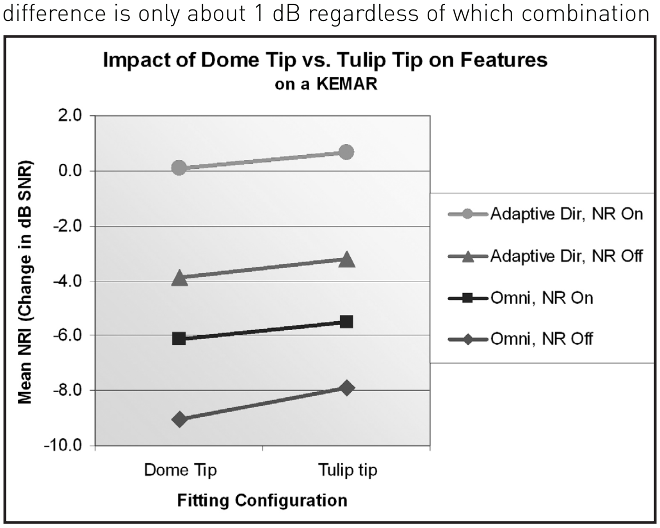

Figure 6

of hearing aid features are enabled.

A consistent improvement in the NRI is apparent as features designed to improve SNR performance are enabled. Adding digital noise reduction to the omni-directional microphone improves SNR performance (i.e., increases the NRI) in both the dome-tip and tulip-tip configurations by over 2 dB. With digital noise reduction disabled, the adaptive directional microphone alone improves the SNR by about 5 dB over the omni-directional condition, and when digital noise reduction is used in conjunction with the adaptive directional system—the typical settings for Ion fittings—the SNR improvement approaches 8.5 dB.

CONCLUSIONS

Regardless of the fitting configuration or which hearing aid features are enabled, NRI values are lower when measured on a KEMAR than when measured in an unobstructed sound field in this test environment.

The unaided KEMAR degrades the NRI by 2.3 dB while microphone placement on the aided KEMAR appears to account for an additional 3 dB or more of degradation.

Opening the ear canal to the environment by using a dome tip in place of a tulip tip degrades the NRI by only about 1 dB regardless of which combinations of digital noise reduction and adaptive directional microphones are enabled.

Digital noise reduction and directional microphones used together are required in order to restore the NRI to a positive value when an 'open-fit' over-the-ear hearing aid is worn on the head.

The benefit from digital noise reduction and directional microphones in the Ion hearing aids is additive, even with 'open' fittings.

The NRI in the present test environment is a rigorous and sensitive tool for characterizing the SNR-changing behavior of an audio system with a variety of signal processing features enabled.

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