COMPARISON OF THREE RECD MEASUREMENT SYSTEMS

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INTRODUCTION

Real-Ear to Coupler Difference (RECD) is an acoustic transfer function that describes the difference between sound pressure level (SPL) measured at 2cm^2 coupler and in the ear canal. The measured RECD transfer function has been shown to depend on the RECD transducer used for the measurement (Munro & Toal, 2005). To address this, Widex has developed an in-situ RECD measurement method, which uses the hearing aid's own receiver and microphone combined with the user's own earmold. The method was designed to simplify the RECD measurement for the clinician and to improve the accuracy of the RECD for output prediction. Also, with the application of the calibration measurement, the variability in sensitivity among receivers of the same type is eliminated.

The current study compared RECD transfer functions measured with the in-situ method with the RECDs measured with two commercially available probe microphone systems, which include a RECD measurement protocol. In addition to the insert earphone method, RECD transfer functions were also measured using the hearing aid's own receiver as the transducer following the recommendations from the manufacturers.

ACOUSTIC IMPEDANCE AND RECD

The RECD depends not only on the differences between the acoustic characteristics of the coupler and the individual ear canal, but also on the acoustic characteristics of the source and the coupling system used for the measurement. The RECD transfer function can be described as a function of acoustic impedances of the ear (Z_e), the coupler (Z_c), and the combined acoustic impedance of the source and the coupling system (Z_s) which may include the earphone, the HA receiver, the earhook, and/or tubing.

$$RECD(\omega) = \frac{Z_E(\omega)}{Z_C(\omega)} \cdot \frac{(Z_S(\omega) + Z_C(\omega))}{(Z_S(\omega) + Z_E(\omega))}$$

The acoustic impedance of a source coupling system is typically comparable in magnitude to the impedances of the ear and coupler, and therefore cannot be eliminated from the equation. The implication of this is that for the most appropriate RECD derivation we need to use the same source and coupling mechanism Z_s in the evaluation of the real-ear response and the coupler response. The error in the RECD transfer functions measured with insert earphones compared to using a hearing aid's own transducer has been shown to be as much as 10 dB (Munro & Toal, 2005).

WIDEX IN-SITU RECD

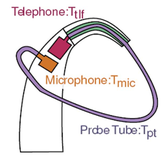

Figure 1: Calibration to coupler reference setup.

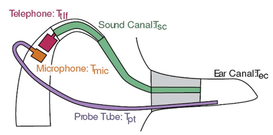

Figure 2: Real-ear measurement setup.

1) The coupler portion is measured indirectly by calibrating the system in reference to the 2cm^2 coupler response measured at the factory. This will account for the variances in the receiver sensitivities among receivers of the same model (Figure 1).

2) The real-ear portion is carried out using a probe-tube kit attached over the microphone of the hearing aid (Figure 2). The fitting software calculates automatically the RECD transfer function where differences in the receiver and the level microphone sensitivities between the devices are removed from the measurements.

METHODS

Subjects

- 6 normal hearing subjects (total of 12 ears).
- 4 males, 2 females.
- Probe insertion depths: 28-29 mm (female), and 30-33 mm (male).
- All measurements carried out using both foam tips, and personal earmolds.

Hearing instrument

- Widex Mind440-9 BTE:
  - ◇ 40 dB flat hearing loss
  - ◇ Linear gain settings
  - ◇ Omni directional microphone
  - ◇ No noise reduction

Three RECD systems

	Widex in-situ RECD	Frye FONIX 6500-CX	Audioscan VERIFIT
Transducer	Hearing aid's own receiver	Insert earphone	Insert earphone
Microphone	Hearing aid's own microphone	Dedicated probe microphone	Dedicated coupler microphone, separate probe microphone
Coupler type	HA-2	HA-1 (or HA-2)	HA-2

RESULTS, STANDARD METHODS

Widex in-situ RECD

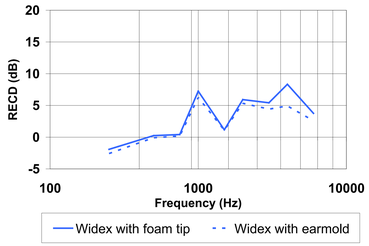

Figure 3: RECD measured with Widex in-situ RECD.

Widex in-situ RECD had a frequency dip at 1500 Hz unlike the typical RECD measured with the insert earphone method. This is characteristic to a RECD measured with a HA-2 coupler and using the hearing instrument as the transducer. In this case the tubing and the ear hook resonances contribute peaks and dips between 1 and 2 kHz. Results with the foam tip and the custom ear mold were within 3 dB.

Audioscan VERIFIT

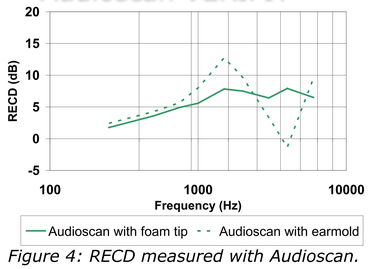

Figure 4: RECD measured with Audioscan.

Audioscan VERIFIT uses insert earphones to deliver the test signal. RECD measured with foam inserts is gradually rising without dips and is similar to the typically reported RECD. Measurement with the custom earmold included the subjects' individual tubing which introduced the effects of tubing resonance to the measured RECD transfer function.

Frye 6500-CX

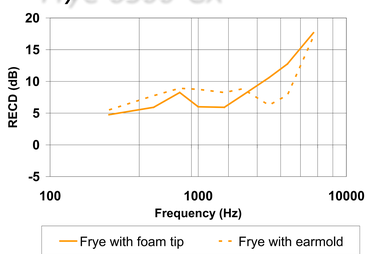

Figure 5: RECD measured with Frye .

Frye 6500-CX measures the RECD with insert earphones using a HA-1 coupler. These results were similar to a "text-book" RECD particularly when using a foam insert earphone. The average RECD ranged from 5 dB at low frequenices to approximately 17 dB at 6000 Hz (just a 2 dB difference from the Sachs & Burkhard (1972) data).

The three methods yield different RECD transfer functions when measurements were performed following the manufacturers' protocols. The differences can be attributed to differences in measurement transducers and the differences in the coupler types (HA-1 or HA-2). To obtain the most appropriate RECD measurement, the use of the subject's hearing instument as the transducer has been suggested (Munro & Toal, 2005).

HEARING AID AS A TRANSDUCER

All three systems

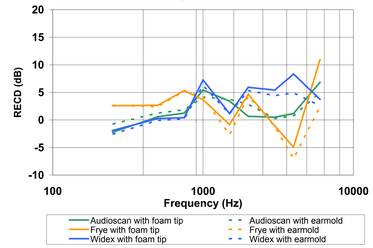

Figure 6: RECD transfer functions measured with hearing aid as a transducer.

The RECD tranfer functions measured with the three systems are closer to each other when measurements are carried out using the hearing aid's own receiver as the transducer (Figure 6). With the probe microphone systems this requires delivering the test signal using an external loud speaker in the sound field. The signal is controlled with use of a reference microphone located near the hearing aid's microphone. The difference between the reference microphone and hearing aid location creates an error.

CONCLUSIONS

All three systems compared in the current study yielded different RECD measurements when following the manufacturers protocols. The differences were as much as 10-15 dB depending on the test frequency and the system. As a consequence, RECD transfer functions measured with different systems are not interchangeable: RECD transfer function measured with one system cannot be used to derive the real-ear performance using another system.

Using the hearing aid to deliver the test signal is believed to be the most appropriate way to measure the RECD. The differences in RECDs in the current study were smaller when using the hearing instrument as a transducer to deliver the test signal. Each hearing instrument results in slightly different RECD transfer functions due to variability in transducer sensitivities among the different hearing aids of the same type. This effect has been taken into account in the Widex in-situ RECD calibration.

REFERENCES

Munro, KJ, Toal, S. (2005). Measuring the Real-Ear to Coupler Difference Transfer Function With an Insert Earphone and a Hearing Instrument: Are They the Same?, *Ear Hear*, 26:27-34.

Sachs, R. M., Burkhard, M. D. (1972). Earphone pressure response in ears and couplers. Project 20021 for Knowles Electronics Inc. Report No. 20021-2.