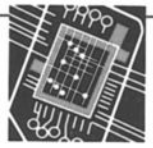
▶ **TECHNOLOGY**

Real-Ear Probe-Microphone Measurements Revisited

A Brief Tutorial on Fundamental Real-Ear Measurements

By Lawrence J. Revit, MA

Real-ear measurements can increase the professionalism of all hearing healthcare specialists and greatly assist them in serving the consumer. Through relatively simple steps, the dispenser can "pre-fit" a hearing instrument to the customer for a more accurate initial fitting and, ultimately, final adjustment. This adds greatly to service, value and image.



It has been a decade since the introduction of the first commercial probe-microphone equipment.[1] Today, the Real-Ear Insertion-gain Response (REIR) is widely accepted as the "measurement of choice" for state-of-the-art hearing aid fittings. Because hearing aids themselves have changed so much in the last decade, it may be a good time to revisit the why's and wherefore's of this useful fitting tool to re-discover its proper applications, advantages and limitations.

The "real-ear insertion-gain response" is a measure of the *increase in the sound level in the ear canal*, accomplished by the act of inserting a hearing aid.

Traditional Uses of the REIR

Measurement of the REIR provides a streamlined improvement to the time-consuming clinical measurement of "functional gain." Functional gain is the difference between hearing thresholds, with and without a hearing aid. Studies have confirmed that insertion gain and functional gain are essentially equivalent.[2] Therefore, if you know the client's unaided soundfield thresholds, you can subtract the insertion gain to estimate the client's aided soundfield thresholds.

This simple relation provides the basis of many popular prescriptive real-ear fitting formulas, such as NAL[3] and POGO.[4] When properly applied, these formulas (whose calculations are done automatically in real-ear measurement equipment) provide a *clinically validated starting point* for assessing the correctness of a fitting.

Larry Revit is senior applications scientist at Etymonic Design, Inc. (Audioscan Division), Dorchester, Ontario, Canada. With a lifelong interest in sound, he holds a BM in music and a MA in audiology.

Using the Prescriptive, Real-Ear Insertion-Gain Approach For Fitting

Step One: The dispenser enters the client's audiogram into the real-ear measurement (REM) system. The REM system automatically calculates a real-ear insertion-gain prescription, based on the entered audiogram and a fitting formula. This prescription is called the "Target REIR." Because hearing aid manufacturers use the 2 cc-coupler response (not the REIR) to design, build and test a hearing aid, the Target REIR must be converted to a Target 2 cc coupler response before the hearing aid can be manufactured. This step can be left to the manufacturer or it can be done in the dispenser's office using the software of the REM system.

Step Two: The hearing aid is ordered by sending the Target 2 cc response and other ordering information to the manufacturer, along with a request that the manufacturer match the Target 2 cc response as closely as possible. Some dispensers[5] believe the audiogram should also be sent with the order, so the manufacturer can modify the prescription based on their extensive experience in

matching audiograms to hearing aids.

Step Three: When the hearing aid arrives, the dispenser checks the delivered instrument in the 2 cc coupler, using the sound chamber that is usually part of the REM system. This pre-fitting hearing aid check serves two purposes: 1) The dispenser can verify the electroacoustic function of the instrument against ANSI standard specifications[6]—basically to see that the instrument is working properly. This step is very easy because most REM systems have automated ANSI test sequences; 2) If the dispenser has created a Target 2 cc prescription (as in Step One), the dispenser can now make pre-fitting adjustments to optimize the trimmer or program settings of the instrument before the client is called for the fitting. This can improve the chances of a successful fit the first time the client tries on the new instrument.

Step Four: Now, the client is called in for the fitting. The dispenser re-enters the client's audiogram into the REM system. The REM system re-calculates the real-ear insertion-gain prescription and displays the target curve on the screen. Unaided and aided real-ear responses are measured (taking only a minute or two), and the REM system displays the resulting insertion-gain response on the screen. Because both the target and the measured real-ear curves are displayed, it's easy to adjust the hearing aid controls or make tubing and venting changes for the best match to the target. Many dispensers also test the real-ear *saturation* response at this time (which, for the sake of brevity, must be left for another discussion).

Having now accomplished the initial fitting of the hearing aid, the dispenser can talk with the client regarding the subjective impressions of the sound of the aid. Final adjustments can then be made. Before concluding the fitting session, it's a good idea to run an additional ANSI 2 cc coupler test with the final settings to check that the noise and distortion of the aid have not been adversely affected by any of the adjustments made during the fitting.[7]

Limitations of Using REIR

As mentioned earlier, prescriptive fitting formulas in use today are based on functional gain and on the equivalence of functional gain to insertion gain. This equivalence is accurate only for linear hearing aids, whose gain remains the same for any input signal. With many of today's signal-processing hearing aids, the gain changes with differing input signals. Because functional gain and insertion gain use different test signals, the equivalence of the two measures can break down.

So how does the dispenser apply prescriptive formulas to fitting signal-processing aids? The best approach, for right now, is to use a low signal level for testing the real-ear insertion gain response; a low signal level keeps the signal processing in the hearing aid to a minimum, thus minimizing the possibility of error. Many dispensers have been successful using a 50 or 60 dB SPL signal for testing the REIR with signal-processing instruments. Researchers are currently working out new fitting protocols geared toward

such instruments.[8] Once the new protocols are validated, most REM systems can be updated with new programming.

Some Novel Uses of REIR

The REIR can assist in estimating aided speech audibility. Recall that aided soundfield thresholds can be estimated from unaided soundfield thresholds by subtracting the insertion gain. This estimate of aided soundfield thresholds allows calculation of the Articulation Index (AI), which is an assessment of speech audibility. Some REM systems automatically estimate aided thresholds and calculate the aided AI. Also, the easy-to-use, "count-the-dots" AI form sheets are available for manual calculation of the aided AI.[9] However, keep in mind that accurate calculation of the AI requires an actual measurement of soundfield thresholds, so the estimates provided by REM systems and count-the-dots methods have some margin of error. These methods, nonetheless, give the dispenser a useful tool for counselling the client on the potential effectiveness of a hearing aid for improving speech audibility.

Another novel use of the REIR is estimating where a hearing aid places signals within the "auditory area." The auditory area is the range of sound levels between threshold and discomfort.[10] If a sound is either below threshold or above discomfort, a person cannot very well use that sound. Yet, if a sound lies between threshold and discomfort, that sound is accessible to the listener. Some REM systems already provide estimates (based on an REIR measurement) of where amplified speech falls relative to the auditory area.[11] This approach will likely be the basis of future protocols for fitting signal-processing instruments.

Adding Service and Value

A fact of life today is that *all* dispensers and consumers have a heightened awareness of the need for professionalism in the marketing of hearing aids. The use of REM can help to increase both the perceived and the effective professionalism of the dispenser. Increased professionalism can, in turn, lead to improved customer confidence and, hopefully, to an increase in both hearing aid sales and hearing aid benefit. ◆

References

1. Nielsen H and Rasmussen S. New aspects in hearing aid fittings. *Hear Instrum* 1984; 35: 18-21.
2. Dillon H and Murray N. Accuracy of twelve methods for estimating the real ear gain of hearing aids. *Ear and Hear* 1987; 8: 2-11.
3. Byrne D and Dillon H. The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid. *Ear and Hear* 1986; 7: 257-265.
4. McCandless G and Lyregaard P. Prescription of gain/output (POGO) for hearing aids. *Hear Instrum* 1983; 34: 16-21.
5. Leadbitter EM and Bonta R. Fitting matrixes put dispensers in control, reduce returns. *Hear Instrum* 1993; 44 (12): 11-12.
6. American National Standards Institute. *Specification of Hearing Aid Characteristics.* ANSI S3.22-1987. New York: American Standards Institute, Inc.
7. Fabry DA. *Recent Advances in Hearing Aid Design: Clinical Implications.* Short course presented at 40th annual state conference of California Speech-Language-Hearing Assn., San Francisco, 1992.
8. Van Vliet D. Fitting forum: Overcoming distorted signal processing. *Hear Instrum* 1993; 44 (10): 10.
9. Pavlovic C. Speech recognition and five articulation indexes. *Hear Instrum* 1991; 42: 20-24
10. Skinner M. *Hearing Aid Evaluation.* Englewood Cliffs, NJ: Prentice-Hall, 1988.
11. Cole W. REM: A multi-purpose tool for fitting, selling and ordering. *Hear Instrum* 1993; 44 (7): 9-11.