Procedure for Predicting Real-Ear Hearing Aid Performance in Young Children

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Direct measures of real-ear hearing aid performance with children are now obtainable using probe-tube microphone systems. Potentially, these systems can significantly reduce both the time and the degree of cooperation required from the child during the hearing aid fitting process. However, there are several problems in using probe-tube microphone systems with young children. One particular concern is that valid, reliable probe-tube microphone measurements cannot easily be obtained with many infants and young children, for several reasons. Many young children are unable or unwilling to remain sufficiently still for these measurements, and some children spontaneously vocalize during the measurement process. Excessive movement and vocalization compromise the validity of the test results. Further, some young children simply will not accept for an extended period the head-worn instrumentation associated with current probe-tube microphone systems. So there is a need to develop an alternative to conventional probe-tube microphone measurements for certain segments of this population.

It is difficult to know beforehand how a given hearing aid with customized earmold coupling will perform when fitted to a young child. The electroacoustic characteristics measured in a 2 cc coupler do not accurately reflect several factors that are known to affect real-ear hearing aid performance. These factors include the acoustic impedance properties of the child’s ear, the residual ear canal volume with an earmold in place, head diffraction/microphone location effects, and acoustic leakage of amplified sound from the occluded ear canal. For this reason, probe-tube microphone measurements of real-ear hearing aid performance should be obtained with children whenever possible (Stelmachowicz & Seewald, 1991). If such measures cannot be made, however, it is still necessary to predict, by some means, how the hearing aid will perform when fitted to the child.

To account for performance differences between couplers and real ears, one approach is to apply a set of average real-ear to coupler transformation values from samples of adult listeners (Bentler & Pavlovic, 1989; Hawkins, Cooper, & Thompson, 1990; Sachs & Burkhard, 1972). With this approach, average real-ear to coupler difference (RECD) values are used to predict real-ear hearing aid performance from the results of coupler-based measurements. Unfortunately, in young children the differences between the absolute sound pressure levels (SPLs) measured in the real ear and the 2 cc coupler typically exceed the average RECD values reported for adults (Feigin, Kopun, Stelmachowicz, & Gorga, 1989; Nelson Barlow, Auslander, Rines, & Stelmachowicz, 1988). In addition, the RECDs that have been measured for preschool children vary as a function of age (Feigin et al., 1989). Thus, the average transformations and corrections that are applied in fitting amplification with adult listeners are of limited use with young children.

Over the years, several procedures for developing individualized predictions of real-ear hearing aid output have been reported (e.g., Seewald, Ross, & Spiro, 1985; Skinner, Pascoe, Miller, & Popelka, 1982; Sullivan, 1987). Sullivan, for example, proposed that the differences in dB between the 2 cc coupler gain and the real-ear aided response (REAR) could be used to predict the real-ear output-limiting characteristic of a given hearing aid/earmold coupling configuration for a specific listener. This requires a valid field measurement of the REAR, which is not always possible with infants and young children.

Recently, Fikret-Pasa and Revit (1992) described a procedure for measuring RECDs in adults that can be used in prescribing custom in-the-ear (ITE) and in-the-canal (ITC) instruments. The procedure uses an insert earphone in combination with a probe-tube microphone system to define a listener’s real-ear to 2 cc coupler transformation. Use of an insert earphone eliminates the variability associated with sound field probe-tube microphone measurements.

Fitting and verifying hearing aids for infants...
and young children might use a similar approach. Specifically, if an efficient and valid measurement of the real-ear to coupler transformation can be obtained for an individual child, it should be possible to predict, with a reasonable degree of accuracy, how a hearing aid will perform when fitted to the child. One primary advantage of such an approach would be that once the RECD transformation has been measured, all subsequent electroacoustic response shaping could be performed in a 2 cc coupler, which would substantially reduce the time and degree of cooperation required from the child during the fitting process.

This report describes an RECD measurement procedure for use in fitting hearing aids in infants and young children. Sample data illustrate how the results of the RECD procedure are used and demonstrate the potential application of this procedure in pediatric hearing aid fitting.

**Procedure for Measuring the Real-Ear to Coupler Difference**

The procedure described here uses the FONIX 6500 electroacoustic analysis system, with probe-tube microphone option, in combination with an EAR-Tone"™ 3A insert earphone, but can be implemented, with some modification, using alternative clinical instrumentation systems. The Appendix provides RECD measurement protocols for the Rasronics portarem (PR20) and Madson IGO 1000 Insertion Gain Optimizer systems.

To measure the RECD using the FONIX 6500 system, select the following operational parameters:

- Manual
- Composite noise
- Signal level: 50 dB SPL
- Smoothing: Log
- Output limiting: 120 dB SPL

Data conversion: Insertion gain
Reference microphone: Disabled
Response measured: Gain
Noise reduction: 16 X

Once the software has been appropriately configured, the insert earphone is connected to the loudspeaker output terminal with a 1/4" to 1/8" phone plug. For the RECD measurement, the FONIX 6500 real-ear measurement system remains in an unlevelled condition. This is because the probe-tube microphone system is being used to measure the relative difference between the levels measured in the 2 cc coupler and the real ear with the voltage that drives the earphone held constant.

A probe-tube is threaded through the calibrator adaptor plug so that the tip of the probe-tube extends no more than 3 mm above the surface of the plug (Figure 1a). The calibrator adaptor plug is then placed into the microphone port of the HA-2/2cc coupler. An HA-2 coupler is used (rather than an HA-1 coupler) to reduce the possibility of low-frequency acoustic leakage in the coupler-based measurement and to allow the acoustic effects of the earmold coupling to be reflected in the measurement of the RECD. The probe-tube microphone is then connected to the probe-tube, and the insert earphone (minus the earmold coupling) is attached to the tubing of the HA-2/2 cc coupler. At this point, the instrumentation system has been configured to measure the coupler response, and a 50 dB SPL speech-weighted composite signal is delivered via the insert earphone into the HA-2/2 cc coupler. The result of this coupler-based measurement is saved to the system memory as the "unaided response."

Figure 1b illustrates the required setup for measuring the real-ear component of the RECD measurement. To obtain the real-ear response, the probe-tube is placed in the individual’s ear at a standard insertion depth from the...
intertragal notch (i.e., adult females, 28 mm; adult males, 31 mm; children, 20–25 mm). A custom earmold is inserted into the ear canal and the insert earmold plastic coupling adaptor attached to the earmold tubing. With the software operational parameters unchanged, the 50 dB SPL speech-weighted composite signal is delivered via the insert earphone/custom earmold coupling into the subject’s ear canal. The resulting real-ear frequency response is saved to the system memory as the “aided response.”

Having measured both the coupler and the real-ear response for the same signal, the RECD values are automatically calculated across frequencies and saved as curve #3 of the multivalue option of the Fonix 6500 system software. This curve is shown in the Fonix 6500’s graphic display as the “real-ear insertion response.” As a result of this procedure, the RECD values (i.e., real-ear response minus the coupler response in dB) are available for all frequencies at 100-Hz intervals from 200 Hz to 8000 Hz.

Using RECD Measures to Predict Real-Ear Performance

The RECD procedure results can be used to predict both the REAR and the real-ear saturation response (RESR) of a specific hearing aid to be fitted. This section uses results from measurements with an adult female subject to illustrate how the measured RECD values are used to predict real-ear hearing aid performance. These results will also be used to demonstrate the extent to which the predicted REAR and RESR values approximate the measured real-ear electroacoustic characteristics of a specific behind-the-ear (BTE) instrument. An adult subject is used in this demonstration because of the difficulties in using a substitution procedure to obtain accurate measures of the REAR and RESR with young children.

Predicting the Real-Ear Aided Response

To predict the REAR from the coupler response, any differences between the two measurement conditions must be defined. For this approach to fitting, we assume that the predicted real-ear response (REARP) is equal to the 2 cc coupler response plus the RECD and any head diffraction/microphone location (HD/ML) effects. Thus, the equation for predicting the REAR across frequencies is:

\[ \text{REARP} = \text{2 cc coupler response} + \text{RECD} + \text{HD/ML effects} \]

The first variable to be entered into the equation for predicting the REAR is the 2 cc coupler response. Figure 2 shows the 2 cc coupler response measured for a Unitron US80 PPA BTE hearing aid in response to a 60 dB SPL composite signal.

The second variable to be accounted for in deriving the REARP is the RECD. Figure 3 shows the RECD measurement procedure results for the subject. For these data, a positive value on the Y-axis indicates that the SPL measured in the real ear exceeded that measured in the 2 cc coupler. The real-ear component of the RECD procedure was performed using a fully occluding custom earmold. If an alternative earmold coupling configuration or an HA-1/2 cc coupler had been used in measuring this individual's

RECD, different RECD values would be expected. The SPL at the microphone of a hearing aid will be affected by the presence of the listener's head and by the location of the hearing aid microphone. The acoustic effects that result from the diffraction of sound by the head and microphone location need to be accounted for when attempting to predict the REAR. The alternatives are to apply a set of average HD/ML effect values that have been reported in the literature (e.g., Bentler & Pavlovic, 1989; Cox & Risberg, 1986) or to measure the interaction effects of these variables for the individual listener. For this demonstration we chose to measure the HD/ML effects for the subject by employing a modification of the procedure

FIGURE 2. The frequency response, in dB SPL, of a Unitron US80 PPA hearing aid (LC = N; HC = 1/2; MPO = -12; Gain Red. = 0; Vol. = 1 1/2; with 680 ohm filtered earhook) measured in an HA-2/2 cc coupler using a 60 dB (SPL) speech-weighted composite test signal (Frye, 1986).

FIGURE 3. The difference, in dB, between the levels of a speech-weighted composite test signal measured in the ear canal of an adult subject and the levels of the same test signal measured in an HA-2/2 cc coupler as a function of frequency. All positive values indicate the extent to which the SPLs measured in the ear canal exceeded the SPLs measured in the 2 cc coupler.
reported by Fikret-Pasa and Revit (1992). For routine clinical applications, however, we apply the values reported by Bentler and Pavlovic (1989). Figure 4 shows the HD/ML effects measured at the hearing aid microphone port as a function of frequency. All positive values indicate an increase in the SPL measured at the BTE hearing aid microphone port relative to the undisturbed field.

By defining the 2 cc coupler response, the RECD, and the HD/ML effects, it is possible to predict the REAR for this subject. The REARp values for nine frequencies are shown in Table 1. The REARp (line 4) is derived by adding the RECD values and the HD/ML effects to the 2 cc coupler response values across frequencies.

To evaluate the accuracy of this prediction, the REAR was measured for the subject using a substitution calibration procedure. Table 1 presents the results of this measurement for the nine frequencies (line 5) along with the differences in dB between the predicted and the measured REAR values (line 6). Figure 5 shows the predicted and measured REAR values obtained for this subject at 100-Hz intervals between 200 and 6000 Hz. For this example, the average difference across frequencies between the measured and predicted values was calculated to be 0.95 dB, with the greatest difference between the two curves being 3.2 dB at 4600 Hz.

**Predicting the Real-Ear Saturation Response**

The following equation is used to predict the RESR of a given hearing aid:

\[ \text{RESRp} = 2 \text{ cc coupler SSPL90} + \text{RECD} \]

From this equation, it can be seen that the predicted real-ear saturation response (RESRp) is equal to the sum of the saturation sound pressure level (SSPL90) of a hearing aid, measured in a 2 cc coupler, and the RECD values across frequencies. HD/ML effects are not used in the calculation of RESRp because it is assumed that the hearing aid will be in saturation when using a 90-dB pure tone signal, and therefore will not be affected by near-field effects. That is, any increase in input SPL attributed to near-field effects will not be reflected as an increase in output at the earmold (Byrne, 1981).

The first variable entered into the equation for predicting the RESR is the SSPL90 measured in a 2 cc coupler. Figure 6 shows the saturation response measured for a Unitron US80 PPA hearing aid in response to a 90-dB SPL pure tone sweep. A pure tone stimulus is used for the measurement of SSPL90 and RESR, as it will best represent potential maximum hearing aid output under any given listening condition (Hawkins, 1992; Revit, 1991; ...

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**TABLE 1. Calculation of the predicted real-ear aided response (REARp), in dB SPL, for an adult female subject as a function of nine test frequencies. Also shown are the measured REAR values and the differences, in dB, between the measured and predicted REARs as a function of frequency.**

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>.3</th>
<th>.5</th>
<th>.8</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupler Response</td>
<td>73.7</td>
<td>79.8</td>
<td>85.7</td>
<td>87.2</td>
<td>82.3</td>
<td>87.3</td>
<td>77.9</td>
<td>62.8</td>
<td>27.0</td>
</tr>
<tr>
<td>+ RECD</td>
<td>5.4</td>
<td>5.6</td>
<td>5.8</td>
<td>5.7</td>
<td>6.1</td>
<td>7.4</td>
<td>9.2</td>
<td>7.5</td>
<td>9.4</td>
</tr>
<tr>
<td>+ HD/ML Effects</td>
<td>0.9</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>2.3</td>
<td>1.1</td>
<td>-0.8</td>
<td>0.3</td>
</tr>
<tr>
<td>Predicted REAR</td>
<td>80.0</td>
<td>85.7</td>
<td>91.8</td>
<td>93.2</td>
<td>88.6</td>
<td>97.0</td>
<td>88.2</td>
<td>69.5</td>
<td>36.7</td>
</tr>
<tr>
<td>Measured REAR</td>
<td>79.4</td>
<td>84.8</td>
<td>91.2</td>
<td>93.4</td>
<td>91.1</td>
<td>95.5</td>
<td>90.3</td>
<td>71.9</td>
<td>37.4</td>
</tr>
<tr>
<td>Difference</td>
<td>0.6</td>
<td>0.9</td>
<td>0.6</td>
<td>-0.2</td>
<td>-2.5</td>
<td>1.5</td>
<td>-2.1</td>
<td>-2.4</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

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**FIGURE 4.** The SPL, in dB, measured at the microphone port of the Unitron US80 PPA hearing aid fitted to an adult subject relative to the SPL measured in the undisturbed field as a function of frequency. All positive values represent the extent to which the SPLs measured at the microphone port of the hearing aid exceeded the SPLs measured in the undisturbed field.

**FIGURE 5.** The predicted and measured REAR values as a function of frequency, in dB SPL (ear canal level), for an adult subject fitted with a Unitron US80 PPA behind-the-ear hearing aid.

The second variable that is accounted for in deriving the predicted RESR is the RECD (Figure 3). For this example, the RESRpt is derived by adding the RECD values plotted in Figure 3 to the SSPL90 for the Unitron US80 PPA hearing aid shown in Figure 6. Table 2 shows the calculation of the RESRpt as a function of nine test frequencies.

To evaluate the accuracy of this prediction, the RESR of the Unitron hearing aid fitted to the adult subject was measured using a substitution calibration procedure. The results of this measurement are shown in Table 2 (line 4) along with the differences in dB between the predicted and the measured RESR values across the nine frequencies. Both the predicted RESR and the measured RESR values, in dB SPL (ear canal level), are plotted as a function of frequency in Figure 7. Note that the average difference between these two sets of values was calculated to be .51 dB. The greatest difference between the measured and the predicted values was 2.8 dB at 6000 Hz.

**Application of the RECD Measurement in Fitting**

This section describes how the RECD measurement procedure results can be applied to individuals for whom it is not possible to obtain valid, reliable probe-tube microphone measures of hearing aid performance directly. The preceding section showed that the results obtained from the RECD procedure can be used to predict real-ear hearing aid performance with a reasonable degree of accuracy. The predictions of real-ear hearing aid performance were developed by measuring the 2 cc coupler response and the SSPL90 of a BTE hearing aid, adding the measured RECD values, and applying measured HD/ML effects when applicable. Conceptually, this process is reversed when applying the results of RECD measures in clinical fitting. The first step in the fitting process is to develop a set of desired real-ear electroacoustic performance characteristics (e.g., target REAR and RESR values) for the child. Second, the measured RECD and measured or average HD/ML effects for REAR are subtracted from the desired real-ear performance values to derive a set of 2 cc coupler gain and output limiting target values. Finally, the electroacoustic characteristics of a hearing aid are modified in the hearing aid test chamber to approximate the set of derived 2 cc coupler target values. An overview of this process is provided below by means of a specific case example.

Figure 8 shows the monaural air conduction thresholds for the right ear of a child with a moderately severe bilateral sensorineural hearing loss. By entering these threshold values into the Desired Sensation Level (DSL); Version 3.0 software system (Seewald, 1992; Seewald, Zelisko, Ramji, & Jamieson, 1991), target REAR and RESR values were derived for this child. Table 3 shows these real-ear electroacoustic performance criteria as a function of the six frequencies for which audiometric threshold data were available.

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>0.3</th>
<th>0.5</th>
<th>0.8</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>6.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSPL90</td>
<td>110.1</td>
<td>114.8</td>
<td>119.3</td>
<td>118.8</td>
<td>111.8</td>
<td>114.9</td>
<td>112.5</td>
<td>104.2</td>
<td>83.0</td>
</tr>
<tr>
<td>+ RECD</td>
<td>5.4</td>
<td>5.6</td>
<td>5.8</td>
<td>5.7</td>
<td>6.1</td>
<td>7.4</td>
<td>9.2</td>
<td>7.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Predicted RESR</td>
<td>115.5</td>
<td>120.4</td>
<td>125.1</td>
<td>124.5</td>
<td>117.9</td>
<td>122.3</td>
<td>121.7</td>
<td>111.7</td>
<td>92.4</td>
</tr>
<tr>
<td>Measured RESR</td>
<td>115.8</td>
<td>120.7</td>
<td>122.7</td>
<td>124.6</td>
<td>119.3</td>
<td>121.7</td>
<td>122.8</td>
<td>112.9</td>
<td>95.2</td>
</tr>
<tr>
<td>Difference</td>
<td>-0.3</td>
<td>-0.3</td>
<td>2.4</td>
<td>-0.1</td>
<td>-1.4</td>
<td>0.6</td>
<td>-1.1</td>
<td>-1.2</td>
<td>-2.8</td>
</tr>
</tbody>
</table>

**TABLE 2. Calculation of the predicted real-ear saturation response (RESRp), in dB SPL, for an adult female subject as a function of nine test frequencies. Also shown are the measured RESR values, and the differences, in dB, between the measured and predicted RESRs as a function of frequency.**

**FIGURE 6. The saturation response of a Unitron US80 PPA hearing aid measured in an HA-2/2 cc coupler using a 90 dB SPL pure tone sweep.**

**FIGURE 7. The predicted and measured RESR values in dB SPL (ear canal level) as a function of frequency for an adult subject, measured with a Unitron US80 PPA behind-the-ear hearing aid.**

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Several alternative electroacoustic selection methods (e.g., National Acoustic Laboratories--Revised Method: Byrne & Dillon, 1986) can be applied in developing a set of real-ear hearing aid performance criteria. However, to use the RECD procedure effectively within the fitting process, it is essential for the clinician to decide how the hearing aid should perform, in terms of its real-ear electroacoustic characteristics, prior to the actual fitting.

The RECD values measured for the child under consideration are shown in Figure 9. For this figure, all positive values indicate the extent to which the SPL measured in the child’s occluded ear canal (with custom earmold) exceeded the levels of the same acoustic signal measured in the HA-2/2 cc coupler. Note that the RECD values vary across frequencies and range from between approximately 1 dB at 700 Hz to a maximum RECD value of 20 dB at 3300 Hz.

By first deciding what the real-ear electroacoustic characteristics of this child’s hearing aid should be and by measuring the RECD values for the child, it is then possible to determine what the electroacoustic performance of the hearing aid should be within the highly controlled acoustic environment of the hearing aid test chamber. To illustrate, the computational process that was used to derive the 2 cc coupler target values for the frequency-gain characteristics of the hearing aid is presented in Table 4. The target 2 cc coupler values have been calculated by subtracting both the RECD and a set of HD/ML effect values for BTE instruments (Bentler & Pavlovic, 1989) from the target in situ gain values. With the target 2 cc coupler gain values in hand, the clinician can subsequently adjust the controls of one or more hearing aids in the hearing aid test chamber to approximate the target gain values across frequencies.

Similarly, a set of SSPL90 values can be derived by subtracting the RECDs from the desired RESR values that were developed for the listener under consideration. The calculations performed to derive the 2 cc coupler target values for the case example are presented in Table 5. Note that the target 2 cc coupler values have been calculated by subtracting only the RECDs from the desired RESR levels at the frequencies for which audiometric thresholds were measured. The resultant values, shown in the bottom row of Table 5, are the target output limiting levels that can be used to guide the SSPL90 adjustment of this child’s hearing aid in an HA-2/2 cc coupler. Thus, with this information the clinician can adjust the output limiting characteristics of a hearing aid within the test box to approximate the target SSPL90 values.

Once a hearing aid that provides a good approximation to the target 2 cc coupler gain and output limiting characteristics has been identified, the instrument can be fitted to the child. How well the desired real-ear hearing aid performance is realized depends on how well the 2 cc coupler target values have been approximated and on any measurement error associated with the RECD and/or electroacoustic measures performed in the test chamber.

**Summary**

Valid, reliable measures of real-ear hearing aid performance cannot always be obtained with infants and young children. An alternative to conventional probe-tube

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**TABLE 3.** REAR (in dB gain) and RESR (in dB SPL) target values, as a function of frequency, selected for the case example using the Desired Sensation Level Method: Version 3.0 (Seewald, 1992; Seewald et al., 1991).

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>.25</th>
<th>.5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>Target REAR</td>
<td>32</td>
<td>40</td>
<td>43</td>
<td>50</td>
<td>57</td>
<td>63</td>
</tr>
<tr>
<td>Target RESR</td>
<td>111</td>
<td>121</td>
<td>119</td>
<td>120</td>
<td>120</td>
<td>122</td>
</tr>
</tbody>
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**FIGURE 8.** Monaural pure tone air conduction thresholds, in dB HL, for the right ear of a child with a moderately severe bilateral sensorineural hearing impairment.

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**FIGURE 9.** The difference, in dB, between the levels of a speech-weighted composite test signal measured in the ear canal of a child and the levels of the same test signal measured in an HA-2/2 cc coupler as a function of frequency. All positive values indicate the extent to which the SPLs measured in the child’s ear canal exceeded the SPLs measured in the 2 cc coupler.
TABLE 4. Calculation of the 2 cc coupler target gain values for the case example.

<table>
<thead>
<tr>
<th>Frequency (kHz)</th>
<th>.25</th>
<th>.5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target REAR (in dB gain)</td>
<td>32.0</td>
<td>40.0</td>
<td>43.0</td>
<td>50.0</td>
<td>57.0</td>
<td>63.0</td>
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<tr>
<td>- RECD</td>
<td>1.6</td>
<td>1.3</td>
<td>5.5</td>
<td>13.2</td>
<td>19.4</td>
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<td>- HD/ML Effects</td>
<td>0.5</td>
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<td>2 cc Coupler Target Values</td>
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</table>

TABLE 5. Calculation of the 2 cc coupler SSPL90 values for the case example.

<table>
<thead>
<tr>
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<th>.5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target RESR 111.0</td>
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<td>119.0</td>
<td>120.0</td>
<td>120.0</td>
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<tr>
<td>- RECD</td>
<td>1.6</td>
<td>1.3</td>
<td>5.5</td>
<td>13.2</td>
<td>19.4</td>
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<td>Target SSPL90 109.4</td>
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<td>106.8</td>
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Microphone measures or sound-field-aided threshold measures of real-ear hearing aid performance is needed. The RECD procedure described in this article offers such an alternative.

To date, we have measured the RECD and applied the results in the fitting process for more than 200 infants and children. The success rate for making the RECD measurement has been better than 90% on the first attempt. The complete procedure, including system setup, requires no more than 5 minutes of the child’s time to complete, with the real-ear measurement itself taking only a few seconds. This is considerably less time than is typically required to perform a repeated series of probe-tube microphone measurements to “fine-tune” hearing aid performance or to successfully complete sound-field-aided threshold testing.

Clinical implementation of this approach to hearing aid fitting necessitates use of REAR and RESR target values. Having first established these real-ear hearing aid performance criteria, a set of corresponding 2 cc coupler targets can then be derived by applying the results of the RECD procedure. From our perspective there are considerable advantages to using this procedure when fitting hearing aids in young children. First, it eliminates the variability associated with sound-field probe-tube microphone measurements with young children. Second, it allows the clinician to perform all electroacoustic response shaping under the highly controlled conditions associated with test chamber measurements. Third, application of this procedure reduces the amount of measurement time and degree of cooperation required from the child. Finally, this approach to fitting can be used even for those children for whom hearing aid performance will be measured using conventional probe-tube microphones. Because most of the electroacoustic adjustments can be made in the hearing aid test chamber, the amount of time and degree of cooperation required for repeated real-ear measures of hearing aid performance can be substantially reduced.

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Real-ear to coupler difference (RECD) measurement procedures for the Raстрonics portaREM (PR20) and the Madsen IGO 1000 Insertion Gain Optimizer: For both systems, the insert earphone 1/4" phone jack will need to be adapted to the loudspeaker output terminal. This requires a two pin DIN jack attached to a 1/4" phone plug. Further, an appropriate 2 cc coupler with a probe-tube microphone vent is required. In the procedures below, a Raстронics type BTE 2 coupler has been used, as the probe-tube vent will accommodate the probe-tubes for both the Raстронics and Madsen systems.

**Raстронics portaREM (PR20)**

1. Calibrate the system in accordance with the manufacturer's recommended protocol. Calibration should be performed at a distance of 18" from the loudspeaker with a 50-dB SPL signal level. This will ensure a safe and comfortable output in the individual's ear canal when the insert earphone is connected.

2. Proceed to the real-ear measurement screen. Ensure that the signal remains at 50 dB SPL.

3. Press the "calibrate" button. The system will be calibrated in a substitution mode. The reference microphone is then deactivated.

4. Press the "start" button, ensuring that the microphone is approximately 18" from the loudspeaker.

5. When the calibration procedure has been completed, unplug the loudspeaker jack from the output terminal, and plug in the insert earphone jack using the two pin DIN to 1/4" phone plug adaptor.

6. Select the REUR measure. Insert a probe-tube into the probe-tube vent of the HA-2 coupler so that the end of the tube is in line with the sound inlet. Attach the probe-microphone to the probe-tube. Couple the plastic tip of the 3A insert earphone to the tubing of the HA-2 coupler. Run a REUR curve. This, of course, is not a REUR curve, but the 2 cc coupler response of the insert earphone.

7. Move to the Insertion Gain mode. Insert the probe-tube microphone into the individual's ear canal to the desired insertion depth. Insert the individual's custom earmold (or the standard insert earphone coupling). Couple the plastic tip of the insert earphone to the earmold tubing. Press "start." The resultant "insertion gain curve" is the RECD. Press the marker button to extract the RECD values at the desired frequencies.

**Madsen IGO 1000 Insertion Gain Optimizer**

1. Calibrate the IGO system in accordance with the manufacturer's recommended protocol. The calibration microphone should be located 18" from the loudspeaker. If the calibration is performed at a distance of 36", the SPL from the insert earphone will be too high in the ear canal. If the calibration is performed at a distance less than approximately 18", the SPL at the reference microphone may be too high, and the system will not calibrate properly.

2. Set the IGO 1000 system for these operational parameters:
   - Select one test procedure (i.e., A, B, or C) to measure insertion gain
   - Desired signal level = 50 dB SPL
   - Calibration mode = substitution
   - Stimulus accuracy = 1 dB
   - Stimulus steps = 12 per octave (fastest) from 250 to 6000 Hz

3. After entering the required client identification information, choose the appropriate test procedure (A, B, or C). Disconnect the loudspeaker and connect the 3A insert earphone using an appropriate two-pin DIN to 1/4" phone plug adapter.

4. Select the REUR measure. Insert a probe-tube into the probe-tube vent of the HA-2 coupler so that the end of the tube is in line with the sound inlet. Attach the probe-microphone to the probe-tube. Couple the plastic tip of the 3A insert earphone to the tubing of the HA-2 coupler. Run a REUR curve. This, of course, is not a REUR curve, but the 2 cc coupler response of the insert earphone.

5. Place the probe-tube microphone in the ear to desired insertion depth, and insert the individual's custom earmold (or the standard insert earphone coupling). Couple the plastic tip of the insert earphone to the earmold tubing. Run an REUR curve. The result is the RECD. Use the marker mode to obtain the desired RECD values at the desired frequencies.