

Using the FONIX 7000 to Verify Coupler and Real-Ear Performance to Adhere to the AAA Guidelines for the Audiologic Management of Adult Hearing Impairment



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Introduction

In 2003, Angela Loavenbruck, then President of the American Academy of Audiology (AAA), asked the second author to consider chairing a Task Force whose goal was to develop a national guideline for fitting hearing aids to adults. Angela felt a new guideline was necessary because a) the AAA guideline for children was about to be published; b) as the national organization for audiologists, AAA needed to formulate its own guideline; and c) numerous advances have been made in technology since the ASHA guideline was published. Angela informed the second author that the current Task Force members included Harvey Abrams, Dennis Hampton, Todd Ricketts, and Robert Sweetow. Soon after assuming the chair, the second author asked Theresa Hnath-Chisolm, Darcy Benson, David Citron, and Helena Solodar to join the Task Force.

Why a New Guideline?

One might ask, "Why a new guideline?" There are several answers to this important question. **First**, as mentioned earlier, the last guideline was published by ASHA in 1998. Since 1998, there have been numerous advances in hearing aid technology as well as the methods used to verify and validate hearing aid fittings. Thus, the current standard needed to be updated to accommodate these advances. **Second**, there is increased interest in other professions in using evidence-based principles (EBP) when developing a new guideline. It was felt that in order for this guideline to have relevance, it too must use EBP to reinforce its recommendations. **Third**, AAA published a pediatric guideline (2004) and felt an adult guideline was also necessary. **Fourth**, there is considerable concern regarding the manner in which hearing aids are dispensed by audiologists. That is, current clinical practices implemented "in the field" may do little to differentiate how hearing aids are dispensed by audiologists and others and therefore would not be in line with AAA's goal for professional autonomy.

How does this Guideline Differ from Previous Guidelines?

The content and organization of this guideline differs significantly from the previously published ASHA guideline in several ways. **First**, it is the only guideline thus far to include a section specifically on auditory and non-auditory needs assessment. **Second**, it is the first to use EBP to support its recommendations. Within the guideline, EBP is also used to point out areas where the evidence may not be sufficient to support implementing some recommendations of the guideline. **Finally**, it is emphasized that a guideline is not static and needs to be re-evaluated every five years to assess the need for revisions as technology and the evidence changes.

Relative to the issue of **verification**, there are some very specific recommendations within the guideline. For example, relative to **quality control** (pages 23-24) there is the statement: "Electroacoustic verification of all hearing aids (new and repaired) is recommended. This verification should be completed prior to fitting to ensure the hearing aid is in working order and to provide a benchmark for future quality control measures." Also, there is a call for "**Verification of features**...prior to the hearing aid fitting." Features can include directional microphones, feedback management, expansion, noise reduction, or control of the occlusion effect. In pages 25-30, there are these additional statements:

- a. “Actual speech or a speech-like signal should be used when attempting verification of prescriptive methods for which targets are based on speech inputs.”
- b. “Verification of the magnitude of the occlusion effect should be verified using probe microphone measures...”
- c. “Prescribed gain from a validated prescriptive method should be verified using a probe microphone approach that is referenced to the ear canal SPL.”
- d. “Maximum hearing aid output (OSPL90) verification is recommended to ensure that it does not exceed the patient’s threshold of discomfort. Simulated real-ear techniques are recommended....”
- e. “In-situ measures of directional efficacy are recommended...the probe microphone technique of front-to-back ratio is recommended...”

Finally, this guide was prepared by the two authors with the idea that the reader has never operated the Frye 7000. Thus, this guide has been prepared as a “Cookbook” approach so the reader can determine the test(s) he/she would like to perform and follow the guide for step-by-step instructions on how to complete the test(s). **Please bear in mind that the information contained within this guide was based on Version 1.62.** If the reader is using a 7000 with a different version then some of the steps outlined in this guide may be in error. Also, if the reader notes any errors within this guide, please contact Michael Valente at valentem@ent.wustl.edu so he may correct the error for future versions of this guide.

BASIC OVERVIEW OF PREPARATIONS FOR COUPLER MEASURES

Before providing a detailed description of various methods one can use to verify the performance of hearing aids using coupler measures, the authors feel it may be beneficial to provide a general overview of preparations for coupler measures. Figure 1 illustrates the correct method to couple a **behind-the-ear (BTE)** hearing aid to a **HA-2** coupler and be placed in the test chamber. In the Frye 7000, it is important to place the hearing aid in the test chamber so the hearing aid microphone is placed in the center of the reference point and facing the right. The reason the hearing aid is facing the right is because in the 7000, the loudspeaker is in the right side of the test chamber and facing up. Also, if the clinician desires to measure battery drain it is important that the correct battery pill be inserted into the hearing aid battery compartment. Figure 2 illustrates the coupling of a **custom hearing aid** to an **HA-1** coupler. Figure 3 illustrates the importance of being sure that the receiver of the custom hearing aid is placed on the HA-1 coupler so that the receiver port is in the center of the hole within the coupler. Figure 4 illustrates how the custom hearing aid is secured to the HA-1 coupler using **Fun-Tak** so that **ALL** possible leaks around the hearing aid case are completely sealed. Also, Figure 4 shows that it is important to cover the vent hole from the lateral side of the custom case. In Figure 5, the upper curve illustrates a peak in the frequency response at ~500 Hz that can occur if the hearing aid is not completely sealed to the HA-1 coupler. The lower curve in Figure 5 illustrates the “correct” smooth frequency response that should occur when the hearing aid is correctly sealed to the HA-1 coupler. When testing **completely-in-the-canal (CIC)** hearing aids it is important to use

the **CIC coupler** and to activate the **CIC sub-menu** (Press [F1] “Coupler”, then [Menu], scroll down using the down arrow key to “Coupler type” and then the right arrow key to “CIC”. Then press [Exit]). Finally, Figure 7 and Figure 8 illustrate the new non-standardized **open coupler** and **open BTE** coupled to the **open coupler**. Figure 9 reports the frequency response of this hearing aid measured in the open coupler (Curve 1), HA-1 coupler (Curve 2), HA-2 coupler (Curve 3) and unaided KEMAR (Curve 4). Although the frequency response of the open coupler does not superimpose upon the unaided KEMAR response, the curve measured using the open coupler is closer to the unaided KEMAR response than when measured in either the HA-1 or HA-2 coupler.

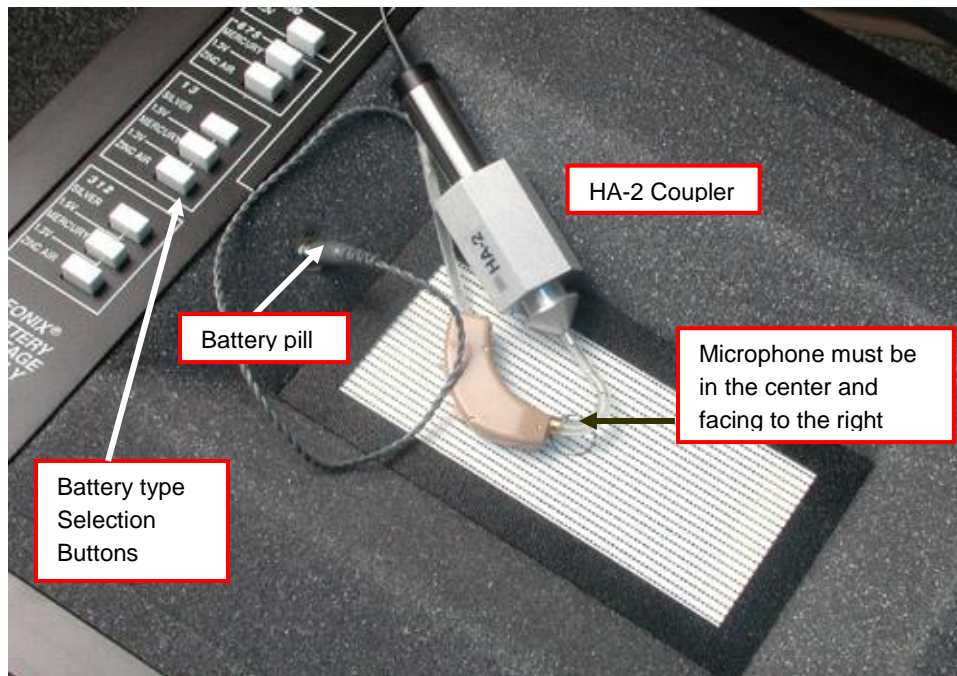


Figure 1 – Configuration of the hearing aid test chamber for performing the electroacoustic analysis of a BTE hearing aid.

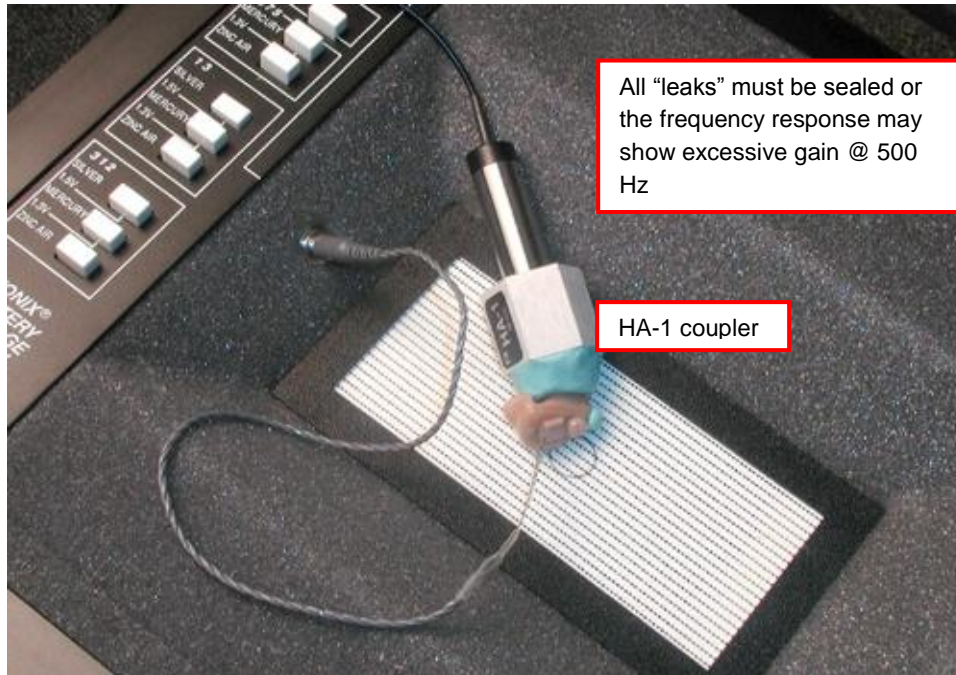


Figure 2 – Configuration of the hearing aid test chamber for performing electroacoustic analysis of a custom hearing aid.

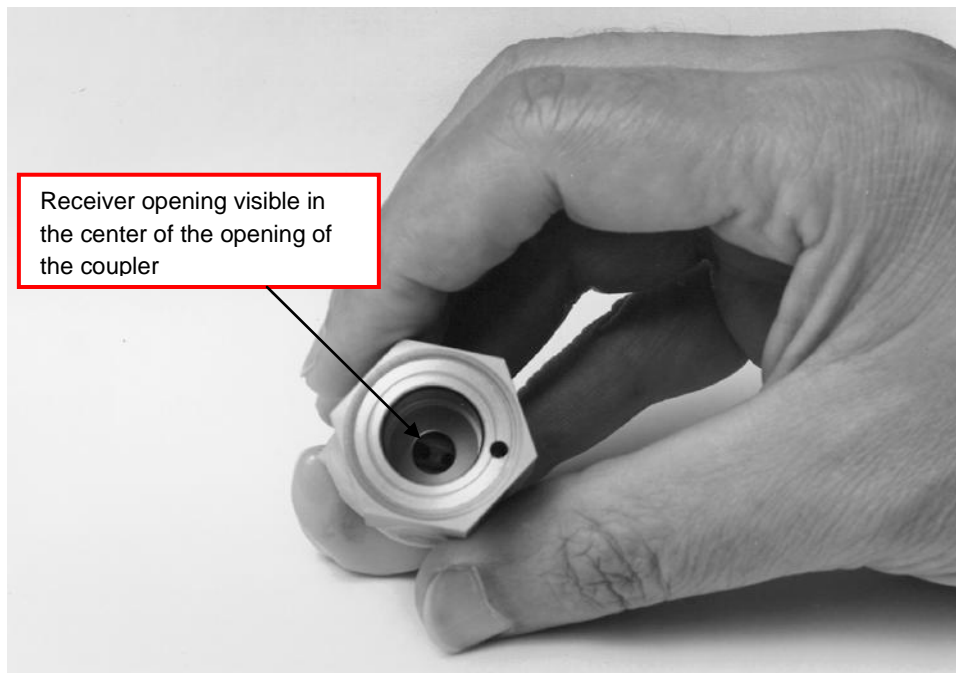


Figure 3 – Illustration showing the receiver port of the hearing aid in the center of the opening of the HA-1 coupler.

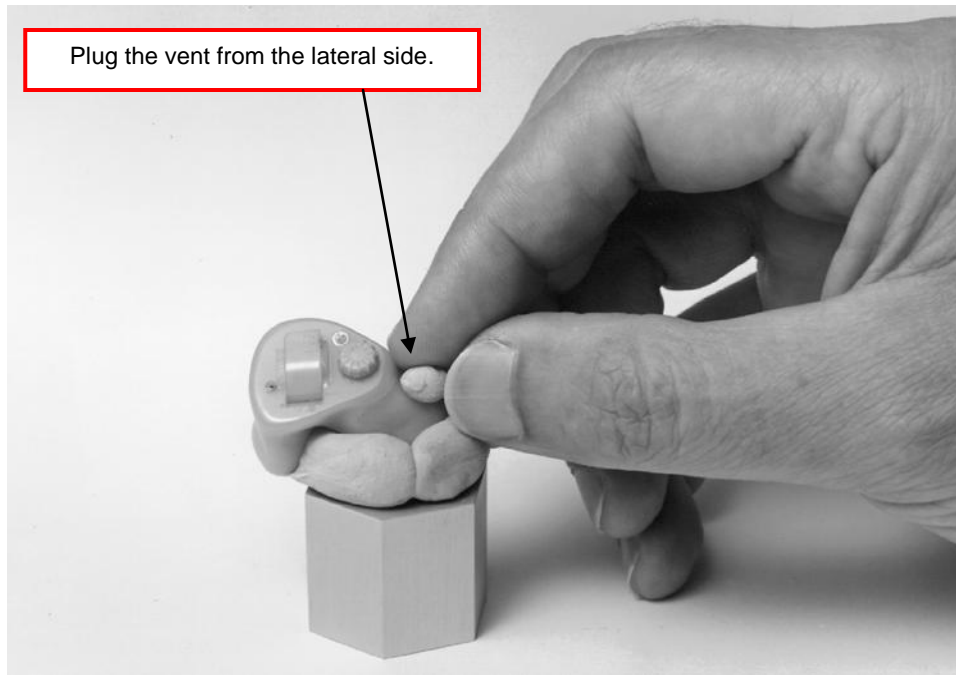


Figure 4 – Illustration of the correct manner to seal the vent of a custom product.

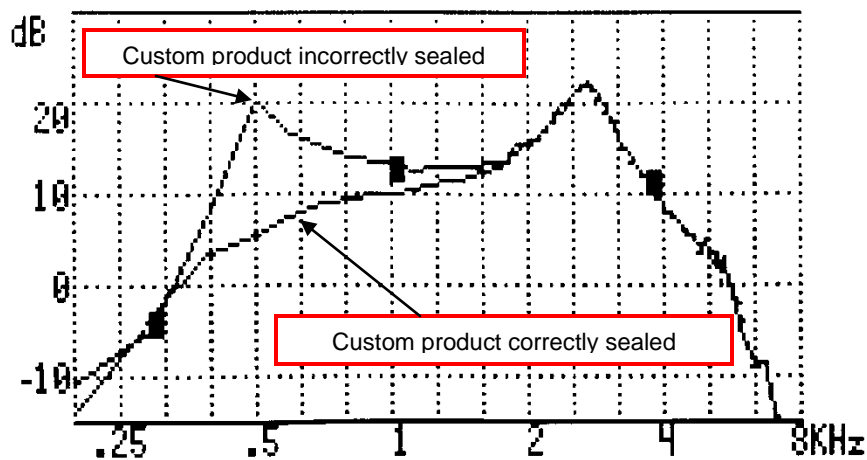


Figure 5 – The upper curve illustrating the presence of a peak @ 500 Hz in the case where the custom product was incorrectly sealed to the HA-1 coupler. The lower curve shows a smoother frequency response when all possible leaks are sealed.



Figure 6 – Sealing a CIC hearing aid to a CIC coupler. Be sure to press [F1] “Coupler”; then [Menu], scroll down using the down ↓ arrow key to “Coupler type” and then the right → arrow key to “CIC” and press [Exit].



Figure 7 – Illustration of the non-standardized Frye open coupler.

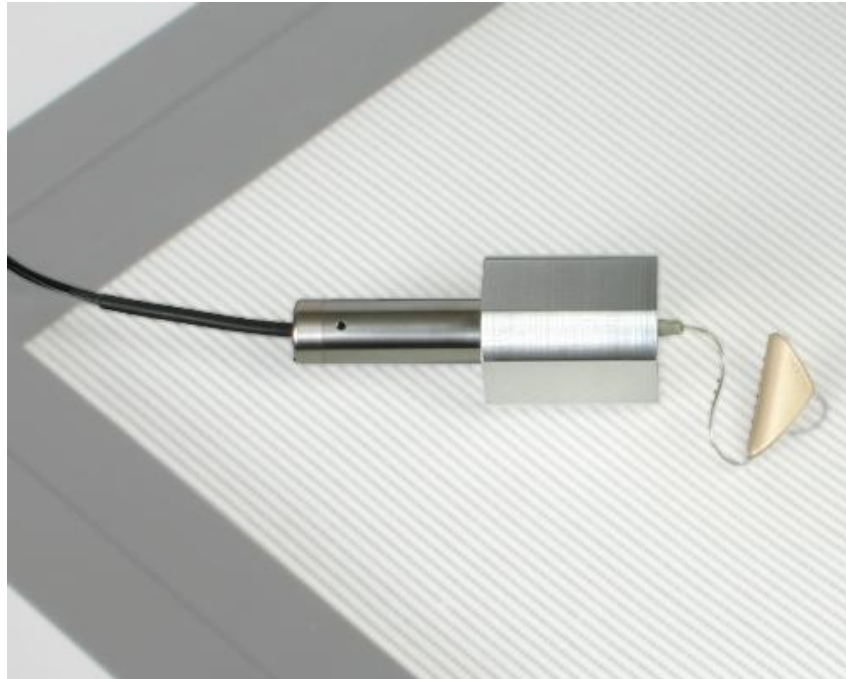


Figure 8 – Illustration of an open hearing aid coupled to the open coupler.

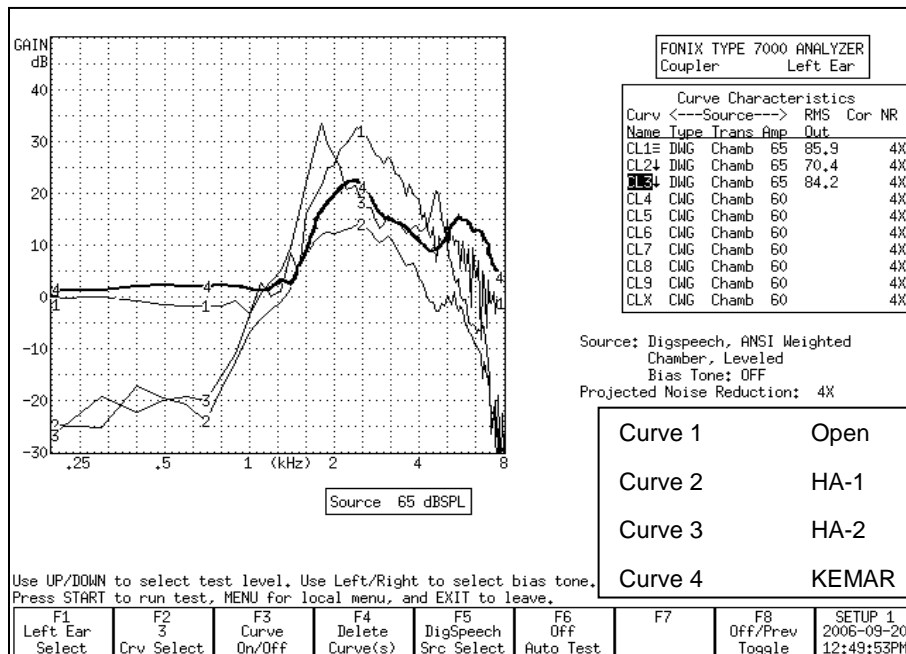


Figure 9 – Frequency response curves of the open hearing aid coupled to an open coupler (Curve 1), HA-1 coupler (Curve 2), HA-2 coupler (Curve 3) and unaided KEMAR.

TEST PROCEDURES

1.1 ANSI S3.42-1992 is a standardized test using a broadband speech composite signal. This test generates a family of frequency response curves in response to varying input levels. This test can be useful to determine (a) if a hearing aid has linear or nonlinear signal processing, and (b) if excessive intermodulation distortion (IMD) is present.

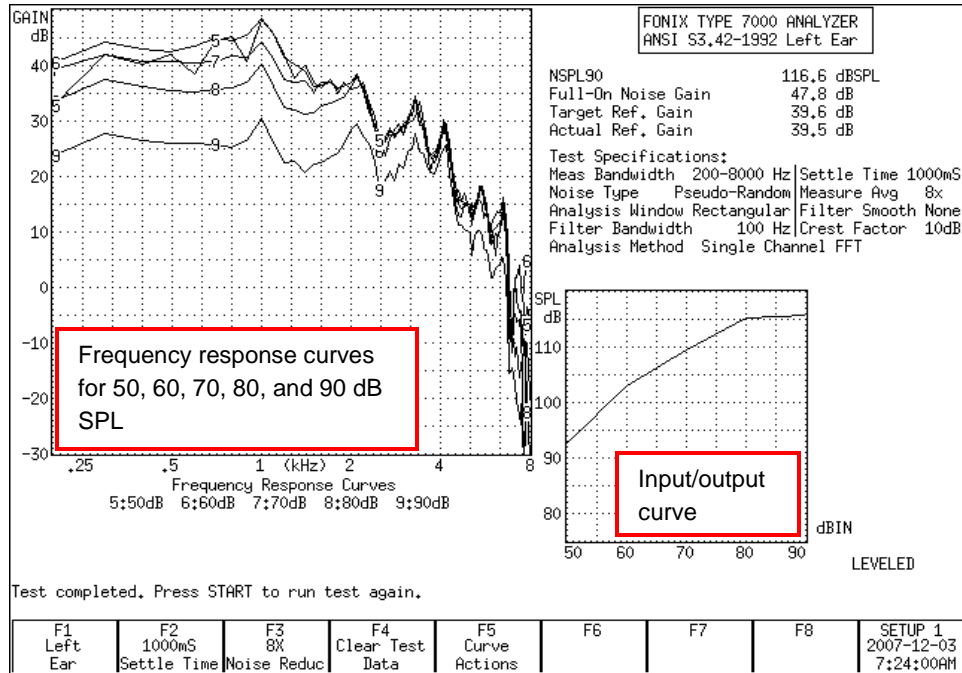


Figure 10 – ANSI S3.42-1992 test results

STEP-BY-STEP

1. Press [F5] in the Opening screen to enter the ANSI S3.42-1992 screen.

If ANSI 1992 is not an established setting in the Opening screen, perform the following steps:

- From the Opening screen, press [MENU] to access the Setup Menu.
- Using the down arrow key, scroll down to the Opening Screen heading.
- Find the first function key setting (labeled F1 through F8) that is listed as "None." Scroll down to this location and use the right arrow key to select ANSI S3.42.
- Press [EXIT] to return to the Opening screen.
- ANSI S3.42 should now appear as a function key option.

F1	F2	F3	F4	F5	F6	F7	F8
Left Ear	1000mS Settle Time	8X Noise Reduc	Clear Test Data	Curve Actions			

Figure 11 – ANSI S3.42-1992 function keys

2. Level the sound chamber (press [LEVEL]).
3. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See *Figures 1 - 6*). Close and lock chamber lid.
4. Use [F1] to select desired ear.
5. Use [F2] to select the settle time used for the test.

Settle time is the amount of time it takes for the system output to remain within a given margin of error of its final value following an input stimulus. Options for settle time include 500, 1000, 2000, or 5000 msec.

6. Use [F3] to select the noise reduction used for the test.

Noise reduction is used when the test environment is noisy. This option allows the Frye 7000 to take multiple measurements for each test and to take the average of the obtained responses. A greater level of noise reduction will provide a smoother frequency response curve, but will increase the length of test time. Both pure-tone and composite noise reduction is available for tests that utilize either a pure-tone or composite sound source, respectively. The magnitude of pure-tone noise reduction is denoted by a single number followed by an "X". Available pure-tone noise reduction options are OFF, 4X, 8X, or 16X. For example, a pure-tone noise reduction setting of "4X" indicates that 172 measurements (43 x 4) will be taken for each pure-tone sweep and will be averaged to formulate a frequency response curve. The magnitude of composite noise reduction is also denoted by a single number followed by an "X." Available composite noise reduction settings are OFF, 4X, 8X, and 16X. This type of noise reduction differs from pure-tone noise reduction in that a composite noise reduction setting of "4X" indicates that only the last four measurements will be averaged.

7. Press [START] to begin the test sequence.

Note... This measurement is useful in determining if a hearing aid is **linear or nonlinear** as well as to determine if the hearing aid has excessive **intermodulation distortion (IMD)**. As is illustrated in Figure 10, the frequency response curves are NOT superimposed. That is, the measured gain below 2000 Hz decreases as the input signal is increased from 50 to 90 dB SPL. Note that gain remains the same (linear) in the frequency range above 2000 Hz illustrating BILL (Base Increase at Low Levels) signal processing. If this hearing aid had linear signal processing the five frequency response curves would have appeared as being superimposed upon each other. Therefore, one may conclude that gain varies with differing input levels and therefore this hearing aid is nonlinear.

Another potential use of ANSI S3.42-1992 is to determine if the hearing aid has excessive IMD. You'll note in Figure 10 that the morphology, or shape, of the frequency response curve for the 90 dB SPL input, although showing less gain, has the same shape as the frequency response curve for the 50 dB SPL input signal. If this hearing aid had excessive IMD, the frequency gain response for the higher input levels would appear as "jagged" or "broken-up." In that case, it would be best practice to attach the printout to the manufacturer repair form and explain that the attached measure suggests the presence of IMD and the hearing aid needs to be repaired. Another use of ANSI S3.42-1992 is the input-output (I/O) curve for the composite signal to the lower right. In this case, the I/O is revealing linear signal process from 50-60 dB

SPL (i.e., the I/O line is 45°). Then the first kneepoint appears at 60 dB SPL revealing a change to nonlinear processing (i.e., the I/O line is less than 45°). This nonlinear processing continues to 80 dB SPL where a second kneepoint is present. From 80 to 90 dB the processing is revealing compression limiting (CL) because there is very little change in the output (~2 dB) relative to the 10 dB change in the input from 80-90 dB SPL.

1.2 ANSI S3.22-2003 is a standardized test using a pure-tone signal to measure the performance of the hearing aid at various hearing aid settings. Measured responses include the maximum output, frequency response, gain, equivalent input noise level, total harmonic distortion, telecoil response, battery drain, and compression characteristics of a hearing aid.

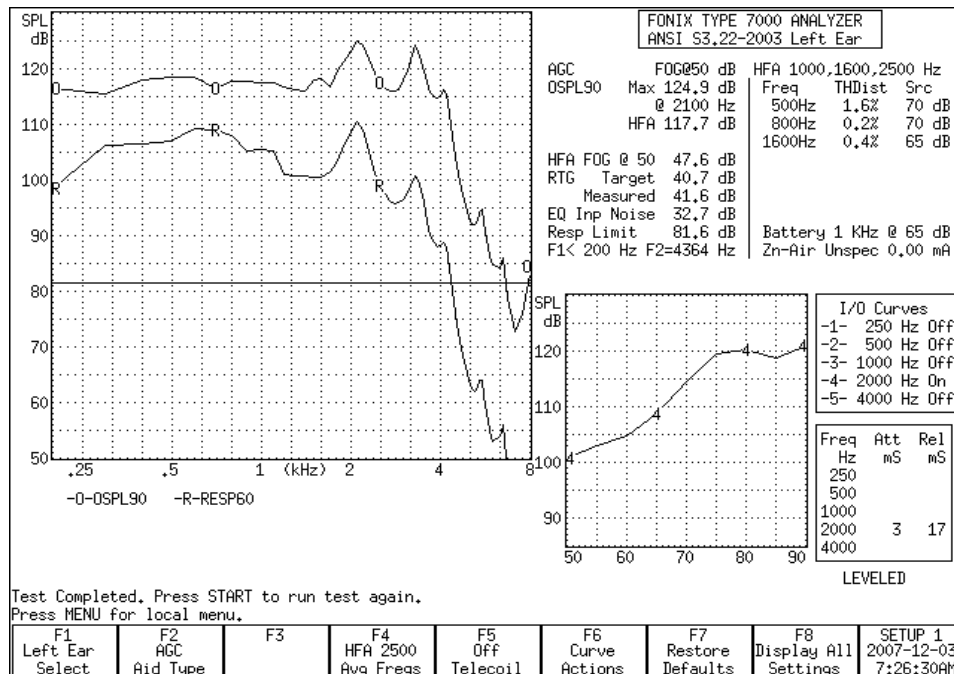


Figure 12 – ANSI S3.22-2003 test results

STEP-BY-STEP

1. Press [F4] from the Opening screen to enter the ANSI S3.22-2003 screen.
2. Level the sound chamber (press [Level]).
3. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See Figures 1 - 6). Close and lock chamber lid.
4. Use [F1] to select the desired ear and [F2] to select the Aid Type.

When navigating the F1-F8 settings: press the UP/DOWN arrows to move the cursor up and down and press the RIGHT arrow to make a selection and return to the test window.

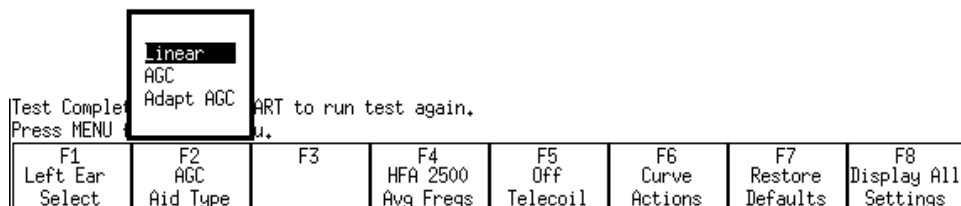


Figure 13 – Aid Type Options

5. Press [F5] to choose whether or not to run the telecoil test.
6. Press [MENU] to make any changes to the local menu options.

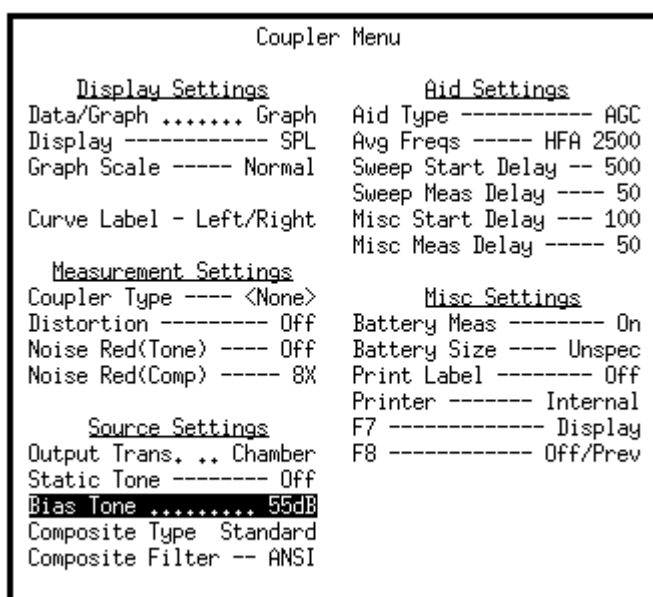


Figure 14 – Coupler Menu

7. Press [EXIT] to return to the test screen.
8. Press [START] to begin the test sequence.
9. If prompted, adjust the volume control so the “RTG Measured” (**Reference Test Gain**) is within 1 dB of the “RTG Target.” Press [START] to continue.

Note...This measurement is **required for new and repaired hearing aids** and should be placed in the patient’s chart. This test can also be completed at scheduled semi-annual or annual patient visits, unscheduled patient visits where the patient has a specific complaint about the performance of the hearing aid(s), and at the hearing aid fitting following programming. When comparing the measured hearing aid performance to manufacturer specifications, the hearing aid should be set to “test mode” or per manufacturer instructions. For example, many manufacturers have a “test mode” or “test measurement settings” option which puts the hearing aid at full-on gain and turns off all noise reduction features. The measurement in Figure 12

(above) was performed with the hearing aid in normal operating mode (not test mode) and therefore would not be comparable to manufacturer specifications.

Measuring the telecoil response of a hearing aid as part of ANSI S3.22-2003.

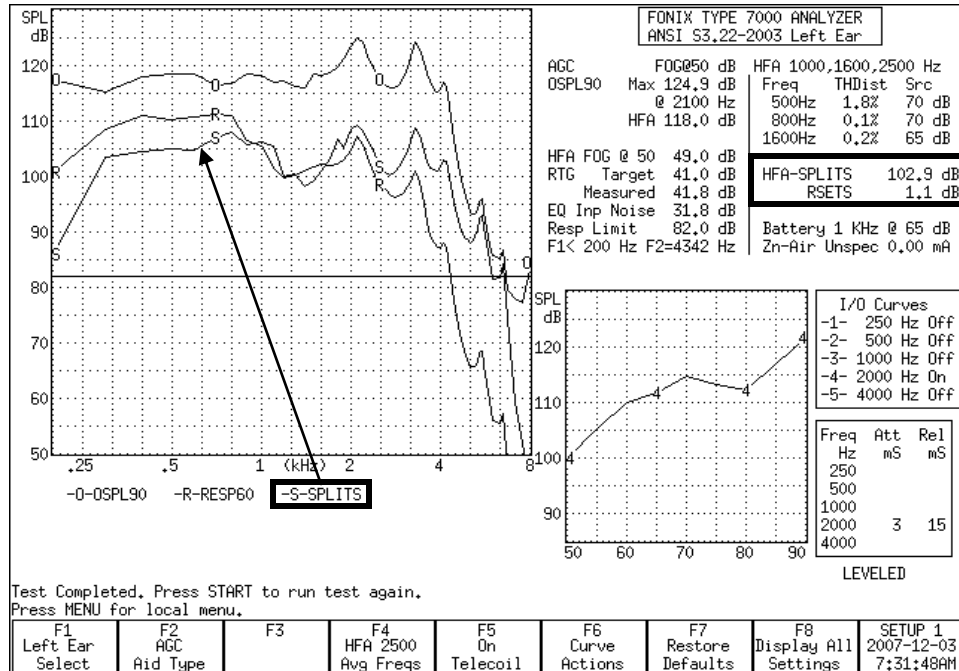


Figure 15 – ANSI S3.22-2003 telecoil test results. Note the boxed sections on **SPLITS**, **HFA-SPLITS** and **RSETS**.

STEP-BY-STEP:

Telecoil performance is typically automatically measured as part of ANSI-S3.22-2003 by simply pressing F5 (“Telecoil”) and then the right arrow key to turn the Telecoil option “On.” In this scenario, the software will automatically stop the ANSI measure at the appropriate time and instruct the clinician of the steps required to measure telecoil performance. In some cases, a clinician may want to measure telecoil performance independent of ANSI S3.22-2003. This section informs the clinician on how to perform this test. This section also informs the clinician on the interpretation of these measures.

1. Press [F5] from the Opening screen to enter the ANSI S3.22-2003 screen.
2. Level the sound chamber (press [Level]).
3. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See Figures 1 - 6). Close and lock chamber lid.
4. Press [F2] to select the Aid Type.
5. Press [F5] to turn the telecoil option on.

Test Completed. Press START to run test again.
Press MENU for local menu.

F1 Left Ear Select	F2 AGC Aid Type	F3	F4 HFA 2500 Avg Freqs	F5 On Telecoil	F6 Curve Actions	F7 Restore Defaults	F8 Display All Settings
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Figure 16 – Function keys with telecoil option turned on

6. If necessary, press [MENU] to make any other changes to the local menu options.
7. Press [EXIT] to return to the test screen.
8. Press [START] to begin the test sequence.
9. If prompted, adjust the volume control so the “RTG Measured” is within 1 dB of the “RTG Target.” Press [START] to continue.
10. When prompted, open lid of test chamber and switch aid to telecoil (if necessary).
11. Reduce any sources of potential magnetic noise, including CRT monitors.
12. Hold the hearing aid in one hand and the **TeleWand** in the other (*see Figure 17*). Position the TeleWand parallel to the hearing aid while monitoring the **HFA-SPLITS** value on the monitor for the position yielding the greatest gain.



Figure 17 – Positioning the TeleWand parallel to hearing aid

13. Press [START] to measure the **Sound Pressure Level in an Inductive Simulator (SPLITS)** curve and the resulting **Relative Simulated Equivalent Telephone Sensitivity (RSETS)**.
14. When prompted, return hearing aid to microphone position, reposition aid at the reference test point, close the lid, and press [START] to complete the ANSI measure.

Note... Difficulty with communicating on the telephone is a major complaint of hearing aid users. The first step in achieving successful telephone use with hearing aids is to verify telecoil performance. **Ideally, the SPLITS frequency response of the telecoil should be the same as the frequency response of the hearing aid microphone so that when the patient switches between microphone and telecoil, the listening situation is seamless and optimal (this of course assumes that the microphone response was optimally programmed to a validated prescriptive target).** Three measurements are performed to test the sensitivity of the telecoil: First, there is the **Sound Pressure Level in an Inductive Simulator (SPLITS)** frequency response curve. Next, there is the **SPLITS high frequency average (HFA-SPLITS in dB)**, and finally there is the **Relative Simulated Equivalent Telephone Sensitivity (RSETS)** measure. Notice in Figure 15 how the SPLITS curve has a similar shape as the frequency response in the microphone position (R curve) and has similar output to the hearing aid microphone in response to a 60 dB SPL input level. From the SPLITS curve, a high frequency average (or special purpose average) is calculated. The RSETS value compares the HFA-SPLITS to the measured RTG plus 60 dB. Ideally, this number should be greater than or equal to 0 dB, indicating that there is more gain or an equal amount of gain when the hearing aid is operating in telecoil versus microphone mode. In the example above, the RSETS is 1.1 dB ($102.9 - [41.8+60]$), which suggests that the user will perceive little or no difference in loudness when listening through the telecoil compared to the hearing aid microphone.

1.3 Measuring the Group Delay on one aid if a monaural fit and both aids if a binaural fit. Simultaneously, the user can measure the **phase** of both hearing instruments in a binaural fit. The phase test informs the user whether or not the wiring to the receiver to the positive and negative posts in each hearing aid is the same. The upper two graphs report the results for the left hearing aid, while the lower two graphs report the results for the right hearing aid. For each ear, the left graph reports delay (in msec) and the right graph reports phase.

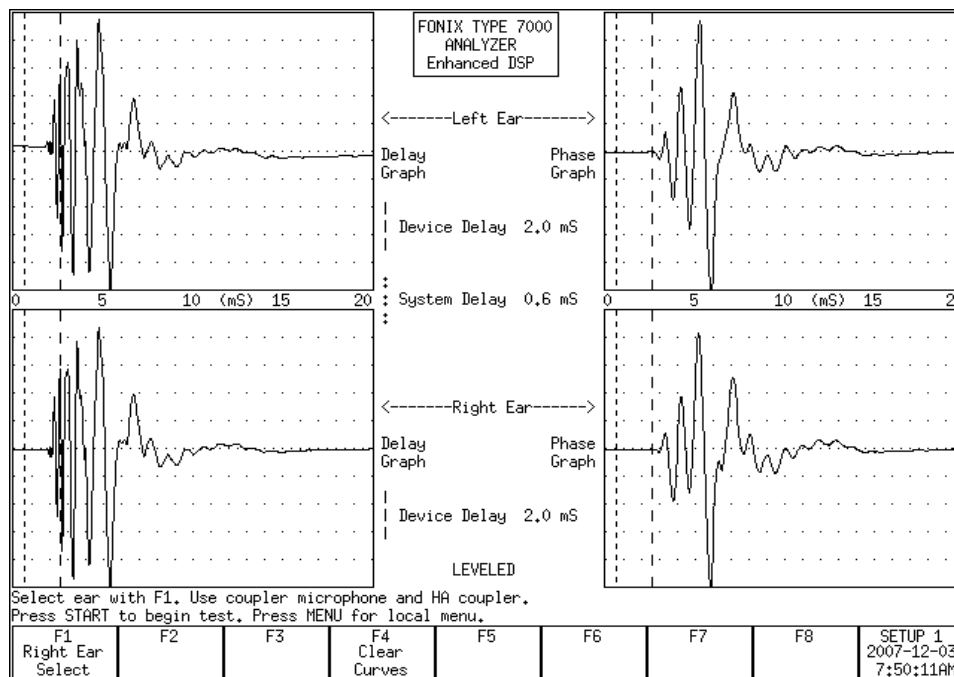


Figure 18 – Group Delay and Phase test results

STEP-BY-STEP

1. Press [F3] in the Opening screen to enter the Advanced Coupler Navigation screen.
2. Press [F4] to enter the Enhanced DSP screen.
3. Level the sound chamber (press [Level]).
4. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See *Figures 1 - 6*). Close and lock chamber lid.

F1 Coupler Multicurve	F2 Real-Ear	F3 Advanced Coupler	F4 ANSI S3.22 2003	F5 ANSI S3.42	F6 None	F7 None	F8 Load Setup Defaults
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Figure 19 – Opening Screen Function Keys

Press a function key to go to that screen. Press EXIT to return to Opening Screen.							
F1 Battery	F2 Coupler I/O	F3 Attack & Release	F4 Enhanced DSP	F5	F6	F7	F8

Figure 20 – Advanced Coupler Function Keys

5. Press [F1] to select the desired ear.
6. Press [START] to perform the group delay and phase tests.
7. When complete, place the second hearing aid in the sound chamber and use [F1] to select the desired ear.
8. Press [START] to complete the group delay and phase test of the second aid.

Note... The group delay informs the user how long it takes for the signal processing of the aid to process the signal from the microphone to the receiver. A shorter (<~15 msec) delay is better than a longer delay. Longer delays can lead to reduced speech intelligibility and sound quality. In Figure 18, it can be seen that the group delay for both aids is 2.0 msec, which is well within the acceptable range. Also note from Figure 18 that when the curve for the left aid was in an upward swing (compression) the same was true for the curve for the right aid. Also, when the curve for the left aid was in a downward swing (rarefaction) the same was true for the curve for the right aid. That is, both aids are “in phase” and the posts to the receivers are wired the same for the pair. If the results revealed the opposite, aids 180° out of phase, the patient might report there is an “echo.” This measurement takes only seconds to complete and is necessary to perform if a patient complains of an echo or imbalance or during general troubleshooting.

1.4 Measuring input/output and input/gain function.

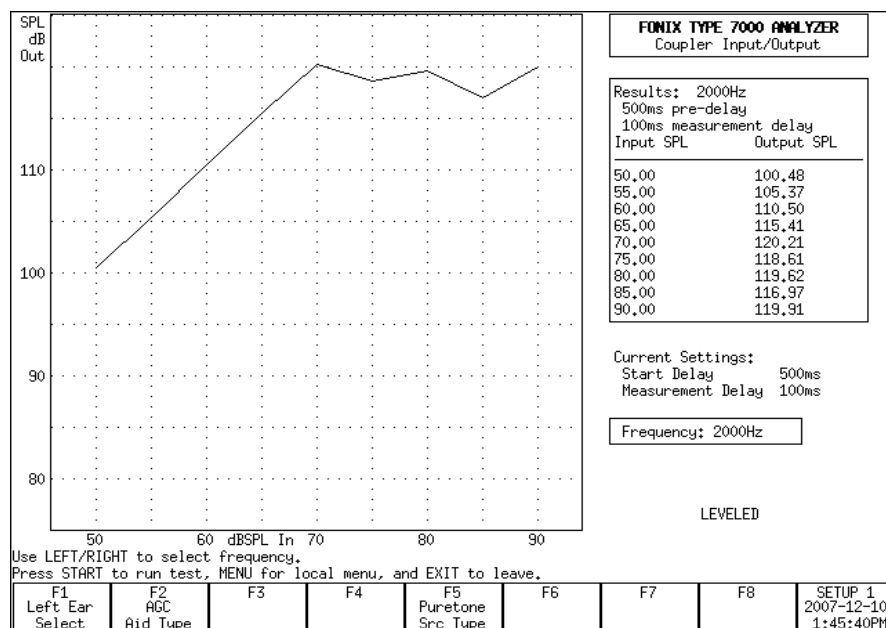


Figure 21 – Coupler input/output (dB SPL) curve

STEP-BY-STEP

1. Press [F3] from the Opening screen to enter the Advanced Coupler Navigation screen.
2. Press [F2] to enter the Coupler Input/Output screen.
3. Level the sound chamber (press [Level]).
4. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See Figures 1 - 6). Close and lock chamber lid.
5. Use [F1] to select the test ear and [F2] to select the aid type.
6. Press [START] to complete the test measurement. The test will stop automatically.
7. The clinician may use the right and left arrow keys to change the test frequency if desired. In addition, a composite signal may be used by pushing [F5].
8. This test can be measured in either Gain or SPL (output). To vary the measurement settings perform the following:
 - a. Press [MENU] from the Coupler I/O screen to open the local menu.
 - b. Use the up and down arrows to select Display under Display Settings.
 - c. Use the left and right arrows to choose either GAIN or SPL.
 - d. Press [EXIT] to return to the Coupler I/O screen.

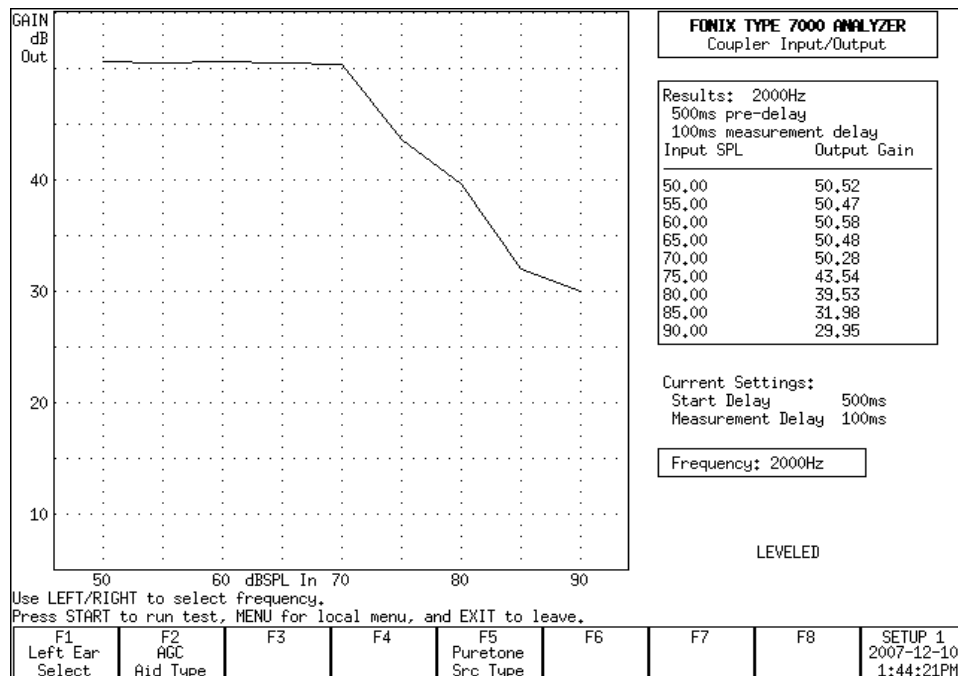


Figure 22 – Coupler input/gain curve

Note...Some clinicians can more easily understand the compression characteristics in the **input/gain** mode rather than the more conventional **input/output** mode.

1.5 Measuring the attack and release time of a hearing aid.

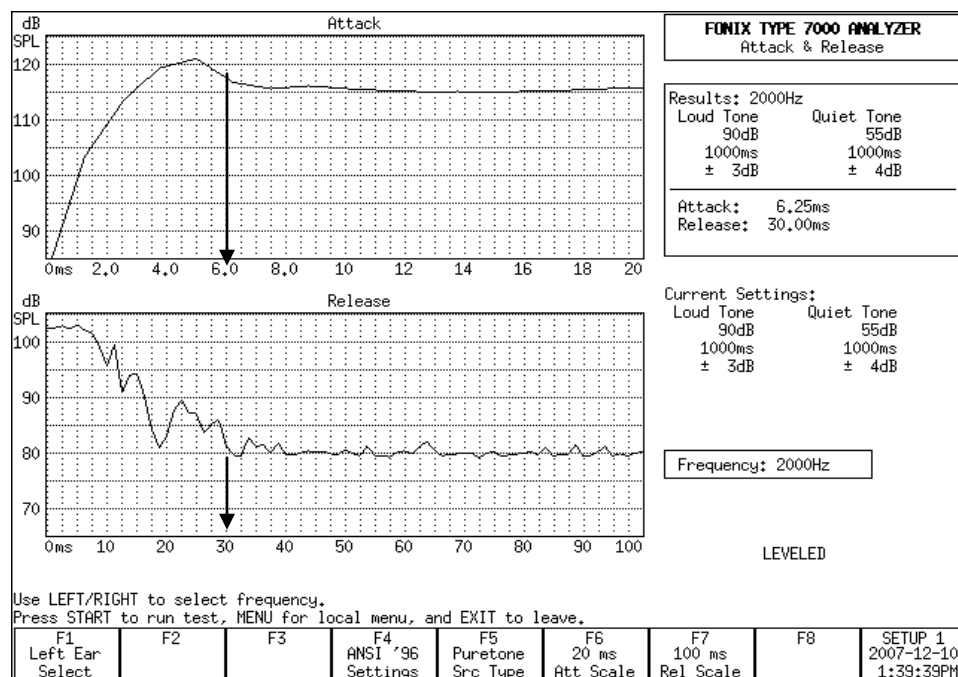


Figure 23 – Coupler attack and release time in response to a pure-tone signal

STEP-BY-STEP

1. Press [F3] from the Opening screen to enter the Advanced Coupler Navigation screen.
2. Press [F3] to enter the Attack & Release screen
3. Level the sound chamber (press [Level]).
4. Set hearing aid to full-on gain, attach to the appropriate coupler, and position the microphone of the hearing aid at the reference point with the hearing aid facing the right side of the test chamber. (See *Figures 1 - 6*). Close and lock chamber lid.
5. Use [F1] to select the test ear, [F4] to use various standards, and [F5] to toggle between a pure-tone and composite source.

[F4] standards include: IEC Loud, IEC Speech, JIS, IEC, and ANSI 96.

6. Press [START] to begin measurement. The test will stop automatically.
7. Following testing, take note of the measured attack and release time. The reader may need to adjust the graphical scale according to the measured values. For example, if the attack time is 10 milliseconds (msec), then use [F6] to select an attack scale of greater than 10 msec. If the release time is 150 msec, then use [F7] to select a release scale of greater than 150 msec.

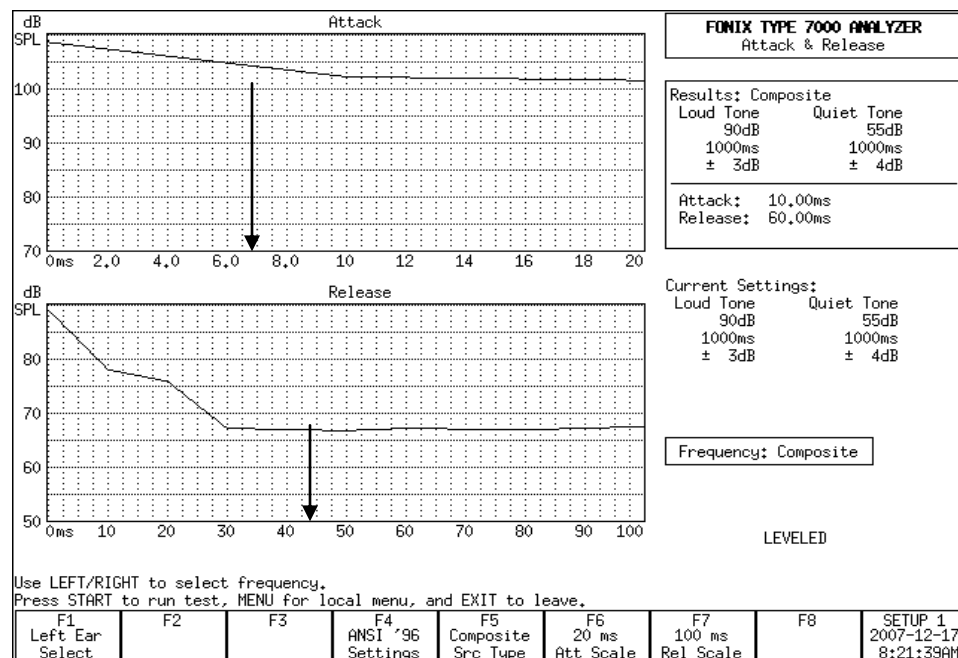


Figure 24 – Coupler attack and release time in response to a composite signal

1.6.1 Verifying the overall noise suppression feature of a hearing aid using a composite versus a digital speech signal.

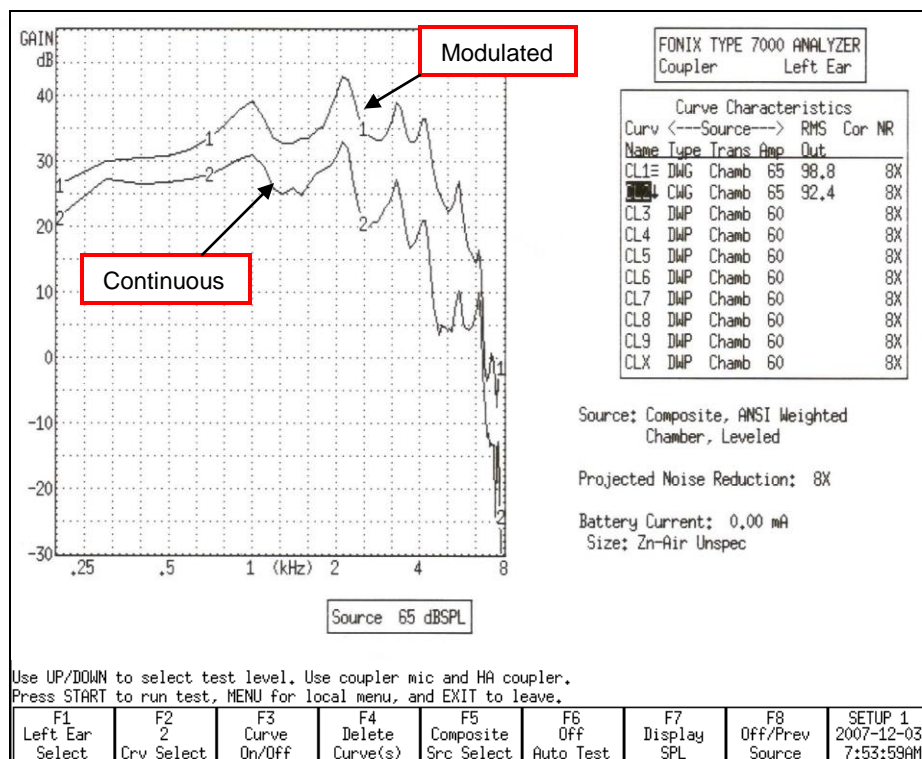
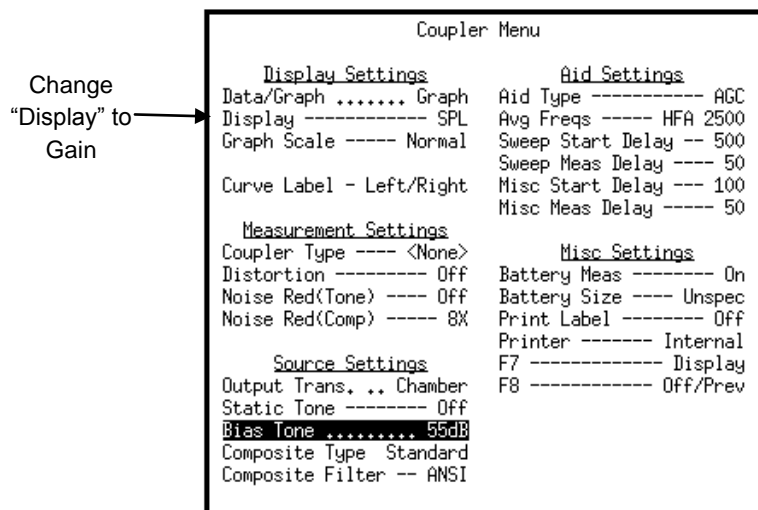


Figure 25 – Noise reduction verification – DigiSpeech vs Composite

STEP-BY-STEP

1. Verify that the noise suppression feature is enabled on the hearing aid.
2. Level the sound chamber (press [LEVEL]).
3. Attach the hearing aid to the appropriate coupler and position the microphone at the reference point (with the hearing aid facing the right side of the test chamber). Close and lock the chamber lid.
4. Enter the Coupler screen by pressing [F1] in the Opening screen.



Verify that the coupler graph ordinate is in dB GAIN ("GAIN" should appear in the upper left corner of the display). If it reads "SPL," the display will need to be changed to GAIN by following these steps:

- a. Press [MENU] from the Coupler screen to open the Coupler menu.
- b. Use the up and down arrows to select Display under Display Settings.
- c. Use the left and right arrows to choose GAIN.
- d. Press [EXIT].

Figure 26 – Coupler menu options

- Use [F2] to select the first curve (CRV 1).

When navigating the F1-F8 settings: press the UP/DOWN arrows to move the cursor up and down and press the RIGHT arrow to make a selection and return to the test window.

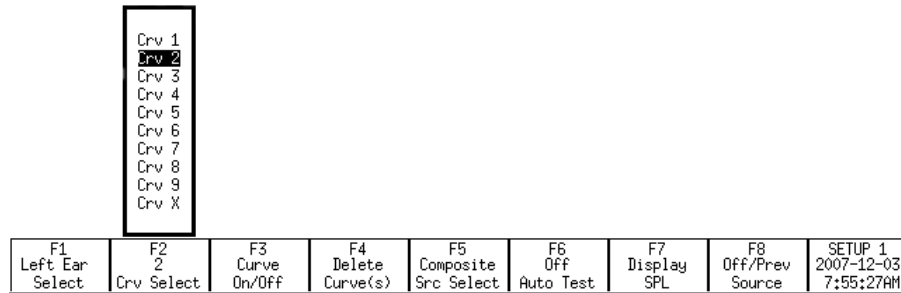


Figure 27 – Select curve options

- Use [F5] to select DIG SPEECH as the signal source.
- Use the up and down arrows to select an amplitude which approximates normal speech. We have used 65 dB SPL.
- Press [START] to begin the measurement.
- When the curve has stabilized press [STOP].
- Press [F2] to select the second curve (CRV 2).
- Press [F5] to change the signal source to COMPOSITE.
- Ensure that the amplitude is the same as was selected in Step 7.
- Press [START] to begin the measurement.
- When the curve has stabilized press [STOP].

It is best to run the composite signal for at least 15 seconds to allow time for the noise suppression to activate.

Note... Compare curve 1 (modulated **Digital Speech** signal) to curve 2 (**Composite signal**). If the noise suppression feature is activated and working properly, Curve 2 should be below Curve 1, indicating that the noise reduction feature reduces gain in response to a continuous steady-state signal (i.e. noise). Notice in Figure 25 that the frequency response curve for the composite signal is below that of the digital signal. In addition, the “RMS Out” in response to the digital signal is 98.8, whereas the “RMS Out” in response to the composite signal is 92.4 dB. Therefore, one may conclude that the noise reduction feature of this hearing aid is functioning properly.

1.6.2 Verifying the noise reduction at several frequency regions of a hearing aid using a bias tone.

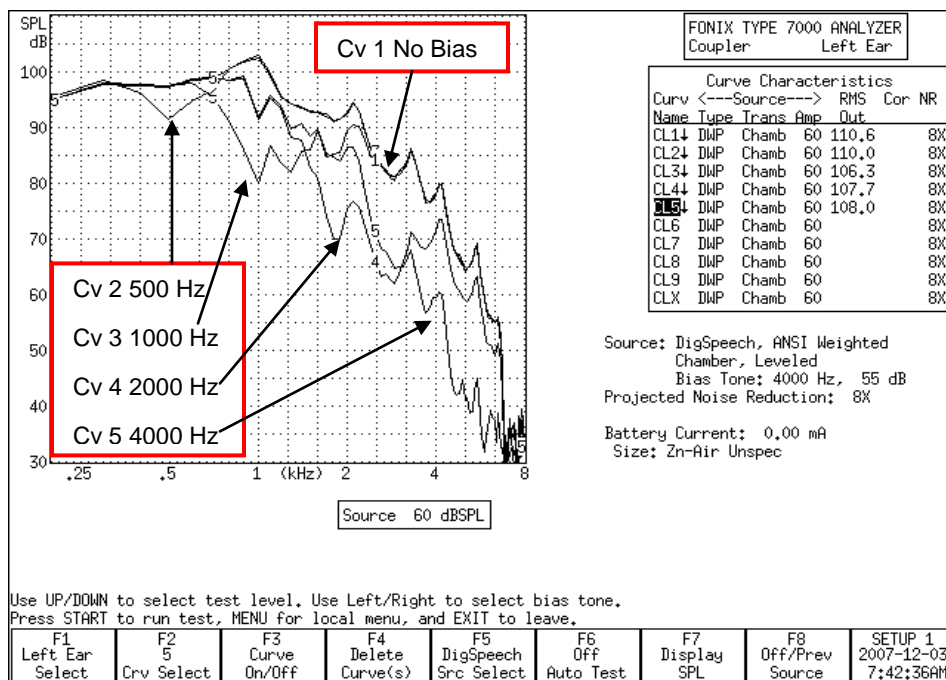


Figure 28 – Noise reduction verification using a bias tone

STEP-BY-STEP

1. Verify that the noise suppression feature is enabled on the hearing aid.
2. Enter the Coupler screen by pressing [F1] in the Opening screen.
3. Level the sound chamber (press [LEVEL]).
4. Attach the hearing aid to the appropriate coupler and position the microphone at the reference point with the hearing aid facing the right side of the test chamber (See Figures 1 – 6). Close and lock the chamber lid.
5. Use [F2] to select the first curve (CRV 1).

When navigating the F1-F8 settings: press the UP/DOWN arrows to move the cursor up and down and press the RIGHT arrow to make a selection and return to the test window.

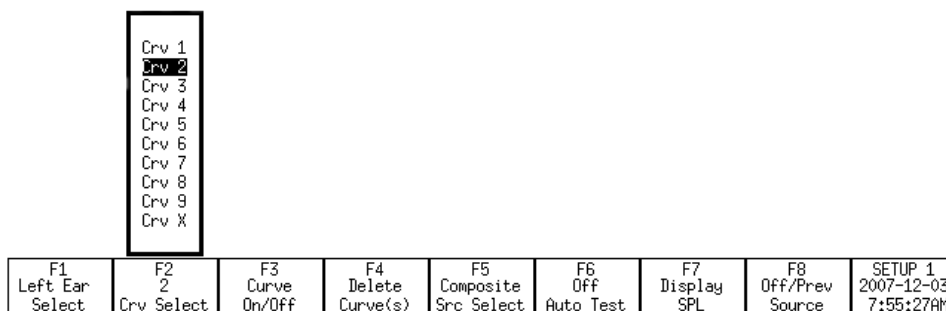


Figure 29 – Select curve options

6. Use [F5] to select DIG SPEECH as the signal source. This serves to provide a reference point for the measures that follow.
7. Use the up and down arrows to select an amplitude approximating normal speech, such as 60 dB SPL.
8. Press [START] to begin the measurement.
9. When the curve has stabilized press [STOP].
10. Press [F2] to select the second curve (CRV 2).

11. Press [MENU] to enter the Coupler menu. Press the down arrow to select **Bias Tone** under the **Source Settings** heading. Use the right arrow to select a bias tone amplitude. An appropriate amplitude is commonly 55 dB SPL. The bias tone is now turned on.

Options for bias tone amplitude include OFF and from 40 to 90 dB SPL, in 5 dB increments.

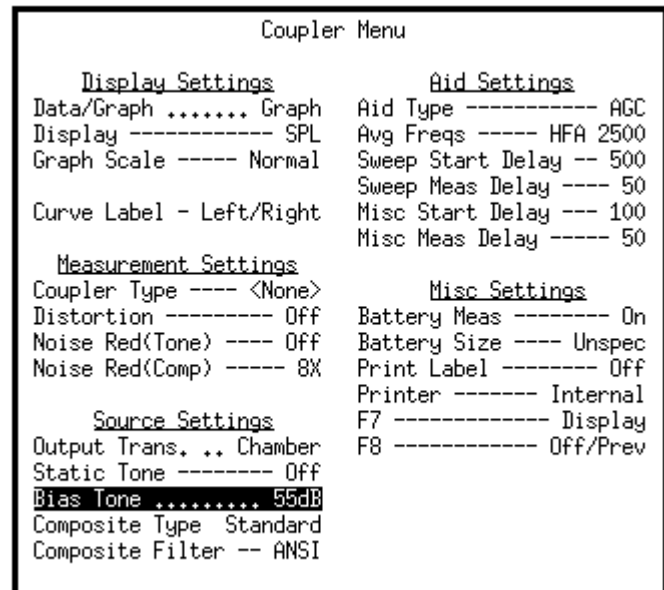


Figure 30 – Coupler Menu Options

12. Press [EXIT] to return to the coupler test screen.
13. Use the right and left arrow keys to vary the frequency of the bias tone.

Options for bias tone frequency range from 200 to 8000 Hz in varying increments.
14. **Ensure that the signal amplitude is 60 dB SPL and that DIG SPEECH is selected as the signal source.** Press [START] to begin the measurement.
15. When the curve has stabilized press [STOP].
16. Use [F2] to select another curve for testing at another bias tone frequency.
17. Repeat steps 13 through 15 for testing at additional bias tone frequencies, **ensuring that the signal amplitude remains 60 dB SPL and the signal source remains digital speech.**

Note... The use of the continuous pure-tone bias signal (available in 100 Hz increments) acting as a noise source presented simultaneously with the modulated speech composite signal allows the clinician to more effectively verify the effectiveness of the noise reduction feature of the hearing aid in reducing the gain/output only in the frequency region surrounding the distracting noise while leaving intact the frequency region above and below the distracting noise. This, theoretically, would result in improved communication and comfort in noise because the reduction in gain will be in a restricted segment of the frequency response instead of a larger segment of the frequency response in response to a noise. It is believed that hearing aids with greater channels of noise reduction could lead to better performance in noise (and feedback management) because in multichannel aids narrower and narrower segments of the frequency response are reduced in response to noise (or feedback) within the environment.

1.7 Test chamber configuration to measure wireless CROS

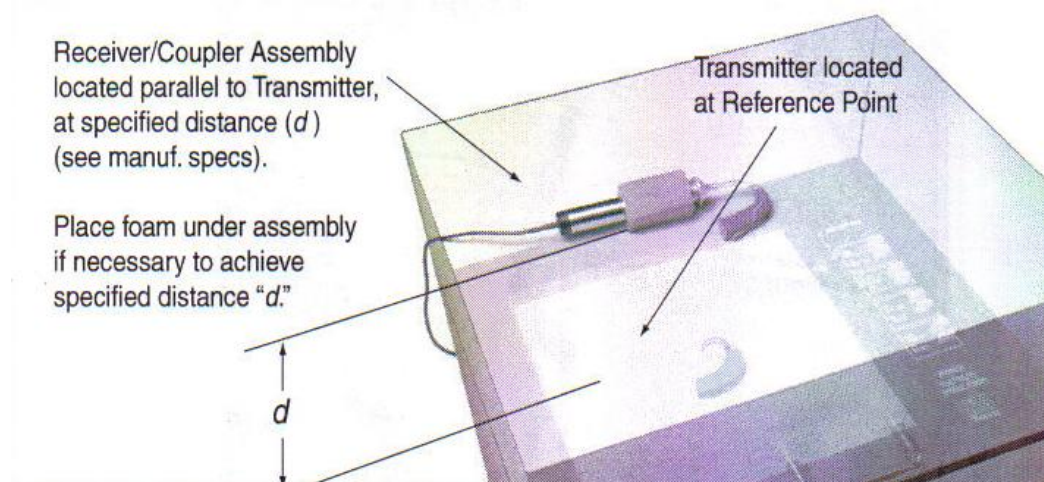


Figure 31 – Test box setup for wireless CROS measurements

STEP-BY-STEP

1. The primary goal is to obtain sufficient separation between the transmitter and receiver. Usually 6" is sufficient.
2. Place the microphone of the transmitter at the reference point and turn on the transmitter.
3. Close the lid
4. Place the receiver side on top of the lid. If greater separation is required, then a foam pad can be placed on top of the lid and the aid + coupler placed on top of the foam pad.

5. Align receiver + coupler assembly on top of the lid so it is vertical to the transmitter in the test chamber.
6. Test as you would any other aid.
7. For BICROS, test the receiver side as you would any aid.

REAL EAR MEASURES

BASIC OVERVIEW OF PREPARATIONS FOR REAL EAR MEASURES

Before providing a detailed description of various methods to verify the performance of hearing aids using real ear measures, the authors feel it may be beneficial to provide a brief overview of preparations for real ear measures in general. Figure 32 illustrates the correct method of placing the reference microphone above the pinna of the test ear and the probe microphone in the ear canal of the test ear. For accurate measures, it is important that the tip of the probe tube be within 6 mm of the tympanic membrane (TM). In the adult patient this can be achieved by placing a mark on the probe tube 30 mm from the tip and being sure this mark rests along side the intratragal notch of the external ear as illustrated in Figure 32. After the clinician has the probe tube in the proper position, it is best to apply tape over the probe tube and adhere it to the face to prevent the probe tube from moving when the hearing aid is inserted into the ear canal. Figure 33 illustrates of the importance of the correct placement of the probe tube (Dirks and Kincaid, 1987). Think of the abscissa as the length of the ear canal (3.0 cm = 30 mm) and what happens to measured SPL near the TM as the probe tube is placed along this line. For example, at 2000 Hz the measured SPL @ 30 mm from the TM is ~ 2 dB less than measured at the TM! Thus, for 2000 Hz and below the measured SPL would be essentially the same regardless of where the probe tube is placed along the ear canal. On the other hand, at 8000 Hz, if the clinician placed the end of the probe tube ~12 mm from the TM, the measured SPL would be ~ 12 dB less than what is present at the TM. The other curves at 3000-7000 Hz reveal similar findings. Thus, if the probe tip is within 6 mm of the TM, then the SPL measured at the probe tip would be the same (+/- 2 dB) as what would have been measured if the probe tip were at the eardrum from 250-8000 Hz. Figure 34 illustrates another method that can be used to assure proper placement of the probe tube in the ear canal. Proper placement will occur when the measured REUG @ 6000 Hz is at 0 dB gain.

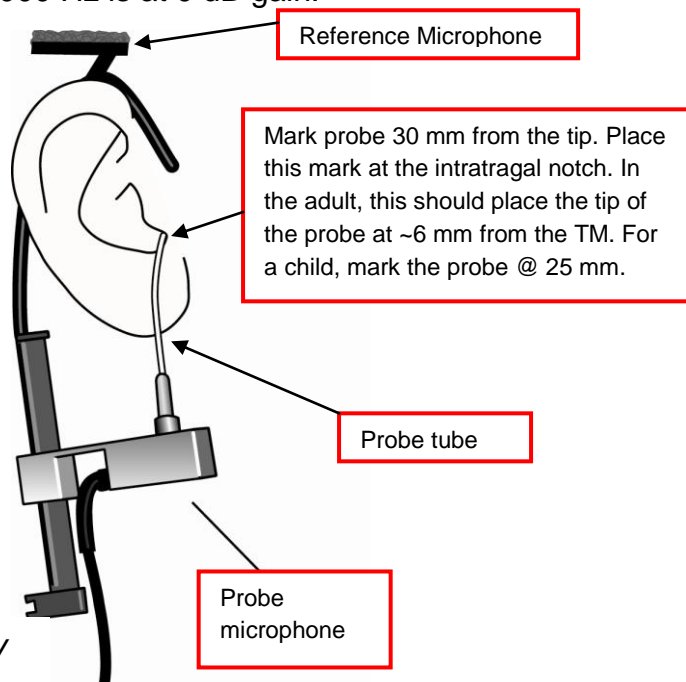
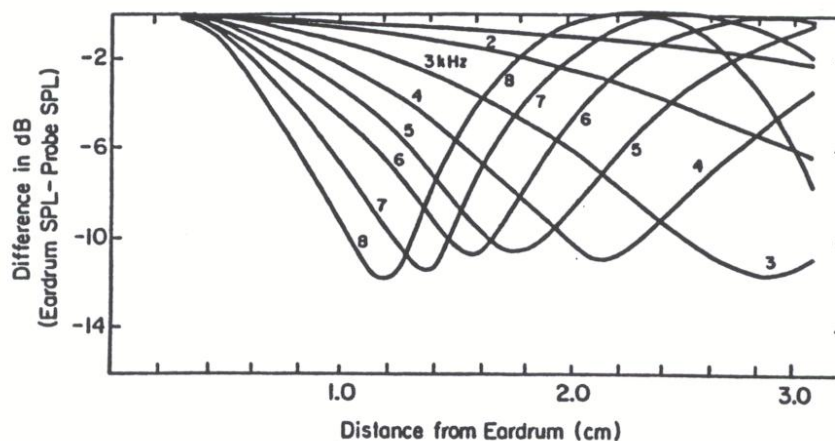


Figure 32 – Probe tube assembly

Figure 33 – Illustrating the importance of the correct placement of the probe tube (Dirks and Kincaid, 1987). Think of the abscissa as the length of the ear canal (3.0 cm = 30 mm) and what happens to measured SPL near the TM as the probe tube is placed along this line. For example, at 2000 Hz the measured SPL @ 30 mm from the TM is ~ 2 dB less than measured at the TM! Thus, for 2000 Hz and below the measured SPL would be essentially the same regardless of where the probe tube is placed along the ear canal. On the other hand, @ 8000, if the clinician placed the end of the probe tube ~12 mm from the TM, the measured SPL would be ~ 12 dB less than what is present at the TM. The other curves @ 3000-7000 Hz reveal similar findings.



On the other hand, @ 8000, if the clinician placed the end of the probe tube ~12 mm from the TM, the measured SPL would be ~ 12 dB less than what is present at the TM. The other curves @ 3000-7000 Hz reveal similar findings.

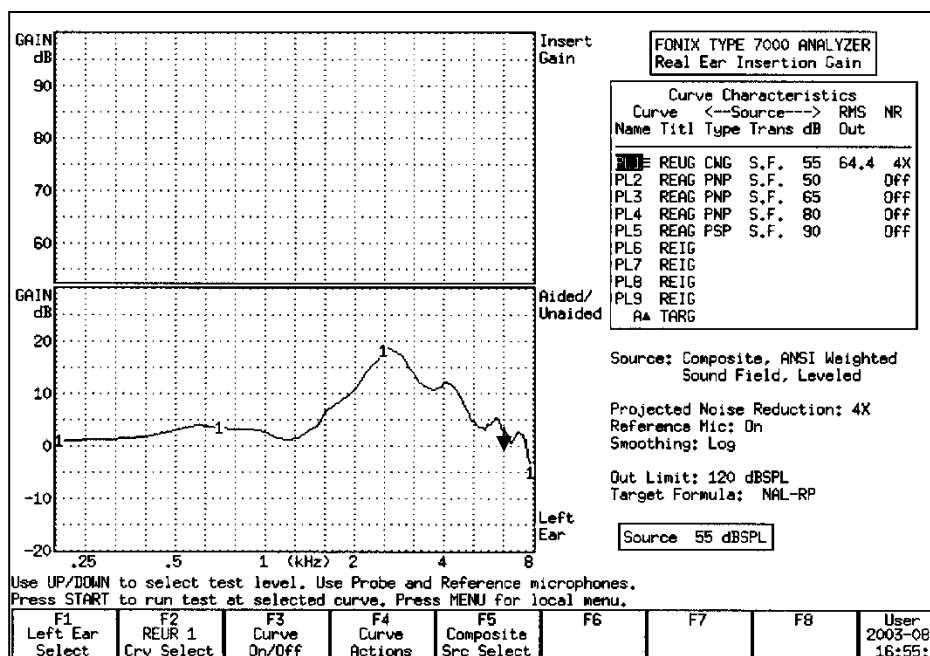


Figure 34 – Illustrating the proper placement of the probe tube in the ear canal where the measured REUG @ 6000 Hz is @ 0 dB gain. This is another method to verify that the probe tube is in its proper place along the ear canal.

2.1 Measuring the real-ear unaided gain (REUG) of the open ear canal.

STEP-BY-STEP

1. Prior to setting up the patient for real ear measurements, it is important to enter the audiogram with the appropriate menu settings. From the Opening screen, press [F2] to enter the Real Ear Navigation screen.
2. Press [F1] in the Real Ear Navigation screen to enter the audiogram entry screen.

F1 Audiogram	F2 Target	F3 Insertion Gain	F4 Real Ear SPL	F5 Visible Speech	F6	F7	F8
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Figure 35 – Real ear navigation screen function keys

3. Press [MENU] to open the real ear audiogram menu and select the appropriate settings based on the patient's audiogram and the hearing aid parameters. These settings are important for the generation of real ear targets.

NOTE: Use the UP/DOWN arrows to select a menu option and press the RIGHT arrow to change a selection. Press [EXIT] to return to the audiogram entry screen.

Real Ear Audiogram Menu	
Targets	
Aud. Transducer -----	ER3
Fitting Rule -----	NAL-NL1
Client Age -----	Adult
Compression -----	40 dB
No. of Channels -----	15
Aid Limit -----	Multichannel
Fit Type -----	Bilateral
Sound Field -----	0 degrees
Ref. Position --	Head Surface
Misc	
RECD Mode -----	Off
Print Label -----	Off
Printer -----	Internal

REAL EAR AUDIOGRAM MENU - TARGET OPTIONS:

Aud. Transducer: OFF, SF (Soundfield), TDH, ER3
 Fitting Rule: NAL-NL1, POGO, BERGER, 1/3 Gain, 1/2 Gain, 2/3 Gain, Direct, NAL-RP
 Age: Adult, 0-2mos, 3-6mos, 7-12mos, 1-2yrs, 2-3yrs, 3-4yrs, 4-5yrs, 5+yrs
 Compression: 40-69 dB
 Channels: 1-18+
 Aid Limit: Multichannel, Wideband, None
 Fit Type: Unilateral, Bilateral
 Sound Field: 0°, 45°
 Reference Position: Head Surface, Undisturbed

Figure 36 – Real ear audiogram menu

4. The clinician may now enter the patient's audiogram. Use [F1] to select an ear and press [F2] to select HTL to enter the patient's hearing threshold levels. Use the UP/DOWN arrow to select a frequency and use the RIGHT/LEFT arrows to select the threshold level in 5 dB steps.

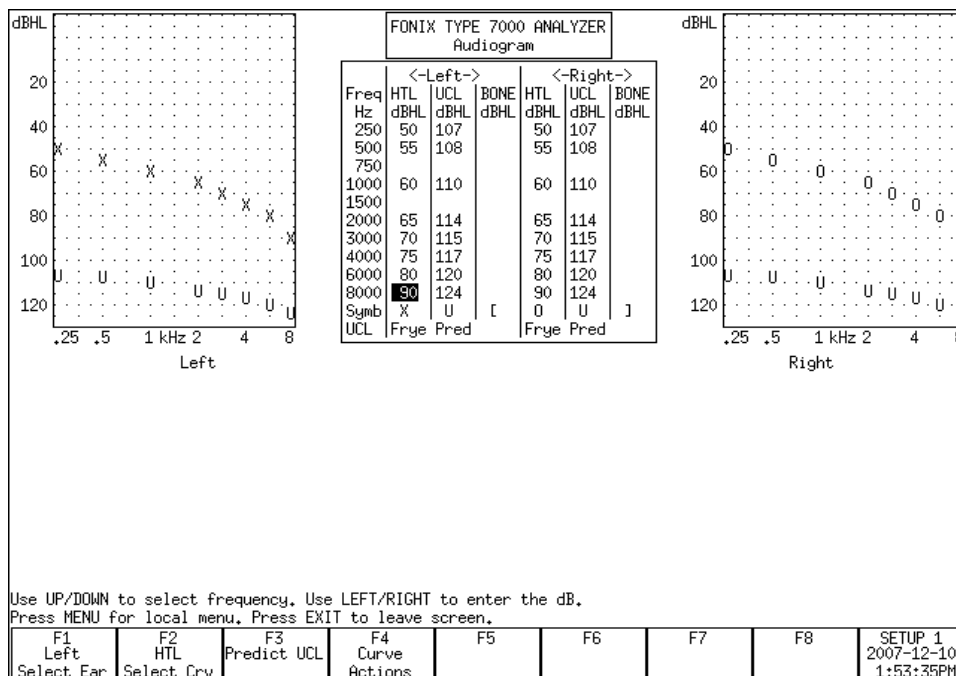


Figure 37 – Audiogram and LDL entry screen

5. If a patient's hearing loss is conductive or mixed, it is important to enter bone conduction thresholds when using the NAL-NL1 target. Press [F2] to select Bone and use the procedure listed in Step 4 above to enter the patient's bone conduction thresholds.
6. Press [F3] to use predicted LDLs or use [F2] to select LDL to enter a patient's measured LDLs using the same procedure listed in Step 4 above. The authors have a very strong preference for using measured and not predicted LDLs.
7. If performing a binaural fitting and a patient has a similar hearing loss bilaterally, you may press [F4] and select COPY EAR to copy data to the opposite ear. To change individual threshold values as necessary, press [F1] to select the appropriate ear and repeat Step 4 in order to make changes to the copied data.
8. Press [EXIT] to return to the Real Ear Navigation screen. Press [F3] to open the Insertion Gain screen.
9. To ensure proper probe tube placement, verify that the bottom graph is labeled as GAIN ("GAIN" should appear in the upper left corner of the display). If it reads "SPL," the display will need to be changed to GAIN by following these steps:
 - a. Press [MENU] from the insertion gain screen to open the local menu.
 - b. Use the up and down arrows to select Display under Display Settings.
 - c. Use the left and right arrows to choose GAIN.
 - d. Press [EXIT] to return to the insertion gain screen.

10. Configure the patient for real ear measurements.

- a. Mark the probe tube either 5 mm from the canal opening of the earmold/custom shell or at 30 mm from the tip of the probe tube.
- b. Place the reference and probe microphone unit on the test ear as illustrated in Figure 32.
- c. After performing otoscopic inspection, insert the probe tube with the mark at the intertragal notch. It is recommended that tape be used to secure the probe tube.
- d. Place the sound-field speaker at a distance of approximately 12 inches from the client's head at 0° azimuth (directly in front of the patient) from the test ear. The height of the sound-field speaker should be even with the test ear. Be sure "0" has been entered in the real ear audiogram menu!

11. Press [LEVEL] in order to calibrate the sound-field speaker and the reference microphone.

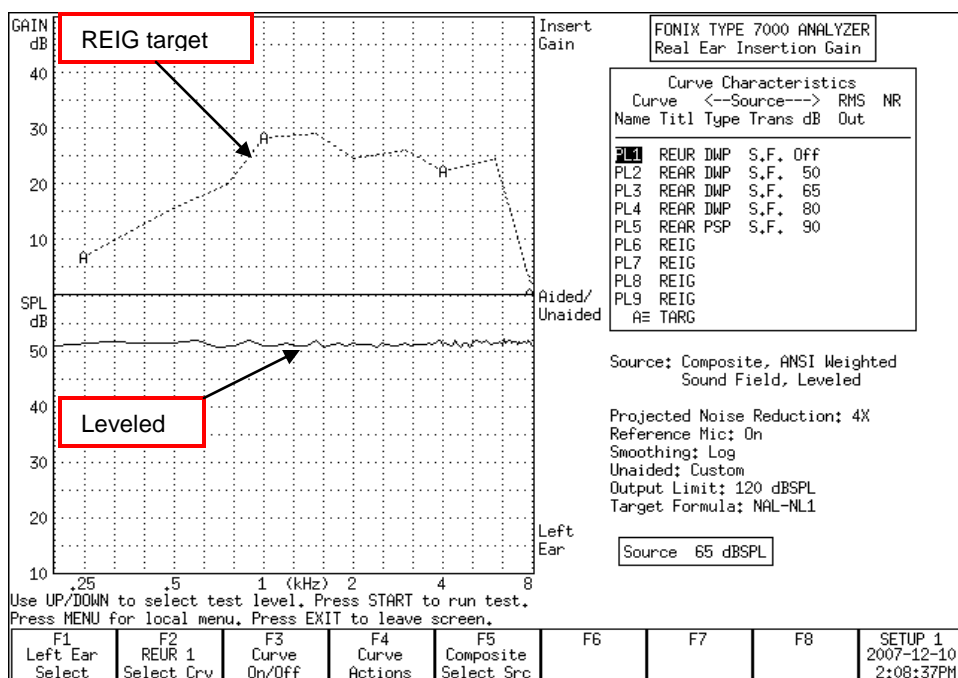


Figure 38 – Leveling of the sound field speaker

12. Use [F2] in the Insertion Gain screen to select REUG 1. Press [START] to begin measurement and press [STOP] to store the measured response.

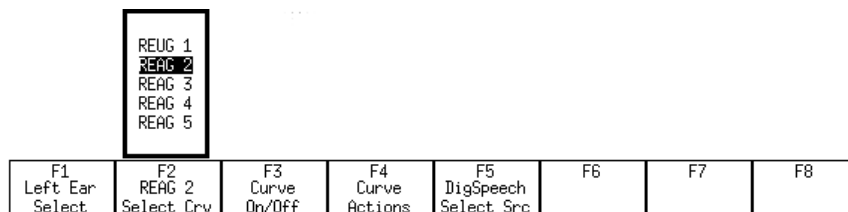


Figure 39 - Real ear select curve options

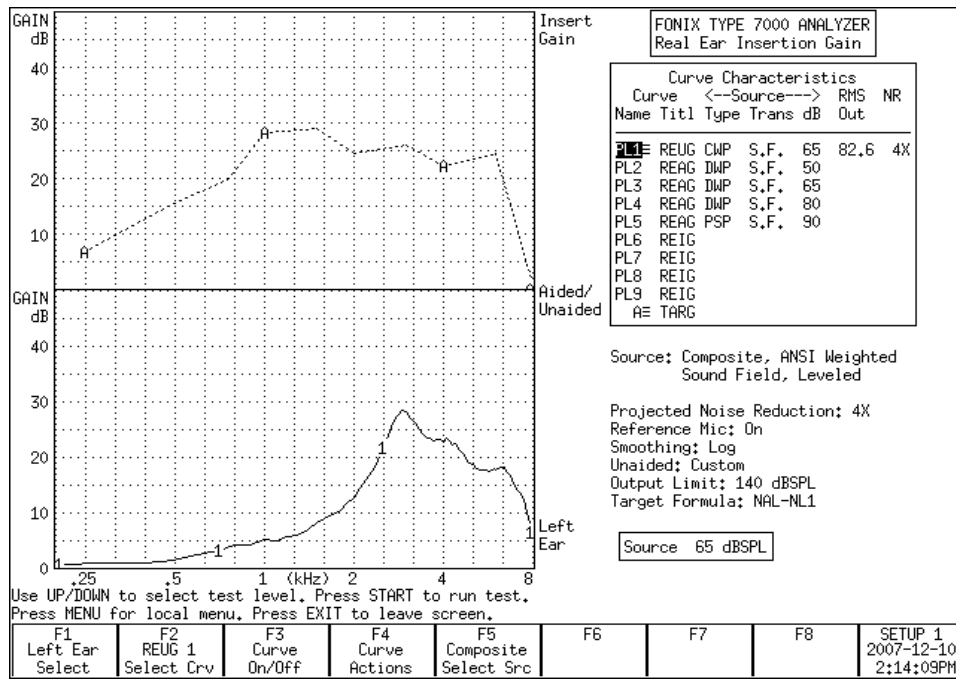


Figure 40 – Real ear unaided gain (REUG) of the open ear canal in the lower curve and the real ear insertion gain (REIG) target in the upper curve.

2.2 Performing real-ear insertion gain (REIG) measurements to verify the appropriateness of a hearing aid’s programming to the prescriptive target.

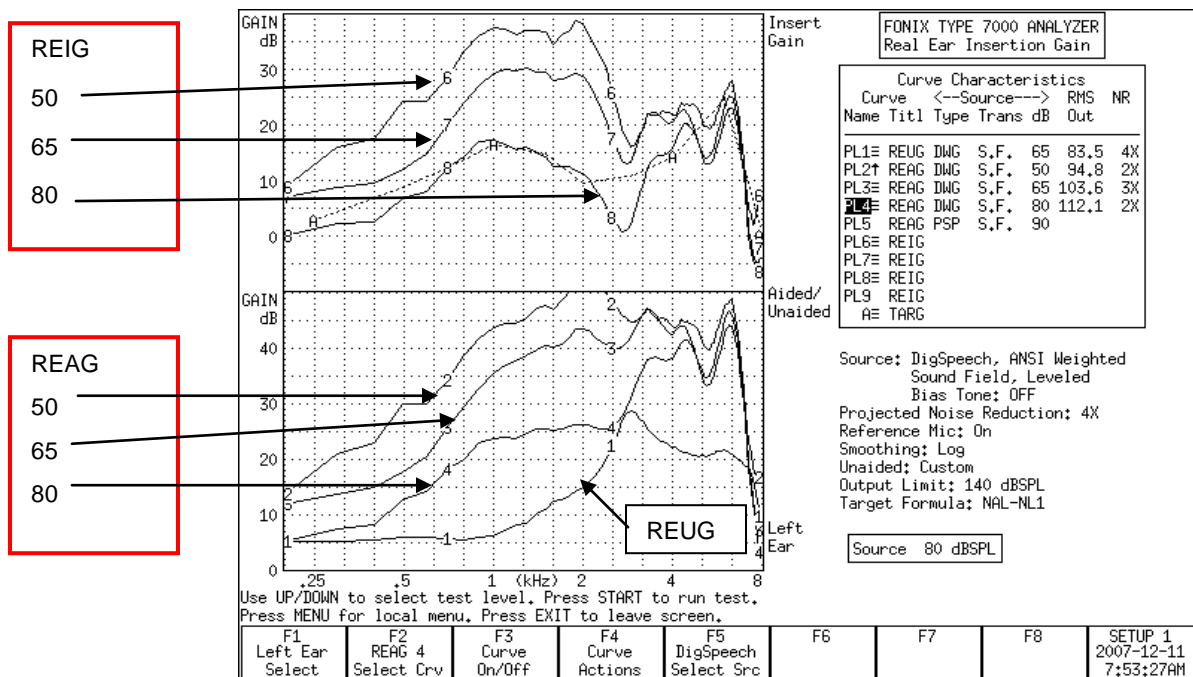


Figure 41 – Real Ear Insertion Gain screen

STEP-BY-STEP

1. Perform Real Ear Unaided Gain measurement as described in Section 2.1.
2. Insert the hearing aid into the ear with special care not to move the probe tube. The hearing aid should be set up for programming in case a need for change exists.
3. Use [F2] to select REAG 3, which uses a 65 dB SPL modulated signal representing a level of average conversational speech. Verify that DigSpeech is selected as the source using the [F5] key.

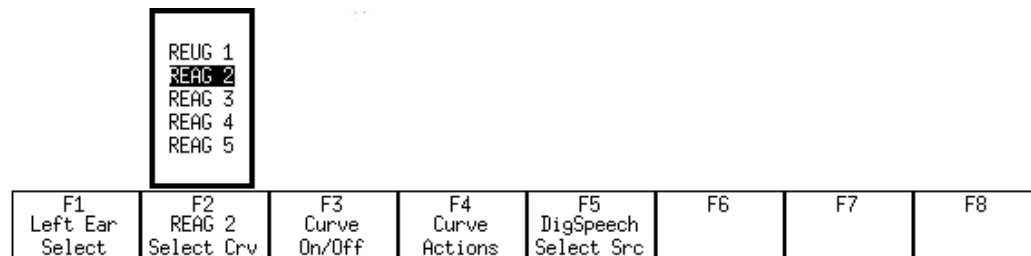


Figure 42 – Real ear select curve options

4. Press [START] to measure the insertion gain of the hearing aid. Press [STOP] to store the curve.
5. Analyze the shape of the insertion gain curve (top graph) in comparison to the target. Make modifications to the hearing aid programming as necessary in order to best approximate the target. Repeat the insertion gain measurement (if necessary) until programming changes have successfully resulted in an approximation to target.
6. Use [F2] to select REAG 2, which uses a 50 dB SPL modulated signal representing soft speech.
7. Repeat Steps 4 and 5 above to measure the insertion gain of the hearing aid to a soft input and program the hearing aid so the measured REIG arrives as close as possible to the NAL-NL1 target for a 50 dB SPL input.
8. Use [F2] to select REAG 4, which uses an 80 dB SPL modulated signal representing loud conversational speech.
9. Repeat Steps 3 and 4 above to measure the insertion gain of the hearing aid to 80 dB SPL and program the hearing aid so the measured REIG arrives as close as possible to the NAL-NL1 target for an 80 dB SPL input.

2.3 Measuring the real ear **front-to-back ratio** in order to determine the efficacy of directional microphones. This measure is easy to perform at the completion of insertion gain verification or may be performed as a separate measure.

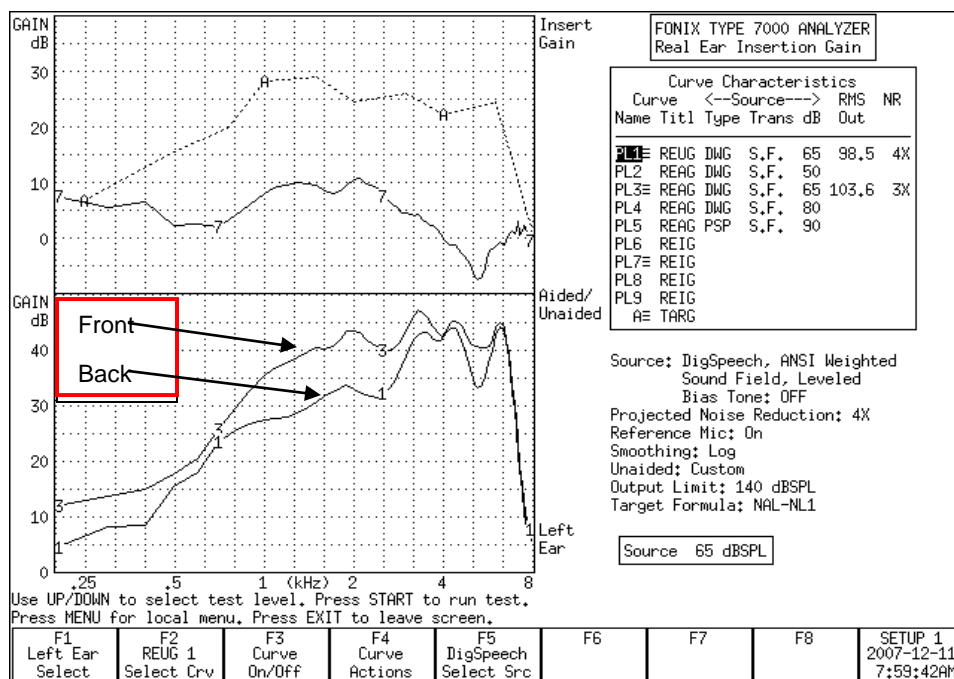


Figure 43 – Real ear insertion gain measurement of front-to-back ratio

STEP-BY-STEP

1. Press [F2] from the Opening screen to enter the Real Ear Navigation screen.
2. Press [F3] to enter the Insertion Gain screen.
3. Use [F1] to select the test ear.
4. Following otoscopic inspection, insert the probe tube in the test ear 6 mm from the tympanic membrane as described in the “Basic Overview of Preparations for Real Ear Measures.”
5. Place the sound field speaker at a distance of approximately 12 inches from the client’s head at 0° azimuth (directly in front of the patient) from the test ear. The height of the sound field speaker should be level with the test ear.
6. Insert the hearing aid into the test ear, taking special care not to move the probe tube.
7. Use [F2] to select REUG 1. Ensure that the source amplitude is 65 dB SPL and use [F5] to ensure that a modulated source is selected (DigSpeech).
8. Press [START] to begin measurement and press [STOP] when the curve is present.

9. Use [F2] to select REAG 3. Ensure that the source amplitude is 65 dB SPL and that DigSpeech is the signal.
10. Press [START] and begin to rotate the client from the starting point so that the speaker is pointing toward the back of the ear (a computer chair or some sort of swivel chair is ideal). Monitor the curve to verify that the back microphone is attenuating the gain and press [STOP] when the curve has stabilized.

Note... It is very important for the clinician to complete this measure on all hearing aids with directional microphones. In the experience of the authors, approximately 5-10% of new hearing aids arriving in the clinic have directional microphones that are reversed (i.e., back microphone is amplifying and the front microphone is attenuating) or the rear microphone simply is not working (i.e., no change in measure gain or output as the loudspeaker is rotated around the patient). **Also, it is important to remember that the distance from the loudspeaker to the hearing aid microphone for both measures must be equal!**

2.4 Measuring the real ear aided response (REAR) of a hearing aid in dB SPL.

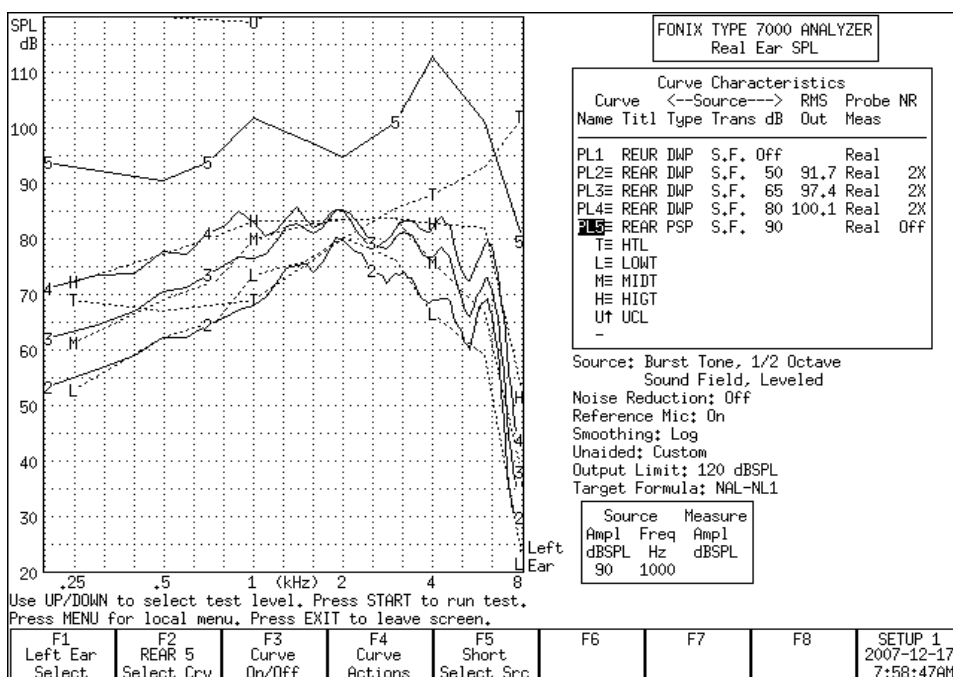


Figure 44 – Real Ear SPL screen

STEP-BY-STEP

1. Press [F2] from the Opening screen to enter the Real Ear Navigation screen.
2. Press [F1] in the Real Ear Navigation screen to enter the audiogram entry screen.

F1	F2	F3	F4	F5	F6	F7	F8
Audiogram	Target	Insertion Gain	Real Ear SPL	Visible Speech			

Figure 45 – Real ear navigation screen function keys

- Press [MENU] to open the real ear audiogram menu and select the appropriate settings based on the patient’s audiogram and the hearing aid parameters. These settings are important for the generation of real ear targets.

NOTE: Use the UP/DOWN arrows to select a menu option and press the RIGHT arrow to change a selection. Press [EXIT] to return to the audiogram entry screen.



TARGET OPTIONS:

Aud. Transducer: OFF, SF(Sound field), TDH, ER3
 Fitting Rule: NAL-NL1, POGO, BERGER, 1/3 Gain, 1/2 Gain, 2/3 Gain, Direct, NAL-RP
 Age: Adult, 0-2mos, 3-6mos, 7-12mos, 1-2yrs, 2-3yrs, 3-4yrs, 4-5yrs, 5+yrs
 Compression: 40-69 dB
 Channels: 1-18+
 Aid Limit: Multichannel, Wideband, None
 Fit Type: Unilateral, Bilateral
 Sound Field: 0°, 45°
 Reference Position: Head Surface, Undisturbed

Figure 46 – Real ear audiogram menu

- The clinician may now enter the patient’s audiogram. Use [F1] to select an ear and press [F2] to select HTL to enter the patient’s hearing threshold levels. Use the UP/DOWN arrow to select a frequency and use the RIGHT/LEFT arrows to select the threshold level in 5 dB steps.

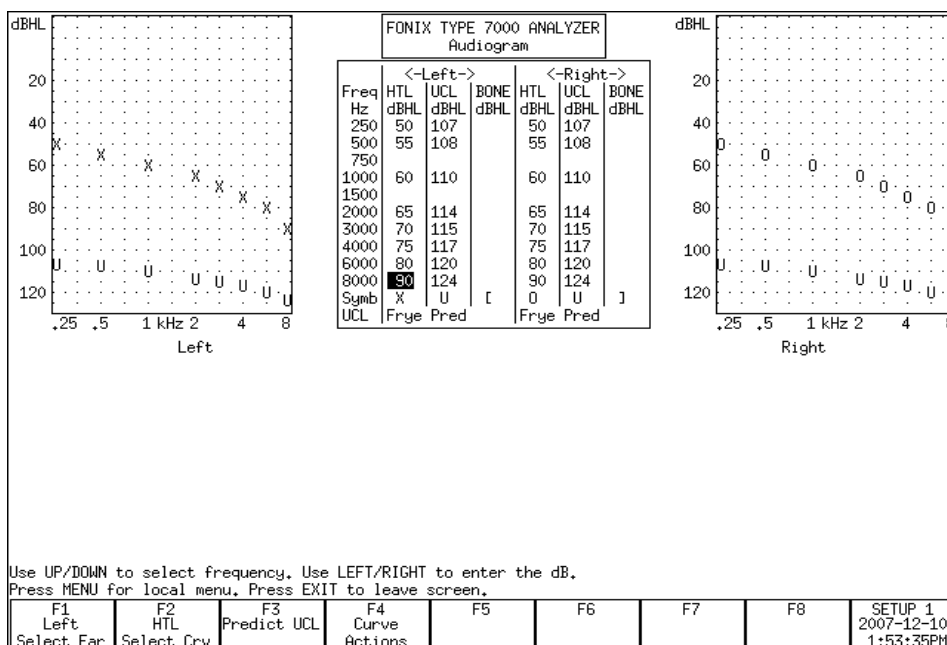
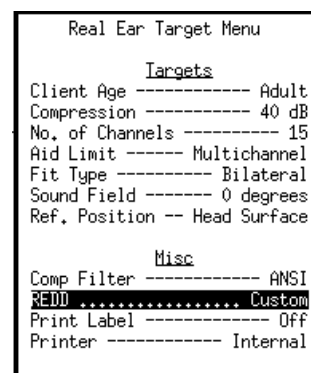


Figure 47 – Audiogram entry screen

5. If a patient's hearing loss is conductive or mixed, it is important to enter bone conduction thresholds when using the NAL-NL1 target. Press [F2] to select Bone and use the procedure listed in Step 4 above to enter the patient's bone conduction thresholds.
6. Press [F2] to select LDL to enter a patient's measured LDLs using the same procedure listed in Step 4 above or press [F3] to use predicted LDLs.
7. If performing a binaural fitting and a patient has a similar hearing loss bilaterally, you may press [F4] and select COPY EAR to copy data to the opposite ear. To change individual threshold values as necessary, press [F1] to select the appropriate ear and repeat Step 4 in order to make changes to the copied data.
8. Press [EXIT] to return to the Real Ear Navigation screen.
9. If measured REDDs are available to be entered, perform the following steps:

- a. Press [F2] to enter the Real Ear Target screen. Press [MENU] to enter the Real Ear Target Menu. Use the UP/DOWN arrows to select REDD and use the RIGHT arrow to select Custom. Press [EXIT].
- b. The clinician may now press [F2] to select REDD and use the same procedure listed in Step 4 above to enter the data.
- c. Press [EXIT] to return to the Real Ear Navigation screen.



*Figure 48 –
Real ear
target menu*

10. Press [F4] to enter the Real Ear SPL screen.
11. Set up the patient for real ear measurements and level the sound-field speaker as described in Section 2.1. Insert the hearing aid into the patient's ear, using special care not to move the probe tube.
12. Use [F2] to select REAR2, which uses a 50 dB SPL input signal. Use [F5] to ensure that the signal source is DigSpeech.
13. Press [START] to measure the output of the hearing aid. Press [STOP] to store the curve.
14. Analyze the shape of the output curve (labeled curve 2) in comparison to the target labeled "L". Make modifications to the hearing aid programming as necessary in order to best approximate the target. Repeat the output measurement (if necessary) until programming changes have successfully resulted in an approximation to target.

15. Use [F2] to select REAR 3, which uses a 65 dB SPL Speech signal.
16. Repeat Steps 13 and 14 above to measure the output of the hearing aid to an average input.
17. Use [F2] to select REAR 4, which uses an 80 dB SPL DigSpeech signal.
18. Repeat Steps 13 and 14 above to measure the output of the hearing aid to a loud input.
19. Use [F2] to select REAR 5, which uses a 90 dB SPL pure-tone sweep.
20. Press [START] to begin the measurement. The test will stop automatically. Compare this curve, which is the **Real Ear Saturation Response (RESR90)**, to the patient's LDLs (labeled "U") and ensure that the curve never exceeds the patient's LDLs.

2.5 Performing live speech mapping to verify the output, in real-time, of a hearing aid in response to an actual speech signal. **This tool is best used as a counseling tool for patients and their family members.**

L, M, H: the real ear targets
l, m, h: unamplified LTASS

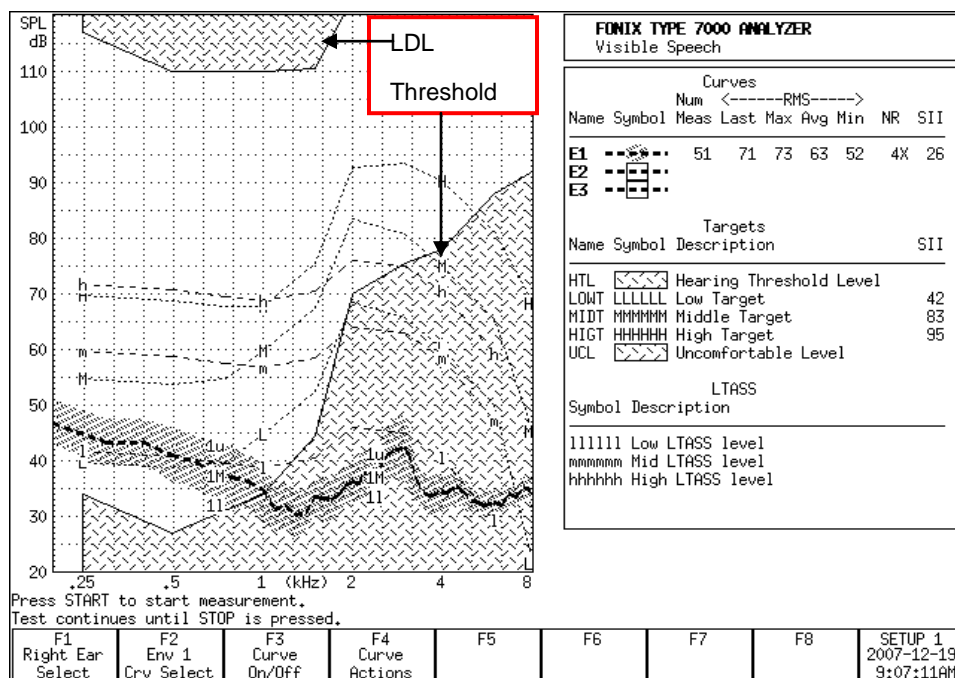


Figure 49 – Visible Speech unaided response

STEP-BY-STEP

1. From the Opening screen, press [F2] to enter the Real Ear Navigation screen.
2. Press [F1] in the Real Ear Navigation screen to enter the audiogram entry screen.

F1 Audiogram	F2 Target	F3 Insertion Gain	F4 Real Ear SPL	F5 Visible Speech	F6	F7	F8
-----------------	--------------	-------------------------	-----------------------	-------------------------	----	----	----

Figure 50 – Real ear navigation screen function keys

3. Press [MENU] to open the real ear audiogram menu and select the appropriate settings based on the patient’s audiogram and the hearing aid parameters. These settings are important for the generation of real ear targets.
4. The clinician may now enter the patient’s audiogram. Use [F1] to select an ear and press [F2] to select HTL to enter the patient’s hearing threshold levels. Use the UP/DOWN arrow to select a frequency and use the RIGHT/LEFT arrows to select the threshold level in 5 dB steps.

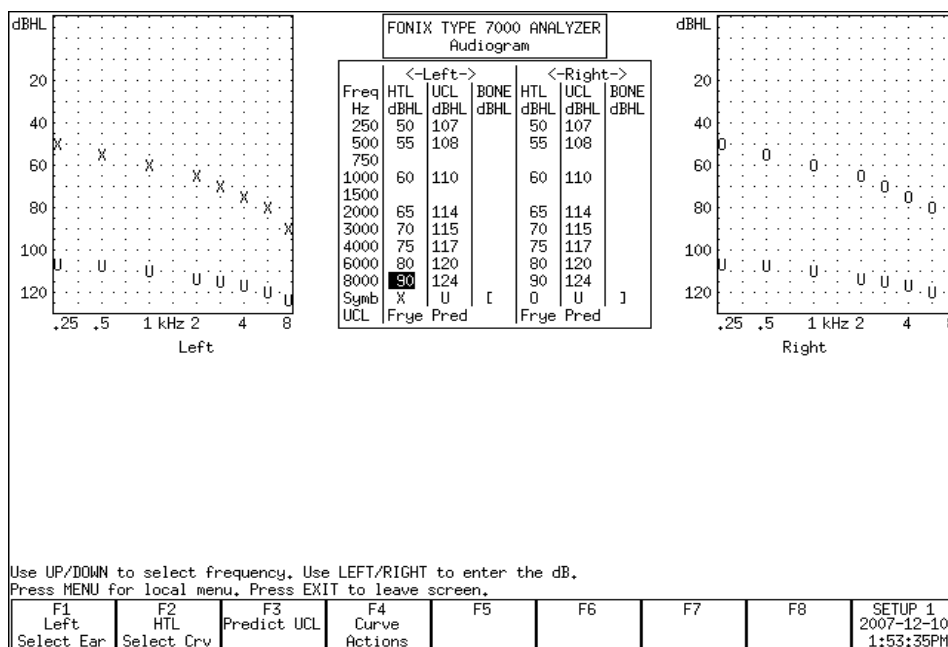


Figure 51 – Audiogram entry screen

5. If a patient’s hearing loss is conductive or mixed, it is important to enter bone conduction thresholds when using the NAL-NL1 target. Press [F2] to select Bone and use the procedure listed in Step 4 above to enter the patient’s bone conduction thresholds.
6. Press [F2] to select LDL to enter a patient’s measured LDLs using the same procedure listed in Step 4 above or press [F3] to use predicted LDLs.
7. If performing a binaural fitting and a patient has a similar hearing loss bilaterally, you may press [F4] and select COPY EAR to copy data to the opposite ear. To change individual threshold values as necessary, press [F1] to select the appropriate ear and repeat Step 4 in order to make changes to the copied data.
8. Press [EXIT] to return to the Real Ear Navigation screen.

9. Press [F5] to enter the Visible Speech screen.
10. Press [MENU] to enter the Visible Speech Menu and ensure that the appropriate target settings are selected. We have found that the optimal settings for visible speech are to turn off smoothing and the min/max options.

NOTE: Use the UP/DOWN arrows to select a menu option and press the RIGHT arrow to change a selection. Press [EXIT] to return to the visible speech screen.

<pre> Visible Speech Menu Targets Fitting Rule ----- NAL-NL1 Client Age ----- Adult Compression ----- 40 dB No. of Channels ----- 15 Aid Limit ----- Multichannel Fit Type ----- Bilateral Sound Field ----- 0 degrees Ref. Position -- Head Surface Settings Noise Reduction (Comp) --- 4X SII Peaks Measured Smoothing ----- Off Min/Max Off Misc Settings Print Label ----- Off Printer ----- Internal </pre>	<p><i>Menu Options</i></p> <p>Fitting Rule: NAL-NL1, POGO, BERGER, 1/3 Gain, 1/2 Gain, 2/3 Gain, Direct, NAL-RP Age: Adult, 0-2mos, 3-6mos, 7-12mos, 1-2yrs, 2-3yrs, 3-4yrs, 4-5yrs, 5+yrs Compression: 40-69 dB Channels: 1-18+ Aid Limit: Multichannel, Wideband, None Fit Type: Unilateral, Bilateral Sound Field: 0°, 45° Reference Position: Head Surface, Undisturbed</p> <p>Noise Reduction: Off, 4X, 8X, 16X SII Peaks: Measured Smoothing: Off, On Min/Max: Off, On</p>
---	--

Figure 52 – Visible Speech Menu

11. Set up the patient for real ear measurements and level the sound-field speaker as described in Section 2.1. Do NOT insert the hearing aid yet.
12. Use [F1] to select the appropriate ear and use [F2] to select the first envelope. *When navigating the function keys: press the UP/DOWN arrows to move the cursor up and down and press the RIGHT arrow to make a selection and return to the test window.*

<table border="1" style="border-collapse: collapse; margin: auto;"> <tr> <td style="padding: 2px;">Env 1</td> </tr> <tr> <td style="padding: 2px;">Env 2</td> </tr> <tr> <td style="padding: 2px;">Env 3</td> </tr> </table>								Env 1	Env 2	Env 3
Env 1										
Env 2										
Env 3										
F1 Right Ear Select	F2 Env 1 Crv Select	F3 Curve On/Off	F4 Curve Actions	F5	F6	F7	F8			

Figure 53 – Select curve options

13. Press [START] to begin the test measurement as the clinician or a family member begins speaking at an average, conversational level.
14. After approximately 15-30 seconds of measuring the live speech stimulus, press [STOP] to store the envelope.
15. Insert the hearing aid into the patient’s ear, using special care not to move the probe tube.

16. Use [F2] to select another envelope. Repeat steps 13 and 14 above.
17. Compare the unaided and aided envelopes and point out the **Speech Intelligibility Index (SII)** values to the patient. In this case, the unaided SII (E1) was 30 and the aided SII (E2) was 59, or an improvement of 29%. These values represent the percentage of the speech signal that is audible to the user and often convey more meaning to patients and their family members than a frequency response curve or a decibel value.

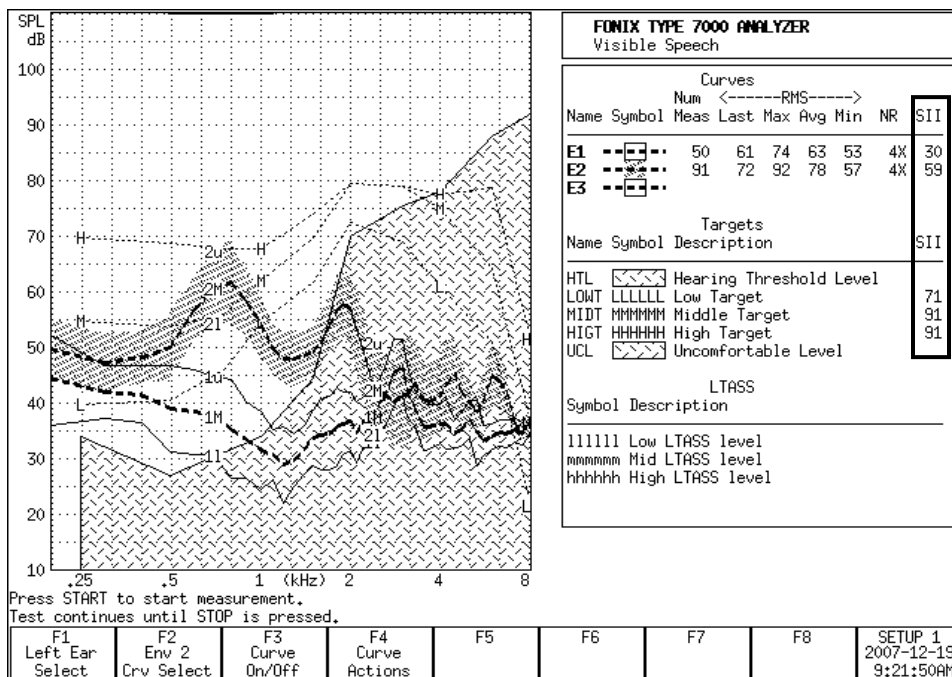


Figure 54 – Visible Speech aided response

Note... Visible speech is a test measurement that should be experimented with in the clinic. Each clinician will find different display settings and demonstrations that he or she will find most useful. For example, one may demonstrate the improved SII that results from turning up the volume control or may demonstrate the decrease in the SII that results from the spouse or family member turning their back to the patient when they are speaking.

2.6 Verifying real-ear noise reduction function of a hearing aid using bias tones

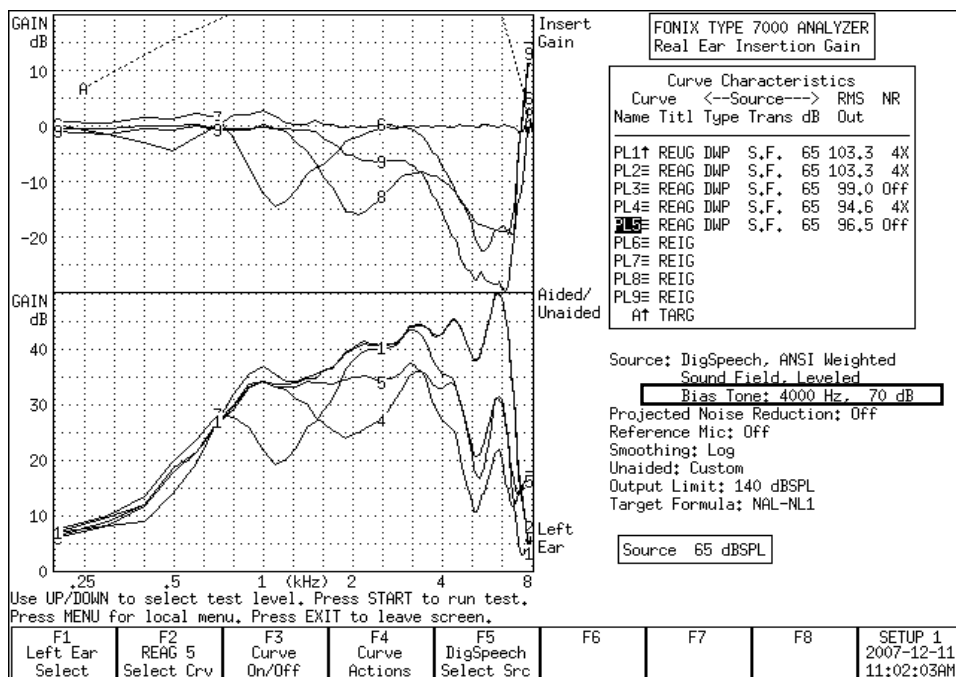


Figure 55 – Real-ear noise reduction verification using bias tones

STEP-BY-STEP

1. From the Opening screen, press [F2] to enter the Real Ear Navigation screen.
2. Press [F2] to open the Real Ear Insertion Gain screen.
3. Set the patient up for real ear measurements and level the sound-field speaker as described in section 2.1.
4. Insert the hearing aid into the ear with special care not to move the probe tube. It is not necessary to perform an unaided measurement since the purpose of this test is only to verify the noise reduction feature of the hearing aid.
5. Use [F2] to select REUG 1, which uses a 65 dB SPL input signal. Verify that DigSpeech is selected as the source using the [F5] key. (Even though you are selecting what is technically an unaided curve, the hearing aid IS in the patient's ear...This allows you the flexibility to measure an additional bias tone frequency.)

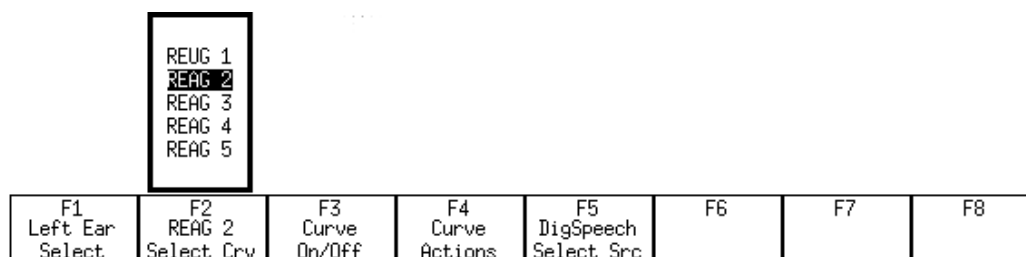


Figure 56 – Real ear select curve options

6. Press [START] to measure the insertion gain of the hearing aid. Press [STOP] to store the curve.
7. Press [MENU] to open the Insertion Gain Menu. Use the up/down arrow to select the **Bias Tone** option under the **Source** heading and use the right arrow to select a bias tone level of 70 dB SPL.
8. Press [EXIT] to return to the test screen.
9. Press [F2] to select the next curve.
10. Use the right and left arrow keys to select the frequency of the bias tone. Note the bias tone frequency location, as indicated in the boxed section of Figure 55.

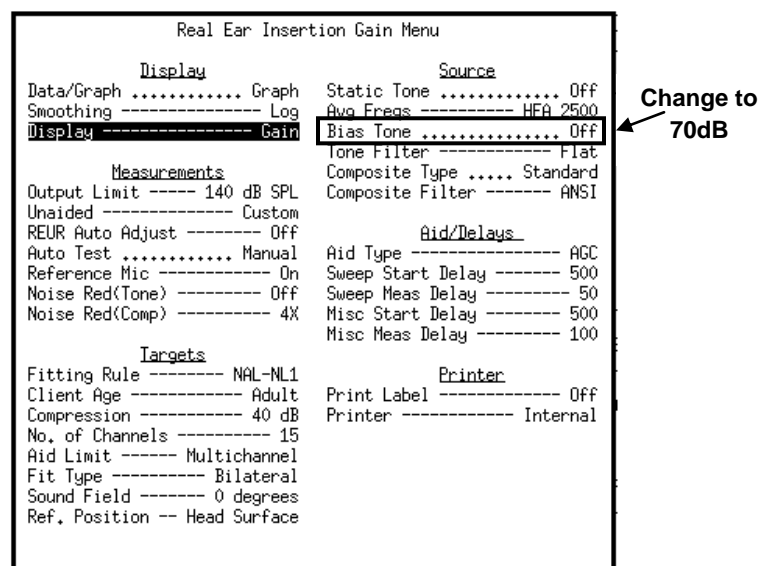


Figure 57 – Insertion gain menu

Options for bias tone frequency range from 200 to 8000 Hz in varying increments.

11. Ensure that the signal amplitude is **65 dB SPL** and the signal source is **DigSpeech**. Press [START] to begin the measurement.
12. When the curve has stabilized press [STOP].
13. Use [F2] to select another curve for testing at another bias tone frequency.
14. Repeat steps 8 through 10 for testing at additional bias tone frequencies, ensuring that the signal amplitude remains 65 dB SPL and the signal source remains digital speech.

Note...The use of the continuous pure-tone bias signal (available in 100 Hz increments) acting as a noise source presented simultaneously with the modulated speech composite signal allows the clinician to more effectively verify the effectiveness of the noise reduction feature of the hearing aid in reducing the gain/output only in the frequency region surrounding the distracting noise while leaving intact the frequency region above and below the distracting noise. This, theoretically, would result in improved communication and comfort in noise because the reduction in gain will be in a restricted segment of the frequency response instead of a larger segment of the frequency response in response to a noise. It is believed that hearing aids with greater channels of noise reduction could lead to better performance in noise (and feedback management) because in multichannel aids narrower and narrower segments of the frequency response are reduced in response to noise (or feedback) within the environment.

2.7 Measuring the magnitude of the occlusion effect.

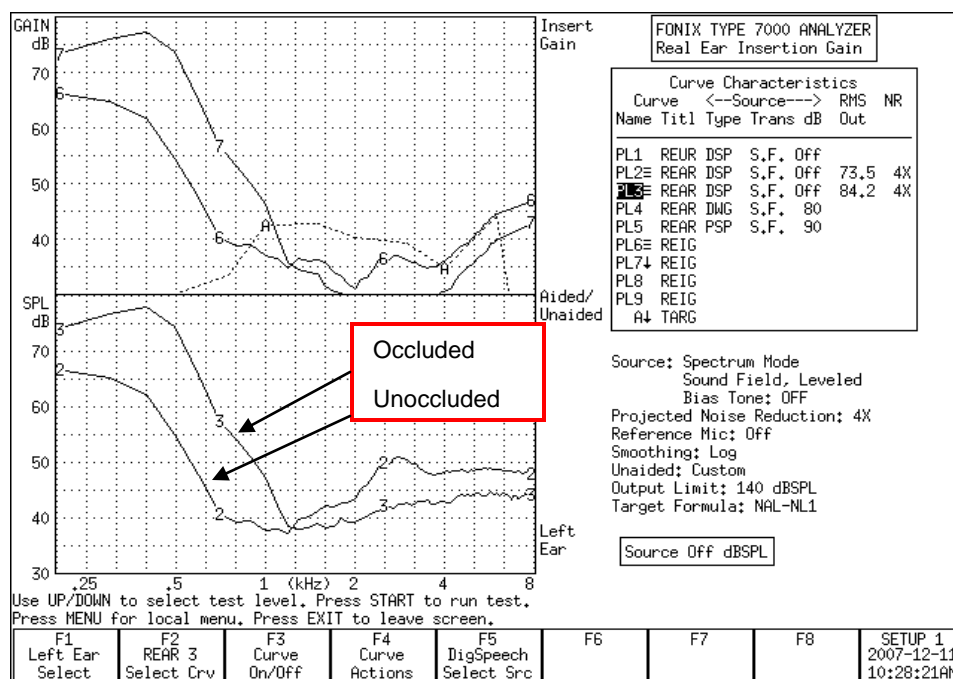


Figure 58 – Verification of the magnitude of the occlusion effect

STEP-BY-STEP

1. Press [F2] from the Opening screen to enter the Real Ear Navigation screen.
2. Press [F2] to enter the Real Ear Insertion Gain screen.

Verify that the bottom graph ordinate is in dB SPL (“SPL” should appear in the upper left corner of the display). If it reads “GAIN,” the display will need to be changed to SPL by following these steps:

- a. Press [MENU] from the Insertion Gain screen to open the local menu.
 - b. Use the up and down arrows to select Display under Display Settings.
 - c. Use the left and right arrows to choose SPL.
 - d. Press [EXIT] to return to the Insertion Gain screen.
3. Set the patient up for real ear measurements and level the sound-field speaker as described in section 2.1.
 4. Use [F2] to select REAR 1. The hearing aid is NOT yet in the ear.
 5. Press the down arrow repeatedly until the source is OFF.
 6. Press [START] to begin measurement. Instruct the patient to vocalize and sustain the “ee” sound. (For greater accuracy, it is recommended that a sound level meter (SLM) be used to maintain a vocalization at approximately 60 dB SPL.)
 7. Press [STOP] to store the response of the unoccluded ear canal.

8. Insert the hearing aid. **MAKE SURE THAT THE AID IS OFF!** Special care should be taken not to move the probe tube.
9. Use [F2] to select REAR 2.
10. Again, press the down arrow repeatedly until the source is OFF.
11. Press [START] to begin measurement. Have the patient sustain the “ee” sound (preferably while monitoring a SLM to maintain the vocalization at approximately 60 dB SPL).
12. Press [STOP] to store the response of the occluded ear canal.

Note... The difference between these two curves represents the occlusion effect (OE). This procedure can be used to verify the lack of occlusion with open fits because in this case the two curves would essentially superimpose. Another use would be to determine the effectiveness of strategies to reduce the OE (e.g., widen a vent so that the occluded response arrives closer to the unoccluded response). Another example might be to verify the effectiveness of occlusion management feature in some current hearing aids.

2.8 Measuring Loudness Discomfort Level (LDL) in dB HL and dB SPL.

STEP-BY-STEP

1. In the Opening Screen press [Menu].
2. Press [F6] for Calibrate Microphones.
3. Use the down ↓ arrow key to select “Probe mic.” On this screen, you will see the measured dB SPL generated in the ear canal from the insert or TDH headset.
4. Instruct the patient:

“The purpose of this test is to find your judgments of the loudness of different sounds. You will hear sounds that increase and decrease in volume. I want you to make a judgment about how loud the sounds are. Pretend you are listening to the radio at that volume. How loud would it be? After each sound, tell me which of these categories best describes the loudness. Keep in mind that an uncomfortably loud sound is louder than you would ever on your radio no matter what mood you were in. When responding to each sound, it is OK to skip a category, or to repeat a category. Do you have any questions?”

Categorical Loudness Anchors

7. Uncomfortably Loud
6. Loud, but OK
5. Comfortable, but Slightly Loud
4. Comfortable

3. Comfortable, but Slightly Soft
2. Soft
1. Very Soft
0. Cannot Hear at All

5. Place the probe tube in the ear canal of the test ear so the tip is 6 mm from the TM and tape the probe tube in place.
6. Position the insert earphone of TDH headset into or onto the test ear.
7. Present a continuous pure-tone from the audiometer to the insert earphone or headset @ 500, 1000, 2000, 3000 and 4000 Hz
8. Complete a practice run @ 1000 Hz
9. Use an ascending procedure starting @ 20 dB SL re: threshold at 1000 Hz.
10. Increase 10 dB until the patient provides a response of “Uncomfortably loud” (7).
11. Decrease 10 dB and begin to ascend in 5 dB steps until the patient provides a response of “Loud, but OK” #6. Then ascend in 5 dB steps until the patient once again provides a response of “Uncomfortably Loud”
12. Decrease 10 dB and increase 5 dB until patient provides the same LDL for a loudness judgment of “Loud, but OK” (#6) half the time. This is the LDL for the test frequency and ear.
13. Repeat at 2000, 3000, 4000 and 500 Hz and then test the opposite ear.
14. At the first test frequency (1000 Hz), present a 70 dB HL signal. On the monitor, the clinician should see a value greater than 70 dB SPL. If the value is less than 70 dB SPL, then either the probe is clogged or pinched. The clinician needs to replace or reposition the probe tube.
15. The difference between the dial reading on the audiometer (70 dB HL) and the measured SPL seen on the monitor is the **REDD (Real-Ear-To-Dial-Difference)**. Quickly repeat this measure at 2000, 3000, 4000 and 500 Hz.
16. You can add the REDD to the audiometric threshold at each frequency to convert audiometric threshold (dB HL) to threshold in dB SPL. This can be a very useful tool for clinicians who believe in the verification process of assuring that soft sounds (in dB SPL) are audible (i.e., live speech mapping). Measuring the REDD and adding these values to the patients audiometric threshold is far more accurate than entering thresholds into a real ear analyzer and have the software complete average transformations!

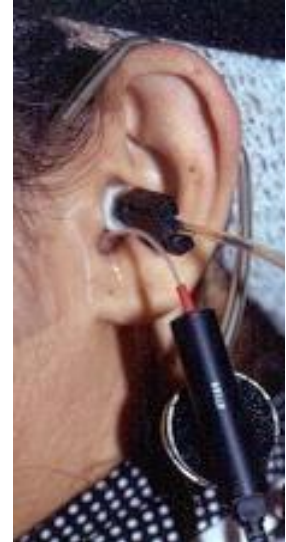


Figure 59 – Probe mic and insert earphone placement for measuring LDLs

17. When the clinician establishes the LDL at each frequency, simply note the value in dB SPL on the monitor. Record that value (as well as the corresponding value in dB HL) on the Table below and place it in the patient's chart to be used later when measuring the real ear saturation response (RESR₉₀) at the time of the fitting.

Table to document LDL in dB HL and SPL and placed in the patient's chart.				
Hz	Right		Left	
	HL	SPL	HL	SPL
500				
1000				
2000				
3000				
4000				

2.9 Measuring Transcranial Thresholds (TCT) dB HL and dB SPL.

Note... Patients with unilateral hearing loss have several fitting options available. One option is a transcranial CROS. This is fitting a high gain/output hearing aid in the poor ear with the goal for the amplified signal to be heard in the cochlear of the better ear. The following procedure allows the clinician to measure the transcranial threshold (TCT) of the better ear. The magnitude of the TCT at any audiometric frequency will be impacted by a] the bone conduction threshold of the better, b] interaural attenuation and c] the REDD. When measured, the TCT can then be used at the time of the fitting to verify that the REAR exceeds the TCT for soft, average, and loud input signals.

STEP-BY-STEP

1. In the Opening Screen press [Menu]
2. Press [F6] for Calibrate Microphones.
3. Use the down ↓ arrow key to select "Probe mic." On this screen that you will see the measured dB SPL generated in the ear canal from the insert or TDH headset.
4. Instruct the patient the same way you would when measuring audiometric threshold.
5. Place the probe tube in the ear canal of the test ear so the tip is 6 mm from the TM and tape the probe tube in place.
6. Position the insert earphone of TDH headset into or onto the test ear.
7. Present a continuous pure-tone from the audiometer to

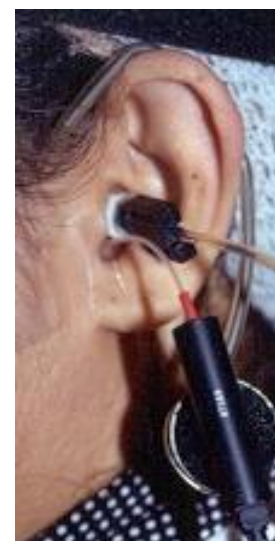


Figure 60 – Probe mic and insert earphone placement for measuring LDLs

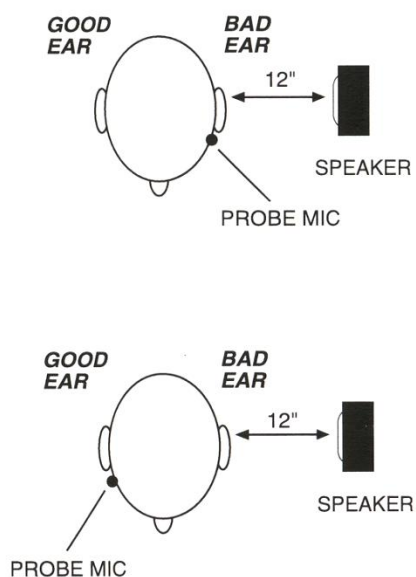
- the insert earphone or headset @ 250, 500, 1000, 2000, 3000 and 4000 Hz.
8. Complete a practice run @ 1000 Hz.
 9. Use an ascending procedure.
 10. Increase 10 dB until patient indicates he/she heard the sound.
 11. Decrease 10 dB and begin second ascend in 5 dB steps until patient once again indicates he/she heard the sound. Find the lowest level the patient responds 50% of the time he/she has just heard the sound (i.e., threshold).
 12. Repeat at the other test frequencies.
 13. At the first test frequency (1000 Hz), present a 70 dB HL signal. On the monitor, the clinician should see a value greater than 70 dB SPL. If the value is less than 70 dB SPL, then either the probe is clogged or pinched. The clinician needs to replace or reposition the probe tube.
 14. The difference between the dial reading on the audiometer (70 dB HL) and the measured SPL seen on the monitor is the REDD (Real-Ear-To-Dial-Difference). Quickly repeat this measure at 2000, 3000, 4000 and 500 Hz.
 15. When the clinician establishes the TCT at each frequency, simply note the value in dB SPL on the monitor. Record that value (as well as the corresponding value in dB HL) on the Table below and place it in the patient's chart to be used later when measuring the REAR at the time of the fitting.

Table to document TCT in dB HL and SPL and placed in the patient's chart.

Hz	Right		Left	
	HL	SPL	HL	SPL
500				
1000				
2000				
3000				
4000				

2.10 Insertion gain measurement of CROS and BICROS Performance

Measuring the Head Shadow Effect



First Measure

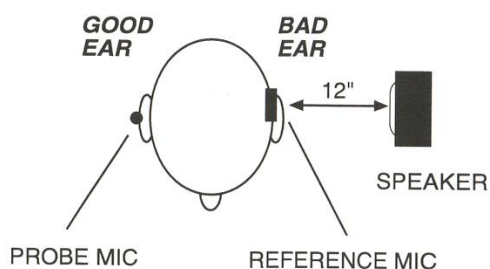
- Reference microphone disabled
- Do not level
- Place probe microphone OVER the bad ear
- Store as UNAIDED

Second Measure

- Place probe microphone OVER the good ear
- Store as AIDED
- Difference REIG curve is seen on the next Figure as the Head Shadow Effect

Figure 61 – Measuring head shadow effect

Measuring how CROS Overcomes the Head Shadow Effect



First Measure

- Reference microphone enabled and placed over the poor ear
- Probe microphone in the good ear
- Level
- Measure REUG and store as UNAIDED

Second Measure

- Place receiver into the good ear and the transmitter is placed over the poor ear
- Measure and store as AIDED
- Difference REIG curve shows benefit from CROS for sounds arriving from the poor ear.

Figure 62 – Measuring how well CROS overcomes the head shadow effect

Measuring how BICROS Overcomes the Head Shadow Effect

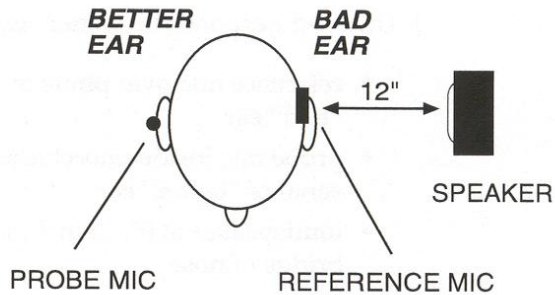


Figure 63 – Measuring how well BICROS overcomes the head shadow effect

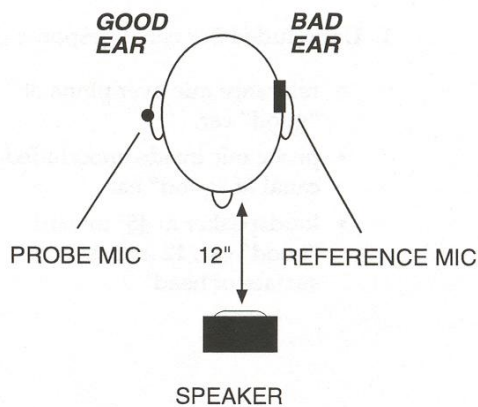
First Measure

- Reference microphone enabled and placed over the poor ear
- Probe microphone in the good ear
- Level
- Place receiver in the good ear and turned ON place transmitter over the poor ear and is OFF
- Measure and store as UNAIDED

Second Measure

- Turn transmitter ON; measure and store as AIDED.
- Difference REIG curve shows benefit of adding the 2nd microphone for signals arriving from the poor ear.

Measuring if the REIG of a CROS fitting matches a valid prescriptive target



First Measure

- Reference microphone enabled and placed over the poor ear
- Probe microphone in the good ear
- Level and store as UNAIDED

Second Measure (REAG of good ear)

- Aid in good ear
- Store as AIDED

Difference REIG curve shows benefit from CROS aid to target

Figure 64 – Measuring overall REIG to target for a CROS aid

Measuring if the REIG of a BICROS fitting matches a valid prescriptive target

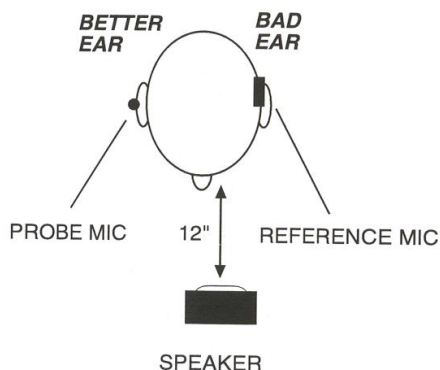


Figure 65 – Measuring overall REIG to target for a BICROS aid.

First Measure: REIG for better ear

- a. Reference microphone enabled and placed over the poor ear
- b. Probe microphone in the good ear
- c. Level and store as UNAIDED

Second Measure: REAG for better ear

- a. Aid in good ear and both microphones are ON
- b. Store as AIDED

Difference REIG curve shows benefit from BICROS aid to target

2.11 Using the Frye 7000 as a spectrum analyzer to measure feedback.

STEP-BY-STEP

1. From the Opening screen, press [F2] to enter the Real Ear Navigation screen.
2. Press [F4] to enter the Real Ear SPL screen.
3. Press [MENU] to enter the Real Ear SPL Menu.

NOTE: Use the UP/DOWN arrows to select a menu option and press the RIGHT arrow to change a selection.

- a. Select **Graph** as the **Data/Graph** option under the **Display** heading.
- b. Turn the **Reference Mic** to **Off** under the **Measurements** heading.
- c. Press [EXIT] to return to the test screen.

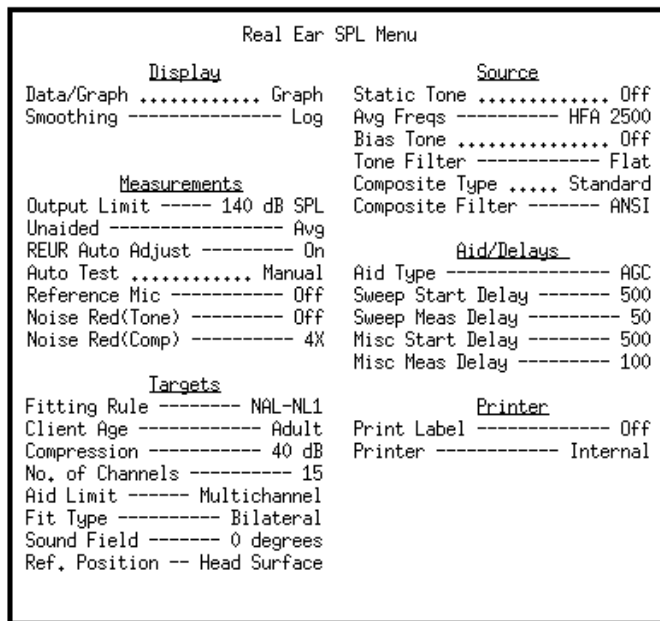


Figure 66 – Real Ear SPL Menu

4. Set the patient up for real ear measurements and level the sound-field speaker as described in section 2.1.
 5. Press [F1] to select the appropriate ear.
 6. Press [F3] and turn off all of the following curves: REUR, HTL re, LOWT re, MIDT re, HIGT re, LDL re, LTASS.
- When navigating the F1-F8 settings: press the UP/DOWN arrows to move the cursor up and down and press the RIGHT arrow to make a selection and return to the test window.

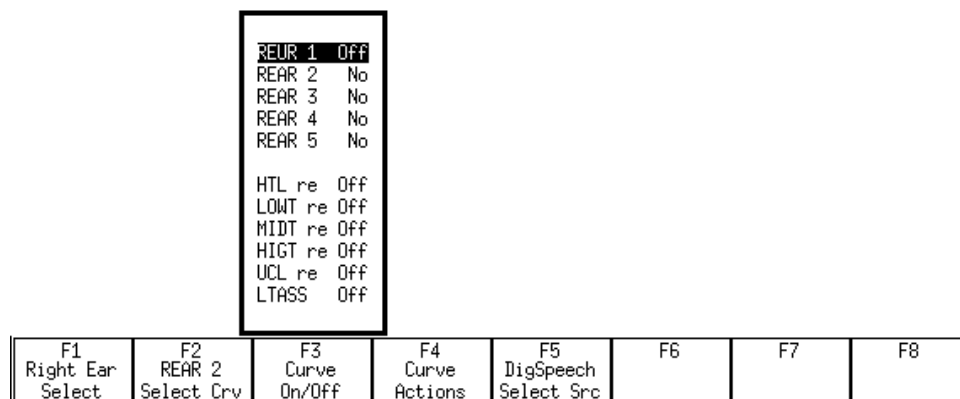


Figure 67 – Curve on/off options with the appropriate curves turned off

7. Use [F2] to select an aided curve.
8. In the Real Ear SPL screen, press the down arrow until the source is OFF.
9. Press [START] to measure the output of the hearing aid. Press [STOP] to store the curve.

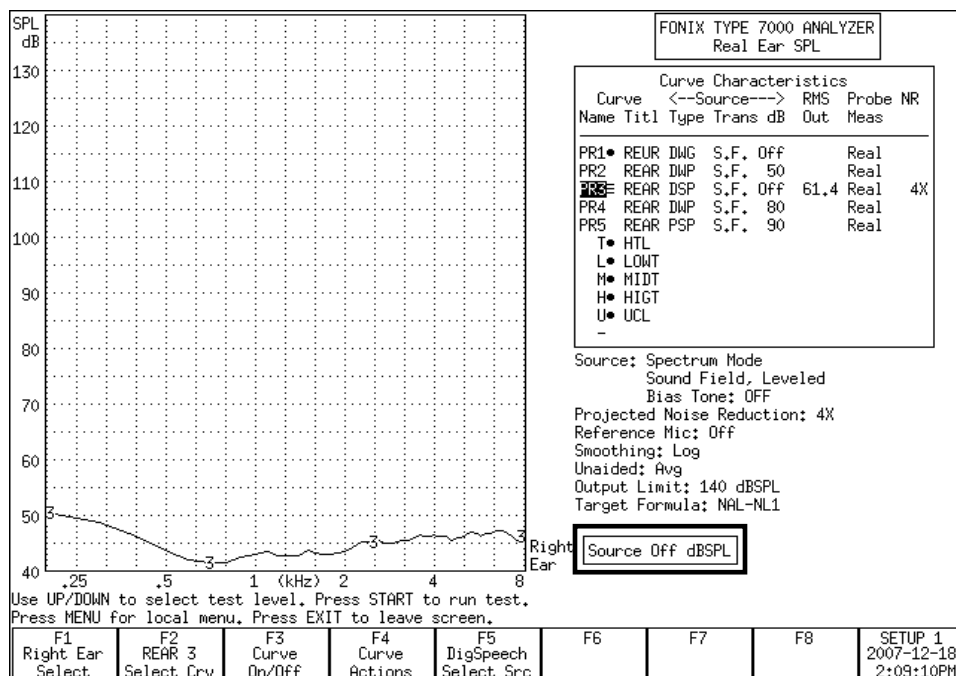


Figure 68 – Spectrum analysis of a hearing aid without feedback

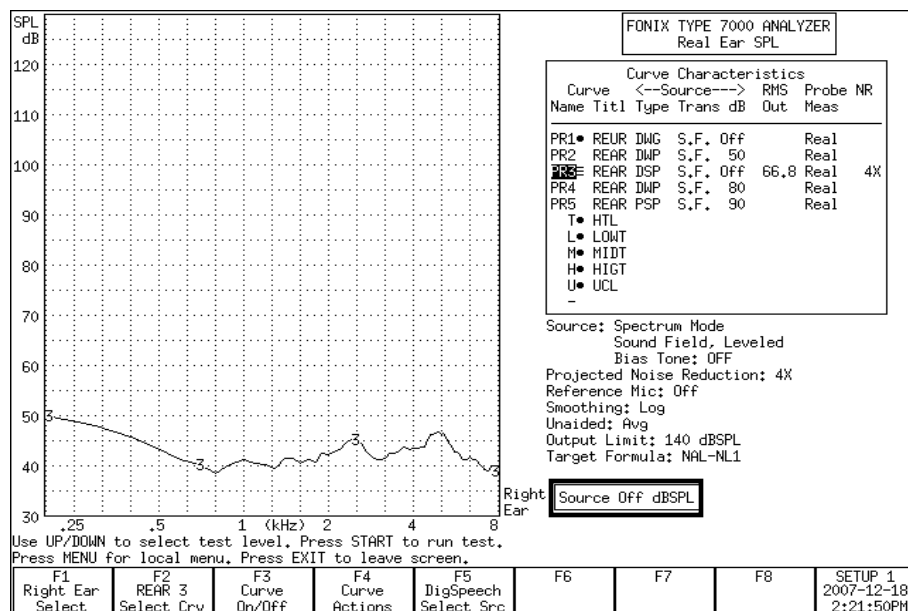


Figure 69 – Spectrum analysis of a HA with feedback as characterized by instability in spectrum analysis and peak at approximately 3000 and 6000 Hz). The clinician can also use the earphones and amplifier (volume control knob) delivered with the Frye 7000 and placed in the probe module to listen for an “echo” and the presence of feedback. Often the perceived presence of the echo is an “early sign” of the feedback and is the beginning of the change of the waveform during this spectrum analysis .

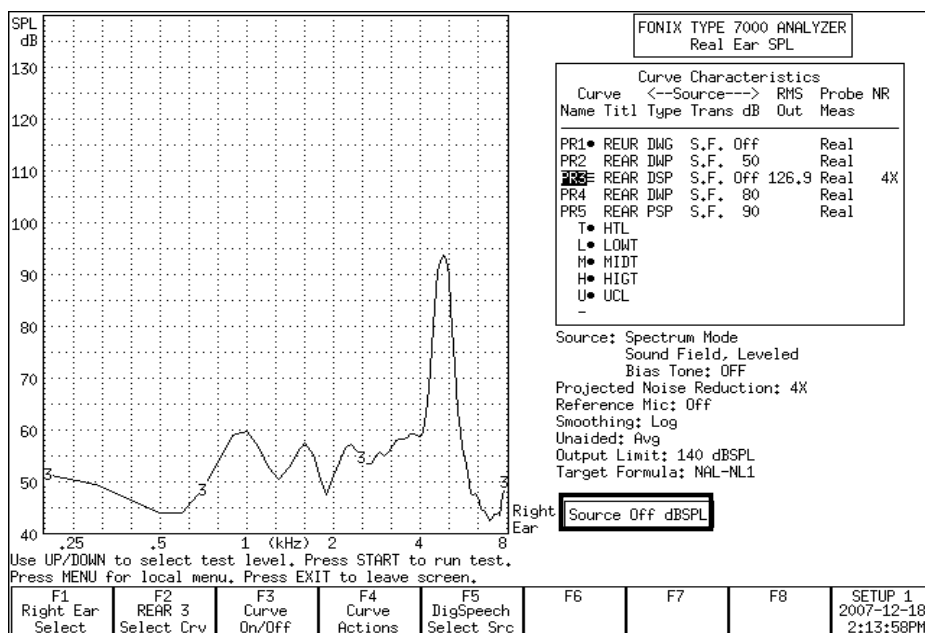


Figure 70 – spectrum analysis of hearing aid with audible “whistling” feedback. It’s interesting to note that a difference as little as 1 dB can change a measure as seen in Figure 67 to the one seen in this Figure!

Note... Verification of the feedback feature requires three measures. The first measure is to determine the **Maximum Stable Gain with the feedback feature off (MSB_{FBoff})**. The second is **Maximum Stable Gain with the feedback feature on (MSG_{FBon})**. The final measure is **Added Stable Gain (ASG)** which is simply $MSG_{FBon} - MSB_{FBoff}$. ASG documents the amount of additional gain provided to the patient with the activation of the feedback feature. MSG_{FBoff} is measured by increasing the overall gain of the hearing aid until the spectrum analysis as shown in Figure 70 is illustrated on the monitor. At this point, the clinician would reduce the gain by 1 dB or until the spectrum analysis as shown in Figure 68 is reported. This measure provides the clinician with a “picture” of the “maximum” output of the aid available prior to the presence of feedback. Now, the clinician activates the feedback feature and repeats this measure (MSG_{FBon}). If the feedback feature is effective, then the MSG_{FBon} will report greater output than MSG_{FBoff} and the difference between these two measures (ASG) is the effectiveness of the feedback feature in providing the patient with greater useable gain/output.

2.12 Measuring the real-ear attenuation of a hearing protector device.

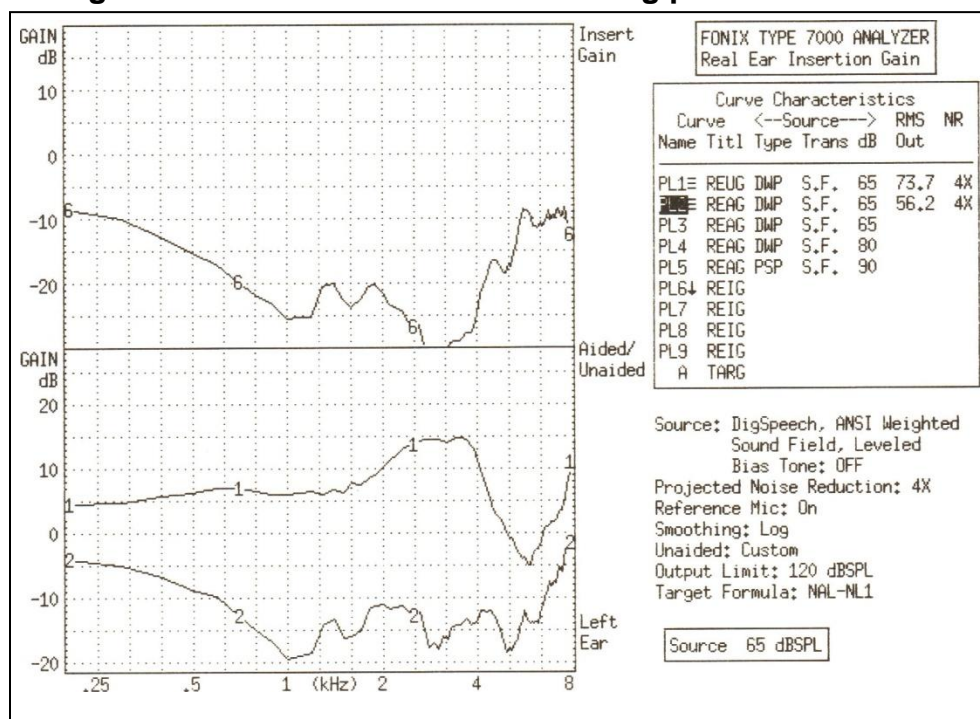


Figure 71 – Real ear attenuation of a foam earplug

STEP-BY-STEP

1. From the Opening screen, press [F2] to enter the Real Ear Navigation screen.
2. Press [F3] to enter the Insertion Gain screen.
3. Set the patient up for real ear measurements as described in Section 2.1.
4. Press [LEVEL] in order to calibrate the sound-field speaker and the reference microphone.

- Use [F1] to select the test ear. Use [F2] in the Insertion Gain screen to select REUG 1. Ensure that the source is DigSpeech and that the level is 65 dB SPL.

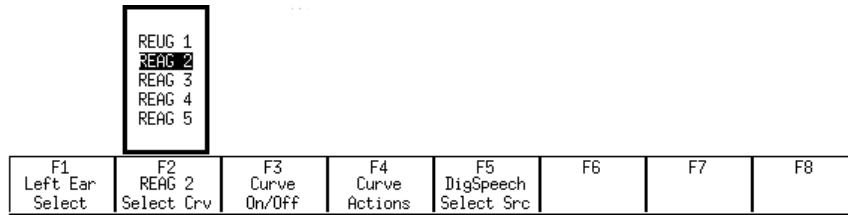


Figure 72 - Real ear select curve options

- Press [START] to begin measurement and press [STOP] to store the measured response.
- Insert the earplug, taking special care not to change the position of the probe tube.
- Use [F2] to select REAG 2. Ensure that the source has remained DigSpeech and use the up arrow to increase the amplitude to 65 dB SPL.
- Press [START] to begin measurement and press [STOP] to store the measured response.

- Press [MENU] to change the Display to “Data,” which will allow you to see the exact decibel attenuation at each measured frequency.
 - Use the up/down arrows to select Data/Graph
 - Use the right arrow to select Data
 - Press [EXIT] to return to the Real Ear Insertion Gain screen.

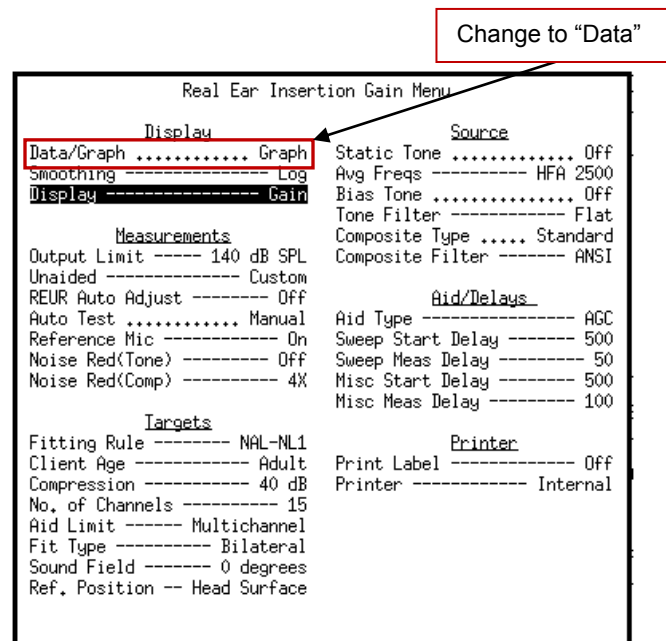


Figure 73 – Real ear insertion gain menu

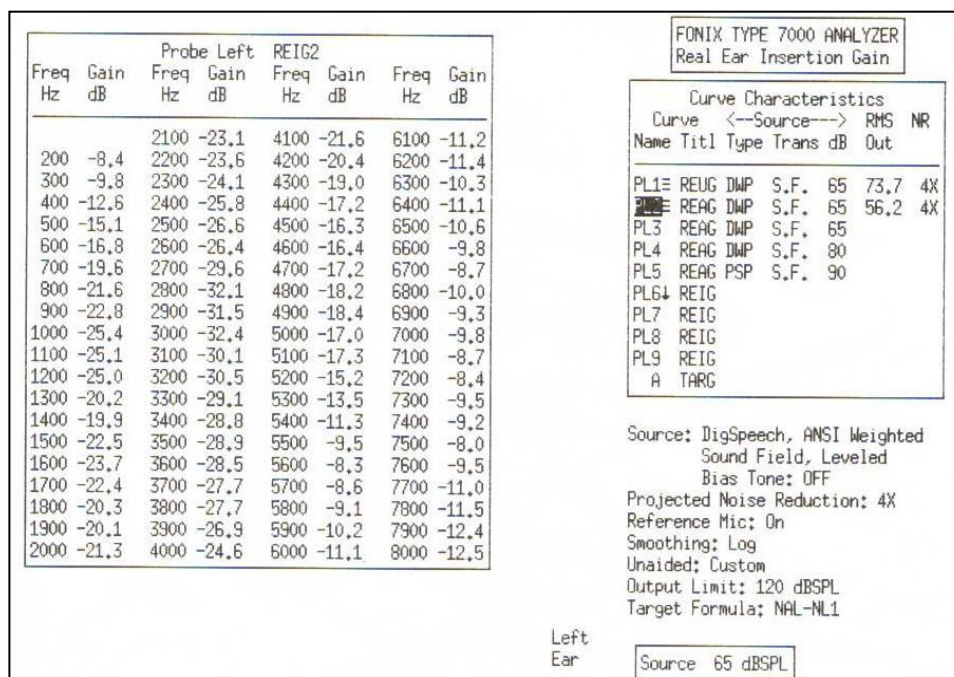


Figure 74 – Insertion gain data providing frequency specific attenuation data for the earplug. Notice that the greatest attenuation, approximately 30 dB, is provided around 3000 Hz.

Note...The top display graph in Figure 71, labeled “Insertion Gain,” illustrates the amount of attenuation provided by the foam earplug across the frequency range. The numerical data in Figure 74, correspond with that insertion “attenuation” curve (labeled 6) in Figure 71. This measurement may be used to verify the response of a musician earplug or may be helpful in counseling employees enrolled in hearing conservation programs as to the proper insertion of hearing protector devices.

References

American National Standards Institute. (1992). *American National Standard for Testing Hearing Aids with a Broad-Band Noise Signal*. (ANSI S3.42-1992). New York: ANSI.

American National Standards Institute. (2003). *American National Standard for Specification of Hearing Aid Characteristics*. (ANSI S3.22-2003). New York: ANSI.

Dirks D, Kincaid G. (1987). Basic Acoustic considerations of ear canal probe measurements. *Ear Hear* 8(5 Suppl):60S-67S.

Guideline for the Audiologic Management of the Adult Hearing Impairment (2006). American Academy of Audiology, 1-44. www.audiology.org

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