Chapter 2: My Hearing Aid Isn't Working Like It Used to…

Lori Zitelli, Au.D.[1] and Catherine Palmer, Ph.D.[1]

ABSTRACT

This chapter will take you through specific patient complaints and the test box measures you can use to address these complaints. These measurements give you data that aid in your decision making about what is wrong, if anything, with the hearing aid and how you might address the problem. Before we discuss specific patient complaints and problems, let us review the American National Standard Institute (ANSI) guidelines for hearing aid testing in a test box.

KEYWORDS: hearing aid troubleshooting, battery drain, total harmonic distortion, ANSI Hearing Aid Standard, hearing aid gain

WHAT IS THE ANSI STANDARD FOR HEARING AID MEASUREMENT?

The American National Standards Institute (ANSI) developed a protocol for hearing aid measurements using test box systems, called the **American National Standard Specification of Hearing Aid Characteristics**. The current (as of 2024) standard is **ANSI S3.22-2014 (R2020)**[1] and it is periodically revised. The ANSI standard consists of several hearing aid tests and specifies the tolerances that each measure may deviate from a manufacturer's specifications. The manufacturer reports data for their hearing aids for every test in the standard. Every hearing aid arrives with a printout of the ANSI hearing aid measurement of the hearing aid that has been delivered to the clinic. The clinician can run the same tests and compare the results to the manufacturer's results. The standard indicates the "tolerance" for each test (how close the agreement should be). Common tests that a clinician might use to check a hearing aid against manufacturer's specifications would be equivalent input noise (EIN), total harmonic distortion (THD), and

[1]Communication Science and Disorders, University of Pittsburgh Medical School, Pittsburgh, Pennsylvania.

Address for correspondence: Lori Zitelli, Au.D., Communication Science and Disorders, Eye and Ear Institute, University of Pittsburgh Medical School, 4th floor, 203 Lothrop Street, Pittsburgh, PA 15213 (e-mail: zitellild@upmc.edu).

Unleashing to Power of Test Box and Real-Ear Probe Microphone Measurement; Guest Editor, Lori Zitelli, Au.D.

Semin Hear 2024;45:1–19. © 2024. The Author(s).

Thieme Medical Publishers, Inc., 333 Seventh Avenue, 18th Floor, New York, NY 10001, USA
DOI: https://doi.org/10.1055/s-0044-1786523.
ISSN 0734-0451.

battery drain (described later in this chapter). Manufacturers also use several of the ANSI tests to describe or categorize hearing aids. The tests included can all be run individually, but most hearing aid test box systems have the option to run an "ANSI test," which includes all of the tests. This may be useful if you want to look at several aspects of the hearing aid at once.

The ANSI standard helps clinicians understand what features of a hearing aid can be measured with a test box and what tolerances are acceptable when comparing measurements to manufacturer specifications. This helps clinicians decide if a hearing aid is functioning reasonably or if a hearing aid should be sent back to a manufacturer for repair or replacement. Remember, just because a hearing aid is functioning according to the manufacturer's specifications does not mean it is adequate for your patient. A good example of this is bandwidth (the frequency range where the hearing aid provides amplification). The manufacturer may specify the hearing aid bandwidth as 500 to 3,000 Hz, but this would not be an adequate response for someone with aidable hearing through 4,000 Hz (necessary frequencies for the perception of /*s*/ for instance). This also would be inadequate for individuals wanting to enjoy music (you would want a response below 500 Hz), unless you were able to leave the vent open enough for low frequencies to pass through naturally (this assumes the individual has good hearing in the low frequencies as well). The manufacturer uses the ANSI tests to describe the basic hearing aid function, but it is up to you to determine what your patient actually needs to be successful.

Historically, many clinics have completed an ANSI test on every hearing aid when it arrived in the clinic. The hearing aid would arrive with the volume setting at full-on and all signal processing (noise reductions, directional microphones) turned off because this was how the hearing aid was tested at the manufacturer and therefore it would be these specifications to which the clinic's measurement would be compared. With the advent of fully programmable hearing aids, it is less interesting to run an ANSI test with these types of artificial settings and more interesting to use these tests for specific purposes (e.g., a distortion test if there are complaints of distortion, a battery drain test if there are complaints of fast battery drain) after the hearing aid is programmed for the patient. It is important to keep in mind that if you are comparing to the manufacturer specifications, you need to set the hearing aid identically to how the manufacturer set the hearing aid when they reported the measurements. If you are doing these tests after the hearing aid has been programmed for an individual patient, then ideally you will have a set of measurements that were completed when you fit the hearing aid with which to compare the new results.

The ANSI Tests

An example of a set of ANSI test results are depicted in Figure 1. Letters (e.g., A, B, C) have been added to indicate various tests that will be described in this chapter. For all these tests, the signal is coming from the test box speakers. The hearing aid is connected to the coupler (which is connected to the coupler microphone) and the display shows either resultant output or gain (calculated as output minus input).

Description of the Results from the ANSI Test

The tests are completed under two different conditions: full-on gain (FOG) and reference test setting (RTS) (both described later). The following tests (items A–C) are completed in the FOG condition. In this condition, the gain of the hearing aid is measured with an input of 50 dB SPL and the volume control set to full-on. It is good to be familiar with these tests and the data that are produced because manufacturers often describe their various hearing aids using these data (e.g., this hearing aid has a particular OSPL90 or a specific frequency response). Understanding the ANSI tests will let you know where these data are coming from.

OUTPUT SPL FOR 90 DB INPUT SPL (OSPL90) CURVE—SEE FIGURE 1 ITEM A

A signal of 90 dB SPL is swept from 200 to 5,000 Hz. The highest point of the curve (maximum: OSPL90) is the maximum SPL output of the hearing aid at the frequency indicated. In Figure 1, maximum OSPL90 is 101 dB SPL at 3,775 Hz. The maximum sound pressure

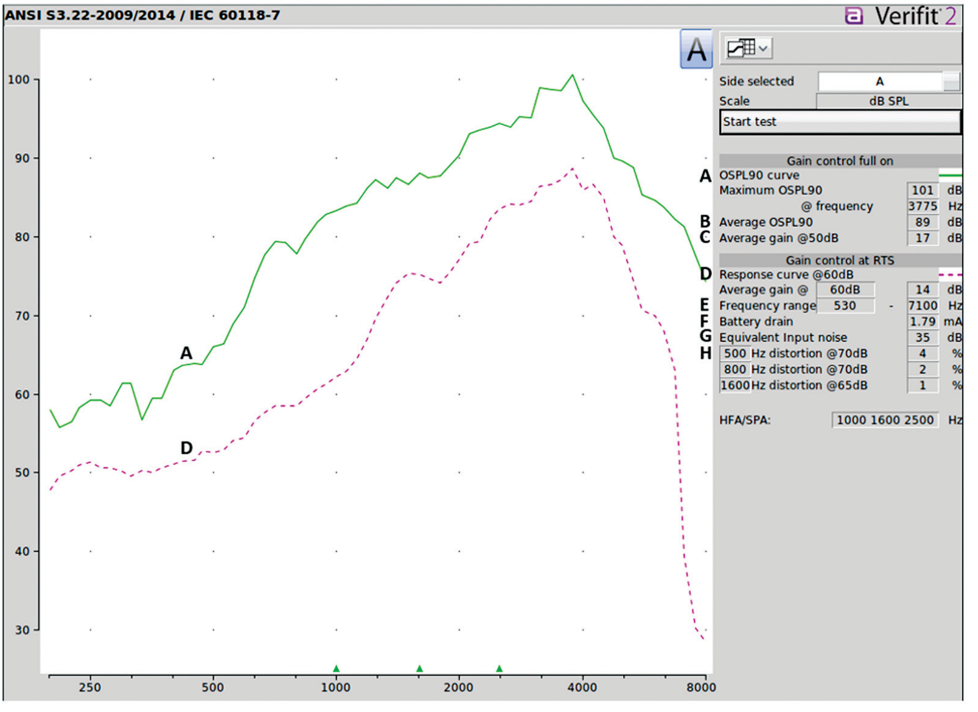

Figure 1 ANSI test results. **A** = OSPL90 curve; **B** = average OSPL90; **C** = average gain at 50 dB; **D** = frequency response curve; **E** = frequency range; **F** = distortion measurements; **G** = EIN; **H** = battery drain.

level (SPL) output should not be more than 3 dB above the manufacturer's specifications.[1]

AVERAGE OSPL90—SEE FIGURE 1 ITEM B

The average of the output values at 1,000, 1,600, and 2,500 Hz is the high-frequency average (HFA). In Figure 1, the average OSPL90 is 89 dB SPL. The HFA for the OSPL90 curve should be within 4 dB of the manufacturer's specifications.[1]

AVERAGE GAIN AT 50 DB—SEE FIGURE 1 ITEM C

The HFA for FOG is the average gain at 1,000, 1,600, and 2,500 Hz with a 50-dB input signal while the volume control is set to full-on (most amplification). In Figure 1, the average gain at 50 dB is 17 dB SPL. Remember that gain is output minus input. The value should be within 5 dB of the manufacturer's specifications.[1]

The remainders of the tests (items D–H) are completed in the RTS. RTS refers to the gain control required to produce a HFA gain within 1.5 dB of the HFA-OSPL90 minus 17 dB.[1] This is assumed to be close to "user gain" setting for an average hearing aid user. When instructed to adjust the gain control on the hearing aid to the RTS, you will see the prompt illustrated in Figure 2, guiding you through a procedure designed to approximate user gain as opposed to FOG.

If the HFA-FOG is less than HFA-OSPL90 minus 17 dB, then the RTS is full-on and you will not be instructed to make any changes in the volume setting. The reference test gain is the HFA gain measured with an input of 60 dB with gain control at RTS.

FREQUENCY RESPONSE CURVE—SEE FIGURE 1 ITEM D

See the discussion on frequency/gain curve later in this chapter for a detailed description and activities. The output as a function of frequency is measured with an input of 60 dB and the volume control at RTS.

FREQUENCY RANGE—SEE FIGURE 1 ITEM E

The bandwidth of the hearing aid is represented by the content labeled "frequency range." In the case of Figure 1, the bandwidth of the hearing aid is 530 to 7,100 Hz. Using instructions from the appropriate ANSI standard,[1] this can also be calculated by hand.

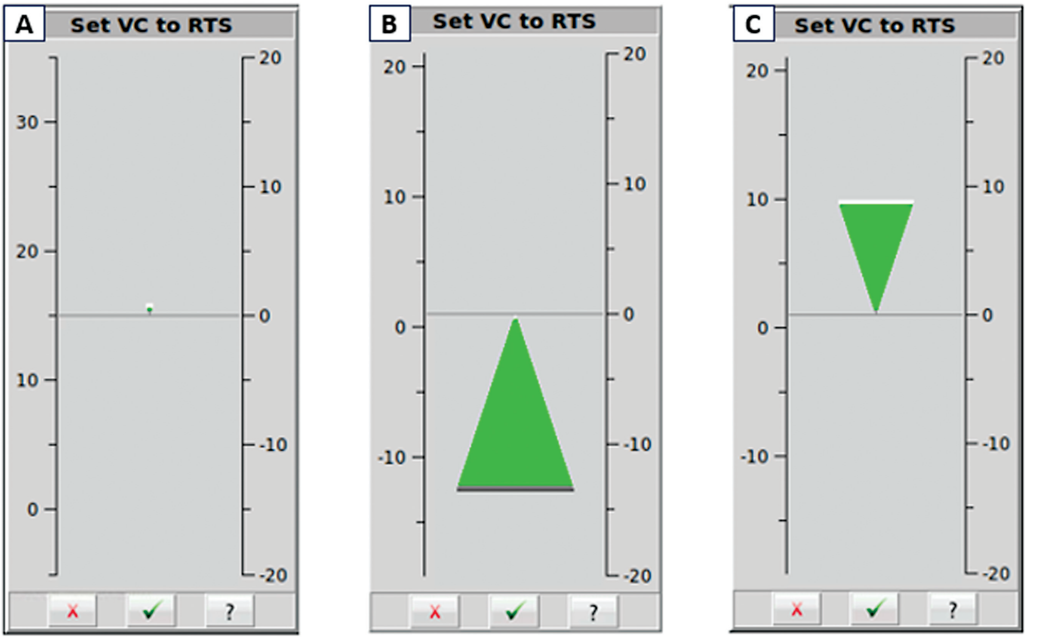

Figure 2 Reference test setting prompts. **A**—the volume control is at RTS (no adjustments needed); **B**—the volume needs to be increased in order to achieve RTS; **C**—the volume needs to be decreased in order to achieve RTS.

1. Determine the average of the output levels at the HFA frequencies on the response curve (not OSPL90 curve). Remember, the HFA is calculated using the output from the curve at 1,000, 1,600, and 2,500 Hz. These frequencies are represented on the ANSI curve by the three green triangles on the bottom of the graph (see Figure 3).
2. Using the values in Figure 3, we can calculate the HFA:
   $62 + 75 + 84 = 221$
   $221 / 3 = 73.6$ (we will round up to 74).
3. Subtract 20.
   $74–20 = 54$.
4. Draw a horizontal line parallel to the frequency axis at the HFA-20 level (see Figure 4).
5. Note the lowest and highest frequency at which the response curve intersects the horizontal line (see Figure 5).

Note that, in this case, the HFA-20 value of 54 dB SPL is *less than* the input level used to obtain the curve (60 dB SPL); in other words, a reported bandwidth of a hearing aid does not automatically translate to usable gain or audibility within that frequency range. Realistically, for many hearing losses, a 54-dB SPL output in the higher frequencies would not provide audibility for the hearing aid user. This is the reason it is essential to measure the hearing aid output in the individual patient's ear. In this manner, you will know exactly what bandwidth (frequency range) is available to your patient.

BATTERY DRAIN—SEE FIGURE 1 ITEM F

See the discussion on battery drain later in this chapter for a detailed description and activities. During the battery drain test, the system measures the battery current in milliamps (mA) with different input signals. This can be completed only if you are powering the hearing aid with a battery pill attached to the measurement equipment. Inserting the battery pill is described in the Battery Drain section later in this chapter. Please see this section for more detailed and actionable information related to measuring and interpreting the battery drain test.

EQUIVALENT INPUT NOISE—SEE FIGURE 1 ITEM F

See the discussion on equivalent input noise later in this chapter for a detailed description and activities. The EIN is determined by subtracting

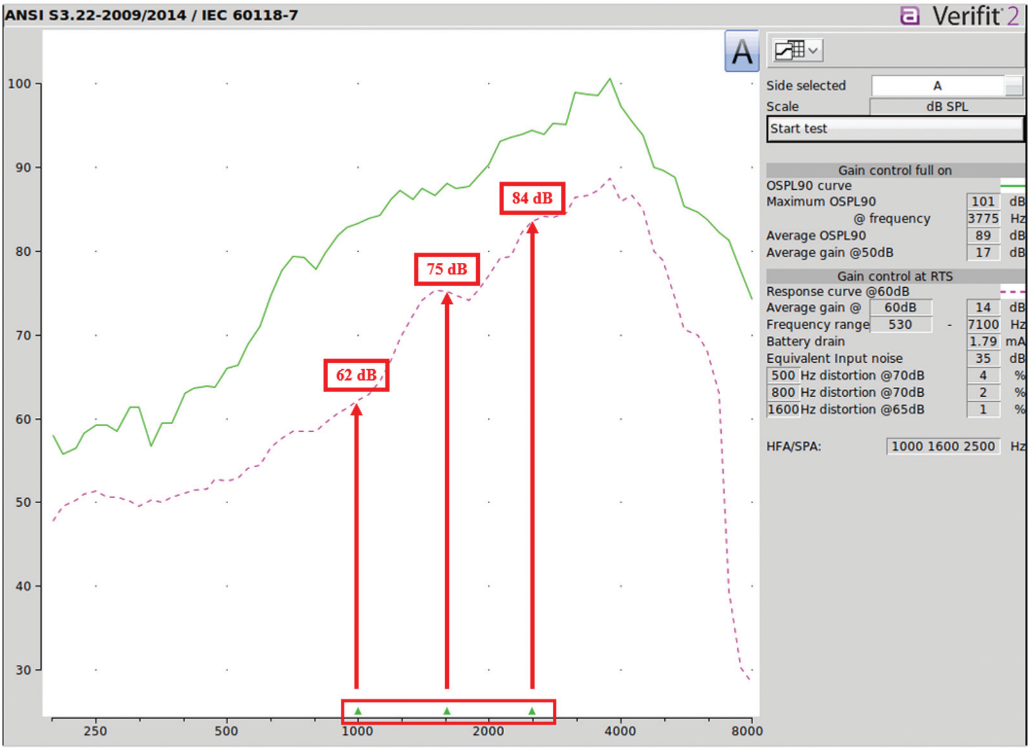

Figure 3 Calculating the HFA for the frequency response curve.

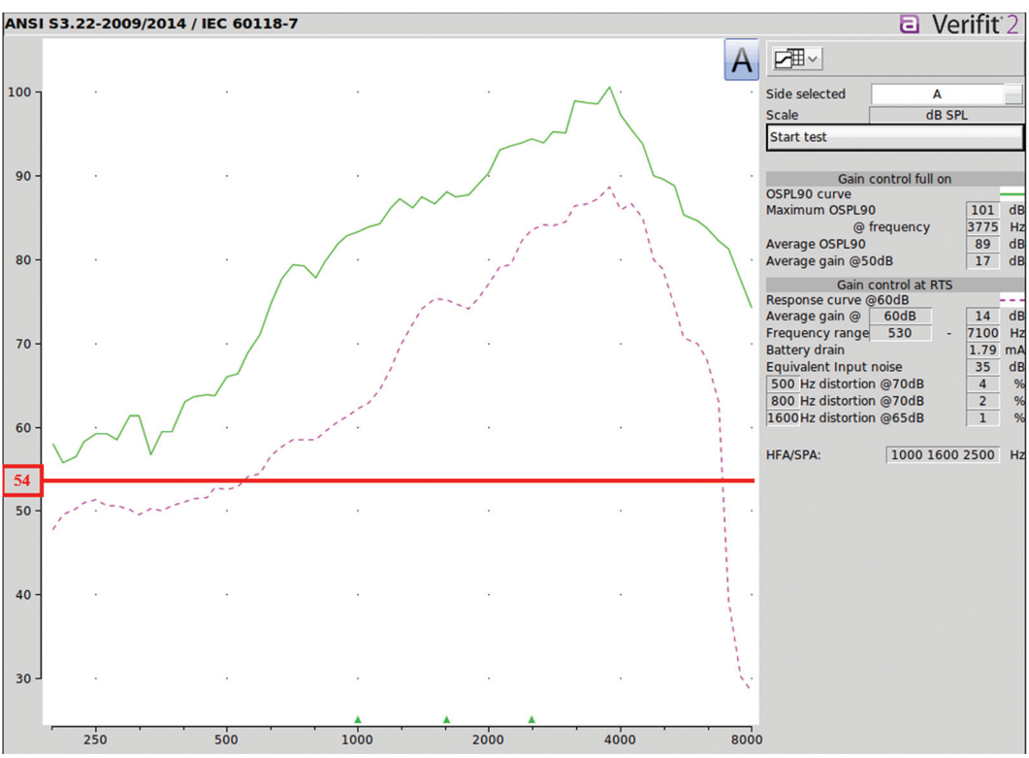

Figure 4 Draw a horizontal line at HFA–20. In this case, we draw a line at 54 dB SPL because the HFA is 74 dB SPL.

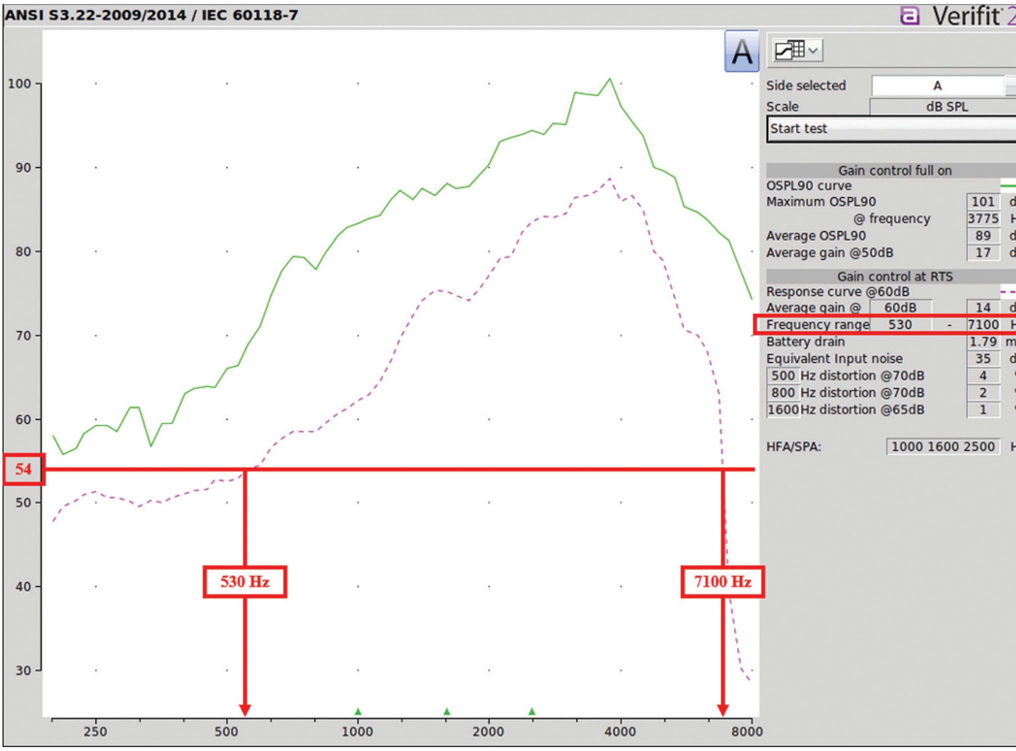

Figure 5 Indication of the lowest and highest frequency at which the response curve intersects the horizontal line at 54 dB SPL. In this example, the frequency range of this hearing aid is reported as 530–7,100 Hz.

the gain of the hearing aid from the magnitude of the noise at the output of the hearing aid. It is called "equivalent input noise" because it is the amount of noise that would have to be put into a noiseless hearing aid for that hearing aid to have the same noise output as the one being tested. This test is computing the EIN averaged across frequency. In Figure 1, it is reported as 35 dB.

TOTAL HARMONIC DISTORTION MEASUREMENTS—SEE FIGURE 1 ITEM G

See the discussion on total harmonic distortion later in this chapter for a detailed description and activities. The distortion test analyzes the distortion components of the waveform produced by a pure tone sent through the hearing aid. Percentage of THD is the most common measurement for this purpose. THD is the distortion for all harmonics summed. This is only one type of distortion; so, the hearing aid might still have distortion even if the THD looks fine. Regardless of the manufacturer's specification, a good rule of thumb is that THD in modern hearing aids should be lower than 10%.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box and a hearing aid that uses a disposable battery.

Activity 1

1. Following the instructions from Chapter 1, level the test box microphones and connect a working BTE hearing aid that uses a disposable battery (powered by a battery pill) to the coupler. For instructions related to inserting battery pills, see the discussion on battery drain test.
2. Right-click the mouse and select **ANSI/ IEC** under "Test box" (see Figure 5). Note that "IEC" stands for International Electrotechnical Commission, an international standards organization.
3. Follow the instructions that are provided to set up the test and the instructions included in this chapter to run the ANSI test.

Materials needed for this activity: Results from Activity 1.

Activity 2

Using the ANSI test results obtained in Activity 1, report the following information.

Average OSPL90: ____________
Average gain at 50 dB: ____________
Bandwidth (frequency range) ____________

Now that you have been introduced to the standard ANSI test box measures, let us dig into the specific measures that will help you to troubleshoot hearing aid problems related to specific patient complaints.

Troubleshooting Tips

If a patient comes in complaining that their hearing aid is not working the way it used to, the first thing you should do is listen to the hearing aid to see if you can detect any issues (see Figure 6). Always replace the battery (if it is disposable) or make sure there is sufficient charge (if it is rechargeable), clean the input port[s] (microphone[s]), and clean the output port (receiver/loudspeaker) of the hearing aid. These are the most common problems with hearing aids. If you do all of this and the hearing aid still is not sounding right, you may want to do an ANSI test, which includes many of the tests that will help you determine the problem and provide an efficient means of completing all of the tests at once. Ideally, you would have completed the ANSI test right after fitting the hearing aid so you would have results with which to compare. Always make sure to record the hearing aid settings that you used during the test (e.g., specific volume control setting if applicable, earmold and behind-the-ear [BTE] hearing aid attached to the coupler or just the BTE without the earmold). Alternatively, you may want to get more information from the patient and pick the specific test(s) that will address the patient's complaints. This would be our suggestion and therefore the rest of the chapter is set up to describe each test in detail that you will select based on your patient's complaint.

Keep in mind, if you are comparing the ANSI test results to the hearing aid manufacturer's specifications, the hearing aid must be set the same way the manufacturer had it set for testing (typically how it arrived in the box to your clinic). This is often with full-on output and gain, but with special signal processing turned off. If you obtained these test results on the hearing aid after you fit it to the patient, then you will want it set to the patient user settings for comparison.

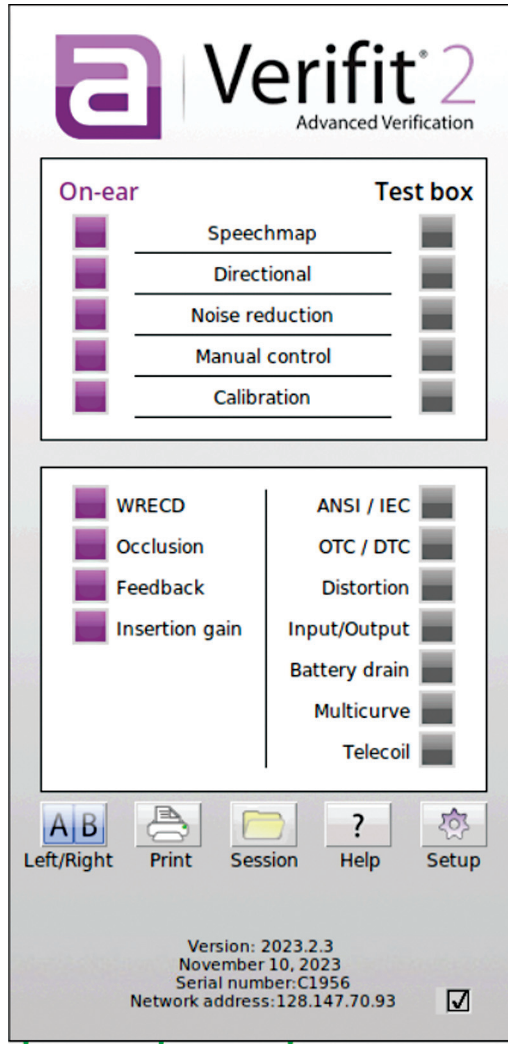

Figure 6 The menu of measurements.

It is always wise to look in the patient's ear in case ear wax is changing the sound that the patient is hearing. If the patient is wearing a hearing aid coupled to any sort of earmold, this should be checked and cleaned. Ear wax, moisture, or debris could be blocking the sound from getting to the ear canal or changing the frequency response of the sound getting to the ear canal (e.g., rolling off the high frequencies because a partial block is creating a reverse horn). For In-The-Ear (ITE), Completely-In-Canal (CIC), and Invisible-In-Canal (IIC) products (custom products), the wax guard and/or receiver should be cleaned of any wax or debris. Dust and other debris also can block the hearing aid microphone; gently vacuuming or brushing the microphone area may clear this. If the hearing aid has a microphone cover, this may be replaced. If you have done all these cleaning and checking steps, plus the test box measures discussed below reveal that the aid is functioning appropriately, it is time to retest the patient's hearing.

In essence, you want to make sure that the problem is not being caused by the ability of the hearing aid to take sound in (microphone) or to deliver sound to the ear canal (earmold, receiver/loudspeaker). Finally, you want to check that the signal is unobstructed from the end of the hearing aid to the tympanic membrane (i.e., check for ear wax or other debris in the ear canal). Always ensure that the patient is using a good battery (or that a rechargeable hearing aid is charged). Even experienced patients can make this mistake. You also may want to check that the battery leads are touching the sides of the battery correctly for hearing aids using disposable batteries. The battery leads are the metal strips on either side of the battery compartment which come in contact with the battery, completing the electrical circuit when the battery door is closed.

Helpful hint: When doing ANSI testing using Verifit 2 equipment, make sure you are using the **left** coupler microphone and reference microphone. You will need to use the **left** coupler/microphone even if you are testing a right hearing aid because the equipment does not support ANSI measurements using the right coupler microphone at the time of this publication.

EXPLORING SPECIFIC TESTS THAT WILL HELP YOU HELP YOUR PATIENTS

The following tests (frequency/gain curves, battery drain, EIN, distortion) are helpful when the patient's complaint is that the hearing aid just does not sound right, does not sound like it used to, or is behaving differently.

Patient Report: "My Hearing Aid Is Weak/Is Not Working"

COMPLETING A FREQUENCY/GAIN CURVE FOR THE PURPOSE OF COMPARING TO A PREVIOUS CURVE

Helpful hints:

- This test gives us the frequency response curve for the hearing aid at one input level (generally between 50 and 60 dB input). The *y*-axis can be output or gain (output–input) but is most commonly reported as gain for this measurement.
- Always run a frequency/gain (or output) curve on a hearing aid after all adjustments have been made at the hearing aid fitting. It is useful to keep in the patient's electronic medical record to refer back to when hearing aid function is in question. You can then quickly run the same curve to see if anything has changed.
- Prior to running tests, always clean the hearing aid, make sure ear wax is not blocking the sound output (receiver), and ensure that debris is not blocking the microphone port.
- If a patient complains that their hearing aid is not working like it used to, but the gain curve has not changed and other electroacoustic measures are normal, do an otoscopic examination, change tubing on BTEs, clean earmolds, and/or re-test the patient's hearing.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box and a hearing aid.

Activity 3

1. Following the instructions from Chapter 1, level the test box microphones.
2. Couple a BTE to the appropriate coupler and microphone.
3. Set the volume control to whatever the setting was for the original frequency/gain curve (previously documented in the

patient's chart). This generally will be "full on" but could be "user setting." The setting should be recorded on the original tracing.

4. Right-click the mouse and select **Multi-curve** under the Test box options.
5. Click on the green arrow related to **Test 1**.
6. Set stimulus to **Swept.**
7. Set the level to 50 dB (or whatever input level was used for original test box curve).
8. Click the **red circle** to start the test.

Helpful hint: Display your results using the same scale as the original results for a quicker comparison. You can choose your desired display in the test screen under "Scale."

Consider the two curves below.

The original graph (Figure 8) was displayed in gain (see "scale – dB gain"). It makes a simpler comparison if future tracings are in gain as well so that a direct comparison can be made. As you will see in Figure 9, the clinician has displayed the results in "gain" as well, so we can make a direct comparison.

Table 1 provides the resulting gain by frequency for the original (Figure 8) and new (Figure 9) measurements for comparison purposes. The gain is not as high as it was originally.

Figure 7 Hearing aid listening check.

What could make this hearing aid's gain be reduced? If the patient has a manual volume control, always make sure the volume control is set to user setting and that the patient knows how to use it. The hearing aid circuit may have become damaged or weak over time. The cause could be a partially clogged receiver, dirty microphone, damaged amplifier, faulty wiring, a bad battery, or bad battery contacts. Some of these things can be solved in the clinic (e.g., new battery, cleaning the receiver, changing the microphone cover), but some of these problems will require that the hearing aid be sent to the manufacturer for repair.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box and hearing aid.

Activity 4

Measure a frequency/gain curve with a 50-dB SPL input to the hearing aid. What is the gain for this hearing aid at the following frequencies?

500 Hz: ________________

4,000 Hz: ________________

NO PREVIOUS FREQUENCY/GAIN CURVE IS AVAILABLE, BUT I WANT TO USE TEST BOX MEASURES TO VERIFY THAT THE HEARING AID IS PRODUCING APPROPRIATE GAIN

If a frequency/gain curve was not obtained when the hearing aid was originally fit, you need something else to which you will compare the frequency/gain curve in order to answer the question "Is this the correct gain for this patient's hearing loss?" The best way to answer this question is to use Speechmapping in either test box mode (Chapter 3) or on-ear mode (Chapter 5) with the individual patient data, but the description below is a quick way to estimate whether the hearing aid is generally programmed with appropriate gain if you are pressed for time and cannot make individual patient measurements. You will only know if the hearing aid is set correctly for moderate input levels using this procedure.

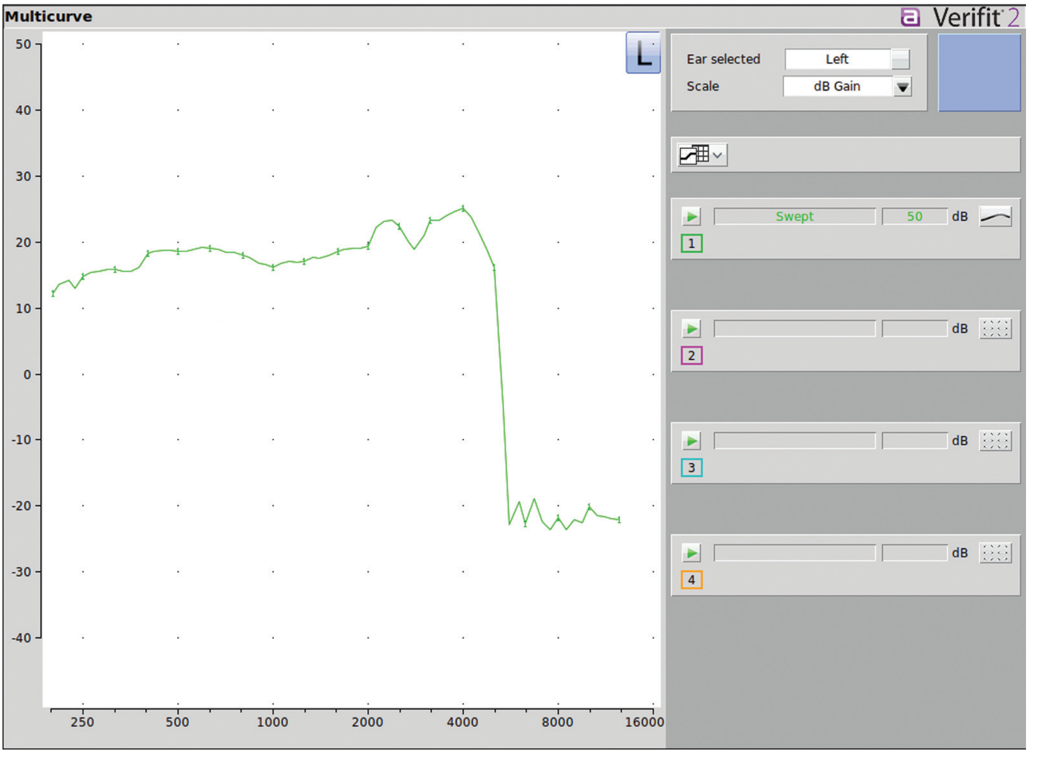

Figure 8 Frequency/Gain curve obtained at the time of the hearing aid fitting.

Table 1 Comparison of gain from original tracing to new tracing

	250 Hz	500 Hz	1,000 Hz	2,000 Hz	4,000 Hz
Original tracing (gain)	15	19	17	19	25
New tracing (gain)	–9	5	7	11	17

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid, patient's recent audiogram.

Activity 5

You are answering the question, "Is the hearing aid programmed with the appropriate gain for moderate input levels when compared to your patient's hearing loss?"

Helpful hint: Always consider when the last audiogram was performed in relation to the probability of a decrease in hearing. For example, if you have an aging patient and it has been 4 years since their last test, it is time for a new hearing test to evaluate the appropriateness of the hearing aid settings.

Relevant case information for Activity 5:

J.K., a 47-year-old long-time hearing aid user, walks into your clinic and drops off his hearing aid complaining that it is weak. You do not have a previous frequency/gain curve of the hearing aid in the chart. You need a process that will allow you to quickly answer this question without the patient present.

Generally, we are interested in measuring soft, moderate, and loud input levels when we are fitting hearing aids, but in this specific instance only the moderate input level will be useful. Your goal for this patient is to provide a quick estimate of whether the gain of this hearing aid for a moderate input level is appropriate with only the audiogram as a guideline.

1. Level the test box if this has not already been done (see Chapter 1).

2. Couple the hearing aid you wish to test to the appropriate coupler and connect this to the coupler microphone. Place the hearing aid at the appropriate distance from the reference microphone.
3. If there is a volume control, put it at "user gain."
4. Right-click the mouse and select **Multi-curve** under Test box.
5. Select the appropriate **ear** (right/left).
6. Select the **scale** you wish to view (dB gain will be the most efficient because these are the values we will compare to our audiogram data).
7. Choose the **format** (graph/table).
8. Click **the green arrow above 1** to start the test. When the test has started, you can choose the type of stimulus and level (chose a moderate level, e.g., 60 dB). Figure 10 is an example of the measurement you will get if you follow the steps above.
9. Because you do not have a previous frequency/gain curve, you are going to compare your frequency/gain data obtained using a moderate input to the patient's audiogram. We will do this in Activity 5, but first let us discuss how you make this comparison (simple math is required).

To compare a frequency/gain curve to a patient's hearing levels, you apply a 1/2 or 1/3 gain rule using the patient's audiogram. You are only using the frequency/gain curve achieved with a moderate input because the 1/2 and 1/3 gain rules are used for moderate input levels. Less intense inputs will have more gain and more intense inputs will have less gain in hearing aids using wide dynamic range compression (most modern hearing aids use wide dynamic compression).

These "gain" rules are coming from the two evidence-based fitting algorithms that are used to generate the fitting targets for hearing aids. The desired sensation level (DSL)[2] approximates a 1/2 gain rule and the National Acoustics Laboratory (NAL)[3] approximates a 1/3 gain rule. This means that the DSL recommends slightly greater gain than the NAL formula. There is more detail about the fitting formula in Chapter 5.

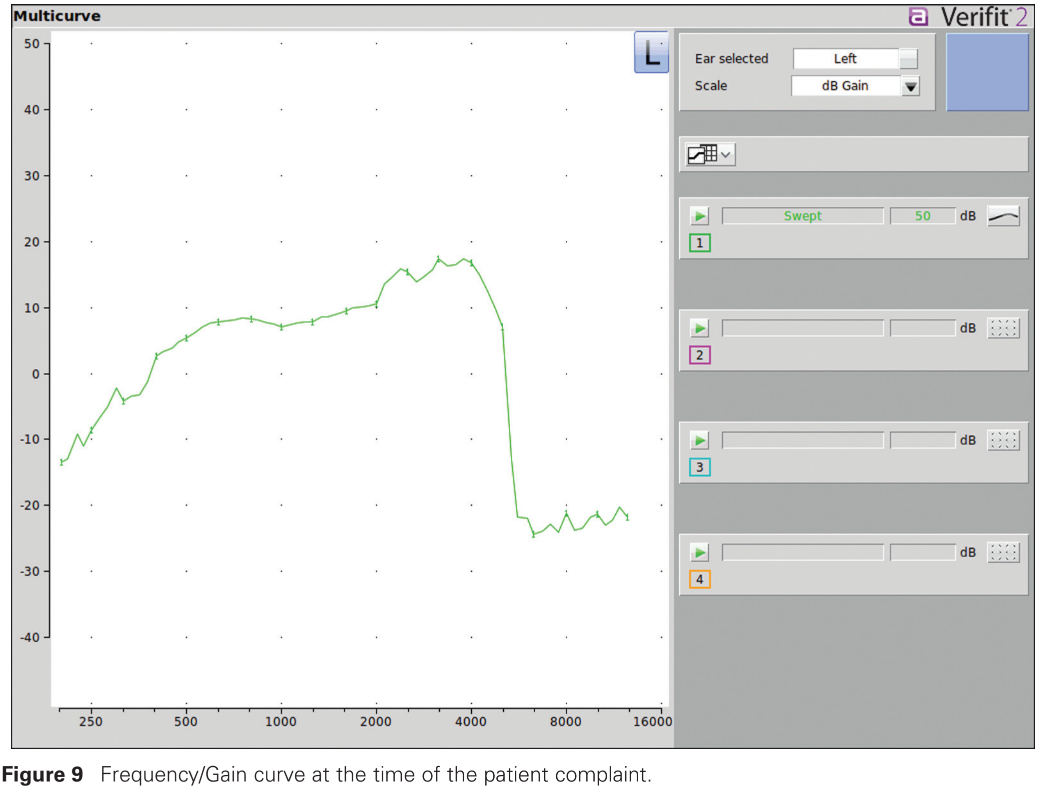

Figure 9 Frequency/Gain curve at the time of the patient complaint.

Helpful hint: The 1/2 gain rule provides more gain than the 1/3 gain rule. Overall, the literature has supported the appropriateness of either rule. If your moderate gain curve falls between the 1/3 and 1/2 rules, odds are the hearing aid has appropriate gain for a moderate input. Patients may be accustomed to one rule over another; therefore, they may still perceive that their hearing aid is weak (or too loud) even when the gain is between the targets for each rule.

1/2 Gain rule: Divide the patient's hearing threshold at one frequency by two to calculate the approximate gain that would be recommended for moderate inputs at that frequency. For example, if the patient has a 60-dB threshold at 1,000 Hz, you will calculate 60 / 2.

- 60 dB HL (threshold at 1,000Hz) / 2 = 30 dB (approximate recommended gain at 1,000 Hz).

1/3 Gain rule: Divide the patient hearing threshold at one frequency by three to calculate the appropriate gain that would be recommended for moderate inputs at that frequency. For example, if the patient has a 60-dB threshold at 4,000 Hz, you will calculate 60 / 3.

- 60 DB HL (threshold at 4,000 Hz) / 3 = 20 dB (approximate recommended gain at 4,000 Hz).

Helpful hint: It is a good idea to calculate the desired gain at a low and high frequency so that you can compare both areas of the measured hearing aid response.

10. Table 2 provides the patient's hearing thresholds as a function of frequency, the gain from the frequency/gain curve that was obtained with a patient's current hearing aid (from Figure 10), and the recommended gain using the 1/3 and 1/2 gain rules. The last column asks whether the hearing aid gain is appropriate based on this hearing loss. To be "appropriate," the measured gain (from the frequency/gain curve) would have to fall at or between the 1/3 and 1/2 gain rule values. In this case, the gain is appropriate at 500, 1,000, 2,000, and 4,000 Hz.

Helpful hint: If the gain appears appropriate for the hearing loss, the patient's perception that the hearing aid is no longer loud enough could be a result of an occluded ear canal (e.g., ear wax) or related to a change in hearing. You will want to check the patient's ear canals for wax occlusion. If the ear canals are clear, it may be time for an updated hearing test.

Materials Needed for this Activity

For these activities, you will need a calculator.

Activity 6

Table 3 provides a patient's thresholds and the results of a frequency/gain measurement with a moderate input level (60 dB SPL). Use the data to answer the following questions.

1. Determine the appropriate gain using the 1/3 gain rule.
2. Determine the appropriate gain using the 1/2 gain rule.
3. Answer the question "Is the HA gain provided appropriate according to either rule?"

Table 2 Comparing hearing thresholds to frequency/gain curve results and applying a 1/2 or 1/3 gain rule

Frequency	Pt thresholds (left ear)	HA gain with 60-dB SPL input	1/3 Gain rule	1/2 Gain rule	Appropriate?
500 Hz	65 dB hearing level (HL)	31 dB SPL	22 dB SPL	33 dB SPL	Yes, 31 is between 22 and 33
1,000 Hz	70 dB HL	30 dB SPL	24 dB SPL	35 dB SPL	Yes, 30 is between 24 and 35
2,000 Hz	70 dB HL	34 dB SPL	24 dB SPL	35 dB SPL	Yes, 34 is between 24 and 35
4,000 Hz	90 dB HL	40 dB SPL	30 dB SPL	45 dB SPL	Yes, 40 is between 30 and 45

Table 3 Determining if the gain is appropriate based on the 1/3 and 1/2 gain rules

Frequency	Pt thresholds (left ear)	HA gain with 60 dB SPL input	1/3 Gain rule	1/2 Gain rule	Appropriate?
500 Hz	30 dB HL	10 dB SPL			
1,000 Hz	45 dB HL	14 dB SPL			
2,000 Hz	65 dB HL	17 dB SPL			
4,000 Hz	70 dB HL	24 dB SPL			

Table 4 Complete the following chart based on your hearing aid measurements

Frequency	Pt thresholds (left ear)	HA gain	1/3 Gain rule	1/2 Gain rule	Appropriate?
500 Hz	30 dB HL				
1,000 Hz	45 dB HL				
2,000 Hz	65 dB HL				
4,000 Hz	70 dB HL				

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid, and a calculator.

Activity 7

1. Obtain a frequency/gain curve (as described in Activity 5) with a 60-dB input for your hearing aid.
2. Fill in Table 4.
3. Using the data in Table 4, make a comparison similar to Activity 6.

Helpful hint: Using the Multicurve option under the Test box menu, you can create a frequency/gain curve that allows you to choose your own input level.

Patient Report: "I Have to Replace the Battery in My Hearing Aid Nearly Every Day"

During the battery drain test, the system is measuring the battery current in milliamps (mA) with different input signals. The battery milliampere-hour (mAh) rating is divided by the measured battery current to determine the battery life in hours. This is divided by the number of hours per day of patient use to estimate how many days a battery should last in that hearing aid with typical use. The display in this test does this math for you and displayed expected days of battery life related to how many hours per day your patient is wearing their hearing aids.

Helpful hints:

- Rechargeable hearing aids have the power source encased in the body of the hearing aid. Therefore, you cannot use the battery drain test which necessitates the use of a battery pill.
- Battery life is affected by several factors, including the gain control, signal intensity, signal processing engaged, amount of streaming in which the individual engages, and environmental variables such as humidity. Therefore, the battery drain test can give only an estimate of battery life; the actual battery life differs among individual hearing aid users.
- If the battery life is appropriate but the patient reports frequent changing of the battery, there may be another cause. The patient may not be opening the battery door at night, and this may be causing the battery to drain all night. There may be a problem with the actual batteries your patient is using. This test does not test the batteries, only the hearing aid.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid that uses disposable batteries, battery pills.

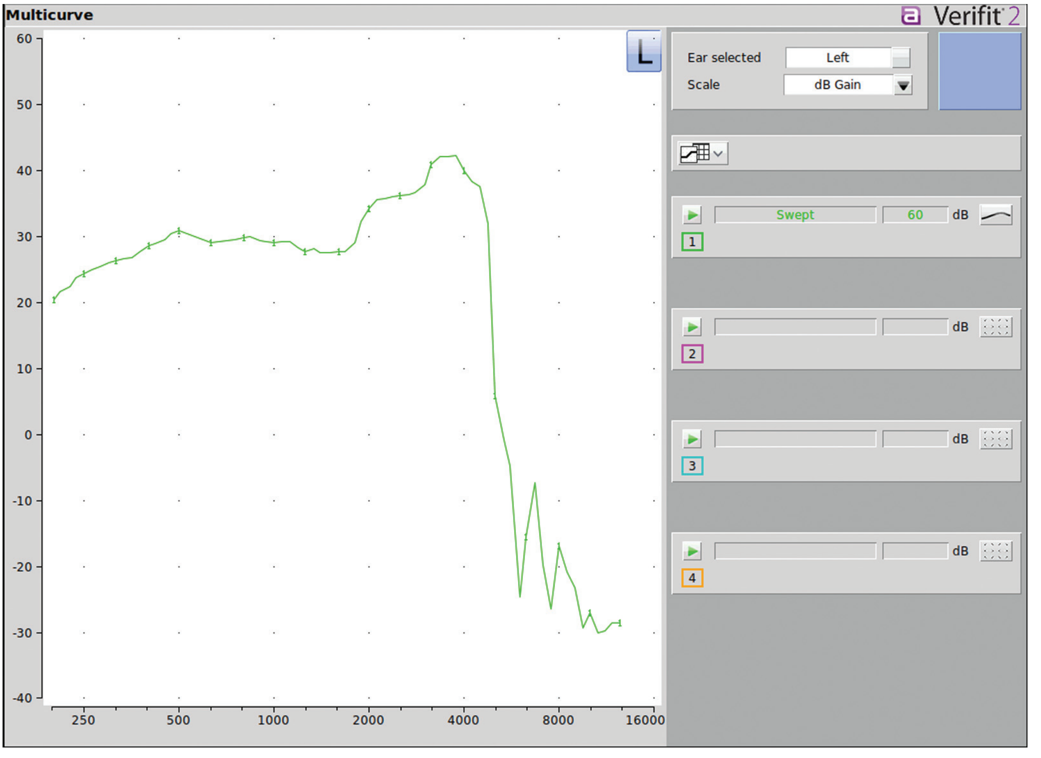

Figure 10 Frequency/Gain response for a 60-dB SPL input signal.

Activity 8

1. Place the appropriate size test box system battery pill in the hearing aid (shown below in Figure 11 with the battery door open), carefully close the battery door, and connect the battery jack cord to the test box port. Be careful to position the battery connector in a way that, when you close the battery door, you do not damage the lead.
2. Set the volume control to user setting.
3. Connect the hearing aid to the appropriate blue coupler (see Figure 12) and position it appropriately near the reference microphone (see Chapter 1).
4. Right-click the mouse and select **Battery drain** under the Test box options.
5. Click **Battery type** and select the installed battery pill size.
6. Click **Hours per day** and select from the drop-down list. You will need this information from the patient or from the hearing aid data logging (accessed through the hearing aid programming software).

Figure 11 Placement of the battery pill into a hearing aid.

Figure 12 Connecting a hearing aid to the correct coupler with the battery pill in place.

7. Click **Start test**. Test setup instructions will be displayed.
8. Click the **green check mark** to start the test.
9. Look under the Estimated New Battery Life label (Figure 13). With the hearing aid set at this volume and the user wearing it 12 hours per day, a new battery is expected to last for 5 to 6 days. Remember, this is only an estimate.

Helpful hint: If you check the battery drain of new hearing aids on the day of programming, you will have a previous result to which you can compare these data when patient indicates a change in performance. The hearing aid you are evaluating comes with specifications (either printed or online). You can check the battery drain results against the battery drain listed in the specifications to see if the battery drain is appropriate for this hearing aid (see the discussion on ANSI in this chapter for tolerances related to manufacturer's specifications).

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid that uses disposable batteries, battery pills.

Activity 9

1. Run a battery drain test on a hearing aid assuming your patient uses the hearing aid 15 hours per day.
2. How many days would you expect a battery to last in this hearing aid? Do you think this battery life would be acceptable to a patient?
3. What factors related to the patient's use of the hearing aid could impact this estimate?

Patient Report: "My Hearing Aid Is Noisy" or "There's a Lot of Static in My Hearing Aid"

This complaint implies that the hearing aid itself is producing noise separate from amplifying noise that may be in the environment. To assess internal (circuit) noise, you will use the EIN test. Remember to listen to the hearing aid first. If you can hear the circuit noise, it may help in the diagnosis of the problem.

Helpful hints:

- The microphone and the amplifier are the first and second noisiest parts of the hearing aid, respectively.
- A measurement of equivalent input noise is valid only when the ambient (outside) noise is low.
- Patients with good low-frequency hearing will be more aware of circuit noise. Manufacturers use expansion to try to reduce this perception. Expansion, the opposite of compression, is when inputs below the compression threshold receive minimal gain instead of maximal gain.

The EIN is determined by subtracting the gain of the hearing aid from the magnitude of the noise at the output of the hearing aid. It is called EIN because it is the amount of noise that would have to be put into a noiseless hearing aid for that hearing aid to have the same noise output as the one being tested. This test is computing the EIN averaged across frequency. Pragmatically, this measure is telling you how much "noise" the hearing aid makes regardless of the input signal. This is circuit noise. All hearing aids have circuit noise. In some cases, it may be intense enough that the patient becomes bothered by it.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid.

Table 5 Suggested allowable equivalent input noise

Frequency (Hz)	Maximum acceptable noise (1/3 Octave dB SPL)	Frequency (Hz)	Maximum acceptable noise (1/3 Octave dB SPL)
300	33	900	19
400	30	1,000	16
500	26	2,000	14
600	24	3,000	14
700	23	4,000	15
800	20		

Source: Adapted from Dillon 2001.[4]

Activity 10

1. Get the equipment ready to make measurements (see Chapter 1).
2. Attach the hearing aid to the appropriate coupler and microphone (see Chapter 1).
3. Set the volume control to full on (you can repeat this test at the user volume control setting as well).
4. Right-click the mouse and select **ANSI/IEC** under Test box.
5. Click on **Start Test**.
6. Follow all steps in the Test Setup window that appears.
7. Click on **the green checkmark** and complete the test.

The manufacturer's specifications will indicate the maximum EIN value allowed for the hearing aid. Table 5 lists the maximum EIN considered acceptable for each frequency that can be used for any hearing aid. The average EIN for this hearing aid is 41 dB SPL (Figure 14). This is high, given the values in Table 5. In this

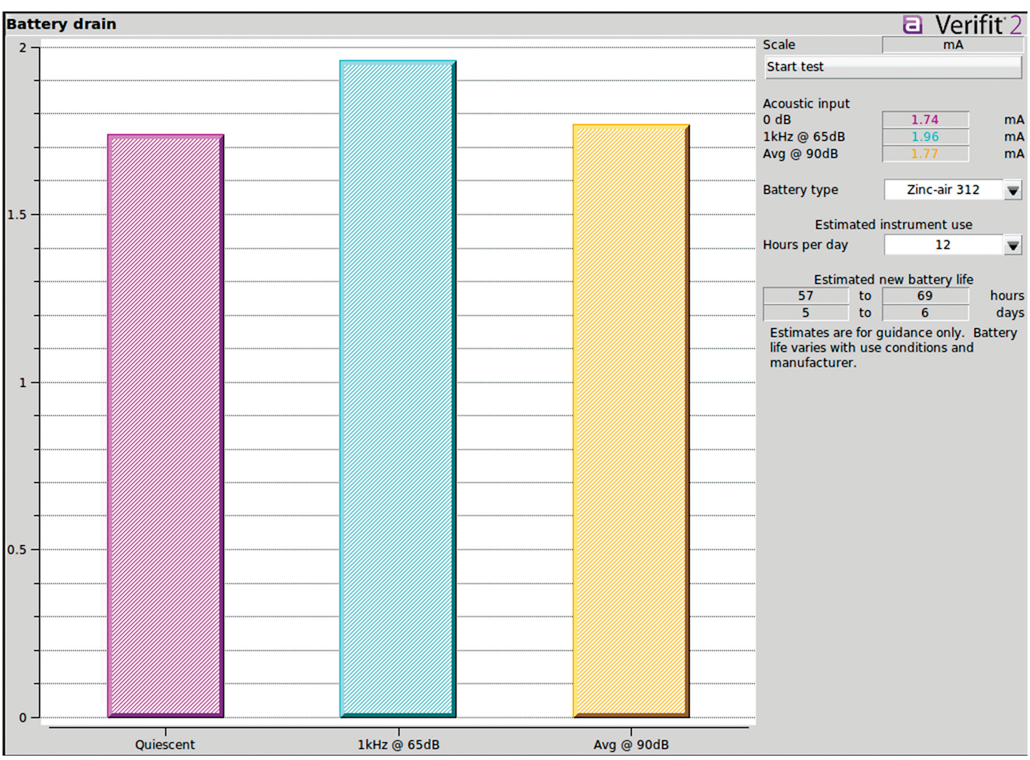

Figure 13 Battery drain test results (also see Figure 1F).

case, you may want to send the hearing aid to the manufacturer for repair. It may be helpful to attach your EIN results to the repair request.

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid.

Activity 11

1. Run an ANSI test on a hearing aid.
2. Follow the instructions in Activity 10. Is the EIN value acceptable according to the data in Table 5?

Patient Report: "My Hearing Aid Is Not Working/Is Noisy/Sounds Different"

The distortion test is analyzing the harmonic distortion components of the signal produced when a pure tone is processed by the hearing aid. Harmonics are sounds that are higher in frequency that are produced because of nonlinearities in the amplifying system. It is normal to have harmonics produced in these systems; the problem is when they are noticeable to the listener and cause a perception of distortion in the sound. Percentage of THD is the most common measurement for this purpose. THD is the distortion for all harmonics summed. This is only one type of distortion; so, the hearing aid might still have distortion even if the THD is low.

Helpful hints:

- Always listen to the hearing aid when a patient complains that it sounds different. When listening, adjust the hearing aid volume control and use different input levels (intensity of your voice) to see how it sounds with various inputs. Use a sentence like, "Joe took father's shoe bench out; she was sitting on my lawn," which tests most of the sounds in the English language. Do this for each of the various programs that use the microphone input (e.g., day-to-day listening program, music setting, restaurant setting).
- Although ANSI standards[1] specify measuring distortion with a 70-dB SPL input, if distortion is

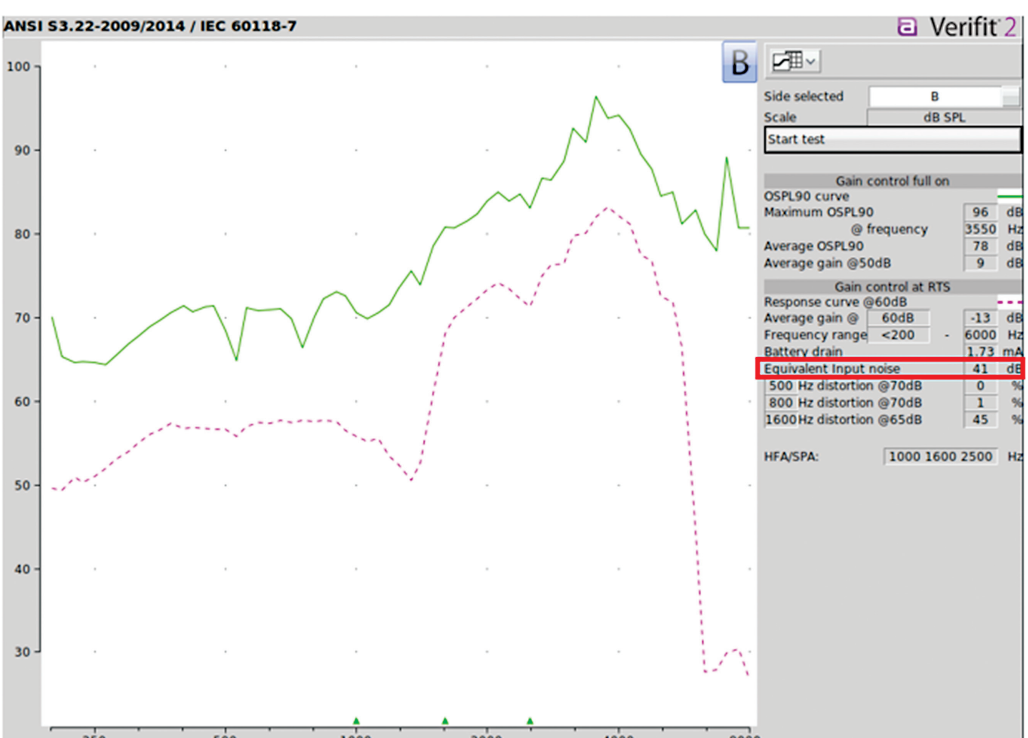

Figure 14 Equivalent input noise test results, shown in highlighted box (also see Figure 1G).

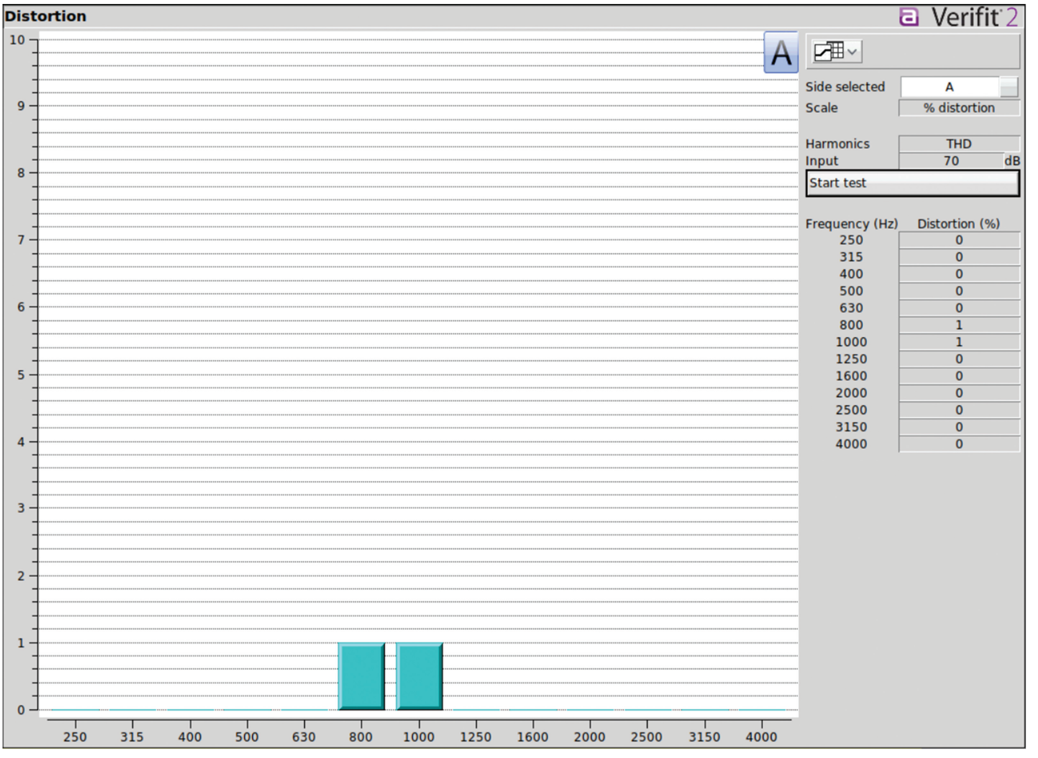

Figure 15 Example of a test of total harmonic distortion (THD) (also see Figure 1H).

suspected, it is useful to measure at higher inputs as well, as they are more likely to cause distortion (85- or 90-dB SPL input).

Materials Needed for this Activity

For these activities, you will need a hearing aid test box, hearing aid.

Activity 12

1. Get the equipment ready to make measurements (see Chapter 1).
2. Attach the hearing aid to the appropriate coupler and coupler microphone.
3. Set the volume control to user setting.
4. Right-click the mouse and select **Distortion** under the Test box options.
5. Ensure the hearing aid is on. Click on **Start test.**
6. Set harmonics to THD and input to 70 dB SPL.
7. Click on **the green check mark** to start the test.
8. Repeat steps 5 to 7 with 85-dB SPL input.
9. The THD of any hearing aid should be less than 10% at each frequency. The only harmonic distortion measured for the hearing aid in Figure 15 is at 800 and 1,000 Hz. Both measurements are less than 10% (close to 1%). You would want to look at the THD results for the 85-dB SPL input as well.

Materials needed for this activity: For these activities, you will need a hearing aid test box, hearing aid.

Activity 13

1. Following the instructions in Activity 12, run a THD test on a hearing aid.
2. Describe whether the hearing aid is significantly distorted.
3. If the hearing aid is highly distorted, what would you do next?

CONCLUSION

Hopefully the descriptions and activities in this section have convinced you that the hearing aid test box is a powerful clinical tool. Audiologists should be empowered to measure many aspects of the function of a hearing aid to assess whether it is functioning and adequate for a given patient. The patient's complaint or your clinical goals will guide you in deciding what test(s) to use. The bottom line is that if a device provides an acoustic output, the resulting output can be measured in a test box and many of its attributes (gain, distortion, etc.) can be evaluated.

CONFLICT OF INTEREST

None declared.

REFERENCES

1. American National Standards Institute/Acoustical Society of America. (2020). Specification of Hearing aid Characteristics (S3.22–2014 [R2020]). Accessed April 10, 2024 at: https://webstore.ansi.org/standards/asa/ansiasas3222014r2020
2. Scollie S, Seewald R, Cornelisse Let al. The desired sensation level multistage input/output algorithm. Trends Amplif 2005;9(04):159–197
3. Keidser G, Dillon H, Flax M, Ching T, Brewer S. The NAL-NL2 prescription procedure. Audiology Res 2011;1(01):e24
4. Dillon H. Hearing Aids. Turramurra, Australia: Boomerang Press; 2001