Headphone Electroacoustic Measurements

by Joe Begin

About This Technote

An AP Application Note published in 2016 [1] contains a high-level overview of the key electroacoustic measurements used to characterize the audio quality of headphones and earphones intended for listening to music and other full-band audio program material. Users who are less familiar with headphone test or who want more background information might want to start with that document.

In this Technote, we provide a more detailed discussion on the choice of test equipment for headphone testing, as well as detailed instructions on how to conduct the tests with APx audio analyzers.

Industry Standards

Ideally, standards represent consensus among industry experts concerning measurement conditions and recommended practices that will help to ensure that devices are tested in a meaningful and repeatable way. As such, it is best to follow industry standards when conducting performance measurements, or to at least use them as a guideline.

In terms of test fixtures used in testing headphones and earphones, the most important standards are Parts 1, 4 and 7 of the IEC 60318 series, titled Electroacoustics – Simulators of the Human Head and Ear [2, 3, 4]. Part 1 specifies an ear simulator for the measurement of on-the-ear and around-the-ear earphones; Part 4 specifies an occluded-ear simulator for measuring earphones coupled to the ear by means of ear inserts; and Part 7 specifies a Head and Torso Simulator (HATS).

In terms of test procedures, the key international standard covering measurements is IEC 60268-7, Sound system equipment, Part 7: Headphones and earphones [6]. This Technote will focus on the following electroacoustic measurements covered by this standard that are most likely to be of interest:

- Characteristic voltage
- Frequency response
- Crosstalk attenuation
- Amplitude nonlinearity
- Electrical impedance

Concerning sound attenuation, IEC 60268-7 specifies that measurements should be conducted according to the ISO 4869 standard for hearing protectors. This topic is covered in a separate Technote [7] on measuring the performance of headphones with Active Noise Cancellation (ANC).

Another important standard in headphone testing is EN50332 [8], which covers the maximum permissible sound pressure level that can be generated by headphones and earphones used with portable music players. This topic is also covered in a separate Technote [9].

Equipment for Headphone Testing

In addition to an audio analyzer, due to the close coupling of headphones and earphones to the ear, a special acoustic test fixture is required for testing headphones, as well as some additional accessories. These are discussed separately below.

Acoustic Test Fixtures

When testing headphones and earphones, acoustic test fixtures serve three primary functions:

1. They incorporate measurement microphones to sense the sound signals generated by the headphones.
2. The microphones may be embedded in ear simulators – small cavities which simulate the acoustic impedance of a typical human ear, to properly load the earphones acoustically.

3. Some ear simulators also simulate the mechanical features of the human pinna, or outer ear. This is important for some headphones, because the interaction of the earphones with the pinnae affects the measured frequency response.

A wide variety of headphone test fixtures is available (Figure 1), and the choice of which one to use depends mainly on the headphone or earphone type (e.g., around-the-ear, on-ear, earbud, insert phone, etc.) and the application (R&D, quality control or production test). Not only are there a large number of test fixtures from which to choose, but each fixture has many additional options in terms of ear simulator (standard, high-frequency, high resolution, low sensitivity or low-noise), pinna type (conventional, anthropometric) and measurement microphone type (externally polarized or pre-polarized).

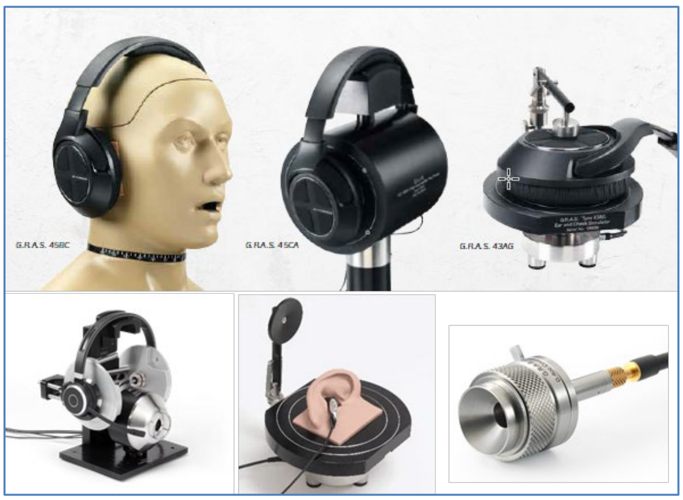

Figure 1. Examples of acoustic test fixtures available for headphone and earphone testing (courtesy of GRAS Sound & Vibration).

Accessories for Headphone Test

In addition to an acoustic test fixture, the following accessories are required for testing stereo headphones[1].

- Power amplifier(s) (2 channels)
- Microphone power module(s) (2 channels)
- Sound level calibrator
- Sense resistor(s), for measuring electrical impedance

For this Technote, we used a GRAS 45CA Headphone/Hearing-protector Test Fixture (Figure 2) with standard ear simulators per IEC 60318-4 (also known as 711 couplers) and conventional pinnae (like the ones in the center photo of Figure 2).


Figure 2. GRAS 45CA Headphone/Hearing-protector Test Fixture

As noted in the section below on Selecting an Audio Analyzer, the APx517B with its built-in headphone amplifiers, CCP power for measurement microphones and 4-wire impedance measurements, is ideally suited for testing headphones and earphones. The accessories below aren't needed with the APx517B, but they are described here for the benefit of users who want to test headphones with a different APx analyzer.

Power Amplifiers

A power amplifier is required to drive each earphone for headphone testing. Although the power requirement is small—typically in the range from a few milliwatts to 500 milliwatts—an audio analyzer's analog outputs are designed to source only a small amount of current. Hence a power amplifier is usually required.

The output impedance of the power amplifier may also be a consideration. For example, some standards, such as EN50332 [8] specify that the output impedance of the test signal source must not exceed 2.0 ohms. When such a requirement exists, the output impedance of the power amplifier should be verified. Note that some consumer devices with headphone jacks we have tested have a much higher output impedance.

Microphone Power Modules

A microphone power module is required for each of the acoustic test fixture's ear simulators (or measurement microphones). For each channel being measured, the power module is connected between the microphone and the

[1] To test one earphone at a time, a 1-channel power amplifier and a 1-channel microphone power supply can be used.

audio analyzer input. Its main purpose is to provide power to the condenser microphone. Some power modules provide additional signal conditioning such as gain and frequency weighting filters. External signal conditioning features are not typically needed with APx audio analyzers due to their ability to accurately measure very low-level input signals and built-in high pass, low pass and frequency weighting filters.

As noted above, measurement microphones are typically one of two types: externally polarized or pre-polarized. Externally polarized microphones require a 200-volt polarization voltage and typically have 7-pin Lemo connectors. Pre-polarized microphones require a constant current power (CCP) source and use coaxial cables with BNC or #10-32 Microdot connectors. Microphone power modules of the same type as the ear simulator microphones are required for headphone testing. GRAS Sound & Vibration offers a variety of suitable microphone power modules including CCP units (with channel counts of 1, 4 and 8), traditional 200 V units (with channel counts of 1, 2, 4 and 8), and a 2-channel unit that supports both CCP and Traditional 200 V types.

Sound Level Calibrator

Microphone sensitivity, usually expressed in units of mV/Pa, is a property indicating the amount of voltage a microphone puts out per unit of sound pressure its sensing element is exposed to. Due to manufacturing tolerances, the sensitivity of a measurement microphone is almost always slightly different than its nominal sensitivity. A sound level calibrator or pistonphone offers a convenient means to capture the sensitivity of a measurement microphone in the audio analyzer software, such that input signals can be analyzed directly in Pa or dBSPL. These devices typically subject the microphone or ear simulator to a known sinusoidal sound pressure level (SPL) – e.g., 114 dBSPL at 250 Hz. The analyzer measures the microphone's output voltage and automatically computes its sensitivity based on the calibrator's sound pressure level.

Calibrators typically generate a sinusoidal pressure at either 250 Hz or 1 kHz. For ear simulators, a calibrator frequency of 250 Hz is preferred, because the resonance caused by the ear simulator cavity has negligible effect at 250 Hz. A calibrator that operates at 1 kHz can still be used, but an offset must be added to the calibrator's reference level to compensate for the resonance effect at 1 kHz.

The GRAS 42AG Multifunction Calibrator has selectable operating frequencies of 250 Hz and 1 kHz, and also supports two reference SPLs, 94 and 114 dBSPL.

Figure 3. GRAS 42AG Multifunction Sound Calibrator.

Sense Resistor

Impedance measurements require measuring the current passing through a driver and the voltage across it simultaneously. The easiest way to do so is with an acoustic Audio analyzer like the APx517B, which has current sense built right into its power amplifiers. When using a conventional audio analyzer, the IMP1 Impedance Fixture is a useful accessory for measuring driver current and voltage. It offers a choice of 0.1 and 1.0 ohm sense resistors, and has connectors which make it easy to connect the various power and sense leads between the power amplifier, driver and audio analyzer.

Figure 4. The IMP1 Impedance Fixture.

Selecting an Audio Analyzer

The following attributes make the APx517B Acoustic Audio Analyzer an ideal choice for testing headphones and earphones:

- 2-channel precision headphone amplifier with standard headphone jack connector.
- 2 analog input channels with CCP power and TEDS support for pre-polarized measurement microphones (or ear simulators).
- Built-in current sense with 4-wire impedance measurements.
- Support for one optional digital audio IO module, (e.g., *Bluetooth®*, PDM, PDM 16, DSIO, DIO, HDMI, etc.).

Aside from the APx517B, virtually any audio analyzer in the APx family, when equipped with the right accessories, can be used to test headphones and earphones. For testing analog stereo headphones, an audio analyzer with at least two analog output channels and two analog input channels is required. While the APx515 meets this requirement, users who also need to test audio quality over digital interfaces such as Bluetooth, PDM, I2S/TDM, or HDMI might want to consider either an APx517B, or a modular 2-channel audio analyzer like the APx525, or the higher performance APx555. And those needing higher analog channel counts for other applications might consider the APx526 (2 output channels x 4 input channels), the APx 582 (2 out x 8 in), the APx585 (8 out x 8 in) or the APx586 (8 out x 16 in).

For headphone applications involving a single earphone, the APx511 Hearing Instrument Analyzer could also be a compelling choice. Its single output channel incorporates a unity gain power amplifier, and its single analog input channel supports CCP microphone power.

For those using an analyzer other than the APx517B, the APx1701 Transducer Test Interface is also a very useful accessory for headphone testing. It has two laboratory grade power amplifiers with built-in current sense resistors, support for two CCP microphones (with or without TEDS), as well as support for two phantom-powered microphones. It comes with ISO 17025 accredited calibration and is fully integrated with the APx500 audio analyzer software.

Conducting the Measurements

Next, we'll describe the practical aspects of conducting the headphone measurements using an APx517B Acoustic Audio Analyzer and a GRAS 45CA-6 Headphone/Hearing-Protector Test Fixture equipped with CCP type IEC 60318-4 ear simulators and standard pinna simulators. The measurements shown in this Technote are for a set of around-the-ear (ATE) stereo headphones that are popular in the professional broadcast industry.

Connections

With the APx517B analyzer, connections between the device under test (DUT), the analyzer and the test fixture are quite simple, especially when the test fixture is equipped with CCP microphones, as shown in Figure 5. The headphones are simply plugged into the Headphone Amplifier jack, and the test fixture's two CCP microphone cables are connected to the Mic Input BNC connectors on the front panel of the APx517B. These connections work for both the acoustic measurements and the electrical impedance measurements.

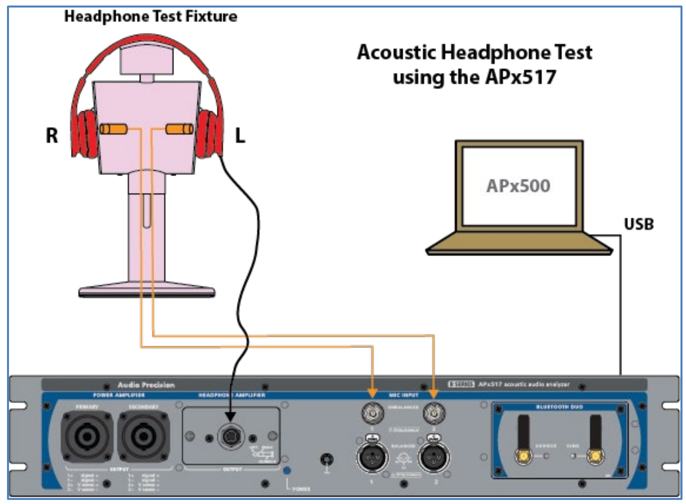

Figure 5. Connections required for headphone testing with an APx517B Acoustic Audio Analyzer.

APx Project File

An APx project file accompanying this Technote is used to illustrate headphone measurements. The project file was created for an APx517B audio analyzer, but can easily be adapted for use with other APx audio analyzers with appropriate test accessories. The sections below contained a detailed description of the measurements, which should help you to adapt it for your own needs.

The project file has four signal paths:

1. Signal Path1 – Cal Ear Simulators: Used to "calibrate" the ear simulator microphones. Includes a prompt to make connections.
2. Signal Path2 – Acoustic: Used to implement acoustic measurements. Includes prompts to install pinnae and place the headphones on the test fixture, as required.

3. Signal Path3 – Impedance-L: Impedance measurement of the left earphone.
4. Signal Path4 – Impedance-R: Impedance measurement of the right earphone.

The project file has five sequences. A sequence in APx is a collection of checked items – signal paths, measurements, results and sequence steps. Once a sequence is selected, the Run Sequence button at the top of the Navigator will run all the checked measurements—including checked sequence steps—in all checked signal paths and accumulate checked results into a report. If the report checkbox is checked, the report is opened at the end of the sequence.

The first sequence, named Cal & Regulate, is configured to "calibrate" the ear simulators and then use a regulation process to find the Characteristic Voltage. The second sequence is configured to run the remaining acoustic measurements, and the third and fourth sequences are configured to run the electrical impedance measurements. The fifth sequence, named "Sequence – All", first prompts the operator for the Device ID, runs all the measurements and sequence steps in the previous four sequences and then opens the test report. The following sections provide detail on how the sequences are implemented.

Ear Simulator Calibration

Prior to conducting acoustic measurements, the ear simulator microphones must be "calibrated". This is not a true calibration per se, but rather the process of entering the microphone sensitivities such that the input signals can be scaled properly to Pa or dBSPL. In the APx software, this is accomplished using Acoustic Input mode, invoked by checking the Acoustic checkbox in the Input Configuration section of Signal Path Setup (Figure 6). Once the Acoustic checkbox is checked, within that signal path, input units are changed from the voltage family of units to Pa/dBSPL.

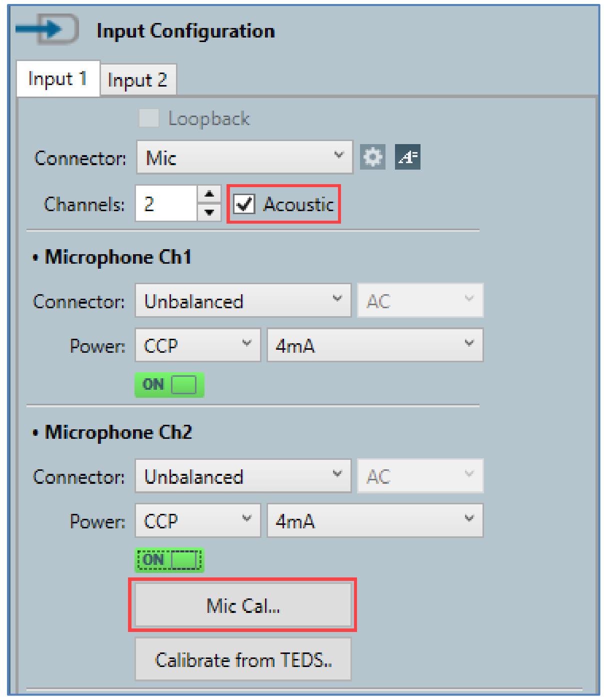

Figure 6. APx Input Configuration section.

In Acoustic Input mode, a button labeled "Mic Cal..." is visible in the Input Configuration section of Signal Path Setup. It can also be accessed from the Acoustic tab of the Input section of the References panel. Clicking this button opens the Microphone Calibration dialog shown in Figure 7. This dialog facilitates "calibrating" connected microphones using a sound level calibrator (or pistonphone). First, you must enter the calibrator Level in the appropriate field in the upper left. The Level fields for each channel in this dialog show the current rms level in volts measured on the enabled input channels. To "calibrate" a microphone (i.e., to capture its sensitivity), slide the calibrator over the microphone and hold it steady until the Level reading stabilizes. Then click the Calibrate button for the corresponding channel. The system will immediately capture the measured rms level in Vrms and use it to calculate the Sensitivity from the specified Calibrator Level and display it in the Sensitivity field.

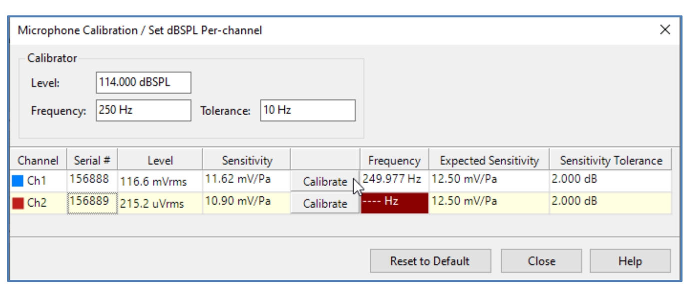

Figure 7. The Microphone Calibration dialog in Acoustic Input mode when calibrating the microphone on channel 1.

Optional fields in the Microphone Calibration dialog can be used to specify the nominal frequency of the calibrator and a frequency tolerance value. If the measured frequency differs from the nominal frequency by more than the specified tolerance, the Frequency field is highlighted in red, as shown for Ch2 in Figure 7. Optional fields for each microphone channel can also be used to specify the Serial Number, the Expected Sensitivity and the Sensitivity Tolerance. Once the Calibrate button has been clicked, the Sensitivity field will be highlighted in red if the difference between the measured and expected sensitivity exceeds the Sensitivity Tolerance.

In addition to the manual process described above, the “calibration” process for each channel can be implemented via a Prompt Sequence Step in the Signal Path Setup measurement. Simply add a Prompt step, configure its Message to Operator field, check the Set dBSPL checkbox, and select the desired channel, as shown in Figure 8.

The sequence step in Figure 8, when executed, displays the prompt shown in Figure 9. In this case, a photograph has been added to the Appearance tab of the prompt for clarity. Note: If the Calibrator Frequency and Expected Sensitivity fields in Figure 7 are populated, out-of-tolerance values in the prompt will be highlighted in red, and will cause the measurement to fail in the sequence.

Note: The APx517B CCP microphone inputs are TEDS capable. If the ear simulator has CCP microphone preamplifiers that are programmed with TEDS, the APx software can read each microphone’s sensitivity (and other key information) directly from a chip inside the preamplifier and assign the sensitivity to the appropriate channel. This can be done manually, or via a sequence step. Sequence steps for this purpose are included in the accompanying project file, but are unchecked.

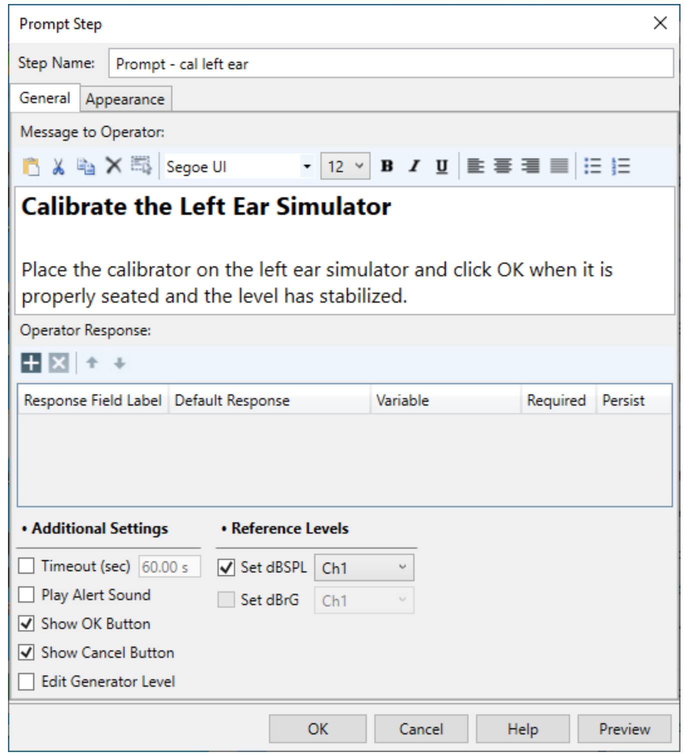

Figure 8. Configuring a Prompt step in Signal Path Setup to "calibrate" the left ear simulator (on Channel 1).

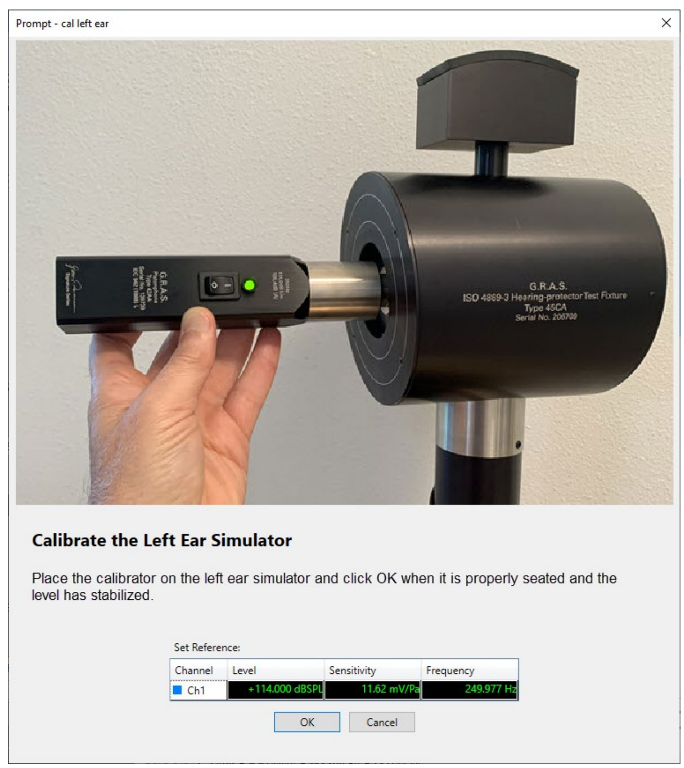

Figure 9. Prompt sequence step with Set dBSPL checkbox checked.

Characteristic Voltage

Once the ear simulator microphones have been "calibrated", we can conduct acoustic measurements.
IEC 60268-7 defines the Characteristic Voltage as the voltage of a sinusoidal signal at 500 Hz, which, when applied to the earphone on a coupler or ear simulator, produces a sound pressure level of 94 dBSPL. This voltage is found through a regulation process, which can be implemented in APx using the Auto Set Gen Level feature. To use the feature, click the button labeled "Auto Gen Level..." in the Output References section of the References panel (Figure 10) in Signal Path Setup. This will invoke the Automatically Set Generator Level dialog (Figure 11), which is configured to regulate the generator's RMS Level to a Target Value of 94 dBSPL at a Frequency of 500 Hz (i.e., the Characteristic Voltage).

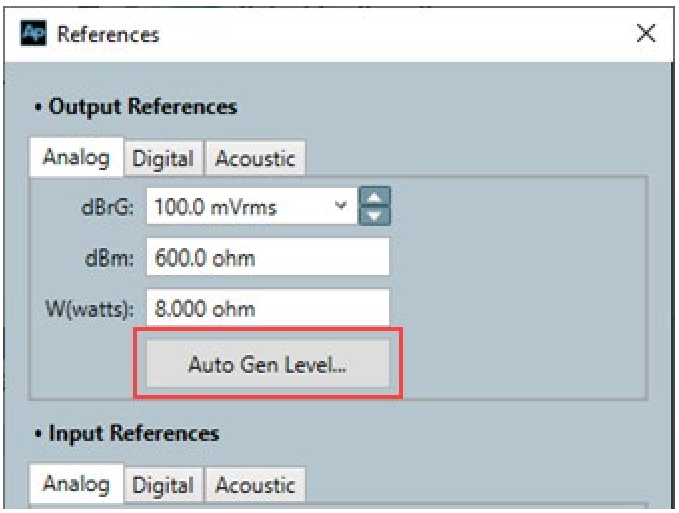

Figure 10. The Output References section of the References panel.

When the Auto Set Generator Level process completes, the system automatically sets the analog output dBrG reference to the generator voltage that causes the target level (94 dBSPL at 500 Hz) in the target channel. Subsequently, this generator level can be set in any measurement in the same signal path by setting the generator level to 0 dBrG. This is how the accompanying project file has been configured.

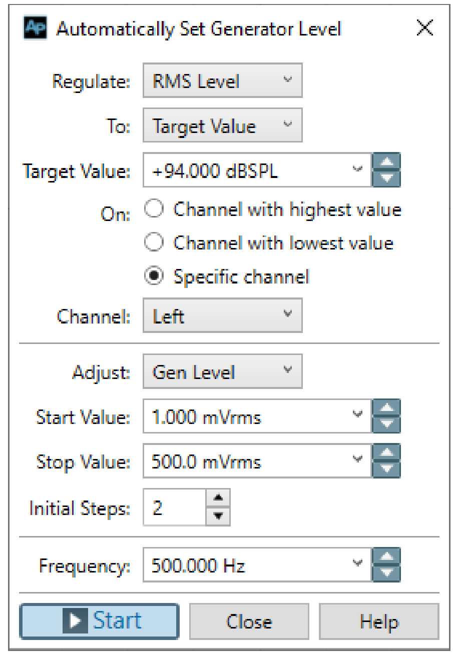

Figure 11. The Auto Set Generator Level dialog used to configure regulation measurements.

Note that you must enter generator level Start and Stop Values that are appropriate for the headphones under test in the Automatically Set Generator Level dialog (Figure 11). These are best found using the Verify Connections panel in Signal Path Setup. There you can turn the generator on, then adjust its level up or down while observing the measured rms level in dBSPL on the target channel, until you find generator levels that cause measured SPLs below and above the target value of 94 dBSPL. Hence, it is best to complete this Verify Connections exercise before configuring the Auto Set Generator Level feature.

Auto Set Generator Level in a Sequence

The Auto Set Generator Level feature can be invoked automatically in a sequence using the Measurement Sequence Settings node of Signal Path Setup (Figure 12). Clicking on this node in the Navigator opens the Measurement Sequence Settings dialog. Note the Auto Set Generator Level checkbox. When it is checked, the regulation process will be run when the sequence progresses to the Measure Signal Path Setup node, at the end of the Sequence Steps branch. As a result, the prompts shown in Figure 12 to install the pinnae and place the headphones on the test fixture are executed before the Auto Set Generator Level procedure.

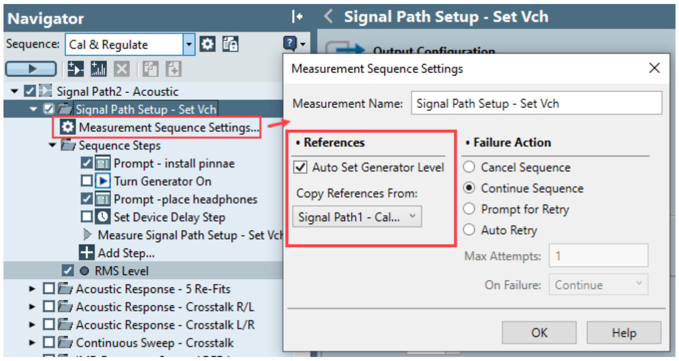

Figure 12. The Measurement Sequence Settings node of Signal Path Setup.

Copying References between Signal Paths

Note also the Copy References From dropdown control in Figure 12, which has been set to “Signal Path1 – Cal Ear Simulators”. This instructs the system to copy all references from Signal Path1 – Cal Ear Simulators to the current signal path (Signal Path2 – Acoustic). This enables the microphone sensitivities and generator dBrG reference voltage to be propagated from one signal path to another.

Frequency Response & THD

Harmonic distortion is one form of amplitude nonlinearity. The Acoustic Response and Continuous Sweep measurements in APx both use the log-swept sine or “chirp” measurement technique, which enables simultaneous measurement of frequency response and total harmonic distortion (THD). As the name implies, Acoustic Response is intended for acoustic measurements, with features such as averaging multiple sweeps to improve signal-to-noise ratio, and a Level and Distortion result which shows RMS Level, THD Level and second (H2) and third (H3) harmonic distortion product levels on one graph. Acoustic Response also enables windowing the impulse response for quasi-anechoic loudspeaker measurements, but this feature is not needed for headphone testing on ear simulators.

The Continuous Sweep measurement is intended for electronic audio measurements, but we’ve included it in the project file because it has a built-in capability to make crosstalk measurements. It offers high-speed and high-accuracy modes. In the high-speed mode, the chirp signal in channel 2 is delayed relative to channel 1, enabling crosstalk to be measured in one sweep. In the high-accuracy mode, a separate sweep is conducted for each measurement channel with the generator disabled for the opposite channel.

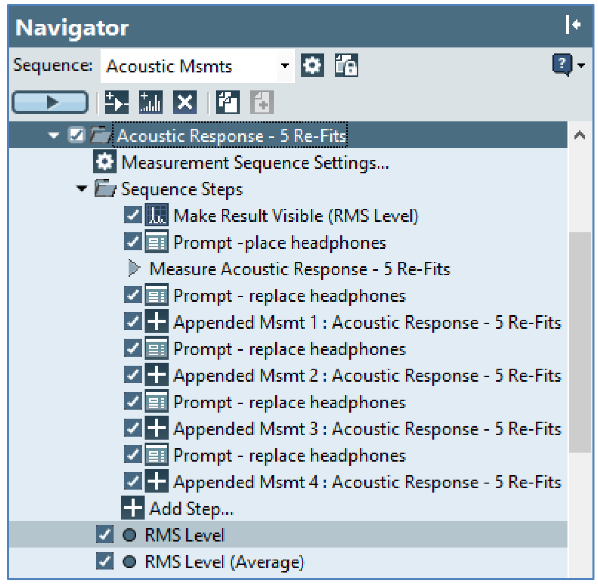

Figure 13. Sequence steps in Acoustic Response.

In the project file, the first Acoustic Response measurement has been renamed to “Acoustic Response – 5 refits”. A series of sequence steps has been added to this measurement to configure it for five measurement repetitions (Figure 13). Prompts before each measurement step instruct the operator to place the headphones on the test fixture (first measurement) or to remove them and replace them on the fixture. The intent here is to make five identical measurements, but with the headphones re-fit to the test fixture each time, so that an average response can be calculated, to account for the response variation due to fit. This is a recommended practice when testing headphones and earphones.

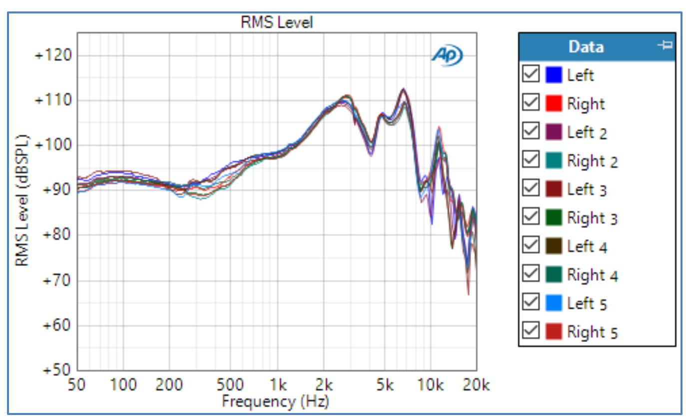

Figure 14. RMS Level response of the headphones with 5 re-fits.

Figure 14 shows the rms level measurement results for the five measurements, for both channels. In this case, the generator level was set to 0 dBrG, to drive the headphones at the Characteristic Voltage, as measured above.

APx Derived Results

There are many "derived results" in the APx software that can be used to perform math operations on measured data, to help you gain insights into a product's performance. Some of these are illustrated below. In APx, derived result graphs are denoted by an *fx* icon.

Figure 15 shows a Power Average result derived from the five data sets in Figure 14, to calculate the response of the left and right earphones averaged over five re-fit operations. This allows us to more easily see the difference in response between the left and right earphones, while accounting for the variation due to fit.

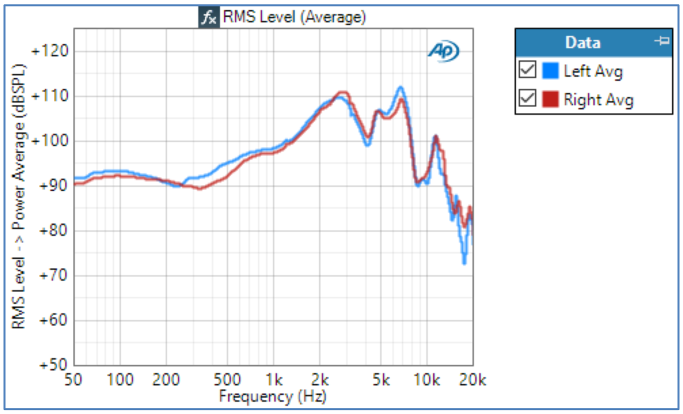

Figure 15. Response of the left and right earphones averaged over five re-fits.

A metric called "left/right tracking" can be used to more easily quantify how well the response of the left and right earphones match one another. Figure 16 shows the left/right tracking result for these headphones, derived from Figure 15 using a Compare derived result, which calculates the level response ratio between channels as a function of frequency. In this case, the left/right tracking curve of a perfectly matched pair of earphones would be a flat line at 0 dB. As shown, limits have been added from 100 Hz to 10 kHz, where the response is less impacted by fit variations, due to leaks at low frequency and interaction between the earphone and features of the pinnae at high frequency.

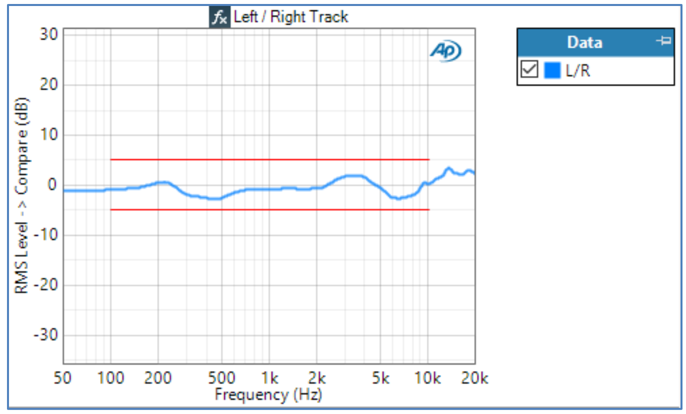

Figure 16. A Compare derived result to quantify Left/Right tracking.

Another useful metric we can derive from the data is the average response within a frequency range—500 Hz to 2 kHz, in this case (Figure 17). This result was derived from a Specify Data Points result, derived from the spatial average data of Figure 15, to get response curves within this frequency range. This represents mid-frequency output level from each earphone due to an input voltage equal to the Characteristic Voltage.

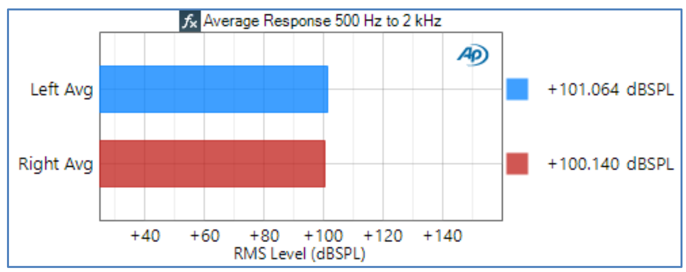

Figure 17. Headphone response averaged from 500 Hz to 2 kHz.

A derived result has also been used to find the phase difference between the left and right earphones, averaged over five re-fits (Figure 18). In this case an Arithmetic Mean XY derived result was used.

Another application of derived results for headphones is comparing their frequency response to a design target curve. This can be accomplished by applying an inverted version of the design target curve to the measured response curve as an EQ derived result. A measured curve that matches the design curve would appear in this EQ'd result as a flat line at 0 dB. Figure 19 shows a frequency response design target curve for ATE headphones published in reference [10]. In the project file, this curve was imported, inverted and saved as an EQ curve. Figure 20 shows how the average left earphone response of the headphones tested compare to this design target curve.

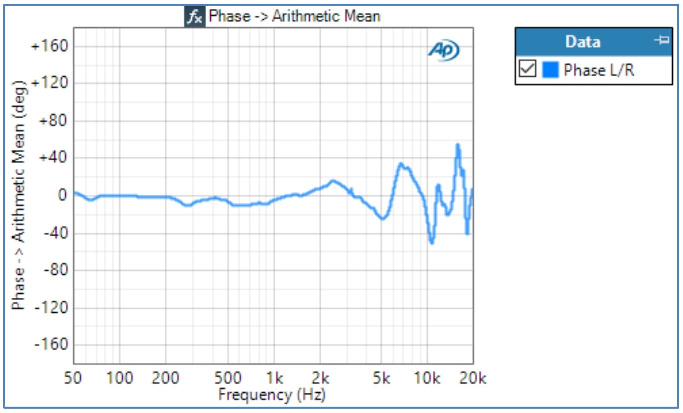

Figure 18. Phase response between the left and right earphones, averaged over five re-fits.

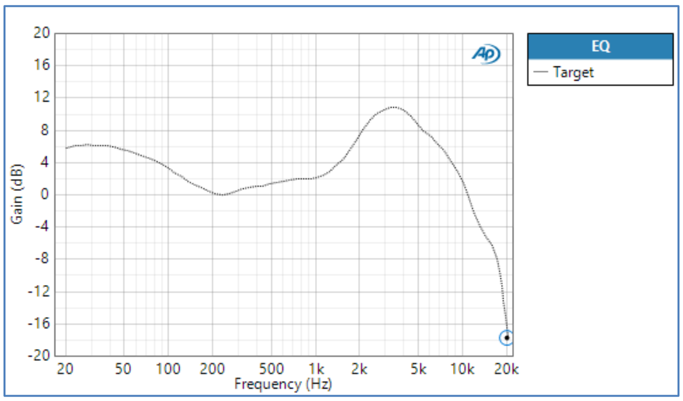

Figure 19. Harman design target curve for AE and OE headphones (digitized from reference [10]).

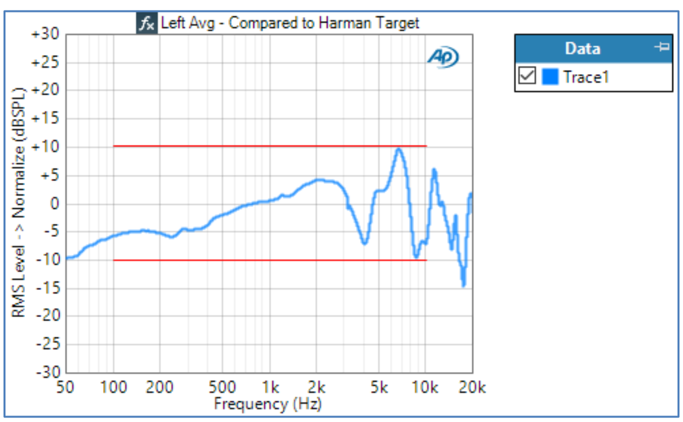

Figure 20. Left earphone average response equalized with the inverted design target curve.

As mentioned above, the Acoustic Response measurement has a Level and Distortion result, which displays the overall rms Level, as well as the levels of total, second and third harmonic distortion versus frequency. The primary result for this measurement with five re-fits has 40 traces (4 components x 2 channels x 5 data sets). Data for the five re-fits of the left earphone only averaged together are shown in Figure 21 – a power average derived result.

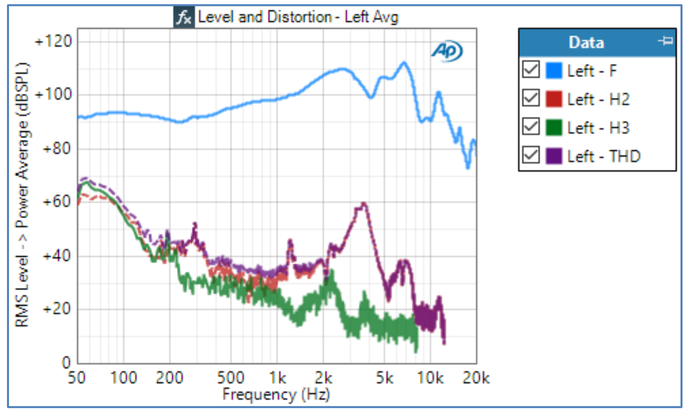

Figure 21. Power Average derived result showing Level and Distortion averaged over five re-fits for the left earphone.

In the Level and Distortion result, THD, and the distortion products H2 and H3 are plotted in terms of their levels in dBSPL, so that they can share a vertical axis with the overall level. THD Ratio in percent is plotted versus frequency for the left earphone in Figure 22. Here again, a power average derived result was used to average the response over five refits for the left earphone.

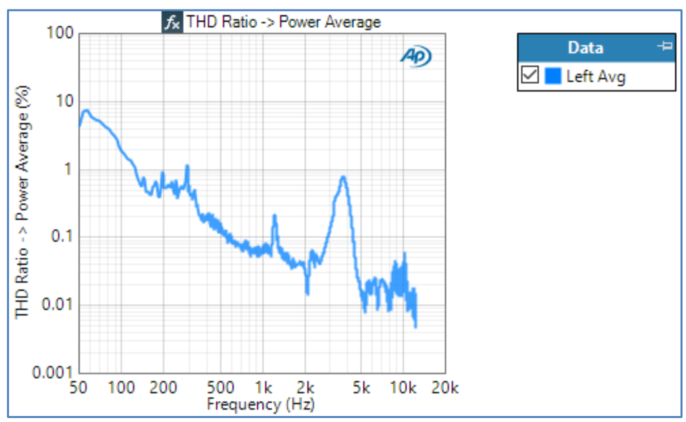

Figure 22. THD Ratio response in percent for the left earphone averaged over five re-fits.

Crosstalk

The Acoustic signal path in the project file contains a Continuous Sweep measurement configured for high-accuracy mode crosstalk. In this mode, the measurement runs once with each output channel disabled (no stimulus) and measures the signal in the opposite channel, to determine the crosstalk between channels. Figure 23 shows the results of this measurement for the headphones tested here. Note that the Crosstalk result for this measurement normally has only one result for each undriven channel (one in this case). To get data for both the left and right channels on the same graph, a right axis was added to the graph and configured for the second channel. When using a graph with two vertical axes, it's best to configure them to have the same range, as shown here.

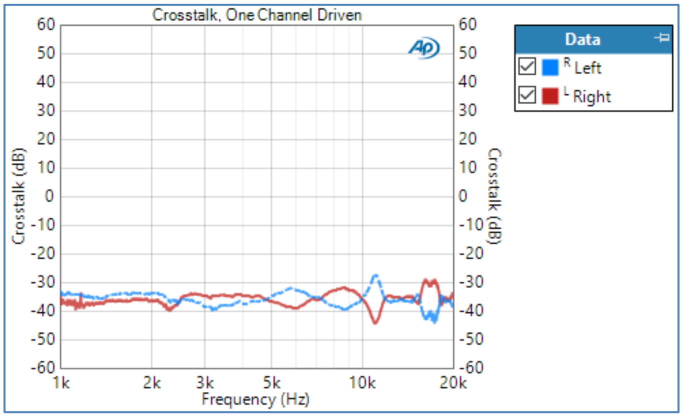

Figure 23. Crosstalk versus frequency, as measured with the Continuous Sweep measurement.

An alternative to the Continuous Sweep measurement for measuring crosstalk is to simply conduct a sweep with one generator channel disabled. Crosstalk can then be determined using a Compare derived result to find the ratio between the level of the undriven channel to the level of the driven channel. The signal path also contains Acoustic Response measurements set up this way – one to measure left-to-right crosstalk and the other right-to-left.

Difference Frequency Distortion

Difference Frequency Distortion (DFD)—a type of intermodulation distortion (IMD)—is another measure of amplitude nonlinearity. As specified in IEC 60268-7, it uses two sinusoidal signals at equal levels, that differ in frequency by 80 Hz, and second and third order (d2 and d3) distortion components are observed. IMD measurements are especially useful in bandwidth-limited systems, because some of the distortion components show up at frequencies lower than the fundamental tones, whereas harmonic distortion components are more likely to occur at frequencies above the pass band of the device.

In Sequence mode, the APx software has a single-tone IMD (DFD) measurement and an IMD Frequency Sweep (DFD) measurement. The measurements can be configured to observe distortion components d2, d3 or both combined (d2+d3). Figure 24 shows the DFD ratio (d2+d3 configuration) versus frequency from 300 Hz to 20 kHz, for the ATE headphones tested in this Technote.

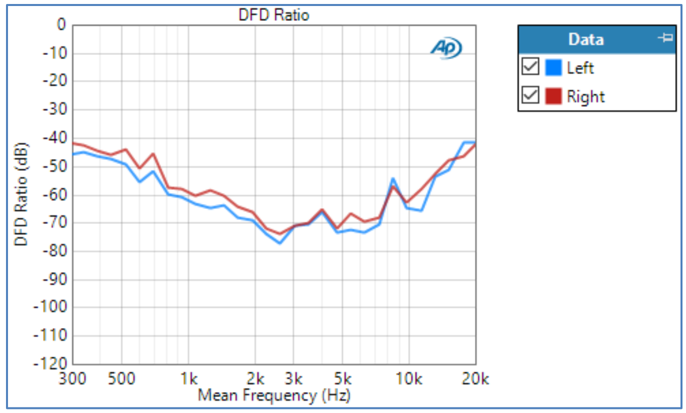

Figure 24. DFD Ratio (d2+d3) versus frequency for the headphones tested.

Electrical Impedance

IEC 60268-7 specifies that the modulus (or magnitude) of the earphone impedance be measured and displayed from 20 Hz to 20 kHz. The rated (or nominal) impedance is the value of a pure resistance which is specified by the headphone manufacturer for the purpose of matching a power amplifier to the device. It should be chosen such that the minimum value of the impedance curve at any frequency is greater than or equal to 80% of the rated impedance value.

When measuring impedance, there are two general approaches:

1. 1-Channel Measurement: Measure the voltage across the sense resistor and infer the voltage across the driver from the generator voltage.
2. 2-Channel Measurement: Measure the voltage across the current sense resistor as well as the voltage across the earphone driver(s).

Option 1 can be less accurate, but it frees up one channel, which can enable, for example, simultaneous measurement of sound pressure level and impedance with a 2-channel analyzer. When using option 1, it is important to use a power amplifier with very low output impedance; many headphone amplifiers have an output impedance of several ohms or more, which can cause errors in the impedance calculation.

Option 2 is the most accurate, but it requires two input channels. This is the method used with the APx517B. Internally, it senses the voltage at the headphone connector, and a sense resistor is built into the feedback loop of each channel of its headphone power amplifier.

Another consideration is that in most headphones, the left and right earphones typically have a common ground connection. It's therefore important to isolate each earphone when measuring impedance, to ensure accuracy. The APx517 takes care of this by only enabling impedance measurements of one side per signal path.

In the APx project file, two signal paths have been added for impedance measurements – one for the left earphone and one for the right. Each signal path includes one instance of the Impedance/Thiele-Small measurement. This is another convenient feature of the APx517B: When conducting impedance measurements with the headphone amplifier, you can select the Left or Right earphone for impedance measurements, and the system will disconnect the opposite headphone during the measurement. This is important because the left and right earphones typically share a common ground, and one earphone should be removed from the circuit for accurate measurements.

Figure 25 shows the measured impedance for the left earphone of the headphones tested, which have a rated impedance of 63 ohms. The curve has two traces labeled Processed and Fit. The Processed curve is a version of the measured impedance curve which has been decimated to logarithmic point spacing at frequencies above the first resonance, to eliminate unnecessary data. The Fit curve is the curve that has been fit to the processed data in the process of finding the Thiele-Small parameters. In this example, the fit has been restricted to the region around the lowest resonance, in the frequency range from 20 Hz to 1 kHz.

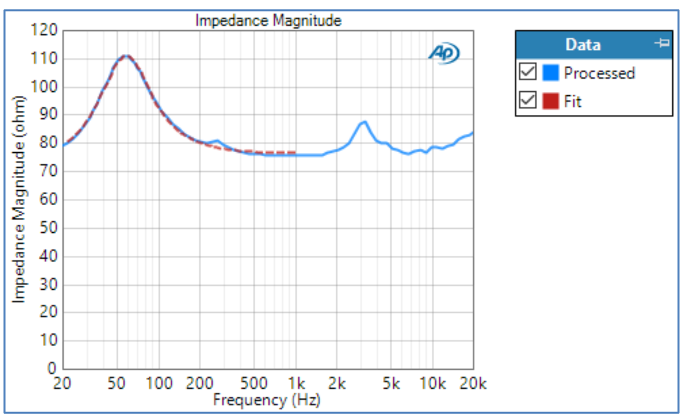

Figure 25. Impedance Magnitude curve for the left earphone of the headphones tested.

Using the Project File

You can run any individual sequence by selecting it with the Sequence dropdown control at the top of the Navigator and then clicking the Run Sequence button. And as noted above, running the Sequence – All sequence will run the entire project and produce a report.

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750 SW Arctic Drive, Beaverton, Oregon 97005 | 503-627-0832
www.ap.com

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