QuickTIPS

Starkey | Government Services

The American Hearing Company

# MEASURING ON-EAR DIRECTIONALITY

Verification measures are encouraged for the purposes of evaluating the performance of hearing instruments and their respective feature settings. On-ear verification measures contribute to a customized optimization of the performance of the hearing instruments and can greatly increase the user's satisfaction and benefit from the devices. These tests can be conducted at the time of the fitting and referenced for comparison at subsequent visits. Additionally, they can be completed at follow-up visits if there are concerns or questions.

Hearing aid directionality is designed to improve the signal-to-noise ratio, improving the patient's ability to understand speech in noisy environments. In the context of modern hearing aids, directionality is achieved through the use of dual omni microphones. Digital processing of the two microphone inputs allows the hearing aid to dynamically switch into a variety of directional patterns in order to provide the best performance in a given environment.

## MICROPHONE DRIFT

In order for dual omni microphones to provide directionality, the two microphones must be closely matched to each other by the manufacturer. Electret microphones, which had traditionally been used in hearing instruments, have a tendency to drift away from each other over time resulting in degraded directional performance. Foreign debris and environmental conditions (temperature, humidity, etc.) can also negatively impact directional performance.

In fact, one study found that traditional directional microphones drift .25 dB, on average, during the first year of use (Tchorz, 2001). To put this into perspective, the polar plots shown below simulate the effect that microphone drift can have on the directional response of the hearing instrument. In these illustrations, the blue line indicates perfectly-matched microphones and the red line indicates a .20 dB difference between the two microphones used to provide directionality.

Essentially, microphone drift erodes the deep "nulls" in the directional patterns. The null is an area where the microphone array is least sensitive. In the absence of a null, the hearing aids are equally sensitive to sounds, regardless of the direction from which they originate; essentially, functioning in an omni directional mode.

In order to provide a more robust directional performance in our devices, Starkey began using MEMS microphones, which are made of silicon. MEMS microphones are preferred over electret microphones because they are less susceptible to microphone drift and can therefore maintain their optimal directional performance over time.

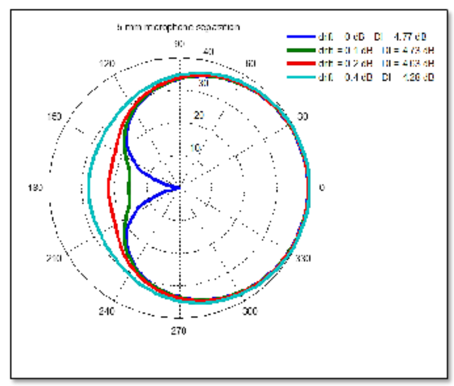

Figure 1. Impact of microphone drift on cardioid pattern directionality.

## DIRECTIONAL SETTINGS

**Omni mode** does not utilize directionality. This state amplifies sound equally from all directions which can provide the user with environmental awareness.

**Fixed Directionality** allows the hearing aid to be put into a directional state for all environments. Because the device will not switch to another directional state, this setting is particularly helpful for verifying directionality either in the test box or on-ear.

**Dynamic Directionality** or **Automatic Directionality** uses a sophisticated switching logic to move between omni and directional modes. This setting allows the user to hear signals from all directions in some environments while maximizing speech intelligibility in more demanding situations. When the hearing aid is set to Dynamic Directionality, it will continually evaluate the ambient noise level of the environment and it will make a determination between the omni and directional modes based upon the signal-to-noise ratio of speech in the two different states. The hearing aid will automatically switch to which ever state provides the most favorable signal-to-noise ratio to the user.

**Adaptive Directionality** uses a very sophisticated switching logic that not only allows the hearing aid to move between omni and directional states, but it also allows the hearing aid to move the direction of the null toward the loudest source of noise. This process is called "null-steering" and it allows the hearing aid to track and suppress moving sources of noise.

## LOCATION OF THE NULL

A directional microphone sensitivity pattern is defined by the location of its null. As previously stated, hearing aid processing allows the hearing aid to form any of the directional patterns illustrated below. These patterns can be dynamically switched, and the null can move off-axis. It is important to understand the nature of directional nulls and their behavior in modern hearing aids because verification measurements can be significantly impacted by this behavior. It is important to compare the point of maximum microphone sensitivity to the null when measuring directional benefit.

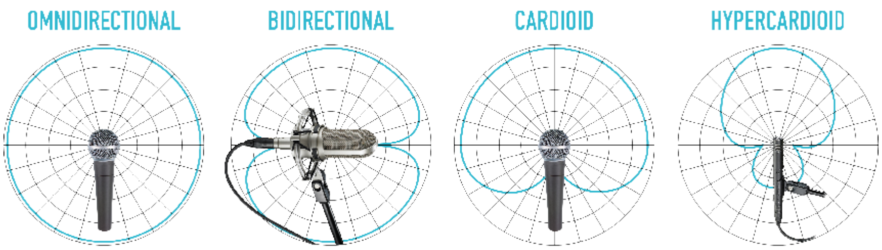


Figure 2. Various microphone sensitivity patterns.

## COMPARING DIRECTIONAL PERFORMANCES

Verification measures can also be used in order to make informed clinical decisions. When comparing the directionality of various hearing instruments, effort to ensure consistency across devices is necessary. Inconsistent parameter settings will yield invalid comparison data.

It should be noted that the best method for testing directionality is to set the hearing instrument to a fixed directional mode and simultaneously measure the sensitivity in the front of the patient and in the null. Not all hearing aid manufacturers make a fixed directional mode available in their software. Other manufacturers may offer a fixed directional mode that is not truly 'fixed' in nature (i.e., there may be a layer of adaptation prior to the device going into a fully directional state). Starkey does utilize a fully-directional state when the "Fixed Directional" mode is selected in the Inspire software.

In order to perform simultaneous measurements, a two speaker verification system is required. During this test, two broadband signals (one from each opposing speaker) are presented simultaneously to the hearing aid microphone at the same stimulus level. Each broadband signal consists of 512 pure-tone frequencies. Since the pure-tones coming from each speaker are unique to that speaker, the Verifit can generate two separate output frequency response curves. For this reason, it is recommended that frequency lowering be turned off during testing. Feedback canceler settings have been shown to affect results in previous versions of software, so it is recommended to set the feedback canceler to a static setting as a troubleshooting technique if verification results deviate from the expected results.

With the patient wearing the hearing aid facing one of the two speakers, the output level differences between these two frequency response curves characterizes the directional microphone benefit. The greater the curve separation, the more the directional advantage available.

A comparison of memory settings is not encouraged for directional testing. While different memory settings may change the hearing instrument into the desired directional state for testing (e.g. omni or directional), the memory settings may also differ in terms of gain, compression, digital noise reduction settings, and other adaptive features. The measured difference, in that scenario, would not be reflective of only directional performance and will probably yield misleading results.

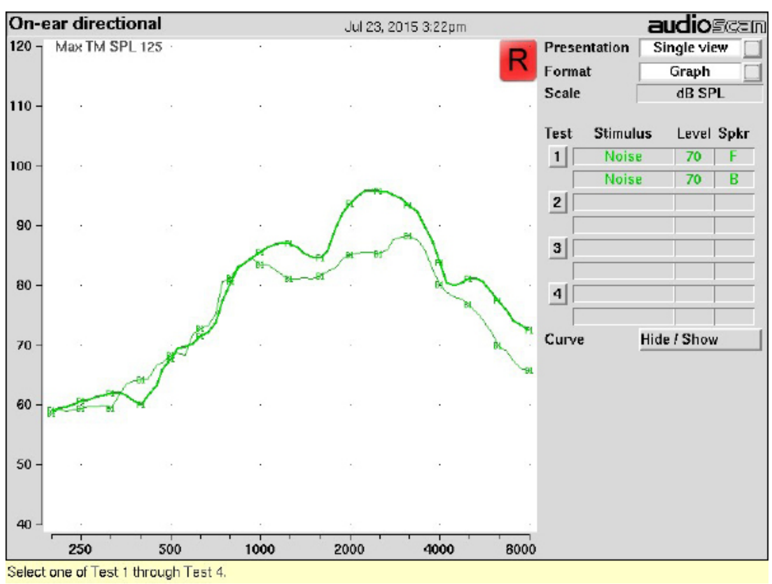


Figure 3. On-Ear directional microphone test results using a Z Series RIC in Fixed Directional mode.

# RECOMMENDED SETUP/PROCEDURE:

## ON-EAR INSTRUMENT MEASURES

*From Verifit® User's Guide Version 3.12, p. 63, 73-74 (May 2015)*

A number of the tests covered in Test box measures can also be performed with the hearing instrument coupled to the ear of a client rather than a 2cc coupler. The on-ear results may be expected to differ from the test box results because of the different acoustic environment and different acoustic load.

### On-ear directional test overview:

Directional characteristics such as polar plots and Directivity Index (DI) are typically measured in a large anechoic chamber using sound from one direction and at one frequency at a time. This means they apply only for a hearing aid set for linear amplification. These are not conditions representative of real use. The Verifit directional test measures directional performance in real-time while using speech. It is compatible with all forms of hearing aid processing, including frequency lowering, feedback compensation, and other non-linear algorithms. (Note: While the current Verifit system is compatible with all forms of hearing aid processing, it is recommended to limit signal processing by turning off frequency lowering during testing.)

The Verifit directional test presents speech at selectable levels from the front speaker and noise, at a selectable signal-to-noise ratio, from the rear speaker. At periodic intervals, the level of the speech and noise is momentarily reduced and an additional burst is played from either the front or rear speaker to measure the response from that direction. This burst is extremely fast and will not influence the behavior of the hearing aid. The coupler SPL is analyzed into two curves labeled F (front) and B (back) to indicate which speaker generated the curve. The real-time nature of the test allows the operation of adaptive directional systems to be readily visualized.

Optionally, speech can be disabled which will cause the directional test to alternate noise burst from the front and back speakers. This test may not produce a directional response with all hearing aids.

Once directional performance is observed, the test may be terminated.

Because this measurement is carried out in a real room, results are not expected to agree with data taken in large anechoic chambers. Due to strong reflected signals, measurements made in small reverberant rooms will show small separation between front and back response curves, just as the benefits of directional technology will become less apparent in similar situations. When performed in a sound booth or large acoustically 'dead' room, microphone array has been correctly assembled and programmed and has not deteriorated due to element drift or the clogging of ports.

### On-ear directional testing:

Best results are obtained using external front and rear sound-field speakers positioned well away from reflective surfaces. (Note: Position the rear speaker at the point of maximal directional attenuation, which is 115-180º. Move the speaker while running the stimulus, watching the response to identify the point of maximal attenuation.) Refer to On-Ear Measures – Setup (found in *Verifit Users Guide Version 3.12, p. 63*) to prepare the system for use and for proper positioning of the client and the probe tube.

1. Insert the earmold or custom hearing instrument into the ear, being careful not to advance the probe tube further into the ear canal. A lubricant in the vicinity of the probe tube will ease insertion and prevent slit leaks.

2. Press <Tests> then highlight and <PICK> [On-ear measures], then highlight and <PICK> [Directional].

3. Highlight and <PICK> Test 1, 2, 3 or 4. Two real-time curves appear on the screen – the heavier one is the response to the front speaker signal and the lighter one the response to the back speaker signal. The two curves will be nearly identical for a non-directional instrument in a sound booth or acoustically 'dead' room. Setting the instrument for directional operation should produce a separation of the curves.

4. On the Test control poster, highlight and <PICK> the Level window, then highlight and <PICK> a level from the drop-down list. For an adaptive directional instrument, a stimulus level between 60 and 70 dB should cause the separation to change over a 15-45 second period. For a noise reducing instrument, both curves may change with time and stimulus SPL.

5. Highlight and <PICK> [Speech S/N] within the Test control poster and select a signal-to-noise ratio from the list box. A S/N ratio between 0 and 6 dB will usually induce directional performance after 15-45 second. Optionally, highlight and <PICK> [Speech S/N] and select Off. This presents noise alternating between the front and back test speakers. Speech-adaptive directional instruments may appear non-directional if [Speech S/N] is Off.

## ALTERNATIVE SETUP/PROCEDURE:

A two-speaker verification system may not be available or practical in all clinical environments; therefore, an alternative directional verification procedure is provided. For this method, a fixed directional mode is preferred. If only a dynamic or adaptive directional mode is available, ensure that each stimulus is presented for 15-45 seconds in order for the hearing aid to adapt to the noise.  This protocol is geared towards the use of Verifit but can easily be translated to other real ear equipment.

1. Insert the earmold, receiver or custom hearing instrument into the ear, being careful not to advance the probe tube further into the ear canal. A lubricant in the vicinity of the probe tube will ease insertion and prevent slit leaks.

2. With the patient facing toward the verification system speaker at $0^{0}$, press <Tests> then highlight and <PICK> [On-ear measures], then highlight and <PICK> [Speechmap].

3. Highlight and <PICK> Test 1. Highlight and <PICK> [Stimulus], then select [Pink Noise] from the list box. Highlight and <PICK> [Level], then select [70] from the list box. Highlight and select [Continue] to capture the response curve.

4. Physically rotate the patient so that they are facing away from the verification system speaker. The speaker should be in the direction of the hearing aid's directional null. The location of the null may vary from one instrument model to the next, but will typically be somewhere between $115^{0}$ to $180^{0}$. (Note: Rotate the patient while running the stimulus, watching the response to identify the point of maximal attenuation.)

5. Highlight and <PICK> Test 2. Highlight and <PICK> [Stimulus], then select [Pink Noise] from the list box. Highlight and <PICK> [Level], then select [70] from the list box. Highlight and select [Continue] to capture the response curve.

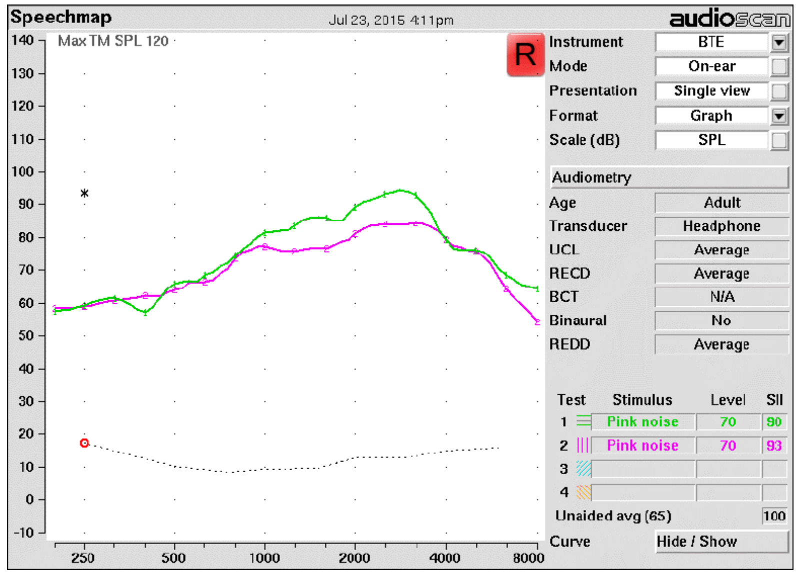


Figure 4. Speechmap using pink noise to show directional microphone benefit using a Z Series RIC in Fixed Directional mode.

### TIPS:

1. Find the directional null for the individual hearing aid model. Directional tests may need to be repeated several times in order to locate the null for that device model. In most instances, the null will be located somewhere between $115^{0}$ to $180^{0}$.

2. Ensure that gain, compression, digital noise reduction settings, frequency lowering, feedback canceler, and other adaptive features remain constant between front and null test conditions.

3. Test directionality using a fixed directional mode setting. If one is not available for a given device, ensure that each stimulus is presented for 15-45 seconds in order for the hearing aid to adapt to the noise.

4. Use a test stimuli of 70 dB or greater. Directionality is a feature that is designed to activate in noisy environments, so it is important to verify the feature with a noise level sufficient enough to activate any dynamic elements of the directionality feature.

**REFERENCES:**

Audioscan. (2015, May). Audioscan Verifit® User's Guide Version 3.12. 63, 73-74.

Tchorz, J. (2001). Effects of microphone mismatch in directional hearing instruments. Hear Rev(8), 54-58.