Can your hearing aid handle loud music? A quick test will tell you

By Marshall Chasin

There are five electro-acoustic parameters that a hearing aid must have to be optimized for processing music. While the following list is not exhaustive, these five have been clinically shown to collectively provide optimal, or nearly optimal, processing for louder music through hearing aids. These parameters and their rationales have been described previously.[1,2]

They are:

(1) a sufficiently high peak input-limiting level (at least 105 dB SPL and preferably 115 dB SPL),

(2) a single channel (or at least a multi-channel system in which each channel has similar compression ratios),

(3) wide dynamic range compression with a knee-point that is 5 to 8 dB higher if the compressor uses a peak detector (and the same if it uses an RMS detector),

(4) less low-frequency amplification for bass instruments such as the cello or bass viol, and

(5) disabled or minimized noise-reduction and feedback-management systems.

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These parameters may necessitate creating a separate "music" channel apart from one used for speech. However, there are commonalities in the processing of speech and music, the best example of which is that both require the broadest bandwidth and smoothest response effectively possible given the constraints of modern technology. This not only helps to improve sound quality, but optimizes the transient response such that amplified music will be a better replication of the original input.

While not all these parameters may be implemented in a single hearing aid, compromises can be made. For example, in an instrument whose feedback-management system cannot be fully disabled, using a gain reduction (e.g., Phonak Perseo) or a modified phase cancellation that is restricted to signals in excess of 1500 or 2000 Hz (e.g., Oticon Syncro, Siemens Acuris) may be helpful.

THE PEAK INPUT-LIMITING LEVEL

The most important of the five parameters is the peak input-limiting level, and it and how to assess it are the focus of this article. The peak input-limiting level refers to the most intense sound that can enter a hearing aid, and is typically implemented as a limiter just after the microphone at the "front end" of the hearing aid.

Excessively intense signals entering a hearing aid can be problematic. For example, too much input can overdrive the analog-to-digital converter that transduces an analog electrical signal into numerical equivalents (i.e., a digital representation). Also, excessive input, if it is limited by an artificially low peak input-limiting level, will generate significant distortion in the hearing aid, and no program (music or otherwise) that is implemented later on in the hearing aid will be able to remove the distortion.

The peak input-limiting level should not be confused with the output of the hearing aid; it refers simply to what can get into the hearing aid at the "front end." The aid can still use some kind of output limiting to limit over-intense signals at the "back end" just prior to the receiver.

The peak input-limiting level is not found on any specification sheet, as its measurement is not a requirement of any reporting standards. It is useful to think of this limiter as a bridge over a river; if it is too low, the mast of a sailboat would be clipped if it passed under the bridge. However, if the bridge is raised, the sailboat, as well as all the smaller boats, could get under the bridge safely. Traditionally, the peak input-limiting level in analog hearing aids was set about 85-90 dB SPL, and it is not uncommon to see modern digital hearing aids with a peak input-limiter level in only the mid-90-dB range.

Historically this peak input limiter has been used as a rudimentary noise-control device. Noise (and other intense non-speech signals such as music) could easily exceed 90 dB SPL, while the most intense components of speech are less than 85 dB SPL. Setting a peak limiter level at 90 dB SPL would let all speech through to be processed by the hearing aid, but would keep out some of the more intense noise (and music). It would, to continue the boat analogy, chop off the tall mast of the sailboat (intense non-speech signals) as it passed under a bridge, even though smaller boats (speech) would be unaffected.

While it's not a great noise-control device, this approach had been used for years in hearing aids with some success. However, it failed to account for the fact that more intense signals are not necessarily noise. Using a peak input limiter would often cause music, which can easily exceed 100 dB SPL, to be limited or clipped. To prevent this unwanted limiting and handle this more intense input, the peak input-limiting level would need to be raised to at least 105 dB SPL, and preferably to 115 dB SPL, the limit of modern hearing aid microphones.

Measurement of the peak input-limiting level can be rather complex[1] and may be affected by non-linear behavior of the hearing aid, especially if output-based distortion measures are used.[3,4] Initial measures used a square notch filter in the input spectrum, and the debris in the notch in the output spectrum was a measure of the distortion.[1,2] This debris, or distortion, created in the hearing aid can be converted to dB; the lower the dB value, the higher the fidelity of the hearing aid. This measurement technique (see Chasin and Russo[2]) is time-consuming and requires spectral analysis software not typically available in most clinical situations.

However, there is a quick but clinically valid method to determine if a particular hearing aid can transduce music and other intense stimuli properly. Keeping in mind that we are testing the level of the peak input-limiting level at the front end of the hearing aid, we used the following test paradigm on an experimental hearing aid in which the peak input-limiting level could be selectively lowered from 115 dB (the limit of modern hearing aid microphones) down to 92 dB (a level typically found in many modern digital hearing aids) in four discrete steps: 115, 105, 96, and 92 dB). Because the hearing aid has been set to its linear mode, the distortion measure of total harmonic distortion (THD) is recommended and is relatively free of artifacts.[3]

APPLYING THE QUICK METHOD

To use the quick method, take the hearing aid test box and select an intense stimulus level of 90 or 100 dB. Many hearing aid test boxes can nominally generate only 90 dB SPL, but if the reference microphone is moved away from the test microphone, or covered (e.g., by means of a bandage or Ad-hear® wax guard with some cotton over the reference microphone port) to reduce its sensitivity, then it's easy to achieve stimulus levels of 100 dB SPL.

To generate input levels on the order of 100 dB SPL, check the level with a sound level meter set to a dBC or "linear" setting. Then, set the hearing aid to its maximum output, *but* with only about 10 dB of gain. The noise-reduction and feedback-control systems should be minimized (disabled) and the aid set to linear processing. The input (100 dB) + gain (10 dB) should be far less than the output (>120 dB) so the hearing aid will not saturate.

Table 1. *The total harmonic distortion (THD) values in percentage at 1600 Hz are shown for each of the four peak input-limiting levels, as measured in a hearing aid test box with a 90-dB-SPL input stimulus, a 100-dB-SPL input stimulus, 10 dB of gain, and an OSPL-90 of >120 dB. Also, for comparison, preference scale results (out of 25 points) were measured for 126 musicians, with 25/25 indicating perfect fidelity. (Adapted from Chasin and Russo[2]).*

	115	105	96	92
Preference Scales	22/25	19/25	9/25	6/25
90-dB input	2	3	12	25
100-dB input	4	4	48	68

Table 2. *The THD (in percentage) at 1600 Hz is shown for five commonly used advanced digital hearing aids with a 90-dB-SPL input, a 100-dB-SPL input, and 10 dB of gain (all set with an output greater than 120 dB SPL). Only Aid #2 could handle the higher-level inputs, so it would be best able (of the five tested) to reproduce loud music optimally.*

	Aid #1	Aid #2	Aid #3	Aid #4	Aid #5
90-dB input	10	3	16	21	16
100-dB input	22	4	54	58	57

Although any test frequency can be used, for these demonstrations a frequency of 1600 Hz has been chosen. This is well within the bandwidth of most musical instruments and it is an intense portion of the spectra of most instruments. Any distortion should then come from the *front end* of the hearing aid and be related to an excessively low peak input-limiting level.

For most hearing aid test systems, you will need to set the software to its "manual" mode. For example, with the Audioscan Verifit™, select "Tests" and then "Manual control" on the Hearing Instrument Test column. Set the stimulus level to 90 dB and choose 1600 Hz as the test frequency. Other manufacturers' systems will use a similar set-up pathway, but with slightly different terminology.

Table 1 shows the total harmonic distortion (THD) values with two different inputs (90 and 100 dB) for four peak input-limiting levels. The higher the percentage number, the greater the distortion.

Table 2 shows the total harmonic distortion for five commercially available hearing aids with two different inputs levels. Note that only hearing aid #2 was able to handle the higher-level inputs typical of most forms of music.

These data suggest that, while there is no significant difference between peak input-limiting levels of 115 dB SPL and 105 dB SPL, significant harmonic distortion is created by having a peak input-limiting level below 100 dB SPL. Levels in the range of 92 to 96 dB will clip or limit the louder music input at the front end of the hearing aid. As a result, regardless of what processing takes place later on in the hearing aid, music will have lost its fidelity.

Of the five advanced digital hearing aids tested with this paradigm, only one (Aid #2) had a high enough peak input-limiting level to handle louder music inputs. It is recommended that as a clinical rule of thumb with this paradigm, the measured THD at 1600 Hz should be less than 10% for optimal reproduction of music.

Once any hearing aid is programmed for *maximum* output and *minimum* gain (e.g., 10-15 dB) this assessment takes less than a minute. It only needs to be performed once for each hearing aid and it provides clear evidence of how any particular hearing aid will be able to handle more intense inputs, such as music.

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