Whether it's Robert Goulet, Bach, Van Morrison, Pink Floyd, Clint Black, or the Black Eyed Peas, in one way or another music impacts on the lives of all of us. In the 1600s, British dramatist William Congreve wrote, "Music has charms to soothe a savage beast, to soften rocks, or bend a knotted oak." Or, as Huck Finn said, "Music is a good thing."

Huck was right—music *is* a good thing. And regardless if it's music from your home stereo, car radio, a concert, or your own musical instrument, it's important that we hear it with the greatest fidelity possible. This goes for hearing aid wearers too.

However, when today's hearing aids are fitted, establishing appropriate gain and output for listening to music is often an afterthought. In many cases, this is for good reason, as understanding speech in quiet and in background noise usually has the highest priority. But what about the person whose highest priority *is* listening to music? Or the many people fitted with multiple memories on their hearing aids, one of which easily could be programmed for listening to music? Do we know how the programming for listening to music should differ from that of listening to speech? Different WDRC ratio settings? Different AGCo knee-point settings? Different compression time constants? And what about adaptive feedback, digital noise reduction, and directional-microphone technology?

We headed north of the border to find someone to answer all these questions. In Ontario, we located one of the world's leading experts on music and audiology, **Marshall Chasin**, AuD. Dr. Chasin is director of auditory research at the Musicians' Clinics of Canada in Toronto. He is also the coordinator of research at the Canadian Hearing Society, and adjunct professor at the University of Toronto (in linguistics). Marshall has been involved with hearing and hearing aid assessment since 1981 and is the author of over 100 clinically based articles. He has lectured extensively and published several books, including two related to music and hearing. His vitae also mentions frequent television appearances on music shows. Could he be one of those guys dancing with Beyonce on MTV?

I think you'll all like reading Marshall's thoughts on how to select and program hearing aids so as to maximize the wearer's enjoyment of music. Good music may not "bend a knotted oak," but it certainly can "soothe the soul."

**Gus Mueller**
Page Ten Editor

# Hear the music... or not?

***By Marshall Chasin***

*Chasin*

## 1 Why should I be interested in music and hearing aids?

Most people with hearing impairments express concern about needing to hear speech. However, more and more patients, including baby boomers and musicians, are telling us that they want their hearing aids to be optimal for listening to music as well. Understandably, most hearing aid design engineers have had speech, not music, in mind. Now, though, long-overdue concern about the fidelity of music processed by hearing aids has begun to emerge.

## 2 What are the main differences between music and speech?

Speech is produced by the human vocal tract and, thus, is generated by a limited number of articulators: the nose, tongue position, and lip configuration. In contrast, music can be generated by a very wide range of instruments and can vary dramatically depending on playing style, type of music, and number of musical instruments.

While speech has an average level of about 65 dB SPL at 1 meter, music may exceed 110 dB SPL and may be listened to through earphones, speakers, or from a concert stage.

Since speech is generated by the vocal tract, the output spectrum is highly damped. Cheeks, lips, the tongue, saliva, and nasal cavity all contribute to this damping of speech. A typical difference between the average level and the peak sound (called the crest factor) is about 12 dB. Music, which is usually generated by hard-walled, minimally damped instruments, has a crest factor of 18-20 dB. This has implications for setting the compression circuit.

## 3 I know about the long-term speech spectrum. Is there a long-term music spectrum?

No. Regardless of the language spoken, the long-term output of speech is remarkably consistent. We can specify a long-term speech spectrum and use that to estimate required hearing aid gain and output. But since music is produced by such a wide range of instruments, it is highly variable.

Music is generally more intense than speech, with larger peaks (greater crest factor) and slightly more low-frequency and high-frequency energy content. This, however, depends greatly on the music source. (Interestingly, rock and classical spectra are more similar than you might think.) We are, therefore, at a bit of a loss to specify exact hearing aid gain and output requirements for music. Generally, though, the optimal values would be less than those of speech since music is more intense.

## 4 It seems to me that certain types of music are more "speech-like" than others. Should I be more concerned about rock than folk?

Folk music is mostly singing, backed up by slightly less intense instrumental music. Therefore, folk music has a good signal-to-noise ratio and the most intense components are roughly those of speech. Hearing aids that are set up optimally for speech are also set up

optimally for folk and other quieter forms of music.

On the other hand, rock (and classical) music can easily have peaks around 110-115 dB SPL. Many hearing aids limit these higher musical inputs, which often causes the hearing aids to distort.

## 5 Why would rock music cause a hearing aid to distort?

Many hearing aids have a limiter just after the microphone. This level of limiting (kneepoint in some cases) is usually set somewhere between 88 and 100 dB. This makes sense because the loudest components of shouted speech are in the range of 85 to 90 dB SPL, so any sound above that is considered noise and should be limited. This simple noise-reduction system has been used in hearing aids for decades.

## 6 How is this limiting accomplished?

Some of today's hearing aids use AGCi, often referred to as "high-level compressor" or "front-end compressor." With these systems, loud music might sound "dead." For example, if the AGCi kneepoint is set to 90 dB SPL, inputs of 110 dB SPL will sound only 2 dB louder (assuming a 10:1 ratio) than inputs of 90 dB SP, regardless of how you program the WDRC or AGCo.

A more serious problem occurs with products that use a peak input limiting leveler. When this technique is used on more intense inputs, including many forms of music, the limiter clips the music, and no amount of processing performed afterwards will reduce the distortion. So-called "music channels" available on many hearing aids will not improve the music once it is distorted. Since rock music can exceed 100 dB SPL, this high-level input will cause significant distortion.

Interestingly, many modern hearing aid microphones (if left to their own devices) can transduce 115 dB SPL with minimal distortion. Thus, in most cases there is no hearing aid-specific (or microphone-based) reason that the input should be clipped for sounds above 85-to-90 dB SPL.

## 7 So, how can we prevent limiting and distortion of rock and classical music?

The most obvious approach is to choose hearing aids that do not alter the fidelity of higher-level inputs. Some instruments don't use an input limiter at all. There are some with a high kneepoint for the front-end compressor, others with a peak input limiting leveler in excess of 100 dB SPL, and several with one up around 115 dB SPL—the limit of the hearing aid microphone.

I have a web site (www.randomizedtimer.net/musicandhearingaids) that demonstrates the deleterious effect of a more intense input on a hearing aid where the peak input limiting leveler was adjusted from 115 dB, to 105 dB, to 96 dB, and finally down to 92 dB SPL. This shows clearly how the music quality is maintained if the peak input limiting leveler is high enough. There is no negative effect on speech. I like to think of it in this way: If a bridge is too low, a low-flying plane will smash into it, but if the bridge is raised, the plane can fly under it safely.



## 8 How can I find out the peak input limiting leveler? I've never seen it on a hearing aid spec sheet.

That's true. Typically, the peak input limiting leveler does not appear on the hearing aid specification sheet. The only test parameters reported are those required by the ANSI hearing aid standard. ANSI is a "reporting" standard, and the peak input limiting level does not have to be reported.

However, representatives of hearing aid manufacturers can supply you with this information if you ask for it. Please note that I am talking here about a limiter at the front end of the hearing aid. Usually the hearing aid will still have WDRC and AGCo, which occur after, and these are mentioned on the spec sheet. Of course, how they are set can also influence the hearing aid user's appreciation of music.

## 9 I don't have the clinical tools to evaluate this. How can I determine which hearing aids are best when the input is music?

There are some "quick and dirty" clinical approaches. One is to route loud music through the hearing aid in a hearing aid test box and listen (or burn a CD) of the output. You can do this with some commercially available test systems.

Another way is to play loud music through the sound field system in the audiometric test suite while the patient wears amplification. You may be surprised how easily people, even those with long-standing hearing loss, can identify the "best" hearing aid (or program) for music listening.

There are other techniques, but they take longer and may not be worth the investment of clinical time and effort. If you are interested, take a look at my article in the July 2003 *Hearing Journal*.

## 10 What if my patient likes to listen to loud music, but has hearing aids with a very low peak input limiting level? What can be done short of getting new hearing aids?

If your patient likes to listen to his stereo or Walkman, turning down the volume on it and turning up the volume on his hearing aids to compensate will help. This

is like making the plane fly lower to get under that bridge.

Another way is to reduce the sensitivity on the hearing aid microphone acoustically. A cover placed over the microphone functions essentially as an acoustic damper. If, for example, the cover provides 20 dB of attenuation, the volume can be turned up 20 dB to compensate. This will give the patient an additional 20 dB of headroom before the signal starts to lose fidelity.

There are also electronic ways to reduce microphone sensitivity that will provide more headroom. However, depending on the implementation, these electronic modifications may raise the noise floor of the hearing aid.

### 11 Nearly all the hearing aids I fit have WDRC. What kind of non-linear compression system should I be using for music?

This is a hotly debated issue. On one hand, it would be optimal to preserve both the temporal and spectral characteristics of the music. On the other hand, the non-linear compression system should be ideal for the individual's hearing loss. The final selection should depend primarily on the individual's hearing loss. For the vast majority of my patients (who have noise/music-induced hearing loss or presbycusis), their gently sloping audiometric configurations and degree of hearing loss seem to make WDRC an optimal scheme.

### 12 Okay, WDRC is fine. But don't I also have to decide on the compression time constants?

You're absolutely right! Today's WDRC hearing aids have a wide range of release times, some as long as 5-10 seconds. For music, I prefer WDRC with relatively fast attack and release times as well as a relatively low compression ratio, with non-linear behavior over a wide range of input intensities. It also appears to be an approximate inverse for the cochlear damage that many of my clients have.

### 13 Any tips on how I should adjust other WDRC parameters for optimal music listening?

Recall that instrumental music has a crest factor of 18-20 dB, whereas that of speech is around 12 dB. This 12-dB speech crest factor has been crucial for selecting the kneepoint and other hearing aid output characteristics for a non-linear compressor. Because music has a higher crest factor than speech, i.e., the peaks are greater relative to the average or RMS, music peaks may tend to cause the hearing aid gain to be reduced prematurely if the compressor is a peak-detector type. If the compressor has an RMS characteristic, then this should not be an issue.

Clinically, I would suggest setting the WDRC kneepoint 5 to 8 dB higher for music than for speech, assuming that the compressor is a peak detector. Regarding the compression ratio, as I mentioned, I usually try to keep it relatively small. Patients' LDLs for music tend to be higher than for other signals. This provides a larger residual dynamic range, so less "squash effect" is necessary.

### 14 How many channels should the hearing aid have?

For speech input, several channels are useful, especially in noisy environments. However, for optimal music perception, the balance of lower-frequency fundamental energy to the higher-frequency harmonic energy is required. When a violin sounds great, it's because the intensity of the fundamental has a certain relationship to the intensity of the harmonics. Multichannel hearing aids may alter this important relationship.

For most types of music, I suggest a one-channel or, at most, two-channel hearing aid. Such a relatively simple hearing aid would serve to maintain an important balance that is not required for speech. I realize that most of your patients need hearing aids for listening to speech *and* music, so single-channel instruments might not be optimal. But, you can take a multichannel hearing aid and program it to function more or less as a one- or two-channel instrument by setting all the WDRC parameters the same in the "music" program.

## 15 What should I do with noise-reduction and feedback-management systems?

This is a fascinating issue, and I am not sure of the answer. Depending on the particular circuitry in the hearing aid, some such systems can confuse music with noise and/or feedback, and therefore reduce its intensity. I know of one hearing aid on the market that turns off all flute sounds, confusing it with feedback. Clinically, I suggest disabling noise-reduction and feedback-management systems. Because of the lower gain and output requirements for music as the input stimulus, there is less of a feedback problem in any event.

## 16 Can you suggest any other hearing aid techniques to handle inputs such as music?

There are some interesting methods, such as reducing the sensitivity of the hearing aid microphone (either acoustically or electronically). For those who have behind-the-ear hearing aids with directional microphones, simply wearing the aids backwards, with the front port pointing to the rear, minimizes the distortion of the music. A person with long hair can get away with this during a performance, but I wouldn't try it with my hairline!

## 17 No comment! But, since you mentioned directional technology, should we encourage patients to use the omnidirectional setting for music listening?

In most cases, there is a fairly good signal-to-noise ratio for the music (vs. the noise), so reducing noise with a directional microphone isn't necessary. Also, many hearing aid fittings with directional microphones are not compensated such that there is a significant low-frequency loss of transduced sound. While this may be beneficial for speech in some environments (and for those with minimal low-frequency hearing loss), it unnecessarily removes valuable musical information. Omnidirectional is usually the best bet for listening to music.

## 18 This is a lot of information. Can you give me a quick summary?

Sure. The optimal hearing aid for loud music either has a high input limiting leveler or is designed to handle higher inputs at the front end of the hearing aid (electrically or acoustically modifying the microphone could help).

I'd use WDRC with relatively short time constants. Assuming that you're fitting a multichannel instrument, program the WDRC of the "music program" to simulate a single-channel product. This should be optimal for many people with mild-to-moderate sensorineural hearing losses. Depending on the nature of the hearing aid compressor, I might set the kneepoint slightly higher than for speech, and I would disable the noise-reduction and feedback-management systems.

## 19 Thanks, I needed that. Before we finish, I have a couple of specific questions about musicians. Can a musician's hearing aid be modified for use as an ear monitor?

Recall that an ear monitor is what many musicians use up on stage to replace those big wedge loudspeakers. They look like hearing aids, but instead of using a hearing aid microphone, they receive input from the engineer's monitor rack back stage. The idea is that the sound that the musician receives not only sounds better, but is also set at a lower level and is safer.

The easiest way to modify a hearing aid for this purpose is to use a direct audio input connection (with the hearing aid microphone switched off) to a BTE hearing aid, or an inductive connection (e.g., neck loop) to the hearing aid telecoil. With this arrangement, the hard-of-hearing musician can receive the optimal "mix" of music without having to fight with the other music sources on stage. In addition, the musician will obtain amplified sound with optimal gain, output, and frequency-shaping characteristics for his hearing loss.

## 20 What about using a hearing aid as a hearing protector for loud music?

If the hearing aid has a significant vent, it can offer very little protection. But when the vent is absent or very small, the hearing aids' compression system can be set to function as a sound attenuator for the more intense elements of the music. In the case of WDRC, for example, this circuit can be set to provide significant amplification for quieter sounds and up to 12 dB of attenuation for the more intense sounds. In this setting, the kneepoint needs to be adjusted to a level that may increase the level of noise in the hearing aid. However, given the level of the music in the environment, the hearing-impaired musician would probably not hear the extra noise. If hearing aid gain and output are connected in a particular hearing aid, the volume control can be reduced and negative gain (because of insertion loss) can be achieved.

When it comes to figuring out how best to listen to music through hearing aids, we are still pretty much in our infancy. I've outlined some hearing aid parameters that have been clinically successful and have a sound theoretical basis. The Musicians' Clinics of Canada web site (www.musiciansclinics.com) has some of this information, which I do my best to update from midnight to 3 am! You can also find a "links" section directing you to any number of interesting music-related sites. One is a chat line for severely and profoundly deaf musicians, some of whom wear cochlear implants. HJ