

# Turn It Up, Eh! Part II - The Horror Continues

by David Clark

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## First, The Bad News

So here I sit in front of my computer, listening to Motörhead and writing another article about hearing loss. Last issue, I said I'd summon the courage to get my hearing tested. Well, I did, and the news is bad! More about that later.

## Measured Effects Of Hearing Loss

### Audiograms

Maybe you're thinking of getting your hearing measured. It's painless and the results are believable to a person with some background in audio. Contrast that to other tests invented by the medical community, like ultrasound. You get a picture that looks like the bottom of an ashtray. "That's your baby's head". An audiogram is a more intuitive result.

The conduct of an audiology exam is simple. You sit in a "soundproofed" booth wearing headphones, holding a little trigger device. The audiologist, who is out of your sight, but can talk to you via the headphones, introduces pure (sine) tones into the headphones at various levels, one ear at a time. You push the trigger when you can hear the tone. The tones are typically distributed on octave intervals with some half-octave tones available to improve the resolution of the measurement if required. The tone frequencies are as follows:

Octave (Principal) Values (Hz)	Half-Octave (Secondary) Values (Hz)
125 (seldom used)	-
250	-
500	750
1000	1500
2000	3000
4000	6000
8000	12000

If you suffer any tinnitus (see last month's article), the quiet booth is your worst case scenario, since the sounds in your head, which might otherwise be masked by environmental noises, are the only sounds you hear. It may be that you confuse the pure test tones with the sounds of tinnitus, in which case, the audiologist can use frequency cycled tones (warbles) to improve the signal to noise ratio of the test.

The audiologist records the least sound that you can hear at each frequency and plots its level in decibels of offset on a standard chart. The levels shown on the chart are normalized to show your threshold response compared to somebody with excellent hearing. This means that the vertical axis is measured in phons, which are decibels weighted by the Fletcher-Munson equal loudness contours. The range defined as "normal" is +10/-25 dB around the theoretical 0 phon line of perfect hearing, so you can have a sensitivity loss of 25 dB in some frequency range and still be considered normal.

After measuring your threshold response, the audiologist may give you a Speech Reception Threshold test to correlate your response values. He or she will read you a selection from a

words, given your individual degree of loss. This checks the "blindness" of the threshold test. If, somehow, you had been able to cheat the test, either to enhance or hide your apparent threshold shift (recall neck braces in the courtroom when auto accident claims are tried), then the word recognition test would highlight the discrepancy.

You may wonder if you could get your hearing tested in third octave intervals, to make the results relevant to your everyday use of 1/3 octave analyzers and equalizers. In fact, there's no point, for three reasons. Firstly, such resolution exceeds the error induced by the experimental method of audiometry. Secondly, hearing damage results in threshold shifts over frequency ranges of an octave or more, showing up as big holes on one octave graphs. Thirdly, the audiogram reflects your ability to detect the tiniest sounds. It is relevant only when listening for the noise floor and does not reflect the frequency response of your hearing above threshold. At approximately 65dBA, the hearing damaged individual shows a frequency response equivalent to that of the normal individual.

You might also ask why the test doesn't examine response at frequencies below 250Hz and above 8kHz. Below 250Hz, many people will confuse hearing with sensation, resulting in large experimental error, in other words, the results are likely to be wrong. Since the voice contains almost no information at the frequencies below 200Hz, to measure this area would be pointless, from an audiologist's point of view. From an audio point of view, it is the presence or absence of noise that we're interested in detecting. Once detected, we can increase the system gain to improve our ability to characterize the noise's frequency response for purposes of troubleshooting. Above 8kHz, the geometry of an individual's ear canal will cause as much variation in the audiogram results as will the absence or presence of hearing damage. The results can vary 20-30dB depending on sinus and muscle conditions, making today's test unreliable for predicting the ear's behavior tomorrow or the next day.

### **Some Disturbing Statistics**

Your fearless editor, Shauna Kennedy, and your humble author had their hearing sensitivity tested at a booth sponsored by Phonic Ear, a manufacturer of hearing assistance systems, at the National Systems Contractors Association annual convention in Indianapolis, Indiana. It turns out that Shauna's hearing is in good shape. The results for mine were the same as measured under more controlled conditions in Toronto. This fact supports the notion that the hearing test was accurate. Good news for Shauna. Bad news for me and 44% of two hundred contractors who took the test, demonstrating significant hearing loss between 1kHz and 8kHz. Most of these people were in the sound business.

At the Musician's Clinic in Hamilton, 90% of all musicians who show up with any complaint (for example, tendonitis or carpal tunnel syndrome) exhibit hearing damage. So, what about wait staff at bars and discos? Ushers at halls and arenas? The security team in front of the mosh pit? What shape is their hearing in after shouting over your mix for two or three hours?

### **Measurement Methods Measurement Parameters**

Since hearing damage is caused by sound that is too loud for too long, the measurement of sound for assessing its potential to cause hearing damage involves some specialized measurement parameters, which highlight the frequency content and duration of sounds. You wouldn't measure your loudspeakers like this, but your ears are far more complicated and merit a more complicated approach to measurement.

Sound level meters (SLM's) incorporate various combinations of the parameters, as follows. SLM's normally present a single number as a result. More expensive SLM's can output more complex data to computers and printers.

### **Weighted Measurements**

Flat (Lin)

"Flat" noise refers to the appearance of the noise as shown on a display of decibels (dB)

sound pressure level (SPL) versus  $\log_{10}$  (frequency), meaning that the noise contains equal energy per octave. In other words, the noise makes a straight line across the LEDs of a garden variety real time analyzer, as pink noise does. This is how you measure your loudspeakers.

#### A-weight (dBA)

A-weighting means that as the noise is measured, it is electronically filtered ("weighted") to model the response of our ears at low levels, especially how they reject low frequencies. It turns out that the dimensions of the structures of the outer ear and the stiffness of the eardrum combine to reject most low frequency sounds. Since the filtering approximates the way we hear things, it is preferred by audiologists for measuring environmental noise, so almost all noise measurement data you'll see will be A-weighted.

#### C-weight (dBC)

This particular filtering, called C-weighting, approximates how we hear at high levels, but is relatively inaccurate, because it models our response to pure tones, which at high levels is quite different from our response to actual complex sounds present in the environment.

### **Impulse Measurement**

Fast, high level transient noises can cause hearing damage, yet be perceived as harmless because our hearing system cannot register events of very short duration. Gunshots in anechoic environments, drop hammers and punch presses are an example. They can result in over-excitation of all of the middle ear components, sometimes exceeding 140dBA, yet seem inoffensive, like firecrackers (hmm..) Some sound level meters can capture these events for subsequent analysis.

### **Equivalent Noise**

Since sound levels of music vary widely over time, it makes sense to adopt a measurement that keeps track of cumulative exposure.  $L_{eq}$ , or Equivalent Continuous Sound Level is a measurement method in which levels are repeatedly measured over a period of time. The results are used to derive a value which represents the level of a steady state noise which would have resulted in the same exposure. "That music was equivalent to a noisy machine that steadily produces 95dBA at the operator's position"

### **Noise Dose**

A noise dose meter is worn in a noisy environment and, like a radiation badge, tells you how much damaging energy you've accumulated, compared to your limit, expressed as a percentage. So who determines what's damaging?

### **Present Standards**

The International Standards Organization (ISO) and the Occupational Safety and Health Administration (OSHA) of the United States have each published standards of what constitutes an acceptable and safe noise exposure. The two standards agree on the baseline. 90dBA for 8 hours is considered safe. The standards vary in their approach to trading off time for exposure. Looking at it mathematically, you'd think that if you're exposed to twice the level (+3dBA), then you should be exposed for half as long to net the same energy exposure. For example, you could withstand 93dBA continuously for only four hours, before you must go to a quiet area for the next four hours. This is the ISO approach. OSHA, however, allows a different tradeoff. Add five dBA before cutting the time in half. This means you can be exposed to 95dBA for four hours before you have to leave the area. The argument here is that the ear can "recover" so it's OK to expose it beyond the mathematical boundaries. Some cynical people among us suspect that this tradeoff was negotiated to ease passage of the legislation, much like clean air standards.

Since the noise being measured is seldom steady, the noise dose meter will integrate the prevailing noise as it comes in, displaying the percentage dose accumulated according to the prevailing standard.

## **Liability Historically**

Generally speaking, contract employees like musicians and crew are not protected by any legislation, which applies only to full-time employees in fixed environments. The audience has no protection, either.

In the United States, two high-profile acts were sued by audience members who claimed their hearing was damaged at concerts. In both cases, the suits were settled out of court.

## **Considerations**

Here's a hypothetical case. A fan has her ears tested on Tuesday, and then attends a heavy metal show that night. Five days later, complaining of tinnitus, she is tested again and found to have suffered significant permanent threshold shift. She sues the promoter who sold her the ticket. The promoter defends himself, saying she entered the concert of her free will. She responds that the promoter had a duty to advise her of the known dangers of entering the concert. What would you say? Suppose further that the promoter sues the band, who in turn sues the sound company, claiming that since the sound operator had her hand on the fader, she's at fault. The sound operator knows that if she doesn't operate the system at high levels, either the band will dismiss her, or the sound company will, because they can't justify the rent of the big system.

I've heard of two approaches to this problem. In one approach, the promoter prints a warning notice on every ticket sold. Since the fan has to redeem her ticket by hand to get in, it could be argued that she has been adequately notified of the danger, so she assumes the risk of damage. The other approach is to post a big sign at the entrance, advising of the danger. Right below the sign is a tub of common earplugs, adequate to reduce the noise to safe levels. It's the fan's choice whether to don the plugs or not, therefore it's her risk. A combination approach might be appropriate.

The unpleasant alternative may be government regulation, perhaps using automatic metering and control systems. One such system is "Audioguard", which hooks a compressor up to the sound system's outputs, with a microphone connected to the detector circuit via an A-weighted filter circuit. Another system, by Goldline, uses mics to monitor levels. When levels exceed a preset threshold, a control output actuates an indicator like a light bulb or an alarm, or notes the event on a strip chart recorder, or introduces a pad into the audio path.

Designers of installed sound systems may face these issues in the future. To avoid liability, we may have to limit system performance, leaving the owner to rent high powered systems as desired. Alternatively, we may have to include noise-monitoring and control equipment as part of the sound system design.

In other news, in December 1993, the Ontario Ministry of Labour published a document entitled "Safety Guidelines for the Live Performance Industry in Ontario". The guidelines include a couple of pages which offer methods and standards for self-regulation of noise exposure for theatrical workers. Although it needs work in the discussion of loudspeaker placement, its very existence serves as an important step toward rational management of the health risks in our business.

## **Raising Awareness In The Audio Community**

Your humble author isn't the first person to wonder about hearing damage. Some organizations actively promote hearing conservation in the music business. Possibly, the most well-known is H.E.A.R. (Hearing Education and Awareness for Rockers), which counts Pete Townshend, Ted Nugent, Huey Lewis, Lars Ulrich and Ray Charles among its advocates. H.E.A.R.'s mailing address is P.O. Box 460847, San Francisco, CA 94146 and their 24hr. Hotline is 415-773-9590. H.E.A.R. has sponsored an enlightening video called "Can't Hear You Knocking".

## **Techniques To Conserve Your Hearing Limit Exposure To Level**

This one's easy. Either wear earplugs, or leave!

You can buy cheap, disposable earplugs at any industrial equipment supply house. The attenuation they provide is stated on the package. I've found that if I carry a bunch in my kit, everybody around grabs a pair - the lighting operator, the security guy, spot operators, friends and family. It's hard to say no, when you know the alternative.

Can you mix while wearing cheap earplugs? Not really, since their attenuation is not constant with frequency. They typically provide 40dB attenuation at 4kHz and 25dB attenuation at 125Hz. However, earplugs have been built for the use of musicians and mixers which approach the ideal frequency response. Made by Etymotic Research, the ER-15® and ER-25®, provide attenuations of approximately 15dB and 25dB respectively and are designed for flat response at the ear. These ear plugs must be fitted by an audiologist.

### **Limit Exposure Over Time**

To limit exposure over time in a meaningful way, you need accurate data about the noise in your environment, so you can relate it to published standards. The noise dose meter is an effective way to monitor exposure and it provides you with solid evidence for your argument that you've been exposed long enough. Since costs are avoided like flesh-eating disease in the music business, you'll have a tough time convincing your employer that he has to hire someone else to mix the opening act.

### **In-Ear Monitoring**

Here's the latest and greatest! Freedom of movement AND hearing protection! In-ear monitors are like earplugs fitted with tiny loudspeakers. They reject ambient sound, so less level is required at the eardrum to achieve a satisfactory signal-to-noise ratio. The amplifier is worn like a Walkman on the belt and the most popular systems incorporate a wireless transmitter/receiver system. It sure beats battling stage volume with ever-louder floor wedges and sidefills. To quote the immortal Ian Gillan, "Could we have everything louder than everything else, please?"

There is a cloud in this otherwise perfect blue sky. By locating the loudspeaker so close to the ear, the sound system can drive the sound level at the eardrum to levels exceeding 120dBA. If the earplug isn't fitted properly with a snug fit beyond the second bend of the ear canal, then ambient noise can leak into the ear canal, reducing the signal-to-noise ratio and driving the wearer to turn up the in-ear level to compensate. Some musicians just like it loud. One guy was found to be running his in-ear monitors at 119dBA. After some education and refinement of the signal chain, he settled down to a more conservative 114dBA. (Hmm... to paraphrase Mike Santucci of Sensaphonics in Chicago, audiologist to the stars, "It's like switching from Camel straights to Camel filters and then feeling immune to lung cancer".)

It appears likely that the manufacturers of in-ear monitors will face product liability claims by musicians who wore the monitors and went deaf anyway. The manufacturers will have to show, in their defense, that had the product been fitted and operated properly, no damage would have occurred. Other concerns include damage due to transients, generic plugs and radio hits. Transients are currently managed by high-quality levellers. As these systems proliferate and the price war drives quality down, we can expect to see more "cost-effective" protection circuitry being substituted for the quality equipment presently in use. Of course, these circuits do nothing for the musician who keeps the beltpack volume control near maximum. Generic plugs, not fitted by an audiologist and therefore cheaper and mass-marketable, are a concern because their rejection of ambient noise may verge on irrelevant, resulting in higher levels at the ear. Current RF systems are of high quality, but you can imagine the "value-leader", non-diversity, non-locked system being sold in the music store of the future and deafening its wearer when the receiver loses the carrier signal. Hopefully, the prospect of settling liability claims will rein in the marketing geniuses and save the ears of the next generation of musicians.

### **And Now, The Bad News**

And so you see the fruits of mixing like a maniac. Is this you, too?

Thanks to Marshall Chasin, Director of Research, Canadian Hearing Society, for his time and his article *Musicians and the Prevention of Hearing Loss*, Journal of Speech- Language-Pathology and Audiology, September 1994; Bill Bailey, Brüel & Kjaer Canada Ltd.; Mike Santucci, Sensaphonics, Chicago; Cindy Lukach, Indy Otolaryngology Associates Inc. The inaccuracies are mine.

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Rev: Feb. 15/96