Hear Ye! Hear Ye!

by Chris Steinwand

Standing behind a console, in a large stadium, doing a sound-check on a hundred thousand-watt sound system. That's my idea of heaven. It ranks right up there with owning a motorcycle that will do a ten-second quarter mile or stomping on the gas pedal of my drop-top 'vette and feeling the front tires come up off the ground.

But even though my motorcycle *is* capable of doing so, I've never actually done a quarter mile on it in ten seconds, and I don't go around stomping on the gas in my 'vette (ok, I've done that a few times…uh…I mean just that *one* time, Honey!). I also don't spend a lot of time in front of massive sound systems anymore. But when I do, I take steps to protect my hearing. If you're working around loud audio, you need to understand the risks of your job and the ways that you can protect yourself.

State-of-the-art design with integrated backup system

However it occurred, whether by divine intervention or random mutation, your ears are the second most complicated of your sensory organs (after your nose), and they are more delicate than you may realize. When I first began researching this article, I was under the impression that occasionally straining your ears couldn't lead to permanent hearing loss. I couldn't have been more wrong.

In order to understand why too much sound can be harmful, you need to understand how the different parts of the ear work together to create the sensation of hearing. Here's a good analogy; when you playback a CD or tape, the encoded or recorded data is read and converted into an electrical signal by the source unit. This signal eventually makes its way to your system's amplifier(s), where it's amplified and then sent on to your loudspeakers. The cones, domes, or other diaphragms in the loudspeaker oscillate back and forth, causing vibrations of air molecules as they convert the electrical signal into waves of acoustic energy.

The energy is carried by the air to your ears (the tag-line from *Alien*, "In space, no one can hear you scream," is true because there's no air in space to carry the sound waves). It first reaches your outer ear, which works like a compression horn in reverse by compressing and focusing the sound waves toward your ear drum. If you look at a diagram of the ear, you'll notice that the drum is situated right next to three little bones that are called the hammer, the anvil and the stirrup.

When waves of acoustic energy cause the ear drum to vibrate, it triggers the hammer, which pounds on the anvil. The anvil is connected to the stirrup, which in turn pushes in a plunging motion against the cochlea. The cochlea is a sealed chamber that contains 30,000 little hair-like cells; it's also filled with fluid. As the stirrup moves the fluid back and forth, the hair cells bend in the current.

All of these parts working together have converted the acoustic energy back into mechanical energy. As a hair bends in the current, it makes contact with a sensory cell located near its base, on the wall of the cochlea. This "contact closure" triggers an electrical charge that goes directly to the brain. The mechanical energy has now been converted back into electrical energy.

There is even a redundancy factor in this process: There are actually two sets of hair cells in each ear—outer and inner. The outer cells send the initial, or pilot, signal along our own information superhighway to our brain for assimilation and decoding. An instant later, the very same information is sent along the pike from the inner set of cells. The brain then oversamples the two signals to check for anomalies and any discrepancies are corrected, in much the same way that a digital-to-analog converter oversamples the signal it decodes to find a common translation.

One, two, three strikes—you're out!

That's what happens in an undamaged ear, at any rate. But if you spend too much time around a high-powered sound system, you run the risk of damaging the delicate structures in your ears. Several types of ear damage are common. The most typical is damage to the hair cells from overexposure to high sound-pressure levels (SPLs). Note that each little hair is a single-cell nerve ending that doesn't have the ability to regenerate itself. Once they're destroyed, they'll never grow back. They'll be history—and so will some portion of your hearing.

The hair cells are arranged in chevrons (sets of three rows each) that look just like the Chevron gas station logo. They grow along the wall of the cochlea. All of the hairs within each set of inner or outer cells are pretty much the same size, so sensitivity to frequency depends on the hair cell's location, not on its size. The highest frequencies register at the front of the cochlea, the lower ones at the back. Damage to the hair cells occurs from over stimulation. Continued exposure to high SPLs causes the cells to swell, like a muscle that's being overworked. While this may be a temporary condition that goes away after the swelling of the nerve cells has gone down, the cells lose resilience over time so the damage can become permanent.

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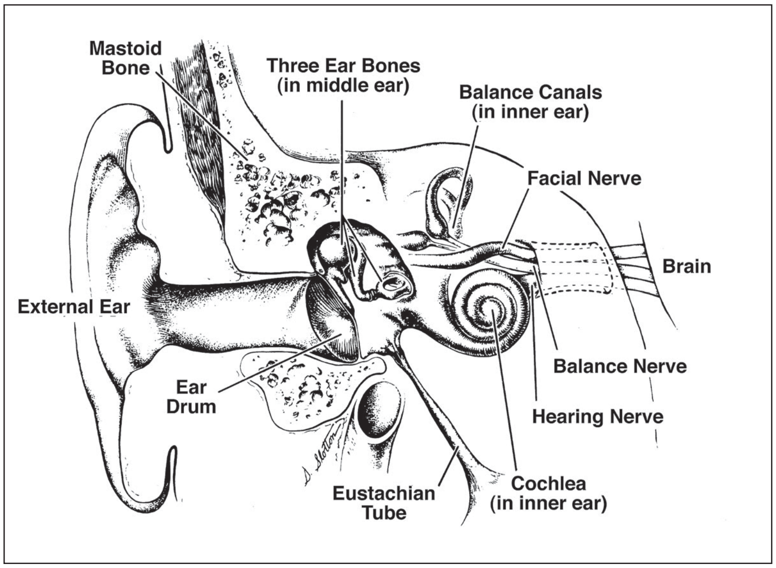

Structure of the human ear. (Printed with permission of the House Ear Institute, www.hei.org.)

Exposure to excessive SPLs often produces a ringing known as "tinnitus." While tinnitus can also have other causes, it is a well-known symptom of over exposure to acoustic energy and should be heeded as a warning signal. If you find yourself hearing this ringing more frequently after being exposed to high SPLs, it's time to change your ways. You are risking permanent noise-induced hearing loss.

According to Dr. John W. House of the House Ear Institute, damage will occur first in the outer set of hair cells, which are longer than the inner cells and more sensitive to the pressure that builds up in the cochlea. In addition to the ringing mentioned above, damage to the outer hair cells can give sounds in the affected frequency range a harsh character. The theory here is that the brain can't accurately perform its over sampling without the pilot signal, which, you'll recall, is normally provided by the outer hair cells.

What's interesting about noise-induced hearing loss is that the affected point of damage usually begins at 4,000 Hz, regardless of what frequencies actually caused the damage. If you listen to a 2,000-Hz test tone at 120 dB for 30 minutes, for example, you'll probably cause permanent damage to your ears, but the damage will first affect your hearing ability at 4,000 Hz before spreading up and down from there. The most critical range of human hearing is between 1,500 Hz and 3,500 Hz. There are two intriguing aspects to this: On the side of divine intervention, it is worth noting that the damage begins slightly above the normal range of human speech. Hard to believe that this is a coincidence. On the other hand, anyone in the loudspeaker design business can tell you that some pretty nasty resonances occur on the surface of a cone while producing a 4,000 Hz signal. What they can't tell you is, why this happens.

Damaging your ears in this fashion is easy to avoid—first, because the dangers have been well-publicized, and second, because it usually happens slowly over time. The real danger lies in ignoring the warnings. Since the ringing begins at such a high frequency, it's easy to overlook. By the time your ability to hear normal speech is affected, it's too late.

Another way to damage your hearing is to tear an ear drum. This type of damage can be hard to recognize even after it happens. Excessive vibration of the ear drum—again, caused by high SPLs—will literally create a miniscule tear in the ear drum tissue. This is your body's way of protecting your inner ear, much like a circuit breaker protects your power lines from overload, except it's a more gradual process. The tear reduces pressure on the drum so it can't damage the delicate bones or the hair cells behind it. A severe tear might cause a constant earache and result in muffled hearing or attenuated hearing across a broad range of frequencies.

Fortunately, this type of damage may not be permanent—at least not initially—since the eardrum usually heals itself. But repeated or excessive tearing can cause scarring, which then affects the ear drum's ability to correctly pass information along. Scarring can sometimes be repaired by a doctor, but not always.

Potentially more dangerous than cumulative exposure to moderately high SPLs is a brief exposure to extreme peaks of sound energy, which can overwhelm the cells. Damage can be suffered in *less than one second* when you're exposed to SPLs above 140 dB, which means that there probably won't be any warning, and it may occur on your first or your hundredth exposure. This type of damage is almost always permanent. This damage is also easy to avoid. Just don't stick your head inside a bass-bin or a compression horn during a sound check or performance and use hearing protection at all times.

Wake up and *hear* the coffee brewing

So, now that we know about the different types of hearing damage and how they occur, what should you do to protect your hearing? Use ear plugs. Working in sound reinforcement is a job, just like working in a factory or on an airport tarmac. Ear plugs are an important tool for doing any of these jobs and there are several types to choose from. Basic foam plugs can be had for about a buck a pair. If you are in a critical listening environment, like say, running the sound console at a live performance, there are more sophisticated plugs available that will attenuate sound equally from 20Hz to 20kHz. They cost more, but what's a hundred dollars or two to protect your hearing?

Another good rule of thumb is to use common sense. Something which I've seen a surprising lack of, not only in the live-sound arena, but in recording studios as well. If the music hurts your ears or makes you wince on certain notes, it's too loud. Ringing in your ears is also an indication that you need to give them some time off. Also keep in mind that since our ears are most sensitive to the midrange frequencies, this is where damage most easily occurs, so be careful around line arrays.

The Occupational Safety and Health Association (OSHA) has put together a hearing safety chart that describes the recommended maximum exposure time at different SPLs. While Dr. House points out that it's impossible to predict any individual's threshold to sound levels, this chart, as a general rule, is accurate. As you can see, even 115 dB—which is common at concerts—is only safe for relatively short periods of time.

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

Permissible noise exposures, per OSHA standards 1910.95 and 1926.52

It's worth noting that the OSHA safety chart was developed using an A-weighted scale. OSHA, as well as the medical experts I consulted, don't consider low bass to be harmful—within reason, at least. At 140 dB SPL, of course, even the lowest frequencies are thoroughly destructive.

The point to all of this is that hearing loss is a serious concern for people who work around high-powered sound systems, whether you are the performer or the guy programming the light show. If you are involved in sound production in any way, you need to take the proper steps to safeguard your hearing.

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