Hearing loss prevention in musicians - violating one rule of physics

BY MARSHALL CHASIN

Whilst enjoying music, we also need to be mindful of the potential effect of producing music for the musician. **Dr Chasin** discusses the development of earplugs for the industry with the added bonus of physics for party goers!

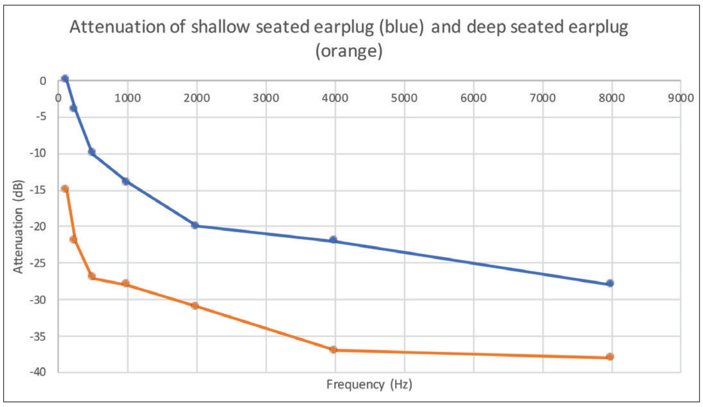

Figure 1. Frequency dependence of a typical foam earplug.

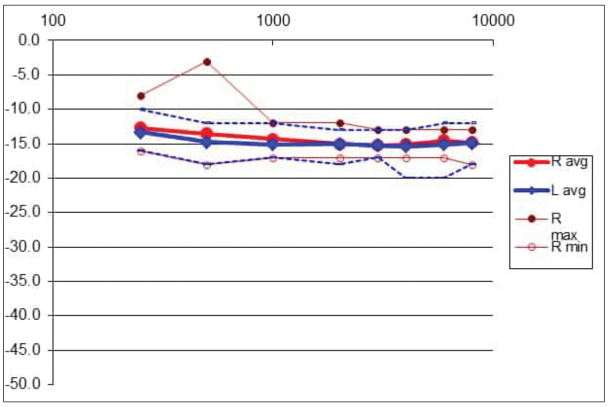

Figure 2. The uniform attenuation pattern for the ER15 for 50 people, along with the range for the right ear (red) and the left ear (blue).

Hearing protection, in one form or another, has been around since the 18th century, whether intentional or not. Of course, mammals, and a few other animal species, have the stapedial reflex which contracts upon louder sounds such as that of our own voices, and that has been around somewhat longer. But for the purposes here, we will restrict ourselves to external man-made devices designed to attenuate, or lessen, the level of external sound.

Earplugs in the form of wound thread around a central solid core were available in the 1930s, as well as mouldable, or one-size-fits-all, plastic and rubber materials in the 1940s and 1950s. And, while more recently semi-compressible polymeric foam earplugs have become the mainstay in industry, some workers (and many musicians) have opted for custom-made silicon moulded earplugs.

Regardless of the material of earplug construction, they all need to follow a law of physics - the acoustic impedance of the acoustic inertance is proportional to frequency. Another way of saying this awful-sounding phrase, which is only useful to bring out at parties to impress your friends, is that an earplug only 'sees' some sound waves, and not others... as much. Earplugs are wonderful at attenuating the higher frequency sounds on the right-hand side of the piano keyboard but are less than stellar for the longer wavelength bass notes on the left side of the piano. It's as if the earplugs acoustically are not as present for the bass notes but work very well for the treble notes. This has everything to do with wavelength, where any obstruction needs to be on the order of at least half of a wavelength before it will even be 'noticed'. Higher-frequency treble notes have short wavelengths, so the earplug notices these and attenuates them, whereas the bass notes have longer wavelengths which are relatively invisible to the sound. Figure 1 shows this frequency dependence of a typical foam earplug (with a shallow insertion of the earplug and a deeper insertion of the earplug), and also a response that is similar to many earmuffs.

This continues to be a problem, even for industrial applications where most of the industrial noise is lower frequency in nature - earplugs attenuate the least where they are needed the most, and attenuate the most, where they are needed the least. It is no wonder that many workers remove their earplugs at work in order to communicate, and also to continue to experience progressive hearing loss even when earplugs are used judiciously.

1988

In the 1980s Elmer Carlson, whose electrical modelling work led to the development of the ubiquitous insert earphones that many audiology clinics use, also developed the math behind what was to become the musicians' earplug. Working closely with Mr Carlson was Dr Mead Killion who took that technology on license from Knowles Electronics and started his own company called Etymotic Research and, among other things, commercialised Mr Carlson's work. In 1988, Etymotic Research (www.Etymotic.com) came out with a product called the ER15 (and, in that same annus mirabulus year, came out with insert earphones and also, at that time, the world's highest fidelity hearing aid).

The ER15 (and in 1992, its cousin, the ER25) were the first earplugs to successfully violate the law of physics that had become so problematic in the use of hearing protection. Specifically, the ER15 did not violate the law, but acknowledged it and did an 'end run' around the problem. A small resonator was built into the custom

Figure 3. ER15 custom-made earplugs (left) and the one-size-fits-all ER20XS earplugs (right).

earplug that replaced most of the lost higher-frequency sound energy - the result was the world's first uniform attenuation (or flat) earplug. Low-frequency bass sounds, mid-frequency sounds, and higher-frequency sounds were all equally attenuated by exactly 15 dB. Figure 2 shows the uniform attenuation pattern for the ER15 for 50 people, along with the range for the right ear (red) and the left ear (blue). Except for one low-frequency outlier in the right ear, the attenuation pattern is rather consistent. The outlier may have been related to a measurement artifact where the measuring probe microphone may have caused a low-frequency leakage. Figure 3 shows a picture of the ER15 and its one-size-fits-all cousin, the ER20XS.

While 15 dB does not sound like a lot, recall that for each 3 dB reduction in sound level; one can be exposed twice as long before the same damage (if any) occurs. A 15 dB reduction means that a musician (or a worker) can be exposed 32 times as long as compared to no hearing protection. The ER25, having a flat attenuation of 25 dB, will allow the musician (or worker) to be exposed more than 250 times as long as without hearing protection.

For music, the benefits of having a uniform or flat attenuation is obvious; the music is attenuated in such a way that it continues to sound like music – the balance between the lower fundamental frequency notes and the harmonics are all precisely maintained.

Although Etymotic Research had performing artists in mind when they designed and marketed the ER15, it can be used in industrial applications where the Leq is less than 100 dBA. Workers are much more likely to wear these earplugs since communication with their colleagues is maintained but, at the same time, the worker is well protected. And of course, industrial workers can wear the ER25 as long as the Leq is less than 110 dBA.

Since patents only have a 20-year lifespan, the last decade has seen the marketing of a wide range of other similar products, and some are quite excellent. Caution needs to be exercised, however, to ensure that these 'musicians' earplugs' are truly flat or uniform attenuation devices and not just something with an air hole vent in them, that may provide some high frequency attenuation of sound, but are not optimal. Any hearing protector can, and should, be assessed by an audiologist using real ear probe tube measurements to ensure that the musician or industrial worker is obtaining optimal benefit.

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Marshall Chasin's new book, Music and Hearing Aids, will be published by Plural Publishing in April 2022