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Why Do My Ears Hurt After A Show (and what can I do to prevent this)

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ABSTRACT

In this brief we review the traditional methods of preventing ear fatigue, short-term ear damage and long term ear damage. A new method to prevent ear fatigue, focused on performing musicians is then presented. This method, which reduces noise and distortion in the artist's mix, is discussed. Qualitative and quantitative results from a series of trials and experiments is presented. Qualitative results from artist feedback indicate less ear fatigue, less ringing in the ears and a better ability to have normal conversations after a performance when noise and distortion in their mix is reduced. Quantitative results are consistent with the qualitative results and show a reduction in the change in otoacoustic emissions measured for a set of musicians when noise and distortion are reduced. The result of the study suggests that there is an important new tool for musicians to use to combat ear fatigue and short term hearing loss.

1. INTRODUCTION

"My ears ring." "My head hurts." "It's hard to have normal conversations after a show." "My mix gets muddy during a show and I find myself cranking my mix to compensate." "I can't trust my ears for 48 hours or more." - These are common complaints, and actual quotes, from musicians and sound engineers after a show or long sessions with In Ear Monitors (IEMs) or headphones. Industry experts have explained clearly that these common complaints are due to what is commonly known as Ear Fatigue or Temporary Threshold Shift. This is an important phenomenon since Temporary Threshold Shift can lead to long term hearing loss.

According to the National Institute on Deafness and Other Disorders, about 15% of American adults aged 18 and over report hearing issues. Musicians, who are largely dependent on hearing for their trade, are 4 times more likely to suffer noise induced hearing loss than non-musicians. These statistics are alarming for musicians, artists and sound engineers since their ears are a key asset of their livelihood. Music-induced hearing loss remains a big problem.

In this brief, we will review traditional methods to combat ear fatigue and introduce a new method to reduce ear fatigue based on noise and distortion suppression. Section 2 will review traditional methods for ear fatigue reduction. Section 3 will review how noise and distortion is generated between your amplifier and IEMs. Section 4 will introduce clinical results that

demonstrate a correlation between ear fatigue and this specific noise and distortion.

2. TRADITIONAL METHODS FOR ARTISTS TO REDUCE EAR FATIGUE

The most common traditional method for ear fatigue reduction is limiting acoustic exposure. One of the most popular guides for noise level exposure comes from the Occupational Safety and Health Administration (OSHA). Specifically, OSHA requires that protective hearing equipment be used when sound levels exceed the time and duration shown in Table 1.

Sound Level (dBA)	Exposure Time (Hours/Day)
90	8
92	6
95	4
97	3
100	2
102	1.5
105	1
110	0.5
115	0.25 or less

Table 1 OSHA Permissible Noise Exposure

OSHA also provides a mechanism to calculate the exposure when multiple noise levels and times are involved.

Keeping exposure below the recommended levels in Table 1 is a typical traditional recommendation for protecting ears from fatigue and damage.

While the OSHA limits may seem more industrial in nature and not geared toward the practical realities of musicians, additional resources can be found that explicitly provide additional tips for musicians. In [1], the author provides an excellent tutorial of hearing protection devices for musicians customized to the specific type of instrument being used. The discussion includes an in depth analysis on earplugs, the use of baffles and dampening equipment in the performance environment, ways to consciously invoke the acoustic reflex in a performers ears and many other practical techniques to reduce the likelihood of ear damage.

3. CONRIBUTING FACTORS TO EAR FATIGUE

Over the past 30 years, there have been several studies regarding the relationship between the type or quality of music or noise and the resulting ear fatigue. Specifically, [2] and [3] compared the fatigue associated with pure noise with the fatigue associated with music of the same energy and concluded that more fatigue was caused by noise exposure than by music exposure. In a novel experiment [8], the author concluded that when exposure levels were equal, subjects experienced less fatigue when exposed to music they preferred compared to music that they did not like.

These studies provided some of the motivation to investigate if the clarity of an artist's IEM mix cam further prevent ear fatigue. This is especially interesting because the artist is typically not casually listening to the mix on stage but rather listening very carefully to pick their own instrument and vocals out of the mix while still wanting to hear other components such as crowd noise and other instruments. The investigation requires a precise understanding of how unwanted noise and distortion can be generated between an amplifier and an IEM which will be discussed in the next section.

4. DISTORTION AND NOISE GENERATORS IN IEMS

Monitor engineers are incredibly talented at delivering the best possible mix to their artists. This is often done in extremely difficult settings. However, the monitor engineer can only control the signal that gets to the artists receiver belt pack. What happens from the belt pack to the IEM is largely up to physics. As the amplifier sends an electrical signal representing the music to the transducers in the IEM, there are several opportunities for noise and distortion to adversely affect the music signal.

When the transducer, or driver, in an earbud moves, its impedance changes dynamically with its position. As it changes, some amplifiers will produce different currents for the same voltage output. For example, a 3 kHz tone will render differently based upon the displacement of

the driver. This results in non-linear current or distortion.

It is well understood that ultrasonic noise can create unwanted intermodulation distortion components in the audible frequency range. There are several sources of ultrasonic noise. Class D amplifiers, used in most battery-powered devices, generate substantial noise that is shaped above 20 kHz, in the ultrasonic region. System clocks and RF carrier tones found in wireless devices are also sources of ultrasonic noise. Each of these can mix with other musical and non-musical components the music to generate audible intermodulation distortion components.

Microphonics, or the ability of an IEM driver to act as a microphone is another source of energy that can cause noise and distortion current to flow into the driver. This can include microphonic currents from stage noise or noise self-generated by the artist or the artist's instrument. Microphonic current will add destructively with the desired musical current in the driver and cause distortion at the audio output.

With an understanding of the noise and distortion that is introduced into the music signal as it is transduced into sound pressure that we hear, the question we asked ourselves is whether less of this noise and distortion can reduce fatigue?

5. CLINICAL TRIAL ON EAR FATIGUE REDUCTION

To study the potential of reducing ear fatigue, we outfitted multiple artists with a new product, the REV33, which reduces distortion and noise in an artist's mix by mitigating many of the unwanted noise and distortion sources described in Section 4. The following sections provide the results of these experiments. Specifically, Section 4.1 provides verbal, qualitative feedback gathered during interviews from seasoned performers who used the REV33 in an on stage environment. Section 4.2 then provides quantitative feedback from double-blind tests conducted on the same members of a band at three separate performances. The band members were given either a REV33 or a 'Blank' that looked identical to a REV33 but contained no electronic components. Immediately before and after each performance, otoacoustic emission (OAE) measurements were conducted on each band member. The OAE distortion product change from before to after the show was calculated. It is widely accepted that this measurement is a key indicator of ear fatigue and short term hearing loss [5] and that the frequently repeated instances of short term hearing loss can result in long term damage [6].

5.1. Qualitative Feedback

Qualitative feedback was collected primarily through interviews of musicians and sound engineers who perform and wear IEMs on a regular basis. The feedback was taken after they were able to use a REV33 for a minimum of 3 shows. The following are a list of key comments received from artists and sound engineers during the interviews:

- My ears no longer ring after a show
- I no longer struggle to hear normal conversations after a show
- Because my mix is much clearer, I no longer turn up my belt pack volume during the night
- I can hear myself in my mix so I have stopped over-singing; my voice is no longer feeling strained
- My head no longer hurts after a show and I hear more detail during a performance.
- I normally pull my IEMs out by the end of the night because I can't hear. I no longer feel the need to do that and my ears feel great.

Consistent feedback regarding the reduction in ear fatigue was obtained from more than 75 REV33 clients. This qualitative feedback is profound and suggests the reduction in noise and distortion in a mix can improve how ears feel after exposure to music in a performance setting.

5.2. Quantitative Feedback

In each of the three shows, the band members using the REV33 were changed and each band member performed at least one show with a REV33 and at least one show without a REV33.

Figure 1 shows the shift in OAE distortion product from before a show to after a show for band members using a REV33 to reduce noise and distortion. Each bar is a specific band member and a specific OAE frequency.

Figure 2 shows the data for band members who did not use a REV33. The same scale is used on both figures.

A larger reduction in the distortion product indicates a larger negative change in the ear's performance, or more ear fatigue.

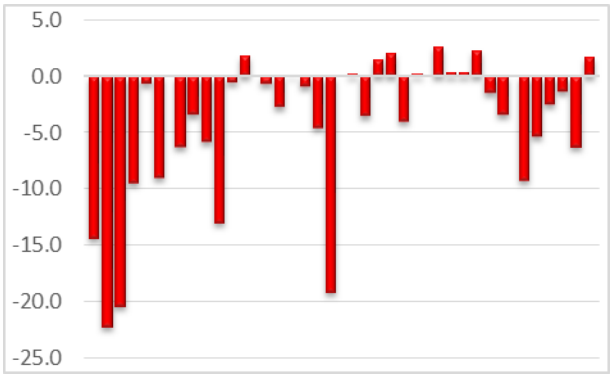

Figure 1. OAE distortion product change – no REV33

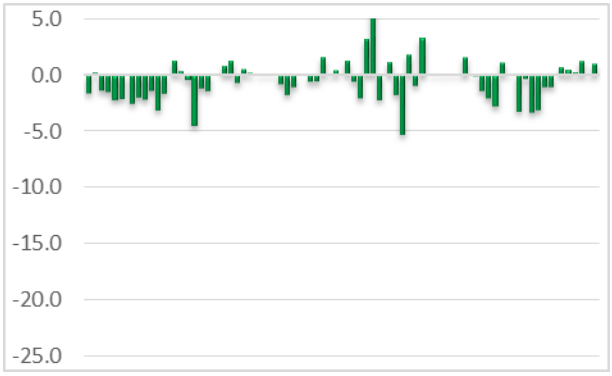

Figure 2. OAE distortion product change - with REV33

Generally, the negative impact on the OAE distortion product was larger for band members not wearing a REV33. In fact, for musicians not using a REV33, over 44% of the distortion products were reduced by 3 dB or more indicating fatigue. For musicians wearing REV33s, less than 5% of the data points were reduced by more than 3 dB.

6. CONCLUSION

The REV33 is designed to reduce noise and distortion that is generated as the music plays out from your amplifier to the transducers in your in-ear monitors, ear buds and headphones.

These results in section 5.2 suggest a correlation between this specific type of noise and distortion and measurable ear fatigue. These measurements also correlate well with the qualitative measurements from Section 5.1, suggesting an important advance in our understanding of how to reduce of ear fatigue.

7. REFERENCES

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