EXPERIMENTAL STUDY ON CUSTOM EARPLUG RETENTION IN REAL-WORLD SITUATIONS

Cécile Le Cocq *1 **and Jérémie Voix** †1
1ÉTS, Université du Québec, Montréal, Québec, Canada

1 Introduction

Every day, millions of workers wear Hearing Protection Devices (HPD) to protect themselves against noise induced hearing loss. For many reasons -listed in [1]- the attenuation provided by HPDs are highly variable across wearers and only individual fit-testing can measure the amount of attenuation achieved by a given HPD for a given individual. However, this measurement is in truth only a "snapshot" revealing the attenuation of a given HPD at the time of measurement. Nothing guarantees that this attenuation value will later be achieved by the wearer in the field. Studies have indeed demonstrated that earplugs are not always consistently fitted [2] and many hearing conservationists suspect that most earplugs work loose with time and require periodic resetting.

This paper addresses the issue of HPD retention, i.e. the HPD's ability to maintain its acoustic seal and attenuation over time, and presents the results of an experimental study of earplug retention in real-world situations. The earplugs chosen for these tests are custom molded earplugs, as these types of HPDs are highly personalized to fit the wearer's earcanal geometry and are often assumed to maintain their attenuation performance for longer periods than non custom earplugs.

2 Material and Method

2.1 Material Used

The earplug used in this study is a SonoCustom™V3 earplug, manufactured by Sonomax (Montreal, QC). The field attenuation estimation system (FAES) used during this experiment to fit-test the custom earplugs is SonoPass™, illustrated in Fig. 1. It performs a so-called field-Microphone-in-real-ear (F-MIRE) attenuation measurement, as a miniature microphone is temporary inserted in a sound-bore within the generic rigid core to measure sound pressure levels in the residual earcanal portion between the HPD and the eardrum. Attached to the back of this internal pressure microphone is an external pressure microphone so that sound pressure level difference across the earplug can be measured in the presence of loud pink noise generated from an outside reference sound source, frontal incidence. The attenuation measurement is performed by a trained technician after the end-user removes and replaces the custom earplug in order to perform the initial attenuation test, at time t=0.

2.2 Experimental Protocol

To assess earplug retention, the individual attenuation will be measured over time with the FAES system previously described. Between the initial attenuation test, at time t=0, and any subsequent testing, great care will be taken to not touch or purposely alter the placement of the earplug. The test-subject is instructed to go back to his/her daily activities, but to not touch or reposition the earplug. Similarly, the F-MIRE microphone doublet is left in place, i.e. inserted inside the earplug's sound bore, with its electrical wires carefully wrapped and secured on the test-subject's shoulder, so that the technician can easily retest the individual earplug attenuation at periodic intervals.

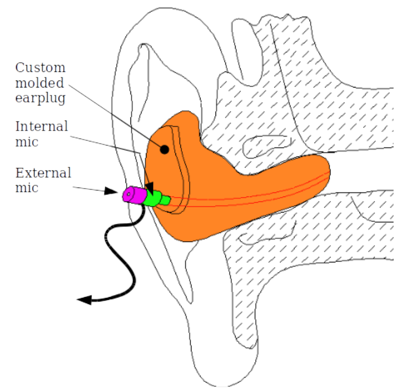

Figure 1: Overview of the custom earplug instrumented with the F-MIRE attenuation measurement device

Two studies were conducted at Sonomax Hearing Healthcare laboratories in 2005, with two groups of in-house employees, as detailed in Table 1. While the first study was conducted on a rather long time span, the second was later conducted on a reduced time span, but with smaller periodic testing intervals, to better reveal the short-term retention issues.

Date	Nb Subj	Nb Ears	Step	Duration
May 2005	3	2	1 h	3 h
October 2005	4	1	20 min	2 h

Table 1: Details on the two studies conducted in 2005

3 Experimental Results

Fig. 2 represents the individual attenuation at each octave-band center frequency and overall (PAR) over time for the four subjects of the October 2005 study.

In order to assess the retention over time for the different subjects, the variation in attenuation values relative to the initial attenuation value, at t=0, will be computed in all subsequent figures. Fig. 3 presents the mean and standard de-

*. cecilelecocq22@gmail.com
†. jeremie.voix@etsmtl.ca

viation of this attenuation variation for the May 2005 study, while Fig. 4 presents it for the October 2005 study.

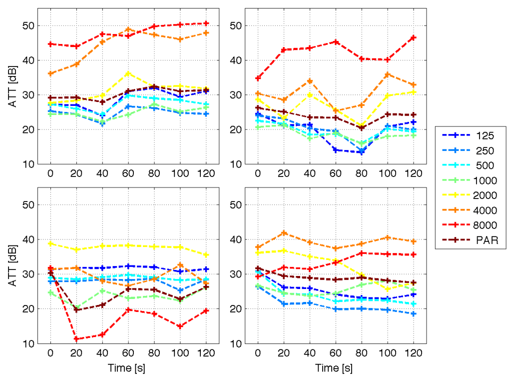

Figure 2: October 2005 - Individual attenuation at each octave-band center frequency and overall (PAR) over time

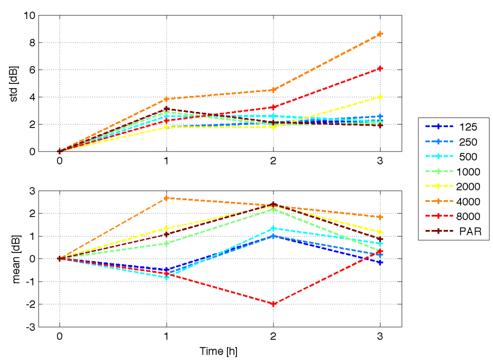

Figure 3: May 2005 - Mean and standard deviation of the attenuation variation at each octave-band center frequency and overall (PAR) over time

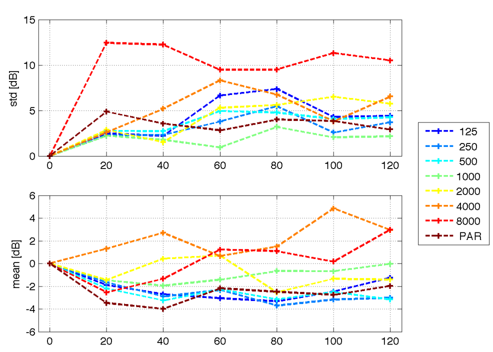

Figure 4: October 2005 - Mean and standard deviation of the attenuation variation at each octave-band center frequency and overall (PAR) over time

4 Discussions

For the first study (May 2005), the group mean attenuation variation remains smaller than 3 dB, over the 3 hour test period, but can be seen on all octave-band frequencies. The standard-deviation after 1 hour already reaches a 3 dB value for most frequencies and becomes even greater after 3 hours. It is particularly interesting to note that the 4 and 8 kHz octave-band are the frequency bands that vary most, as they contain the occluded ear canal resonances. The residual earcanal length might have slightly evolved over time, indicating a light displacement of the earplug within the earcanal.

For the second study (October 2005), the much smaller periodic testing interval shows that the group average attenuation varies very quickly, and reaches maximums in less than 40 minutes. What is of particular interest is that the group tends to lose attenuation over time, and the low frequencies, 125 – 500 Hz, are most affected by the -assumed- earplug displacement. The higher frequencies, 4 – 8 kHz, appear to behave differently, as their mean attenuation does actually increase over time to reach a maximum after 2 hours. The standard-deviations show that high frequencies are the most variable attenuation values, which could be again explained by the shifted occluded earcanal resonances.

5 Conclusions

This experimental study presented the findings on custom earplug retention in real-world situations and showed that custom earplugs may work loose very quickly after having been fitted (<40 min.). As custom molded hearing protectors are often assumed to maintain their attenuation performance over longer periods than non custom earplugs, this retention issue might even be more significant with non-custom earplugs. Further research is therefore urgently needed to collect such experimental data on non-custom earplugs. This data could guide the hearing conservationist to substantiate his recommendations for periodic resetting of earplugs. Both retention variability data on custom and non-custom earplugs could also be used and accounted for within fit-testing systems, so that the reported attenuation may be factored in regarding a correction for this field discrepancy.

Acknowledgments

The authors would like to thank Mr. Michael C. Turcot for releasing the experimental dataset initially collected at Sonomax Hearing Healthcare facilities in 2005. The first author is also thankful to the *Sonomax-ÉTS Industrial Research Chair in In-Ear Technology* for its financial support of the present work and re-analysis.

References

[1] E.H. Berger. Chap. 10. hearing protectors. In *The Noise Manual, 5th Edition*. American Industrial Hygiene Association, 2003.

[2] Jérémie Voix and Cécile Le Cocq. Intra-subject fit variability for field microphone-in-real-ear attenuation measurement of foam , premolded and custom molded earplugs. *International Journal of Acoustics and Vibration*, 15(4) :pp. 196–200, 2010.