INFLUENCE OF SOURCE LOCATION, SUBJECTS AND HPD SIZE ON THE SOUND FIELD AROUND EARMUFFS

Cécile Le Cocq[1], Hugues Nélisse[2], Jérôme Boutin[2], Jérémie Voix[1], and Frédéric Laville[1]
[1]Dépt. de Génie mécanique, École de technologie supérieure, Montréal, Québec, Canada
[2]Institut de recherche Robert-Sauvé en santé et en sécurité du travail, Montréal, Québec, Canada

1. INTRODUCTION

In most noisy workplaces, workers are exposed to complex sound fields ranging from diffuse field to more directional field conditions. Hearing protection devices (HPD) attenuations are generally measured in a laboratory either subjectively or objectively in a diffuse sound field (ANSI 2008). Other sound field conditions are usually not considered even though attenuation of HPDs is known to vary with the incident sound field direction (Gaudreau et al 2007). The Field-MIRE (F-MIRE) technique has been developed to objectively quantify the attenuation of earplugs using two microphones: one is located under the HPD while the other one is used to capture the exterior sound field (Voix and Laville 2009). Recently, this method has been employed on earmuffs in the workplace but the authors raised some concerns regarding the location of the exterior microphone (Nélisse et al 2011). Moreover, advanced hearing protectors (level-dependant, active noise control, etc.) make also use of an exterior microphone to control and adjust the attenuation as a function of the incident sound field (Giguère et al 2011). It is therefore important to assess the effect of the location of this exterior microphone located on an earmuff with respect to the incident sound field (type, location, frequency content) in order to better understand its impact on the evaluation of the attenuation of HPDs.

This paper presents a short laboratory study performed in semi-anechoic and diffuse-field conditions where various earmuffs, microphone positions, source locations and subjects were tested. The methodology is presented and examples of results are given and discussed.

2. METHODS

The objective of the experiment is to demonstrate the influence of the type and location of the source as well as the location of the microphone on the measurement of the incident sound pressure on earmuffs. The tests were conducted in a diffuse field in a reverberant room and in a free field in a semi-anechoic room on 4 subjects with 5 different earmuffs (EAR 1000, Peltor Optime 95, Peltor Optime 98, Peltor Optime 101, and Peltor Optime 105) and without earmuffs. In free field conditions, twelve sound directions from -150° to 180° with 30° steps were considered as depicted on the left part of figure 1. Six miniature microphones were fixed on each earmuff as illustrated on the right part of figure 1 for the right ear. In the experiments without earmuffs, only one microphone was used and positioned, close to the ear canal entrance for each ear. The sound pressure level (SPL) was measured in third octave bands. To take into account the individual frequency responses of the 12 microphones, the free-field SPL measurements were normalized by the microphone responses obtained in a diffuse field where all microphones were located at the same location in the reverberant room. The tests in the semi-anechoic room were realized with a pink noise of about 85 dB overall SPL.

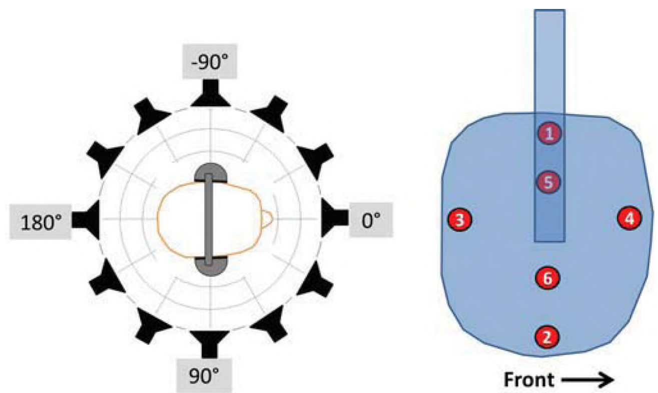

Figure 1. Location of the speaker for the free field experiments (left). Position of the microphones for the right ear (right).

In the next section, examples of results are presented. A more complete analysis is currently under way. .

3. RESULTS

In this section, two specific are presented. The first one is related to the effect of the sound source location while the second one is related to the effect of the microphone location on the earmuff.

3.1 Effect of sound source location

On figure 2, mean values of the normalized SPL for the microphones located on the right cup are depicted for three frequency bands as a function of the angle of the sound source. The mean value was taken over 4 subjects, 2 ears, 5 earmuffs, and 6 microphones (240 data sets). Vertical lines represent ± one standard deviation.

As expected, SPL variations are more important at high frequencies compared to low frequencies. At 5000 Hz, the normalized SPL varies from -5 ±3 dB at -90° to +8 ±2.5 dB at +90°; whereas at 500 Hz, the normalized SPL varies from -4 ±1.5 dB at -120° to +2.5 ±1 dB at +90°.

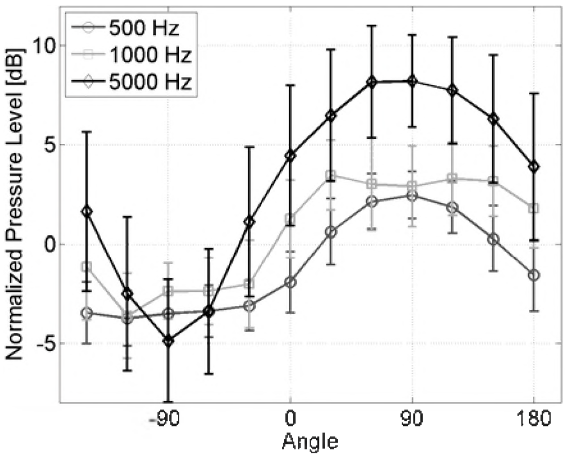

Figure 2. Mean normalized SPL on 4 subjects, 2 ears, 5 earmuffs, and 6 microphones for three third octave frequency bands as a function of the sound source location.

3.2 Effect of microphone location on the earmuff

On figure 3, mean and standard deviation values of the normalized SPL on the right earmuff are represented for the six microphones, when the sound source is directly facing the subject (0° angle). The mean value is taken over 4 subjects and 5 earmuffs (20 data sets). For this frontal incidence, it can be seen that for two of the microphones (positions 3 at the back and position 4 at the front of the earmuff) the normalized SPL is significantly different than for the other four. At the front of the earmuff, the mean and the standard deviation values of the normalized SPL are the highest for all frequencies, whereas at the back of the earmuff, the mean and the standard deviation values are the smallest for all frequencies.

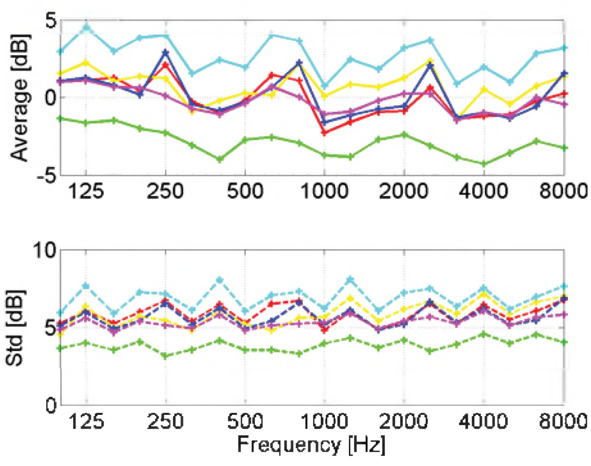

Figure 3. Mean and standard deviation values of the normalized SPL on the right earmuff for the six microphones when the sound source is located directly in front of the subject (0° angle) (color online).

On figure 4, the mean and the standard deviation values of the normalized SPL on the right earmuff is again represented for the six microphones but now when the sound source is on the right of the subject (90° angle). The mean value is calculated over 5 earmuffs and 4 subjects (20 data sets). For this lateral incidence, for every microphones position considered, the mean and the standard deviation of the normalized SPL are very similar from one microphone to the other.

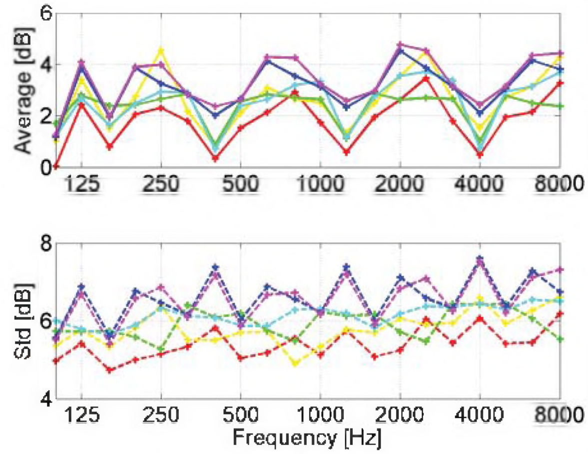

Figure 4. Mean and standard deviation values of the normalized SPL on the right earmuff for the six microphones when the sound source is located at the right of the subject (90° angle) (color online).

4. DISCUSSION AND CONCLUSIONS

Both the sound source location and the microphone location on the earmuff seem to have a significant effect on the measured sound pressure level. In order to adapt the F-MIRE technique from earplugs to earmuffs, the location of the exterior microphone is of first importance especially since one are interested to measure the attenuation of the HPD. Hopefully, the set of data obtained in this study will help to better quantify the deviations observed in the attenuation when using an external microphone in comparison with standardized tests (e.g. REAT or IL)

REFERENCES

ANSI (2008) Methods for Measuring the Real-Ear Attenuation of Hearing Protectors. American National Standards Institute, S12.6-2008.

Gaudreau M-A, Laville F, Voix J, et al. (2007) Variabilité de l'atténuation des protecteurs auditifs mesurée par la méthode field-mire en fonction de la direction du son incident et des bruits du porteur. Proceedings of the annual conference of the Canadian Acoustical Association. Annual conference of the Canadian Acoustical Association, Montréal, Canada.

Voix J, Laville F. (2009) The objective measurement of individual earplug field performance. The Journal of the Acoustical Society of America 125(6): 3722.

Nélisse H, Gaudreau M-A, Boutin J, et al. (2011) Measurement of hearing protection devices performance in the workplace during full-shift working operations. Accepted for publication in The Annals of Occupational Hygiene.

Giguère C, Laroche C, Vaillancourt V, and Brammer A. (2011) Advanced hearing protection and communication: progress and challenges. Proceedings of the 10th International Congress on Noise as a Public Health Problem (ICBEN). The 10th International Congress on Noise as a Public Health Problem (ICBEN), London, UK.