ESTIMATION OF NOISE LEVELS AND HPD ATTENUATION IN THE WORKPLACE USING MICROPHONES LOCATED IN THE VICINITY OF THE EAR

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1. INTRODUCTION

With the increase popularity of individual fit testing and miniaturization of electronic components and microphones, the Field-microphone-in-real-ear approach (F-MIRE) is becoming more appealing and well suited for estimating hearing protection devices (HPD) attenuation both in laboratory (Berger et al., 2008; Voix and Laville, 2009) or in "real" occupational conditions (Nélisse et al., 2012). The F-MIRE approach utilizes two miniature microphones to simultaneously measure the sound pressure levels in the ear canal under the hearing protector, as well as outside of the device. The location of this outside microphone is of primary importance for accurate and precise measurement of the HPD attenuation. A previous study by the present authors (Le Cocq et al., 2011) focusing on earmuffs in laboratory settings was performed in semi-anechoic and reverberant conditions where various earmuffs, microphone positions, source locations and subjects were tested. The study allowed making recommendations regarding an "optimal" position of the external microphone on the earmuffs for attenuation measurement purposes. Additionally, the results also suggested that recordings from this microphone could also be used to assess the sound pressure levels that would exist in the absence of the subject. Such data could be of interest if one is interested in performing noise survey while measuring, simultaneously, HPD attenuations in the workplace.

The present study focuses primarily on examining how the data obtained in the previous study can be used to propose a simple approximation for estimating the noise levels that would exist without the subject's presence. The first part presents the methodology used in a laboratory to establish this approximation and the second part presents the method proposed to validate it, i.e a simulation of "controlled" workplace conditions. Examples of results illustrating the findings are finally shown and discussed.

2. METHODS

In the first part, explained in more detailed in the previous study (Le Cocq et al., 2011), 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 and without earmuffs. In free field conditions, twelve sound directions from -150° to 180° with 30° steps were considered. Six miniature microphones were fixed on each earmuff. 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 both rooms were realized with a pink noise of about 85 dB overall SPL. The results were then used to compute the difference between the SPL at the microphone location and the SPL at the center of the head without the subject. This difference, noted Δ in the rest of the paper, is expressed in dB. Values of Δ were then used to establish an approximation which can be used to estimate the SPL in the absence of the subject from microphones located on the earmuff.

In the second part, a "controlled" simulation of a workplace environment was performed to validate the approximation,. As illustrated in figure 1, a background sound field was created using four speakers placed in a mechanical shop where two machines were running at the same time. The objective was to create a sound field which could be more directional at certain location. A subject was asked to stand still at 9 different locations in the room with 4 different head orientations. Binaural recordings were performed by using two microphones (one per ear) located on the upper part of an earmuff. This choice of microphone position was made after analysis of the results of the first part. Microphone recordings were also made at the nine subject locations without the subject presence, at the head center positions.

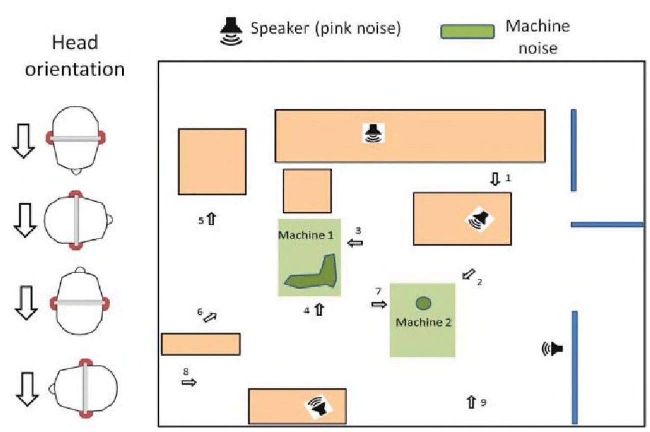

Figure 1: Overview of the room and speaker setup used for the workplace simulation

One objective was to apply the proposed correction factor to the microphone measurements made on the earmuffs and then compare these estimates to the measurements done without subjects.

3. RESULTS

3.1 Approximation for Δ

To establish a simple and practical approximation, the values of Δ were computed for four different zones of noise source location: Zone 1- Source in the front/back of the head (-30°<θ<30° or -150°<θ<150°); Zone 2 – Ear/mic facing the source; Zone 3 – Ear/mic in the shadow zone (source facing the opposite ear); Zone 4- diffuse field. Figure 2 shows the mean and standard deviation for the difference Δ computed, in each zone, for all subjects and earmuffs tested. Simple regression lines which can be used as approximation curves are also plotted. Results for zone 4 (diffuse field) are not shown here because they were found to be very similar to zone 1 results. Consequently, the three regression lines can be used to correct the earmuff microphone readings as long the source location can be determined.

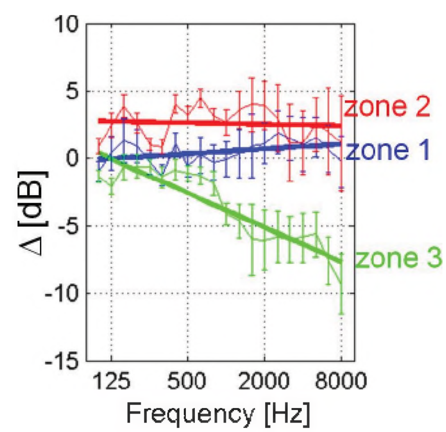

Figure 2: Mean SPL differences Δ for the three source location zones

3.2 Validation with workplace simulation

To estimate the source location when a subject was placed in the workplace simulated environment, binaural recordings were used as follow: 1) compute the overall SPL at each ear; 2) compare the overall levels between left and right ears; 3) if the difference is below a certain threshold, consider the source to be either in front of the head, in the back of the head or to be a diffuse field. If the left/right difference is positive (negative) and above the threshold level, consider the source to be facing the left (right) ear; 4) apply the appropriate correction to the earmuffs microphone SPL readings using the regression lines proposed above. This procedure was applied for all subjects, earmuffs, locations in the room and head orientations. Figure 3 presents the results for all instances where the earmuff microphone was considered in zone 2 (facing the source) using a threshold of 1.5 dB to select source zone. Values of Δ are plotted as a function of frequency. The upper line represents the bare "uncorrected" data while the line with the circle symbol represents the corrected estimate. While a difference of 0 dB represents the target to achieve, it is found that applying the proposed correction Δ allows to obtain a reasonable estimate within a ±2 dB range.

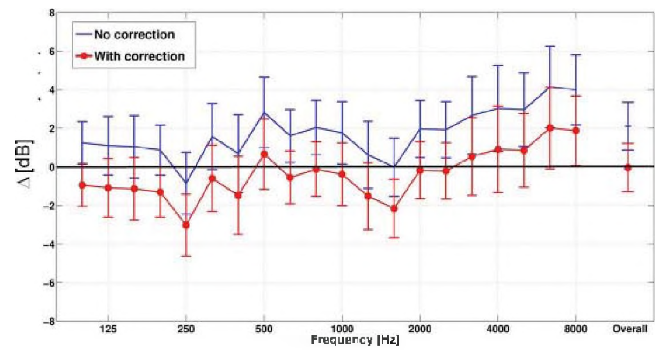

Figure 3: Comparison of the SPL difference Δ with and without correction (microphone determined to be in zone 2)

4. DISCUSSION AND CONCLUSIONS

Results of the study suggested that values of Δ on average did not exceed 2.5 dB when the microphone was well "seen" by the noise source. When the microphone was in a "shadow" zone, significant differences were observed. A simple and practical preliminary approximate correction could then be derived. It allows obtaining, using simple binaural recordings, fairly good estimates of the SPL values that could be measured without the presence of the subject. In the context of assessing HPD attenuation at the same time as performing noise survey, work is currently under way to refine the approximation and to repeat the experiment with earplugs. In this case, larger differences are expected as different elements of the external ear (eg. pinna) will be affecting more the sound field.

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