EXPERIMENTAL VALIDATION OF THE OBJECTIVE MEASUREMENT OF INDIVIDUAL CUSTOM EARPLUG FIELD PERFORMANCE

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INTRODUCTION

To address the current issues [1] of discomfort (from both a physical and perceptual perspective) and unknown performance of existing Hearing Protection Devices (HPD), a new concept of a re-usable earplug has been recently developed [2,3,4]. For physical comfort this earplug is instantly custom-fitted with soft biocompatible silicone rubber. A sound bore through the earplug is used in two ways: first, for the measurement of the sound pressure level inside the earplug (see [3] for the assessment of the earplug attenuation) and, second, for the filtering of the earplug with passive acoustical dampers (see [2] for the customization of the attenuation to limit speech and warning signals degradation following CSA Z94.2 recommendations [5]). The expandable earplug is illustrated in Fig. 1. with the dual microphone probe and the sound source for field performance measurement.

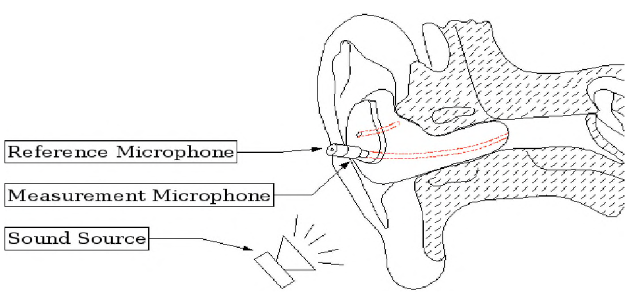

Fig. 1. The expandable custom earplug instrumented.

Once the fitted earplug has cured in the user's ear, a Noise Reduction (NR) measurement is performed on the earplug: a loud pink noise is generated with the reference sound source and the Transfer Function (TF) between the two microphones is computed including the corrections from the daily calibration TF and the sound bore length correction. A so-called Field-MIRE (Microphone In Real Ear) method presented by the first author [3] is used to predict, from this octave-band NR measurement, the Real Ear Attenuation at Threshold (REAT) i.e. the difference between open and occluded-ear hearing thresholds as reported by human subjects.

From this octave-band REAT prediction, a single number value representing the overall HPD attenuation is computed: the Predicted Personal Attenuation Rating (P-PAR). The P-PAR is computationally similar to the Noise Reduction Rating (NRR), but it is obtained from an objective F-MIRE measurement (not from a subjective evaluation of the attenuation), on a particular user (not on a population sample), under realistic wearing conditions for the hearing protector (not under laboratory conditions), as opposed to standard REAT attenuation rating of HPD [5,6].

EXPERIMENTAL VALIDATION

2.1 Experimental protocol

The prediction method has been validated using results of tests conducted by an independent third-party research laboratory [7]: the P-PAR measured by the dedicated measurement device (dubbed SonoPass™) is compared side-by-side, for the same earplug on the same individual, to the attenuation that is measured using the REAT method. A group of twenty “naive” (as per ANSI S12.6 “Method B” requirements [6]) subjects were used. Each of the twenty subject tests included two parts:

1. Two determination of the REAT of two fits of the same earplug. Each test subject had been instructed prior to the entering of the REAT test room, to not remove/touch his earplug after final REAT testing.

2. A first measurement on the test subject in the same earplug fitting condition of the NR and prediction of the octave-band attenuation. This NR measurement is performed only once the subject exits the test room following the two sets of REAT measurements (because “Method B” requires the subject to stay isolated in the test chamber for the two REAT tests). A second measurement on the test subject of the F-MIRE attenuation, after the earplug has been removed and re-fitted by the subject himself, outside the REAT test room.

2.2 Experimental results

Fig. 2. presents the comparison between REAT and F-MIRE of the overall attenuation values of the twenty subjects, using three frequency ranges (125-2000, 125-4000 and 125-8000 Hz). The best predictions errors (overall prediction error is always less than 10 dB for each of the twenty cases tested) are actually obtained when using only the low-frequency octave-bands. This observation confirms that the low-frequency octave-band attenuation could be a good predictor of the overall attenuation [8], since most earplugs do anyway attenuate very well in high frequency. This observation also suggest that the high-frequency attenuation prediction is not -at least in that studied case- adding much information and appears to actually disturb the prediction capabilities of the measurement system.

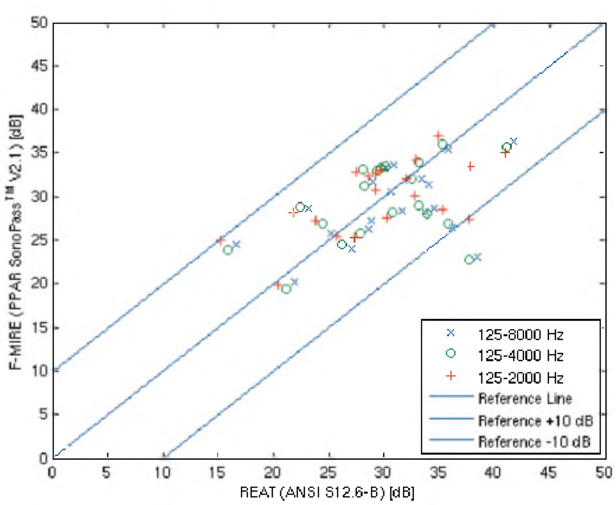

Fig. 2. Comparison between REAT and F-MIRE of the overall attenuation values of the twenty subjects, using the 125-2000 Hz (red '+'), 125-4000 Hz (green 'o') and 125-8000 Hz (blue 'x') ranges.

CONCLUSIONS

The presented approach was developed to meet the need to improve earplug field performance prediction accuracy by changing from average group performance prediction to individual performance prediction. The individual earplug field performance is objectively measured by a Field-MIRE method: the individual attenuation is predicted from the field measurement of the Noise Reduction through the earplug. The individual attenuation is first obtained as a set of values for each octave band center frequency and these values are then combined in a single number, the Predicted Personal Attenuation Rating (P-PAR). This P-PAR is the equivalent to the individual NRR obtained from the classical REAT attenuation testing. The method has been validated experimentally by an independent third party laboratory and the overall prediction error has been found perfectly suitable for improved hearing conservation practices.

ACKNOWLEDGEMENTS

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