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NEW METHOD AND DEVICE FOR CUSTOMIZING IN SITU A HEARING PROTECTOR

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1. INTRODUCTION

To address the issues of discomfort (from both a physical and perceptual perspective) and unknown performance of existing hearing protectors, a new concept of a re-usable earplug has been developed [1,2]. For physical comfort this earplug is instantly custom-fitted with soft biocompatible silicone rubber [3]. A sound bore through the earplug is used two ways: first, for the measurement of the sound pressure level inside the earplug (see [2] and [4] for the assessment of the earplug attenuation) and, second, for the filtering of the earplug with passive acoustical dampers (see [1] for the customization of the attenuation to limit the speech and warning signals degradation). This paper will present how all those features have been integrated over the last 2 years into a field solution for customizing, in situ, a hearing protector.

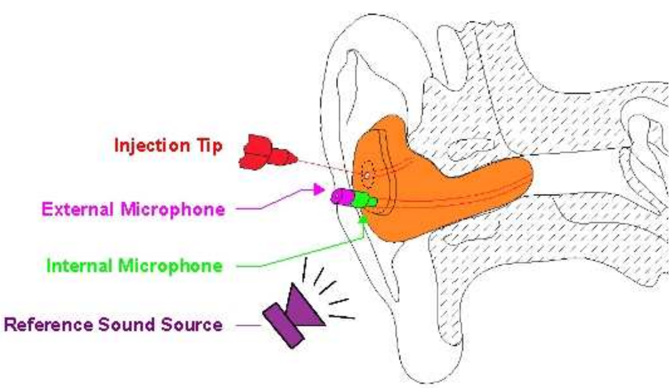

Fig. 1. Schematic Overview of the Custom Earplug and the Measurement Device

2. IN-SITU ATTENUATION MEASUREMENT DEVICE

Field Calibration of the Device

Daily Calibration Check

This check is performed prior to any use of the device. The dual microphone probe is clipped in the middle of the Reference Sound Source speaker grid (acoustic near field), and a Transfer Function (TF) measurement is performed between the External and Internal microphones while the sound source is generating a moderate pink noise level. This check ensures that the Sound Source is functioning properly (since the Sound Pressure Level measured at the reference microphone must be within a given range) and that both microphones are working correctly (since the measured TF must respect a given template). The TF is stored for later usage.

Microphone Probe Length Correction

The acoustical length of the microphone probe tube is increased when the probe microphone is inserted inside the earplug sound bore. This added length is merely a function of the earplug size and the associated level correction can be stored per octave band in a table to be used later on.

In-Situ Attenuation Measurement

Noise Reduction Measurement

Once the fitted earplug has cured, 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 between the 2 microphones is computed including the corrections from the daily calibration TF and the sound bore length correction. A method presented by the authors [2] is used to predict the REAT (Real Ear Attenuation at Threshold) by octave band from this NR measurement.

Predicted Personal Attenuation Rating

From this REAT prediction, a new indicator has also been proposed [5]: the P-PAR (Predicted Personal Attenuation Rating). The P-PAR is comparable to an NRR (*Noise Reduction Rating,* a single number value representing the attenuation [6]) but it is obtained from an objective measurement (not from a subjective evaluation), on a particular user (not on a population sample), under realistic wearing conditions for the hearing protector (not under laboratory conditions).

3. CUSTOMIZING IN SITU THE EARPLUG

Adaptation of the Earplug Attenuation

Attenuation of the Filtered Earplug

The use of an acoustical damper creates a second sound path that has been quantified using REAT measurements with and without the damper in place following ANSI standards [7]. The prediction of the *filtered* earplug attenuation can then be obtained by combining the predicted attenuation of the *unfiltered* earplug with the quantified attenuation of the damper. This latter value is essentially function of its acoustical resistance which is guaranteed by the manufacturer to be very stable between samples The attenuation of the filtered earplug can consequently be reliably predicted per octave band enabling filter selection which is described in the following paragraph.

Filter Selection

Following existing recommendations [8,9], the filter that leads to a protected exposure level ranking between 70 and 85 dBA will be selected among a set of 5 available filters as presented by the authors [1].

Performance Tests

Respectively from the rough NR measurement (see “Noise Reduction Measurement” section), the PPAR computation (see “Predicted Personal Attenuation Rating” section) and the Protected Exposure Level (see “Attenuation of the Filtered Earplug” section), three performance tests are undertaken: the first is an *Acoustical Seal Test* that checks if the earplug provides a proper and comfortable fit; the second is a *Rating Test* that checks if the earplug is efficient and provides at least the NRR it has been rated for (thereby ensuring that the earplug does not need to be “de-rated”), and the third is a *Protection Test* that checks that the filtered earplug offers an amount of protection that matches the user's noise exposure, therefore avoiding overprotection and the resulting voice and warning signals intelligibility degradation. These performance tests are undertaken a first time right after the earplug has been fitted (*Post-Curing Test*) and a second time after the earplug has been removed and replaced by the user himself (*Subject-Fit Test*); the comparison between the two not only ensures the robust prediction of field performance but is also an effective indicator that helps training the user to properly insert the earplug.

4. CONCLUSION

The recent developments of a method and the associated hardware/software system for a custom-fitted earplug have been integrated into a comprehensive in situ approach that includes in situ attenuation measurements, adaptation of the attenuation with an acoustical damper and several performance tests. This is a first step towards meeting the goal established by NIOSH (National Institute for Occupational Safety and Health) of finding a way for workers to be individually fitted and to offer them increased comfort and the ability to hear speech and warning signals [10] while being protected.

ACKNOWLEDGEMENTS

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REFERENCES

1. Voix, J., F. Laville, and J. Zeidan. *Filter Selection to Adapt Earplug Performances to Sound Exposure*. in *Acoustics Week in Canada PEI 2002*. 2002. Province of Prince Edward Island (PEI).
2. Voix, J. and F. Laville. *Expandable Earplug With Smart Custom Fitting Capabilities*. in *InterNOISE 2002*. 2002. Dearborn, MI, USA.
3. McIntosh, I. and R. Saulce, *Expandable in-ear device*. 2004, Sonomax Hearing HealthCare Inc.: United States Patent.
4. Voix, J. and F. Laville, *Method and apparatus for determining in situ the acoustic seal provided by an in-ear device*. 2004, Sonomax Hearing Healthcare Inc: United States Patent.
5. Voix, J. and F. Laville. *Problématiques associées au développement d'un bouchon d'oreille "intelligent" (Problematics associated with the development of a "smart" earplug)*. in *RRSSTQ-Congrès annuel de l'ACFAS*. 2004. Montréal,QC, Canada.
6. EPA, *Noise Labeling Requirements for Hearing Protectors*, in *Fed. Regist. 44(190), 40CFR Part 211*. 1979.
7. ANSI, *American National Standard Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs*. 1974, American National Standard Institute: ANSI S3.19-1974 (R 1990).
8. CSA, *Hearing Protection Devices - Performance, Selection, Care, and Use*. 2002, Canadian Standards Association: Z94.2-02.
9. EN458:1993, *Hearing Protectors - Recommendations for selection, use, care and maintenance - Guidance Document EN 458, CEN (European Committee for Standardization)*. 1993.
10. NIOSH, *Criteria for a Recommended Standard-Occupational Noise Exposure*. 1998, (National Institute for Occupational Safety and Health)