Real-time estimation of the passive attenuation for otoacoustic emission measurement probes (Abstract ID: 2713881)

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1. Context

Over 22 million North American workers are exposed daily to excessive noise doses that may induce Noise-Induced Hearing Loss (NIHL) [1]. Hearing conservation programs only require that workers' hearing health status is updated once a year, not frequent enough to detect that NIHL is being acquired. Besides, hearing protection devices (HPD), when used, are often incorrectly inserted or even removed (for better communication in noise, for example) therefore dramatically reducing their effective attenuation.

As a result, NIHL remains one of the biggest causes of invalidity and indemnity in North America [1].

2. Problem

There is a need to improve hearing health monitoring, before NIHL is acquired, and to simultaneously measure the effective attenuation of HPDs. Currently, no system is designed to continuously monitor hearing health and to simultaneously measure the good fit of hearing protectors in a noisy environment.

3. Proposed Approach

To address these issues, a new type of advanced HPD system is proposed where hearing status is assessed using Distortion Product Otoacoustic Emission (DPOAE) measurements [2] and where the proper fit of the HPD can be assessed *in-situ*, using adaptive filtering, without disturbing the workers routine and enabling them to know if they are correctly protected prior to being exposed to noise. The adaptive filter approach is used to identify the loudspeaker response in the ear, as an incorrect hearing protector fit decreases the magnitude in low frequencies.

4. Objectives

1. Evaluate, *in-situ*, the fit quality of the hearing protector equipped with otoacoustic emission probe components;
2. Simultaneously calibrate the primary tones used for DPOAE measurements.

5. Methodology

Using a wide-band sound source, the adaptive filter coefficients will converge to the transfer function of the loudspeaker response combined with the ear canal and in-ear microphone response, referred here as the secondary transfer function $H(z)$, as described in [3]. The magnitude response of the estimated secondary transfer function $\hat{H}(z)$ is calculated from the filter coefficients. The **fit-test value** can then be estimated at a discrete frequency f, for example $f = 150$ Hz.

The transfer function magnitude is used to evaluate the quality of the fit, and also to calibrate the levels of the stimuli signals at $f = f_1$ and at $f = f_2$ used for DPOAE measurements. The sound signal source is sent to the two loudspeakers subsequently. The calibration of the stimuli signals consists in adjusting the gain for the discrete primary tones based on the difference between 0 dB and the magnitude at these discrete frequencies.

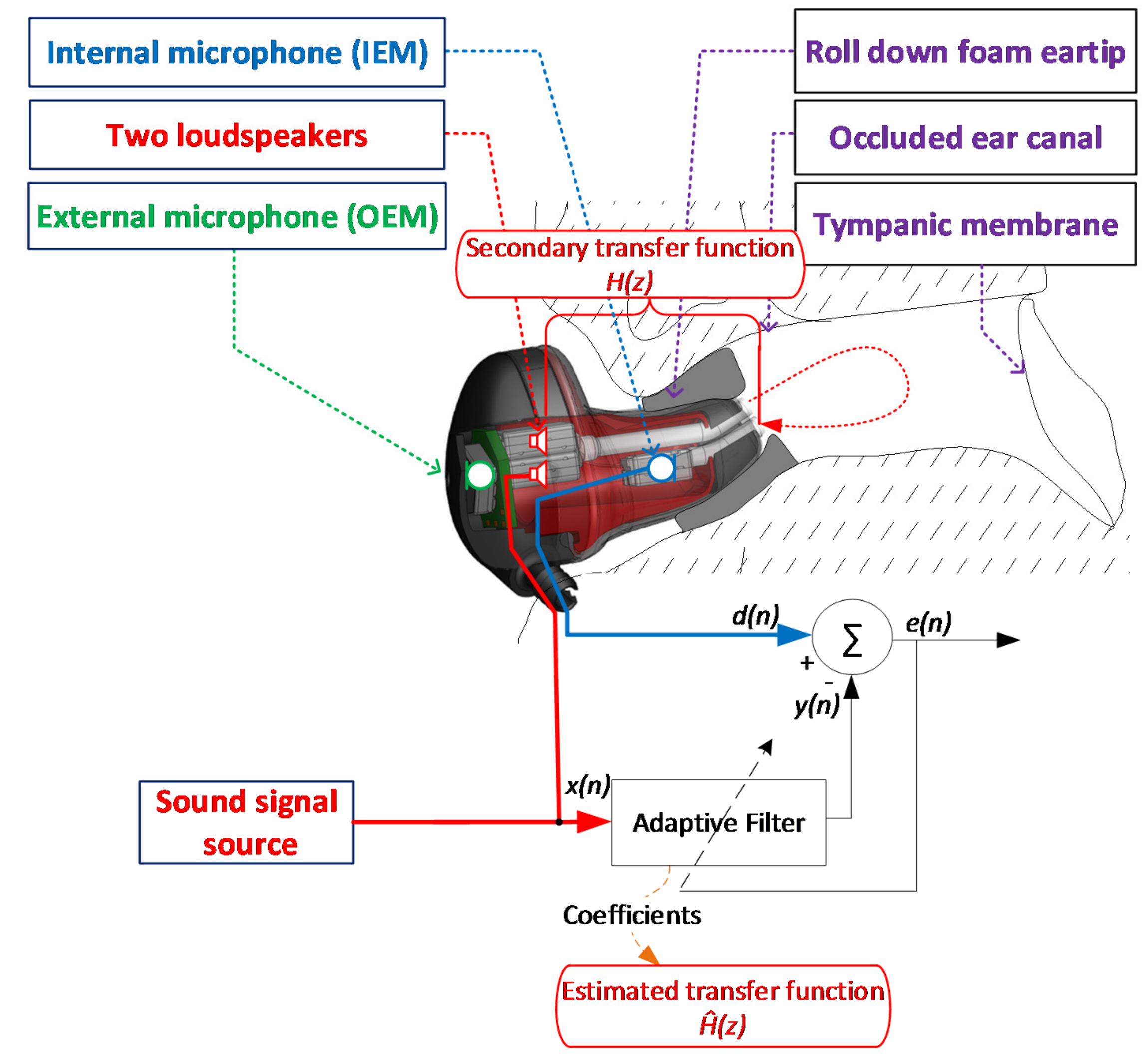


Fig. 1: Schematic of the procedure to identify the loudspeaker frequency response to evaluate the good fit of a hearing protector.

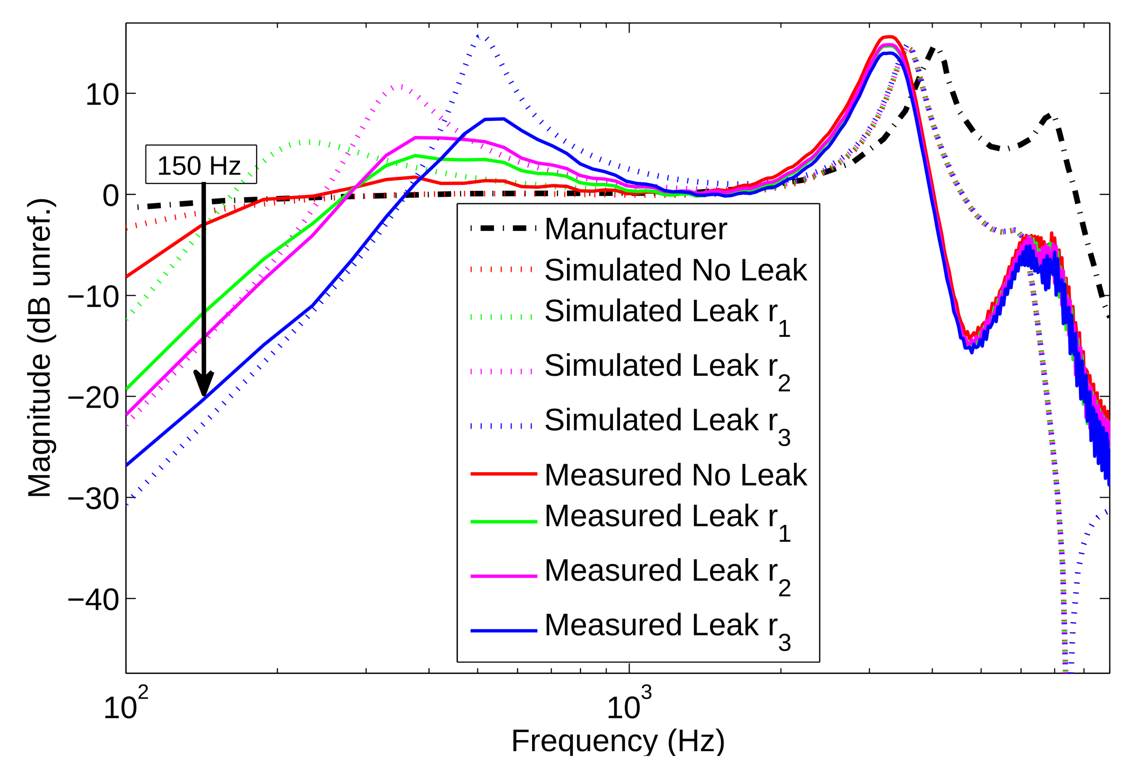


Fig. 2: Examples of different normalized miniature loudspeaker responses, with decreasing fit quality (acoustic leak equivalent diameter increasing from r_1 to r_3). The importance of the leak can be assessed by measuring the response magnitude around 150 Hz where the magnitudes differ the most between curves.

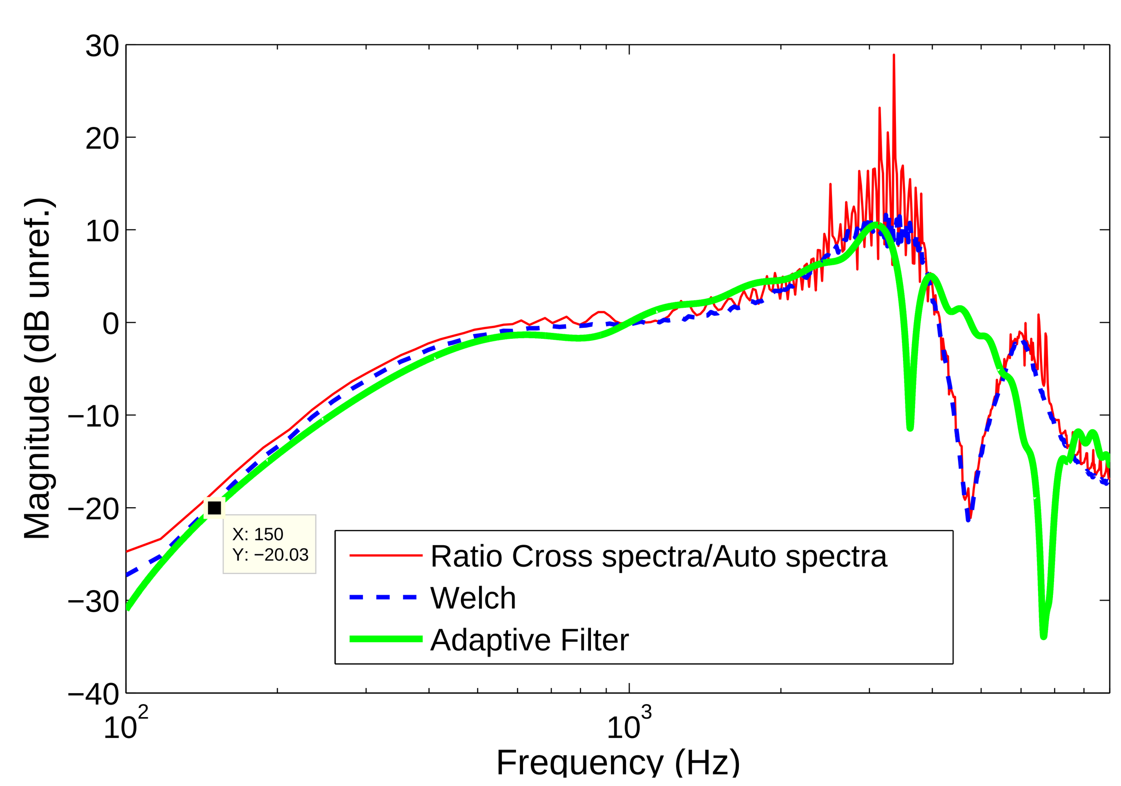
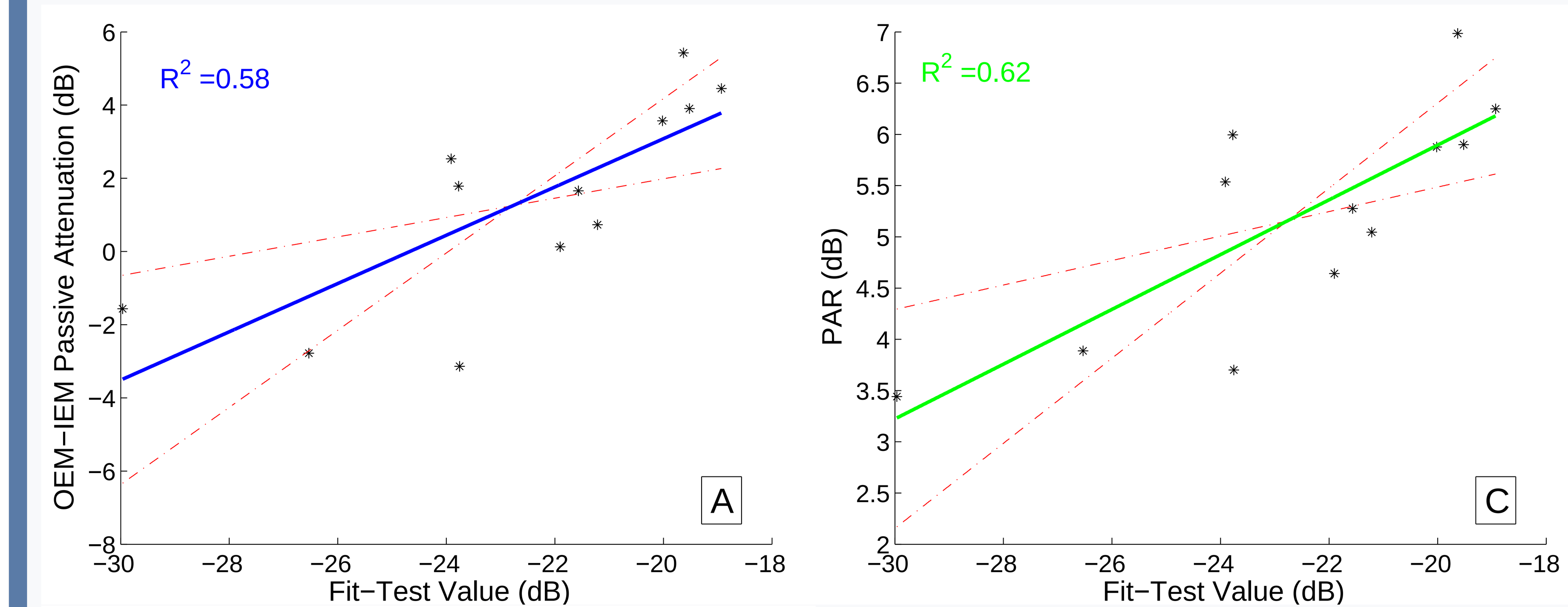
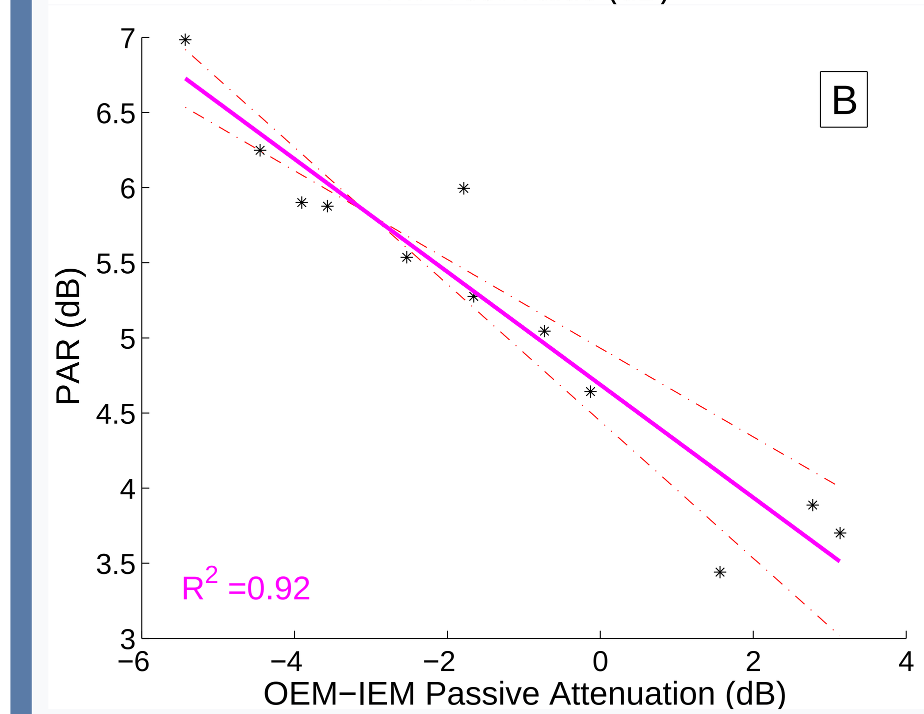


Fig. 3: Example of an estimate of the loudspeaker transfer function in low frequencies with the adaptive filter coefficients, similar to the transfer functions identified using the ratio of the cross spectra/auto spectra and the Welch estimator.

6. Experimental Results





Linear regressions between A) the **fit-test value** at 150 Hz and the passive attenuation of the earplug at 500 Hz, B) the passive attenuation at 500 Hz and the Personal Attenuation Rating (PAR) and C) the fit-test value at 150 Hz and the PAR. The results indicate that the fit-test value calculated from the adaptive filter coefficients is a good estimator (R^2=0.62) for the PAR.

7. Discussion and benefits

- Proposed method does not require external noise sources to evaluate the HPD's fit and passive attenuation;
- Proposed method can be used simultaneously to calibrate the DPOAEs primary tones, reducing the number of steps to proceed with DPOAE measurements;
- DPOAE probes' in-ear microphones and their conditioning circuit have high sensitivity to detect very low sound pressure levels (e.g. -20 dB(SPL)), therefore the signal to identify the secondary transfer function can be at a very low level, e.g. 0 dB(SPL), inaudible to the user and would have a negligible effect on the total noise dose received.
- The proposed method could be used continuously to evaluate the quality of the fit of any given HPD, and as a result could also improve the signal-to-noise ratio of DPOAE measurements.

References

[1] National Institute for Occupational Safety and Health. 2016. "National Institute for Occupational Safety and Health Website" . Online. <https://www.cdc.gov/niosh/topics/noise/>.

[2] Nadon, V., Bockstael, A., Botteldooren, D., Lina, J.-M. and Voix, J. 2017. Design Considerations for Robust Noise Rejection in Otoacoustic Emissions Measured In-Field Using Adaptive Filtering. Acta Acustica United with Acustica, 103(2), 299âĂŞ310.

[3] Nadon, Vincent, Hami Monsarrat-Chanon and Jérémie Voix. 2017. "Continuous fit-testing of electronic in-ear devices using adaptive filter coefficients of electroacoustic transducer responses". PROVISIONAL APPLICATION, USPTO, June 2017.