# Continuous Hearing Health Monitoring using Otoacoustic Emissions

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## Context

Over 22 million North American workers are exposed daily to noise doses that may induce hearing loss [1].

In hearing conservation programs, worker's hearing health status is only updated once a year.

Current legislation does not consider the differences in individuals' susceptibility to Noise Induced Hearing Loss (NIHL) nor the various characteristics of the noise such as the frequency spectrum and level variations over time.

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

## Problem

Currently, no system is designed to continuously monitor hearing health in a noisy environment.

Therefore, hearing health is usually tested after the damage is irreversible.

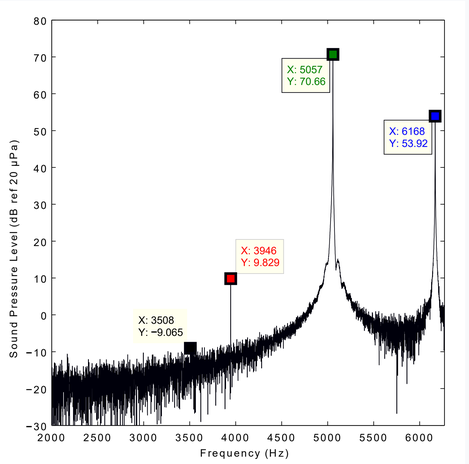
## Research Objectives

- Develop a device to detect the early onset of hearing fatigue.
- Establish a **"noise dose ↔ ear response"** relationship.
- Define the individual's susceptibility to noise.
- Prevent hearing loss.

## Proposed Approach : DPOAE

Distortion product otoacoustic emissions (**DPOAEs**):

- small acoustical signals generated inside the cochlea ($f_{dp}$) in response to two pure tone stimuli ($f_1$,$f_2$);
- used to detect, at an early stage, the onset of hearing loss.



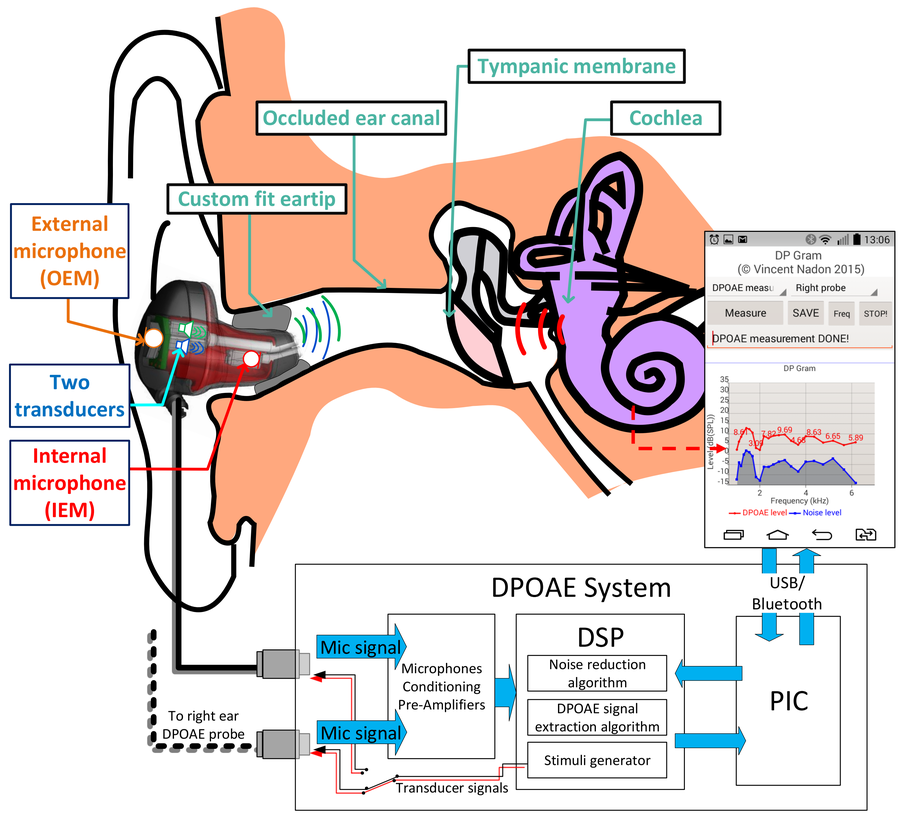

## Developed System

A portable DPOAE monitoring system using adaptive noise rejection [2] and robust signal extraction algorithms was designed to measure the **inner-ear response** in noisy environments.

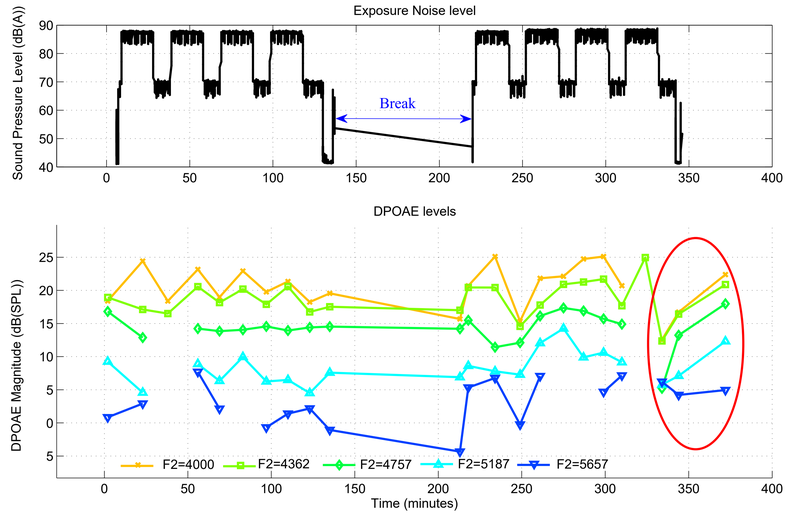
This DPOAE system consists of :

- two DPOAE probes which are also hearing protectors,
- a device with signal conditioners and Digital Signal Processors (DSP) to process the DPOAE signals,
- a smartphone application to control the device and display the DPOAE levels and save the data in a file.

The upcoming version of the system will include **in-ear dosimetry** to automatically establish the **dose-response relationship** and warn the worker when the DPOAE measurement should be done, to prevent hearing damage.




## Experimental Results




Typical timeline of exposure noise level (top) synchronized with DPOAE variations at 5 different $f_2$(Hz) test frequencies measured with the developed system during an experiment on a human participant (bottom). Blank data points for certain frequencies result from the post-processing threshold method removing outliers.

DPOAE levels decrease towards the end of the $L_{eq\ 8h} = 82$ dBA noise exposure and after this exposure they recover to pre-exposure DPOAE levels, or higher, as shown in the red circle. This variation in DPOAE levels indicates that the noise exposure had an effect on cochlear activity which could potentially result in hearing damage if the noise exposure duration or level is increased.

## Benefits of the proposed approach

- Provide a reliable tool for scientists to conduct research on hearing recovery mechanisms.
- Warn workers of their hearing fatigue before hearing loss is irreversible.
- Define appropriate legislation to protect workers against occupational NIHL.
- Reduce indemnity paid to workers due to hearing loss.

## 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, Vincent, Annelies Bockstael, Dick Botteldooren, Jean-Marc Lina, et Jérémie Voix. 2015. "Individual monitoring of hearing status: Development and validation of advanced techniques to measure otoacoustic emissions in suboptimal test conditions". In *Applied Acoustics*, March, vol.89, p. 78–87.