# Use of Passive Hearing Protectors and Adaptive Noise Reduction for Field Recording of Otoacoustic Emissions in Industrial Noise

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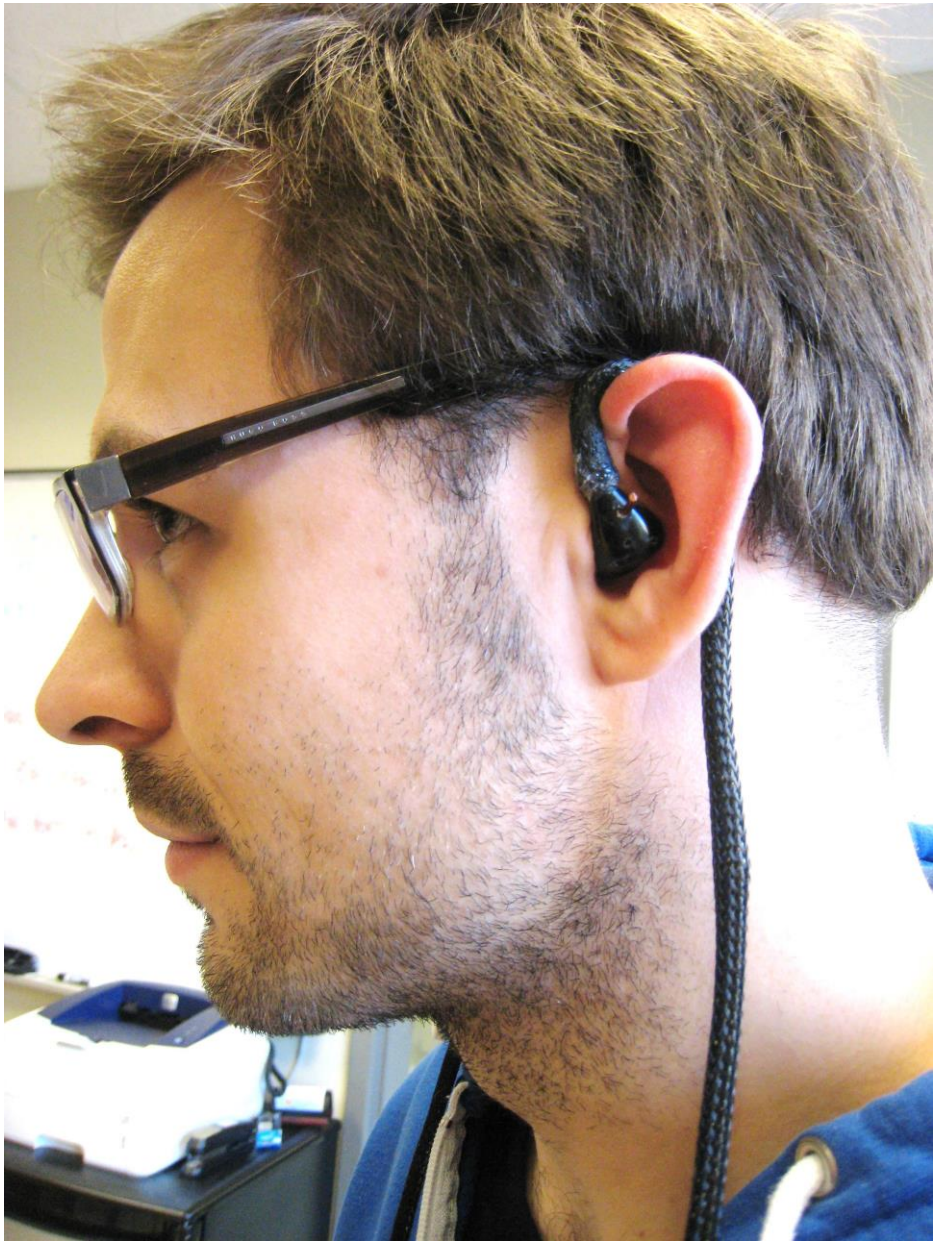
# Hearing Health Monitoring Earplug



Objectives of my presentation:

- **Inform** hearing conservationists about available technologies for hearing health monitoring
- **Motivate** hearing conservationists to request manufacturers for such technologies
- **Invite** manufacturers to offer such advanced hearing protection devices

# Outline

- Motivation
- Proposed approach
- Methodology
- Research problem
- Developed system
- Experimental validation
- Results
- Conclusions

# Motivation

Despite all our efforts…

**…hearing loss** is still a **major occupational issue**

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# Proposed Approach

What is the best way to prevent hearing loss?

## Traditional answer

Limiting noise exposure!

a) Noise control at the source
b) Administrative means (limit duration)
c) Hearing protection

## Our proposed approach

**Use of a hearing protector that continuously monitor's the hearing health status of each individual**

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# Methodology

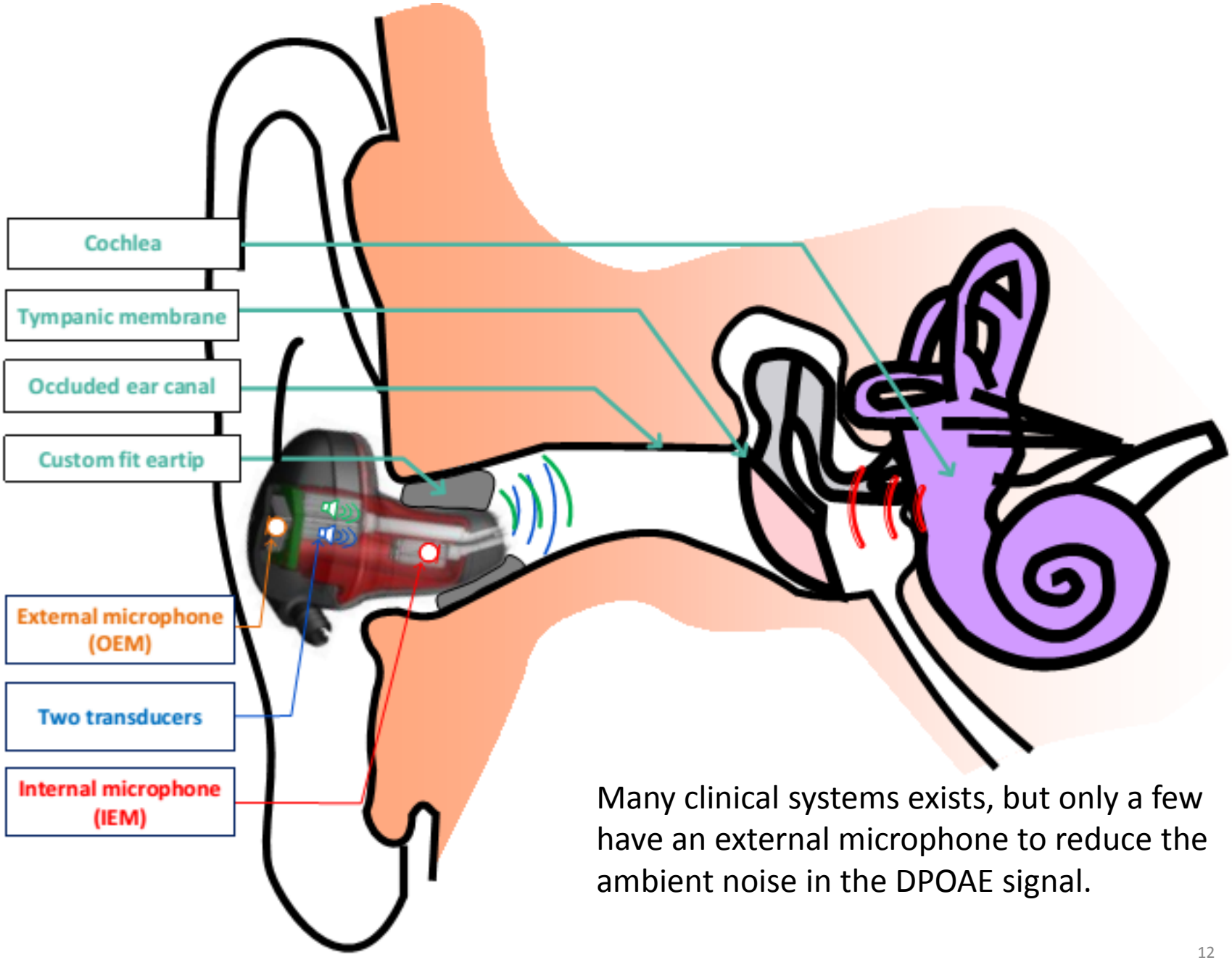
Continuous **monitoring** of **hearing health**

OAE monitoring system will **measure** the worker's hearing health with distortion product OAEs (**DPOAE**s) **daily**.

# Methodology

**Use of a hearing protector that continuously monitor's the hearing health status of each individual**

Measurement of distortion product otoacoustic emissions (DPOAEs) to **quickly** and **objectively** detect hearing damage.




Many clinical systems exists, but only a few have an external microphone to reduce the ambient noise in the DPOAE signal.

# Methodology

Hearing protection

**Custom molded** OAE probe providing **high passive attenuation**

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# Research problem

Otoacoustic emissions are very sensitive to background noise.

Could adaptive noise reduction algorithm (**ANR**) **reduce physiological** and **ambient** noise enough to measure DPOAEs in a loud environment?

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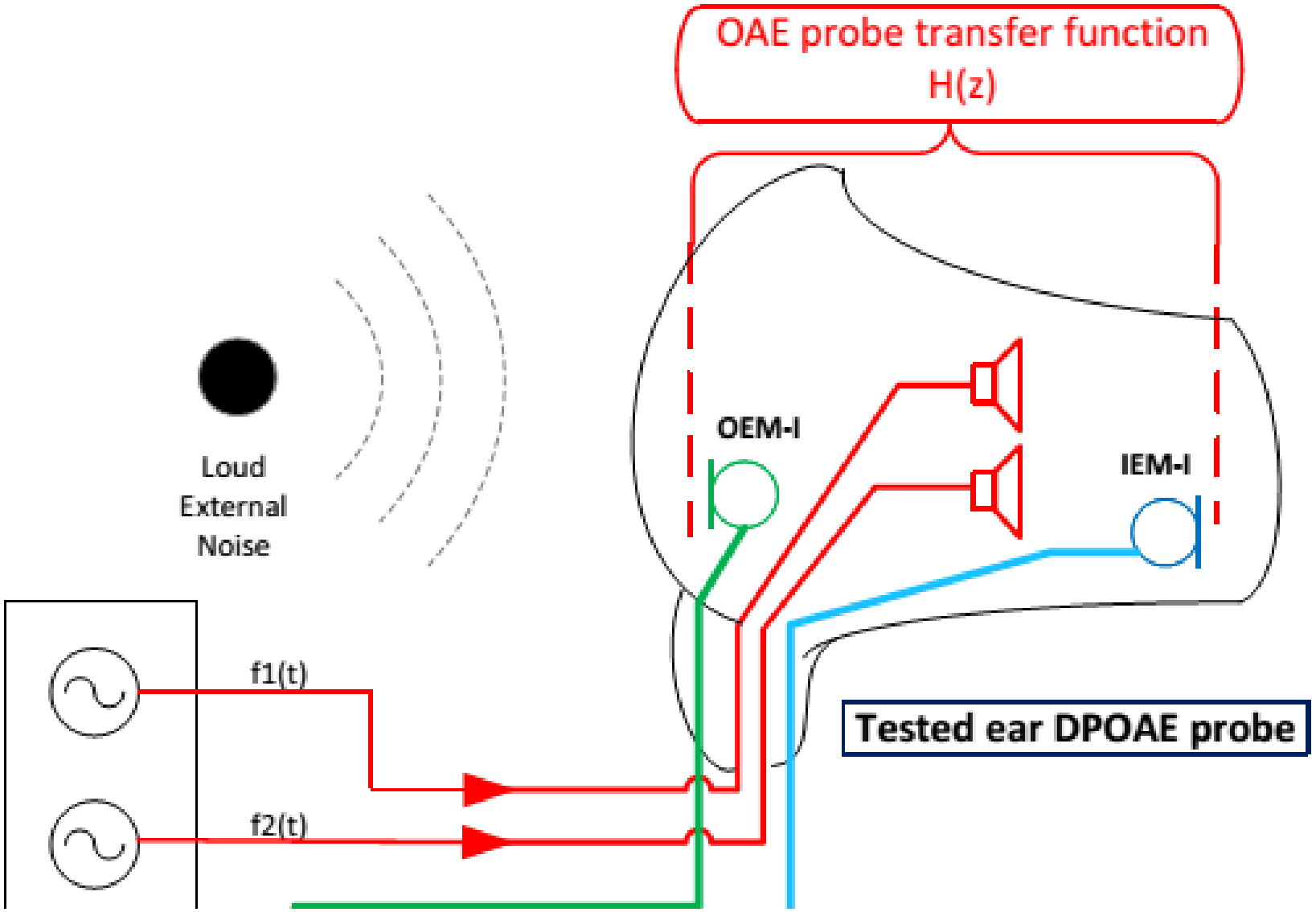
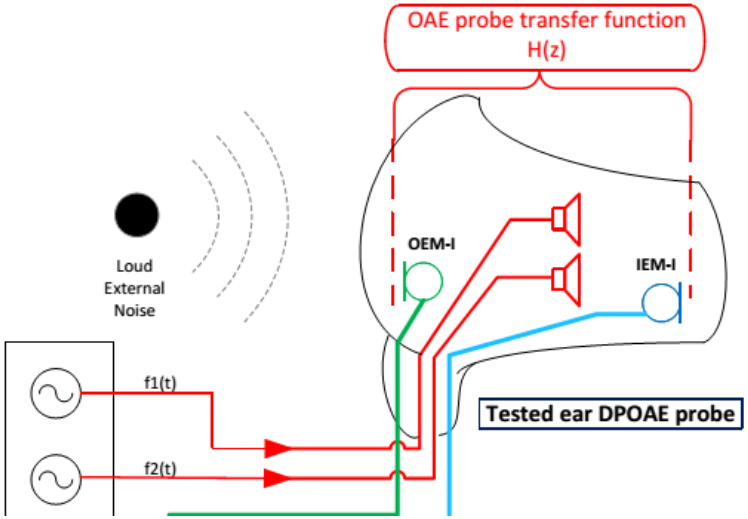

OAE probe transfer function
H(z)
Loud
External
Noise
OEM-I
IEM-I
f1(t)
f2(t)
Tested ear DPOAE probe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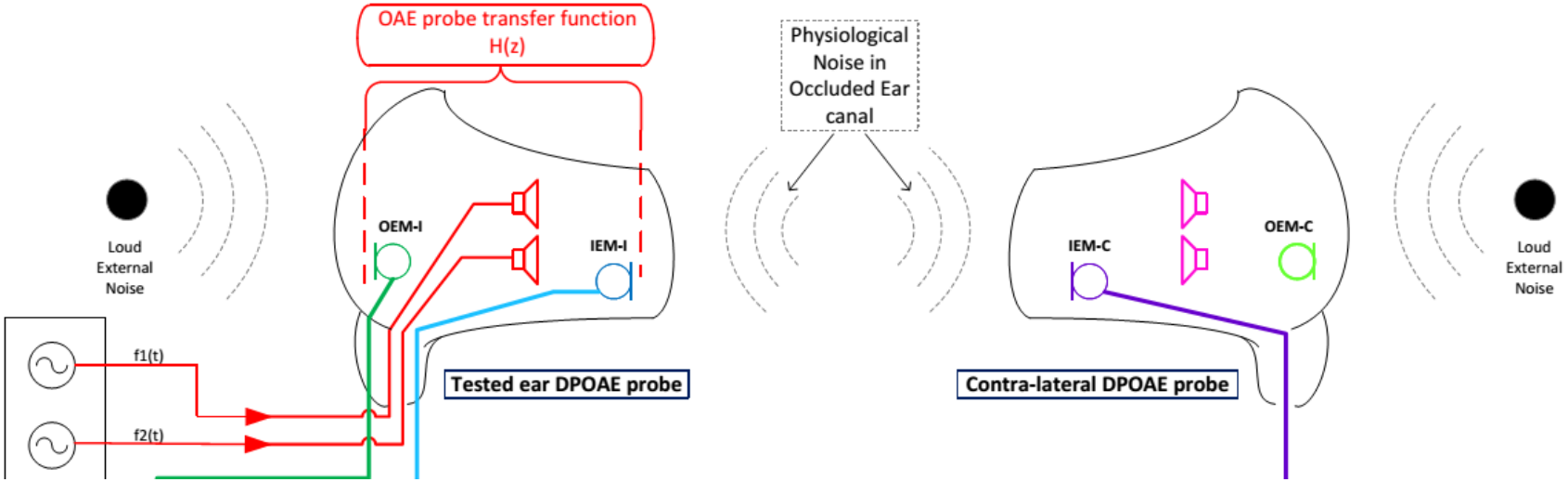
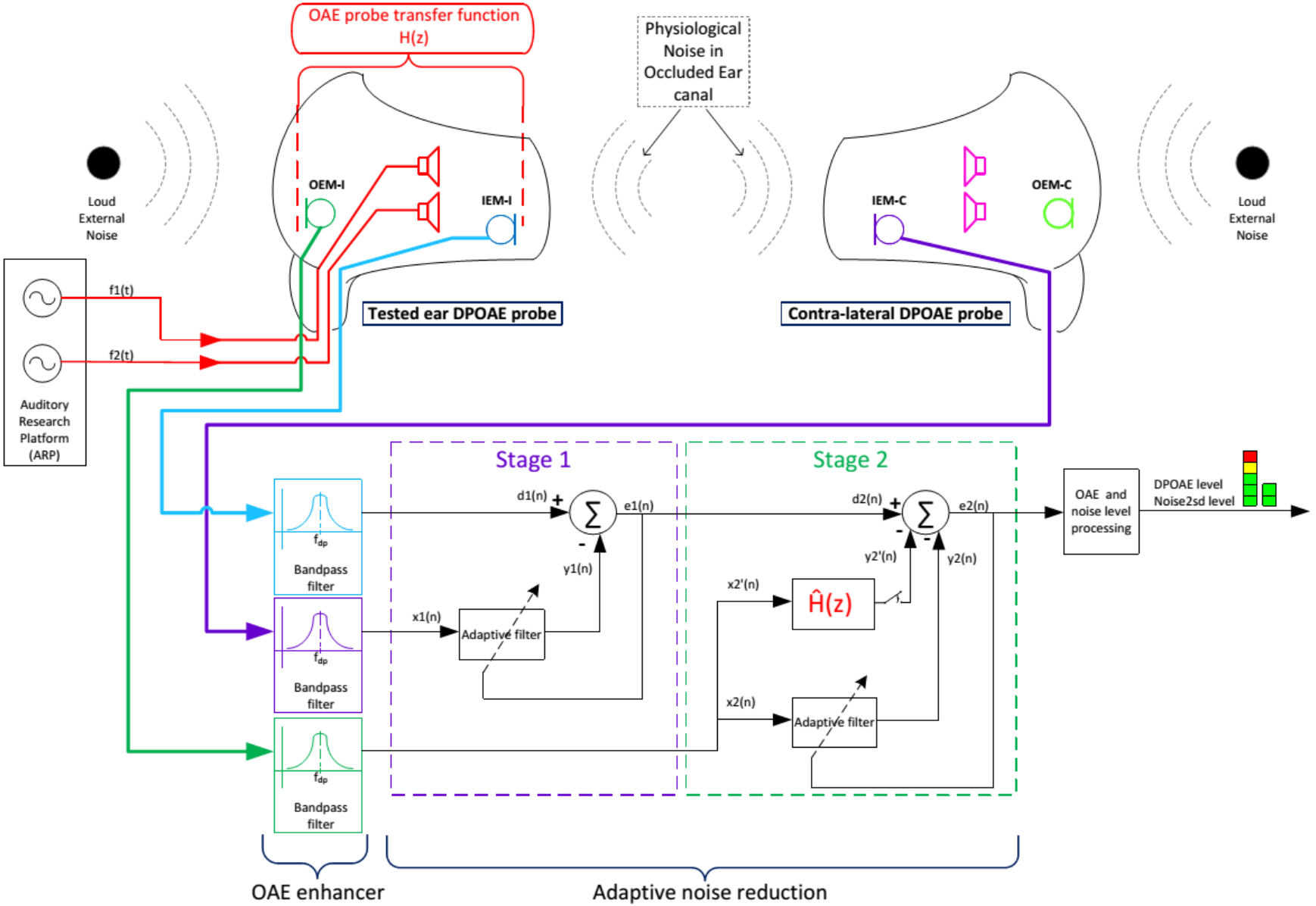
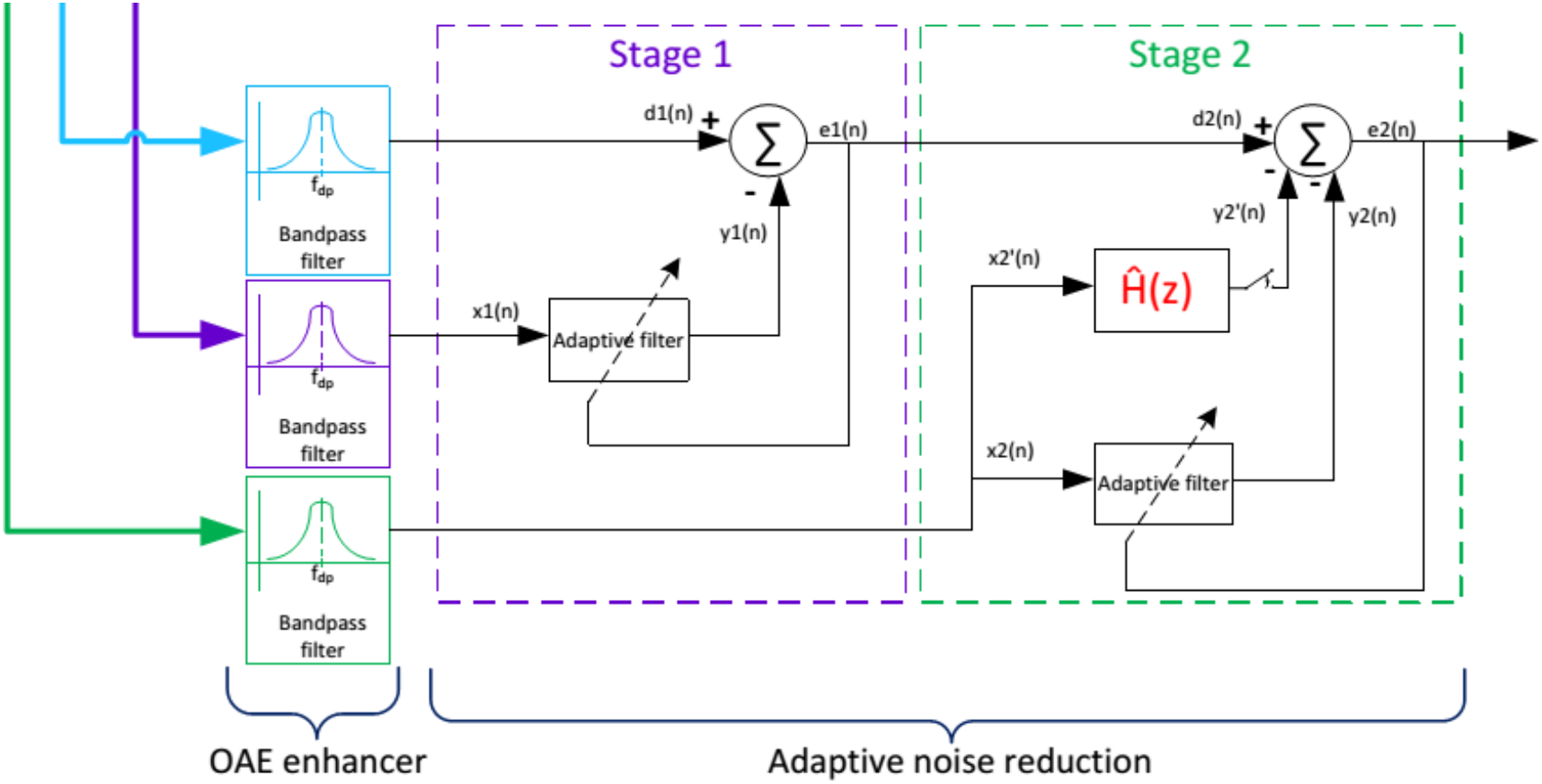
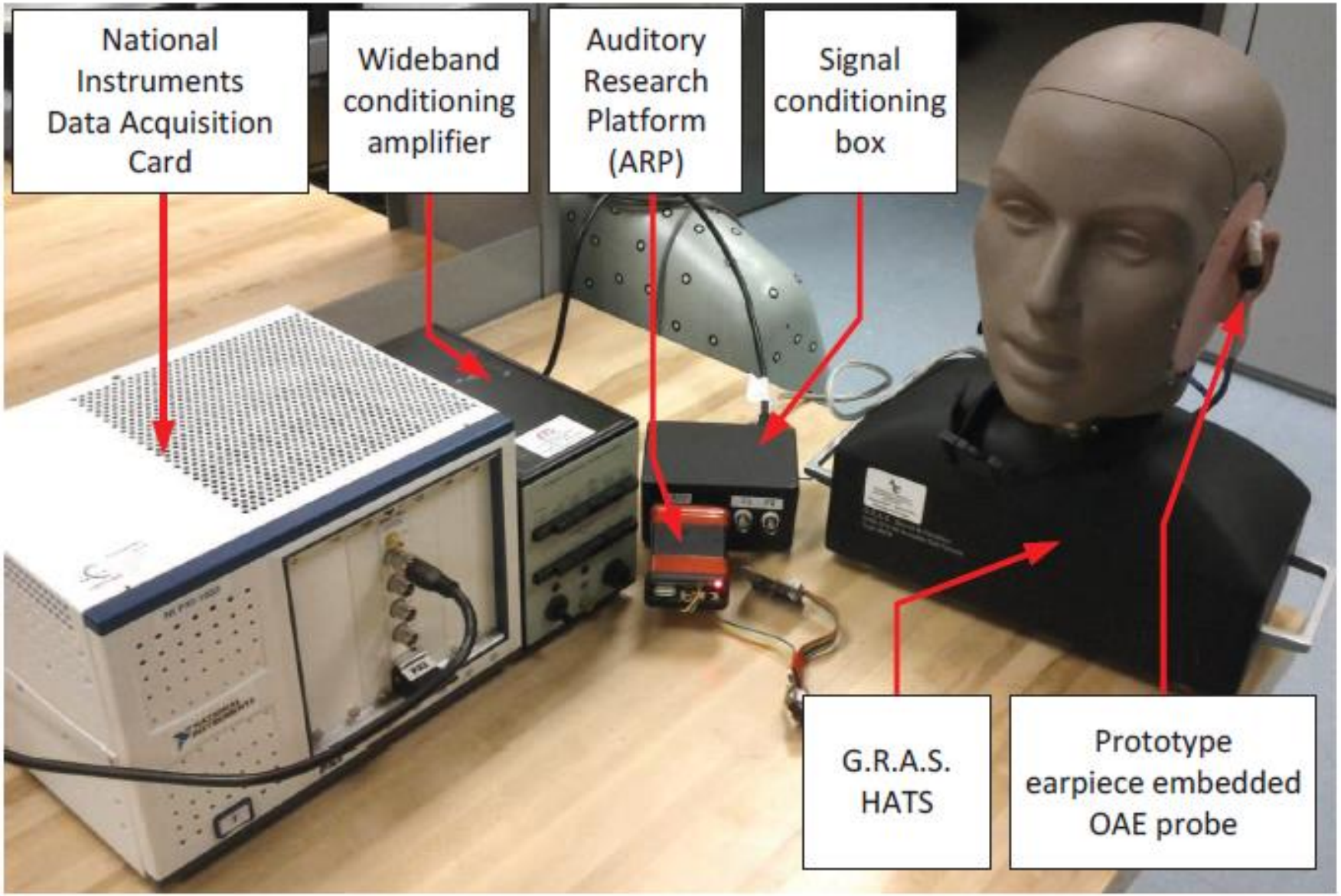

OAE probe transfer function
H(z)
Physiological
Noise in
Occluded Ear
canal
Loud
External
Noise
OEM-I
IEM-I
f1(t)
f2(t)
Tested ear DPOAE probe
IEM-C
OEM-C
Contra-lateral DPOAE probe
Loud
External
Noise


OAE probe transfer function H(z)
Physiological Noise in Occluded Ear canal
Loud External Noise
OEM-I
IEM-I
IEM-C
OEM-C
Loud External Noise
f1(t)
f2(t)
Auditory Research Platform (ARP)
Tested ear DPOAE probe
Contra-lateral DPOAE probe
Stage 1
Stage 2
d1(n)
e1(n)
y1(n)
x1(n)
Adaptive filter
d2(n)
e2(n)
y2'(n)
y2(n)
x2'(n)
Ĥ(z)
x2(n)
Adaptive filter
OAE and noise level processing
DPOAE level
Noise2sd level
Bandpass filter
Bandpass filter
Bandpass filter
OAE enhancer
Adaptive noise reduction


Stage 1
Stage 2
$f_{dp}$
Bandpass filter
$f_{dp}$
Bandpass filter
$f_{dp}$
Bandpass filter
d1(n)
e1(n)
y1(n)
x1(n)
Adaptive filter
d2(n)
e2(n)
y2'(n)
y2(n)
x2'(n)
$\hat{H}(z)$
x2(n)
Adaptive filter
OAE enhancer
Adaptive noise reduction


National Instruments Data Acquisition Card
Wideband conditioning amplifier
Auditory Research Platform (ARP)
Signal conditioning box
G.R.A.S. HATS
Prototype earpiece embedded OAE probe

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# Validation

- Tests conducted
  - in double-wall audiometric booth;
  - on 8 otologicaly normal human subjects;
- Comparison with a clinical reference system;
  - in quiet conditions;
  - against Otodynamics ILO DPEchoport
- DPOAE Measurements
  - with white noise , condition [W70]
  - with industrial noise fragments (NOISEX database)
  - at 3 different sound pressure levels
    - 65dB(A), condition [I65]
    - 70dB(A) , condition [I70]
    - 75dB(A) , condition [I75]

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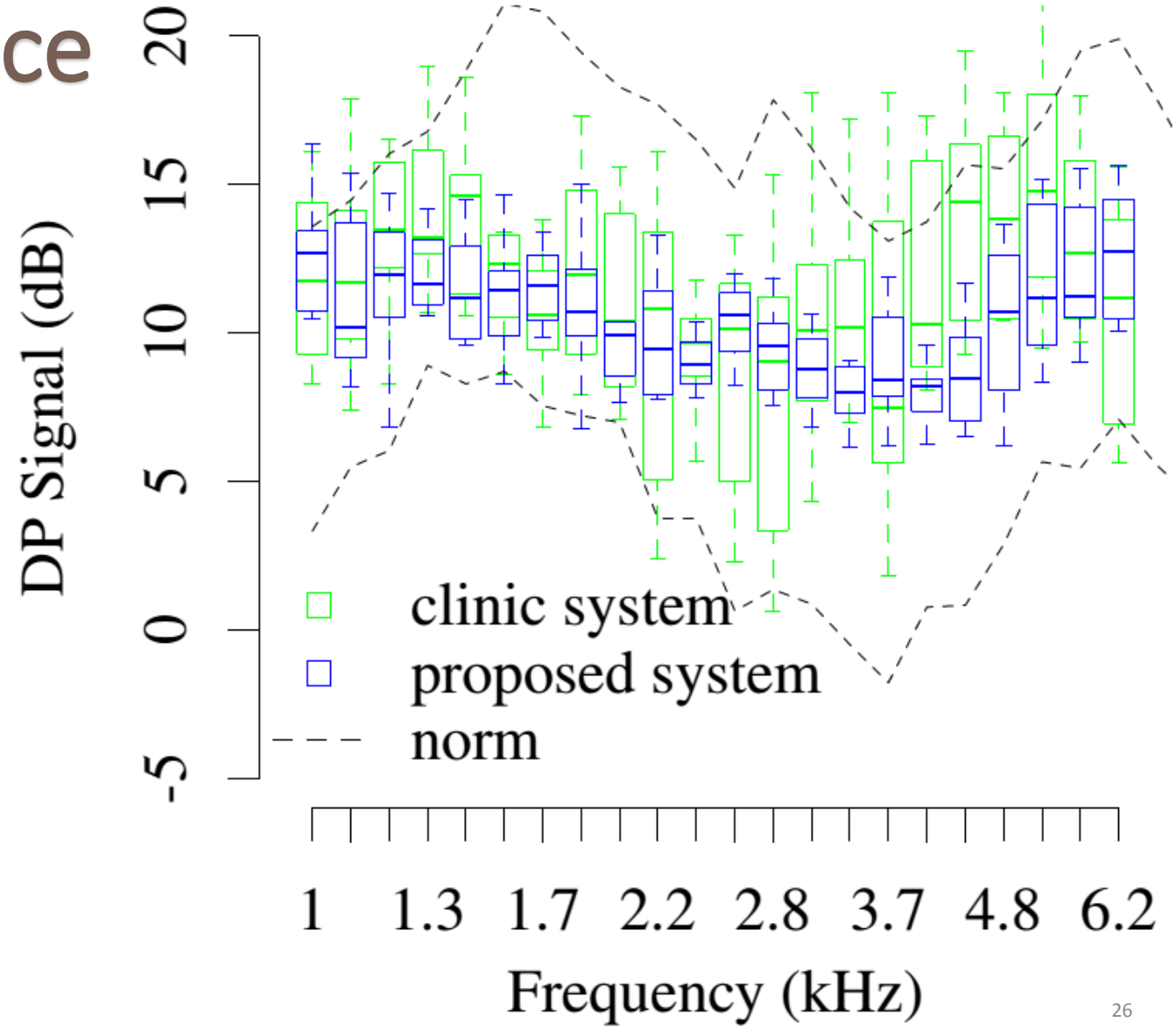
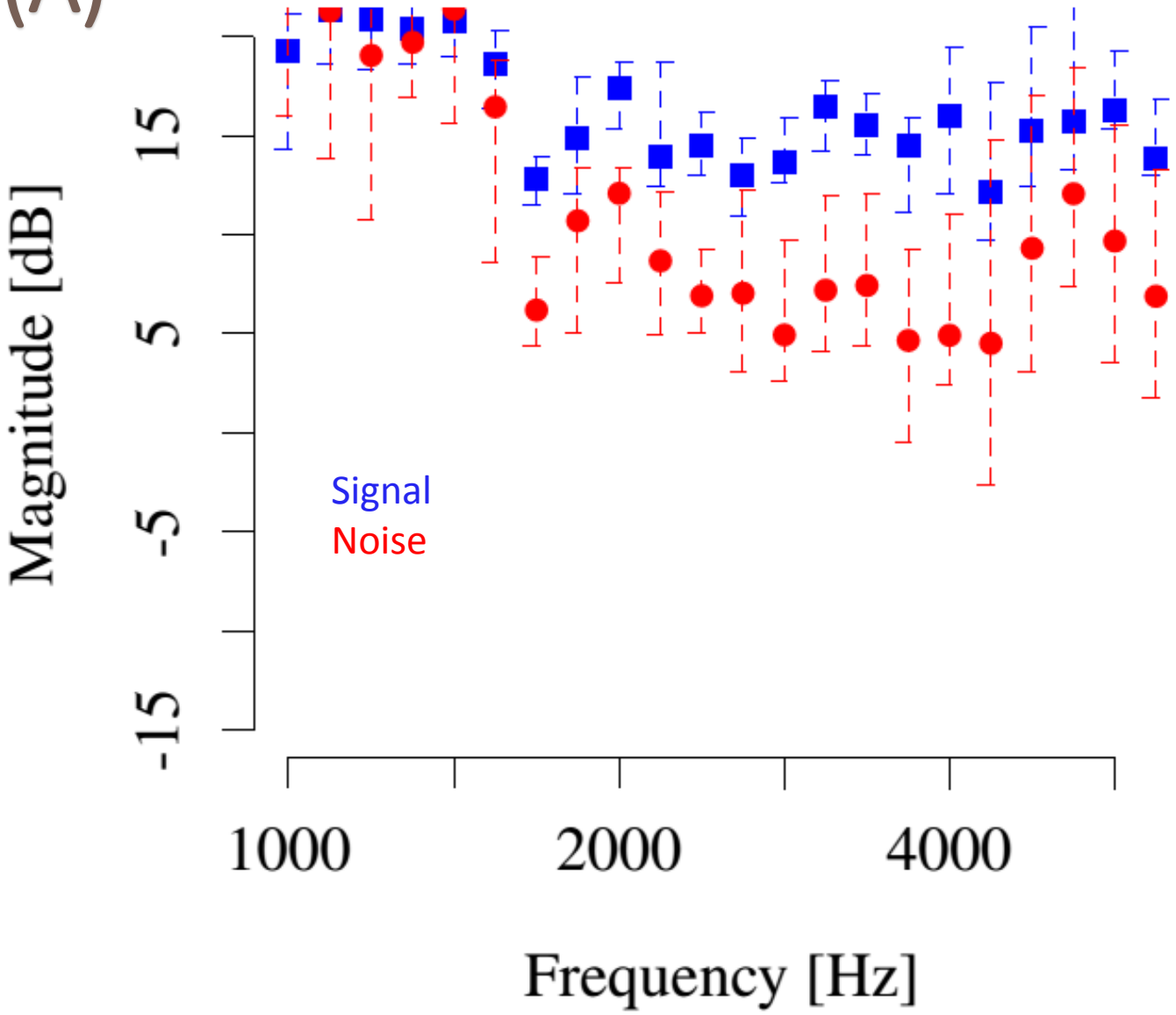
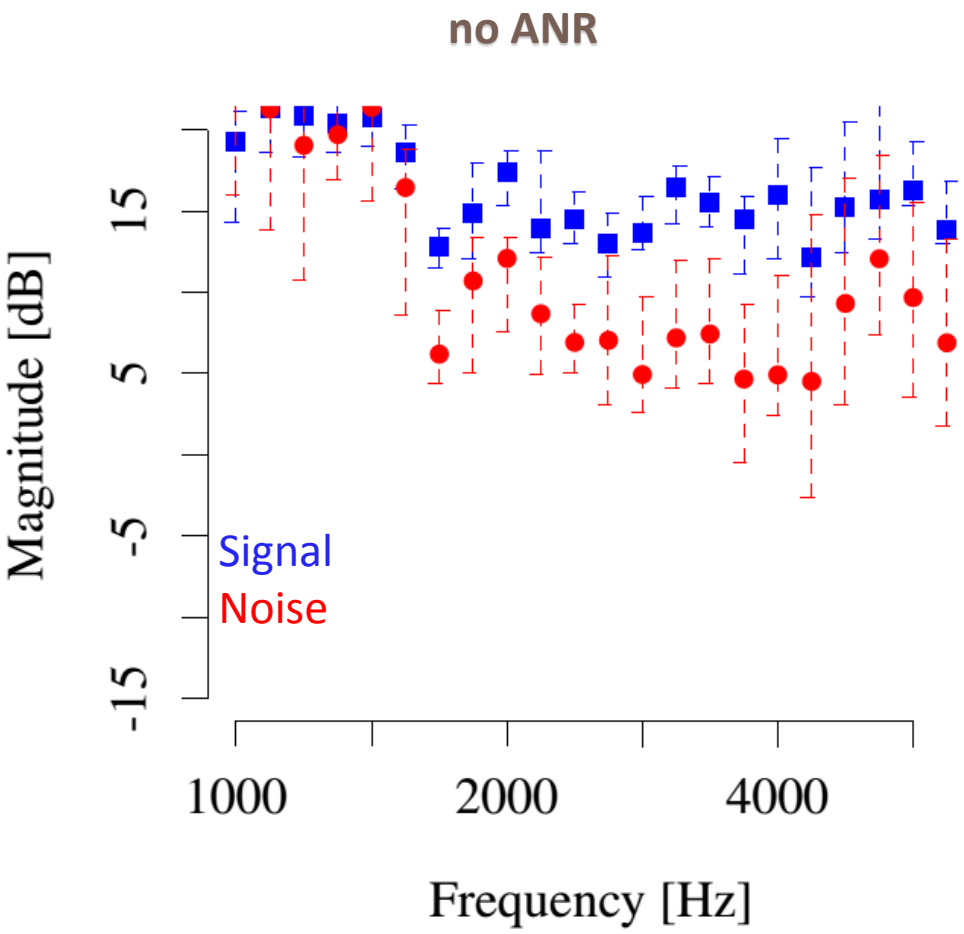
# Results in silence

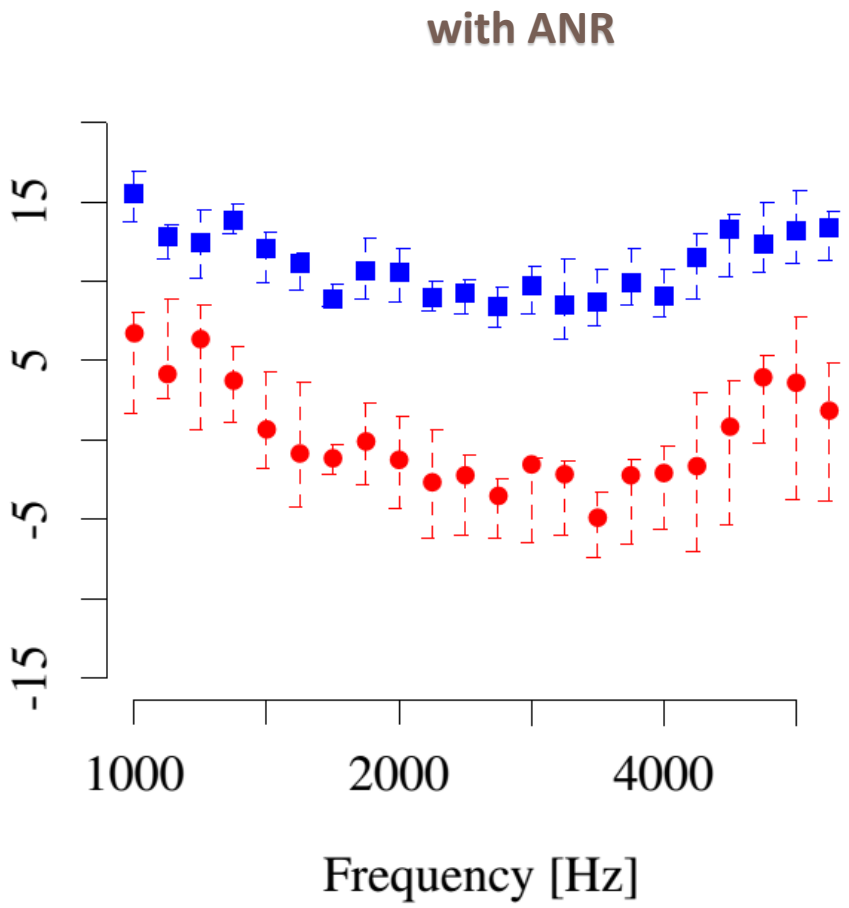


# Results at 70dB(A) no ANR

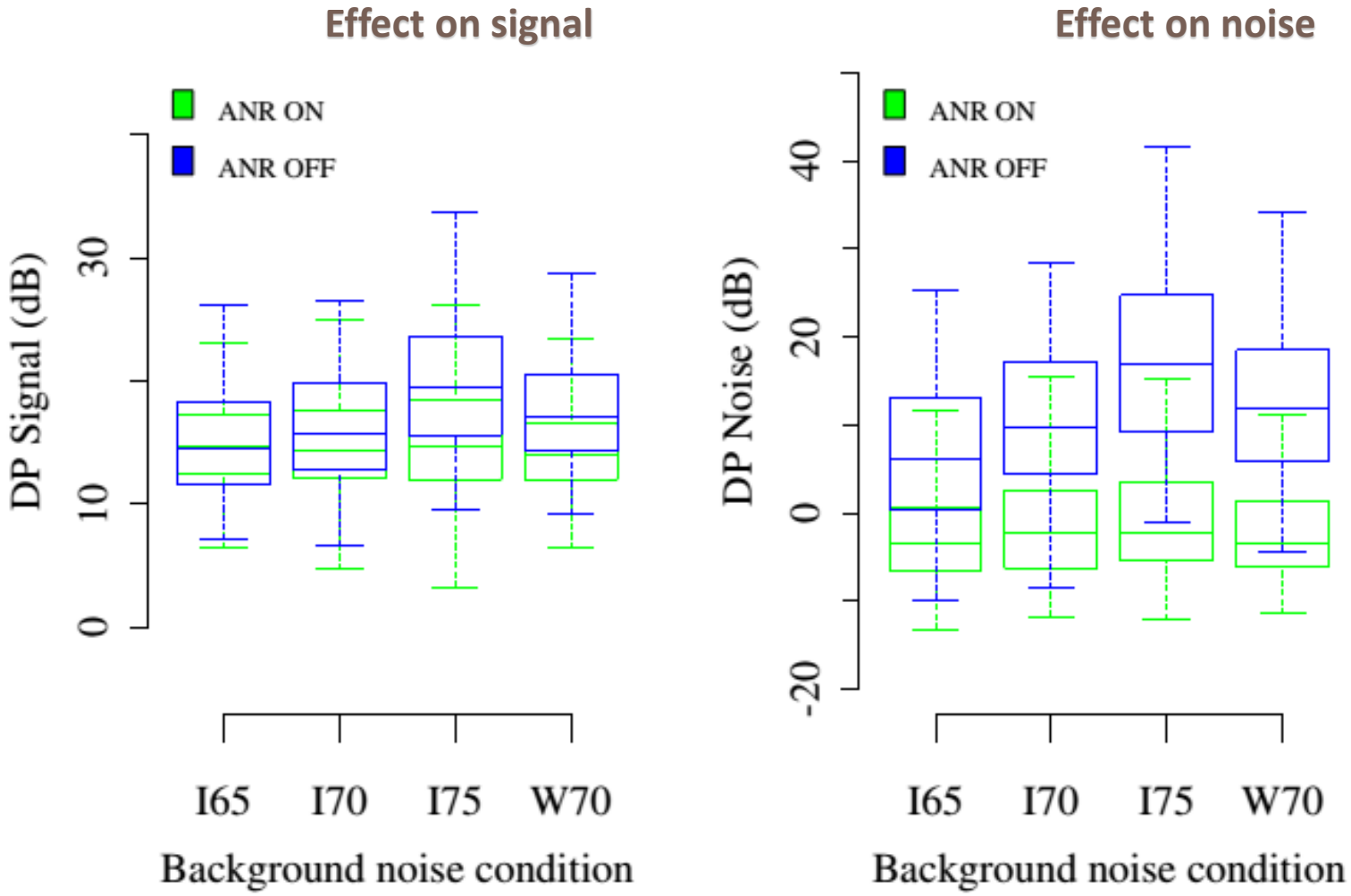


# Results at 70dB(A)



# Results

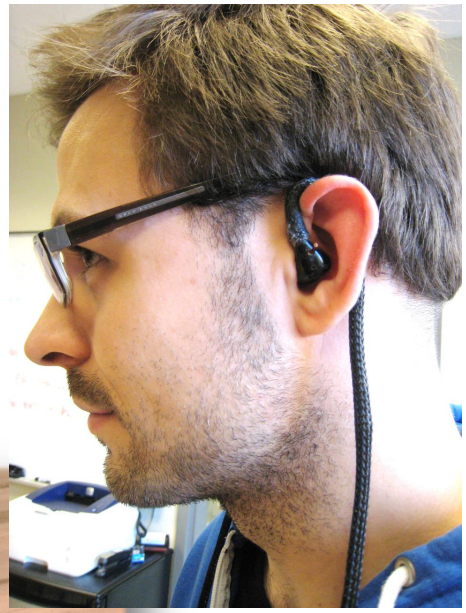

Effect on signal
ANR ON
ANR OFF
DP Signal (dB)
0
10
30
I65
I70
I75
W70
Background noise condition
Effect on noise
ANR ON
ANR OFF
DP Noise (dB)
-20
0
20
40
I65
I70
I75
W70
Background noise condition

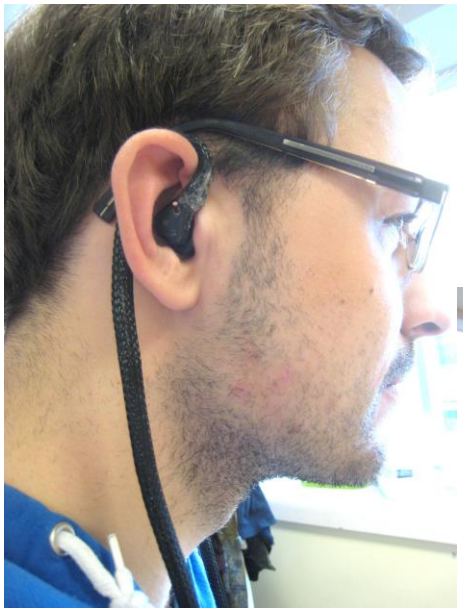
# Conclusions

- A prototype of a hearing protector that continuously monitor's the hearing health status was successfully developed.

- The developed noise reduction algorithm can reduce physiological as well as ambient noise.

- Conducted tests have shown that it is possible to measure DPOAEs in environments with ambient noise levels up to 75dB(A).





# Future work

- Real world validation on a larger group;
- Automatically warn the wearer when a DPOAE shift is detected;
- Integration of an in-ear dosimeter to link the noise exposure to the auditory fatigue and assess personal exposure limit;
- Warn the wearer when he has reached his personal exposure limit.

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