The Smart Hearing Protection Device: System Evaluation

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1- Background

Approximately 15 % of North Americans between the ages of 20 and 69 suffer from hearing loss due to noise exposure either at work or during leisure activities [1].

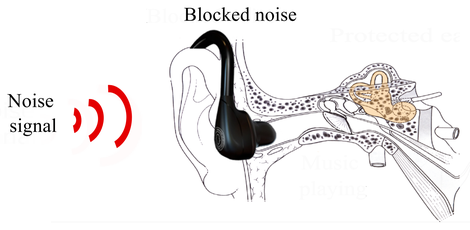
The wear of hearing protection devices (HPDs) represents the best and less expensive solution to protect the ear from hazardous noise levels.

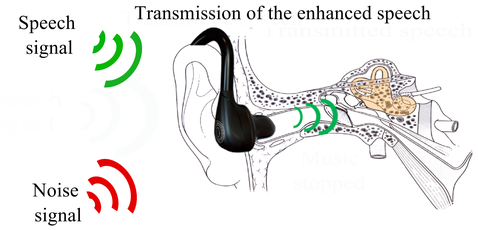
Unfortunately current HPDs block not only unwanted sounds such as background noise, they also block wanted sounds such as speech.

2- Proposed Solution

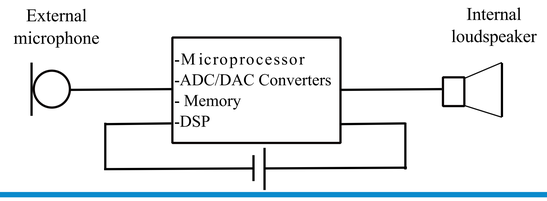
The Smart Hearing Protection Device (S-HPD):

An active HPD that guarantees protection while discriminating between speech and noise to allow noise reduced speech signals to get through to the protected ear.

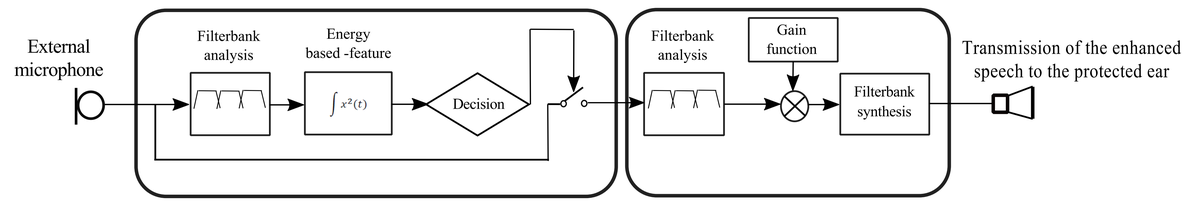




The hardware components embedded in the envisioned S-HPD are illustrated below:



3- The Algorithms



4- Hardware Implementation and Real-Time Evaluation

Steps followed:

1. Voice activity detection and noise reduction algorithms implementation in the S-HPD platform.
2. Speech and noise playback in an audiometric booth with 5 and 0 dB Signal-to-Noise Ratio (SNR).
3. Signals recording through the HATS mic with and without the S-HPD.
4. Off-line evaluation of the recorded signals using objective metrics.

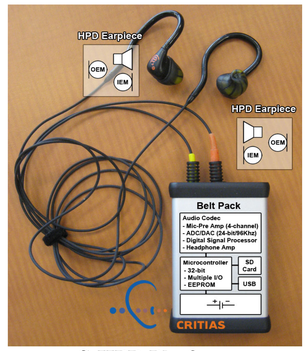
Two objective evaluations:

1. Speech detection assessment by calculating the true and false positive rates.
2. Noise reduction and speech quality assessment by calculating the frequency weighed segmental SNR (fwsegSNR), and the perceptual evaluation of speech quality (PESQ).

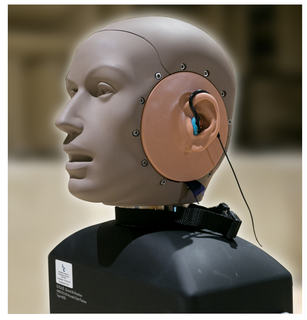
Speech and Noise databases

Speech from the TIMIT database [5] corrupted by Buccaneer noise from the NOISEX database [6].

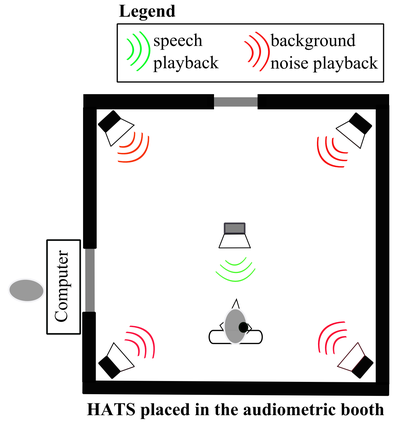
Noise level measured at the HATS mic and fixed to 80 dBA. Speech level measured at the HATS mic and fixed to 75 dBA, and 80 dBA.



S-HPD Platform



HATS wearing the S-HPD



HATS placed in the audiometric booth

6- Results

Speech Detection Assessment

True positive rate (TPR) and false positive rate (FPR) of the voice activity detection algorithm.

SNR (dB)	TPR(%)	FPR(%)
5	83.6	0
0	70.5	0

Noise reduction Assessment

The PESQ and the fwsegSNR calculated for the recorded signals with and without the S-HPD.

Metric	SNR (dB)	without S-HPD	with S-HPD
pesq	5	2.03	2.14
	0	1.90	2.29
fwsegSNR	5	-6.71	-4.93
	0	-7.06	-5.54

7- Contributions

The S-HPD enables:

- Detection of speech,
- Protection from noise,
- Reduction of the the background noise when speech is present,
- Enhancement of the perceptual quality of the speech signal compared to the noisy signals.

As future work, subjective evaluation of the S-HPD needs to be performed.

References

[1] NIDCD, National Institute on Deafness and Other Communication Disorders, "Noise Induced Hearing Loss", 2016.
[2] N.Lezzoum, G.Gagnon, and J.Voix. "Voice activity detection system for smart earphones". IEEE Transactions on Consumer Electronics, 2014.
[3] N.Lezzoum, G.Gagnon, and J.Voix. "A Demonstration of a Single Channel Blind Noise Reduction Algorithm with Live Recordings". International Conference on Acoustics Speech and Signal Processing, Show and Tell 2014.
[4] J.Voix, N. Lezzoum and G.Gagnon "Evaluation of a digital earplug featuring a multi-band adaptive gain control noise reduction algorithm for enhanced audibility in noisy environments", International Conference in Sound and Vibration, 2015.
[5] V.Zue, S.Sennef and J.Glass. "Speech database development: TIMIT and beyond". Speech Communication, 1990.
[6] NOISEX-92, 2012. Rice University e digital signal processing (DSP) group.