Objective Audiometry in Hearing Aids
Agenda

• Introduction to ear-EEG
• Ear-EEG based hearing threshold estimation
• Perspectives of ear-EEG in hearing aids
Ear-EEG (sketch of principle)
Electric Fields in the Ear

Early Prototype Platform

Dry-Contact Instrumentation

Input impedance: $> 10\,\Omega$.
Noise: $< 0.05\,\mu V/\sqrt{Hz}$.
2×14 bit ΣΔ-ADC.
Nyquist sampling rate 500 Hz.
Power consumption: $< 200\,\mu W$.
Technology: 180 nm TSMC CMOS.

High-Density Ear-EEG

15 electrode ear-EEG

Objective
Evaluate the feasibility of ear-EEG in audiometric characterization of hearing thresholds.

Significance
Ear-EEG can be integrated into hearing aids, thereby allowing hearing assessment to be performed by the hearing instrument.
Method (1/2)

Subjects
- 15 normal-hearing subjects (30 ears included)
- 19 hearing impaired subjects (31 ears included)

Recordings
- Auditory steady-state response (ASSR) recorded from 3 scalp and 12 ear electrodes.

Stimulus
- Narrow band CE-Chirps centered on 0.5, 1, 2 and 4 kHz.
- Presentation levels: Starting with 45 dB nHL for 500 Hz and 35 dB nHL for 1, 2, and 4 kHz, decreasing down to -5 dB nHL in 5 dB steps.
- Repetition rates:
  - left ear: 88.5, 89.5, 90.5 and 91.5 Hz for the 0.5, 1, 2, and 4 kHz chirps.
  - right ear: 88, 89, 90 and 91 Hz for the 0.5, 1, 2, and 4 kHz chirps.
Method (2/2)

Electrode configurations

C. B. Christensen et al., “Ear-EEG based objective hearing threshold estimation evaluated on normal hearing subjects”, under review IEEE TBME.
Results (1/2)

Normal hearing subjects

Hearing impaired subjects
Results (2/2)

Normal hearing subjects

Hearing impaired subjects

[Graphs showing the results for normal and hearing impaired subjects with various threshold measurements and statistical significance levels marked with stars.]

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HEARING AID DEVELOPERS FORUM
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Perspectives for ear-EEG in hearing aids

Audiometry in hearing aids:
• Hearing threshold
• Masking
• Compression
• …

Feedback to audio processing
• Auditory attention
• Listening effort
• Fatigue
• …

Brain-computer interfaces (Passive BCIs)
• Mental state / capacity
• Training / rehabilitation
• …

Health monitoring
• Stress level
• Sleep quality
• Progression of hearing impairment
• …