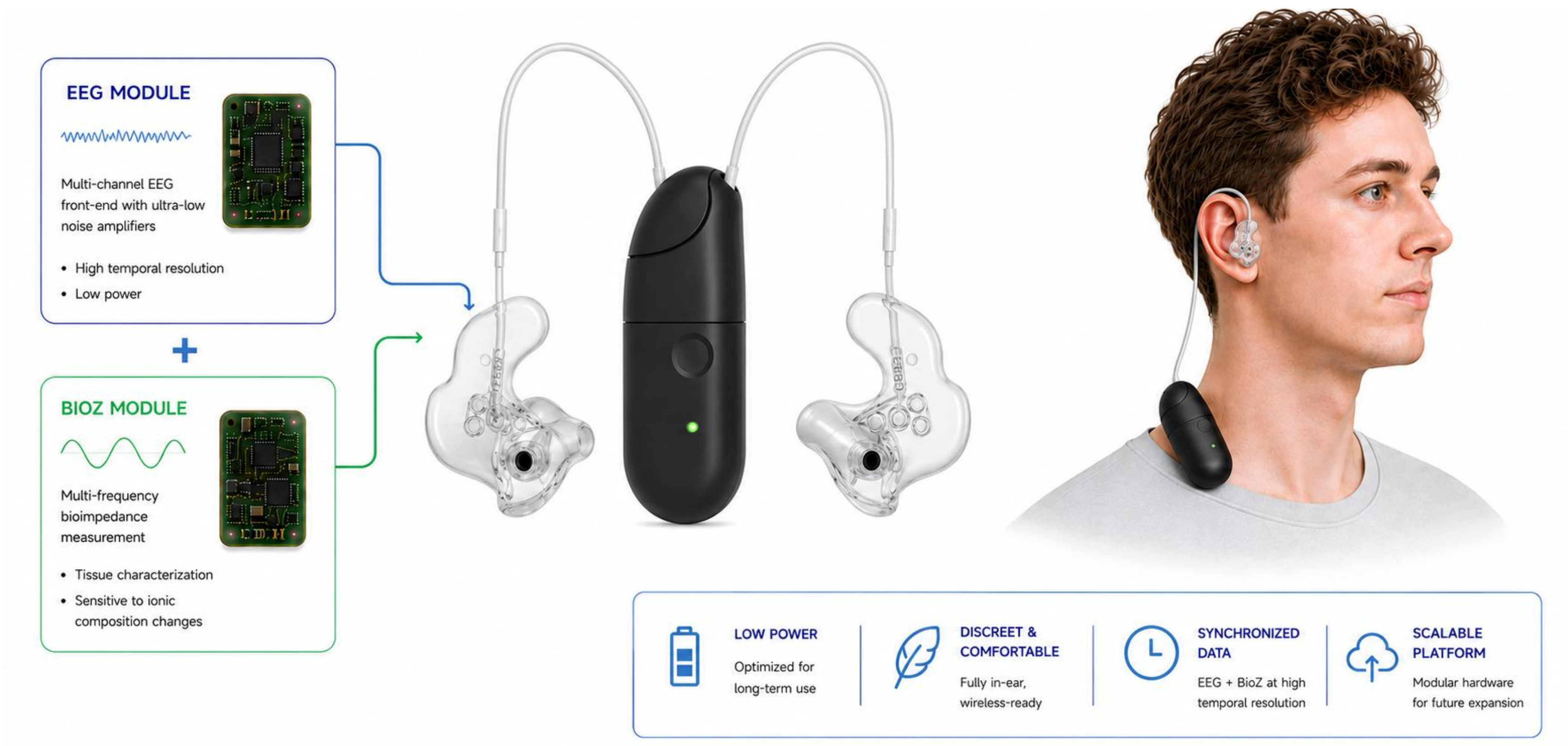
Institute of Mechanical and Electrical Engineering

Collaborators

Wearable Design and Multi-Modal Monitoring of Brain Disorders

Presented by:
Alexander Borch Kristensen, PhD Researcher, University of Southern Denmark, SDU Microelectronics

With it's scalability, high-temporal resolution, and portability Electroencephalography (**EEG**) is one of the most popular modalities for recording instantaneous physiological activity in the brain. Transcranial bioimpedance (**BioZ**) as a modality offers physical characterization of the underlying tissue, reflecting instantaneous cerebral components information. The **NeuroEar** project aims to combine both modalities into one discreet in-ear recording device, with low power consumption, thereby offering long term combined physiological and physical characterization for research in various brain disorders.



Conceptualization of the NeuroEar device, combining EEG and BioZ in a discrete device for long-term measurement. Conceptualization was developed with the use of AI tools (GPT-5.5, OpenAI)

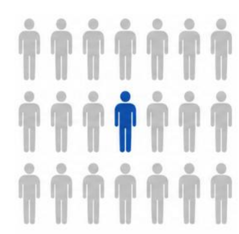
Burden of Epilepsy

~50 million

~50 million people worldwide live with epilepsy

30%

About **30%** of epilepsy cases are resistant to drug treatment



1 in 26

1 in 26 people will develop epilepsy during their lifetime

Background

With challenges posed by the indiscreet nature of conventional EEG, the design of behind-ear and in-ear EEG systems has advanced over the last 1-2 decades. In these systems, electrode density and some of the already low signal-to-noise ratio are sacrificed for extra portability, low power consumption, and comfort. This allows for long-term recordings of individuals in natural settings without restricting their movement.

In-ear EEG is capable of recording temporal lobe seizure characteristics [1], thereby lending itself as a non-restricting, discreet signal for seizure-onset detection. Unrelated to this, bio-impedance has been used to characterize epileptogenic tissue for almost a decade, both to compare the physical tissue properties with those of healthy and scar tissue [2], and more commonly through electrical impedance tomography (EIT), where time-resolved volumetric images are generated from impedance recordings. It is, therefore, well established that bio-impedance changes in response to ictal activity.

Purpose

The NeuroEar project aims to design a low-power, in-ear EEG + BioZ sensing device for long-term recordings. As BioZ reflects the neuroanatomical information and is influenced by ionic composition and distribution in the tissue, we hypothesize this combined data-stream will improve seizure detectability. By clinical testing our hypothesis we will indicate the usefulness of multimodal in-ear sensing for continuous seizure detection with the NeuroEar device.

Methods

First, preliminary measurements of Bioimpedance in parallel with EEG, is recorded to map design specifications and illustrate concept feasibility. Then, a discrete component bioimpedance measurement system, compatible and synchronized with EEG recording system, is implemented on PCB to verify that the specifications can be met. Integrated system on a chip (IC) is implemented for low-power consumption and longevity, ensuring ease of use for patients.

Impact

The low-power wearable NeuroEar device could bring continuous seizure detection into everyday life of patients with drug-resistant epilepsy. Those for whom existing treatment methods often provide insufficient control. Beyond seizure control, the platform enables long-term, real-world recordings of EEG and BioZ simultaneously capturing the brain's electrical and physical activities. This unique multimodal dataset could not only deepen our understanding of epilepsy but form the foundation of monitoring and studying a broad range of neurological disorders in natural settings.

References

[1] Zibrandtsen, I.C., Kidmose, P., Christensen, C.B., & Kjaer, T.W. (2017) Ear-EEG detects ictal and interictal abnormalities in focal and generalized epilepsy – A comparison with scalp EEG monitoring. *Clinical Neurophysiology*, **128**, 2454–2461.

[2] Lagarde, S., Modolo, J., Yochum, M., Carvallo, A., Ballabeni, A., Scavarda, D., Carron, R., Villeneuve, N., Bartolomei, F., & Wendling, F. (2024) Modification of brain conductivity in human focal epilepsy: A model-based estimation from stereoelectroencephalography. Epilepsia, 65, 1744–1755.