# A Wearable System Based on Cooperative Sensors for Multi-lead ECG Monitoring and Electrical Impedance Tomography Imaging

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*Most of the currently available electrical impedance tomography (EIT) systems are limited by the number of electrodes. In view of overcoming this limitation we have developed a fully wearable EIT system based on cooperative sensors which allows for a variable number of electrodes. Another advantage of the proposed approach is that synchronous ECG is also recorded. Preliminary measurements on a healthy volunteer are presented.*

The developed system is based on cooperative sensors (CS). CS are a measurement architecture based on active electrodes specially designed for acquiring bio-signals. In contrast to traditional approaches, CS neither require shielded or complex multi-conductor cables nor a central electronic unit. This advantage significantly simplifies their connection and integration in a garment. We have previously shown ambulatory ECG measurement with CS [1]. In this report, we show that our wearable CS system can also be used to simultaneously measure multi-lead ECG and multichannel bio-impedance signals for EIT imaging.

The electronic architecture enabling for this simultaneous measurement of ECG and EIT is detailed in [2]. Figure 1 shows an example of such a system when integrated in a vest. The system consists of one master sensor (black sensor) and an EIT belt with 16 CS (8 for current injections and 8 for voltage measurements). In the present configuration, 64 bio-impedance channels are measured at 80 frames per second and fully in parallel (via frequency-division multiplexing). In the current implementation, 4 CS were added on the thorax to measure additional ECG leads. Moreover, the master sensor has additional sensing functionalities, namely measuring body movements via an accelerometer and quantifying the blood oxygen saturation (SpO2) via an optical system [3].

*Figure 1: System under test made of dry-electrode CS embedded in a vest.*

Figure 2 shows a typical ECG signal measured with CS, and Figure 3 shows a set of raw bio-impedance signals measured during normal breathing (four first cycles) and deep breathing (four last cycles). Raw bio-impedance signals can then be transformed into EIT images using a commonly used reconstruction algorithm such as GREIT [4]. Figure 4 shows an image sequence acquired during a normal breathing cycle. The size variation of the red regions representing the air volume variation in the lungs.

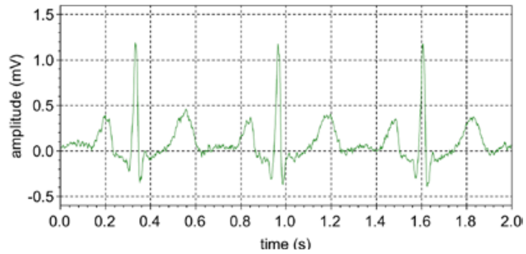


*Figure 2: Typical ECG measured with CS.*

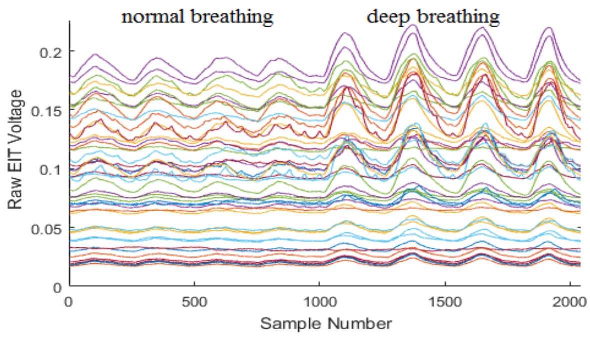


*Figure 3: Raw bio-impedance signals measured with CS (8×8=64 bio-impedance signals).*

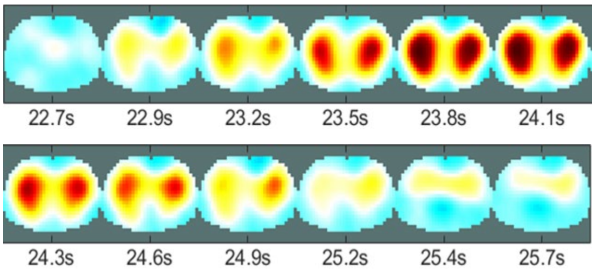


*Figure 4: Typical EIT images sequence reconstructed during a normal breathing cycle.*

In conclusion, this report shows a novel sensor system for ambulatory multi-channel bio-impedance and multi-lead ECG signal monitoring. The device is fully wearable thanks to the CSEM-patented CS technology, which allows connecting the sensors only with a bus of two unshielded wires, and does not require any central electronic unit. Such a system is able to synchronously measure multi-lead ECG and multichannel bio-impedance signals, paving the way towards a new generation of wearable EIT systems for non-invasive cardiovascular monitoring.

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