

Imaging stimulation currents in deep brain stimulation using acousto—electric imaging

Basic Principle: Acousto—electric signal is a result of interaction of pressure and current (Fig 1.). A pressure wave will locally change the density therefore the conductivity of the medium through which it propagates. It causes an increase in conductivity when the pressure falls and a decrease when the pressure rises. Consequently if electrical current is flowing through the medium potential changes will take place and can be measured to reflect the local conductivity of the medium.

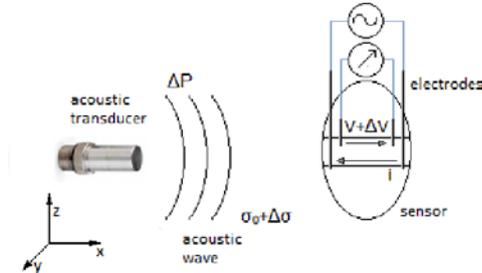


Fig 1. The principle of acousto-electric interaction signal. The pressure wave (ΔP) causes a local change in conductivity ($\Delta\sigma$) of the solution. When electrical current (i) flows between two electrodes, perpendicular to the propagation direction of the acoustic wave, it generates electrical field within specific area. Operating simultaneously, they give a rise to a signal generation (ΔV), measured between two recording electrodes, that is both proportional to the acoustic wave and the current flowing.

The acousto—electric effect can be described by:

$$\frac{\Delta\rho}{\rho_0} = -k_i\Delta P \quad (1)$$

where $\Delta\rho$ is the resistivity change, ρ_0 the direct current (DC) resistivity, ΔP the acoustic pressure, and k_i a constant of interaction whose value is about 0.04%/MPa in cardiac tissue. If an electrical current is flowing through the medium at the same time a periodical voltage change will take place due to the change in conductivity. The resulting acousto—electric signal origin is at the location of the pressure changes. The signal can be described by:

$$V(t) = \iiint_{medium} J^l \cdot J^i (\rho_0 - k_i\Delta P\rho_0) dx dy dz \quad (2)$$

Where J^l is the lead field of the recording electrodes and J^i the distributed current source and V is the signal detected by electrodes. This equation can be broken into a low frequency and a high frequency part as following:

$$V(t) = \iiint_{medium} J^l \cdot J^i \rho_0 dx dy dz - \iiint_{medium} J^l \cdot J^i k_i\Delta P\rho_0 dx dy dz \quad (3)$$

The first term is a low frequency part of the injected current but the second term is the high frequency acousto—electric signal. This signal can easily be filtered from other signals as it is locked to the frequency of the ultrasound wave.

Project Aim: We want to non-invasively map the location, magnitude and polarity of current generated by a clinical deep brain stimulation (DBS) device mounted inside the human brain. Ultrasound with frequency ranges of 1-4 MHz at can be used to modulate the conductivity of the part of the brain as short current pulses are injected across different DBS electrodes. A recording electrode detected the high-frequency acousto—electric signal.

The projects starts with theory and modelling the acousto—electric phenomena in biological tissue then simple excremental setup with single element transducer and electrodes should be used for measuring the acousto—electric signal in vitro (Fig 2).

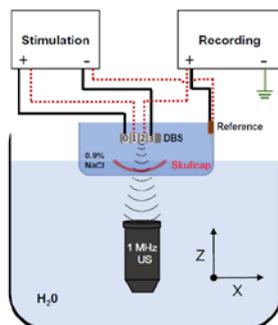


Fig 2. Schematic depicting an in vitro setup for measuring the acousto—electric signal.

In the next step, the setup will be upgraded to include ultrasound linear arrays and combining

the acousto—electric recordings with the pulse echo ultrasound images. For this part a Verasonic vantage 256 ultrasound accusation system will be used (Fig 3.). After this step the method will be validated in vitro in realistic head and brain phantoms. The end point of the project which will be in vivo imaging of the stimulation currents in deep brain stimulation in patient who have undergone operations.

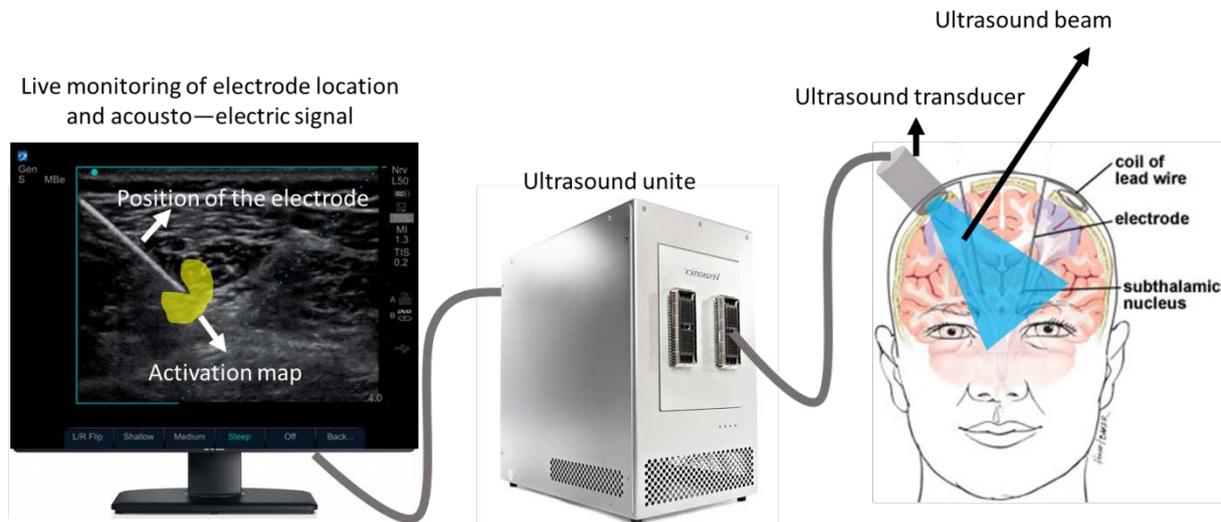


Fig. 3. Schematic depicting the ultrasound imaging and acousto—electric mapping in a patient with implanted electrodes for deep brain stimulation.

Exchange program:

There is a possibility for spending part of your project time in Basel, Switzerland where the clinical part of this study is performed.

Literatures:

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