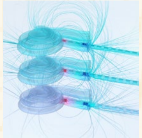

Bringing light to the insertion of cochlear implants using tetrapolar bioimpedance measurements

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Introduction

Impedance measurements from the electrodes of a cochlear implant (CI) have been proposed as a positioning sensor, which do not need integration of extra electronics in the electrode array (EA), to provide feedback during CI surgery [1]. Here, we present a simulation approach to study the feasibility of using tetrapolar impedance measurements to estimate the pose of CIs inside the cochlea.

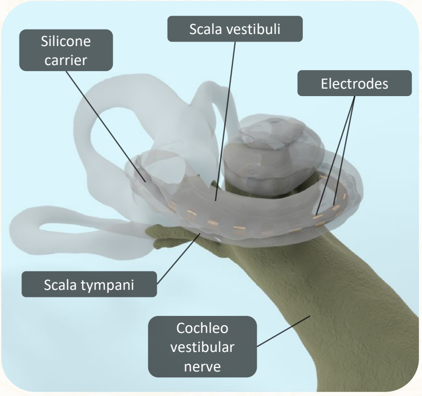

Figure 1 – Cochlear implant electrode array implanted into a human cochlea [2].

Method

Aim: Estimate EA orientation within the cochlea during insertion using tetrapolar impedance measurements.
Approach: Cochlea model and an EA with 4 electrodes inserted into the ST (Fig. 2).

Cochlea model: ST, scala vestibuli (SV) and basilar membrane (BM). Modification of open-source model from [3] for the ST to include SV and BM. Spherical domain around cochlea with bone properties.
EA: 18 mm long; 0.5 mm diameter; 18 Pt electrodes, separated 0.4 mm, with 0.25 mm^2 surface area and 0.01 mm thickness.
FEM model: Electric currents module in COMSOL Multiphysics (COMSOL Inc., Sweden). Conductivities used are reported in [4]. Contact impedance condition applied over each electrode to model electrode-electrolyte interface. Surface capacitance and resistance used are reported in [5].
Assessment: Geselowitz sensitivity theorem and reciprocity to assess the EA geometry. Interchange of current injection and measuring electrodes to check reciprocity.
Simulation: Spectroscopic impedance measurements at 1 kHz, 10 kHz, 100 kHz and 1000 kHz. Electrodes at 0° angle when facing the modiolar wall. Measurements from -120° to 120° in 20° intervals.

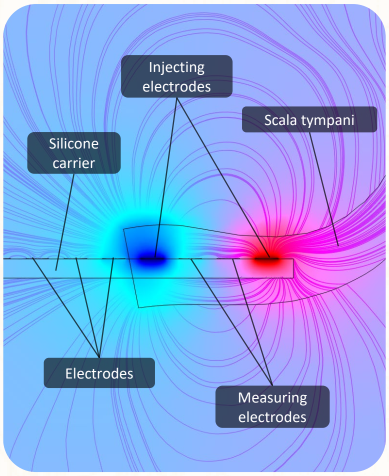

Figure 2 – Cross section showing the components of our model. Surface colours represent the electric potential field and tubes represent the current density.

Results

The impedance measured interchanging injecting and measuring electrodes at 1 kHz to assess reciprocity are 183.34 Ω and 183.42 Ω respectively. In Fig. 3a we show the simulation output at 1000 kHz when the EA is at 0°, 40° and 80°. The impedance values computed for different angles and frequencies are shown in Fig. 3b.

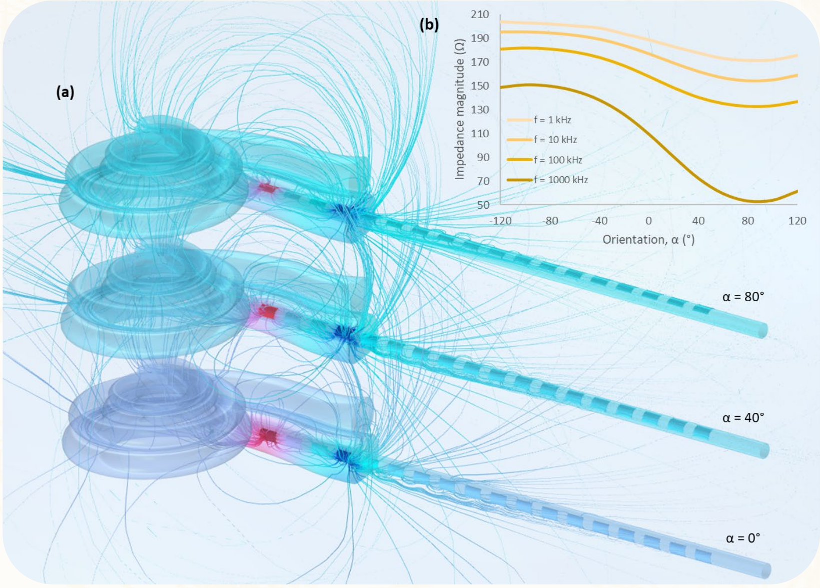

Figure 3 - (a) Surface illustration of the electric potential field in the cochlea and electrode array (EA) model. Tubes represent the current density. (b) Plot showing the change in impedance magnitude for different EA angles and stimulation frequencies.

Discussion

The impedance sensor shown here can be a solution to provide feedback of the EA while it is inserted into the ST. The simulations conducted to study the feasibility of using this sensor satisfy reciprocity with 0.08 Ω error and show that impedance changes as a function of EA orientation.
These results reaffirm that **impedance measurements can be used as a sensor to estimate orientation during CI surgery**.

Future work

- Study impedance for different positions.
- Study how the electrode topology and shape affect the EA sensitivity and in turn, their effect on estimating the EA position and orientation.
- Conduct experiments to validate these findings.

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