DESIGN OF AN INTRA-OPERATIVE IMAGING SYSTEM FOR THE INSERTION OF A COCHLEAR IMPLANT

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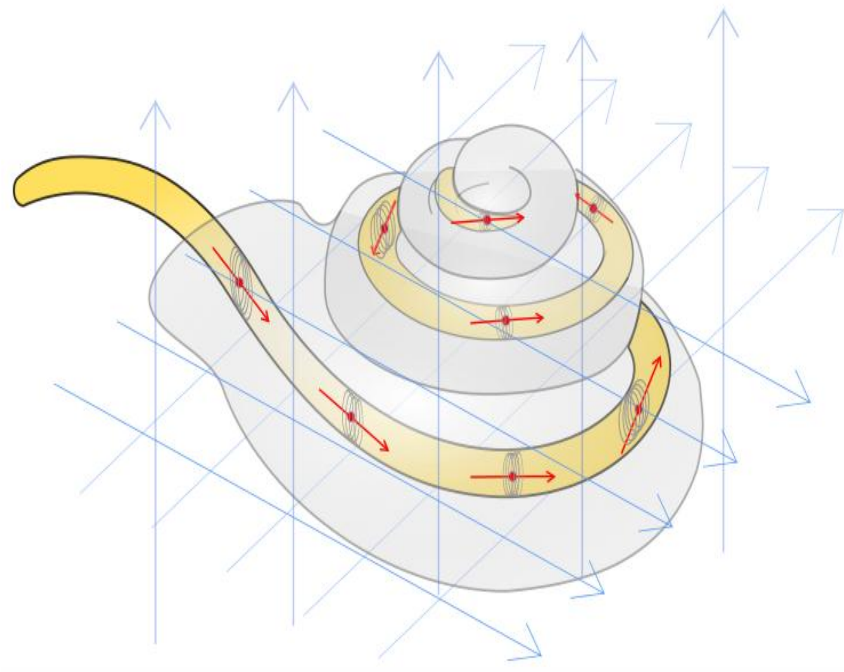
INTRODUCTION

Research has shown that Cochlear Implants perform significantly better in recipients when the placement of the array is located closer to the inner wall of the cochlea corridor. It becomes more difficult to aim for closer proximity, due to the risk of damaging delicate structures along the wall. Currently there are no available live visualization techniques to evaluate electrode placement.



AIM

Visual assistive feedback to the surgeon during an insertion procedure would provide a guide for optimal placement of the electrode while minimizing trauma. A 12-week university project was lead out to create a proof of concept model by using magnetic induction. This thesis project aims to continue to prove feasibility of the system in terms of accuracy, performance, and scale.

INDUCE → SENSE RESPONSE → PRE-PROCESSING → ACQUIRE → FILTER → DEMODULATE → PLOT

SYSTEM APPARATUS

- A set of 3-axis Helmholtz Coils are used to create three orthogonal magnetic fields oscillating at high frequencies.
- A prototype electrode array is developed with densely wounded ablated contacts replacing the traditional pad electrodes.
- Windings can be used together as an inductive sensor array and its contour can be inferred by inducting emfs along the sensors by a magnetic field produced by large external Helmholtz Coils.

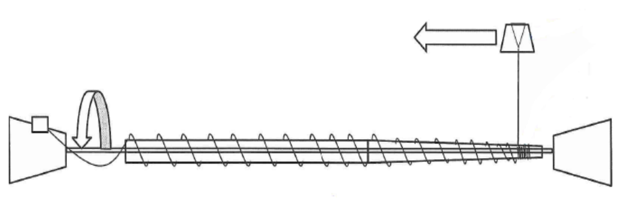
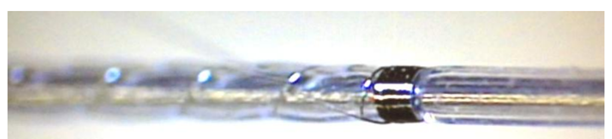
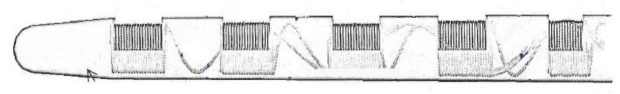


Fig 1. a) Manufacturing process



b) Microphoto of Electrode array



c) Electrode array with ablation technique

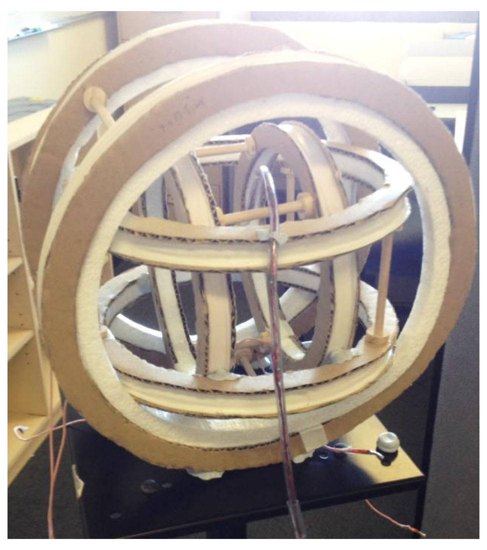
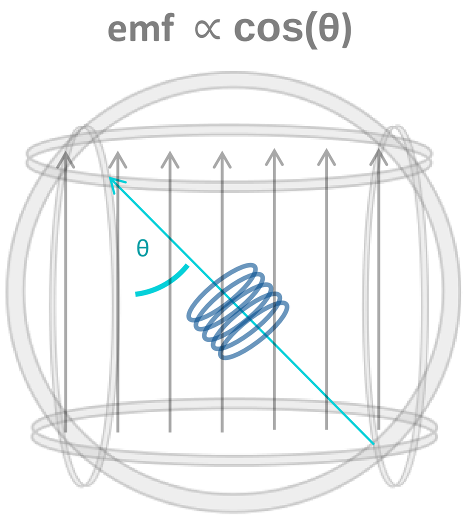


Fig 2. a) Helmholtz system

emf ∝ cos(θ)



b) Helmholtz with one sensor

INDUCE & SENSE

- To maximize the emf (ε) induced across the sensors, in the internal electrode coils, frequency (ω) and number of turns (N) are of concern.

$$\boldsymbol{\varepsilon = -NA\frac{d}{dt}Bcos(\omega t)\ \times cos(\theta)}$$

- Field strength (B) of Helmholtz coils:

$$\boldsymbol{B = \left(\frac{4}{5}\right)^{\frac{3}{2}}\frac{u_0 nI}{r}}$$

- At high frequencies resistance of the coils increase due to the skin effect. Using Litz AWG 38 wire, gives tolerance to skin effect till approximately 180kHz.
- Chosen operating frequencies for each directional field: 85kHz, 103kHz, 120kHz.

ANALOGUE FRONT-END

Tuning and Pre-processing

- Microinductor sensors are tuned by adding a coupling capacitor to band pass centre frequency band 103kHz.
- Adding resistance, widens the bandwidth for emf to pass outer frequencies.

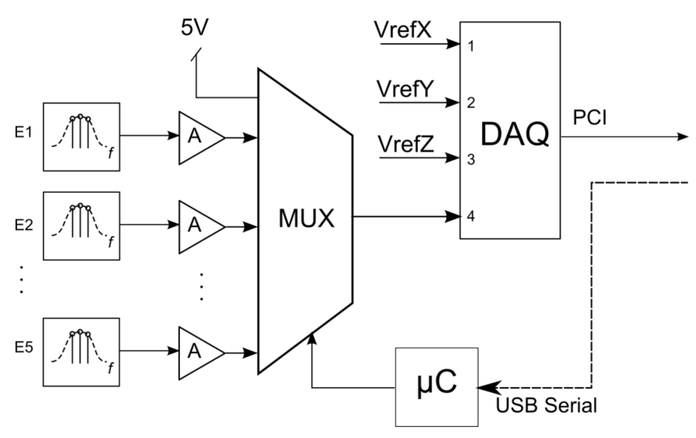
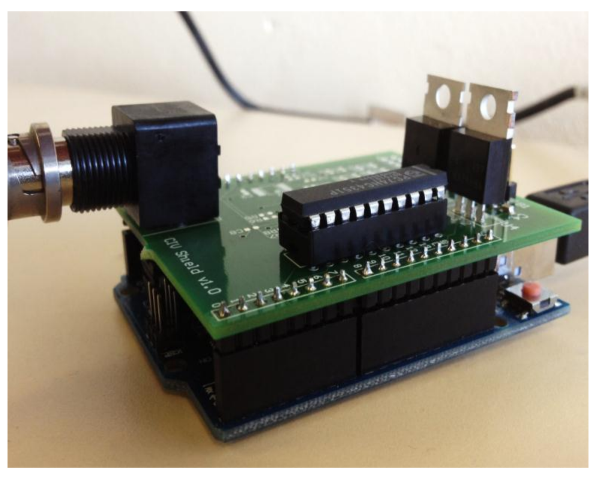


Fig 3. a) Analogue front end design

DAQ Hardware

- Custom made PCB for an Arduino shield to readily interface with sensors and DAQ.
- An Arduino microcontroller used to multiplex and identify the sensor being read, without tethering to computer while sampling.
- PCI-slot 12-bit, 4-ch, synchronous sampling with 10 MS/s (max).



b) Custom Arduino Shield

SIGNAL PROCESSING

Acquisition

- Three reference wave forms from the Helmholtz coils are acquired simultaneously with sensor data. (4 synchronous channels)
- Reference waveforms are required for attaining positive and negative directions, by measuring phase differences.

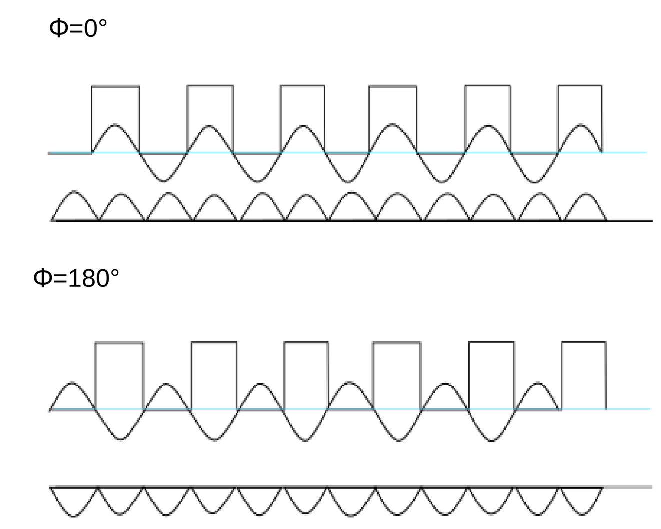


Fig 4. Phase-sensitive Demodulation

- Readings from each sensor are decoded, before extracting orthogonal components by band pass filtering and demodulating with references from each frequency.

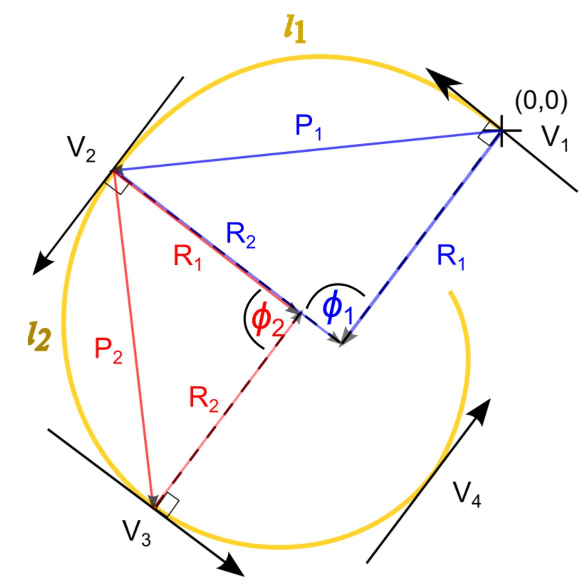


Fig 5. 2D projection of the array's 3D contour reconstruction

Contour Reconstruction

- Three signal components define each orthogonal component of direction vector in 3D space.

$$\hat{\boldsymbol{v}} = \cos\theta_x \boldsymbol{i} + \cos\theta_y \boldsymbol{j} + \cos\theta_z \boldsymbol{k}$$

- Knowing the distances between each sensor allows to approximate contour by constructing uniform radius arcs.

SYSTEM VALIDATION AND PEFORMANCE

- **System validated for 10:1 electrode array model by visualization**
- **Fast to at least 12fps rate.**
- **Adequate processing time available for frame averaging to reduce unsteady change**
- Angular and positional accuracy due to each stage to be verified.

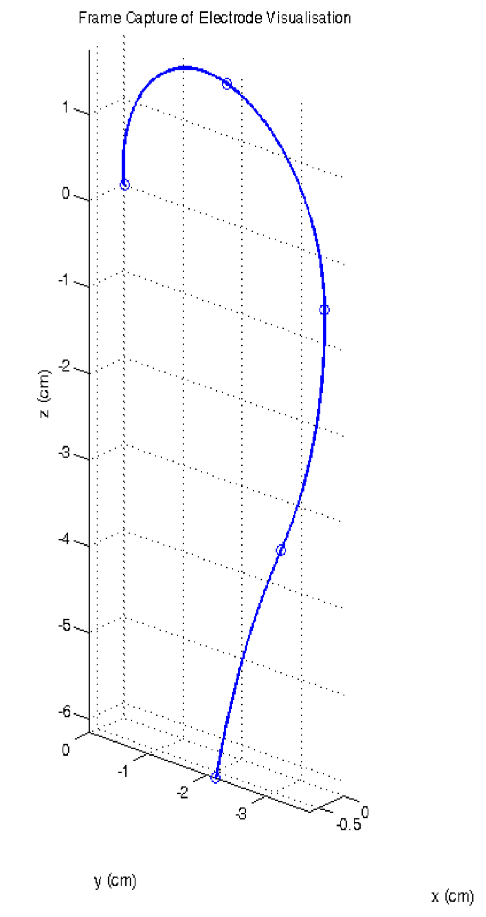


Fig 6. Screenshot of array visualisation

CONCLUSION

The model system was validated, with a fast enough frame rate for live visualization. Frame noise should be reduced by frame averaging. Leveling effective field strengths by increasing supply to Helmholtz coils can also increase resolution. Future feasibility work would look into surveying the feasibility of the system to end user requirements, and reducing cost of design.