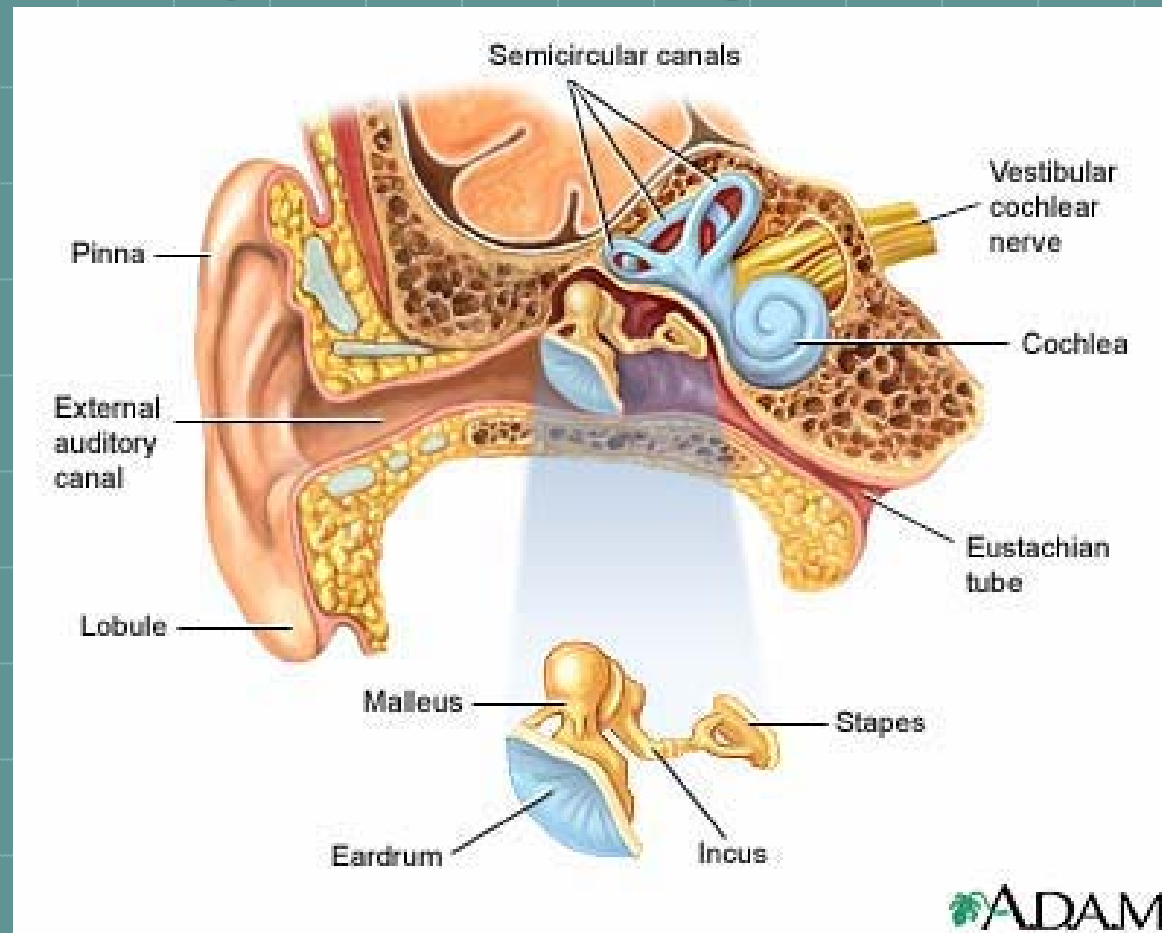


A Three Dimensional Cochlear Implant Simulation With Circuit Model

Weidong Zhang

Ear Anatomy and Hearing Loss (Medline Plus)



Cochlear Implant (NIH)



Drawbacks

- ◆ Unknown current flow and short circuits in the scala tympani require strong current.
 - ◆ Interaction between stimulation points.
 - ◆ Facial nerve stimulation.
 - ◆ High energy consumption.

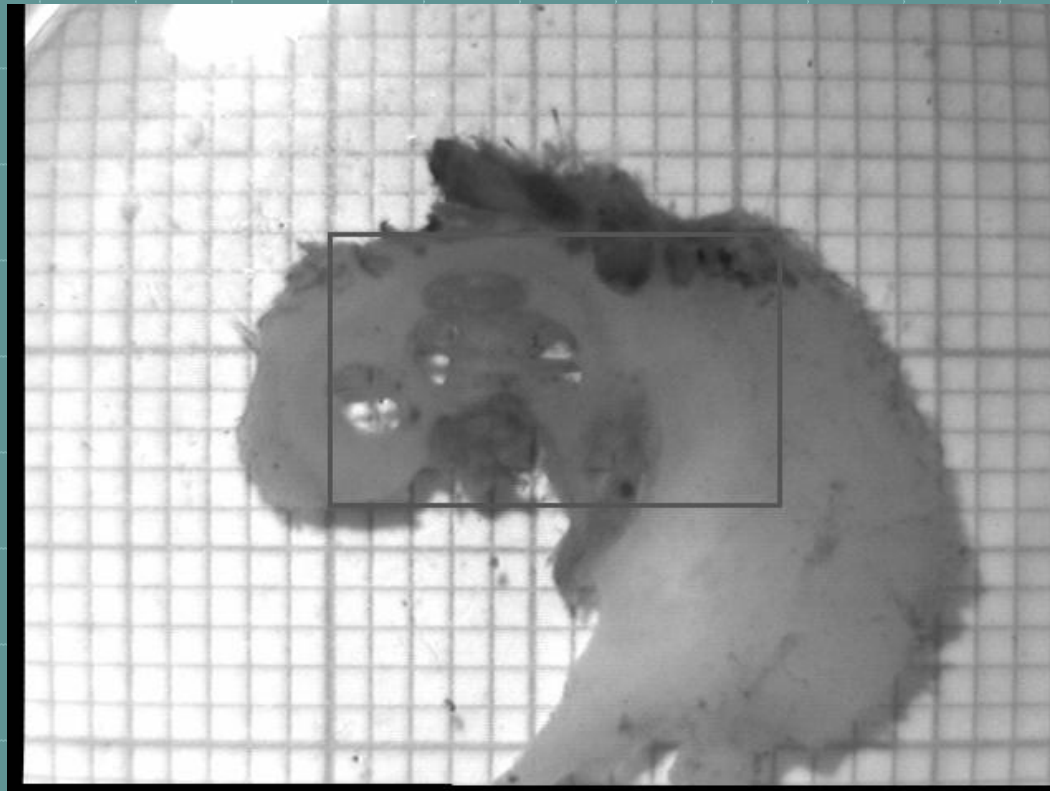
Cochlear Simulation

- ◆ Lumped element model: unroll the cochlear
 - ◆ Finite element method
 - ◆ Passive nerve fiber
 - ◆ Ignore interaction and crossflow
- ◆ Rotationally boundary element model
- ◆ Circuit model

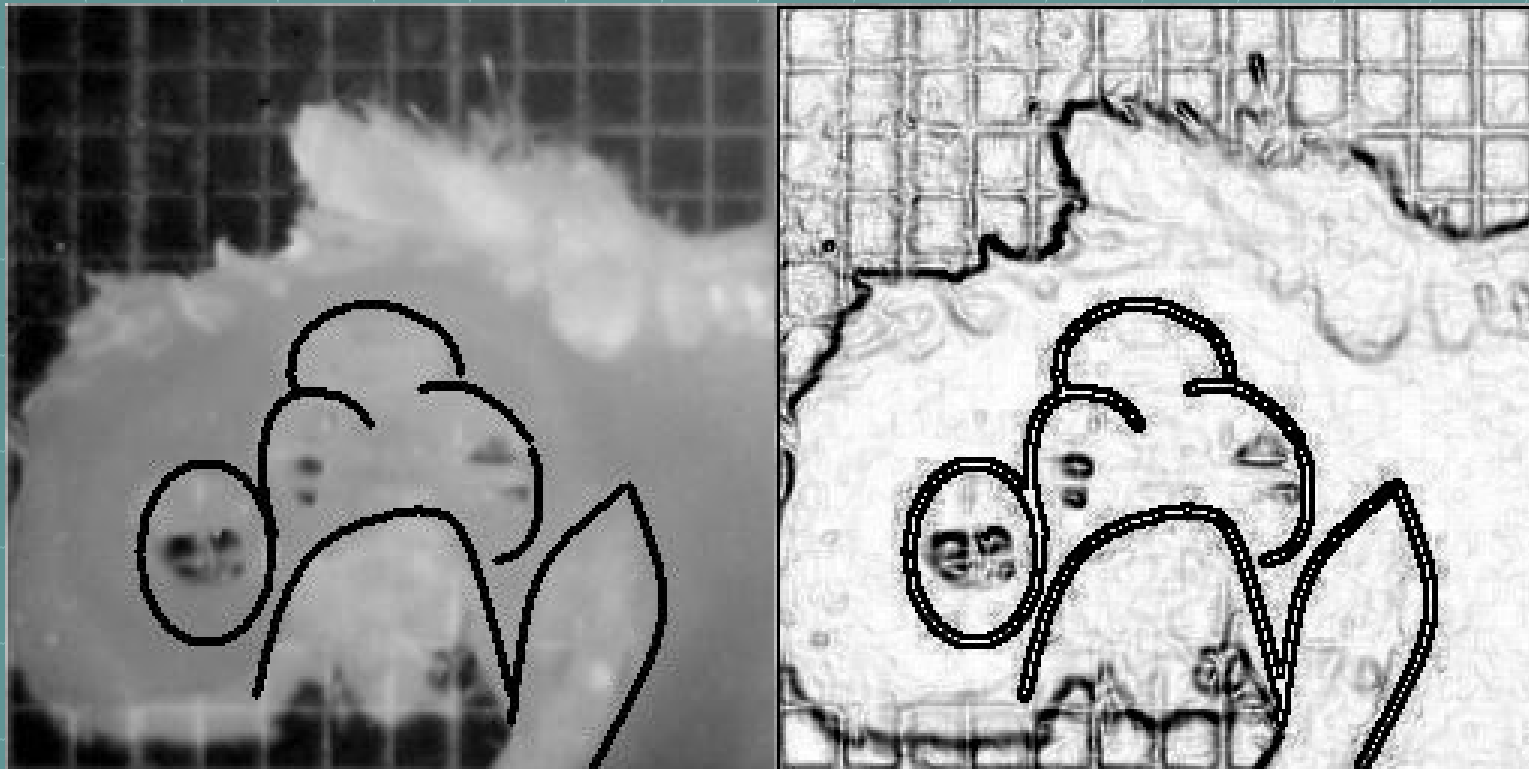
Project Scope

- ◆ Create a 3D circuit model to simulate the cochlear implant.
- ◆ Supply a powerful tool to observe the current flow, to manipulate and simulate the implant.
- ◆ Serves as a base for the future development work.

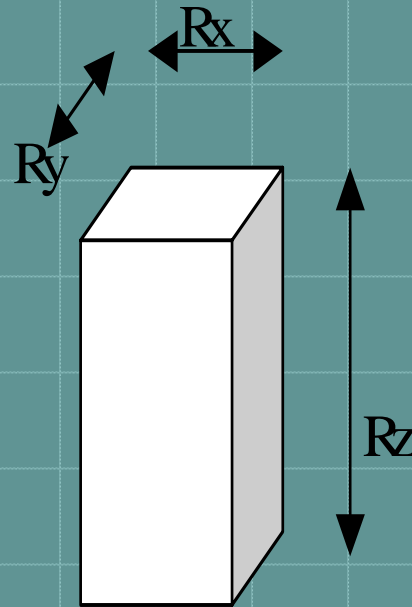
Layer 0 Is Cut Parallel to the Mid-modiolar Plane



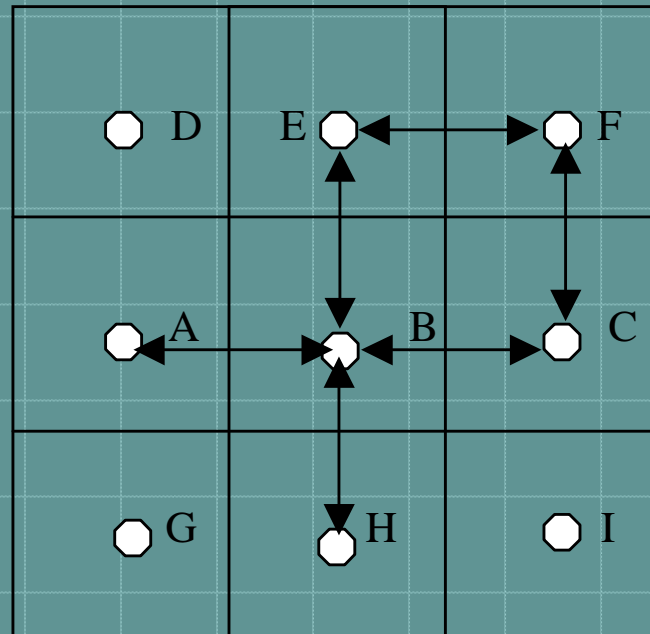
Cochlear Layer Image Processing



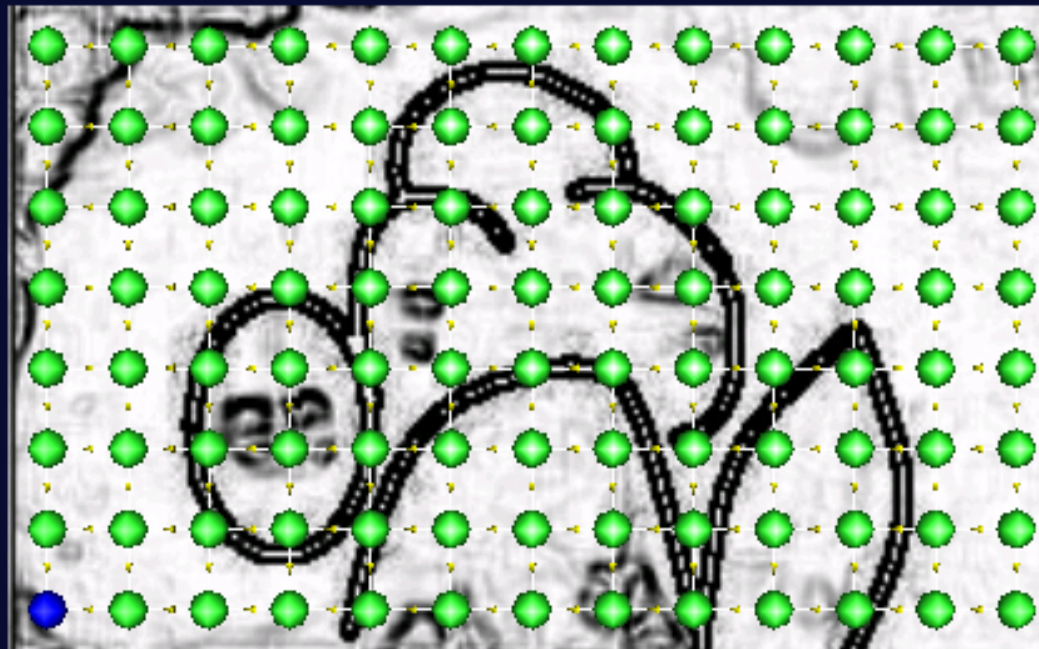
Block and Edge



2D Node Relations in Z Plane



Layer View of Blocks Represented With Nodes



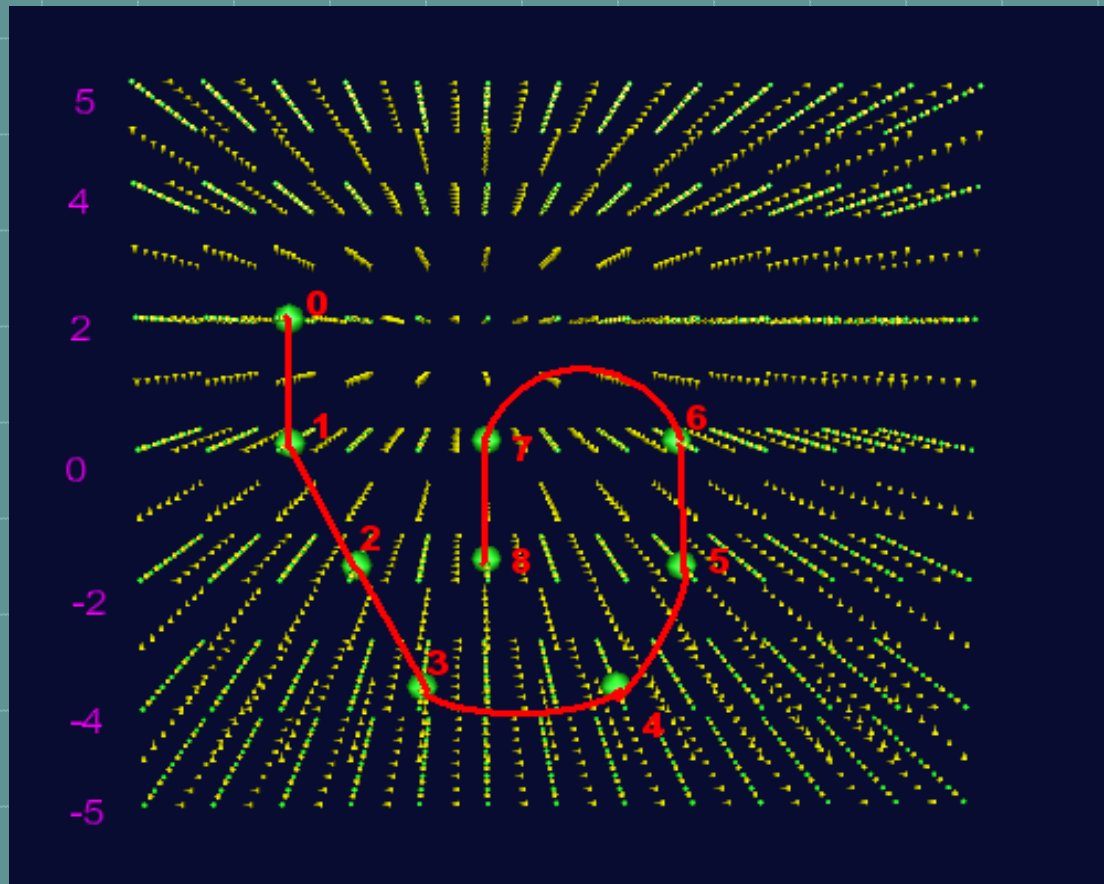
Mathematical Model

$$\sum_j I_{ij} = I_{i-source}$$

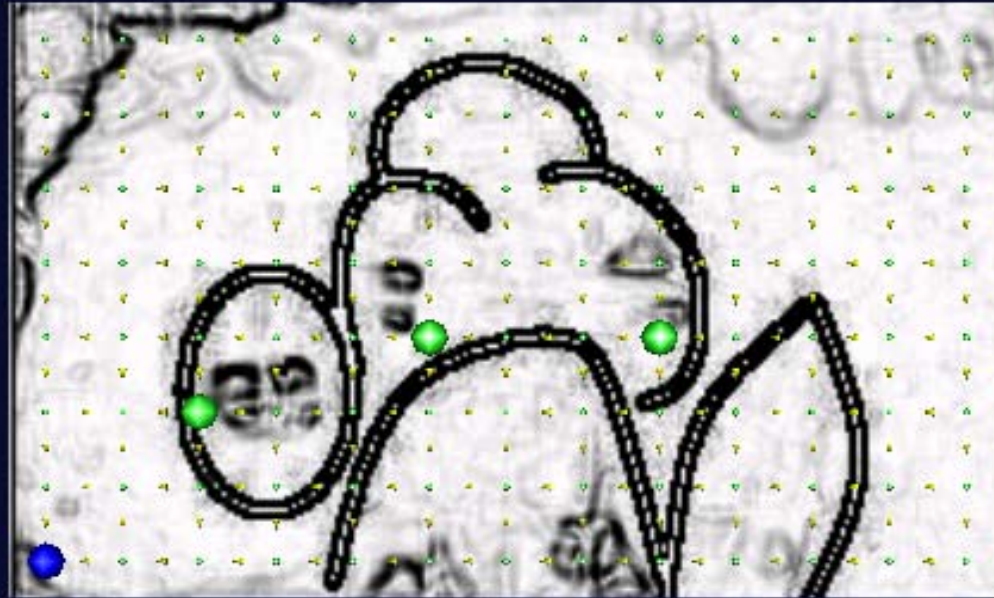
$$U_{i1} - U_{i2} = I_i R_i$$

Boundary Conditions: Known voltage U_i of node

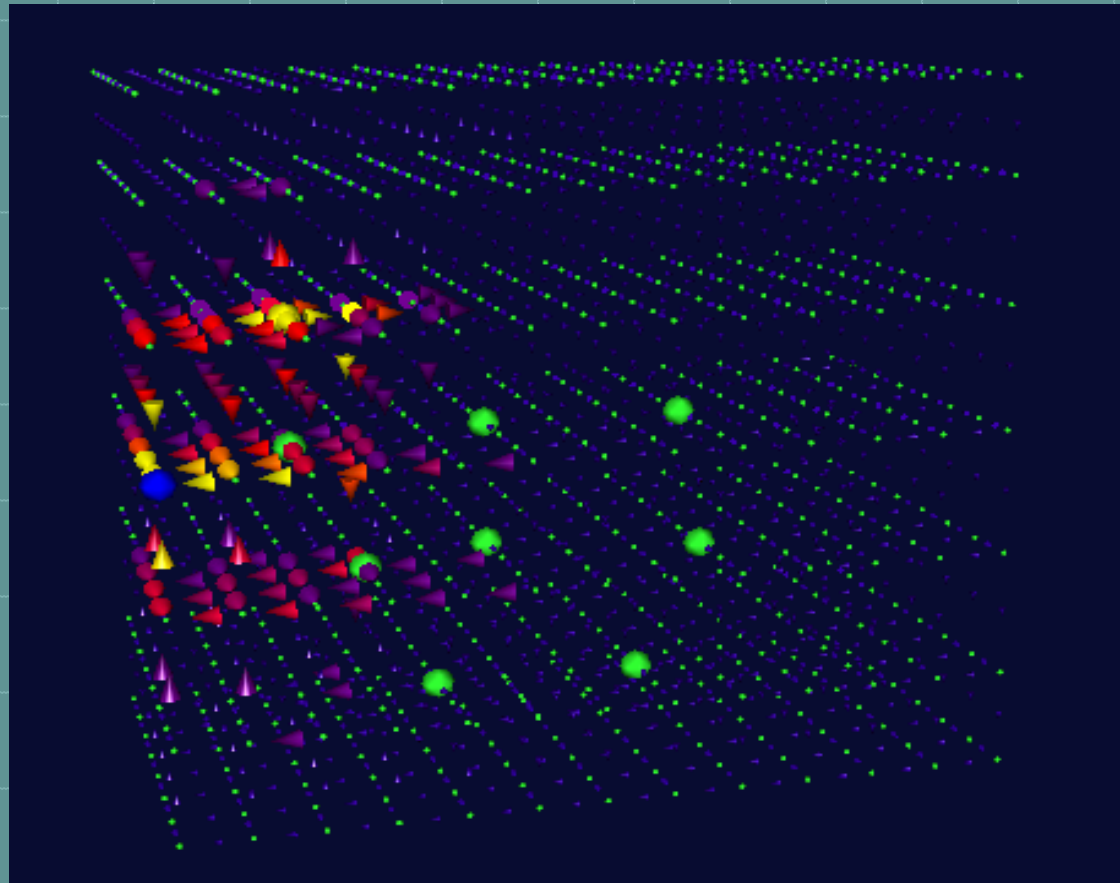
Cochlear Implant in 3D View



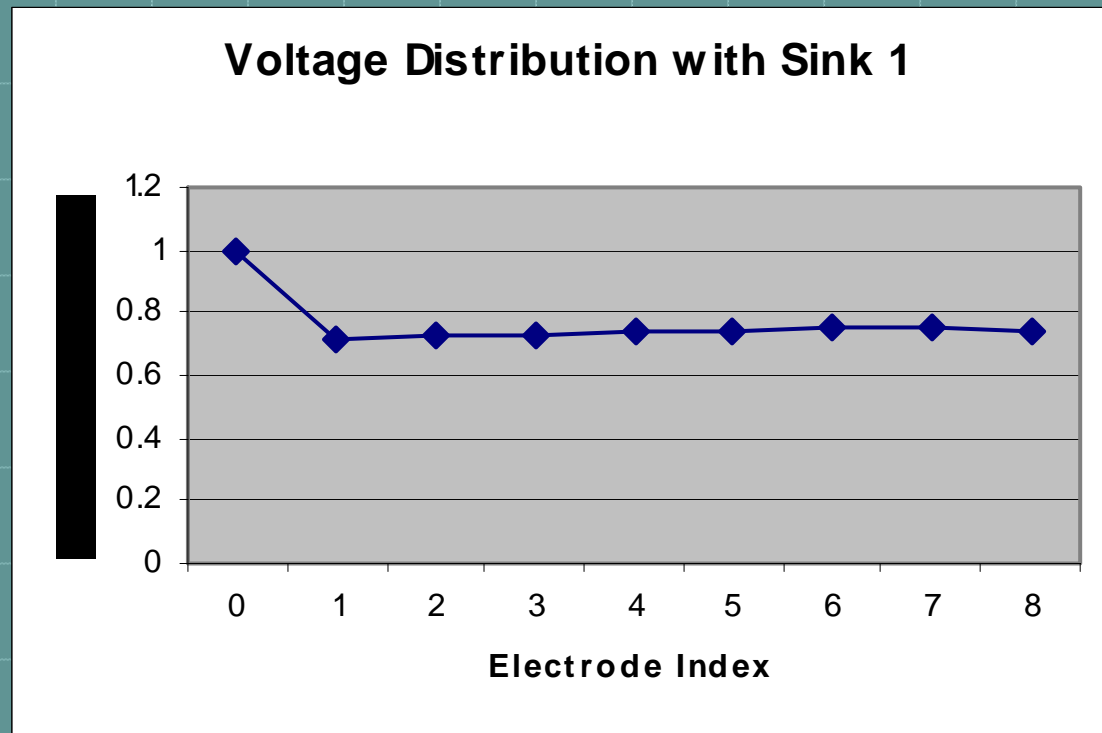
Electrodes in Layer 0



View of Current Flow With Sink 1 and Source Electrode 0



Voltage Distribution With Sink 1 and Source Electrode 0



Conclusions

- ◆ The circuit model maintains the relative details of the cochlear structure. In general, the simulation matches with the expectation.
- ◆ The current flows inside the cochlear are mostly following the cochlear structure – tube.
- ◆ There are always some kind cross structure flows between the electrodes and the sink.
- ◆ The voltage distribution across the electrodes is uniform.

Conclusions (Cont.)

- ◆ High voltages are related to the bone area sink, while low voltages are related to the auditory nerve sink
- ◆ For both sink locations, the voltage difference between none source electrodes are very small.
- ◆ Although in the simulation the selected electrodes show the relation with the structure, there is mismatch between the electrode locations and the current flow. This is due to the block generation, which doesn't describe the detailed structure information. A fine mesh will improve the resolution.

Future Works

- ◆ Increase the number of nodes
- ◆ Introduce more boundary points
- ◆ Get high resolution images of the cross section of the cochlear
- ◆ Save the physical model
- ◆ Generate and display 2D figures

Acknowledgements

- ◆ I would like to thank Dr. Peter Nelson, Dr. Claus-Peter Richter, and Dr. Edward Overstreet for their unwavering support and assistance. They provided guidance in all areas that helped me accomplish my work. A special thanks to Dr Claus-Peter Richter who supplied the impedance data and cochlear intersection images for this project.