UNIVERSITY OF Southampton
Institute of Sound and Vibration Research

Modelling the Voltage Distribution of a Cochlear Implant

*Contact : rs1604@soton.ac.uk

Rami Saba*, Stephen J. Elliott, Shouyan Wang

Aim

Simulating the voltage spread in a coiled cochlear model due to cochlear implant stimulation

Coiled Non-uniform Model

A simplified coiled cochlear model was constructed using a three dimensional package and used to simulate the voltage spread in the cochlea. This is a conductive media problem which is solved using the finite element method [1,2]. This was plotted along the spiral ganglion pathway close to the position of the nerve bundles for an inner and outer placement of a 22-electrode array.

Focusing

The voltage spread could be controlled using multiple electrodes stimulated simultaneously. van den Honert [3] reports that focusing could be achieved by calculating an ideal current based on an ideal voltage spread using measured impedance along the electrode array. This study shows how focusing could be improved by using impedances along the spiral pathway to calculate the ideal current, referred to as neural focusing (NF).

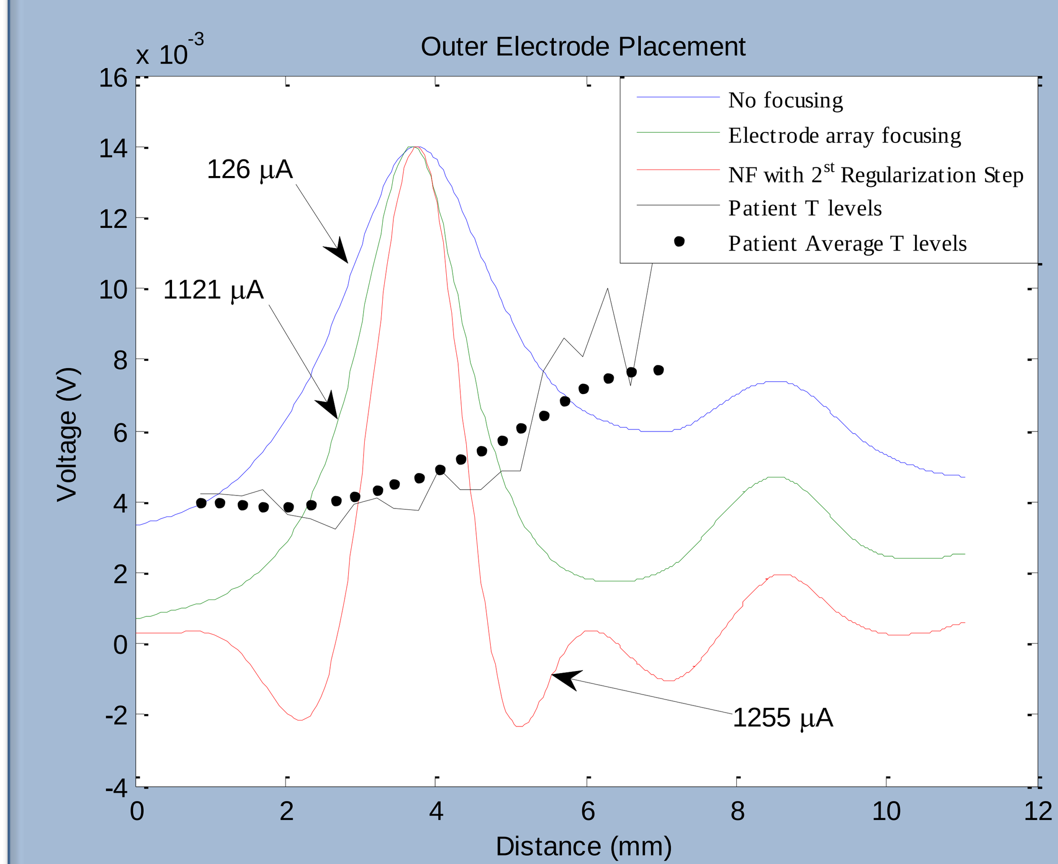

Figure 5 – The comparison of using impedance information along the electrode array and the neural pathway through the spiral ganglion to focus the voltage distribution towards a target region of nerves. Neural focussing is shown to improve the degree to which voltage distribution is focussed.

Model

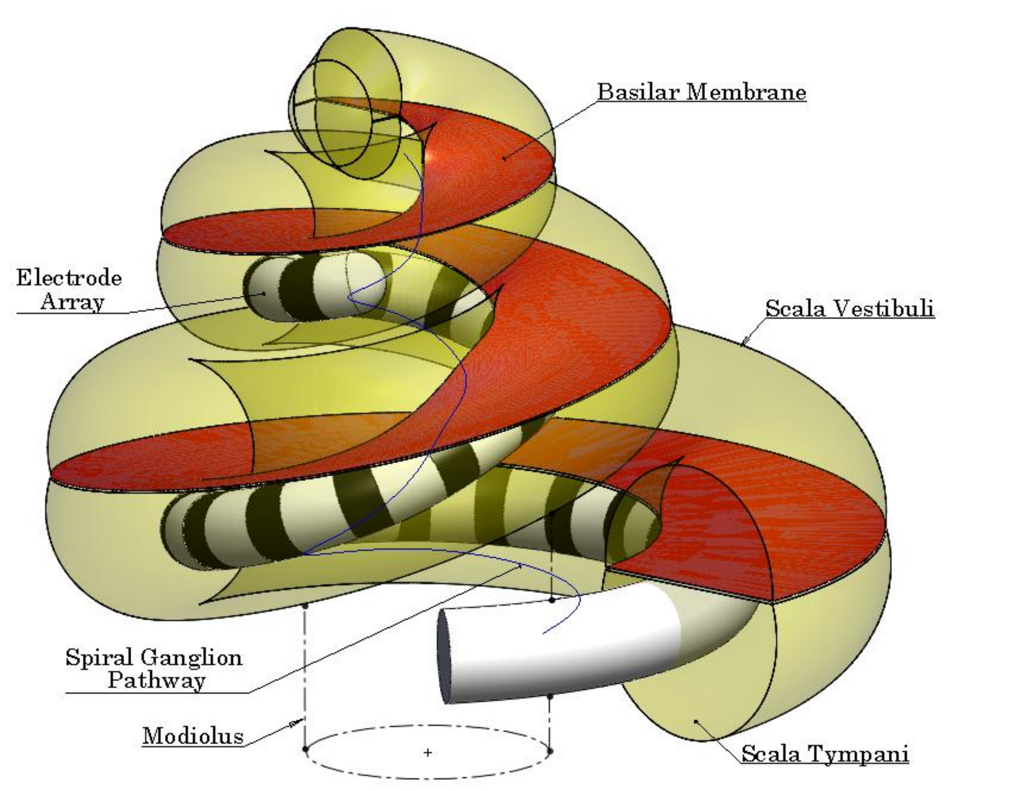

Figure 1 – The model consists of a bone compartment within which lies the scala tympani, scala vestibuli, basilar membrane and a 22-electrode array placed close to the modiolus. The cross-sectional areas of the model vary non-uniformly along the basilar membrane.

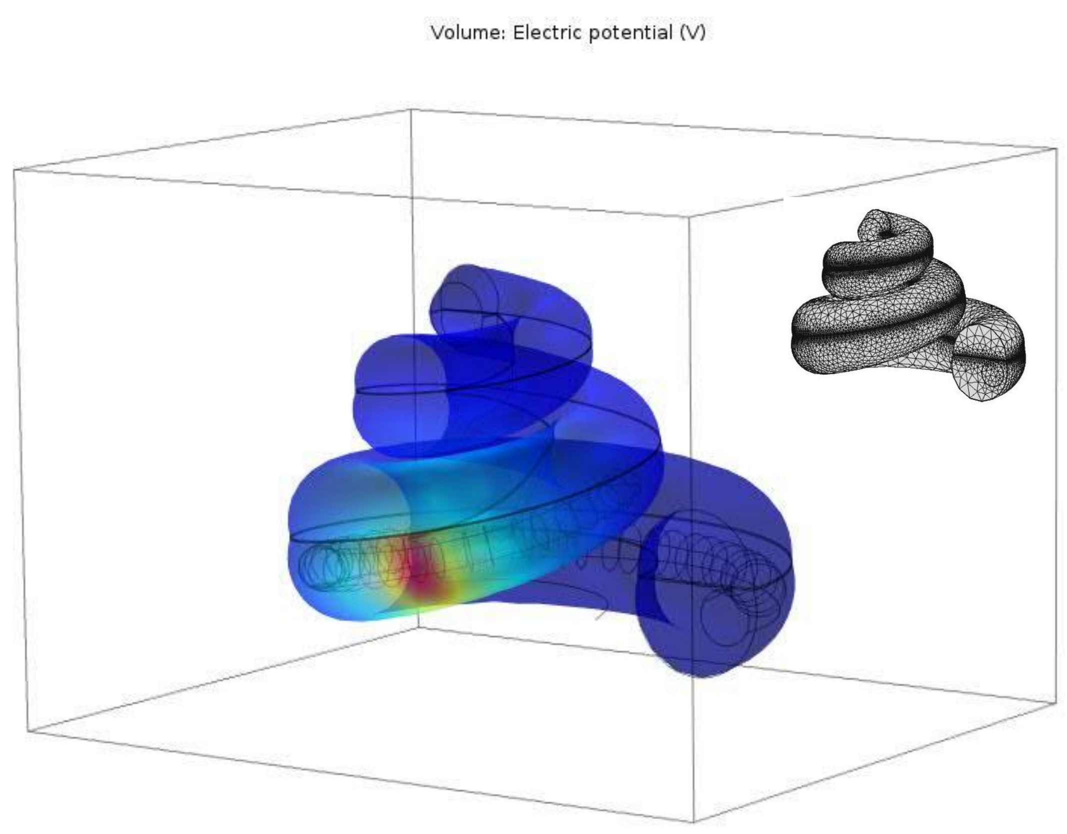

Figure 3 – Finite element solution showing the voltage distribution within the cochlear model. One electrode is activated and the outside of the bone enclosure is set to ground to simulate the effect of the reference electrodes.

Voltage Distribution

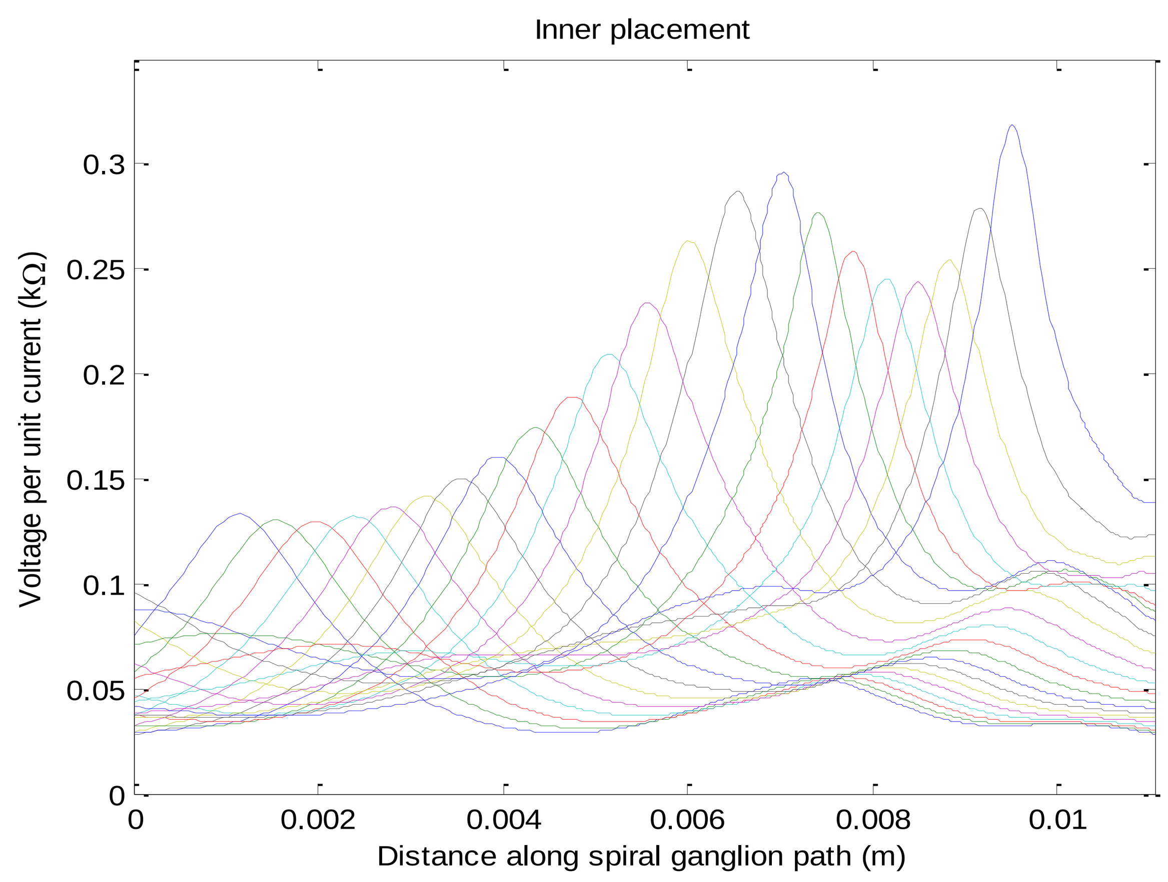

Figure 2 – The above plot shows the voltage distribution for the non uniform coiled model with an inner placed electrode array. This gives a non uniform distribution with multiple peaks for each individual electrode stimulation.

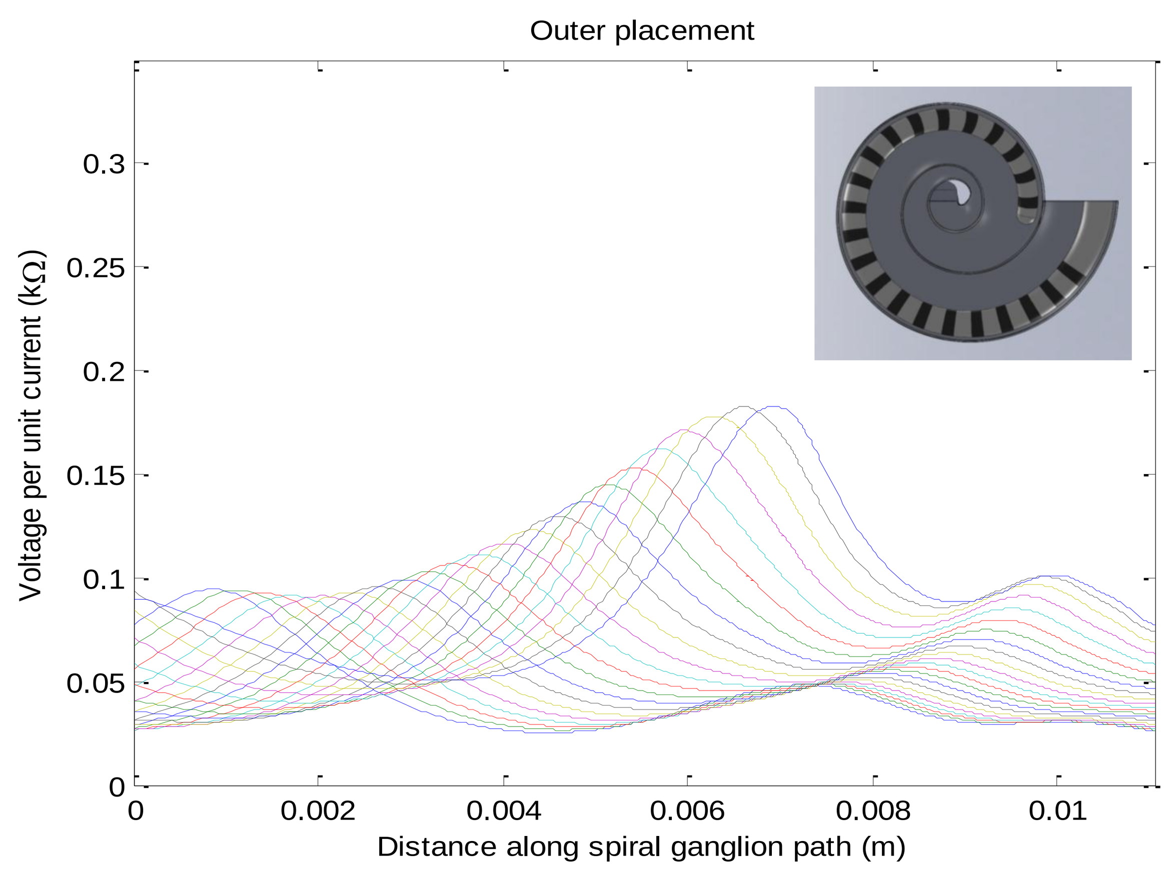

Figure 4 – This shows the voltage distribution for an outer placed electrode array. The peak voltages per unit current are reduced and voltage distribution is broader for individual electrodes. Also, an outer placed electrode array penetrates less of the cochlea.

Applications of the Model

The model could be used to simulate variations in cochlear geometry such as pathological conditions or natural variation of the cochlea. An electrode tissue interface could be implemented into the model to simulate changes in impedance over time from implantation. The model could be coupled with a neural model to simulate nerve stimulation. Different electrode arrays, commercial and conceptual, could be modeled and compared. Such simulations could provide answers to questions regarding certain pathological variations and their compatibility with different electrode configurations.

Conclusion

The simulations above have shown that stimulation in one turn of the cochlea does affect the voltage field at the next turn due to the coiled nature of the cochlea. The placement of the electrode array within the cochlea affects the voltage power and distribution characteristics. It was also shown that impedance data obtained from the model at the neural pathway improved the focused voltage distribution towards the target nerves.

References:
1. Hanekom, T. (2005). "Modelling encapsulation tissue around cochlear implant electrodes." Medical & Biological Engineering & Computing **43**(1): 47-55.
2. Rattay, F., R. N. Leao, et al. (2001). "A model of the electrically excited human cochlear neuron. II. Influence of the three-dimensional cochlear structure on neural excitability." Hearing Research **153**(1-2): 64-79.
3. van den Honert, C (2007). "Focused intracochlear electric stimulation with phased array channels." Conference on Implantable Auditory Prostheses:3703-3716.