Estimation of Initiated Local Field Potential by Neurons in Heterogeneous Tissue Environment using Admittance Method

Jordan W. Cline(1), Clayton Bingham(2), Kyle Loizos(1), Gene Yu(2), Phillip Hendrickson(2), Jean-Marie Bouteiller(2), Theodore Berger(2), and Gianluca Lazzi(1)

(1) Department of Electrical and Computer Engineering, University of Utah, SLC, UT 84112, USA

(2) Department of Biomedical Engineering, Center for Neural Engineering, University of Southern California, Los Angeles, CA 90089, USA

In order to decode the relationship between the activity of neuronal networks in the brain and the physiological response, multiple recording methods are available to monitor the spatial-temporal response of the neurons. Compared to single neuron recording that is useful for finding neuronal response, local field potential (LFP) recording allows for analysis of a larger neuronal network response. LFP is a combinational effect of the asynchronous action potentials from multiple neurons and can be recorded using implanted microelectrodes. Accurately calculating the LFP of a simulated neuronal network allows for optimal electrode placement for electrical stimulation and recording. The simulated LFP on a proximal recording electrode due to the neuronal firings of a multineuron network can be compared with the recorded LFP from a relevant experiment. In this work we compare two different methods for solving multineuron network field potentials.

A simple method to solve for a local field potential treats each discretized neuron as multiple electric point sources with homogenous surrounding tissue. To more accurately solve for the LFP, we explored an alternative approach using a three-dimensional multiresolution admittance method network in order to model heterogeneous tissue around the cells and the recording electrode. The admittance method allows for the simulation of the electrode geometry and material based on the relevant experimental setup. A computational model of a rat's hippocampus slice with the metallic recording electrode was created and anatomically dependent electric properties of the tissue (conductivity, permittivity) were assigned to the multiresolution admittance network to simulate the LFP response inside a heterogeneous tissue environment. Using the membrane currents of the neurons, the temporal distribution of the LFP is calculated at the recording site. The LFP results are compared to the experimental recordings.

In this work, we present a full verification and comparison of an admittance method and a point source method to solve for local field potentials. The ability to capture the anisotropy, the electrode-electrolyte interface, and electrode properties increase the accuracy of this method compared to the point source method without significantly increasing the simulation time.