BMC Neuroscience

Poster presentation

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An analytical solution of the cable equation predicts the frequency preference of a passive non-uniform cylindrical cable in response to extracellular oscillating electrical fields

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from Eighteenth Annual Computational Neuroscience Meeting: CNS*2009
Berlin, Germany. 18–23 July 2009

Published: 13 July 2009

BMC Neuroscience 2009, **10**(Suppl 1):P38 doi:10.1186/1471-2202-10-S1-P38

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P38

Under physiological and artificial conditions, the dendrites of neurons can be exposed to electrical fields [1-3]. Recent experimental studies suggested that the membrane resistivity of the distal apical dendrites of cortical and hippocampal pyramidal neurons may be significantly lower than those of the proximal dendrites and the soma [4-6]. To understand the behavior of dendrites in time varying extracellular electrical fields, we obtained analytical solutions of the cable equation for finite cylindrical cables with and without a leak conductance at one end by employing the Green's function method. The solution of a cable with leak at one end for DC electrical fields shows a reversal of polarization at the leaky end (Figure 1), as has been shown previously by employing the method of variable separation and Fourier expansion [7]. The solution of a cable with leak at one end for AC electrical fields shows that the leaky end has a frequency preference in the response amplitude (Figure 2).

Our results suggest that a passive dendrite with low resistivity at the distal end would show a frequency preference in response to sinusoidal extracellular local field potentials. The Green's function obtained in our study can be used to calculate response for any form of extracellular electrical field.

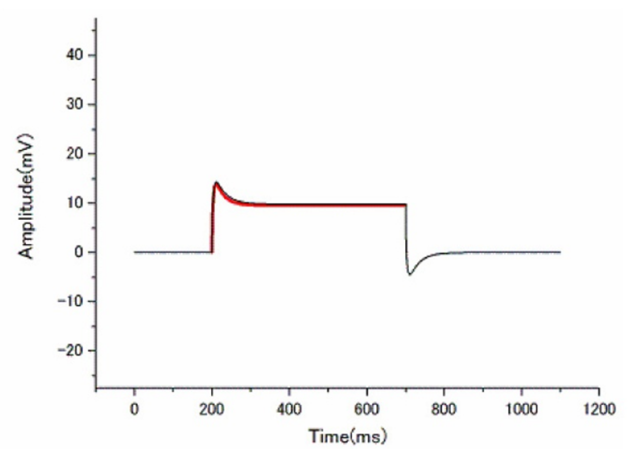

Figure 1
Response to extracellular DC fields. The black line is a numerical solution of the cable equation by using the implicit method, and the red line is a theoretical solution by using the Green's function method. The theoretical solution shows slower hyperpolarization after rapid depolarization, i.e., a biphasic change.

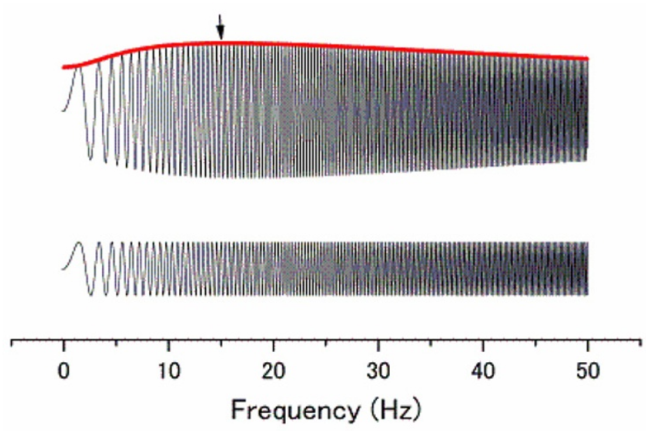

Figure 2
Response to extracellular AC fields. By applying an AC field with a linearly changing frequency (below), the numerically obtained amplitude of the AC responses (black line) was maximized at a certain frequency, i.e., frequency preference (Arrow). The red line denotes the amplitude of the theoretical solution.

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