MAR05-2004-001984
Abstract for an Invited Paper
for the MAR05 Meeting of
the American Physical Society

Stochastic signalling in excitable ion channel clusters

GERHARD SCHMID, University of Augsburg, 86135 Augsburg, Germany

The electric properties of axonal cell membranes are predominantly determined by the dynamics of the voltage-dependent gating of potassium and sodium ion channels. The inherent stochastic dynamics of the gating process generates the so-called channel noise. These fluctuations of the number of open ion channels initiate spontaneous excitations. By use of a stochastic generalization of the Hodgkin-Huxley model we investigate the dependency of the spike production on the number of ion channels within a cluster. There exist an optimal cluster size for which solely the internal noise causes a most regular spontaneous generation of action potentials – the effect of intrinsic coherence resonance – and an optimal system size induced Stochastic Resonance in presence of external driving [1,2]. In addition to the variation of the size of ion channel clusters, the living organisms may adopt the densities of different ion channels in order to regulate the spontaneous spiking activity. We vary the densities, i.e. the number of the specific ion channels for a given membrane patch size by poisoning the potassium, or the sodium ion channels yielding either an increase or decrease of the regularity of the spiking dynamics [3].

We also investigate the influence of the gating charge on spontaneous spiking: the ion channels contribute to the membrane capacity, since the switching of the channel gates between an open and a closed configuration is always connected with charge movement within the cell membrane. Especially, for the case of relatively large densities of ion channels (such as in nodes of Ranvier), this may play a crucial role for nerve excitation. Surprisingly, the gating charge do not dramatically change the excitation behavior. This even holds true even for extremely dense ion channel assemblies; instead the membrane capacity at rest exhibits a bell-shaped dependence on the ion channel density.

[1] G. Schmid, I. Goychuk and P. Hänggi, Europhys. Lett **56**, 22 (2001).
[2] G. Schmid, I. Goychuk, P. Hänggi, S. Zeng, and P. Jung, Fluct. Noise Lett. **4**, L33 (2004).
[3] G. Schmid, I. Goychuk, and P. Hänggi, Physical Biology **1**, 61 (2004).