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A universal model for spike-frequency adaptation. (English) Zbl 1052.92010

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Summary: Spike-frequency adaptation is a prominent feature of neural dynamics. Among other mechanisms, various ionic currents modulating spike generation cause this type of neural adaptation. Prominent examples are voltage-gated potassium currents (M-type currents), the interplay of calcium currents and intracellular calcium dynamics with calcium-gated potassium channels (AHP-type currents), and the slow recovery from inactivation of the fast sodium current. While recent modeling studies have focused on the effects of specific adaptation currents, we derive a universal model for the firing-frequency dynamics of an adapting neuron that is independent of the specific adaptation process and spike generator. The model is completely defined by the neuron's onset $f-I$ curve, the steady-state $f-I$ curve, and the time constant of adaptation.

For a specific neuron, these parameters can be easily determined from electrophysiological measurements without any pharmacological manipulations. At the same time, the simplicity of the model allows one to analyze mathematically how adaptation influences signal processing on the single-neuron level. In particular, we elucidate the specific nature of high-pass filter properties caused by spike-frequency adaptation. The model is limited to firing frequencies higher than the reciprocal adaptation time constant and to moderate fluctuations of the adaptation and the input current. As an extension of the model, we introduce a framework for combining an arbitrary spike generator with a generalized adaptation current.

MSC:

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adaptation dynamics; signal transmission properties; spike generation; conductance based models

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