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Weak noise effects on rhythmic spiking in point and spatial models

Noise has most often been associated with the acceleration of neuronal spiking. For example, with noise the expected value of the membrane potential in the usual LIF models is always towards depolarized states. This is probably generally the case for strong noise, but weak noise can have severe inhibitory effects on rhythmic spiking. This has been demonstrated theoretically in the original Hodgkin-Huxley system of ordinary differential equations (called a point model) as well as experimentally. Near the bifurcation to repetitive spiking, weak noise (or any other appropriate stimulus) may easily drive the system from a limit cycle to a stable rest point, leading to a cessation of spiking for a possibly very long time. Transitions back to the limit cycle may occur with small probability with weak noise but with strong noise the system may switch back and forth from rest to spiking with a small first passage time, leading to an apparent overall increase in spiking activity. Several results are presented which indicate that with increasing weak noise a minimum in spike rate versus noise (called "inverse stochastic resonance") can occur for values of the signal (as opposed to noisy component) near the bifurcation value.

On turning to the spatial version (SPDE's), it was found that with noise uniform throughout the length of the neuron, the same sort of phenomena occurred. However, it was a surprise to discover that the only part of the noise which interfered with spiking activity was that where the signal occurred. The probability that there was interference with spiking was investigated as a function of the amount of overlap of signal and noise. If signal and noise were on disjoint intervals, then there was no interference, even if the regions of signal and noise were juxtaposed and no matter how large the region of noise (note that this applies only for weak noise). As the amount of overflap increases, the anount of interference increases to a maximum when the overflap is complete.

Unforrtunately there is a paucity of results on the propagation of travelling waves in nonlinear systems of reaction-diffusion systems with noise, so only very heuristic explanations for the SPDE results are presently available. Related results for other neural models will also be presented.