

Stimulus Induced Desynchronization of Oscillators Coupled with Delay: Theory and Application to neurological Patients

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In a proposed dissertation work author studies several systems of phase oscillators coupled with delay. Systems were written in a form of differential equations. These systems serve as models of certain aspects of neuronal dynamics in brain. They were subjects to an external stimulation. The stimulation is represented through additional term in equations. Possible dynamical regimes of the systems were investigated, using analytical methods, bifurcation theory and computer simulations; synchronization in the systems was one of main targets of research.

In the first system was considered two phase oscillators modeling the phase dynamics of two instantaneously interacting functional units, accompanied by a delayed feedback of each oscillator onto itself. This system is subject to external short-pulse stimulation and noise. The strong stimulus induces a phase reset of the oscillations followed by the transient dynamics leading towards multiple synchronized states. It is studied the stimulus-induced transient response of the oscillators in different synchronous regimes emerging in the considered system. It is shown that depending on the stimulation parameters used the response of the system to the stimulus may result in qualitatively different types of behavior ranging from cross-trial phase clustering to complete desynchronization. The mechanisms of in- and post-stimulus clustering of the system responses are explained. Author also emphasizes the role of the stable manifold of a saddle-focus fixed point on the cluster formation process.

The second model considered is a system of two phase oscillators modeling phase dynamics of two neuronal populations interacting with delay. The one of two oscillators is a subject to external short-pulse stimulation and both oscillators are subjects to noise. It is studied the response of the stimulated oscillator to the administered stimulation as well as a transmission of the stimulus to the second oscillator. Author proposes a novel technique for evaluation of the stimulus-induced responses and transmission time and compares it with established standard methods based on averaging procedures. It is shown that the standard techniques refer not to the transmission phenomenon itself but rather to oscillatory dynamics of the oscillators. In contrast, the suggested method based on the phase-resetting analysis is able to give a good estimate not only to stimulus transmission time but can estimate the delay time in the system.