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Stability criteria for splay states in networks of "generalized" neuronal models

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Splay states represent collective modes emerging in networks of fully coupled oscillators, they have been observed in Josephson junction arrays, laser systems, pulse-coupled neuronal networks [1]. Recently, their stability analysis has been redone by reducing a model of globally coupled differential equations to suitable event-driven maps which relate the internal configuration at two consecutive spike-emissions. [2]. This analysis has revealed that the mean-field analysis reported in [1] has neglected a part of the Floquet spectrum associated to "short wavelengths (SW) modes".

The aim of the present analysis is to show that the SW part of the Floquet spectrum can be crucial for the stability of the splay states in fully pulse-coupled networks when generic neuronal models, different from the usual leaky integrate-and-fire (LIF) model are considered. For the LIF case corresponding to a force field $F(x) = a-x$, the SW Floquet spectrum is fully degenerate and marginally stable in the limit of infinite network, however for finite number of neurons N, the splay state is stable and the maximal exponent approach zero as $1/N^2$.

We have performed the stability analysis for a generic (non)-linear periodic force field, by rewriting the dynamics of the network as approximated event-driven maps (correct up to fourth order in the mean interspike interval, that is proportional to $1/N$). For continuous force fields, the splay state appears to be neutrally stable along most of the directions (apart a finite number). These findings generalize to a larger class of systems a previous result by Watanabe and Strogatz [3]. While for discontinuous force fields the stability or instability of the splay state is simply determined by the sign of the force field difference taken at the extrema of the definition interval.

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