Network resonance: impedance interactions and frequency response alternating maps (FRAM)

Abstract:

Generation of neuronal network oscillations are not well understood. We view this process as the individual neurons' oscillations being communicated among the nodes in the network, mediated by the impedance profiles of the isolated (uncoupled) individual neurons. In order to test this idea, we developed a mathematical tool that we refer to as the Frequency Response Alternating Map (FRAM). The FRAM describes how the impedances of the individual oscillators interact to generate network responses to oscillatory inputs. It consists of decoupling the non-autonomous part of the coupling term and substituting the reciprocal coupling by a sequence of alternating one-directional forcing effects (cell 1 forces cell 2, which in turn forces cell 1 and so on and so forth). The end result is an expression of the network impedance for each node (in the network) as power series, each term involving the product of the impedances of the autonomous part of the individual oscillators. For linear systems we provide analytical expressions of the FRAM and we show that its convergence properties and limitations. We illustrate numerically that this convergence is relatively fast. We apply the FRAM to the phenomenon of network resonance to the simplest type of oscillatory network: two non-oscillatory nodes receiving oscillatory inputs in one or the two nodes. We discuss extensions of the FRAM to include non-linear systems and other types of network architectures.