

Resonance-based mechanisms of generation of oscillations in networks of non-oscillatory neurons

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Abstract: Several neuron types have been shown to exhibit (subthreshold) membrane potential resonance (MPR), defined as the occurrence of a peak in their voltage amplitude response to oscillatory input currents at a preferred (resonant) frequency. MPR has been investigated both experimentally and theoretically. However, whether MPR is simply an epiphenomenon or it plays a functional role for the generation of neuronal network oscillations, and how the latent time scales present in individual, non-oscillatory cells affect the properties of the oscillatory networks in which they are embedded are open questions. We address these issues by investigating a minimal network model consisting of (i) a non-oscillatory linear resonator (band-pass filter) with 2D dynamics, (ii) a passive cell (low-pass filter) with 1D linear dynamics, and (iii) nonlinear graded synaptic connections (excitatory or inhibitory) with instantaneous dynamics. We demonstrate that (i) the network oscillations crucially depend on the presence of MPR in the resonator, (ii) they are amplified by the network connectivity, (iii) they develop relaxation oscillations for high enough levels of mutual inhibition/excitation, and (iv) the network frequency monotonically depends on the resonator's resonant frequency. We explain these phenomena using a reduced adapted version of the classical phase-plane analysis that helps uncovering the type of effective network nonlinearities that contribute to the generation of network oscillations. Our results have direct implications for network models of firing rate type and other biological oscillatory networks (e.g, biochemical, genetic).

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