Electromagnetic induction on neurons through field coupling and Memristor

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Abstract. In the present work, the effect of field coupling on the electromagnetic induction and the corresponding modes of electrical activities of neurons are examined. An improved Hind marsh -Rose neuron model, where the membrane potential and magnetic flux are bridged by using cubic flux controlled memristor is selected to analyze the kinetics of neurons. For isolated and coupled neurons, multiple modes in electrical activities are examined for increase in the intensity of field coupling. As the external forcing current is varied the system exhibits various dynamics. For the network of 300 H-R neurons, the neuron oscillator exhibits incoherent as well as synchronization behavior. Control inputs for the system is analysed and the stability of system is confirmed by the negative values of Transverse Lyapunov exponent plot. It is observed that under field coupling the excitability of neurons can be changed and this coupling can benefit signal exchange between neurons even if synapse is absent.

Introduction

Neuron is the basic unit in neuronal system and its electrical activities show distinct nonlinear properties. The electromagnetic radiation on neuronal electrical activity can affect energy metabolism, genomic responses, neurotransmitter balance, cognitive function and various brain diseases[1]. Lisi et al. [2] investigated the effect of electromagnetic radiations (EMF) of frequency of 50 Hz on the development of cerebellar granule neurons (CGN). Also multiple modes of electrical activities [3,4] can be induced by electromagnetic radiation and these results are consistent with biological experiments. Studies based on a new cardiac tissue model explained the potential mechanism for heart disease induced by electromagnetic radiation. Field coupling between neurons can also give a new sight to understand the collective behaviors in neuronal networks. Researches based on collective responses in electrical activities of neurons under field coupling has been reported[3],where the synchronization or pattern selection of network connected with gap junction can be modulated by field coupling. In the present paper the effect of electromagnetic induction on four variable Hindmarsh -Rose neuron model neurons through field coupling and memristor is analysed. In order to illustrate the effect of field superposition on neuronal discharges, different external stimuli are applied. For isolated neurons, as the external forcing current increases, the system shows diversity in behavior. Oscillation suppression behavior for low current is changed into tonic spiking on increase of current. For coupled system the increase of the intensity of external stimuli leads to enhancement of the synchronization of neurons. The simulation of 300 neuron oscillators show incoherent as well as synchronization behavior. Control inputs for the system is analysed. Stability of synchronization is examined through negativeness of Transverse Lyapunov Plot.

Results and discussion

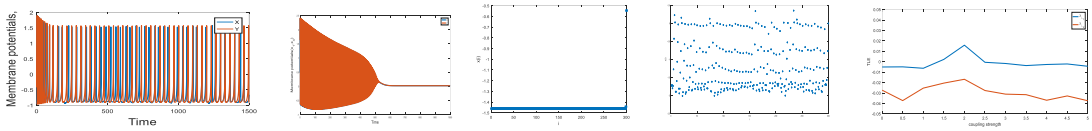

Figure 1:(a, b) multiple modes in electrical activities by increasing the intensity of field coupling, (c, d) The dynamics of 300 H-R neurons for g = 0 . 1 (desynchrony) and 1.0 (complete synchrony) (d)The TLEs of coupled HR neural network

For isolated and coupled neurons multiple modes in electrical activities are analysed by increasing the intensity of field coupling. Various dynamics such as oscillation death, tonic spiking, desynchronization and synchronizations are resulted in. under the high coupling strength the oscillation suppression of coupled systems can be achieved by high value of external current. The H-R neuron network with field coupling have the negative Lyapunov function derivative in the presence of the controller.

$$\dot{V} = -g \sum_{i=1}^{n-1} e(i, x_{4i})^2$$

References

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