Epileptic seizure induced by square current pulse in neuronal network model

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1st Perspectives on Oscillation Control

Introduction

Epileptic seizures exhibit excessively synchronous activities of some neuronal population [1]. The unbalance between the influence of synaptic excitation and inhibition are recurrently associated to appearance of seizures [2]. However, only this condition can be not sufficient to generate epilepticform activities. For this reason, we have analyse the application of different intensities of square current pulse (SCP) to induced synchronization in the neuronal network. We have studied the effect of SCP inside and outside of a bistable regime.

Methodology

We have considered a network of N=1000 adaptive exponential integrate-and-fire [3] neurons randomly connected by excitatory and inhibitory synapses. The network consist of 80% excitatory and 20% inhibitory neurons where the probability of connection is p=0.1. The state of each neuron i of the network are represented by the variable V_i (membrane potential), w_i (adaptation current) and g_i (synaptic conductance).

The time evolution of the neuronal network is described by the set of equations below

$$
\begin{aligned}
C_{\rm m}\frac{dV_i}{dt} &= -g_L(V_i-E_L)+g_L\Delta_T\exp\left(\frac{V_i-V_T}{\Delta_T}\right)\\
&+ I_i - w_i + \sum_{j=1}^{N}(V_{\rm REV}^{j}-V_i)M_{ij}g_j + I_{\rm ext},\\
\tau_w\frac{dw_i}{dt} &= a_i(V_i-E_L)-w_i,\\
\tau_s\frac{dg_i}{dt} &= -g_i.
\end{aligned}
$$

The parameters of this simulation correspond to that considered in previous work (Borges, 2017) [4]. These neuronal parameters exhibit spike activities for uncoupled configuration. I_{ext} identify the square current pulse of duration T_I and amplitude A_I which is applied in the time 1s. When the potential of neuron i is above a V_{thes}, the reset condition, is applied

$$
\begin{aligned}
V_i &\to V_r = -58\text{mV},\\
w_i &\to w_i + 70\text{pA},\\
g_i &\to g_i + g_s,
\end{aligned}
$$

where g_s assume value g_{exc} when i is an excitatory neuron and $g_{inh}=g{\cdot}g_{exc}$ when inhibitory ones. g represent the relative inhibitory coupling.

Results

Figure 1 shows raster plot, instantaneous firing-rate, and SCP applied on all neurons of the network, respectively. Depending on the applied amplitude A_I considered by T_I=100ms, the neuronal network can change from desynchronous spike to synchronous burst activity. In Figure 1 (a), we considered A_I=50pA which does not change the neuronal dynamics after a transient time. In Figure 1 (b), A_I=100pA changes de neuronal dynamics. The synaptic conductances g_{exc}=0.4nS and g=3, correspond to a bistable regime of network, where desynhronous spikes or synchronous burst activities can occur for the same value parameters [5].

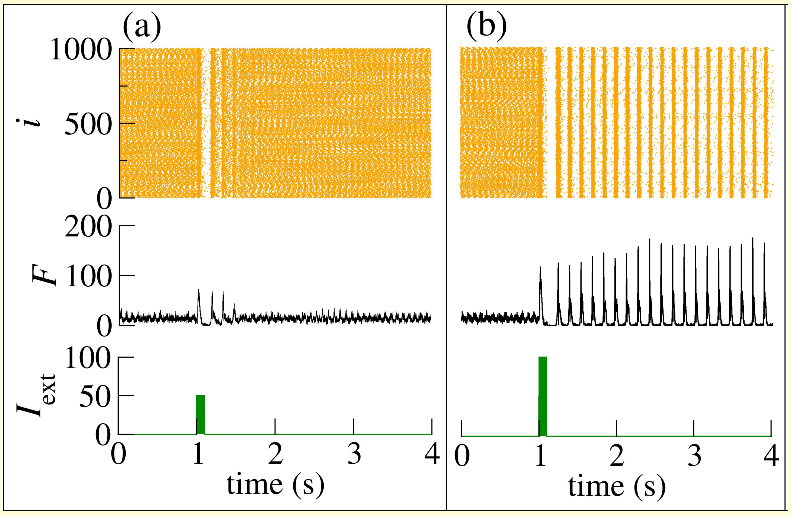

Figure 1 – Application of SCP for g_{exc}=0.4nS, g=3, (a) A_I=50pA and (b) A_I=100pA .

Conclusions

Square current pulse (SCP) can induced synchronized burst activities in a bistable regime of a neuronal network randomly connected by excitatory and inhibitory synapses. The application of SCP does not induced synchronization outside the bistable regime. Thus, low amplitude stimuli might induce epileptic seizures in bistable regimes.

References

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Acknowledgment