Controlling the frequency of oscillations by changing the GABA synapse time constants

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Abstract

1 Introduction

We are interested in the GABA synapses, because the time constants of these synapses affect the frequency of oscillations in the circuit. In this document, we first give the equations that describe the behavior of the GABA synapse in the simulations and then present numerical experiments varying the synaptic time constants, decay and rise time.

2 The GABA synapse model

The synaptic currents corresponding to GABA synapses are described, by the following equation:

$$igaba = W * g\_gaba * (v - Erev\_gaba)$$

where W is the weight of the synapse, g_gaba is the conductance and $Erev\_gaba$ is the reversal potential of GABA.

The conductance is further decomposed into a maximal conductance term and a gating variable (which has its own dynamics) and also neuromodulatory factors.

The dynamics of the gating variable r_gaba take on the following form, which is similar to the Hodgkin-Huxley formalism, except that the time constants in the equation are not time dependent:

$$r\_gaba' = AlphaTmax\_gaba * on\_gaba * (1 - r\_gaba) - Beta\_gaba * r\_gaba$$

$AlphaTmax\_gaba$ here is the inverse of rise time, with units $(1/ms)$ and similarly $Beta\_gaba$ is the inverse of the decay time. These are the two parameters that we control in the present simulations.

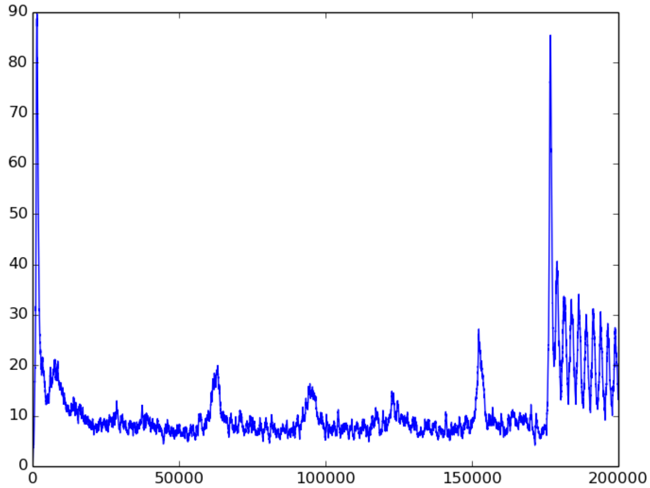

Figure 1: Oscillations at baseline

3 Simulation design

To probe how $AlphaTmax\_gaba$ and $Beta\_gaba$ affect the frequency of the oscillations in the model, we varied these parameters in four experiments. We increased $AlphaTmax\_gaba$ 10-fold, decreased it 10-fold and did similarly for $Beta\_gaba$.

4 Baseline simulation

Plot 1 shows the lfp signal from simulation with the original time constant values. The plot shows some low-frequency oscillatory activity, which we would hope to enhance.

5 Increasing $AlphaTmax\_gaba$ 10 times

Plot 2 shows the lfp signal from the simulation with $AlphaTmax\_gaba$ increased 10 times.

6 Decreasing $AlphaTmax\_gaba$ 10 times

Plot 3 shows the lfp signal from the simulation with $AlphaTmax\_gaba$ decreased 10 times.

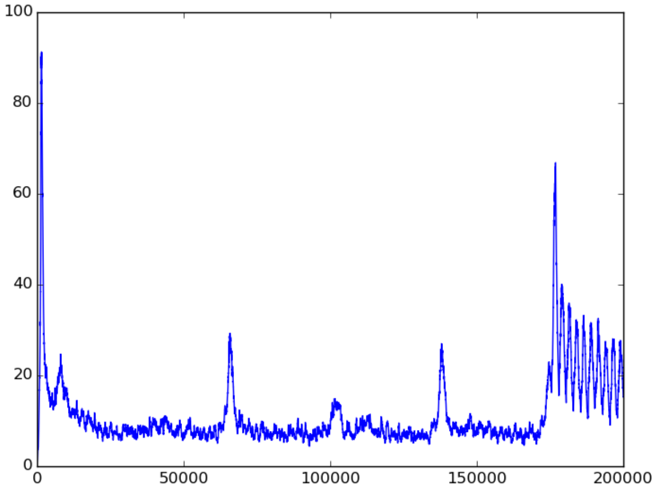

Figure 2: Increasing $AlphaTmax\_gaba$ 10 times

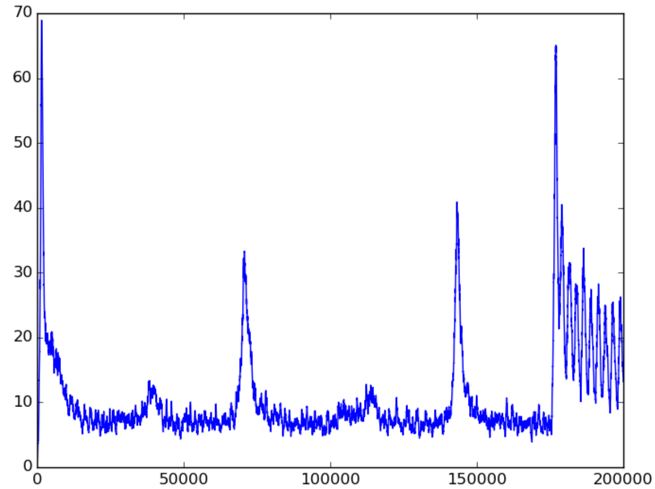

Figure 3: Decreasing $AlphaTmax\_gaba$ 10 times

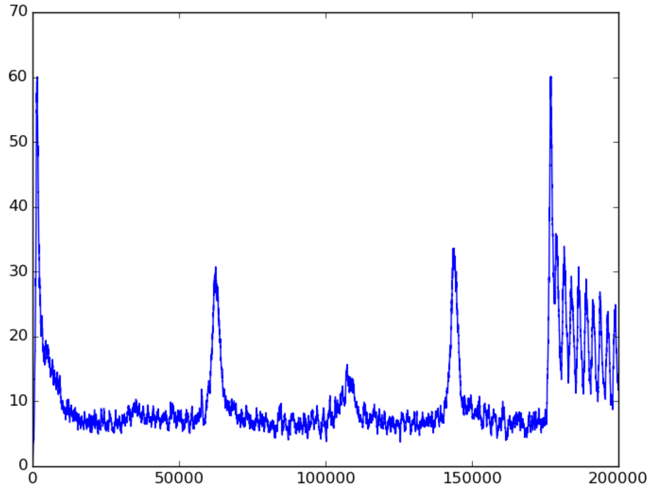

Figure 4: Increasing *Beta_gaba* 10 times

7 Increasing *Beta_gaba* 10 times

Plot 4 shows the lfp signal from the simulation with *Beta_gaba* increased 10 times.

8 Decreasing *Beta_gaba* 10 times

Plot 5 shows the lfp signal from the simulation with *Beta_gaba* increased 10 times.

9 Conclusion

The experiments identified the decay time constant of the GABA synapse as primarily responsible for increasing the frequency of the oscillations. However, the power spectrum of plot 5 reveals that while we managed to increase the frequency of oscillations by controlling *Beta_gaba*, we are still far away from getting gamma frequency oscillations.

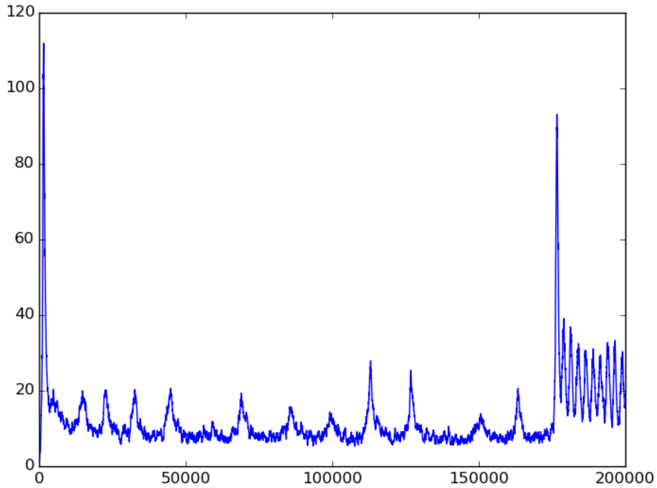

Figure 5: Decreasing $Beta\_gaba$ 10 times

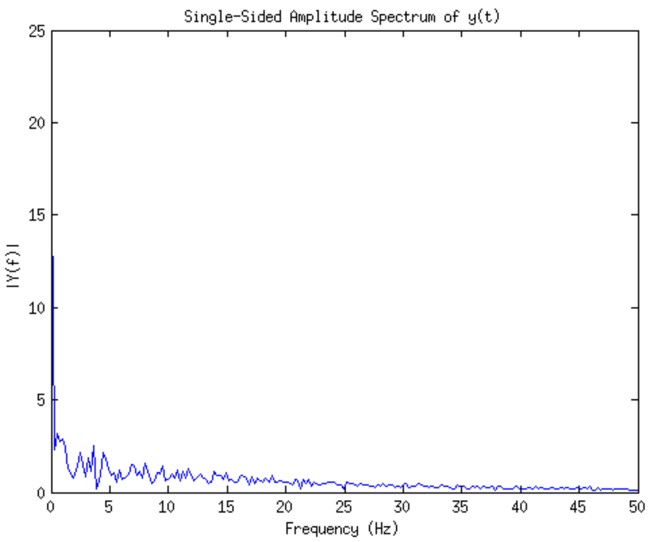

Figure 6: Power spectrum of decreasing $Beta\_gaba$ 10 times

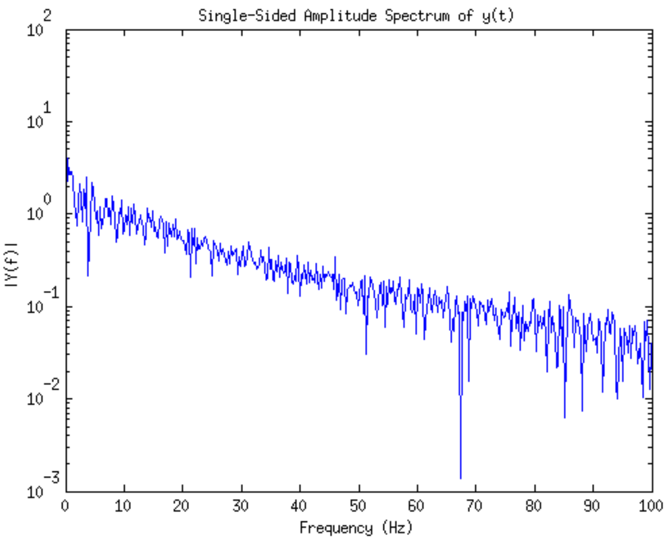

Figure 7: Power spectrum of decreasing $Beta\_gaba$ 10 times