Report of I&F Neuronal Network Simulation

Report of Week 10

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Apr. 25, 2017

Contents

* Intensity of TDMI signals influenced by post network neuronal number contributed to LFP as well as their dynamical state.
* Comparison between TDMI signal of spike trains of excitatory pre-network neurons and their one-degree LFP and inhibitory neuronal spike trains and theirs.
* Contribution of excitatory and inhibitory neuron to LFP in post-network based on point current source model of local field potential.
* Study of two-degree LFPs and their TDMI signals.

General simulation setups

Basically, the simulating system consists of two one dimensional integrate-and-fire neuronal network, called it two-network system.

1. Each network contains 100 neurons;
2. Neuronal connecting density is 3, which means that each neuron directly connects with 6 other neurons within its own loop;
3. Each network has a regular structure, which means each of its neuron connects with 6 nearest neurons;
4. Each neuron in loop 1 has 10% probability connecting with every single neuron in loop 2;
5. Spiking signals generatd by one of those two network, which called 'loop 1' or pre-network, can transmit to the other network, which I called it 'loop 2' or post-network; and the spiking information flow cannot transmit backwards;
6. simulation time range is [0, 10] s; timing step $= 1/32$ ms

Neuronal Parameters

1. Neurons are driven by feedforward excitatory spiking signal generated by Poisson process with 1.5 kHz mean driving rate; Roughly speaking, a neuron receives 30 spikes from feedforward Poisson process and its membrane potential, as a result, would increase from resting potential to firing threshold.
2. The intensity of neuron-neuron interaction is identical to the intensity of feedforward inputs; And the effect of single neuron towards the change of conductance of ion channel for both excitatory and inhibitory are identical, too.

About LFP model

* In the following results, I choose neuronal data, including membrane potential and different component of membrane conductance, from 1000 to 10000 ms to generate local field potential, which can prevent the disturbance from the transition process of network dynamics at the first one second.
* One-degree LFP: local field potential generated by neurons directly connected with target neuron in post-network;
* Two-degree LFP: local field potential generated by neurons connected with first order connected neurons of target neuron; a neuron cannot be first order neuron and second order neuron at the same time;

General Views

All neurons in the system are identical excitatory neurons.

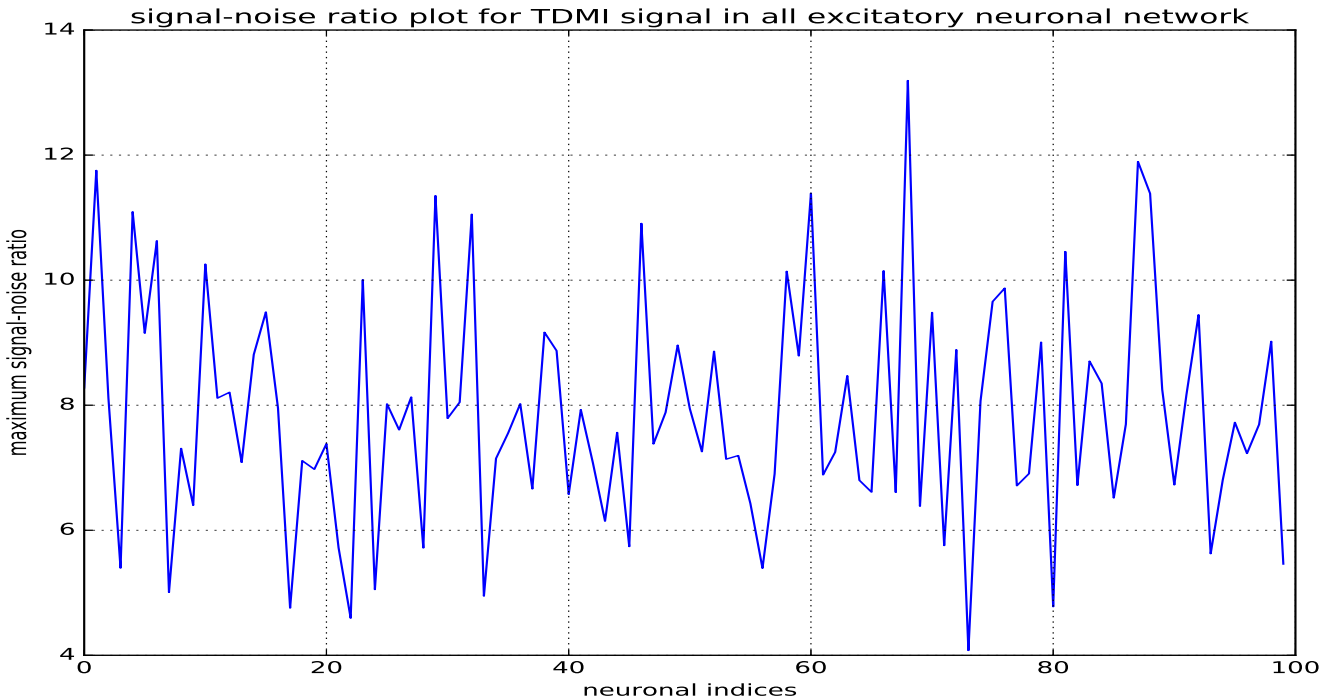


Figure: signal-noise ratio is defined as the ratio of the maximum value of effective MI signal and mean value of noise level of TDMI. Here, the results reflects that all neuron in pre-network have effective MI signals with their one-degree LFPs.

One neuron case

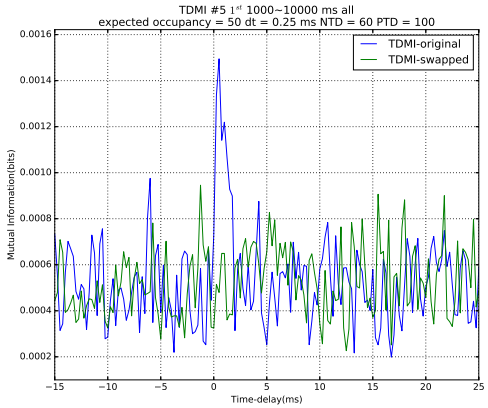
Choose #0 neuron in loop-1 as the target neurons for spike train. It randomly connects with 9 neurons in loop-2. Now, we regard the membrane current of each neuron as LFP, and apply TDMI analysis among them. Results are shown below.

index	mean firing rate	signal noise ratio	peak time	time constant
5	22.30	2.840166	0.50	0.776910
32	21.60	2.214518	-1	-1
37	20.40	2.638657	0.25	0
43	21.70	2.452756	0.25	1.510032
45	22.60	2.007208	-1	-1
52	26.50	2.009227	-1	-1
57	22.00	2.252543	0.25	0
83	21.10	2.735426	-1	-1
84	21.10	2.906195	0.25	0

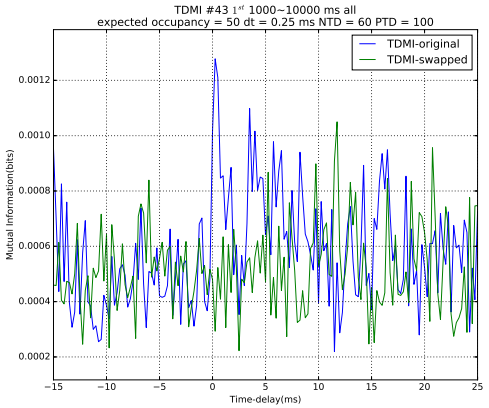
Denote: If peak time equals to -1, there is no MI signal in TDMI graph. If peak time is positive and time constant equals to 0, there is a weak MI signal while it cannot be treated as an effective signal.

One neuron case - Comparison

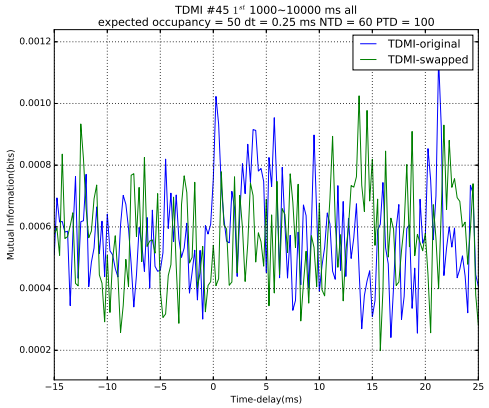
According to the tabular in previous slide, for most of cases, there is no effective TDMI signal. Here, we show the TDMI graphs from #5, #43 and #45 neuron.



(a) #5 neuron



(b) #43 neuron



(c) #45 neuron

ANALYSIS: Based on this comparsion, we can observe weak MI signals in #5 neuron and #43 neuron cases, while find nothing in #45 neuron case. Since all these three neurons are connected with identical neuron in loop-1, we make an assumption that such a difference results from different dynamical states that neurons have.

One neuron case - Comparison

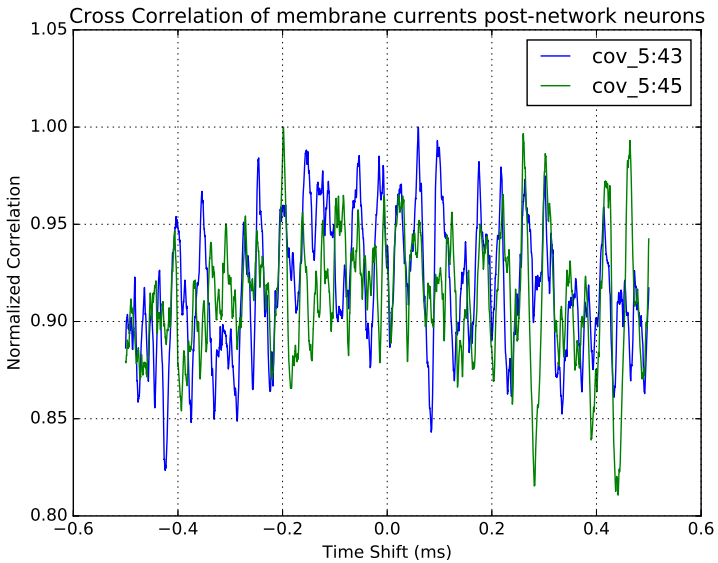


Figure: Cross correlation between total membrane current of neurons.

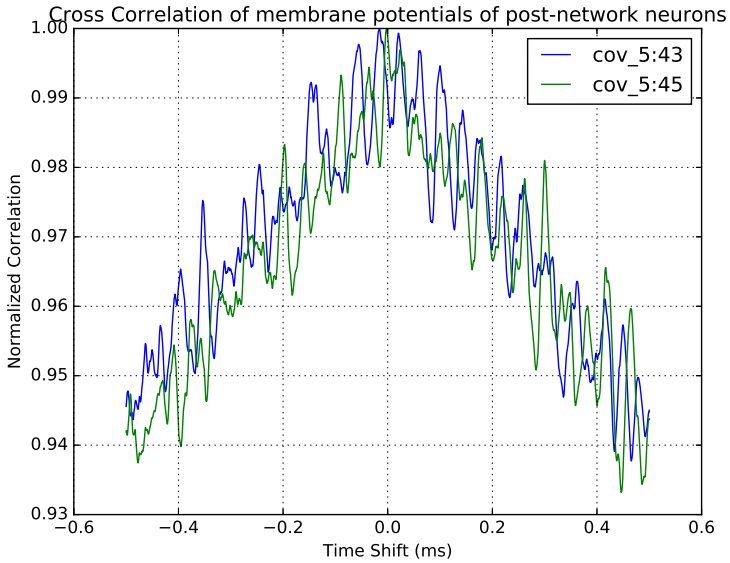


Figure: Cross correlation between membrane potential of neurons

Figure: Cross correlation between single neuronal states

Multi-neuron case

For multi-neuron case, here, we take #0, #40 and #80 neurons as examples. Brief summary of properties of these neurons are listed below.

Index	Type	No. of direct connection	Mean firing rate (Hz)
0	exc	9	14.50
40	exc	11	13.80
80	exc	5	14.00

We calculate the signal-noise ratio of TDMI signal for all possible sub-clusters in their directly connecting neuronal cluster, and make a few plot to show their dependence towards some parameters.

Signal-Noise Ratio vs. Neuronal Number in Clusters

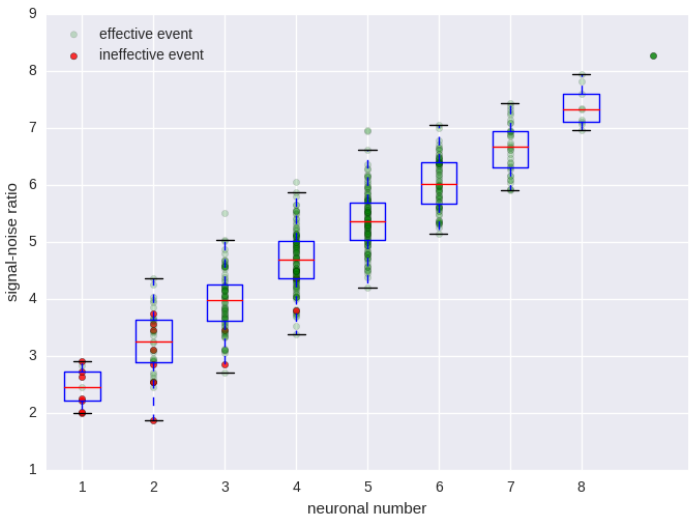


Figure: #0 neuron

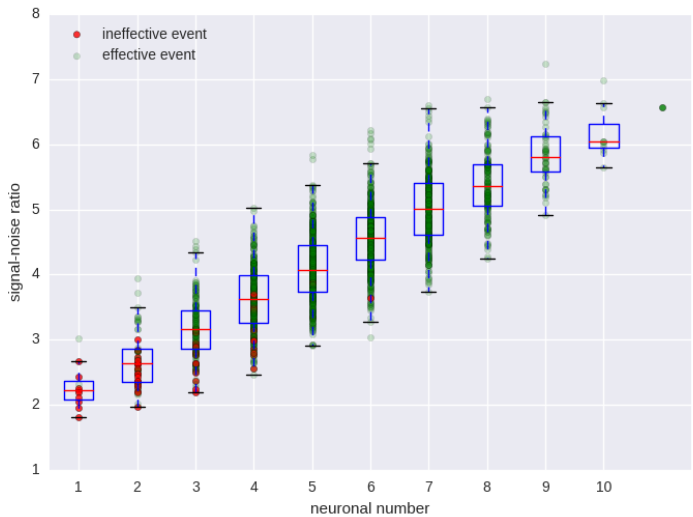


Figure: #40 neuron

Signal-Noise Ratio vs. Mean Firing Rate of Clusters

Figure: #0 neuron

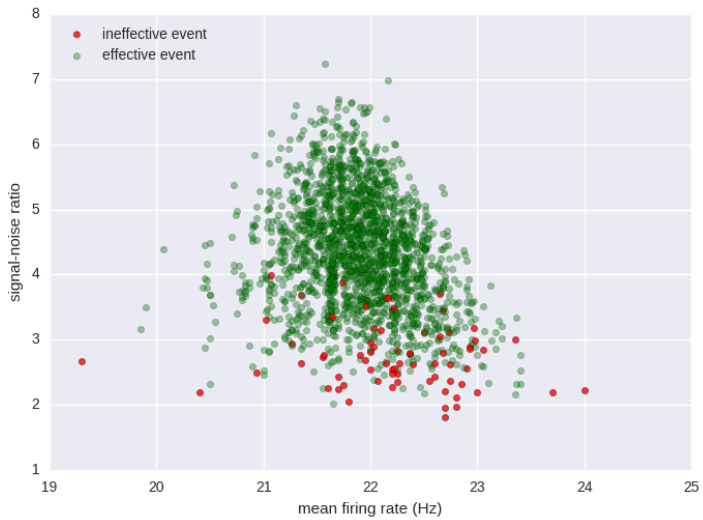


Figure: #40 neuron

General Views

Neurons in pre-network are 80% excitatory and 20% inhibitory. All neurons in post-network are identical excitatory neurons.

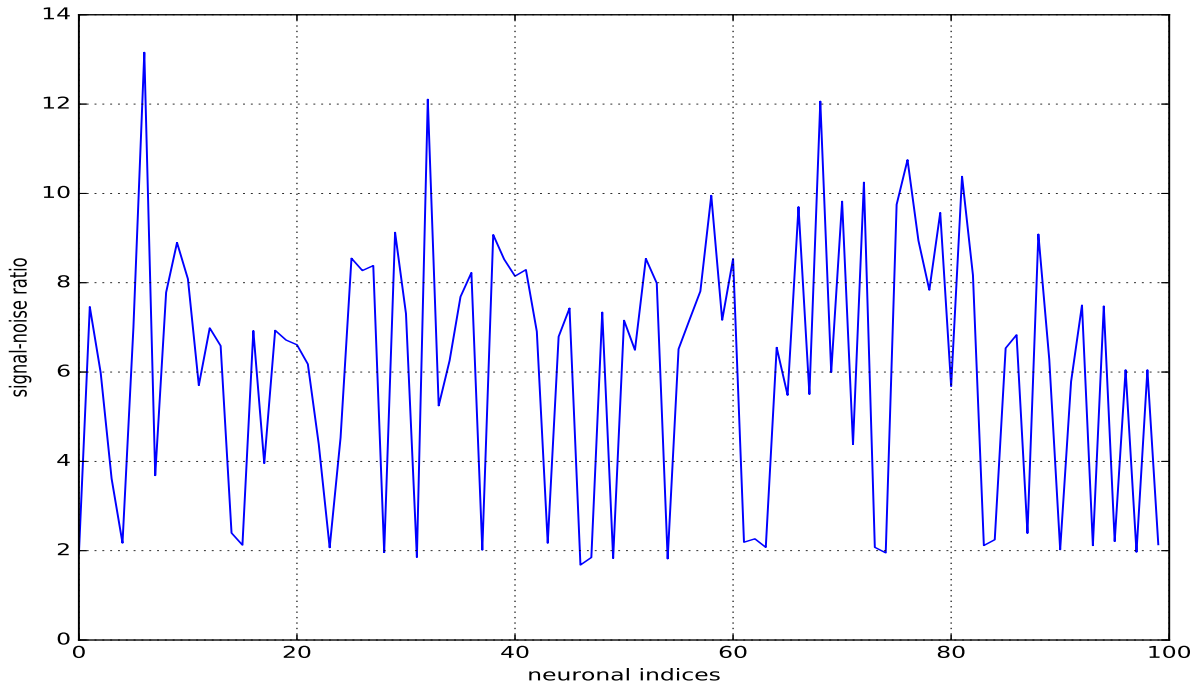
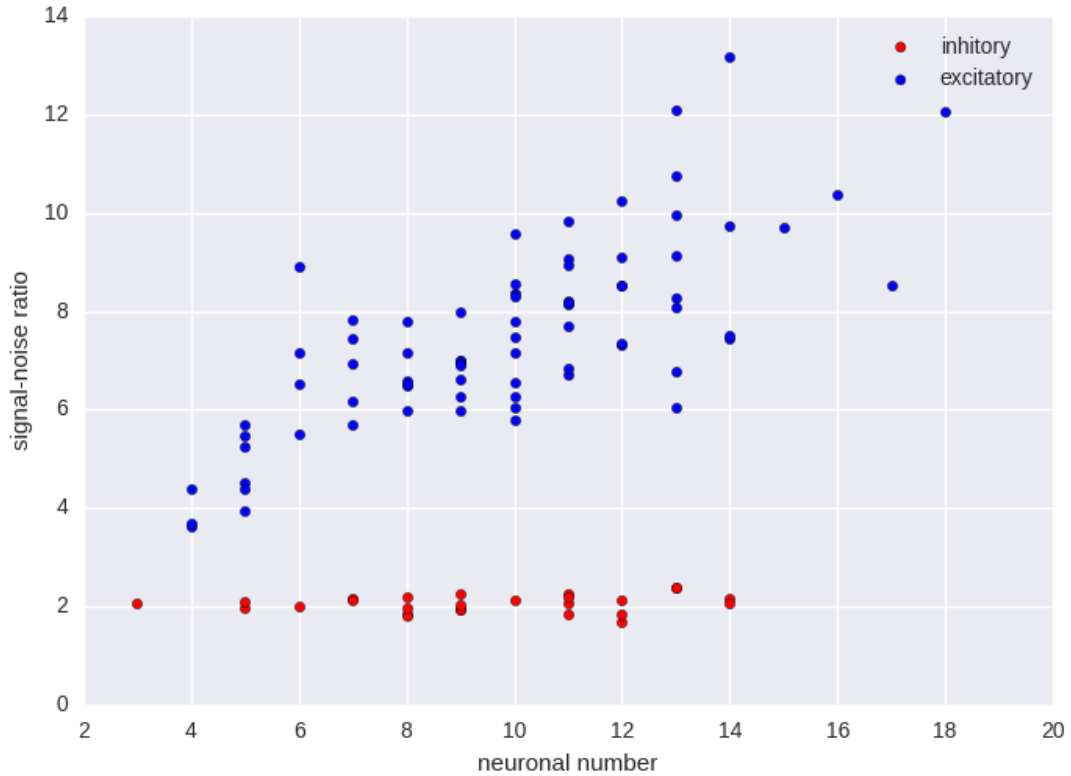


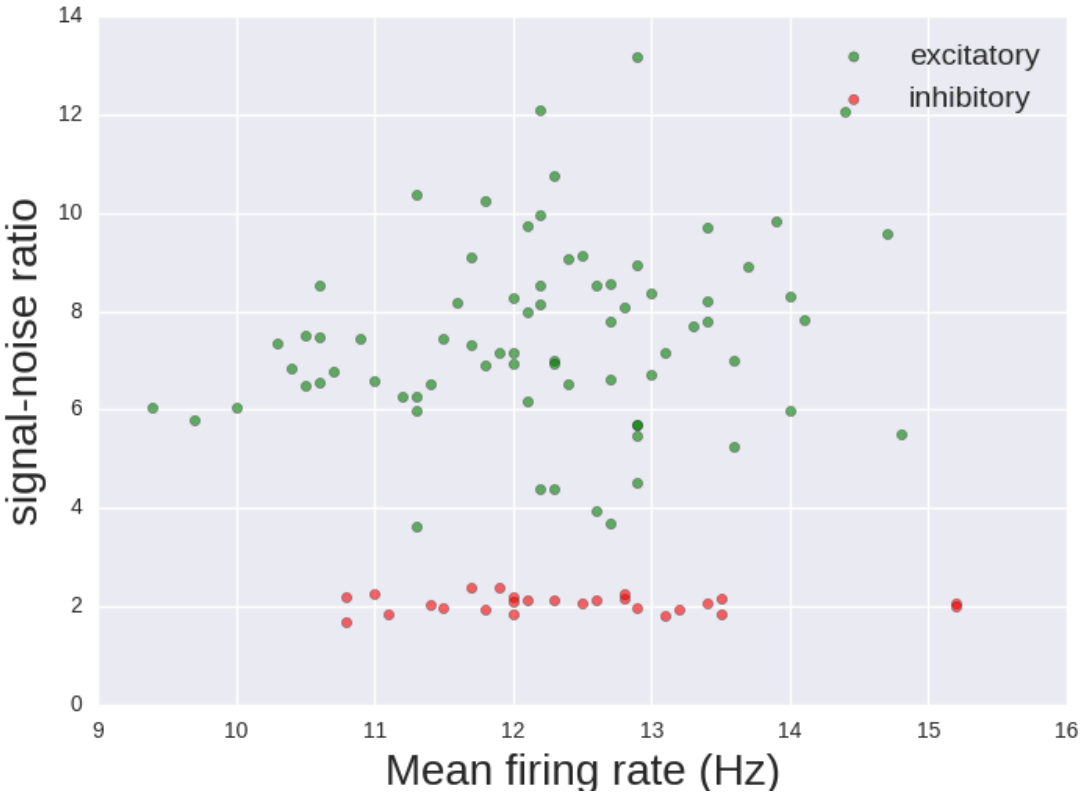
Figure: Signal-noise ratio of TDMI signal for all neurons with their one-degree LFP.

Neuronal Type vs. No.of Connection vs. Signal-noise Ratio



Number of connection is not an essential factor that leads TDMI signal pattern of inhibitory neuron.

Neuronal Type vs. Mean Firing Rate vs. Signal-noise Ratio



Mean Firing Rate is not an essential factor that leads to TDMI signal pattern of inhibitory neuron.

General Views

All neurons in pre-network are identical excitatory neurons. Neurons in post-network are 80% excitatory and 20% inhibitory.

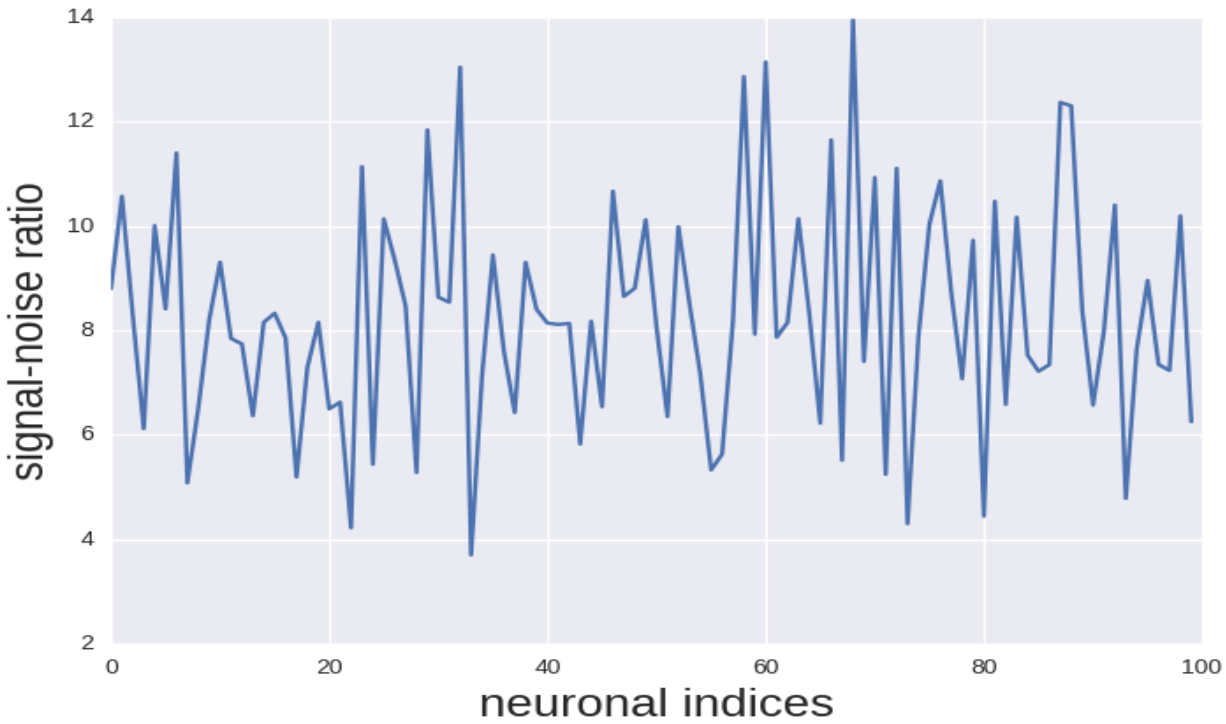


Figure: Signal-noise ratio of TDMI signal for all neurons with their one-degree LFP.

Signal-noise ratio vs. Neuronal Type

#0 neuron: Connects with 5 excitatory neurons and 4 inhibitory neurons

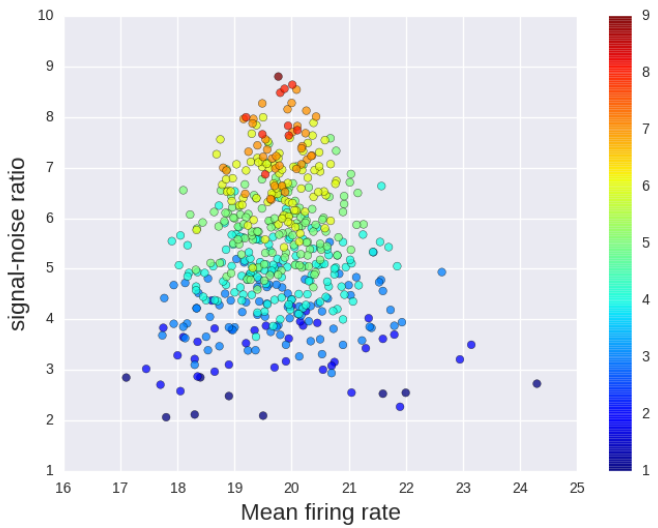


Figure: Colorbar represents number of connections

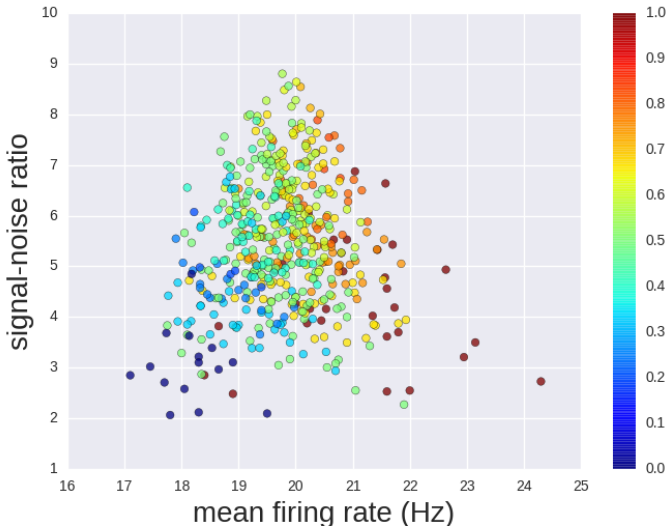


Figure: Colorbar represents portion of excitatory neurons in cluster

Neuron type in post-network clusters is not an essential factor that leads to effective TDMI signal pattern.

Signal-noise ratio vs. Neuronal Type

#92 neuron: Connects with 5 excitatory neurons and 5 inhibitory neurons

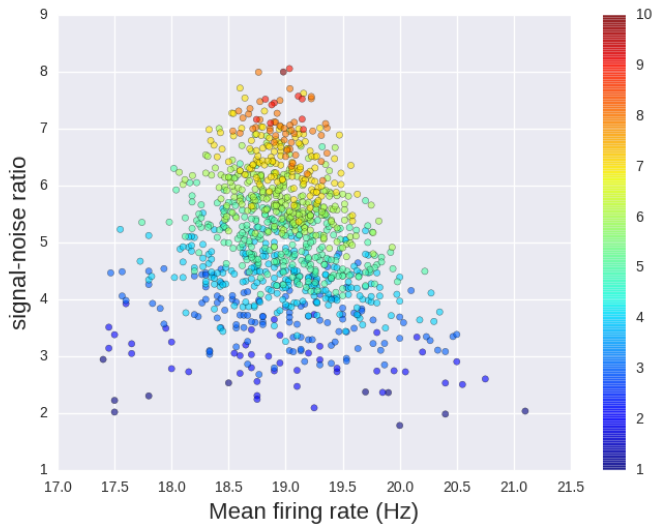


Figure: Colorbar represents number of connections

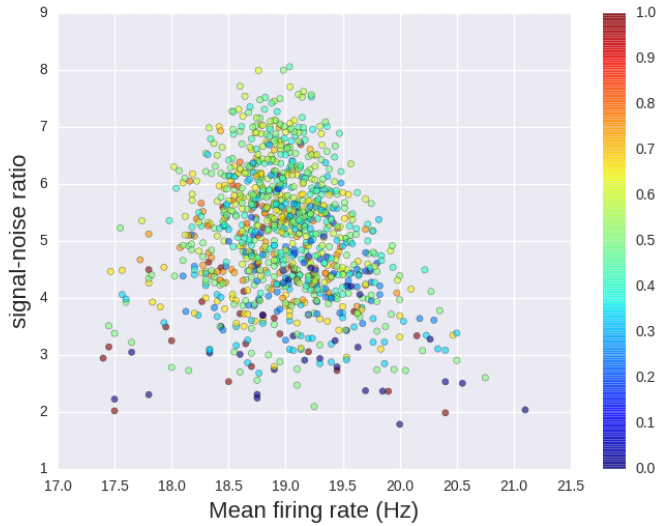


Figure: Colorbar represents portion of excitatory neurons in cluster

Neuron type in post-network clusters is not an essential factor that leads to effective TDMI signal pattern.

General Views

All neurons in system are identical excitatory neurons.

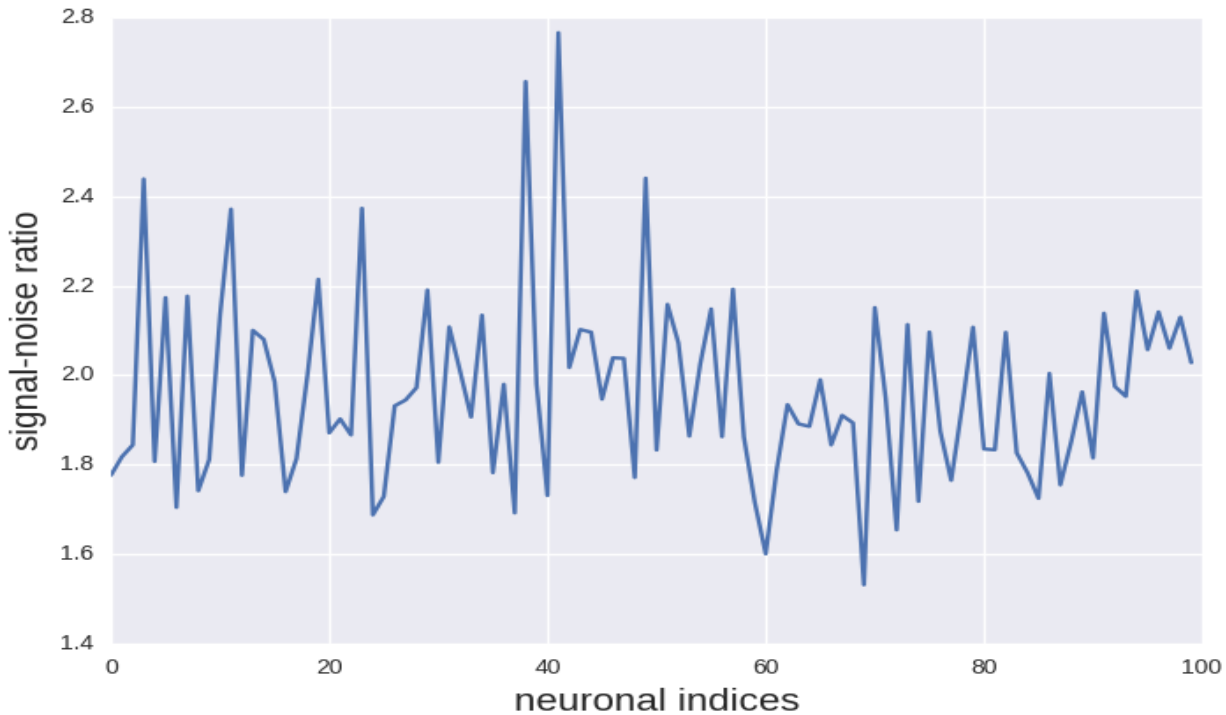


Figure: Signal-noise ratio of TDMI signal for all neurons with their two-degree LFP.