Role of noise in the transmission of dynamic sensory stimuli

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2. Juli 2017

Goal

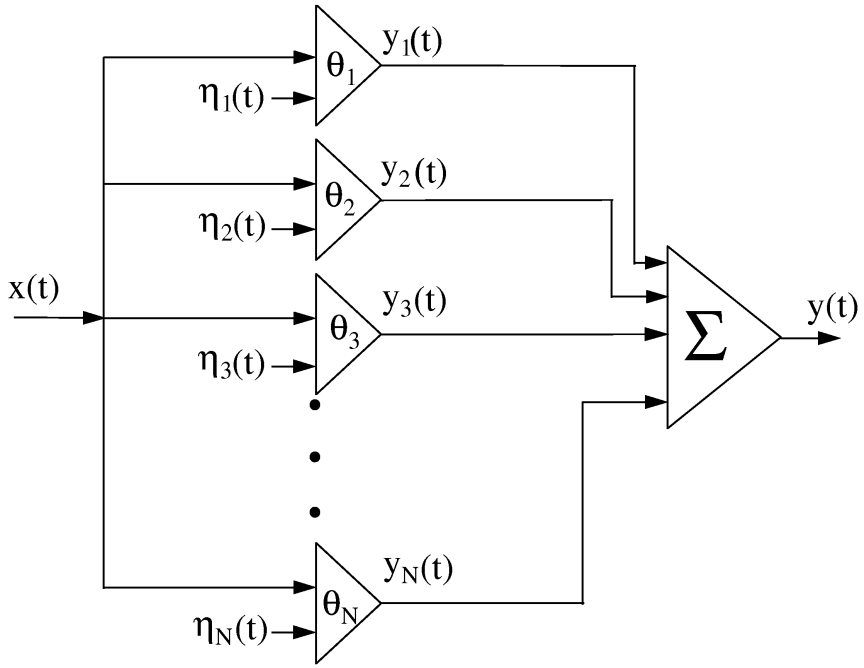
Investigate the relationship between coding and intrinsic noise.

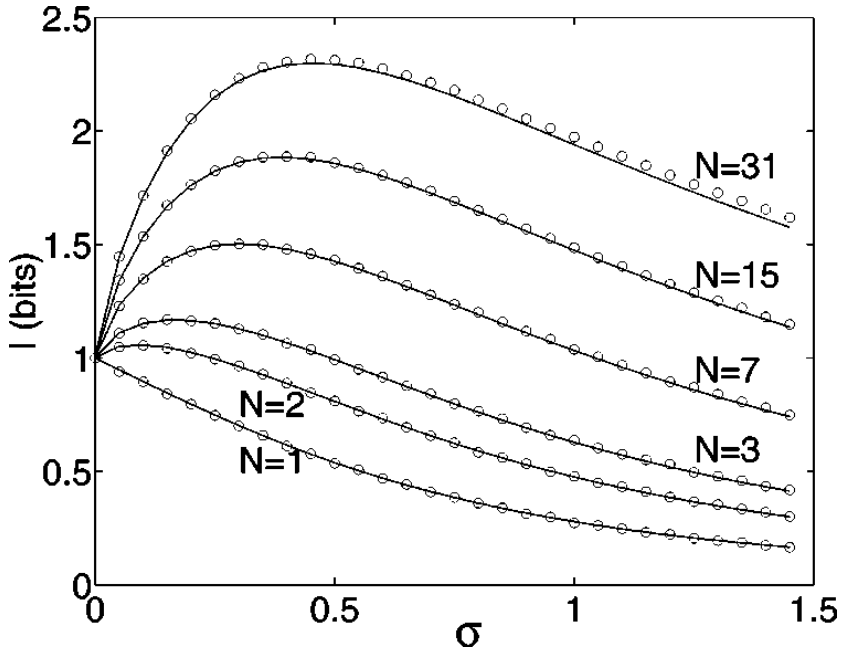
Stochastic Resonance

1

[1] Simonotto, E; Riani, M; Seife, Charles; et al. (1997). "Visual Perception of Stochastic Resonance"(PDF). Physical Review Letters. 78 (6): 1186.

Stochastic Resonance



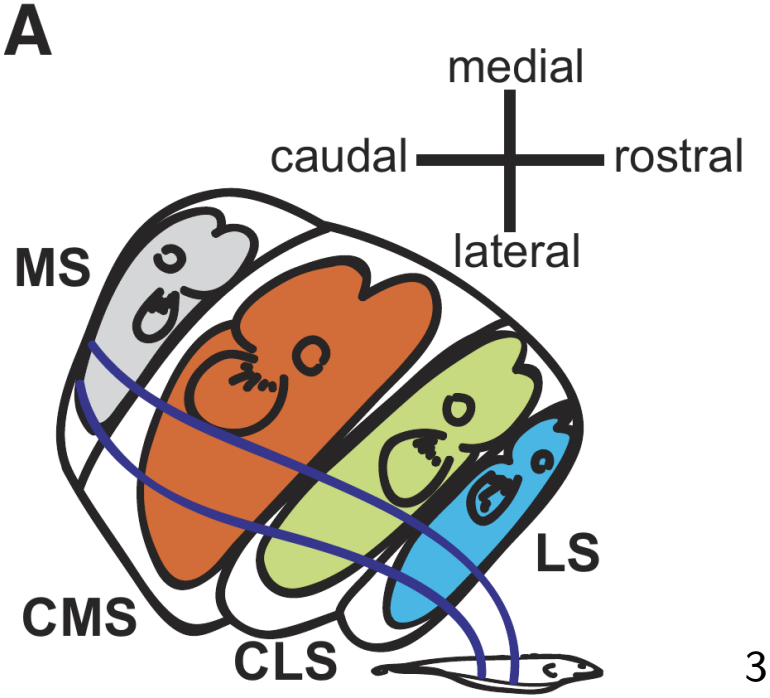


2

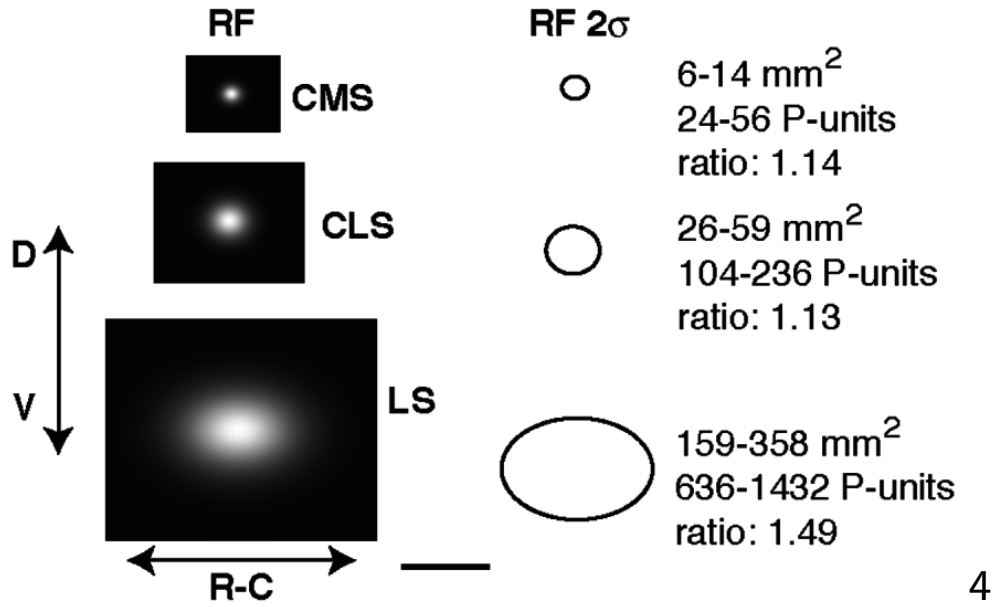
[2]Stocks, N. G. (2001). Information transmission in parallel threshold arrays: Suprathreshold stochastic resonance. Physical Review E, 63(4), 041114.

Motivation: Weakly electric fish

Pyramidal cells of *Apteronotus leptorynchus*.



[3]



[4]

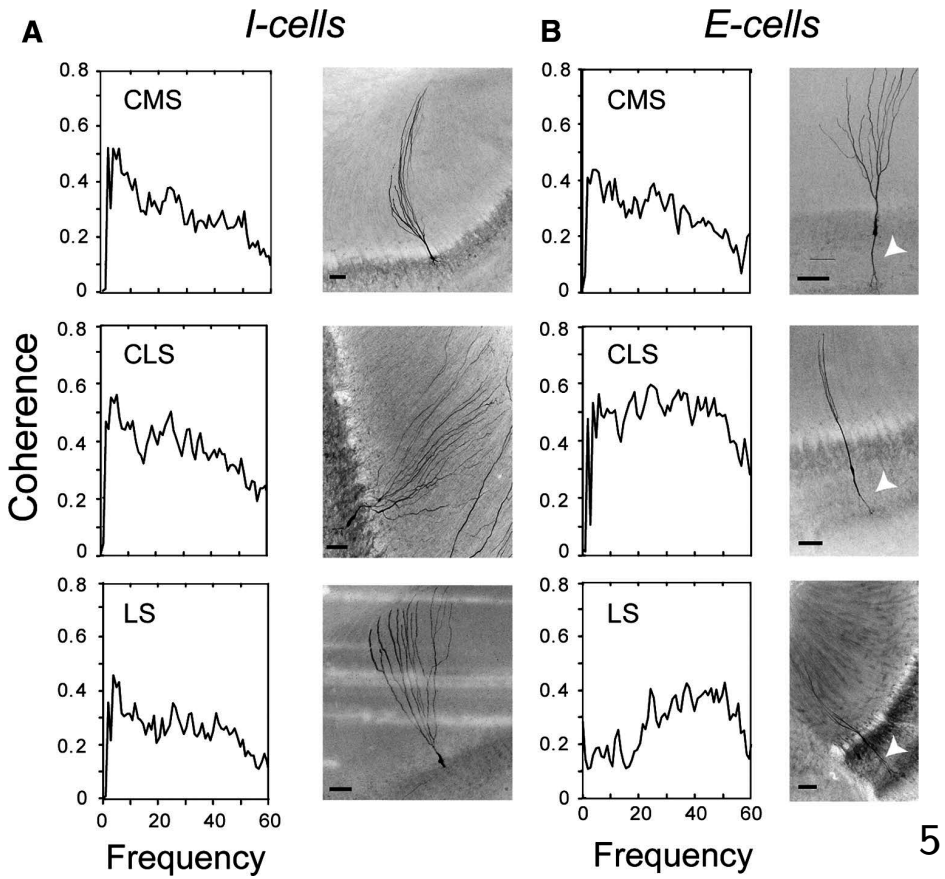
Perfect model system for feed-forward networks.

Easy to access and manipulate; networks of different sizes.

[3] Krahe 2008

[4] Maler 2009

Motivation: Weakly electric fish



5

Frequency differences in slice preparations (single cells).

No *in vivo* data for frequencies $> 100\,\mathrm{Hz}$, weak signals or MS. Effects of the network only visible *in vivo*.

[5] Mehaffey 2008

Model

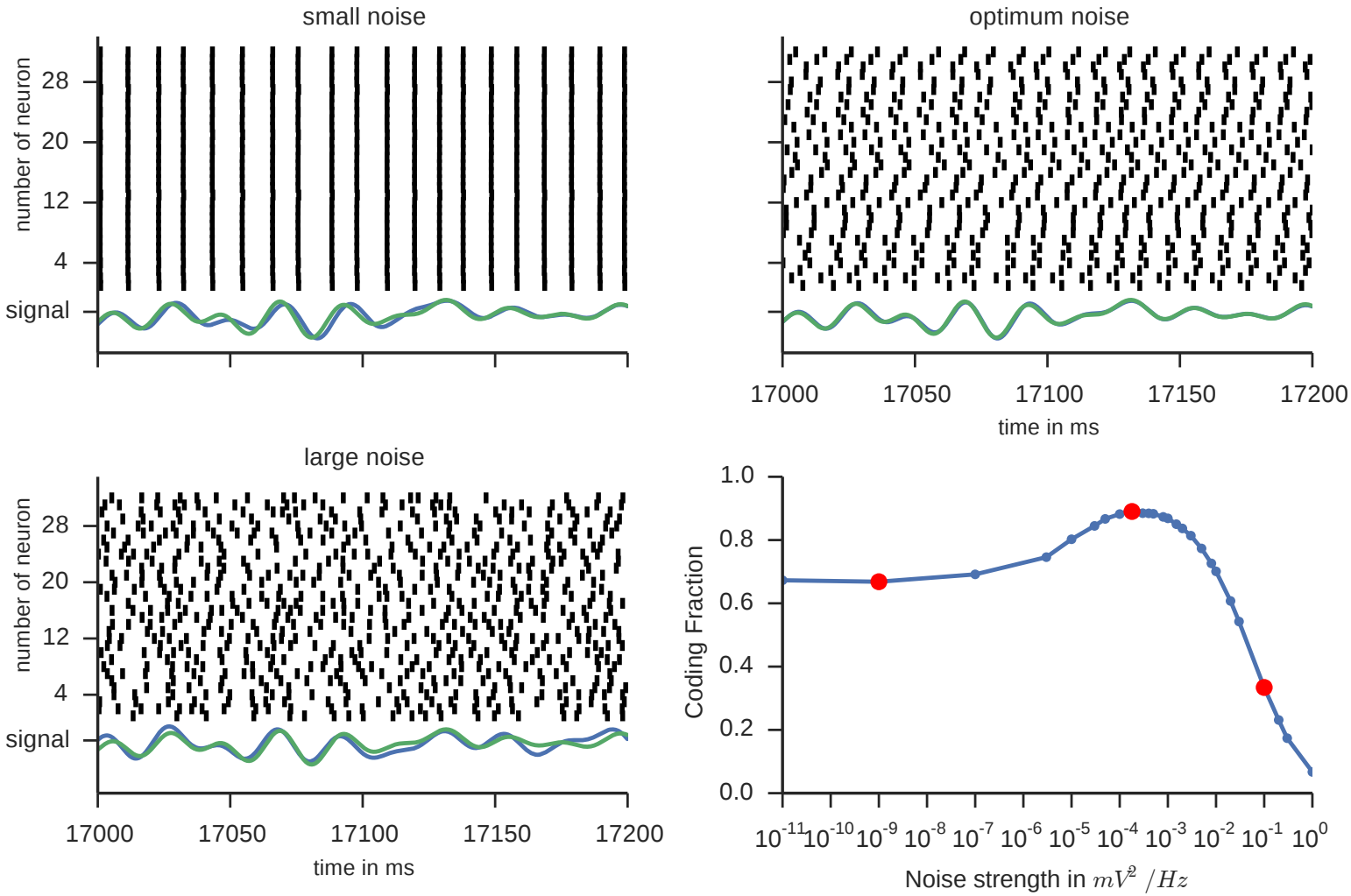
Leaky-Integrate-and-Fire Neurons:

$$\dot{V}\tau = -(V - V_E) + As(t) + \sqrt{2D}\xi(t)$$

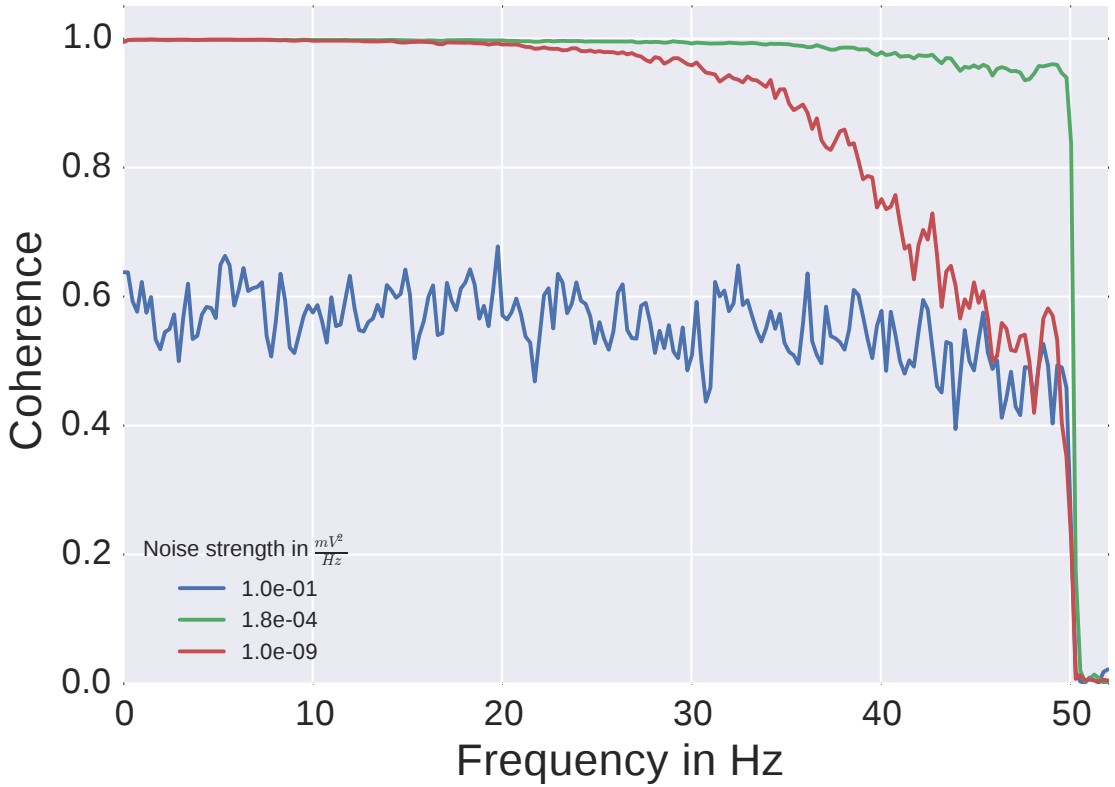
Up to 4096 neurons, simulations of 500s with a simple Euler method.

Repeating a simulation with a slightly different input signal yields the same result ($<$1% difference).

Suprathreshold Stochastic Resonance for dynamical stimuli



Coding fraction ξ and coherence γ



Coding Fraction: $\xi = 1 - \sqrt{\frac{\epsilon^2}{\sigma^2}}$

$\epsilon^2 = \langle s_{est}(t) - s(t) \rangle^2 = \int_0^\infty P_s(f)(1 - \gamma^2(f))df$

$\sigma^2 = \langle (s(t) - \langle s(t) \rangle)^2 \rangle = \int_0^\infty P_s(f)df$

Lower bound of Mutual Information: $I_{LB} = -\int_0^\infty \log_2(1 - \gamma^2(f))df$

Frequency dependence

- Does the optimal noise strength depend on the frequency band?

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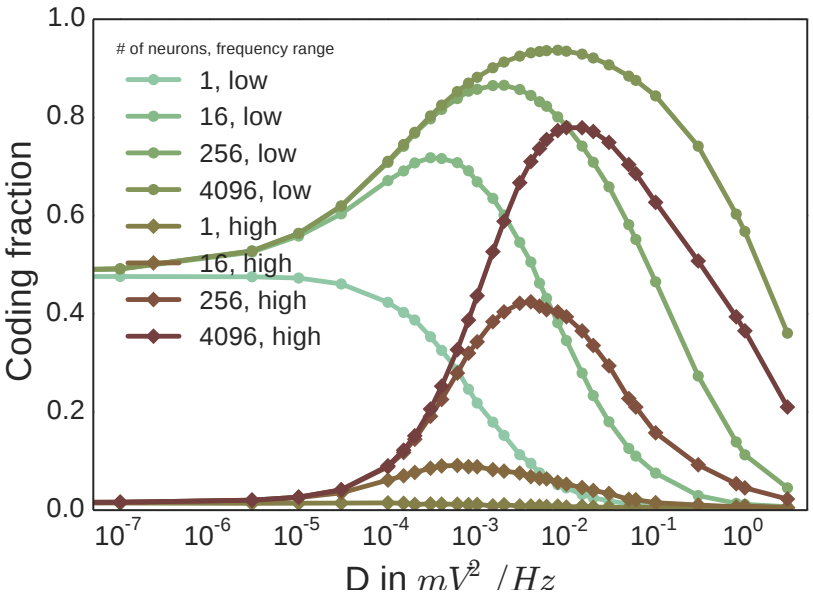
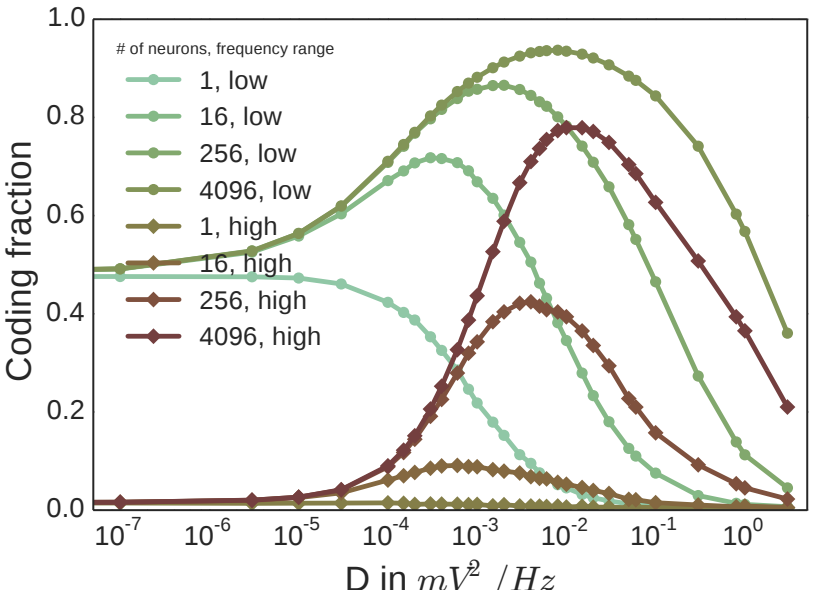
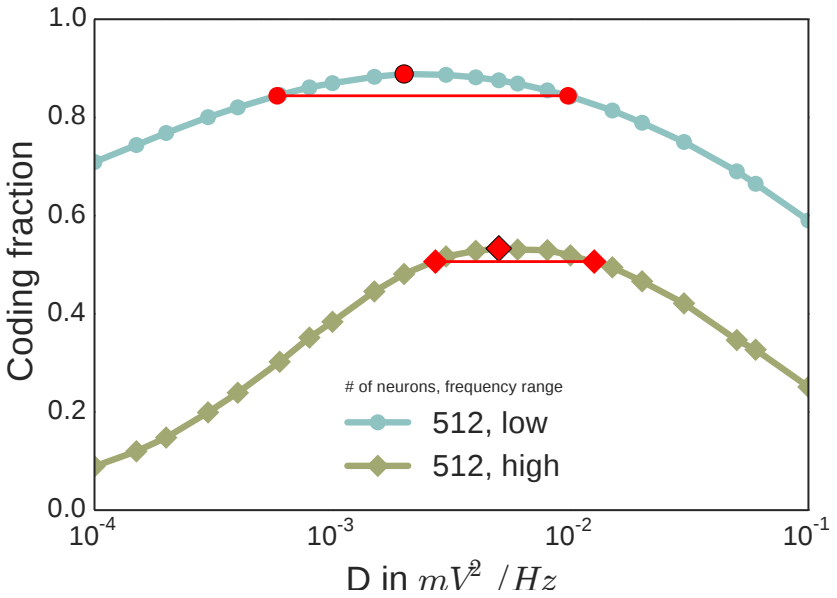


Frequency dependence

- Does the optimal noise strength depend on the frequency band?
- Can we optimize for multiple bands at the same time?





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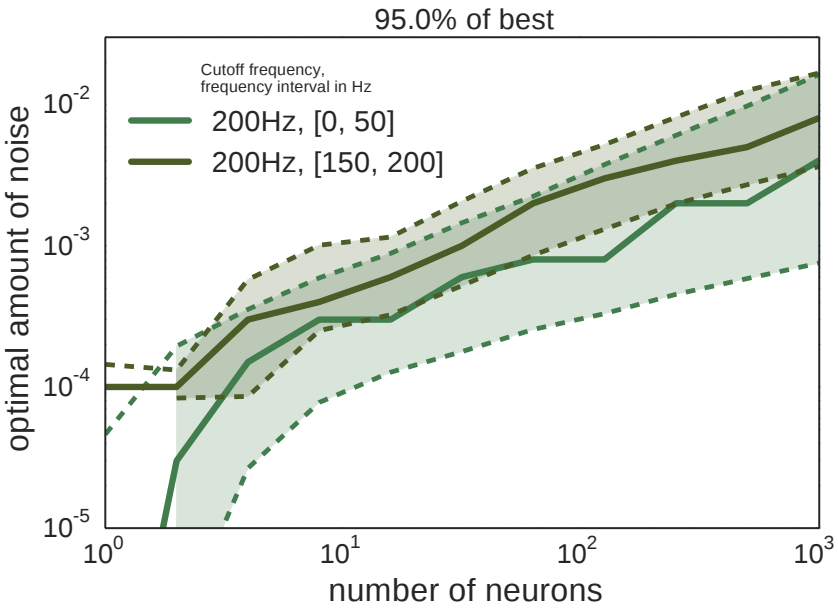
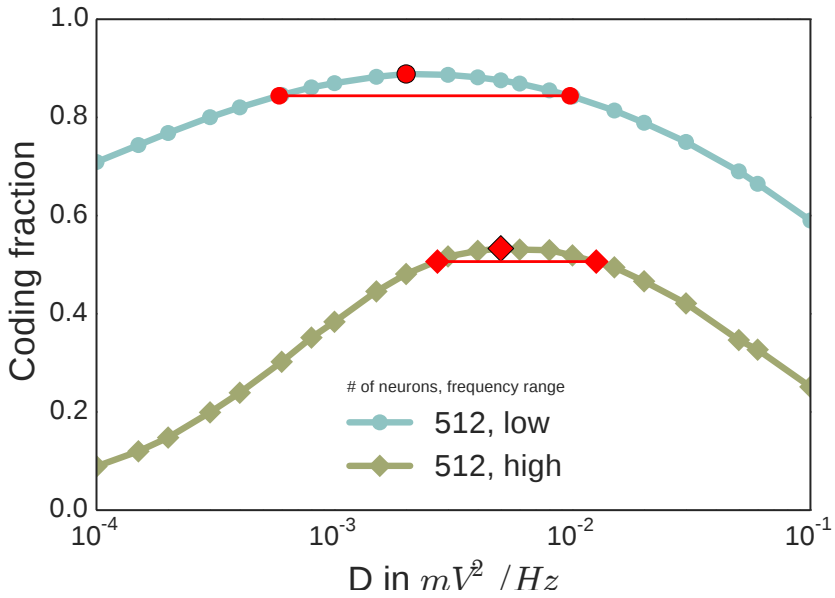
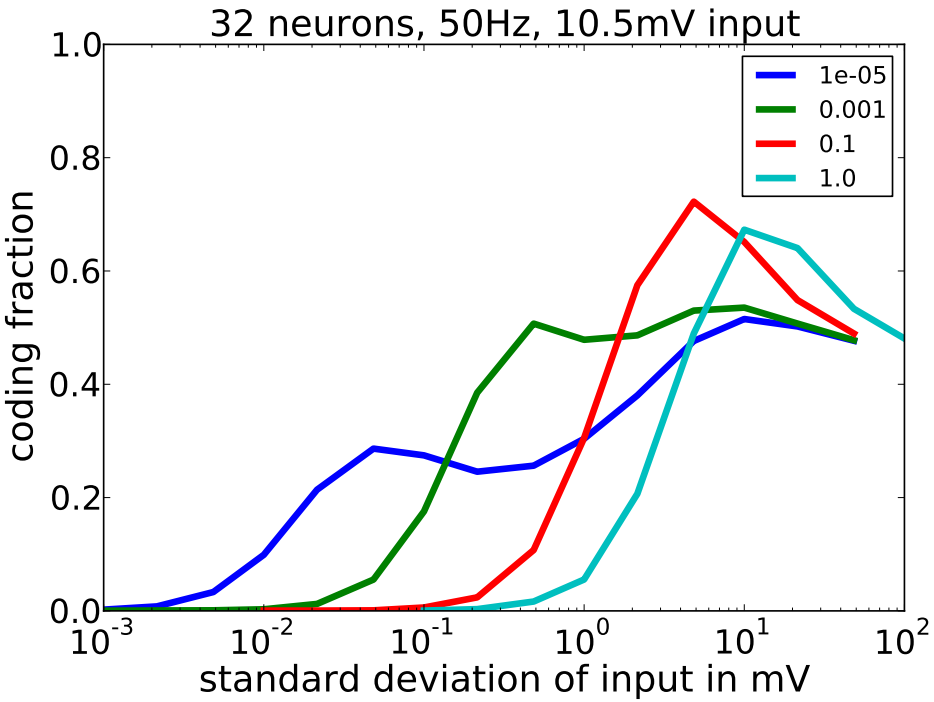




Dependence on Input Strength

Each line is a different background (white) noise in mV^2/Hz.



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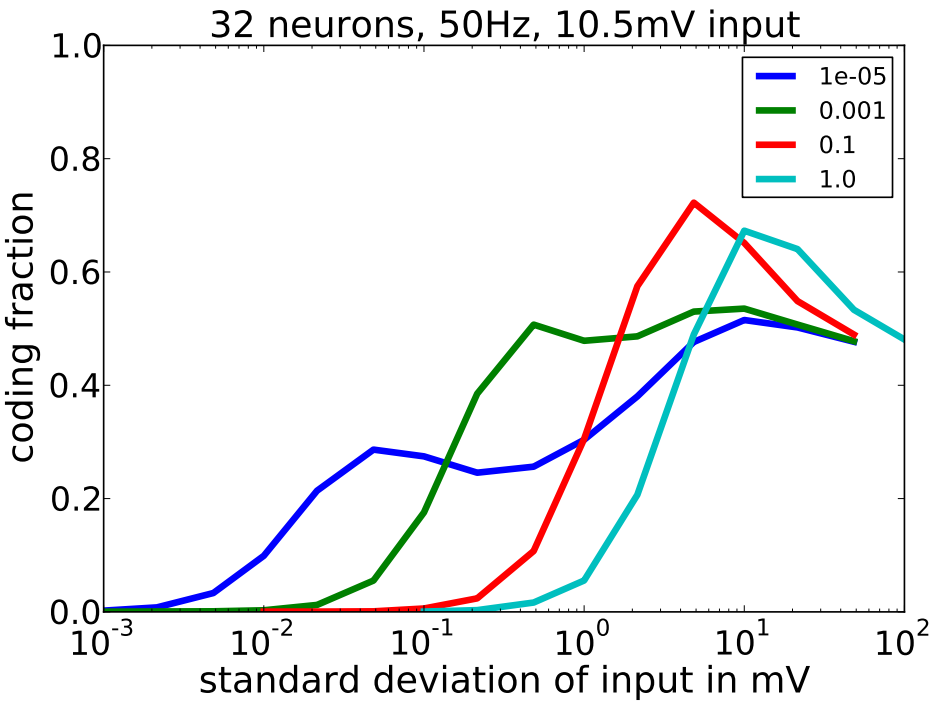
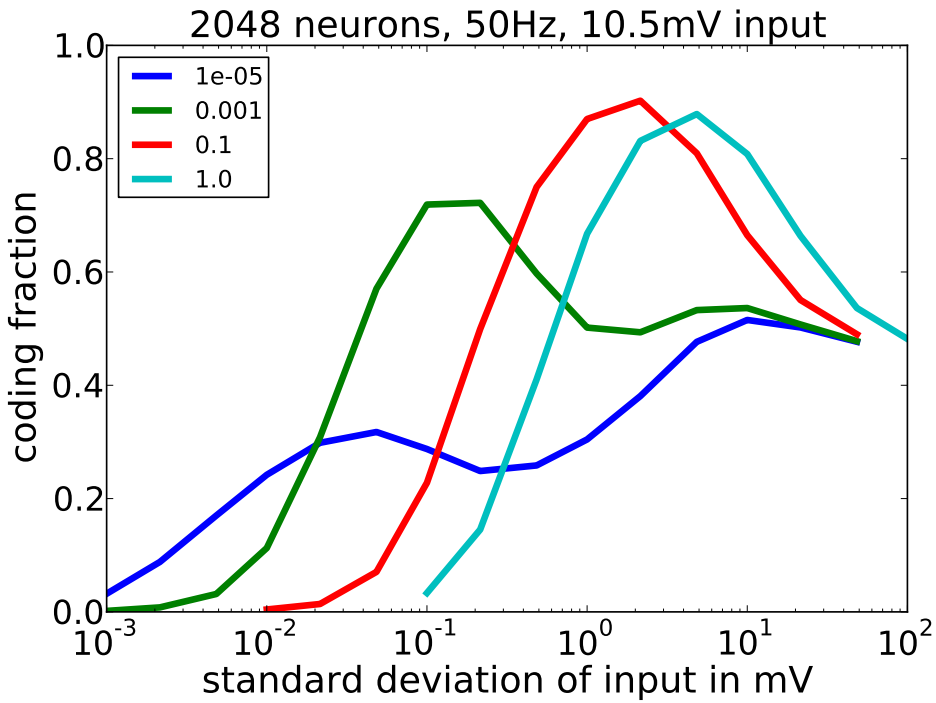
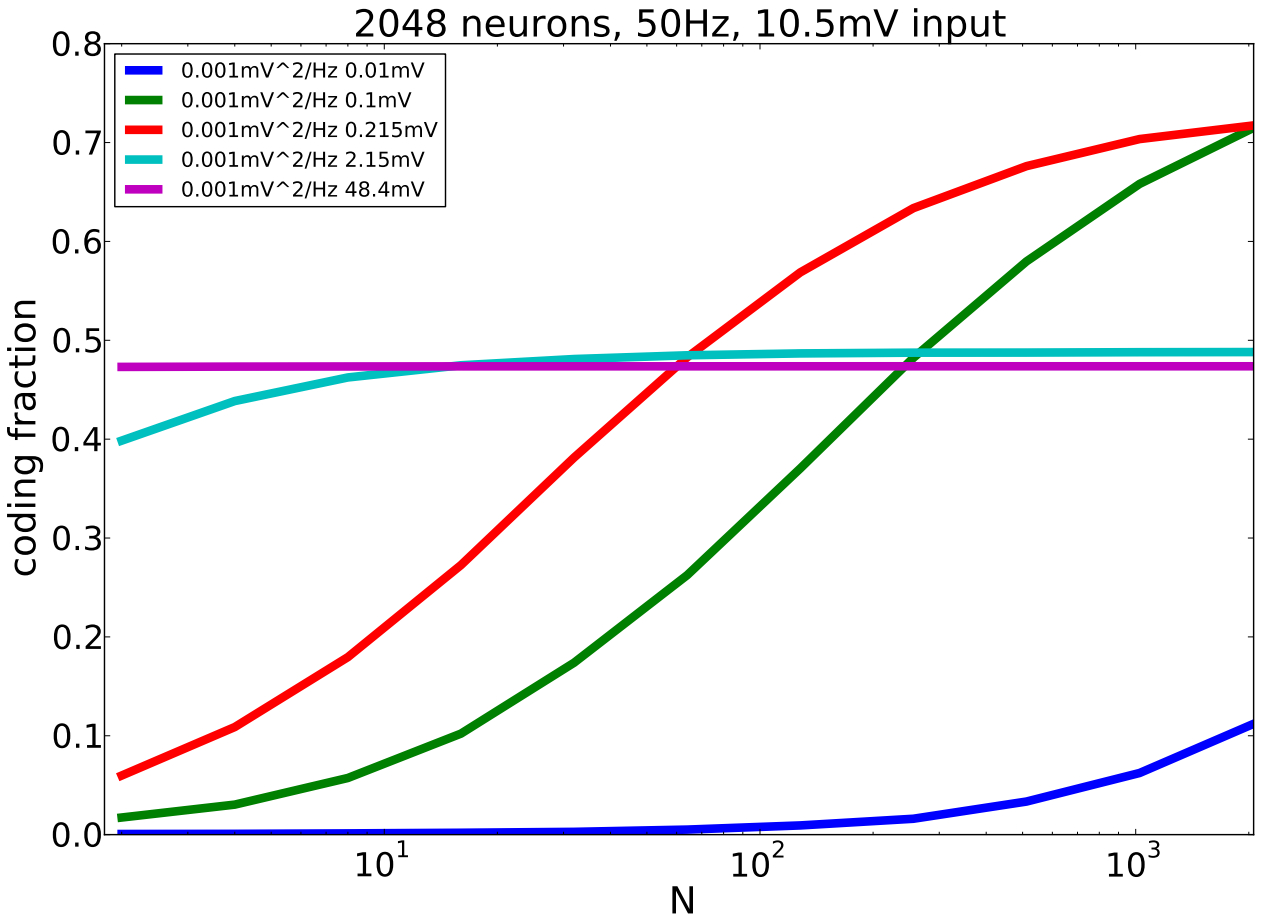




Influence of Network Size for Different Inputs



Summary

- For a given dynamic input signal and network size, there is an optimal amount of noise.
- The optimum depends on frequency of the signal, also the frequency we are interested in.
- The optimum depends on variance of input.
- Larger number of neurons especially important for weak signals.