# Introduction

- Previous work has shown that action potential generation is a reliable phenomenon (Mainen & Sejnowski 1995). Repeated presentations of the same fluctuating input yield patterns of spiking that vary by less than 2 ms.
- Here we use the in vitro slice preparation of rat prefrontal cortex to study the dependence of this reliability on the amplitude and frequency content of the inputs, and the eventual differences in reliability between pyramidal cells interneurons.
- We also construct a compartmental model of pyramidal cells and interneurons with intrinsic noise in order to reproduce and explain the data.
- Information transmission was then analyzed using optimal linear reconstruction techniques.

# Method

- Experiments: We use whole cell patch clamp to record from regular spiking layer 5 pyramidal cells and layer 2/3 interneurons of young rat prefrontal cortex (pre- and infra-limbic areas). ACSF contains mM: NaCl 125, NaHCO3 25, Glucose 10, KCl 2.5, CaCl2 2, MgCl2 1.3, NaH2PO4 1.25. Internal solution contains mM: K-MeS 140, HEPES 10, NaCl 4, EGTA 0.1, ATP 4.0, GTP .3, Phophocreatine 14.0. Lucifer Yellow or Biocytin were added to characterize the morphology of the cells. Data acquisition and stimulation were achieved using custom written software (Labview, Nat. Instrument) and analyzed in Matlab (Mathworks). 10 interneurons and 11 pyramidal cells have been used in this study.

- Modeling: For the pyramidal cell, we use a 1 compartment model (Golomb and Amitai 1997), to which $I_h$ and voltage dependent noise have been added. For the interneuron, we use a generic multi-compartmental interneuron reconstructed from hippocampus stratum radiatum. In this model, dendrites are passive, and the soma includes $I_{Na}$, $I_{kdr}$ (Traub et al. 1992) and $I_M$.

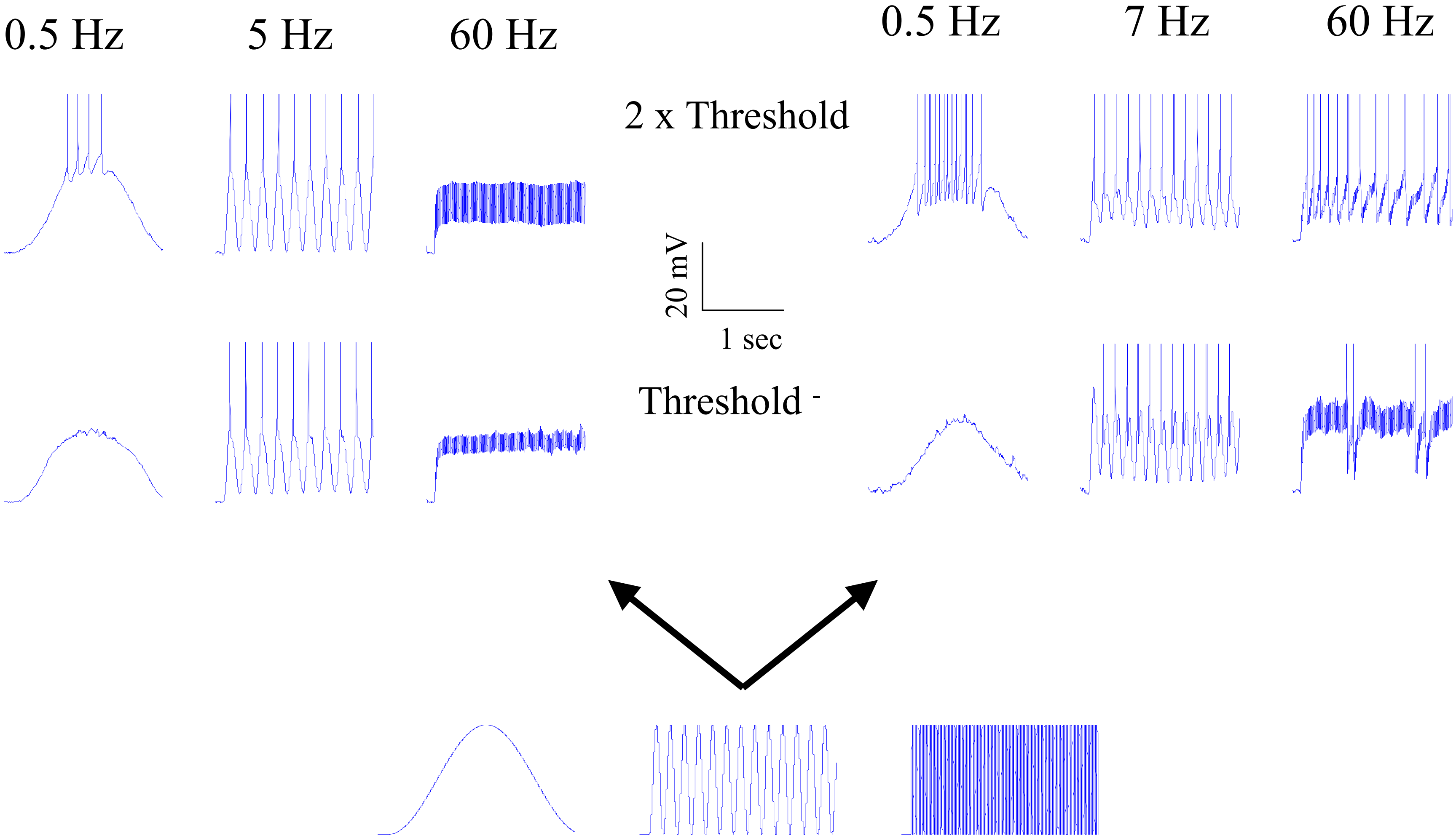
- Information Theory:

| | |
|---|---|
| Filter: | $h(\omega) = P_{xs}(-\omega)/P_{xx}(\omega)$ |
| Reconstruction: | $S(t) = h(\omega) \ast X$ |
| SNR: | $P_S(\omega)/P_{S-I}(\omega)$ |
| Coding Fraction: | $1-\varepsilon/\sigma_s$ with $\varepsilon^2(h) = MSE(S-I)$ |

# Sample Response to Sine Waves

Pyramidal Cells

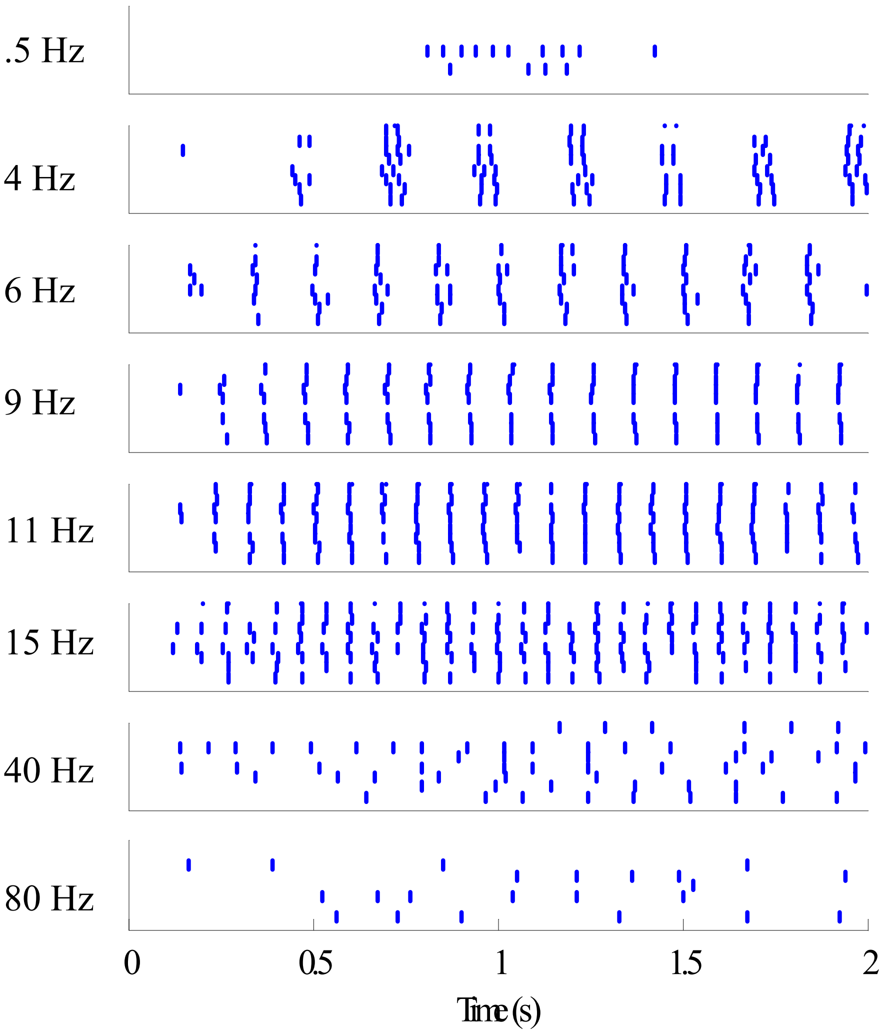
Interneurons

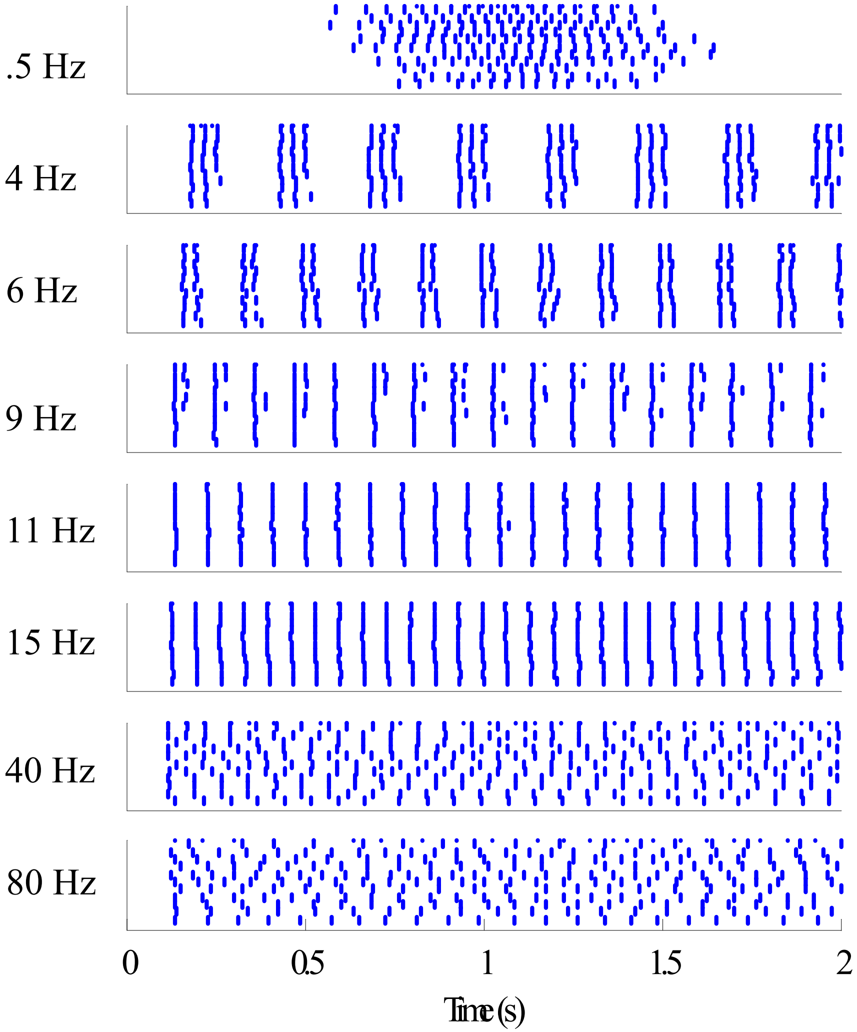


# Repeated Stimulations

## Low Amplitude (T$^-$)

## High Amplitude (2T)

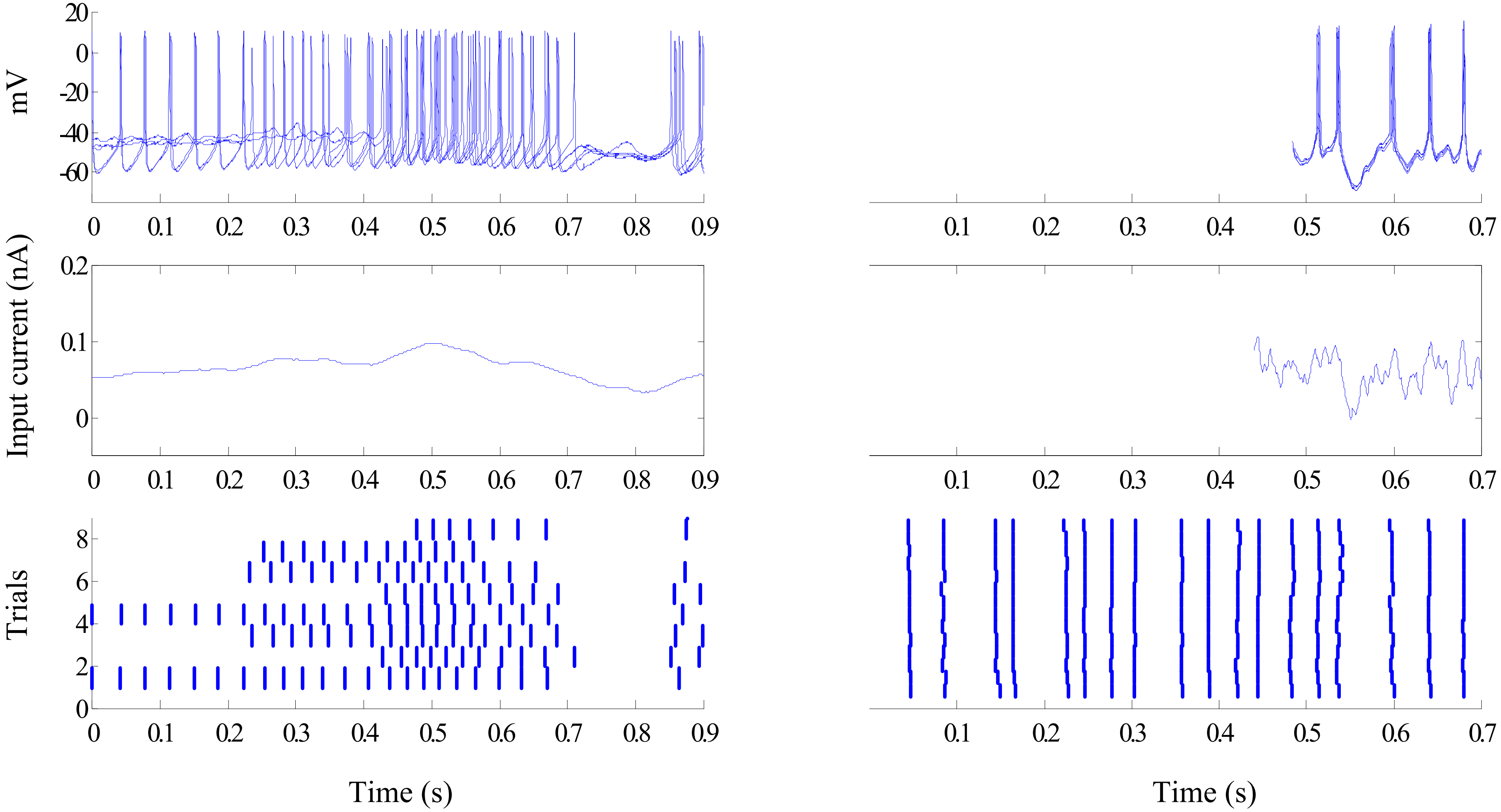




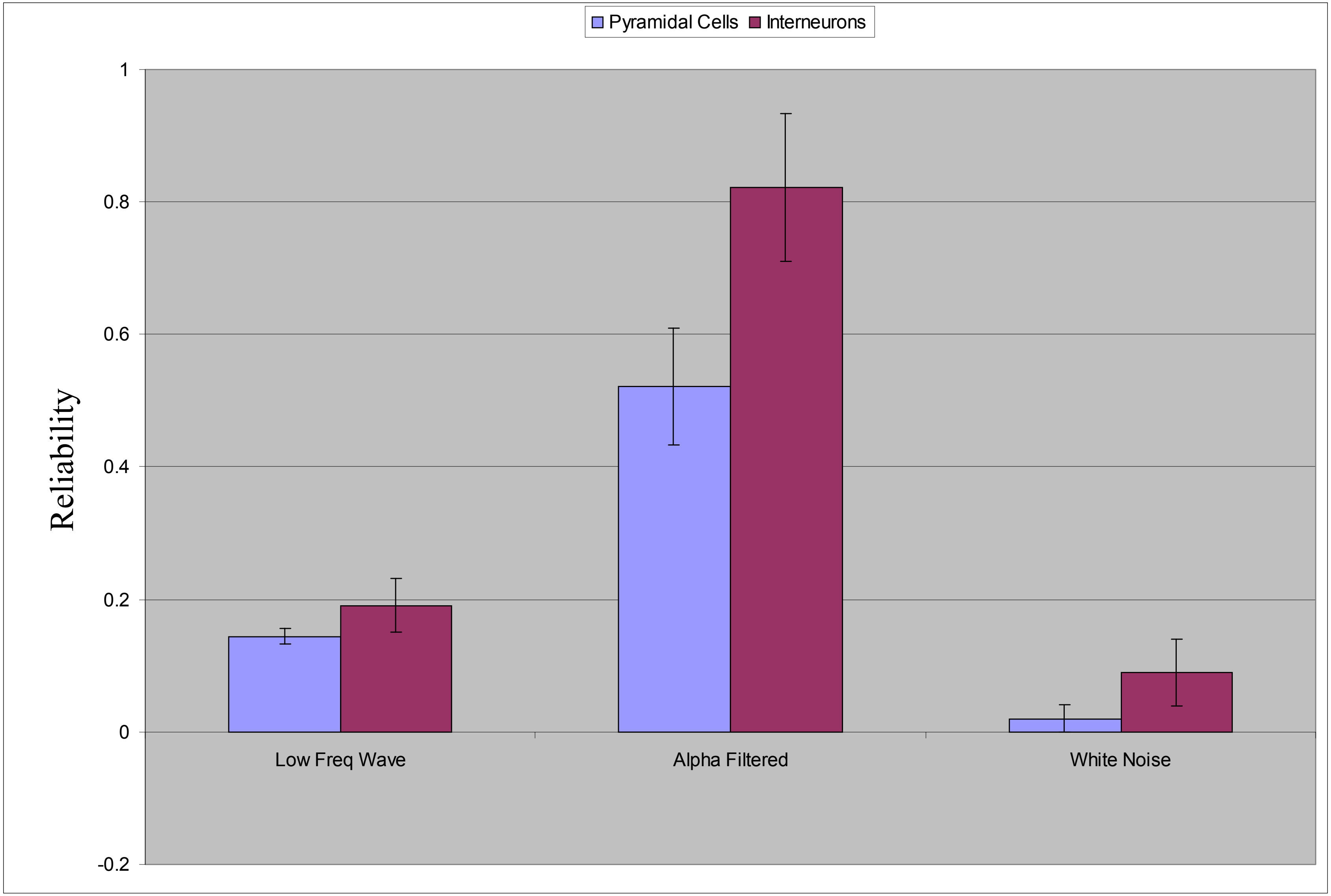
# Fluctuating Stimuli

## Alpha-Filtered (100 ms)

## Alpha-Filtered (4 ms)

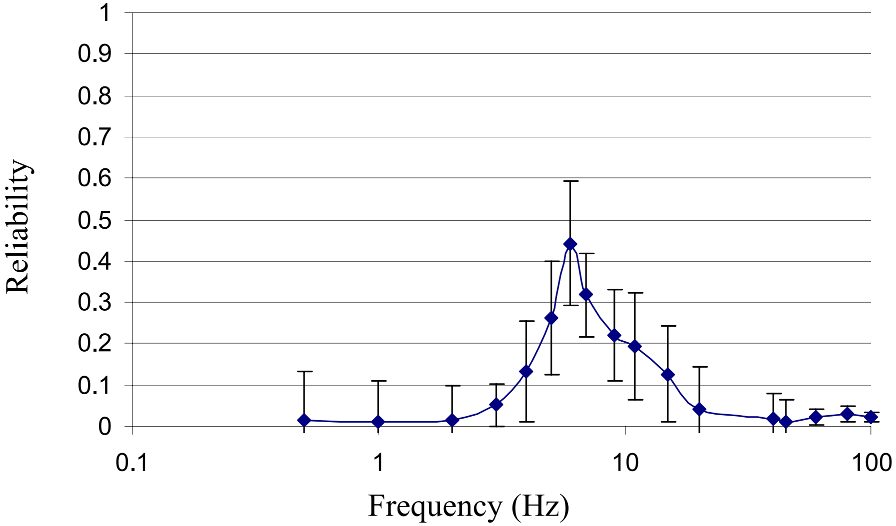


# Fluctuating Stimuli Reliability

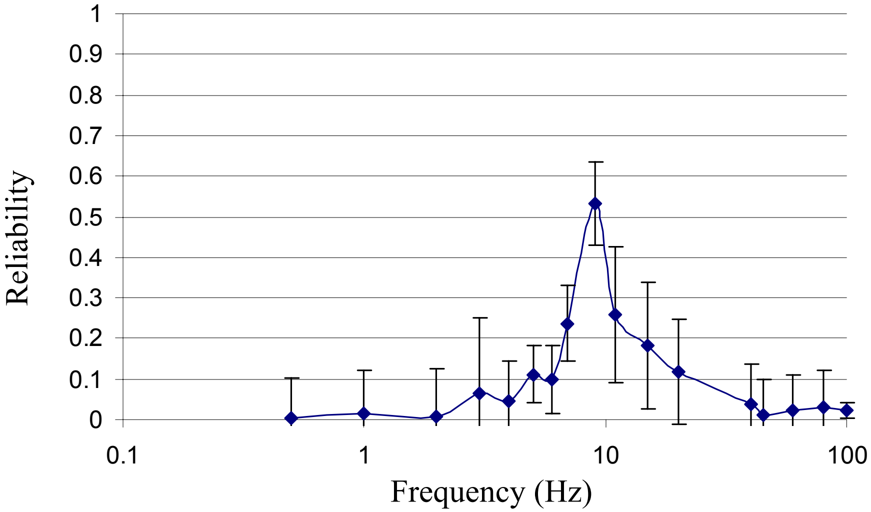


# Pyramidal Cell Reliability

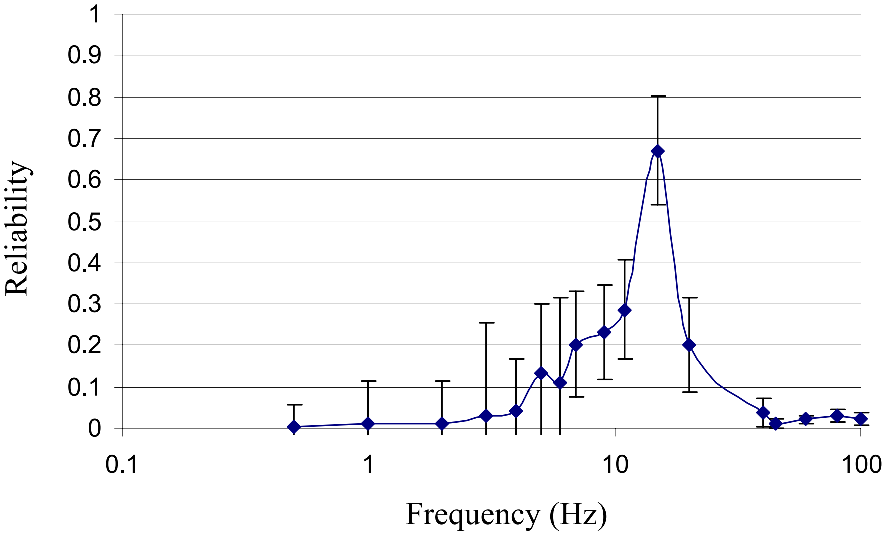
## Low Amplitude (T-)



## Medium Amplitude (1.5xT)

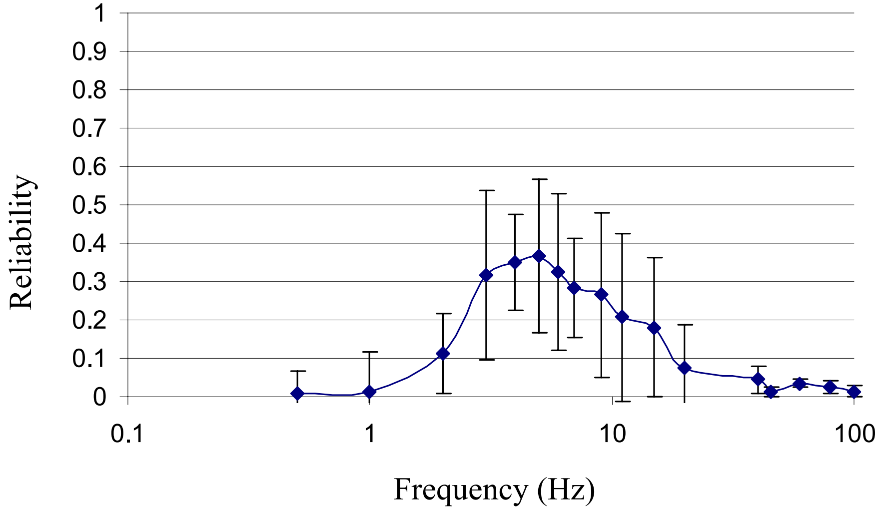


## High Amplitude (2xT)

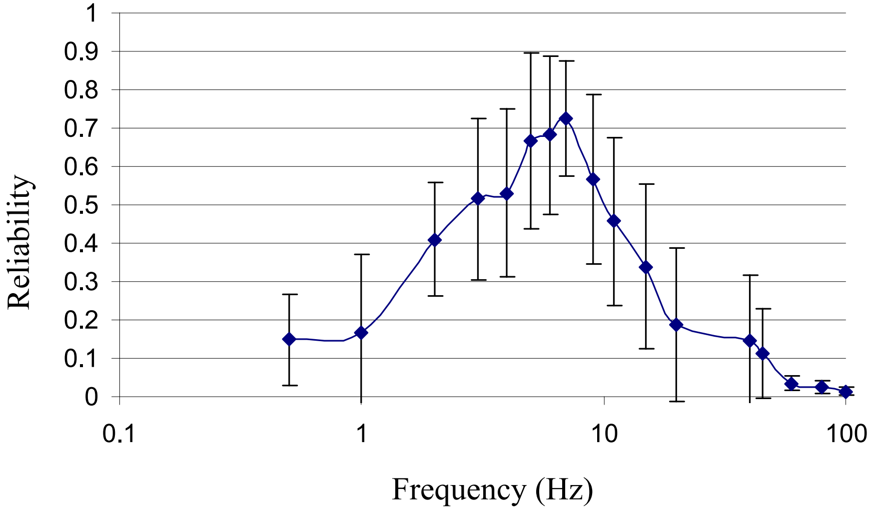


# Interneuron Reliability

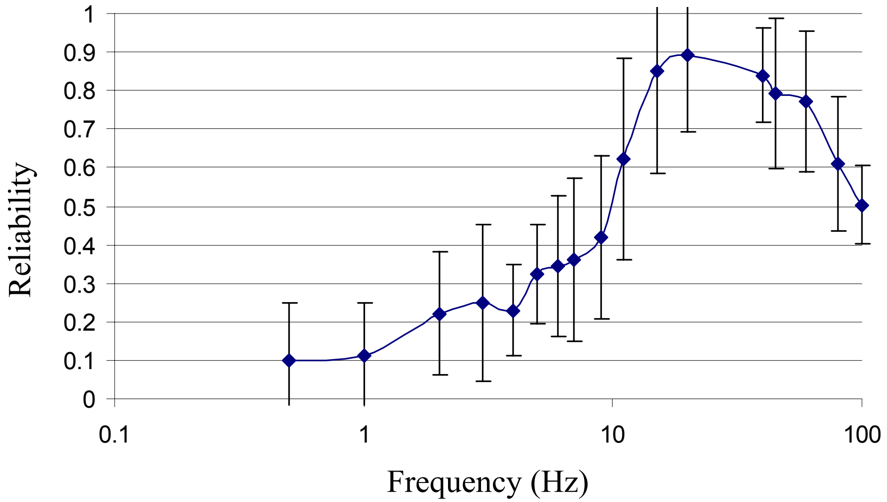
## Low Amplitude (T-)



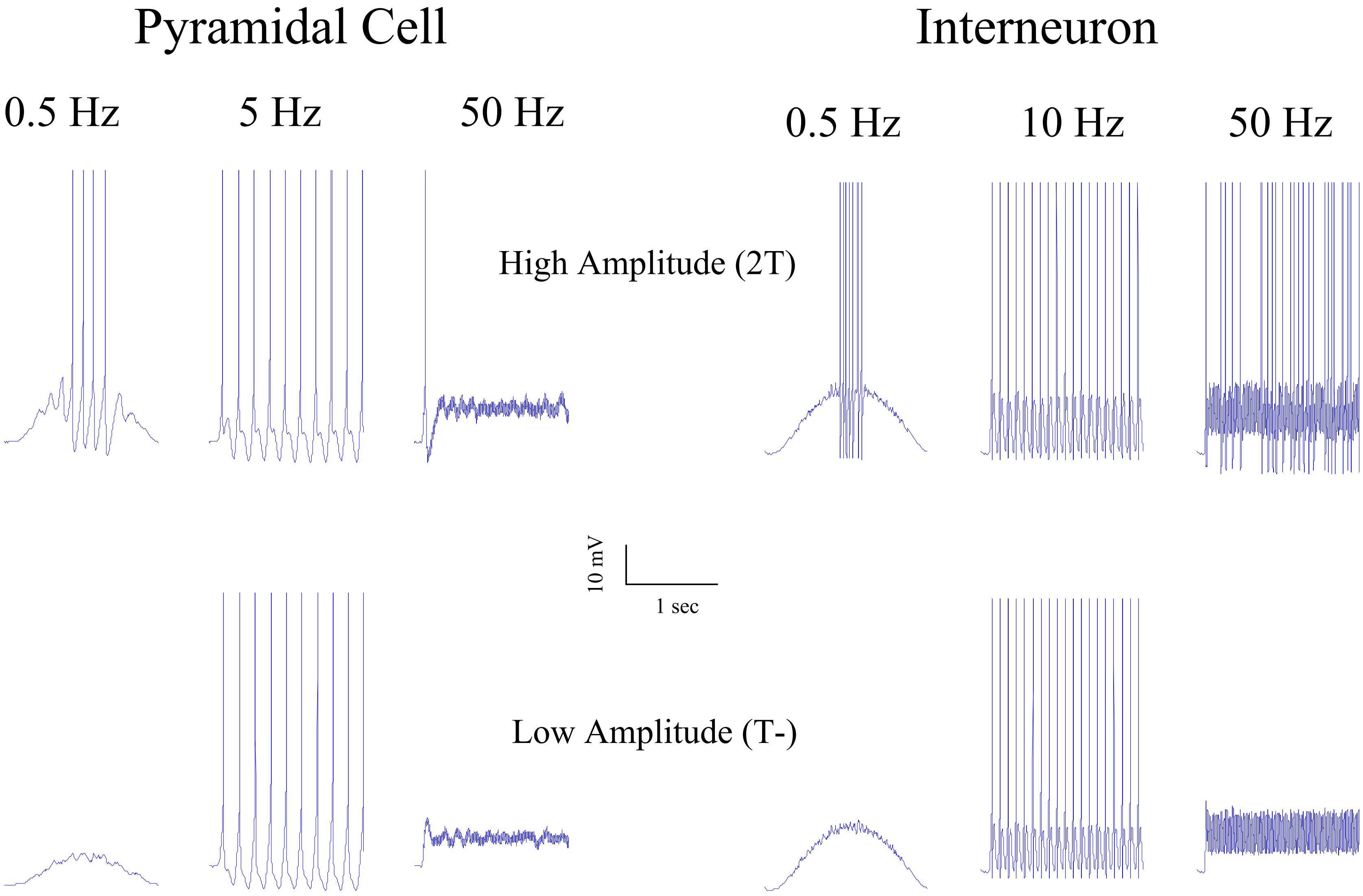
## Medium Amplitude (1.5xT)



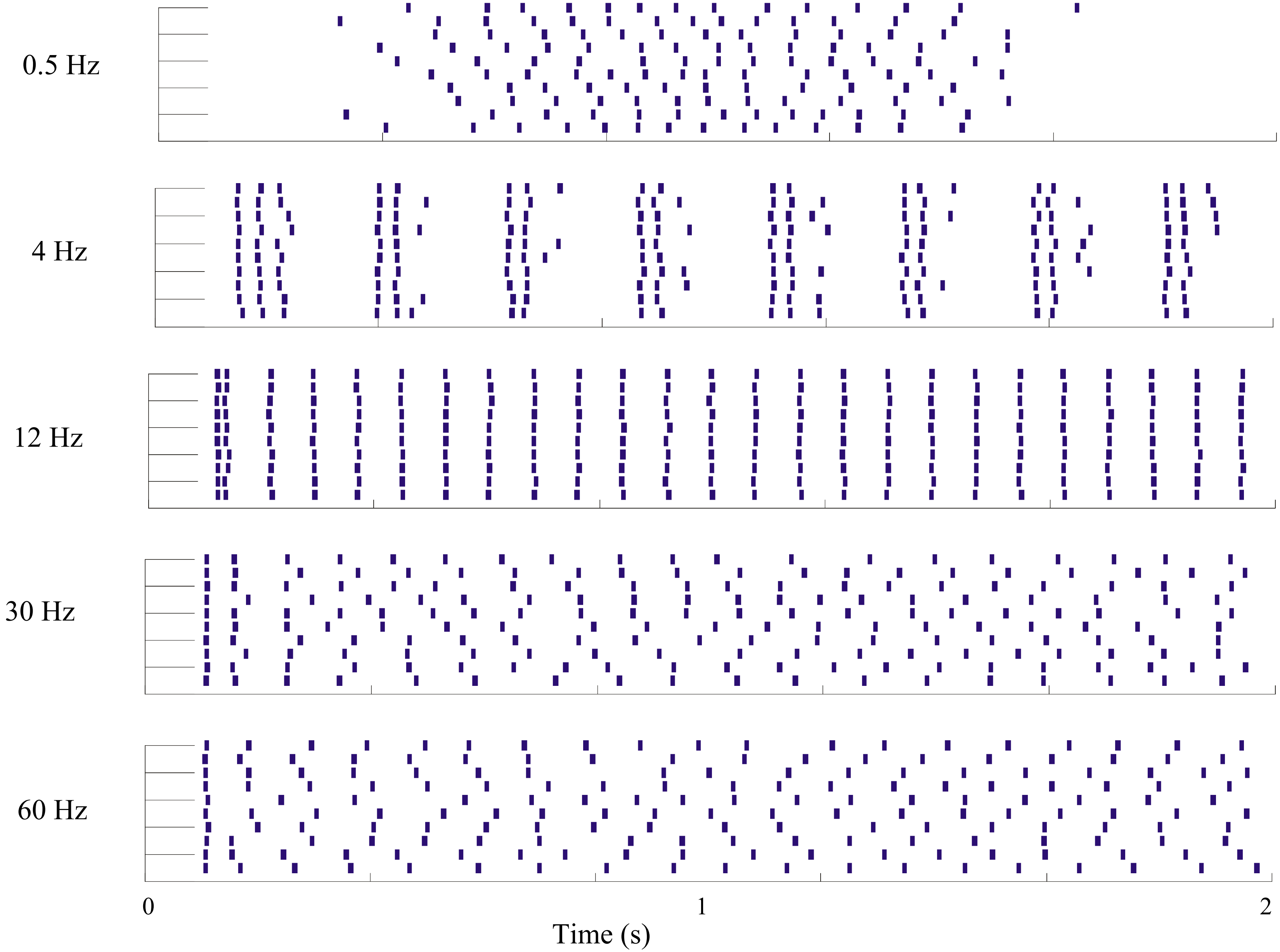
## High Amplitude (2xT)



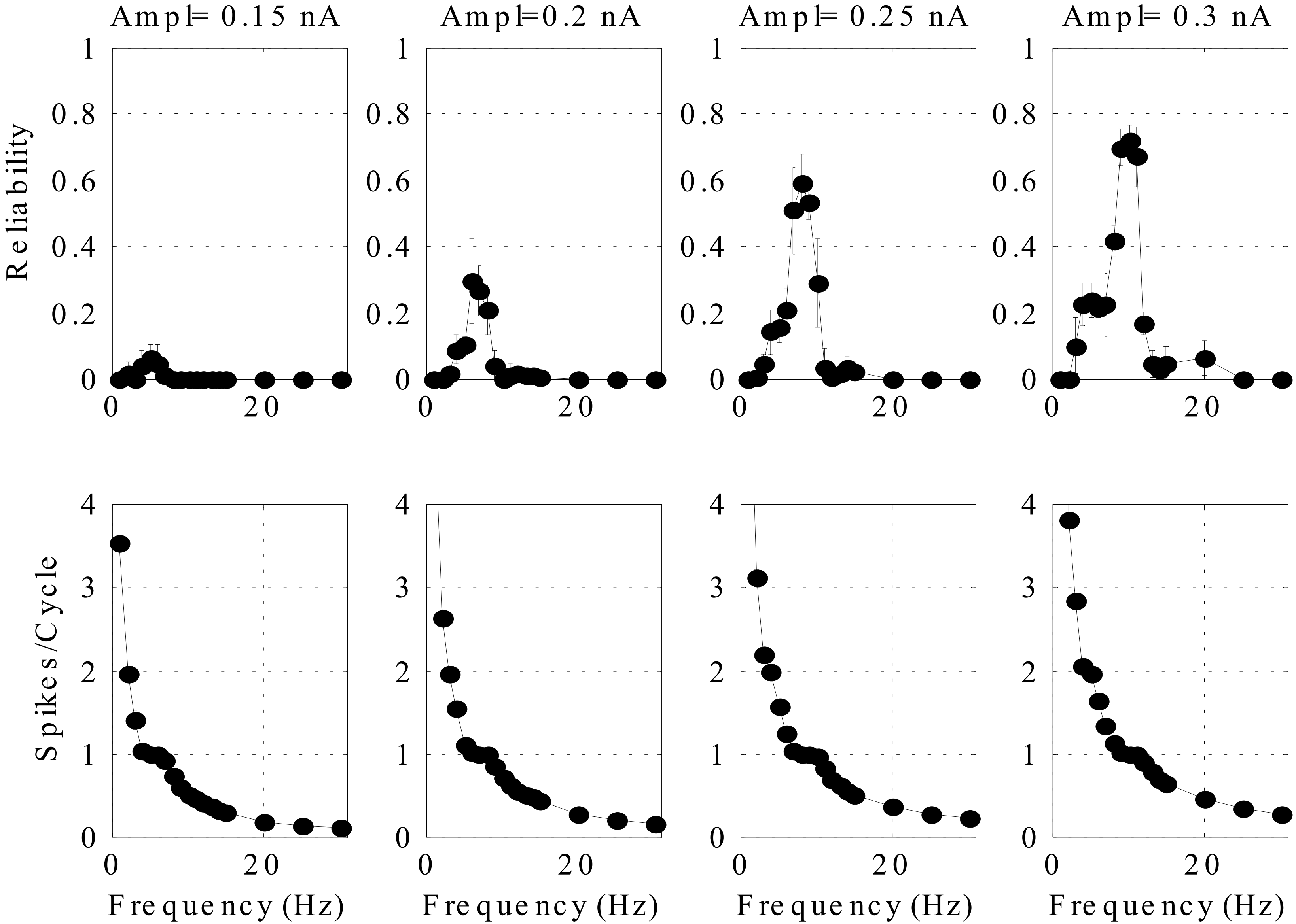
# Model: Responses to sine waves



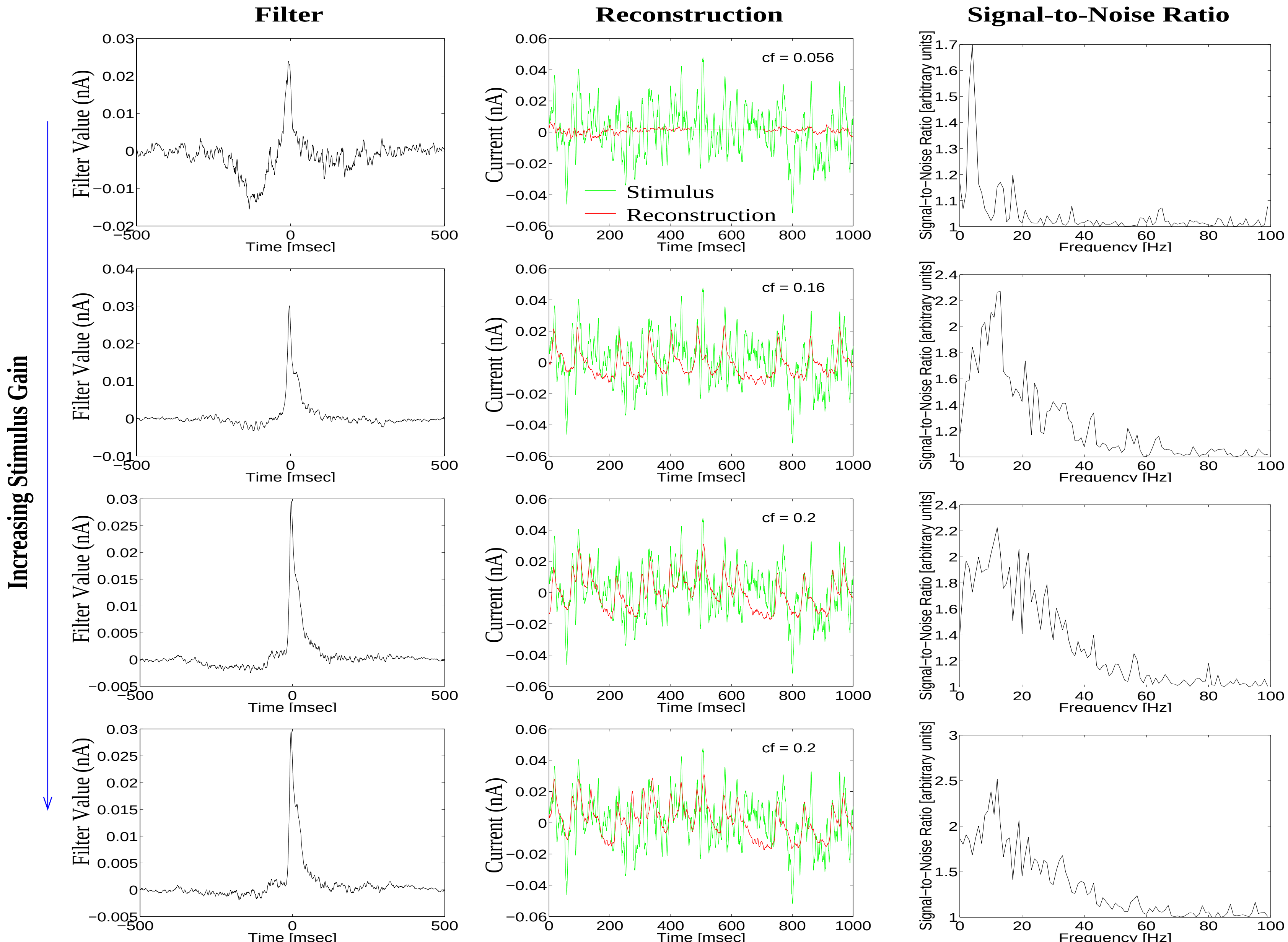
# Model: Pyramidal Cell Reliability



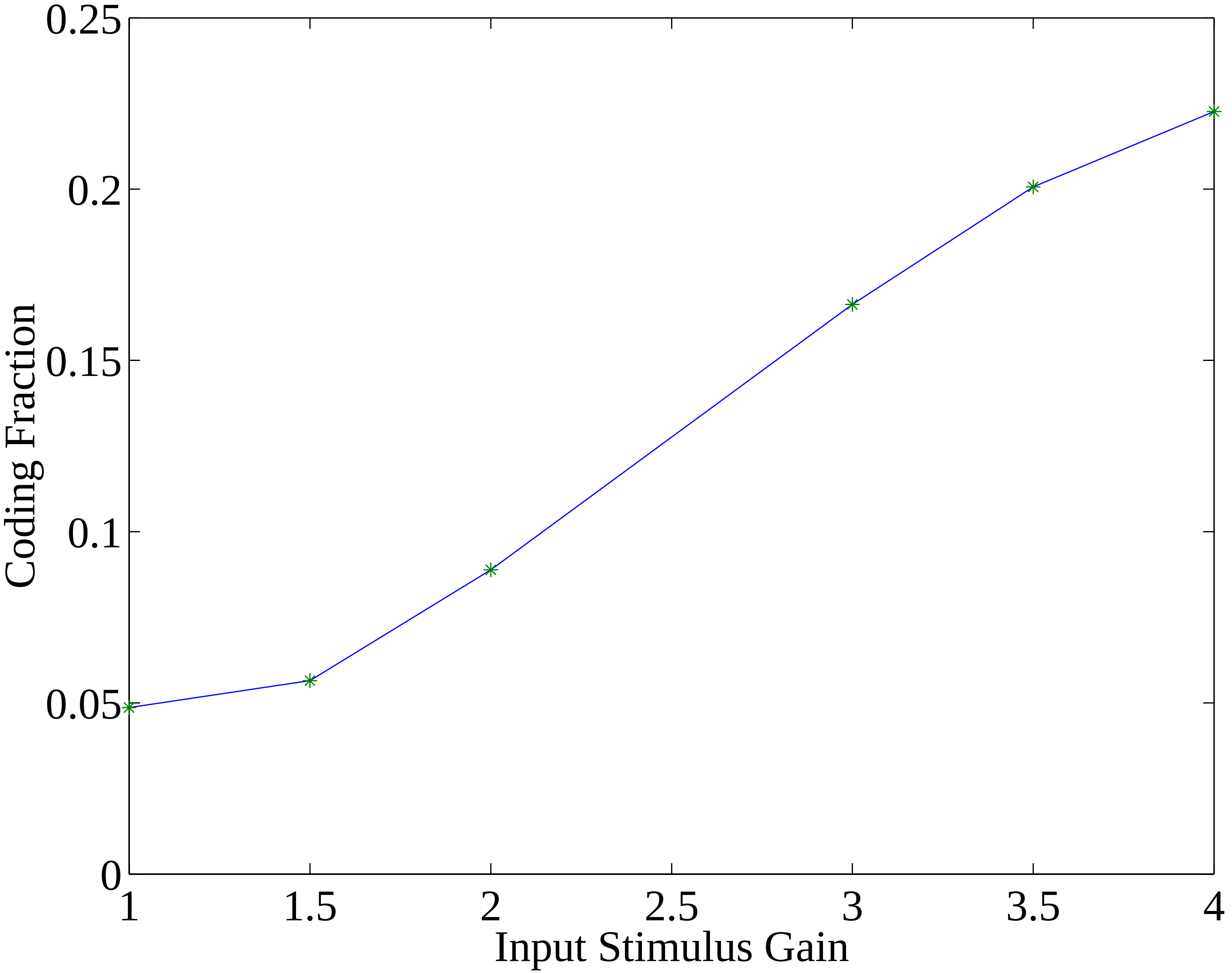
# Model: Pyramidal Reliability



# Reconstruction: Noisy Stimulus



# Coding Fraction as a Function of Stimulus Gain



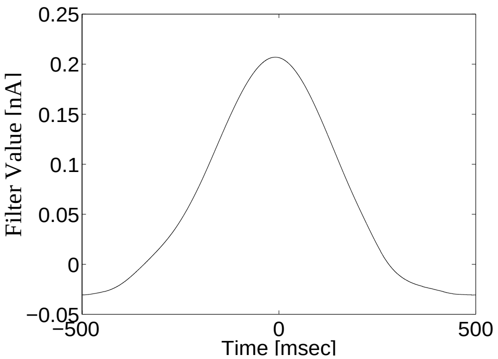
# Reconstruction: Sinusoidal Stimuli

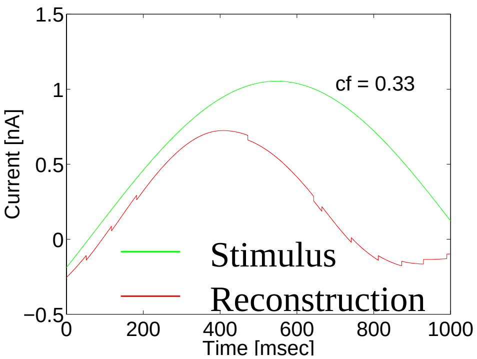
## Filter

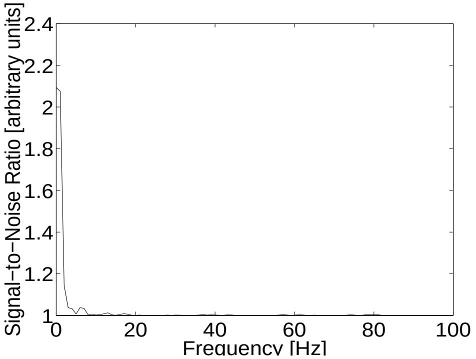
## Reconstruction

## Signal-Noise Ratio

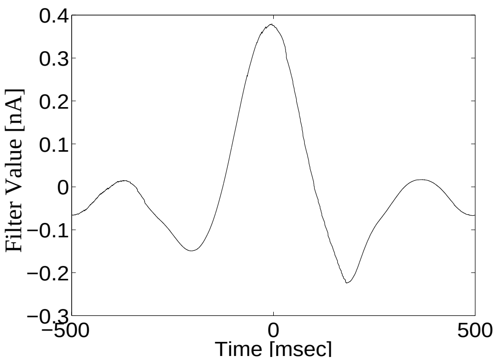
**0.5 Hz**

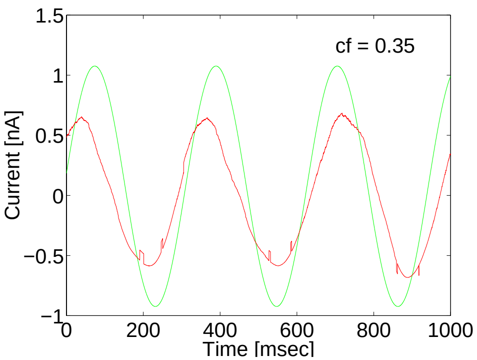


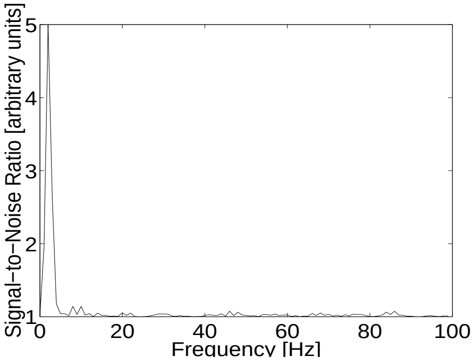




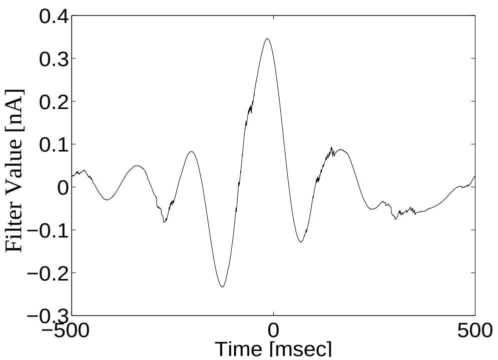
**2 Hz**

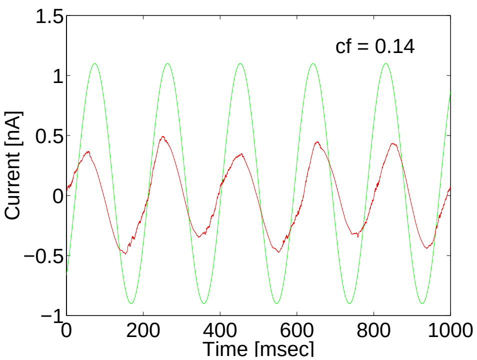


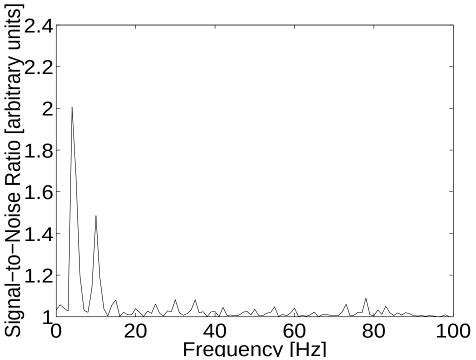




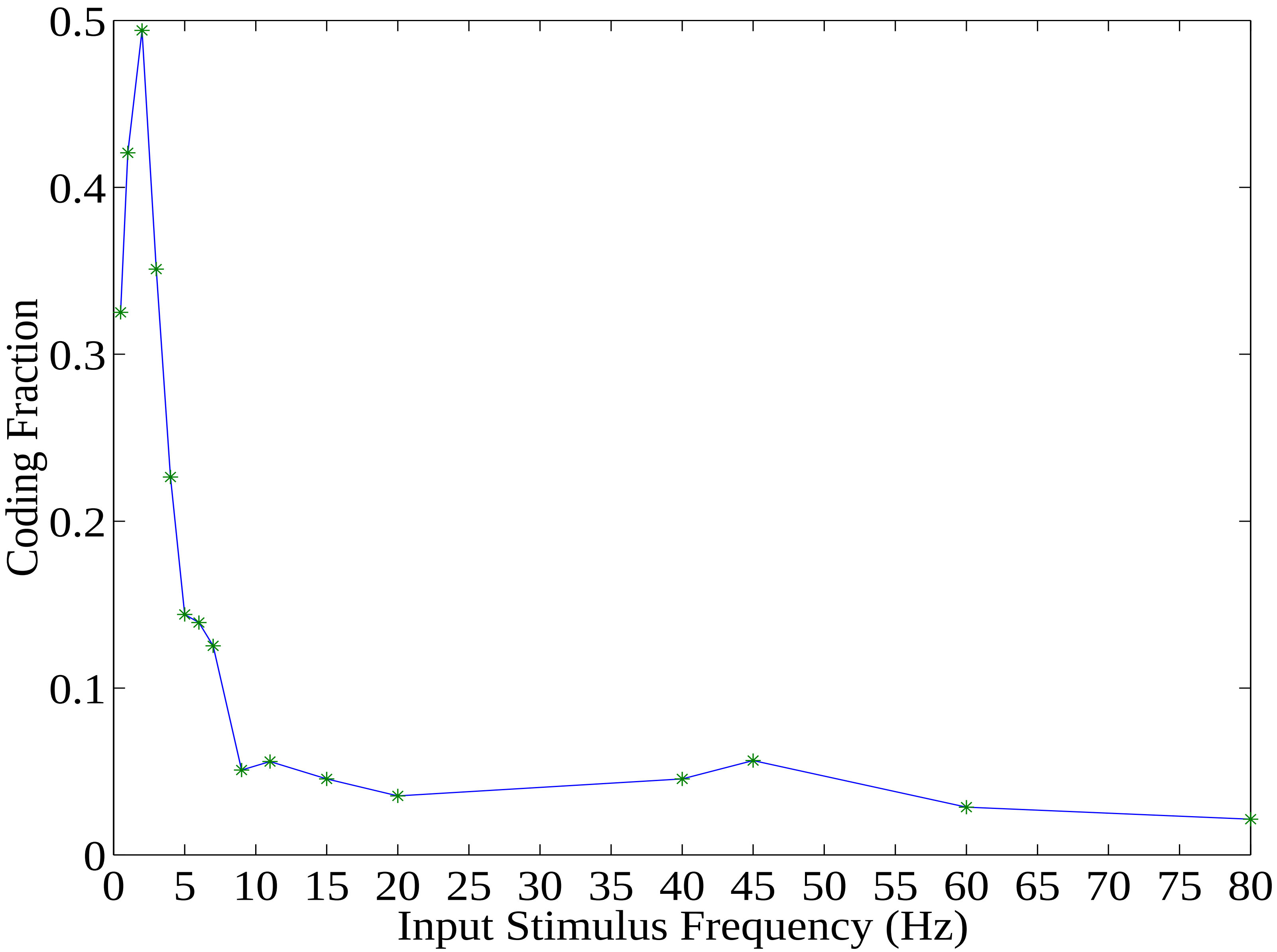
**5 Hz**







# Coding Fraction as a Function of Frequency



# Conclusions

- Pyramidal cells are more reliable when their inputs fluctuate in the theta range (5-13 Hz).

- Interneurons are more reliable in the theta range for low stimulus amplitudes, but more reliable in the gamma range (35-60 Hz) for high stimulus intensities.

- Overall, interneurons are more reliable than pyramidal cells.

# Conclusions

- The firing characterisctics with sine wave injections is reproduced by compartmental models of a pyramidal cortical cell and an interneuron that include a voltage-dependent intrinsic noise source.

- Linear reconstruction shows that the coding fraction increases linearly with stimulus gain, and presents a maximum at low frequencies.

# References

- Golomb D. and Amitai Y. Propagating neuronal discharges in neocortical slices: Computational and experimental studies. J. Neurophysiology, 78(3):1199-211, 1997

- Mainen Z.F., Sejnowski T.J. Reliability of spike timing in neocortical neurons. Science, 268:1503-6, 1995.

- Traub R.D., Miles R. and Buzsaki G. Computer simulation of carbachol-driven rhythmic population oscillations in the CA3 region of the *in vitro* rat hippocampus. Journal of Physiology, 451:653-672, 1992.