Neuronal correlates of pitch in the Inferior Colliculus

Didier A. Depireux
David J. Klein
Jonathan Z. Simon
Shihab A. Shamma

Institute for Systems Research
University of Maryland
College Park, MD 20742-3311

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Methods

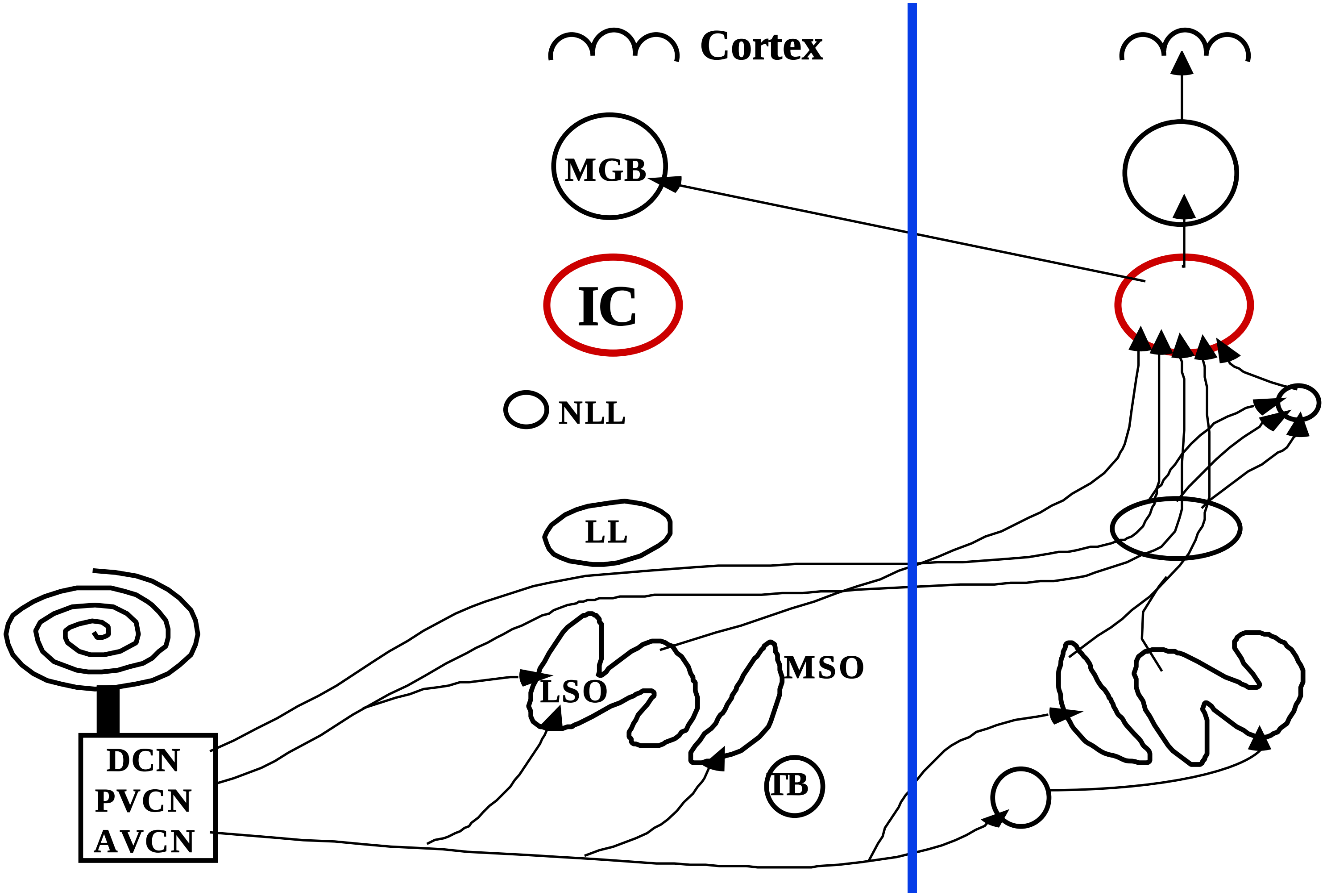
- Responses of single units in **Inferior Colliculus (IC)** and Primary Auditory Cortex (AI) in the **barbiturate-** or **ketamine-anesthetized ferret** were recorded with single tungsten electrodes. Data were collected from 13 ferrets, weighing 1.3 - 2.1 kg.

- Surgery and Preparation: The techniques involved are described in detail in Shamma et al. (1993). The ferrets were anesthetized with pentobarbital sodium and maintained in an areflexic state using a continuous IV infusion of pentobarbital or ketamine and xylazine, diluted with dextrose-electrolyte solution for metabolic stability. Data collection typically lasted 48-72 hours.

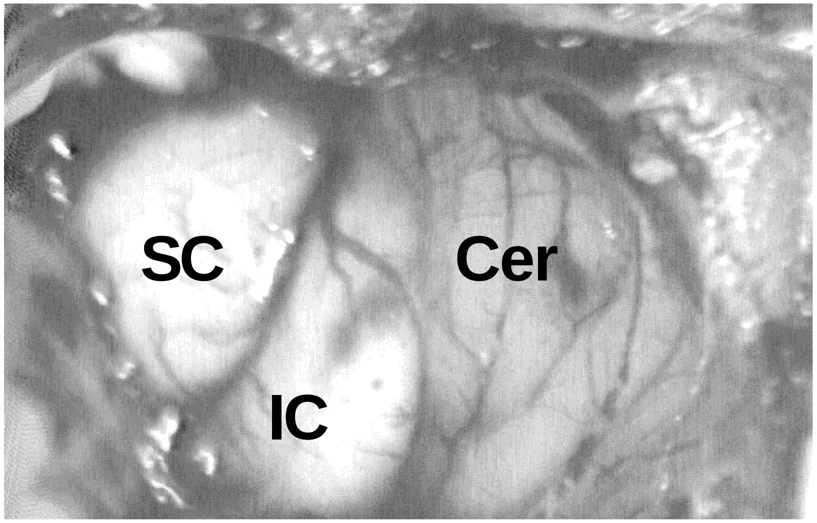
- Recording Procedures: Single-unit action potentials were recorded using glass-insulated tungsten microelectrodes with 5 to 6 MΩ impedance. The recorded signals were led through amplifiers and filters. Depending on the paradigm, a stimulus was presented every few seconds, and raster plots with time resolution of up to 0.1 ms were produced.

- IC was exposed by removal of (visual) cortex, and electrodes were lowered until ICC was reached, following standard criteria. Poorly defined best frequencies were very high at first, but went down very quickly as the electrode was lowered, corresponding to the ICX. When we reached the lowest Best Frequency (BF), corresponding to the top of the ICC, the responses changed qualitatively, and the BFs were better defined.

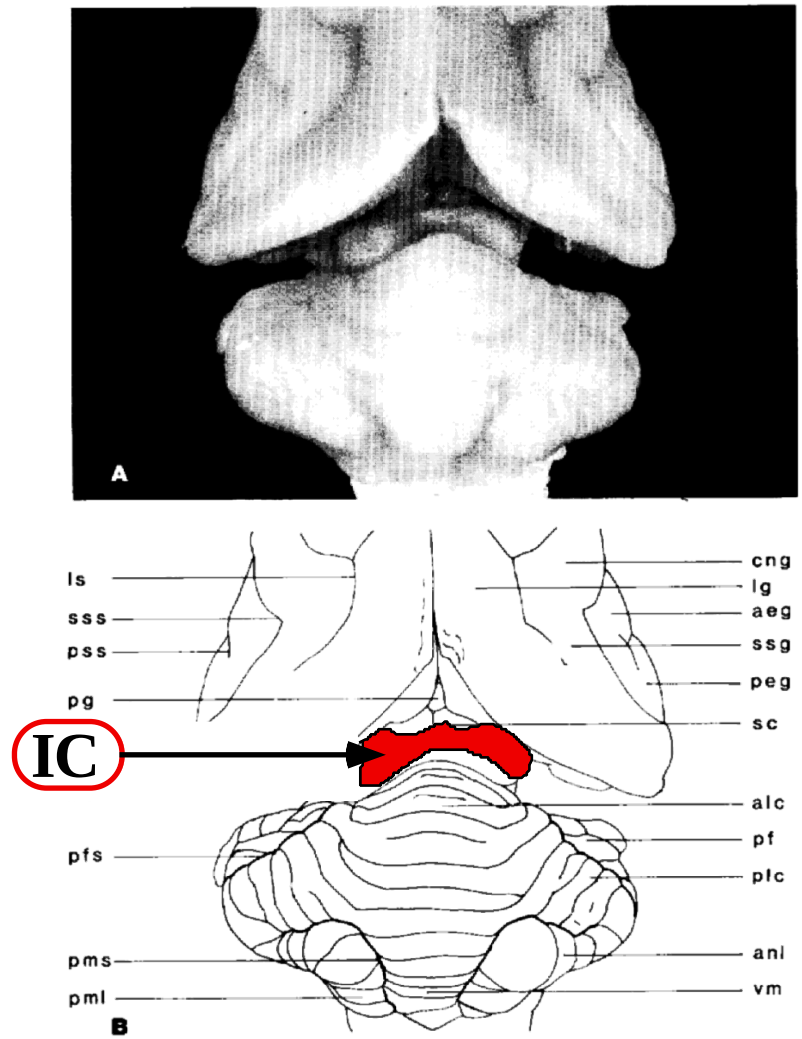
Auditory Pathway



The Inferior Colliculus



Rostral *Caudal*



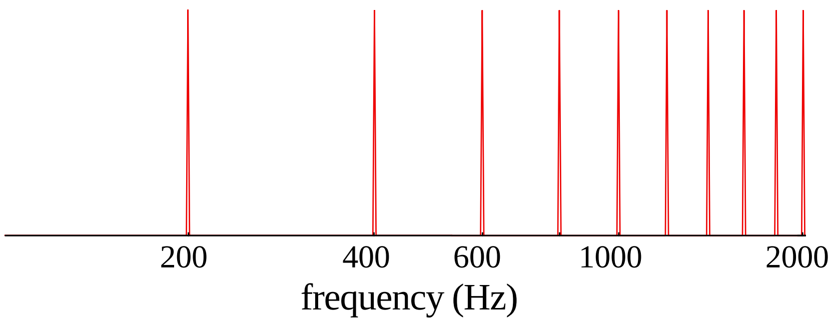
Why the IC?

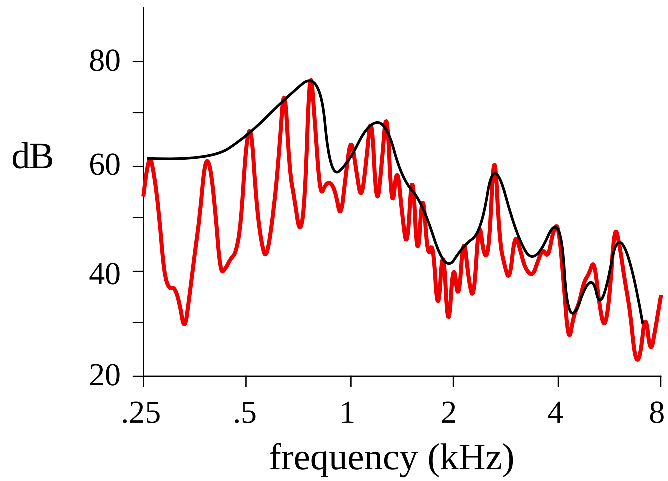
- Midway up to Cortex
- Reports of IC maps and BMFs
- Observe good temporal responses

Theories of Pitch

Spectral

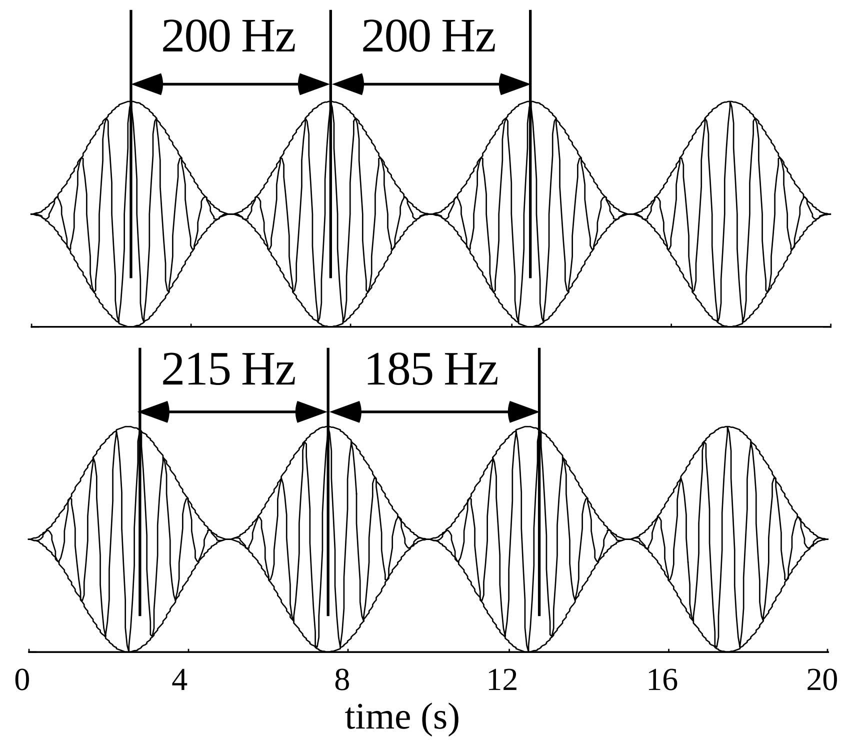
At minimum, there exists a resolved spectrum
200 + 400 + 600 + . . . + 2000 Hz



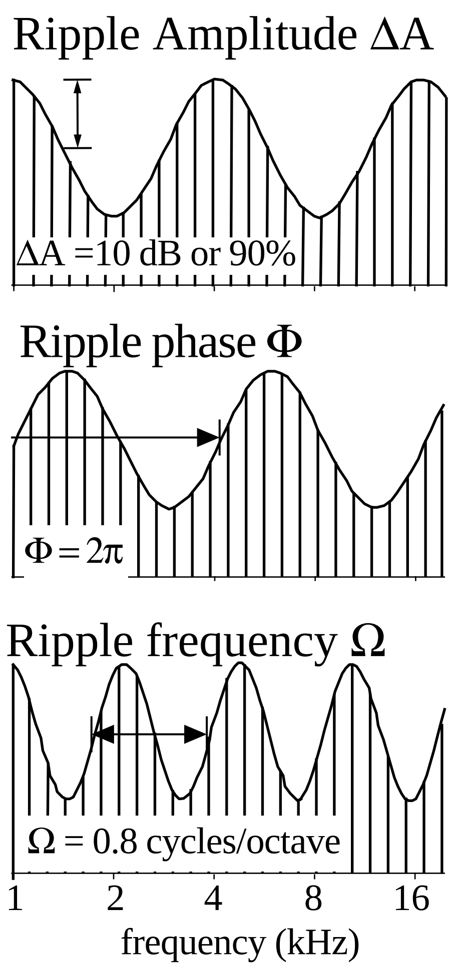


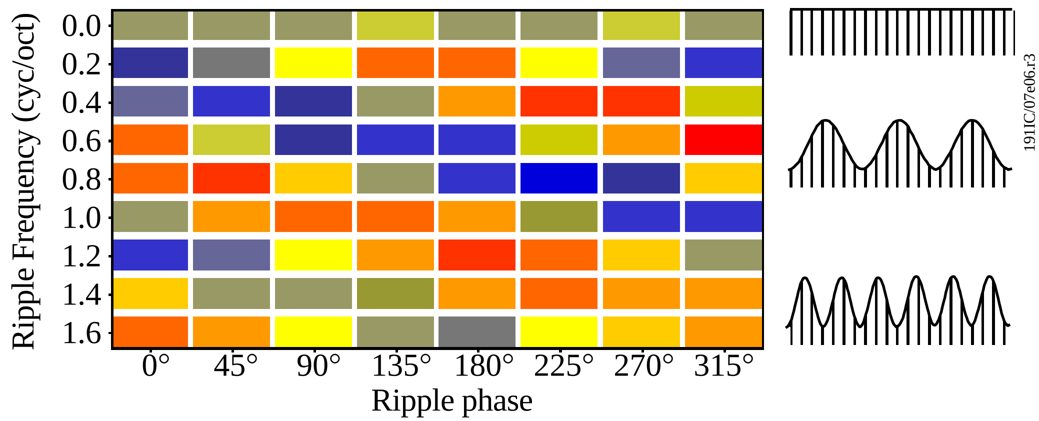
Temporal

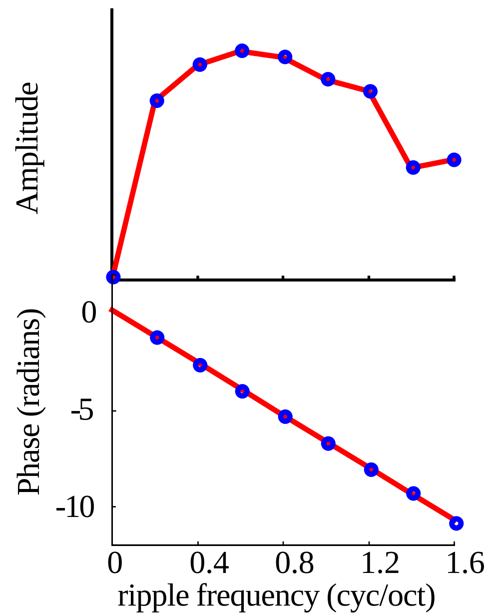
No need for resolved spectrum
but **must** exist temporal properties of the response

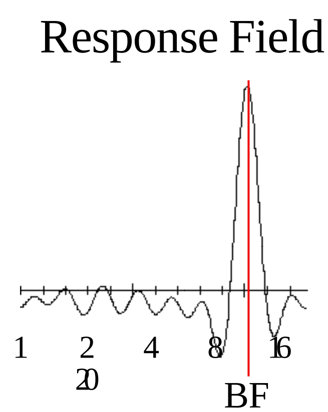


Spectral Resolution & Ripples

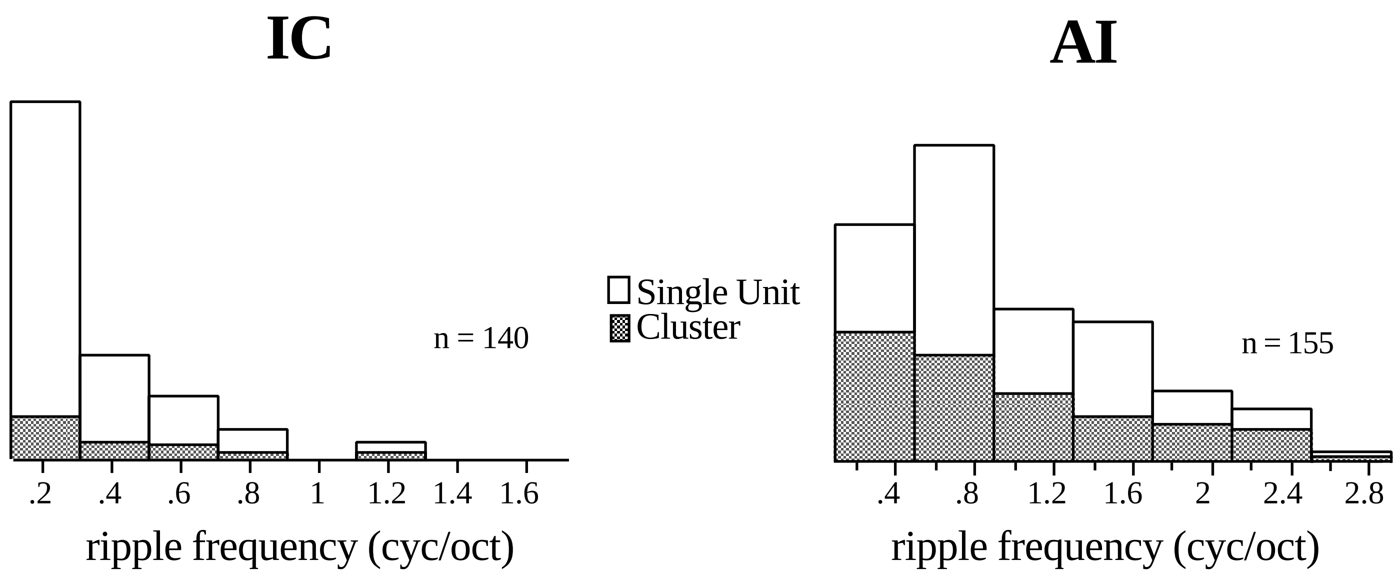






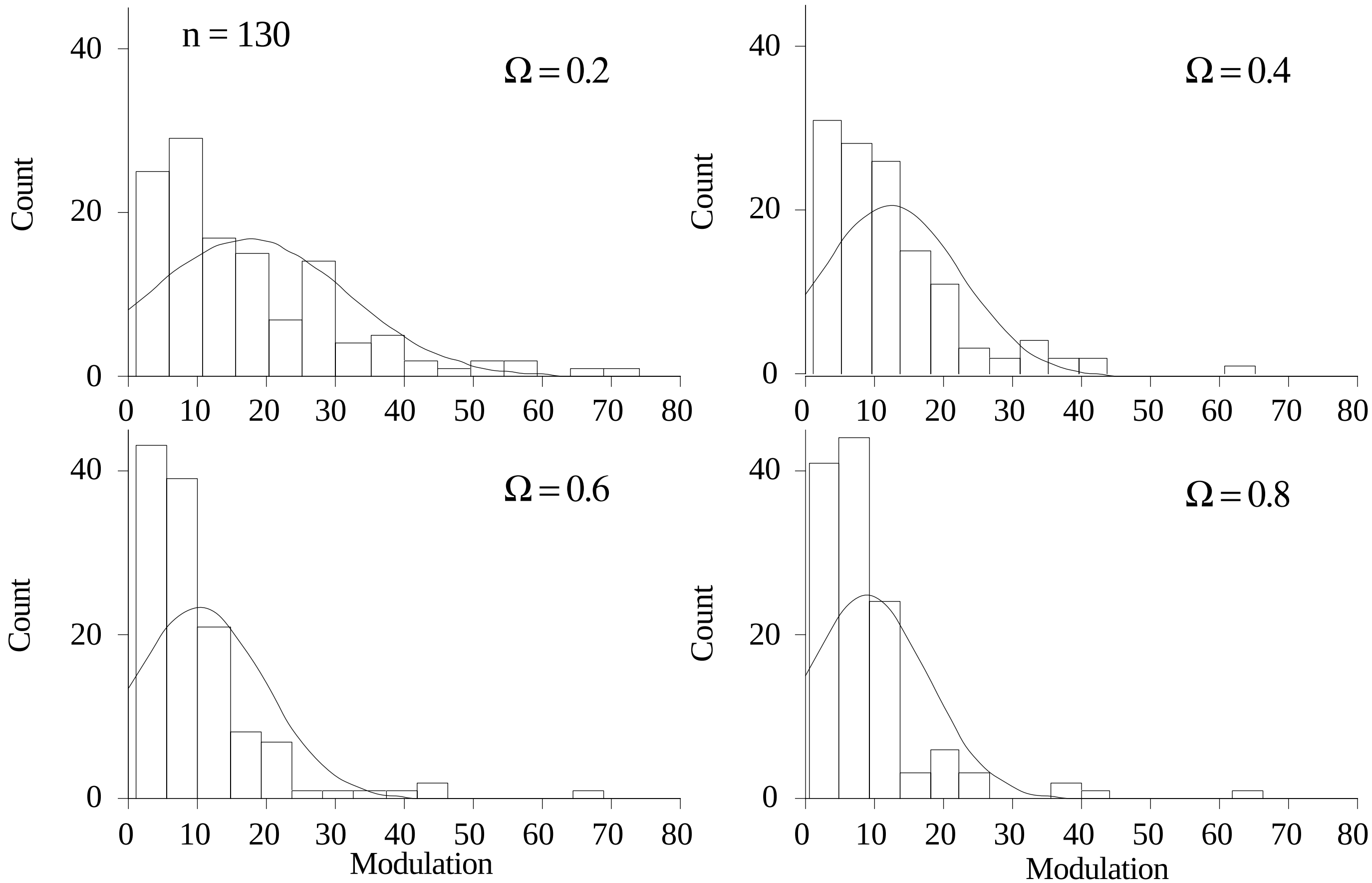


Spectral Tuning to Ripples



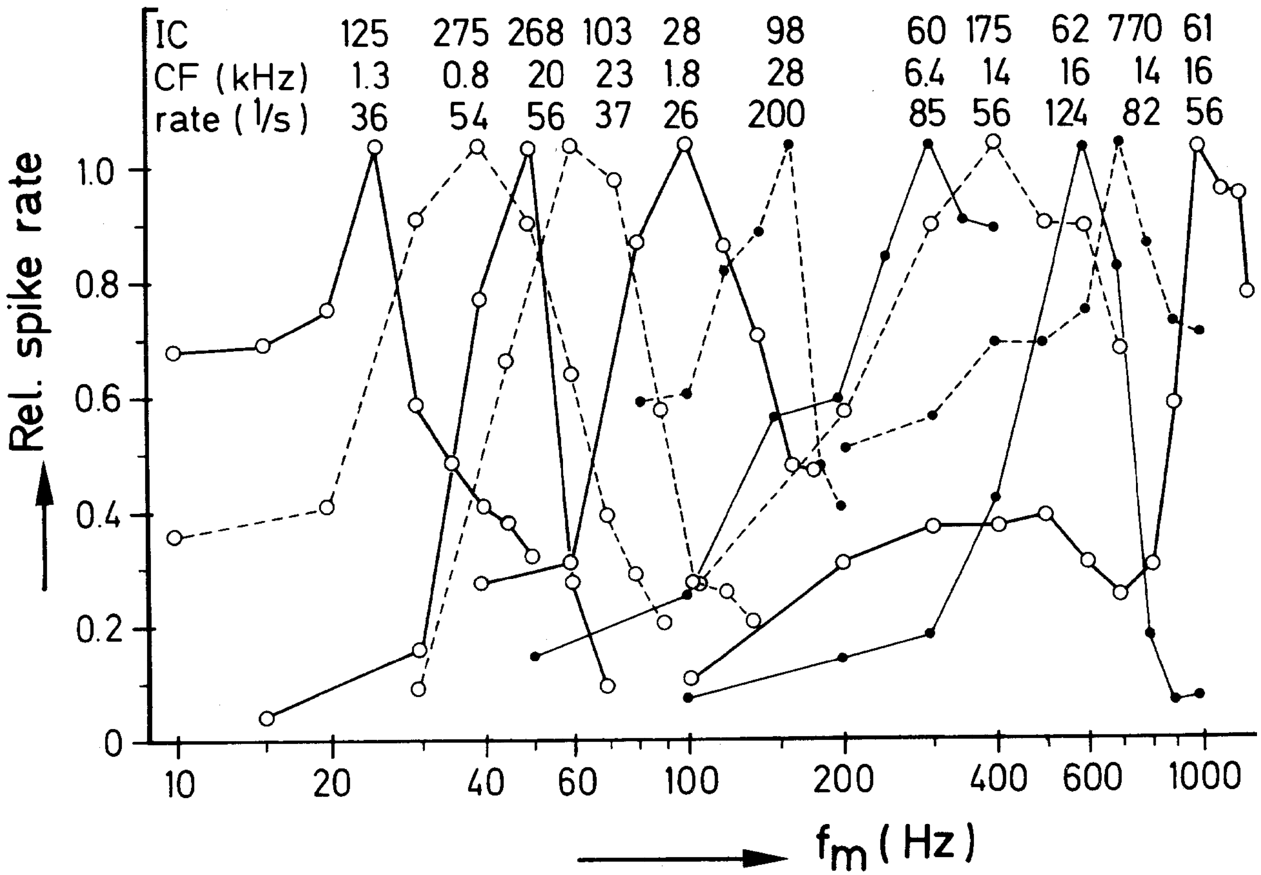
Tuning to ripples based solely on Best Ripple Frequency indicates that cells'response areas are too broad to resolve harmonics.

Spectral Resolution & Ripples II



The modulation of the response to stationary ripples as a function of ripple phase decreases sharply as the ripple frequency increases, unlike in cortex. *Modulation* indicates the ratio of the maximum to the minimum response to a ripple of a given ripple frequency.

AM Rate Transfer Functions



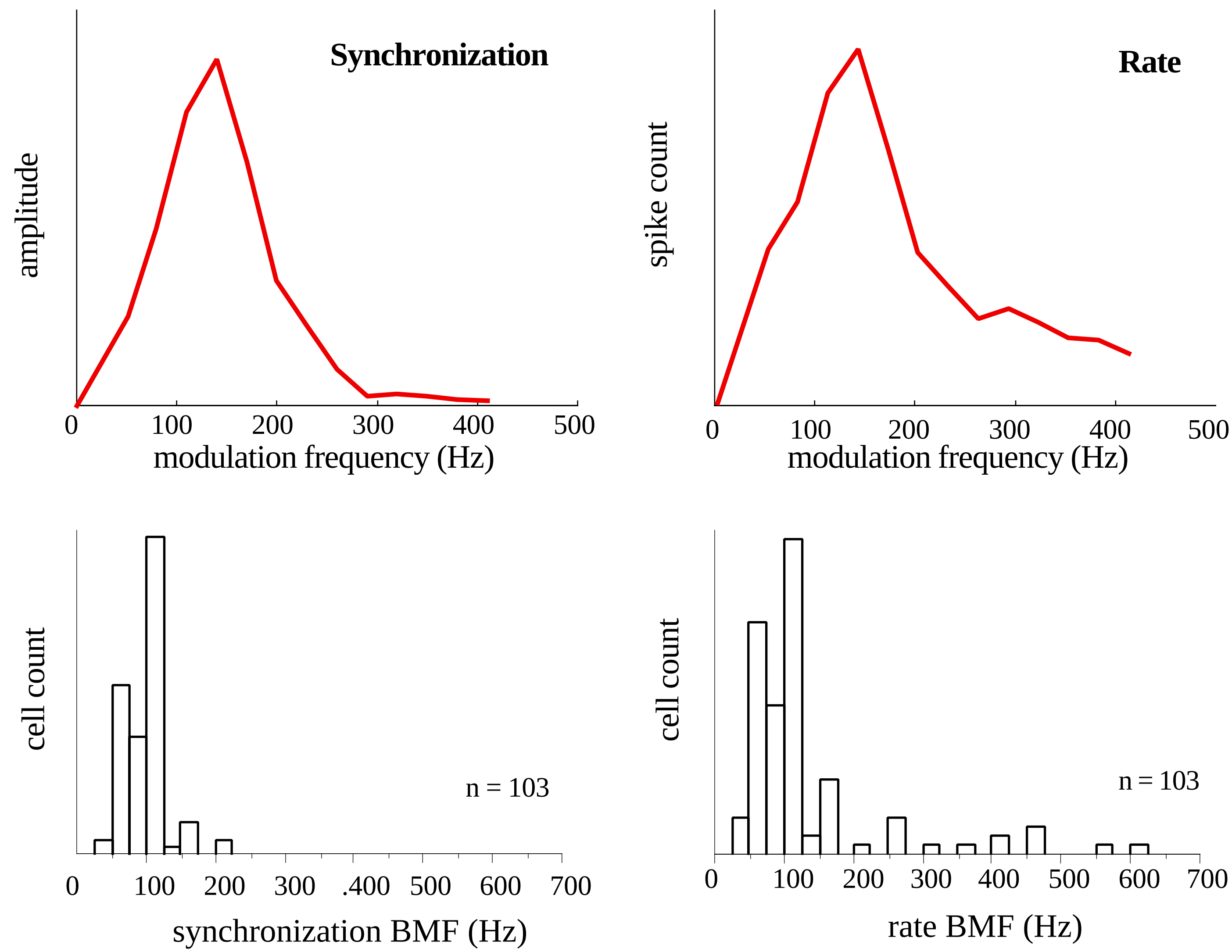
Langner and Schreiner, *e.g.*, find that rate BMFs exhibit bandpass characteristics.

Langner and Schreiner (1988)

BMFs for AM Transfer Functions

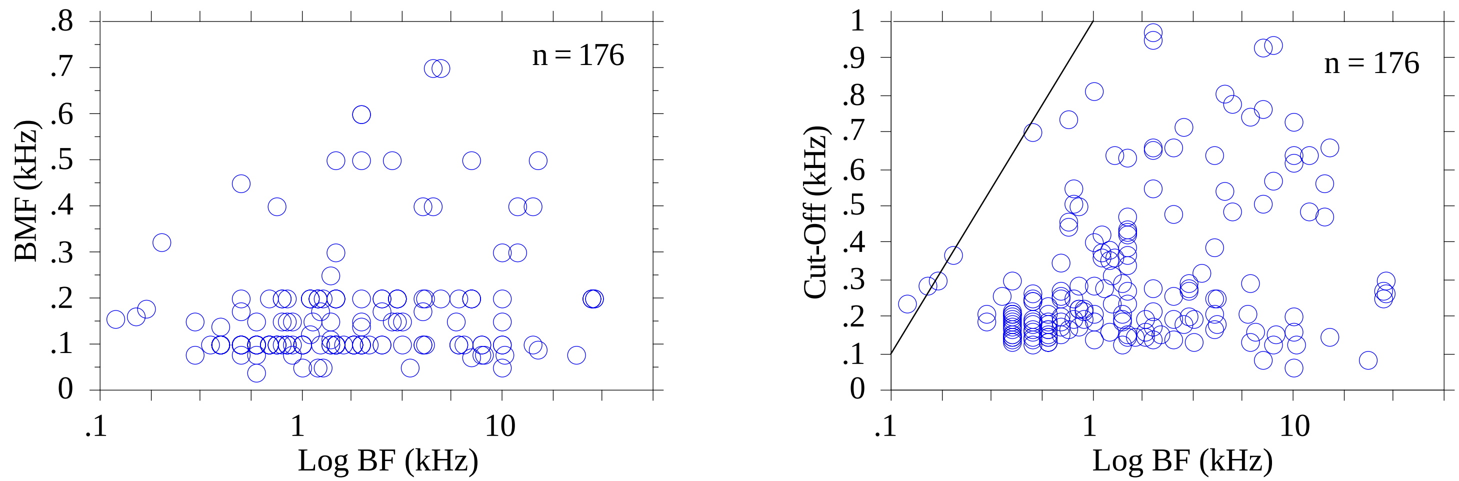
Single cell transfer functions

Population statistics of transfer functions



AM Transfer Function Characteristics

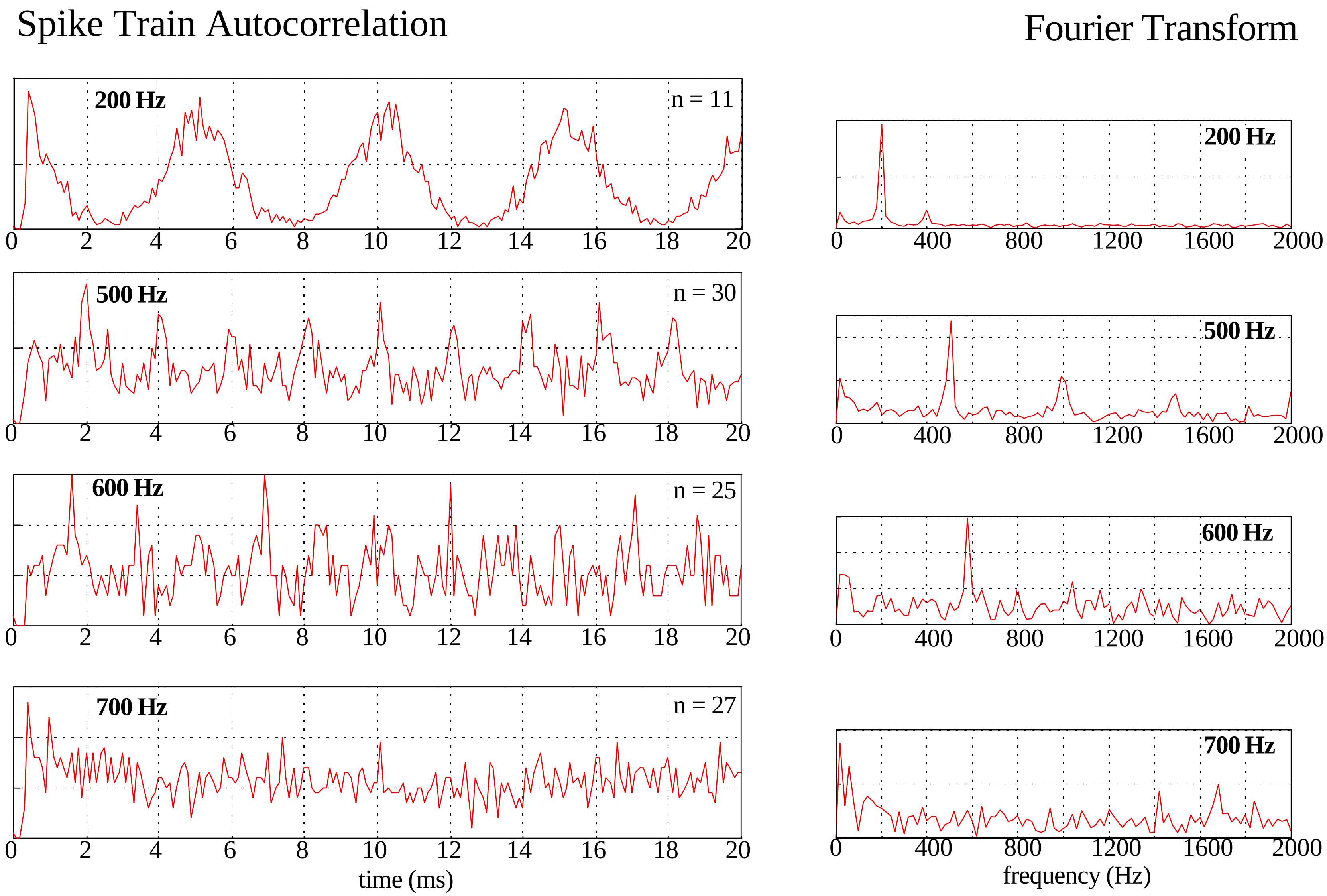
Synchronization



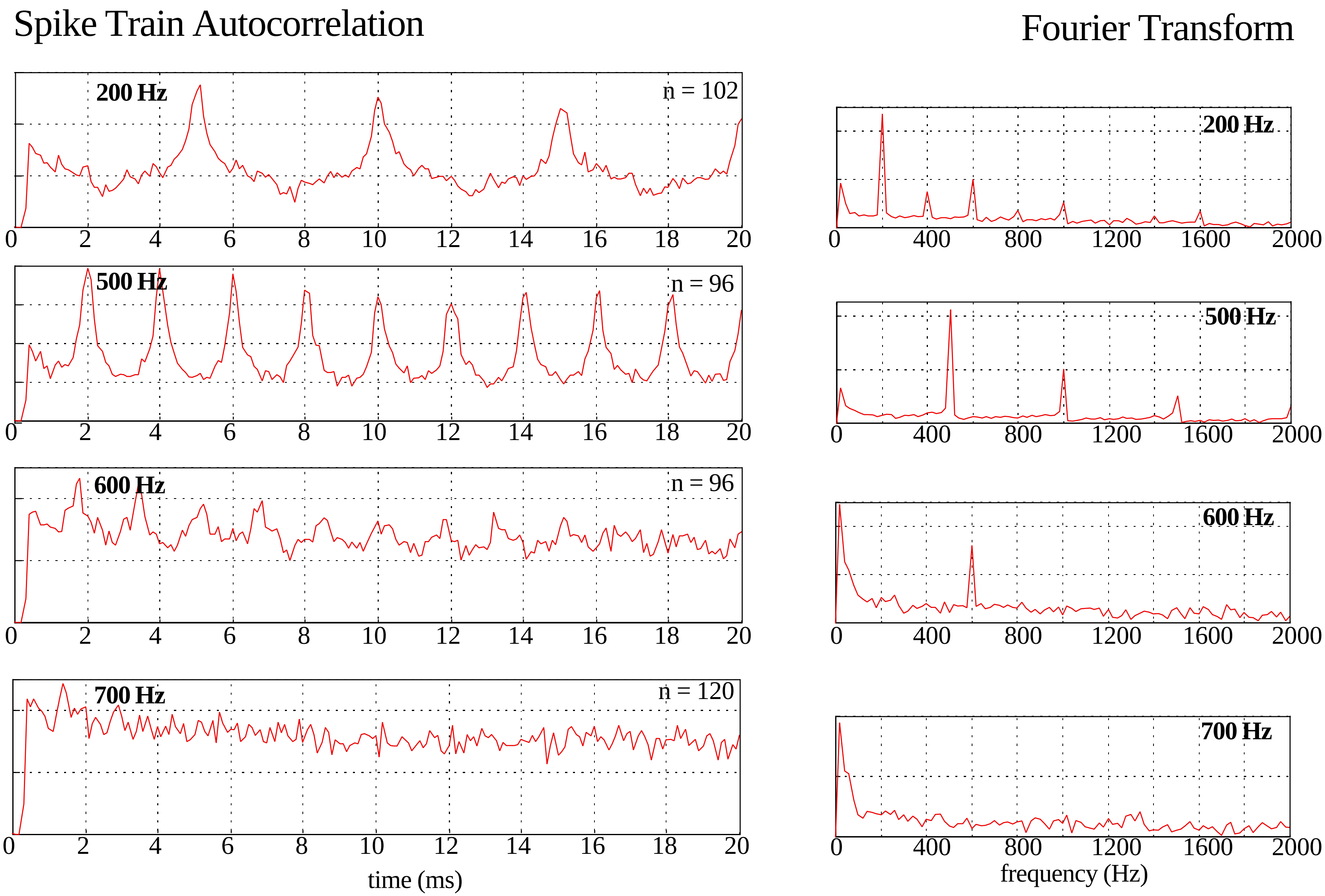
We characterize the AM synchronization transfer function by its peak or Best Modulation Frequency (BMF), as and upper cut-off, i.e. the frequency at which the synchonization coefficient is 50% of the peak value.

We find that the majority of cells have a BMF around 100 Hz, but with a range of cut-off frequencies.

Temporal Response to Pure Tones



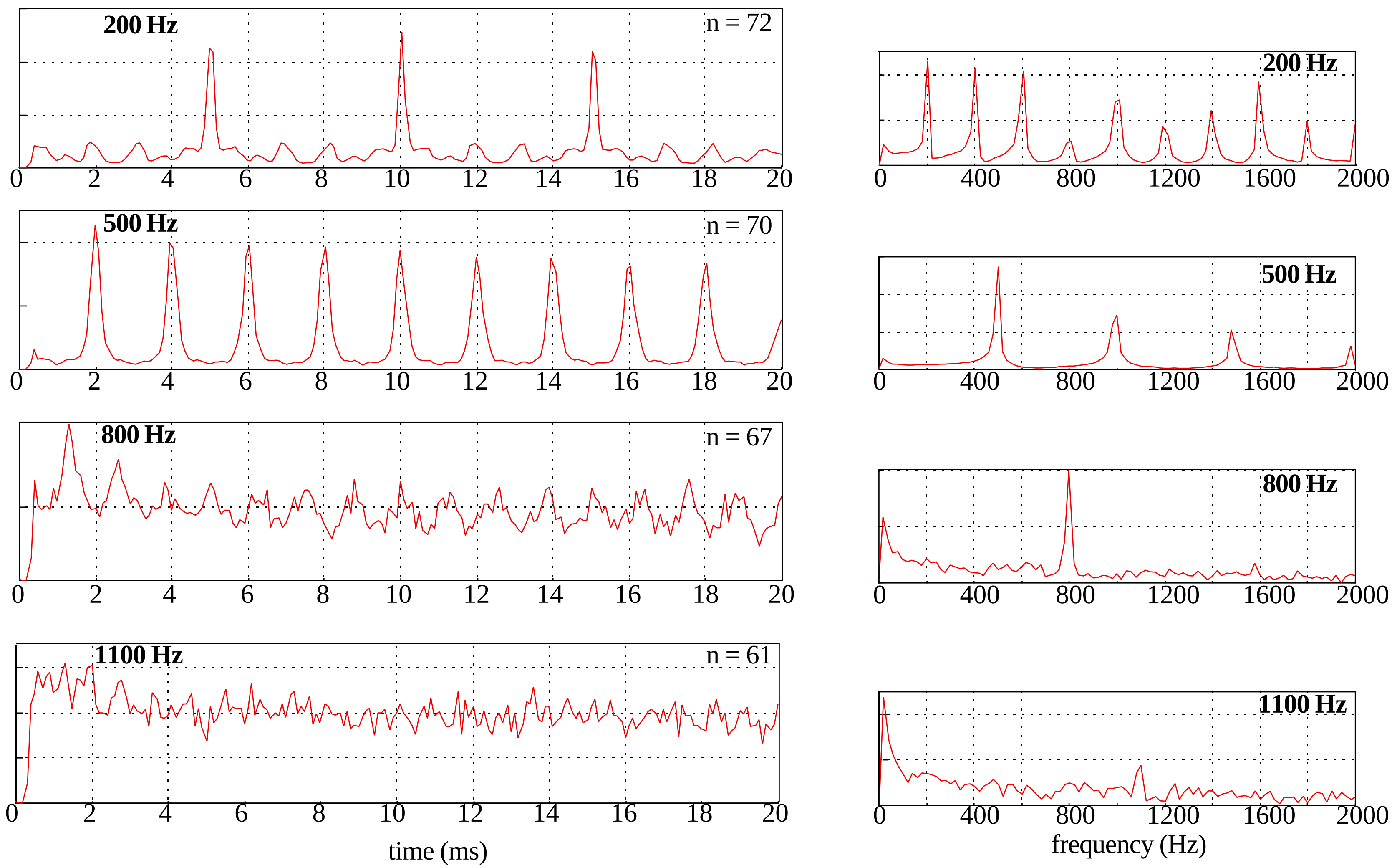
Temporal Response to AMs



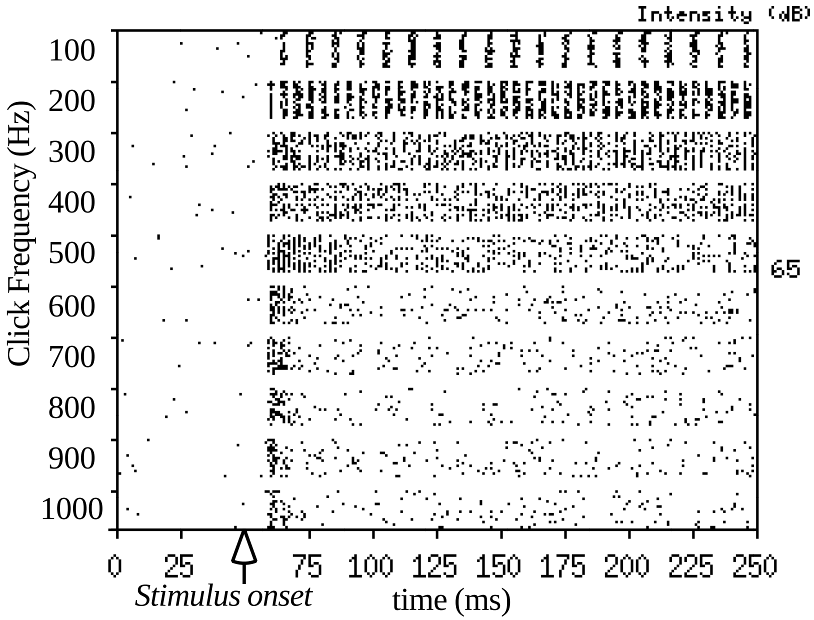
Temporal Response to Click Trains

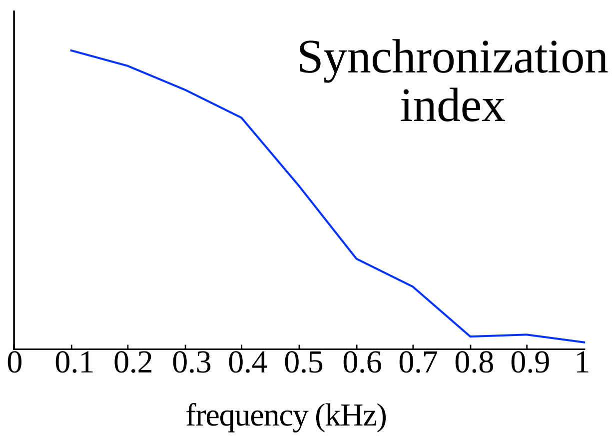
Spike Train Autocorrelation

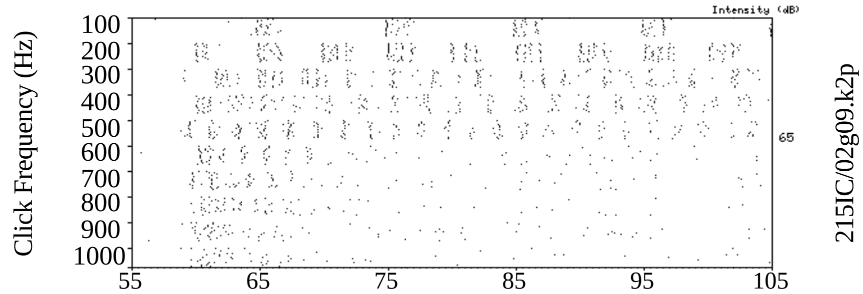
Fourier Transform

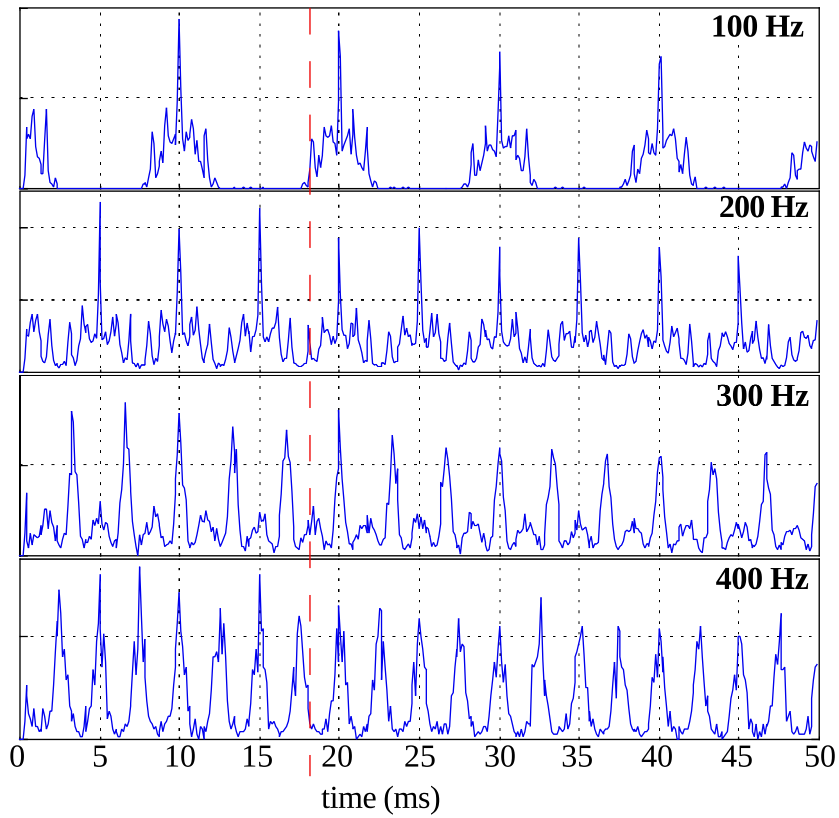


Fast Temporal Response I





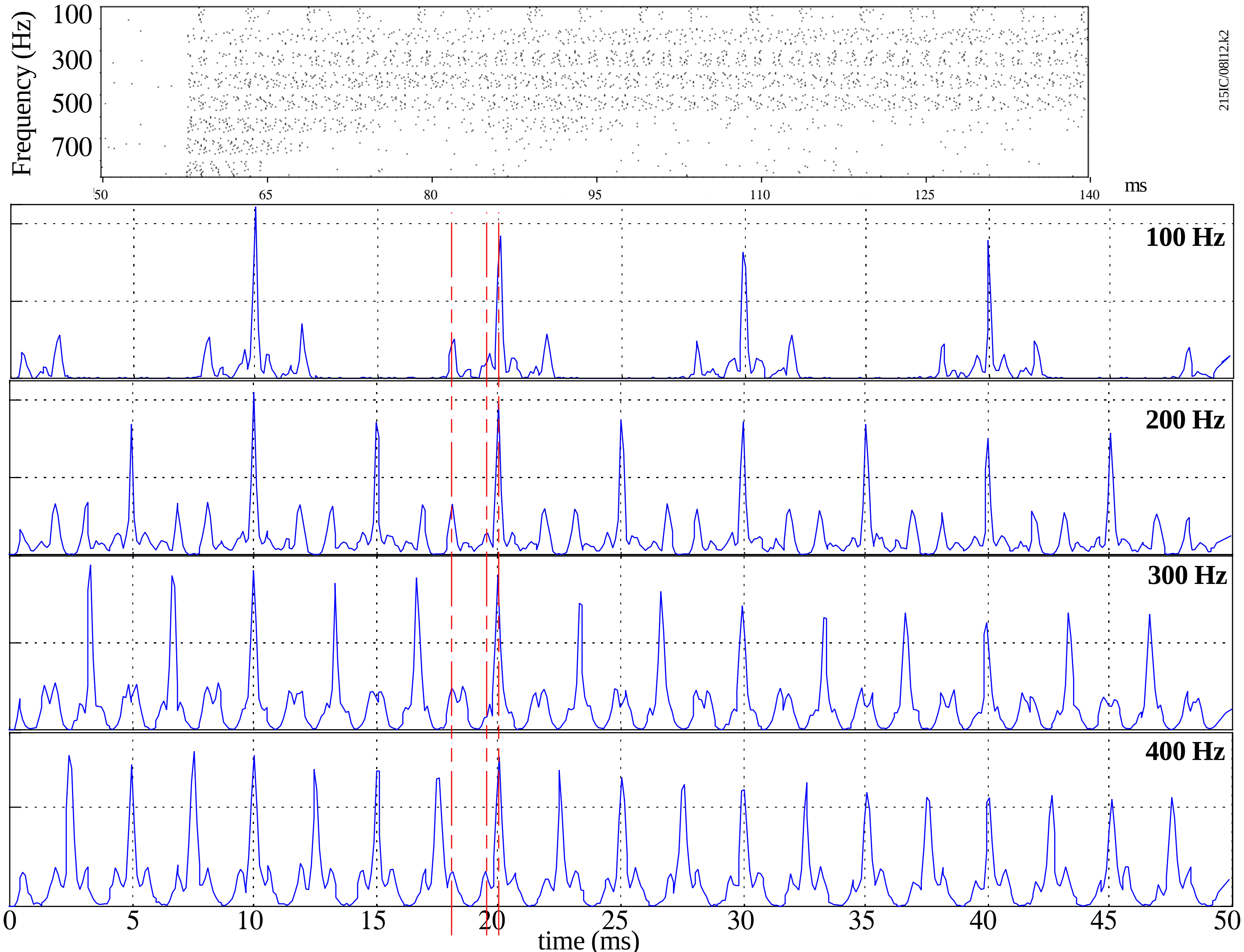




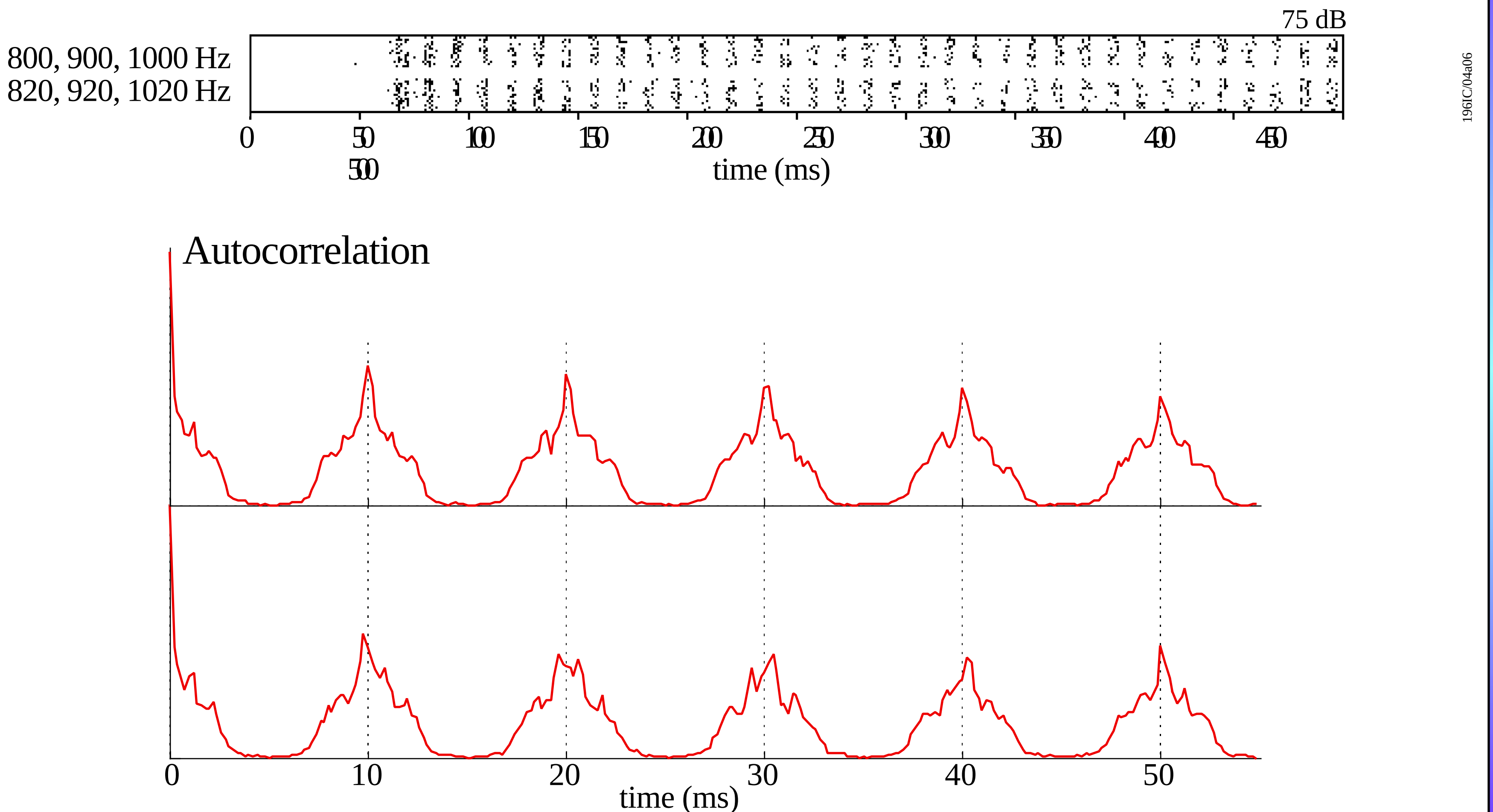
Fast Temporal Response II

Raster of responses to a click train. Note that clicks' phases are random from sweep to sweep

Autocorrelation function for the first four frequencies



Inharmonic Stimulus



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