

Ripples in the Anterior Auditory Field and Inferior Colliculus of the Ferret

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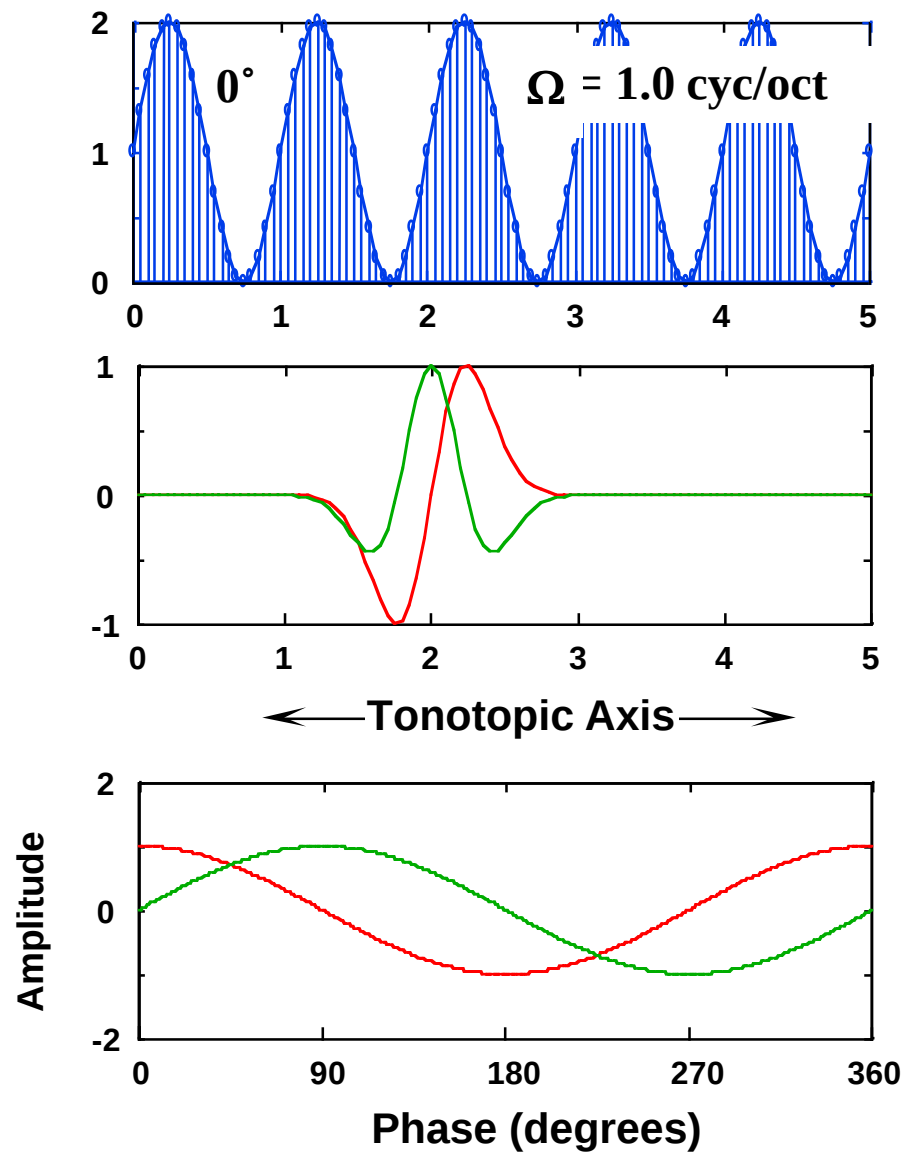
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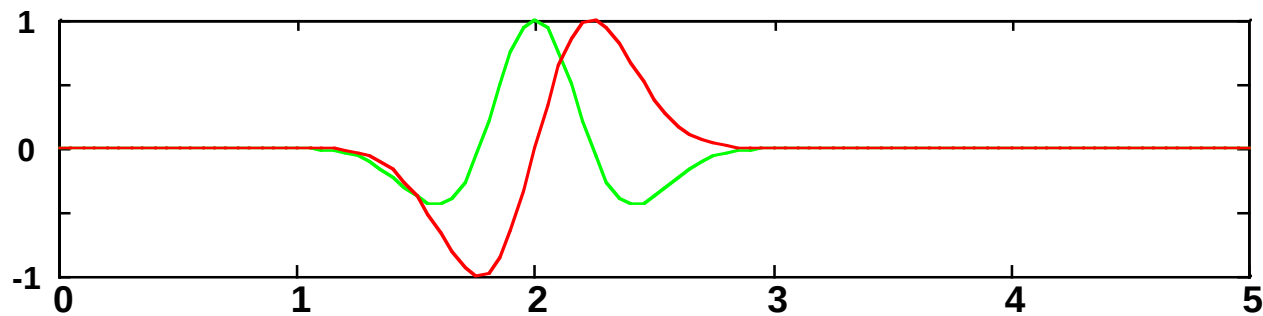
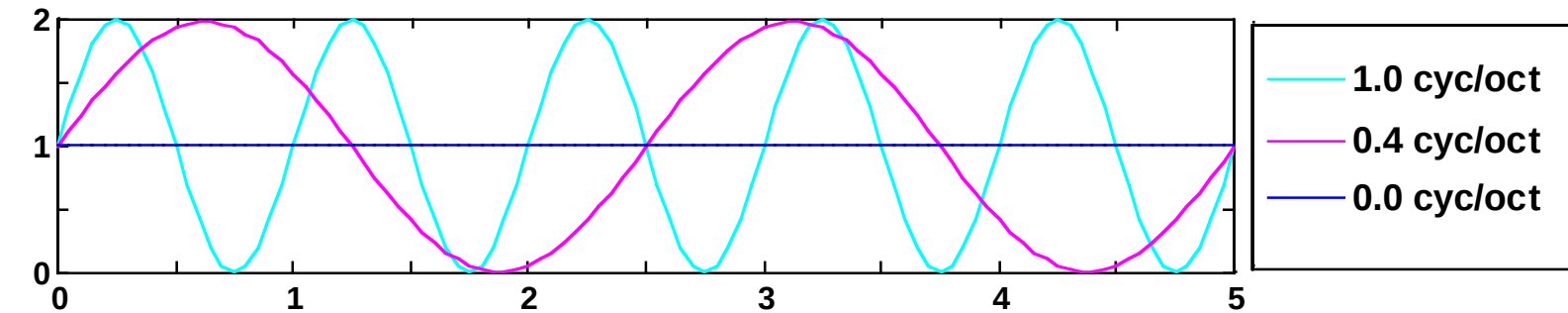
Methods

- Responses of single units in AI, anterior field (AAF), and Inferior Colliculus (IC) in the barbiturate-anaesthetized ferret were recorded with single tungsten electrodes. Data were collected from a total of 7, 5 and 11 (resp.) ferrets, each weighing between 1.5 - 2.1 kg.
- Surgery and Animal Preparation: The techniques involved in the surgery and preparation for recording are described in detail in Shamma et al. (1993). The ferrets were anesthetized with pentobarbital sodium (40 mg/kg IP) and maintained in an areflexic state using a continuous IV infusion of pentobarbital (~ 5 mg/kg/hr) diluted with dextrose-electrolyte solution for metabolic stability. Data collection typically lasted 60-70 hours.
- Recording Procedures: Single-unit action potentials were recorded using glass-insulated tungsten microelectrodes with 5 to 6 M Ω impedances. The recorded signals were led through amplifiers and filters. Depending on the paradigm, a stimulus was presented every few seconds, and raster plots with 1ms time resolution were produced.
- In AI, recordings were typically made at depths of 300 - 600 μ m (layers III and IV). In AAF, electrode penetrations were made parallel to the depth of the suprasylvian sulcus (SSS), approximately 0.5 mm caudal of the sulcus so that cortical layers III and/or IV were reached. IC was exposed by removal of (visual) cortex, and electrodes were lowered until ICC was reached, following standard criteria.

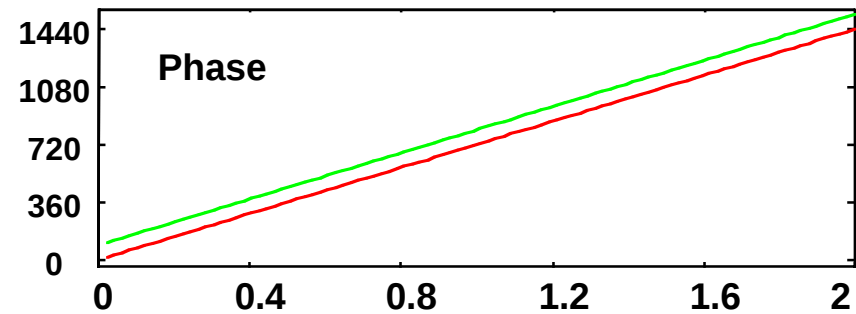
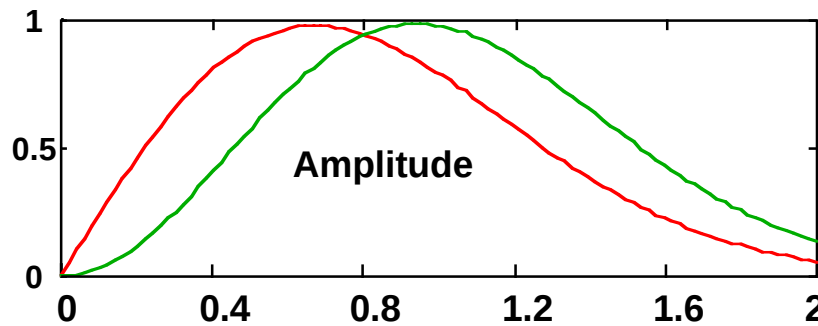
Change in Ripple Phase



Measuring the Ripple Transfer Function



← Tonotopic Axis →

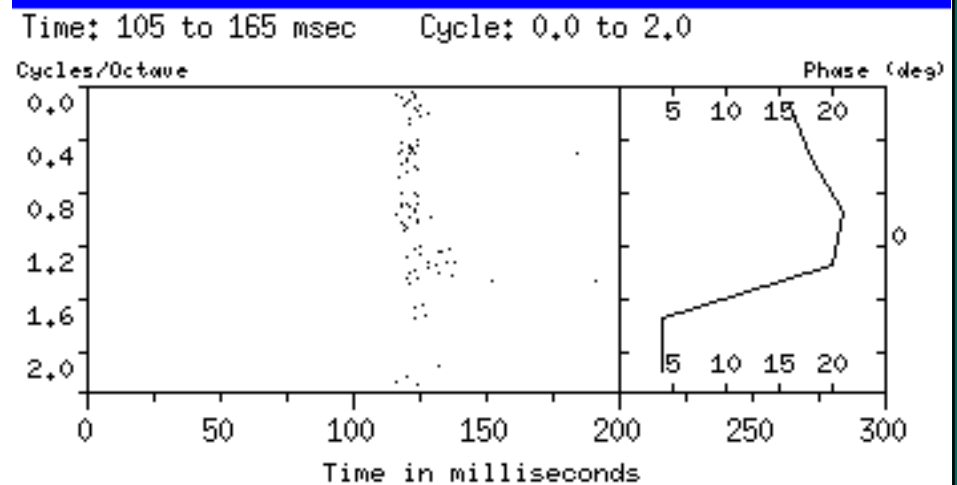
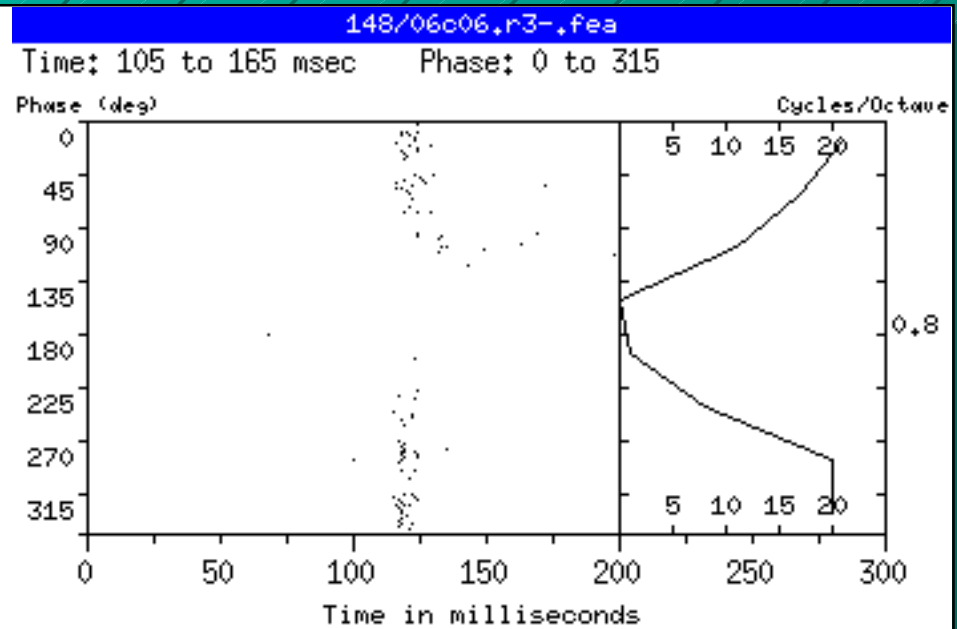


Ripple Frequency (cyc/oct)

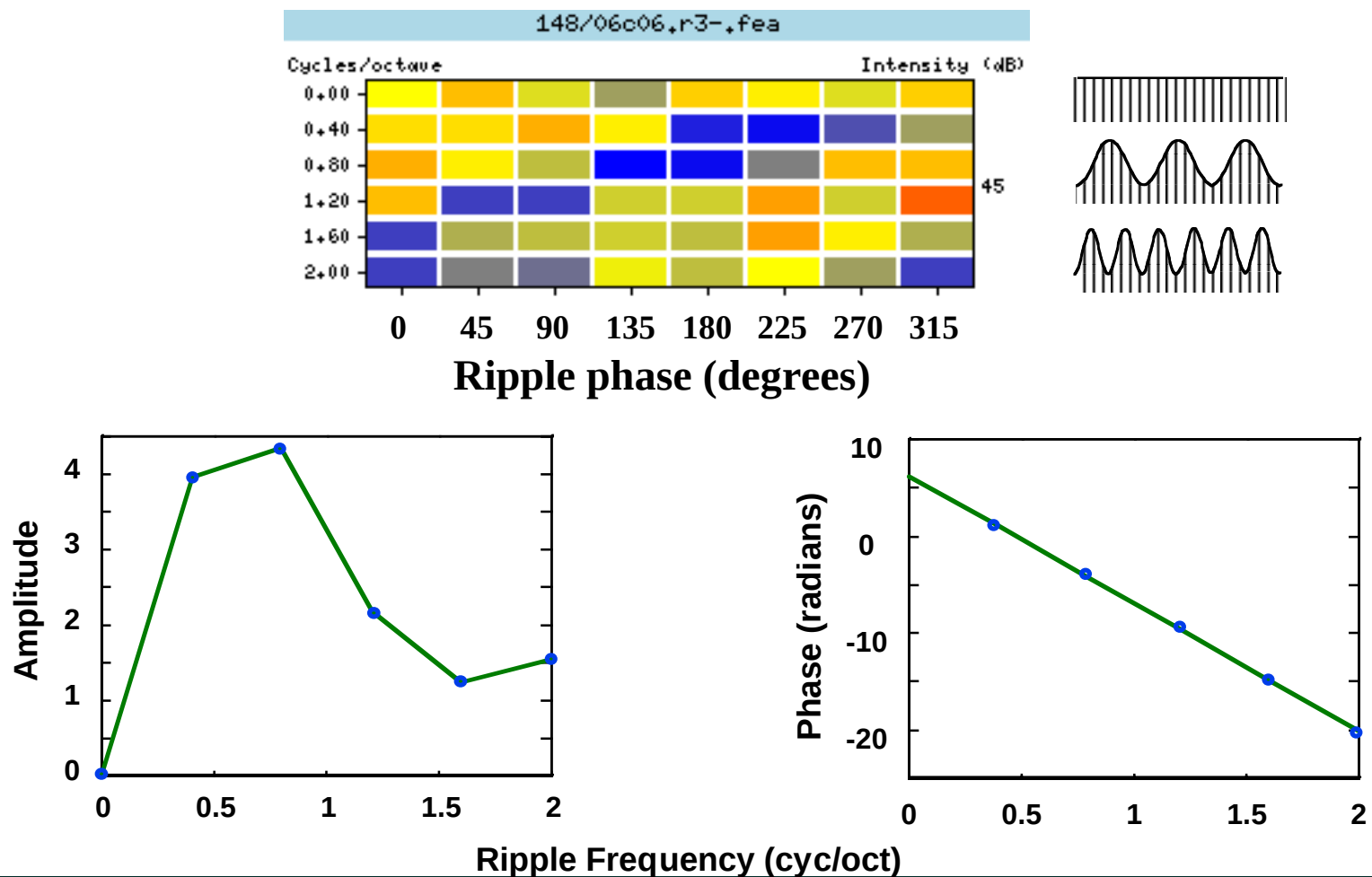
0.8 cycles/octave
at 8 different phases

Stimulus onset: 100 ms
Stimulus offset: 150 ms

0 phase ripple at
6 different ripple freq.



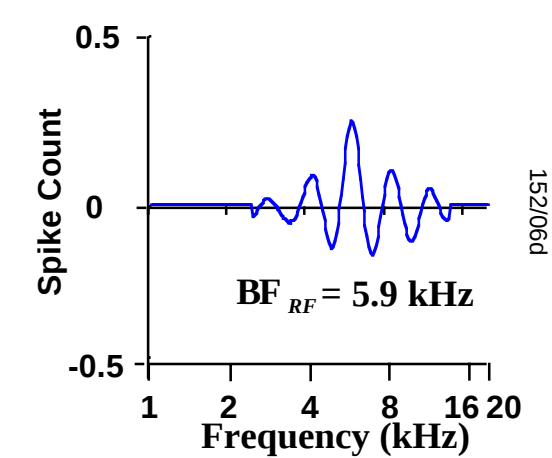
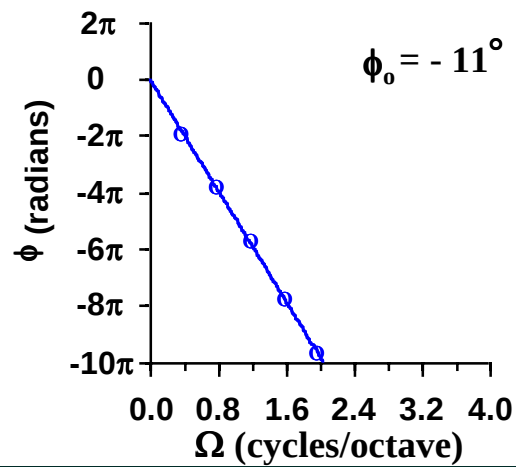
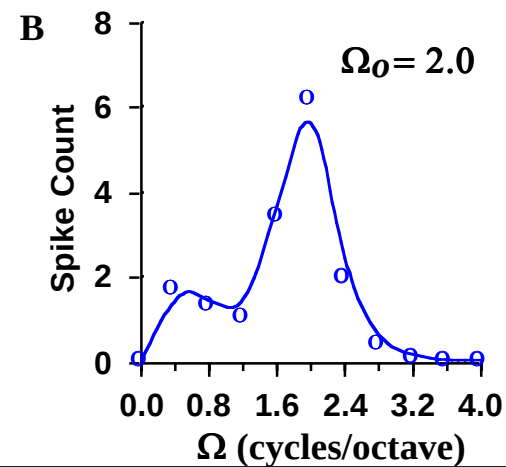
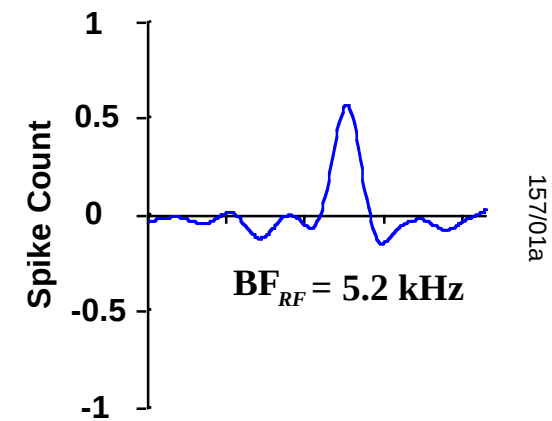
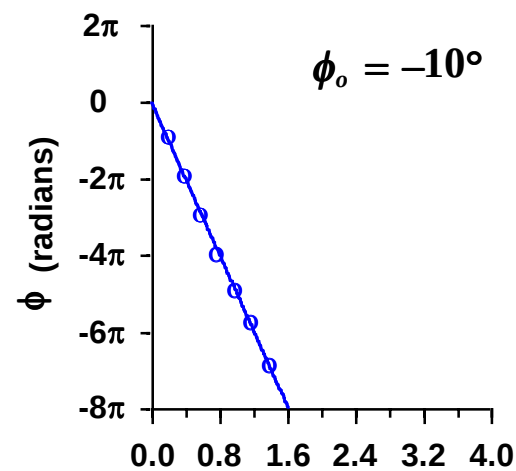
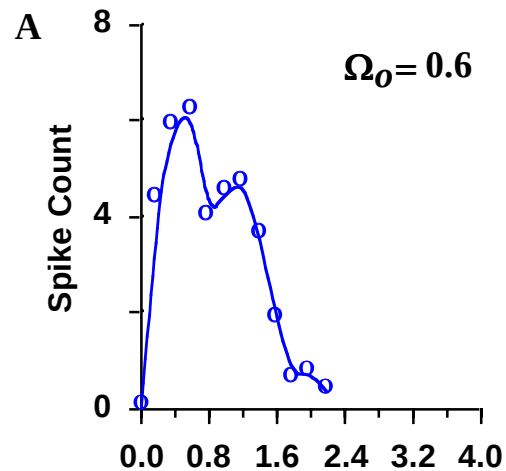
Tuning as a function of Ripple Frequency and Phase



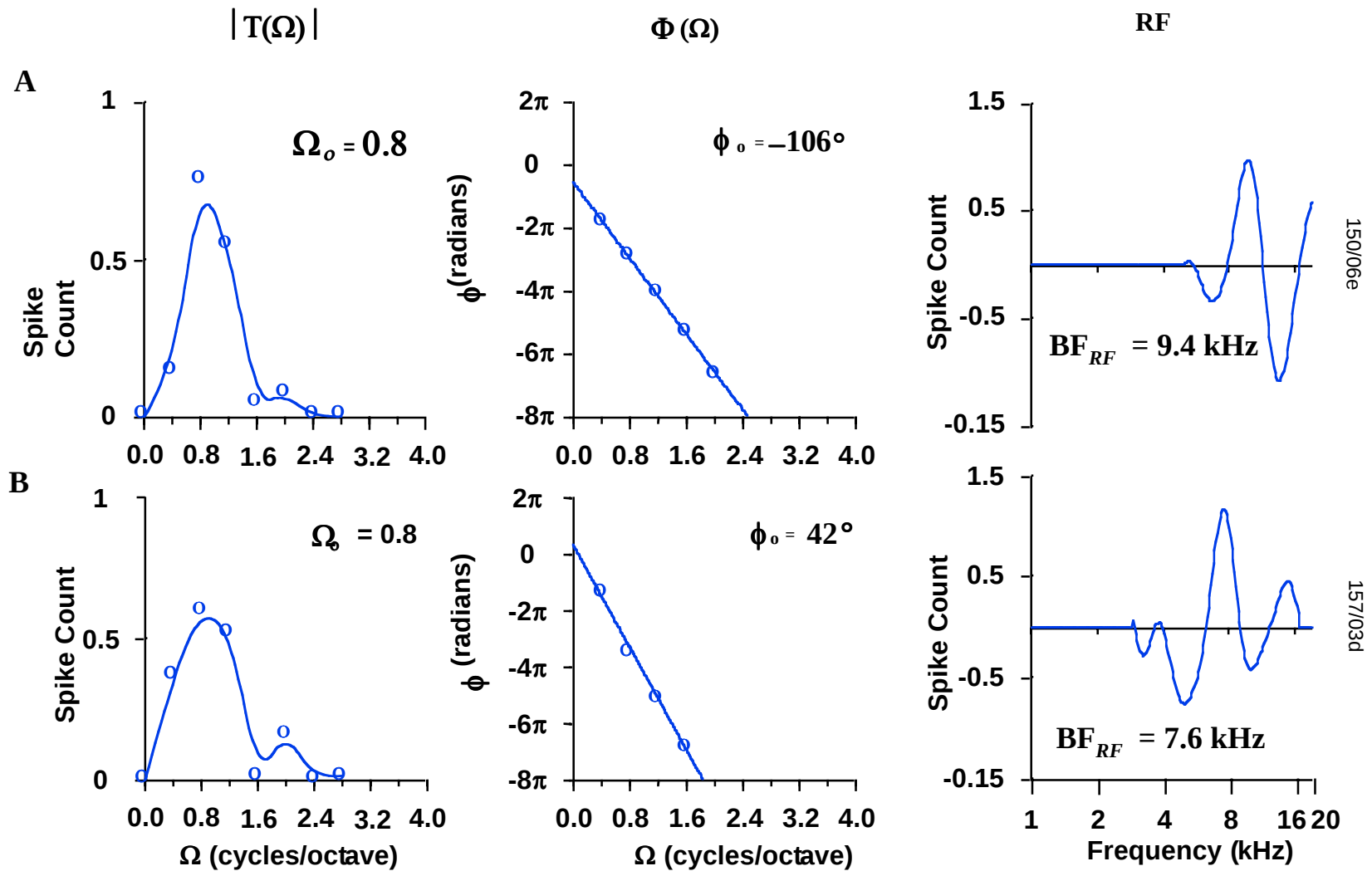
Response fields of varying bandwidth

$$|\mathbf{T}(\Omega)|$$
$$\Phi(\Omega)$$

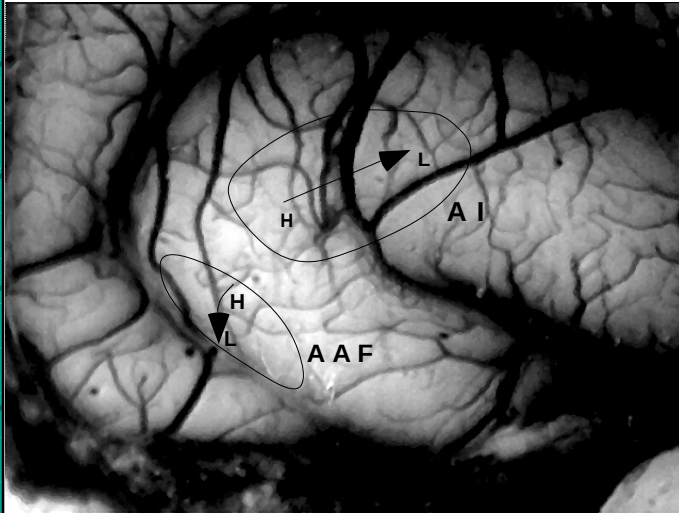
RF



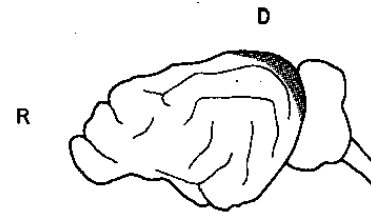
Response Fields with varying asymmetries



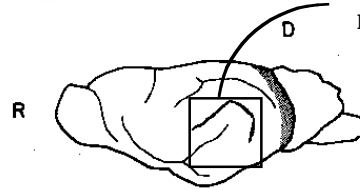
The Anterior Cortical Field



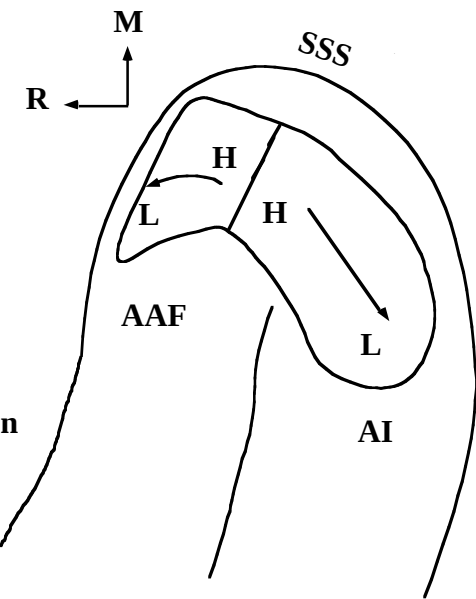
CAT



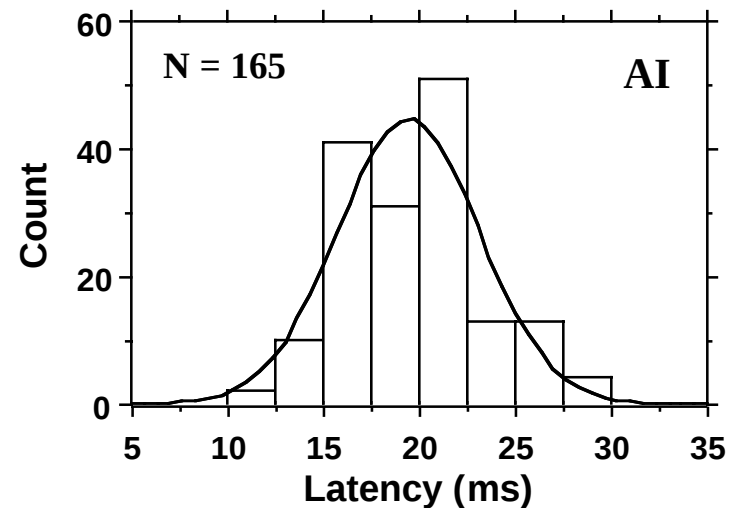
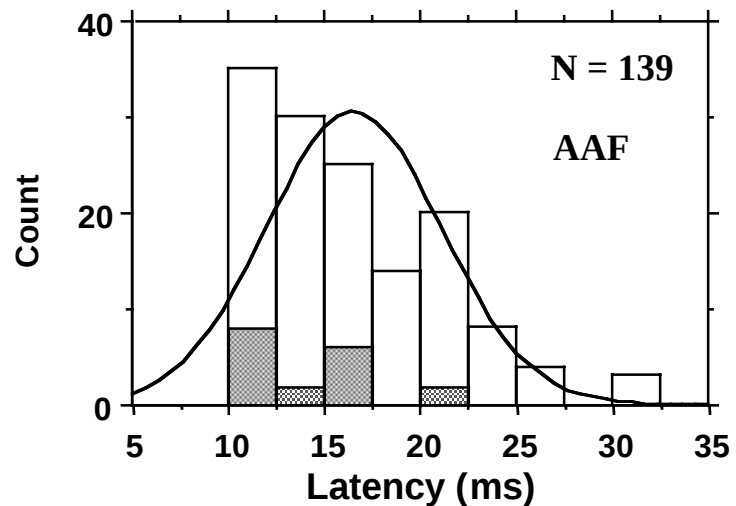
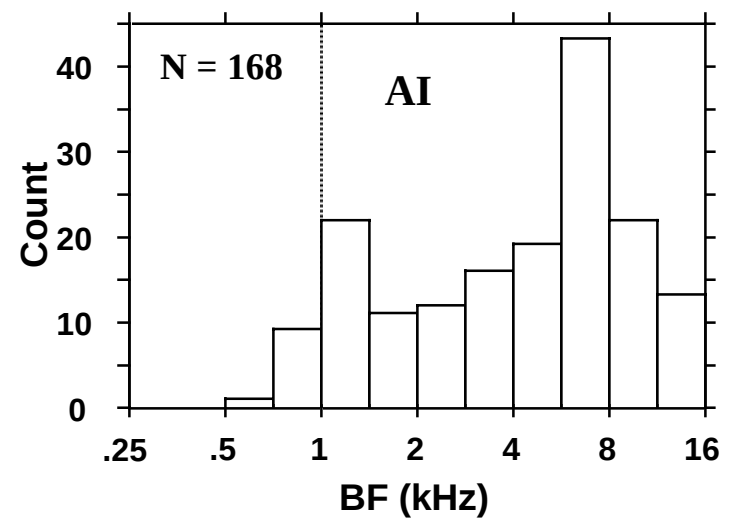
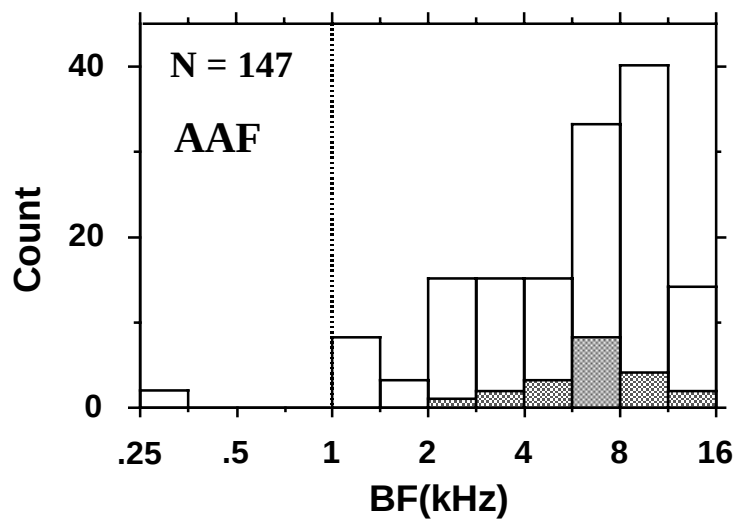
FERRET



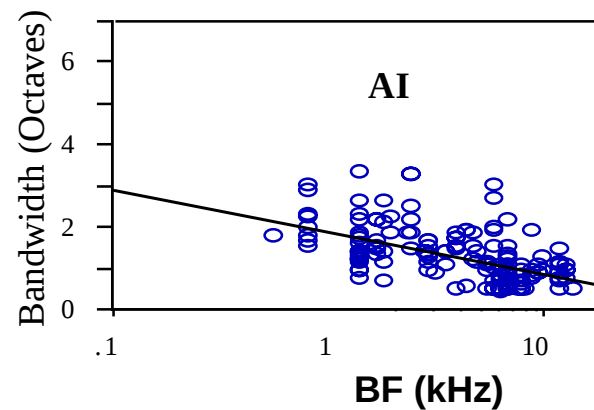
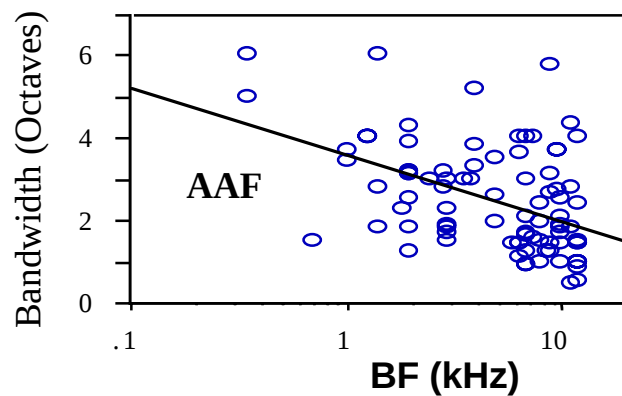
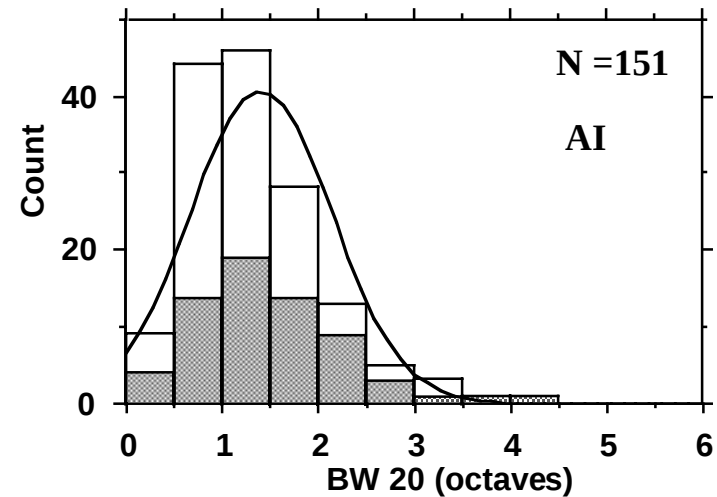
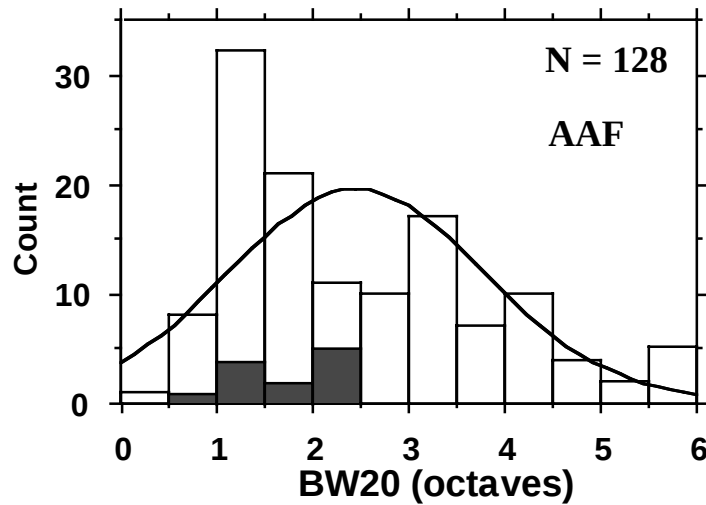
Area of magnification



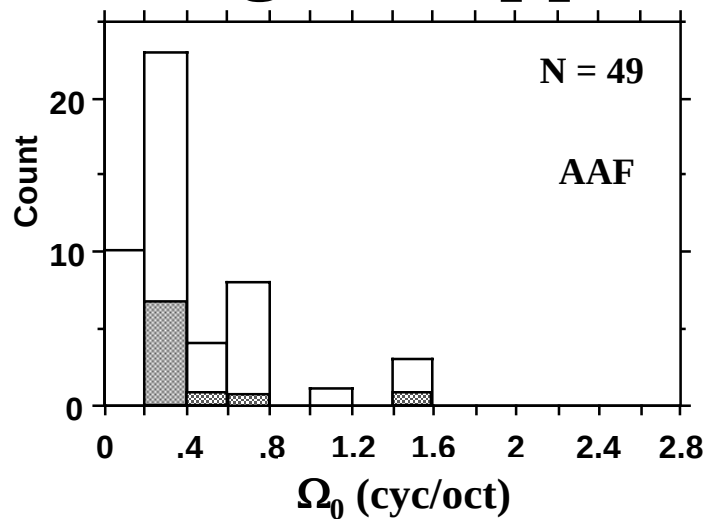
BF's and latencies are similar



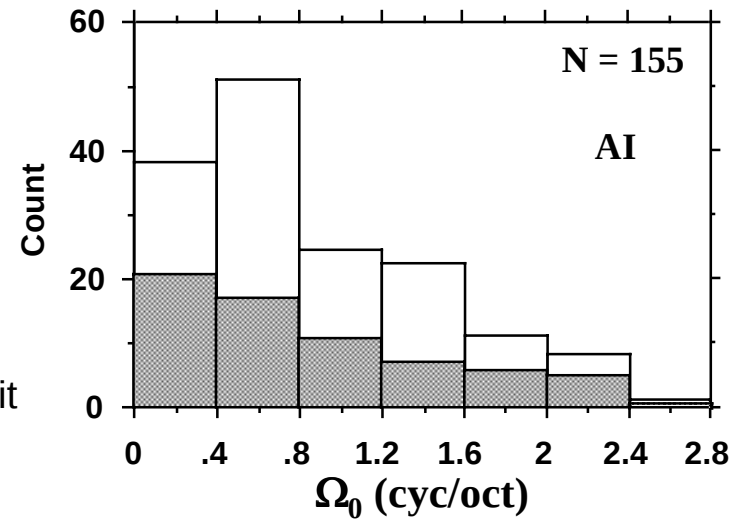
Bandwidths (BW20) are larger in AAF



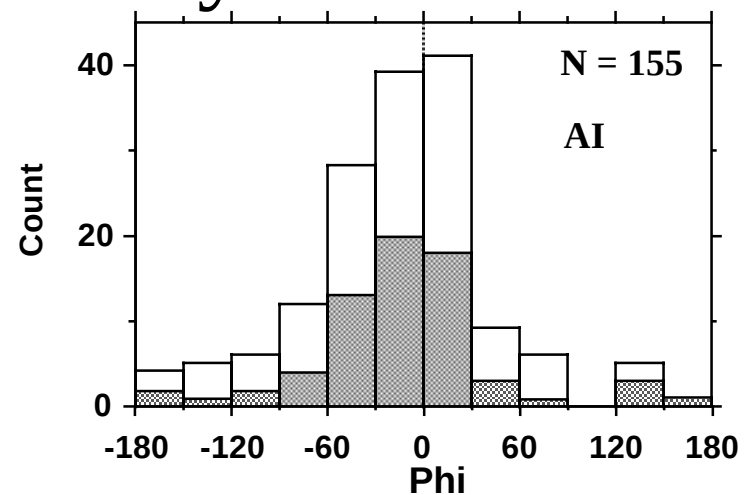
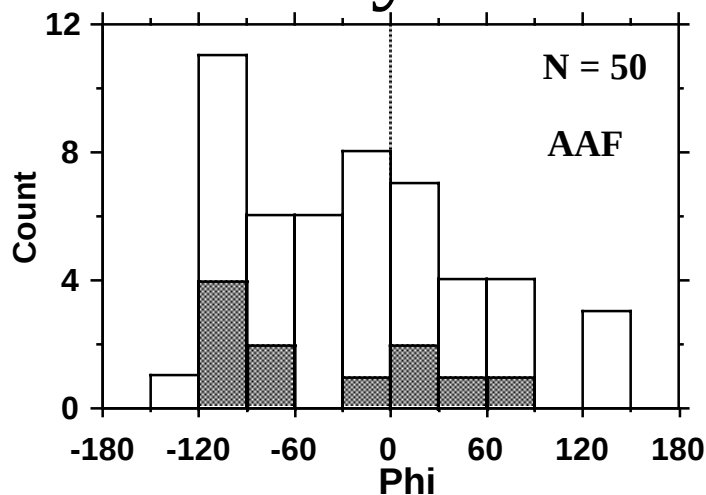
Tuning to Ripples tends to be lower in AAF



Ω_0 = Best
Stationary
Ripple
Frequency
(cyc/oct)

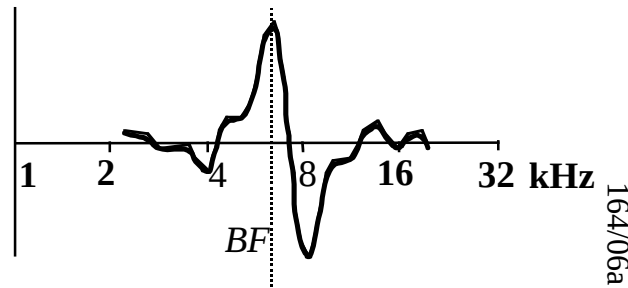


RF's asymmetries are evenly distributed

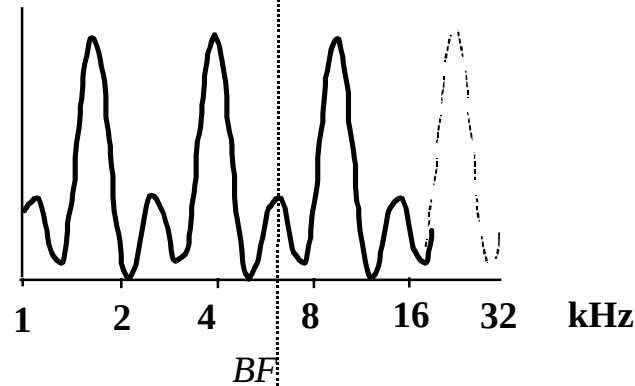


Predictions Using Stationary Ripples

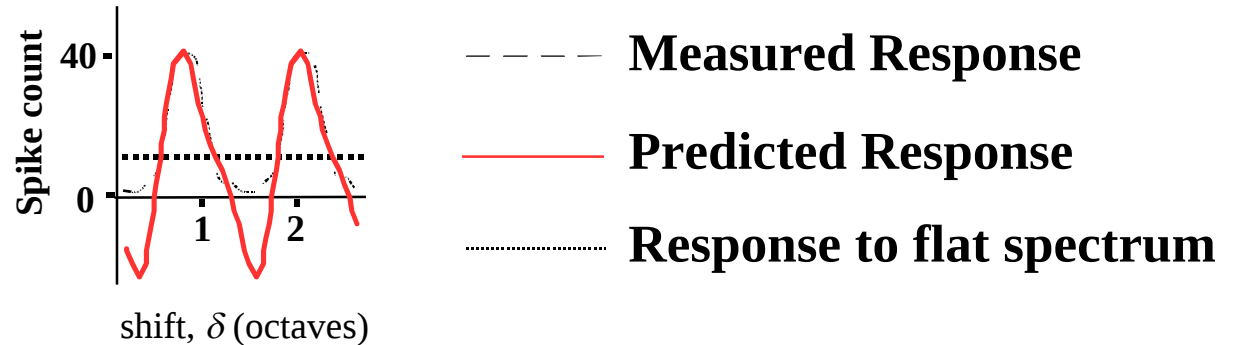
**Response Field
of Cell**



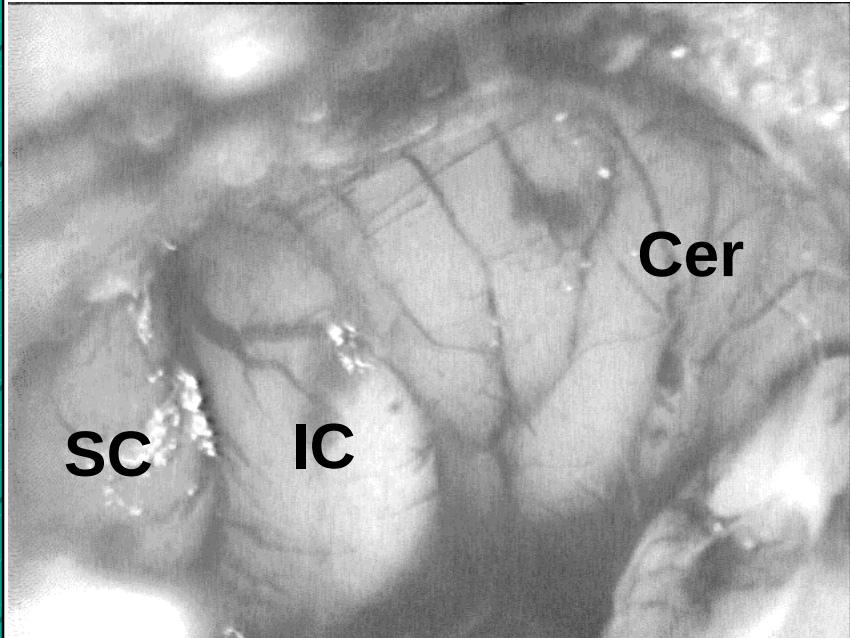
**Spectral Profile
of stimulus**



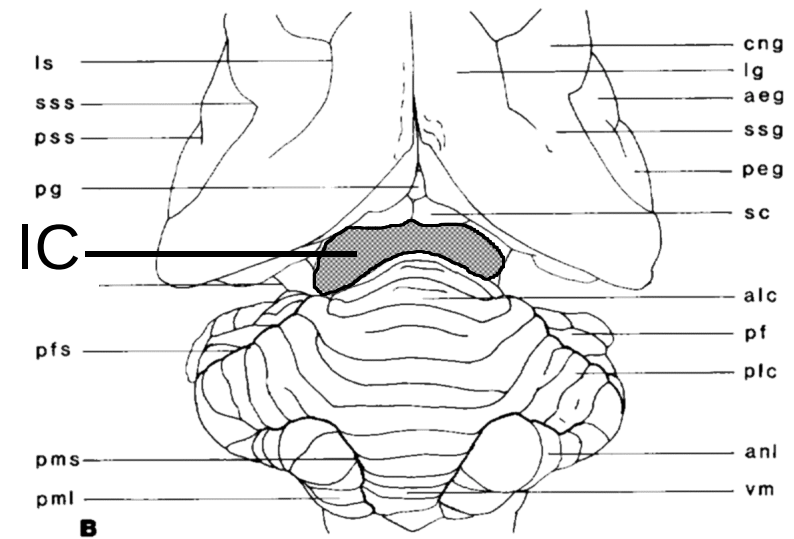
**Response of Cell
to Profile**



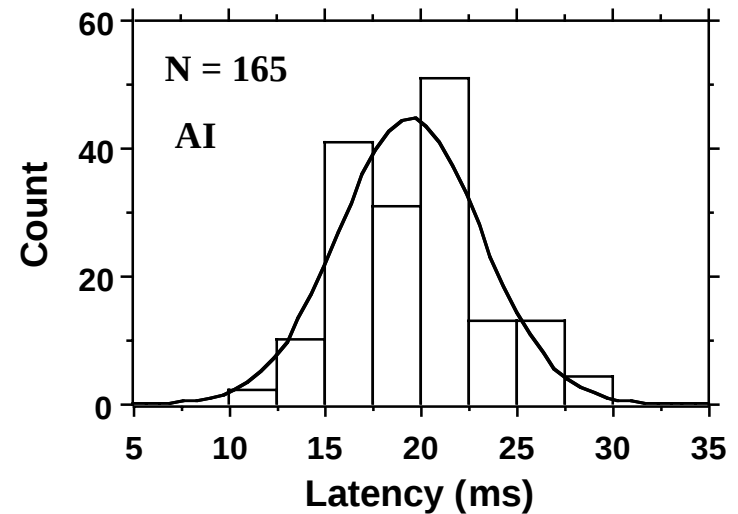
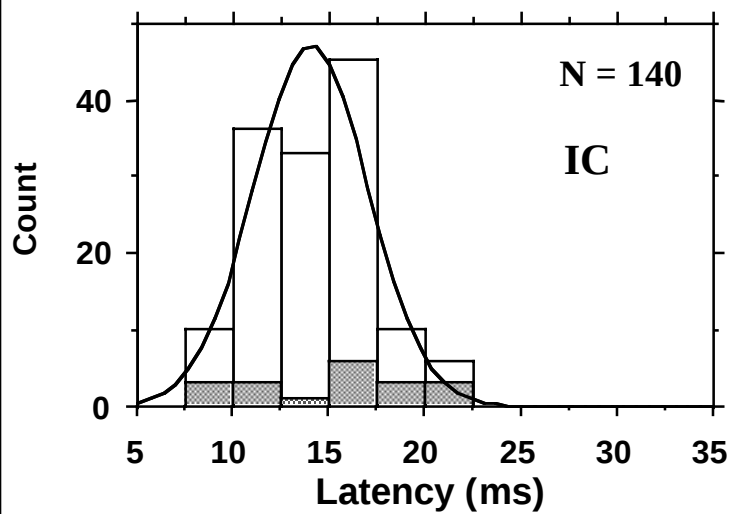
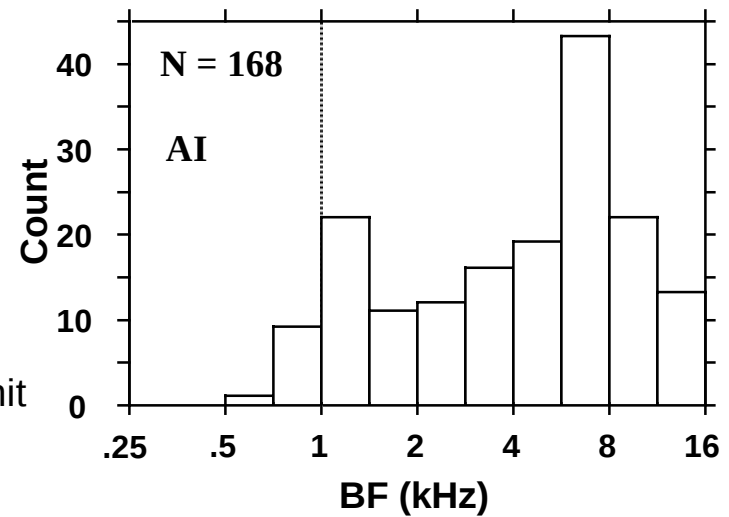
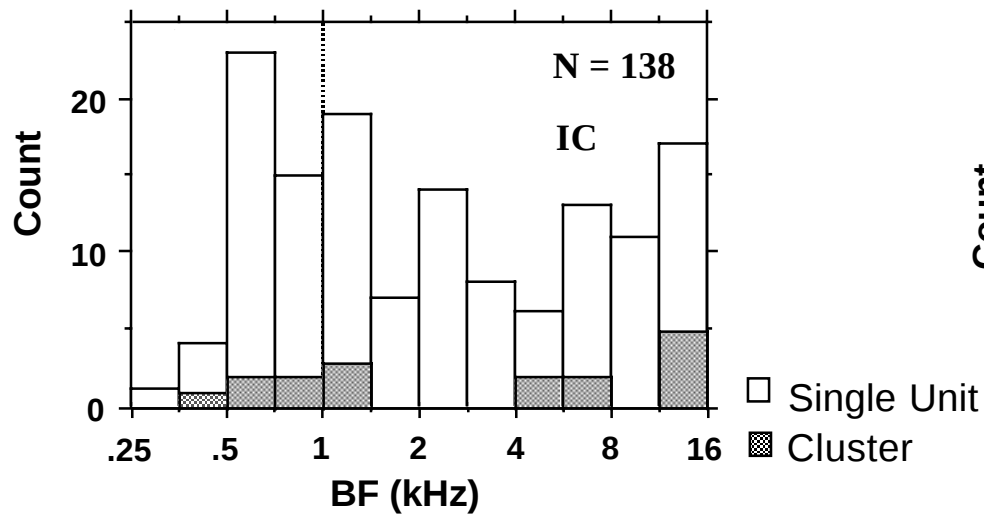
The Inferior Colliculus



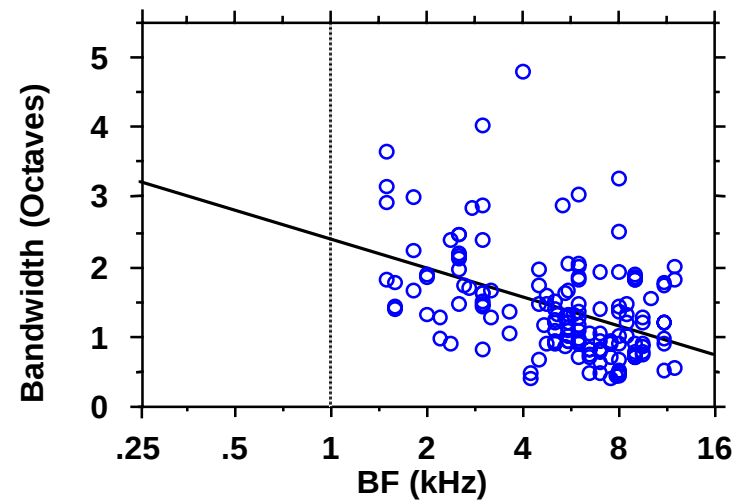
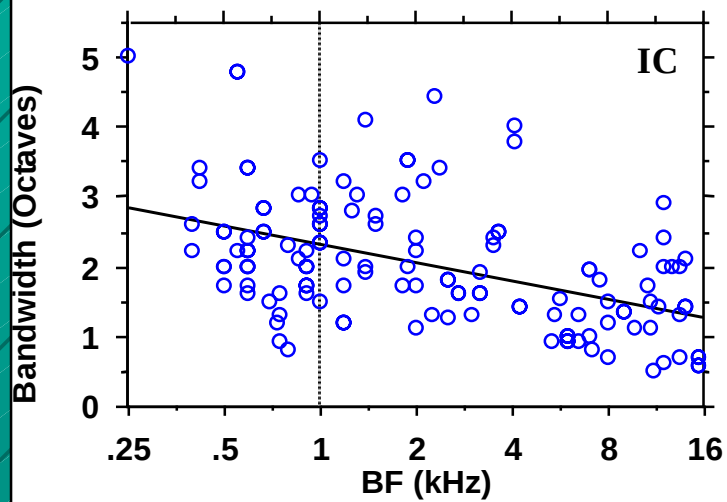
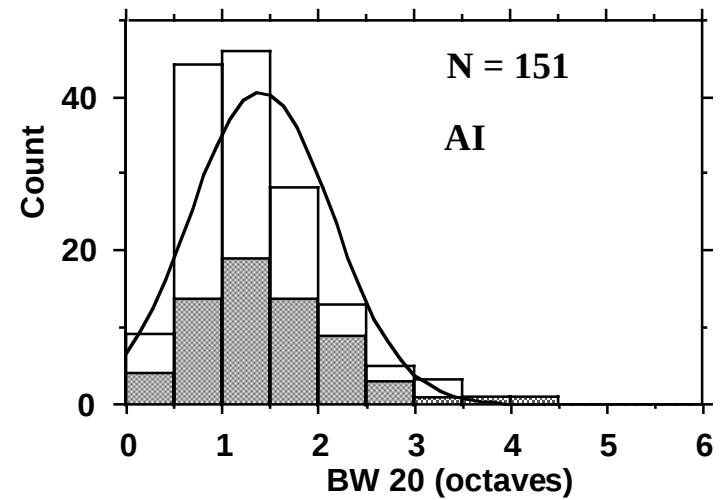
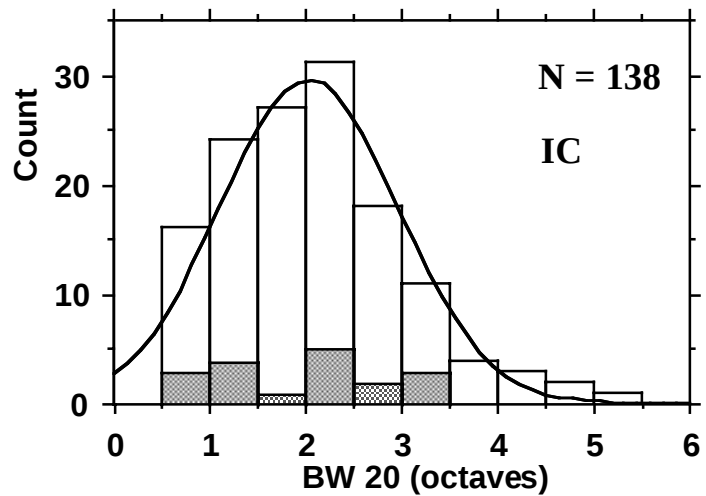
R
L



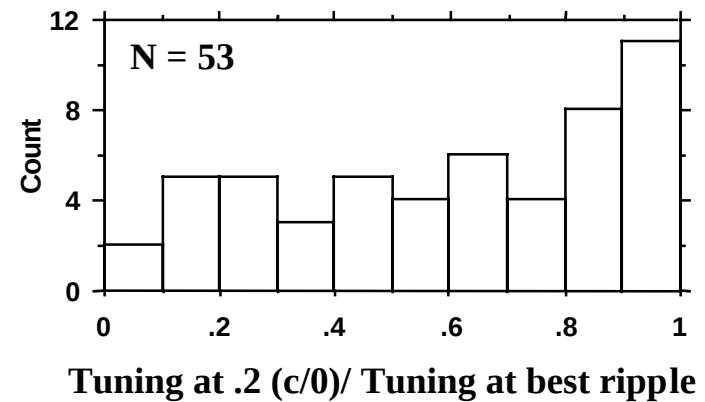
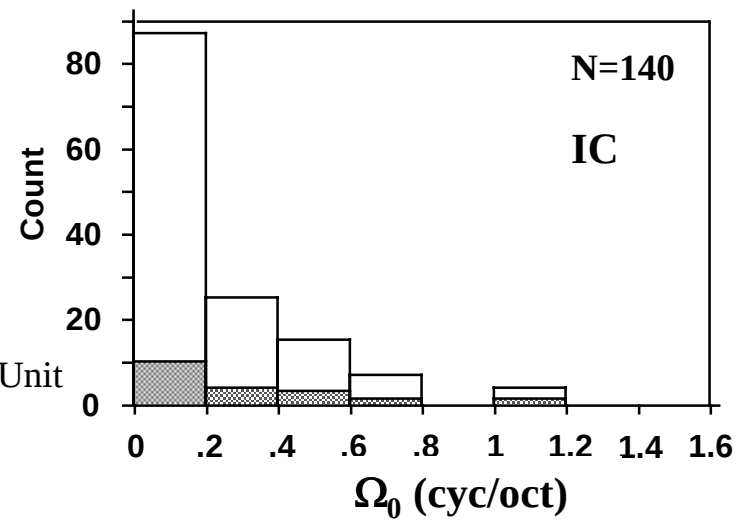
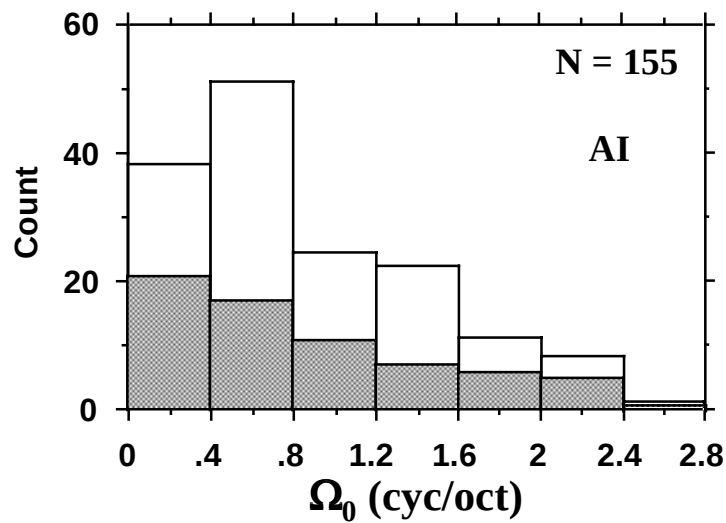
Of BF's and Latencies



Bandwidths

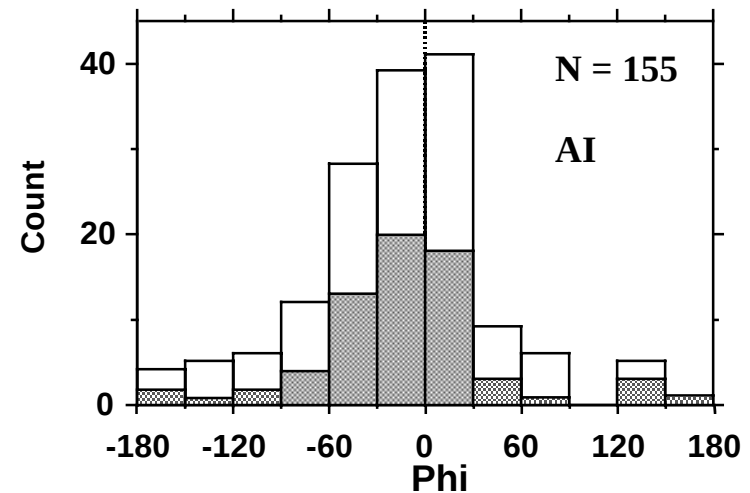
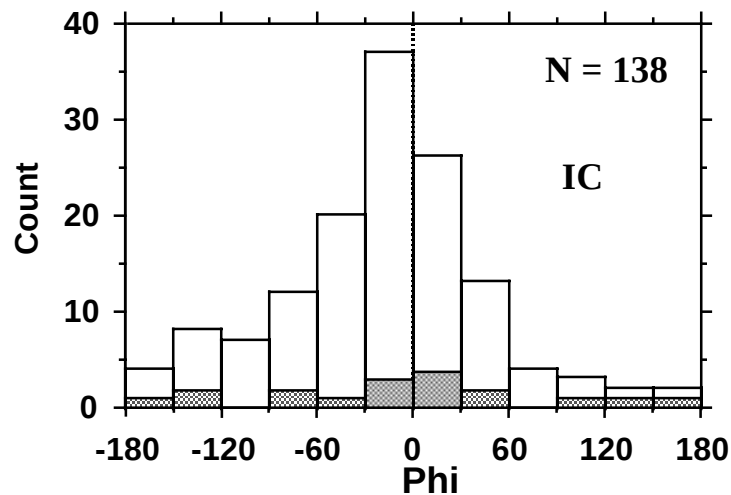


Best Ripple Frequency



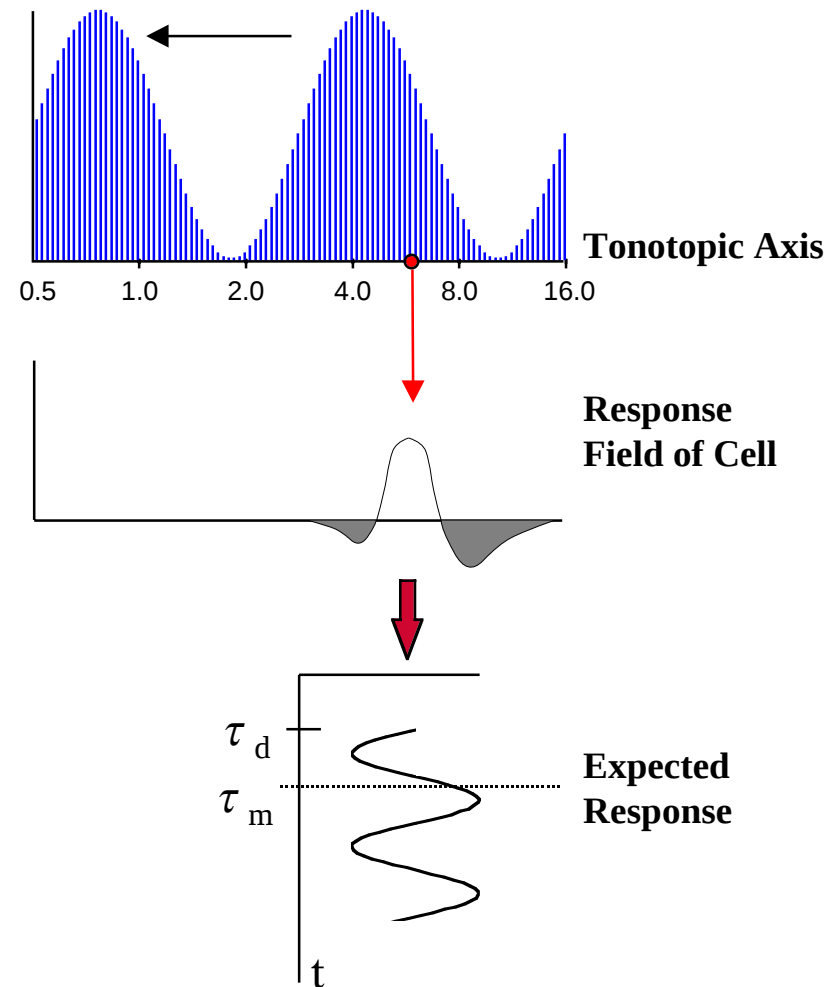
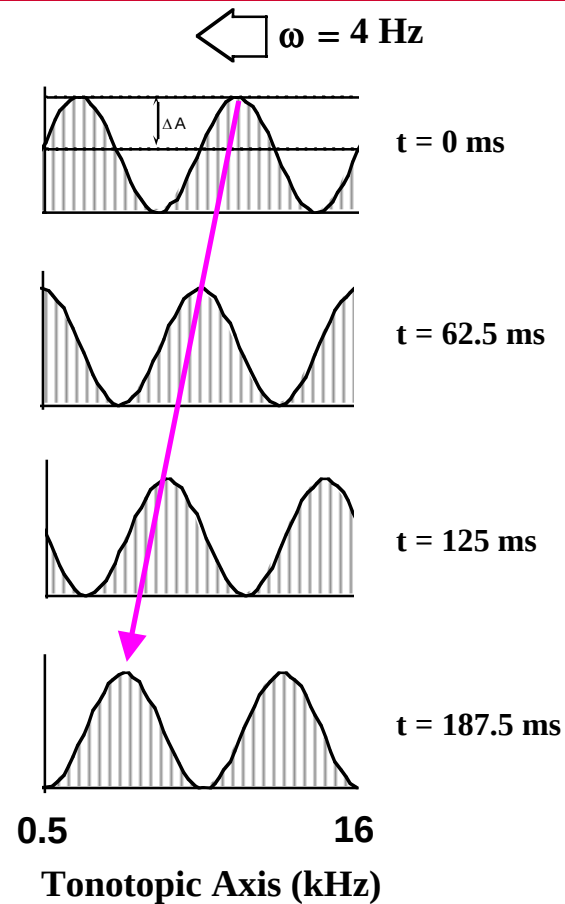
Ω_0 = Best Ripple Frequency

RF's are more symmetrical in IC



□ Single Unit
▨ Cluster

Temporal properties: Moving Ripples

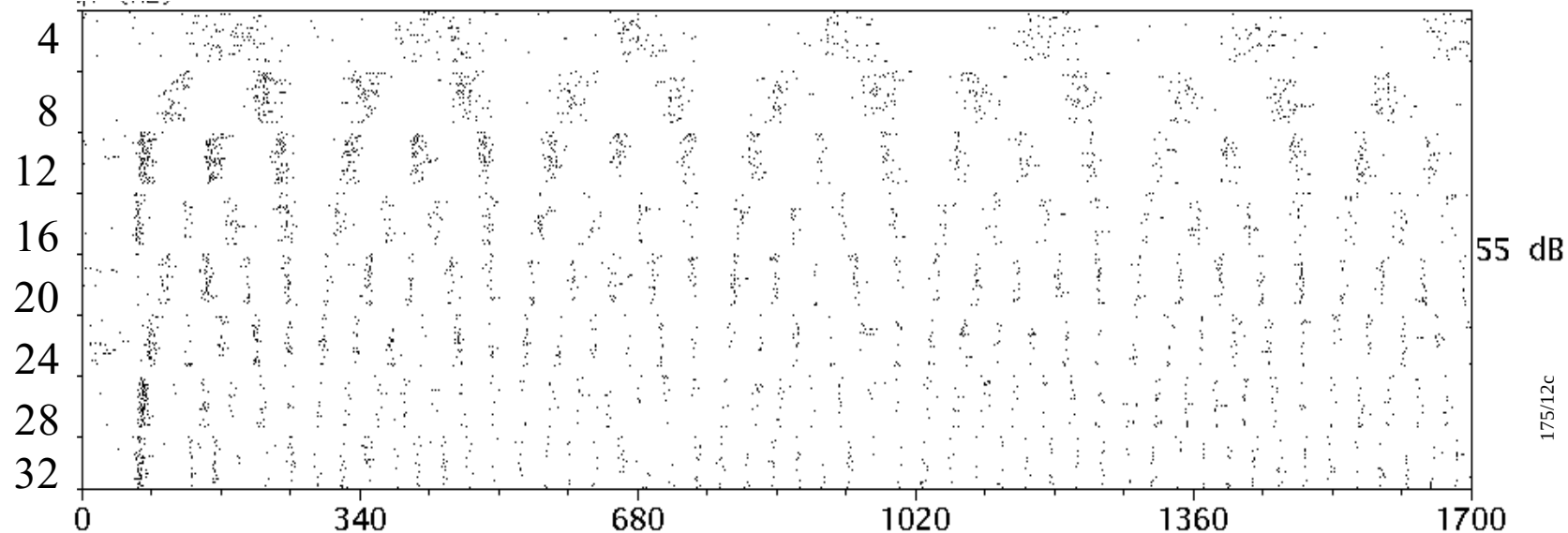


- Ω = ripple frequency in cycle/octaves
- ω = temporal frequency in Hz

Responses to Moving Ripples

Ripple Frequency is 0.4 cycles/oct

Temporal Frequency (Hz)



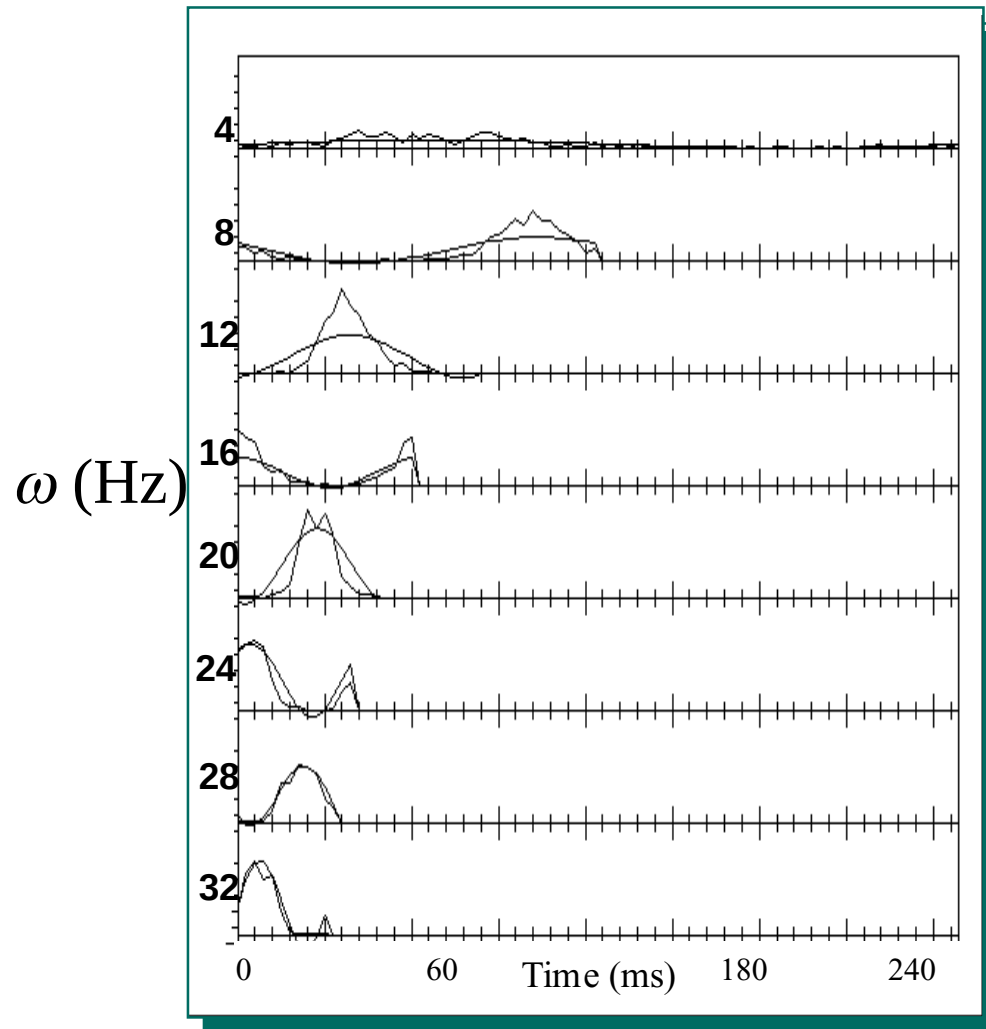
$\Omega = 0.4$ cyc/oct

$\omega = 4$ to 32 Hz

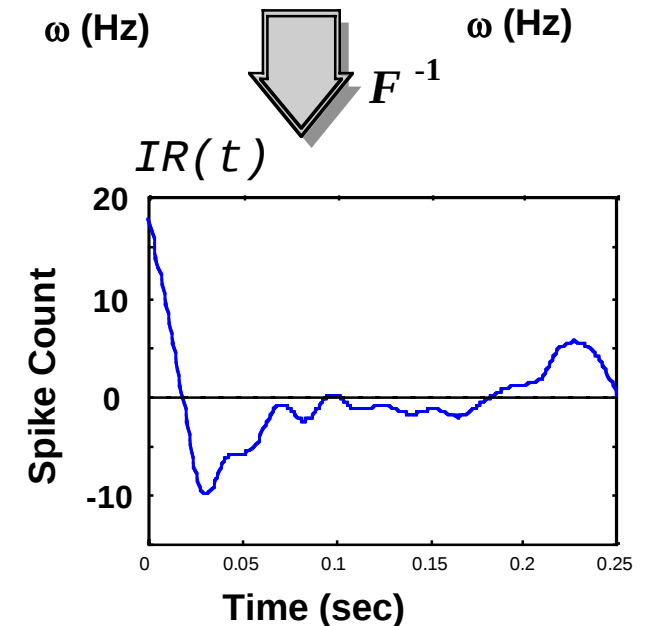
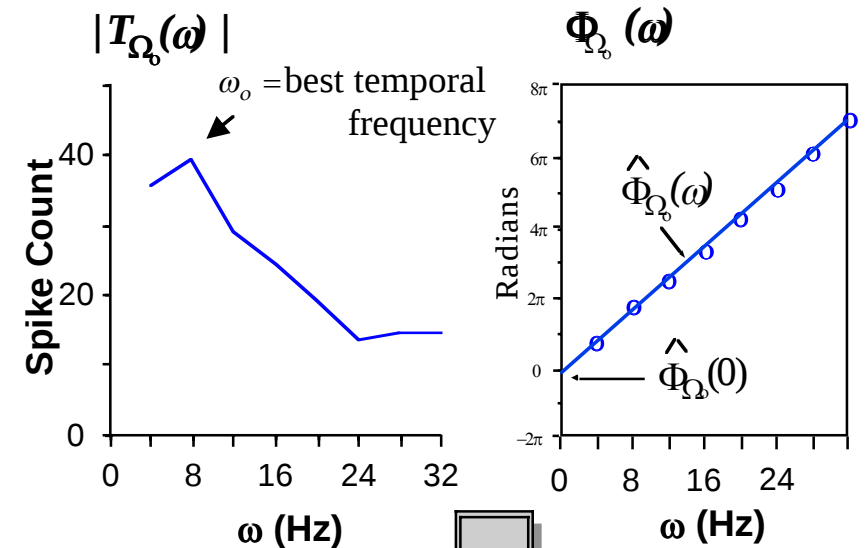
Time (ms)

30 sweeps per ω

Step 1. From Spike Count to Period Histogram



Step 2. Magnitude and Phase of Best Fit



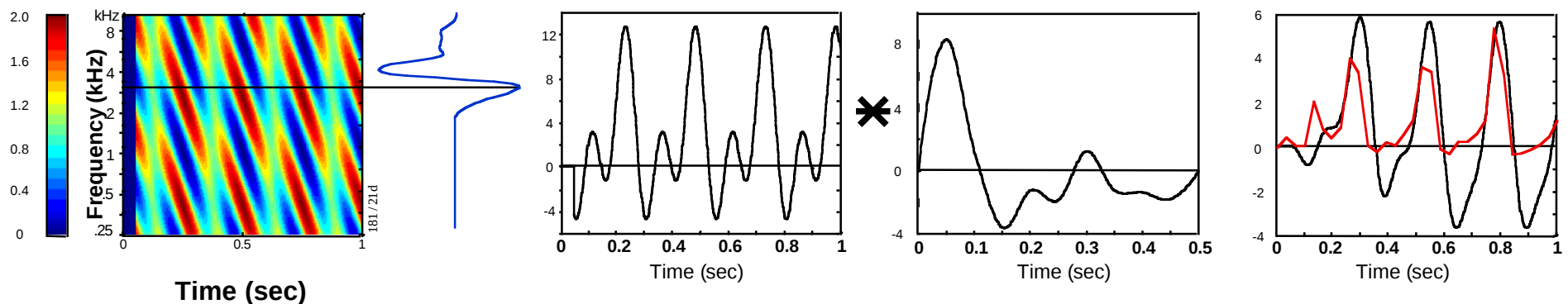
Impulse Response Function

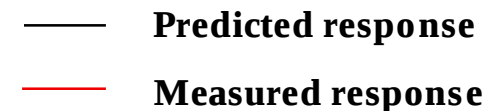
Linearity of responses in the Auditory Cortex

AI and AAF display similar characteristics

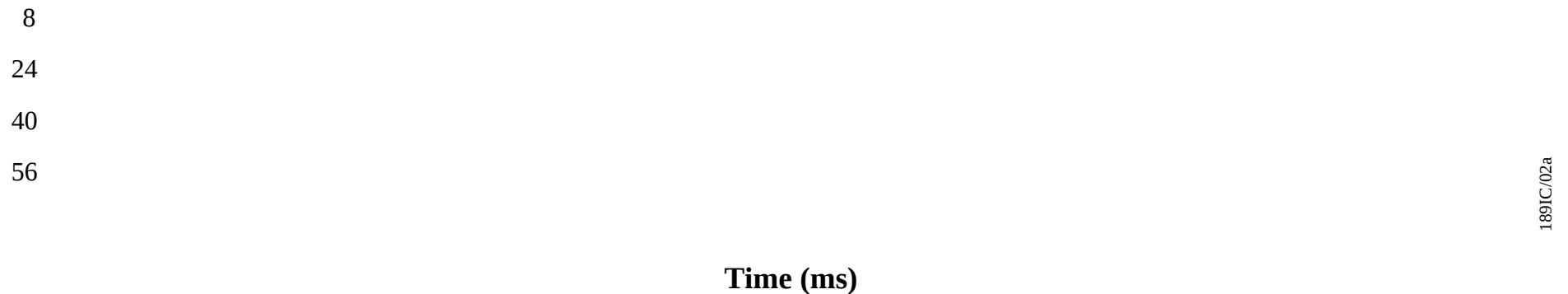
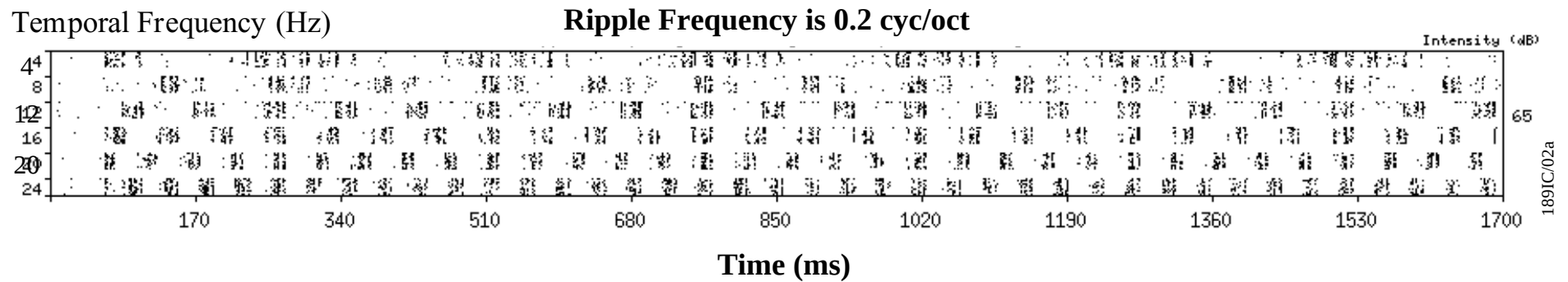
Anterior Field:

(A) Stimulus Spectrogram, $S(x,t)$ (B) $RF(x)$ (C) $\sum_x RF(x) \cdot S(x,t)$ (D) $IR(t)$ (E) Predicted Response





Inferior Colliculus Responses



$$\Omega = 0.2 \text{ cyc/oct}$$

15 sweeps per ω

$$\omega = 4 \text{ to } 64 \text{ Hz}$$

Summary

- Stationary and traveling ripples can be used to extract spectral and temporal properties of auditory cortical neurons.
- Linearity: Responses to a broad-band complex stimuli, decomposed into a linear combination of ripples, can be predicted by summing the neuronal responses to the individual ripples.
- Only Cortical neurons are selective to ripple frequencies; Collicular neurons are low-pass with respect to ripple frequencies.
- Therefore, AI and AAF neurons could perform a multi-scale analysis of spectral shape: the spectral profile is analyzed at different degrees of resolution by neurons with receptive fields of different best frequencies, bandwidths and asymmetries.

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