

Bachelor Project Final Presentation

Representation of auditory signals by neuronal spike trains

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LCN, 7 June 2013

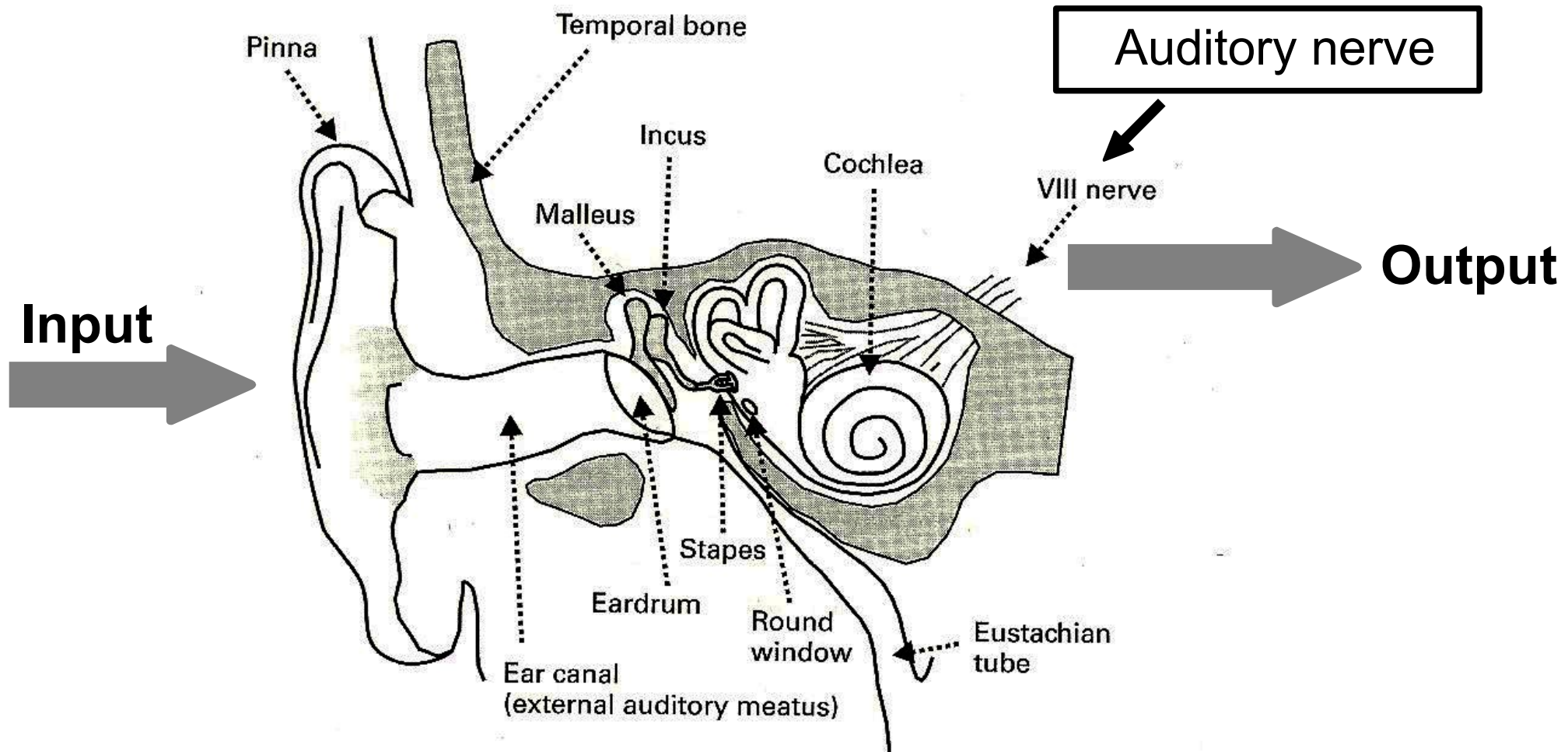
Plan

- Presentation in three parts :
 - Introduction
 - Results
 - Summary

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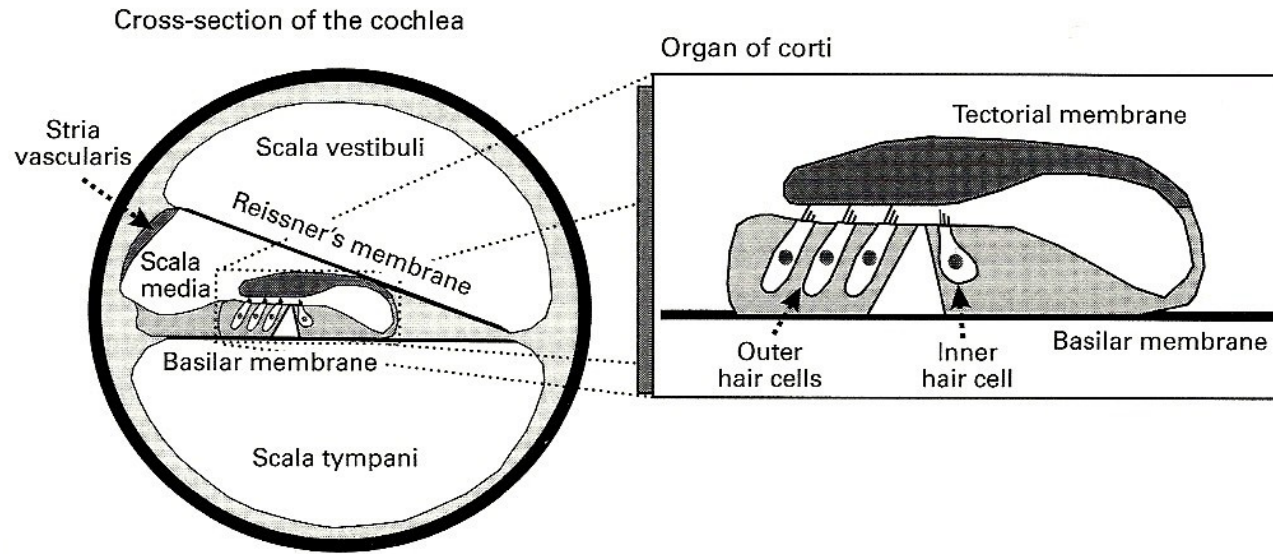
Auditory System



- Input : air pressure signal
- Output : spikes

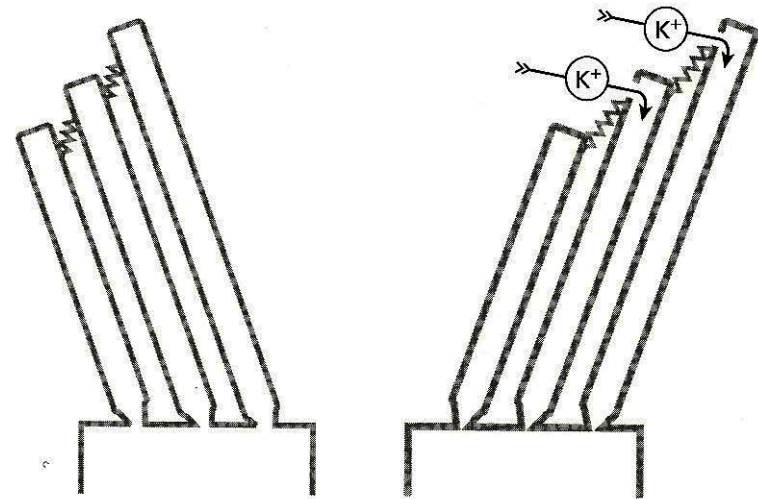
Image source : «Auditory Neuroscience »,
Schnupp et al., 2011, MIT Press p52

Auditory System



Cross-section of cochlea

Hair cell transduction mechanism :



Goal of project

- Study the influence of absolute refractory period on signal encoding

Approach

- Use computational model for cat auditory-nerve responses from Zilany et al. (JASA, 2009)

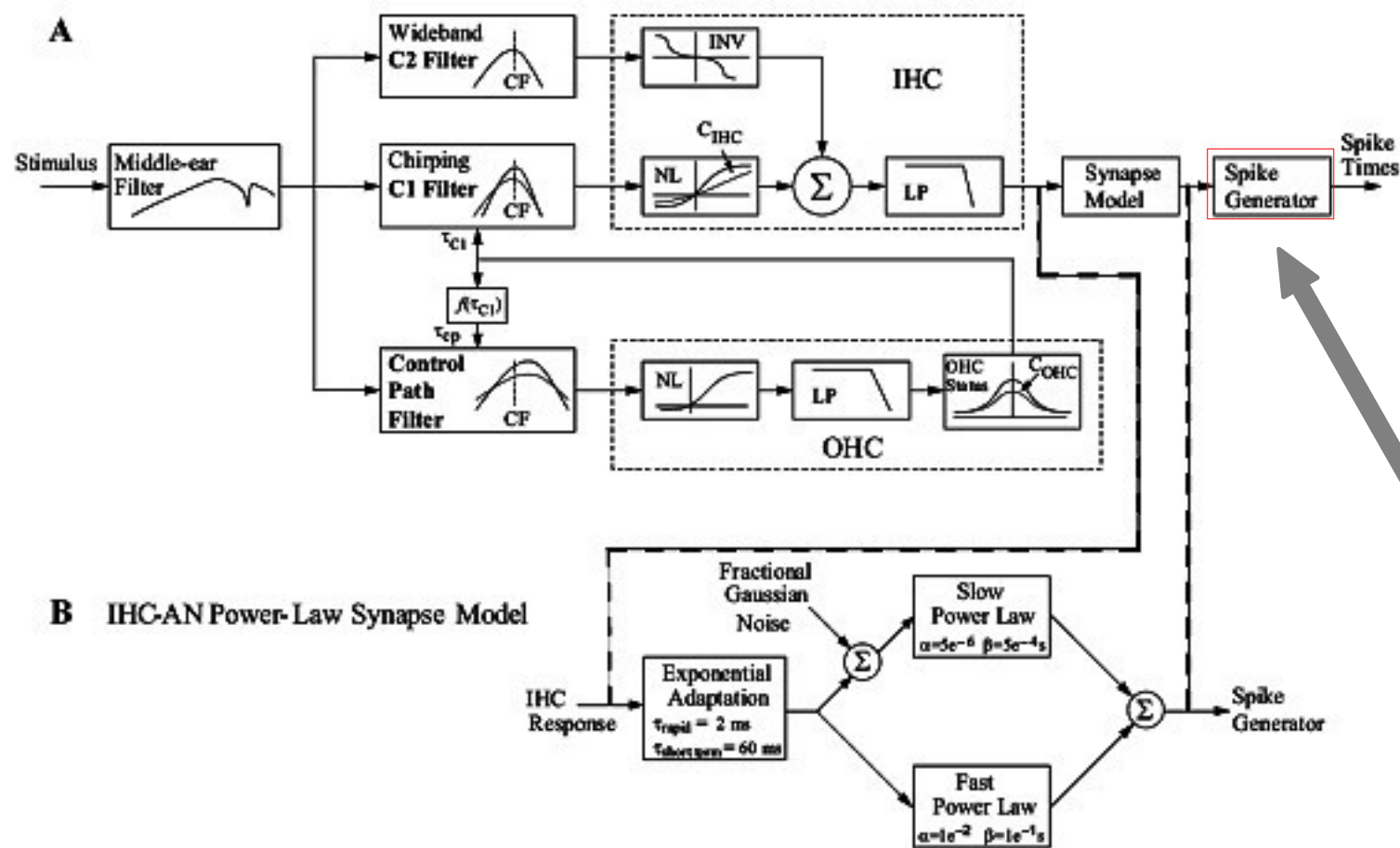
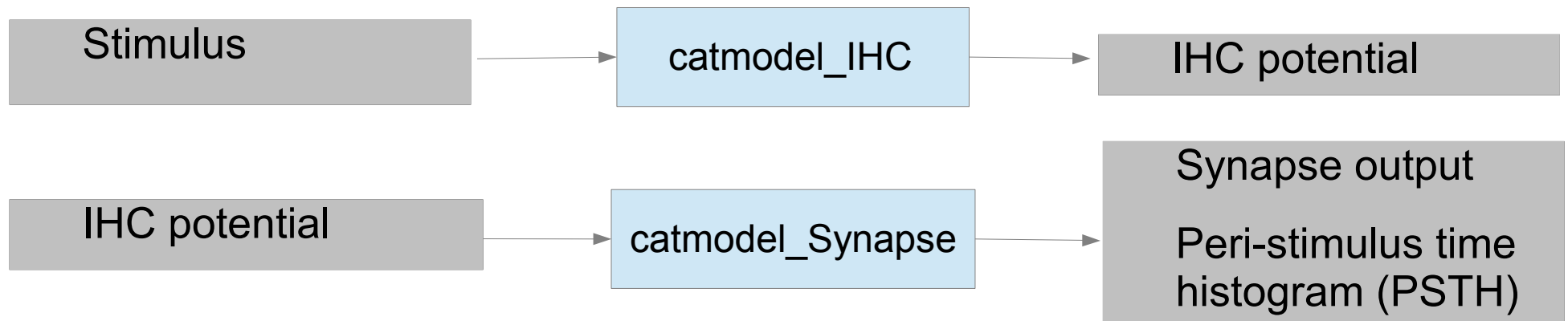


Image source :
<http://www.bme.rochester.edu/people/faculty/bio/project.php?id=229&projectId=203>,
 04.04.2013

- Modify value of the absolute refractory period

Model use

- Main shema:



We must also specify to the model :

sampling rate

time before repetition and number of repetitions of experiments

characteristic frequency (CF) of the IHC and fiber we want to test

type of fiber : low, medium or high spontaneous rate (SR)

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Two parts

- First, use of an ad-hoc measurement (rate modulation depth), to see difference between cases with and without absolute refractory period (ARP)
- Second, see if Fourier coefficients of response to sinusoidal stimuli match predictions of Deger et al. (2010)

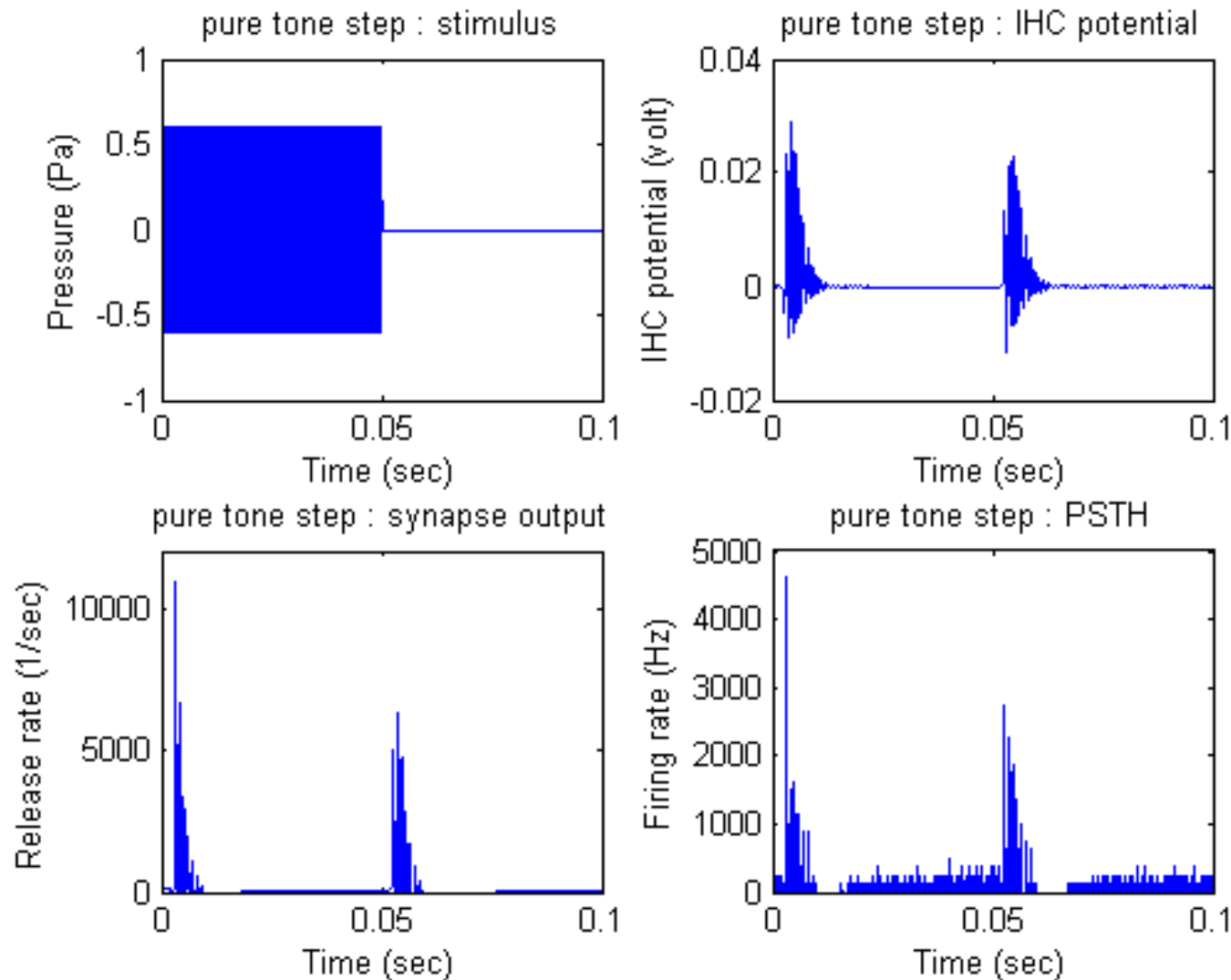
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Experiments

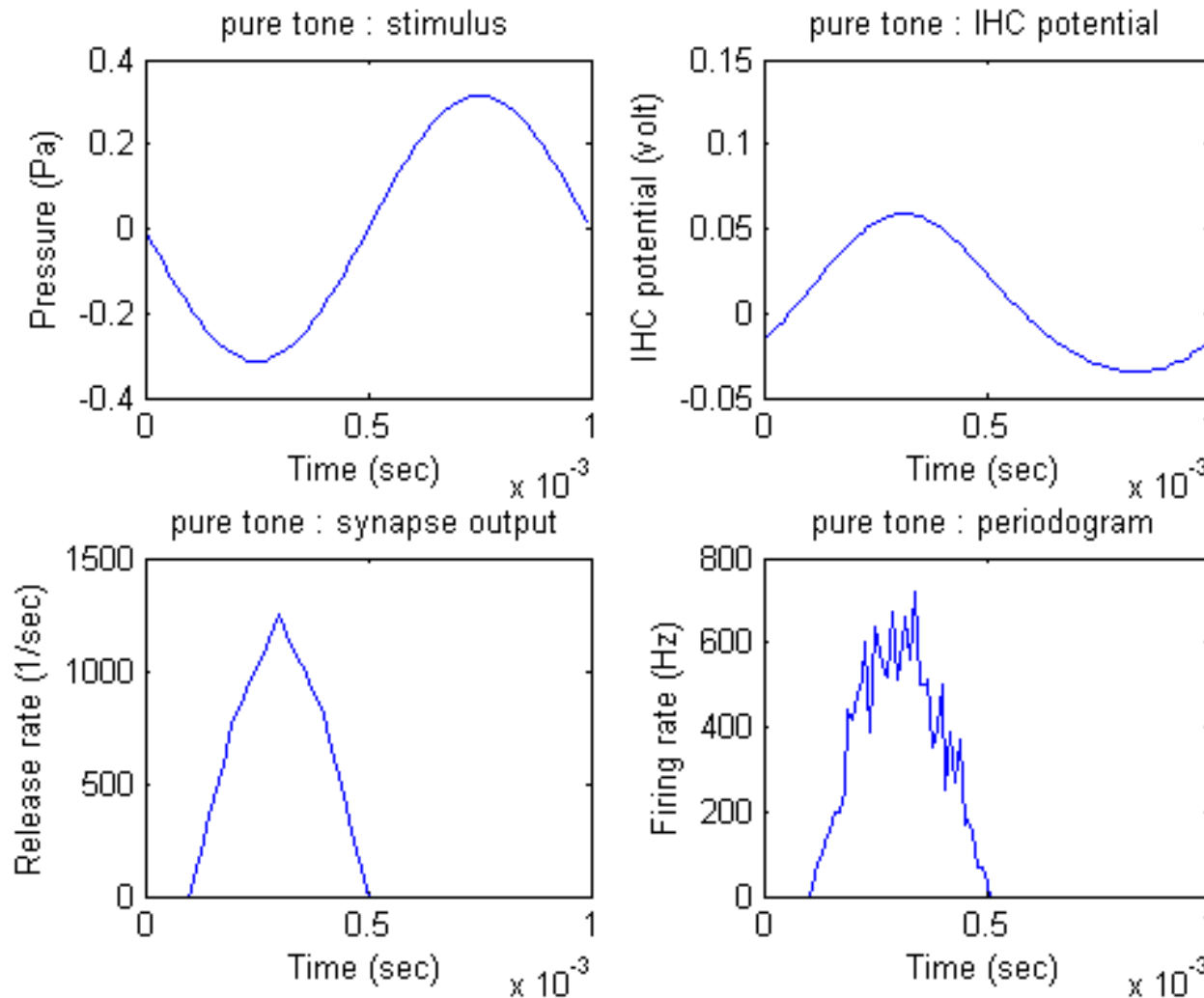
- 4 types of experiments (stimuli):
 - Pure tone
 - Click
 - Noise step
 - Pure tone step
- Each of them with or without absolute refractory period

Pure tone step experiment



- Stimulus : pure tone 10kHz in 50 ms steps
- Period time : 100ms
- Fibertype : high SR
- Sampling rate : 100'000 Hz
- 800 repetitions
- CF : 1kHz
- With absolute refractory period

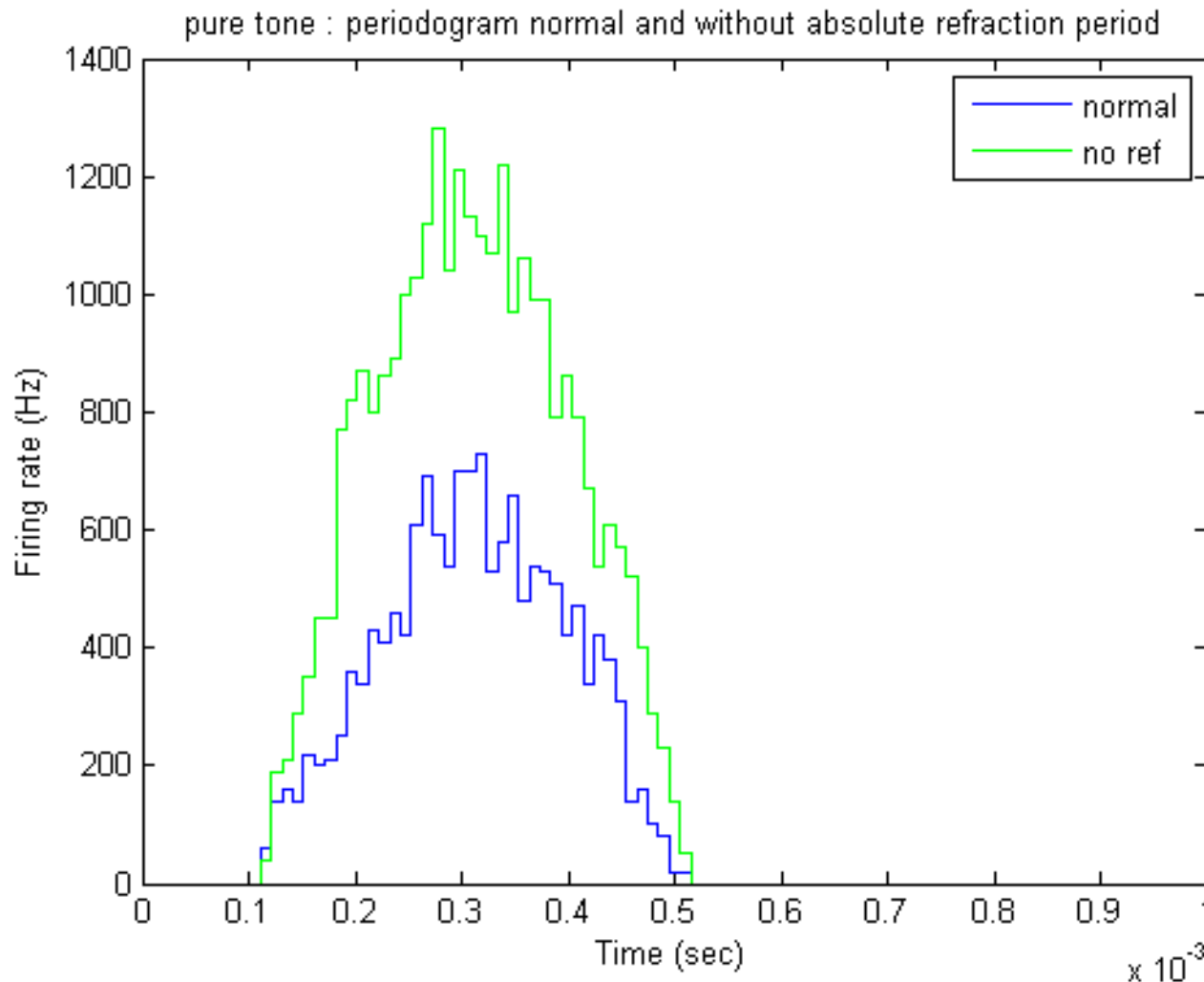
Pure tone experiment



- Stimulus : pure tone
1kHz, amplitude
 $6.32e-3$ Pa
- Period time : 1ms
- Fibertype : medium
SR
- Sampling rate :
100'000 Hz
- 10'000 repetitions
- CF : 1kHz
- With absolute
refractory period

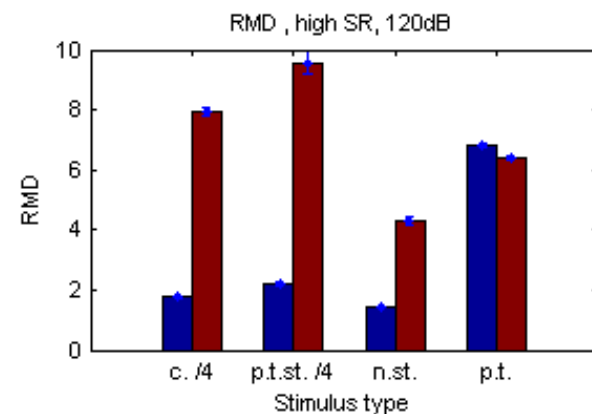
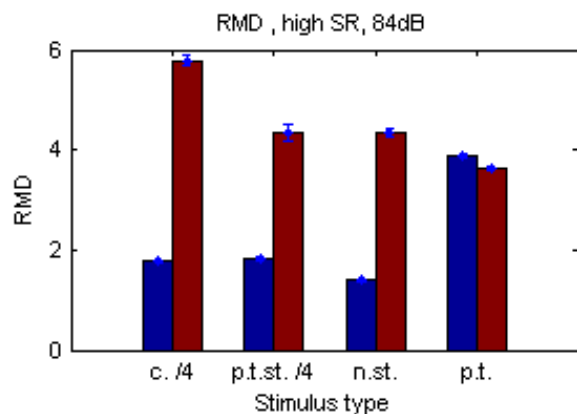
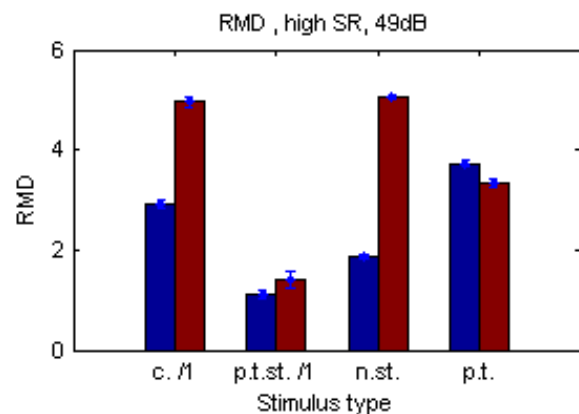
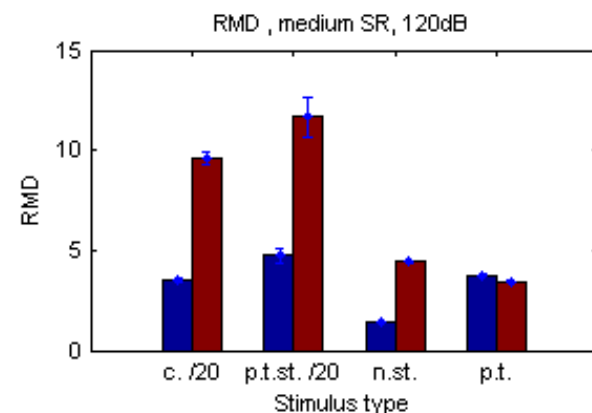
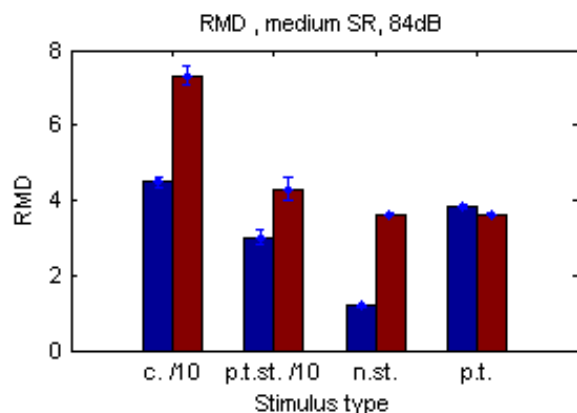
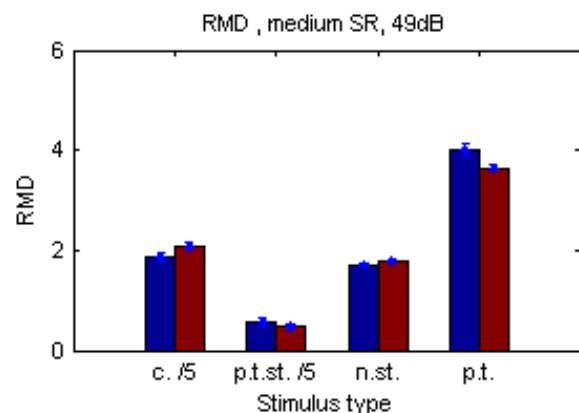
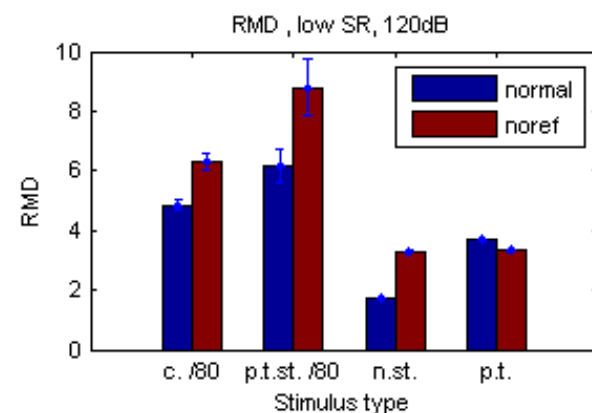
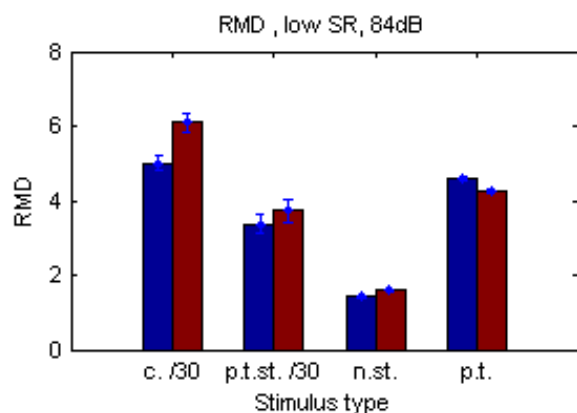
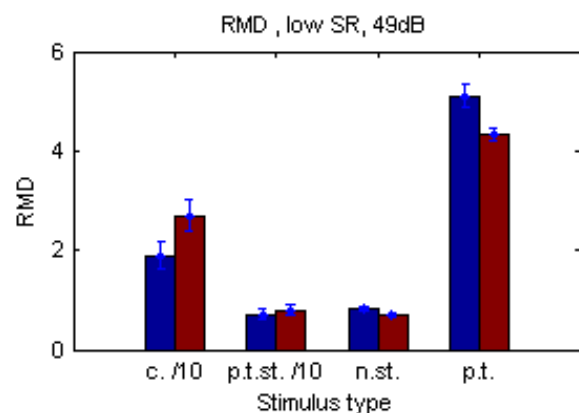
Refractory period comparison

- Example for the pure tone:



Rate modulation depth (RMD)

- Measure of how peaked is the response compared to baseline
- On the form $(x-y)/y$, $x = \max(\text{periodogram})$ for all experiments; y is the baseline
 - Click : $y = \text{periodogram on } 0 \text{ Pa stimulus}$
 - Pure tone : $y = \text{mean}(\text{periodogram})$
 - Modulated noise : $y = \text{periodogram just before the end of the step}$
 - Modulated pure tone : $y = \text{mean of pure tone periodogram when IHC saturated}$



Rate modulation depth result

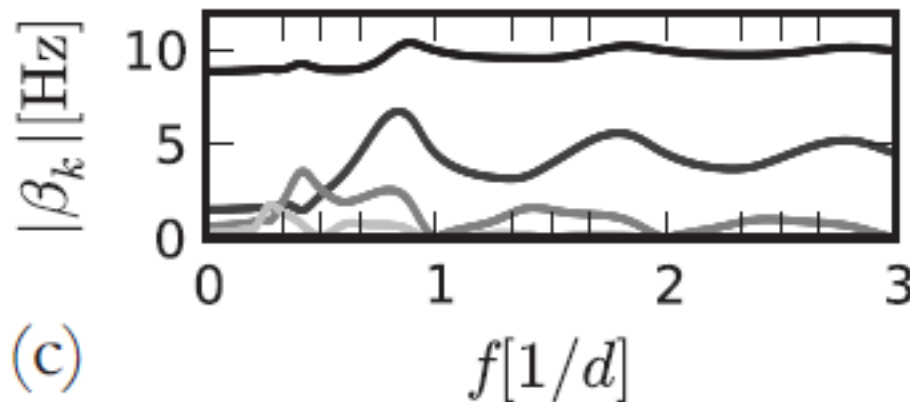
- Experiment done for each fiber type and for 3 different intensities (49 dB, 84 dB, 120 dB)
- Similar results for each experiment for difference between the two cases
 - Clicks and steps (either of noise or of pure tone) have bigger RMD without ARP
 - Pure tone have lower RMD without ARP
- Sudden changes triggers a lot of the non-linearities of the model : ARP effects hidden
- With pure tone, less interaction with non-linearities, ARP effects are visible : increases precision

Two parts

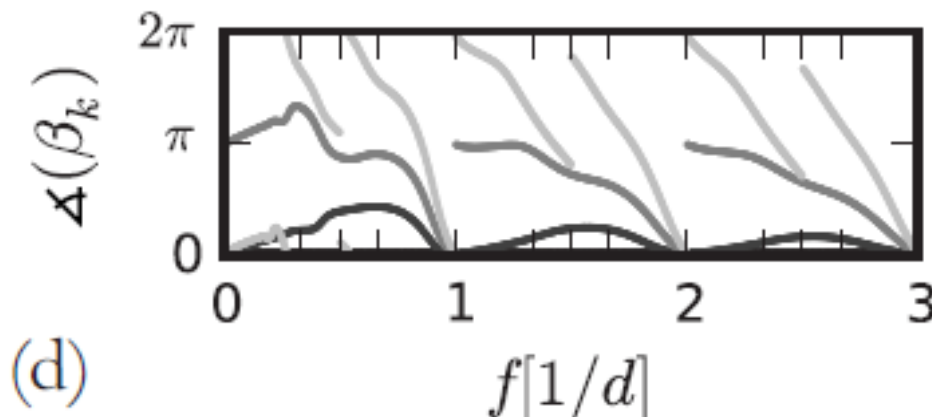
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Predictions for sinusoidal stimulus

- Prediction for norm :



- Prediction for angle :



- β_k is the Fourier coefficient of harmonic k
- d is the refractory period (80 ms)
- f is the stimulus frequency (Hz)
- From «Nonequilibrium dynamics of stochastic point process with refractoriness », Deger et al. (2010)

Experiments

- Stimulus : modulated pure tone at 49 dB, characteristic frequency 1 kHz, carrier frequency 10 kHz
- $y(t) = A(1 + \sin(2\pi t f_m)) \sin(2\pi t f_c)$
- modulation frequency from 50 Hz to 4000 Hz, 50 Hz steps
- Similar to the pure tone case, because IHC can not follow carrier frequency and their synaptic release rate will follow modulation frequency.

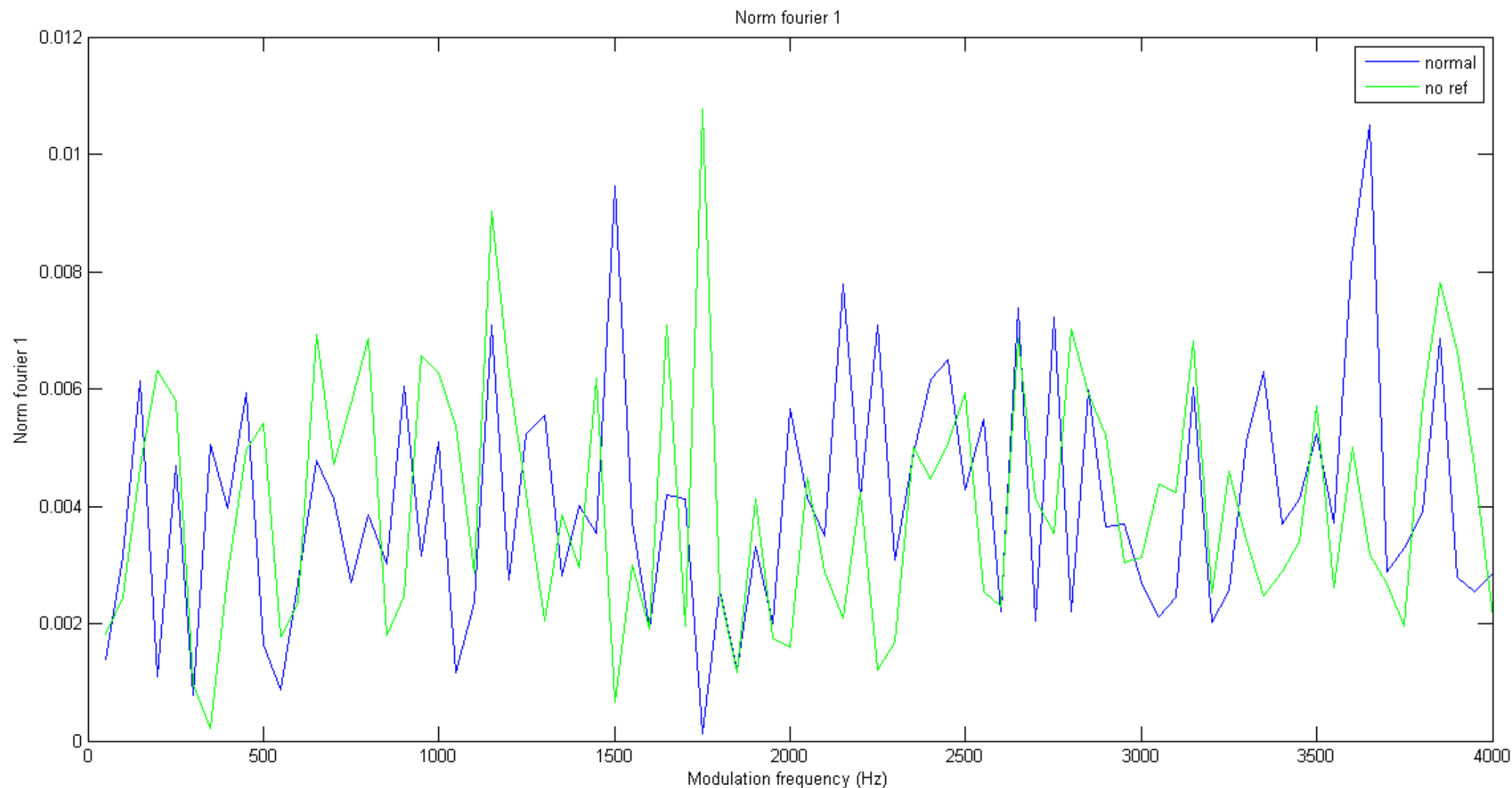
Experiments

- Absolute refractory period of 0.75 ms in the model
- Multiple of 1/ARP : 1333 Hz and 2666 Hz in our experiment
- Calculation of Fourier coefficients :

$$\beta_k = \frac{1}{T} \sum_{j=0}^{\frac{T}{\Delta t}} e^{i\omega_k j \Delta t} z(j \Delta t) \Delta t$$

Results

- Too noisy to conclude anything
- Example of norm of harmonic 1:



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Summary

- Absolute refractory period influences output
- It increases precision for a pure tone stimulus, but not for clicks or steps (sudden changes)
- More data is needed for assessing the prediction of Deger(2010), we have too noisy results by now to conclude anything