Bachelor Project Final Presentation

Representation of auditory signals by neuronal spike trains

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Plan

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

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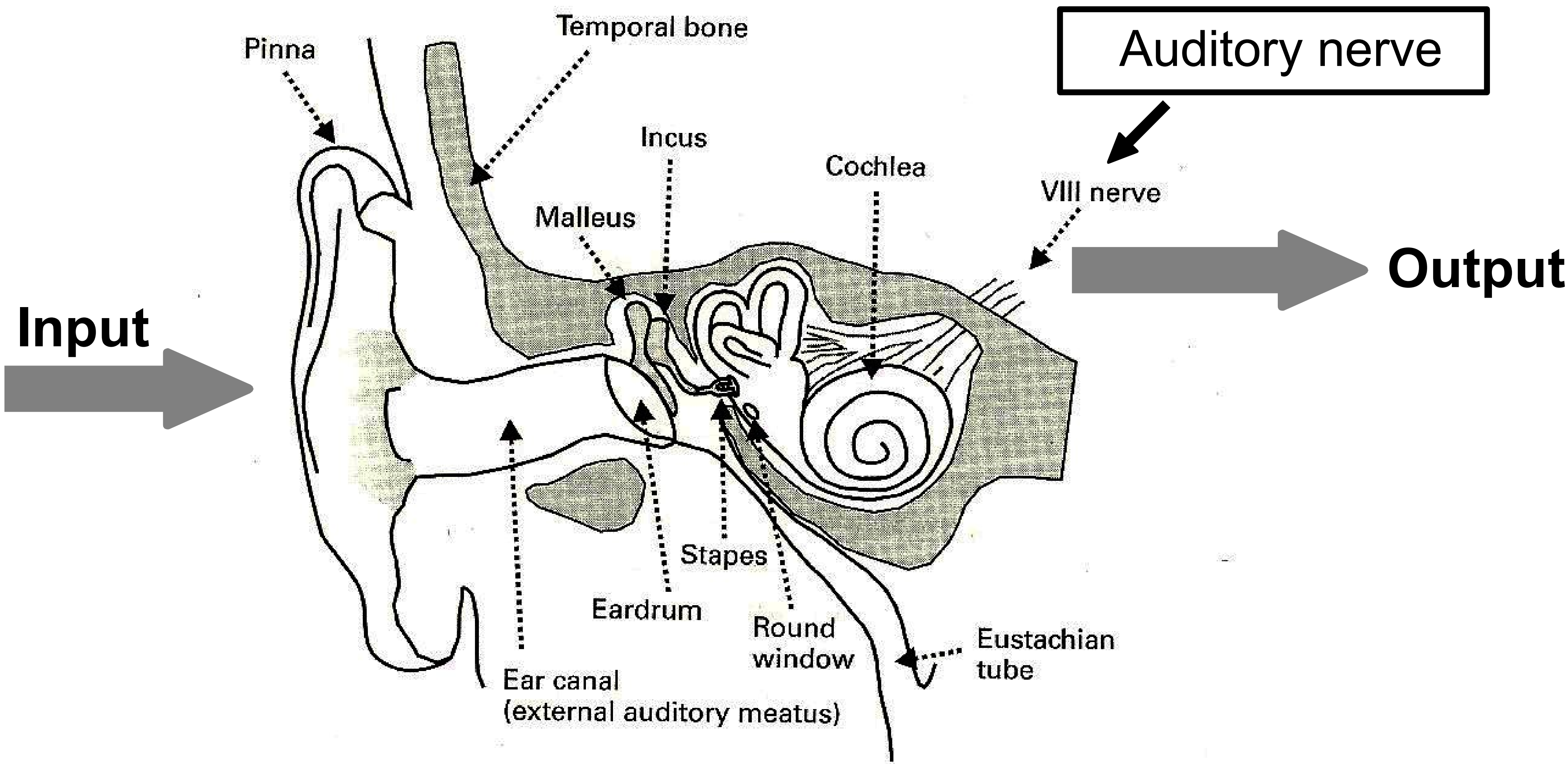
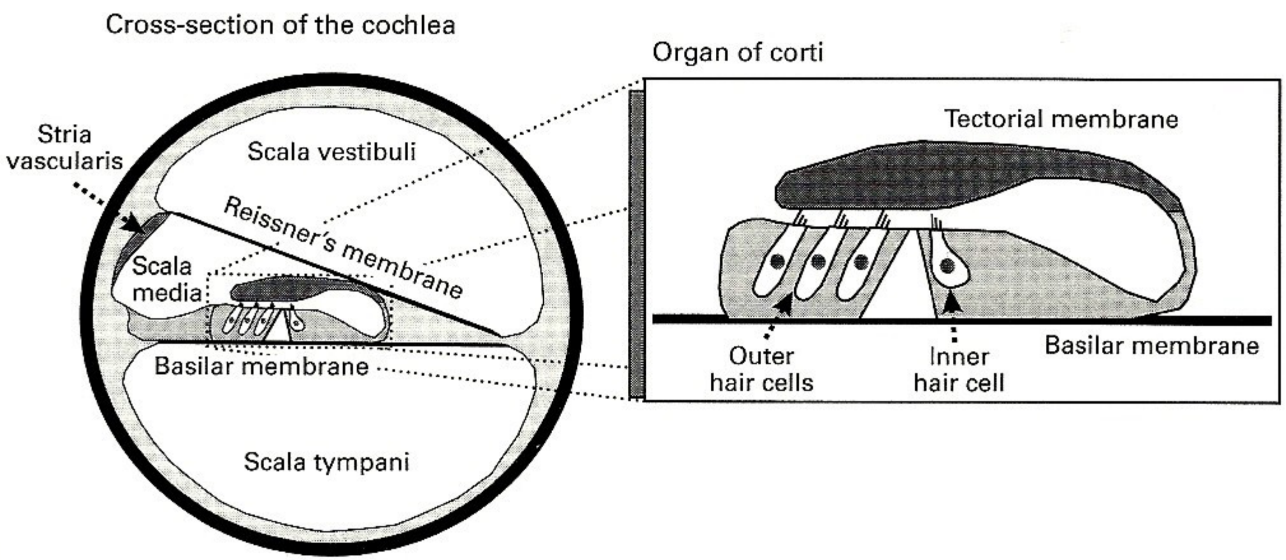
Auditory System



- 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 :

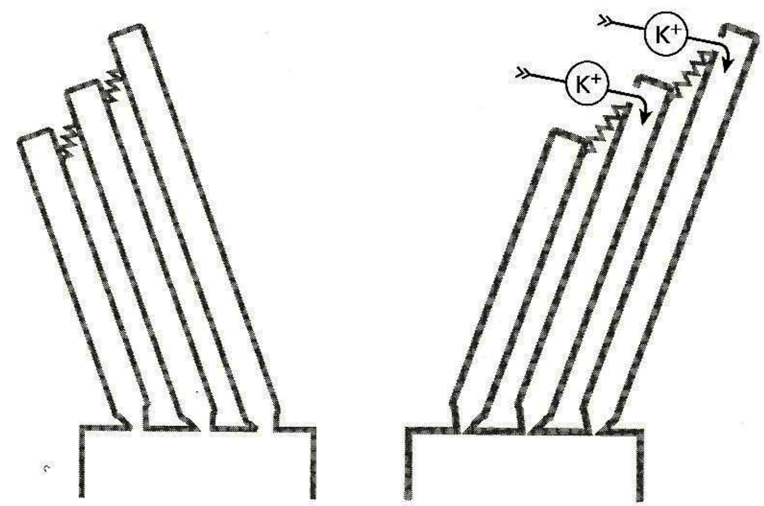


Image source : «Auditory Neuroscience », Schnupp et al., 2011, MIT Press p 65, 66

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)

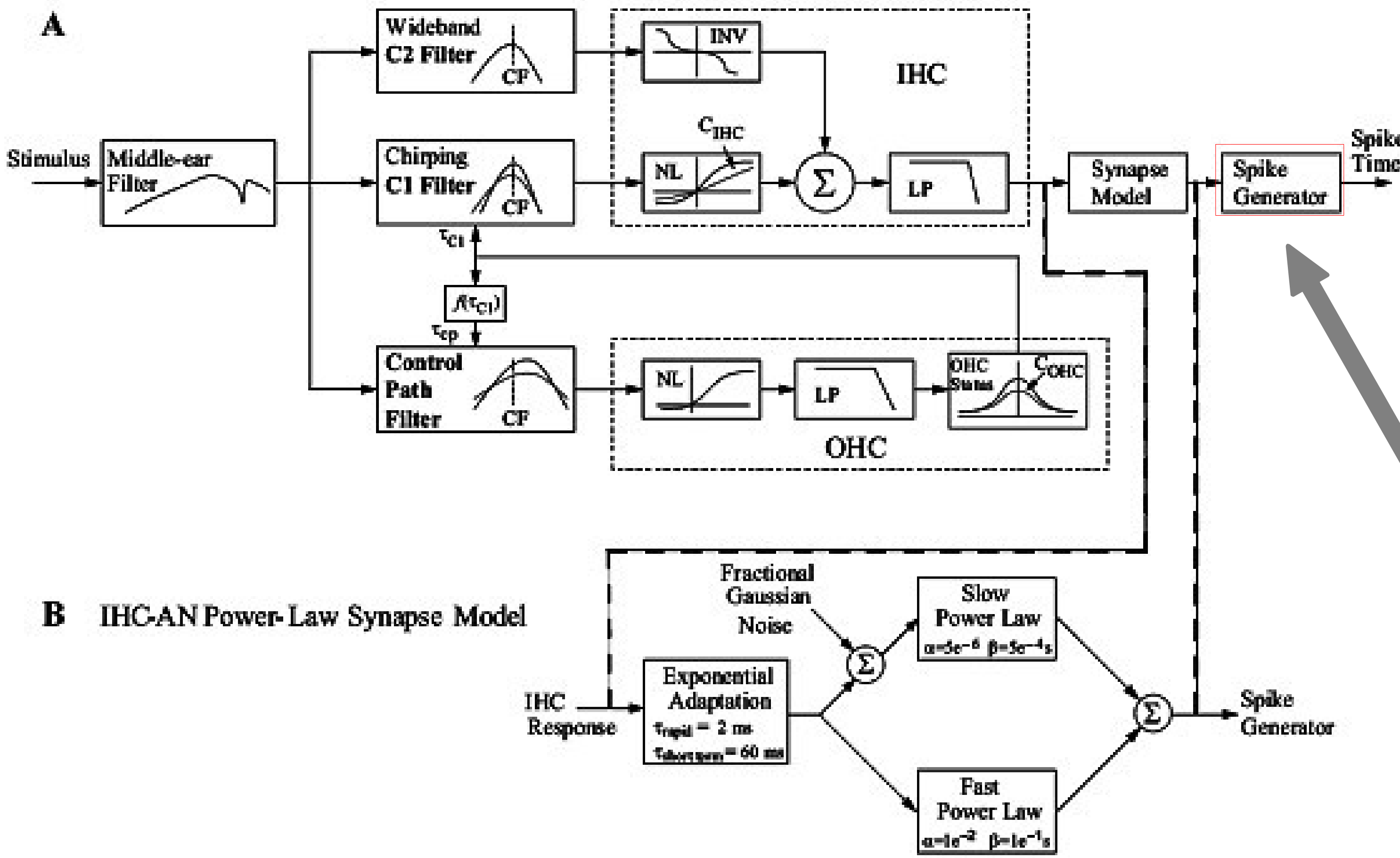


Image source :
http://www.bme.rochester.edu
/people/faculty/bio/project.ph
p?id=229&projectId=203 ,
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- Modify value of the absolute refractory period

Model use

- Main shema:

Stimulus → catmodel_IHC → IHC potential

IHC potential → catmodel_Synapse → Synapse output; Peri-stimulus time histogram (PSTH)

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 refratory period (ARP)

- Second, see if Fourier coefficients of response to sinusoidal stimuli match predictions of Deger et al (2010)

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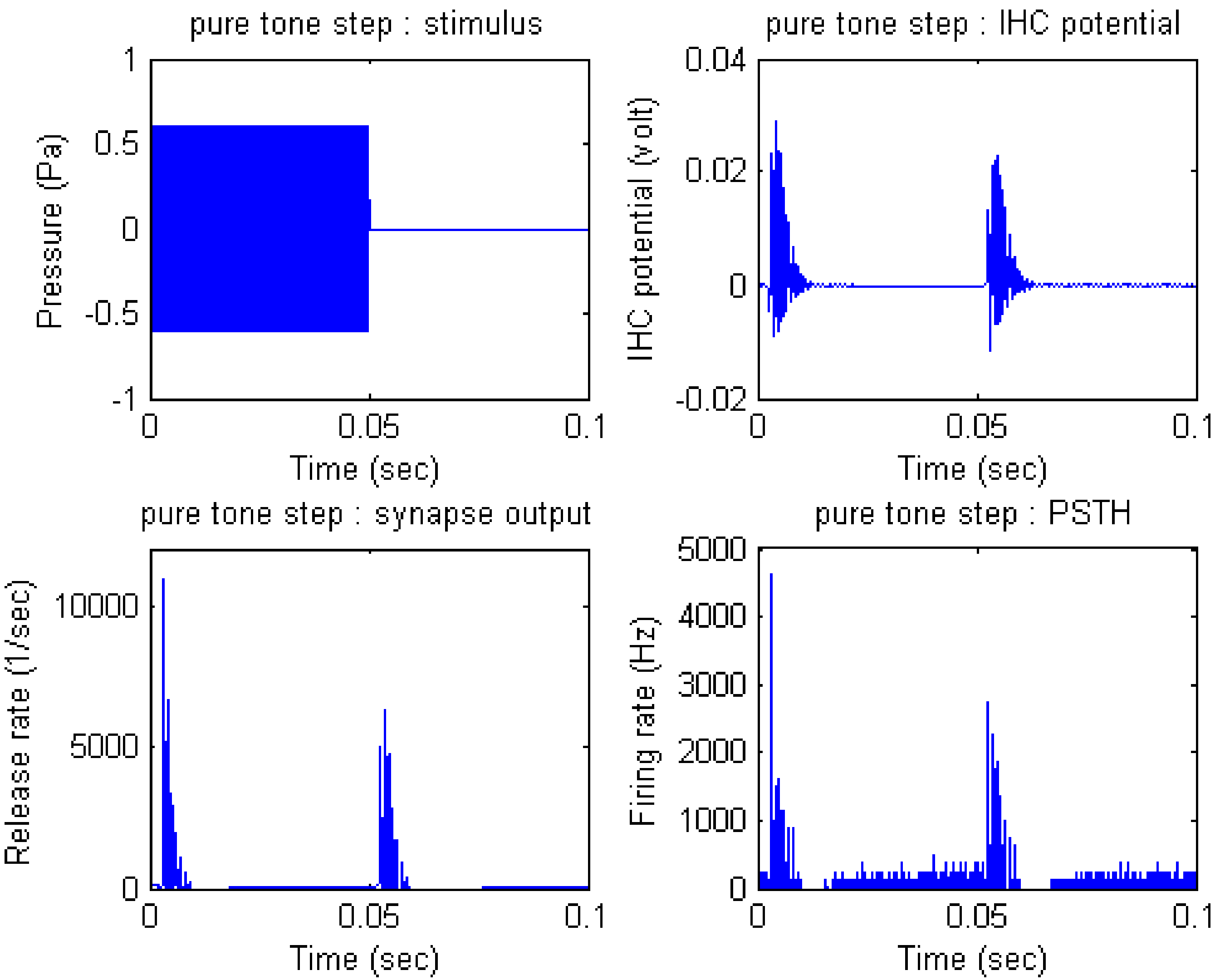
Experiments

- 4 types of experiments (stimuli):
  - Pure tone
  - Click
  - Noise step
  - Pure tone step

- Each of them with or without absolute refractory period

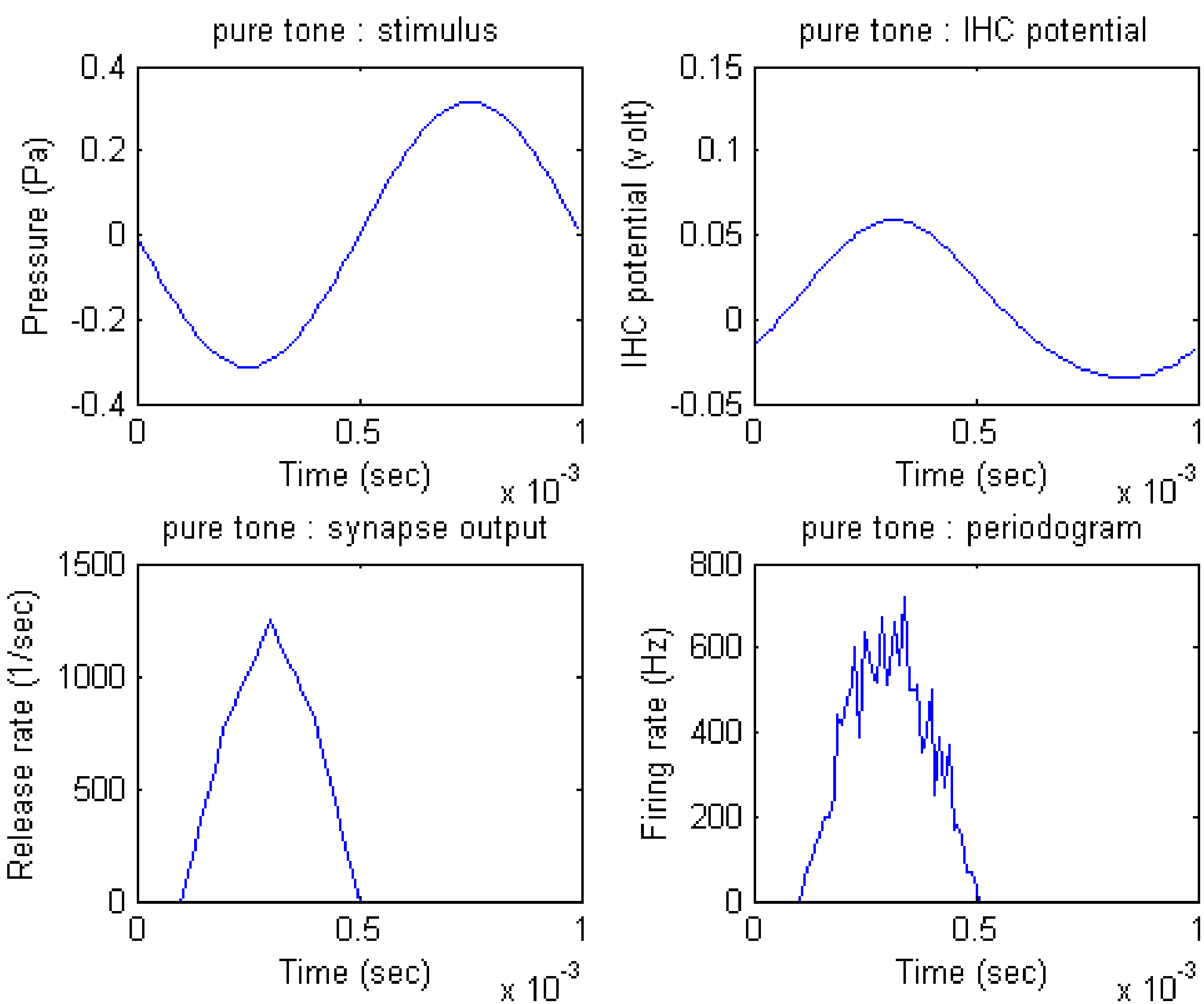
Pure tone step experiment



- 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

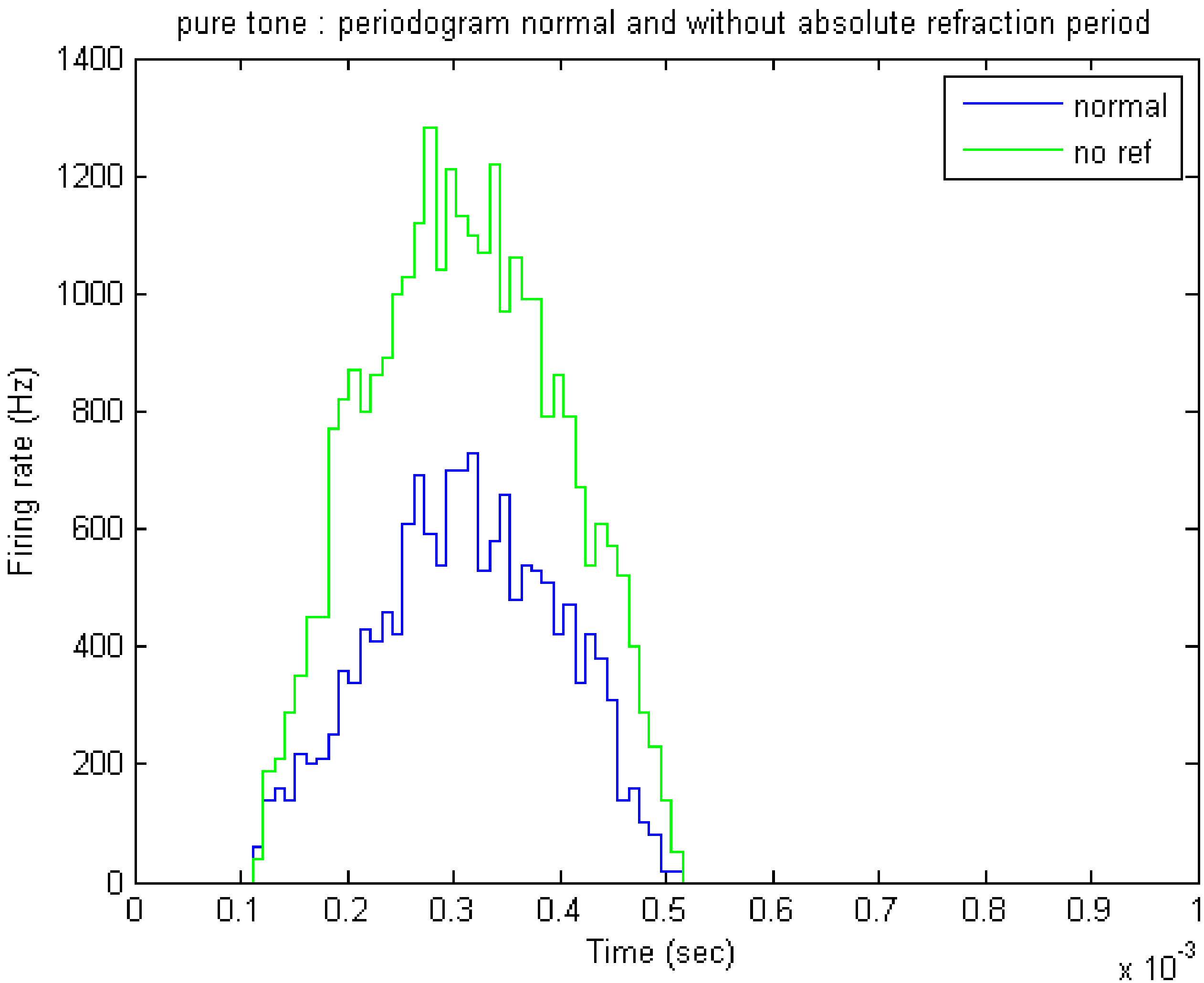
Pure tone experiment



- 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

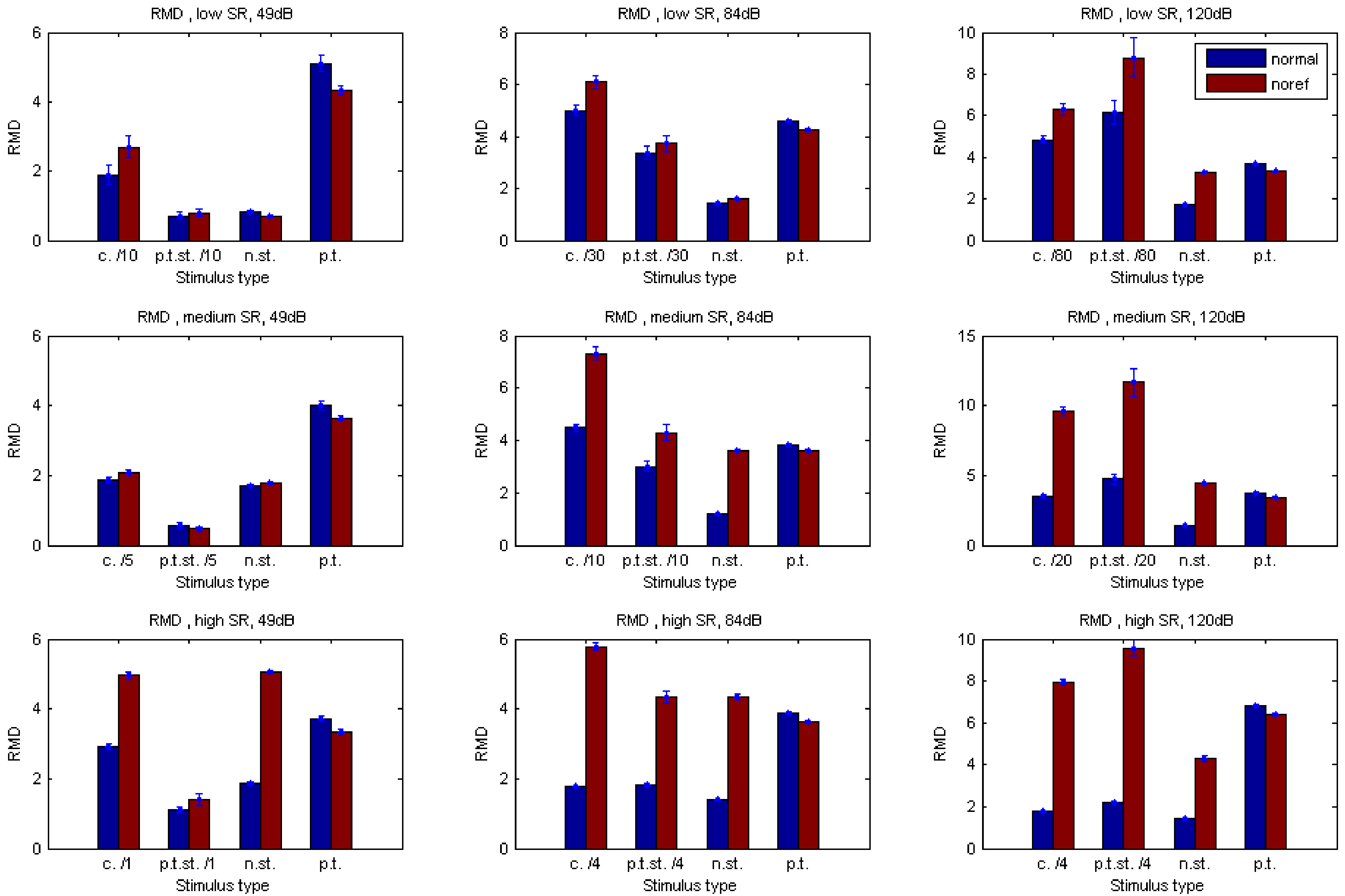
Refractory period comparison

- 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(periodogram) for all experiments; y is the baseline
  - Click : y = periodogram on 0 Pa stimulus
  - Pure tone : y = mean(periodogram)
  - Modulated noise : y = periodogram just before the end of the step
  - Modulated pure tone : y = mean of pure tone periodogram when IHC saturated


RMD , low SR, 49dB
RMD , low SR, 84dB
RMD , low SR, 120dB
normal
noref
RMD , medium SR, 49dB
RMD , medium SR, 84dB
RMD , medium SR, 120dB
RMD , high SR, 49dB
RMD , high SR, 84dB
RMD , high SR, 120dB
RMD
Stimulus type
c. /10
p.t.st. /10
n.st.
p.t.
c. /30
p.t.st. /30
c. /80
p.t.st. /80
c. /5
p.t.st. /5
c. /20
p.t.st. /20
c. /1
p.t.st. /1
c. /4
p.t.st. /4

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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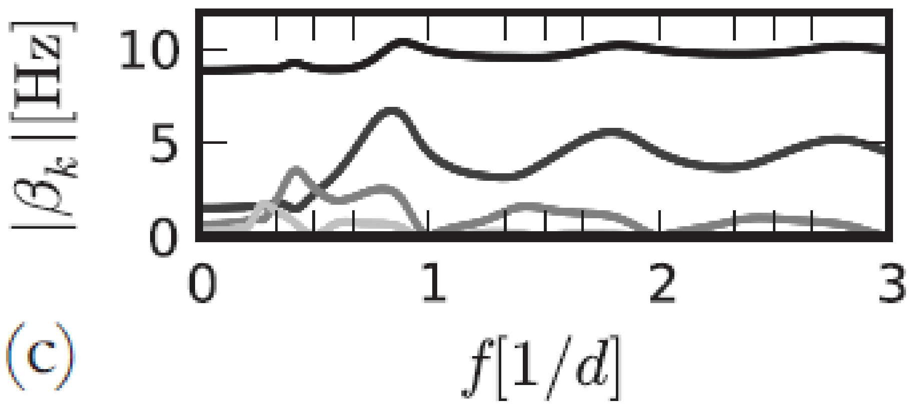
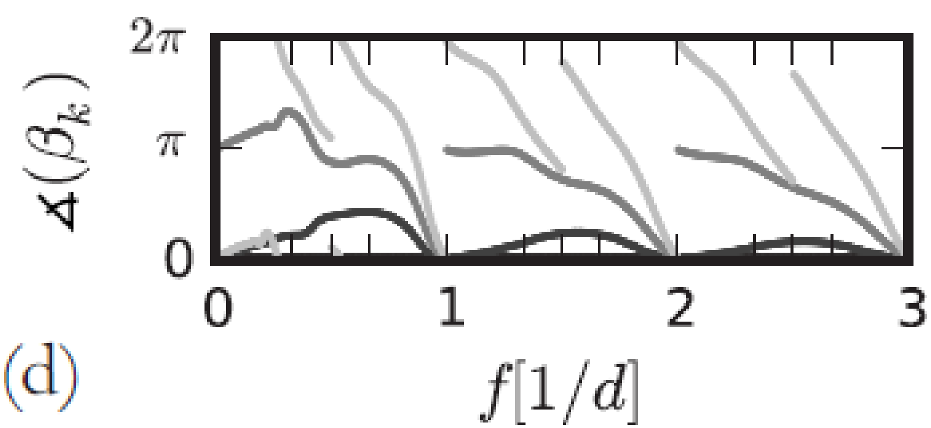
Predictions for sinusoidal stimulus

- Prediction for norm :



(c)

- Prediction for angle :



(d)

- 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 84 dB
- $y(t) = A\left(1 + 0.5sin\left(2\pi t f_m\right)\right) sin\left(2\pi t f_c\right)$
- Calculation of Fourier coefficients :

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

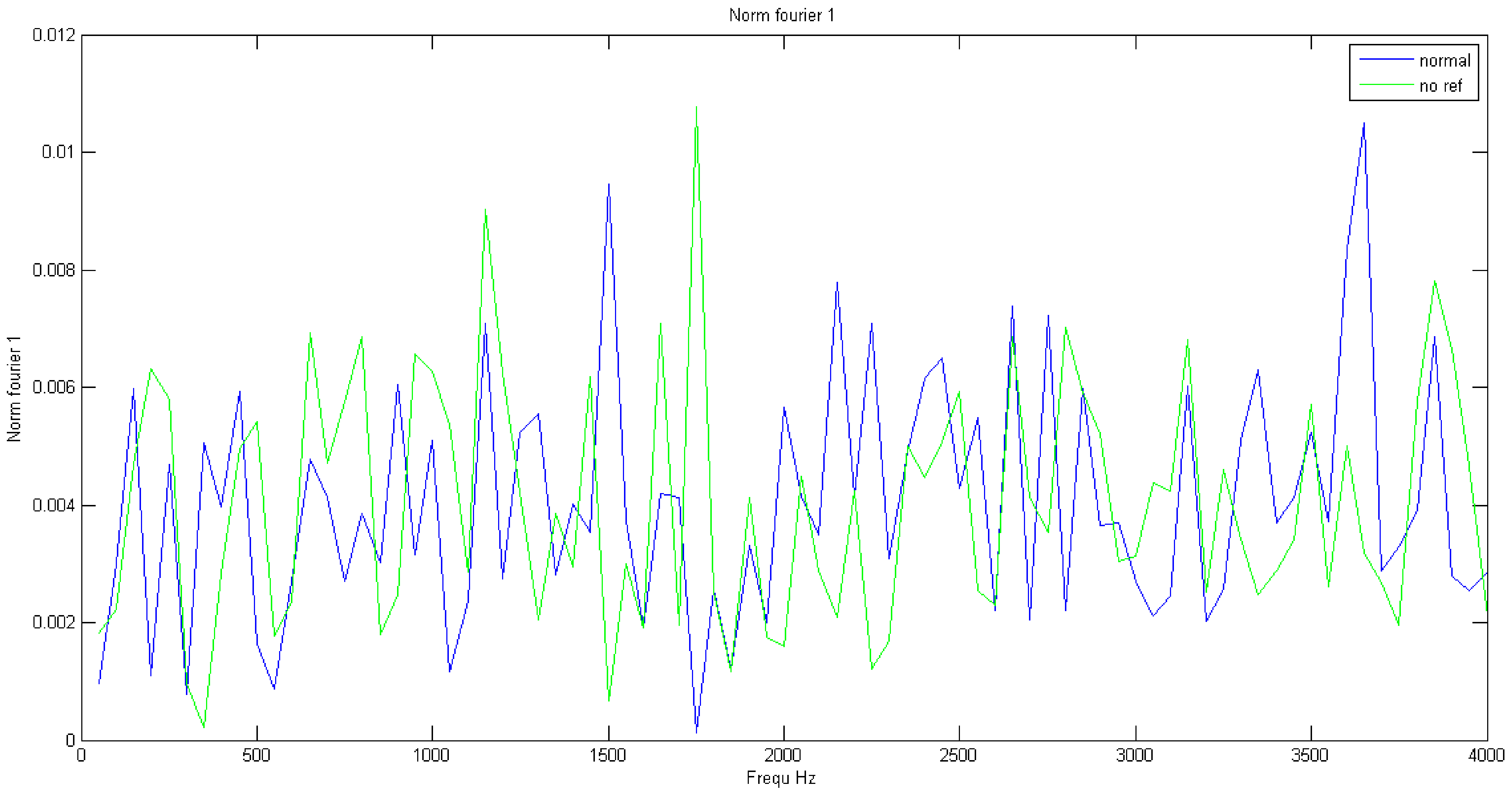
- Similar to the pure tone case, because IHC can not follow carrier frequency and their synaptic release rate will follow modulation frequency.

Experiment

- Absolute refractory period of 0.75 ms in the model
- f, modulation frequency from 50 Hz to 4000 Hz, 50 Hz steps
- Multiple of 1/ARP : 1333 Hz and 2666 Hz in our experiment
- Carrier frequency : 10 kHz
- Experiments with characteristic frequency 5 kHz

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