Lab 2-9 Cochlear Simulation (Revised)

Introduction

The cochlea is a complex bio-mechanical structure which performs extraordinary feats of sound sensitivity and selectivity. To gain an understanding of the cochlear encoding of loudness, timbre and the pitch of pure and complex tones, we use a computer simulation. The simulation is simplified but exhibits many aspects of the behaviour of a real cochlea.

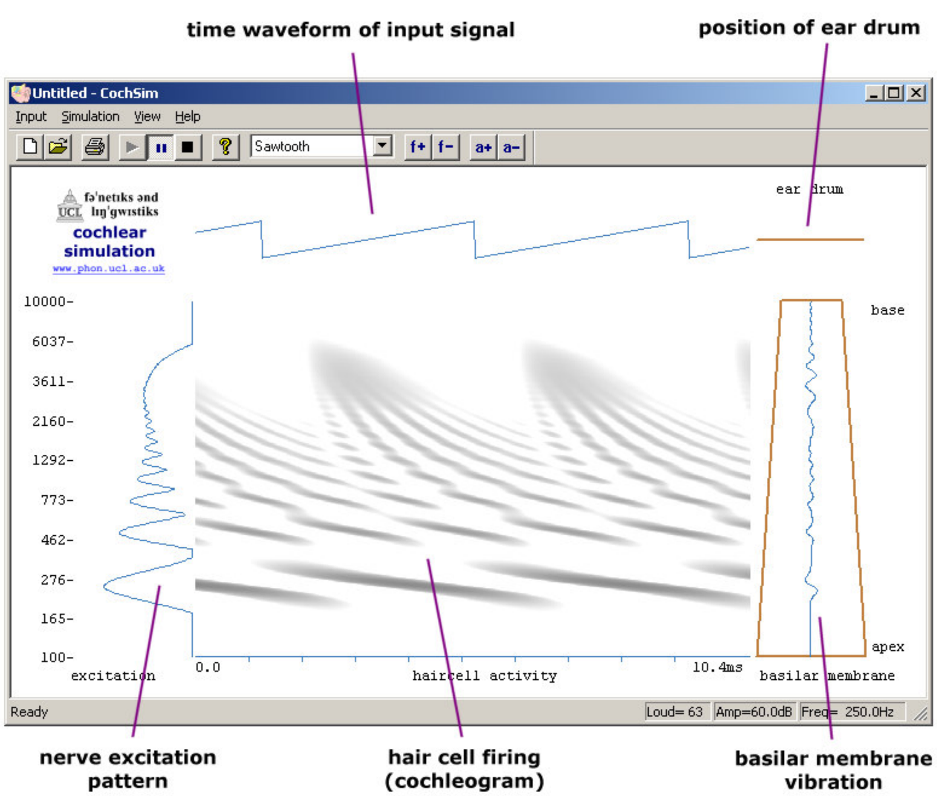
In this experiment we look at how this 'model cochlea' reacts to a range of simple stimuli and hence gain a better understanding of some aspects of cochlear function, including: place and temporal coding, the band-pass filter analogy, the determination of fundamental frequency and the phenomenon of beats.

Learning Objectives

By the end of the laboratory session you should:

- understand what is meant by place and temporal coding of the pitch of pure tones
- understand how changes in the amplitude or the frequency of a pure tone can be detected in changes in the excitation pattern
- understand how the fundamental frequency of a complex tone is encoded in the temporal pattern of the excitation
- understand how the band-pass filter analogy can be used to predict the excitation pattern for a complex sound
- understand what causes 'beats'.

Simulation Display



Observations

1. Use the simulation to process a sinewave signal at a number of frequencies and amplitudes.

   a) In the simulation how is 'place' coding represented?

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   b) What evidence can you see that haircell firing is synchronised to the phase of the stimulus?

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   c) How is 'temporal' coding represented?

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   d) How is 'loudness' represented? (Make sure you consider the situation when the excitation pattern at the stimulus frequency is saturated)

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   e) Find the threshold level for a sinewave at 250Hz and 4000Hz. (i.e. find the input dB level that gives a loudness just greater than zero). Why are these thresholds not the same?

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2. Process a sawtooth waveform with a fundamental frequency of 250Hz.

   a) Why are the harmonics not equally spread along the basilar membrane?

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b) Why does the "rippling" pattern from the harmonics disappear above 3000Hz or so?

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c) How could the fundamental frequency be determined by the place coding mechanism?

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d) How could the fundamental frequency be determined by the temporal coding mechanism?

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e) Process a Sawtooth waveform missing the first harmonic. How does the absence of the first harmonic affect the place and temporal coding of its pitch? Given that subjects report that the removal of the first harmonic does not affect the pitch, what does this suggest about the relative importance of the two mechanisms?

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3. Process an [i] vowel with fundamental frequencies varying from 150 to 250Hz. Study the pattern to see which aspects change and which stay the same. You can print these out if that makes them easier to study.

a) How is the vowel quality represented in the excitation pattern (independent of fundamental frequency)?

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b) Check your answer to a) by processing an [ɑ] vowel. Estimate the formant frequencies of the two vowels.

c) Why are the higher formants easier to see in the excitation pattern than F1?

d) Using the WASP program, record an [ɜ] vowel at a sampling rate of 44100 samples/sec. Save a section of the centre of the vowel to a WAV file, then load this file into the simulation. Estimate the fundamental frequency and the formant frequencies from the simulation, then check against the values given to you by WASP.

4. Process two sinewaves through the simulation. The first sinewave is fixed at 3925Hz. Move the second sinewave towards it, looking at the excitation pattern that arises from their interaction. In particular, study the excitation pattern when the second sinewave is at 3775Hz (150Hz different) and 4000Hz (75Hz different).

a) What do you think would be the pitch of these complexes and why?