INTRODUCTION TO MUSICAL TIMBRE

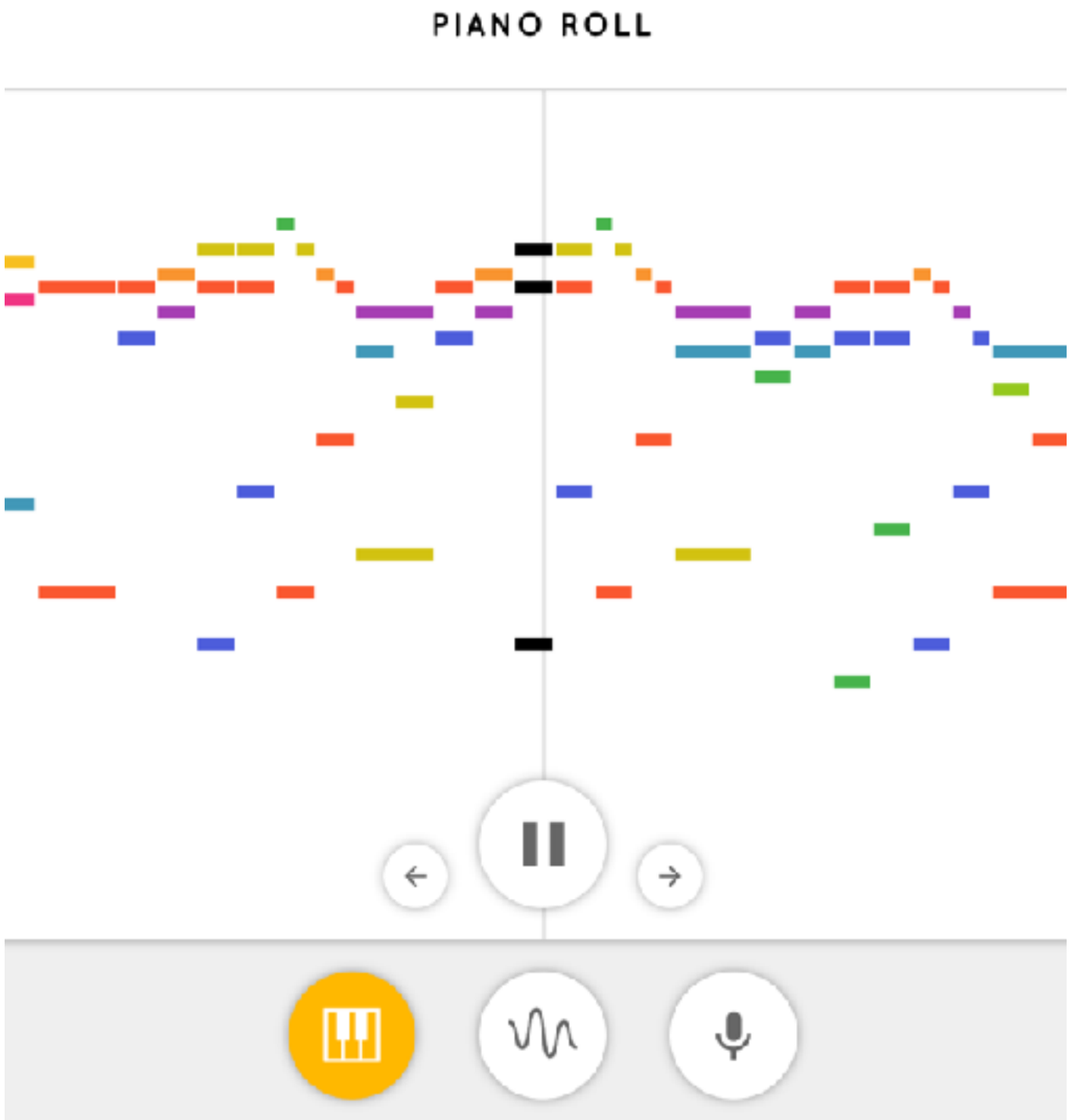
YU / LAMONT

FEBRUARY 20, 2018

UMASS AMHERST

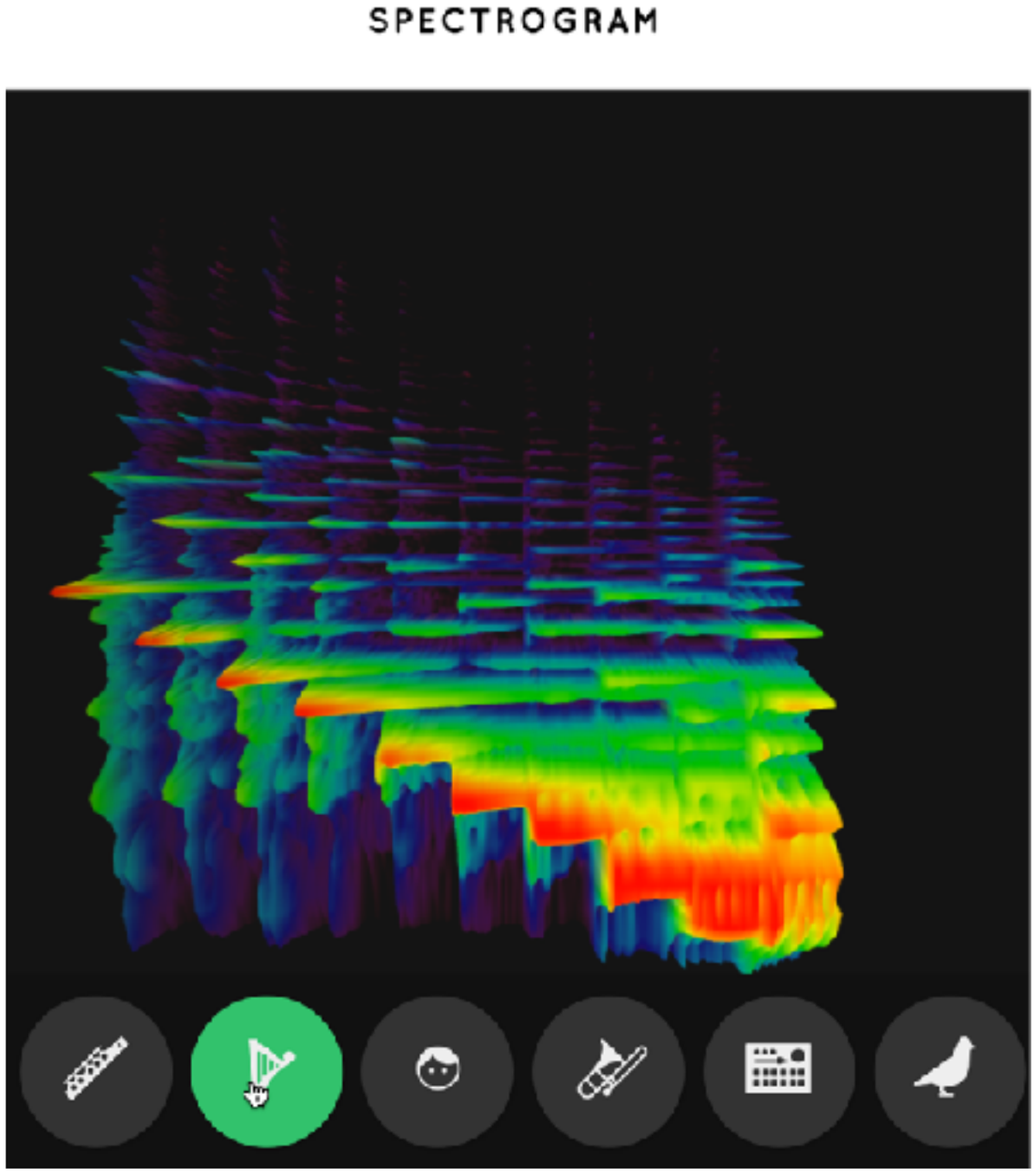
CHROME MUSIC LAB: PIANO ROLL

http://musiclab.chromeexperiments.com/Piano-Roll



CHROME MUSIC LAB: SPECTROGRAM

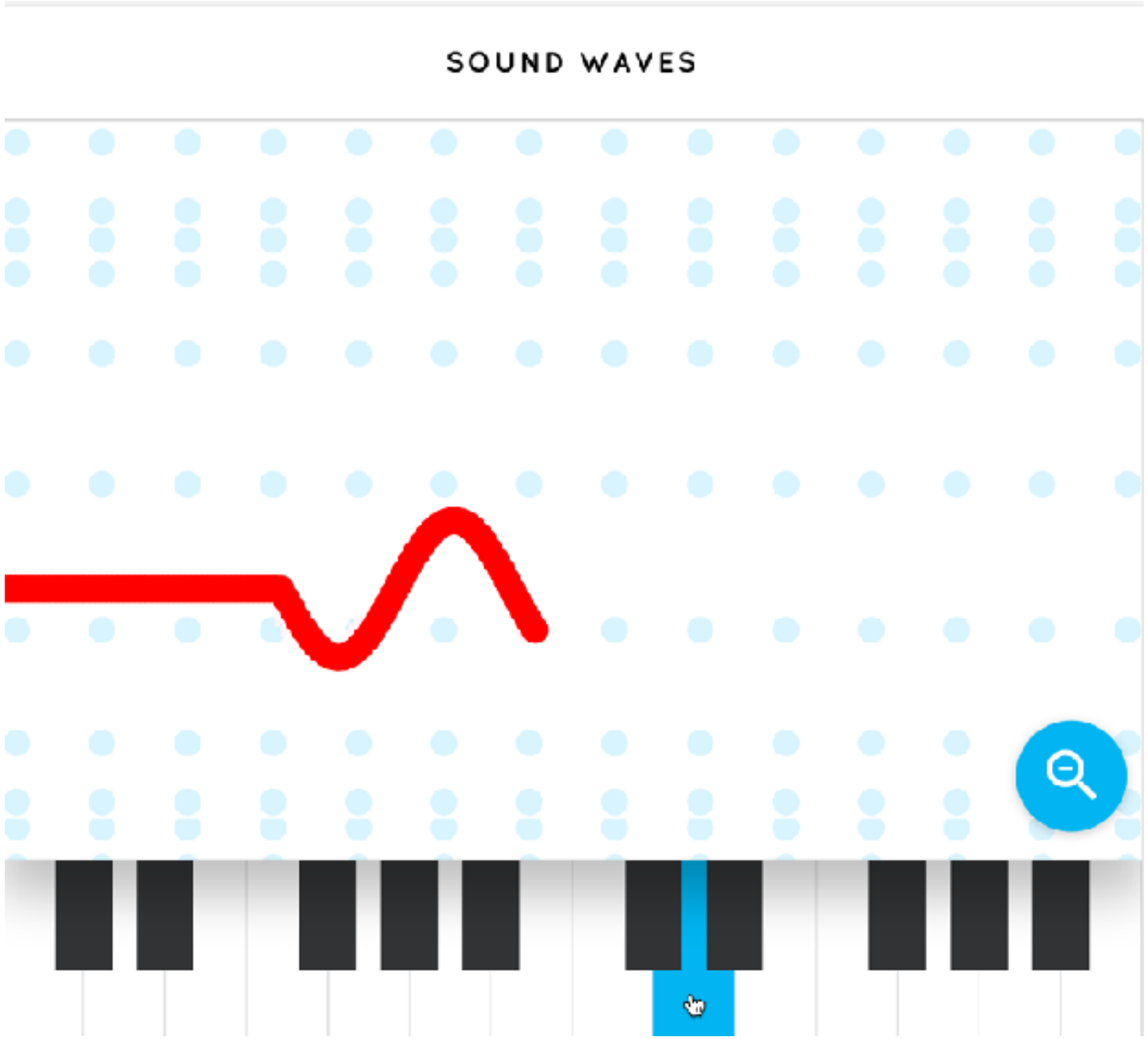
http://musiclab.chromeexperiments.com/Spectrogram



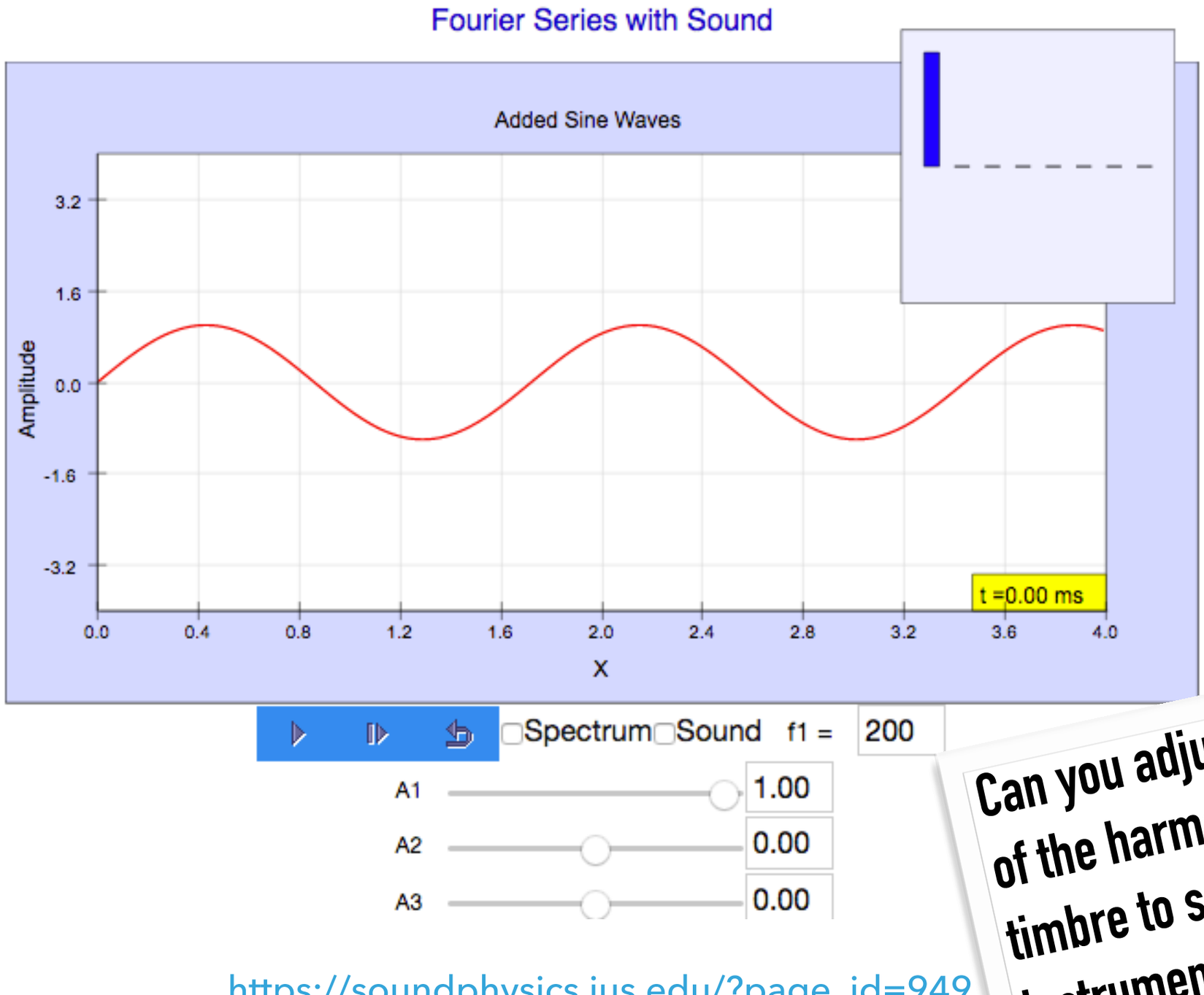
BRIEF REMINDER: HARMONICS AND COMPLEX WAVES

FROM PURE TONES TO COMPLEX WAVES

http://musiclab.chromeexperiments.com/Sound-Waves



EXERCISE: SOUND OF ADDING IN HARMONICS

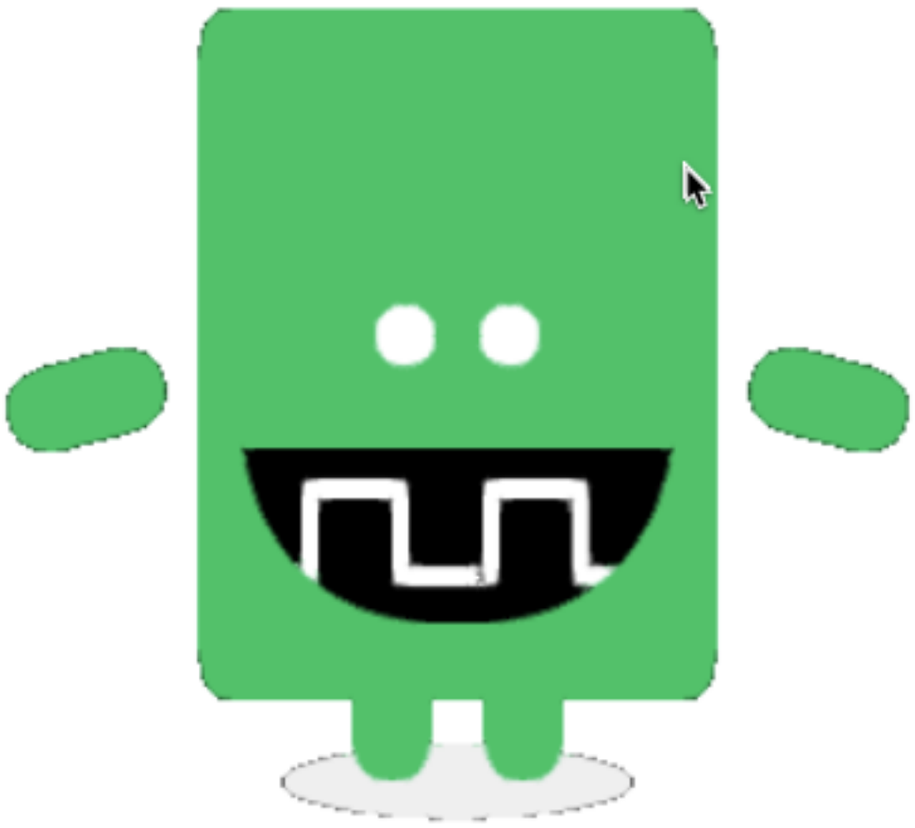


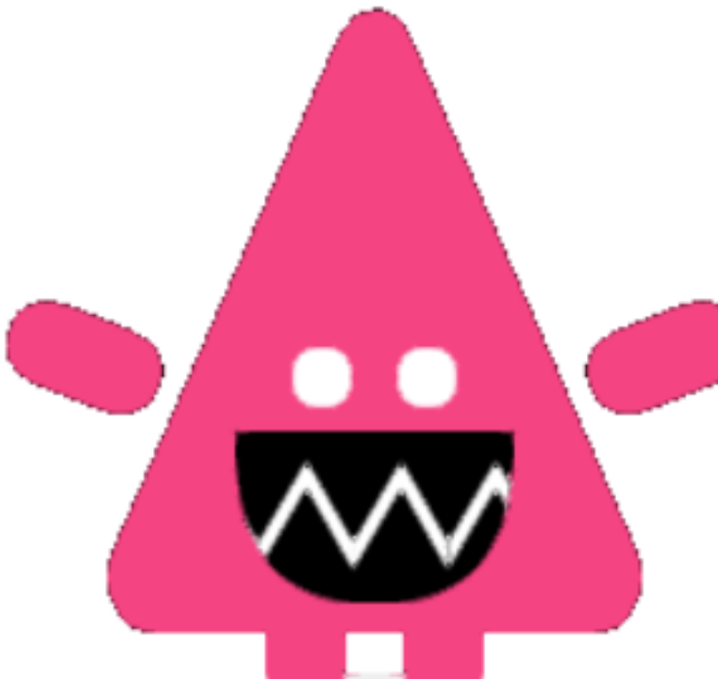
https://soundphysics.ius.edu/?page_id=949

Can you adjust the amplitudes of the harmonics to get the timbre to sound like some instrument you like?

DEMO: COMPLEX WAVES

https://musiclab.chromeexperiments.com/Oscillators

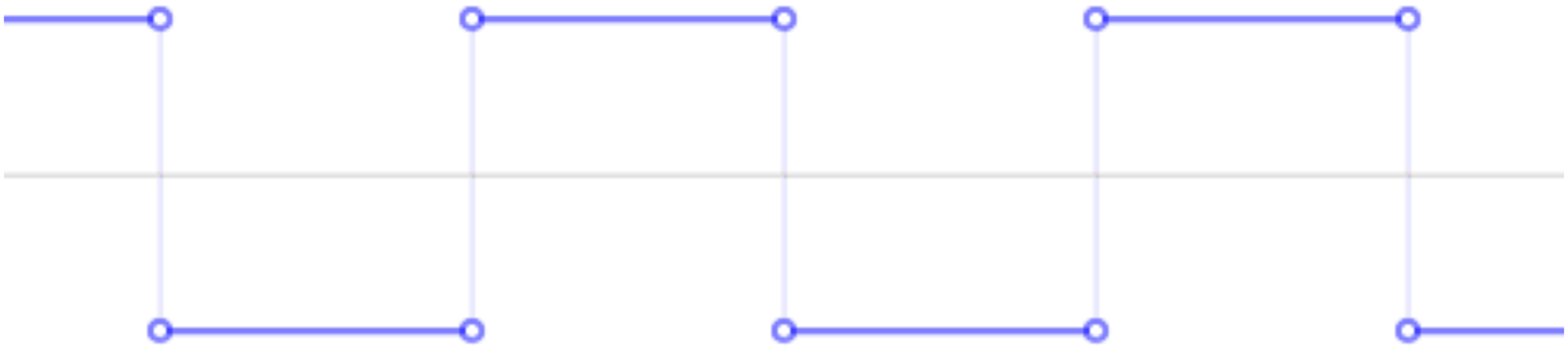




```
oscillator.type = 'square';

oscillator.frequency.value =
```

BUILDING UP A SQUARE WAVE WITH SINES



N = 0

https://en.wikipedia.org/wiki/User:LucasVB/Gallery#/media/File:Synthesis_square.gif

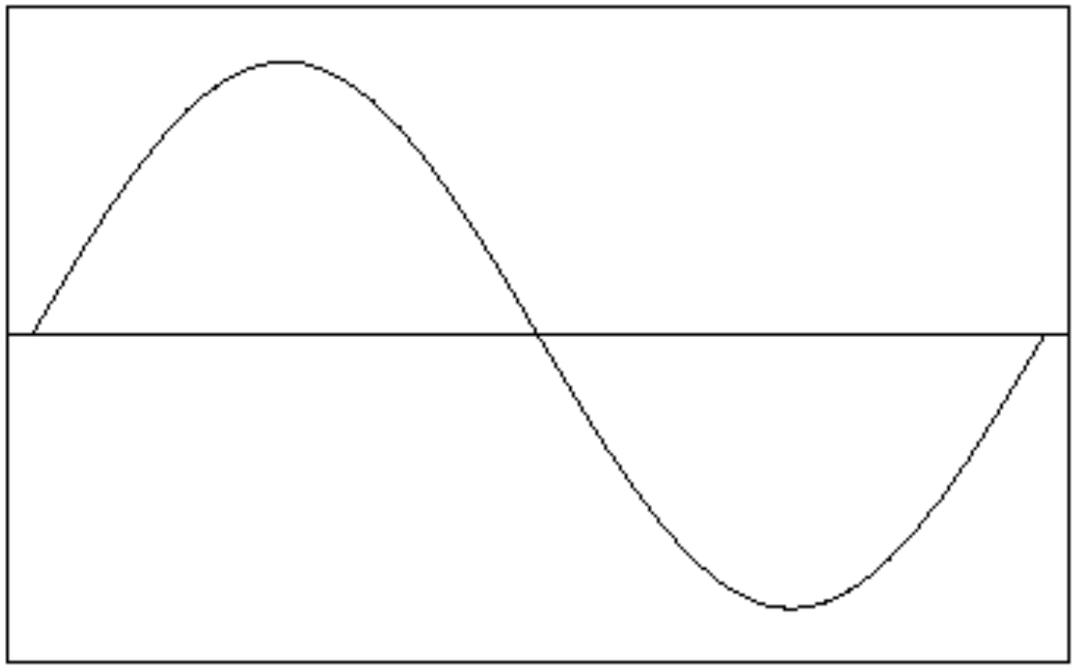
BUILDING UP A SQUARE WAVE

https://en.wikipedia.org/wiki/User:LucasVB/Gallery#/media/File:Fourier_transform_time_and_frequency_domains.gif

TWO REPRESENTATIONS OF SQUARE WAVE

https://en.wikipedia.org/wiki/User:LucasVB/Gallery#/media/File:Fourier_transform_time_and_frequency_domains.gif

HARMONIC AMPLITUDES



https://sites.google.com/a/georgiasouthern.edu/julia-inozemtseva/teaching-math-animations-and-pics?tmpl=%2Fsystem%2Fapp%2Ftemplates%2Fprint%2F&showPrintDialog=1#TOC-Fourier-Series

BUILDING UP A TRIANGLE WAVE WITH SINES

N = 0

https://en.wikipedia.org/wiki/User:LucasVB/Gallery#/media/File:Fourier_transform_time_and_frequency_domains.gif

ADDITIVE SYNTHESIS

http://meettechniek.info/additional/additive-synthesis.ht

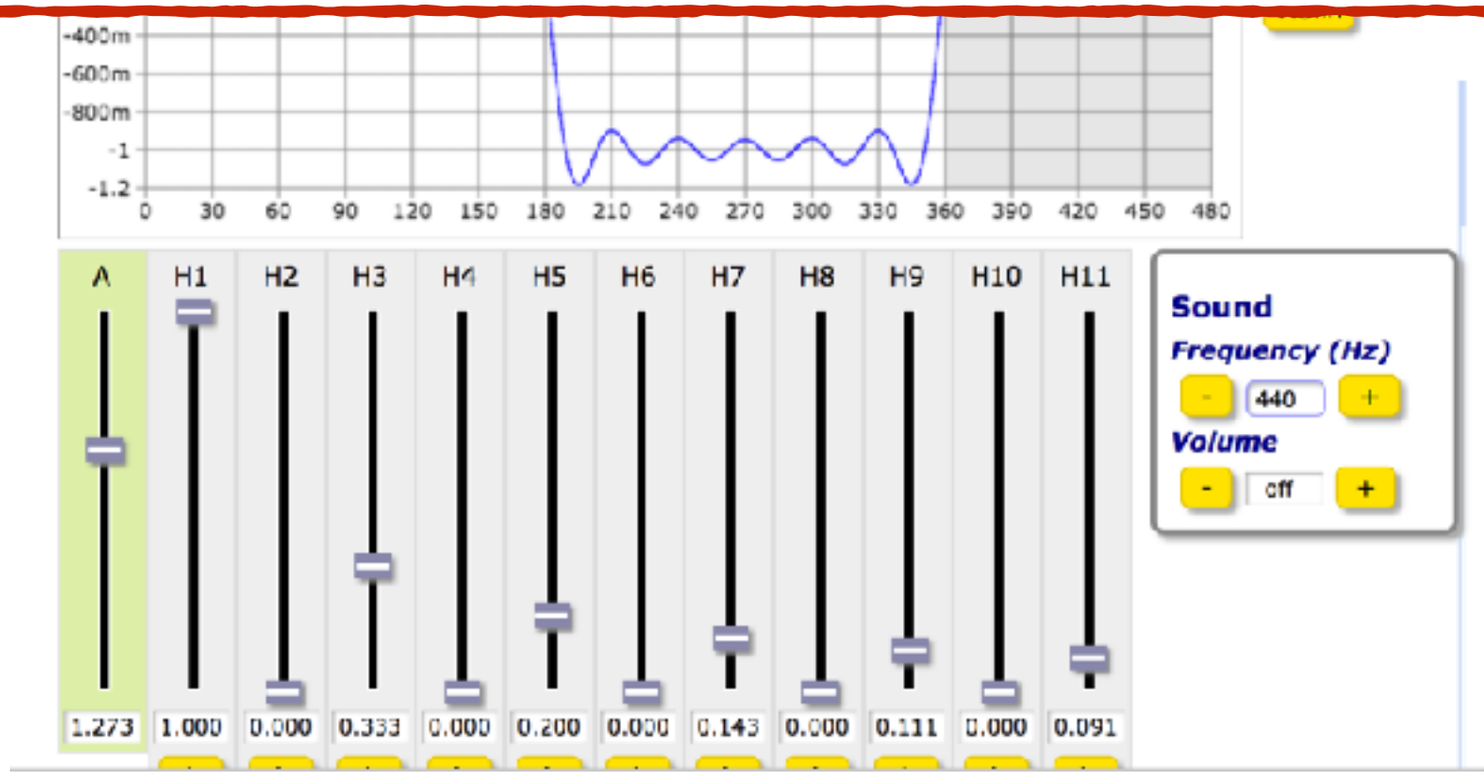
Additive synthese waveform generator

Last Modification: January 23, 2013

Every randomly shaped waveform can be composed by adding one ore more sine waves signals with each a different frequency, phase and amplitude. This is also called additive synthesis. The frequency range consists of the fundamental and his harmonics.

The wave shape in the tool beneath can be modified by adjusting the sliders H1 t/m H11. These will set the amplitudes of each harmonic. The phases of each harmonic can be set with the buttons below each slider.

Can you use an additive synthesizer to try to replicate the timbre of an instrument?



RESONANCE

RESONANCE

Resonance occurs when a force applied to a vibrating system varies with a frequency at or near the natural frequency of a system

Rossing (1990): The Science of Sound.

http://stmary.ws/HighSchool/Physics/home/notes/waves/animations/AnimFact/swing_set_playground_traci_closeup_hg_wht.gif

BREAKING A WINE GLASS WITH SOUND

http://courses2.cit.cornell.edu/physicsdemos/secondary.php?pfID=17

A speaker is aimed at a wine glass, and played at single frequency. This frequency is the resonant frequency of the glass, so energy begins to be stored in the glass. As the glass begins larger oscillations, one can see the straw move around. Finally the glass cannot store any more energy and it shatters.

STRING RESONANCE

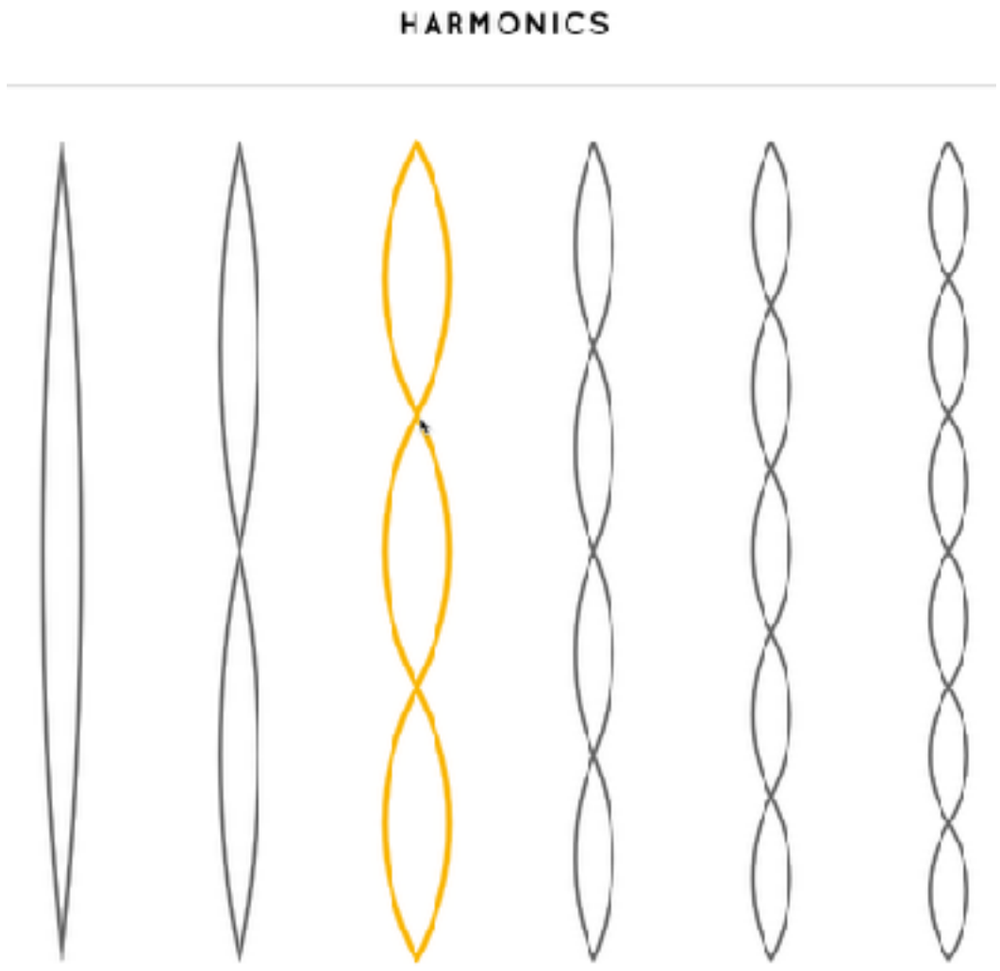
https://upload.wikimedia.org/wikipedia/commons/5/5c/Standing_waves_on_a_string.gif

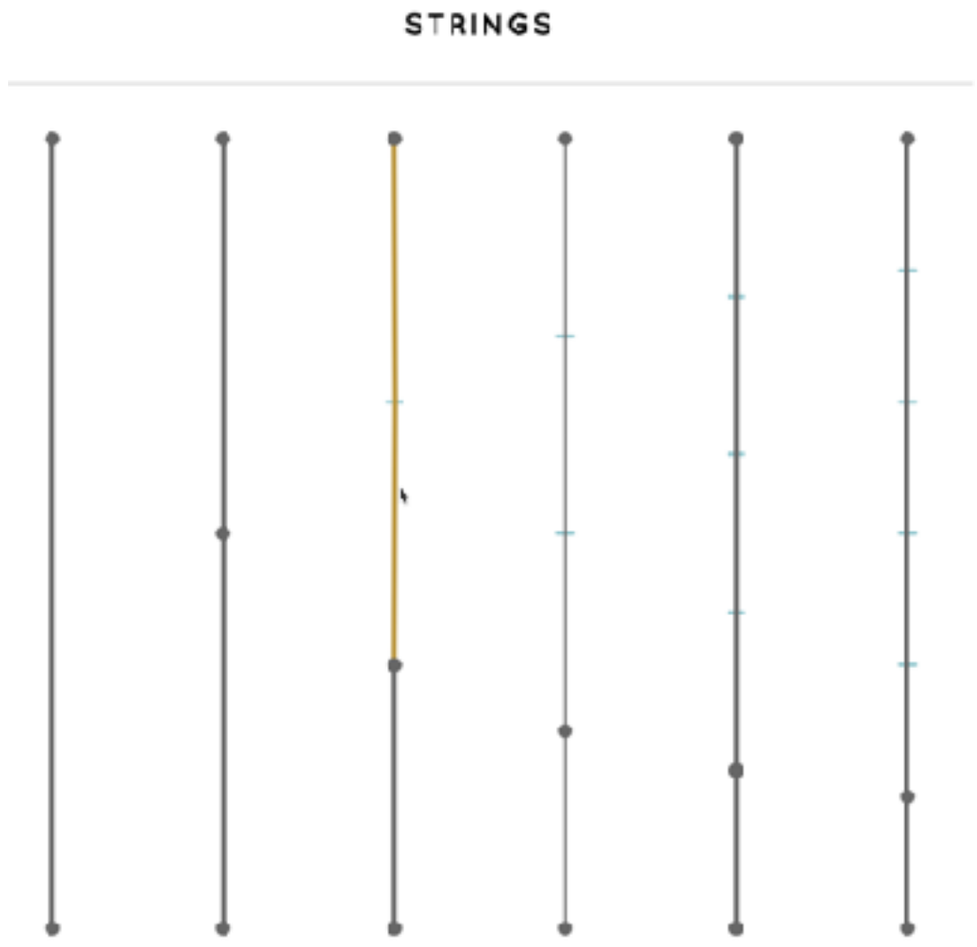
Strings naturally vibrate at a fundamental frequency, and at harmonics that are integer multiples of the fundamental

CHROME MUSIC LAB: STRING RESONANCE

https://musiclab.chromeexperiments.com/Harmonics

https://musiclab.chromeexperiments.com/Strings





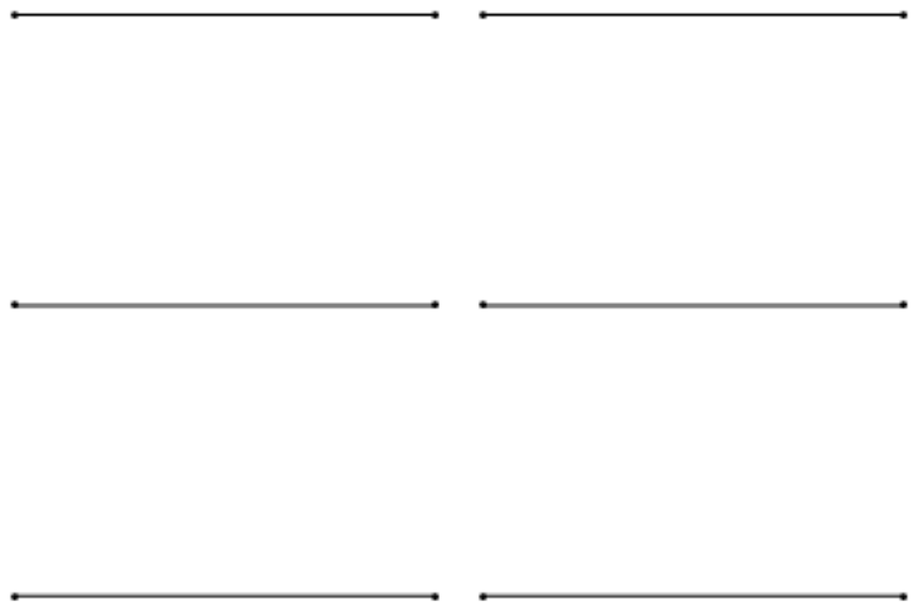
MOVIES: STRING RESONANCE

https://youtu.be/ttgLyWFINJI

https://youtu.be/oZ38Y0K8e-Y?t=8s

STRING RESONANCE: CALCULATIONS

https://upload.wikimedia.org/wikipedia/commons/5/5c/Standing_waves_on_a_string.gif



The "length" of a standing wave vs. the cycle "length" of a traveling wave: wavelength in space is like period in time for a traveling wave

How long is the wavelength relative to the length of the string for the fundamental?

SYMPATHETIC VIBRATION: TUNING FORKS

https://youtu.be/zWKiWaiM3Pw

Other fun resonance videos at:
http://blog.prosig.com/2011/09/20/5-videos-that-explain-resonance/

EXAMPLE: SYMPATHETIC RESONANCE

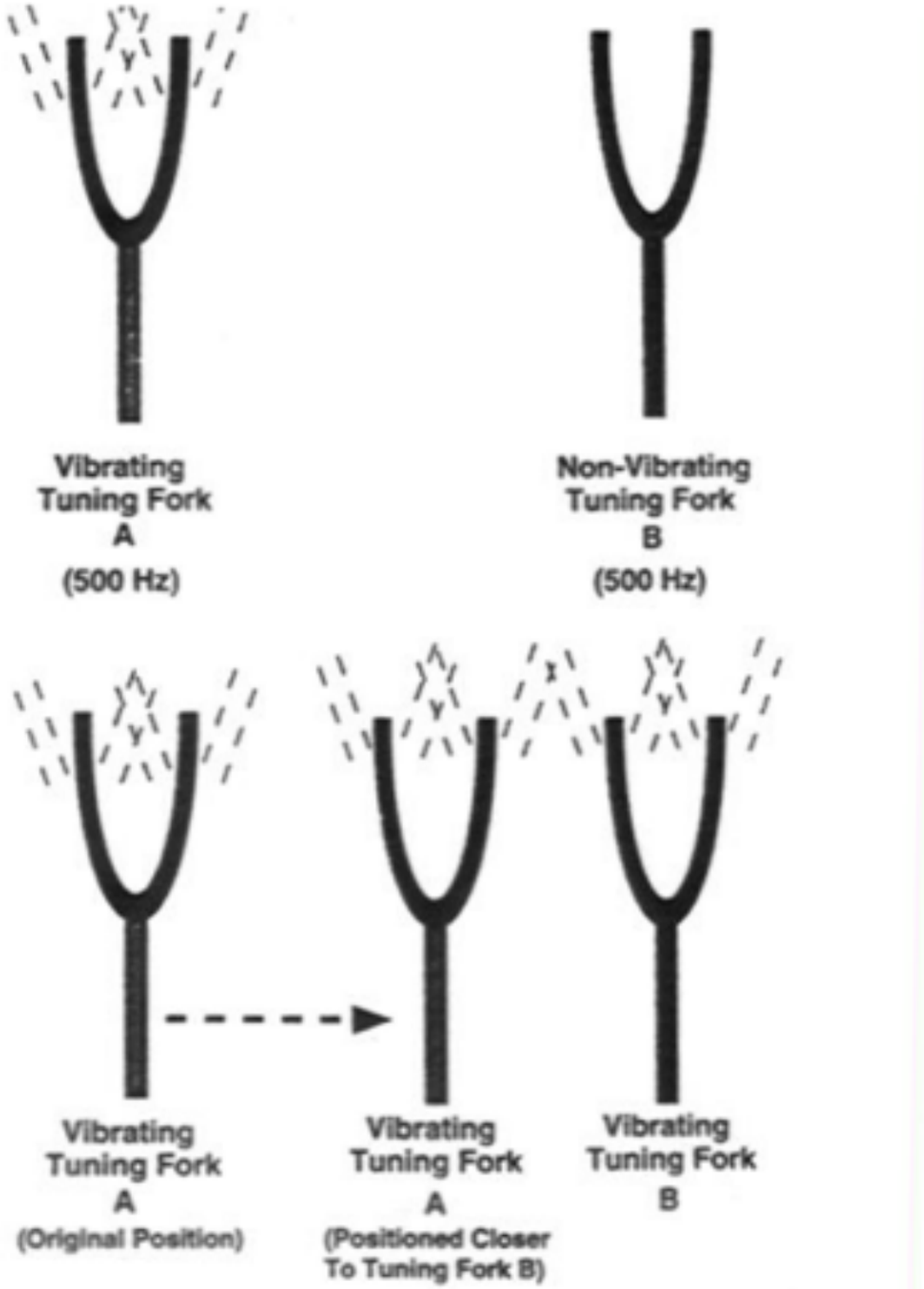


FIGURE 4-2 Sympathetic Vibration

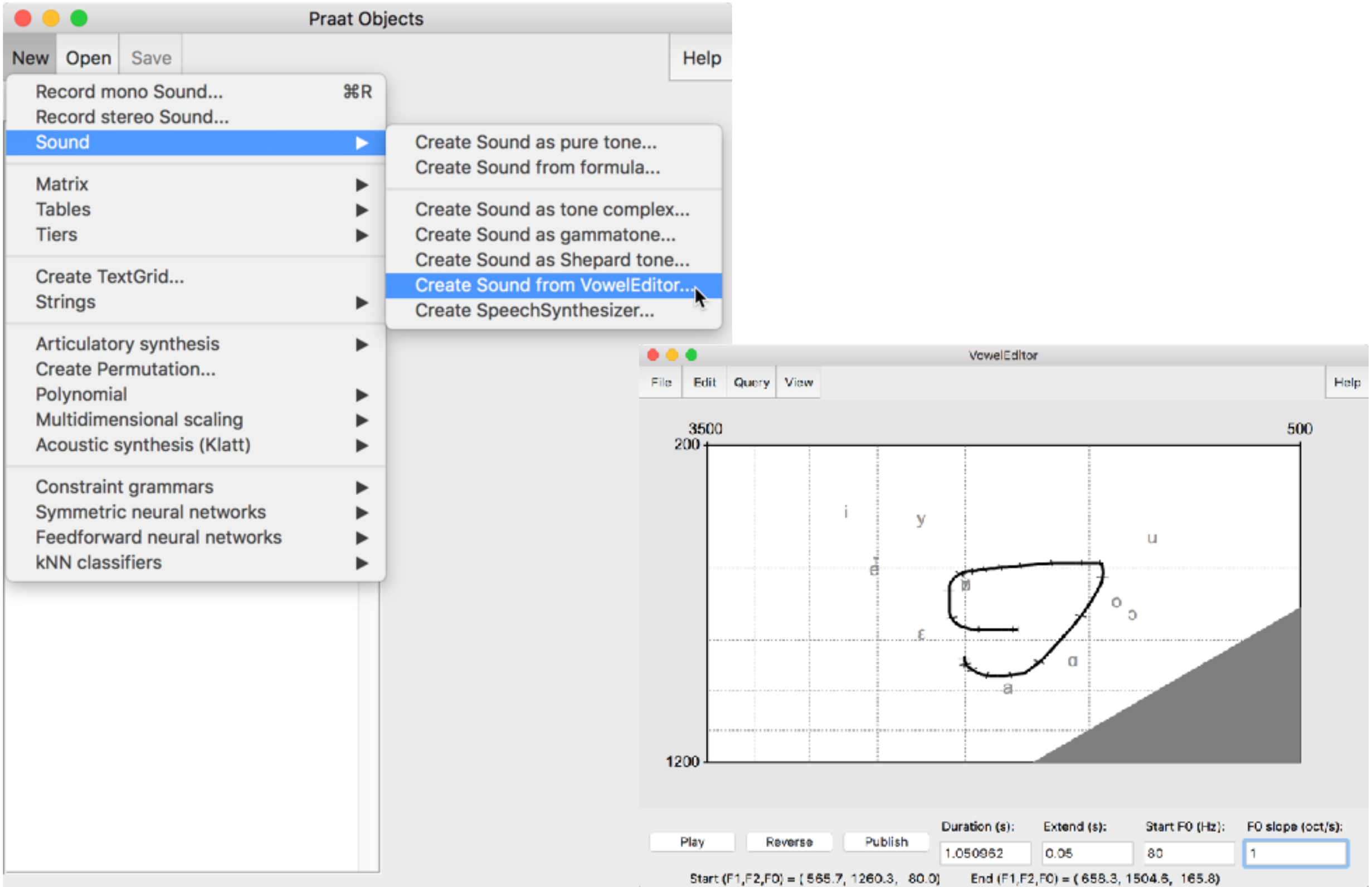
B resonates to A if B's vibrations make A vibrate too.

Effect: B has more energy than it did

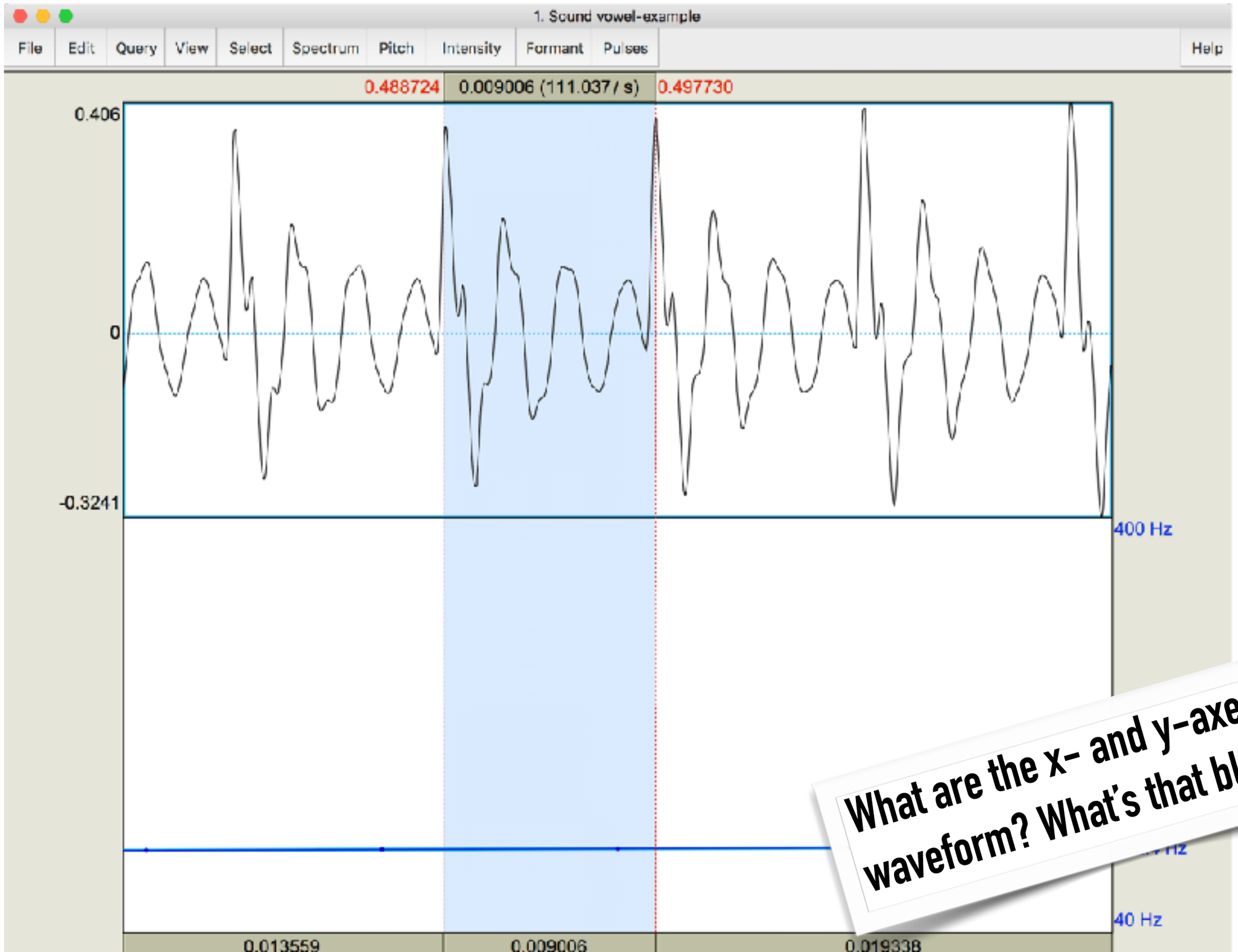
The closer B's natural frequency is to A's the stronger the vibrations of B

WAVEFORMS, SPECTRA, AND SPECTROGRAMS

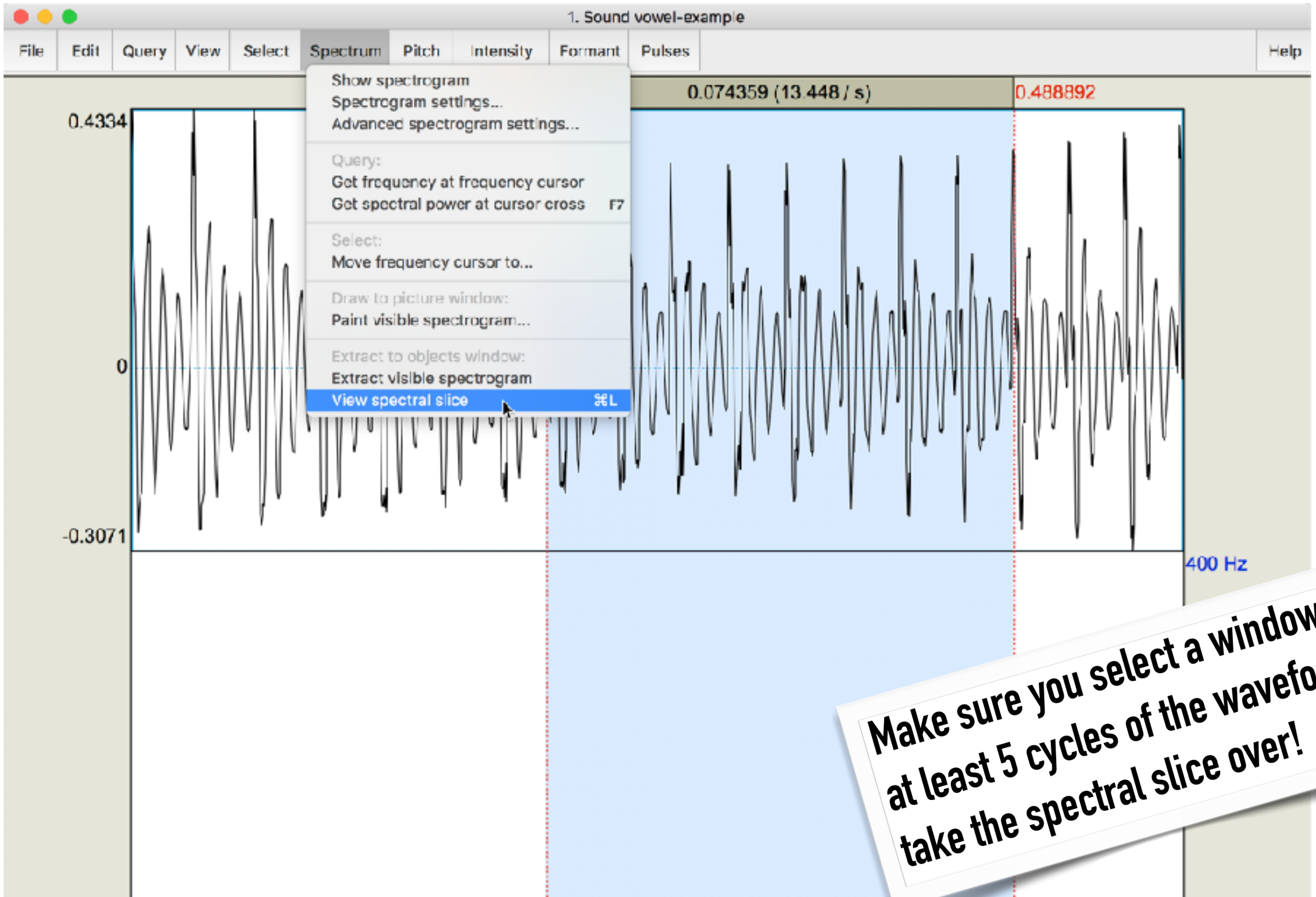
SYNTHESIZE A VOCALIC SOUND . . .



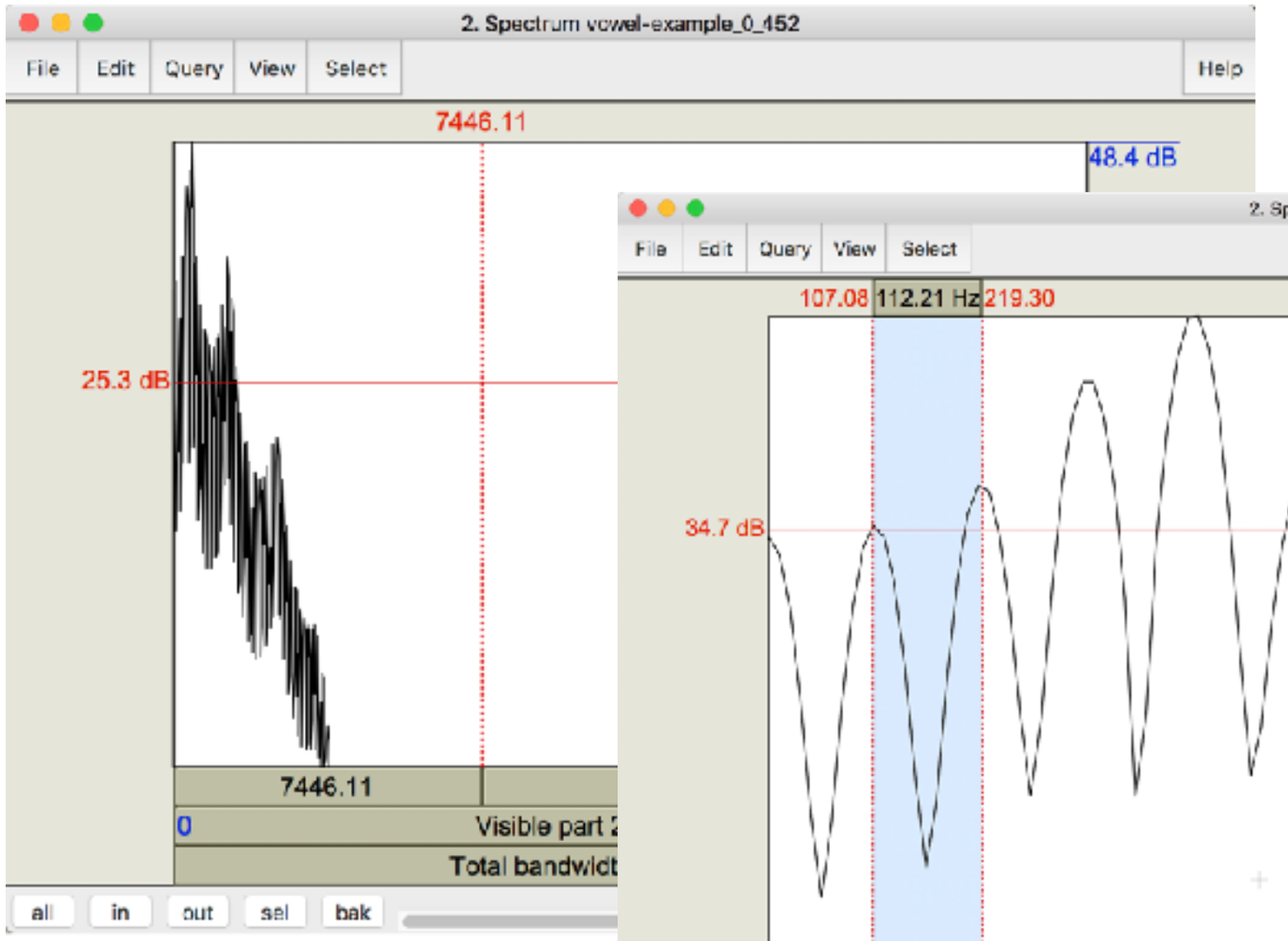
REVIEW: FIND PERIOD FROM THE WAVEFORM

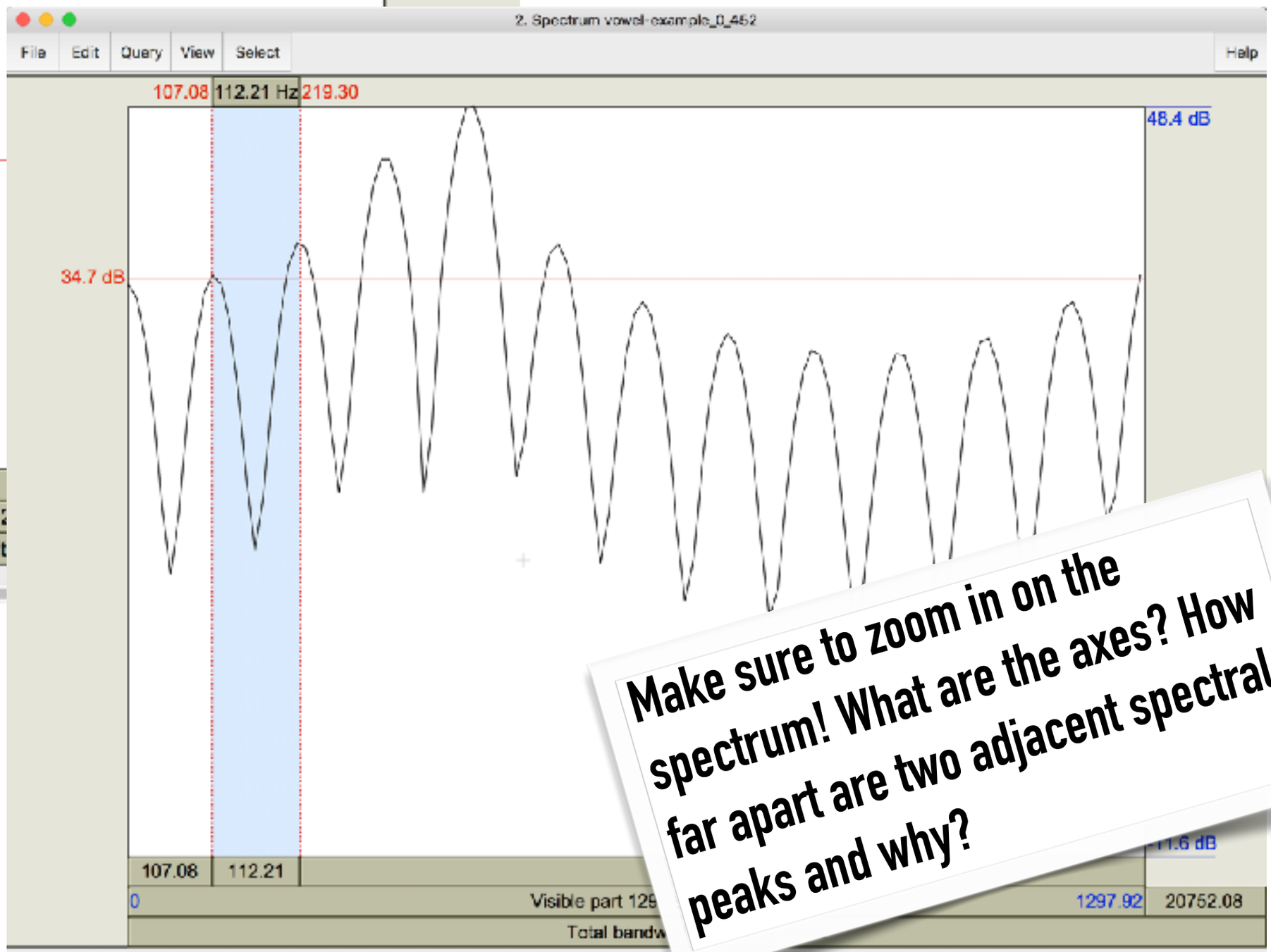


REVIEW: TAKE SPECTRAL SLICE (SPECTRUM)

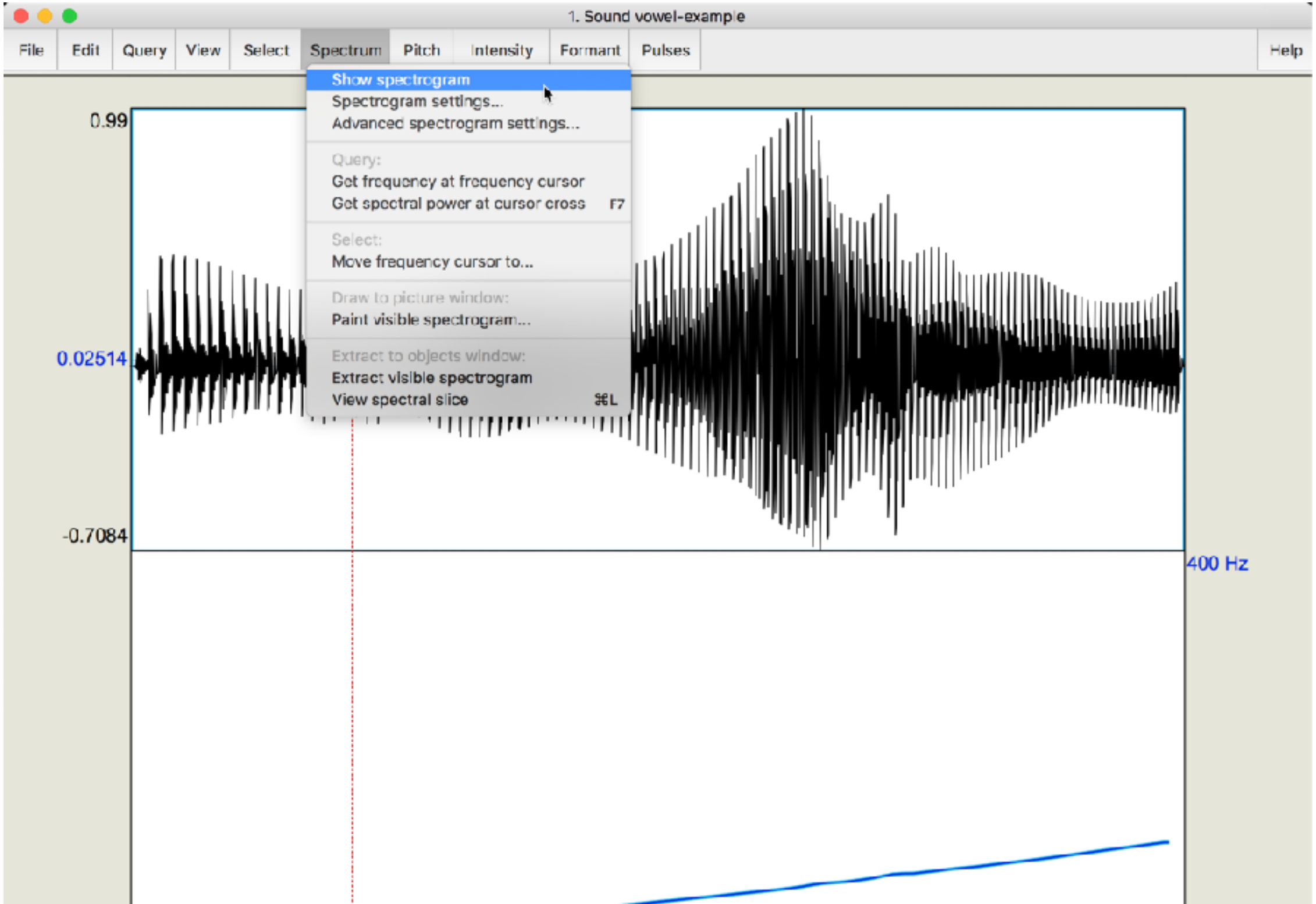


REVIEW: UNDERSTANDING THE SPECTRUM

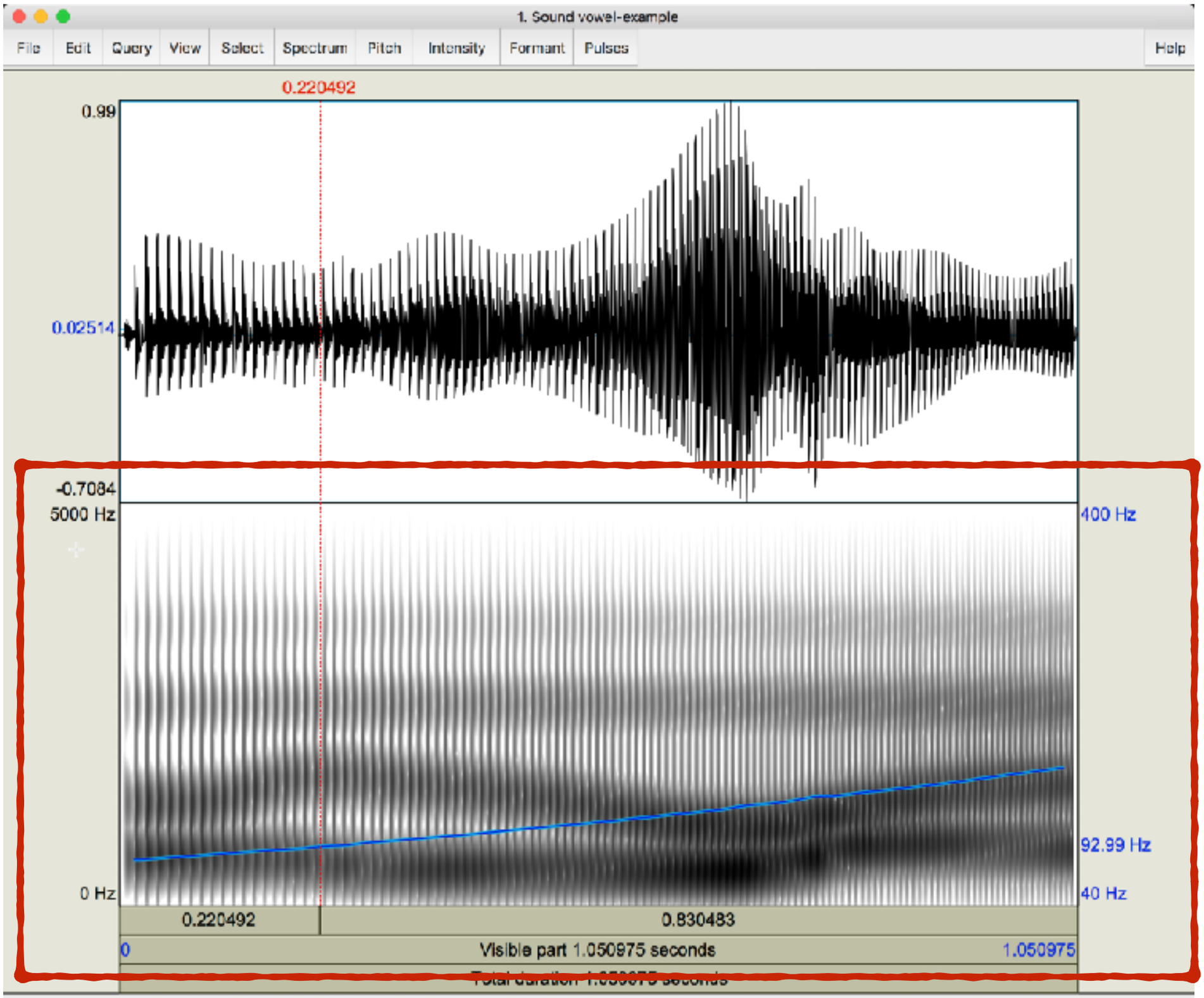




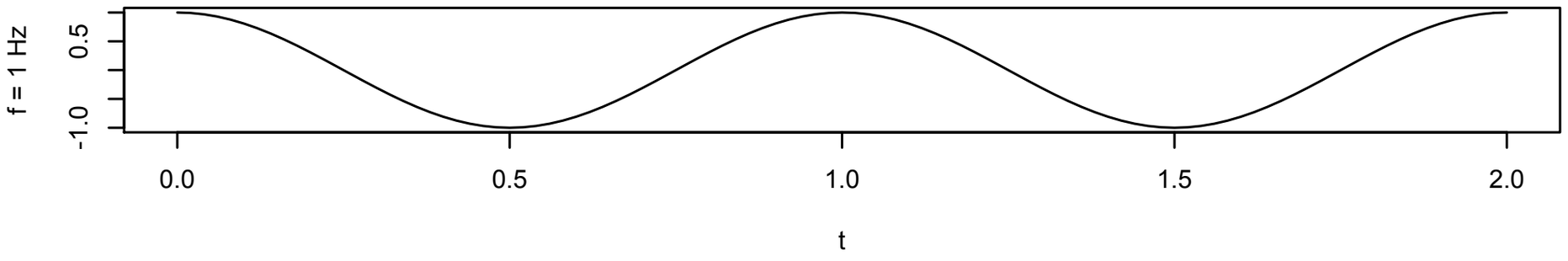
NEW: THE SPECTROGRAM!

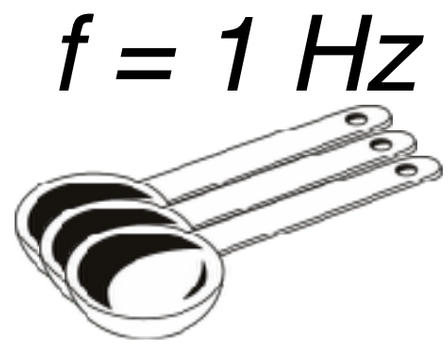


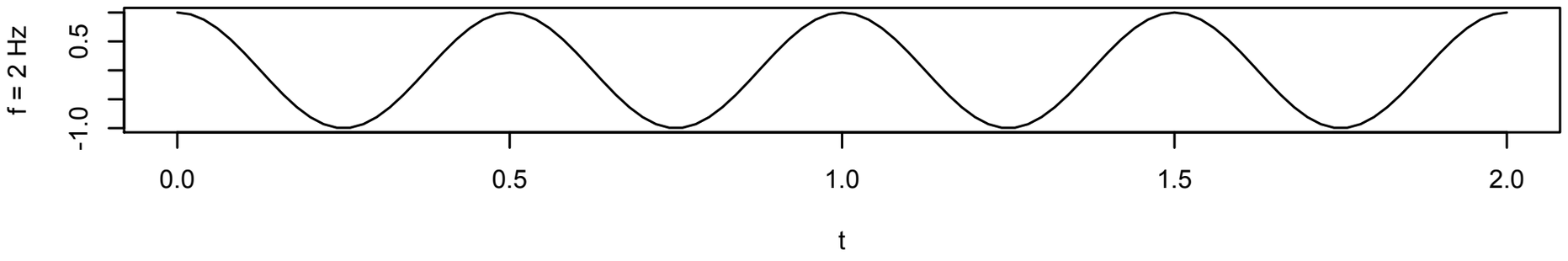
NEW: THE SPECTROGRAM!

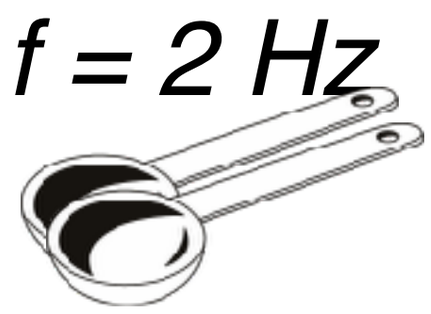


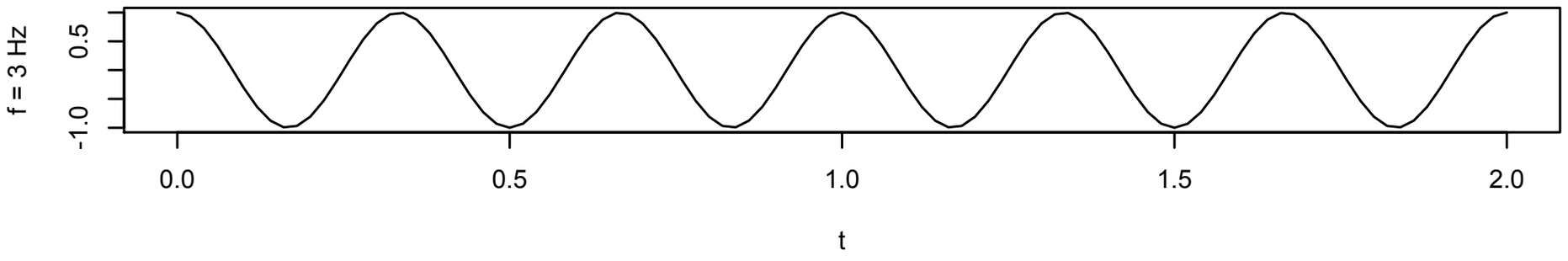
FROM THE SPECTRUM TO THE SPECTROGRAM

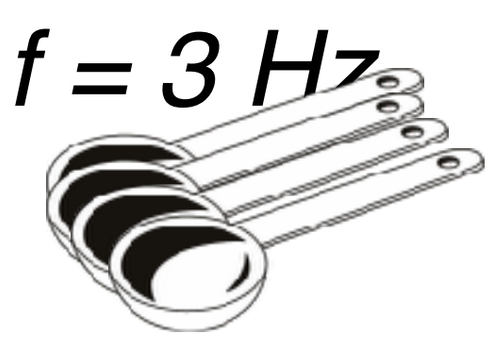

f = 1 Hz
0.5
-1.0
0.0
0.5
1.0
1.5
2.0
t

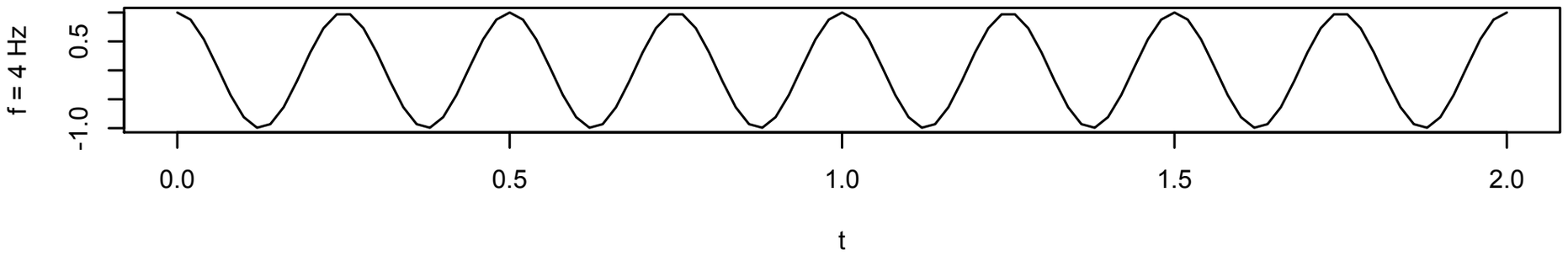

f = 1 Hz

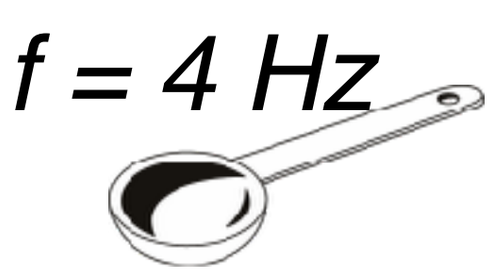

f = 2 Hz
0.5
-1.0
0.0
0.5
1.0
1.5
2.0
t


f = 2 Hz

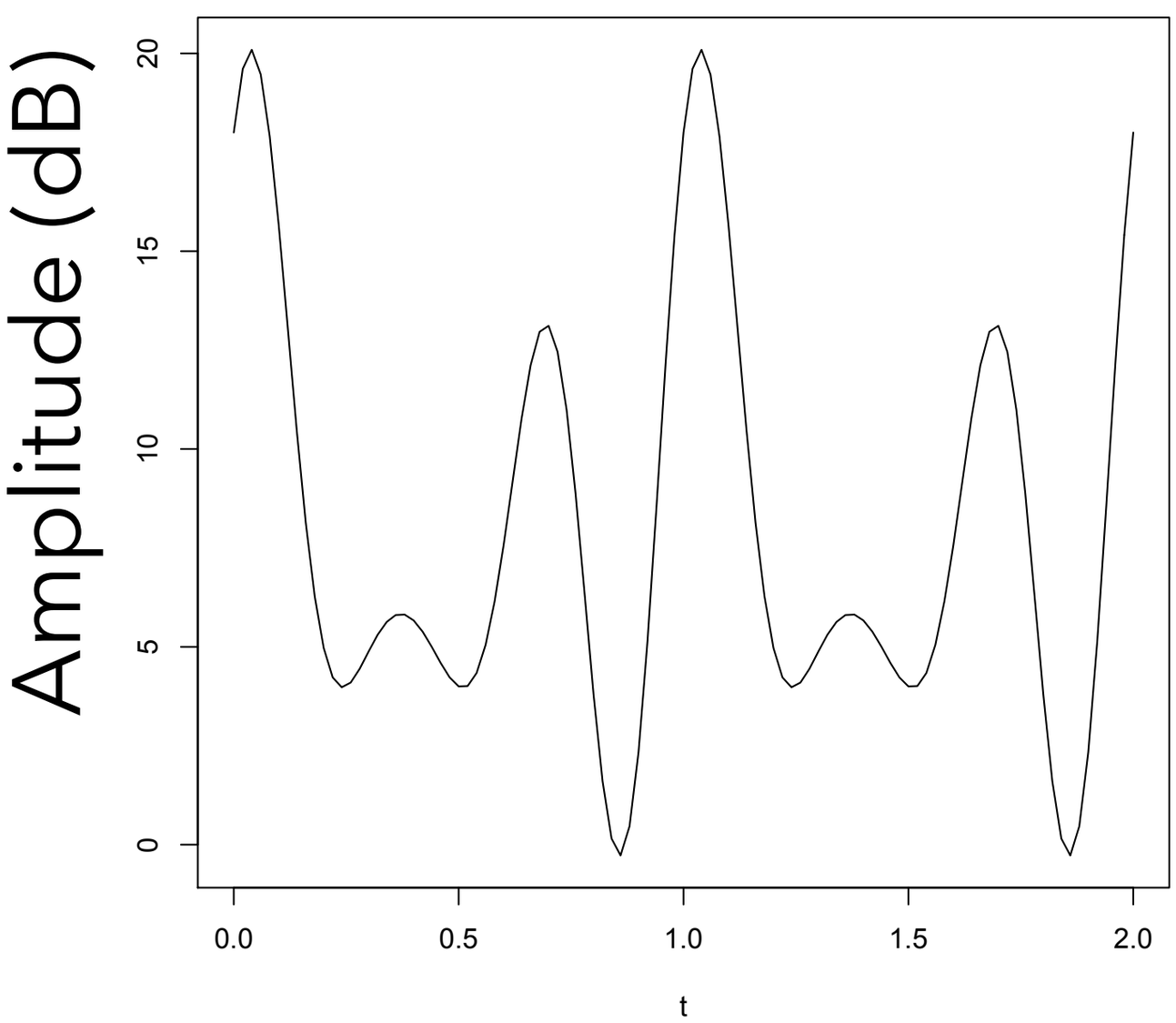

f = 3 Hz
0.5
-1.0
0.0
0.5
1.0
1.5
2.0
t


f = 3 Hz

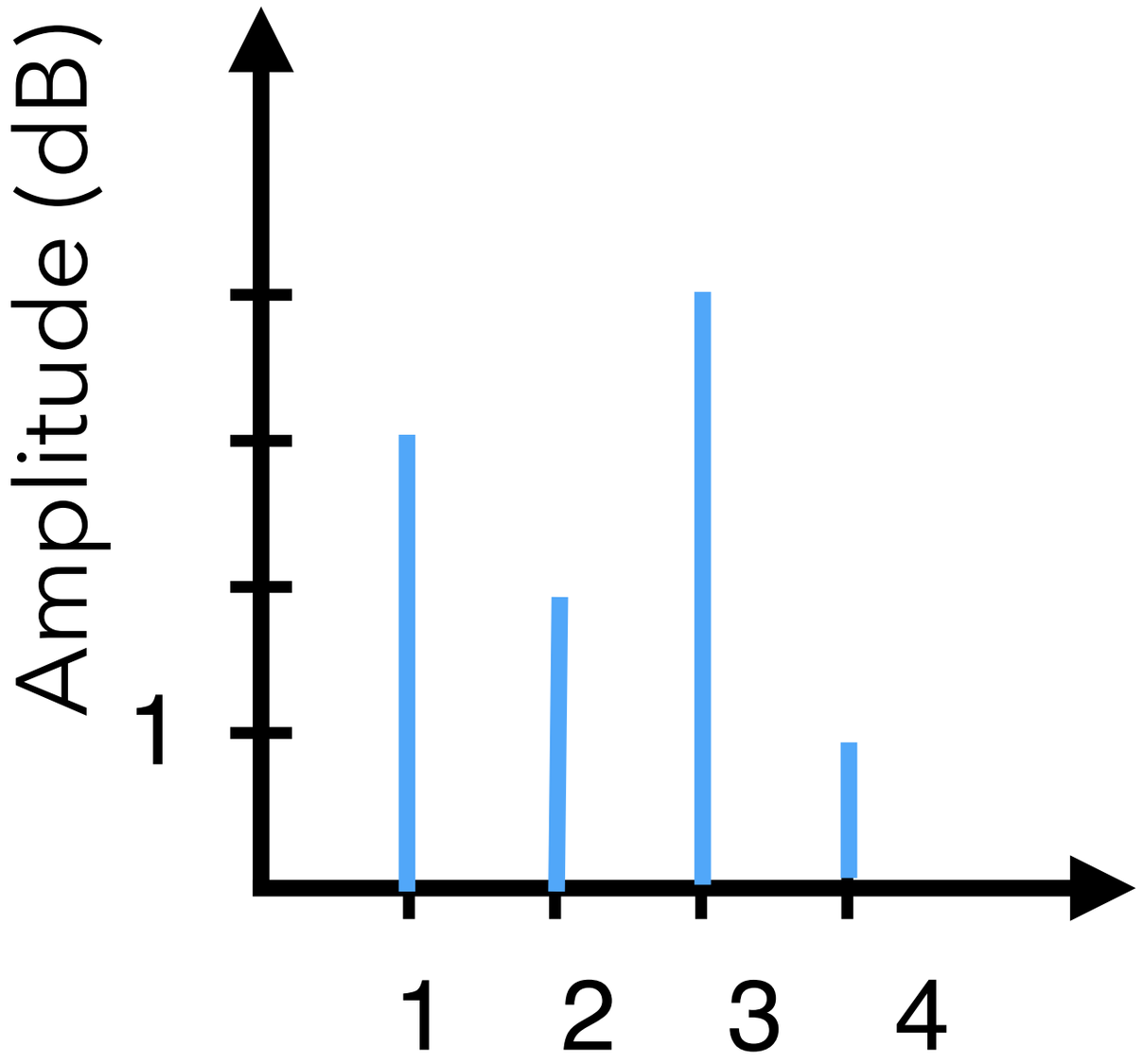

f = 4 Hz
0.5
-1.0
0.0
0.5
1.0
1.5
2.0
t


f = 4 Hz

SPECTRUM OF COMPLEX WAVEFORM

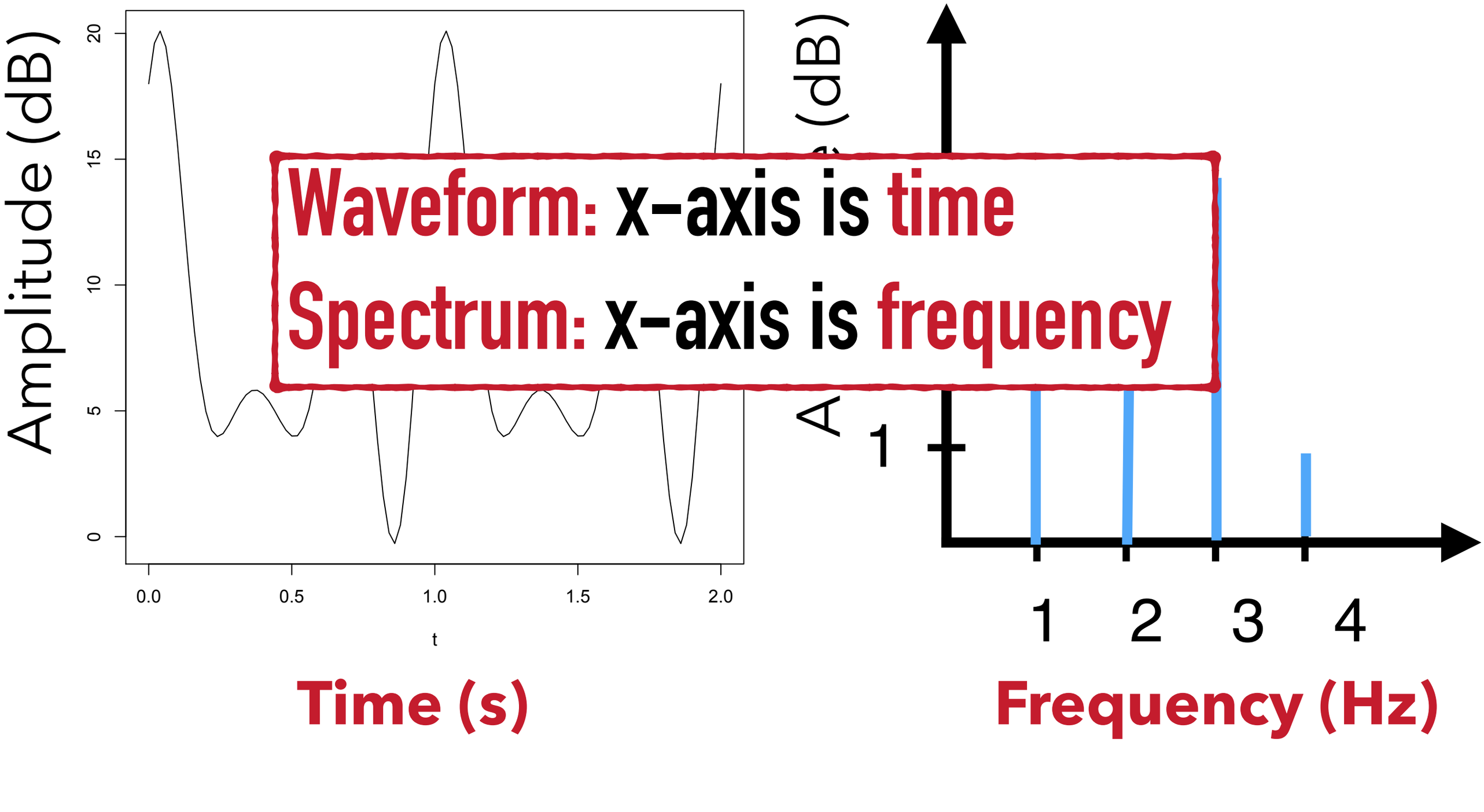


Time (s)

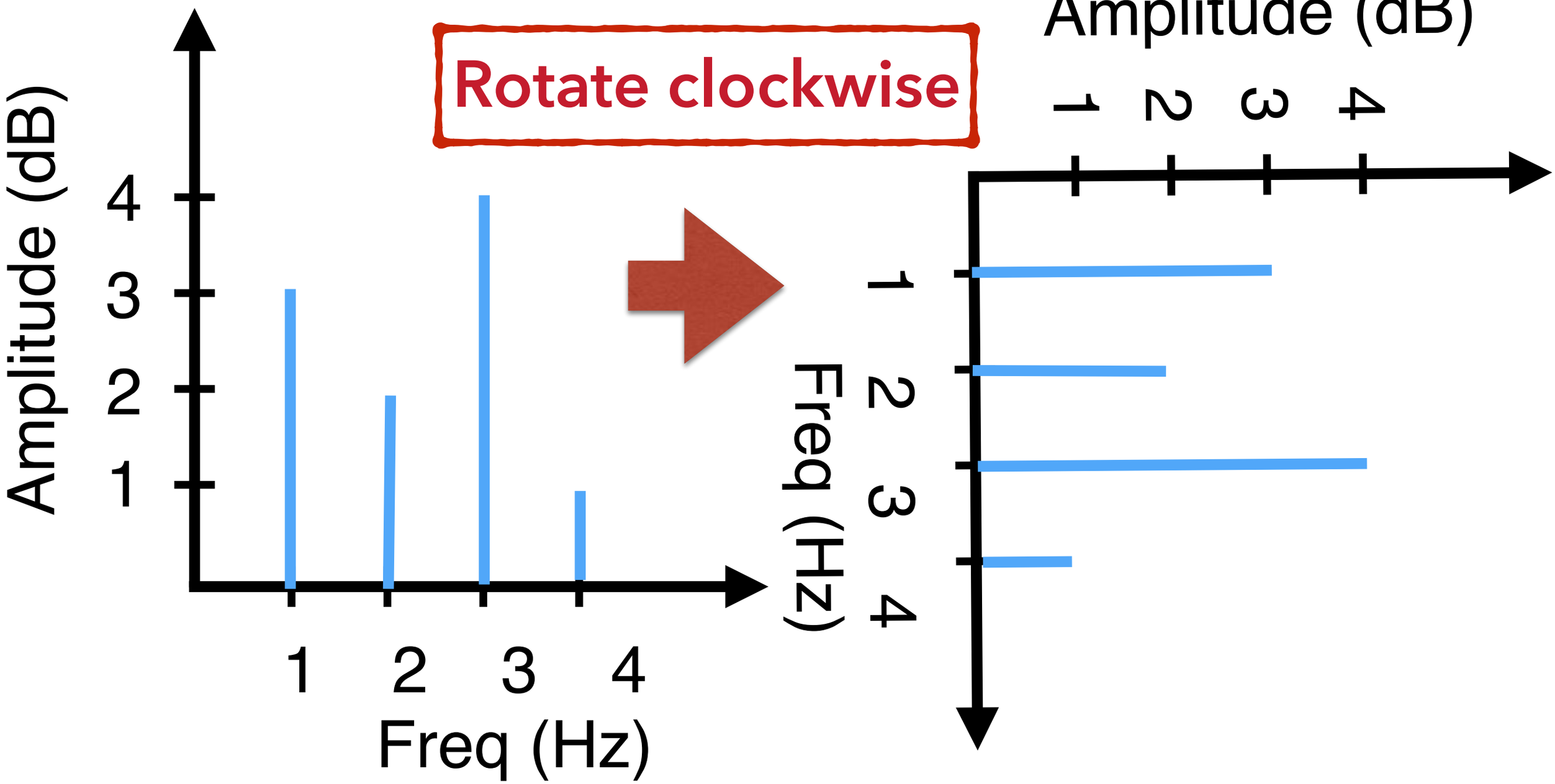


Frequency (Hz)

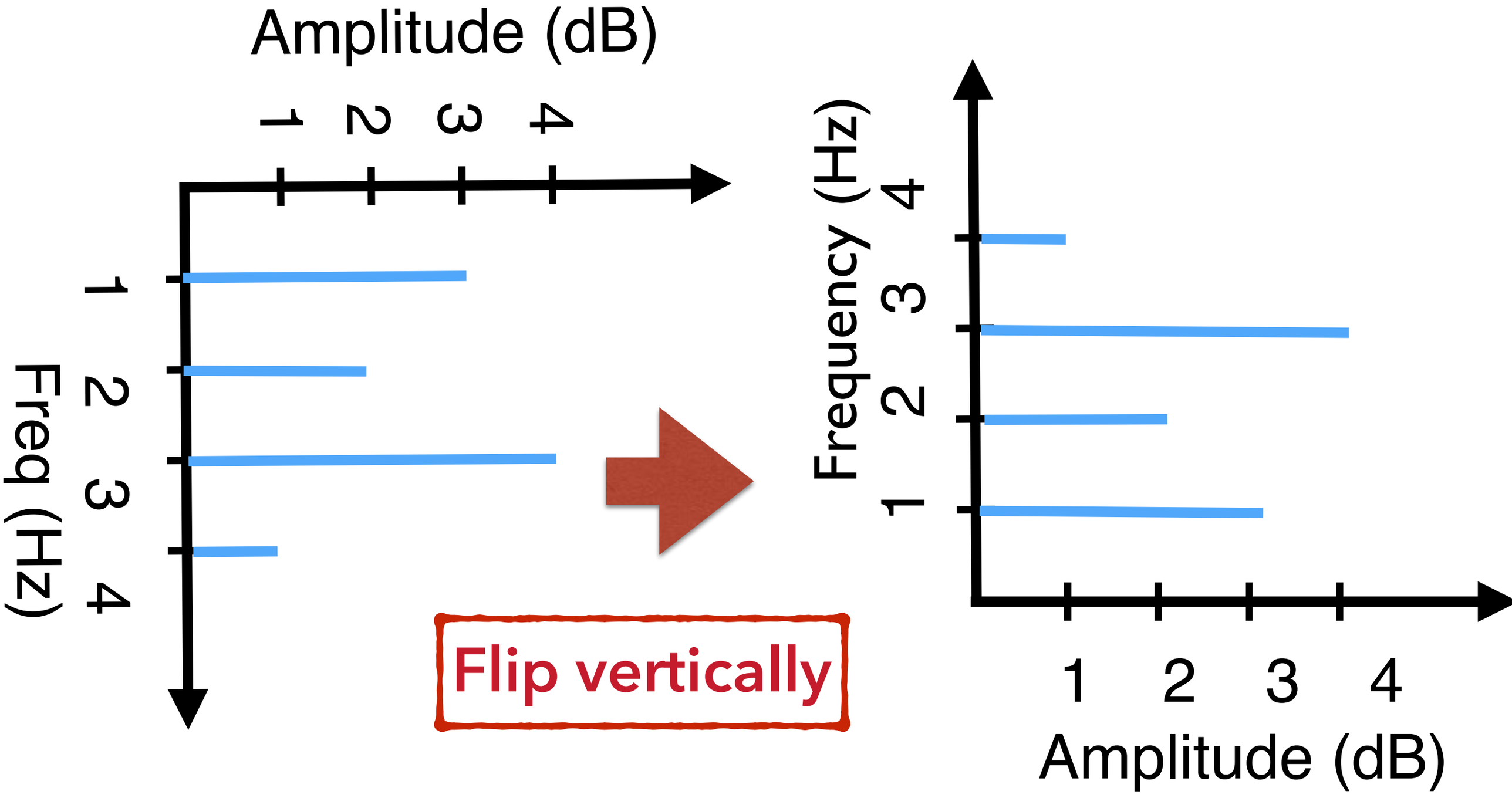
SPECTRUM OF COMPLEX WAVEFORM



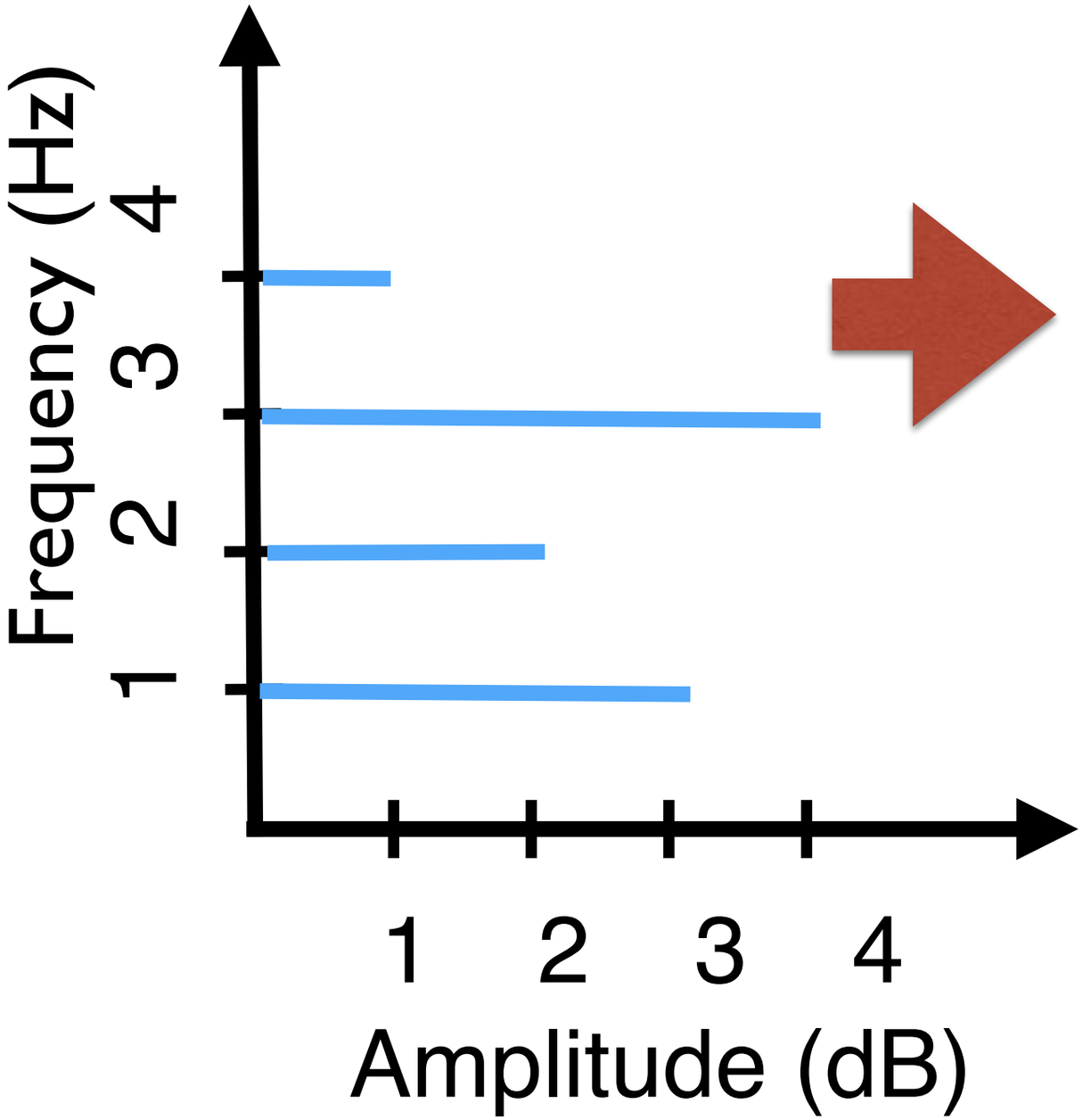
FROM SPECTRUM TO SPECTROGRAM: STEP 1



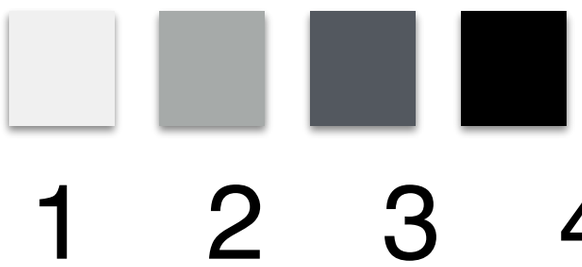
FROM SPECTRUM TO SPECTROGRAM: STEP 2



FROM SPECTRUM TO SPECTROGRAM: STEP 3



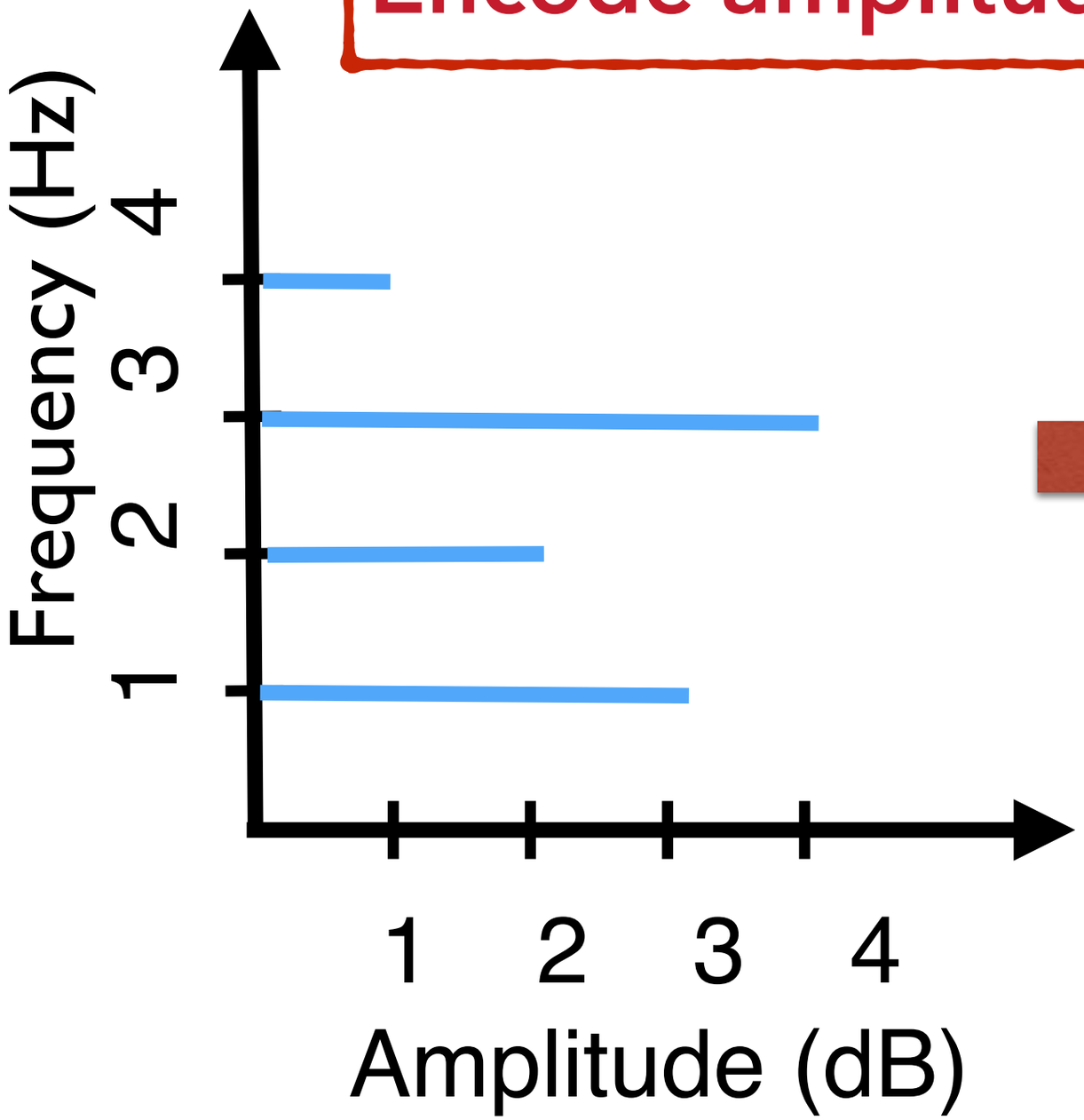
Encode amplitude levels (the height/ length of the blue spikes) in grayscale*

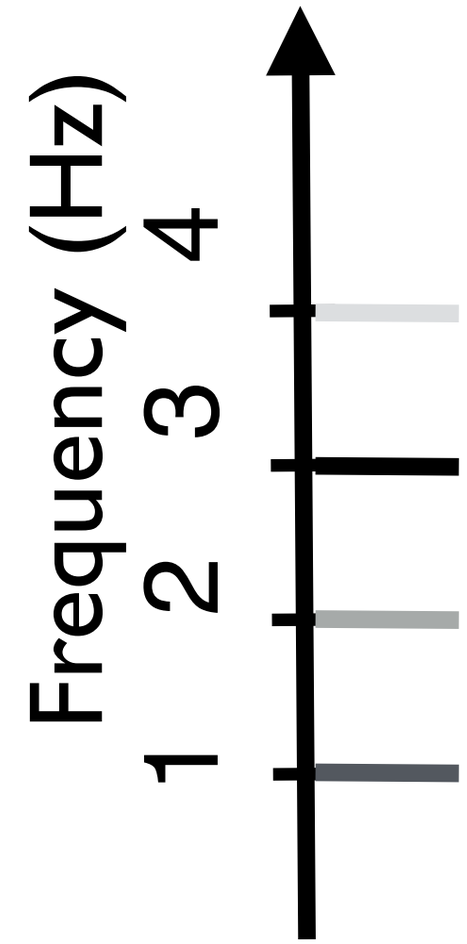


*or with heat map

FROM SPECTRUM TO SPECTROGRAM: STEP 4

Encode amplitudes in grayscale...

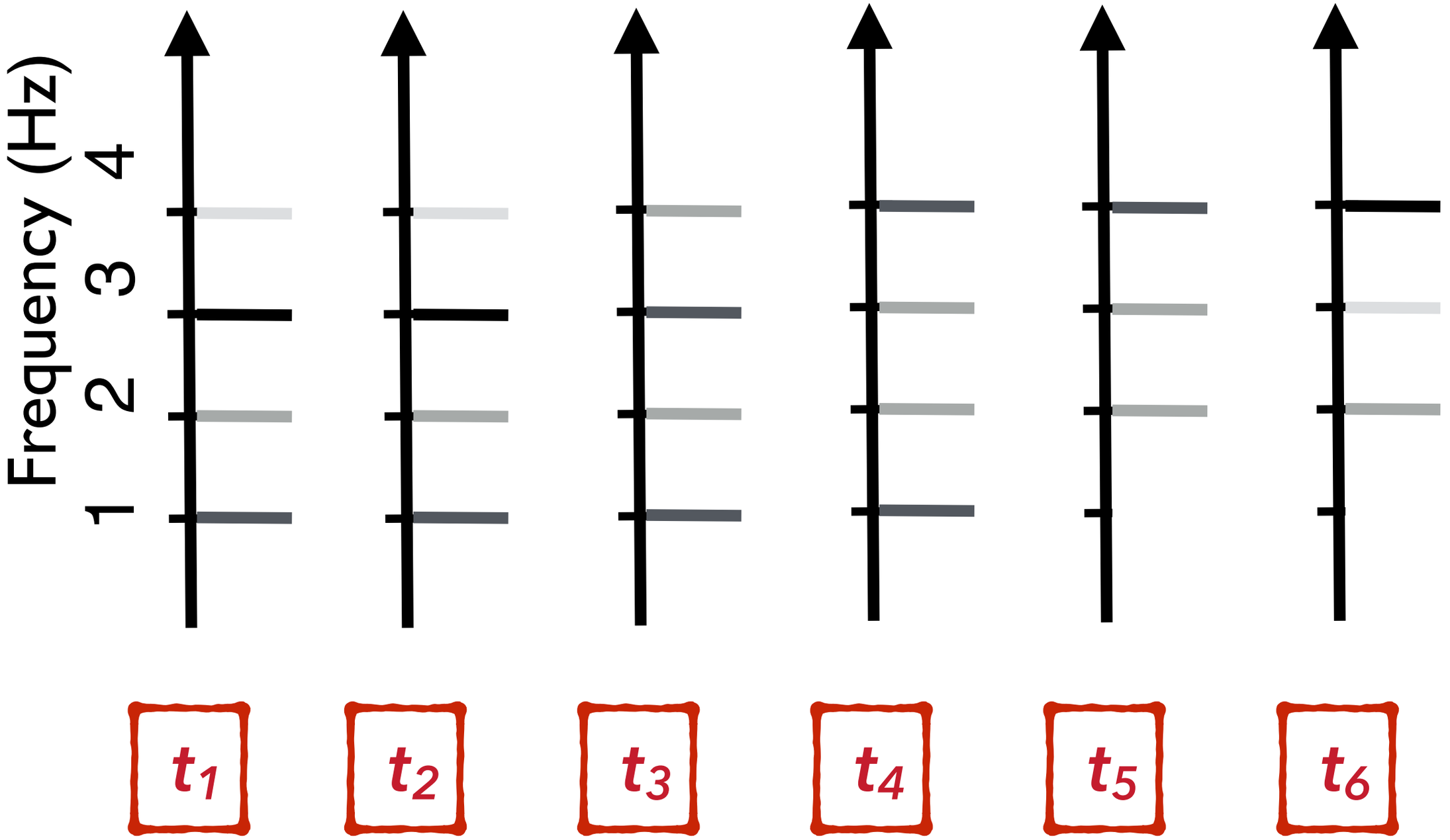




...at time t_1

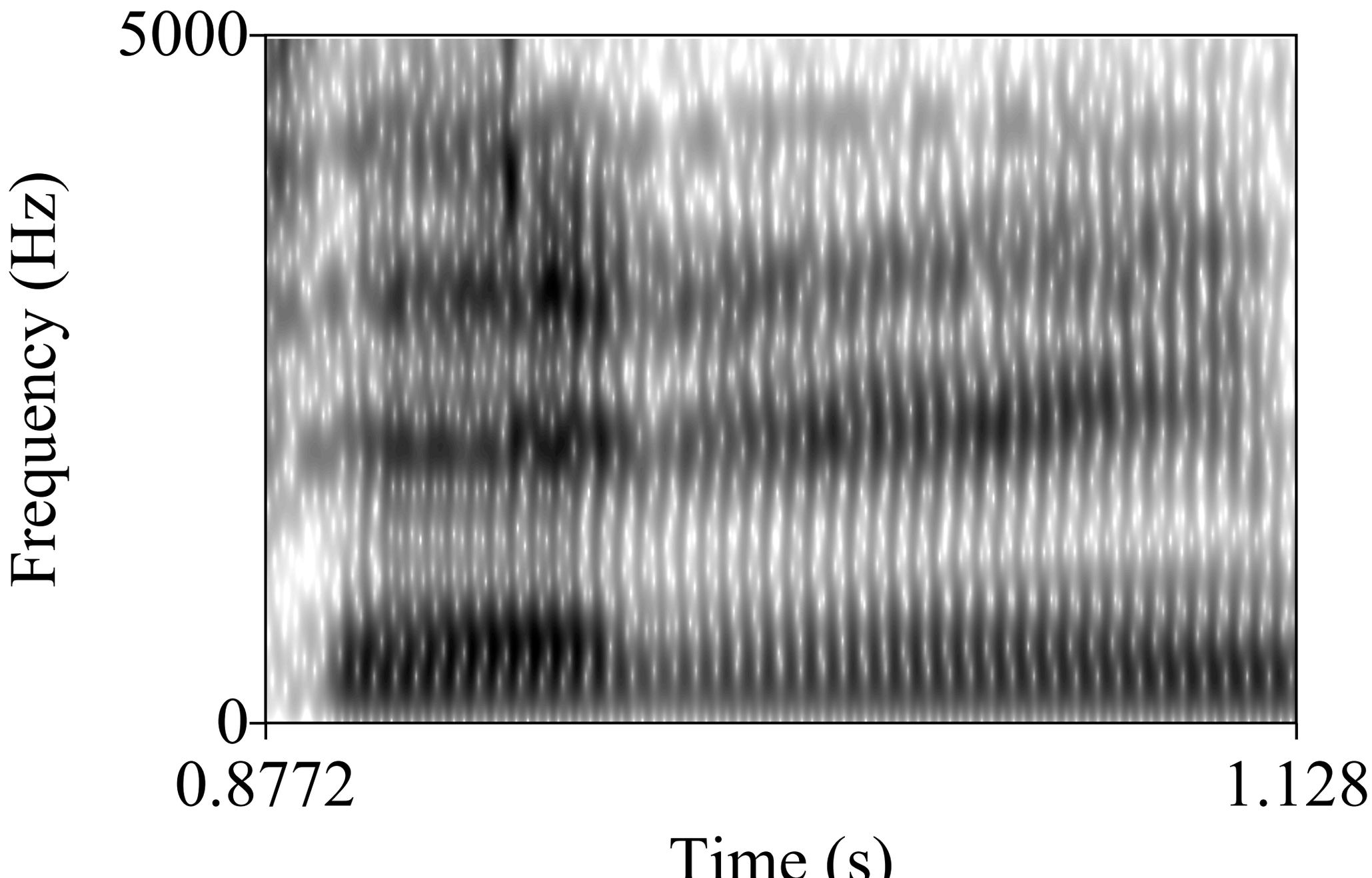
FROM SPECTRUM TO SPECTROGRAM: STEP 5

Line up spectral slices taken over time…



FROM SPECTRUM TO SPECTROGRAM: FINIS

…and you have a spectrogram

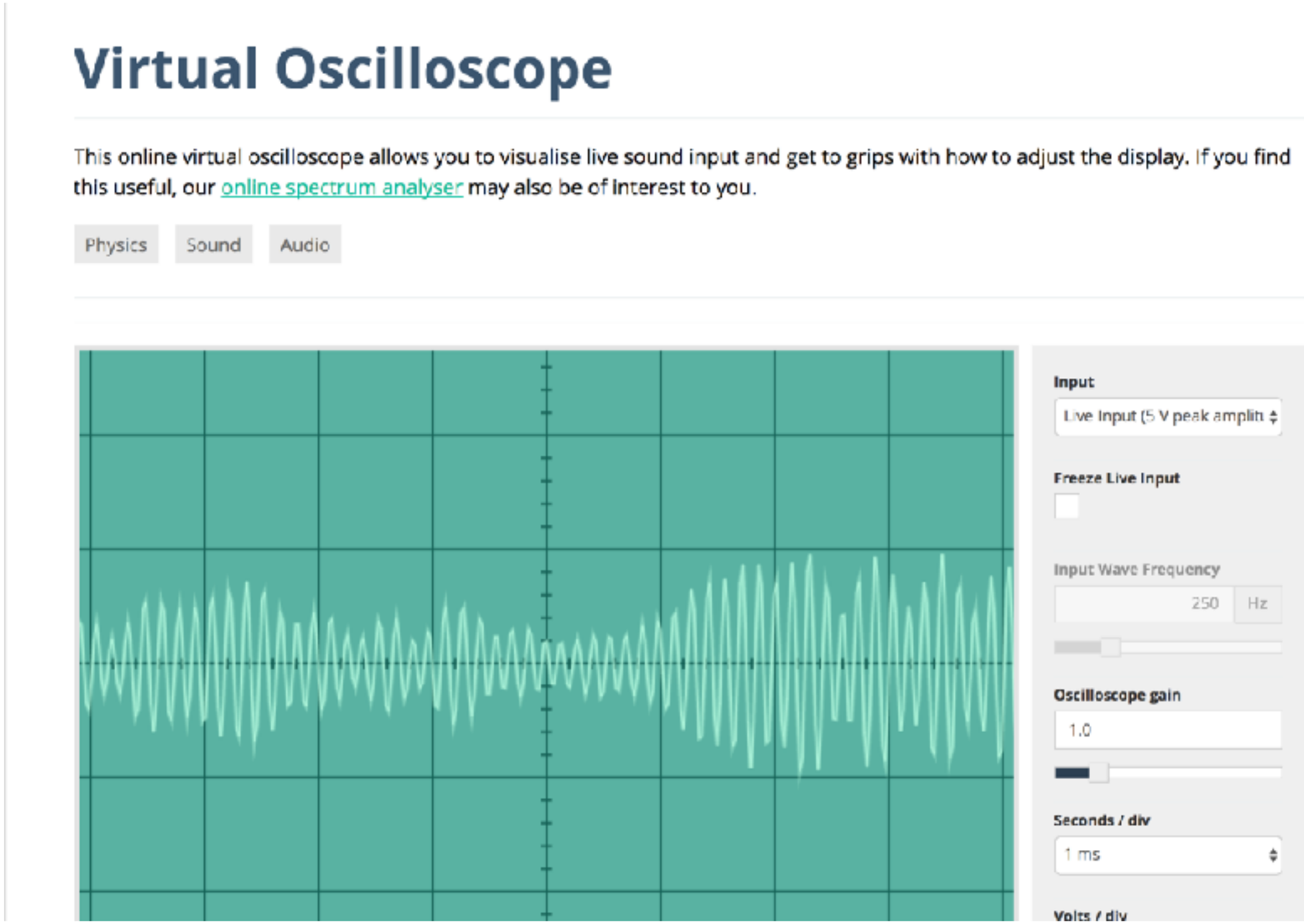


MUSICAL INSTRUMENTS AND TIMBRE

RECORDINGS OF INSTRUMENTS IN PRAAT

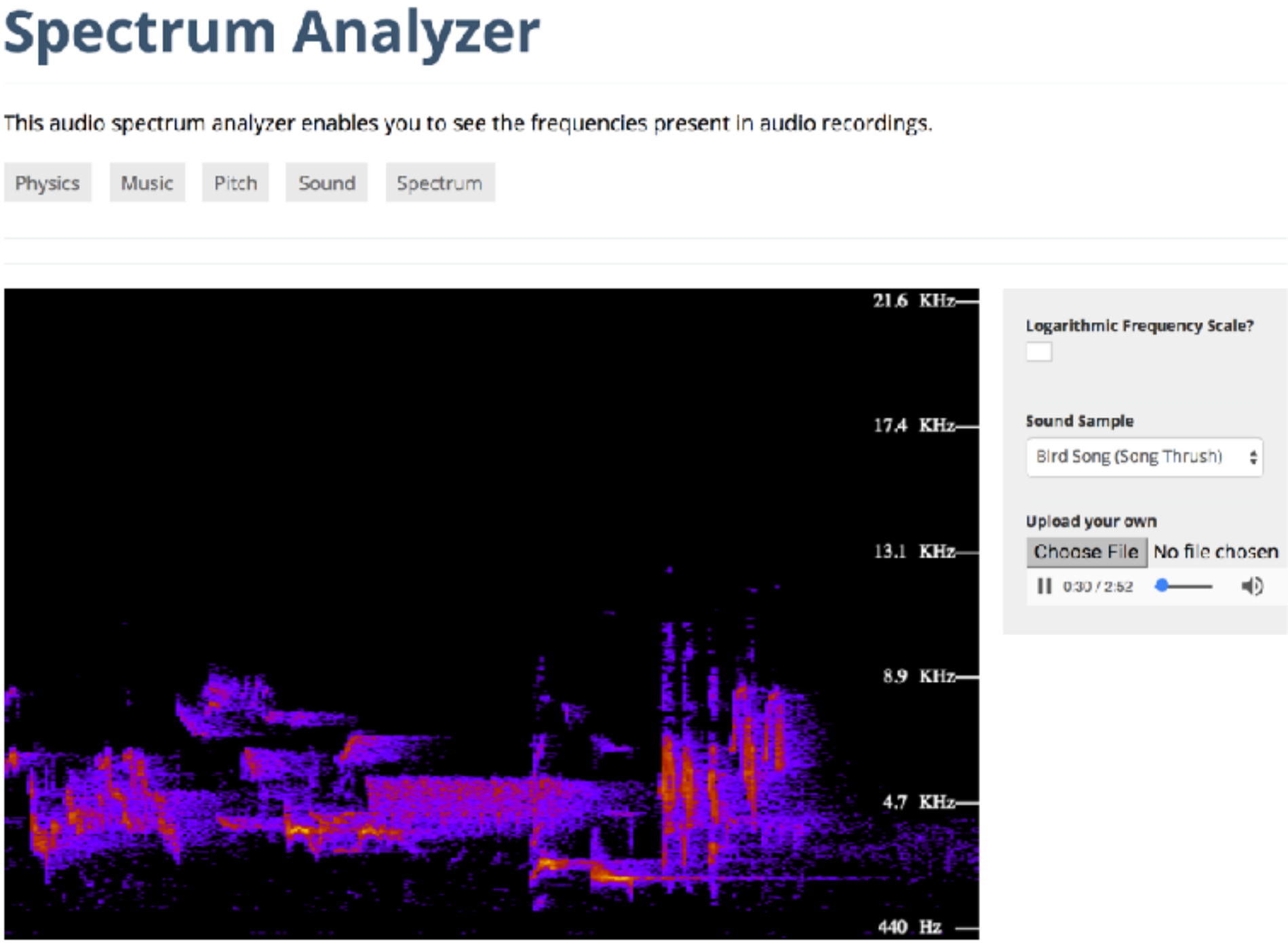
Homework: bring in a musical instrument Thursday! Let's do some recordings of your musical instruments in Praat!

REAL-TIME OSCILLOSCOPE



http://academo.org/demos/virtual-oscilloscope/

REAL-TIME SPECTRUM ANALYZER



http://academo.org/demos/spectrum-analyzer/

REAL-TIME SPECTRUM ANALYZER II

http://musiclab.chromeexperiments.com/Spectrogram