ANALYZING AND GENERATING SOUND FILES WITH MATLAB

BASIC CONCEPT: SAMPLING FREQUENCY.

EXERCISE I: PLAYING AND VISUALIZING A SOUND FILE

A. LOAD THE FILE handel (load handel)

B. PLAY THIS FILE USING sound(y, Fs)

C. Fs IS THE SAMPLING FREQUENCY. EXPLORE PLAYING THIS FILE WITH DIFFERENT FREQUENCIES.

D. PLOT THE SOUND AS FUNCTION OF TIME (SEC). HOW MANY SECONDS LONG IS THE FILE?

BASIC CONCEPTS:

WAVE PROPERTIES: AMPLITUDE (loudness), PERIOD, FREQUENCY (pitch).

EXERCISE II:

A. GENERATE A 5 SECOND LONG, 440HZ WAVE, SAMPLED AT 8000HZ WITH A 0.4 AMPLITUDE.

B. PLOT IT AS FUNCTION OF TIME FOR THE FIRST 0.01 SEC.

C. PLAY IT USING sound.m

D. SAVE IT USING wavwrite.m

EXERCISE III: BEATING. INTERACTION OF WAVES WITH SIMILAR FREQUENCY

A. GENERATE ANOTHER 5 SECOND LONG, 450HZ WAVE, SAMPLED AT 8000HZ WITH A 0.3 AMPLITUDE.

B. PLOT THE SUM OF THE TWO WAVES FOR THE FIRST 0.4 SEC.

C. PLAY THE SUM USING sound.m

D. VISUALLY, OBTAIN THE PERIOD AND FREQUENCY OF THE BEAT.

E. USE THE FOLLOWING TRIGONOMETRIC IDENTITY TO FIND THE PERIOD AND FREQUENCY OF THE BEAT.

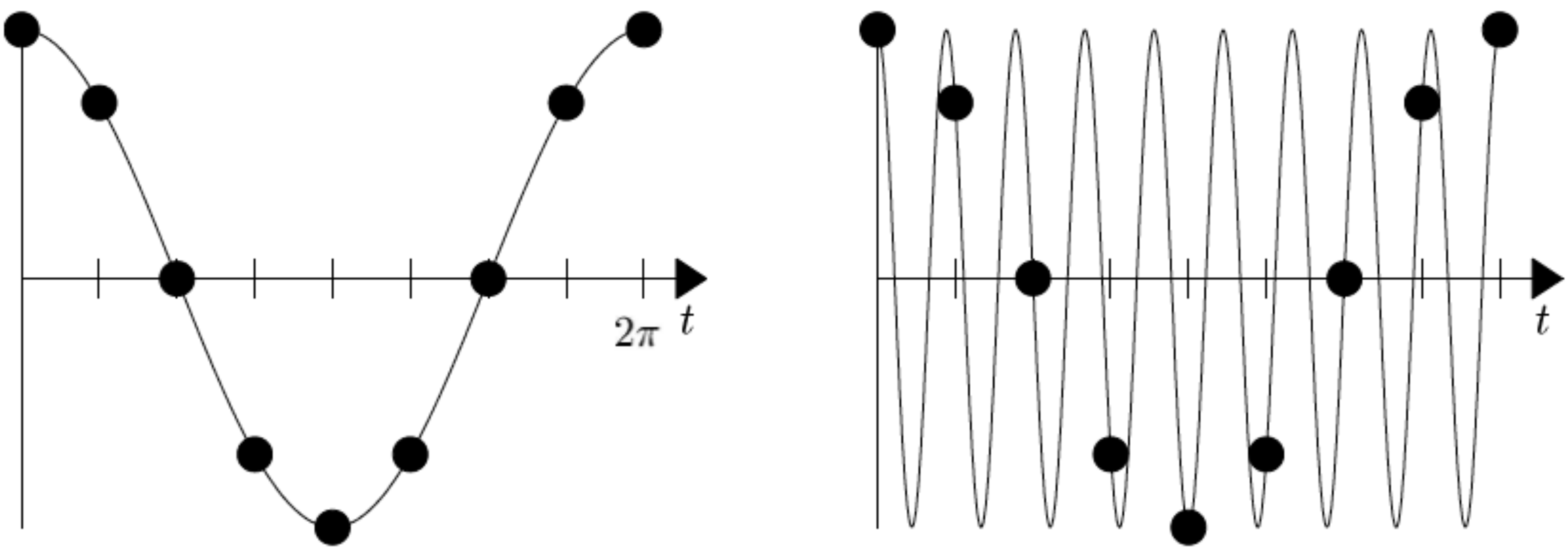
$$\sin\theta \pm \sin\varphi = 2\sin\left(\frac{\theta \pm \varphi}{2}\right)\cos\left(\frac{\theta \mp \varphi}{2}\right)$$

F. SAVE IT USING wavwrite.m

A LITTLE BIT ABOUT SAMPLING AND THE NYQUIST FREQ.:

IN ORDER TO RESOLVE A TONE OF A CERTAIN FREQUENCY (F0, T0=1/F0) , YOU NEED TO SAMPLE AT LEAST AT T=T0/2 (THAT IS F=2/T0=2F0).

EXAMPLE (WIKI): CD'S HAVE Fs=44,100Hz. HIGHEST FREQ. THEY CAN RESOLVE: 22,050Hz. HIGER FREQUENCIES WILL 'FOLD' INTO LOWER FREQUENCIES:



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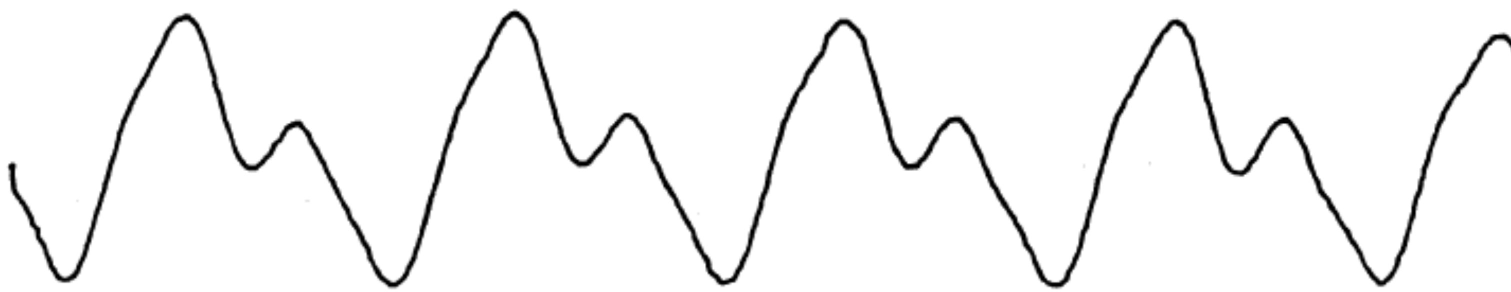
HARMONICS:

SIGNATURE OF A FLUTE PLAYING MIDDLE A CONSISTS MOSTLY OF 'FUNDAMENTAL' AT 440Hz AND THE 2ND HARMONIC AT 880Hz:

FLUTE



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EXERCISE 4:

CREATE THE INTERACTION BETWEEN THESE TWO HARMONICS WITH THE 2ND ONE HAVING $\frac{3}{4}$ THE AMPLITUDE OF THE 1ST.

PLOT THEM AND PLAY THE SOUND.

FOURIER TRANSFORM: DECOMPOSING A SIGNAL INTO ITS HARMONICS (HARMONIC ANALYSIS):

$$F(t) = b_0 + \sum_{n=1}^{N} a_n \sin(2\pi n f_0 t) + \sum_{n=1}^{N} b_n \cos(2\pi n f_0 t)$$

$$a_n = \frac{2}{T}\int_{-T/2}^{T/2} F(t)\sin(2\pi n f_0 t)dt, \quad b_n = \frac{2}{T}\int_{-T/2}^{T/2} F(t)\cos(2\pi n f_0 t)dt$$

f_0=1/2T, N is determined by the Nyquist freqency, $N<FsT$

FOURIER THEOREM: THIS DECOMPOSITION IS UNIQUE!

FAST-FOURIER-TRANSFORM (FFT): A MATHEMATICALLY EFFICIENT WAY TO PERFORM THIS DECOMPOSITION. REQUIRES THAT DATA BE EQUALLY SPACED AND WITH A 2^M NUMBER OF DATA POINTS.

Example: first 3 terms of Fourier expansion for a string:

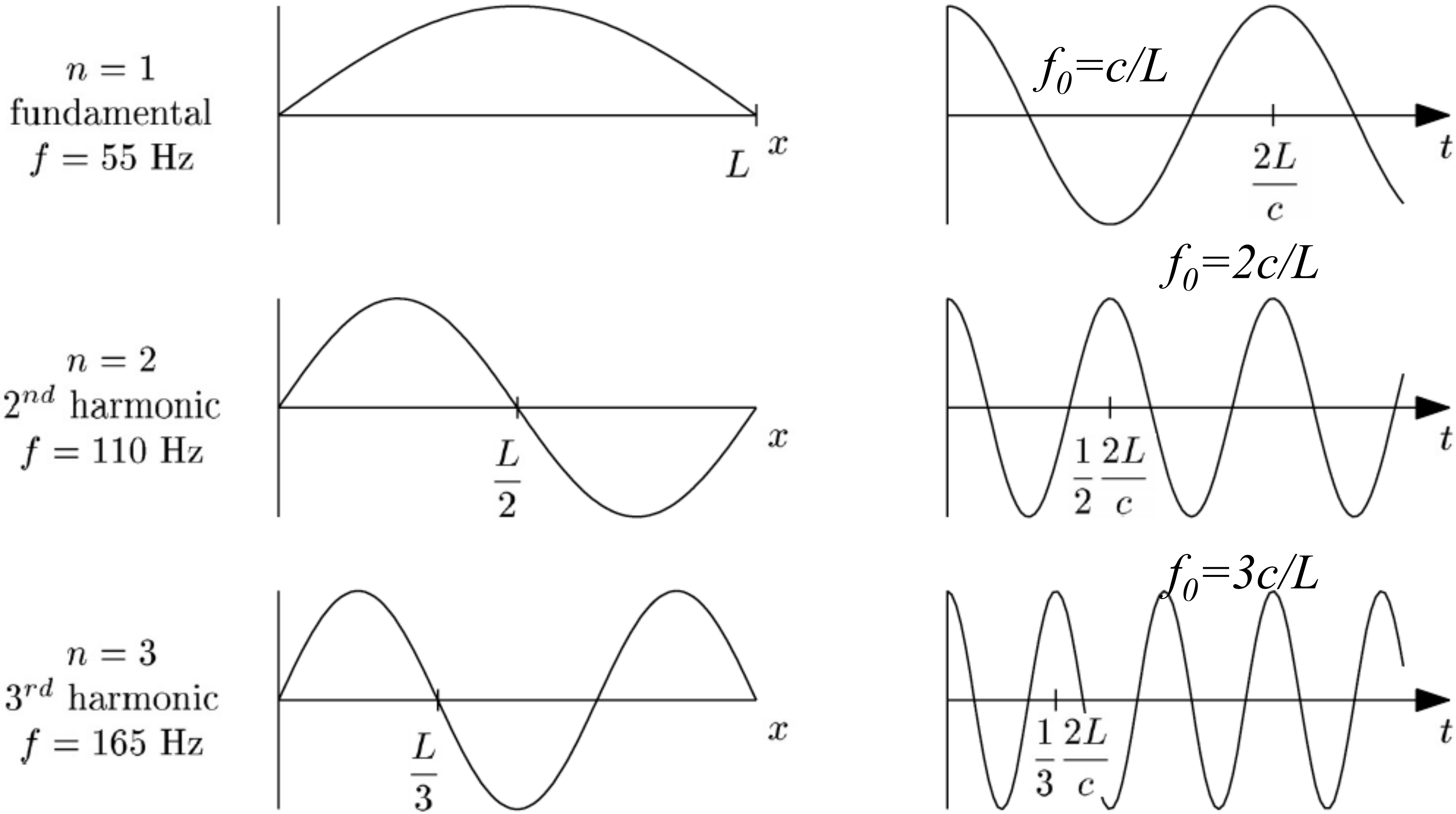


Figure 1. Modes of a vibrating string.

Power spectrum

$$|G(f_n)|^2 = a_n^2 + b_n^2$$

$$|F(t)|^2 = |G(f)|^2 = \sum_{n=1}^{N} a_n^2 + b_n^2$$

Takes the energy (variance) and distribute it to the frequencies contributing to it.

EXERCISE 5:

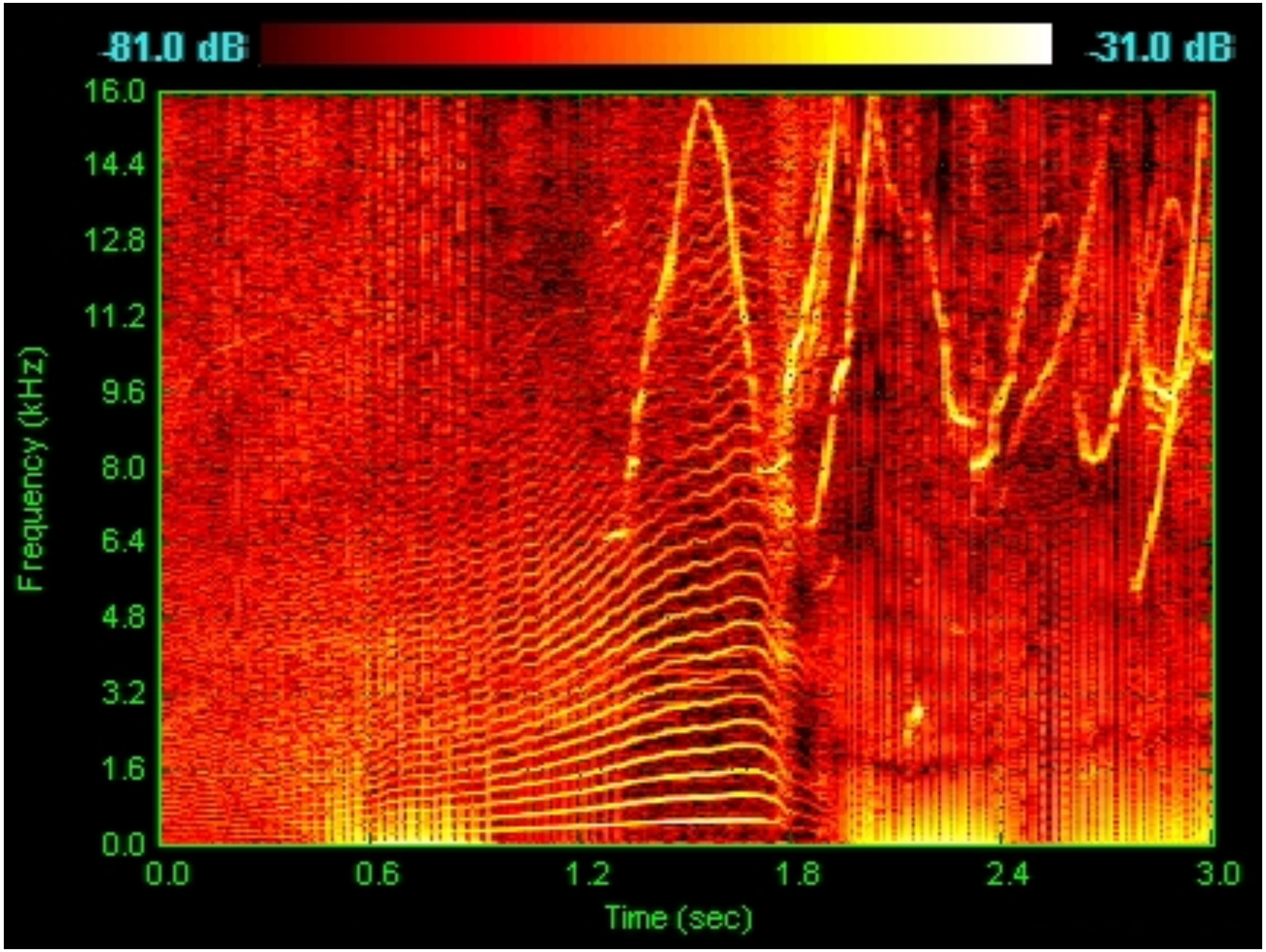
USING Petersen's analyze.m COMPUTE THE POWER SPECTRA OF:

1. low, middle and high A on a piano.
2. Middle A played by different instruments.
3. The beating pattern you generated before.

Plot time varying signal (for ~0.02s) and spectra for each. Are they consistent (that is, is the energy in the band you expect)?

Spectogram

Displaying spectra as they change in time:



Spectrogram of dolphin vocalizations; chirps, clicks and harmonizing are visible as inverted Vs, vertical lines and horizontal striations respectively (http://en.wikipedia.org/wiki/Spectrogram)