025:250 Composition: Electronic Media I
Sept. 12, 2005
Signal Processing: Spectral Analysis/Resynthesis

1. **SoundHack** is a sophisticated signal processing program that requires some basic theoretical background in Spectral Analysis/Resynthesis.

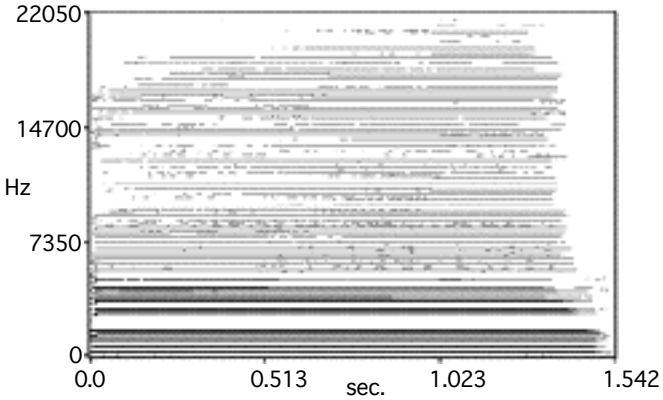
2. Background
   a. Jean-Baptiste Fourier

   b. *On the Propagation of Heat in Solid Bodies* (1807)
   c. Any periodic wave can be represented as a sum of sine waves whose frequencies are integral multiples, and whose amplitudes and phases are properly adjusted.

3. Fourier series for middle C, where f = 261.65 Hz

12f	3139.80 Hz	
11f	2878.15 Hz	
10f	2616.50 Hz	
9f	2354.85 Hz	
8f	2093.20 Hz	
7f	1831.55 Hz	
6f	1569.90 Hz	
5f	1308.25 Hz	
4f	1046.60 Hz	
3f	784.95 Hz	
2f	523.30 Hz	
1f	261.65 Hz	C4

4. Spectrogram of an Oboe playing F4.



   Note. Frequency on vertical axis, time on horizontal axis, amplitude represented by dark-light lines.

5. Blackboard representation of frequency on horizontal axis and amplitude on vertical axis. Time represented by movement of these positions or on a y axis.

6. Blackboard representation of frequency as a stack of sine waves, the interference of which produces a sum wave.

7. **Terminology**
   a) Fourier Analysis analyzes a complex signal into sinusoid components. These sine waves have frequency relations of 1f, 2f, 3f, … where f is the fundamental frequency of the complex signal. A resynthesis recombines these sine was into the original (one hopes) complex signal.

   b) Fast Fourier Transform (FFT) is an algorithm that analysizes short, discrete segments of the complex signal, ranging from 1 ms to 1 second. This time is often measured in samples.

   c) A Window is an analysis segment described above with an amplitude envelope imposed on the segment, usually in a fade in/ fade out manner resembling a bell curve. Different windows have unique envelope shapes. Common windows are Hamming, Hanning (or von Hann), Gaussian, Kaiser, and others. A useful window in **SoundHack** is Sinc, which has the shape of the first 180 degrees of a sine wave.

   d) Overlapping Windows create a smooth transition between segments, similar to fade in/ fade out effects. Unfortunately, smearing occurs. 0.5x overlaps produce the least amount of smearing and is best suited for maintaining the rhythmic characteristics of the signal. 1x, 2x, 4, 8x, overlaps produce very smooth smearing that is useful when clean, stable, steady-state pitches are desired.

   e) In general, the determinate (steady-state) parts of the original signal are maintained throughout the analysis/synthesis. However, the indeterminate, transient, noisy parts of the signal are often lost or misrepresentated. Currently, researchers are exploring ways of extracting the noise before doing the analysis, then putting it back in during resynthesis. Much work remains to be done in this area. Virtually all researchers in analysis/synthesis use the Iowa database for these studies because there is so little smearing of the original signal in an anechoic chamber.

   f) Phase Vocoder Model: One compositional advantage of spectral analysis/resynthsis is that during the resynthesis stage, the frequency of the sine wave components can be manipulated independently from their time characteristics. This is most useful in time-stretching with **SoundHack's** Phase Vocoder process.