Class 7

- Listen to Csound
- Listen to *Mutations* (really!)
- Additive synthesis
- Noise
- Modulation (Amplitude)
- Csound Instrument Design

Additive Synthesis

Synthesis by summation of elemental waveforms (usually sinusoids).

- Additive synthesis (with sinusoids) allows independent control of frequency and amplitude envelopes for each spectral component in a sound.
  - Given a sufficient number of sinusoids, almost any sound can be synthesized.
- Additive synthesis (with sinusoids) *requires* independent control of frequency and amplitude envelopes for each spectral component in a sound.
  - Huge volume of data and control parameters.
  - “Fusion” may be difficult to achieve.

Non-sinusoidal Additive Synthesis

Additive synthesis need not use only sinusoids:

- Could use waveforms having complex frequency spectra.
- Could use noise generators.

When using non-sinusoidal waveforms:

- Frequency and amplitude envelopes control the evolution of many spectral components at once.
- Wavetables (oscillators) can be mixed dynamically to vary the harmonic amplitudes ("spectral interpolation").
- Harmonicity is **not** possible with a single oscillator.

"Additive Synthesis" almost always implies summation of sinusoids.

... but not in my work ...

Noise

- Noise spectra are not comprised of vertical lines.
- Noise energy is not concentrated at discrete frequencies.
- Noise generators spread energy “evenly” across all frequencies.
- Noise energy can be concentrated somewhat using the interpolating noise generator described in Dodge and Jerse (**`randi`**).

Modulation

Variation of an input parameter of one generator according to the output of another generator.

Most often, the frequency or amplitude of an oscillator is varied or *modulated* according to the output of another generator.

- Frequency Modulation - (oscillator) frequency is modulated by another signal.
- Amplitude Modulation - amplitude is modulated by another signal.

Enveloping is the simplest form of modulation - sub-audio unipolar modulating signal.

Spectra of Modulated Signals

Modulation of a waveform introduces new spectral components, not present in the unmodulated waveform.

Spectral components in modulated signals:

- *Carrier* components - frequency depends only on the unmodulated waveform. Carrier components are components that are present in the unmodulated waveform, possibly at different ampitudes.

- *Sideband* components - frequency depends on both the unmodulated waveform and the modulating signal (“modulator”).

Classical Amplitude Modulation

- amplitude of modulator is scaled by the *modulation index* (M)
- modulator is *added to* the amplitude of the carrier generator (A)

In the case of sinusoidal carrier (f_c) and modulator (f_m), the resulting spectrum is comprised of:

- carrier component at frequency f_c and amplitude A
- sidebands at frequencies $f_c + f_m$ and $f_c - f_m$, and amplitude $A * \frac{M}{2}$

```
csound -o am.wav -W am.orc am.sco
```

Ring Modulation

- amplitude of modulator is scaled by the *modulation index* (M)
- modulator *scales (multiplies)* the amplitude of the carrier generator (A)

  Ring modulation = waveform multiplication.

In the case of sinusoidal carrier (f_c) and modulator (f_m), the resulting spectrum is comprised of:

- sidebands at frequencies $f_c + f_m$ and $f_c - f_m$, and amplitude $A * \frac{M}{2}$

Note: this operation is symmetrical (carrier and modulator are interchangeable).

```
csound -o rm.wav -W rm.orc rm.sco
```

Amplitude Modulation Spectra

Modulation of a sinusoid at frequency f_c by a waveform having two spectral components, f_{m1} and f_{m2} yields spectral components at frequencies:

$$f_c + f_{m1} \quad f_c - f_{m1} \quad f_c + f_{m2} \quad f_c - f_{m2}$$

Modulation of a waveform having two spectral components, f_{c1} and f_{c2} by a sinusoid at frequency f_m yields spectral components at frequencies:

$$f_{c1} + f_m \quad f_{c1} - f_m \quad f_{c2} + f_m \quad f_{c2} - f_m$$

Amplitude modulation can yield harmonic spectra if the carrier and modulator frequencies are harmonically related, or inharmonic spectra if they are not.

Instrument Design Examples

```
csound -o noiserm.wav -W noiserm.orc noiserm.sco
```

```
csound -o drum.wav -W drum.orc drum.sco
```

For more on instrument design, see Introduction to Sound Design In Csound, the first chapter in *The Csound Book*.

For Next Time

- Experiment with the instrument designs in section 4.11. Be prepared to discuss your experiments in class.

- Begin Chapter 5 (to 5.1D)