**Sound**
- Synthesized
- MIDI

**Synthesis**
- Nyquist Theorem: any sound can be created from component sinusoids
- Frequency Modulation (FM)
- Wave Table

**FM**
- modulate a carrier signal
- = add another signal to a base (carrier)
- many ways to do this (Fig. 6.7)
- ex:
  - if $t =$ time, $\cos(2\pi t)$ sounds half the pitch of $\cos(4\pi t)$
### An Example

- $A(t)\cos(\omega_c t + I(t)\cos(\omega_m t + \varphi_m) + \varphi_c)$
- $A(t)$ controls amplitude of synthesized signal
- $I(t)$ controls amplitude of modulation signal
- $\omega_c, \omega_m$ are carrier and modulating freq.
- $\varphi_m, \varphi_c$ (phase) delays for each signal

### Problem

- Quality of sounds is like tofu (don’t try to make it sound like something else - it won’t exactly sound like it)

### Wave Table

- Collect samples of an instrument
- Algorithmically modify pitch, duration, etc.
- Advantage: more realistic sound
- Disadvantage: memory required

### Demo Garage Band

- Synthesis demo
- Show loop basics, demonstrate piano
- Show loop editor, demonstrate change pitch
- GarageBand capabilities, relate to iMovie
## MIDI

- Musical Instrument Digital Interface
- Language for describing note sequences; very similar to network protocols
- Note has a pitch, duration, volume
- Commands include note on, note off, select instrument (channel)

## TERMINOLOGY

- Synthesizer: sound generator
- Sequencer: edit sequences of commands/notes
- Controller: outputs MIDI messages rather than sounds