FM EXAMPLES

Exploring the sound world of FM synthesis

Examples

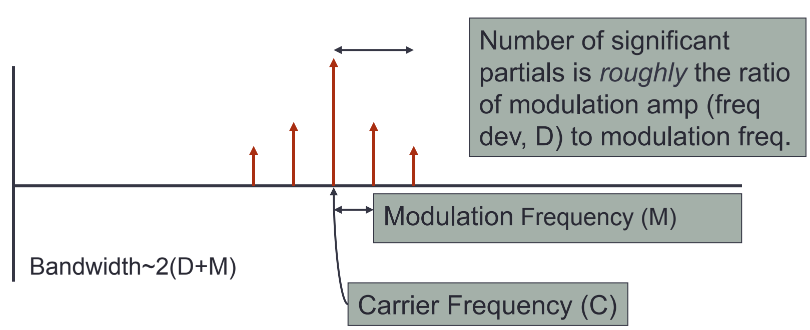
- See Code 4 (code_4.sal)

Why FM Synthesis?

- We've already seen wavetable or table-lookup synthesis:
  - Very efficient
  - Create any harmonic spectrum
  - Simple frequency and amplitude control
- What's missing?
  - Time-varying control over the spectrum
  - Inharmonic spectra
- Various Approaches:
  - Synthesize each sinusoid separately – tedious, costly
  - Filter the output of table – useful, but only harmonic output
  - FM Synthesis

FM Synthesis

- When modulation frequency is in the audio range, interesting things happen.



Mathematics of FM

- The exact amplitudes of the partials generated by FM are described by Bessel functions
- These functions are messy, their evolution is messier, and there is no simple way to invert the functions
- Many lives of FM:
  - 1967-1968 Invented by John Chowning, patented 1975
  - 1983-1986: Yamaha DX7 160,000 sold
  - 1990-1995: IBM PC-compatible Sound Cards
  - 2000's: FM synthesis provides polyphonic ring tones

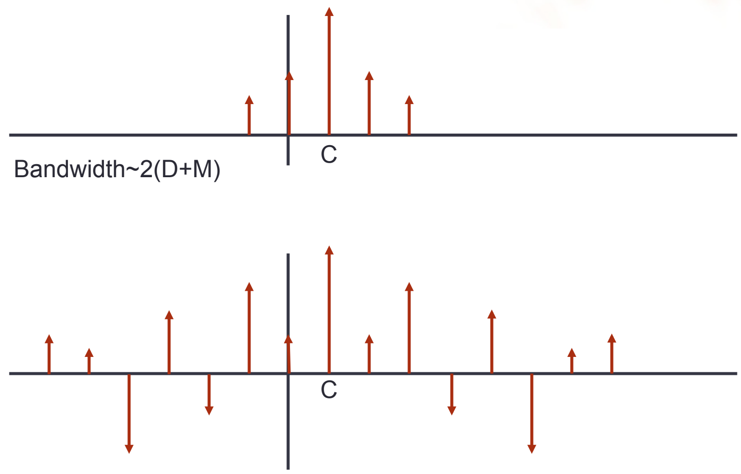
FM and Harmonics

- Generated frequencies are:

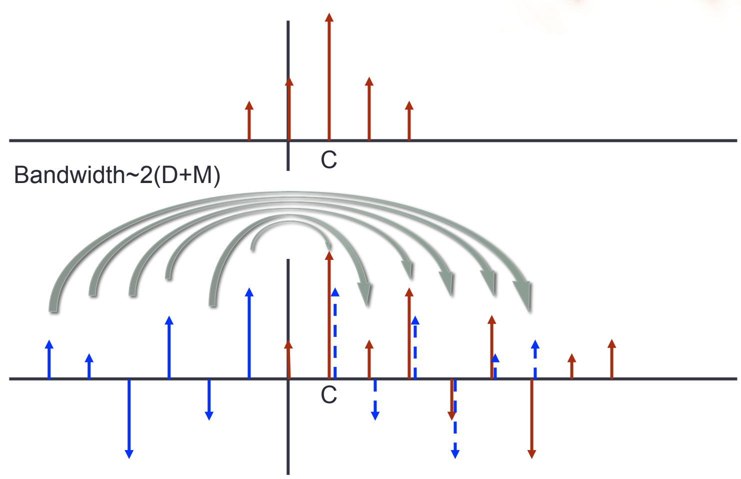
$$C \pm nM$$

- Where C = "Carrier" and M = Modulator
- Simplest case: C = M
- Generated frequencies are:
  C+nM gives us C, 2C, 3C, 4C, …
- What about negative frequencies?

FM and Harmonics (2)

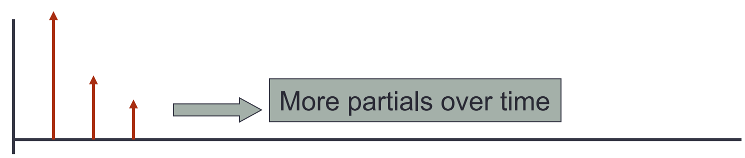


FM and Harmonics (3)



Classic FM brass sound

- Characterized by a rise in upper partials
- Generated by increasing depth of modulation
- Uses 1:1 Carrier:Modulation frequency



- See example in code_4.htm

Odd Harmonics

$$C \pm nM$$

- Let M = 2C
- Resulting frequencies are C, 3C, 5C, …
- Negative frequencies are -C, -3C, -5C, …
- Try it…

Other Harmonic Schemes

$$C \pm nM$$

- Let M = i/j x C, for small integers i and j
- Let F = C/j, then M = iF
- C = jF, C+M = (i+j)F, C+2M = (2i+j)F, etc.
- All frequencies are harmonics (integer multiples) of F
- Try it…

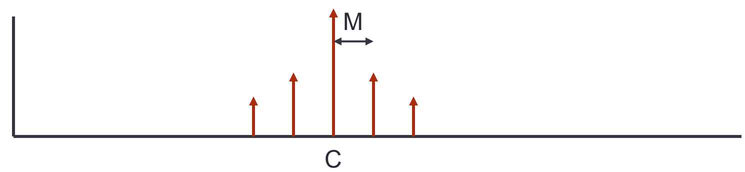
Inharmonic Partials

$$C \pm nM$$

- Let M = not i/j x C
- Resulting frequencies are not harmonics
- Negative frequencies are not harmonics
- Try it…

Formants

- Resonances (especially in the vocal tract) emphasize frequencies around the resonant frequency
- We can simulate resonances (and voice) by placing a carrier near the desired resonant frequency and modulating it to create nearby harmonics:



Summary

- FM Synthesis
  - Time varying spectra
  - Low cost (simplest case is only 2 oscillators)
  - Simple parametric control
  - Musically useful results
- FM Control
  - Carrier:Modulator ratio
    - Harmonic or inharmonic spectra
    - Odd or all harmonics
    - Formants
  - Depth of modulation
    - Number of partials

See examples in code_4.sal