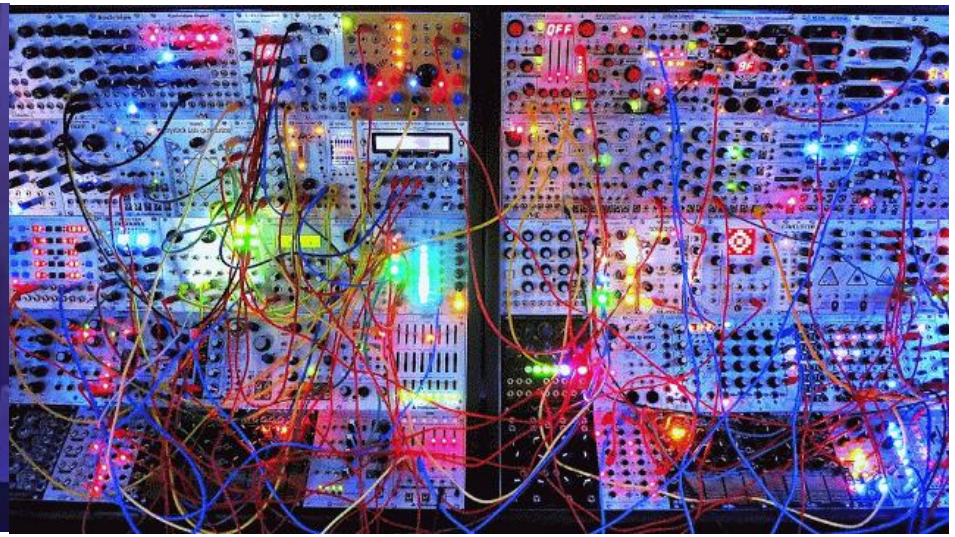
MUSC 4820/5820 Digital Music Techniques 001

Week 10: Sound Synthesis 2 – Modulation Synthesis and Physical Modeling Synthesis



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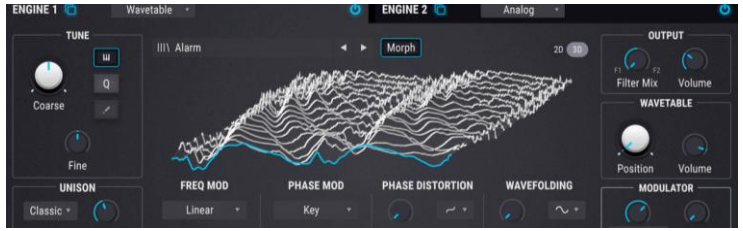
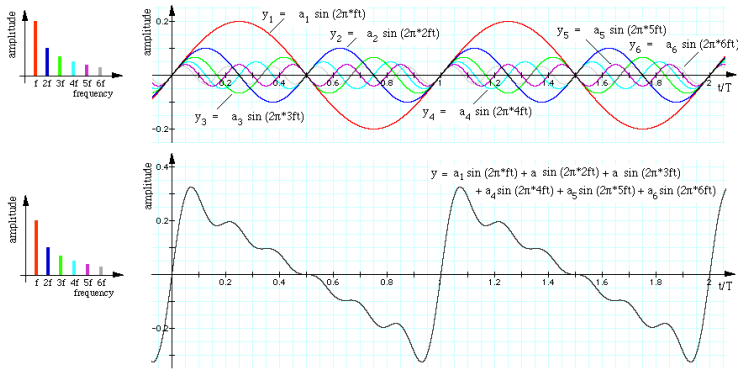
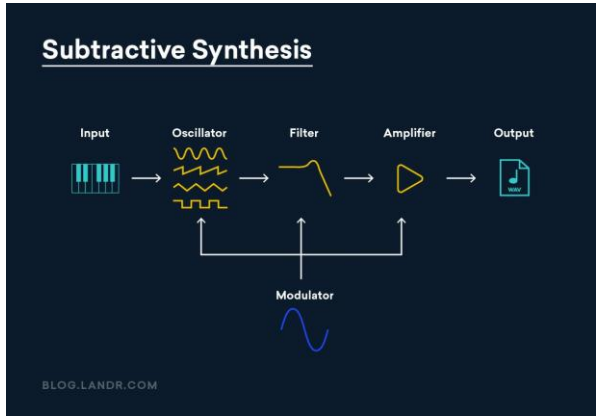






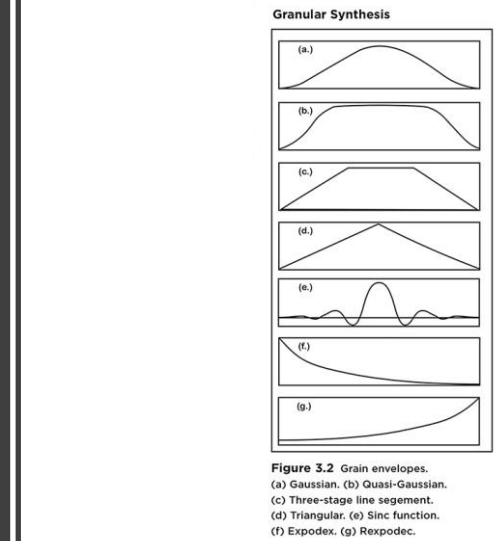


Figure 3.2 Grain envelopes.
(a) Gaussian. (b) Quasi-Gaussian.
(c) Three-stage line segement.
(d) Triangular. (e) Sinc function.
(f) Expodex. (g) Rexpodec.

Recap of Spectrum/Waveform Synthesis

The Beating Effect

The beating effect occurs when you play two similar frequencies of sound at the same time – this is simply adding two waveforms

What is Modulation?

- A Modulator is an audio or any Signal that changes (modifies) the original sound or signal (Carrier) over time.
- Modulating a sound can add a sense of **movement**, add or change dimension, or create depth.

Modulators can be used to:

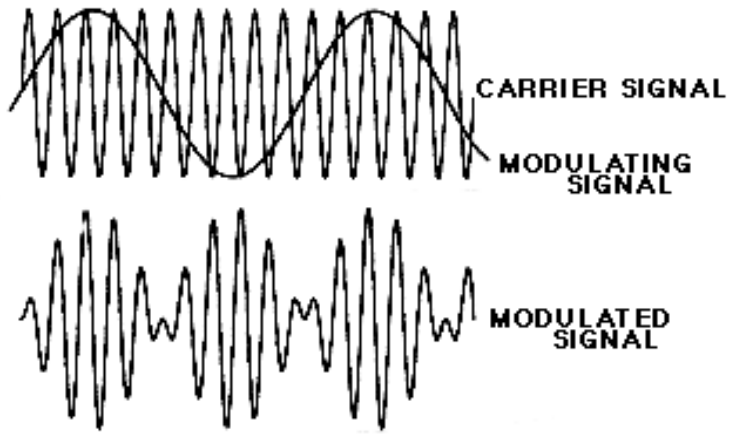
1. Change the frequencies of a sound
2. Alter the gain or volume
3. Change the position of a filter on a sound
4. Move controls on effects and instruments

Common Modulators include:

1. LFOs
2. ADSR Envelopes
3. Modulation Wheels
4. Step Sequencers
5. Modulation Effects

Any signal can be modulated by any other signal ☺

Modulation In Sound Synthesis



- Modulation requires a “Source Signal” called a Modulator that controls another signal called the “Carrier Signal”. For example, LFO (a Source Signal, also called “modulator”) was applied to the oscillator or the original signal (carrier). Essentially, the Synth’s original sound wave is the **Carrier Signal!**
- For AM (Amplitude Modulation) and FM (Frequency Modulation), the carrier signal is always there nonmatter how many sideband frequencies would be created – this is the theory behind the whole AM and FM radio signal transmission.
- Some modulators, like the LFO or envelopes, produce a signal… but they do not produce an audible sound. The job of the Modulator is to change the original sound, not produce one itself. HOWEVER, you can always use an audio rate signal as a modulator, complex spectrum will be created this way – this is also why we often use a sine wave as a modulator because complex waveform modulator created too complex modulation results - this sometimes sounds very noisy

Modulation Effects

Modulation Effects are a group of effects, some of which you may have never considered a Modulator.

They include:
1. LFO
2. Chorus
3. Flanger
4. Phaser
5. Auto Pan
6. **Tremolo (AM)**
7. **Vibrato (FM)**

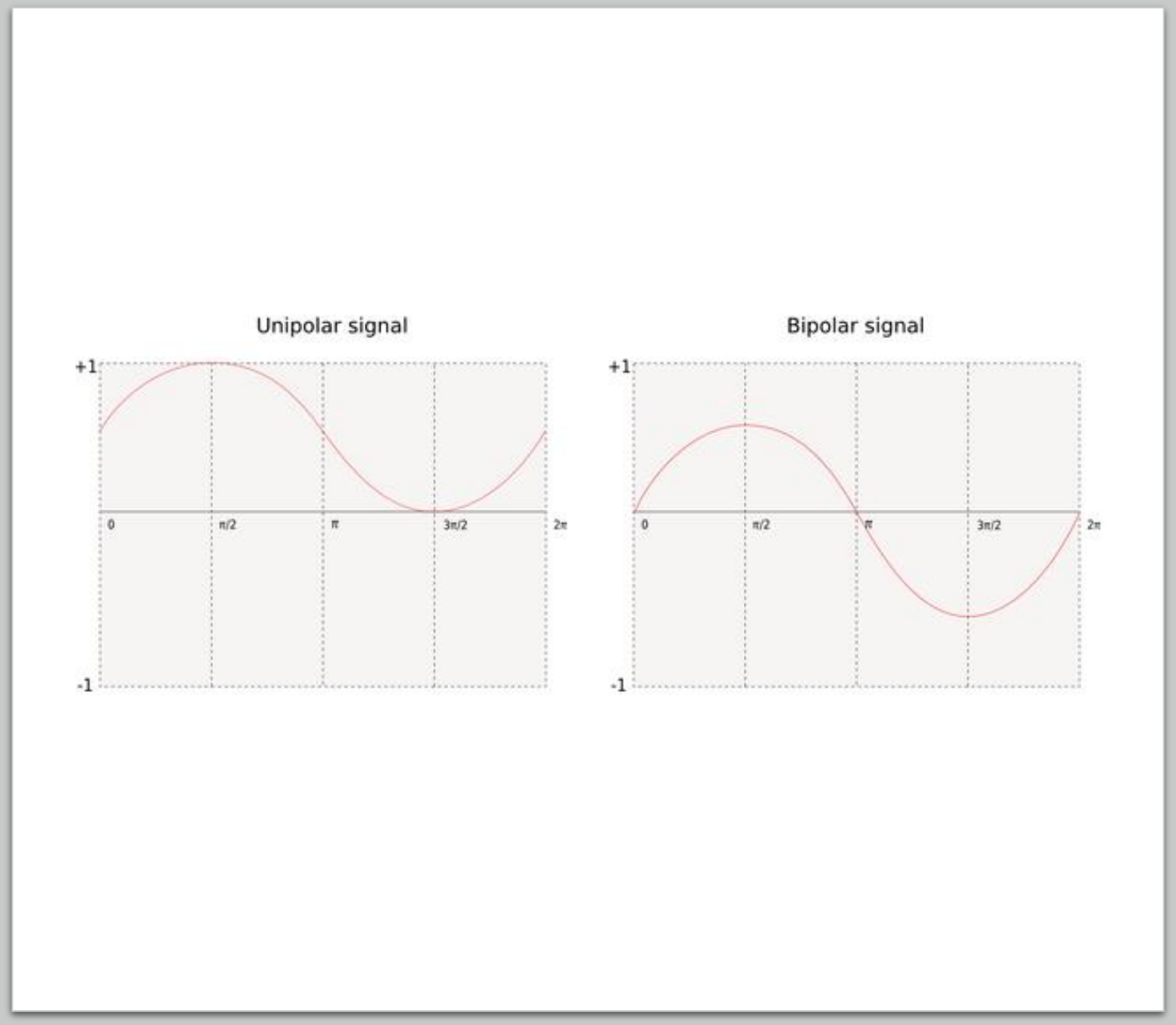
All of these are considered Modulators because they add:

- movement, width, depth, or change the character of the original sound.

Additionally, we can take an existing audio file (samples) and shape it and give it more movement (modulation)!

Modulation Synthesis

- **Bipolar and Unipolar Signals**
- **Rectifier**
- **Carrier Signal**
- **Modulator/ modulation signal**
- **Modulation Index**
- **Cross-modulation modules – Warps**



Amplitude Modulation

Where:

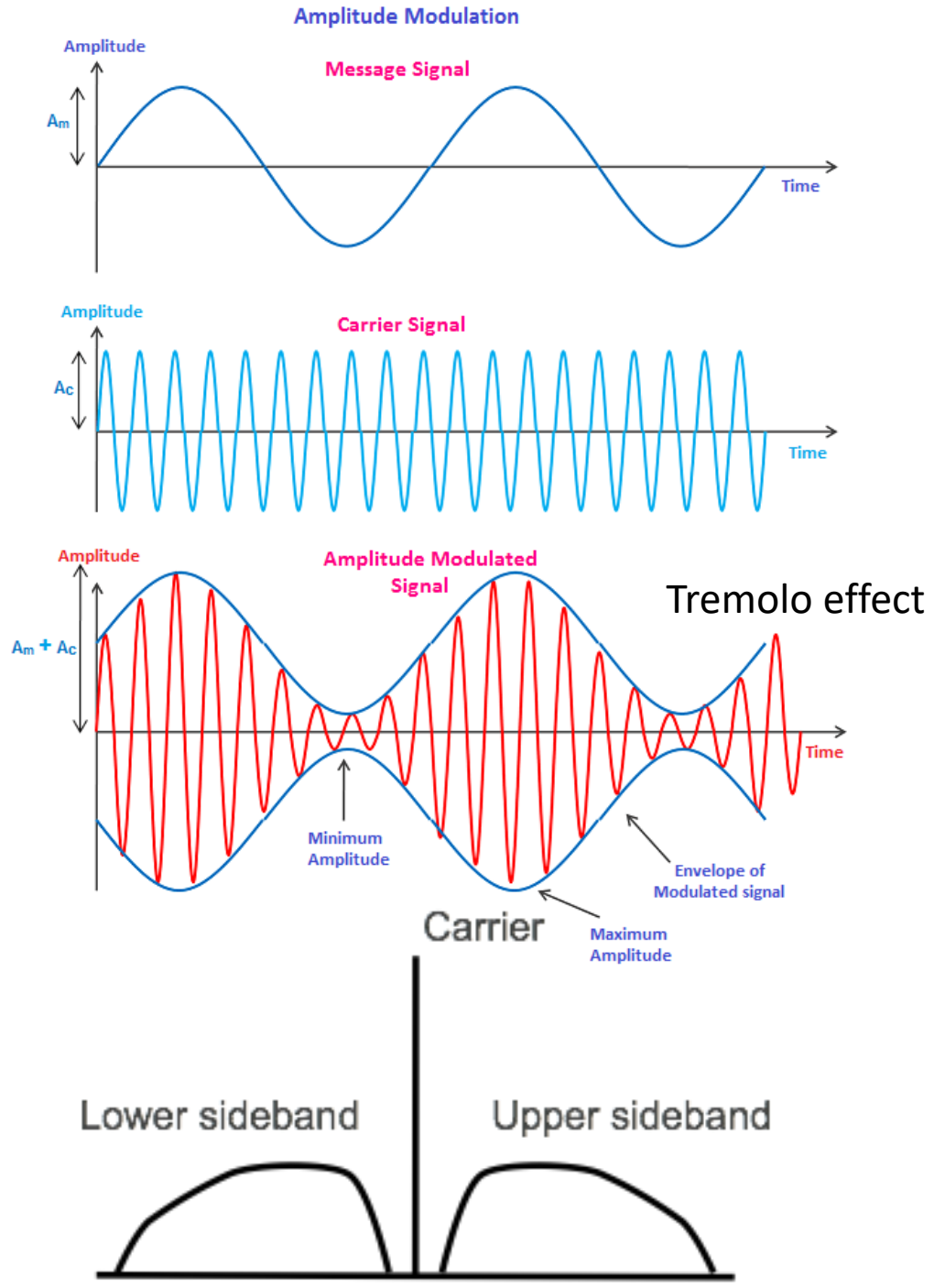
carrier frequency in Hertz is equal to ωc / 2 π
C is the carrier amplitude
ϕ is the phase of the signal at the start of the reference time

Where:

modulating signal frequency in Hertz is equal to ωm / 2 π
M is the carrier amplitude
ϕ is the phase of the signal at the start of the reference time

Where:

The constant A is required as it represents the amplitude of the waveform.

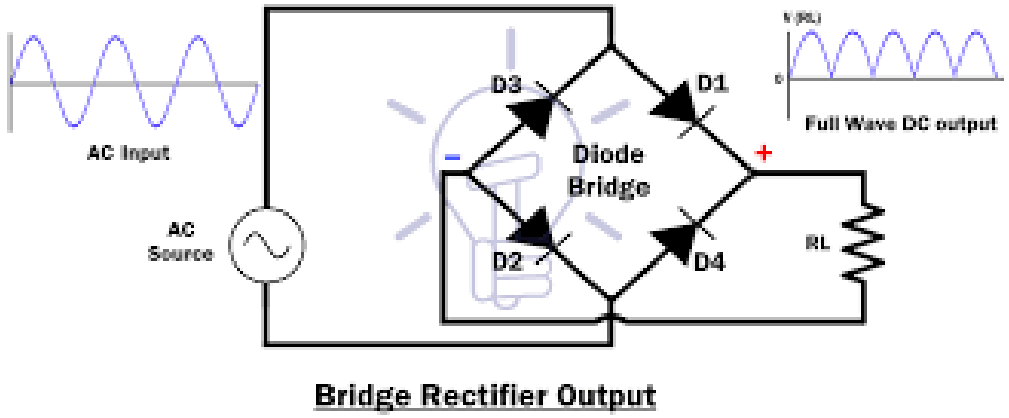


Ring Modulation

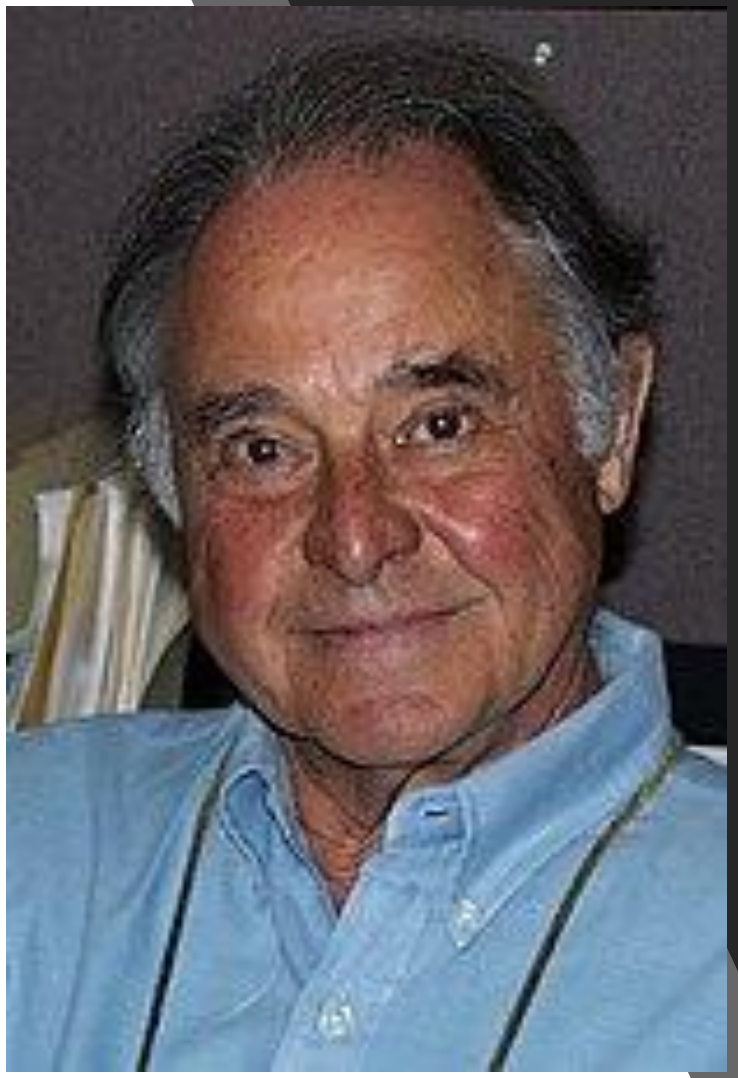
- A **ring modulator** is an electronic device for ring modulation. The function derives its name from the fact that the analog circuit of diodes. The circuit is similar to a bridge rectifier
- The difference with ring modulation is that neither of the input signals, carrier or program, appear at the output.

$$y = A_m \cdot cos(f_c) \cdot cos(f_m) = A_m \cdot \frac{cos(f_c + f_m) + cos(f_c - f_m)}{2}$$

- Convolution in the time domain is the multiplication in the frequency domain
- **convolution** is a mathematical operation on two functions (f and g) that produces a third function that epresses how the shape of one is modified by the other.
- Therefore, the output waveform contains the sum and difference of the input spectral components.



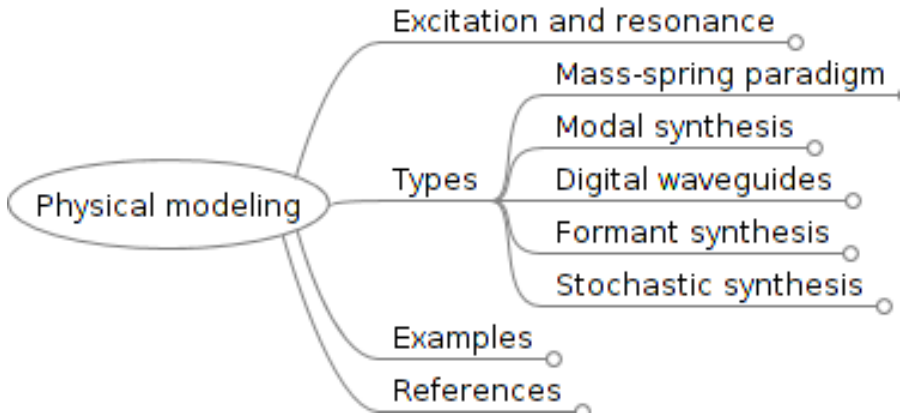
Fun Modules: https://www.modulargrid.net/e/tags/view/19



Frequency Modulation

- The FM-method published in 1973 by John Chowning (Born in 1937), the founder of CCRMA (Center for Computer Research in Music and Acoustics) at Stanford University, also the inventor of YAMAHA DX-7
- FM has the basic formula form $e=A\sin(\alpha t+I\sin\beta t)$
- where ***e*** is the deviation of the wave from its position of rest,
- ***t*** is time,
- A is the maximum deviation (amplitude)
- ***α*** and **β** are the periods (frequencies) of the carrier and the modulation waves, respectively.
- Vibrato Effect
- Multiple-Carrier FM
- Multiple-Modulator FM (parallel and series)
- Feedback FM: YAMAHA's patent to solve uneven amplitudes of the harmonic partials

Physical Modeling



- **Physical modelling synthesis** refers to methods in which the waveform of the sound to be generated is computed using a mathematical model, a set of equations and algorithms to simulate a physical source of sound
- The first commercially available physical modelling synthesizer made using waveguide synthesis was the Yamaha VL1 in 1994.
- A book of Physical Modeling https://ccrma.stanford.edu/~jos/pasp/
- Physical Modeling is computationally more expensive
- Source separation and high-order spectrum analysis
- Some basic concept: Interactions between Excitation (excitors: the cause of vibrations–non-linear) and Resonance (resonators: frequencies that are resonating thus producing unique pitch and timbre – usually is linear for acoustic instruments – it can be harmonical or non-harmonical). Damping, feedback, boundary conditions, initial state, impedence (the resistance of striking force), are also the common parameters for generating a *wave equation* for physical modeling
- Mass-spring paradigm for string instrument. (model synthesis)
- Karplus-strong Synthesis for plucked string and Drum