Frequency Modulation

Frequency modulation

Frequency modulation gives the waveform additional frequency components. Very complex periodic and nonperiodic waveforms, or waveforms with inharmonic relationships between the frequency components, can be established using this technique.

The modulation process

Frequency modulation, at its simplest level, is a process in which the waveform of one frequency is varied constantly through interaction with a second frequency. The frequency being modulated is called the **carrier frequency;** the one doing the modulating is called the **modulator frequency.***

When a tone is frequency modulated, additional frequency components, called **sidebands,** are added into the harmonic structure. These sidebands lie above and below the center frequency, each separated by an interval equal to the frequency of the modulator frequency. For example, an 880 hertz carrier wave modulated by a 220 hertz modulator wave has sidebands above and below the 880 hertz center frequency at intervals of 220 hertz each.

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* For a detailed discussion on the use of FM in sound wave synthesis, see John Chowning, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation" in *Journal of the Audio Engineering Society,* Vol. 21, No. 7 (1973), pp 526-534. Reprinted in *Computer Music Journal,* Vol. 1, No. 2 (1977), pp. 46-54.

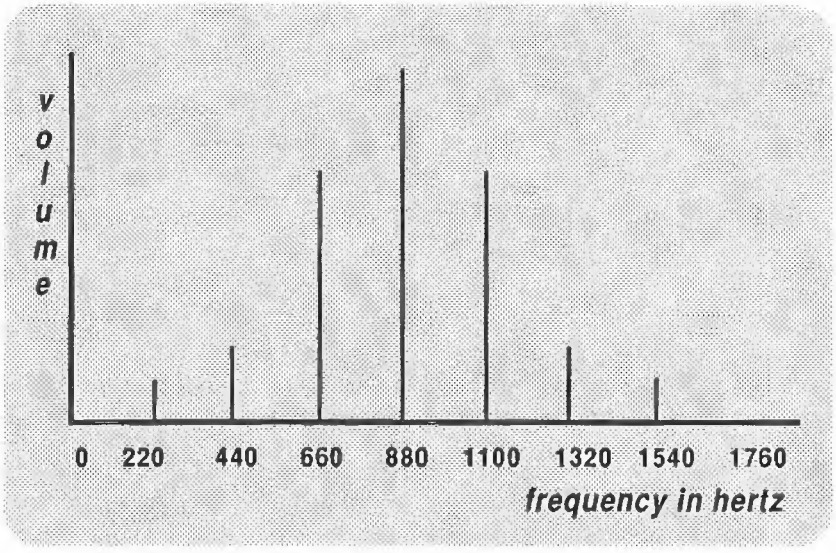


figure 3.1
Frequency spectrum of an 880-hertz sine wave modulated by a 220-hertz sine wave

Frequency modulation (con't)

Setting the modulating wave frequency

The first step in programming FM is to set the modulating wave frequency. This is usually set at a ratio to the carrier frequency.

1. Press the **f.m. ratio** button in the first panel.

2. Dial in a positive value (.01 to 16.00) with the control knob.

You can also press **f.m. ratio** repeatedly to set integer (whole number) ratios of 1.00 to 16.00.

Setting an integer ratio between the modulator and carrier frequencies produces sidebands that coincide with, and thus strengthen, the natural harmonics of the carrier wave.

A non-integer ratio produces sidebands that are inharmonically related to the carrier wave and clash with its harmonics.

Thus, small changes in the FM ratio (integer to non-integer or the reverse) may produce dramatic changes in tone color.

Setting a fixed modulator frequency

A fixed modulator frequency independent of the carrier frequency is set by pressing **f.m. ratio** and dialing in negative values (-0.1 to -999.9).

With a fixed modulator frequency, whether a partial timbre contains harmonic or inharmonic frequencies depends on the note played.

For example, with a fixed modulator frequency of 440 hertz, an A played on the keyboard has its harmonics reinforced by harmonically related sidebands. G, however, has inharmonic sidebands clashing with the harmonics.

Frequency modulation (con't)

The FM harmonic envelope

The number of **significant sidebands** (sidebands that affect the quality of the tone) depends on the **depth of modulation**, or volume of the modulator wave. The relative strength of each sideband is described by a set of mathematical functions known as Bessel functions. The basic theory states that

> as the depth of modulation increases, the strength of the carrier frequency decreases and the strength of the sidebands increases.

Compare, for example, the two frequency spectra of an 880 hertz sine wave modulated by a 220 hertz sine wave shown opposite. The volume of the carrier wave is the same for both waves, while the depth of modulation (volume of the modulating wave) is different for each wave.

Notice that the modulated wave on the top has a strong fundamental frequency (880 hertz) plus strong frequency components at 220, 440, 1320 and 1540 hertz. This means that the sound includes the two A's below the high A fundamental, plus the E and G above high A.

The modulated wave on the bottom, however, has an attenuated fundamental frequency with strong frequency components at 440, 660, 1100 and 1320 hertz. This means that the sound includes middle A, the E above high C, the C# above that and the G above that.

Each sound is distinctly different from the other.

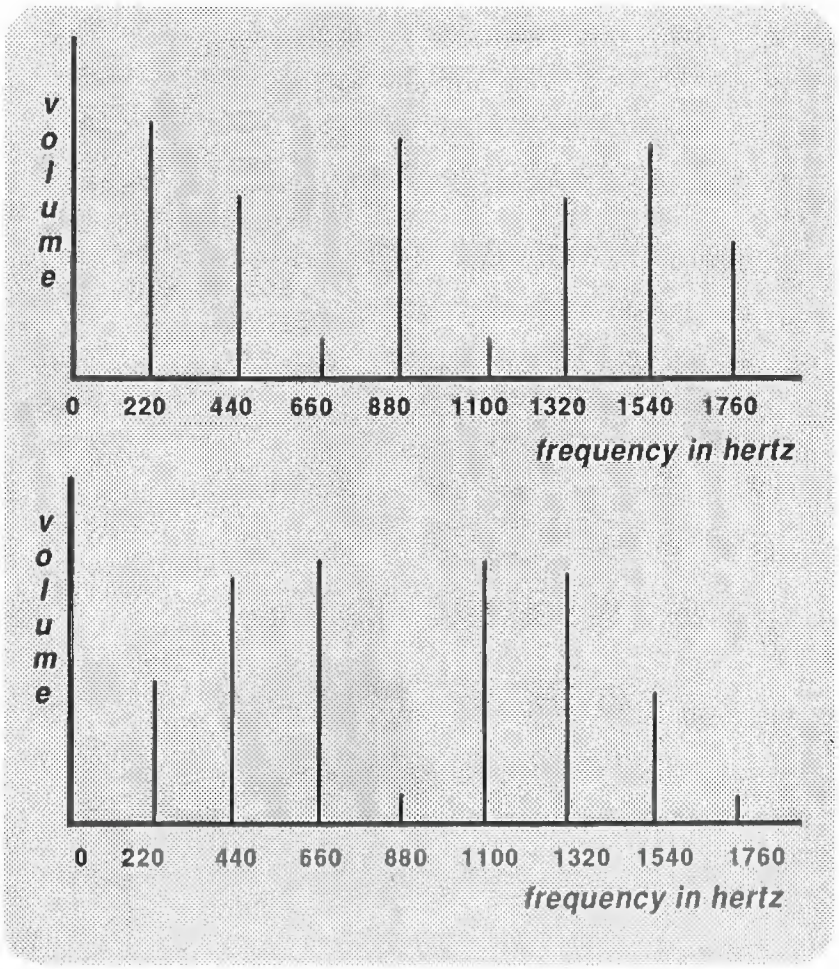


figure 3.2
Frequency modulated harmonic spectra

Frequency modulation (con't)

Creating a harmonic envelope

On the Synclavier, you control the depth of modulation by creating a **harmonic envelope (he)** which transforms a steady state modulator sine wave into a wave that varies in volume over time.

At zero depth of modulation, no sidebands are introduced into the harmonic structure of the carrier wave. At the greatest depth of modulation, the sidebands are at their strongest and the carrier frequency is attenuated. Thus, a frequency modulated tone varies from its original harmonic structure to a tone having additional FM generated harmonic components depending on the programming of the FM harmonic envelope.

You create a harmonic envelope by setting four time intervals and two volume levels.

Time intervals

delay	time from key depression to beginning of sound
attack	time from beginning of sound to peak volume level
initial decay	time from peak volume level to sustain volume level
final decay	the time from key release to end of sound

Volume levels

peak	relative volume of sound at the instant attack changes to initial decay
sustain	relative volume of sound from the end of initial decay to key release

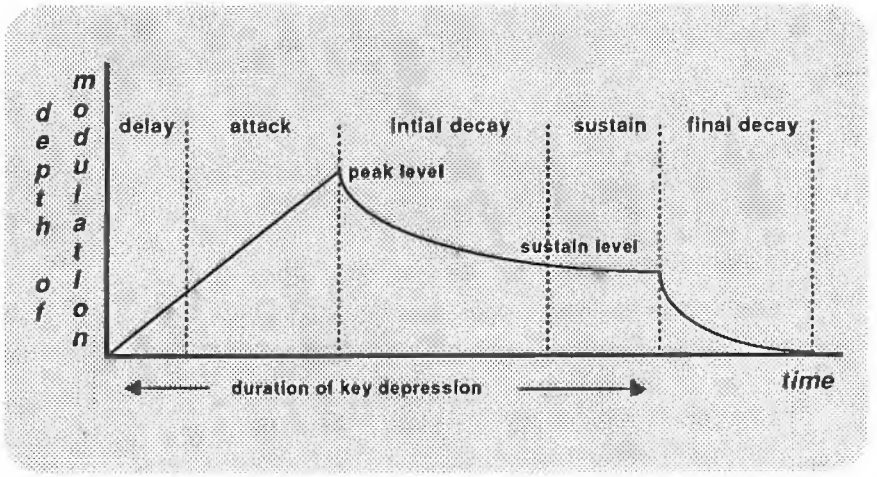
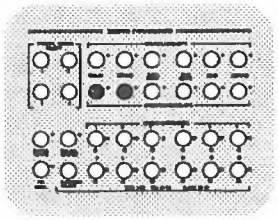
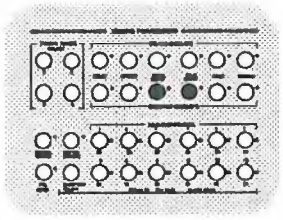


figure 3.3
Typical harmonic envelope

Frequency modulation (con't)



delay, attack
panel 1



initial decay,
final decay
panel 1

Setting the harmonic envelope time intervals

1. Select the partial timbre you want to change by pressing the appropriate **partial timbre select** button.

2. Press the **delay** button, if you want the FM to start after the key is depressed.

   The button lights.

3. Turn the control knob to select a delay time between 0 and 30,000 milliseconds.

   The values appear in the display window.

4. Press **attack** and turn the control knob to select an attack time between 0 and 15,000 milliseconds.

5. Press **initial decay** and turn the control knob to select an initial decay between 0 and 30,000 milliseconds.

6. Press **final decay** and turn the control knob to select a final decay between 0 and 30,000 milliseconds.

Setting the harmonic envelope volume levels

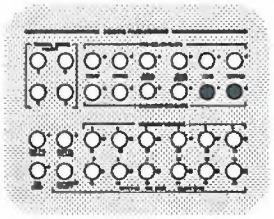
Once the time intervals are selected, set the volume levels.

1. Press **peak** and turn the control knob to select a volume level between 0 and 100.0. A zero setting gives no depth of modulation, a 100 setting gives maximum depth of modulation.

   The value appears in the display window

2. Press **sustain** and turn the control knob to select a sustain volume level between 0 and 100.0.

   The value appears in the display window.

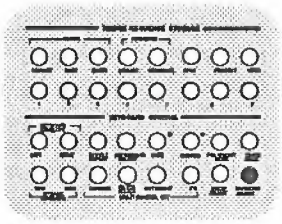


peak, sustain
panel 1

Adjusting FM across the keyboard

The harmonic adjust feature allows you to adjust the depth of modulation of a partial timbre across the octaves of the keyboard. You can create a partial timbre with strong FM sidebands on the bottom notes and very slight ones on the top notes, or vice versa.

With this feature, you can increase the brilliance of mushy lower notes without producing harshness in the upper notes. Timbres created from partial timbres programmed this way sound more consistent across the keyboard. The need for external equalization is reduced.



harmonic adjust panel 4

To activate the harmonic adjust function:

1. Press the **harmonic adjust** button in the fourth panel.

2. Turn the control knob to select an adjust factor between -30 and +30.

Dialing a positive number increases the sidebands gradually above middle C while decreasing those below. Dialing a negative number gives the partial timbre gradually more FM on the lower notes and less on the higher ones.

Changing the attack with FM initial decay

You will find the **initial decay** parameter particularly useful in controlling the depth of FM. If a partial timbre has an **he peak** level higher than the **he sustain** level, you can use the **initial decay** setting to lengthen a bright attack.

For example, try a sine wave with these settings,

he sustain	20
he peak	200
he initial decay	50
	50
	1000

If a partial timbre has a low **he peak** level and high **he sustain**, the **initial decay** setting can be set so that maximum brightness is reached gradually. Try the following settings:

he sustain	200
he peak	20
he initial decay	50
	500
	1000