Analyzing the Effects of Non-Sinusoidal Carrier Waves on FM Synthesis Using the LittleBits Synth Kit

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Abstract

Frequency modulation (FM) synthesis is a technique that causes interactions between a carrier and a modulating sound wave. Using the LittleBits Synth Kit, the effects of non-sinusoidal carrier waves and approximately sinusoidal modulating waves in FM synthesis was explored. The shape of the carrier wave determines the resulting synthesized waveform. The resulting spectrum is not centered around the carrier frequency, as predicted by FM synthesis models, but is centered around the second or third most dominant harmonic.

Synthesizing Sounds with the LittleBits Synth Kit

The LittleBits oscillator produces square or sawtooth waves with frequencies ranging from 32.7 Hz to 12,542 Hz. The LittleBits filter cuts off all frequencies above a certain point, which can range from 1 Hz to 18 kHz. When these components are combined, a sinusoidal wave is produced by cutting off frequencies above that of the oscillator. An example of this can be seen in Figure 2.

The envelope and random noise generator were previously studied. The LittleBits envelope shapes the attack and decay of the wave. Attack is how long it takes for the wave to hit its peak amplitude, and decay is how long it takes to get from its peak to the end of the wave. The random noise generator outputs white noise, a combination of all frequencies, which aided in the study of the filter.

Spectral Analysis

In order to study LittleBits components, sounds were recorded in Audacity at a 24 bit bit rate and 48kHz sampling rate [1]. Recordings were analyzed using Sonic Visualizer, which provides visualizations of the waveform and frequency spectrum [2]. The spectrum used Fourier analysis to identify frequencies present. The Fourier analysis was done with a window size of 8,192 samples and window overlap of 93.75%. Higher values for these parameters provide greater resolution in both frequency and time domain.

Frequency Modulation Synthesis

FM synthesis is a well understood sound synthesis technique. When a sinusoidal carrier wave is modulated with a sinusoidal wave, the resulting spectrum is centered around the carrier frequency C at multiples of the modulating frequency M, as seen in Figure 1 [3].

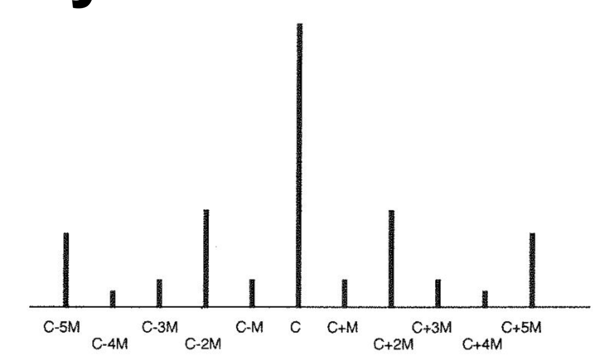

Figure 1: Model for frequency spectrum distribution around carrier frequency C at multiples of modulating frequency M, as depicted in *The Computer Music Tutorial* by Curtis Roads [3].

This study explores the interactions between a sinusoidal modulating wave and non-sinusoidal carrier waves. Combining the LittleBits oscillator and filter creates sinusoidal modulating waves, which is fed into the carrier frequency. The carrier frequency is either a square or sawtooth wave, which can be decomposed into a sum of sinusoidal waves. Figure 2 displays the experimental setup and the waveforms of the components.

FM Synthesis with Non-Sinusoidal Carrier Waves

Figure 3 shows waveforms and spectrums for different C:M ratios. The synthesized sound waves resemble the shape of the carrier frequency. The frequency spectrums are not distributed evenly around the carrier frequency, as the FM models predict. However, the expected distribution can be seen around the second or third most dominant harmonics. The harmonics of the non-sinusoidal carrier frequency, which is a linear combination of several sine waves, interact with the sinusoidal modulating frequency to produce novel frequency spectrum distributions.

Conclusions

Modulating a non-sinusoidal wave with a sinusoidal wave produces sound waves that differed from the simple FM synthesis models. However, the expected spectrum distribution can be seen around the harmonics of the resulting sound waves. Future work includes trying to find a mathematical model that can accurately predict the outcome observed in this study as well as repeating this experiment with two non-sinusoidal waves.

References

[1] Audacity(R) software is copyright (c) 1999-2014 Audacity Team. Web site: http://audacity.sourceforge.net/. It is free software distributed under the terms of the GNU General Public License. The name Audacity(R) is a registered trademark of Dominic Mazzoni.

[2] Chris Cannam, Christian Landone, and Mark Sandler, *Sonic Visualiser: An Open Source Application for Viewing, Analysing, and Annotating Music Audio Files*, in Proceedings of the ACM Multimedia 2010 International Conference.

[3] Roads, Curtis. *The Computer Music Tutorial*. MIT Press, 1996.

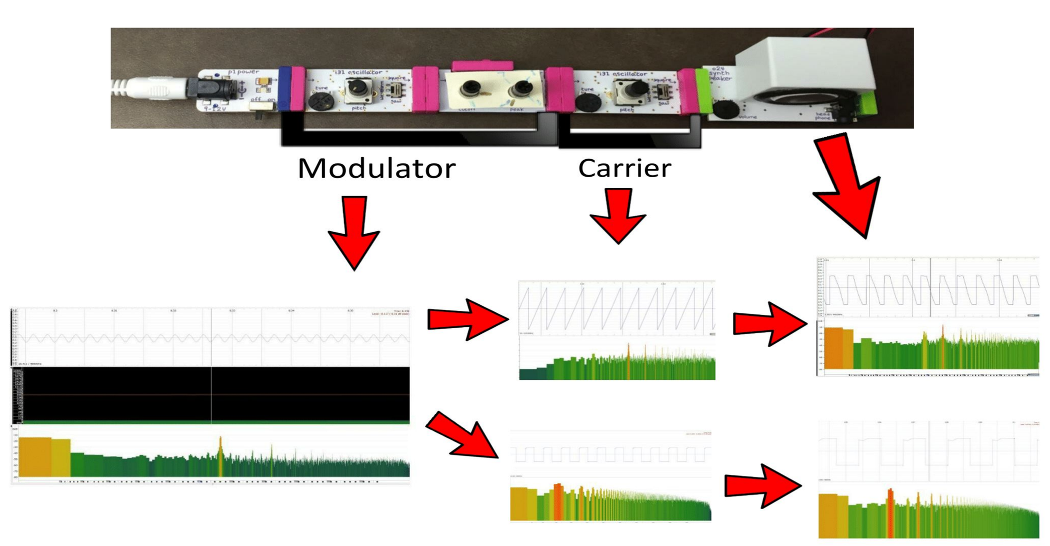

Figure 2: Experimental setup for combining sinusoidal modulator waves with non sinusoidal carrier waves.

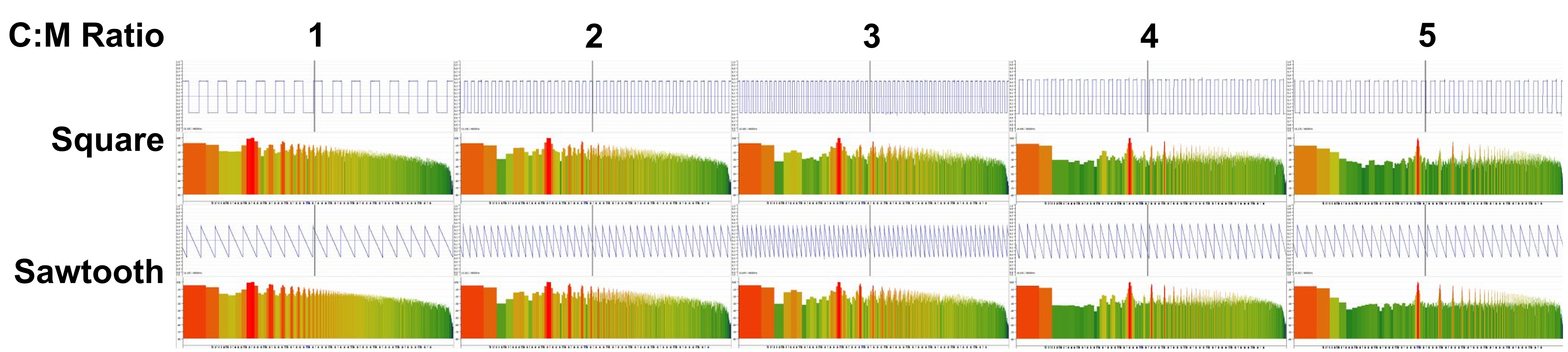

Figure 3: Waveforms and spectrums for square and sawtooth carrier waves and sinusoidal modulating waves. In each experiment, the modulating frequency M is set to 261.6 Hz. The carrier frequency C is adjusted to achieve different C:M ratios. When the C:M ratio is less than 5, the fundamental frequency is significantly lower than the carrier frequency.