Lab 3

In this lab we will explore the basic synthesis techniques of Amplitude Modulation (AM) and Frequency Modulation (FM).

Amplitude Modulation

The basic concept of Amplitude Modulation is that a function's magnitude will vary over time. Generally this refers to a sinusoid (although it could refer to more complicated signals), being scaled by another sinusoid. Since we're audio/music engineers, we like sinusoids, so we'll stick strictly with sinusoids. A general expression to represent a sinosoid can be expressed as

$$A * \cos(\omega t)$$

Suppose that A, rather than being a scalar, is a sinusoidal function. This means that you're changing the peak amplitude of your sinusoidal signal over time. Convention is to call this function the modulator signal because it modulates the amplitude function over time. The signal being modulated is called the carrier signal. So our carrier signal is

$$A_c \cos(\omega_c t)$$

and the modulator is

$$A_m \cos(\omega_m t)$$

So the overall Amplitude modulation formula looks like this:

$$AM = [A_c + A_m * \cos(\omega_m t)] * \cos(\omega_c t)$$

For more info, check out the wikipedia article at: http://en.wikipedia.org/wiki/Amplitude_modulation

Frequency Modulation (FM)

Much like Amplitude Modulation, FM is a carrier signal whose frequency is modulated over time (usually by a sinusoid). Suppose your carrier signal was a sinusoid. It would look something like this:

$$A_c \cos(\omega_c t)$$

Exactly the same as with AM. However, this time, rather than modulating A_c, we're going to modulate ω_c by

$$A_m \cos(\omega_m t)$$

Giving us the overall equation

$A_c\cos([\omega_c + A_m\cos(\omega_m t)] t)$

This time you'll notice that increasing the amplitude A_m does not increase the amplitude of the overall signal. This is referred to as your modulation depth, and you can have a much higher modulation depth with FM than you can with AM. Try playing around with your modulation depth to see how different it sounds.

NOTE: You will need to use the same method that we used in Lab 2 for a dynamically changing frequency value.

Assignment

When completing the following problems, use the magPlot function to plot the magnitude spectrum. You can see information on the usage simply by typing "help magPlot" in the command window. NOTE: You must copy the file into your current working folder.

Problem 1: Amplitude Modulation

A. Write Matlab code that creates AM synthesis with a 500Hz carrier signal and a 200Hz modulator signal. Plot the magnitude spectrum (frequency domain), and hear the output sound. Save the sound to a .wav file using wavwrite(). Try different values for the carrier and modulator frequencies. Note: in general, the carrier frequency is significantly higher than the modulator frequency.

B. Write Matlab code that creates AM synthesis with a 700 Hz carrier signal and a modulator signal that sweeps from 50 Hz to 400 Hz. Listen to the output signal and save it to a .wav file. **Note: Be sure to use the swept frequency technique discussed in Lab 2.** Given what you observed about the spectrum in Part A, what do you think is happening as we increase the frequency of the modulator signal?

C. Write Matlab code that creates a tremolo like effect using an audio wav file as the carrier signal and a sine wave with a frequency below the audio range (<20 Hz, i.e. 6Hz) as the modulator signal. Plot the output signal and hear the output sound. Save the sound to a .wav file using wavwrite(). NOTE: This effect is best heard when the "carrier" sound is fairly continuous.

BONUS. Experiment on your own and try to find the relationship between the frequency of the carrier, the frequency of the modulator, and the resulting spectrum. How do the amplitude of the carrier and the amplitude of the modulator affect the spectrum?

Problem 2: Frequency Modulation

Note: When plotting the waveform, please only show a few periods, so that the shape of the waveform is clear.

A. Synthesize an FM signal whose carrier frequency is 900 Hz and modulator frequency is 600 Hz. Use a modulator depth (A_m) of (1200 Hz). Plot the waveform, magnitude spectrum, and save the signal to a .wav file. What instrument does this sound like?

B. Who invented FM synthesis as a musical tool? Cite the paper where he/she first published his/her findings.

C. Synthesize an FM signal whose modulator depth sweeps from 0 to 4000 Hz. Save the signal to a .wav file.

D. Be creative and find a set of parameters that sounds interesting/cool/crazy. Save the signal to a .wav file.

BONUS. According to the paper you found in Part B, how might we modify the parameters in Part A to get a brass-like tone?

BONUS. What are some of the advantages of FM synthesis as compared to methods that were used previously?

Submission Notes

- Be mindful of which plots I do or do not ask for in each part, some problems only need a wav file.
- For plotting the spectrum you will need to use the magPlot function.
- Please limit wav files to only a few seconds.
- Please include your MATLAB code either as .m files or as part of the write up.
- Plots should be exported as .png files using the "Save As" command, NOT as screen shots.

In your write-up, explain what you did and what problems (if any) you encountered while writing your code.

<u>Lab 3</u>

Nate Paternoster 9/25/13

Code:

```
fs = 44100;
ts = 1/fs;
tfinal = 4;
t = 0:ts:tfinal;

%1a)

wm = 200*2*pi;
wc = 500*2*pi;
y = (1+cos(wm*t)).*cos(wc*t);
magPlot(y,fs,'Magnitude spectrum');
sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-1(a).wav');

%1b)

f = linspace(50,400,length(t));
dtheta = 2*pi*f*ts;
theta = cumsum(dtheta);
ym = cos(theta);
wc = 700*2*pi;
y = ym .* cos(wc*t);
sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-1(b).wav');

%1c)

yc = wavread('121030__thirsk__130-rhodes-1.wav',(fs*4)+1);
                %the second parameter sets the number of samples
played. fs
                %times the number of seconds it's played plus an extra
                %sample
yc = (yc(:,1)+yc(:,2))/2;
yc = yc';
wm = 10*2*pi;
ym = cos(wm*t);
y = ym.*yc;

magPlot(y,fs,'Magnitude spectrum');
sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-1(c).wav');

%2a)

wc = 900*2*pi;
wm = 600*2*pi;
Am = 1200*2*pi;
w = wc + Am*cos(wm*t);
dtheta = w*ts;
theta = cumsum(dtheta);
y = 0.5*cos(theta);
```

```
magPlot(y,fs,'Magnitude spectrum');
sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-2(a).wav');

%2c)

wc = 900*2*pi;
wm = 600*2*pi;
Am = linspace(0,4000,length(t));
w = wc+Am.*cos(wm*t);
dtheta = w*ts;
theta = cumsum(dtheta);
y = 0.5*cos(theta);

sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-2(c).wav');

%d)

wc = 450*2*pi;
wm = 15*2*pi;
Am = 100*2*pi;
w = wc+Am.*cos(wm*t);
dtheta = w*ts;
theta = cumsum(dtheta);
y = 0.8*cos(theta);

sound(y,fs);
wavwrite(y,fs,'NatePaternoster-Lab3-2(d).wav');
```

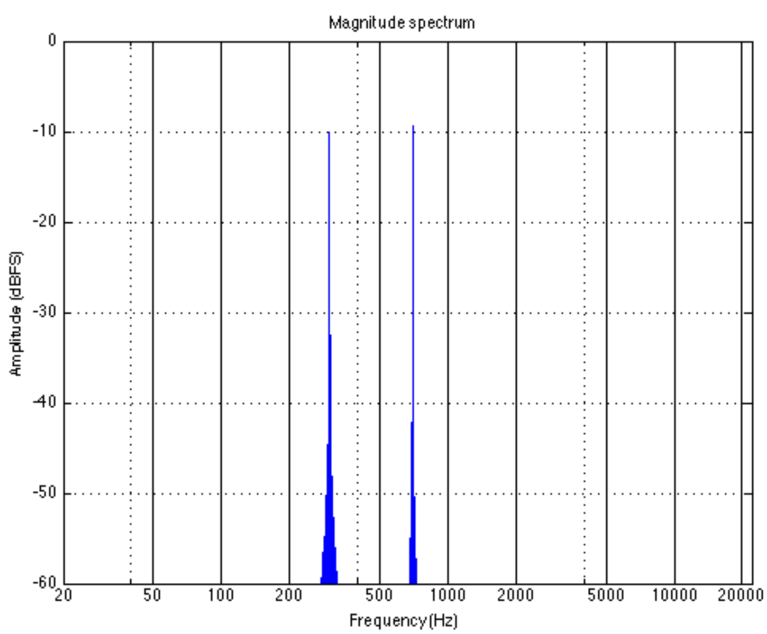

Figure 1.a – AM synthesis using a 500Hz carrier and a 200Hz modulator

1b) As we increased the frequency of the modulator signal, the distance between the carrier signal's frequency and the modulator's signal frequency increased. Therefore, as the modulator's frequency rises, the carrier's frequency drops.

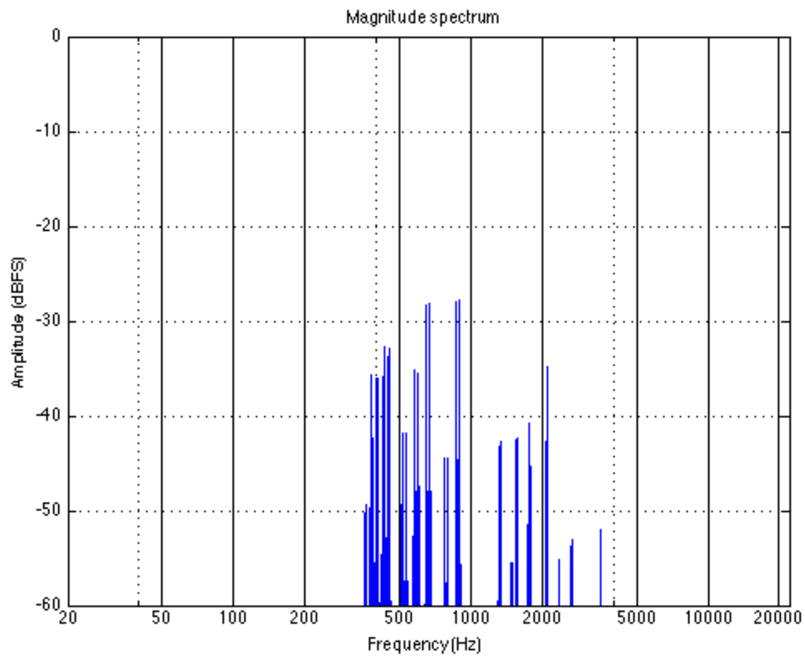

Figure 1.c – A tremolo effect demonstrated on a Rhodes keyboard sample

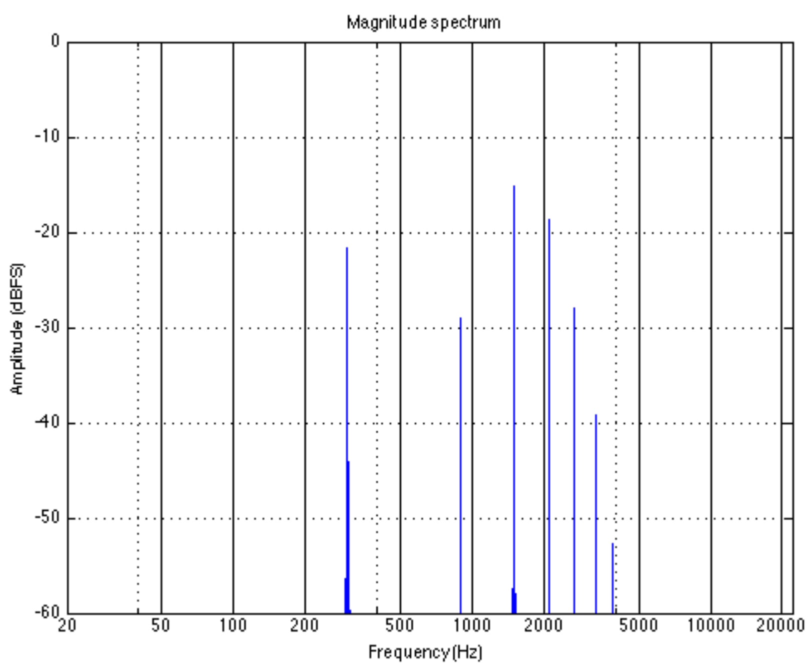

Figure 2.a – FM synthesis using a 900Hz carrier, 600Hz mod frequency, and 1200Hz mod depth

2a) This signal sounds very similar to a clarinet.

2b) The inventor of FM synthesis as a musical tool, John Chowning, wrote an important paper on the topic that was cited in Dodge & Jerse 1997 p. 115). His technique of using digital implementation of frequency modulation as a musical tool was patented in 1975 and later licensed to Yamaha.