

Lab 2 – Periodic Signals – Triangle and Square Waves

EQUIPMENT and PREPARATION

- Computers
- Know how to screen snap so that images can be sent home by students.
- Headphones
- Microphones + Preamps + cables and associated connectors, adaptors and cables. It should be possible to record sound into the computer using Adobe/Audition. **Do a record sound check on all computers!**
- Microphone stands
- Musical instruments and/or sound-making devices
- Pasco open speakers
- Oscilloscopes, and way to connect speaker to oscilloscope (BNC to banana adapter + banana plug cables)

Warning: do not place speakers near oscilloscope screens as they can damage the CRT screen.

INTRODUCTION

In this lab we explore the gap between electronics and music by generating and observing signals while listening to them. We will explore the relation between the shape (waveform) of a sound, its spectrum and the timbre or character of the sound. We will have the chance to create some sounds of our own and record them onto the computer. The computer software lets us look at sound waves as a signal as a function of time (waveform view) and as in terms of their frequency distribution (frequency or spectral view). To do compute the spectrum we will use the algorithm known as the Fast Fourier Transformation (FFT). The FFT is an efficient computational algorithm that breaks down a signal into a number of basic sine waves of specific frequencies.

In this lab we will become familiar with the Adobe-Audition audio software.

Triangle, square and sine waves are all periodic signals. In this lab we will find that periodic signals have frequency spectra with particular properties (integer harmonics). We can record our voice and music instruments and will find that the spectra of these sounds have similar properties to the periodic signals generated by a function generator.

PROCEDURE

Part I – Setup

1. Make sure the computers are on.
2. If there is a lot of noise in the room, you can use headphones by unplugging the speakers and connecting the headphones into the speaker jack. If you are using speakers connected to the computer, make sure they are turned on (turn the knob on one of the small speakers).
3. Make sure that your microphone is connected to the preamp and that the preamp is plugged in. The green power indicator should light up. The +48V button should be pushed in. This is to power the microphone that employs a capacitor. The capacitor creates an electric field between two plates. The plates respond to small pressure variations (such as those made by sound waves) creating a signal that is amplified by the preamp and passed on to the computer where it is converted into digital format. Powered microphones are usually superior to un-powered ones.
4. Make sure that the preamp is connected to the computer through the preamp's output jack and the computer's input microphone jack.

Physics of Music PHY103 Lab Manual 2011

5. Run the application Audition on the computer by double clicking the AU icon.

Part II – Looking and Listening (triangle, square and sine waves)

In this part of the lab you will generate tones using Adobe-Audition, you will view their waveforms and listen to their sound.

1. Click the generate menu and choose TONES. The first time you do this a window titled “New Waveform” will come up. Set the sample rate at least at 48000Hz. Set the Channel to “MONO”. Set the Resolution to at least 16 bit. Then click OK.
2. In the box labeled “Presets” choose a A440 default.
3. On the bottom right, set the duration to 1.0 seconds.
4. Just above that, in the box labeled “General”, chose a “flavor” of “Sine”. The flavor is the type of waveform created. You can listen to this by clicking “Preview”. Click OK. Now you have a wave.
5. Click on the wave you have created and hit the key on your keyboard labeled “END”. This will send the cursor to the end of your sound file. You will now create two mores sounds with the same pitch.
6. Repeat step #4 with a flavor of “Triangle/Sawtooth”. Repeat step #5.
7. Repeat step #4 with a flavor of “Square”. Hit the “Home” key on your keyboard to place your cursor at the beginning of the file.
8. You now have 3 one second waves. Click on the green right arrow key (bottom left) to play the sounds. You can adjust the volume with the volume icon on the computer on the lower right or with the knob on one of the speakers.
9. Describe in your notebook your perception of these sounds.
10. Looking at the waveforms. Left click on the waveform somewhere. Use the magnifying glass button (top row, on bottom of screen, circle with a + sign in it) to expand the x-axis. Take a closer look at the waveforms. You can play the sounds again while watching the waveforms move by hitting “Home” and then play. You can click and drag the green bar above the waveform to view different parts of the wave. You can also expand the horizontal axis by right clicking and dragging. To zoom out: right click on the axis and choose “Zoom full.” The button with a circle and a - sign will also allow you to zoom out.
11. Draw in your notebook, the shape of the waveforms (including labeling the x and y-axes) or send yourself a snapped view.

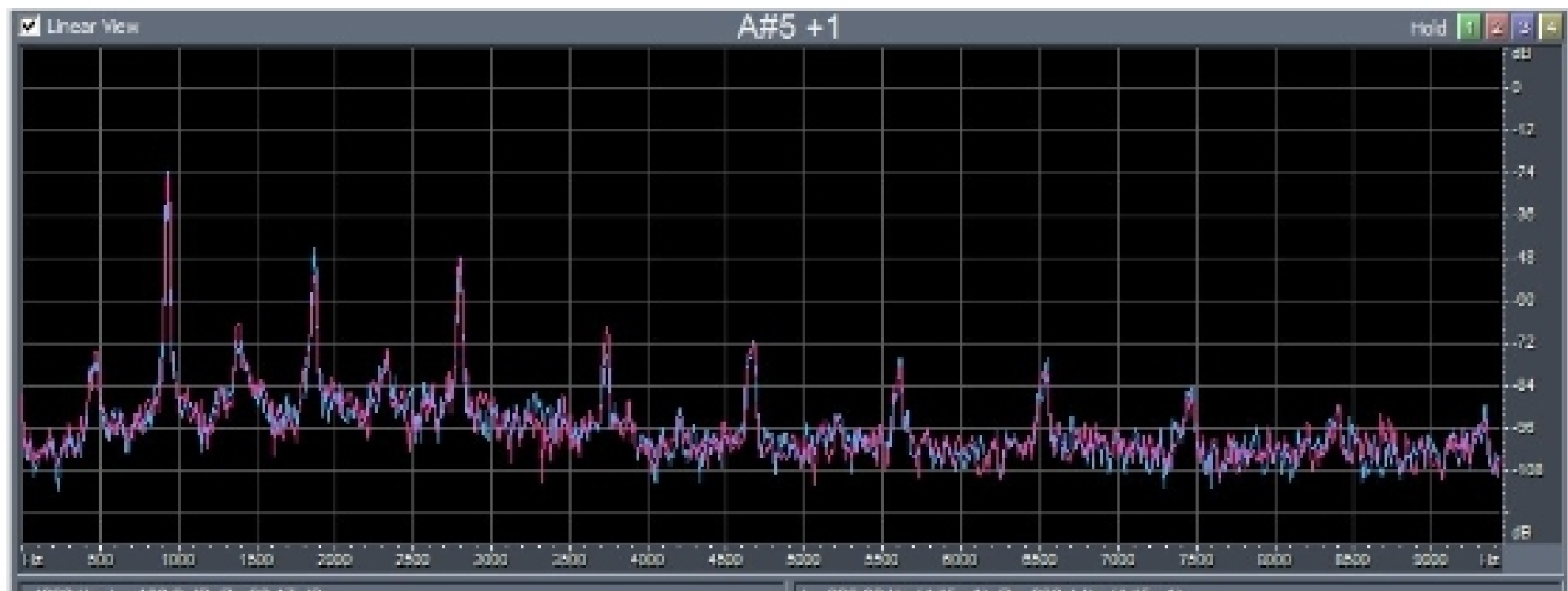


Figure 1. Above is a spectrum of a flute playing note A#5. Each peak is an overtone (partial or harmonic). The vertical scale is in dB, or $20\log_{10}$ (amplitude) or $10\log_{10}$ (power). You can measure the strengths of the overtones from the strengths of each peak. The fundamental is at about 932 Hz, the first harmonic is at about twice this at 1900Hz and is weaker than the fundamental. Notice that 1900Hz is about twice as big as 930Hz. The note played is A#5 (the A# in the octave above middle C) but actually the lower octave A# is also weakly excited and you see some A#4 in the spectrum corresponding to peaks at 466 and 1400Hz.

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You can adjust the x-axis of the spectral window to make a better measurement of the frequencies of the peaks. The y-axis here is in dB which means decibels. This is a logarithmic scale (note the negative numbers!). A small change in dB represents a pretty big change in power. A change of 10 dB is a factor of 10 in power. The first few overtones are strong and narrow and so will allow both an accurate frequency measurement and strength measurement. The higher overtones are weaker and so harder to measure. The uncertainties in their measurements will be larger than the lower overtones.

Screen shots. If you would like to save images that you can later put in your lab report you can save a screen shot with the following procedure: Simultaneously hold the keys Command-Shift-4. Then select the area you would like to snap by left-clicking and holding the mouse. When you release the left button the image will be saved to your Desktop. You can convert to other image formats (such as PDF or GIF) by doubling clicking on the image and saving it (save as).

Audition 5.5 notes:

To see a spectrogram click on View → Show Spectral Display.

To see a single spectrum click on Window → Frequency Analysis

To record a new file click on File → New → Audio File then choose Mono.

Most of the time we will be working in Waveform not MultiTrack mode (upper left).

The window size (resolution) for the spectral display can be adjusted in Audition → Preferences.

Part III – Frequency Analysis

You can now learn to use a tool that enables you to look at the frequencies in the sound wave. This tool will give you a graphical representation of the fundamental tone and its harmonic frequencies.

1. Click on **Window** → **Frequency Analysis**. Click on “Advanced” (if not already set to this) to bring up more options. Set the FFT Size to an intermediate resolution of 4096.
2. Left click on your waveform window in the middle of a region showing one of your generated waves. The frequency analysis window should now be showing the spectrum of that region.
3. Using the right mouse button, in the frequency analysis window, click on the horizontal rule at zero Hz and drag to 1000Hz. This allows you to see the frequency distribution between 0 and 1000Hz. Your ear is sensitive past this to 20,000 Hz but most musical tones are well below this. For example concert A is at 440Hz. Expanding the x axis to between 0 and 1000Hz will allow you to measure the amplitude and frequency of the fundamental mode.
4. If you right click on an axis and zoom out you will be able to see more overtones. If you generated a tone that is 440Hz, twice this would be 880Hz and three times this would be 1320Hz. Look in a region from 0 to 10000Hz. Are the overtone frequencies integer multiples of the fundamental? Odd integers? Even integers? Exact integers?
5. In the waveform window, click on different regions of the sound file. Look at the different frequency spectra for the sine wave, the triangle wave and the square wave. Draw the frequency spectra that you see, or save/snap images of them that can later be placed into your lab report.
6. Click on a peak in the frequency analysis window. The frequency of this spot should appear on the lower left in the frequency analysis window. Record the frequencies and strengths of the fundamental and overtones for each waveform. Are the overtones integer multiples of the fundamental and if so which integers? Write down the strengths of the overtones. The y-axis of this window is dB or decibels which is a log scale. Don't be concerned if you have negative numbers as a decibel is a log scale and the log of a small number is negative.
7. Compare the strengths of the harmonics or overtones between the different sounds. Are there overtones in each sound? Are the overtones at the same frequencies for the triangle and square wave? Are they the same amplitudes (strengths)?
8. Experiment with the FFT. What happens to the spectrum as you change the FFT size or window length? What happens to the spectrum as you change the window function? Is there a relation between precision and FFT size? If the FFT length is too long then different notes can run together.