2 Laboratory exercise

2.1 Fourier Transform

Your scope is capable of displaying the Fourier transform of its input signal. We have already used this feature in Lab 3 in "observing" the Fourier coefficients of periodic signal inputs. In this section we will learn how to examine non-periodic inputs in the frequency domain.

1. No circuit is used for this part of the laboratory. Connect the "W" pin (signal generator output) to the "1" pin (Channel 1 input) and connect both grounds.
2. To generate the "non-periodic" square wave from Signal Generator in Scopy, you will play the recorded square wave signal from .wav files made by TAs.
   - Download the complimentary files from ECE 210 webpage and unzip it.
   - In the Signal Generator module, select "Buffer" and click "Load file", then select the .wav file named "square.wav" from the complimentary files.
   - Set the Amplitude to 1 V , SamplingRate to 5 Mhz, and 0 for Offset and Phase. The setting should be similar to Figure 3.
   - Click "Run" to start generating the signal.
   - Go to the Oscilloscope module, set the Time Base as 500 µs and click "Single". Zoom in the signal by selecting a smaller region in the display panel, you should see some clear "rectangles" that periodically repeat but with large intervals, similar to Figure 4.

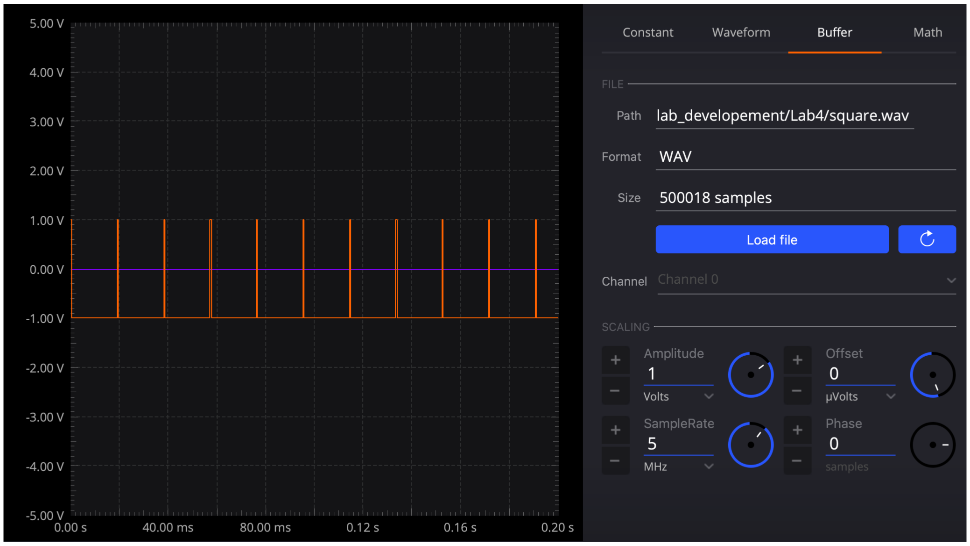


Figure 3 – Buffer panel for loading the recorded square wave

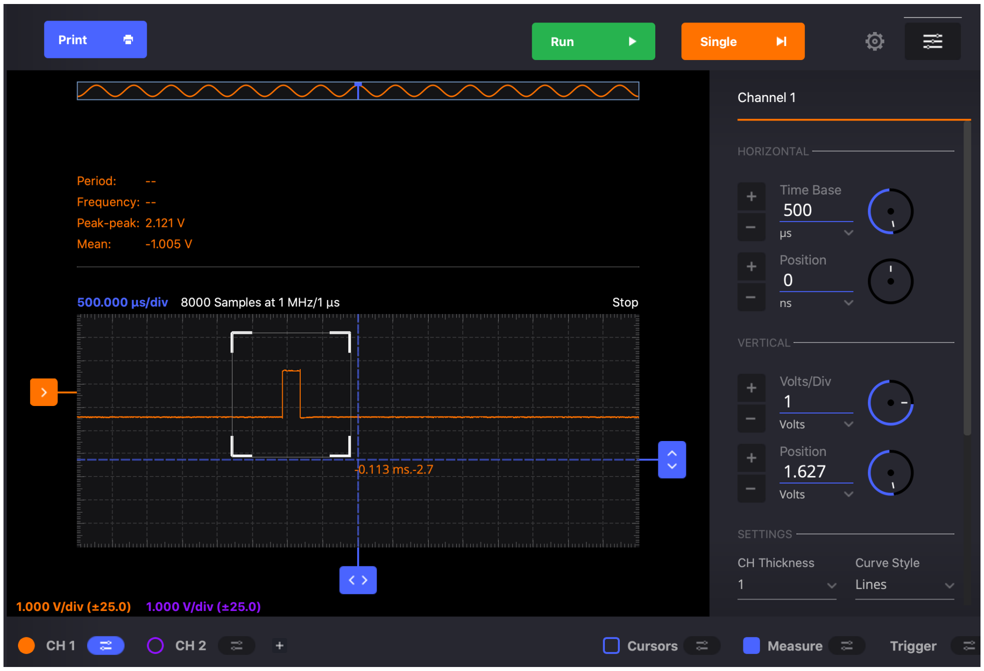


Figure 4 – Select the rectangle waveform and zoom in

- Next, measure the rectangle width τ choosing an adequate time scale (zoom in):

$\tau =$ 0.3ms	(____/2)

3. Go to the Spectrum Analyzer module and adjust the Sweep settings to the following:

   - Frequency Start at 1 kHz, Stop at 50 kHz
   - Resolution BW at 97.66 Hz
   - Units of dBV as shown in Figure 5.

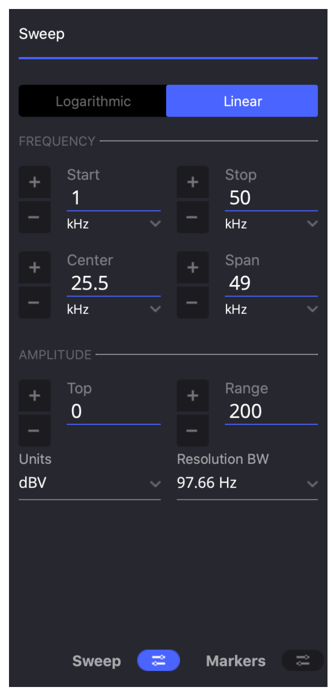
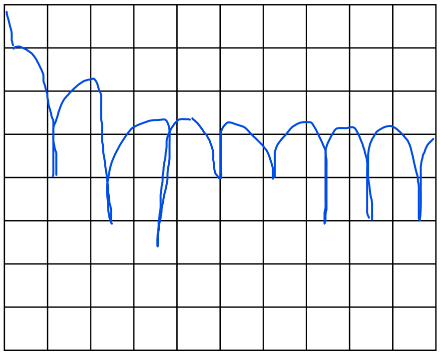


Figure 5 – Settings for Sweep panel in Spectrum Analyzer

4. Sketch only the frequency spectrum $|F(\omega)|$ (in dB) of the Spectrum Analyzer and compare with theory (Hint: look back to Problem 4 in the Prelab).



Span : 50kHz Center : 25kHz Scale : 20kHz (____/2)

Write down the Fourier transform pair:

rect(t / tau) <> tau*sinc(w*tau / 2)

(____/2)

Compare the obtained spectrum with the theoretical expectation:

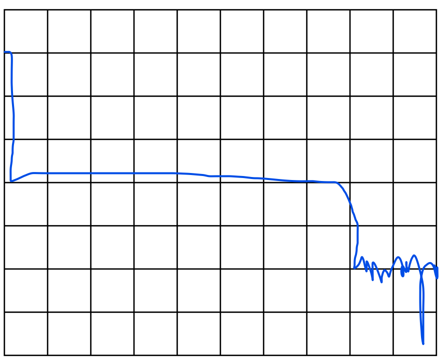
The spectrum analyzer output is similar to the sinc function from the prelab, with the zeroes located at approximately the same points predicted

(____/2)

5. Now, let's examine the Sinc function. Load the file with name "sinc.wav" from the complimentary files in the Signal Generator module under "Buffer" tap. Use the same setting as used for the rectangular signal. Go to the Oscilloscope and focus on one Sinc function after zooming in, estimate the time difference (ΔT) between the immediate zero-crossing surrounding the main lobe of the sinc function and calculate the corresponding value of W (Be aware of the DC offset of the signal, the "zero" to the sinc function is not exactly at zero).

$\Delta T =$ 60 micro sec	(____/2)	$W =$ (2*pi) / (60 * 10^-6) $\frac{\text{rad}}{\text{s}}$	(____/1)	$W =$ 1 / (60 * 10^-6) Hz	(____/1)

6. Go to the Spectrum Analyzer module and adjust the Sweep settings as shown in Figure 5. Then compare with theory.



Span : 25kHz Center : 12.5kHz Scale : 10dB (____/2)

Write down the Fourier transform pair:

sinc(Wt) <> (pi / W) * rect(w / (2W))

(____/2)

Compare the obtained spectrum with the theoretical expectation:

The spectrum output closely matches the predicted output, right up until the frequencies cannot be distinguished from the noise of the circuit system. The spectrum ends around the 19kHz / 20kHz mark, and is very similar to the prediction.

(____/2)

2.2 AM Signal in Frequency Domain

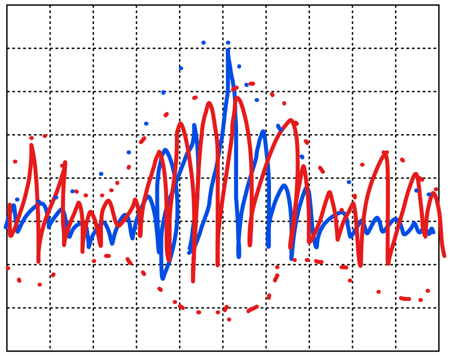
Amplitude Modulation (AM) is a communications scheme that allows many different message signals to be transmitted in adjacent band-pass channels. Before the message signal is multiplied by the high-frequency sinusoidal carrier, a DC component is added so that the voltage of the message signal is always positive. This makes it easy to recover the message signal from the envelope of the carrier. In Lab 1, you synthesized an AM signal with the function generator and then displayed it on the oscilloscope in the time domain. Let's see how the AM signal looks in the frequency domain. The two recorded AM signals use some single frequency sinusoid as message signal and 13 kHz sinusoidal carrier. (Hint: Use the modulation property to interpret what you will see on Oscilloscope module):

1. No circuit is used for this part of the laboratory. Connect the "W" pin (signal generator output) to the "1" pin (Channel 1 input) and connect both grounds.

2. In the Signal Generator module, load the .wav file named "Sine_modulation.wav",set the Amplitude to 1 V , SamplingRate to 1 Mhz, and 0 for Offset and Phase.

3. Go to the Spectrum Analyzer module and adjust the Sweep settings as in Figure 5.

4. Sketch both, the time domain AM signal and its frequency spectrum and explain what you see in terms of the modulation property of the Fourier transform. (Hint: What is the frequency spectrum of the message signal (co-sinusoid of 880 Hz) plus a DC component in base band, i.e. before modulation?)



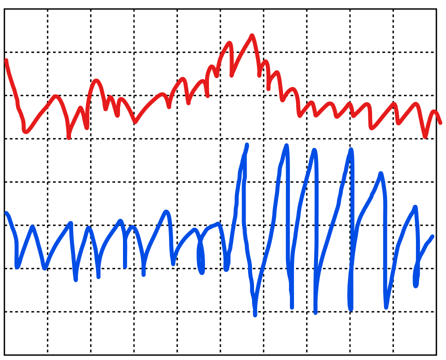
Span : 15kHz Center : 12.5kHz Scale : 10 dB

V/div : 1/6 t/div : 50 micro sec. (____/2)

Explain the shape of the frequency spectrum. (____/4)

The frequency spectrum has a shape of three delta functions, and is symmetric around the 12.5Khz center

5. Then, in the Signal Generator module, load the .wav file named "Square_modulation.wav." Set the Amplitude to 1 V , SamplingRate to 1 Mhz, and 0 for Offset and Phase.. Sketch the AM signal in time domain and its frequency spectrum and explain what you see. (Hint: Remember the Fourier analysis of the square wave performed in Lab #3.)



Span : 15 kHz Center : 13 kHz Scale : 15 dB

V/div : 0.5 t/div : 100 micro sec. (____/2)

Explain the shape of the frequency spectrum. (____/4)

The signal decays in a manner similar to the sinc function as it travels away from the 13 kHz mark.

2.3 AM Radio Receiver

The most popular AM communications receiver is the superheterodyne receiver, which was developed for greater sensitivity and selectivity. A block diagram for the superheterodyne receiver is shown in Figure 6.

The antenna, RF amplifier, and frequency mixer all rely on electrical components not covered in the textbook, but their effects on the incoming signal should be familiar. You built the remaining components of the circuit in Labs 1 through 3. In this section, you will combine all of the components to tune in a simulated AM radio broadcast and follow the signal from after the RF module to the loudspeaker.

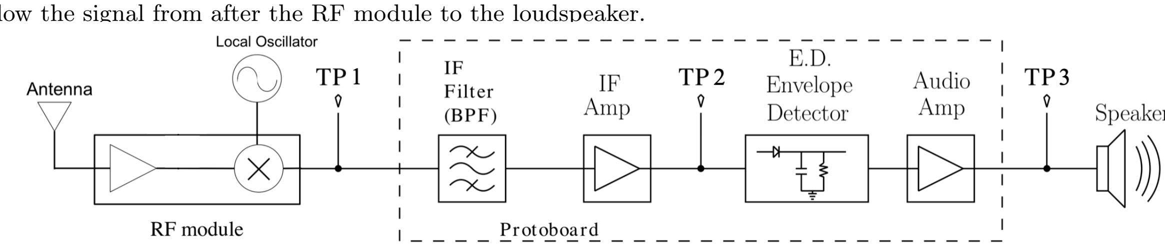


Figure 6 – Superheterodyne AM receiver.

1. The test signal is recorded after the RF module (TP 1.) Assuming the signal is from WILL 580 (580 kHz) station. What are the theoretical frequencies you should use for the Local Oscillator, so that

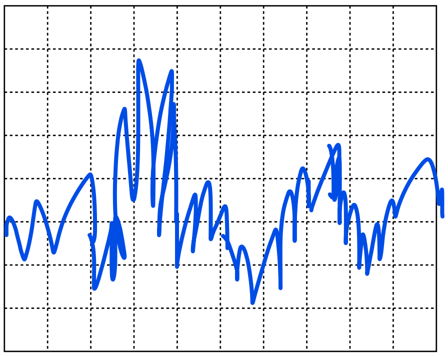
the AM station shifts in frequency from its carrier frequency to the intermediate frequency (14 kHz) ? (____/2)

The test signal should be mixed with the Local Oscillator, which itself should have a significantly higher frequency than 580 kHz. Theoretically, a higher frequency in the Local Oscillator should produce a better result.

2. Power the op-amps by enabling the DC supplies with 5 V.

3. In the Signal Generator module, load the file named "TP1_recorded_x.wav", where x can be 1,2,3,4 (There are four audio files, choose any of them). Then set the Amplitude to 330 mV and click "Run."

4. Connect your "2" pin (Channel 2) to TP 2 and observe the spectrum in the Spectrum analyzer module. Sketch both spectrum of Channel 1 and Channel 2.



Span : 50 kHz Center : 25 kHz Scale : 10 dB (____/2)

Which part of the spectrum gets attenuated ? Explain your reason (____/4)

. Any part of the spectrum outside of the range of the bandpass filter gets attenuated, or excluded from the final output

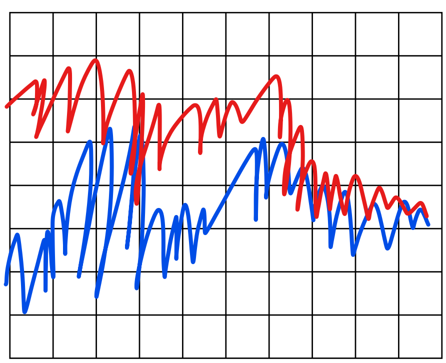
5. Connect your "2" pin (Channel 2) to TP 3 and move your "1" pin (Channel 1) to TP1, go to the Oscilloscope module and observe the signal in the time domain.

- Click "Single" to have a snapshot of the signal in the time domain.
- Zoom in to a proper region where you can clearly see the oscillation of Channel 1.

Compare the signal from Channel 1 to Channel 2, what does the envelope detector accomplish in the time domain ? (____/2) .

In Time Domain, the Envelope Detector recovers the envelope of the original signal before it was mixed, tuning out the higher frequency signal

6. Now, let's examine the frequency domain. Go to the Spectrum analyzer module, use the same sweep setting as given in Figure 5 and click Run. Sketch both the spectrum of Channel 1 and of Channel 2.



Span : 50 kHz Center : 25 kHz Scale : 10 dB

(____/2)

What are the differences that you notice ?

There are more low frequencies after passing the signal through the envelope detector (____/2)

Compare the spectrum from Channel 1 to the one from Channel 2. What does the envelope detector accomplish in the frequency domain ?

In Frequency Domain, the Envelope Detector essentially cuts out the higher frequency that we used to mix the original signal (____/2)

7. **(Demo required)** Connect the loudspeaker to TP 3, your speaker should start playing something if everything connected correctly.

What do you hear from the speaker ? Does your circuit accomplish the job of demodulation ? . (____/4)

I hear a coarse audio of a girl singing some melody. It does not have enough quality to be considered equal to a radio, but it serves as proof of concept for demodulation since there is enough left of the original signal to discern it through the noise.