EEL 4514C: Communication Systems and Components (Fall 2025)

Lab 2

Deliverables Due: At 11:59pm on September 29, 2025.

Background

In this lab, we will introduce one of the simplest forms of modulation. At this point in the class, we can interpret the word modulation as "modifying a carrier sinusoid to carry information".

By a carrier sinusoid, we mean a sinusoidal signal that has much higher frequency than the highest frequency of the information signal. For RF communications, transmitting information on a carrier achieves several goals including:

- Allowing for efficient radiation and detection. To radiate effectively, the typical antenna size is on the order of the wavelength (for example, a half-wave dipole is one-half a wavelength long). Signals with very low frequencies cannot be radiated or detected effectively because we cannot build big enough antennas in most cases.
- Allowing for multiple radio signals to exist in the same area by frequency division. That is, we divide the frequency domain into different frequency bands and let different users radiate in different bands.

Carriers have three aspects that can be modulated: their amplitude, frequency, and phase. In this lab, we consider modifying the amplitude.

Pre-Lab

1. Start by drawing frequency domain representations (sketches of the real and imaginary parts of the Fourier transform) for a carrier waveform. Draw the frequency domain representations for both $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$.
2. Now suppose we have an information (message) signal that is itself a sinusoid at frequency f_i, where $f_i \ll f_c$. Let the message signal be $m(t) = \cos(2\pi f_i t)$ and the carrier be $\cos(2\pi f_c t)$. We say that we "mix" $m(t)$ up to carrier frequency f_c when we multiply $m(t)$ by the carrier to create the modulated signal

$$s(t) = m(t)\cos(2\pi f_c t)$$

   Draw the real part of the Fourier Transform of $s(t)$. Use the following two approaches to determine the Fourier Transform of $s(t)$:

   (a) Use the Fourier Transforms of $m(t)$ and $\cos(2\pi f_c t)$ and the fact that multiplication in the time domain is convolution in the frequency domain.

   (b) Use a trigonometric identity to rewrite $s(t)$ in the time domain. Then take the Fourier transform of $s(t)$.

(c) Approach a) is more general, as it allows us to visualize the Fourier Transform of any $m(t)$. Sketch the real part of the Fourier Transform of $s(t)$ if the real part of the Fourier Transform of $m(t)$ is a positive symmetric triangle centered at $f = 0$ with absolute bandwidth much less than f_c.

3. The result in part 2 is the transmitted signal for a type of amplitude modulation called double-sideband suppressed carrier (DSB-SC).

   (a) Explain why it is called “double sideband”.

   (b) Explain why it is called “suppressed carrier”.

4. Now we will consider what happens if we receive a DSB-SC signal and mix it with a carrier at the same frequency f_c.

   (a) Use the approach from 2a to visualize the Fourier Transform for the DSB-SC signal for message signal $m(t) = \cos(2\pi f_i t)$ after it is mixed with a carrier again.

   (b) Use the approach from 2a to visualize the Fourier Transform for the output of the second mixer when the input is a DSB-SC signal with $M(f)$ a positive symmetric triangle centered at $f = 0$ with absolute bandwidth much less than f_c.

5. Complete the “Low Pass Filter Example” tutorial at `https://wiki.gnuradio.org/index.php?title=Low_Pass_Filter_Example`.

Lab–Part 1: First simple mixer (analog modulator) design by using GRC

GRC components:

- Signal Source blocks
- 1 Multiply block
- 2 Throttle blocks
- 1 Audio Sink block
- 2 QT GUI Range blocks
- 1 QT GUI Time Sink block
- 1 QT GUI Frequency Sink block
- 1 Options block (by default)
- 1 Variable block (by default)

Design Requirements:

1. Construct a signal flow graph using the blocks above to mix a sinusoidal information signal up to a desired carrier frequency.
2. Build a QT GUI to display the time and frequency domain of the information and modulated signals.
3. Use one of the Signal Source blocks to generate the information signal and the other block to generate the carrier.

4. Use the QT GUI Range blocks to allow users to select the information signal frequency and the carrier frequency using the QT GUI: The allowable range of information signal frequency should be from 100 to 2000 Hz The allowable range of carrier frequency should be from 5000 to 20000 Hz
5. Use Audio Sink block to play the information signal sound.
6. The sampling frequency used by all blocks should be set to 44.1 kHz.
7. Also determine if the Throttle blocks are needed for your implementation.
8. Take screen captures of the output of for the sinusoidal input and the noise input.
9. In your lab report, discuss whether the message signal is still present at baseband.

Lab–Part 2: First simple mixer with non-sinusoidal signals

1. Modify Part 1 to use a square wave for the message signal. Capture the plots of the time and frequency signals. Should the signal still be considered "suppressed carrier"? If not, explain why the message signal causes this.
2. Modify Part 1 to use a triangle wave signal for the message signal. Capture the plots of the time and frequency signals. Should the signal still be considered "suppressed carrier"? If not, explain why the message signal causes this.

Lab–Part 3: Mixing a DSB-SC signal with a carrier

Additional blocks:

- 1 Signal Source blocks
- 1 Multiply block

1. The output from Parts 1 and 2 are DSB-SC signals with different information. One of the first steps in receiving such a signal is often to mix it with a carrier at the same frequency. Add a second mixer at the carrier frequency fc and capture the output for each of the three message signals.
2. Carefully inspect the frequency-domain output for each message signal and determine a baseband frequency range that contains the majority of the message signal and contains minimal sidebands from copies of the signals that are centered at higher frequencies. You can click on the graph in the QT Frequency Sink block to have it display particular frequencies and amplitudes. Report your observations in your lab report.
3. In your lab report, discuss whether the message signal is present at baseband. What other frequencies is the message signal present at after the second mixer?

Lab–Part 4: Recovering a message signal from a DSB-SC signal

Additional blocks:

- 1 Low Pass Filter block

1. Modify the flowgraph from Part 3 to add a Low Pass Filter block after the second mixer. Set the parameters to output a baseband version of the message signal.
2. Take screen captures of the time and frequency graphs of the output of the Low Pass Filter.
3. In your lab report, discuss the accuracy of recovering the different message signals. Explain why this is true.