ECE 146A: Analog Communication Theory and Techniques
Lab 2: Amplitude Modulation and Demodulation

Lab Report Due: 5:00 p.m., Tuesday, January 29, 2008
(Place in the ECE 146A Homework Box on the 3rd Floor of HFH or Bring to Class)

1 Objective

To goal of this lab is to implement three types of amplitude modulation: conventional amplitude modulation (AM) (also known as double sideband (DSB) with carrier), single sideband (SSB), and double sideband suppressed carrier (DSB-SC). You will observe and analyze these different types of modulated signals in the time and frequency domains.

2 Equipment

Matlab, Simulink, and the Communications Toolbox software are available on the ECI workstations.

3 Generating Signals Using Simulink

Implement the three types of amplitude modulation using Simulink and the formulas given below. You may do so using any blocks available to you including the Communications Toolbox. In your designs, strive for a single block from which you can choose a modulation type, such as the Analog Filter block where you can decide from various types of filters using a pull-down menu. For each case, use different message signals, such as a square wave, a periodic triangular function, and a sinusoidal function.

3.1 Conventional AM:

$$s(t) = A_c[1 + A_m m(t)] \cos(2\pi f_c t) \tag{1}$$

where A_m is the amplitude of the message $m(t)$ and A_c is the amplitude of the carrier with frequency f_c.

3.2 DSB-SC:

$$s(t) = A_c A_m m(t) \cos(2\pi f_c t). \tag{2}$$

3.3 SSB:

$$s(t) = \frac{A_c A_m}{2} m(t) \cos(2\pi f_c t) + \frac{A_c A_m}{2} \hat{m}(t) \sin(2\pi f_c t) \quad (3)$$

where $\hat{m}(t)$ is the Hilbert transform of $m(t)$.

4 Examining Signals Using Matlab

Next, implement the three types of modulation using Matlab and conduct the following experiments. You should review your results in the time and frequency domains.

4.1 Conventional AM

4.1.1 Varying the Modulating Frequency

Using a sinusoidal message signal, let $A_m = 0.8$, $A_c = 1.0$, $f_c = 1$ kHz, and $f_m = 100$ Hz. Note that the envelope should be clearly visible. Increment f_m in steps of 100 Hz up to 1 kHz, and answer the following questions.

(1) At what frequency do you no longer see a well-defined envelope?

(2) Explain why the envelope has been lost, and interpret your result in terms of the traditional definition of an envelope.

(3) Once the envelope has been lost, can the message be detected by (a) a rectifier, (b) a square-law detector, and (c) a synchronous demodulator?

4.1.2 Varying the Modulating Amplitude

Using a sinusoidal message signal, let $A_m = 0.6$, $A_c = 1.0$, $f_c = 4$ kHz, and $f_m = 800$ Hz. Increment A_m in steps of 0.2 up to 1.4 and observe the resulting modulated signal, paying attention to the envelope and the carrier.

(4) What happens when A_m (a) equals A_c and (b) exceeds A_c?

(5) Observe closely the signal in the region where the envelope appears to reach zero and change sign. Can you determine whether it is the envelope that changed sign or the carrier phase was shifted by $180°$?

(6) Let $A_m = 2$ and observe the resulting waveform. Can the signal be demodulated by a synchronous detector? Explain.

4.2 DSB-SC

Using a square-wave message signal, let $A_m = 0.6$, $A_c = 1.0$, $f_c = 1$ kHz, and the modulating frequency be 20 Hz.

(7) Describe the envelope. Where in the modulated signal can you see evidence of the square wave? How would you demodulate this waveform?

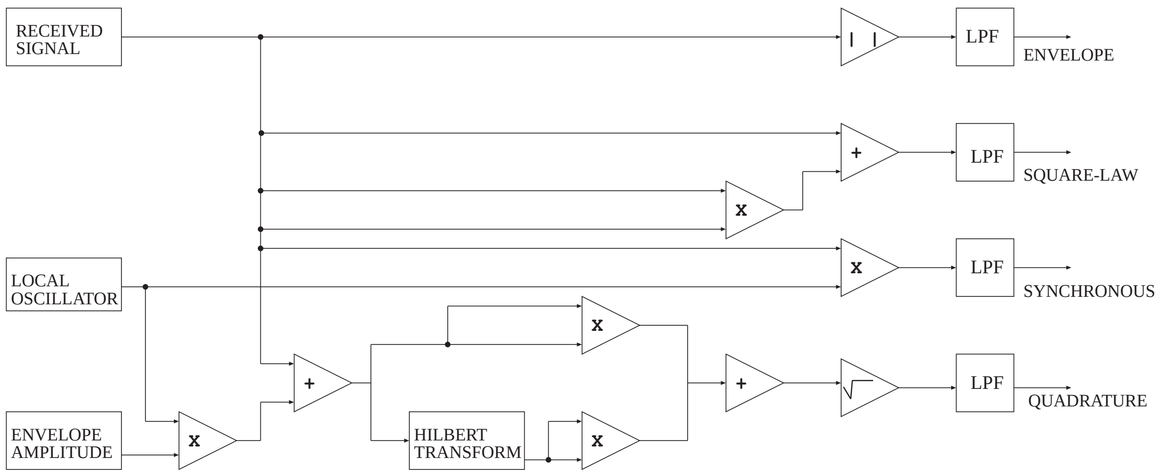

Figure 1: Methods of demodulation.

(8) How does the spectrum of the modulated signal relate to that of the modulating signal?

(9) Set the square wave frequency to 200 Hz and compare the spectra of the message and modulated waveforms. Explain the changes that the frequency increase has caused.

4.3 SSB

Using a square-wave message signal, let $A_m = 0.6$, $A_c = 1.0$, $f_c = 1$ kHz, and the modulating frequency be 100 Hz.

(10) Generate the SSB signal by starting with the DSB-SC format in (2) and removing one of the sidebands. Plot the spectrum of this signal.

(11) Generate the SSB signal directly by using (3) and plot its spectrum. Do you observe any differences between the two SSB signals?

(12) Which sideband is generated (upper or lower)? How would you obtain the other sideband?

(13) Repeat question (7).

(14) Repeat question (8).

5 Demodulation

Next, you will design systems using Matlab for demodulating the previous signals. These methods include envelope detection, square-law demodulation, synchronous demodulation, and a quadrature receiver. A block diagram illustrating the various demodulation techniques is shown in Figure 1.

For the following questions, use a square-wave message signal with $A_m = 0.5$, a modulating frequency of 400 Hz, $A_c = 1.0$, and $f_c = 4$ kHz. Design the low-pass filter (LPF) with an appropriate order and cutoff frequency that yield good signal reconstruction results.

5.1 Envelope Detector

AM signals without overmodulation can be detected using a rectifier followed by a low-pass filter, whereas DSB-SC cannot be demodulated using this approach.

(15) Compare the results for conventional AM and DSB-SC and explain why the rectifier can detect AM but not DSB-SC.

5.2 Square-Law Demodulation

A square-law demodulator can, with certain constraints on the amplitude, demodulate a conventional AM signal.

(16) By trying different amplitudes for the message signal and observing the reconstructed output, determine the signal constraint needed to obtain an acceptable result. Explain why this constraint is necessary for a square-law demodulator.

5.3 Synchronous Demodulation

Observe the output of this demodulator for the three different kinds of AM modulation, in both the time and frequency domains.

(17) Do you observe any discrepancies between the original and demodulated signals for any of the three modulation techniques? If so, suggest reasons why this happens.

(18) Examine the effects of phase misalignment by shifting the phase of the local oscillator by $45°$ (i.e., $\pi/4$). (Note that such a large shift is not required to observe these effects, but it highlights the problem of phase offsets in synchronous demodulation.) Describe these effects for the three modulation formats.

(19) Examine the effects of frequency misalignment by shifting the oscillator frequency by 50 Hz in either direction (i.e., use either 4050 Hz or 3950 Hz). What are your observations for DSB-SC and SSB?

5.4 Quadrature Receiver

Based on the block diagram in Figure 1, build a quadrature receiver based on the Hilbert transform.

(20) Determine how large the constant added to the received signal must be in order to make the demodulated signal be visually indistinguishable from the original message. Does quadrature detection work better for conventional AM or SSB? Explain.

6 Audio Signal

(21) Design a transmitter for an audio signal (audio.mdl) and demonstrate that it works. Compare the spectrum of the original message with that at the output of the transmitter.

(22) Design a receiver for the modulated signal. Compare the spectrum of the demodulated signal with that of the original message.

7 Lab Report

- Answer all questions and print out the most useful plots to support your answers.
- Include printouts of the various modulation schemes, with all Matlab and Simulink models that you designed.
- Include a table that summarizes the effectiveness of the various demodulators for each modulation type.
- Write a paragraph about any questions or confusions that you may have experienced with this lab.