School of Engineering Science, Simon Fraser University
ENSC-327
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Lab #2 — Amplitude Modulation using Simulink

Report format: A "formal report" is required for this lab: single column, 12-point font. Include the **involvement level** of each group member on the cover sheet.

1. OBJECTIVES

- To simulate and study the modulation and demodulation of AM.
- To measure the modulation factor in time domain and frequency domain.

(CEAB indicators: 1.4: Discipline-specific Knowledge, 3.3: Data Collection, 3.4: Data Analysis and Integration)

2. THEORY

Amplitude modulation results when a DC bias is added to the message signal **m(t)** prior to the modulation process. The transmitted signal can be written as

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

For a baseband signal of the form $m(t) = A_m \cos(2\pi f_m t)$, we can write

$$s(t) = A_c\left[1 + \mu\cos(2\pi f_m t)\right]\cos(2\pi f_c t), \tag{2}$$

Where $\mu = k_a A_m$ is called the modulation factor or modulation index.

The modulation factor can be measured from the observed waveform on the scope when the modulating signal is a pure sine or cosine wave, as shown in Fig. 1.

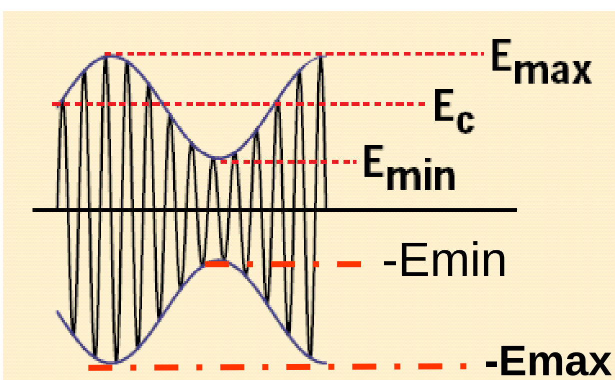

Fig. 1. Scope output for AM modulation.

In this case, the max amplitude Emax = (1+μ) Ac, and the min amplitude Emin = (1- μ) Ac. Therefore

$$\mu = \frac{E_{\max} - E_{\min}}{E_{\max} + E_{\min}} \tag{3}$$

In practical measurement, we can use the marker function of the scope to measure the difference between Emax and –Emax, as well as the difference between Emin and –Emin. This way there is no need to center the waveform around a reference line, and the accuracy of the measurement can be improved.

Note: The above formula only applies to AM modulation of a single-tone sinusoidal signal. For finding the modulation index of AM modulated signal with a general message, m(t), the above formula should be modified.

The modulation factor can also be measured in the frequency domain sing the spectrum analyzer.

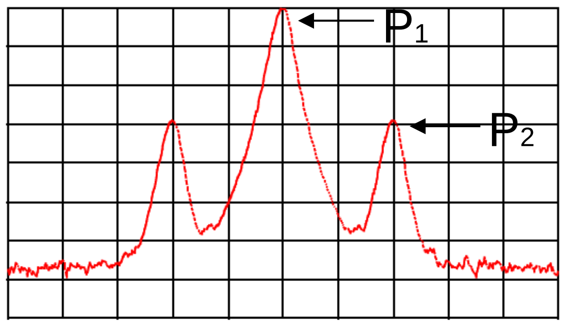

Fig. 2. Spectrum analyzer output for AM modulation.

Fig. 2 shows the output of the spectrum analyzer. The three peaks correspond to the carrier and the two sidebands for a single-tone input. When the modulating signal is a normalized sine or cosine wave, the reading of the spectrum analyzer (in log scale) is in dBm scale (see Lab 1 for definition).

3. Required Simulink Components and Parameters

The following building boxes are required for this assignment:

- From the Simulink/Sources sub library: Sine Wave, Constant.
- From the Simulink/Math Operations sub-library: Product, Add, Gain.
- From the Simulink/Sinks sub library: Scope.
- From the DSP (meaning Digital Signal Processing) Block set, Sinks sub library: Spectrum Analyzer. (You may have to install the DSP block set if not already installed.)
- From Communications library: Lowpass Filter (May require to be installed).

Refer to your Lab 1 or other online resources for a tutorial on Simulink.

<u>Module Parameters and Configuration</u>

Set the parameters of your simulation as follows:

Sample frequency: Set the sampling frequency to 500 kHz

Simulation Stop Time: Set stop time 20 ms.

Scope: From “View” tab of the Scope, click on “configuration properties. In the “configuration properties” window, set “number of input ports” as you want. Click on “layout” and choose the favorite layout.

Spectrum Analyzer: Set the “window length” of Spectrum Analyzer to 2^13=8192.

Saturation:

Lower limit=0, Upper limit should be set based on your choice of AM parameters such that it is larger than the maximum value of your AM signal.

Lowpass Filter:

- Filter Type: FIR
- Passband Edge Frequency: Slightly larger than the frequency of the message (~4 KHz)
- Stopband edge frequency: ~10 KHZ
- Maximum passband ripple: between 0.1~1
- Maximum stopband attenuation: more than 80

You can click on "View Filter Response" to see the frequency response of the designed filter.

4. AM MODULATION and DEMODULATION in SIMULINK

4.1 Modulation

Single tone AM signal is defined by eqn. (2) (repeated below):

$$s(t) = A_c\left[1+\mu\cos(2\pi f_m t)\right]\cos(2\pi f_c t),$$

1- Using the appropriate Simulink blocks build an AM modulated signal with the following parameters:
Message: Amplitude=1(V), Frequency=2 kHz
Carrier: Amplitude = Choose a value between 1 and 3 (V), Frequency=20 kHz
Modulation Index (μ): Start with 100% (one) and later as explained below, you will adjust μ to different values.

2- Add a "Scope" and a "Spectrum Analyzer" to your Simulink model. The scope should display the message and the modulated signal, and the spectrum analyzer should display the modulated signal only. Refer to Section 3 for the configuration of these and other blocks in your simulation.

3- View the AM modulated signal and the message signal on the "Scope". At this stage, since you have set your $\mu = 1$, you should have an AM modulated signal with a 100% modulation index. What you see on the Scope should look similar to Figure 3. Set up the view of your Scope window such that about 5 periods of the signals are displayed. Make sure the signals fit appropriately in the display window and are not cut off. **Include a screenshot of what you see on the scope and attach it to your report.**

4- Now, observe the modulated signal on the Spectrum Analyzer (SA) and record the power level of the carrier and each of the two sidebands (powers are measured in dBm). Adjust the Spectrum Analyzer's zoom level so that you can see the peaks clearly. Use the "Peak Finder" option to record power and frequency values (similar to figure 4.) **Take a screenshot of what you see on the SA and attach to your report.** Calculate the power efficiency using a power measure and verify that the efficiency is 33%.

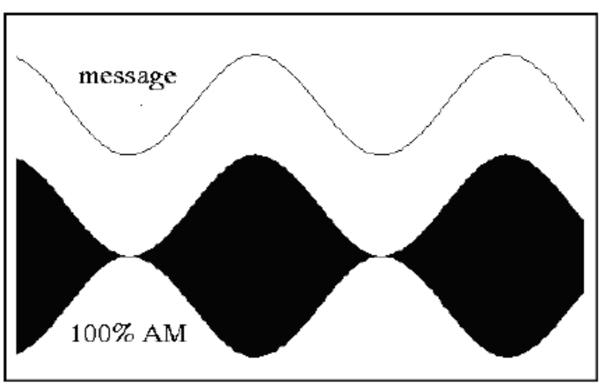

Fig. 3. AM with $\mu = 1$

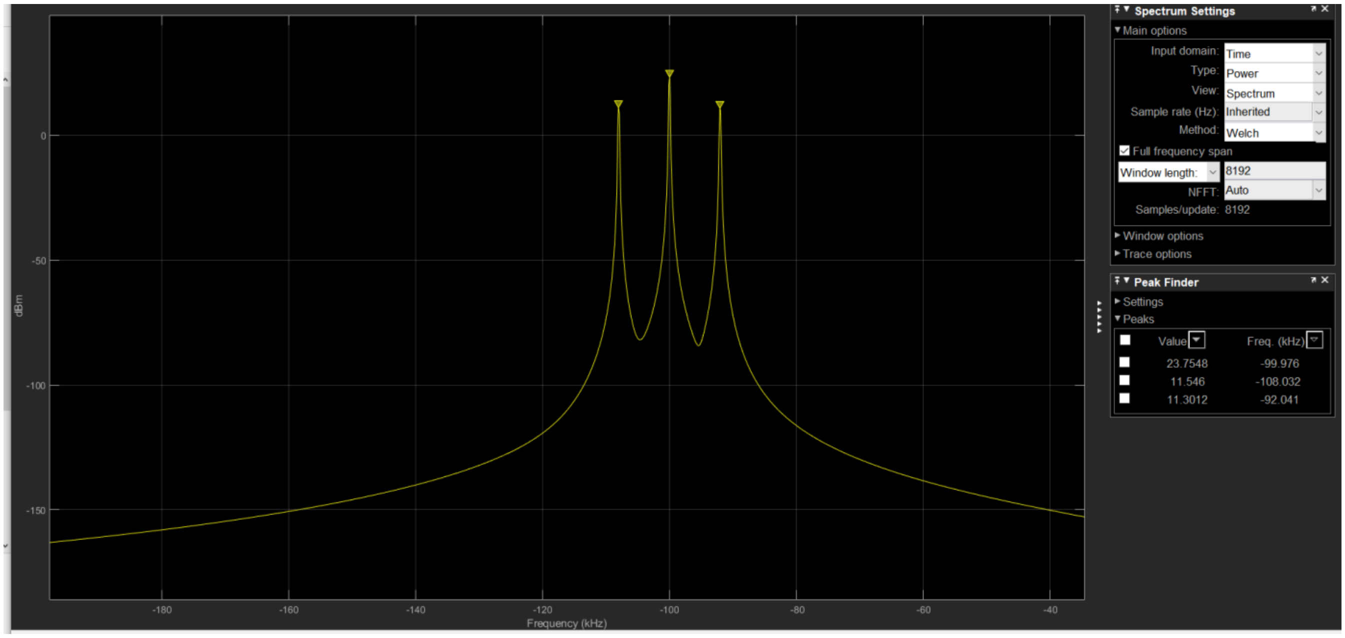

Fig. 4. A sample screenshot of Spectrum Analyzer.

4.2 Demodulation with Envelope Detection

In this part of the lab, we will look at the envelope detector for the demodulation of standard AM signals. The envelope detector can be implemented by a rectifier. Figure 4 shows the AM demodulator module. It consists of a Saturation block which acts as a rectifying diode (only passes the positive values of the signal), a Digital Lowpass filter which acts as an envelope detector, and Gain Block to amplify the envelope, and a Constant for DC to remove the DC value of the output signal.

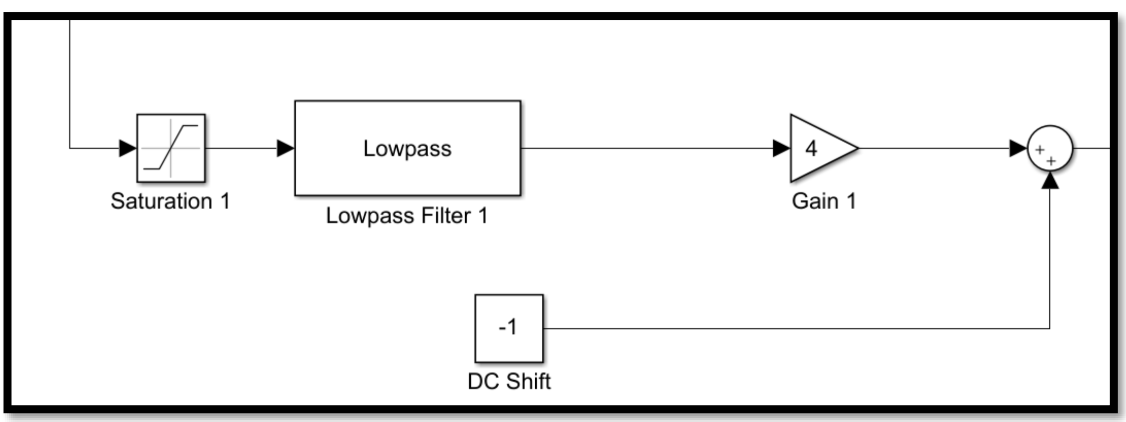

Fig. 5. Modelling the ideal envelope detector with Rectifier.

1- Build the Demodulator as illustrated in Figure 5.
2- Connect the demodulator output to the same scope. Refer to “Module Configuration Settings” for set up of this module.
3- Adjust the DC shift and gain values to see both the message signal and demodulated signal clearly with almost the same amplitudes.
4- Display the modulated, demodulated and message signals on the Scope (Message and demodulated signals in one display and the modulated signal in another display).

4.3 Effect of Modulation Index

1- Repeat the experiment by generating and demodulating three more AM waveforms with different modulation indices. **Choose two modulation indices below 100% and one above 100%**. Use a **table** to record the power level of the carrier and each of the two sidebands for each case, the power efficiency based on simulation (using the SA), and the power efficiency using the theoretical formula using the value of μ. Attach figures in time and frequency domains for one case of modulation index below 100% and one above**. Include the table in your report.**

2- In your report, provide **time and frequency screenshots** (scope and SA), of one set of signals with a modulation index below 100% and the signals with a modulation index above 100%. Again, your zoom level and other setups should be such that signals are easily visible. See Fig. 6 as an example.

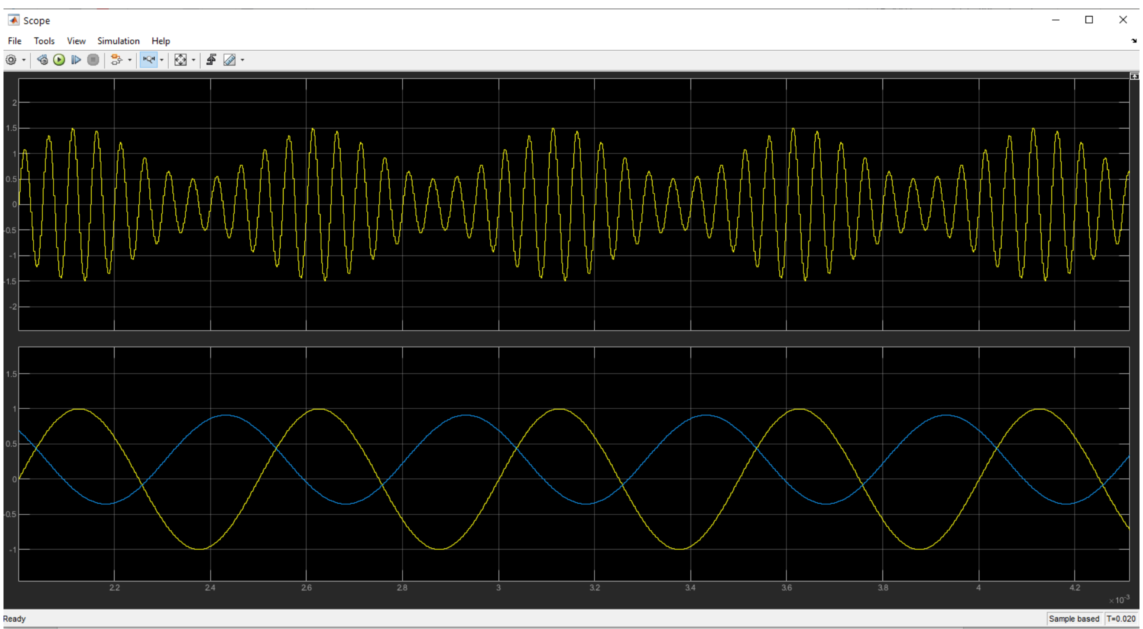

Fig. 6. A sample screenshot of the scope.

4.4 Analysis

1. Explain the changes observed in the AM waveform in time and frequency domain as the modulation index is changed.

2. Plot the power efficiency vs. μ, for both the simulation and theoretical values. Explain the trend of power efficiency as μ increases. Comment on whether the simulation and theoretical result agree.

3. For the case of modulation index above 100%, explain the output of the demodulator. Is the original message recovered from the modulated signal? Why?