

EE 218 – LINEAR SYSTEMS II LABORATORY
Missouri University of Science & Technology

LAB 7: AM MODULATION

Aim: In this lab you will modulate and demodulate a sinusoid using AM modulation and demodulation. You will measure the modulated signal in the time and frequency domain and compare the measurements to theoretically expected values.

Introduction: In a classic communications problem, we want to get a message waveform from one location to another. The message, $m(t)$, may be voice, music, video, digital data, etc. Most messages have a low-pass amplitude spectrum. This means $|X(f)|$ extends from 0 Hz (or close to 0 Hz), up to some highest frequency f_h . Typical frequency ranges are given below

- Voice: 300 Hz -4 kHz
- Music: 50 Hz -20 kHz
- Video: 0Hz-4MHz
- Digital Data: 0 Hz -B Hz (B = number of bits per second being transmitted)

Many times we want these signals to go over a radio link. This brings up many problems including:

- Radio antennae are roughly the size of the wavelength of the electromagnetic radiation they transmit/receive. Antennas that transmit straight voice or music signals would have to be many miles long. To get reasonably antenna sizes, we need to transmit signals that use frequencies in the range of MHz or GHz.
- There are many people that want to transmit radio signals, so we need to divide up the frequency spectrum into non-overlapping bands, and assign different bands to different users.

These restrictions mean we need to modify $m(t)$ before we send it through a radio antenna. We need to somehow move the spectrum of $m(t)$ up to a higher frequency band, and make sure it uses only the band assigned to us. When we receive this signal, we need to move it back down to the original frequency band. These operations are called modulation and demodulation.

One of the first modulation methods developed was Amplitude Modulation, or AM. In this format, the amplitude of a high frequency 'carrier' is proportional to the message you want to transmit like this:

- $x(t) = A(1 + a \cdot k \cdot m(t)) \cdot c(t)$
- $x(t)$ = transmitted signal
- A = scaling constant that helps control the power of the transmitted signal.
- a = scaling constant called the modulation index. Range: 0 to 1, usually expressed as 0% to 100%.
- k = scaling constant selected so that the minimum value of $k \cdot m(t)$ is exactly -1 volt.
- $c(t)$ = the "carrier". A sinusoidal signal at a high frequency, usually with an amplitude of 1 volt.

In this laboratory, you will modulate and demodulate an AM signal. You should see how both the oscilloscope and spectrum analyzer are useful for examining these signals.

Procedure:

1. Adjust one of the signal generators in the lab to produce a 2 kHz sine wave (this is your message signal $m(t)$).

2. Adjust a second signal generator in the lab to produce a 1 MHz sine wave with an amplitude of 1 volt (this is your carrier $c(t)$).

3. Connect the output of the 2 kHz generator to the AM input of the 1 MHz generator.

4. Look at the 1 MHz output on the oscilloscope. Adjust the amplitude of the 2 kHz source, so that the 1 MHz signal varies in amplitude from 500 mV to 1.5 V. To get pretty pictures, you may wish to synchronize the scope to the 2 kHz signal source.

5. Measure the amplitude spectrum of the AM signal on the spectrum analyzer. Compare this measurement to the one predicted by theory. If you don't have access to a spectrum analyzer that goes up to 1 MHz, lower the carrier frequency so you can use one of the Fourier Analyzers on the bench.

6. The AM signal you created can be demodulated by a circuit called an envelope detector shown below:

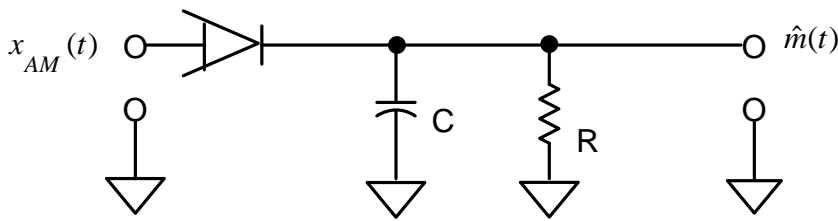


Figure 1. Envelope Detector

Build an envelope detector, and find the RC time constant that minimizes the distortion of the output signal (use a carrier frequency of 1 MHz). Describe what happens if the RC time constant is too large, or too small.

7. Create an AM signal that uses a voice or music signal as the message, and see if the RC time constant you selected above is still a good choice. If you have an AM radio handy, you should be able to place it close to your output wire, and listen to the signal by setting the dial to 1000.

For Your Report:

- Make sure to calculate the theoretical $x(t)$ for the signals you used. Compare the theoretical $x(t)$ to the one you observed in lab on the oscilloscope.
- Make sure to calculate the theoretical amplitude spectrum of $x(t)$, i.e. $|X(f)|$. Compare the theoretical $|X(f)|$ to the one you measure in lab on the spectrum analyzer.
- Include a “rough” time domain sketch of the output of your envelope detector. What should the time domain output look like?
- Observe the envelope detector output on the spectrum analyzer, record data points and provide this plot in your lab. What should the amplitude spectrum of the envelope detector output look like?
- Here’s a fun question: What is the impulse response of the envelope detector?