EE357 – Communication Systems

Laboratory Session 1 – Amplitude Modulation and Demodulation

Objective: Investigate amplitude modulation and demodulation

Part 1: Amplitude Modulation

Theory

Amplitude Modulation

The block diagram representation of the amplitude modulator is shown in Figure 1.

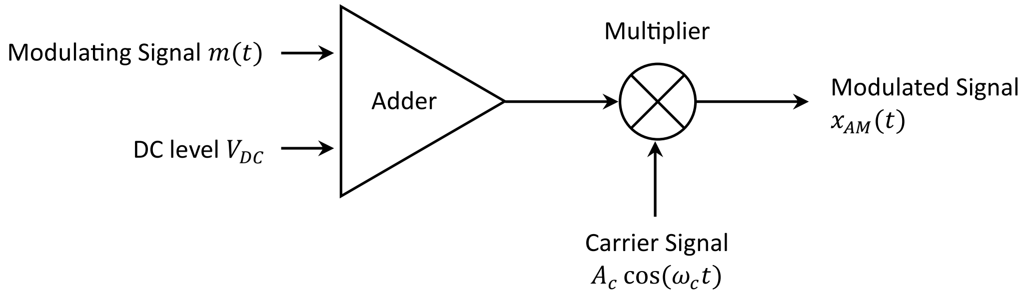

Figure 1: Amplitude Modulator

The multiplier output which is the AM signal can be written as,

$$x_{AM}(t) = KA_c[V_{DC} + m(t)]\cos(\omega_c t).$$

For $m(t) = A_m \cos(\omega_m t)$,

$$\begin{aligned} x_{AM}(t) &= KA_c[V_{DC} + A_m \cos(\omega_m t)]\cos(\omega_c t) \\ &= KV_{DC}A_c\left[1 + \frac{A_m}{V_{DC}}\cos(\omega_m t)\right]\cos(\omega_c t) \\ &= KV_{DC}A_c[1 + \mu\cos(\omega_m t)]\cos(\omega_c t), \end{aligned}$$

where K is a multiplier constant.

Modulation Index (μ)

The modulation index μ can be found either using the time domain representation of the AM signal $x_{AM}(t)$ or its frequency domain representation $X_{AM}(f)$.

When time domain representation is used,

$$\mu = \frac{x_{AM,max} - x_{AM,min}}{x_{AM,max} + x_{AM,min}}. \tag{1}$$

When frequency domain representation is used,

$$\mu = \frac{2 \times \text{Sideband RMS Voltage}}{\text{Carrier RMS Voltage}}. \tag{2}$$

Efficiency (η)

Efficiency of the AM or DSB-SC modulated signals can be calculated using,

$$\eta = \frac{\text{Power of a sideband}}{\text{Total power}}. \tag{3}$$

Demonstration Session

Apparatus:
1. Mixed Domain Oscilloscope
2. Function Generators (SIGLENT – SGD810 and RIGOL – DG811)

Procedure

1. Using the SIGLENT SGD810 function generator, generate a sinusoidal modulating signal (i.e., message signal) with a frequency of 1 kHz, an amplitude of 10 V.
2. Use the Amplitude Modulation option on the RIGOL DG811 function generator and generate a sinusoidal carrier signal that has a frequency of 100 kHz, an amplitude of 2 V, and an offset of 0 V.
3. Connect the modulating signal output to the Ext. Mod input of the carrier function generator.
4. Use the ‘external’ modulation option to enable amplitude modulation.
5. Use the SPAN (or Modulation Depth) button to change the modulation index of the AM signal. For $\mu = 0.25$, 0.50, and 1.00, observe the time and frequency domain representation of the signal using the mixed domain oscilloscope.
6. Calculate the modulation index μ using the equations (1) and (2) and verify whether they correspond to the values you specified in the function generator.
7. Calculate the efficiency of the modulation using (3) for all three μ values.
8. Change the modulating signal to a square wave and redo steps 4 and 5.
9. For $\mu = 0.5$, change the duty ratio of the modulating signal to 25% and 50% and observe the changes in both time and frequency domains.
10. Change the modulating signal to a triangular pulse and redo steps 4 and 5.
11. For $\mu = 0.5$, change the duty ratio of the modulating signal and observe the changes in both time and frequency domain.

Part 2: AM Demodulation using Envelope Detection

Apparatus:
1. Mixed Domain Oscilloscope
2. Function Generators
3. Components for the demodulator Circuit

Procedure

1. Implement the following envelope detector circuit using the components given on a breadboard. Use the following values:

$R_1 = 5.6\ \mathrm{k\Omega}$	$R_2 = 320\ \mathrm{k\Omega}$	$R_3 = 100\ \mathrm{k\Omega}$
$C_1 = 100\ \mathrm{nF}$	$C_2 = 1\ \mathrm{nF}$	$C_3 = 1\ \mathrm{nF}$

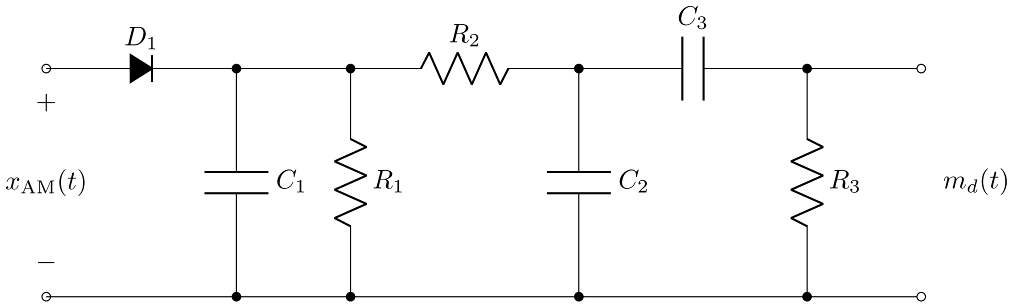

Figure 2: Envelope detector circuit

2. Generate an AM signal $x_{AM}(t)$ so that $\mu \leq 1$.
3. Set $f_c = 100\ \mathrm{kHz}$ and $f_m = 1\ \mathrm{kHz}$.
4. Connect the AM signal to the demodulator circuit and the output of the demodulator circuit to the mixed domain oscilloscope.
5. Observe the time domain representation of the demodulated waveform $m_d(t)$.
6. Discuss and identify the reason for the presence of an offset in the demodulated signal.
7. Observe the frequency domain representation of the demodulated waveform.
8. The envelope detector-based AM demodulation circuit is made of capacitors, resistors, and a diode. Selection of proper capacitor values specifically will influence the quality of the demodulated signal. Verify that $f_m < 1/RC \ll f_c$.
   a. By finding the range of f_m for $f_c = 100\ \mathrm{kHz}$
   b. By finding the range of f_c for $f_m = 1\ \mathrm{kHz}$

Part 3: Simulation of AM Demodulation using a Synchronous Detector

Simulation Session

Objective: To generate an AM signal, demodulate it using a synchronous detector, and analyse the results.

Theory

Synchronous demodulation, also known as coherent demodulation, is a technique used to extract the original message signal from an AM signal. In this method, the AM signal is multiplied by a locally generated carrier signal that has the same frequency and phase as the transmitter's carrier. This process shifts the message signal back to baseband. A low-pass filter is then used to remove high-frequency components, leaving the desired message signal.

Procedure

1. Generate and visualize signals
    a. Generate a message signal $m(t) = A_m \cos(2\pi f_m t)$ with:
        i. Amplitude $A_m = 1\ \mathrm{V}$,
        ii. Frequency $f_m = 1\ \mathrm{kHz}$,
        iii. Plot the time-domain waveform of $m(t)$.

    b. Generate a carrier signal $c(t) = A_c \cos(2\pi f_c t)$ with:
        i. Amplitude $A_c = 2\ \mathrm{V}$,
        ii. Frequency $f_m = 1\ \mathrm{kHz}$,
        iii. Plot the time-domain waveform of $c(t)$.

2. Generate an AM signal
    a. Combine the message and carrier signals to create the AM signal:
    $$s(t) = [A_c + m(t)]\cos(2\pi f_c t)$$
        i. Assume the modulation index $\mu = 0.8$.
        ii. Plot the waveform of $s(t)$.

3. Synchronous demodulation
    a. Generate a local oscillator signal to generate $c_{LO}(t) = \cos(2\pi f_c t)$, ensuring the same frequency and phase as the carrier signal.

    b. Multiply the AM signal $s(t)$ by the local oscillator signal $c_{LO}(t)$:
    $$v(t) = s(t)c_{LO}(t)$$
    Plot the waveform of $v(t)$.

    c. Pass $v(t)$ through a low-pass filter with a cut-off frequency of $5\ \mathrm{kHz}$ to extract the message signal $m(t)$. Use a second order Butterworth filter.

    d. Plot the demodulated signal $m(t)$ and compare it with the original message signal.

Discussion

1. Discuss the need for modulation using two specific examples.
2.
    a. In AM demodulation with the envelope detector, why must be the maximum modulation index less than one?
    b. Consider the envelope detector and product detector used for amplitude demodulation. Discuss the advantages and disadvantages of each method.
3. AM broadcasts are used on several frequency bands such as longwave broadcasting, medium-wave broadcasting, shortwave broadcasting, and VHF AM broadcasting.
    a. Discuss the frequencies used for these bands that are allocated to the radio stations.
    b. Compare the advantages and disadvantages of AM operation in the above bands. Also, if you are given the choice of selecting one band over another for AM broadcasting, state the main reasons behind your selection.
4. State and discuss two problems that a designer should consider, when planning the design of a new AM transmitter.
5. How do sparks, lightning, and power lines impact amplitude modulation?
6. How do land and sea conditions affect AM transmission?
7. Discuss the impact of using different modulation indices ($\mu = 0.50$ and $\mu = 1.00$) in a synchronous demodulator simulation on the quality of the demodulated signal.