Experiment 3: Amplitude Modulation (With carrier) and Demodulation

Aim: This experiment is intended to make the student to code Amplitude Modulation (with carrier) and its demodulation using MATLAB.

A – Generation of AM with Carrier:

AM with carrier follows the equation ***y(t) = (A + m(t)) * Cos (2*pi*f_c*t);*** where, ***m(t)*** is the message signal, ***A*** is the carrier amplitude and ***f_c*** is the carrier frequency.

In this experiment, let the message signal and carrier be sinusoids of frequencies 2KHz and 100 KHz, respectively. Let the message signal and carrier be of 2V and 6 V peak-to-peak, respectively.

1. Generate the time-domain waveform of the AM signal using the above equation.
   Hint : use .* operator where ever required in the equation.

2. Plot the message, carrier, and AM wave in a single plot, one below the other.
   Hint : Choose a proper sampling frequency fs and time interval should be inverse of fs.

3. Plot the spectra of each of these signals, one below the other, in a separate plot.
   Hint : Explore commands like fftshift , fft.

Answer the following:

1. In the spectrum of the AM signal plot, mention the significance of the three observed peaks.
   Hint: What does the Fourier transform of the AM signal look like?
2. Is the total power in sidebands is equal to the message power in modulated signal?
3. Is the carrier power in time domain is same as measured in frequency domain?

Table 1. Time & Spectral Domain Measurements on AM Signal (with carrier)

Message Amplitude (V)	Message Power (W, dBW)	Carrier Amplitude A (V)	Carrier Power (W, dBW)	Message Power in modulated signal = message power /2	DC Bias Value of *(A + m(t))*	Frequency of First Peak	Power of first Peak	Frequency of second Peak	Power of second Peak	Frequency of third Peak	Power of Third Peak

B – Modulation Index Calculations:

1. Modulation index can be calculated from the message & carrier amplitudes. Calculate and fill the appropriate column (4) in Table 2. It can also be calculated as in column (5), where P & Q are taken from the modulated signal. See the picture below. Compare the modulation indices from both calculations. Calculate the modulation efficiency as in column (6).

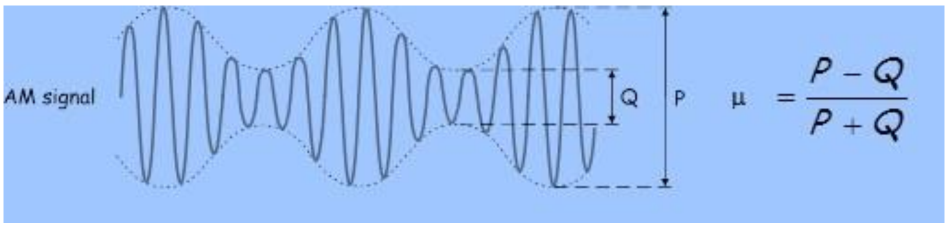

Figure 1: Modulation Index Measurement

Table 2.Modulation Index and Efficiency ofAM Signal (with carrier)

Sl. No	Maximum Message Amplitude (1)	A (2)	Modulation Index μ = (max(m(t)) / A (4)	P	Q	Modulation Index μ = (P-Q)/(P+Q) (5)	Single tone Efficiency $\eta = \mu^2 / (2 + \mu^2)$ (6)

2. Next, compute the efficiency of AM for different modulation indices. For this, vary the amplitude of the message signal till the “Q” value reduces to zero. The AM signal would look like the one in the following picture. Perform the required measurements, calculate the modulation index and the efficiency and tabulate in Table 2.

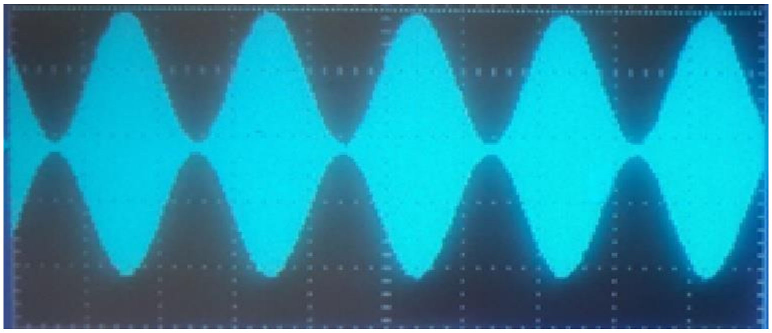

Figure 2: AM signal With Carrier for $\mu = 1$

3. Compute and plot the spectrum of the AM signal when Q = 0. Note the frequencies and power of each of the peaks. Answer the following:
    a. What is the power in each of the sidebands in dBW and Watts ?
    b. What is the total power in both sidebands put together?
    c. What is the carrier power in dBW and Watts?
    d. Calculate the total power of AM signal by using the powers calculated above.
    e. Compute the efficiency.
    f. Also try comparing the efficiency of different kind of wave forms.
    g. Which among them will give the maximum efficiency.
    h. Does this efficiency number match with the one calculated from the time domain measurements?
4. Next, vary the message amplitude till "overmodulation" occurs and the modulated waveform looks as in the picture below. Compute and plot its Fourier transform. What difference do you observe in its spectrum in comparison to the other two cases? [You may answer this after performing the demodulation part.]

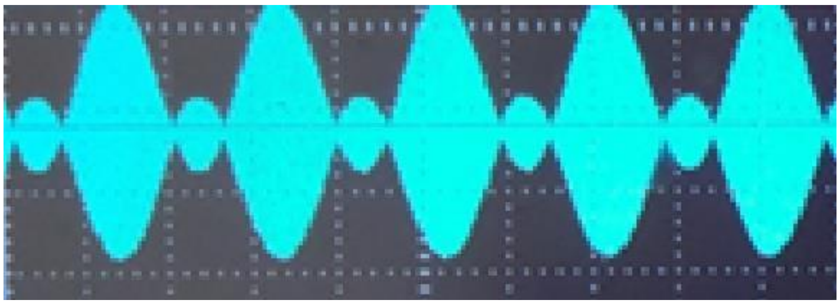

Figure 3: AM signal With Carrier for μ>1

C –Demodulation of AM with Carrier:

Demodulation of AM with carrier is accomplished by using an envelope detector, which is typically implemented using a low-pass filter in MATLAB.

1. Plot the demodulated signal in both the time-domain and the spectral-domain for each case of under modulation, critical modulation and overmodulation.
   Hint: Explore butter worth filter, filter commands in MATLAB. Use fftshift command if required.
2. Compare and contrast the message signal and demodulated signal plots for each case.
3. How does the demodulated spectrum look like?
4. Give the significance of modulation index?

D –Conclusions:

1. List out your learnings from the experiments.