Communication Systems Lab Experiment 3

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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:

We are given a sinusoidal message signal m(t) with frequency 2KHz, Amplitude(A) 1V, and a carrier signal with frequency 100KHz, Amplitude 3V.
We have the AM signal y(t) = (A + m(t)) *cos(2*pi*fc*t)

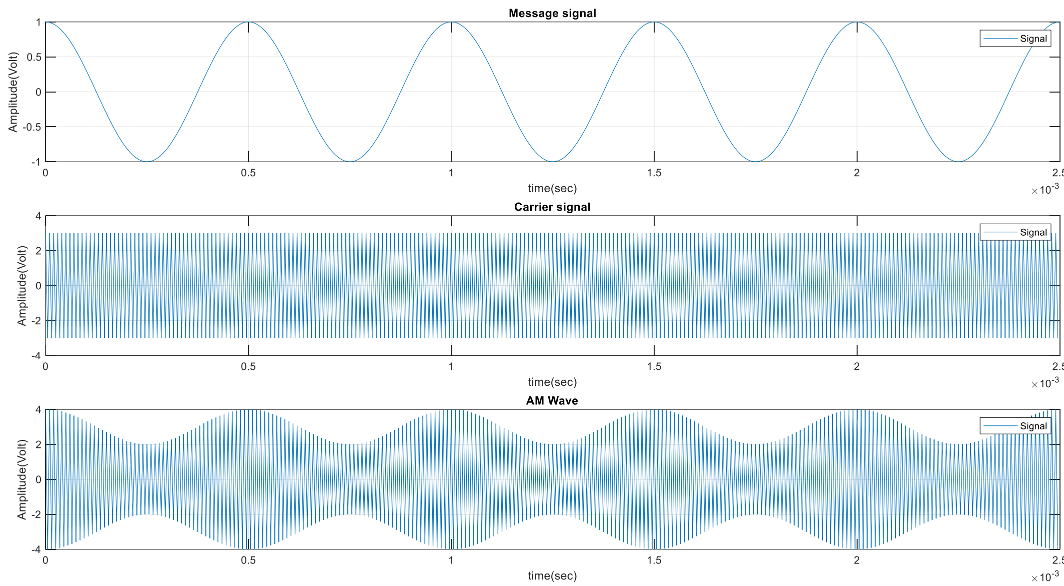
We first find the waveforms of each of the above signals next the frequency spectrum:

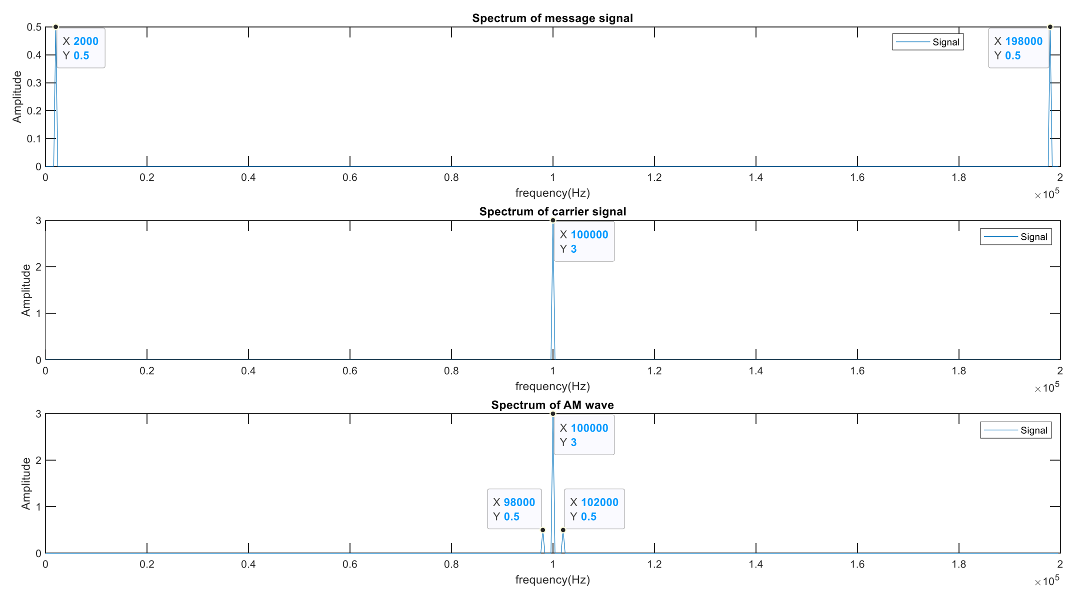
Code:
```
clear;
clc;
close all;

Fs = 200*1000;
T = 1/Fs;
L = 500;
t = (0:L-1)*T;
Fm = 2000;
Fc = 100000;

m = cos(2*pi*Fm*t);
c = 3*cos(2*pi*Fc*t);


subplot(3, 1, 1);
plot(t, m);
title('Message signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
```

```
legend("Signal");
grid;
subplot(3, 1, 2);
plot(t, c);
title('Carrier signal');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
grid;

y = (3 + m).*(c/3);

subplot(3, 1, 3);
plot(t, y);
title('AM Wave');
xlabel("time(sec)");
ylabel("Amplitude(Volt)");
legend("Signal");
grid;

%freq spectrums'

f = Fs*(0:(L-1))/L;


figure;
M = fft(m);
P2_1 = abs(M/L);
P1_1 = P2_1(1:L/2+1);
P1_1(2:end-1) = 2*P1_1(2:end-1);

subplot(3, 1, 1);
plot(f, P2_1);
title('Spectrum of message signal');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Signal");


C = fft(c);
P2_2 = abs(C/L);
P1_2 = P2_2(1:L/2+1);
P1_2(2:end-1) = 2*P1_2(2:end-1);

subplot(3, 1, 2);
```

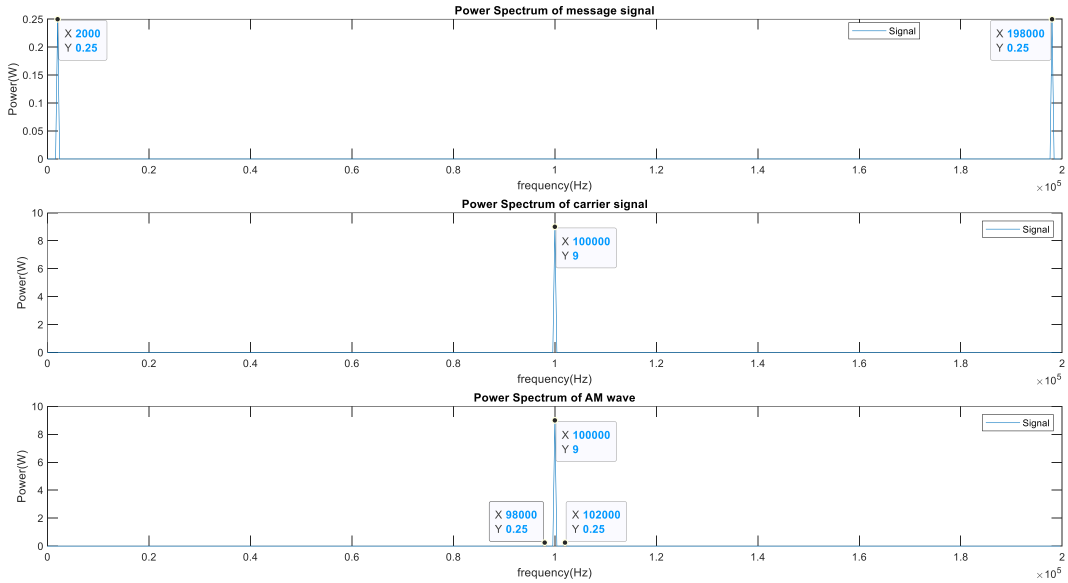
```
plot(f, P2_2);
title('Spectrum of carrier signal');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Signal");


Y = fft(y);

P2_3 = abs(Y/L);
P1_3 = P2_3(1:L/2+1);
P1_3(2:end-1) = 2*P1_3(2:end-1);

subplot(3, 1, 3);
plot(f, P2_3);
title('Spectrum of AM wave');
xlabel("frequency(Hz)");
ylabel("Amplitude");
legend("Signal");


figure;
subplot(3,1,1);
plot(f,P2_1.^2);
title('Power Spectrum of message signal');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Signal");

subplot(3,1,2);
plot(f,P2_2.^2);
title('Power Spectrum of carrier signal');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Signal");

subplot(3,1,3);
plot(f,P2_3.^2);
title('Power Spectrum of AM wave');
xlabel("frequency(Hz)");
ylabel("Power(W)");
legend("Signal");
```

Results:





Power spectrum



1) In the AM signal plot, the highest peak indicates the frequency of the carrier signal while the 2 other peaks indicate the message peaks. The central peak has a magnitude of 1.8MW at 100KHz, the sidebands have a magnitude of 50KW each at 98KHz (100-2) and 102KHz (100+2). The carrier signal is represented by the central peak, while the message signal (located at fc+/-fm) is represented by the sidebands.
2) The total power of the AM Spectrum's sidebands (0.25+0.25W) is equal to the message spectrum's power (0.5W).

3) Yes, carrier power in the time domain and carrier power in the frequency domain are the same.

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 modulate d 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**
1	0.5W, -3.01dBW	3	4.5W, 6.53dBW	0.25W, -6.01dBW	3 V	98KHz	0.25W	100KHz	9W	102KHz	0.25W

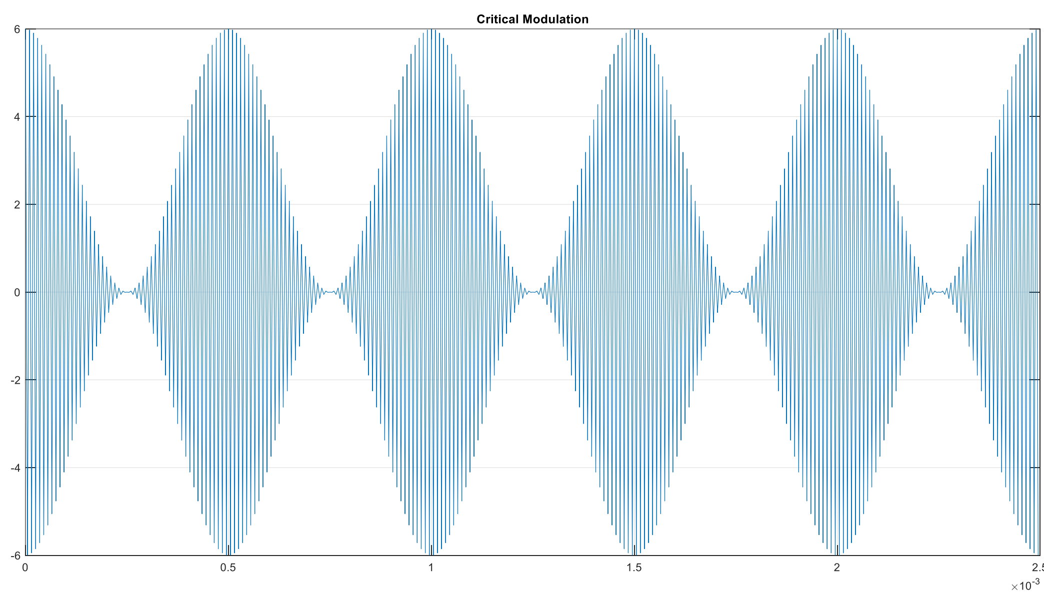
B – Modulation Index Calculations:

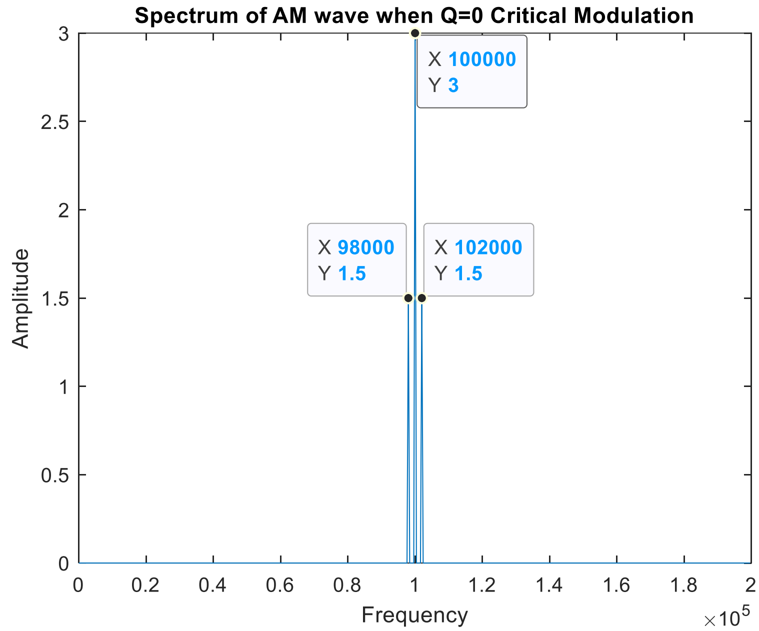
1) The readings are as follows for the original message amplitude till the value of Q comes to be 0 the Modulation Index is:
2) The efficiency is:

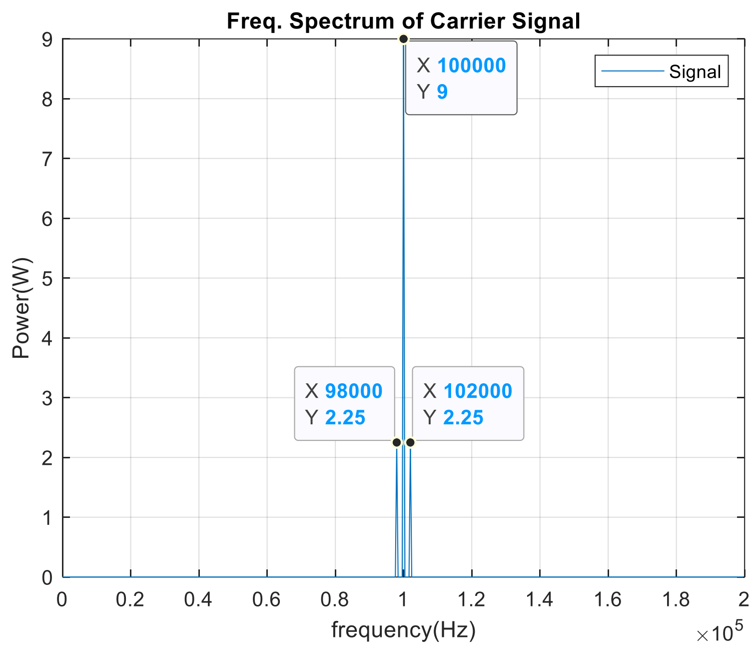
Table 2. Modulation Index and Efficiency of AM Signal (with carrier)

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)
1.	1	3	1/3	8	4	1/3	1/19
2.	1.5	3	1/2	9	3	1/2	1/9
3.	2	3	2/3	10	2	2/3	2/11
4.	2.5	3	5/6	11	1	5/6	1/4
5.	3	3	1	12	0	1	1/3

3) Critical Modulation (When Q = 0, the Power plots look like the following (Am = A = 3):

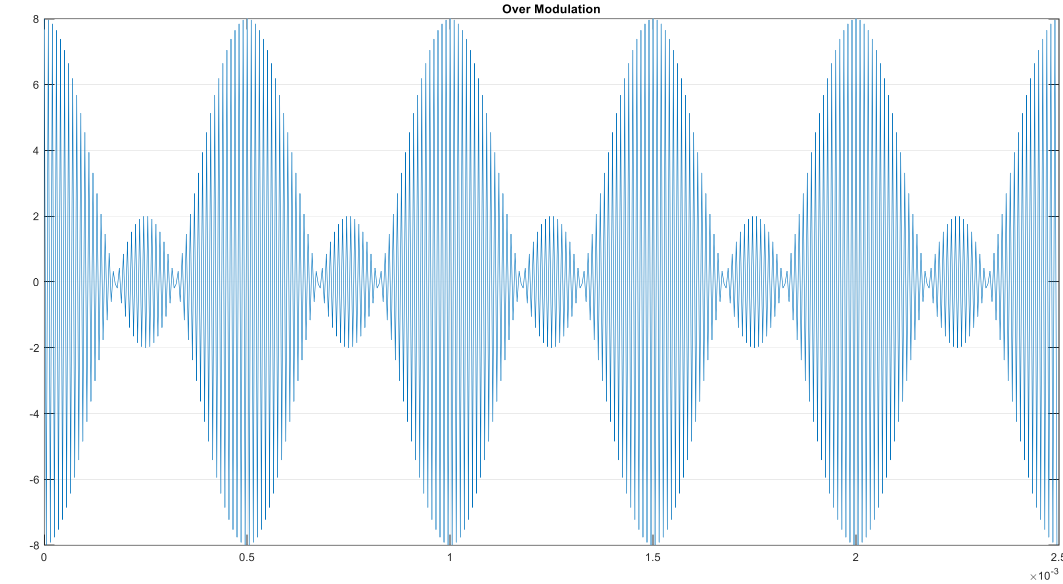


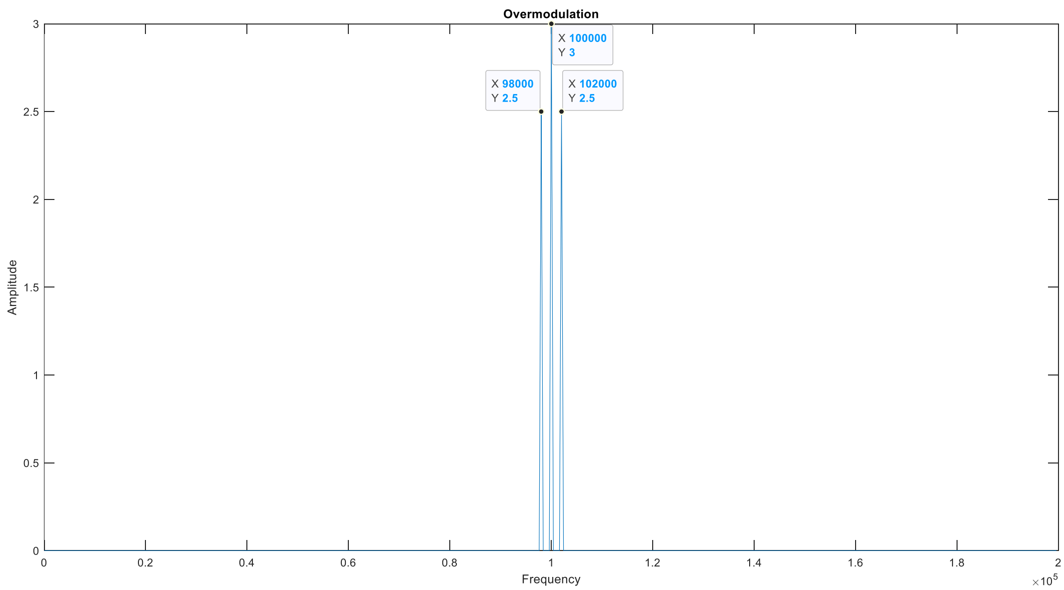


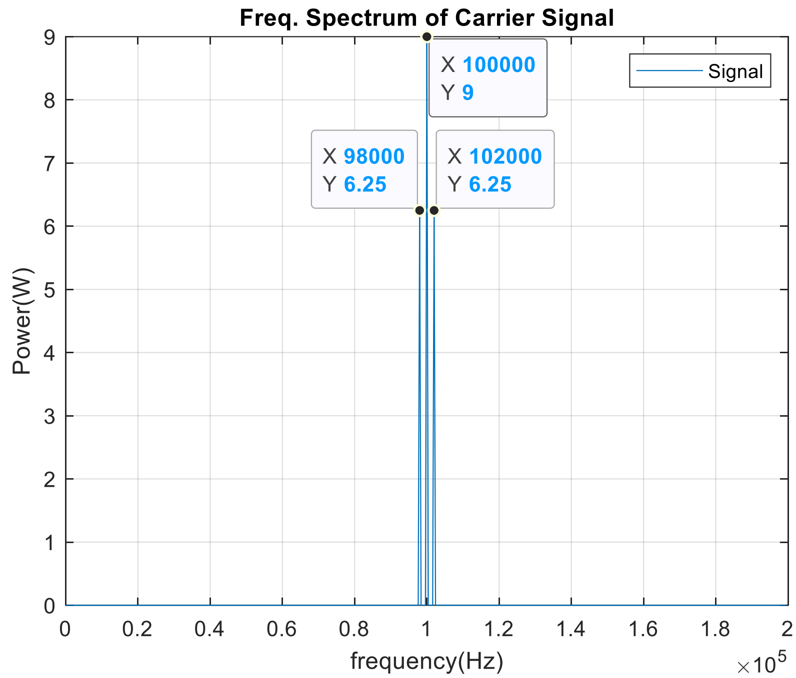


a) Power in each sideband is **2.25W, 3.52dBW**.
b) The total power in both sidebands is **4.5W, 6.53dBW**.
c) Carrier power is **9W, 9.54dBW**.
d) Total power of AM signal is **9W+2.25W+2.25W** = **13.5W, 11.30dBW**.
e) Efficiency is 4.5W/(9W+4.5W) = ⅓ = **0.33**
f) We can compare the efficiencies of different kinds of waveforms from table 2. Increasing the value of Am to A (or decreasing the value of Q to 0) improves efficiency.
g) Q = 0 has a maximum efficiency of ⅓.
h) This efficiency **⅓ = 0.33** matches with the efficiency calculated using the formula in the above table 2.

4) Overmodulation (mu>1) (Am = 5)





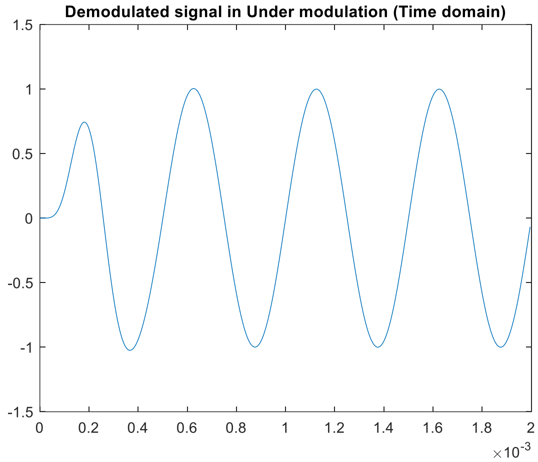


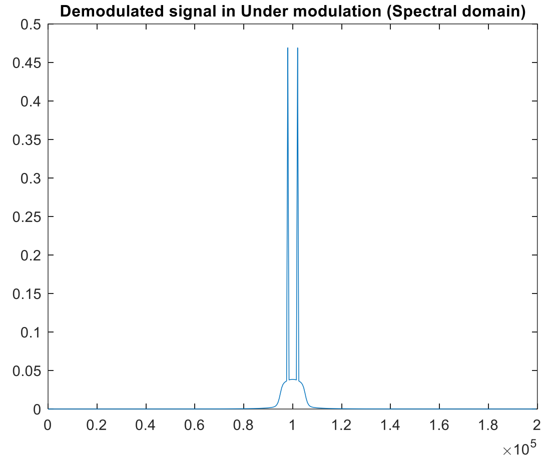
Power Spectral Density in case of Overmodulation (Taking Am = 5)

We can see that the power contributed by the message signal is comparable to the power contributed by the carrier signal. This makes it much harder to distinguish the signals and hence demodulate it, as verified by the skewed nature of the AM signal in such a case.

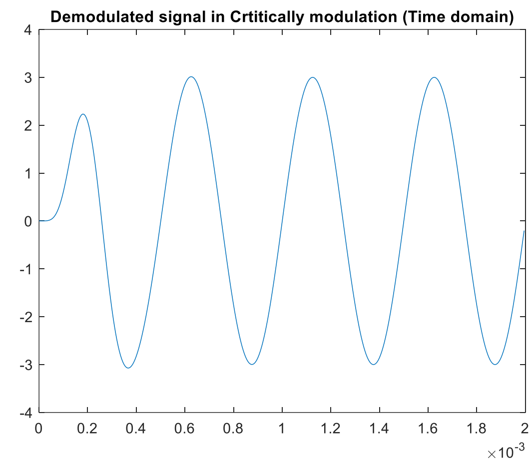
C –Demodulation of AM with Carrier:

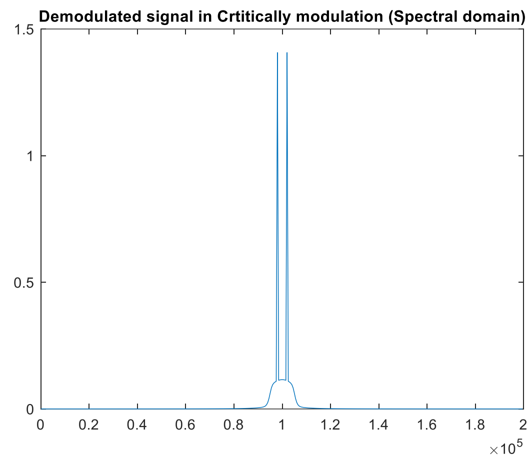
1.Under Modulation (Am = 1, A = 3)



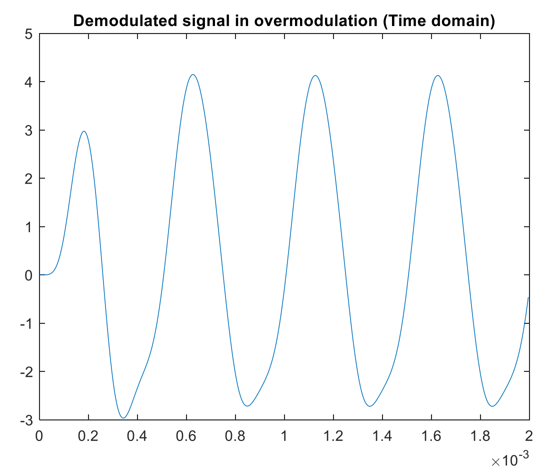


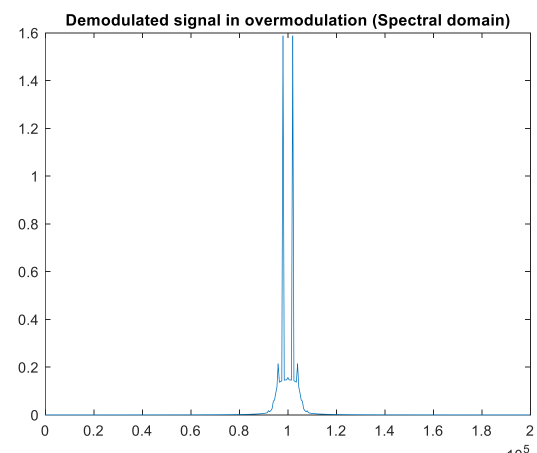
2.Critical Modulation (Am = 3, A = 3)





3.Over Modulation (Am = 4, A = 3)





D –Conclusions:

- Through this experiment, we were able to analyze amplitude modulation using MATLAB. We started by plotting the AM signal, as well as the carrier and message signals.
- By applying the Fourier transform to the signals, we were able to calculate the different power values at the three peak frequency values.

- In the second part, we experimented with message signal amplitude values in order to generate a table with the corresponding modulation index values. The modulation index reaches a value of unity when the message and carrier signal have the same amplitude.
- Any value less than one results in an under modulated signal, while any value greater than one results in an overmodulated signal.
- We also made some observations after analyzing the spectrum of a perfectly modulated signal (Q=0, mu =1).

- The third part of this lab exercise focuses on using an envelope detector in MATLAB to demodulate an AM signal.
- We finished the experiment by plotting the demodulated signal in both the time and frequency domains and comparing it to the message signal in three different cases: under modulation, critical modulation, and overmodulation.