Amit Kumar Yadav
194107 / ECE-A

Comm. Sys. LAB

Experiment-01

Aim - To study about modulation and demodulation of an Amplitude Modulated Signal.

Software Used - MATLAB R2021b on a windows 10.

Theory - The amplitude of the carrier signal varies in accordance with the instantaneous amplitude of modulating signal.

It means that amplitude of carrier signal has no information and varies as per signal containing information at each instant

$$m(t) = A_m \cos(2\pi f_m t)$$

$m(t) \rightarrow$ message signal

$$c(t) = A_c \cos(2\pi f_c t)$$

$c(t) \rightarrow$ carrier signal.

A_c, A_m are amplitudes of carrier signal and modulating signal respectively and f_c, f_m are their frequencies.

Thus, eqn of amplitude modulated wave is -

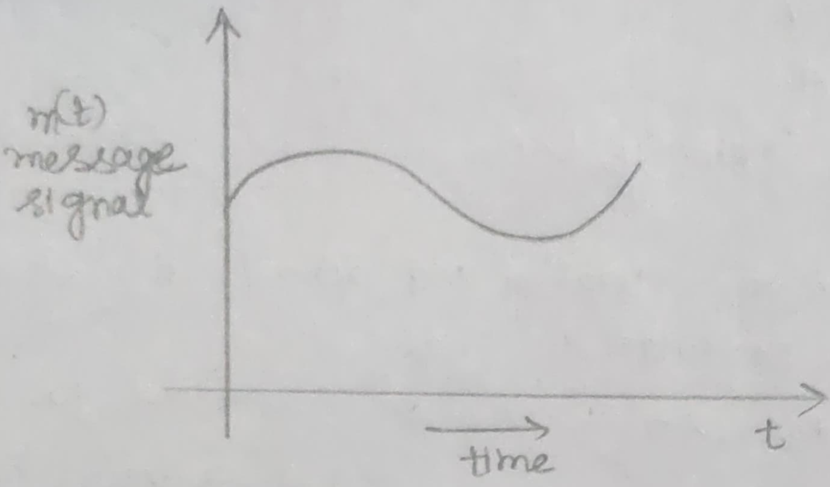
$$s(t) = [A_c + A_m \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

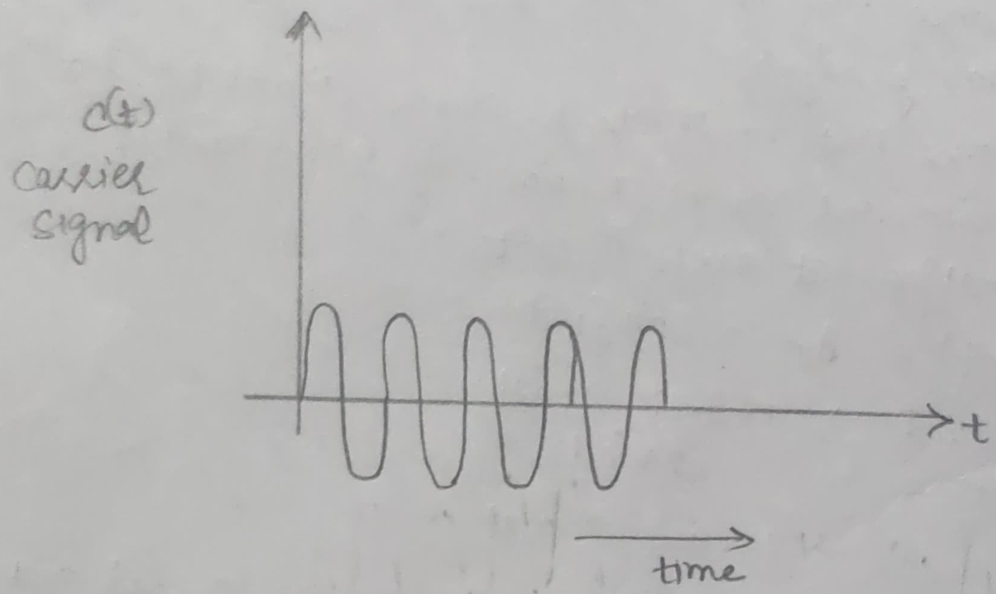
or

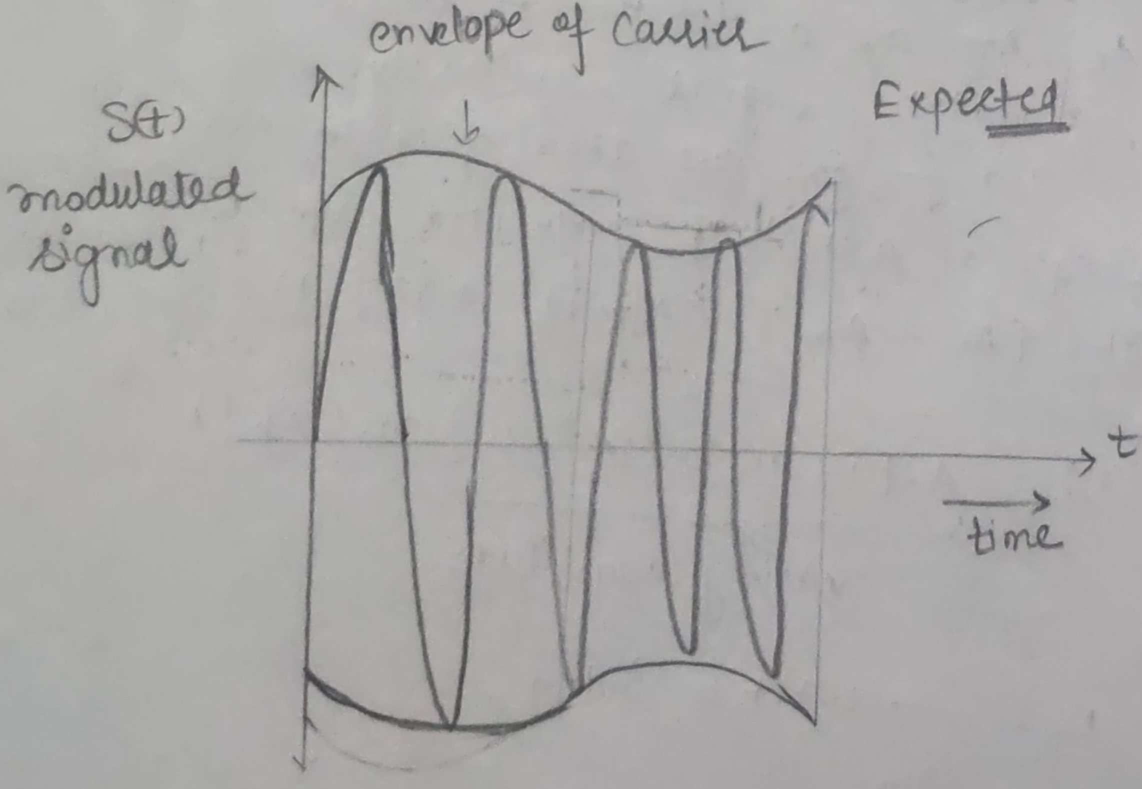
$$s(t) = \underbrace{A_c[1 + \mu \cos(2\pi f_m t)]}_{\text{varying amplitude}} \cos(2\pi f_c t)$$

μ = modulation index.

$$= \frac{A_m}{A_c}$$

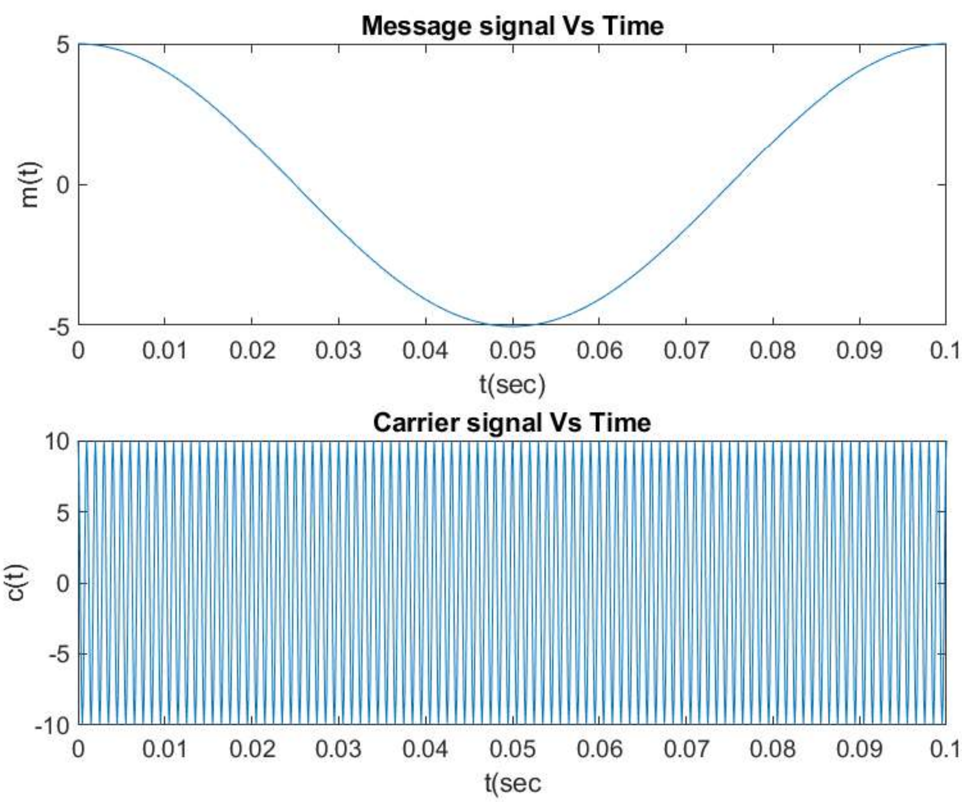

m(t)
message
signal
t
time


c(t)
carrier
signal
t
time

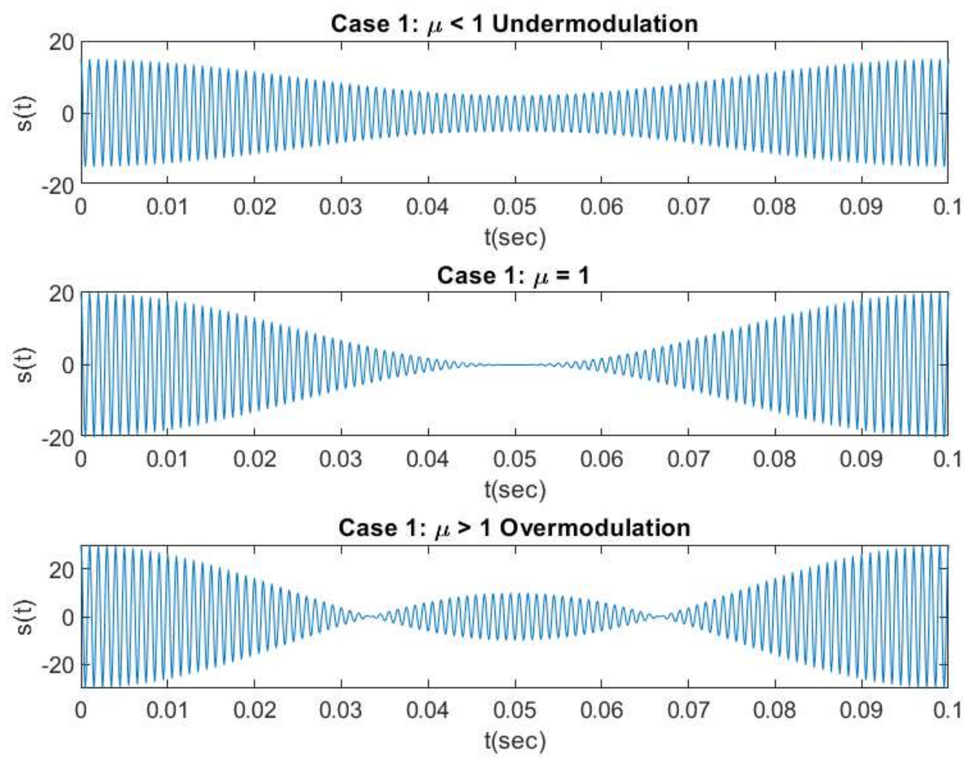

envelope of carrier
Expected
S(t)
modulated
signal
t
time

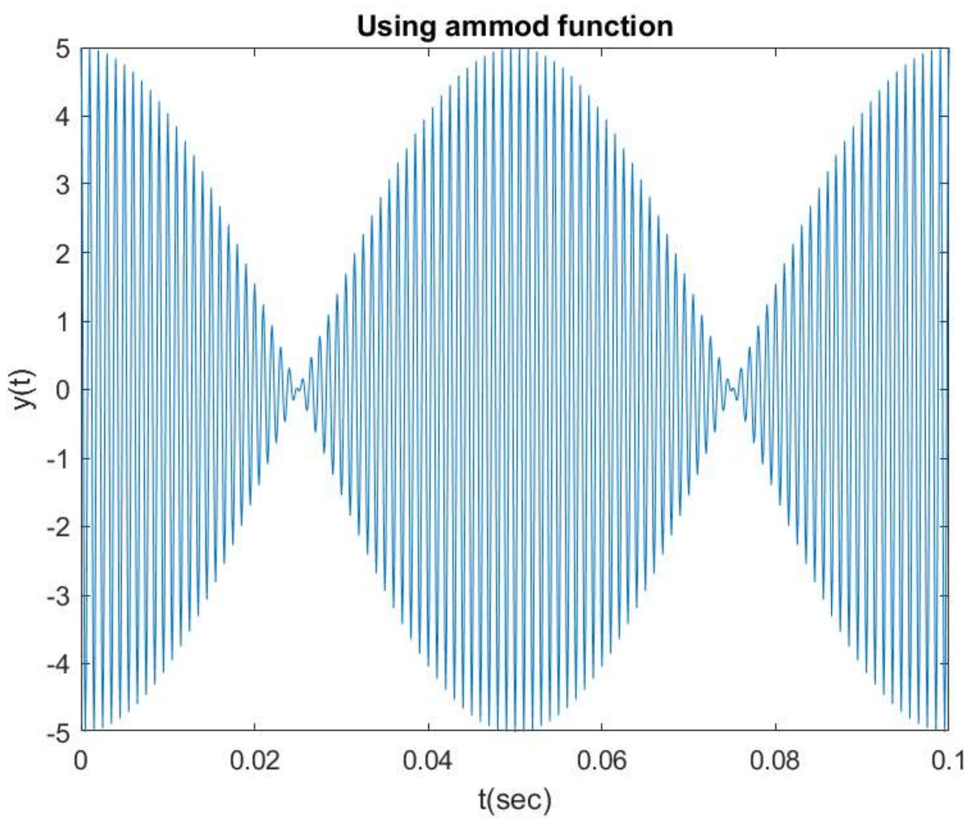
```
%%%%%%%%%%%%%
% Author: Amit Kumar Yadav
% Roll: 194107 (ECE-A)
% Lab Date: 17-01-2022
%%%%%%%%%%%%%
close all;
clc;

% AM modulation
Ac=10; %amplitude of carrier wave (volts)
Am=5; %amplitude of message signal (volts)
fm=10; %frequency of message signal (Hz)
fc=1000; %carrier frequency (Hz)
F=10000; %sampling frequency (Hz)
mi=Am/Ac; % modulation index
T=1/F;
t=0:T:0.1;% time vector

%1. message signal
m=Am*cos(2*pi*fm*t);
figure(1);
subplot(211); % plot at 1st position in a 2-by-1 grid
plot(t,m); xlabel('t(sec)'); ylabel('m(t)');
title('Message signal Vs Time')

%2.Carrier signal
c=Ac*cos(2*pi*fc*t);
figure(1); subplot(212);
plot(t,c); xlabel('t(sec'); ylabel('c(t)');
title('Carrier signal Vs Time');

%3. Amplitude modulated wave
%case1: mu<1
s = Ac*(1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t);
figure(2); subplot(311);
plot(t,s); xlabel('t(sec)'); ylabel('s(t)');
title('Case 1: \mu < 1 Undermodulation' );
%case2: mu=1
mi = 1;
s = Ac*(1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t);
figure(2); subplot(312);
plot(t,s); xlabel('t(sec)'); ylabel('s(t)');
title('Case 1: \mu = 1');
%case3: mu>1
mi = 2;
s = Ac*(1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t);
figure(2); subplot(313);
plot(t,s); xlabel('t(sec)'); ylabel('s(t)');
title('Case 1: \mu > 1 Overmodulation' );
```

```
% Using ammod Function
% Y = ammod(X, Fc, Fs) uses the message signal X to modulate the carrier
% frequency Fc(Hz) using amplitude modulation. X and Fc have sample
% frequency Fs (Hz). The modulated signal has zero initial phase. The
% default carrier amplitude is zero, so the function implements suppressed
% carrier modulation.

y = ammod(m,fc,F);
figure(3);
plot(t,y); xlabel('t(sec)'); ylabel('y(t)');
title('Using ammod function');
```



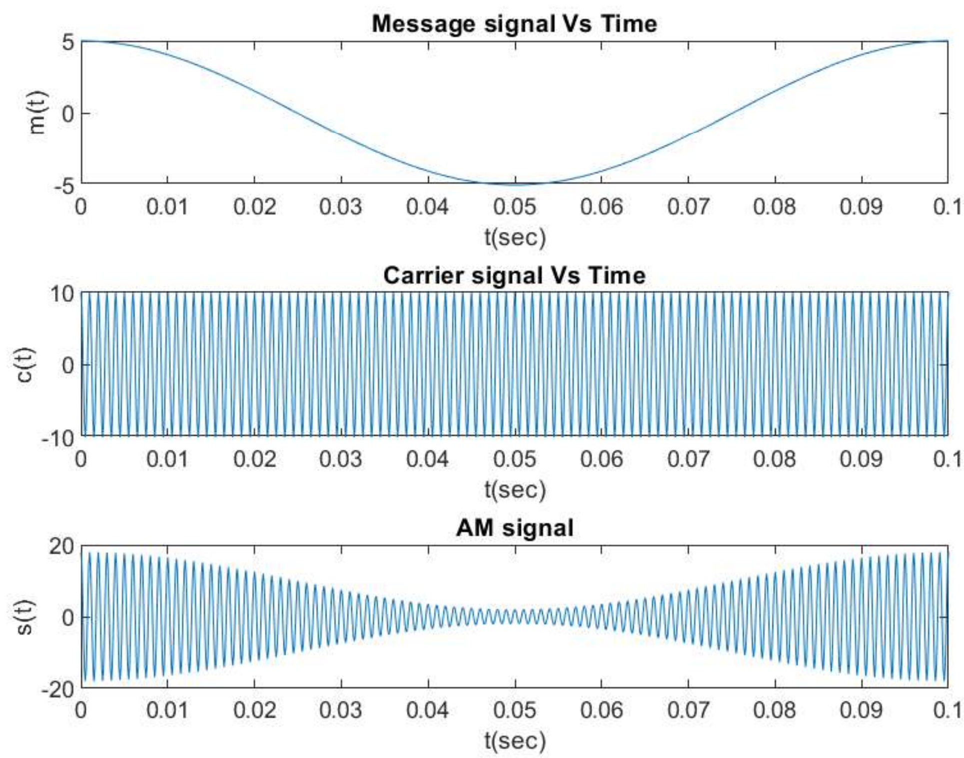
Message signal Vs Time
m(t)
5
0
-5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec)
Carrier signal Vs Time
c(t)
10
5
0
-5
-10
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec

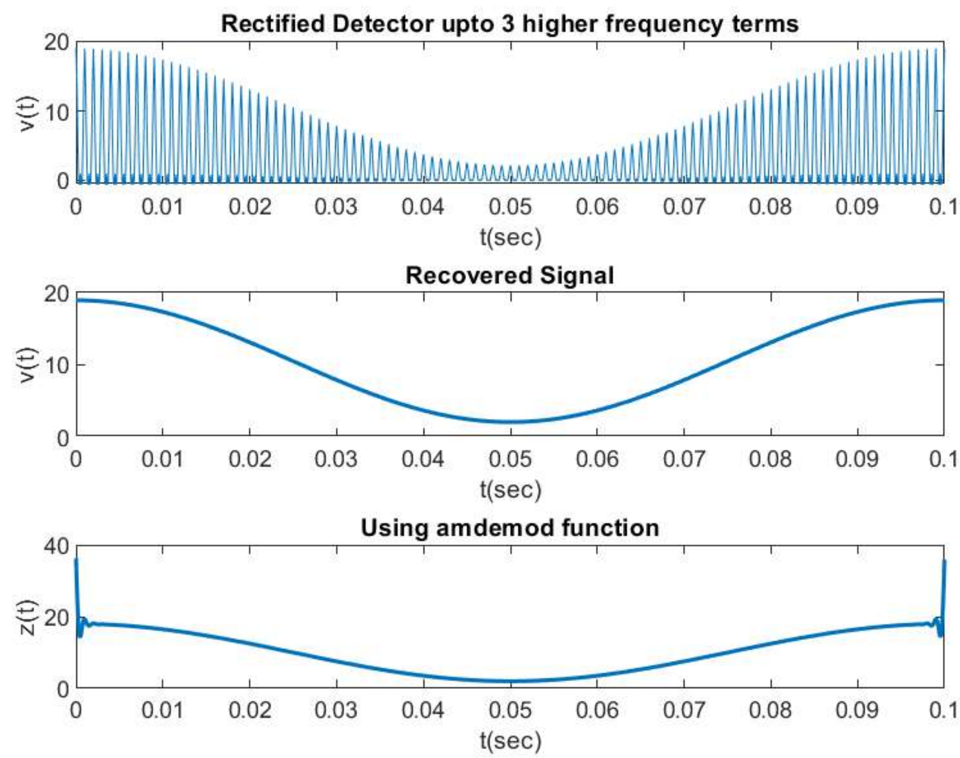

Case 1: μ < 1 Undermodulation
Case 1: μ = 1
Case 1: μ > 1 Overmodulation
s(t)
t(sec)
20
0
-20
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

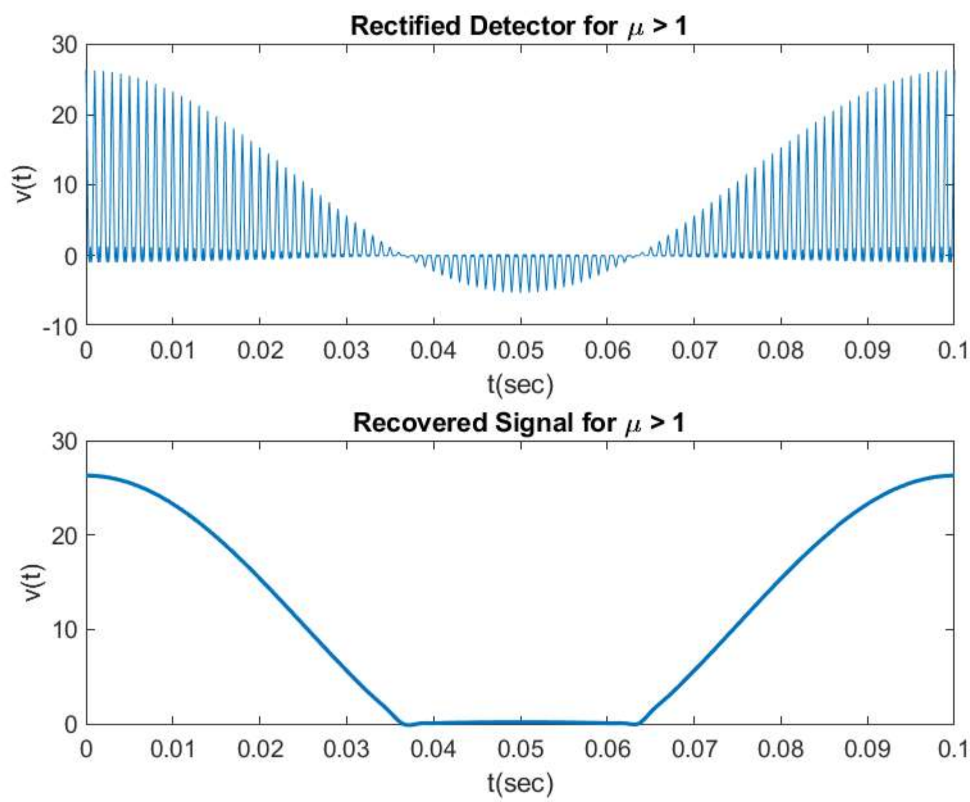

Using ammod function
5
4
3
2
1
0
-1
-2
-3
-4
-5
y(t)
0
0.02
0.04
0.06
0.08
0.1
t(sec)

```
%%%%%%%%%%%%%
% Author: Amit Kumar Yadav
% Roll: 194107 (ECE-A)
% Lab Date: 17-01-2022
%%%%%%%%%%%%%
close all;
clc;

% AM modulation
Ac=10; %amplitude of carrier wave
Am=5; %amplitude of message signal
fm=10; %frequency of message signal (Hz)
fc=1000; %carrier frequency (Hz)
F=10000; %sampling frequency (Hz)
mi=Am/Ac; % modulation index
T=1/F;
t=0:T:0.1;% time vector

%1. message signal
m=Am*cos(2*pi*fm*t);
figure(1);
subplot(311); % plot at 1st position in a 2-by-1 grid
plot(t,m); xlabel('t(sec)'); ylabel('m(t)');
title('Message signal Vs Time')

%2.Carrier signal
c=Ac*cos(2*pi*fc*t);
figure(1); subplot(312);
plot(t,c); xlabel('t(sec)'); ylabel('c(t)');
title('Carrier signal Vs Time');

%3. Amplitude modulated signal
mi = 0.8;
s = Ac*(1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t);
figure(1); subplot(313);
plot(t,s); xlabel('t(sec)'); ylabel('s(t)');
title('AM signal');

% Demodulation
%using rectified detector
v = Ac*((1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t)).*(0.5+ (2/pi)*(cos(2*pi*fc*t)-(1/3)* ↙
(cos(3*2*pi*fc*t))+(1/5)*(cos(5*2*pi*fc*t)) ));
figure(2); subplot(311);
plot(t,v); xlabel('t(sec)'); ylabel('v(t)');
title('Rectified Detector upto 3 higher frequency terms' )

%plotting envelope
figure(2); subplot(312);
[up, lo] = envelope(v, 10, 'peak');
```

```
plot(t,up,'LineWidth',1.5); xlabel('t(sec)'); ylabel('v(t)');
%xlim([0 0.1]); ylim([0 40]);
title('Recovered Signal');
%using amdemod function of MATLAB
% Z = amdemod(Y,Fc,Fs) demodulates the amplitude modulated signal Y from
% the carrier frequency Fc (Hz). Y and Fc have sample frequency Fs (Hz).
% The modulated signal Y has zero initial phase, and zero carrier
% amplitude, for suppressed carrier modulation. A lowpass filter is used
% in the demodulation. The default filter is: [NUM,DEN] =
% butter(5,Fc*2/Fs).
z = amdemod(s,fc,F);
figure(2); subplot(313);
plot(t,z,'LineWidth',1.5); xlabel('t(sec)'); ylabel('z(t)');
title('Using amdemod function')

% case of mu>1
mi = 1.5;
v = Ac*((1 + mi*cos(2*pi*fm*t)).*cos(2*pi*fc*t)).*(0.5+ (2/pi)*(cos(2*pi*fc*t)-(1/3)* ↙
(cos(3*2*pi*fc*t))+(1/5)*(cos(5*2*pi*fc*t))));
figure(3); subplot(211);
plot(t,v); xlabel('t(sec)'); ylabel('v(t)');
title('Rectified Detector for \mu > 1' );
%plotting envelope
figure(3); subplot(212);
[up, lo] = envelope(v, 10, 'peak');
plot(t,up,'LineWidth',1.5); xlabel('t(sec)'); ylabel('v(t)');
%xlim([0 0.1]); ylim([0 40]);
title('Recovered Signal for \mu > 1' );
```


Message signal Vs Time
m(t)
5
0
-5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec)
Carrier signal Vs Time
c(t)
10
0
-10
t(sec)
AM signal
s(t)
20
0
-20
t(sec)

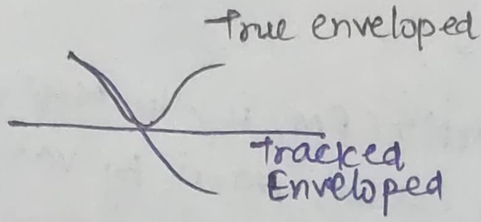

Rectified Detector upto 3 higher frequency terms
v(t)
t(sec)
Recovered Signal
v(t)
t(sec)
Using amdemod function
z(t)
t(sec)



Rectified Detector for μ > 1
30
20
10
0
-10
v(t)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec)
Recovered Signal for μ > 1
30
20
10
0
v(t)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
t(sec)

Explaination →

In figure, we see the case of phase reversal in modulating signal. What happens is when modulating index ($\mu > 1$) then true envelope becomes different from tracked one.



[Envelope distortion]

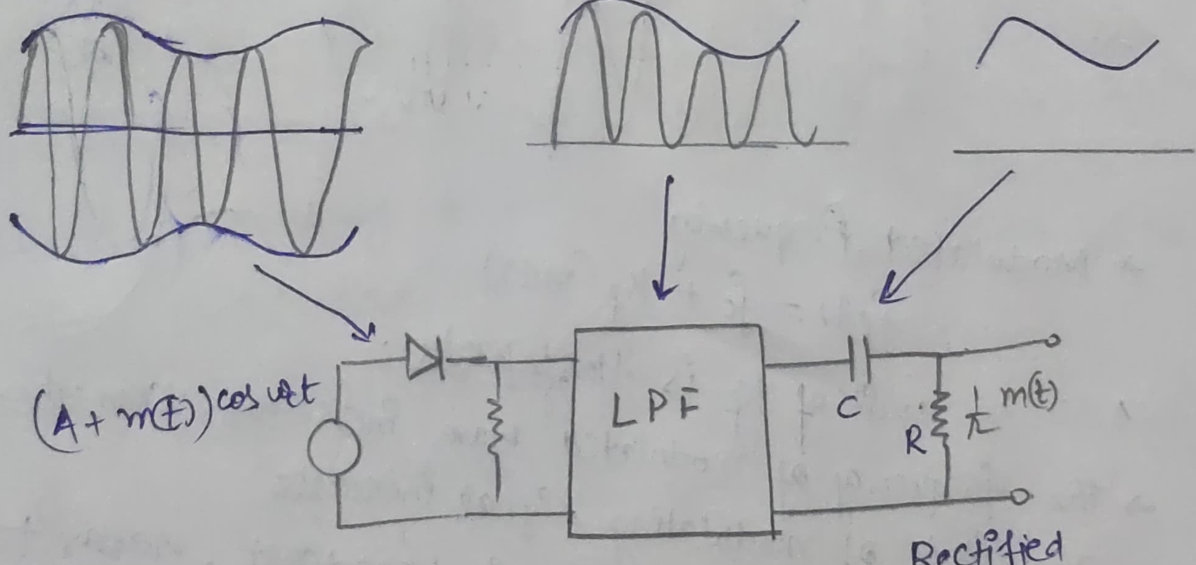
So, to avoid envelope distortion,

$$1 + \mu . m(t) \geq 0$$

(or) $$\mu [\min (m(t))] \leq 1$$

modulation index = sensitivity × amplitude of message signal

⇒ Envelope Detection -



Conclusion -

- when simulated, we save a modulation in amplitude of carrier signal which varied as per message signal.
- for $\mu > 1$, we saw overly modulated signal in which phase reversal takes place and its not possible to demodulate it.