Date 14/10/2020.

Expt. No. 7 Adm No : U19CS048 Page No.s: 105-122

Experiment No : 07
EFFECT OF AWGN OF AM AND FM

Objective: To study the transmission amplitude modulated (AM) and frequency modulated (FM) signal under the additive Gaussian noise signal using the Matlab/ Simulink and draw the distorted waveform for different signal to noise (SNR) values.

Software: Matlab/Simulink

Theory: AWGN is a basic noise model used to mimic the effect of many random process that occurs in nature.
Channel produces Additive white Gaussian Noise.

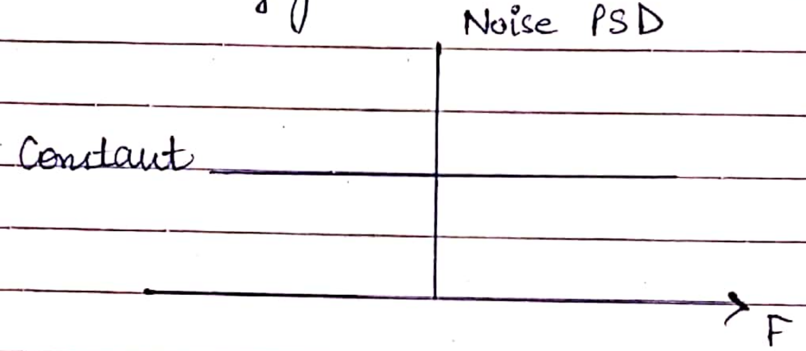
Additive – The received signal equals the transmit signal plus some noise, where the noise is statistically independent of the signal.

$$r(t) = s(t) + w(t)$$

$s(t)$ → message signal
$w(t)$ → noise

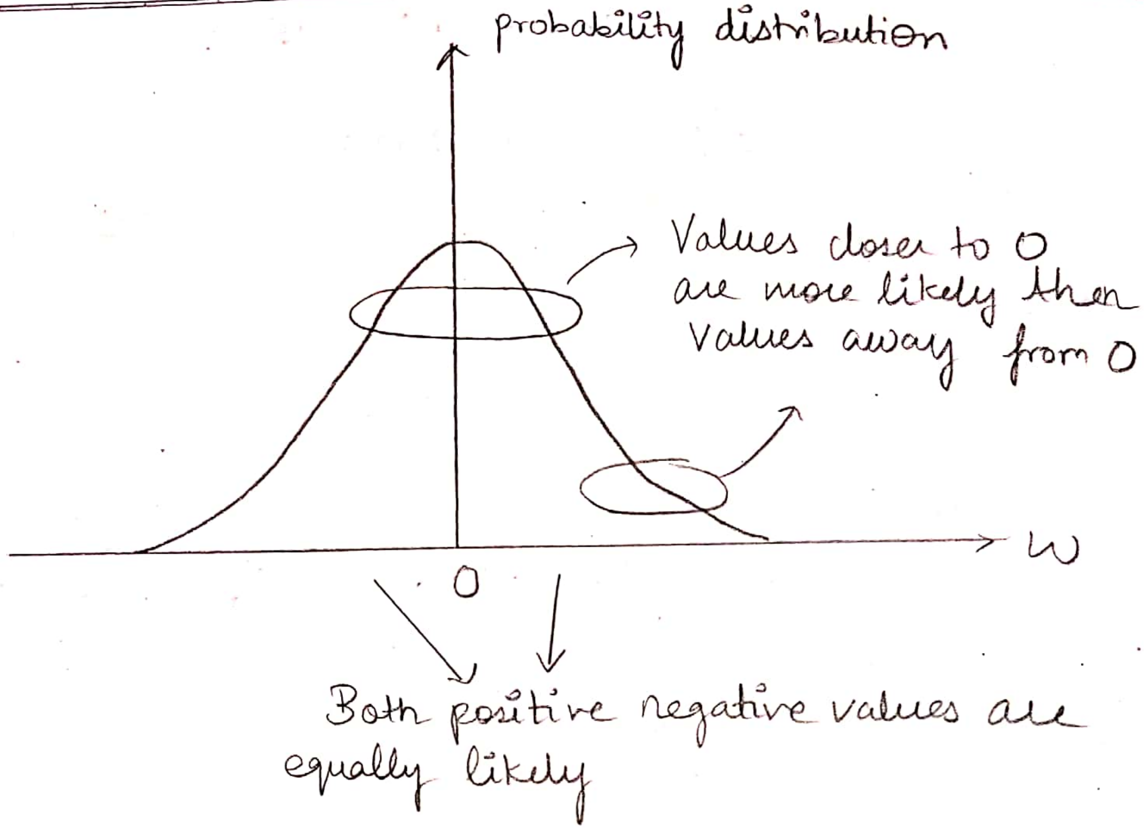
White: It refers to the noise has some power distribution at every frequency or it has uniform power across the frequency band for the information system.

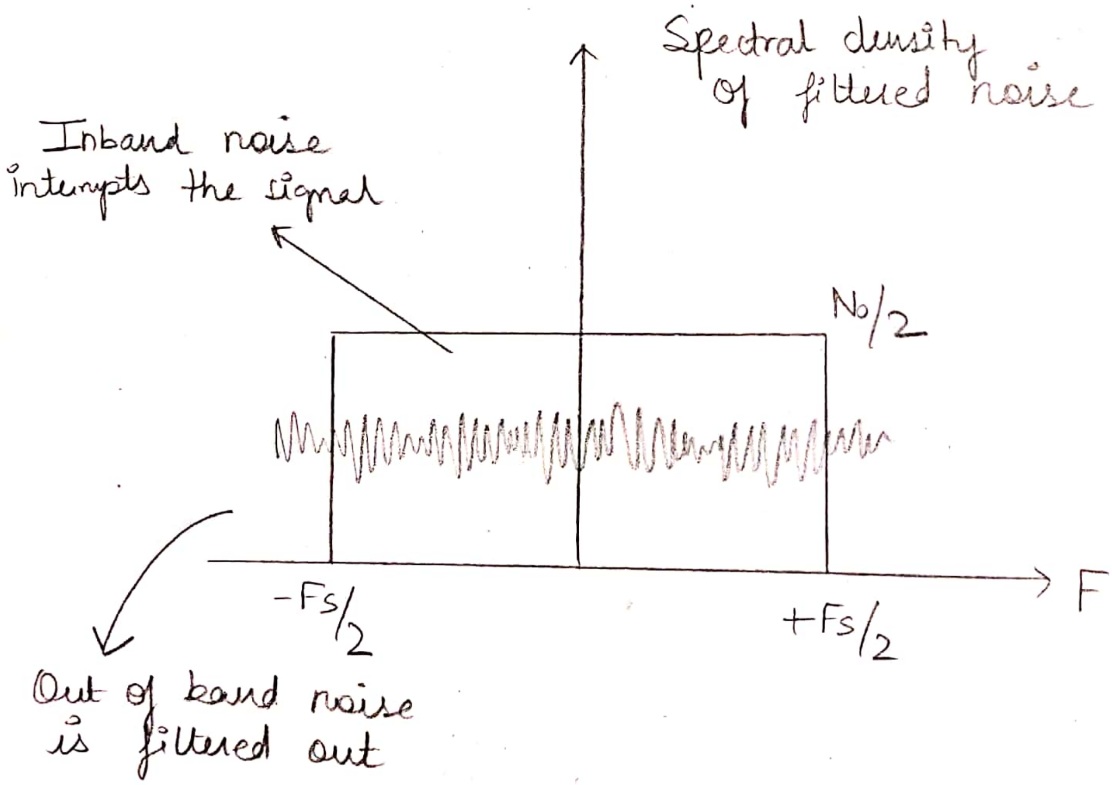
It is an analogy to the color white which has uniform emission at all frequency in the visible spectrum. if we focus a beam of light for each color on the visible spectrum onto a single spot whose combination would result in a beam of white light, as consequence power spectral density (PSD) of white noise is constant for all frequency ranging from $-\infty$ to $+\infty$ as shown in figure.



Gaussian → Gaussian distribution, or a normal distribution, has an average of zero in time domain, and is represented as a bell-shaped curve. The probability distribution of the noise sample is Gaussian with a zero mean.
The value close to zero has a higher chance of occurrence while the values far away from zero are less likely to appear.

In reality, the ideal flat spectrum from $-\infty$ to ∞ is true for frequency of interest in wireless communication (a few KHz to hundreds of GHz) but not for higher frequency.


probability distribution
Values closer to 0 are more likely than values away from 0
w
0
Both positive negative values are equally likely


Spectral density of filtered noise
Inband noise interrupts the signal
No/2
-Fs/2
+Fs/2
F
Out of band noise is filtered out

Signal-to-Noise Ratio:

The SNR or S/N is a measure used in science and engineering that compare the level of a desired signal to the level of background noise. It is defined as the ratio of signal to power to noise power, often expressed in decibel (dB). A ratio higher than 1:1 (greater than 0dB) indicate more signal than noise.

SNR, bandwidth, and channel capacity of communication channel are connected by Shannon-Hartley theorem.

$$SNR_{dB} = 10\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right)$$

Shannon-Hartley theorem: It indicates that channel capacity (bits per second) or information rate of data that can be communicated at low error rate using an average received signal power through communication channel subject to AWGN of power.

$$C = B\log_2\left(1 + \frac{S}{N}\right)$$

where B is bandwidth of channel in Hertz.

We can see that it is related to SNR.

Different case for SNR values.

5dB - 10dB → is minimum level to establish a connection, due to noise level being nearly indistinguishable from desired signal

25 dB - 40dB → is deemed to be good.

41dB or higher → is considered to be excellent.

AWGN over AM (amplitude modulation)
Let $E_m(t) = E_m \sin W_m t$ be message signal
and $E_c(t) = E_c \sin W_c t$ be carrier signal
then we know that,

$$e_m(t) = (E_c + E_m(t)) \sin W_c t$$

$$e_m(t) = (E_c + E_m \sin W_m t) \sin W_c t$$

MATLAB Code:
For performing AWGN effects over AM →

```
clc;
clear all;
t = 0:0.001:1:1
Vm = 6;
Vc = 12;
fm = 5;
fc = 30;
m = Vm * sin (2* pi * fm * t);
c = Vc * sin(2 * pi * fc * t);
amp = Vc + Vm * sin (2 * pi * fm * t);
am = amp * sin (2 * pi * fc * t);
y = awgn (am, 15; 'measured');
subplot (4,1,1);
plot (t, m);
xlabel ('time');
```

```
ylabel ('amplitude');
title ('Carrier Signal');
Subplot (4,1,3);
plot (t, am);
xlabel ('time');
ylabel ('amplitude');
title ('amplitude modulated signal')
Subplot (4, 1, 4);
plot (t, y);
xlabel ('time');
ylabel ('amplitude');
title ('amplitude modulated signal with AWGN');
```

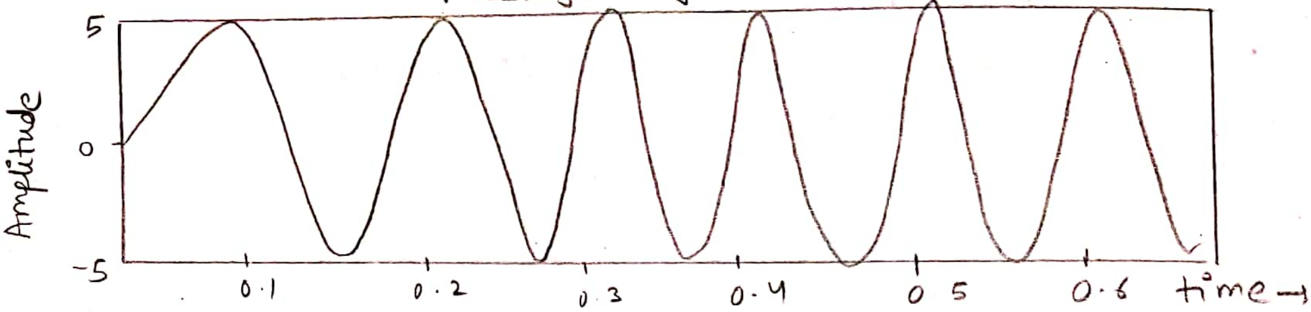
Matlab Code for AWGN effect on different functions (Sine, Cosine, Sawtooth)

```
clc;
clear all;
t=(0:0.1:10);
x = Sawtooth(t);
y = awgn (x, 10, 'measured');
plot (t, [x y])
legend ('Original Signal', 'Signal with AWGN')

clc;
clear all;
t = (0:0.1:10);
x = Sin (t);
```

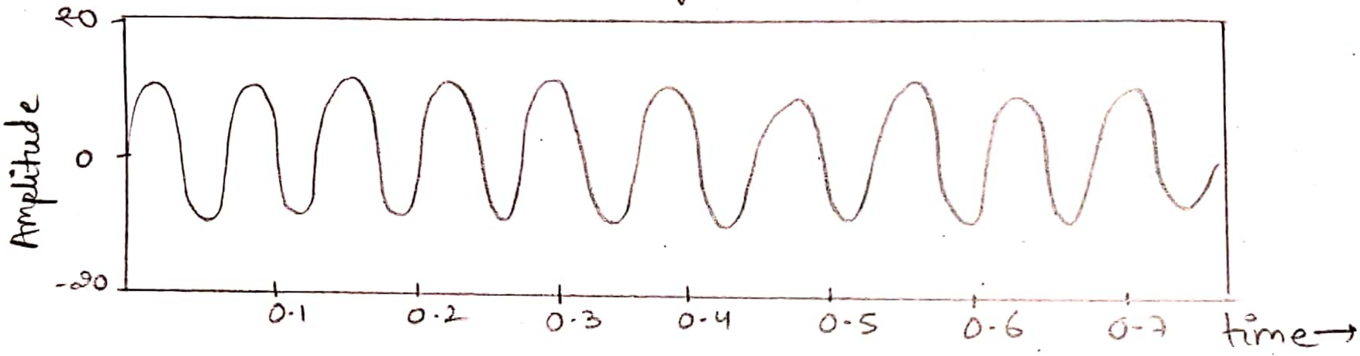
Scanned by CamScanner

AWGN Effect over AM

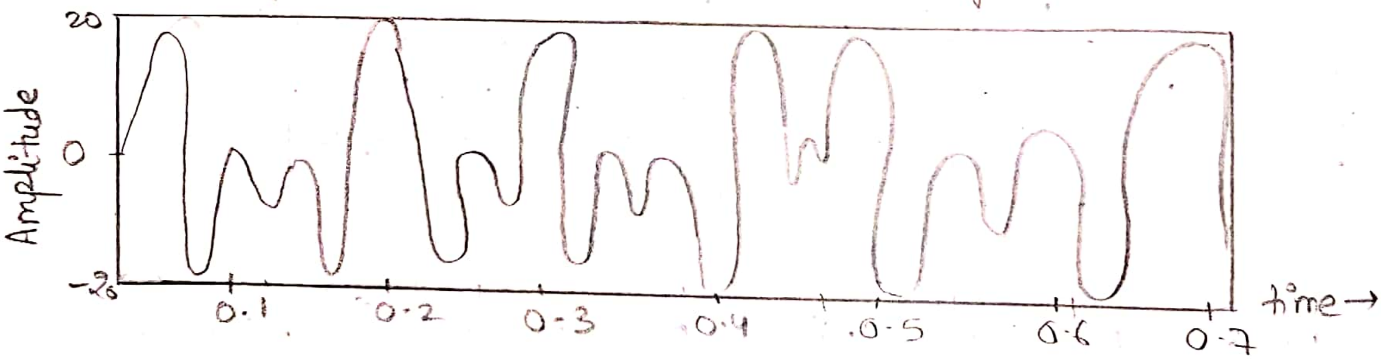
Message Signal



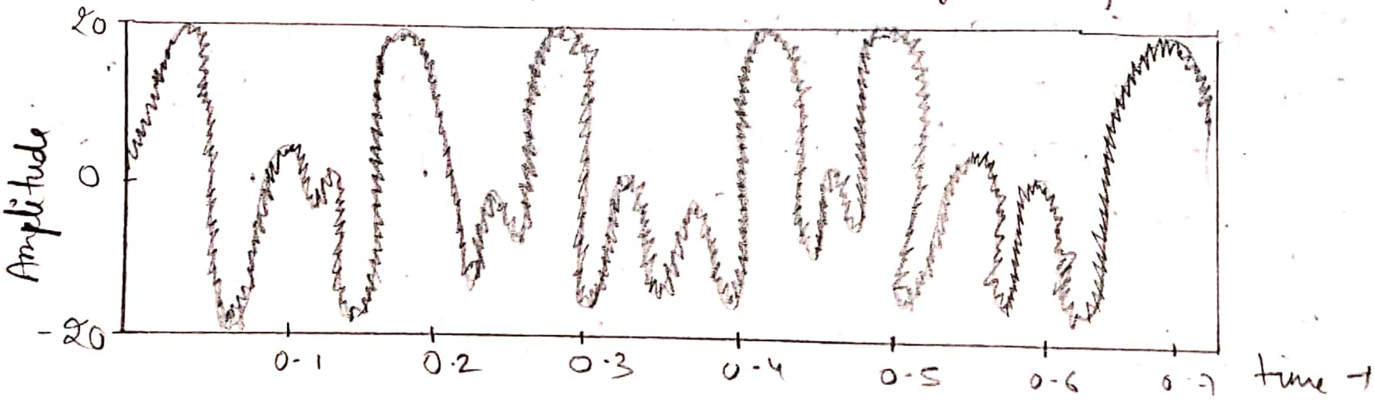
Carrier Signal



Amplitude Modulated Signal



Amplitude Modulated Signal Using AWGN



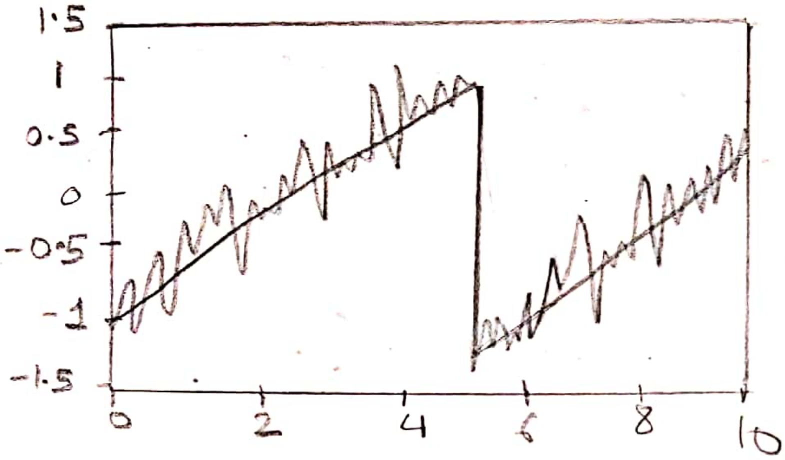
```
y=awgn(x,10,'measured');
plot(t, [x y])
legend('Original Signal', 'Signal with AWGN');

clc;
clear all;
t=(0:0.1:10);
x= Cos(t);
y= awgn(x,10,'measured');
plot(t,[x y])
legend('Original Signal', 'Signal with AWGN')
```

MATLAB CODE FOR AM WITH DIFFERENT SNR VALUES

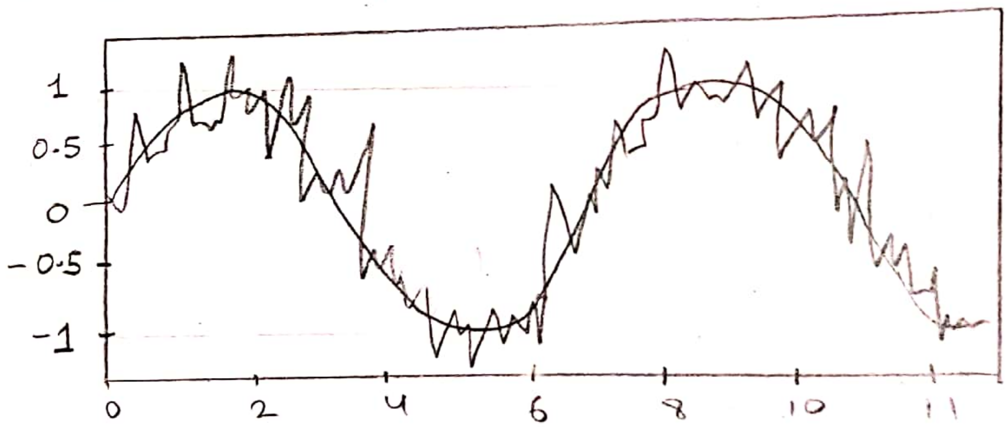
```
clc;
clear all;
t =0:0.001:1;
Vm = 5;
Vc=10
fm=2;
fc=25;
m= Vm*Sin(2*pi*fm*t);
c= Vc* Sin(2*pi*fc*t);
amp = Vc+Vm* Sin(2*pi*fm*t);
am= amp.*Sin(2*pi*fc*t);
y1 = awgn(am,10,'measured');
y2 = awgn(am,100,'measured');
```

AWGN Effect on different functions

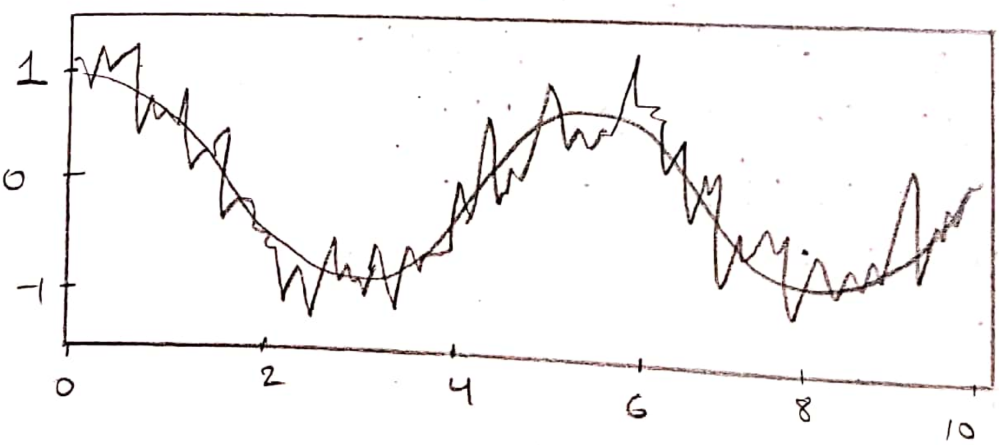
- Sawtooth:



- Sine:



- Cosine:



Date

Expt. No. 7

Page No. 114

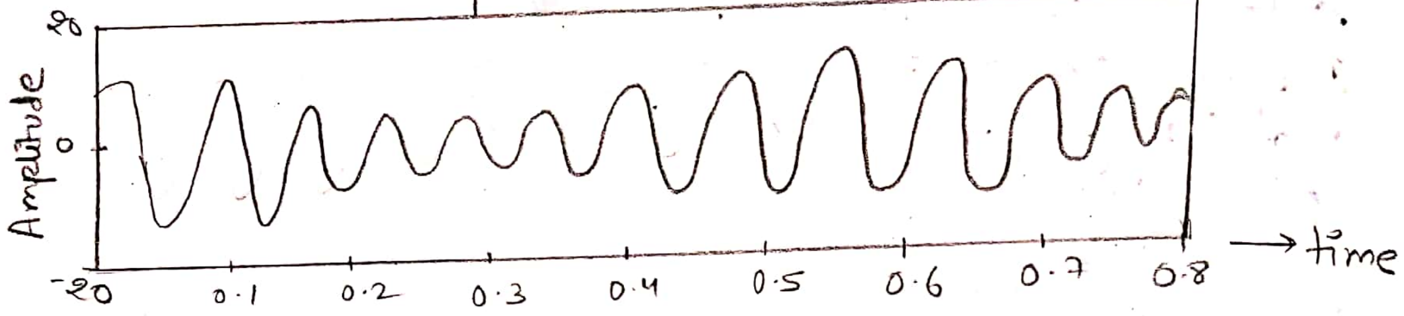
```
y3 =awgn(am, 1000, 'measured');
Subplot (4,1,1);
plot( t, am);
xlabel ('time');
ylabel ('amplitude'); title('amplitude modulated signal');
Subplot (4,1,2);
plot (t, y1);
xlabel ('time');
y label ('amplitude').
title('Amplitude modulated signal with AWGN [Snr 10]);
Subplot ( 4,1,4);
plot ( t, y3);
xlabel (' time');
ylabel ('amplitude');
title ('amplitude modulated signal with AWGN [Snr 1000]');
```

MATLAB CODE FOR FM SIGNAL UNDER AWGN:

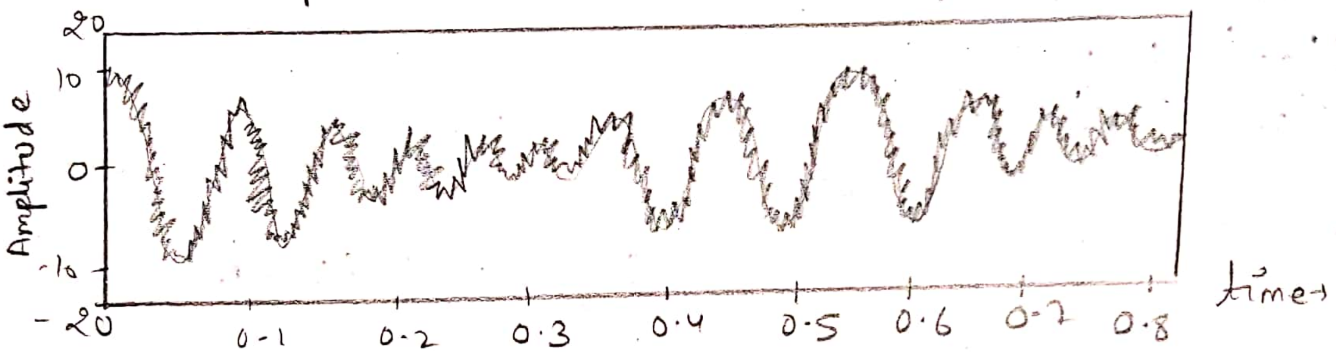
```
clc;
clear all;
t=0:0.001:1;
Vm = 5;
Vc=5;
fm =2
fc = 25
fd = 5;
msg = Vm* sin (2*pi *fm*t);
C = Vc* Sin (2*pi * fc *t);
y = Vc* sin(2*pi*fc*t+fd.*Cos (2*pi * fm* t));
```

AM With Different SNR Values

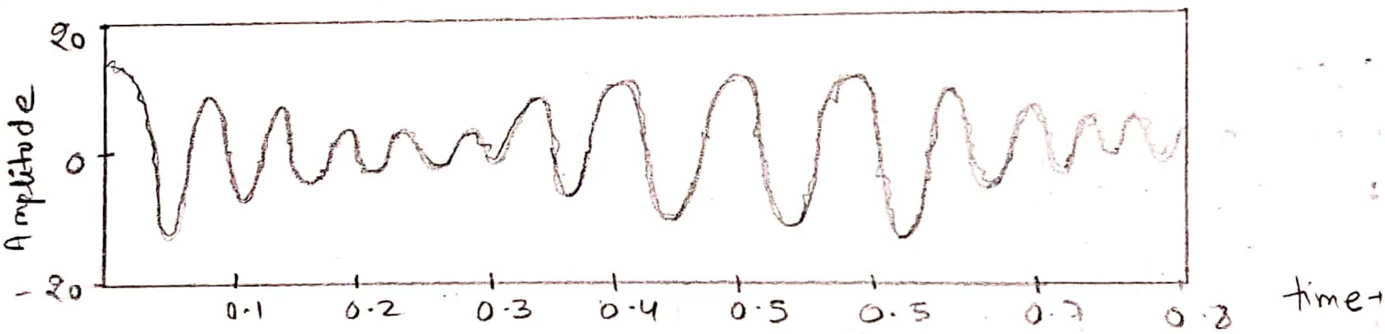
Amplitude Modulated Signal



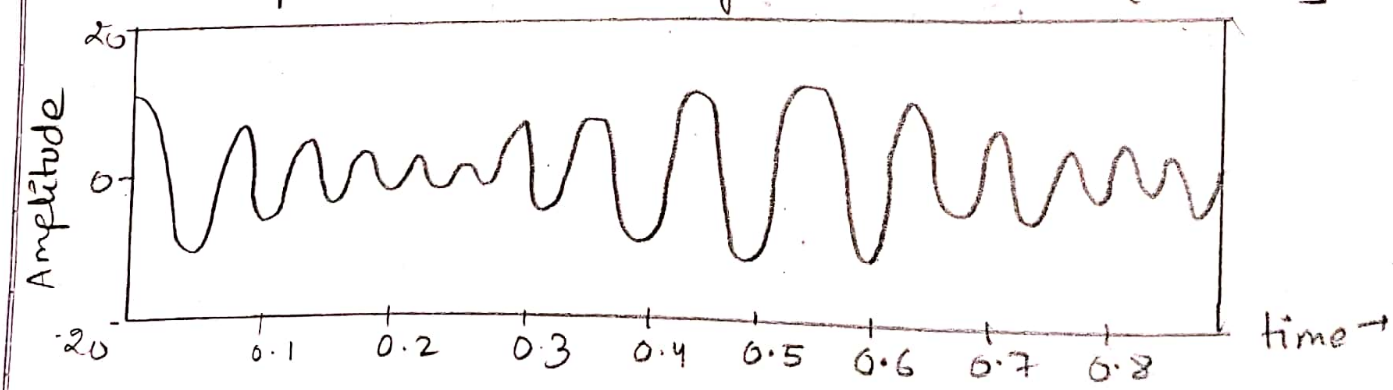
Amplitude Modulated Signal with AWGN [Snr 10]



Amplitude modulated Signal with AWGN [Snr 100]



Amplitude modulated signal with AWGN [Snr 1000]



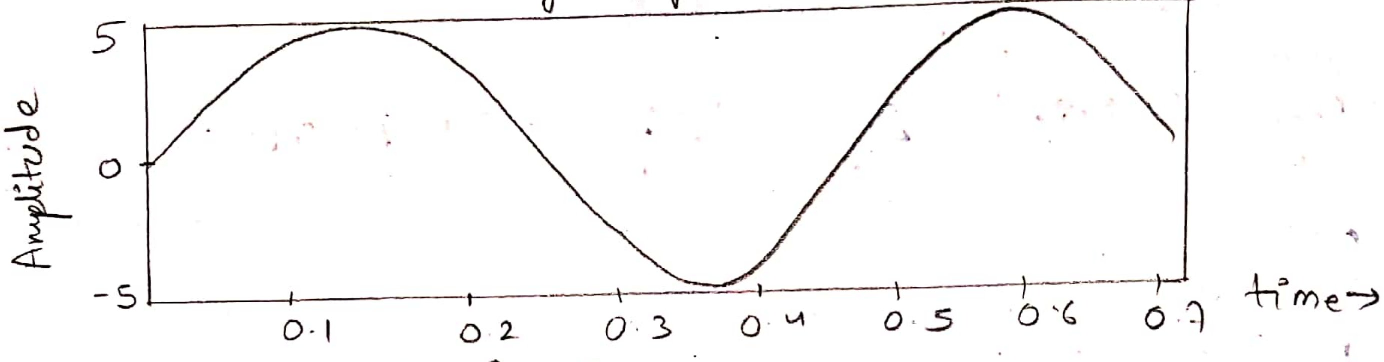
```
Z = awgn (y, 5, 'measured');
subplot (4,1,1);
plot(t, msg);
xlabel ('time');
ylabel ('amplitude');
title('message signal');
Subplot(4,1,2); plot (t, c)
xlabel ('time');
ylabel ('amplitude');
title('carrier signal');
subplot(4,1,3); plot (t,y);
Xlabel ('time');
ylabel( 'amplitude');
title ('Frequency modulated Signal');
subplot (4,1,4);
plot (t, z)
xlabel('time');
ylabel ('amplitude');
title(' Frequency modulated Signal with AWGN');
```

Matlab Code for Different SNR in FM

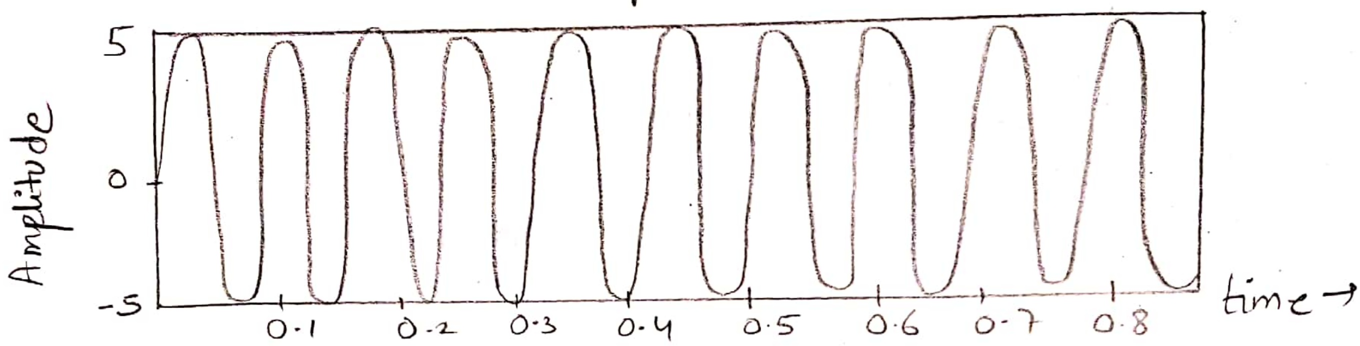
```
clc;
clear all;
t=0:0.001:1;
Vm=10
Vc=5
fm=2
fc=25
```

FM under AWGN

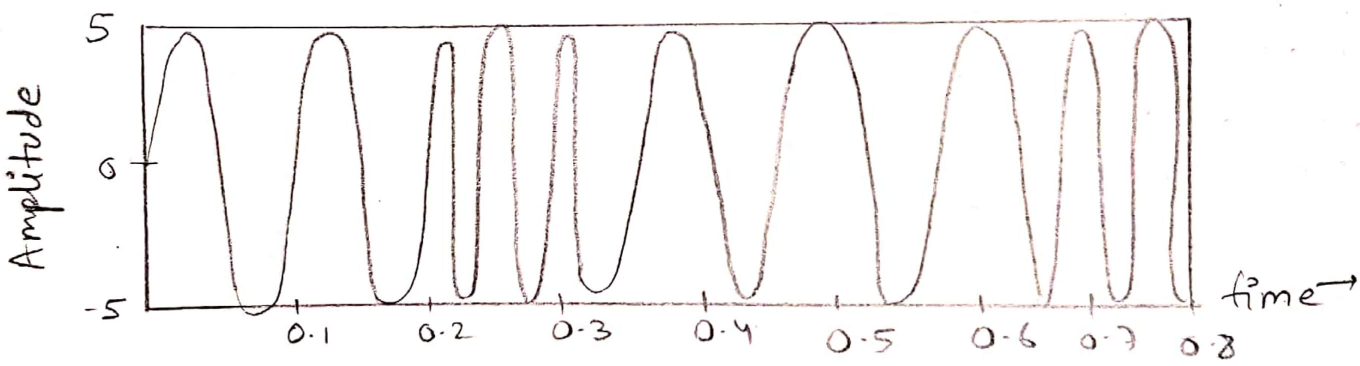
Message Signal



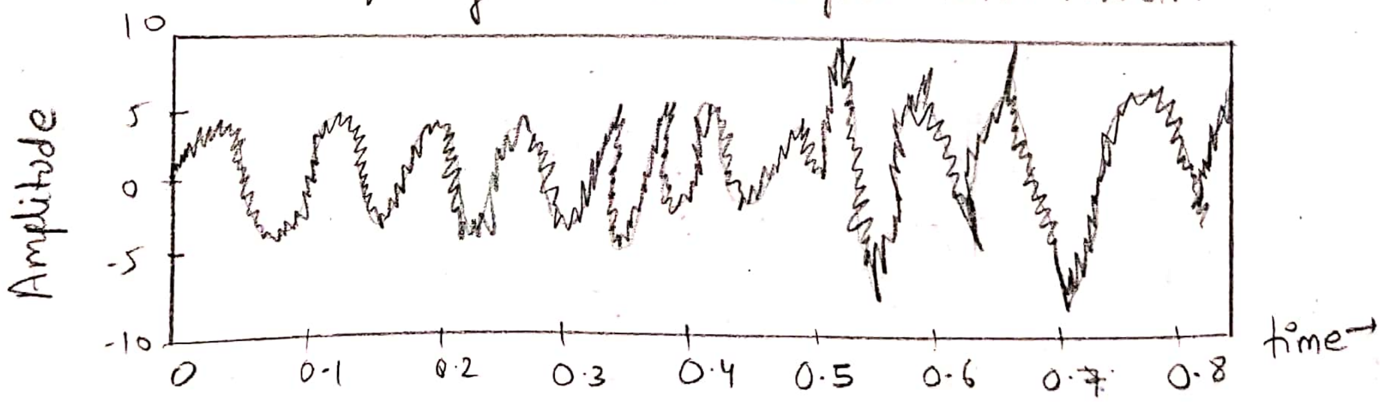
Carrier Signal



Frequency Modulated Signal



Frequency Modulated Signal With AWGN



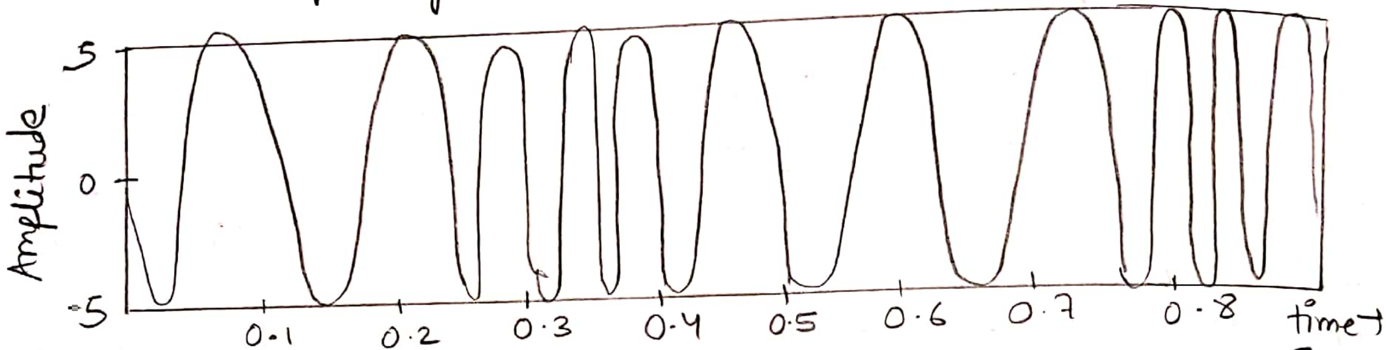
Date

Expt. No. 7 Page No. 118

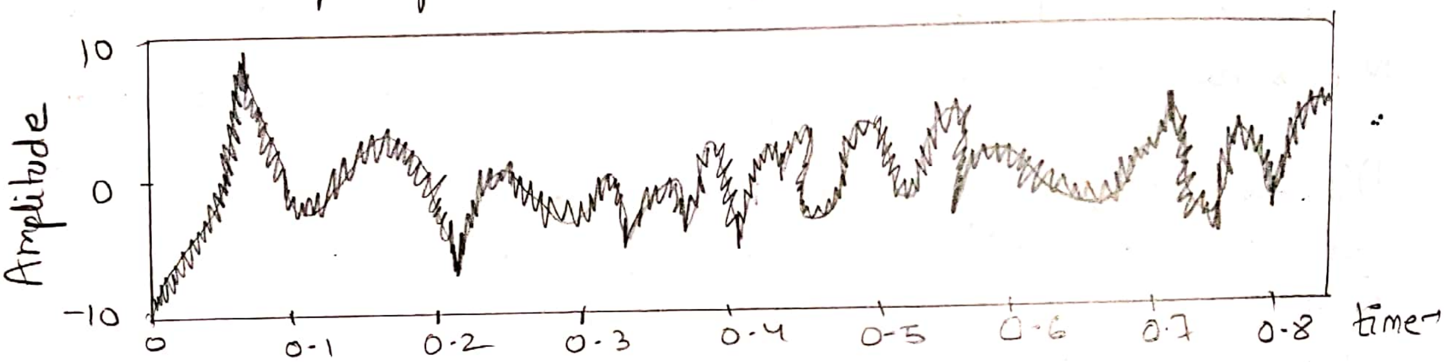
```
fd=10;
m= Vm* Sin(2* pi *fm * t);
C = Vc* Sin (2* pi * fc *t);
amp = Vc + Vm * Sin(2* pi * fm * t);
y= Vc * Sin( 2* pi * fc * t + fd. * cos (2*pi*fm*t));
y1 = awgn (y, 1, 'measured');
y2 = awgn (y, 10, 'measured');
y3 = awgn (y, 100, 'measured');
subplot( 4, 1, 1);
plot (t, y);
xlabel('time');
ylabel ('amplitude'); title ('Frequency modulated Signal');
Subplot ( 4, 1, 2);
plot (t, y);
Xlabel ('time');
ylabel ('amplitude');
title ('Frequency modulated Signal with AWGN [snr 1]');
Subplot ( 4, 1, 3);
plot (t, y2);
xlabel ('time'); Ylabel ('amplitude');
title ('Frequency modulated signal with AWGN [snr 10]');
Subplot ( 4, 1, 4)
plot (t, y3);
Xlabel ('time');
ylabel('amplitude')
title('Frequency modulated signal with AWGN [snr 100]');
```

AWGN for different SNR in FM

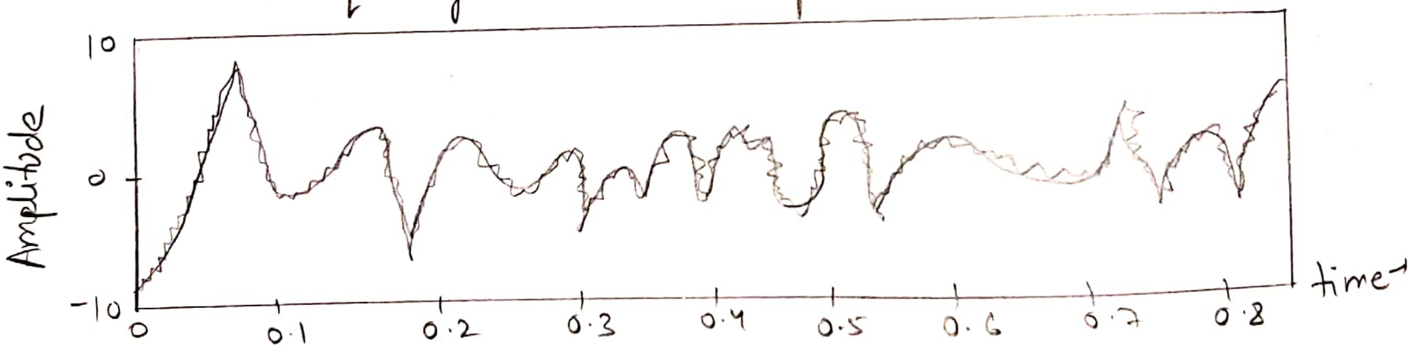
Frequency Modulated Signal



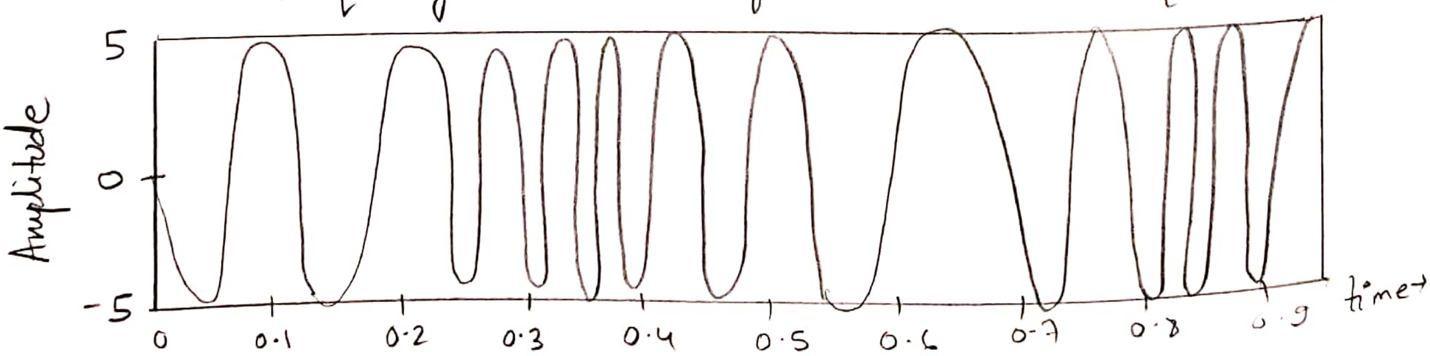
Frequency modulated signal with AWGN [snr 1]



Frequency modulated signal with AWGN [snr 10]



Frequency modulated signal with AWGN [snr 100]

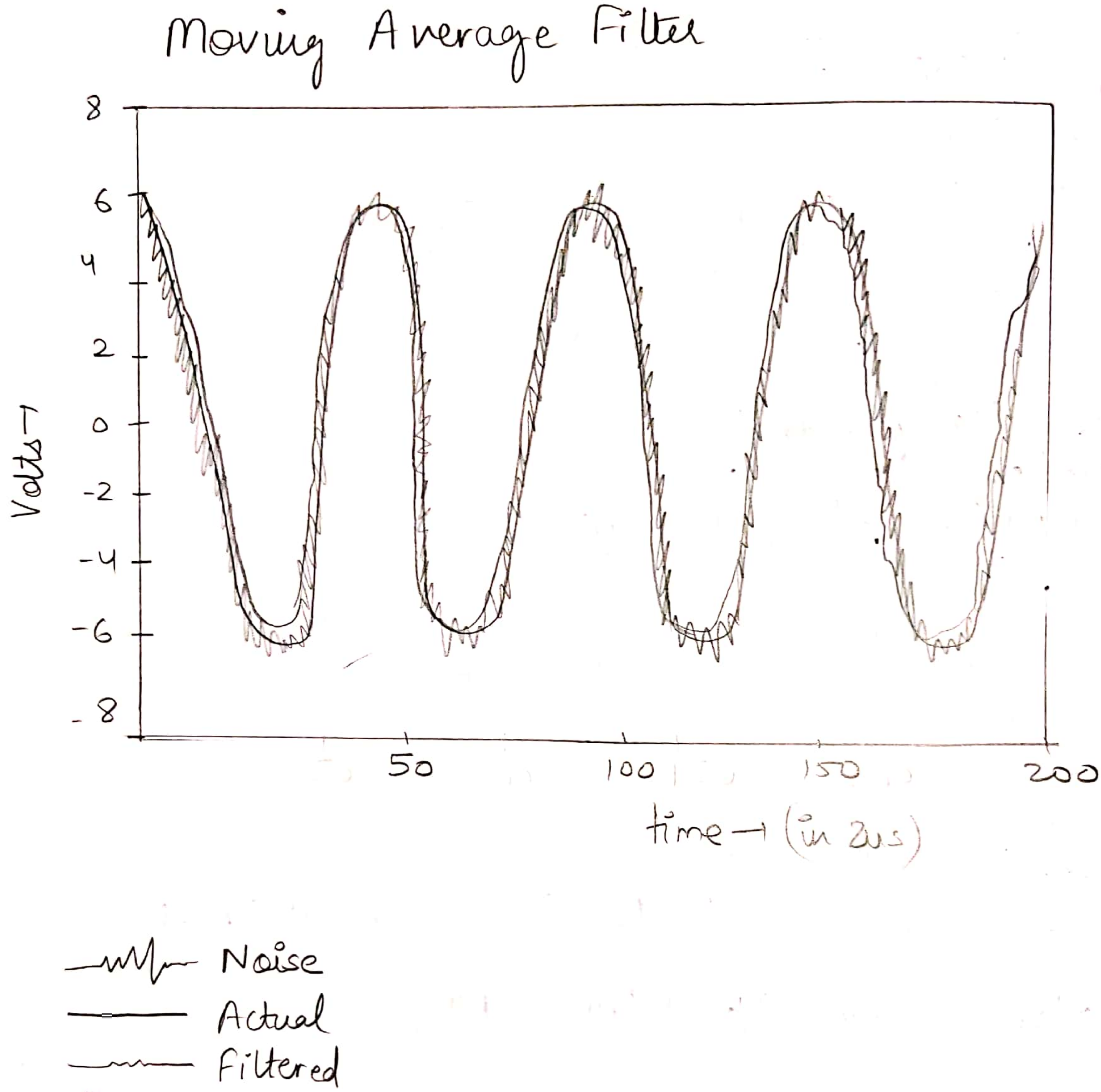


Date ________

Expt. No. 7

Matlab Code for Moving Average Filter to retrieve the Signal by Averaging the Noise Fluctuation

```
%moving average filter
clear all;
close all;
clc;
fs = 500000;
fm = 10000;
t = 1:200;
x= 5* cos(2* pi * (fm/fs) *t);
z= awgn(x,5); %average white Gaussian noise to the
                               input with S/N =5
plot(x,'g','linewidth',15);
hold on;
plot(z)
hold on;
for i=1:194;
y(i)=(z(i)+z(i+1)+z(i+2)+z(i+3)+z(i+4)+z(i+6))/6;
end
plot(y,'r','linewidth',1.5);
legend('Actual','Noisy','Filtered');
title('moving Average filter','font size',12);
xlabel('--> time in 2us');
ylabel('--> volts');
```


Moving Average Filter
8
6
4
2
0
-2
-4
-6
-8
Volts→
50
100
150
200
time→ (in 2us)
Noise
Actual
Filtered

Date

Expt. No. 7

Page No. 122

Advantages of AWGN:

- The noise is additive i.e the received signal is equal to the transmitted signal plus noise. This gives the most widely used equality in communication systems.
- The result of summing a large number of different & independent factors which allows us to apply an important result from probability and statistics, called the central limit theorem

Applications:

It is often used as a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a gaussian distribution of amplitude.

Conclusion:

Succesfully observed the AM and FM under AWGN using Matlab software and drew the waveforms for different signal to noise values.