EXPERIMENT 7 : [U19CS012]

EFFECT OF AWGN on AM and FM

AWGN : Additive white Gaussian noise

AIM: To study the transmission of Amplitude modulated (AM) and Frequency modulated (FM) signal under the Additive Gaussian Noise channel.

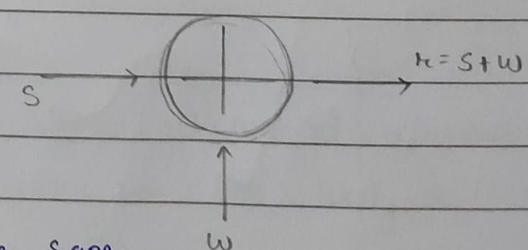
APPARATUS:- MATLAB

THEORY: 1.) Additive White Gaussian Noise (AWGN)

A Basic Noise model used to mimic the effect of many random processes that occur in nature. Channel produces Additive white Gaussian Noise. (AWGN)

(a) Additive - The received signal equals the transmit signal plus some noise, where the noise is statistically independent of the signal.

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

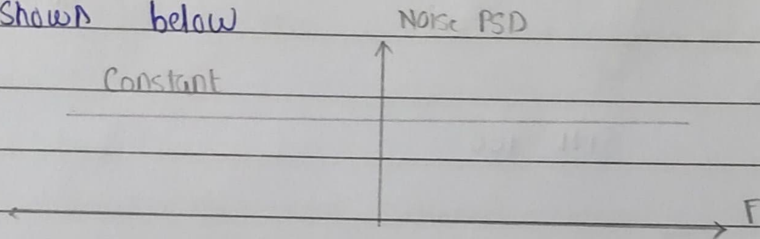


(b) White : It refers that the noise has the same power distribution at every frequency OR it has uniform power across the frequency band for the information system.

Teacher's Signature:

- It is an analogy to the color white which has uniform emissions at all frequencies in the visible spectrum. If we focussed a beam of light for each color on the visible spectrum onto a single spot, that combination would result in a beam of white light.

- As a consequence, the Power Spectral Density (PSD) of white noise is constant for all frequencies ranging from $-\infty$ to $+\infty$ as shown below



(c) Gaussian - Gaussian distribution, or a normal distribution, has an average of zero in the time domain, and is represented as a bell shaped curve.

- The probability distribution of the noise samples is Gaussian with a zero mean.

- The values close to zero have a higher chance of occurence while the values far away from zero are less likely to appear.

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

2.) Signal to Noise Ratio

- The SNR or S/N is a measure used in science and engineering that compares the level of a desired signal to the level of background noise.

- It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1 : 1 (greater than 0 dB) indicates more signal to that noise.

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

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

Shannon-Hartley Theorem

It states that the channel capacity (bits per second) OR information rate of data that can be communicated at low error data using an average received signal power through communication channel subject to additive white Gaussian noise (AWGN) of power.

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$, B = Bandwidth of channel in Hz

- It is related to signal to noise (SNR) or carrier to noise (CNR) [Linear Power ratio]

- 5 dB - 10 dB ⇒ It is below the minimum level to establish a connection due to the noise level being nearly indistguishable from the desired signal (useful information)

- 25 dB - 40 dB = deemed to be good.

- 41 dB or higher = considered to be Excellent

3.) Mathematics of AM

- Let modulating signal be $e_m = E_m \sin(\omega_m t)$
  carrier signal be $e_c = E_c \sin(\omega_c t)$

$$\therefore E_{AM} = E_c + e_m$$
$$= E_c + E_m \sin(\omega_m t)$$

The instantaneous value of the amplitude modulated wave can be given as

$$e_{AM} = E_{AM} \sin(\theta)$$
$$= E_{AM} \sin(\omega_c t)$$
$$e_{AM} = (E_c + E_m \sin(\omega_m t)) \sin(\omega_c t)$$

This is an equation of AM wave.

4.) Mathematics of FM

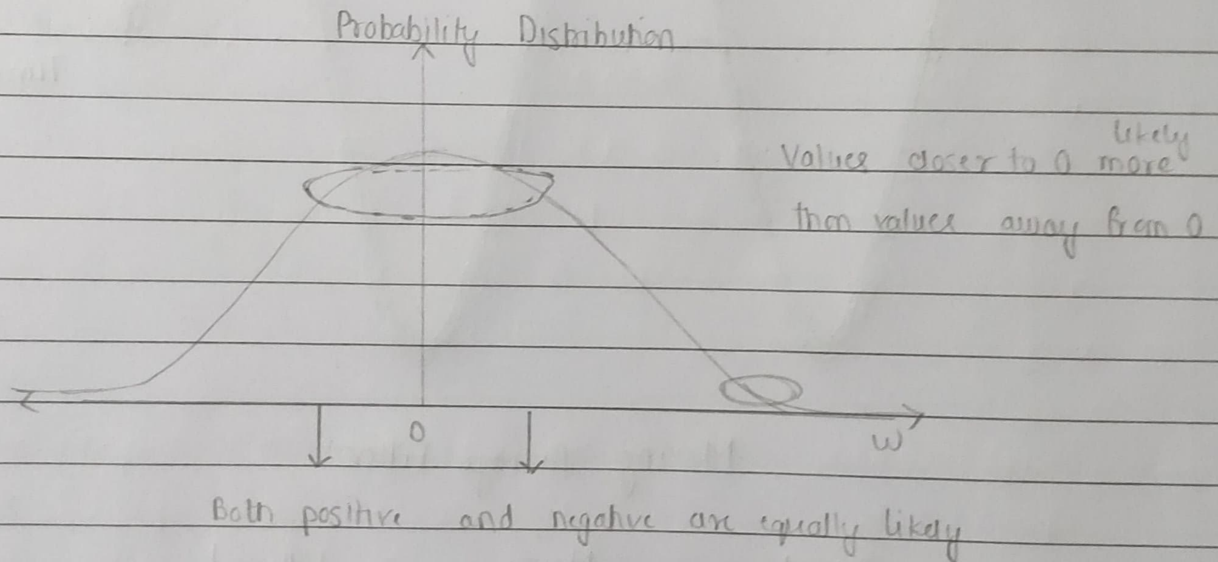
$$s(t) = E_s \sin(\omega_c t + m_s \sin(\omega_m t))$$

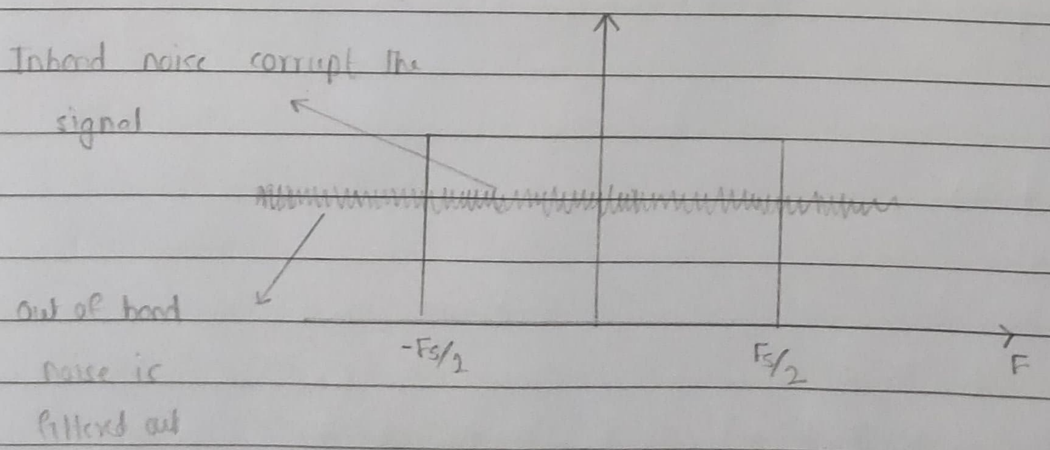
This is the expression for FM wave, m_f = modulation index

$$m_F = \frac{\text{Frequency deviation}}{\text{Modulating Frequency}} = \frac{\Delta f}{f_m}$$

- Frequency deviation Δf = represents the maximum departure of the instantaneous frequency $F_i(t)$ of the FM wave from the carrier frequency F_c.

⇒ Gaussian





Teacher's Signature:

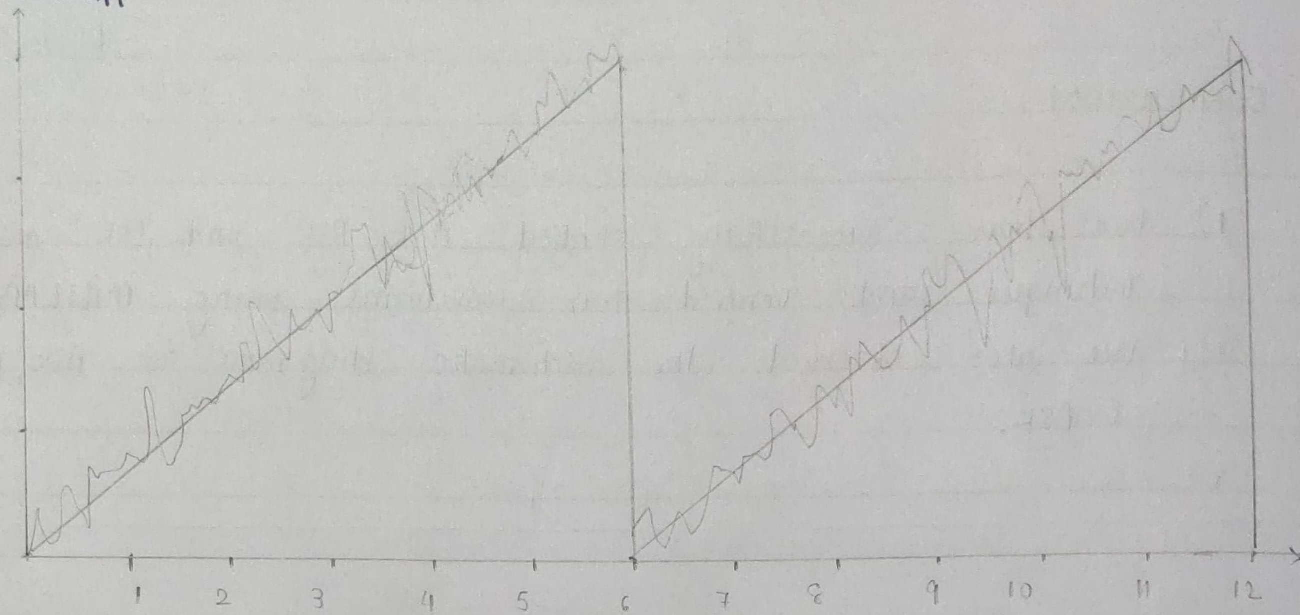
MATLAB CODE :

AWGN in different function

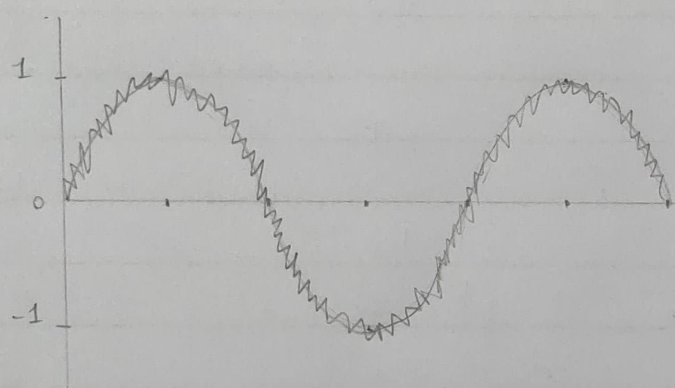
```
clc;
clear all;
t= 6:0.1 :10);
x= sawtooth (t);
y= awgn (x, 10, 'measured');
plot( t, [x,y]);
legend ('original Signal', 'Signal with AWGN');

clc;
clear all;
t= (0 : 0.1 : 10);
x = sin( t);
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');
```

AWGN Effect on Different functions

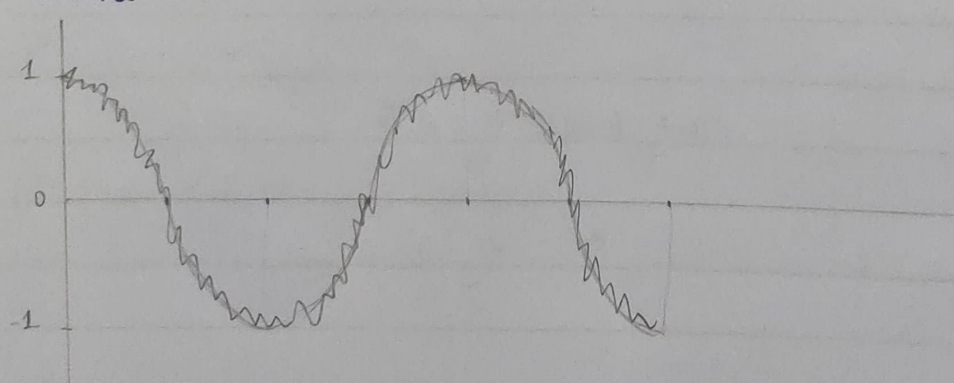
1) Sawtooth



2) Sine



3) Cosine



MATLAB CODE :

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AWGN in AM

```
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);
y = awgn (am, 10, 'measured');
```

①

```
subplot (4,1,1);
plot (t, m);
x label ('time')
ylabel (' amplitude)
```

②

```
subplot (4,1,2);
plot( t, c);
xlabel ('time');
ylabel ('amplitude');
```

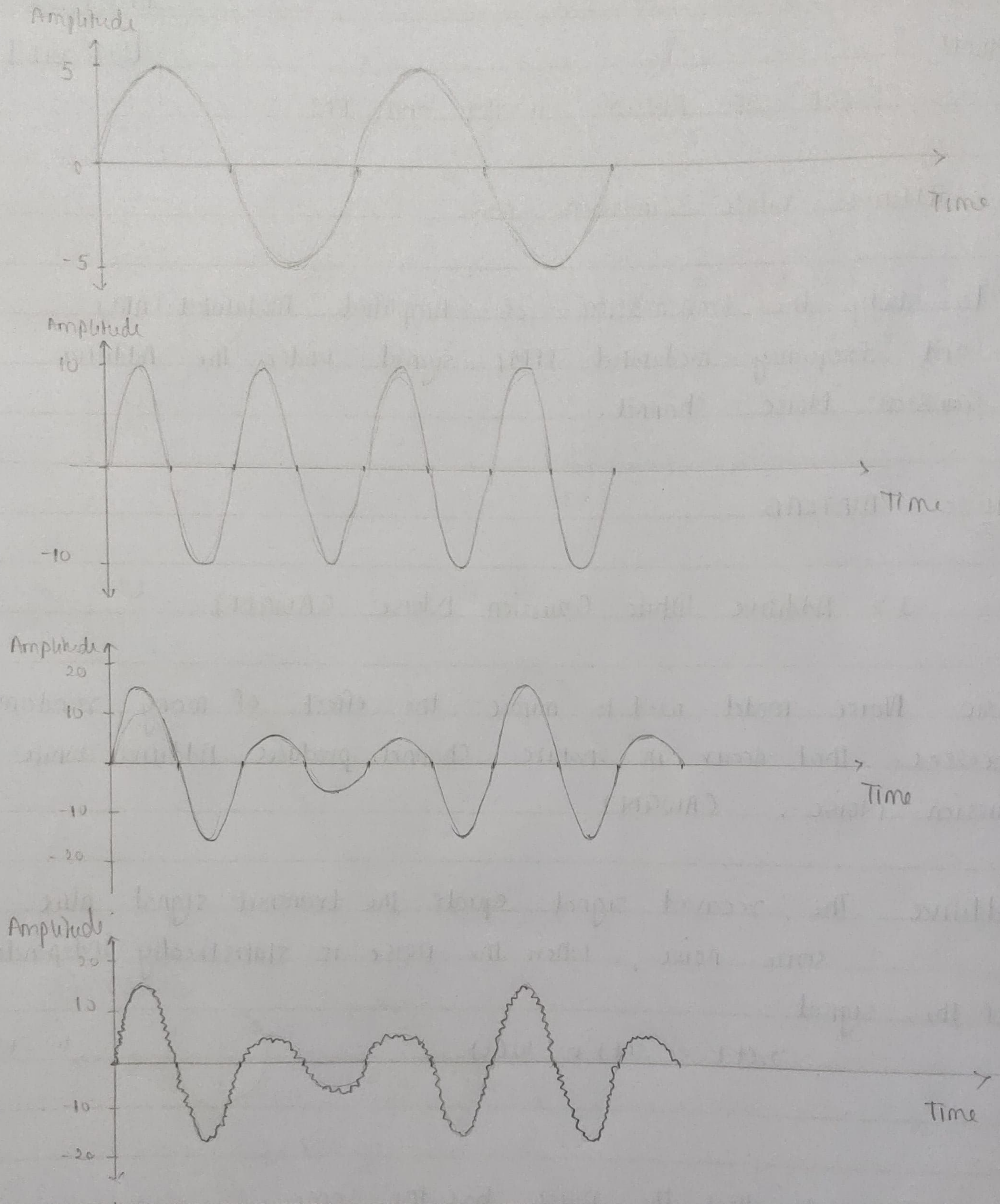
③

```
subplot ( 4,1,3);
plot (t, am);
xlabel ('time')
ylabel ( 'amplitude')
```

④

```
subplot ( 4,4, 4);
plot ( t, y);
x label ('time')
y label ('amplitude')
title ( 'amplitude modulated signal with AWGN');
```

AM signal under AWGN



AWGN in different SNR

```
clc; clear all;
t = 0 : 0.001 : 1;
Vm = 5;      fm = 2;
Vc = 10;     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');
y3 = awgn ( am, 1000, 'measured');
```

①

```
subplot (4,1,1);
plot (t, am)
xlabel ('time');
ylabel ('amplitude');
title ('amplitude modulated signal');
```

②

```
subplot(4,1,2);
plot( t, y1);
xlabel ( 'time' )
ylabel ( 'amplitude')
title ('AM signal with AWGN [snr 10]');
```

③

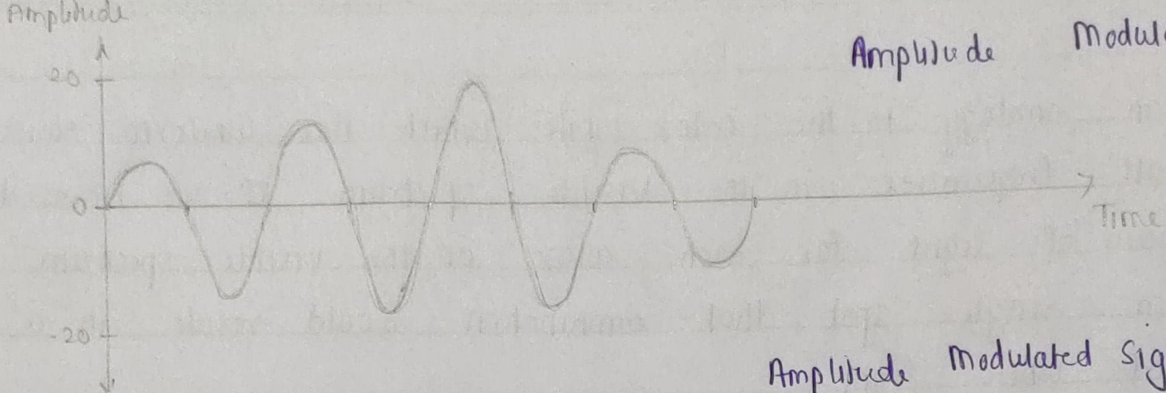
```
subplot (4,1,3);
plot ( t, y2);
xlabel ( 'time');
ylabel ( 'amplitude');
title ( 'AM signal with AWGN [snr 100]');
```

④

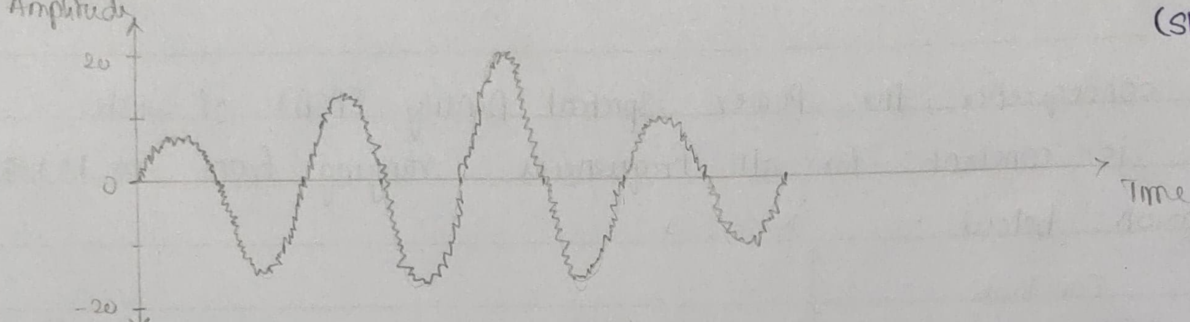
```
subplot (4,1,4);
plot ( t, y3);
xlabel ('time')
ylabel ('amplitude')
title ('AM signal with AWGN
[snr 1000] ');
```

AM Signal with different SNR values

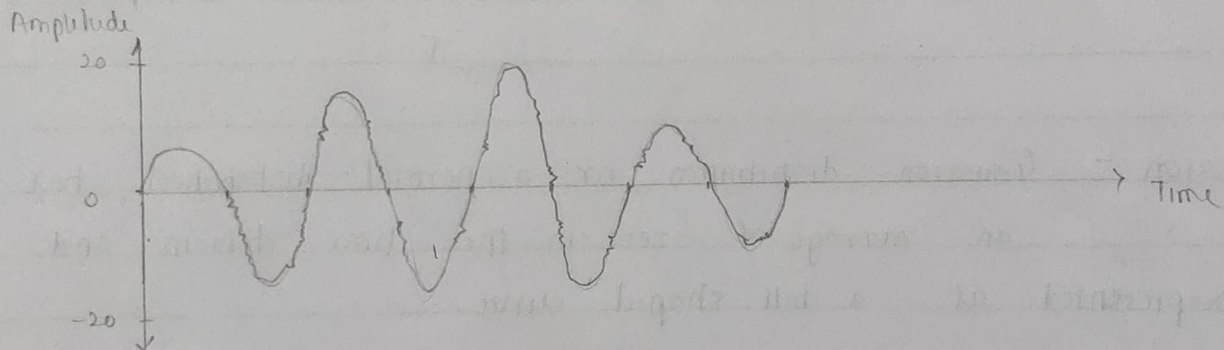
Amplitude Modulated signal



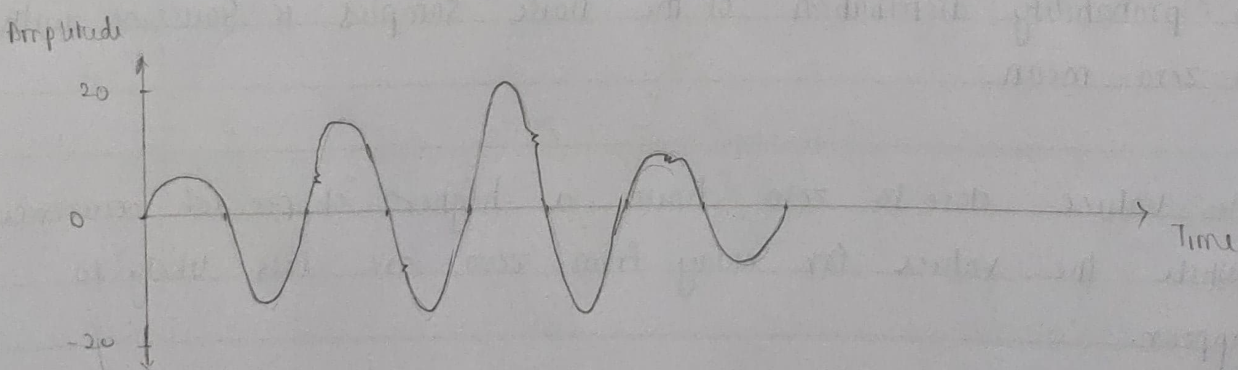
Amplitude Modulated Signal with (AWGN)
(SNR = 10)



SNR = 100



SNR = 1000



AWGN in FM

```
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)) ;
z = awgn ( y, 5, 'measured');
```

(1)

```
subplot( 4,1,1);
plot ( t, msg );
xlabel ('time');
ylabel ('Amplitude');
title ('message signal');
```

(2)

```
subplot (4,1,2);
Plot ( t, c);
xlabel ('time');
ylabel ('amplitude');
title ( 'carrier signal');
```

(3)

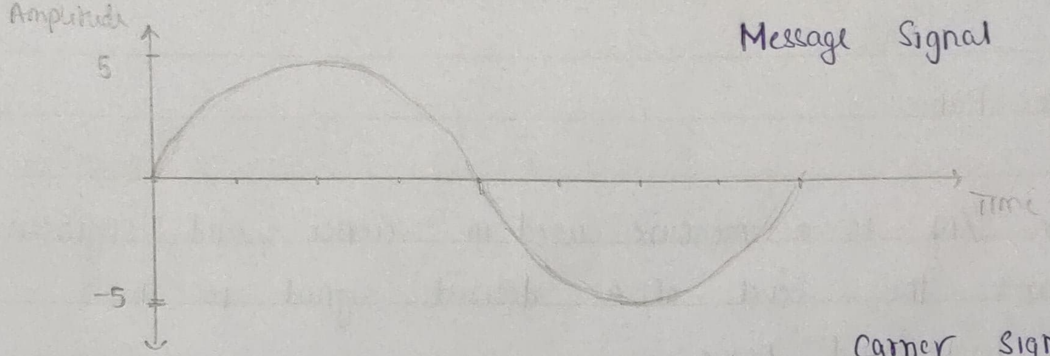
```
subplot (4,1,3);
plot(t,y);
xlabel ('time');
ylabel ('Amplitude');
title ('Frequency modulated signal')
```

(4)

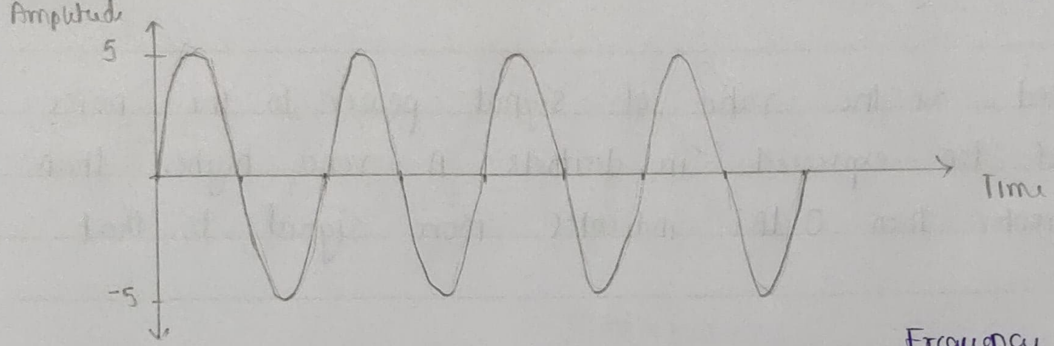
```
subplot (4,1,4);
plot ( t,z);
xlabel ('time');
ylabel ('amplitude');
title ('Frequency modulated signal with AWGN');
```

FM Signal under AWGN

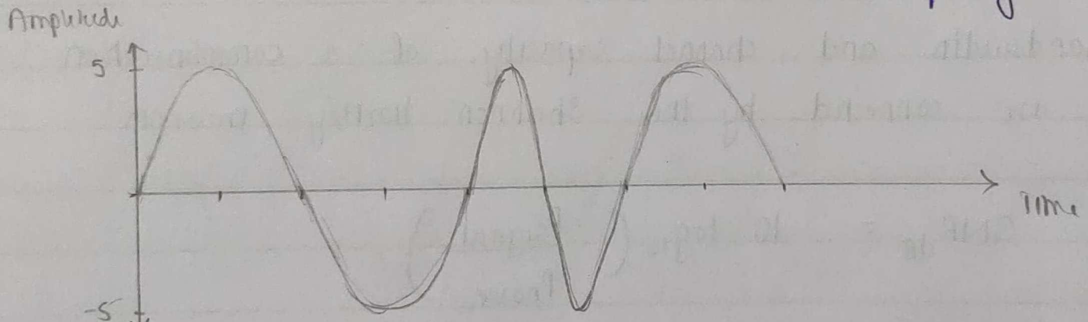
Message Signal



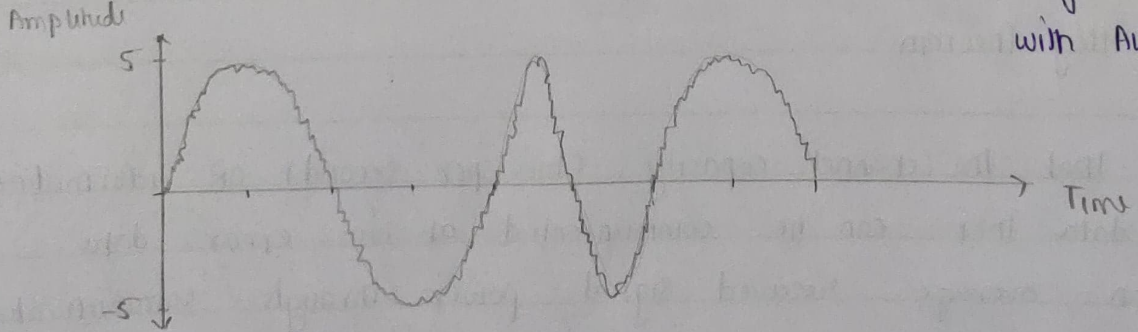
Carrier Signal



Frequency Modulated Signal



Frequency Modulated signal with AWGN



FM in Different SNR

```
clc;  clear all;
t = 0: 0.001 : 1;
vm = 10;        fm = 2;
vc = 5;         fc = 25;
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');
```

①

```
subplot (4,1,1);
plot ( t, y);
xlabel ('time')
ylabel('amplitude')
title ('Frequency modulated signal')
```

②

```
subplot (4,1,2);
plot( t, y1);
xlabel ('time');
ylabel ('amplitude');
title (' snr 10');
```

③

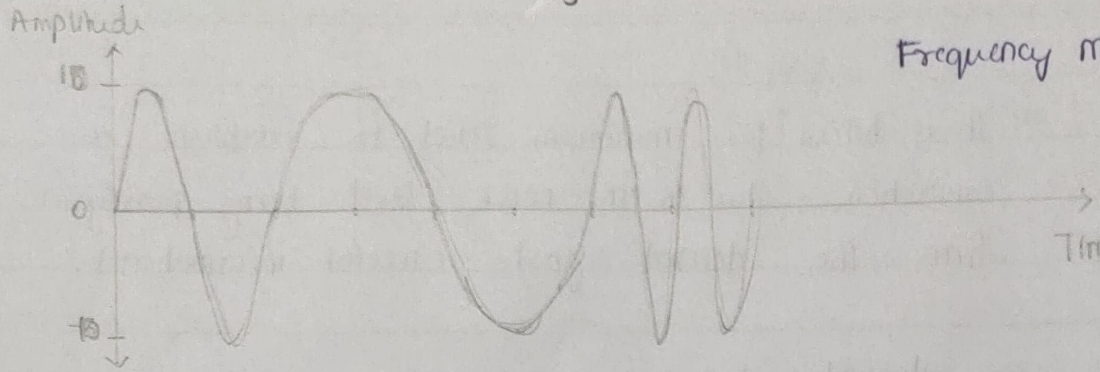
```
subplot (4,1,3);
plot ( t, y2);
xlabel (' time');
ylabel (' amplitude');
title (' AWGN [snr 100] FM');
```

④

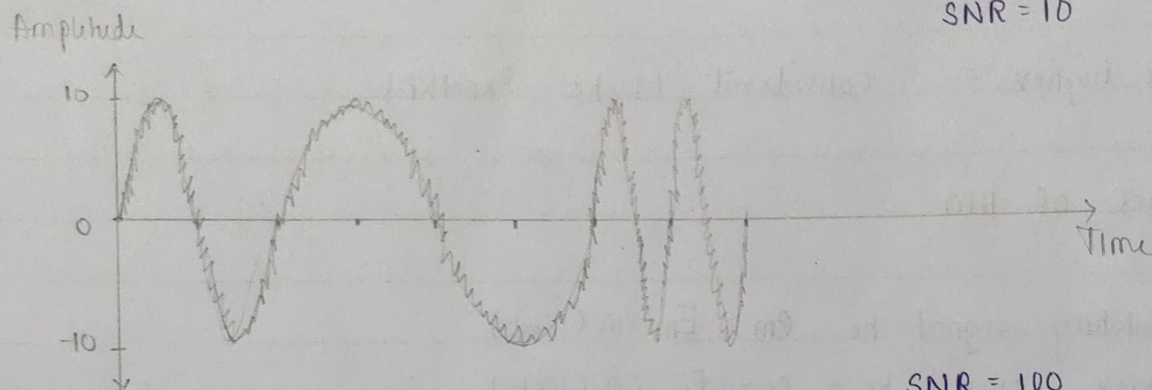
```
subplot (4,1,4);
plot ( t, y3);
xlabel ('time');
ylabel ('amplitude');
title ('AWGN [snr 1000] FM');
```

FM signal with different SNR

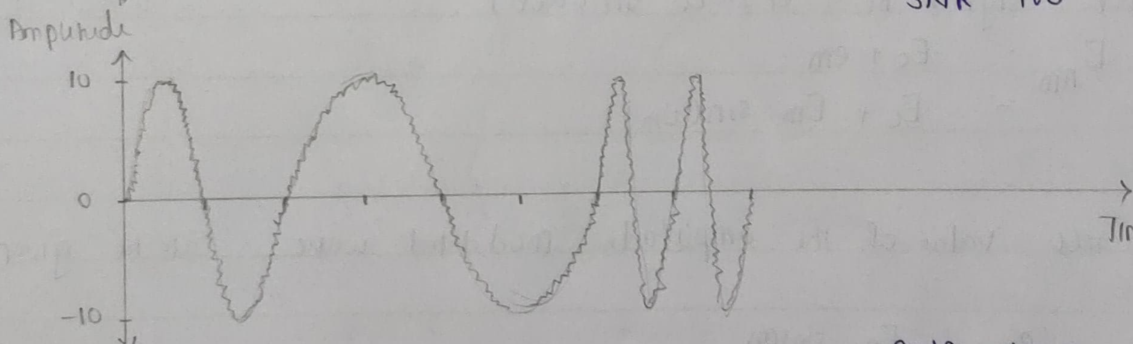
Frequency modulated Signal



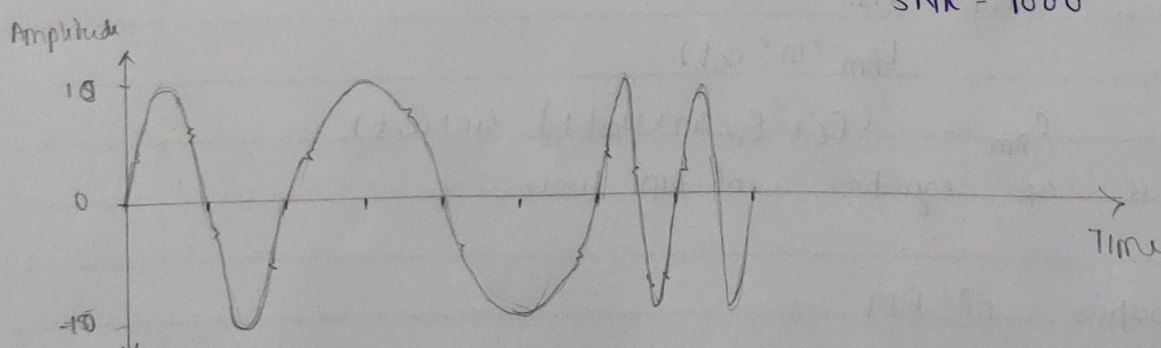
SNR = 10



SNR = 100



SNR = 1000



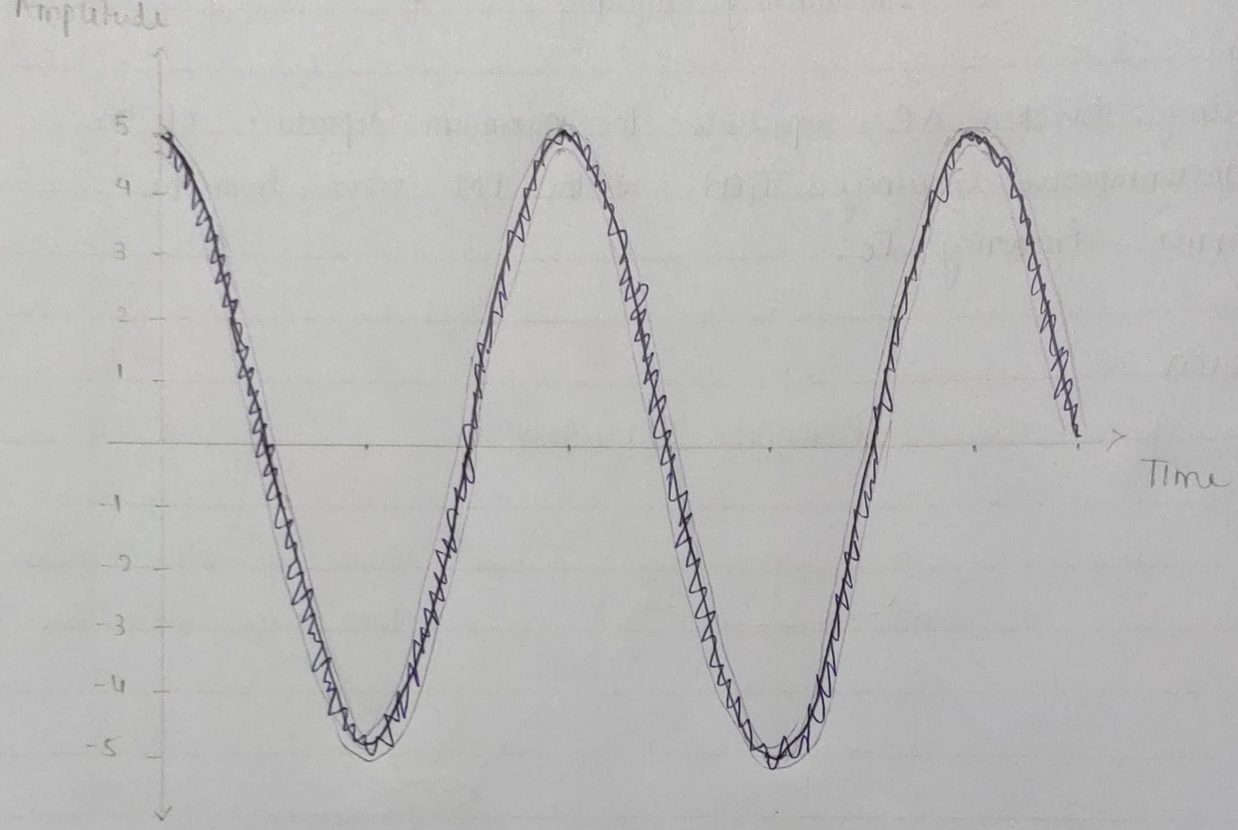
[U19CS012]

Moving Average Filter

```
clear all;    clc;
close all;
fs = 500000;
fm = 10000;
t = 1:200;
x = 5* cos( 2*pi* (fm/fs) *t );
z = awgn(x,5);
plot (x, 'g', 'linewidth', 1.5);
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', 'fontsize', 12);
xlabel ( '--> time in 2us' );
ylabel ( '--> volts' );
```

> CONCLUSION: We have successfully studied the effect of AWGN on transmission of Amplitude modulation (AM) and Frequency Modulation (FM).

Use of moving average filter to retrieve the signal by averaging the noise fluctuation



Moving Average Filter

— = Actual — = Noisy - Filtered