# HAND WRITTEN LABORATORY JOURNAL

*Submitted in partial fulfillment of the requirement*
*For the Subject*

# "DIGITAL COMMUNICATION"

**(EC 209)**

**: Prepared & Submitted By :**

**Mr. Krishna Pandey**
**(Admission No. U20CS110)**

**B. TECH. II (CSE) 3rd Semester**
**(Academic Year : 2021-22)**
**ONLINE MODE**

(July to Dec - 2021)

**DEPARTMENT OF ELECTRONICS ENGINEERING**
Sardar Vallabhbhai National Institute of Technology
Surat-395 007, Gujarat, INDIA.

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**DEPARTMENT OF ELECTRONICS ENGINEERING**

**Academic Year : 2021-22**

## SUB : DIGITAL COMMUNICATION (EC209)

## CERTIFICATE

This is to certify that the **Laboratory Journal** is prepared & submitted by **B. Tech. II (CSE-3rd Semester)** student **Mr. Krishna Pandey** bearing **Admission No. U20CS110** in the partial fulfillment of the requirement for the **Subject Digital Communication (EC209)** through ONLINE MODE.

The evaluation is done for the journal submitted herewith.

**Laboratory Teachers :**

| Name | Signature with date |
|---|---|
| 1. | |
| 2. | |
| 3. | |

**July -Dec. 2021.**

# DIGITAL COMMUNICATION (EC209)
# (Academic Year 2021-22)

## LIST OF EXPERIMENTS
## ONLINE MODE

| Sr. No. | LIST OF EXPERIMENTS | PAGE NO. |
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| 1. | To study Spectrum Analyzer and observe the spectrum of sinusoidal signal and square wave. Draw the input waveforms in time domain and their output spectra for five different set of frequencies and amplitudes for each input. | 1 to 5 |
| 2. | To examine sampling and reconstruction of signal, verify the Nyquist criteria by varying sampling frequency. Draw the sampled version of waveform for the conditions: (i) $f_s < 2f_m$, (ii) $f_s > 2f_m$ and (iii) $f_s = 2f_m$; where $f_s$ - sampling frequency; $f_m$ - maximum baseband frequency and represent the output responses for different order low pass filter. Use virtual mode with appropriate software. | 6 to 9 |
| 3. | To study amplitude modulated (AM) technique, modulation-index (m), draw waveforms, spectra and trapezoidal display. Illustrate the observed AM signals for double sideband with and without carrier by changing m as: m>1, m<1 and m=1 and draw it. Use virtual mode with appropriate software. | 10 to 13 |
| 4. | To demonstrate frequency modulation (FM) and demodulation process by observing the waveforms in time domain and their spectra in frequency domain by varying the parameters of massage signal. Draw waveforms and spectra. Use virtual mode with appropriate software. | 14 to 19 |
| 5. | To examine of pulse amplitude modulation (PAM), pulse position modulation (PPM) and pulse width modulation (PWM) and verify and draw the resultant waveforms. Illustrate the circuit diagrams for PAM and PWM. Show & draw the output waveforms using the Matlab code/Simulink using virtual mode. | 20 to 26 |
| 6. | To study of amplitude shift keying (ASK), frequency shift keying (FSK) and phase shift keying (PSK) modulation technique and verify waveforms. Illustrate the schematic diagrams for ASK, FSK and PSK. Show & draw the input/output waveforms using Matlab code/Simulink using virtual mode. | 27 to 31 |

| | | |
|---|---|---|
| 7. | | |
| 8. | | |
| 9. | | |
| 10 | | |
| 11 | | |

- Submitted By

Name : Krishna Pandey
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Date

Expt. No. 01

Page No. 1

Experiment No - 1

Spectrum Analyser and observe spectrum

Aim: To study spectrum analyser and observe spectrum of sinusoidal signal and square wave. Draw the input waveforms in time domain and their output spectra for 5 different set of frequencies and amplitudes for each input.

Apparatus: Spectrum Analyser (9 KHz - 3 GHz) Function Generator.

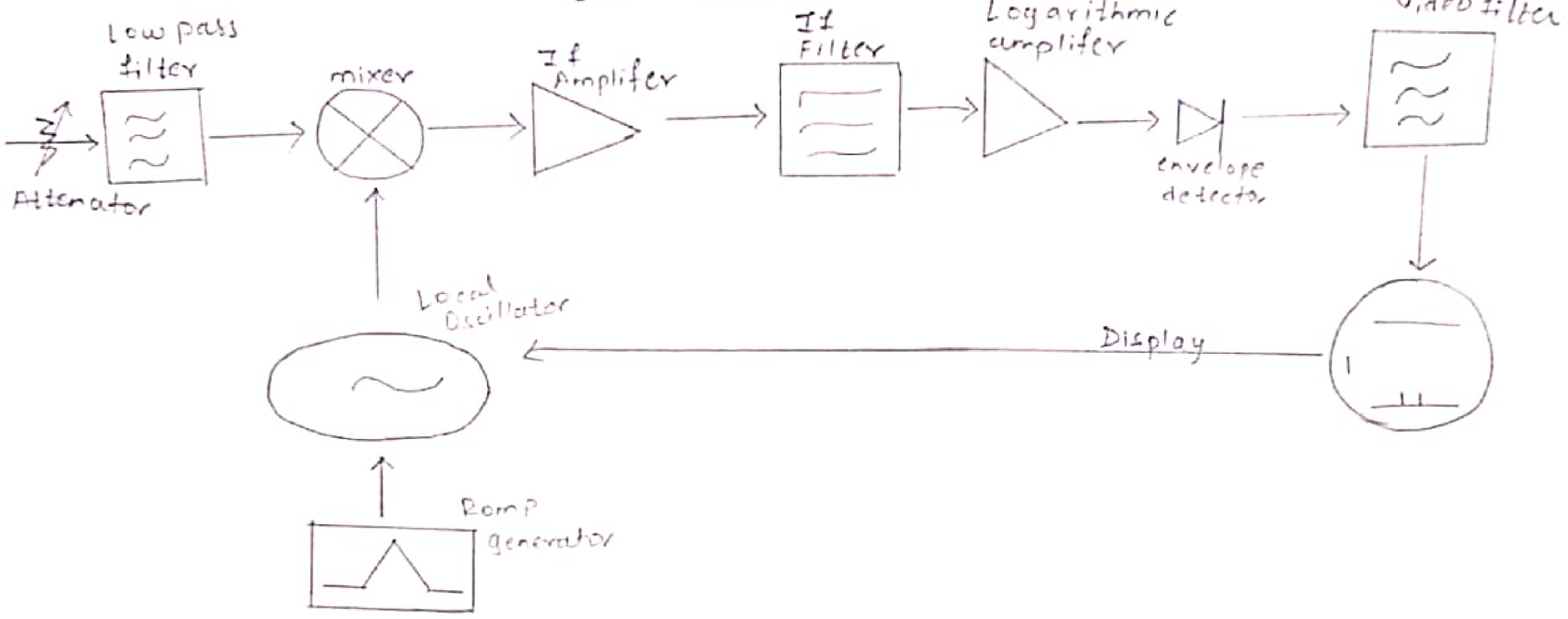
Theory: A spectrum analyzer is a laboratory instruments that displays signal amplitude (strength) as it varies by signal frequency. The frequency appears on horizontal axis and the amplitude is displayed on vertical axis.

A spectrum analyser can be used to determine wheather a wireless transmitter is working according to the federally defined standards for purity of emissions. Output signals at frequencies other than the intended communications frequency appears as vertical line (pips) on the display.

A spectrum analyser interface is a device that can be connected to a wireless reciever or a personal computer to allow visual detection and analysis of electromagnetic

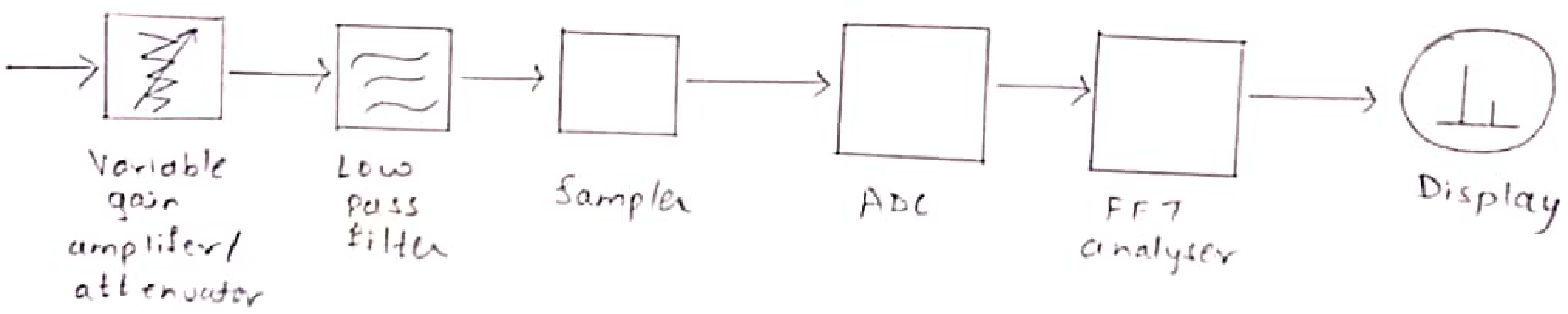
Teacher's Signature :

BLOCK DIAGRAM




(superheterodyne or swept frequency spectrum analyzer)

Block diagram



signals over the defined band of frequencies.

Features of LAB INSTRUMENT GSP-830 (GWINSTEK)

- 5 markers with delta markers and peak function
- 3 traces
- split windows with separate setting
- 6.4" TFT Color LCD, 640 X 480 resolution
- AC/DC/ battery multi-mode power operation
- Autoset
- 9 KHz - 3 GHz frequency range.

Frequency selection and their selection method

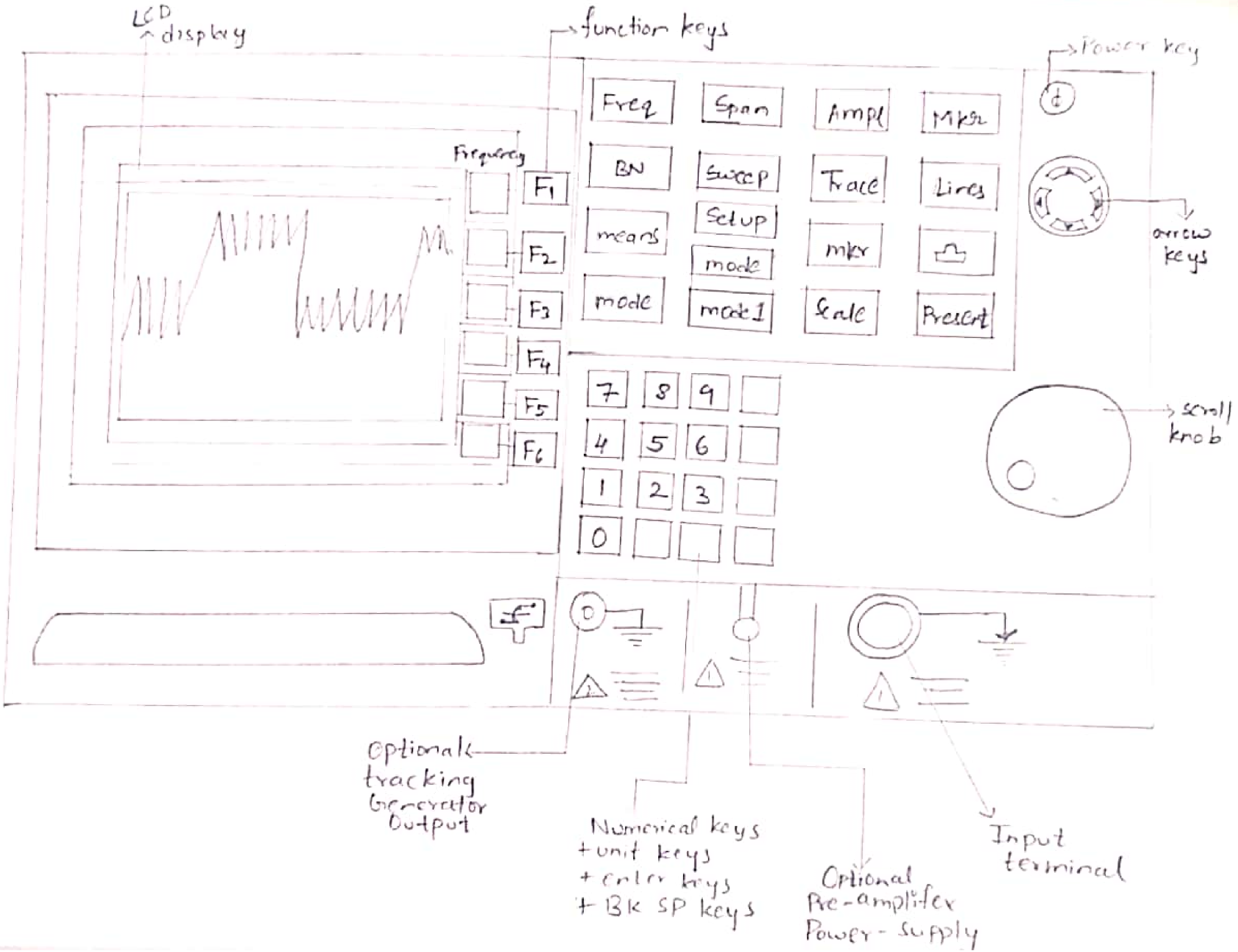
(1) Frequency

- Frequency/span: The frequency key together with span key sets the frequency together
- View Signal (Center & span) center and span methods defines the center frequency and the left right bandwidth (span) to locate the signal.
- Setting frequency adjustment step: frequency adjustment step defines arrow key resolution for center, start and stop frequency

2) Range: 9 KHz to 3 GHz

3) Set Center frequency Panel operation:

- Press frequency key
- Press F1 Center
- Enter the values using numerical and unit keys

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4) Set frequency Span Panel operation:
- Press span key
- Press F1 span
- Enter the value using num. key and unit keys. arrow keys and scroll nope

5) View Signal (Start and stop)
- Start and Stop method defines the begin & end of frequency range.

6) Set start frequency (Panel operation:)
- Press frequency key, Press F2 key and Enter the value.

7) Set stop frequency Panel operation:
Press frequency key. Press F3 (stop) and Enter the value.

8) Full or Zero span: It sets the span to extreme values (3 GHz full) or 0KHz (Zero).

9) Display full frequency span Panel operation:
- Press span key and then press F2 (full span)
- Range 3GHz (fixed) and Centre frequency 1.5 GHz
- Start frequency 0KHz to Stop frequency 3 GHz

10) Zero span display
Zero span key can be obtained by pressing F3 key

# Observations

Waveform: SINE

| S.NO. | Frequency (KHz) | Amplitude (mV) |
|---|---|---|
| 1 | 2 | 1 |
| 2 | 2.5 | 1.1 |
| 3 | 3 | 1.5 |
| 4 | 4 | 2 |
| 5 | 5 | 2.4 |

Waveform Square

| S.NO | Frequency (KHz) | Amplitude (mV) |
|---|---|---|
| 1 | 2 | 1 |
| 2 | 2.5 | 1.2 |
| 3 | 3 | 1.5 |
| 4 | 4 | 1.6 |
| 5 | 5 | 2 |

Amplitude Selection and settings Method

① Amplitude Amplitude key sets vertical attribute of the display, including the upper limit, vertical range and compensation for gain and loss

② set vertical scale: It is defined by reference amplitude, amplitude range, measurement unit and external gain/loss.

③ set reference amplitude It defines the amplitude at the top of displayed range

④ Select amplitude scale Panel operation:

- Press amplitude key and $F_2$ (Scale dB/div)

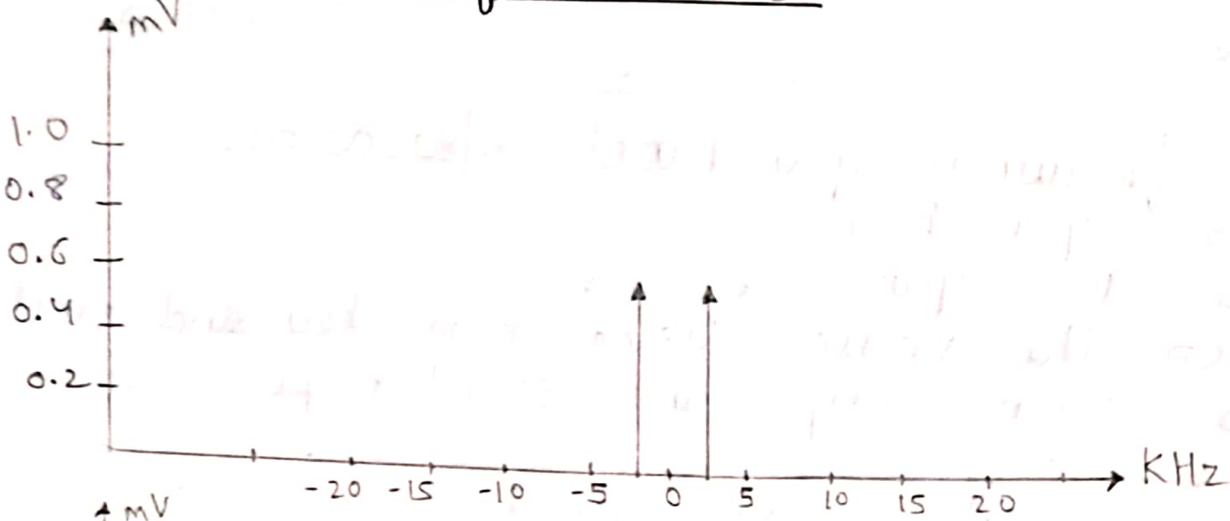
Range: 10, 5, 2, 1 dB/div

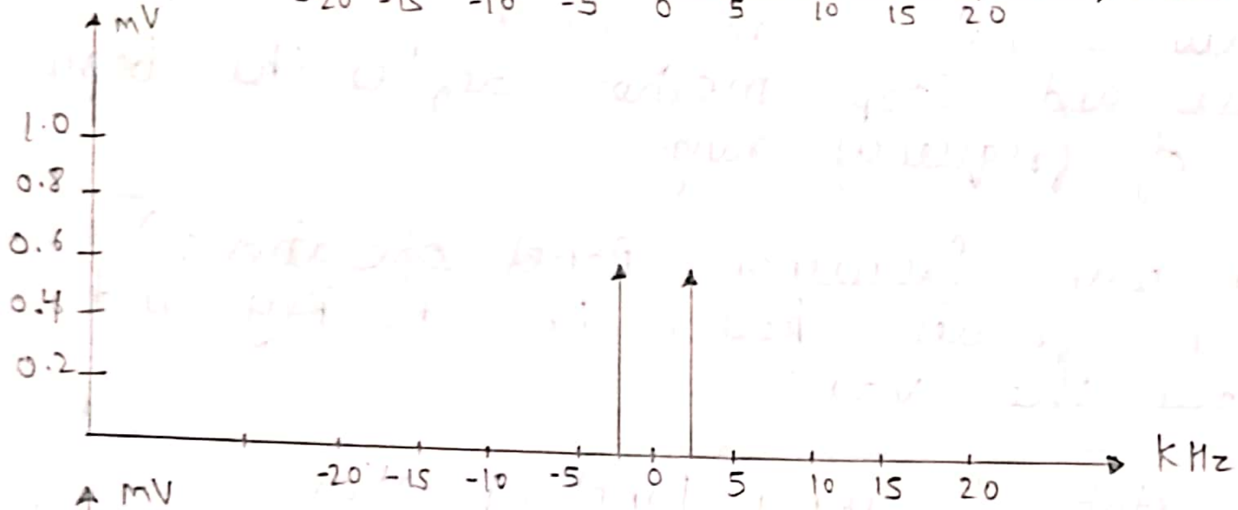
Panel operation:

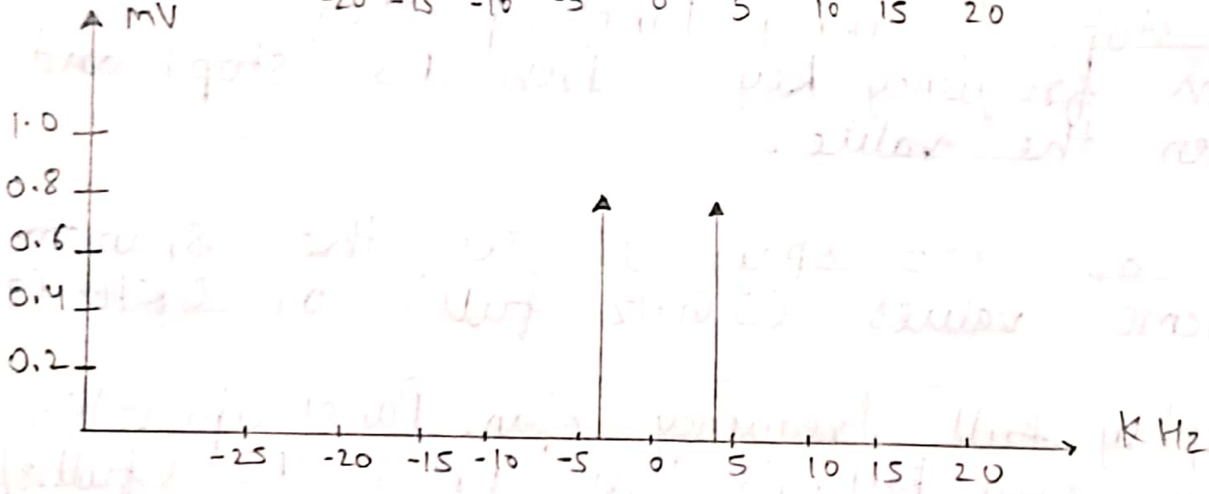
- Press amplitude key
- Press F3 (units)
- select and press the unit from F1 (dBm), $F_2$ (dBmV) and F3 dB(μV)
- Press F6 (return to go back to previous menu)
- dBmV -110 to +20 dBm, 0.1dB resolution

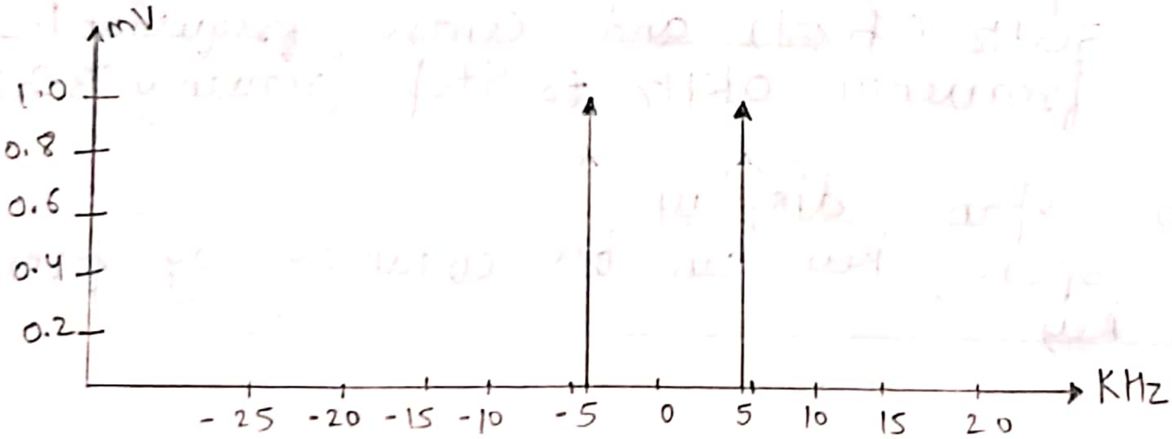
Background The external offset compensates the amplitude gain or loss caused by an external network or device.

## Waveform: SINE

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## Icon:

→ The amplitude Icon appears at the bottom of the display when the external offset changes.

- To check whether external spectrum analyser working properly
- To generate auxillary signal: press system key, press auxially signal, select an option from given menu. following signal will generate. It generates 10 MHz signal with 10 dB amplitude

## Safety Guidelines

- Measurement input power
- Static charge protection
- Proper grounding
- Cooling measures

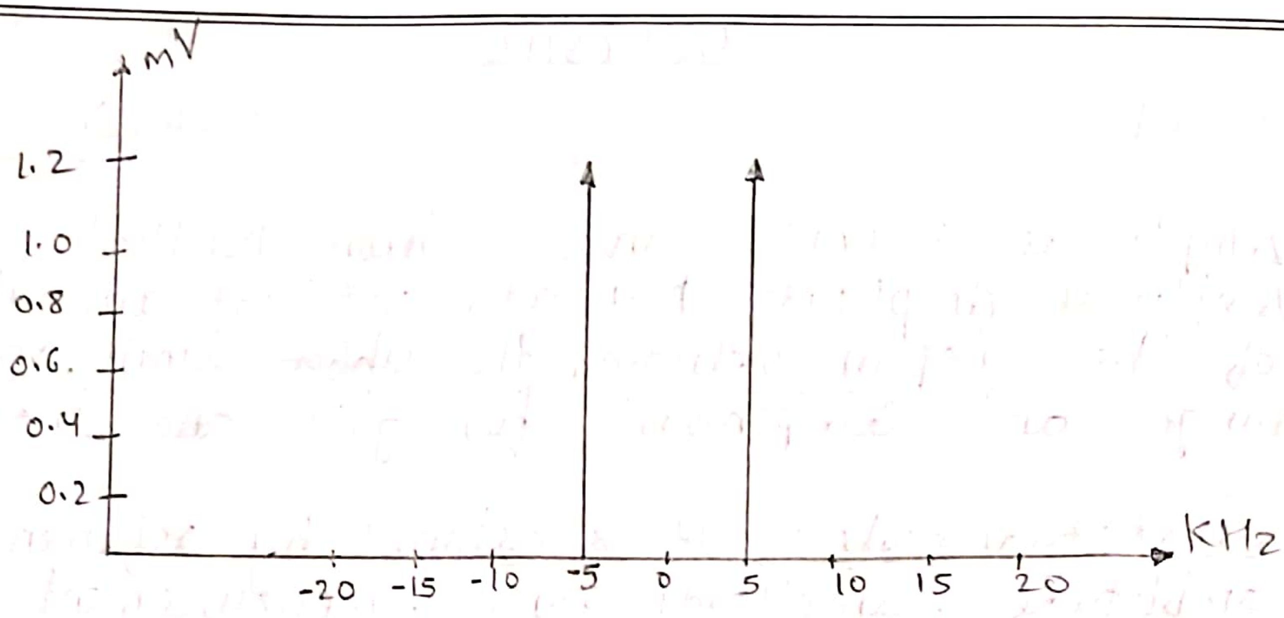
## Types of Connectors

- SMA
- SMB
- BNC
- N-type
- UFL

## Conclusion

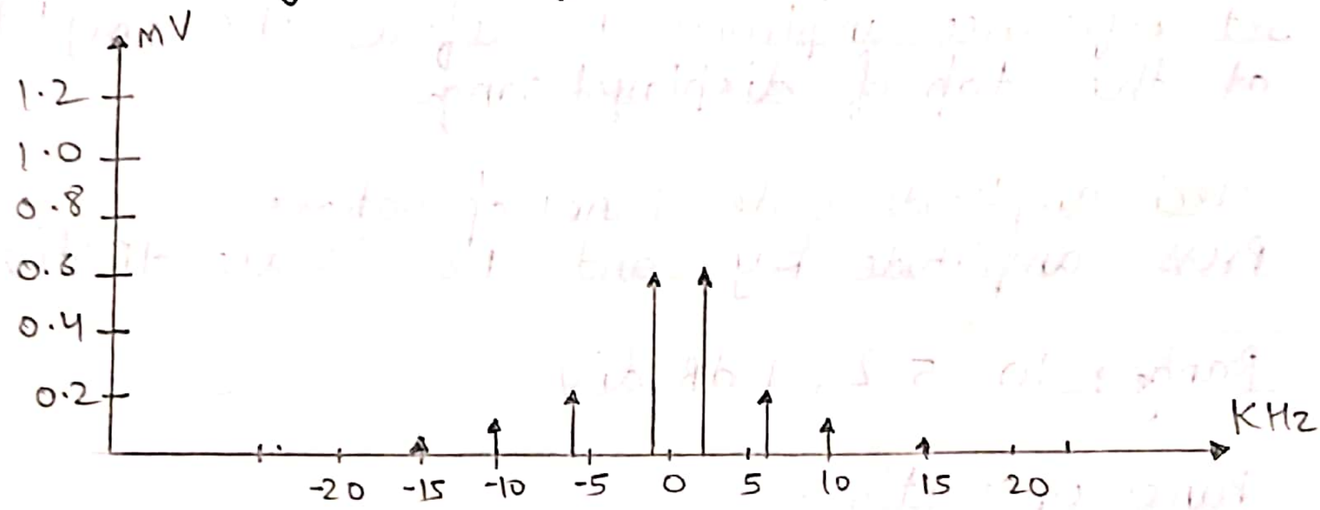
In this experiment we have verified and analysed the spectrum of sine and square waveform for different frequencies & amplitudes

5)




Waveform (Square)

1)

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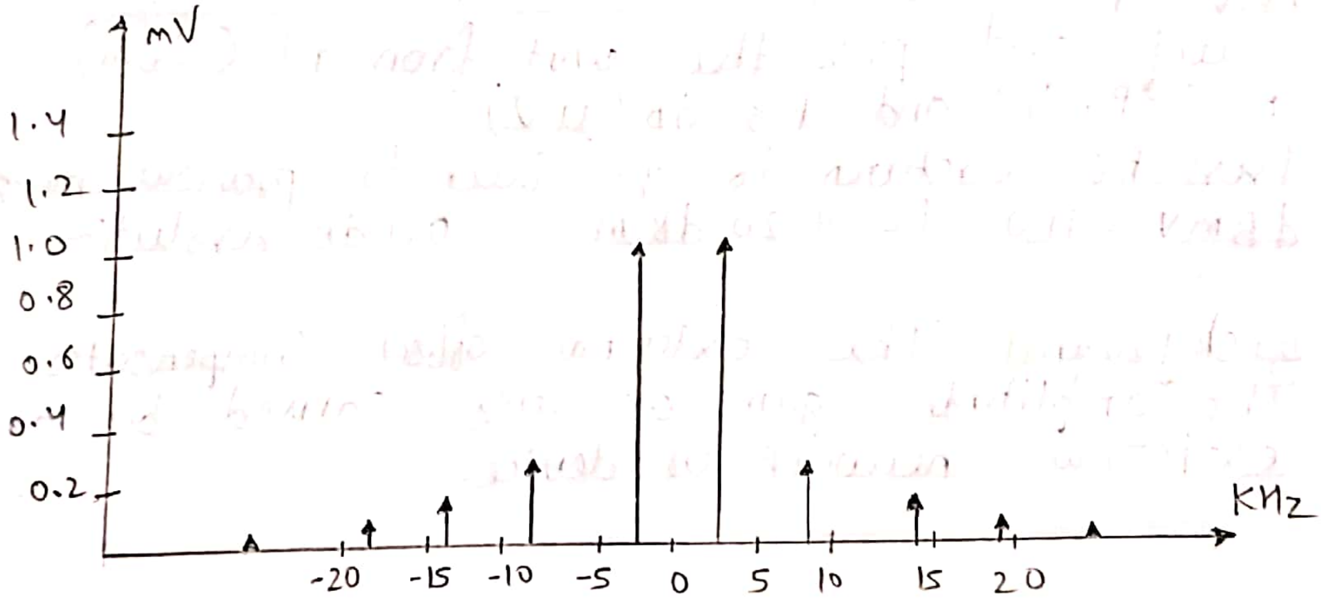
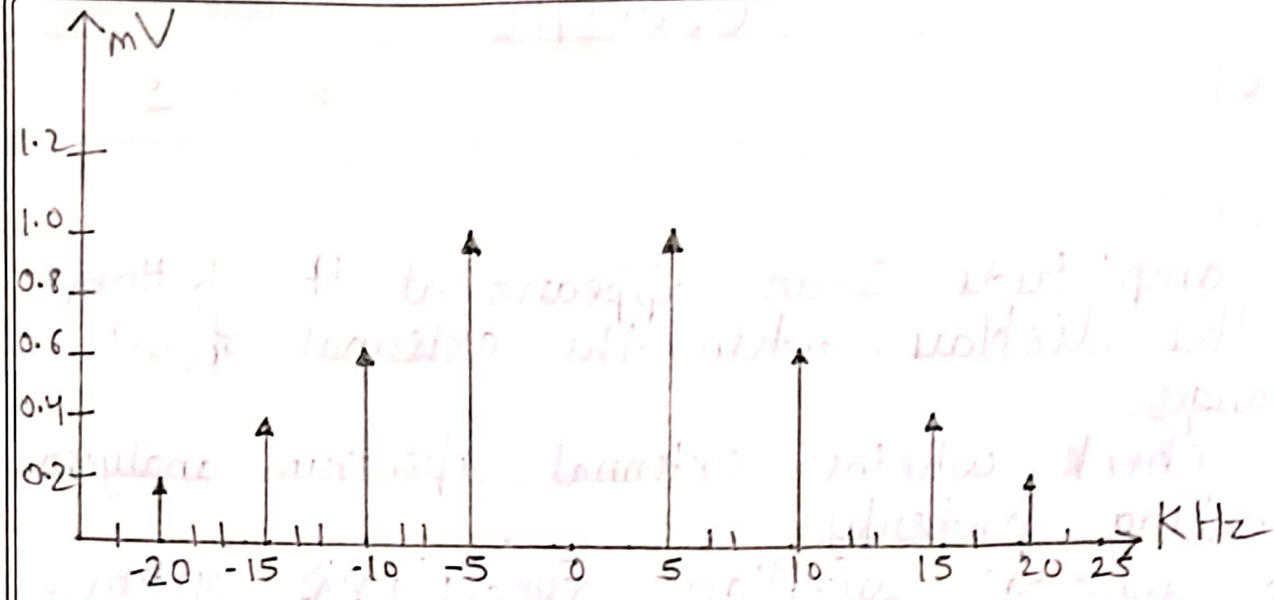
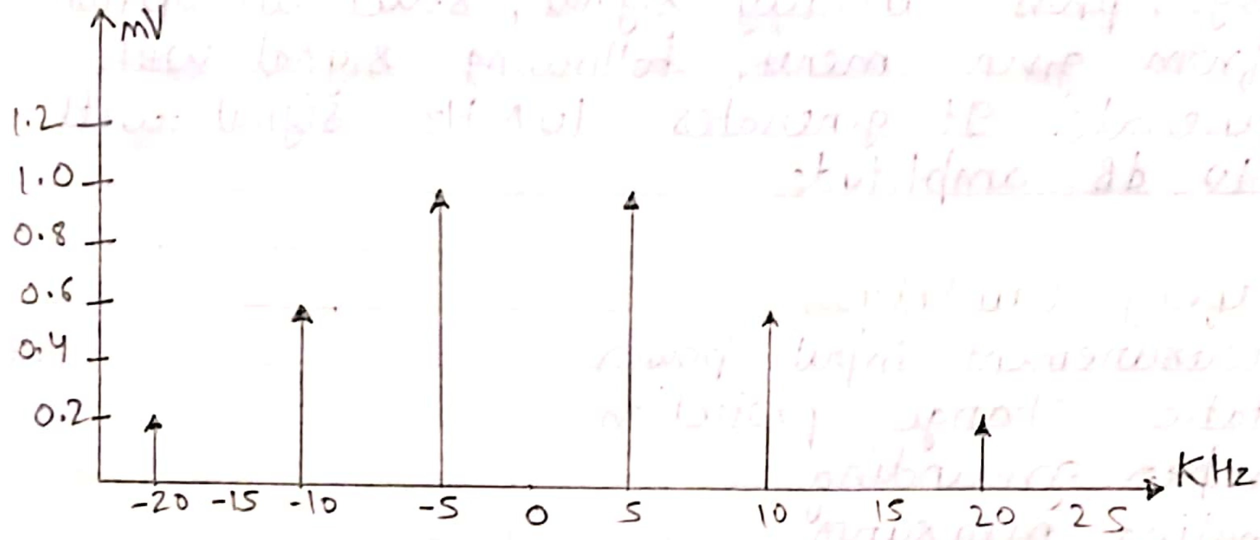


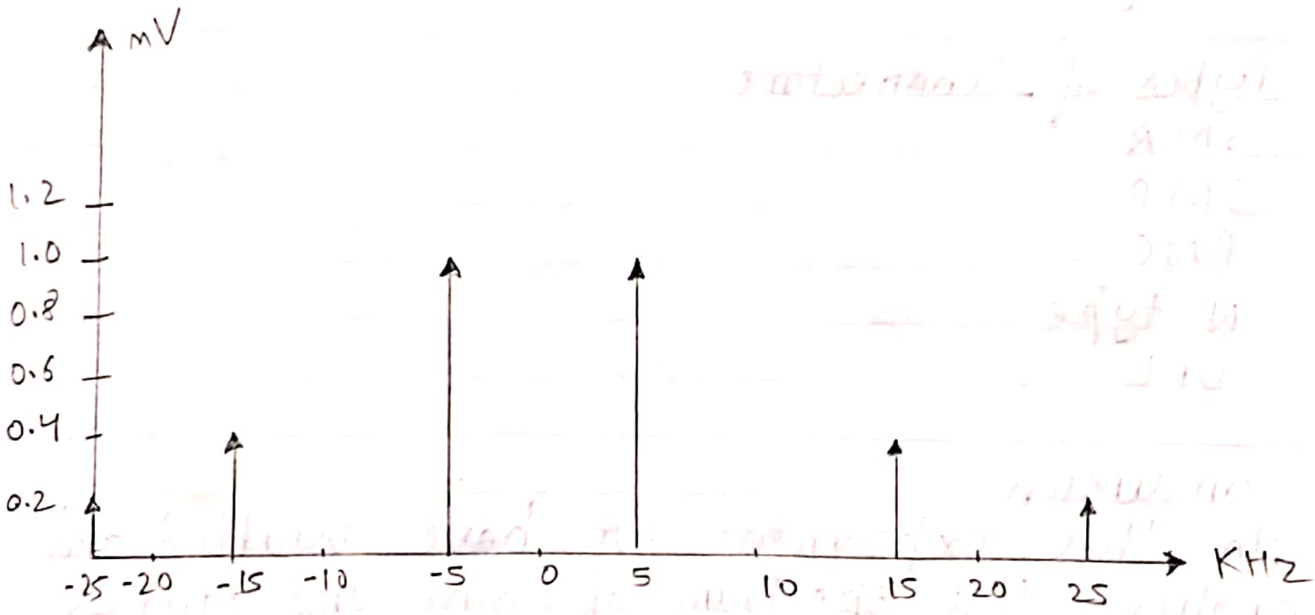
3)


mV
1.2
1.0
0.8
0.6
0.4
0.2
-20
-15
-10
-5
0
5
10
15
20
25
KHz

1)


mV
1.2
1.0
0.8
0.6
0.4
0.2
-20
-15
-10
-5
0
5
10
15
20
25
KHz

5)


mV
1.2
1.0
0.8
0.6
0.4
0.2
-25
-20
-15
-10
-5
0
5
10
15
20
25
KHz

U20CS110

Date

Expt. No. 02 Experiment - 2 Page No. 6

Aim: To examine sampling and reconstruction of signal, verify Nyquist criteria by varying sampling frequency. Draw the sampled version of waveform for the conditions. (i) $F_s < 2F_m$ (ii) $F_s > 2F_m$ and (iii) $F_s = 2F_m$ where $F_s$ = sampling frequency, $F_m$ = maximum base band frequency and represents the output response for different order LPF. Use virtual mode with appropriate software.

Apparatus
Nyquist applet.

Theory A continious time (or analog) signal can be stored in a digital computer, in the form of equidistant discrete points or samples. The higher the sampling rate (or sampling frequency, fs), the more accurate would be stored information and the signal reconstruction from its samples. However high sampling rate produces a large volume of data to be stored and make neccessary the use of very fast analog-to-digital convertor.

Analog signal - continious time varying feature

Digital signal - It represents data as a sequence of discrete values, at any given time it can take one of finite number of values.

Teacher's Signature :

Techniques that can be used for analog to digital conversion:

PULSE CODE MODULATION (PCM):

- Sampling
- Quantization
- Encoding

Sampling:

- It is the process of measuring the instantaneous values of continious time signal in discrete form.
- Sample is a piece of data taken from the whole data which is continious in time domain
- When a source generates an analog signal and if that has to be digitized, having 1's and 0's i.e. high or low, the signal has to be discretized in time and this discretization of analog signal is called sampling.

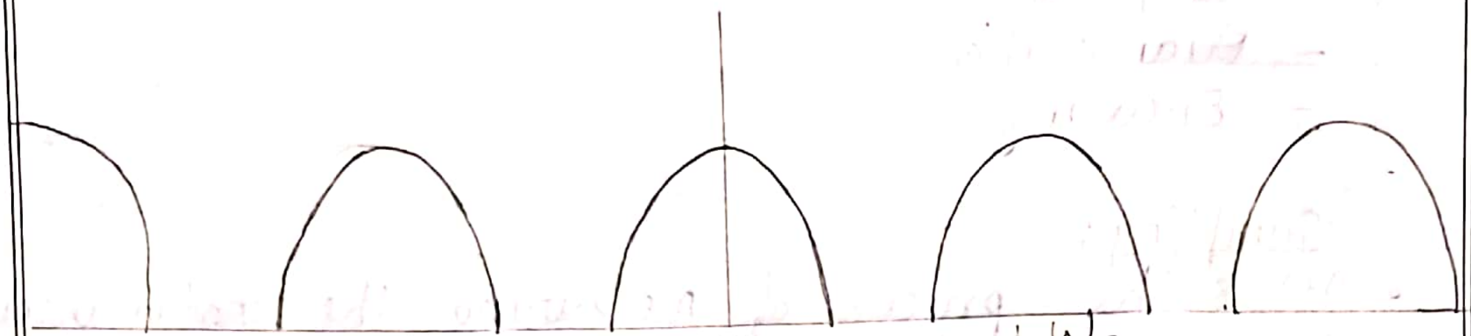
It is obvious that much higher sampling rate is required for sampling a signal which is rich in high frequency.

The minimum sampling frequency of a signal that it will not distort its underlying information should be double the frequency of its highest frequency component. This is the Nyquist sampling Theorem.

Condition -1 ($f_s > 2W$)

- Oversampling If sampled at higher rate than $2W$ in the frequency domain ($f_s > 2W$)

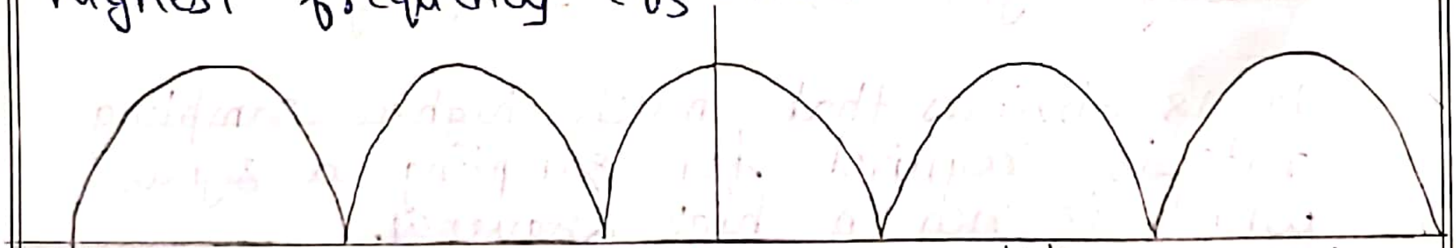
$$X_s(\omega) = \frac{1}{T_s} \sum_{n=-\infty} X(\omega - n\omega_0)$$




Here the information is reproduced without any loss. There is no mixing up and hence recovery is possible.

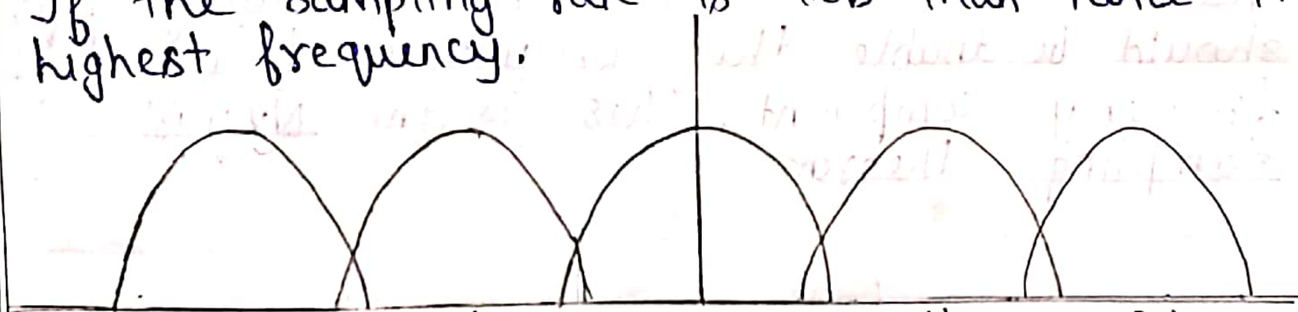
Condition -2 ($f_s = 2W$)

- If the sampling rate is equal to twice the highest frequency ($f_s = 2W$)



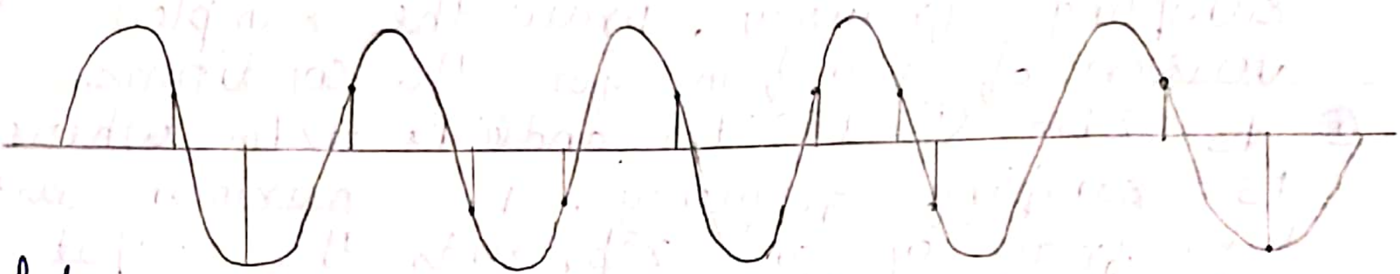

Condition -3 ($f_s < 2W$)

If the sampling rate is less than twice the highest frequency.

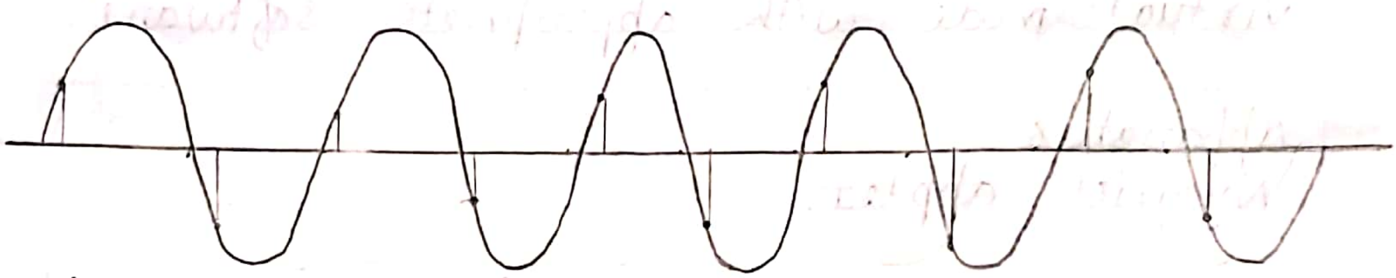


Sampling of a sinusoidal signal of frequency $f_s$ at different sampling rates $f_s$ with dashed lines are shown the alias frequency occuring when $\frac{f_s}{f} < 2$

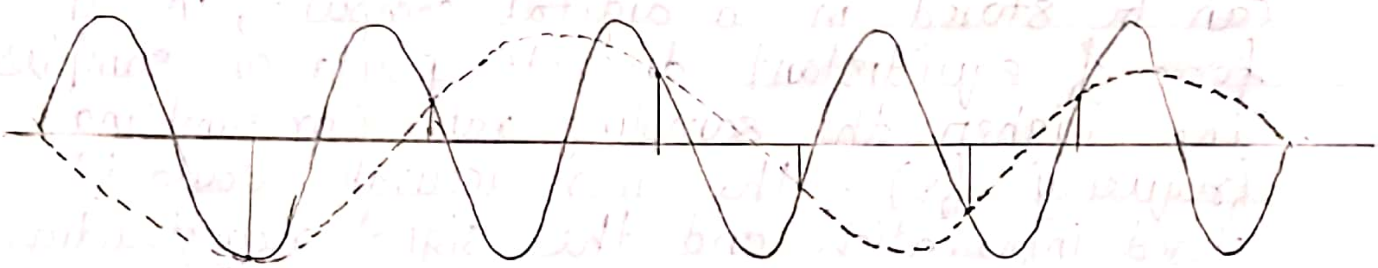
→ $f_s/f = 2.6$



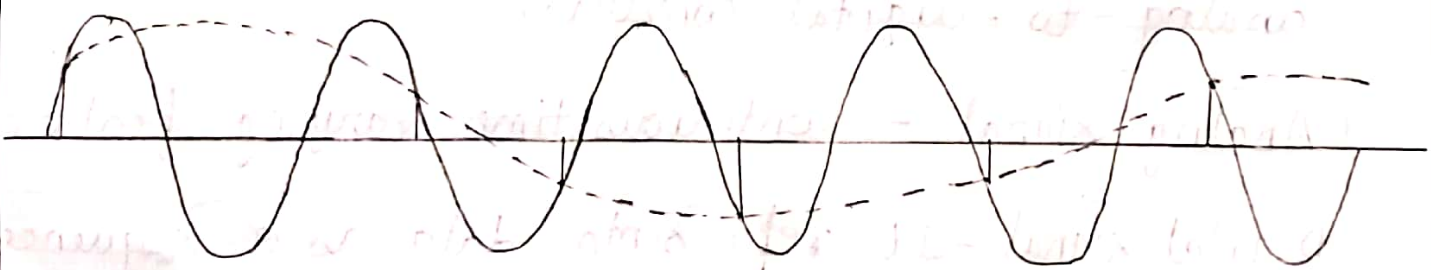
$f_s/f = 2.0$



$f_s/f = 1.4$



$f_s/f = 0.8$



Nyquist Rate -

- suppose that a signal is band-limited and 'w' is highest frequency. Therefor the effective reproduction of the original signal the sampling rate should be twice the highest frequency.

$$\boxed{f_s = 2W}$$

$f_s \rightarrow$ sampling rate
$W \rightarrow$ highest frequency.

This rate of sampling is called Nyquist rate, and theorem called sampling theorem

(4) Quantization: This method of sampling chooses few points on the analog signal and then these points are joined by round off the value of near stablized value is called quantization.

(5) Encoding
→ The digitization of analog signal is done by encoding.
→ After each sample is quantized, the number of bits per sample is decided.

→ Each sample is changed to an n bit code

→ Encoding is also used to minimize the bandwidth

## Observation

Signal Frequency = 10 Hz

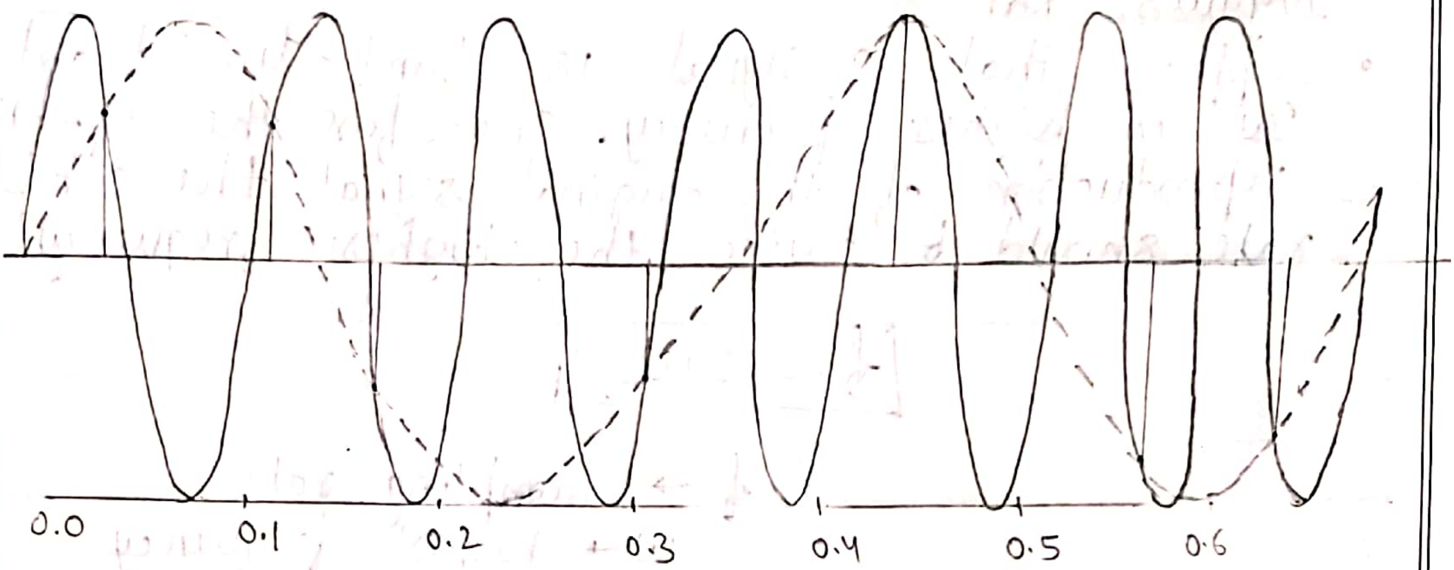
| SAMPLING FREQUENCY | ALIAS FREQUENCY |
|---|---|
| 7 | 3 |
| 10 | 0 |
| 15 | 5 |
| 20 | – |
| 22 | – |

Signal Frequency = 20 Hz

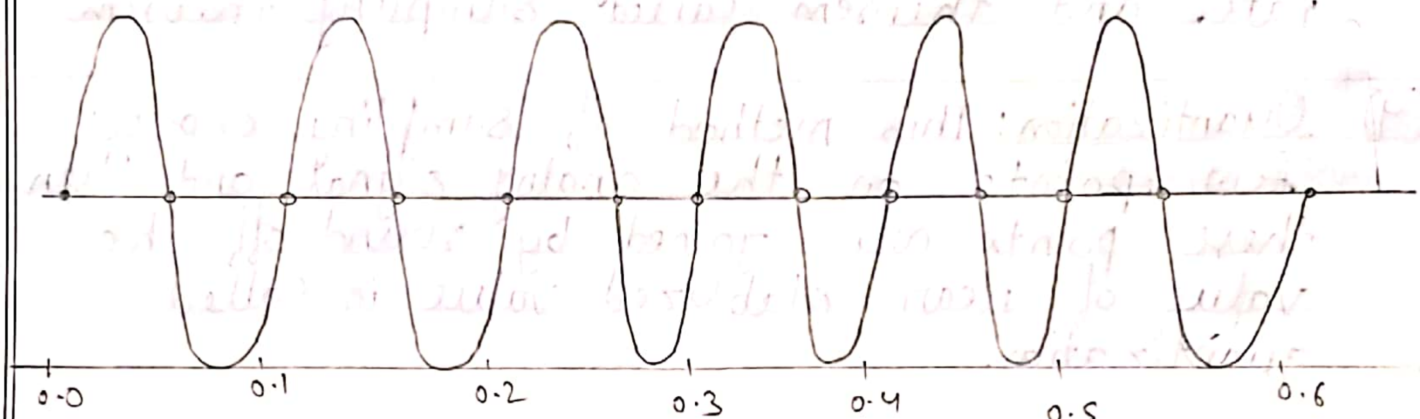
| Sampling freq | Alias Freq |
|---|---|
| 19 | 0 |
| 20.1 | 0.1 |
| 30 | 10 |
| 40 | – |
| 42 | – |

SIGNAL FREQUENCY: 10Hz

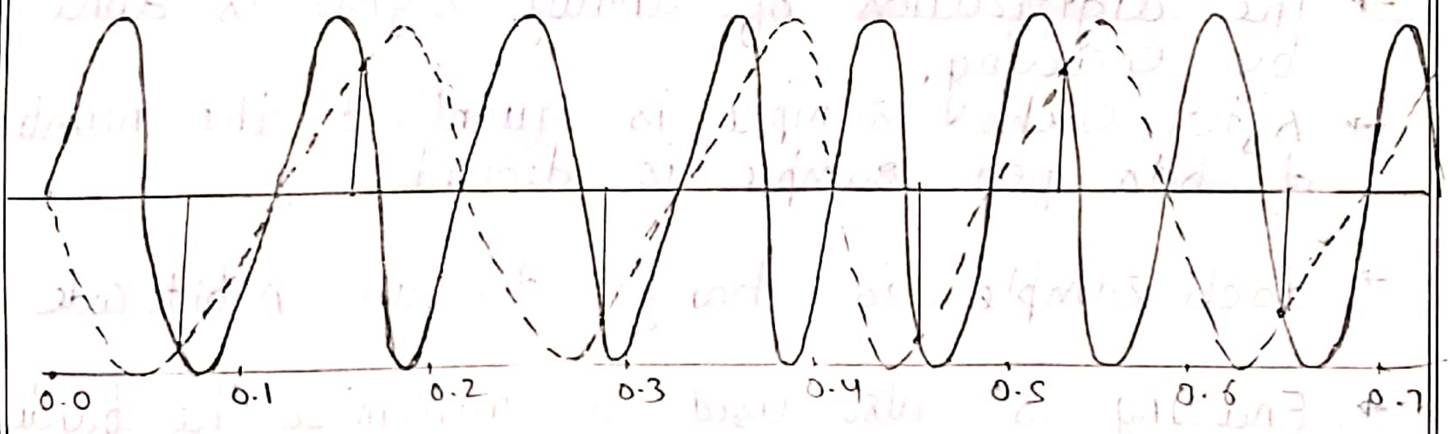
1) Sampling frequency = 7 Hz



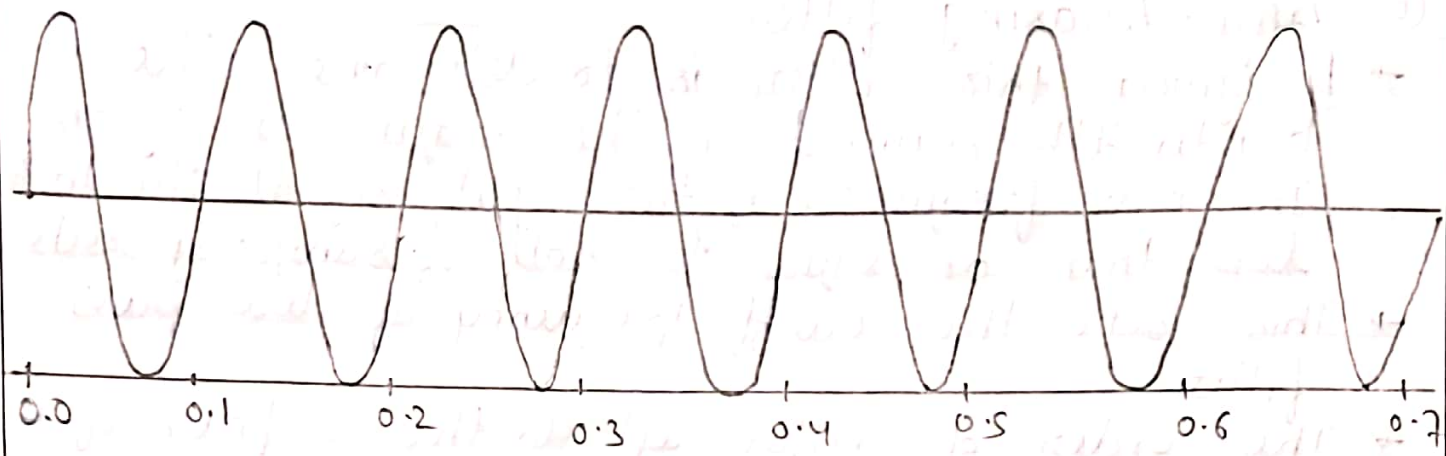

2) Sampling frequency = 10 Hz



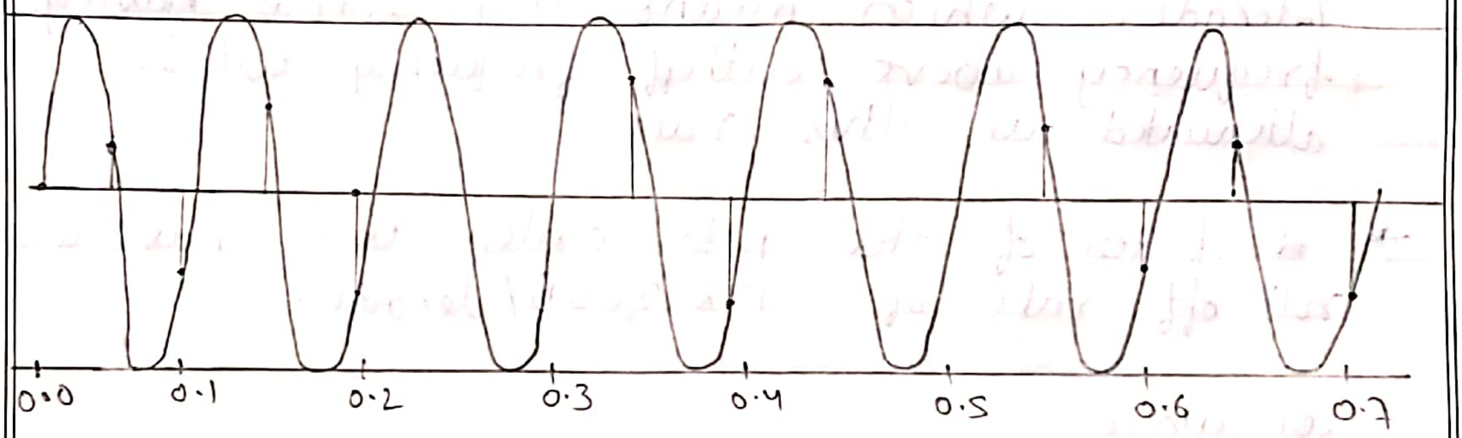

3) Sampling frequency = 15 Hz



4) Sampling Frequency = 20Hz




5) Sampling frequency = 22 Hz

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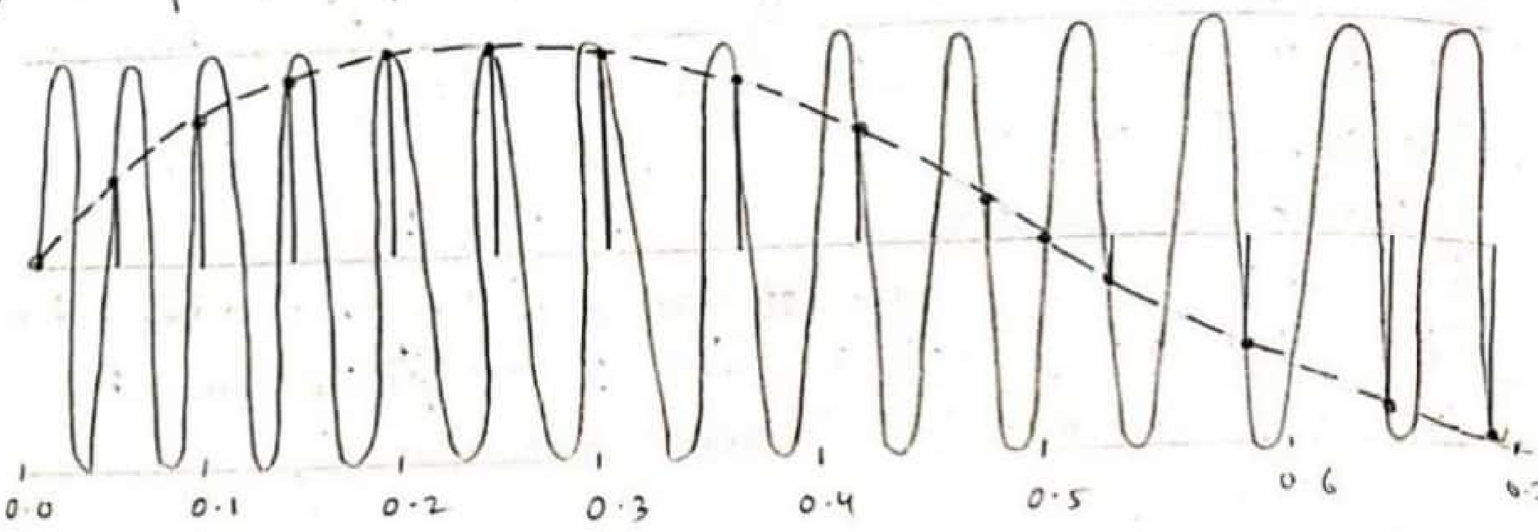
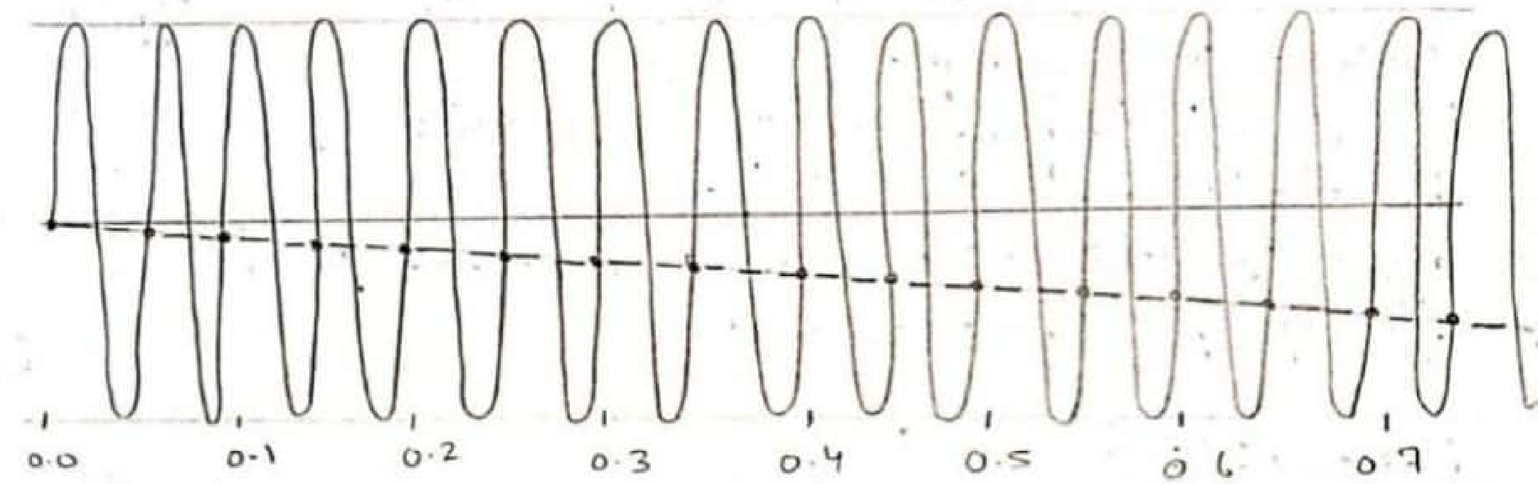
Signal Frequency = 20Hz

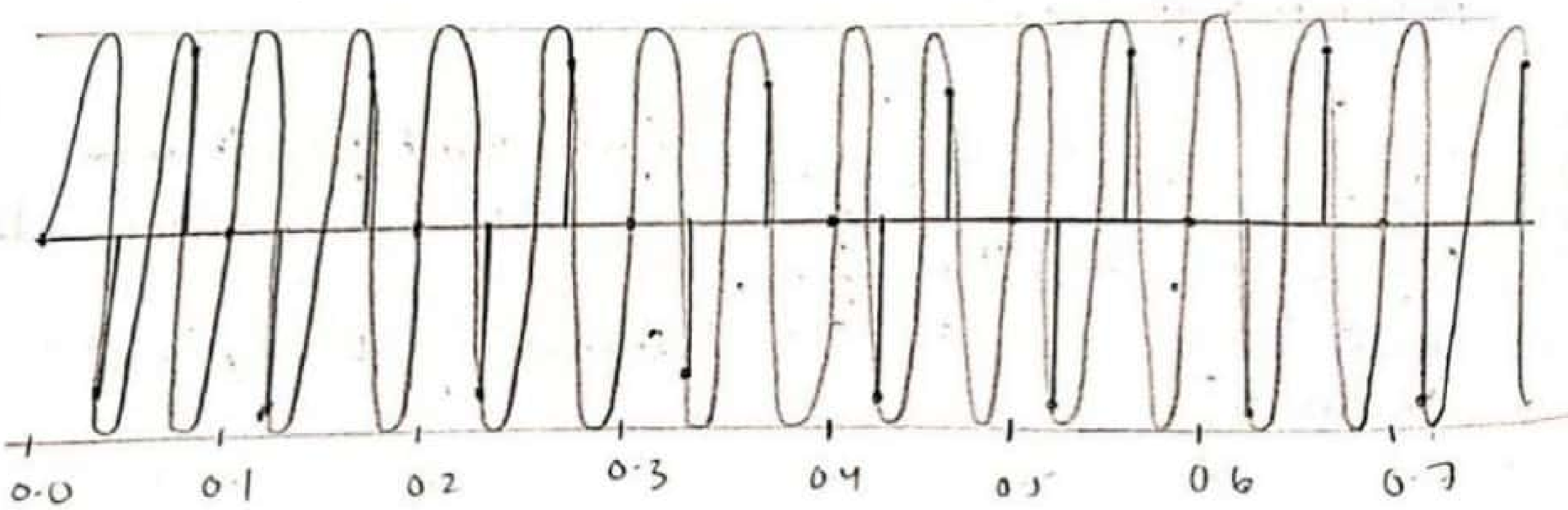
1) Sampling Frequency = 19 Hz



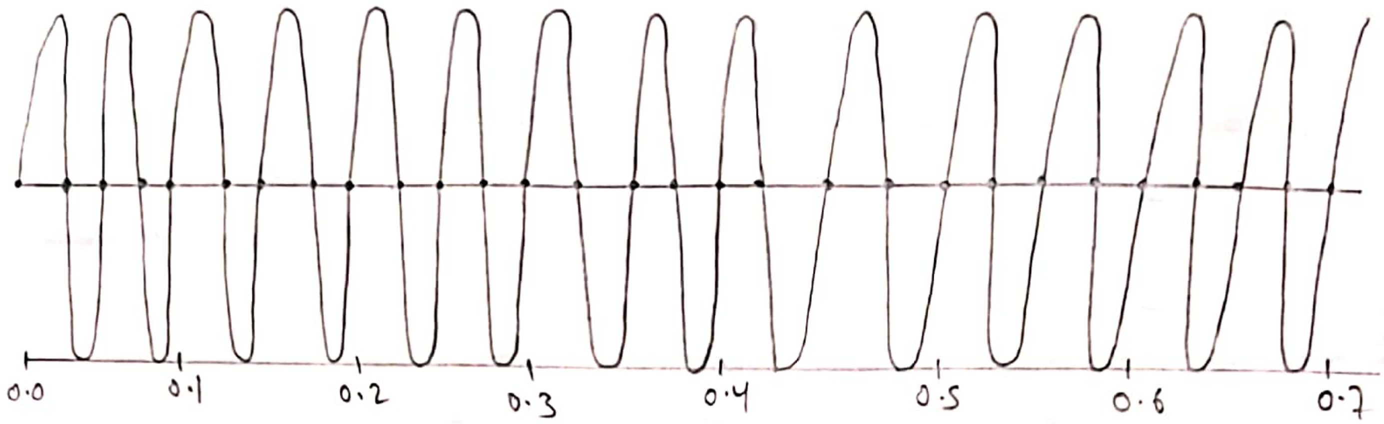

2) Sampling Frequency = 20.1 Hz



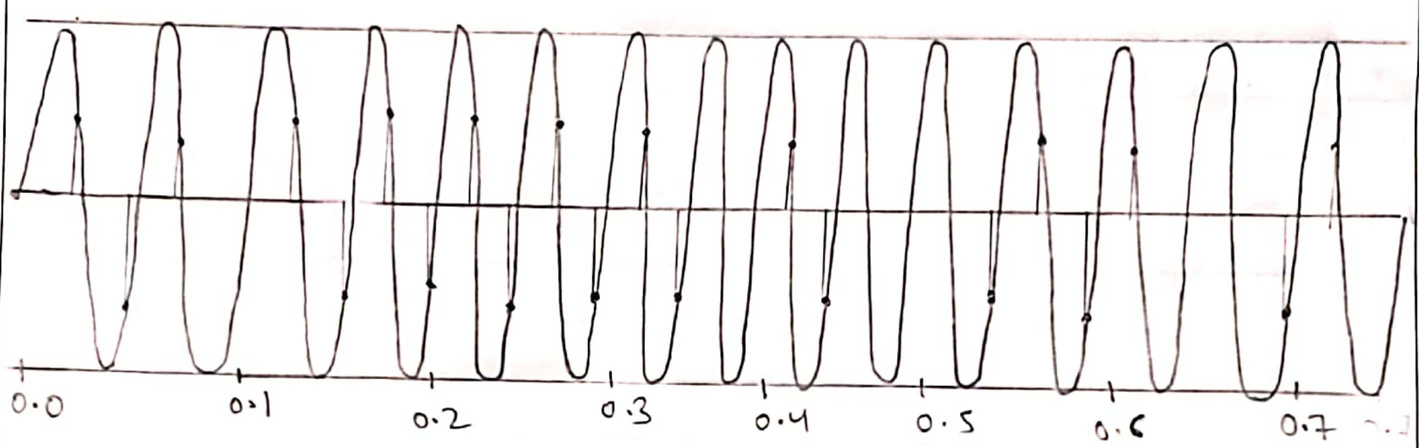

3) Sampling Frequency = 30Hz



4) Sampling frequency = 40Hz




5) Sampling frequency = 42 Hz



(6) Anti-Aliasing filter

→ Designing this filter is to determine the bandwidth required in the acquisitian system The max frequency of the input signal should be less than or equal to half of sampling rate

→ This sets the cutoff frequency of low pass filter

→ The order of filter affects the stepness of the transmitter region roll-off and hence the width of the transmittor region.

→ A first order filter has a roll-off of 20dB 1decade, which means any signal having frequency above cuttoff frequency will be attenuated at this rate

→ A filter of the nth order will have a roll off rate of n x 20dB/decade.

Conclusion

Therefore, sampling and reconstruction of the signal has been performed successfully on Nyquist Applet and Nyquist criteria has been verified

Expt. No. 03 **Amplitude Modulation** Page No. 10

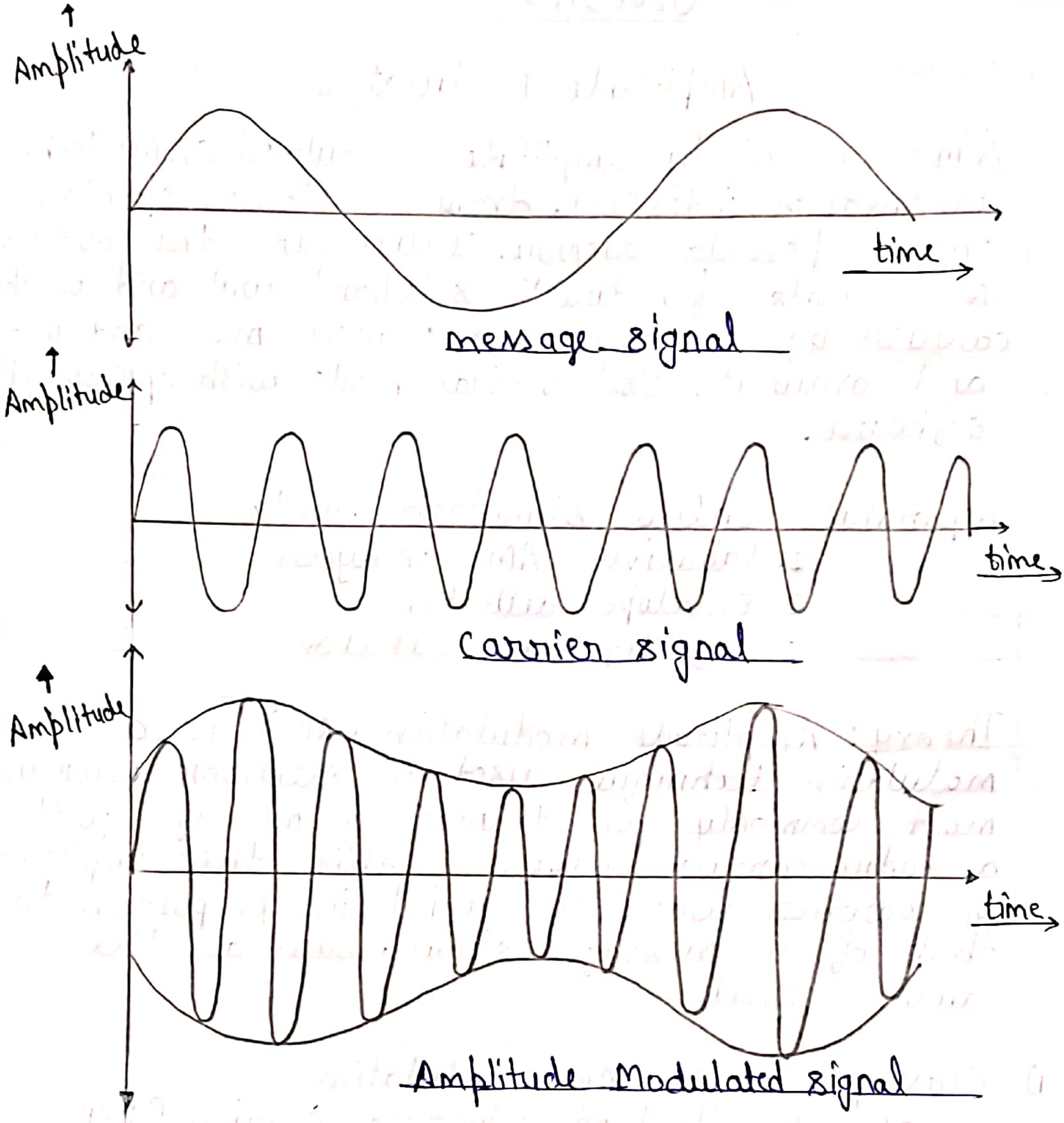
Aim: To study amplitude modulated (AM) technique, modulation index (m), draw waveforms, spectra and trapezoidal display. Illustrate the observed AM signals for double sideband with and without carrier by changing m as: m>1, m<1 and m=1 and draw it. Use virtual mode with appropriate software.

Apparatus - online stimulation tools
1. labalive AM analyser
2. Envelope dettector
3. synchronous detector

Theory: Amplitude modulation (AM) is a modulation technique used in electronic communication most commonly for transmitting messages with a radio carrier wave. In this, the amplitude of carrier wave is varied in proportion to that of a message signal, such as the audio signal.

1) Classification of AM modulation
- Double side band suppressed carrier (DSB-SC)
- Double side band with carrier (AM)
- Single side Band (SSB)
- Vestigal side Band (VSB)

2) AM - let modulating signal be m(t)




Amplitude Modulation of a sinusoidal wave

$m(t) = A_m \cos(2\pi f_m t)$, carrier signal be $c(t) = A_c \cos(2\pi f_c t)$

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

$$= A_c \left[1 + \frac{A_m}{A_c} \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$

modulation index, $m = \frac{A_m}{A_c}$

$$s(t) = A_c [1 + m \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

$$s(t) = A_c \cos(2\pi f_c t) + \frac{m}{2} A_c \cos[(2\pi)(f_c - f_m) t]$$
$$+ \frac{m}{2} A_c \cos[2\pi (f_c + f_m) t]$$

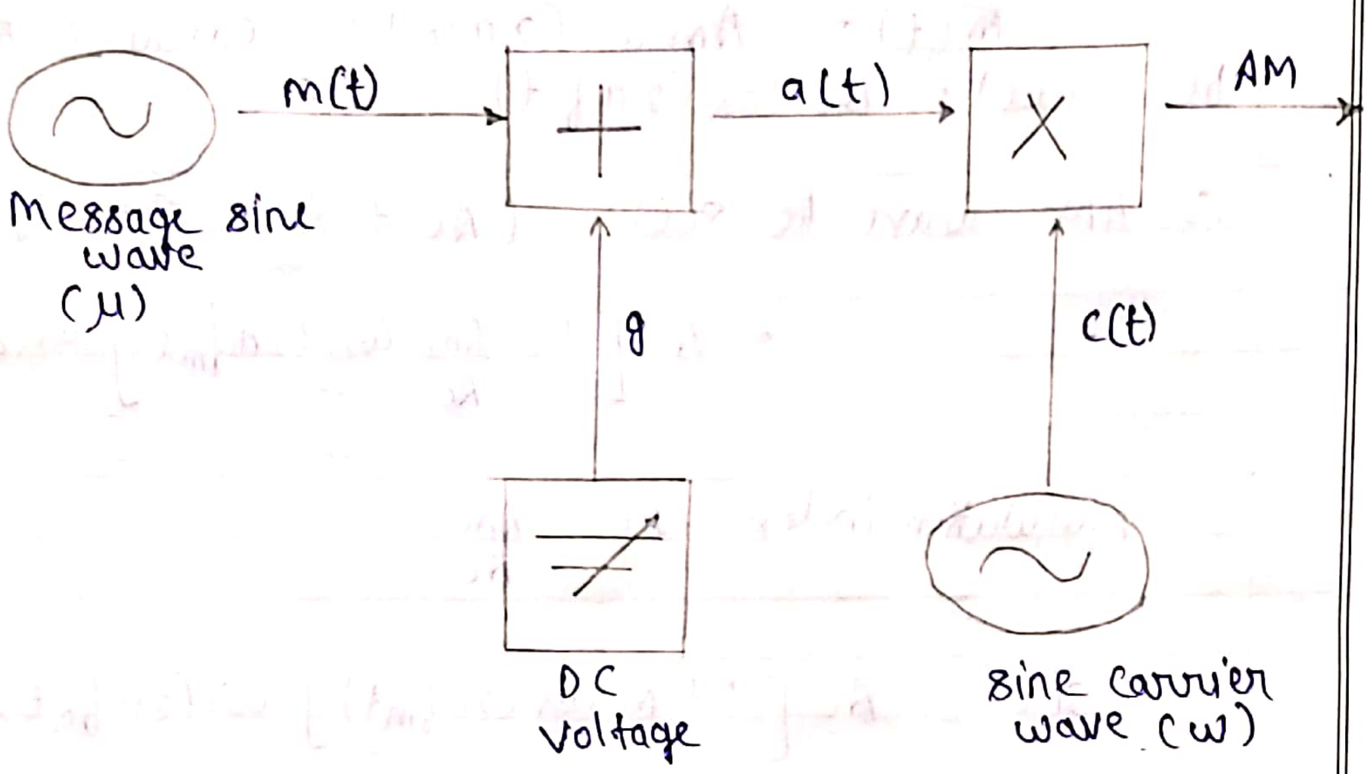
3) Measurement of 'm'

- The magnitude of 'm' can be measured directly from the AM signal itself
- maximum and minimum amplitudes of the transmissi signals envelope, determine the modulation depth.

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

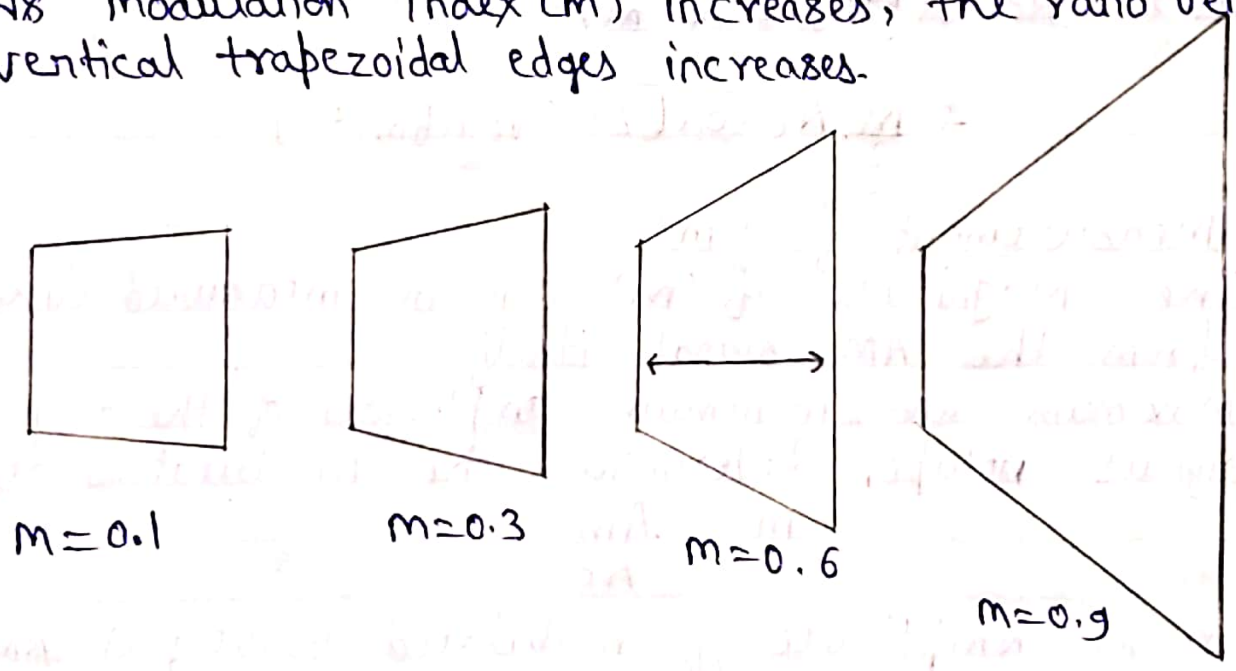
max. Amplitude of modulated wave; $a = A_m + A_c$
min Amplitude of modulated wave; $b = A_c - A_m$

## Block Diagram :-




## Trapezoidal Display

As modulation index (m) increases, the ratio between vertical trapezoidal edges increases.




- The Trapezoid width is unaffected by modulation depth

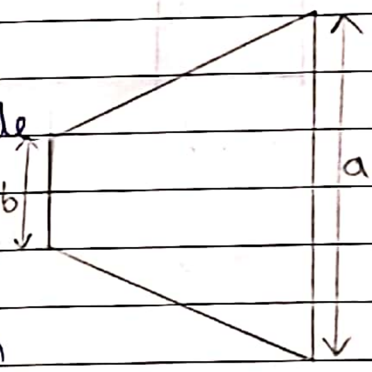
$$\therefore A_c = \frac{a+b}{2}, \quad A_m = \frac{a-b}{2}$$

$$\boxed{m = \frac{(a-b)}{(a+b)}}$$

4) Envelope detector :- The non-Coherent detection doesn't require a carrier recovery circuit. In its simplified form, it consists of rectifier diode and a low pass filter

5) Synchronous detector: AM without a carrier envelope detection can't be deployed because the transmitted signals envelope changes sign. transmit spectrum of DSB-SC.

Trapezoid Method
We can calculate 'm' in the time domain using an oscilloscope and the trapezoid method.




- The slope is placed in XY mode
  - X : modulating signal
  - Y : modulated signal

- The modulating index is then calculated from the vertical edge length using

$$\boxed{m = \frac{a-b}{a+b}}$$

## Observation

1) Double sideband with carrier (DC offset = ON)
m = modulation index

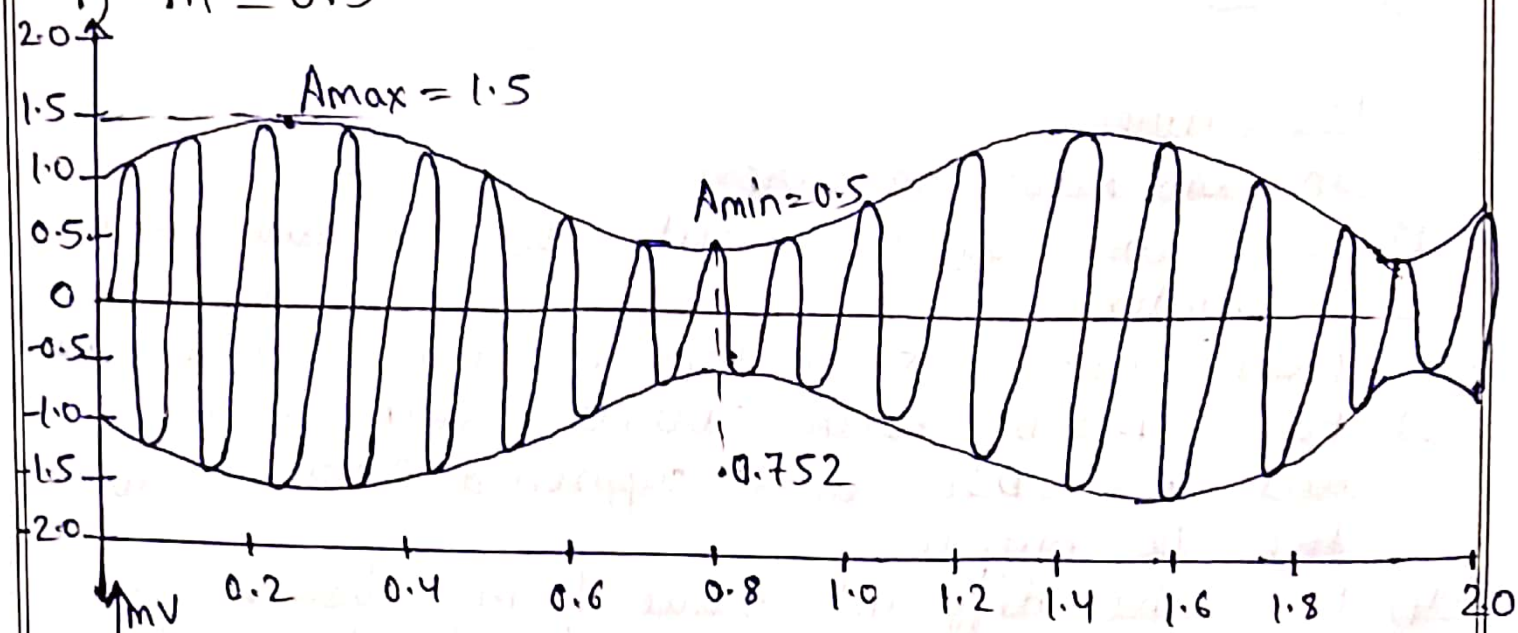
| Sr. No. | relation | m (modulation index) |
|---|---|---|
| 1 | $m<1$ | 0.5 |
| | | 0.8 |
| 2 | $m=1$ | 1.0 |
| 3 | $m>1$ | 1.2 |
| | | 1.5 |

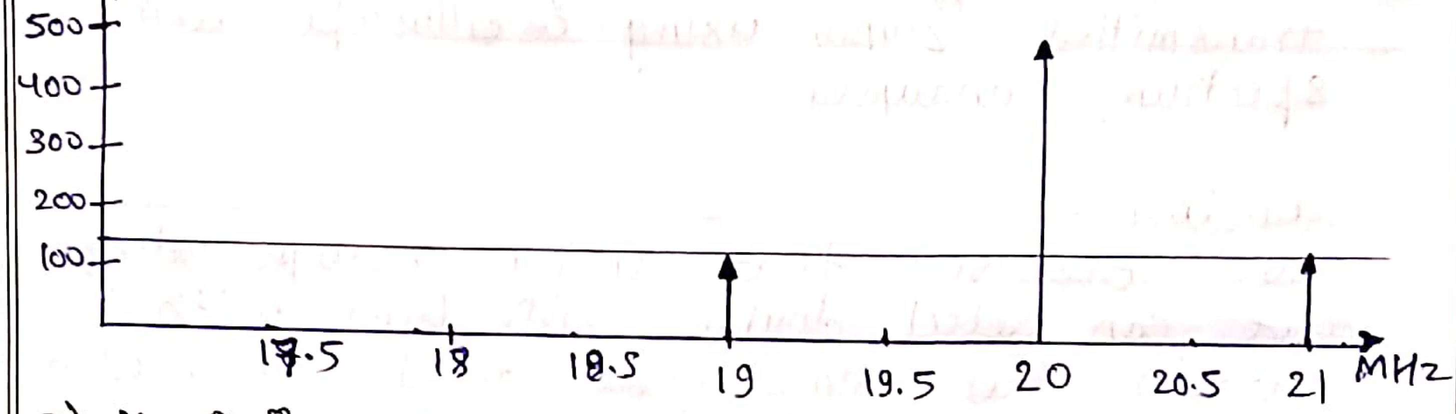
2) Double sideband carrier (DC offset = off)

| S. No. | relation | m (modulation index) |
|---|---|---|
| 1 | $m<1$ | 0.5 |
| | | 0.8 |
| 2 | $m=1$ | 1.0 |
| 3 | $m>1$ | 1.2 |
| | | 1.5 |

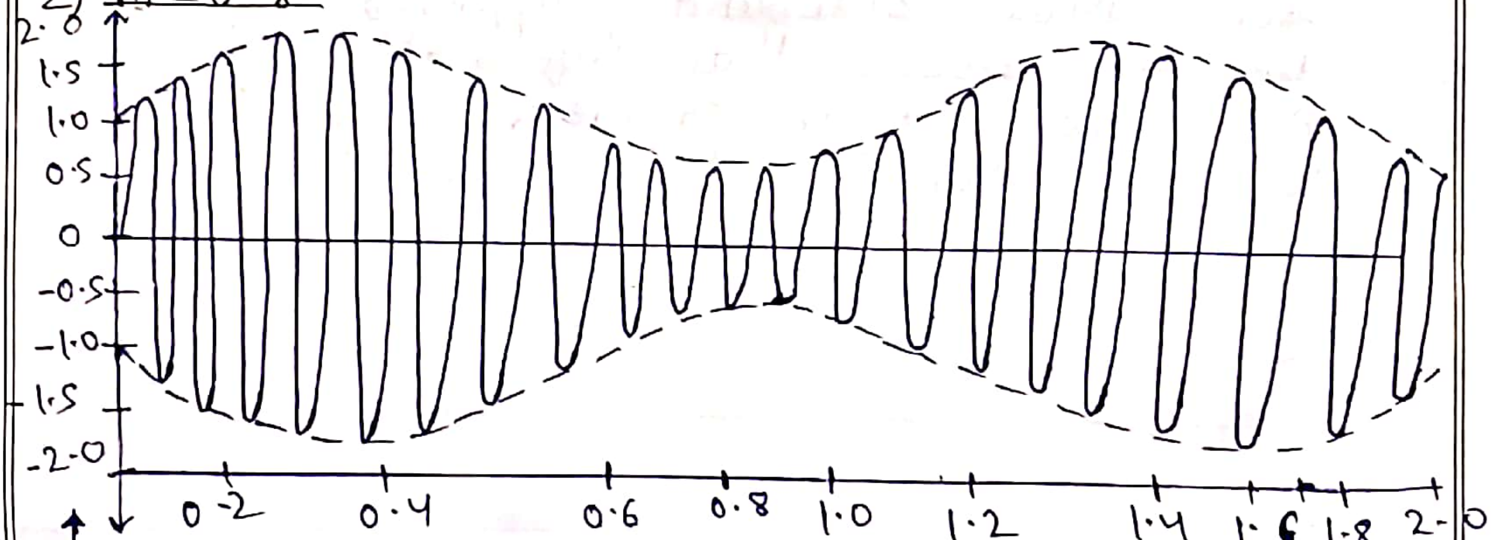
# Double side band with Carrier

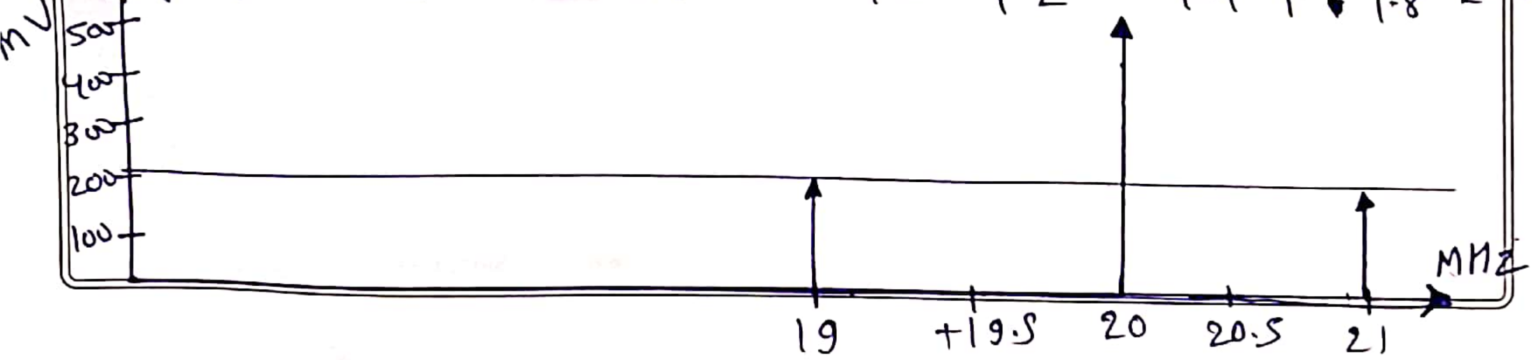
1) $M = 0.5$



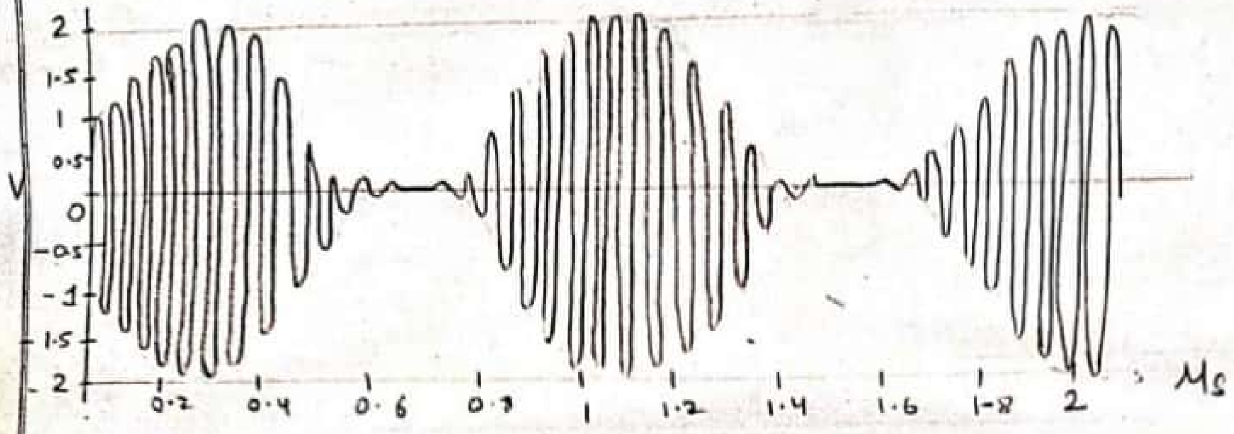



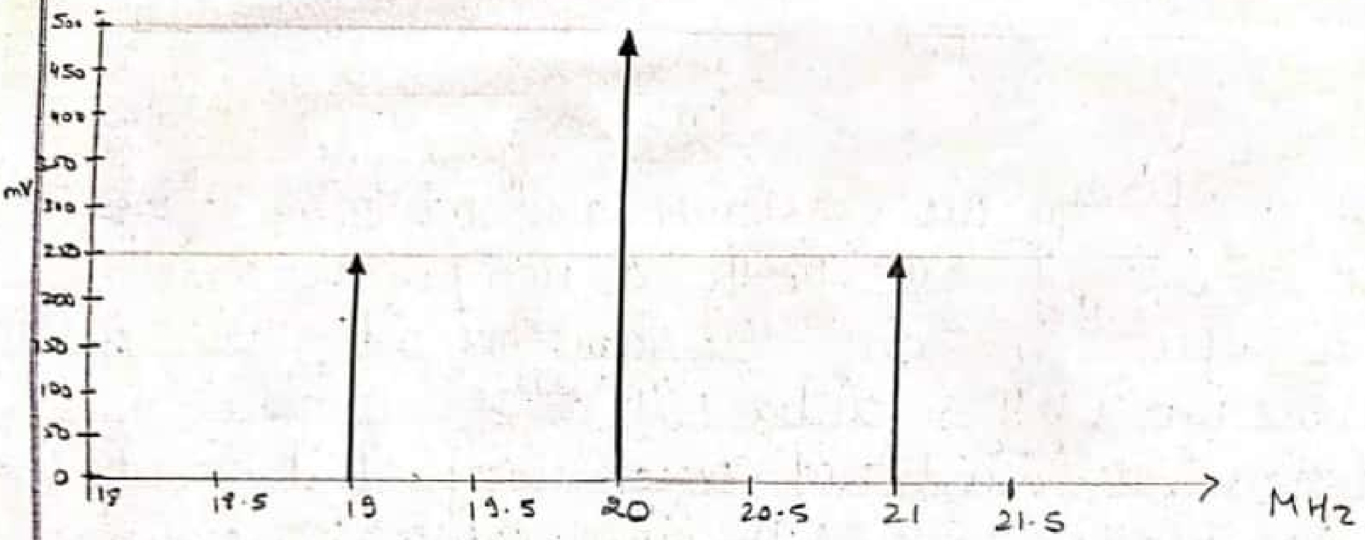

2) $M = 0.8$



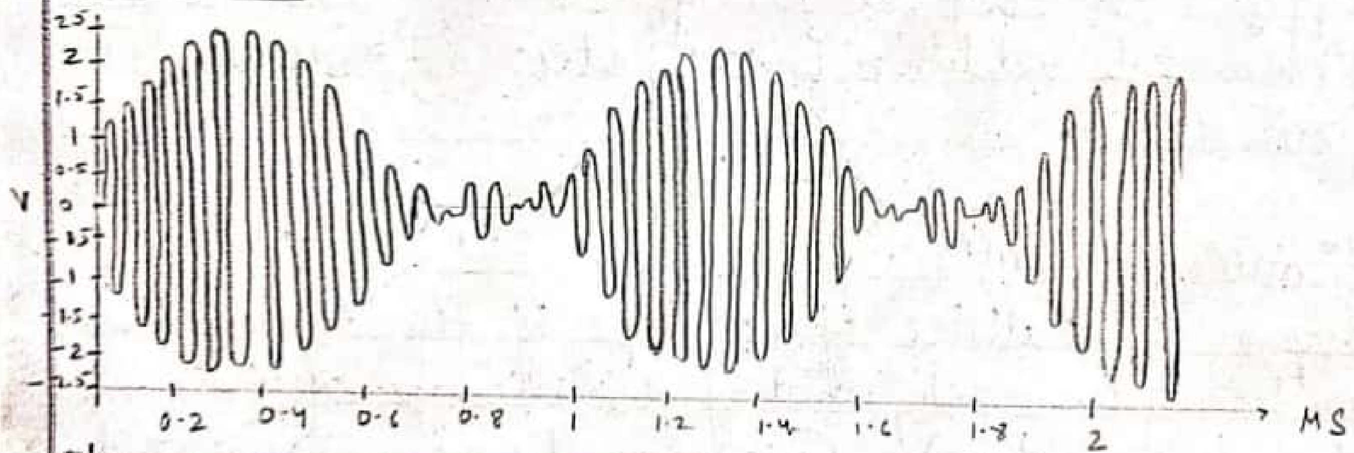



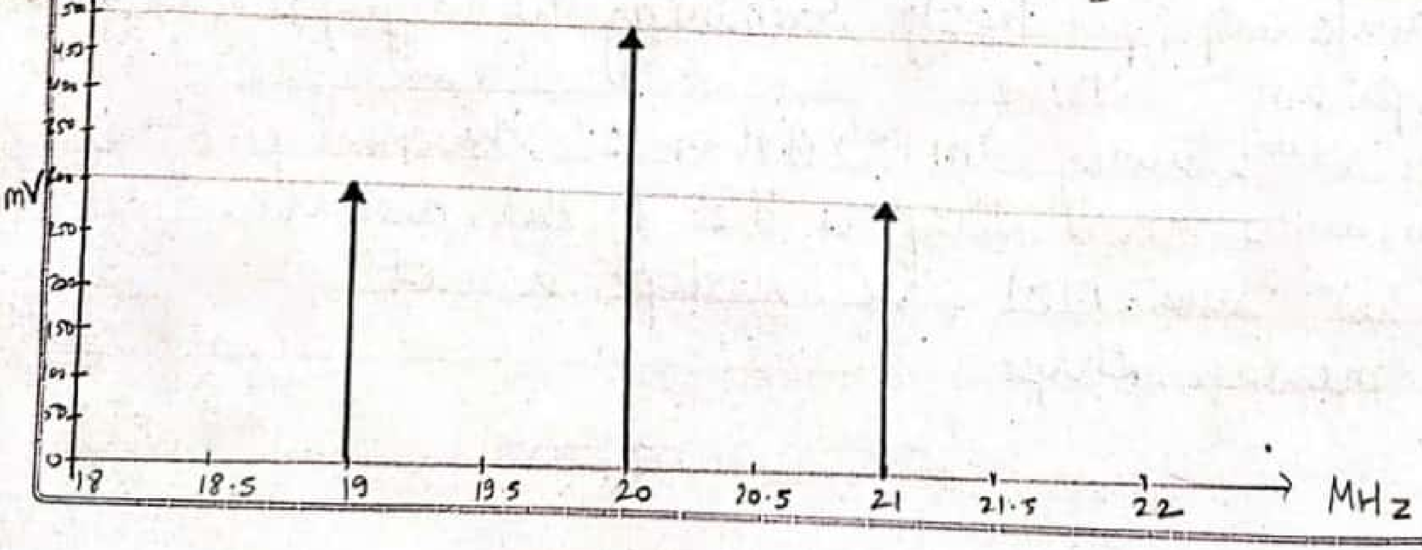
3) m = 1


V
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0.2
0.4
0.6
1
1.2
1.4
1.6
1.8
2
Ms

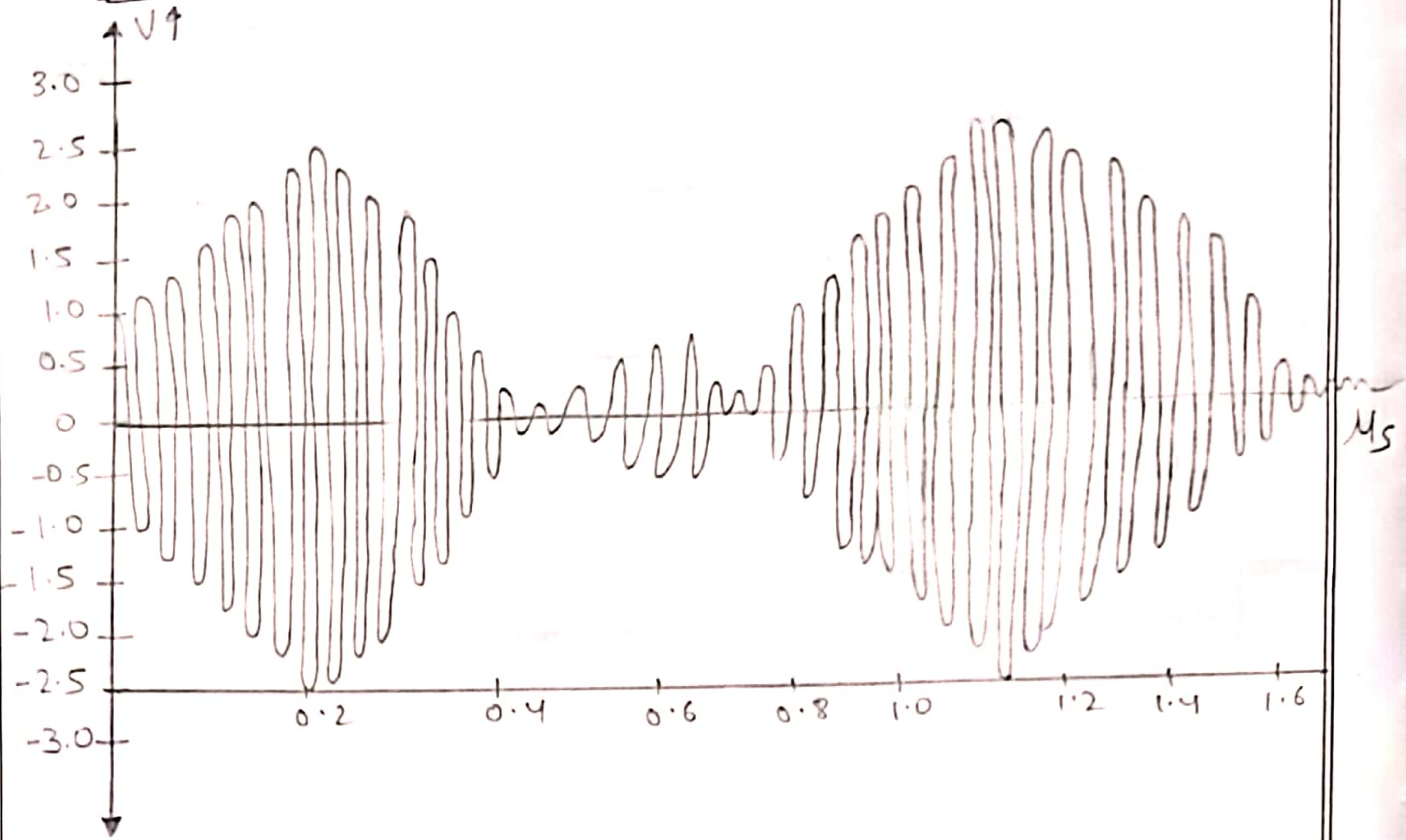

mV
500
450
400
0
18
18.5
19
19.5
20
20.5
21
21.5
MHz

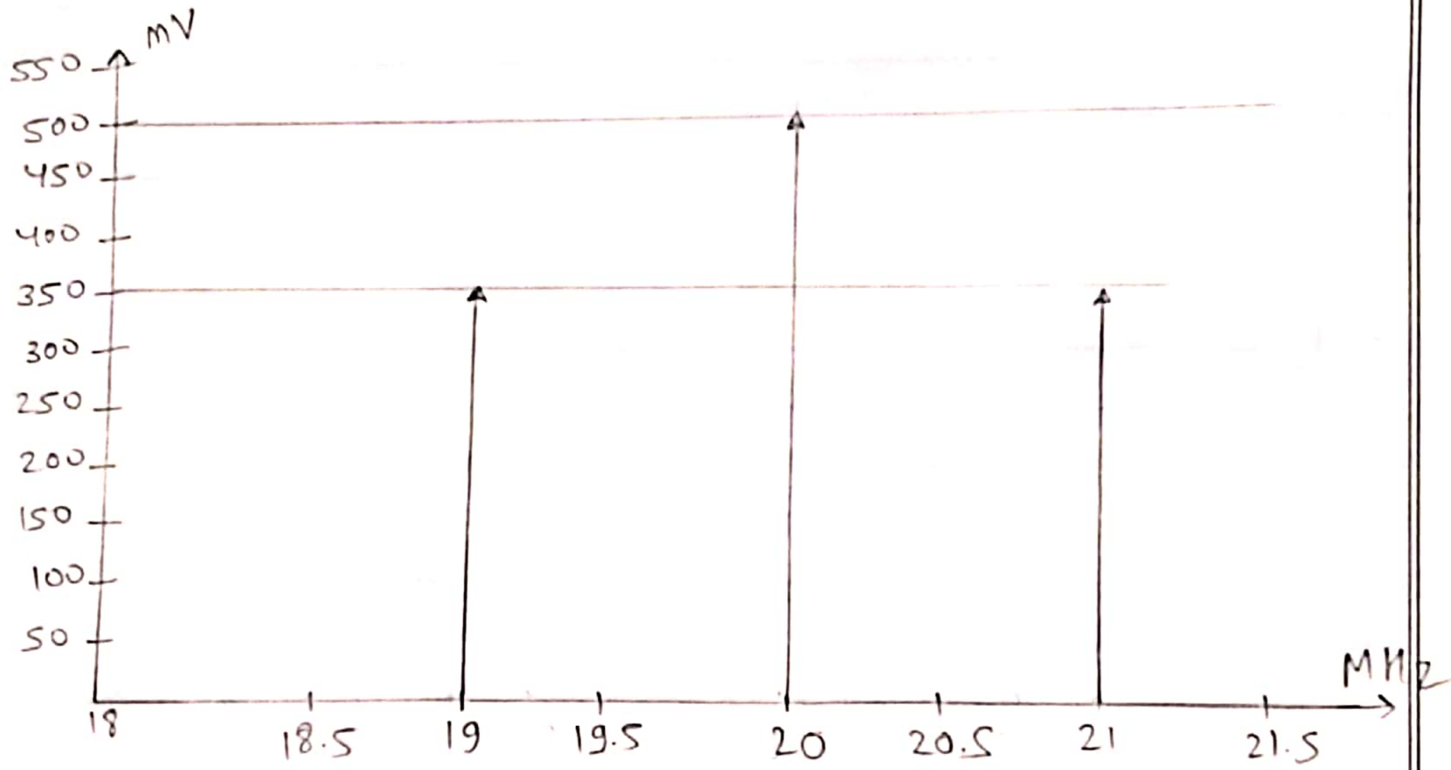
4) m = 1.2


V
2.5
2
1.5
1
0.5
0
-1
-1.5
-2
-2.5
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
MS


mV
0
18
18.5
19
19.5
20
20.5
21
21.5
22
MHz

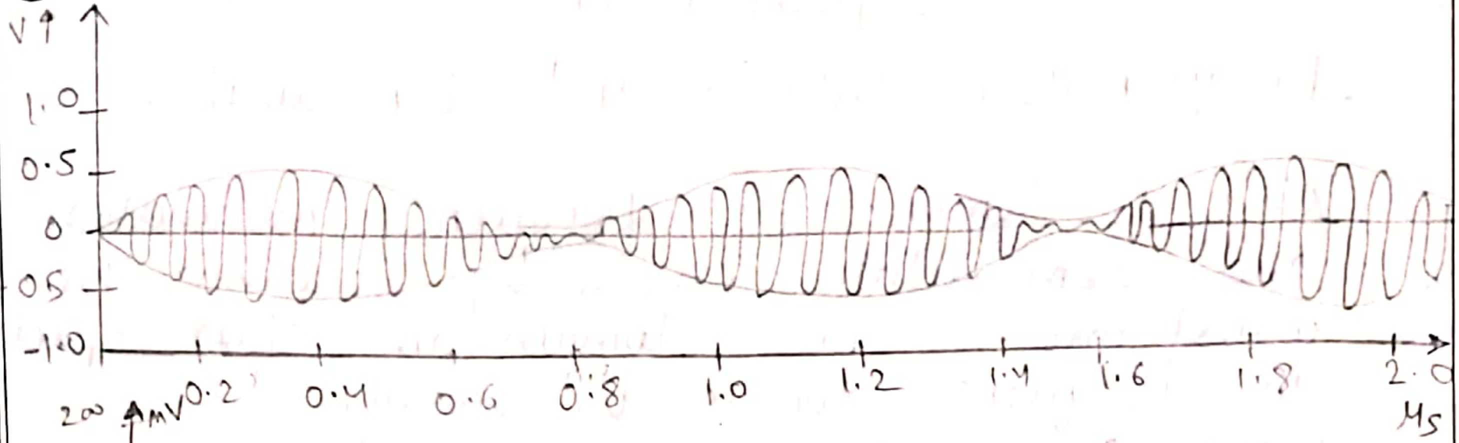
5) M = 1.5

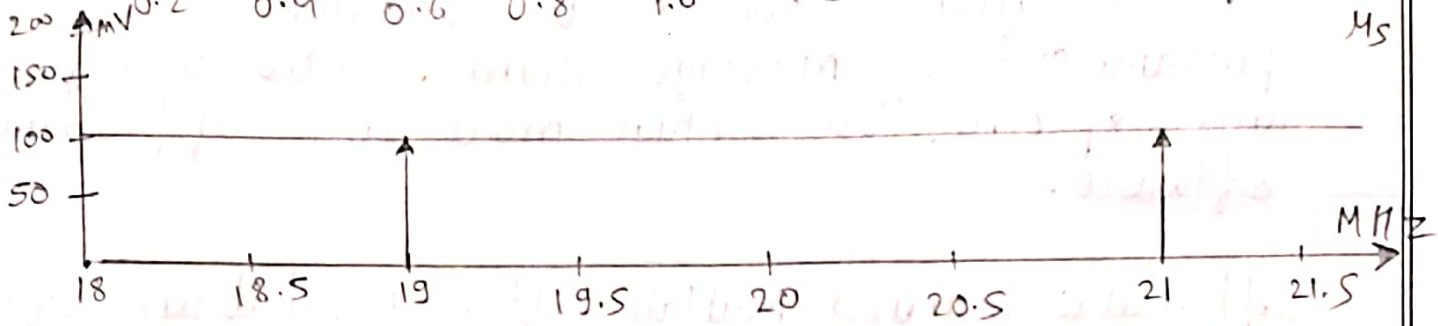

V
3.0
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
μs


mV
550
500
450
400
350
300
250
200
150
100
50
18
18.5
19
19.5
20
20.5
21
21.5
MHz

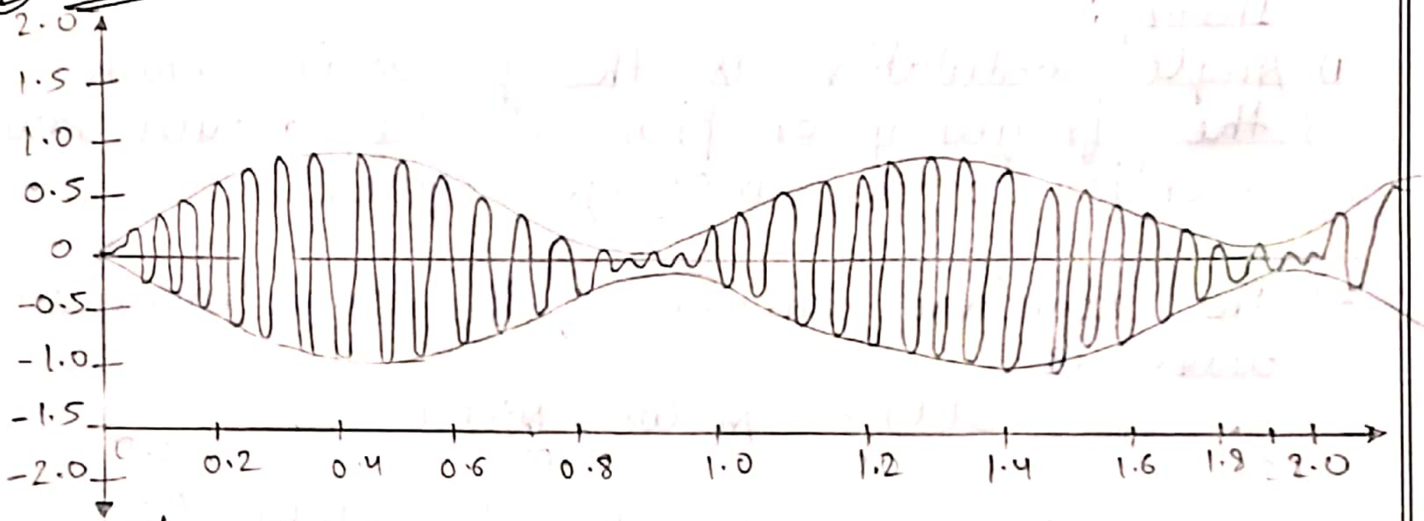
Double Sideband Suppressed Carrier:

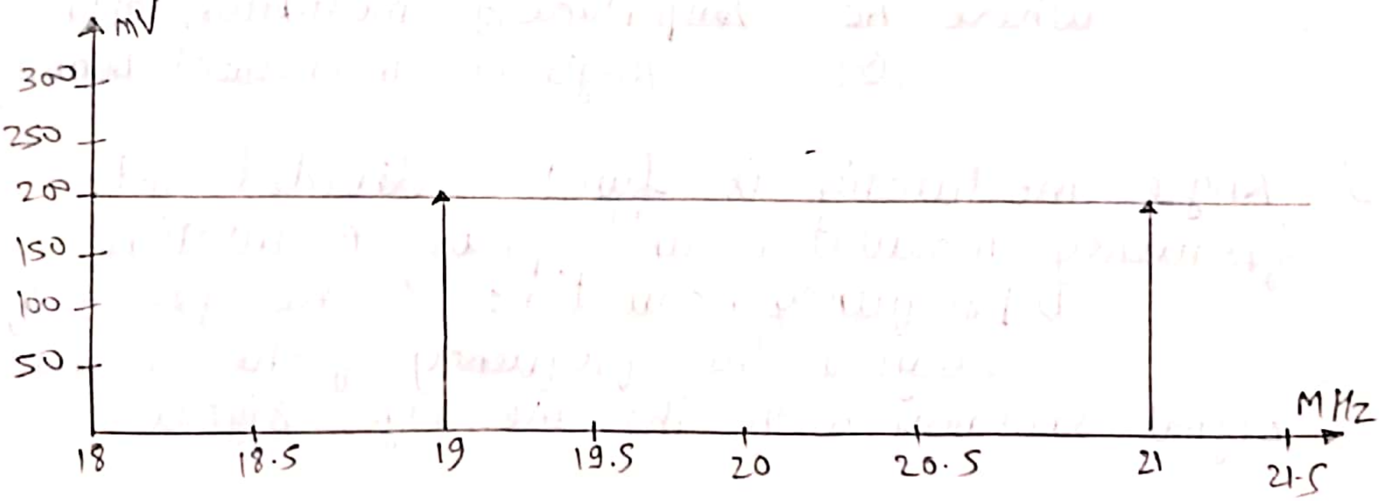
① m = 0.5



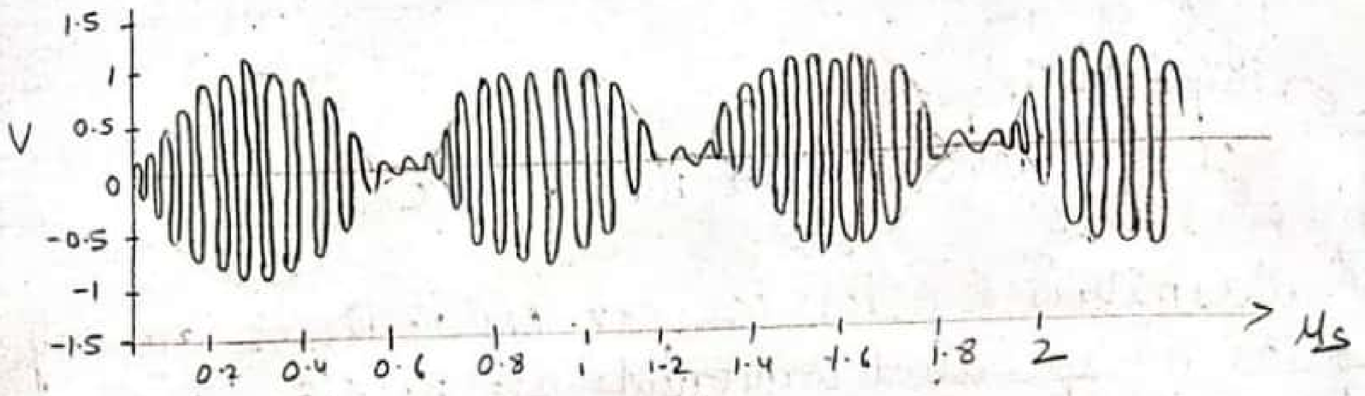



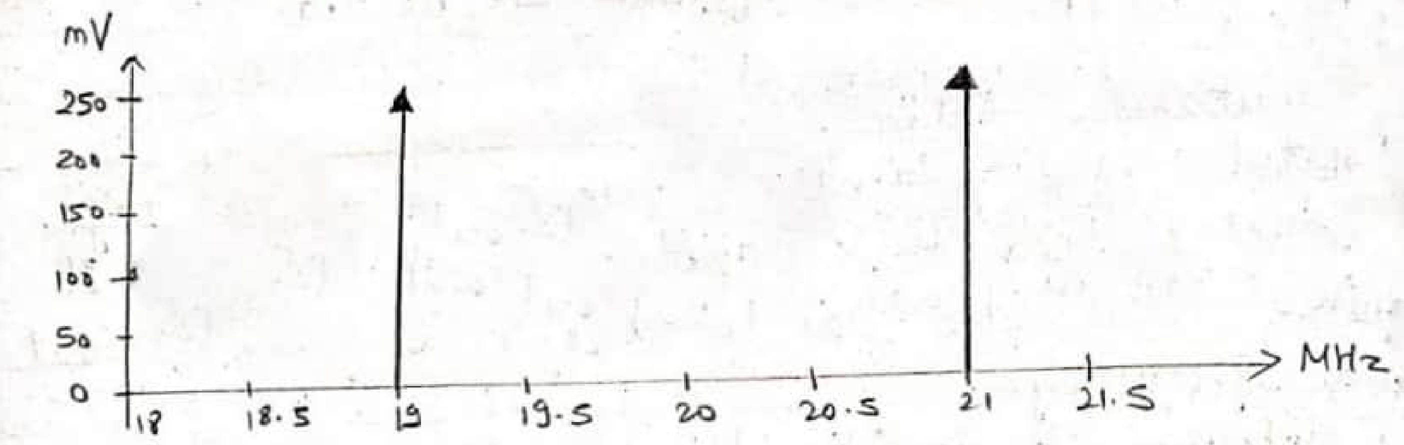

② m = 0.8



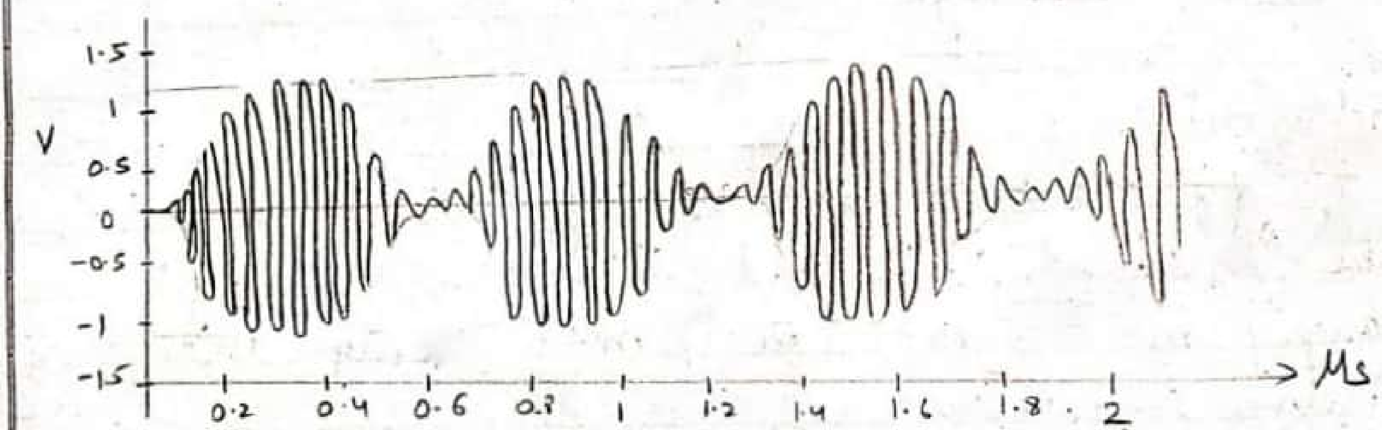



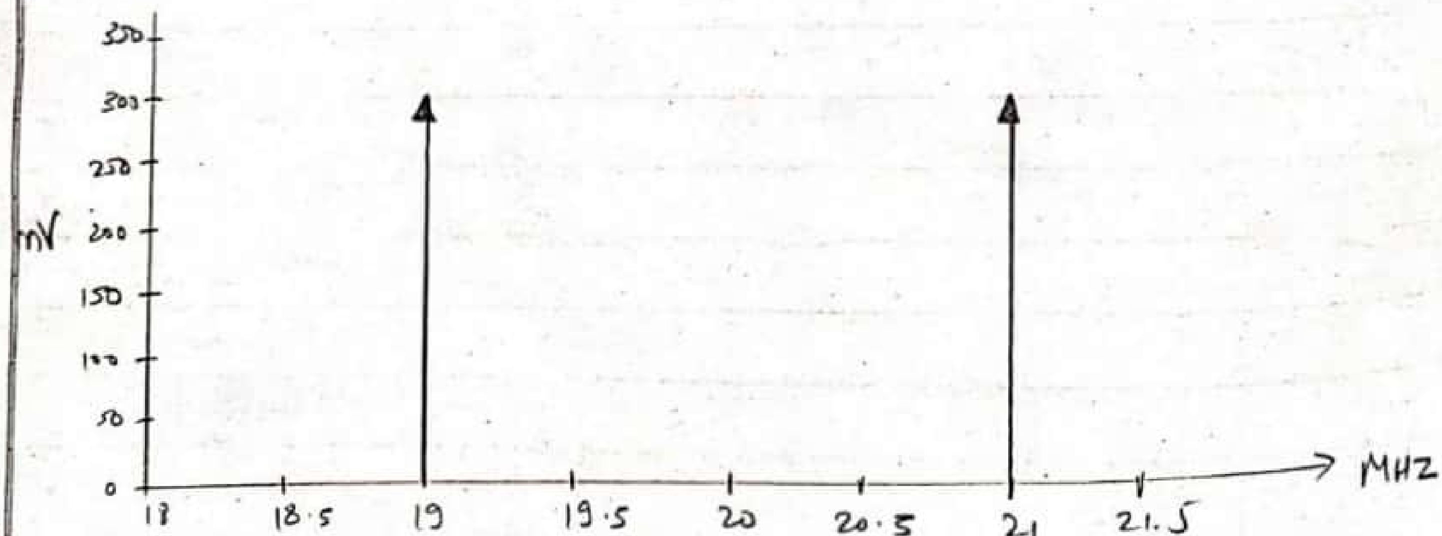
3) m = 1


1.5
1
0.5
0
-0.5
-1
-1.5
V
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Ms

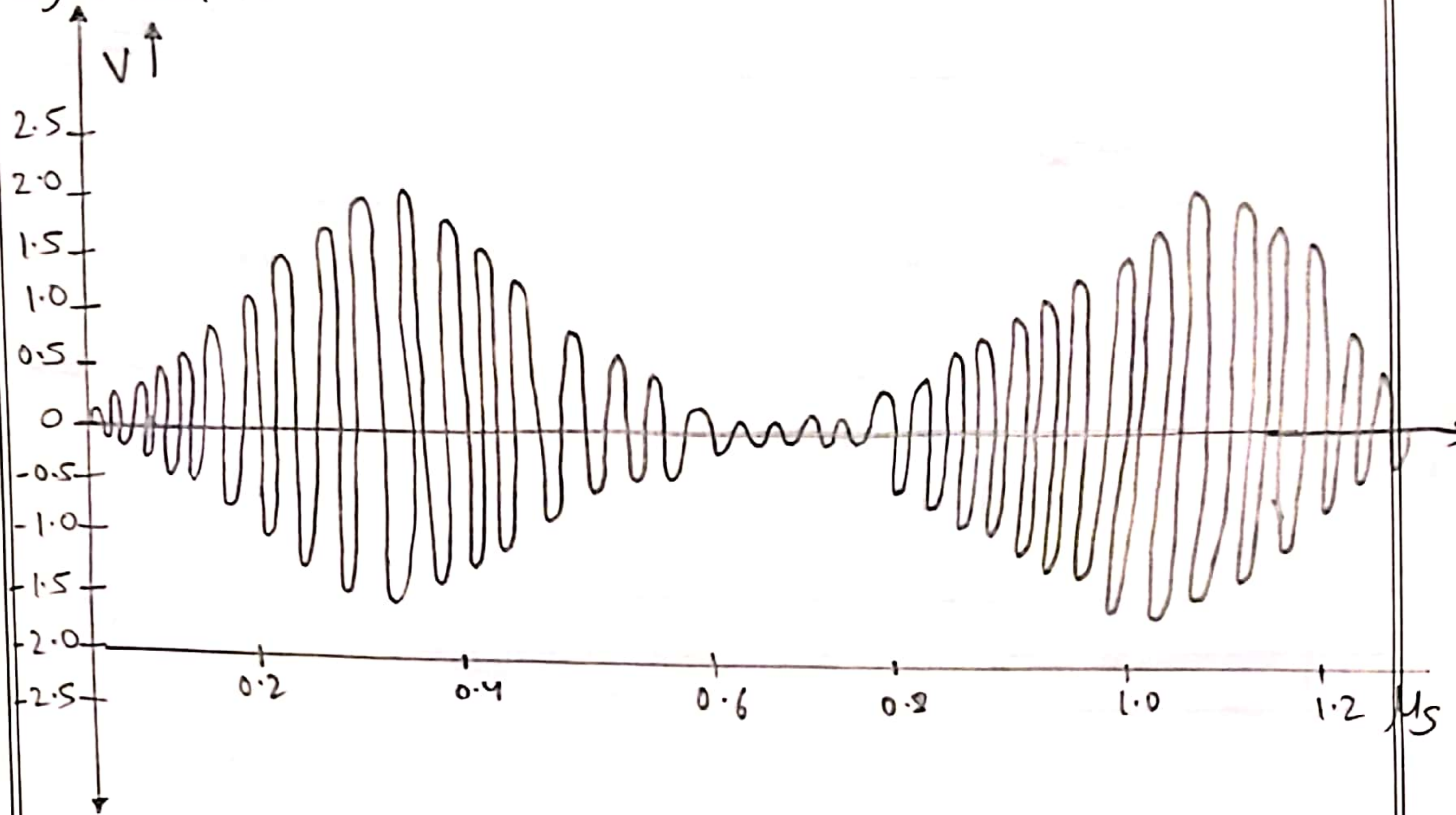

mV
250
200
150
100
50
0
18
18.5
19
19.5
20
20.5
21
21.5
MHz

4) m = 1.2

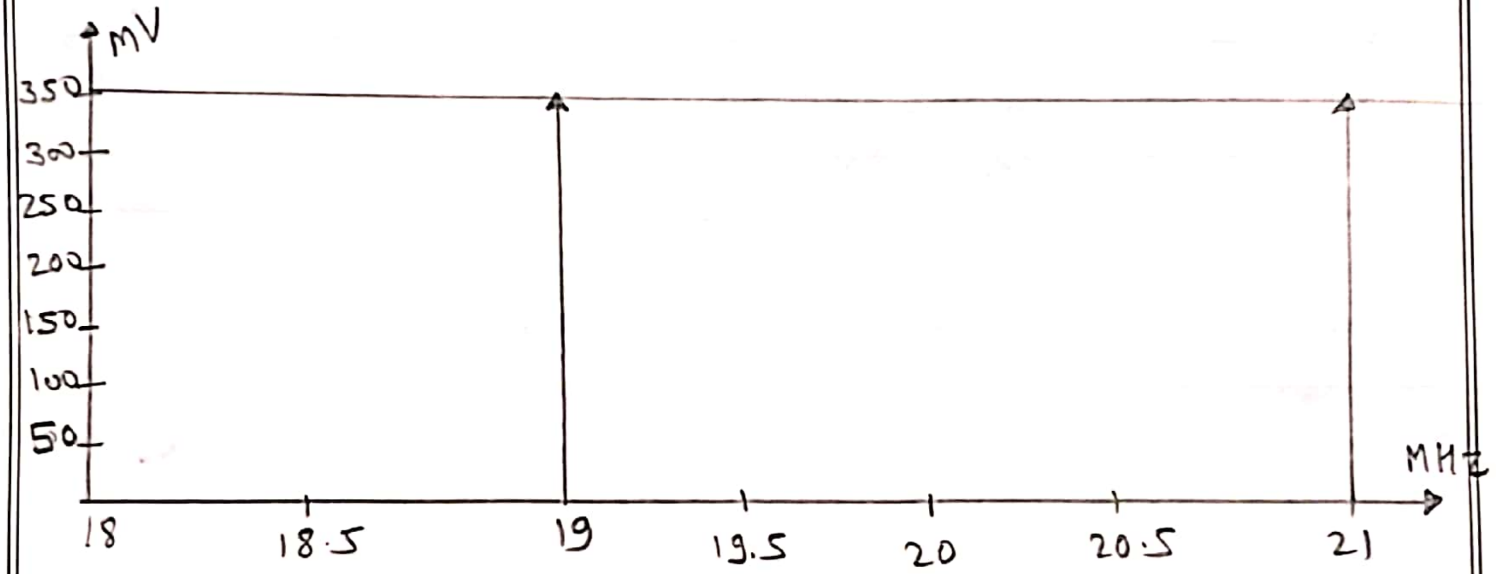

1.5
1
0.5
0
-0.5
-1
-1.5
V
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Ms


350
300
250
200
150
100
50
0
mV
18
18.5
19
19.5
20
20.5
21
21.5
MHZ

5) m = 1.5



V
2.5
2.0
1.5
1.0
0.5
0
-0.5
-1.0
-1.5
-2.0
-2.5
0.2
0.4
0.6
0.8
1.0
1.2
μs

mV
350
300
250
200
150
100
50
18
18.5
19
19.5
20
20.5
21
MHz

Procedure
In lab-Alive software
1) We will first execute the AM analyser simulator
2) Then click on $\hat{S}$ in the AM modulation window.
3) For D.S.B with carrier click on D.C. and for DSB with suppressed carrier off the DC output.
4) For the different value of m observe the transmitted signal using oscilloscope and spectrum analyser

Conclusion
we observe that using envelope detector we can detect double side band with carrier but synchronous detector is needed for double sideband suppressed carrier. We also observe that information lies in sidebands and in carrier. Using DBS, we can minimize the power usage.

# Experiment No. - 4

## Frequency Modulation and Demodulation

**Aim:** To demonstrate frequency modulation and demodulation process by observing the waveforms in time domain and their spectra in frequency domain by varying the parameters of massage signal. Draw waveforms and spectra. Use virtual mode with appropriate software.

**Apparatus required** Matlab software, Labalive software

**Theory:**

1) Angle modulation is the process in which the frequency or phase of the carrier varies according to the message signal.

2) The standard equation of the angle modulation wave is

$$S(t) = A_c \cos(\theta_i(t))$$

where $A_c$ = Amplitude of modulated / Carrier wave
$\theta_i$ = Angle of modulated waving

3) Angle modulation is further divided into frequency modulation and phase modulation

1) Frequency Modulation: is the process of varying the frequency of the carrier signal linearly with the message signal

2) Phase Modulation is the process of varying the phase of carrier signal linearly with message signal.

4) ~~As Phase~~ frequency of modulated wave increases, the amplitude of the modulating or message signal increases. Similarly, the frequency of modulated wave decreases, when the amplitude of modulated signal decreases.

Note: The frequency of modulated (carrier) wave remains constant and is equal to the frequency of carrier signal, when amplitude of modulating signal is zero.

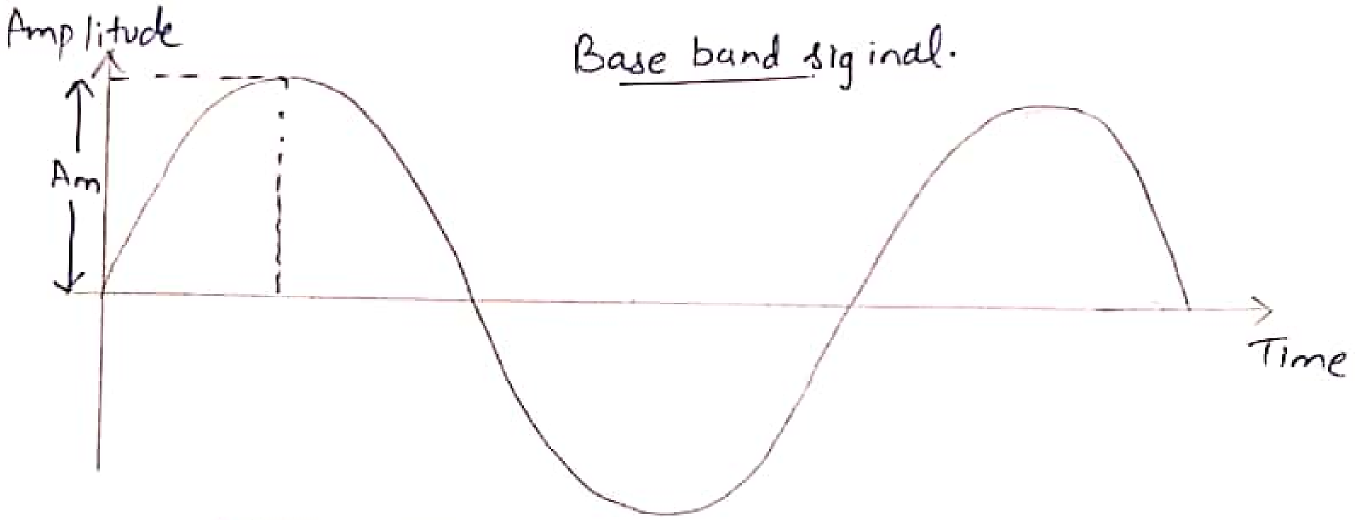
5) Mathematically, the equation for instantaneous frequency $f_i$ in FM modulation:

$$\boxed{f_i = \underbrace{f_c}_{\text{carrier frequency}} + \underbrace{(K_f)}_{\text{frequency sensitivity}} \underbrace{m(t)}_{\text{message signal}}} \quad \text{——} \ (1)$$

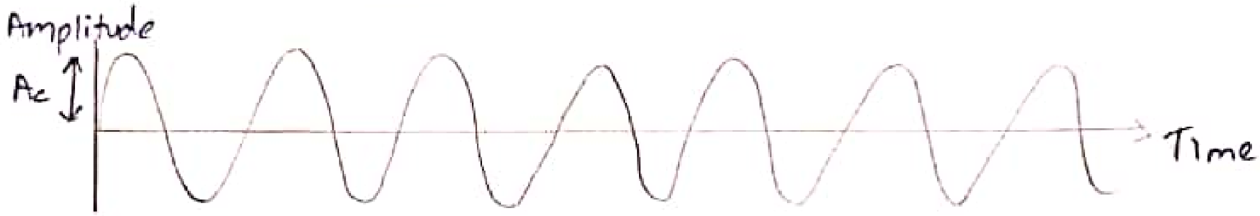
6) We know relationship between $\omega_i$ and $\theta_i(t)$

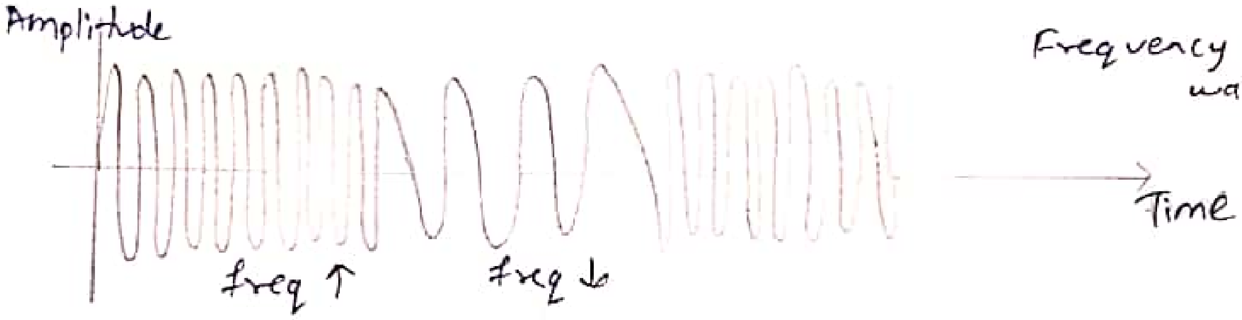
$$\left[\omega_i = \frac{d(\theta_i)}{dt}\right] \quad \text{——} \ (2)$$

Base band signal.



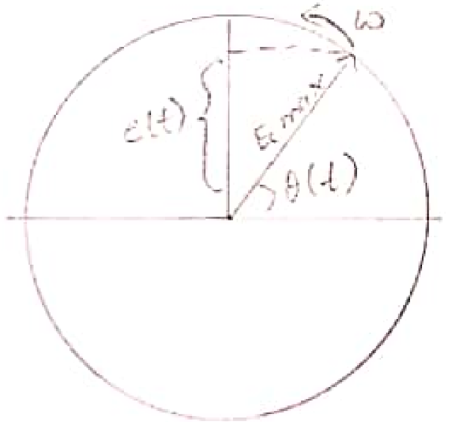

Carrier wave



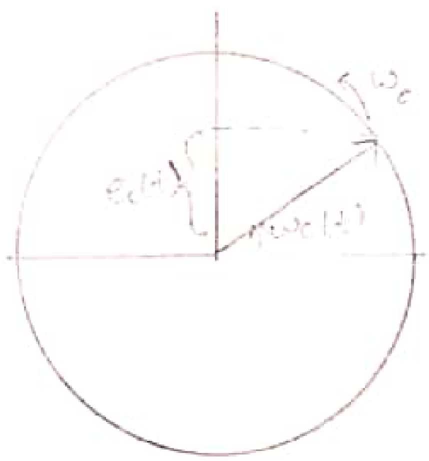




Frequency modulated wave.

Rotating phasor representation of carrier of amplitude $E_c max$.




a) Instantaneous angular velocity $\omega_i(t)$




b) at constant angular velocity ($\omega_c$)

$$2\pi f_i = \frac{d\theta_i}{dt}$$

$$d\theta_i(t) = 2\pi f_i \, dt$$

substitute $f_i$ from eqn 1

$$\boxed{\theta_i(t) = 2\pi f_c + 2\pi K_f + \int m(t)dt} \quad -3$$

substitute $\theta_i(t)$ of value in standard eqn of angle modulation

$$\boxed{S(t) = A_c \cos(2\pi f_c t + 2\pi K_f \int m(t)dt)} \quad -4$$

eqn of FM wave

7) Finally, eqn of FM wave

$$\boxed{S(t) = A_c \cos[2\pi f_c t + 2\pi K_f \int m(t)dt]} \quad -4$$

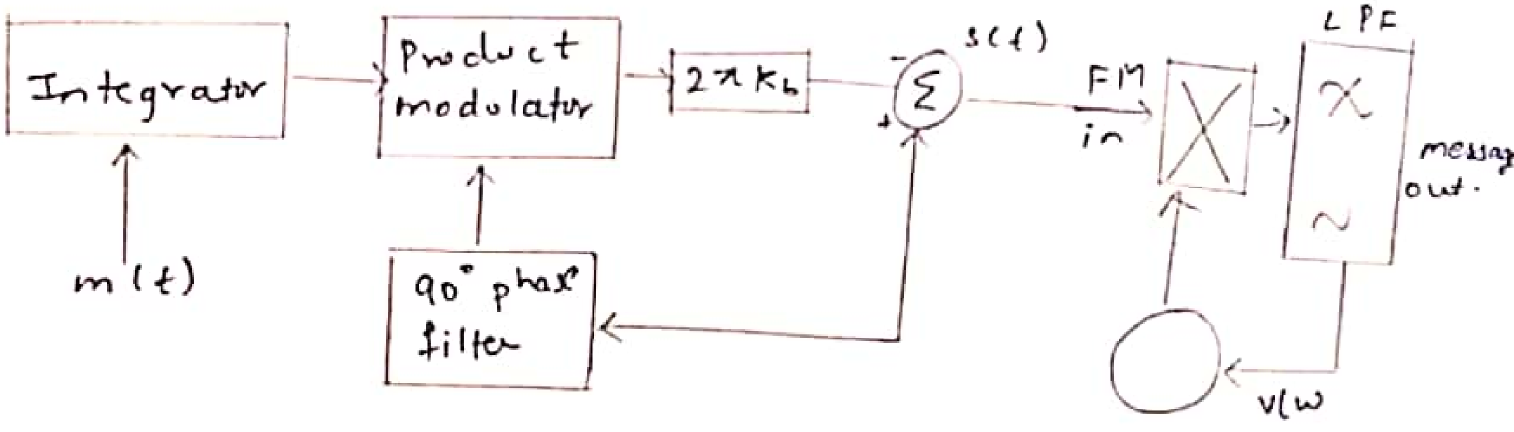
If modulating signal $m(t) = A_m \cos(2\pi F_m t)$ then eqn of FM

$$\boxed{S(t) = A_c \cos[2\pi f_c t + \beta \sin(2\pi f_m t)} \quad -5$$

$$\boxed{\beta = \frac{K_f A_M}{F_M} = \frac{\Delta F}{F_m} \text{ - modulating index}}$$

Teacher's Signature :

Block diagram of FM modulator & demodulator.



8) The difference between FM modulated frequency (instantaneous) and normal frequency is termed as frequency deviation.
It is denoted by $[\Delta F = (f_i - f_c) = K_f A_m]$

9) The amount of change in carrier frequency produced, by the amplitude of input modulating signal, is called frequency deviation.

$$\boxed{f_d = f_{max} - f_c = f_c - f_{min}}$$

10) Bandwidth $= 2 \times [f_m + \Delta f]$

11) In FM, carrier amplitude is constant.
∴ Transmitted power is constant and transmitted power does not depend on modulation index.

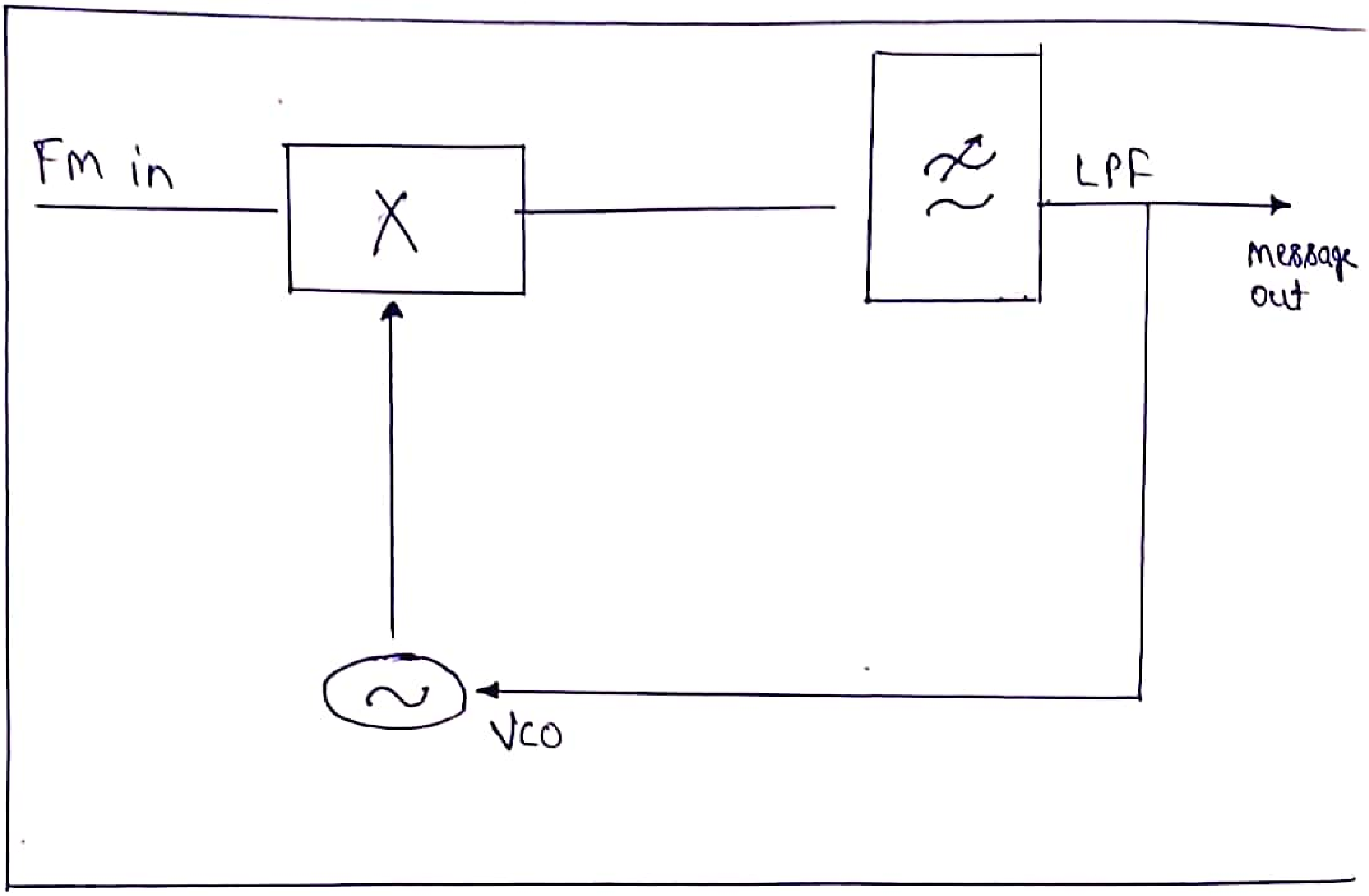
12) Applications and Advantages of FM

→ FM is resilient to noise and interface.
∴ It is used for high quality broadcast transmission

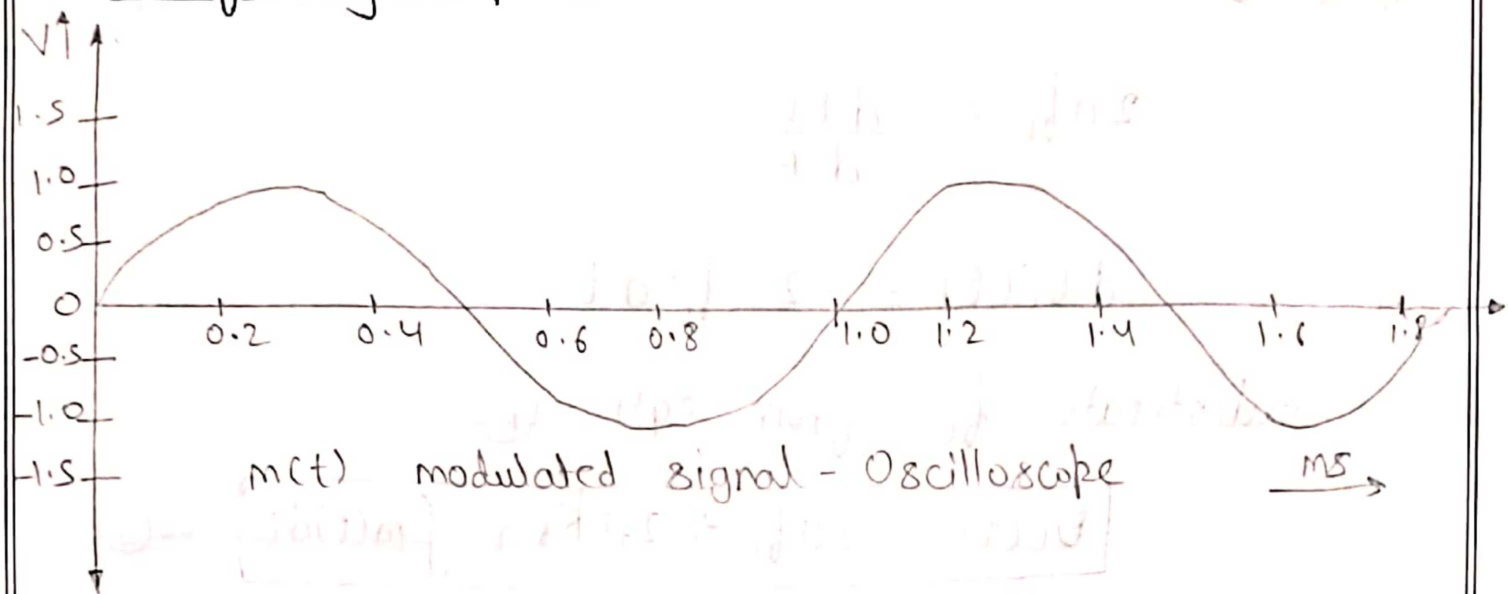
→ FM is ideal for mobile radio communication application including more general two way radio communication or portable application where signals levels are likely to very considerably.

→ Radar, Telemetry, observing infants through ECG.

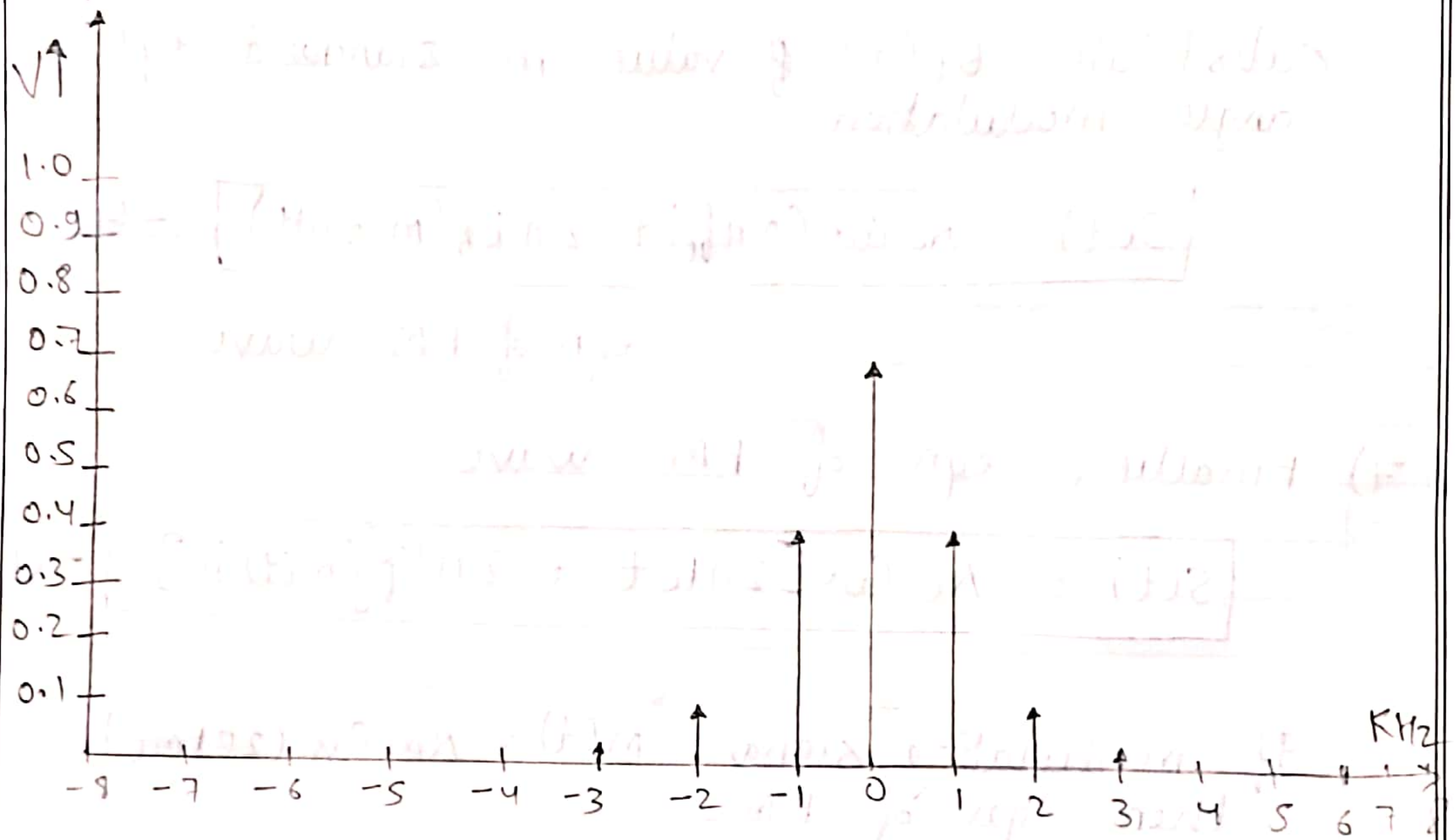
# FM Demodulator



# Frequency Spectrum




m(t) modulated signal - Oscilloscope



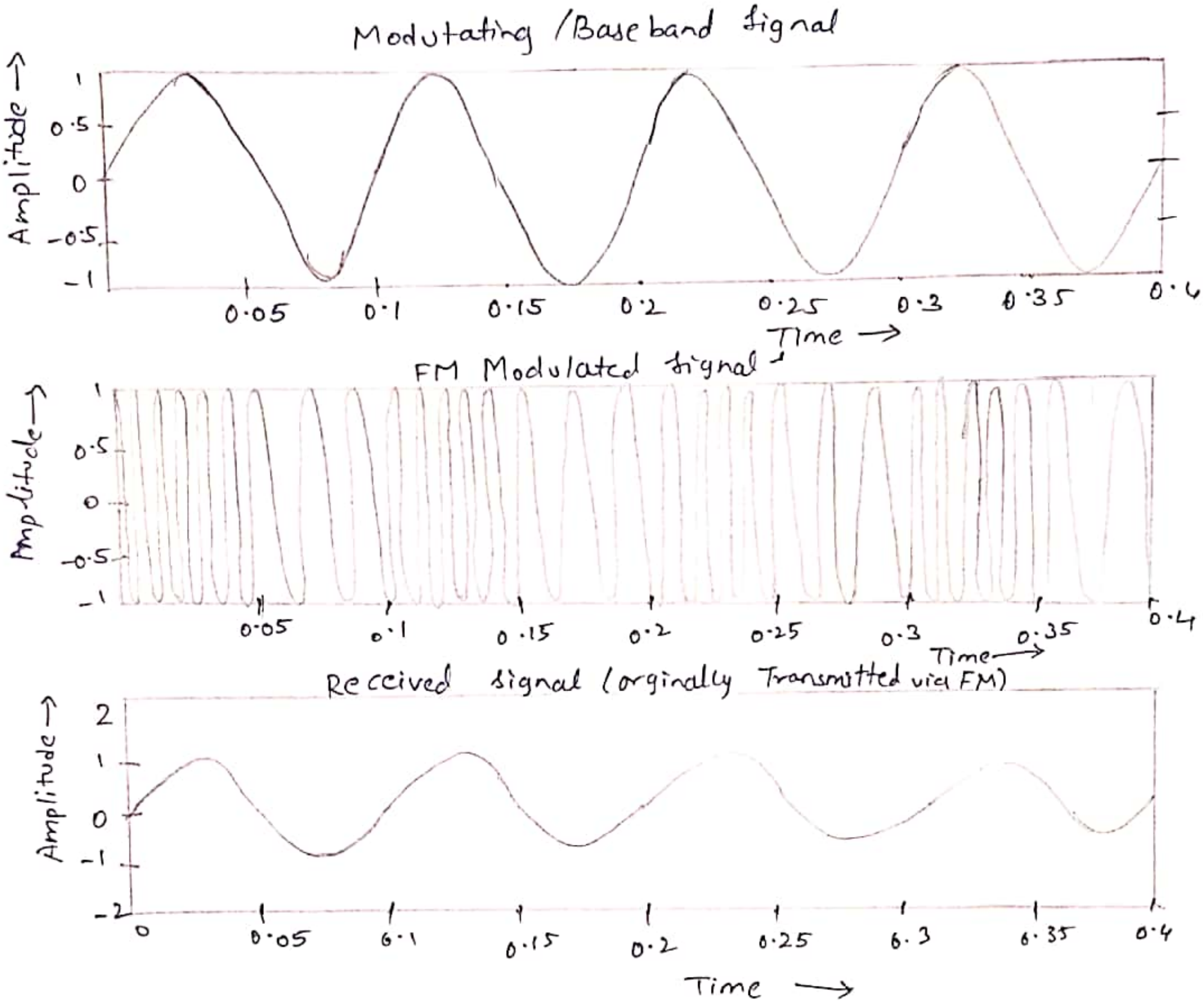

|S(f)| Transmitted signal - Spectrum Analyzer

MAT-LAB CODE

```
clc; clear all; close all;
fs = 5000;
fc = 200;
t = (0:1/fs:0.4);
m = sin(2*π*10*t);
% + sin (2*π*30*t);
fDev = 100; % Frequency deviation value.
%% FM Modulation
y = fmmod (m, fc, fs, fDev)
%% plotting the base band signal
Subplot (311);
Plot (t, m);
title ('Modulation/Baseband signal');
x label ('time -->');
y label ('Amplitude -->');
%% plotting the fm signal
Subplot (312);
plot (t, y);
title ('' FM Modulated signal');
x label ('Time -->');
y label ('Amplitude -->');

%% Frequency deviation
z = fmdemode ( y, fc, fs, fDev);
subplot (313);
plot (t, z, 'r');
```

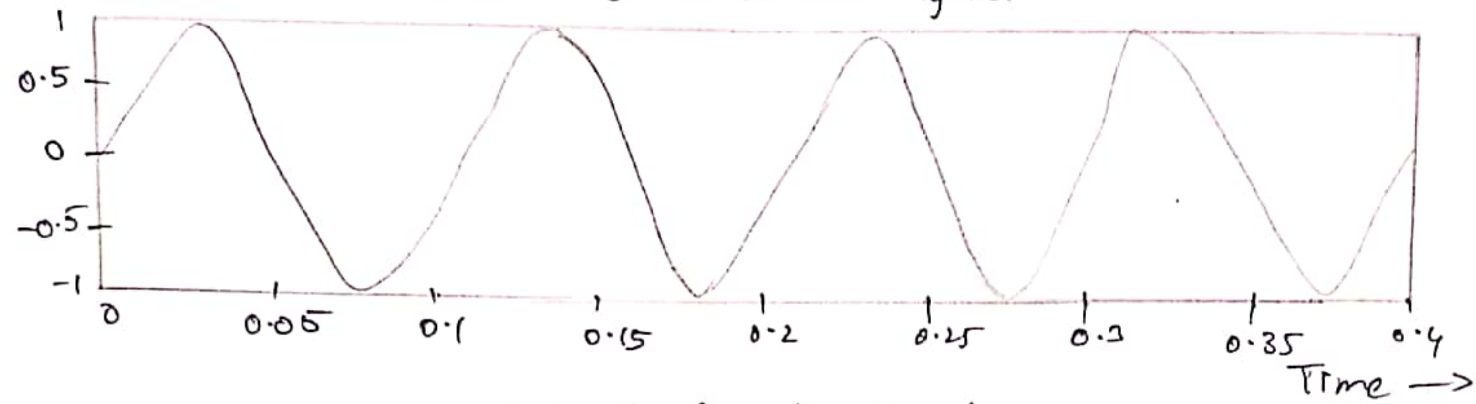
Teacher's Signature :

Frequency deviation 100 Hz.

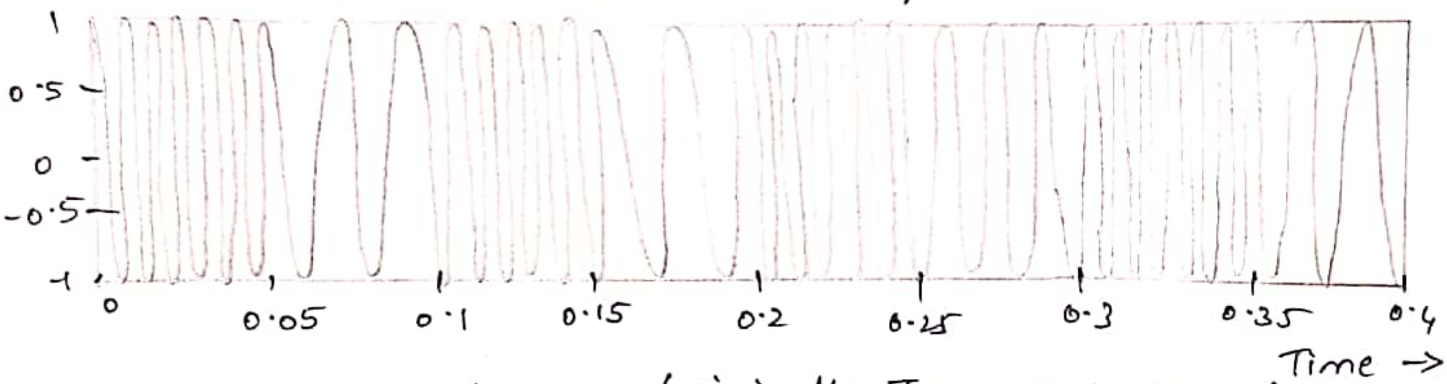


Frequency deviation 150Hz

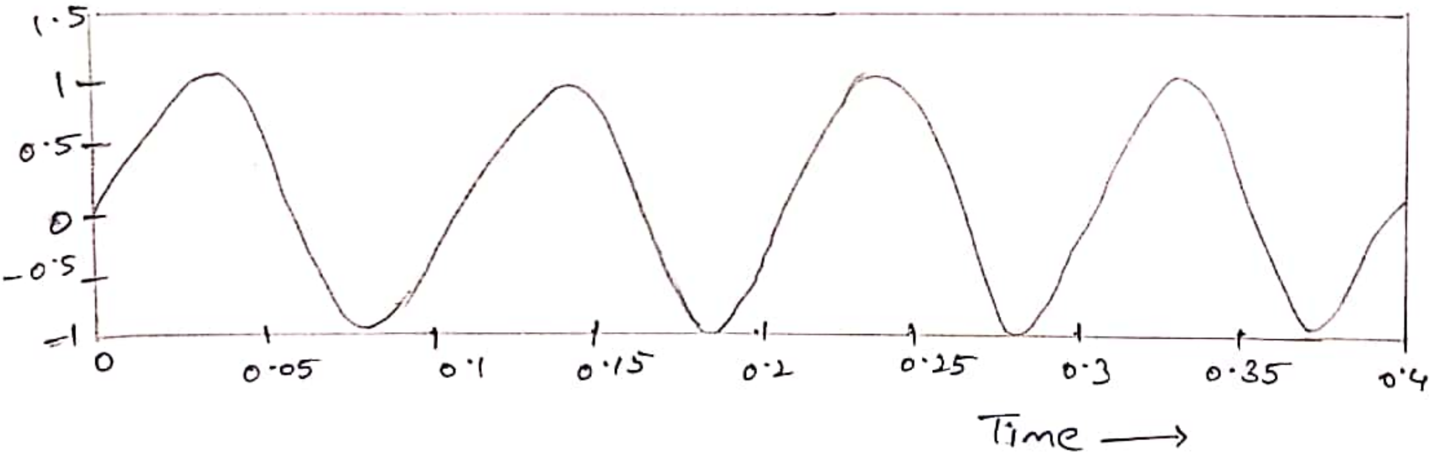
Modulating /Baseband Signal




FM Modulated signal




Received Signal (originally Transmitted via FM)



```
title ('Recieved signal (Originally transmitted)
                via FM)');
xlabel ("time -->");
ylabel ('Amplitude-->');
```

Conclusion

We have successfully verified and understood the concept of frequency modulation and demodulation using MATLAB and also learnt applications of FM.

Teacher's Signature :

# Experiment -5

## Pulse Amplitude Modulation (P.A.M)
## Pulse Position Modulation (P.P.M)
## Pulse Width Modulation (P.W.M)

Aim: To examine PAM, PPM and PWM and verify and draw the resultant waveforms. Illustrate the circuit diagram for PAM and PWM. Show and draw the output waveforms using Matlab code/simulink using virtual mode

Apparatus: Matlab software (online)

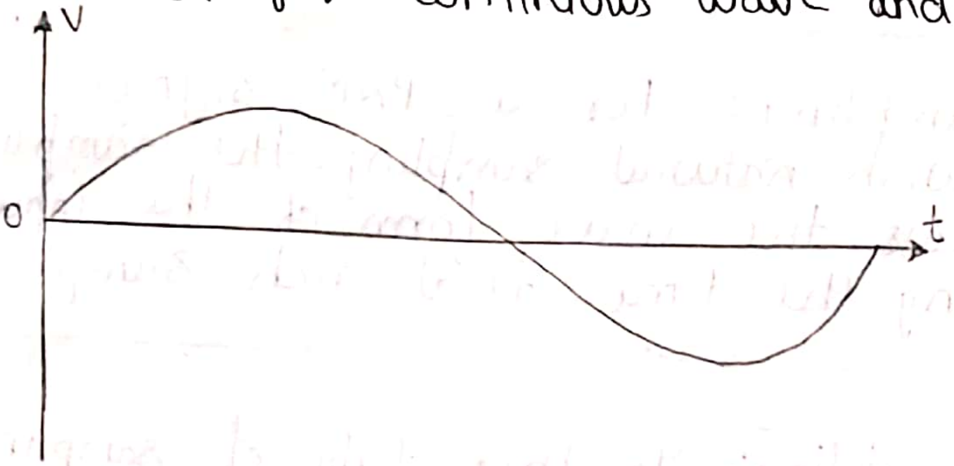
Theory:

1) Pulse modulation is a type of modulation in which the signal is transmitted in the form of Pulses. Pulse modulation is further divided into analog and digital communication and further analog and digital is subdivided in PAM, PWM, PPM, PCM, DM (digital Modulation).

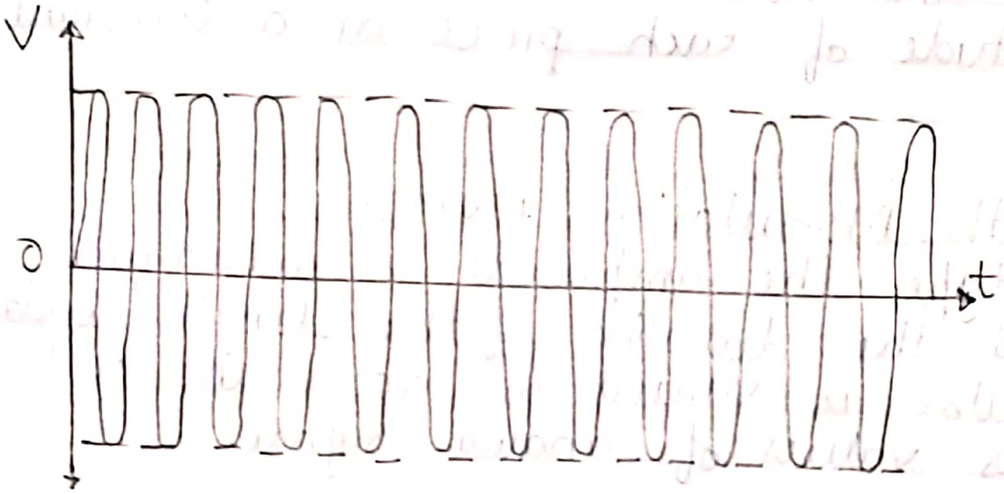
2) Pulse Amplitude Modulation (PAM)
In PAM, a pulse signal is used to sample an analog signal. The result is the train of constant width pulses. The amplitude of each pulses is propotional to the amplitude of message signal at the time of sampling.

→ PAM signal generation:- We can generate PAM signal by 2 types of sampling processes.

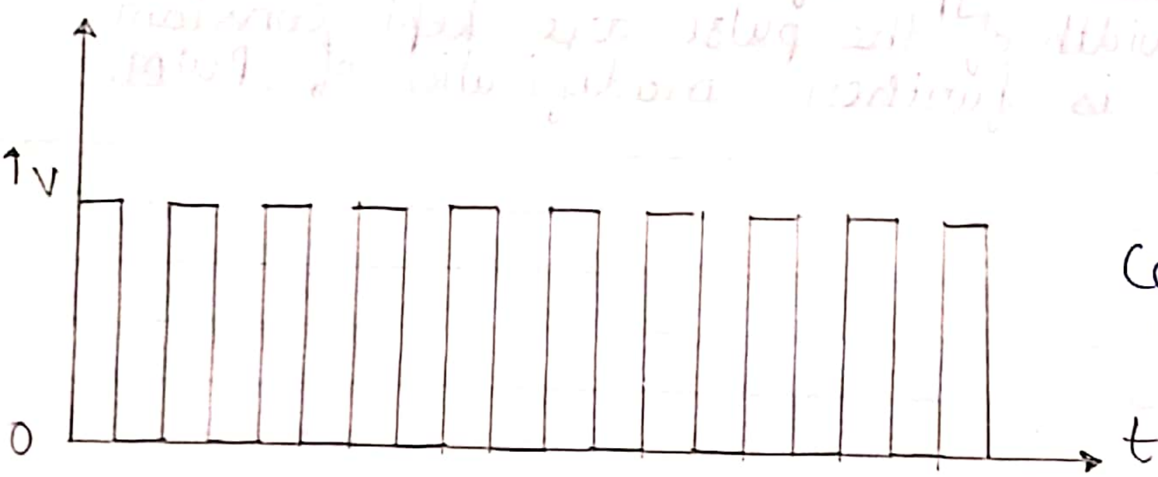
Carrier for Continious wave and pulse modulation




Modulating signal (same for both techniques)




Carrier for continious wave modulation (AM, FM, PM)




Carrier for pulse modulation

- **Natural Sampling:-** For a PAM signal produced with natural sampling, the sampling signal follows the wave form of the input signal during the time that each sample is taken.

- **Flat-Top sampling:-** In this type of sampling, a sample and hold circuit is used to hold the amplitude of each piece at a constant level.

3) **Pulse width Modulation (PWM):**

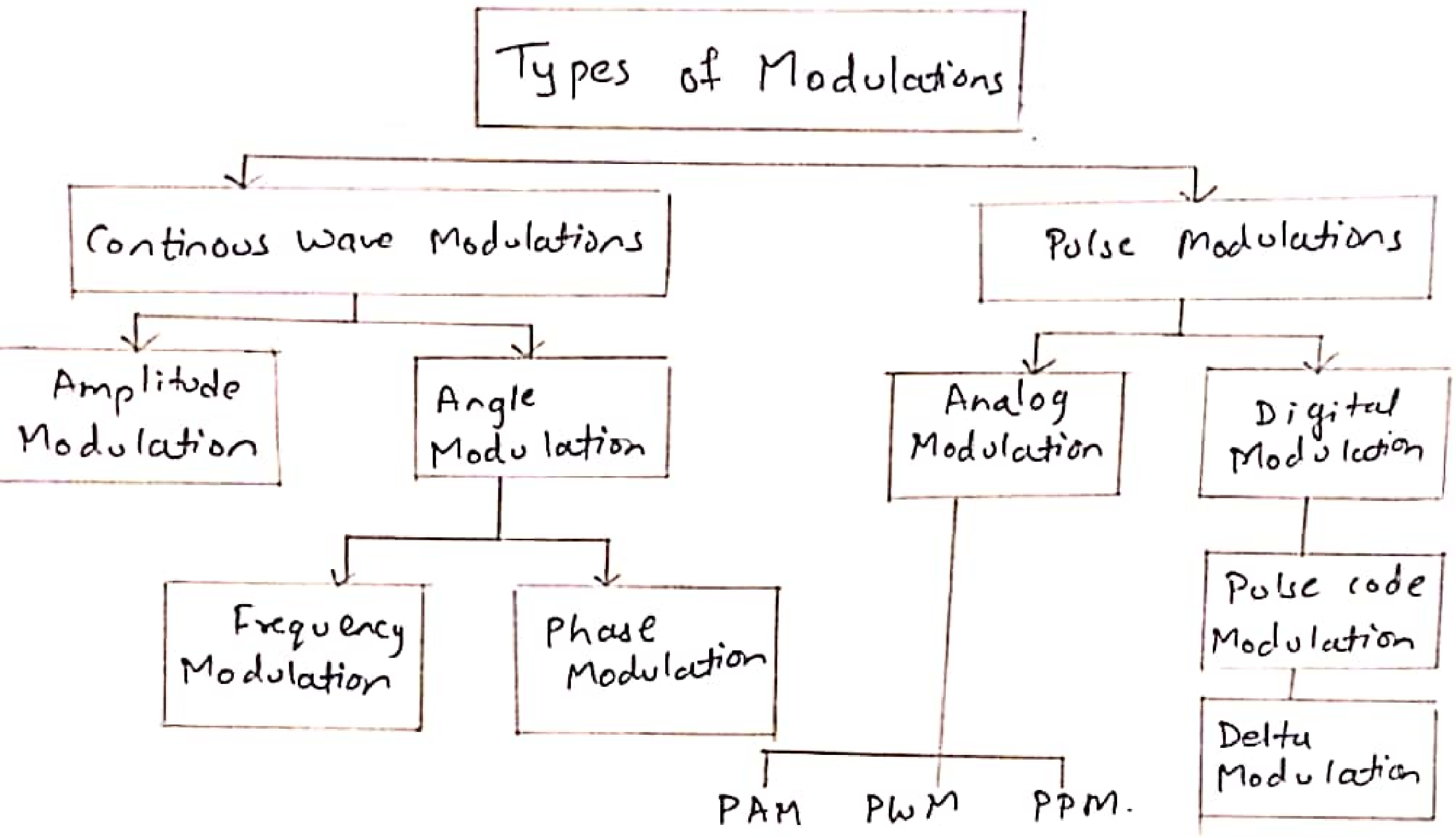
→ In this type the amplitude is maintained constant but the duration of the length/width of each pulse is varied in accordance with instantaneous values of analog signal.

4) **Pulse position Modulation (PPM):-**

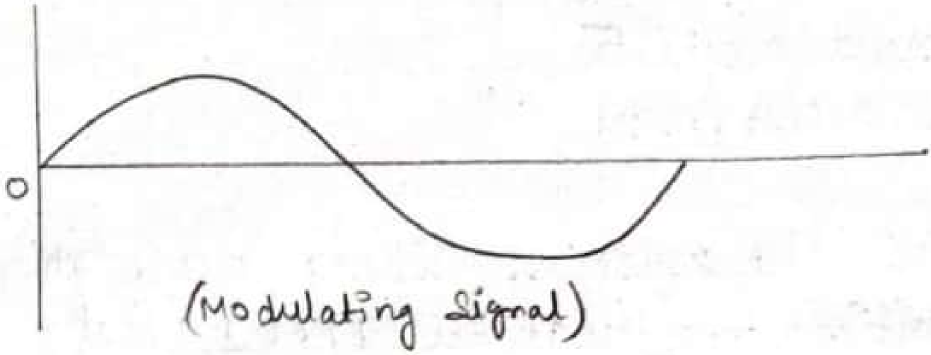
In this type of modulation, both the amplitude and width of the pulse are kept constant.

→ PPM is further modification of PWM.

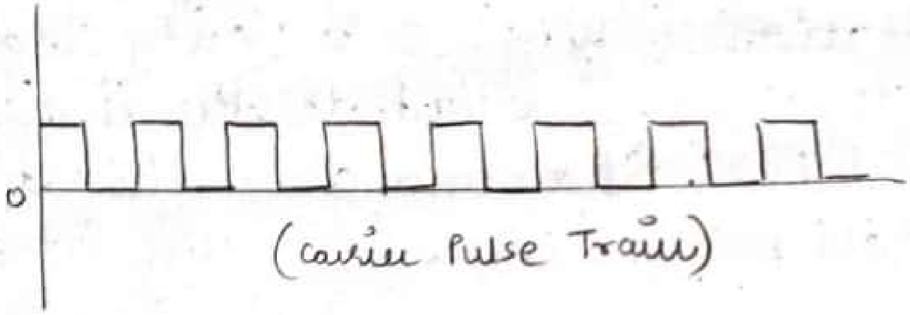
Block Diagram Showing Basic Classification



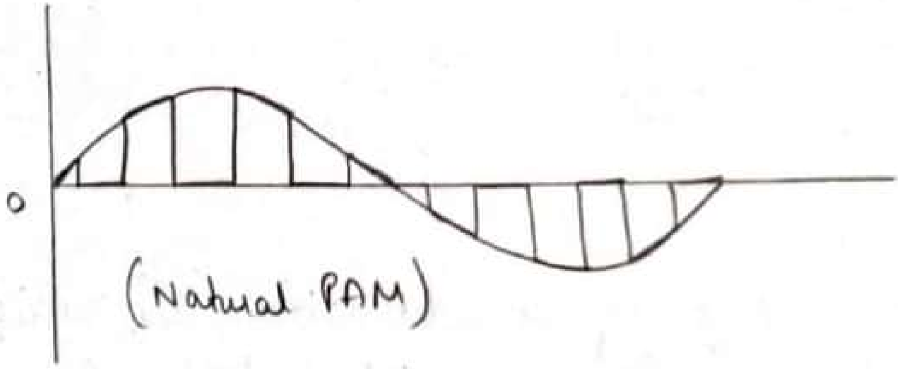
## Natural Sampling :-



(Modulating Signal)

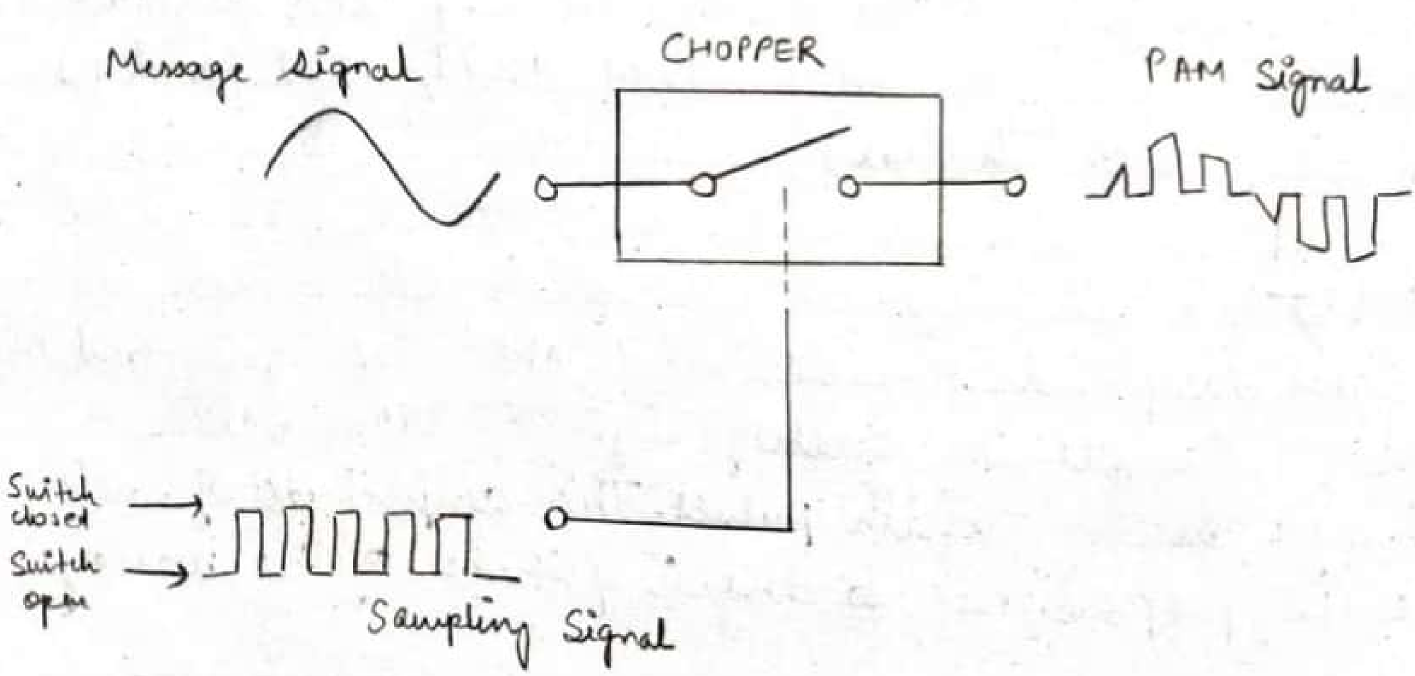


(carrier Pulse Train)

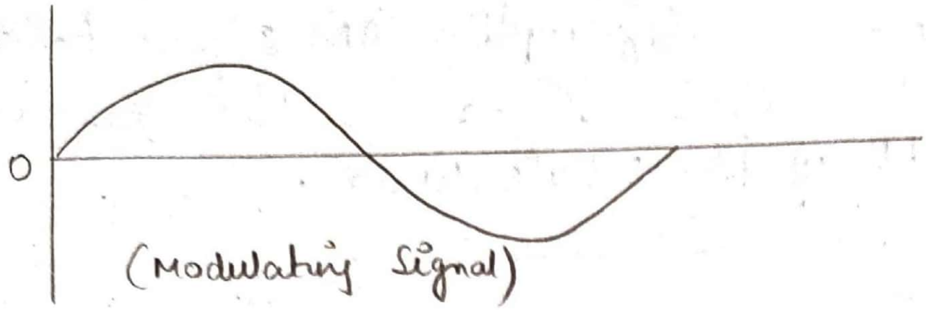


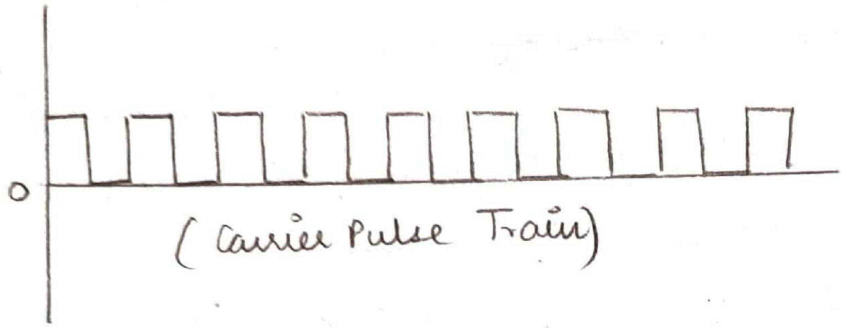
(Natural PAM)

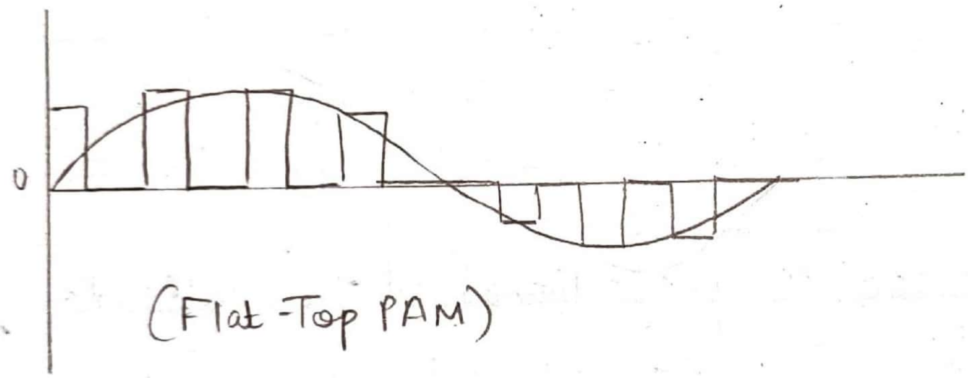
## Generation of PAM by Natural Sampling :



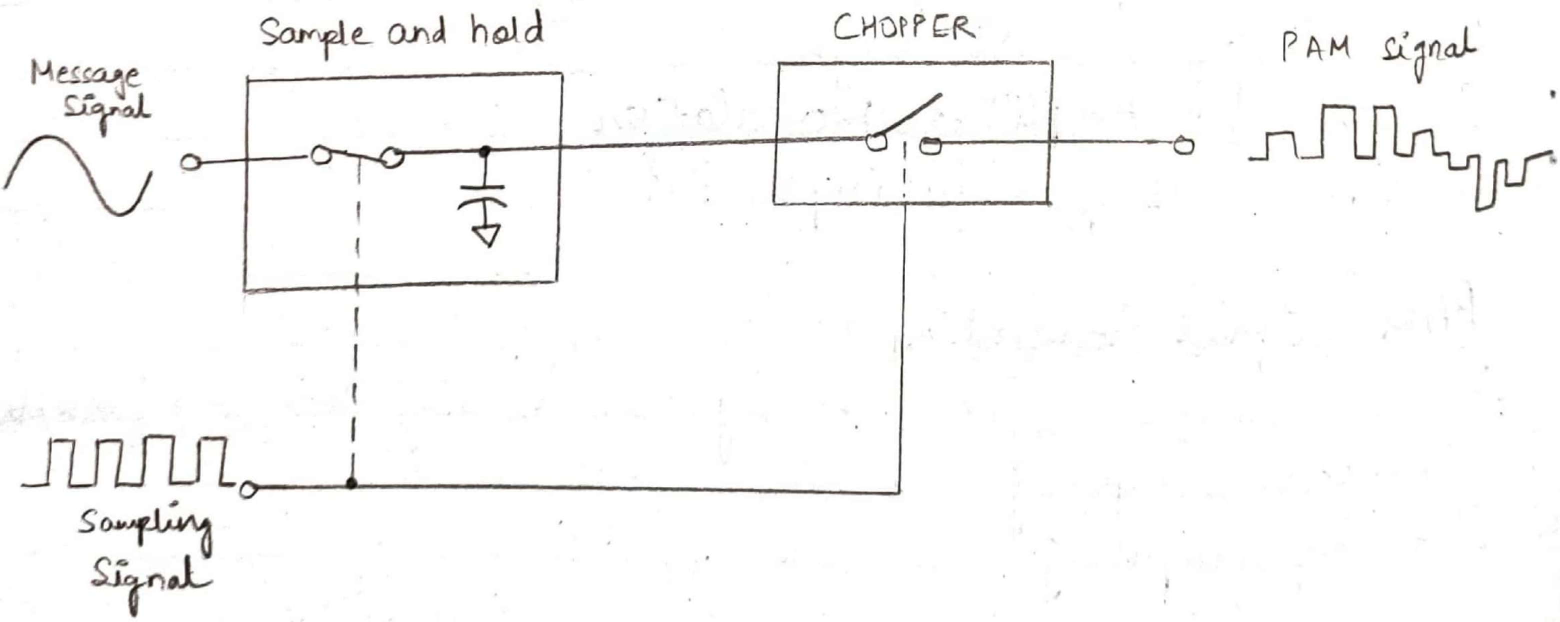
## Flat Top Sampling :-




## Generation of PAM by Flat-Top Sampling:

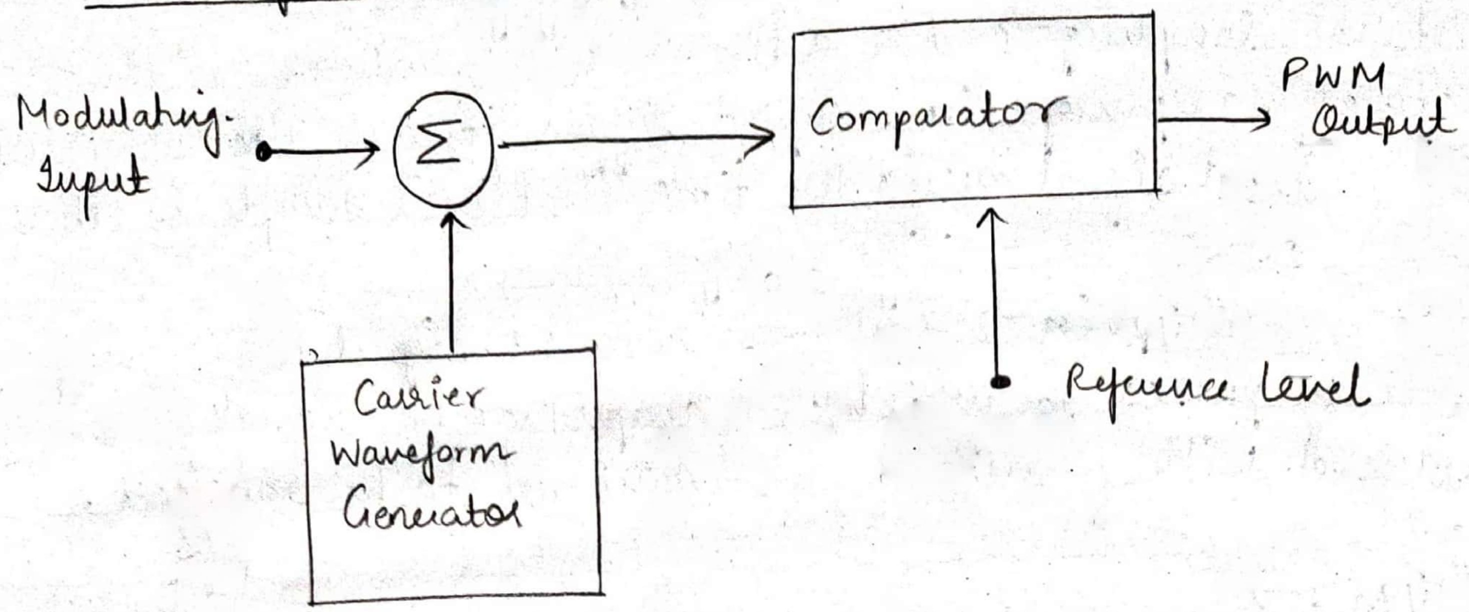


5) Comparison of PAM, PWM and PPM

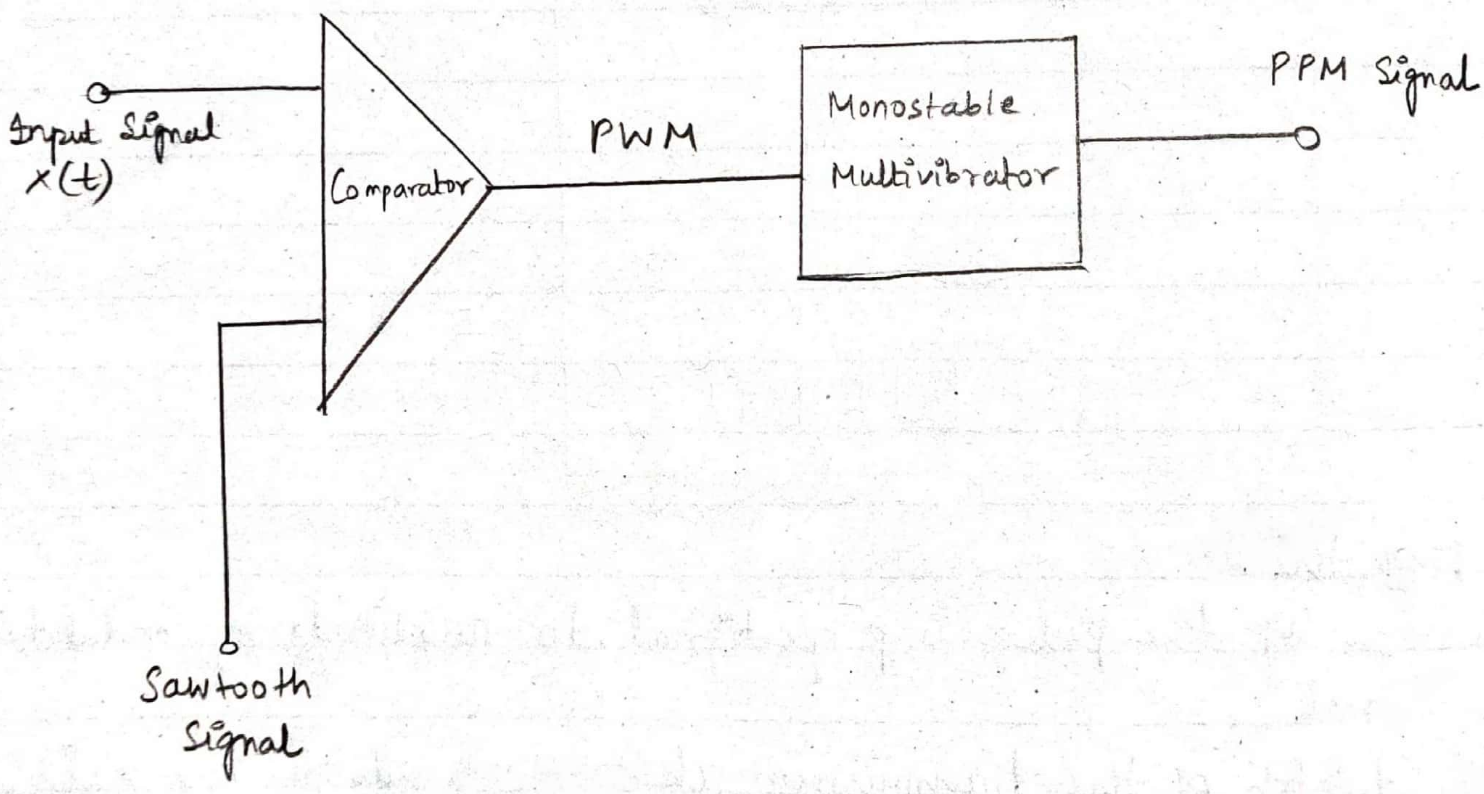
| S.NO | PAM | PWM | PPM |
|---|---|---|---|
| 1) | Amplitude of the pulse is propotional to amplitude of modulating signal | Width of the pulse is propotional to amplitude of modulating signal | Relative position of Pulse is propotional to amplitude of modulating signal |
| 2) | Instantaneous power of transmitter varies | varies | constant |
| 3) | Bandwidth of the transmission channel depends on the pulse width | Here it depends on the rise of time of pulse | Depends on the rising time of pulse |
| 4) | Noise interference is high | Minimum | minimum |
| 5) | System is complex to implement | simple to implement | simple to implement |
| 6) | Similar to amplitude modulation | Frequency modulation | Phase modulation |

Teacher's Signature :

## PWM Signal Generation:




## PPM Signal Generation:

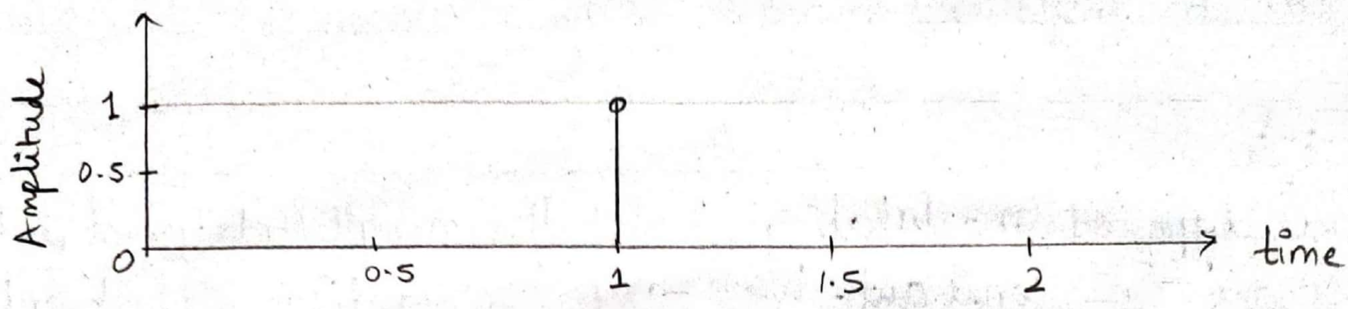


Matlab Code

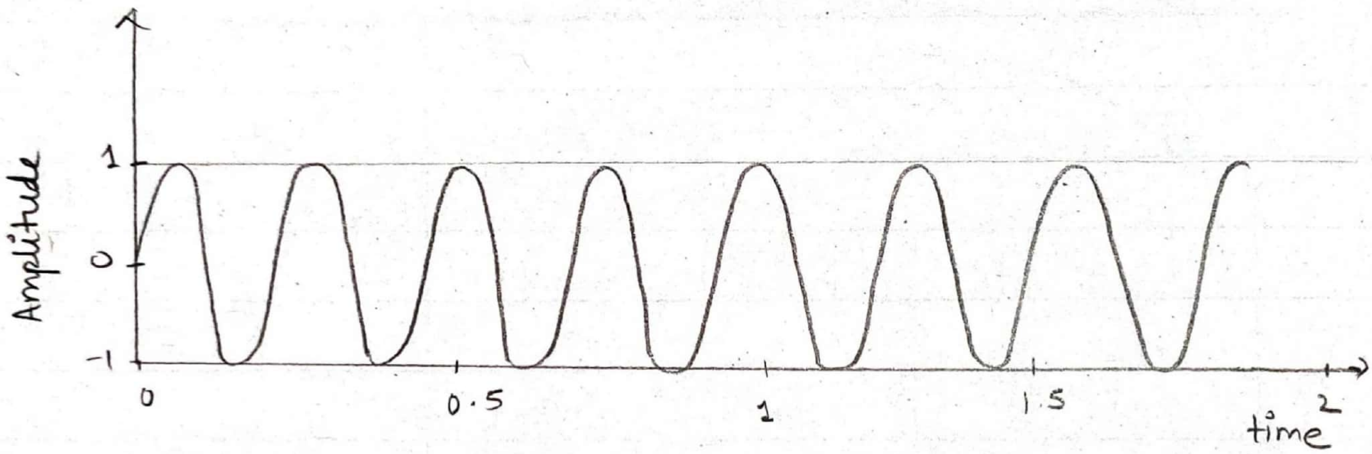
```
% PAM Signal
clc; clear all; close all;
 fc = 100
 fm = fc/10
 fs = 100 * fc
 t = 0:1/fs:4/fm ;
Msg-sgl = cos (2* pi* fm * t);
carr_sgl = 0.5 * square (2* pi* fc*t) + 0.5
 Mod-sgl = Msg-sgl * Carr_sgl;
  tt [];
  for i=1; length ( mod_sgl)
        if mod-sgl (i) == 0;
        tt = [tt, Mod_sgl(i)];
        else
          tt= [tt, mod_sgl(i)+2];
        end
end
figure(1)
subplot (4,1,1)
plot (t, Msg-sgl, 'm');
title ('message signal);
x label ('Time period');
y label ('Amplitude');

 Subplot (4,1,2);   Plot (t, Carr_sgl);
 title ('carrier signal');
 X-label ('time period');
```

(Amplitude = 1, freq = 5)

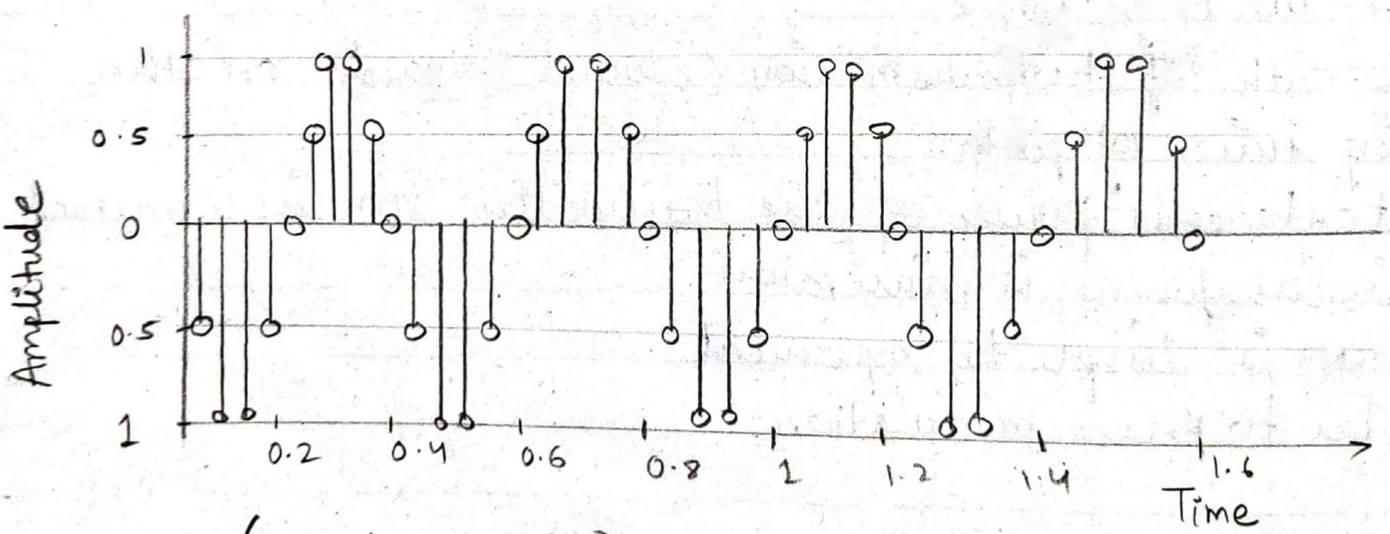
Impulse Signal:




Sine Wave:




PAM Wave:



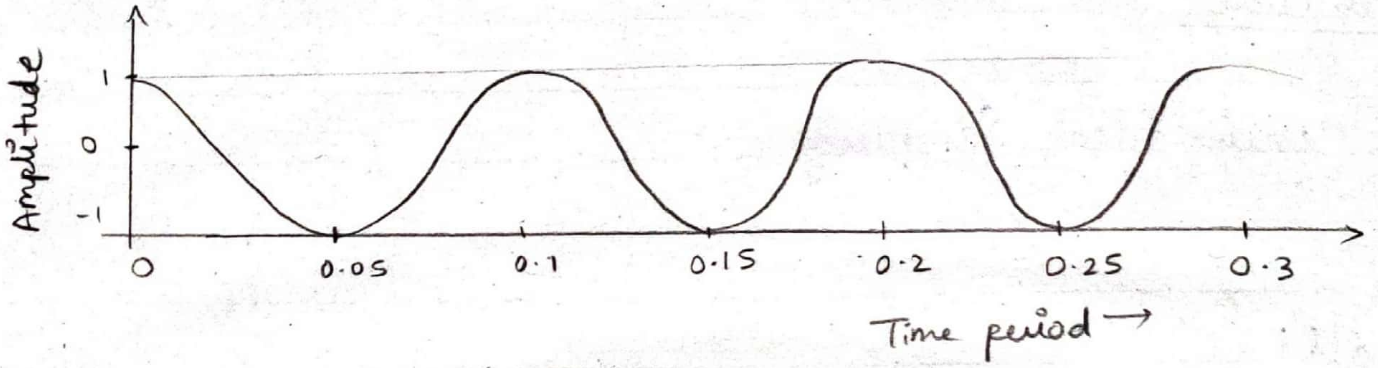

(Ideal Sampling)

Scanned with CamScanner

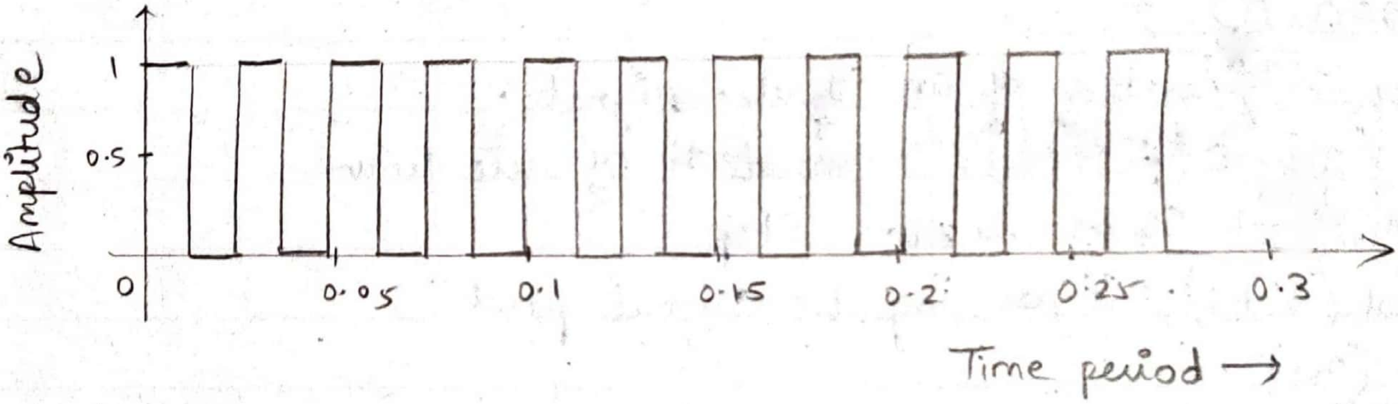
```
ylabel ('Amplitude');
sub(4,1,3);   Plot(t, Mod-sgl, 'r');
title ('PAM Modulated Signal');
xlabel ('Time Period');
ylabel ('Amplitude');

% PPM Signal
clc; clear all; close all;
fc = 1000;
fs = 10,000;
fm = 200;
t = 0:1/fs:((2/fm)-(1/fs));
x = 0.5 * cos(2*pi*fm*t) + 0.5;
y = modulode (x, fc, fs, 'PPM');
subplot (2,1,1);   Plot(x);
title ('msg-Signal');
subplot (2,1,2);  plot(y);
axis([0,500 -0.2 1.2]);
title ('PPM');

% PWM-1 signal
clc; close all; clear all;
t = 0:0.0001:1;
s = sawtooth (2*pi*10*t + pi);
m = 0.75 * sim(2*pi*1*t);
n = length(s);
```

Teacher's Signature :

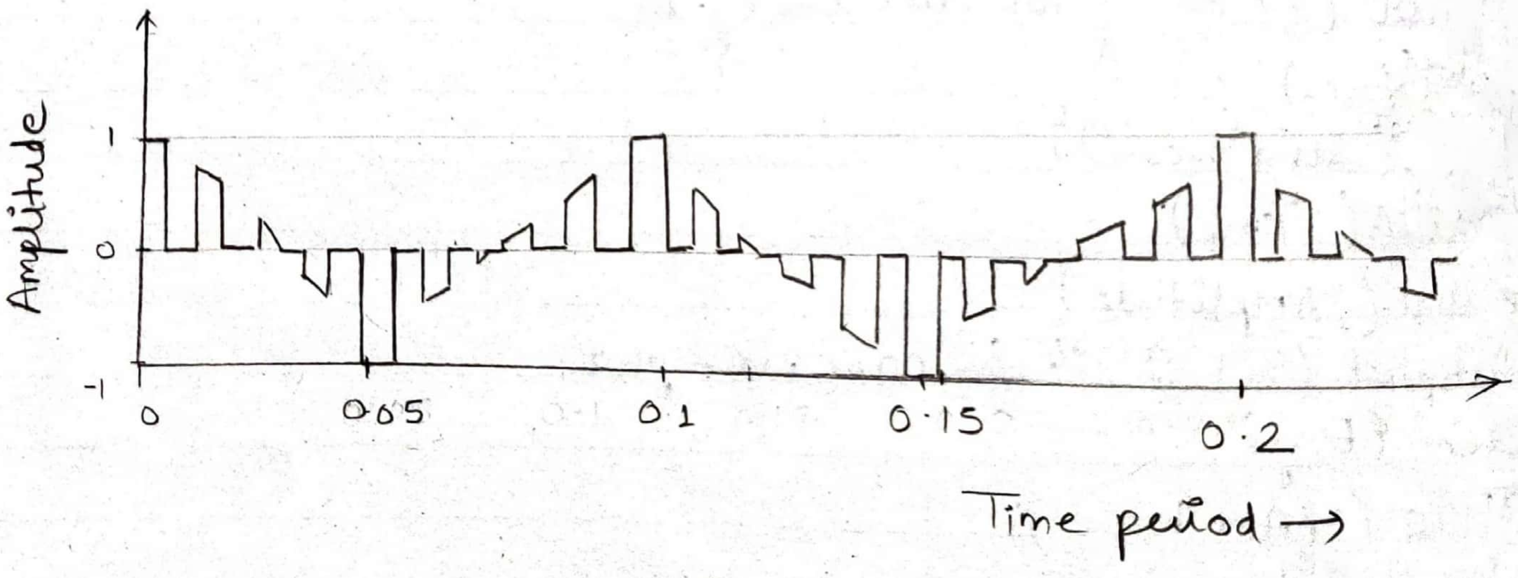
Message Signal:




Carrier Signal:




PAM Modulated Signal:

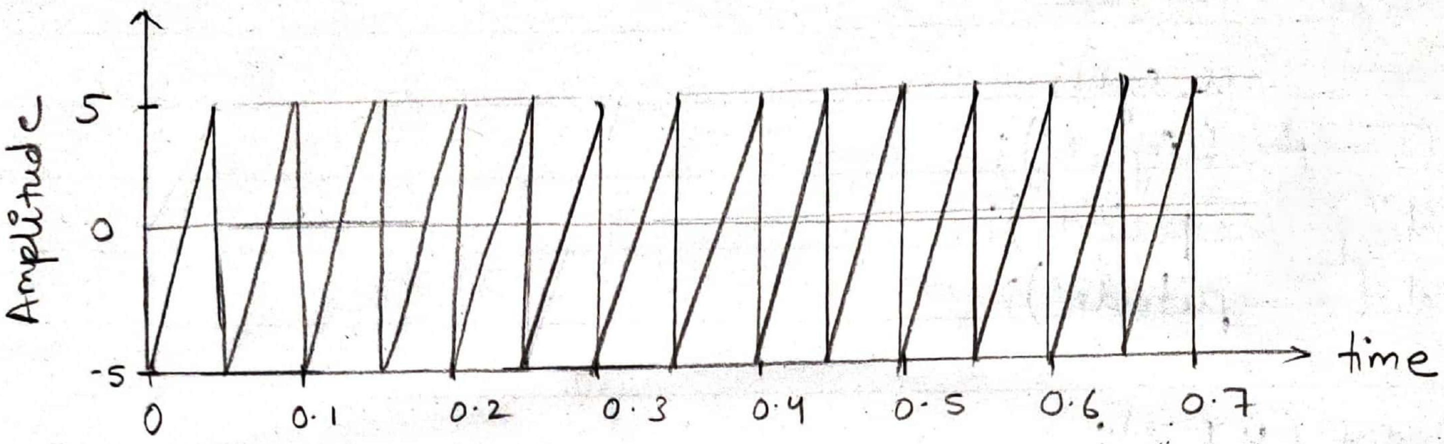



Scanned with CamScanner

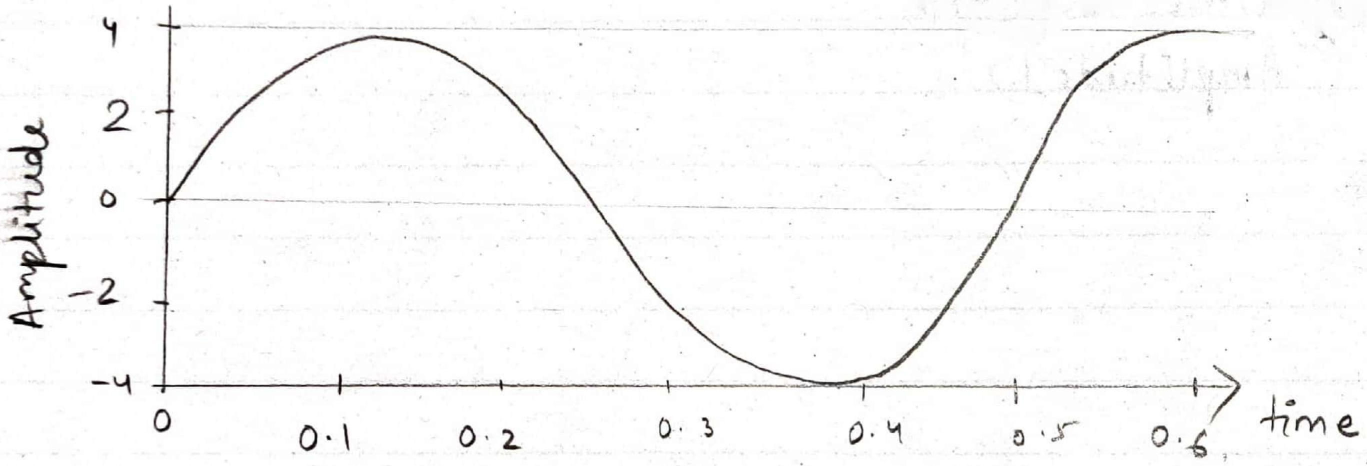
```
for i= 1:n
        if (m(i) >= s(i))
        pwm (i) = 1;
        else if (m(i) <= s(i))
         pwm(i) = 0;
         end;
end;
plot (t, pwm, 'o', t, m, m,'r', t, s,'b');
 y label ('Amplitude');
 axis ([0, 1, -1.5. 1.5]);
 x label ('Time index');
 title ('PWM wave');
 grid on;
```

```
% PWM-2 signal
clc; clear all; close all;
  t= 0:0001:1;
  s= sawtooth (2*Pi*10*t + Pi);
  m= 0.75 x sin (2*Pi*1*t);
   n= length(s);
   for i= 1:n
          if [m(i) >= s(i)]
           pwm (i) = 1;
          else if (m(i) <= s(i))
             pwm(i) = 0;
         end
end
```

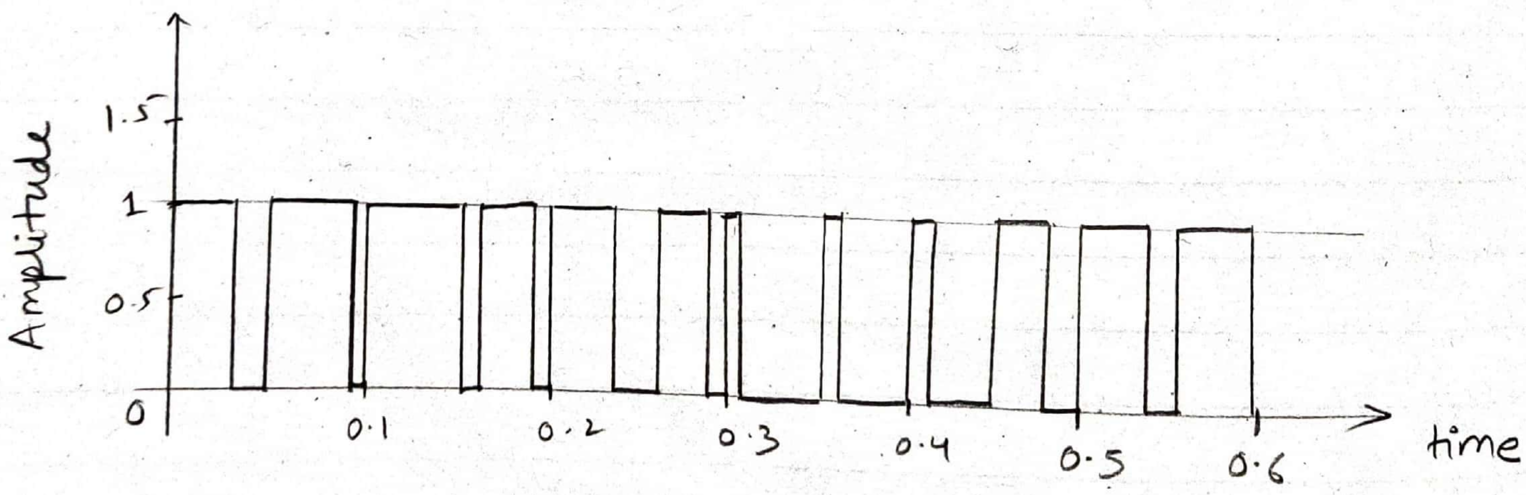
Carrier Sawtooth wave:



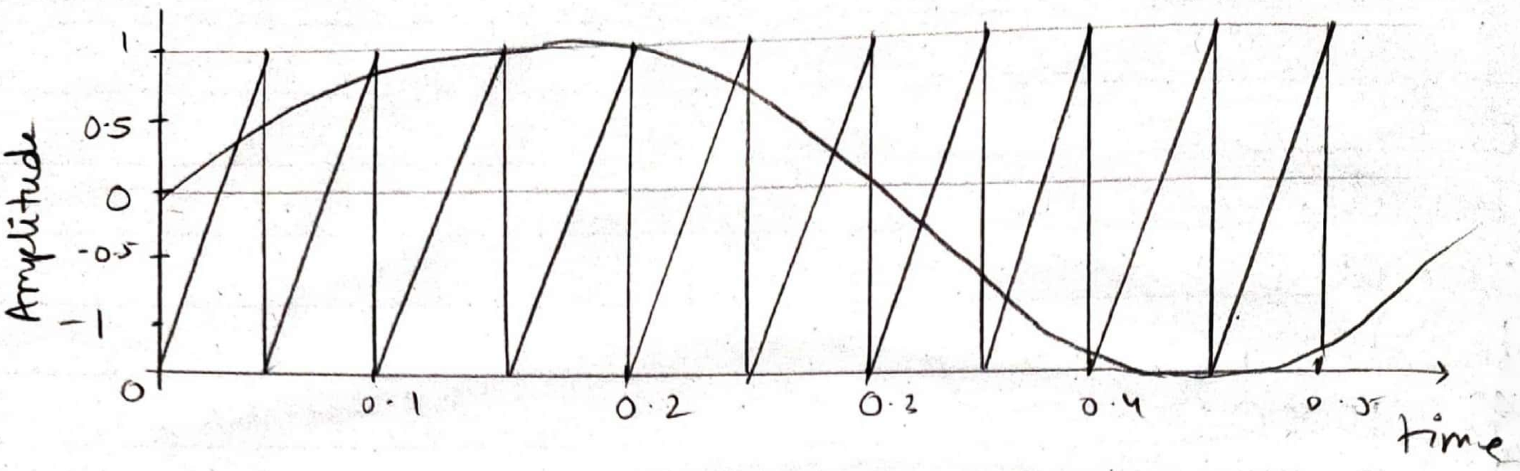

Message signal:



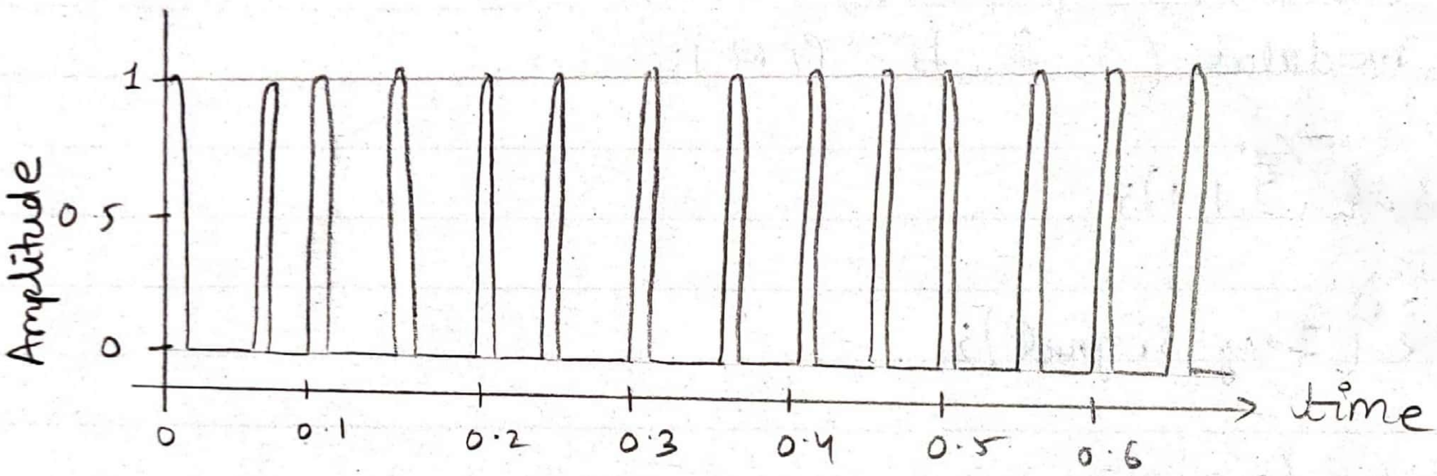

Plot of PWM:



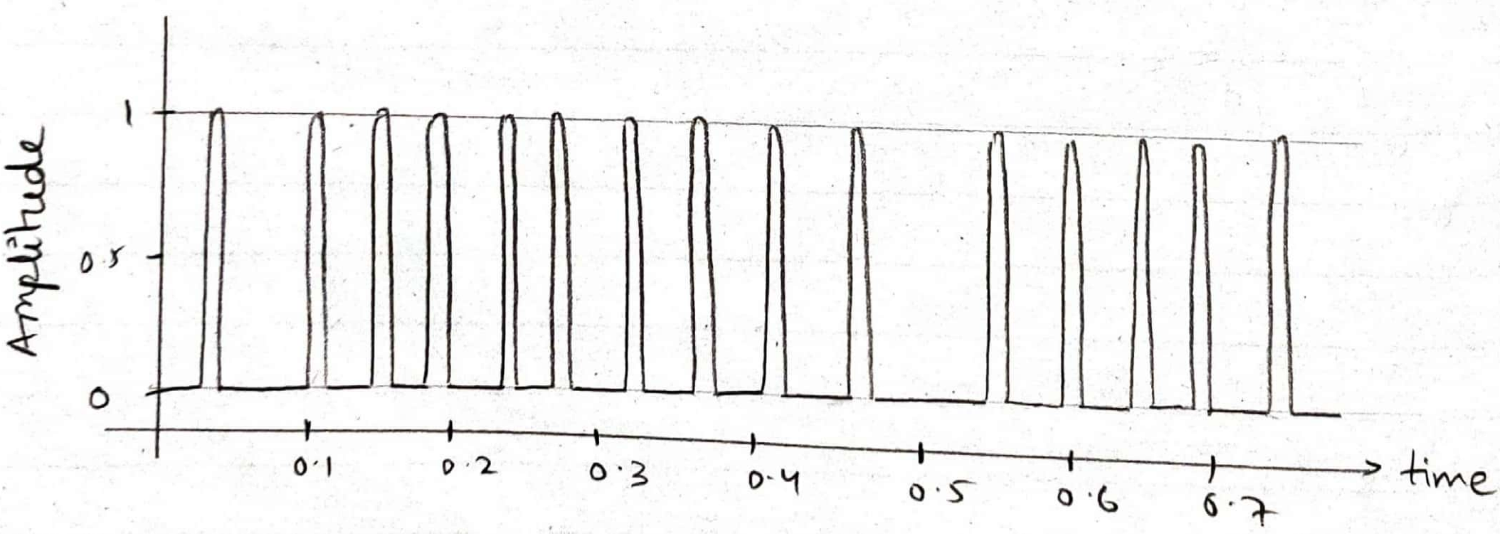
Message Signal :




Pulse Train :




PPM Signal :



```
subplot (3,1,1);
plot(t, m, 'm');
ylabel ('Amplitude');
axis ([0 1 -1.5 1.5]);
xlabel ('Time Index');
grid on;

subplot (3,1,2);
plot (t, s, 'b');
ylabel ('Amplitude');
axis ([0, 1 -1.5 1.5]);
xlabel ('Time index');
title (['PWM WAVE']);
grid on;

subplot (3,1,3);
Plot (t, PWM, 'r');
ylabel('Amplitude');
axis ([0 1 -1.5 1.5]);
x-label ('Time index');
grid on;
```

Conclusion

We succesfully examined PAM, PWM, PPM and also verified their waveforms. We also illustrated circuits for PAM & PWM. We performed our experiment succesfully using MATLAB.

U20CS110

Date

Expt. No. 06

# Experiment 6

Page No. 27

## Amplitude SHIFT KEYING (ASK)
## Frequency SHIFT KEYING (FSK)
## PHASE SHIFT KEYING (PSK)

AIM:- To study ASK, FSK and PSK modulation techniques and verify waveforms.

Apparatus: MATLAB

Theory:

1) Modulation:- It is a process by which same characteristics of a carrier wave is varied in accordance with a modulating (message) signal.

Digital Modulation:- It is a special kind of modulation where the message signal is digital in nature and the carrier wave is analog (sinusoidal in nature).

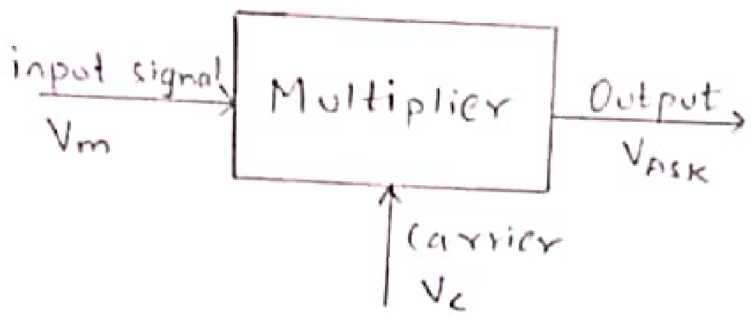
The ASK, FSK and PSK are analogues to AM, FM and PM. The difference is that it is digital and that is analog in nature.

2) ASK:- In ASK the amplitude of the carrier wave is changed acc to the digital input signal (modulating signal).

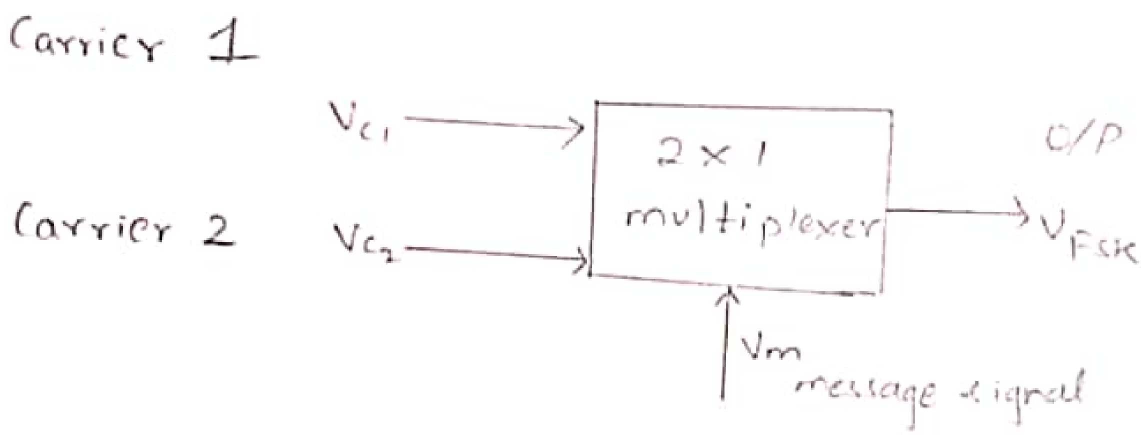
Teacher's Signature :

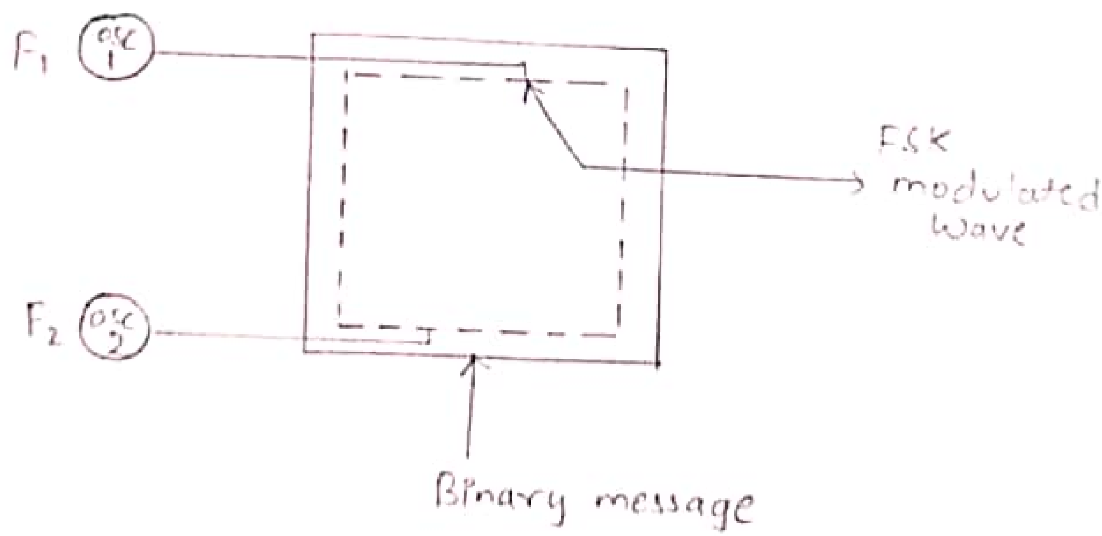
# BLOCK DIAGRAM

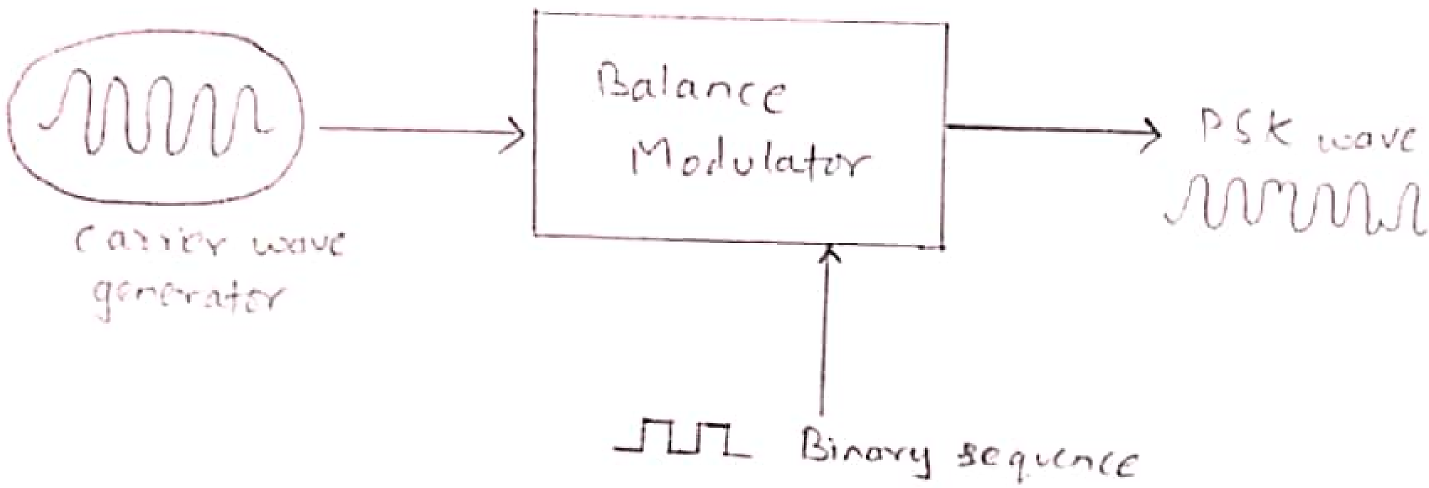
1) Block diagram of generation of ASK signal.




2) Block diagram of FSK Generator






Block diagram showing generation of PSK.

Application of ASK : 1) Wireless Base station
2) Low frequency RF applicatn
3) Industrial network Devices.

3) FSK :-
If the frequency of sinusoidal carrier wave is varied depending on the input signal, then it is known as FSK.

Application of FSK :- High frequency radio transmission

4) PSK :-
In PSK, phase of the carrier wave (analog in nature) is switched as per the input digital signal

Application of PSK : 1) It is widely used for wireless LAN's,
RFID and bluetooth Communicatn

MATLAB CODE

```
% ASK Signal
clc; clear all; close all;
fc = input('Enter the freq of sine wave carrier');
fp = input('Enter the frequency of periodic binary pulse');
amp = input('Enter the amplitude (for carrier & Binary)');
t = 0: 0.0001 : 1;
c = amp * sin(2*π*fc*t);
```

```
c = amp * sin (2*pi*fc*t);
Subplot (3,1,1)
plot (t, c);
x label ('Time');
Y label ('Amplitude');
title ('Carrier wave');

m = amp/2 x square (2*Pi*fp*t) + (amp/2);
Subplot (3,1,2);
Plot (t,m);
x label ('Time');
Y label ('Amplitude');
title ('Binary message pulse');
w = cxM;
subplot (3,1,3);
plot (t, w);
xlabel ('time');
Y label ('Amplitude');
title ('Amplitude Shift keyed signal');

% FSK Signal
clc; clear all; close all;
fc1 = input ('Enter the frequency of 1st sine
                    wave carrier');
fc2 = input('Enter the freq of 2nd sine wave carrier);
fp = input('Enter the freq of periodic binary pulse)
amp = input('Enter the amplitude (For both carrier
               and binary pulse message);
```

1)

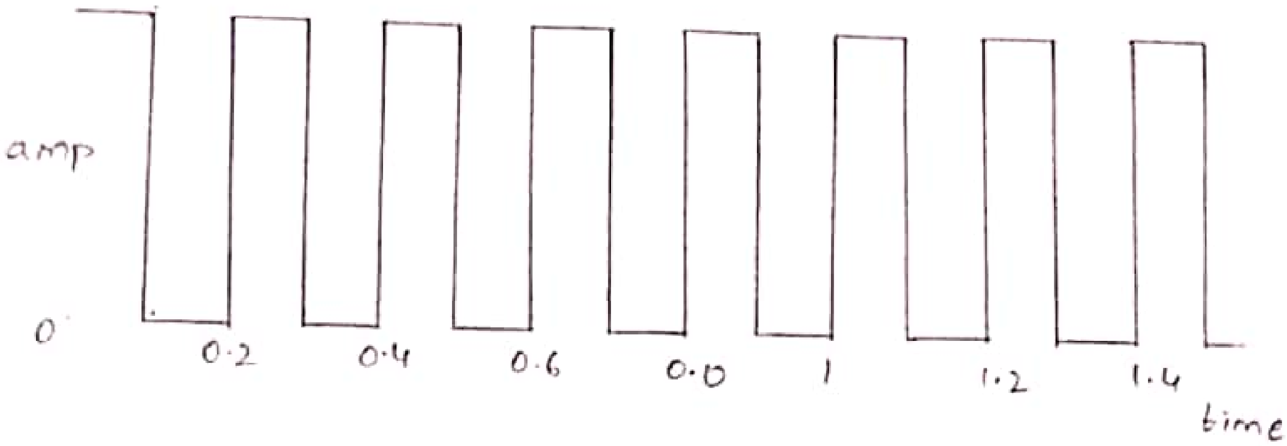
# ASK

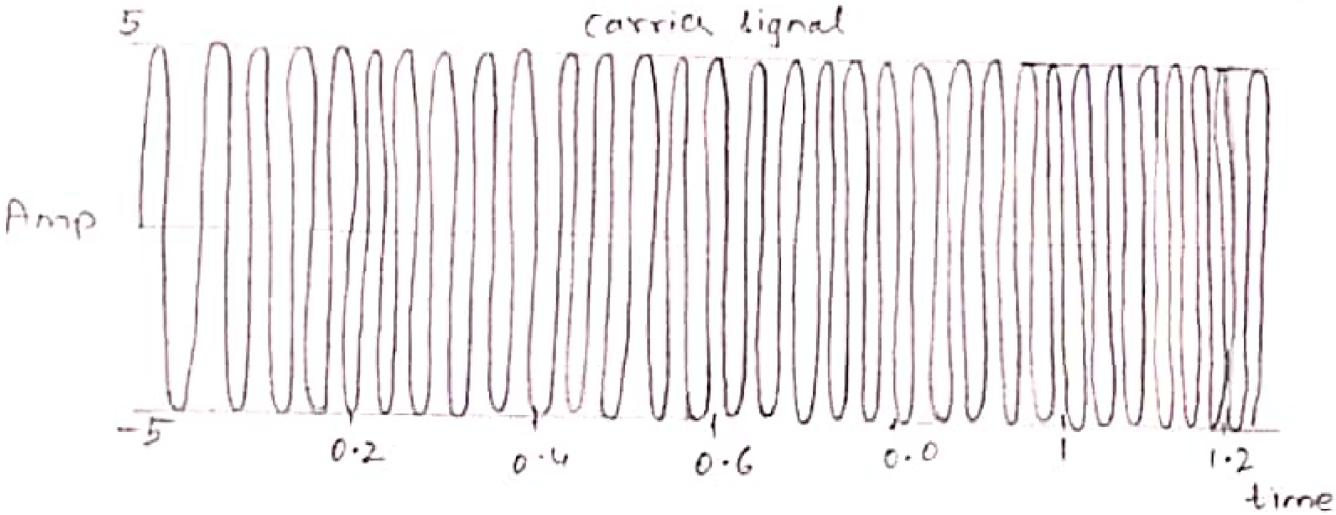
$f_c = 20Hz$

$f_p = 5Hz$

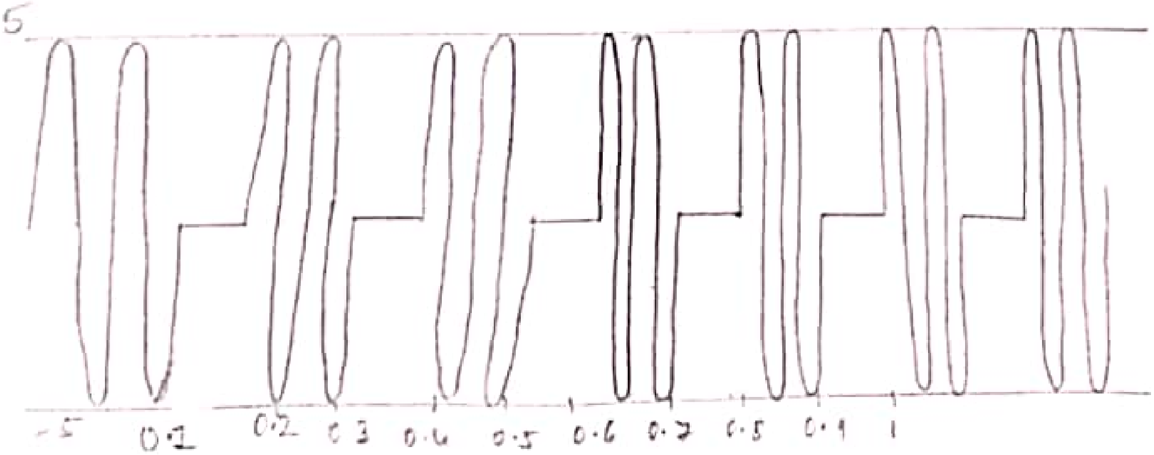
amp = 5

message signal



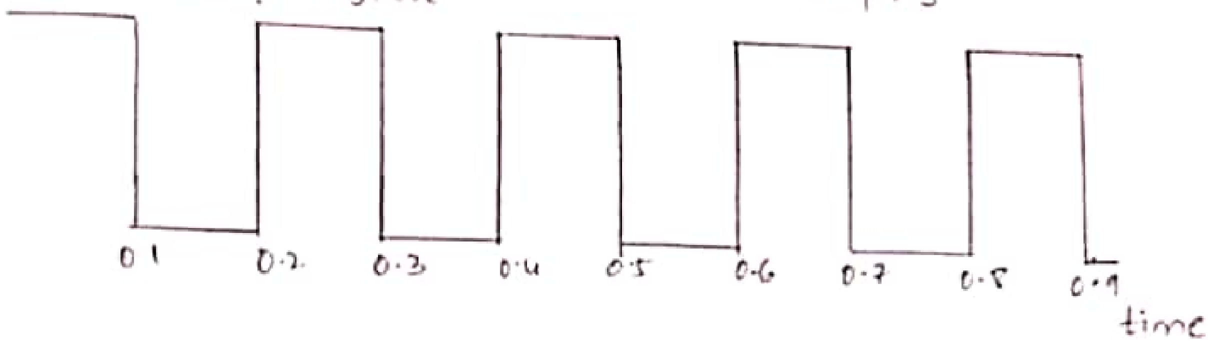

Amplitude shift keying signal



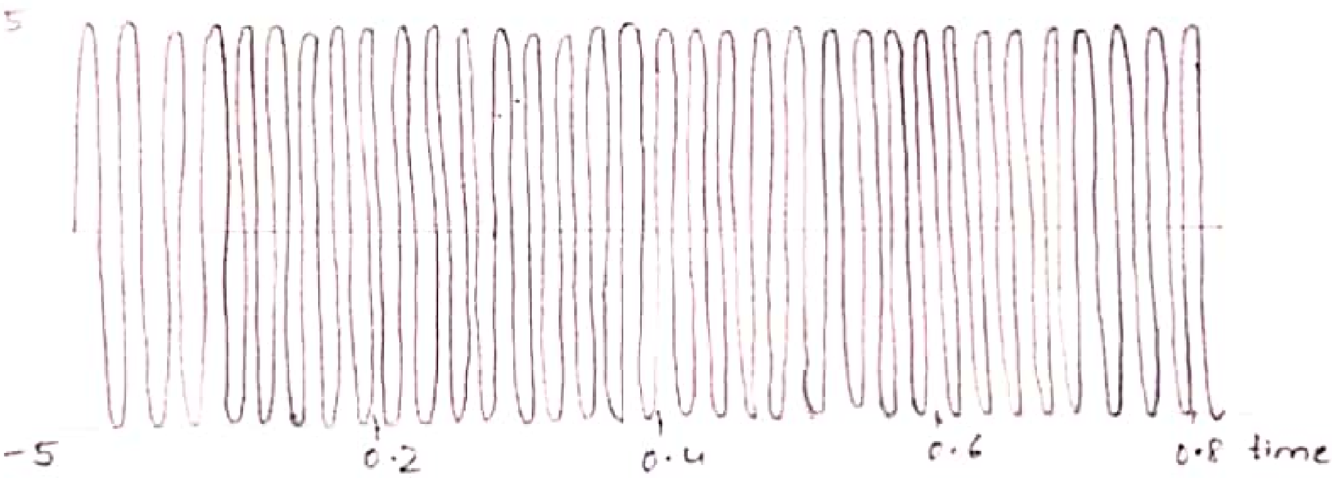
2) ASK

$F_c = 45\,Hz$
$F_p = 5\,Hz$
amp = 5

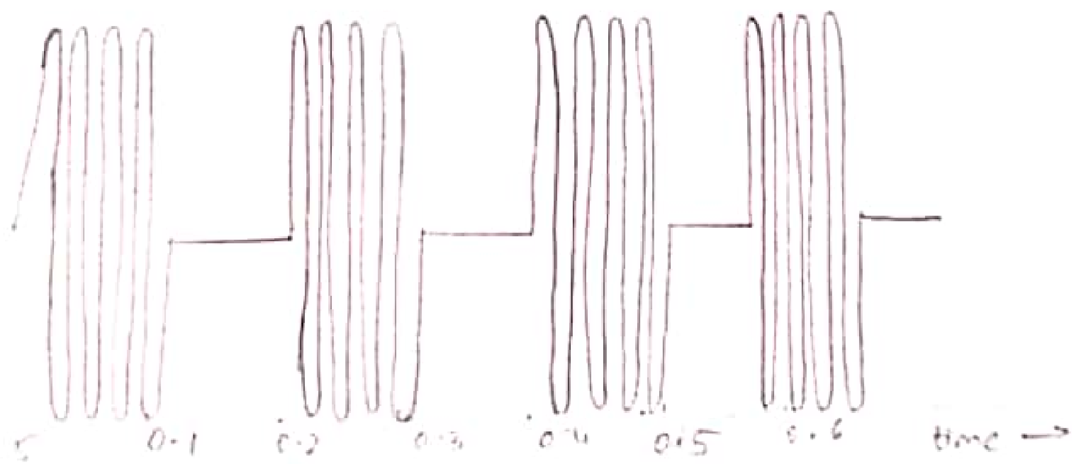
Message signal




Carrier signal



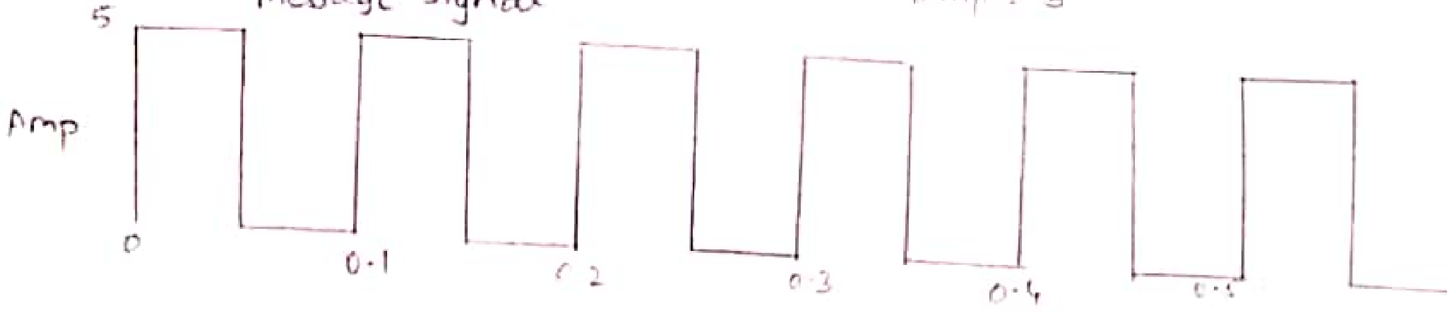

Amplitude shift keying signal



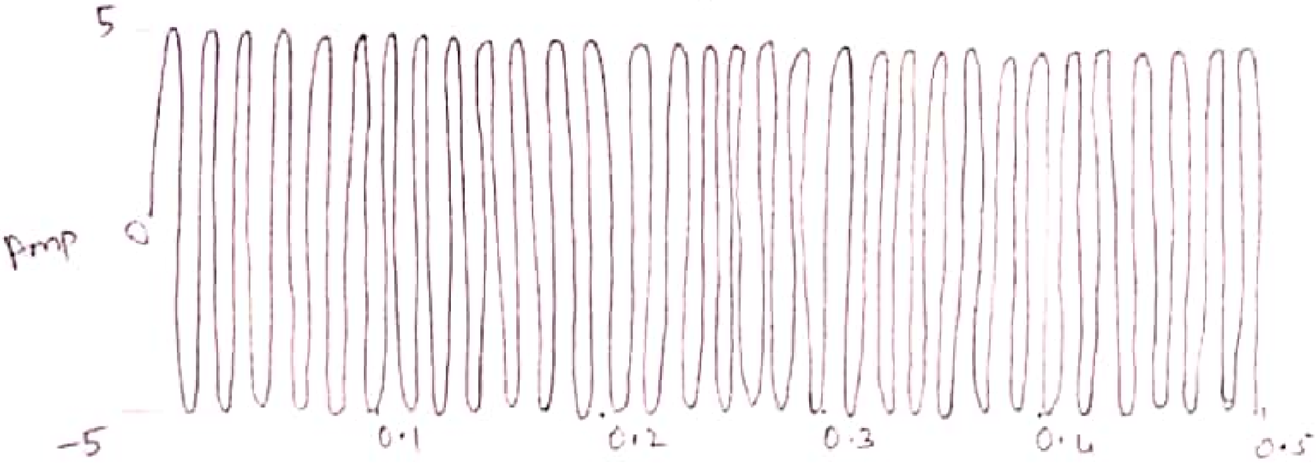
3) ASK

$f_c = 50Hz$
$F_p = 10Hz$
Amp : 5

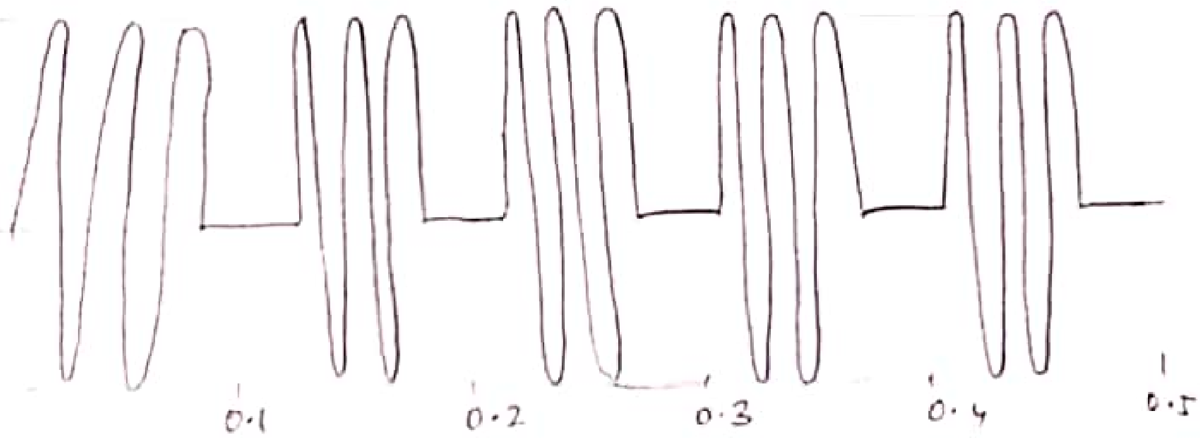
Message Signal




Carrier signal



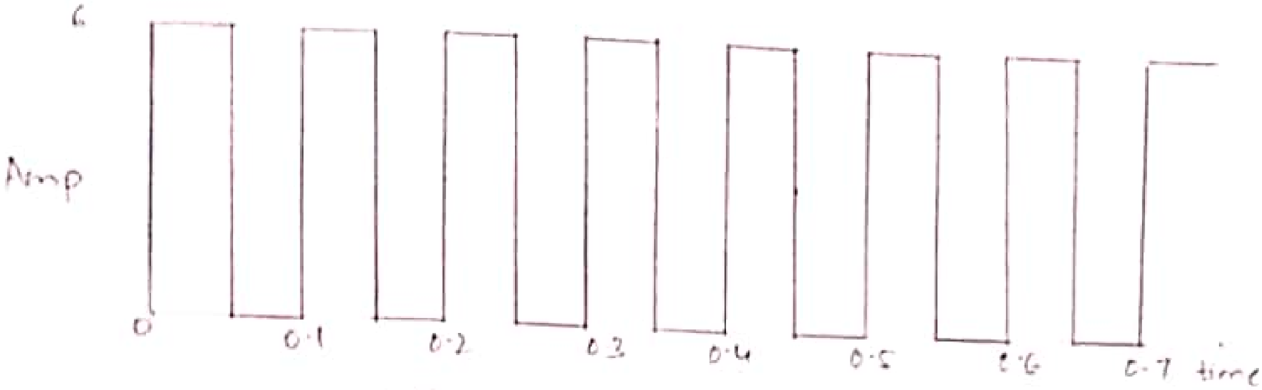

Amplitude shift keying signal



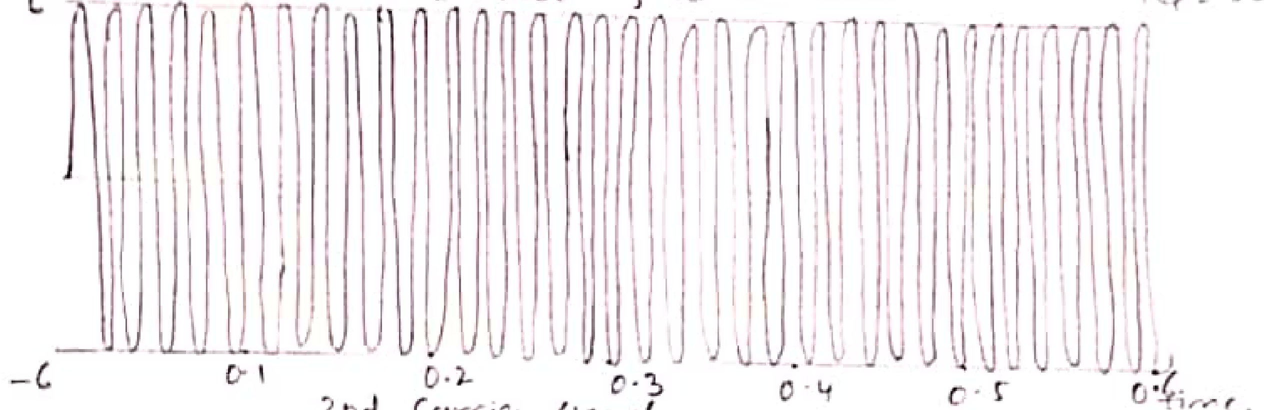
```
amp = amp/2
t = 0:0.001:1;
c1 = amp x sin(2xpix fc1xt);
c2 = amp x sin (2xpix fc2xt);
subplot (4,1,1);
Plot(t, c1);
xlabel('time'); Y label('Amp litude');
title ('carrier wave 1');
subplot(4,1,2);
plot (t,c2);
x label('Time'); Y label('Amplitude');
title ('carrier 2 wave');
m= amp x square (2x pi x fpxt) + amp;
subplot (4,1,3);
plot (t,m);
x label('time'); Y label ('Amplitude);
title ('Binary message pulse');
for i = 0:1000
    if m(i+1) == 0
        mm(i+1) = c2 (i+1);
    else
        mm (i+1) = c1(i+1);
    end
end
subplot (4,1,4);
plot (t, mm)
x label('Time'); Y label ('Amplitude');
Title ('modulated wave');
```

1) FSK

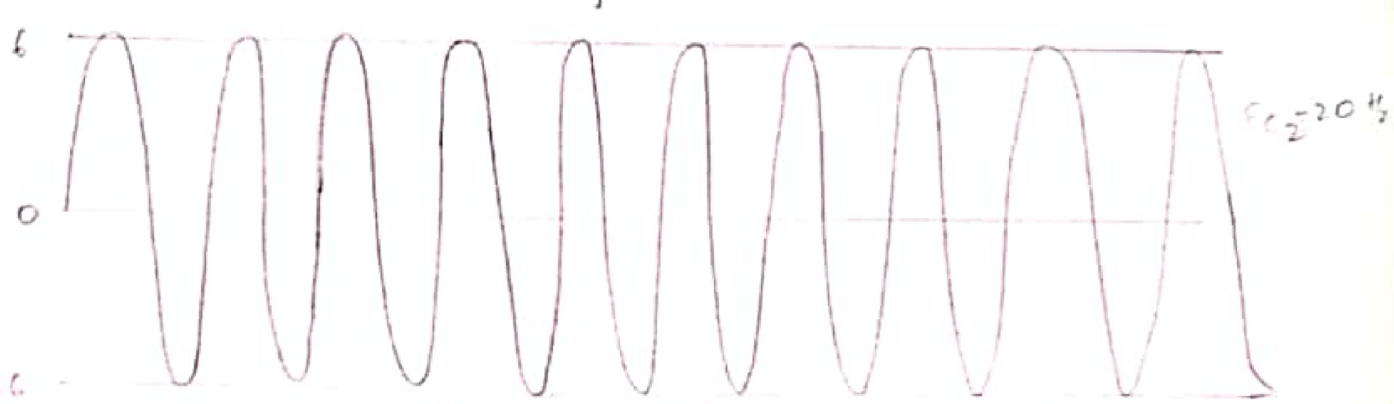
$F_{c1} = 50Hz$ $f_s = 20Hz$
$F_p = 10Hz$ amp = 6




1st Carrier signal




2nd Carrier signal

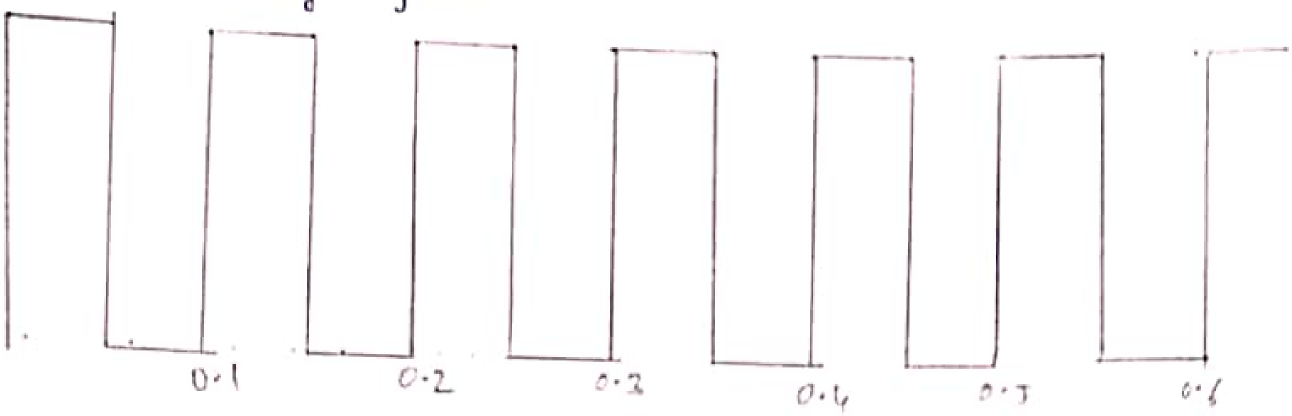



Frequency shift keying signal

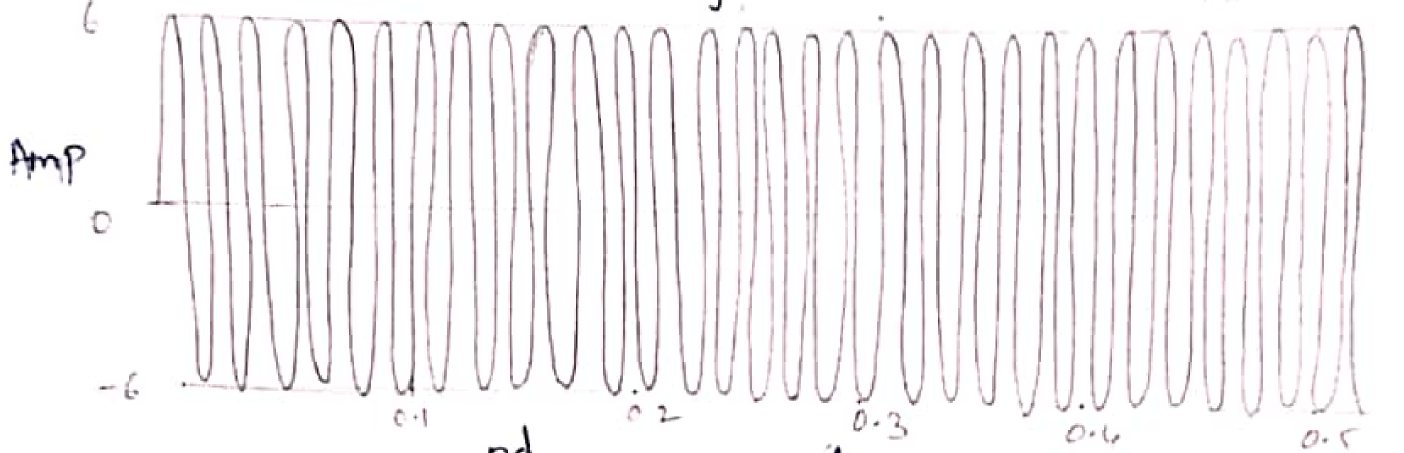
# 2) FSK

$F_{c_1} = 50Hz$ $F_{c_2} = 30Hz$
$F_p = 10Hz$ amp = 6.

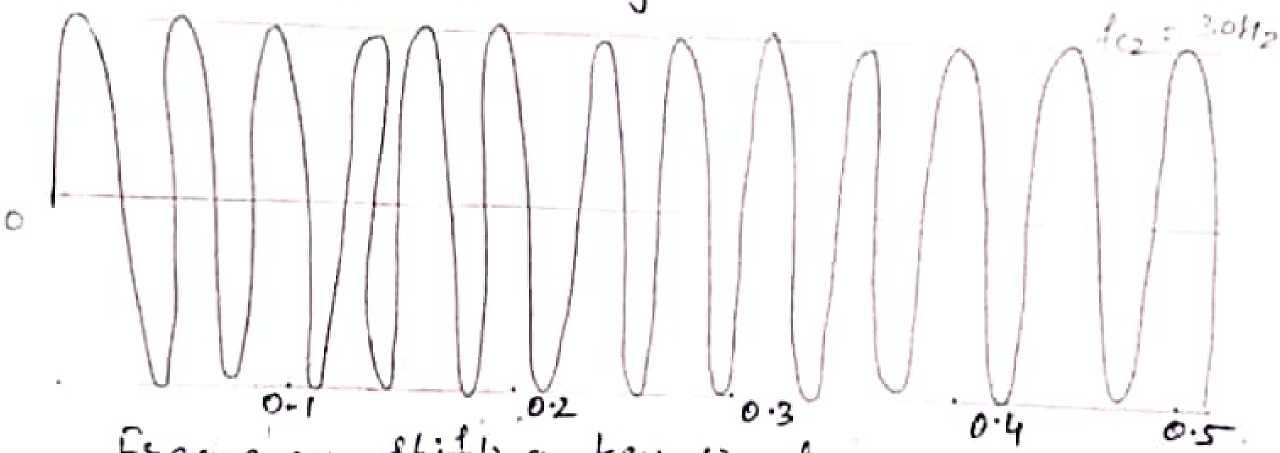
Message signal.



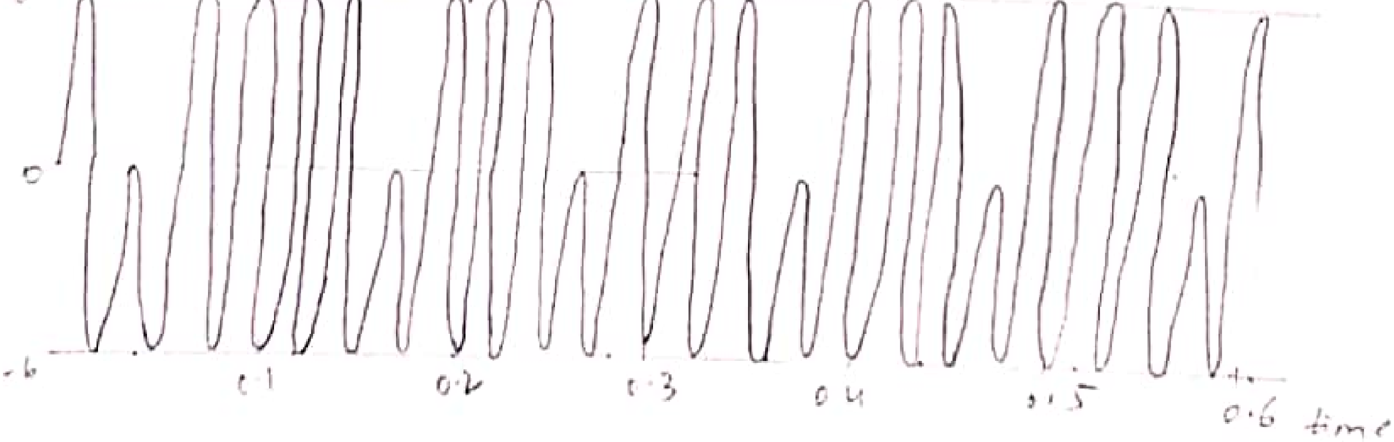

$1^{st}$ carrier signal




$2^{nd}$ carrier signal




Frequency shifting key signal

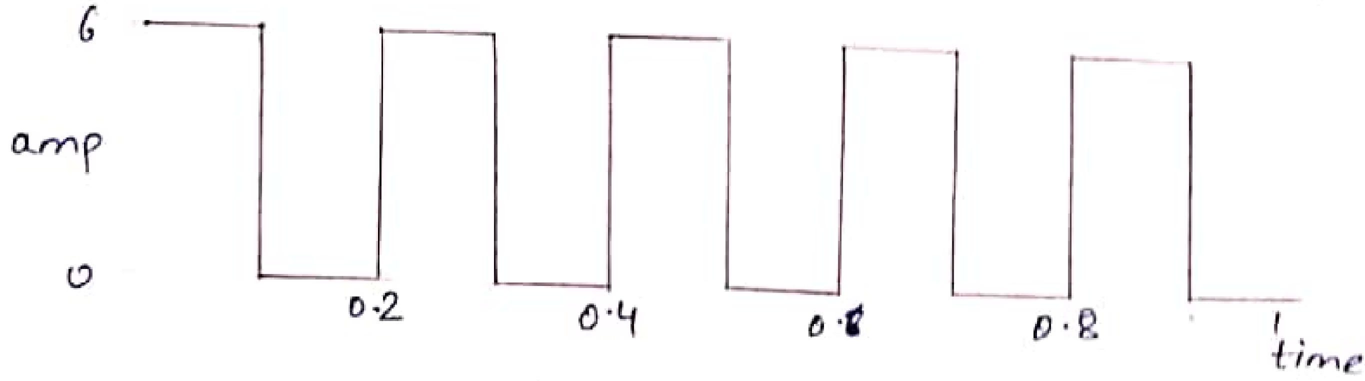


3) FSK

$F_{c_1} = 30\,Hz$ $F_{c_2} = 10\,Hz$

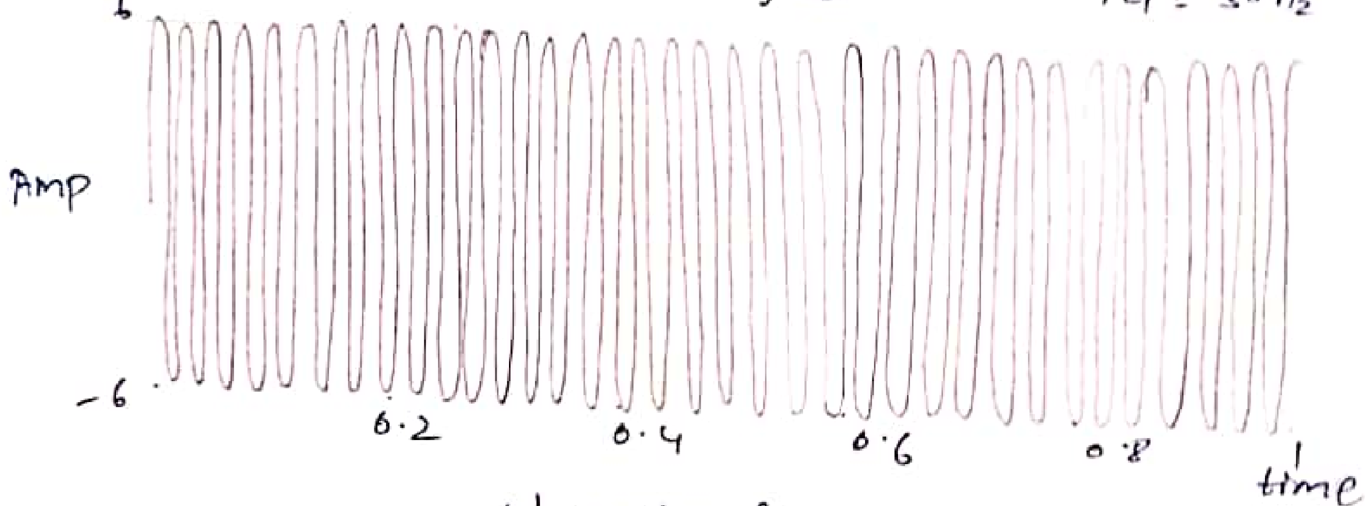
$F_p = 5\,Hz$ amp = 6

Message signal



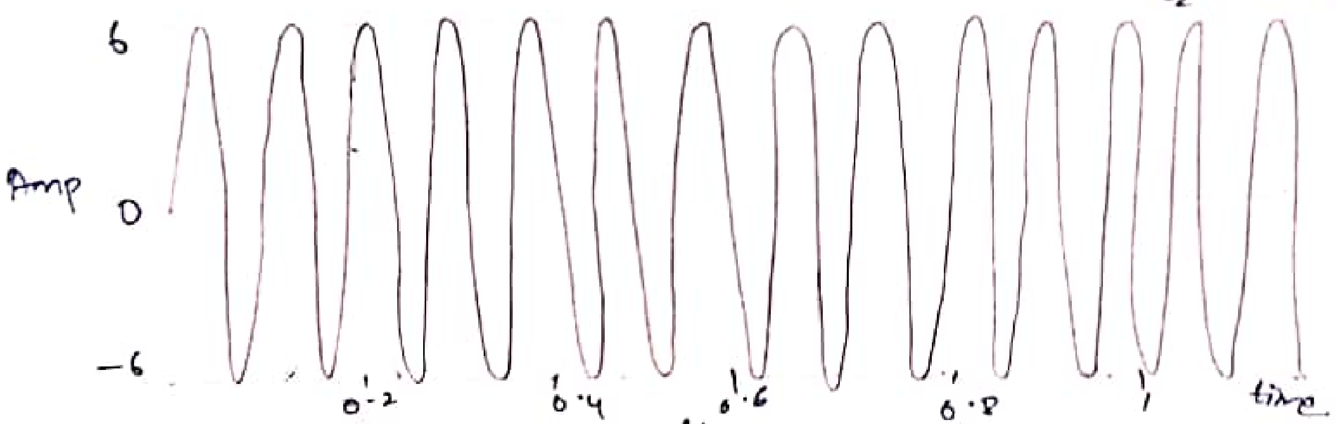

1st carrier signal

$F_{c_1} = 30\,Hz$

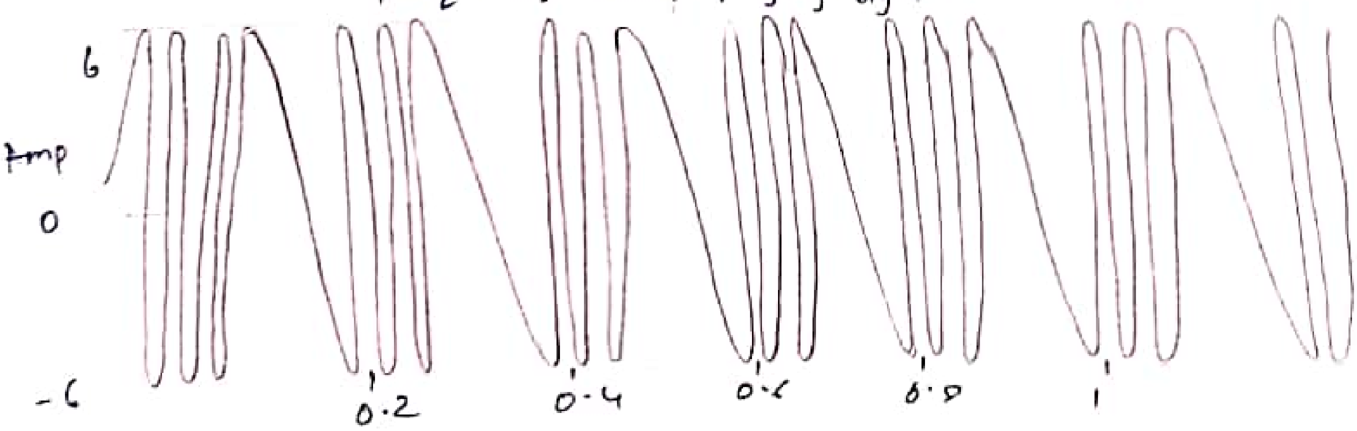



2nd carrier frequency

$f_{c_2} = 10\,Hz$




Frequency shift keying signal.



```
%PSK Signal
clc; clear all; close all;
fc = input('Enter the frequency of sine wave carrier');
fp = input('Enter the frequency of periodic binary Pulse');
amp = input('Enter the amplitude');

t = 0:0.001:1;
c = amp x sin(2x Pi x fc x t);
subplot(3,1,1); Plot(t,c);
xlabel('Time'); Ylabel('Amplitude');
Title('Carrier wave');
grid on;
m = square(2x Pi x fp xt);
subplot(3,1,2); Plot(t,m);
xlabel('time'); Ylabel('Amplitude');
title('Binary message pulse');
w = c x m;
subplot(3,1,3);
plot(t,w);
xlabel('time'); Ylabel('Amplitude)
grid on;
```

Conclusion

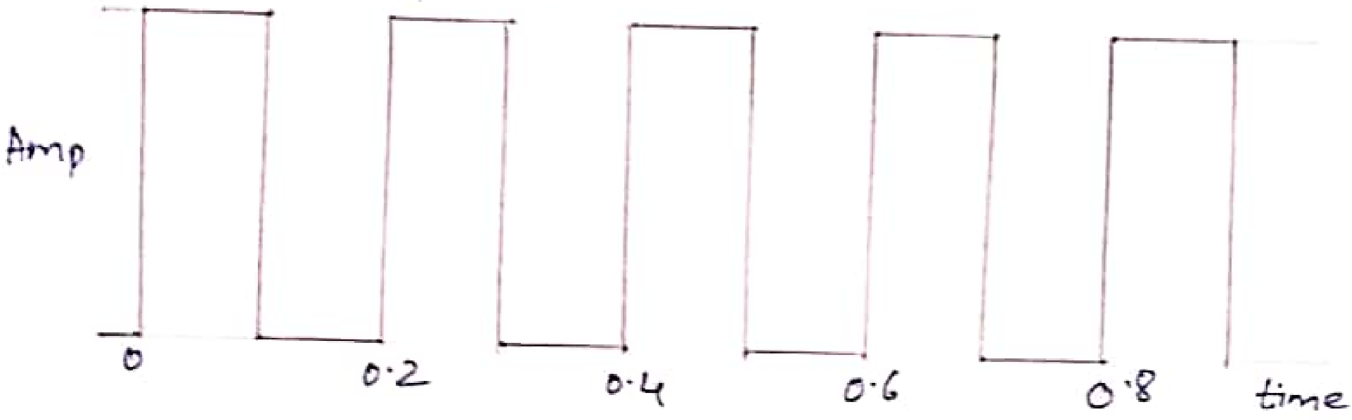
we have successfully studied ASK, PSK, FSK modulation technique and verified their waveforms using MATLAB. we also observe the Schematic diagram for ASK, PSK and FSK

1) PSK

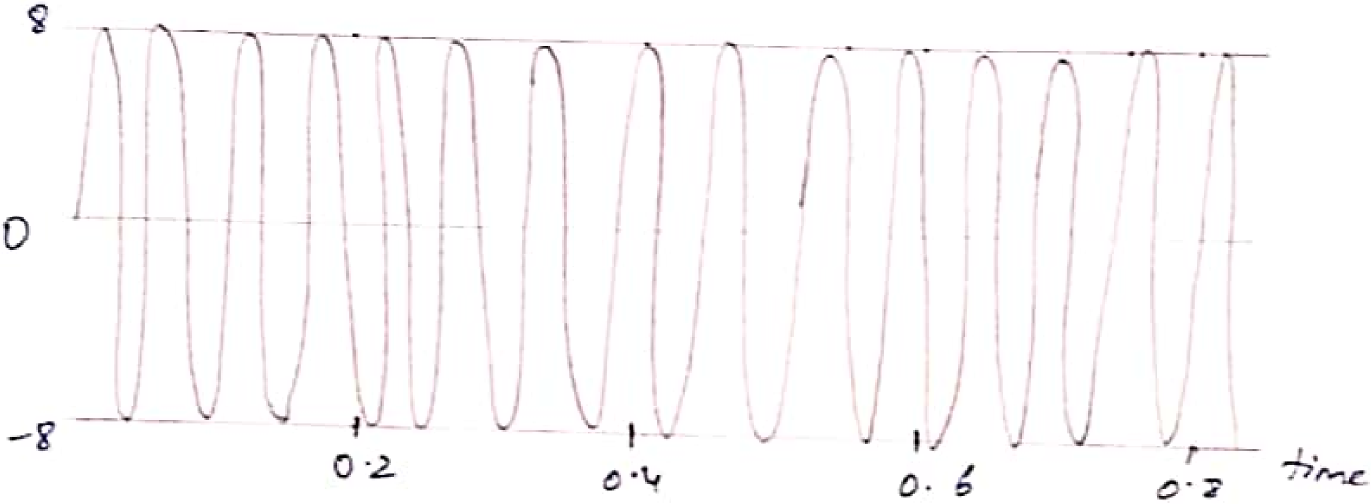
$F_c = 15Hz$  $F_p = 5Hz$

amp = 8

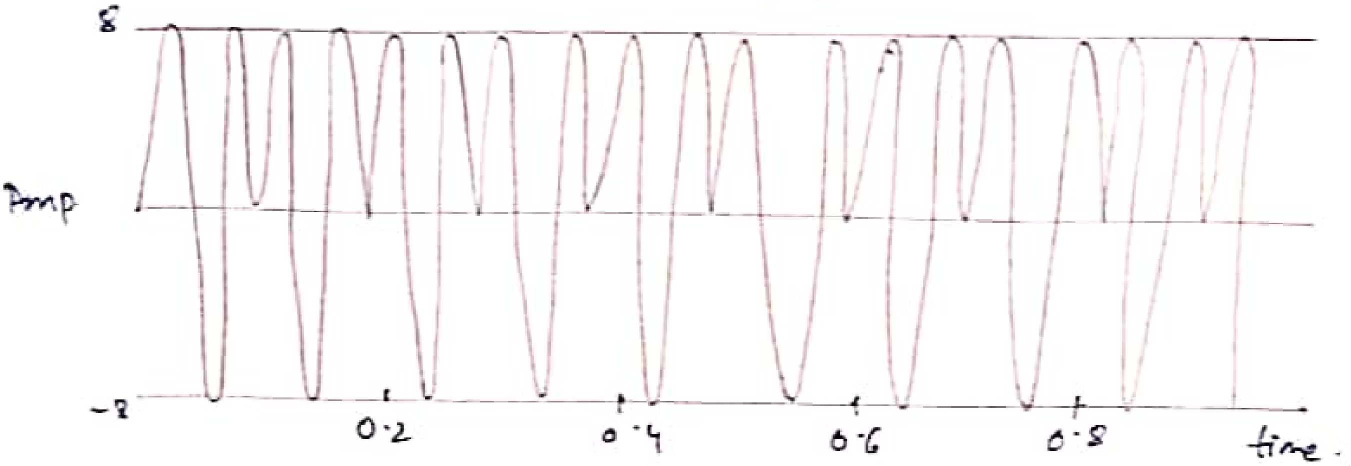
Message signal




Carrier signal




Phase shift keying signal

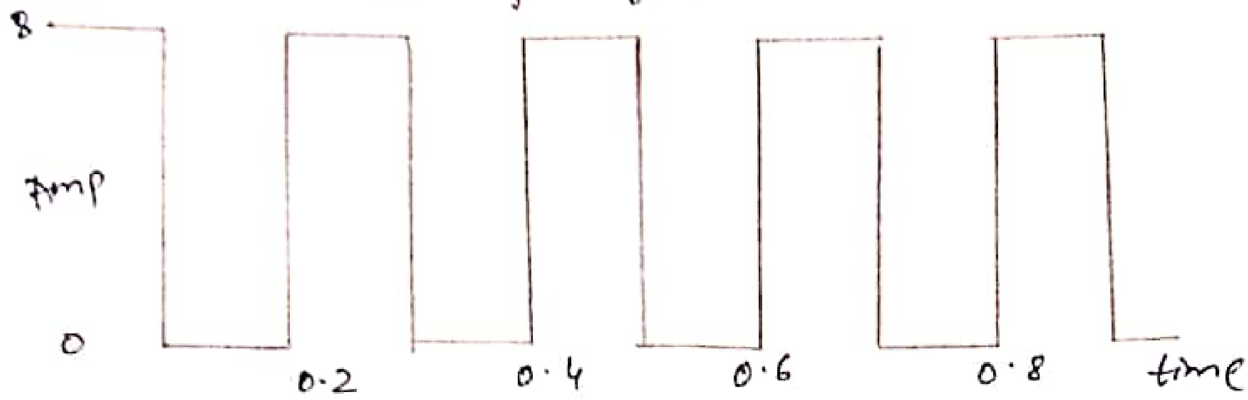


2) PSK

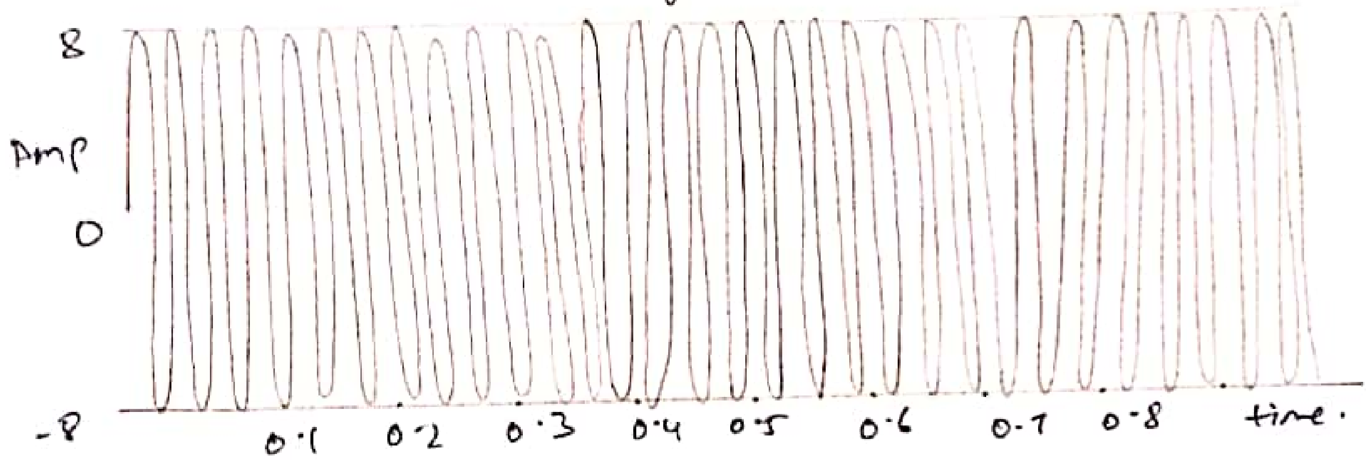
$f_c = 2.5 Hz$  $f_p = 5 Hz$

amp = 8

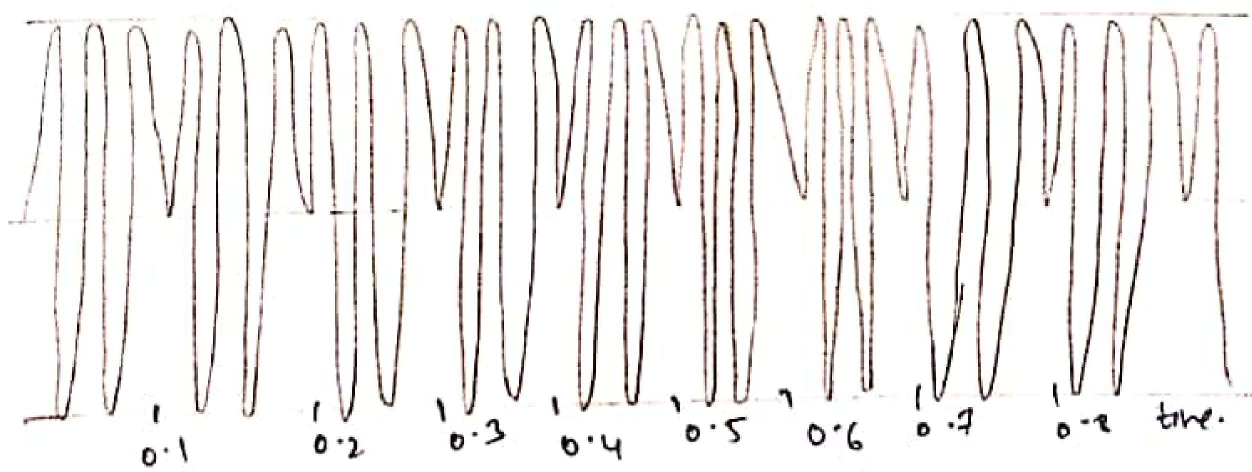
Message signal.




carrier signal



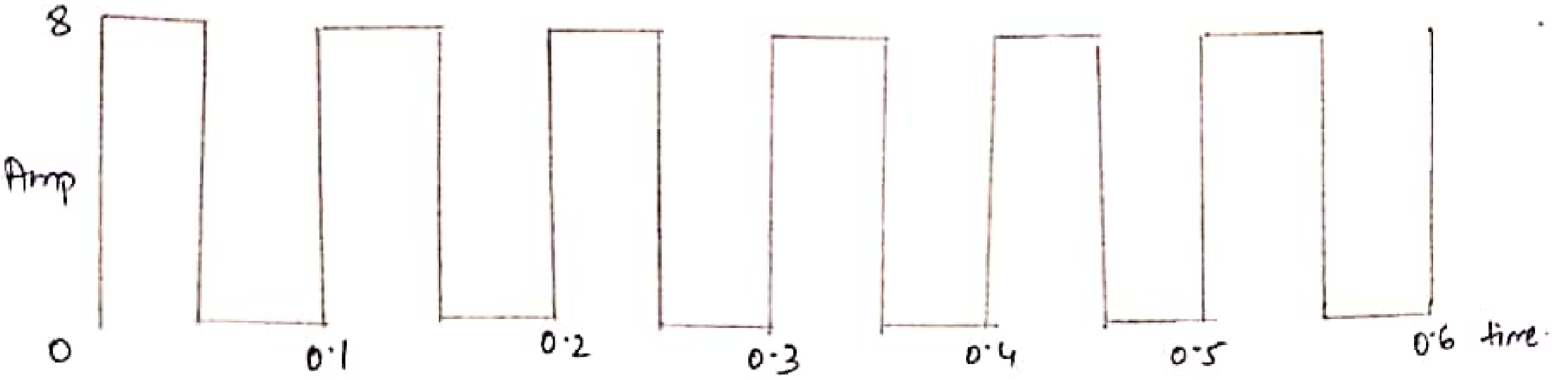

Phase shift keying signal



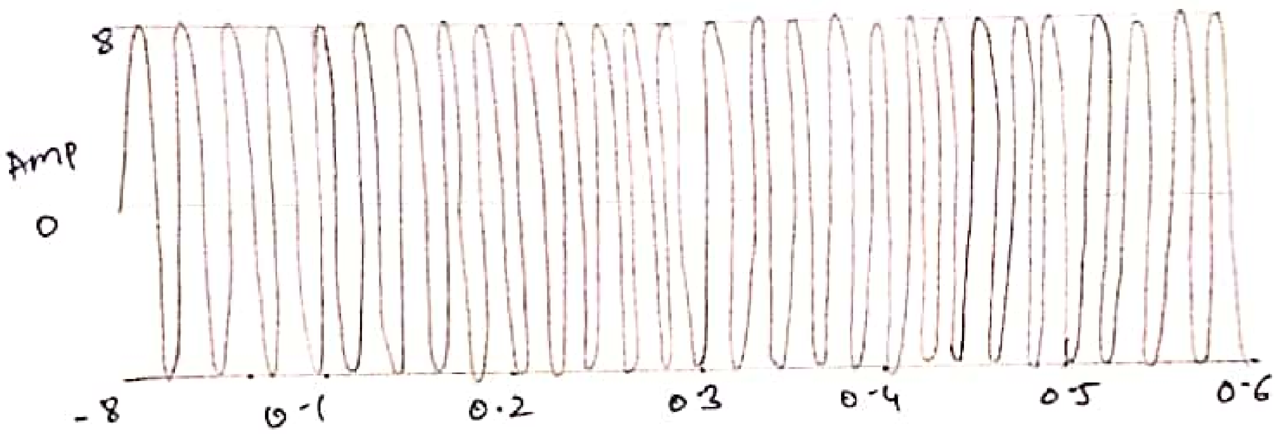
3) PSK

$F_c = 40\,Hz$ $F_p = 10\,Hz$.
amp = 8

Message signal




carrier signal




Phase shift keying