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COMMUNICATION SYSTEMS
IA-2

REPORT ON
PULSE AMPLITUDE MODULATION

BY
GROUP- 8

Name	Roll No.	Contribution
Mrunmayee More	**1913030**	Theory of Pulse Amplitude Modulation, Matlab Simulation of PAM
Navya Jain	**1913031**	Simulink Simulation, Preparation of step-by-step guide, Compilation to form a group report
Chinmay Nayak	**1913032**	Sampling Theorem, Observation Table, Result, Conclusion
Jayesh Nirve	**1913033**	Abstract, Introduction, Software used, Advantages, Disadvantages, Applications

SUBMITTED TO
PROF. ESTHER JENNIFER ISSAC

Abstract:

Pulse amplitude modulation (PAM) is a modulation method used in digital communication systems to facilitate transmission of digital information. The modulation method is used in baseband as well as carrier-modulated systems. A PAM modulator maps binary information (bits) into analog waveforms which differ only in amplitude. In this report, we provide a mathematical as well as a theory-based description of PAM signals and its applications. We also simulated and generated an amplitude modulated wave.

Introduction:

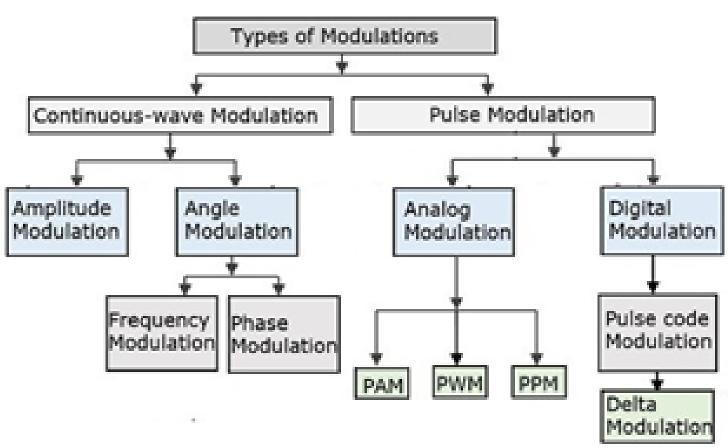
Pulse-amplitude modulation (PAM), is a form of signal modulation where the message information is encoded in the amplitude of a series of signal pulses. It is an analog pulse modulation scheme in which the amplitudes of a train of carrier pulses are varied according to the sample value of the message signal. It can also be defined as the data transmission by altering the amplitudes (power levels or voltage) of every pulse in a regular time sequence of electromagnetic pulses. The possible number of amplitudes can be infinite.

Theory:

Modulation is categorized into two types depending on the type of signal.

1. Continuous-wave Modulation
2. Pulse Modulation

Further classification is shown in the diagram:



Pulse Modulation

Pulse modulation is a technique in which the signal is transmitted with the information by pulses. This is divided into Analog Pulse Modulation and Digital Pulse Modulation.

Analog pulse modulation is classified as

1. Pulse Amplitude Modulation (PAM)
2. Pulse Width Modulation (PWM)
3. Pulse Position Modulation (PPM)

Digital modulation is classified as

1. Pulse Code Modulation
2. Delta Modulation

Pulse Amplitude Modulation

- It is a modulation system in which the signal is sampled at regular intervals and each sample is made proportional to the amplitude of the signal at the instant of sampling.
- This technique transmits the data by encoding in the amplitude of a series of signal pulses.

Types of Pulse Amplitude Modulation

Pulse amplitude modulation is categorized into two types:

1. Single Polarity PAM: A fixed DC level bias is added to the signal so that it is always positive.
2. Double Polarity PAM: Here the pulses are both positive and negative.

Generation of PAMs

There are two types of sampling techniques for transmitting a signal using PAM

1. **Natural PAM**
    a. The amplitude of each pulse is directly proportional to modulating signal amplitude at the time of pulse occurrence.
    b. Then follows the amplitude of the pulse for the rest of the half-cycle.
    c. For demodulation the natural sampling is complex and difficult since it has several amplitude variations in a wave.

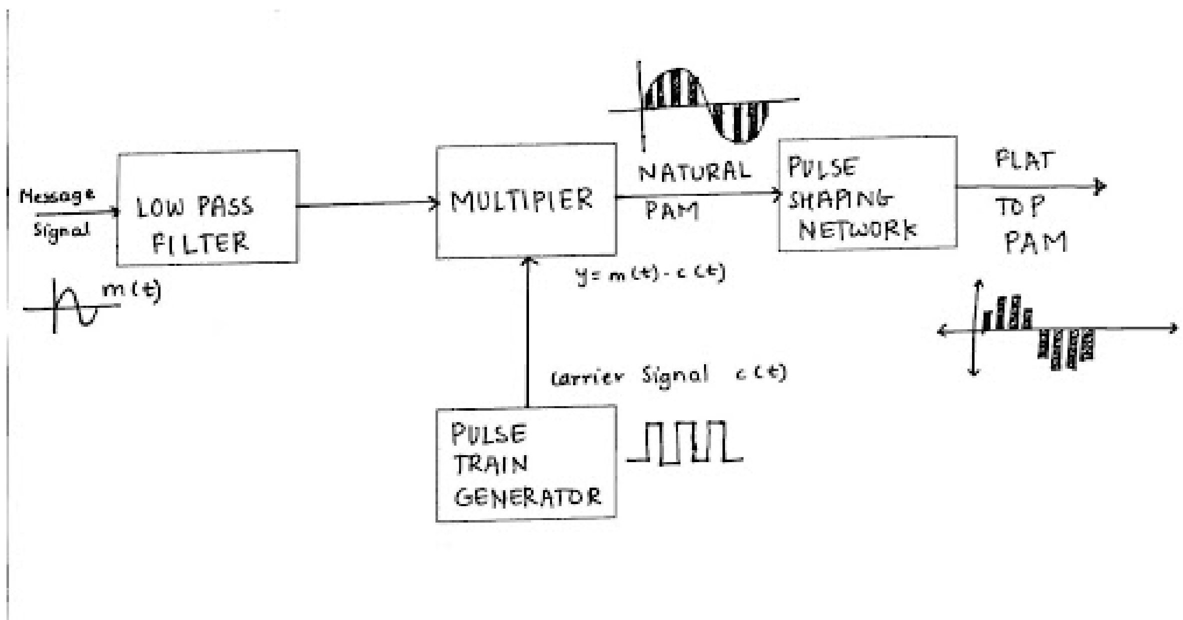
2. **Flat Top PAM**
   a. Flat top sampling is like natural sampling i.e; practical in nature. In comparison to natural sampling flat top sampling can be easily obtained.
   b. In these sampling techniques, the top of the samples remains constant,flat and is equal to the instantaneous value of the message signal m(t) at the start of the sampling process.
   c. Flat top PAMs are easily generated by the repeaters and can be used for transmission over long distances.
   d. During Demodulation, a signal sampled at the Nyquist rate is reconstructed, by passing it through an efficient Low Pass Frequency (LPF) with exact cutoff frequency but it cannot recover the signal without distortion. Hence to avoid this noise, flat-top sampling is done.

Aliasing- It is an effect that causes different signals to become indistinguishable.

What is Band Limiting?

1. For a proper transmission of a signal channel width> signal band width.
2. For transmission of rectangular pulse, a channel having infinite BW is required but for practical channel, BW should be finite.
3. Therefore, band limiting is required.
4. To band limit a signal, all of its significant frequency components have to be retained and insignificant frequency components should be eliminated.
5. Significant frequencies are low frequencies which contain almost 95% - 99% of total strength of signal,hence low pass filters are used.

Block Diagram for Modulation



1. Initially a modulating signal is passed through the **Low Pass Filter** to band limit the message signal.
2. The band limiting is necessary to avoid the aliasing effect in the sampling process.
3. A Pulse train Generator is used to generate the pulse which acts like the carrier signal.
4. A Natural PAM is obtained when the modulating and the carrier signal are multiplied in the multiplier.
5. Pulse shaping network does the shaping work to five flat tops.

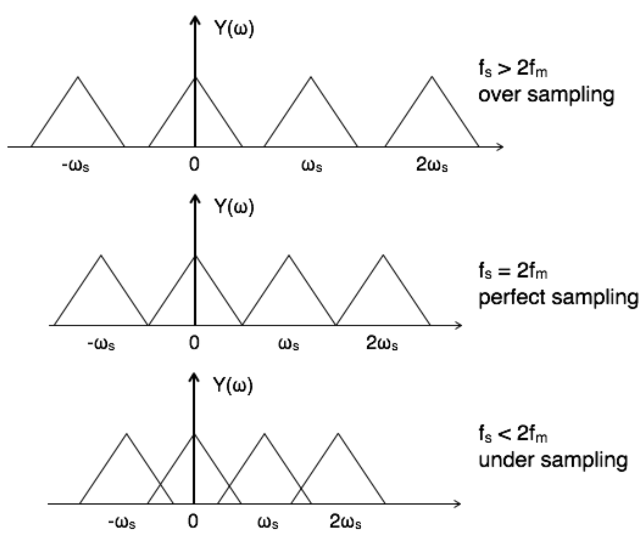
If the generated pulses are narrow then the PAM signal requires little power for transmission and is suitable for time division multiplexing

Nyquist Rate

Nyquist rate is the rate at which sampling of a signal is done so that overlapping of frequencies does not take place. When the sampling rate becomes exactly equal to $2f_m$ samples per second, then the specific rate is known as Nyquist rate. It is also known as the minimum sampling rate and given by: $f_s = 2f_m$

Sampling Theorem

A signal can be represented in its samples and can be recovered back when the sampling frequency is greater or equal to twice of maximum frequency component present in the signal. If a continuous time signal contains no frequency components higher than f_m hz, then it can be completely determined by uniform samples taken at a rate f_s samples per second where $2f_m \leq f_s$



Software used:

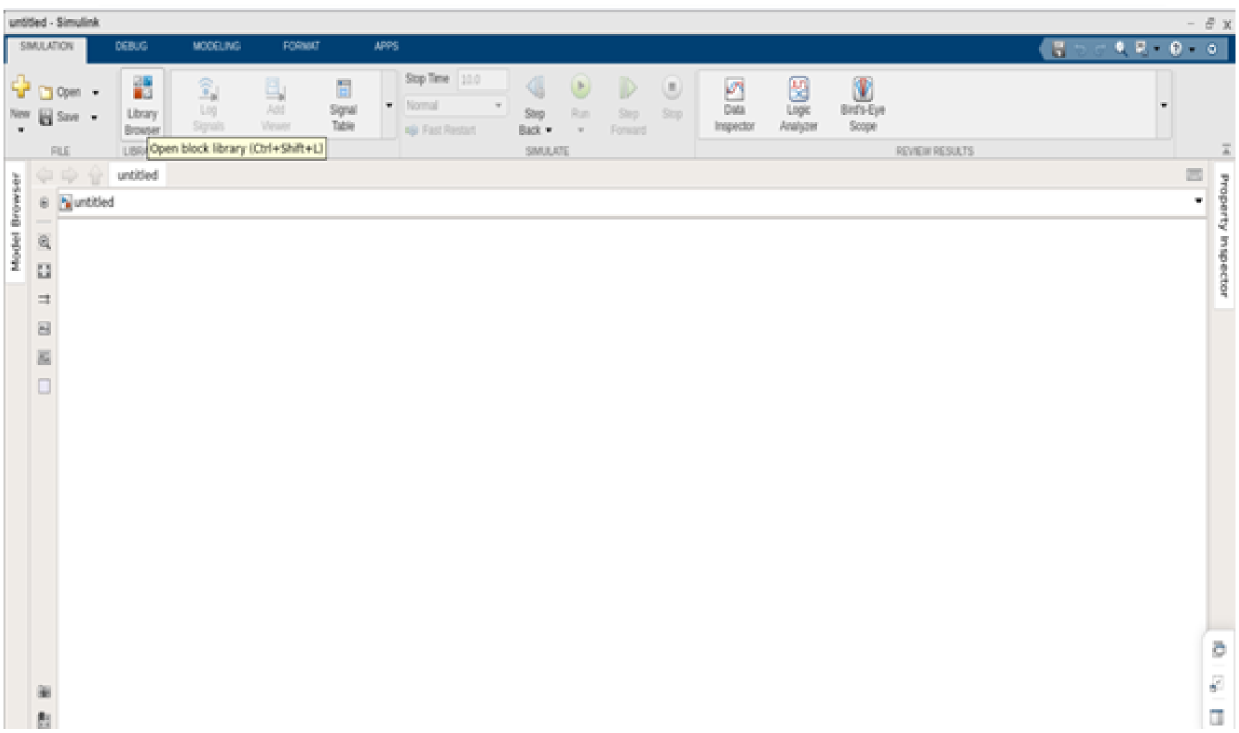
We have used Simulink to simulate a working concept of pulse amplitude modulation. Simulink is a MATLAB-based graphical programming environment for modeling, simulating and analyzing multi domain dynamical systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries.

Simulation on Simulink:

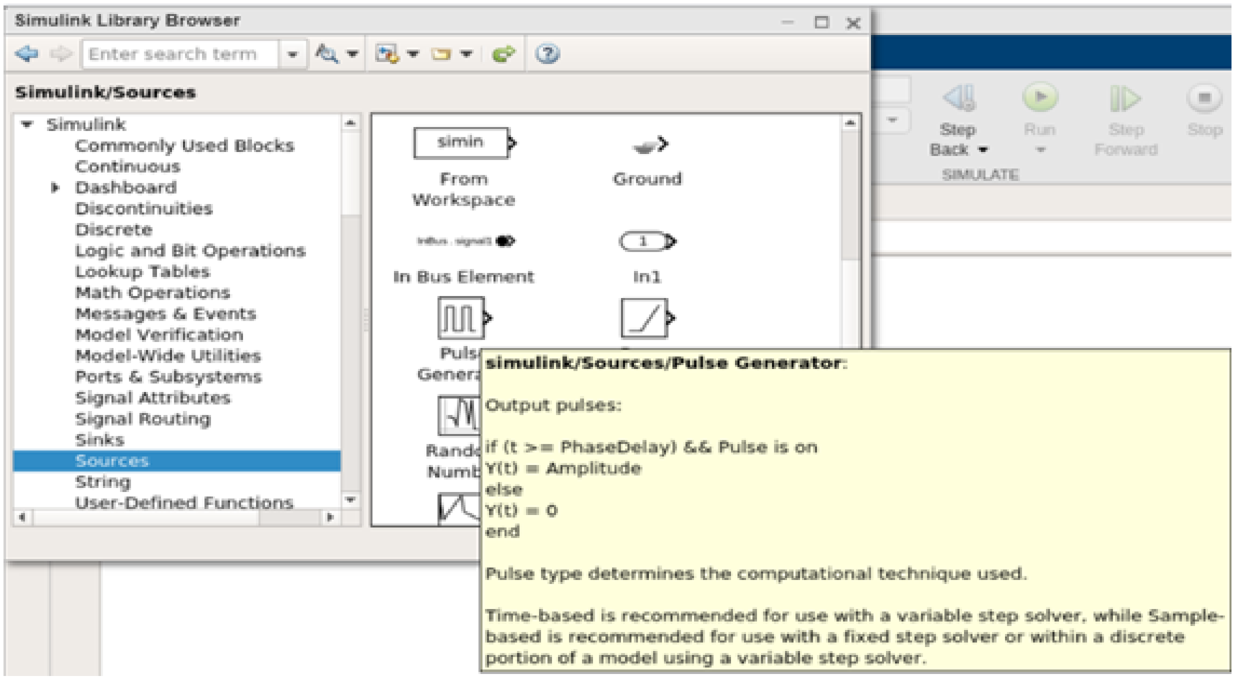
Design Steps

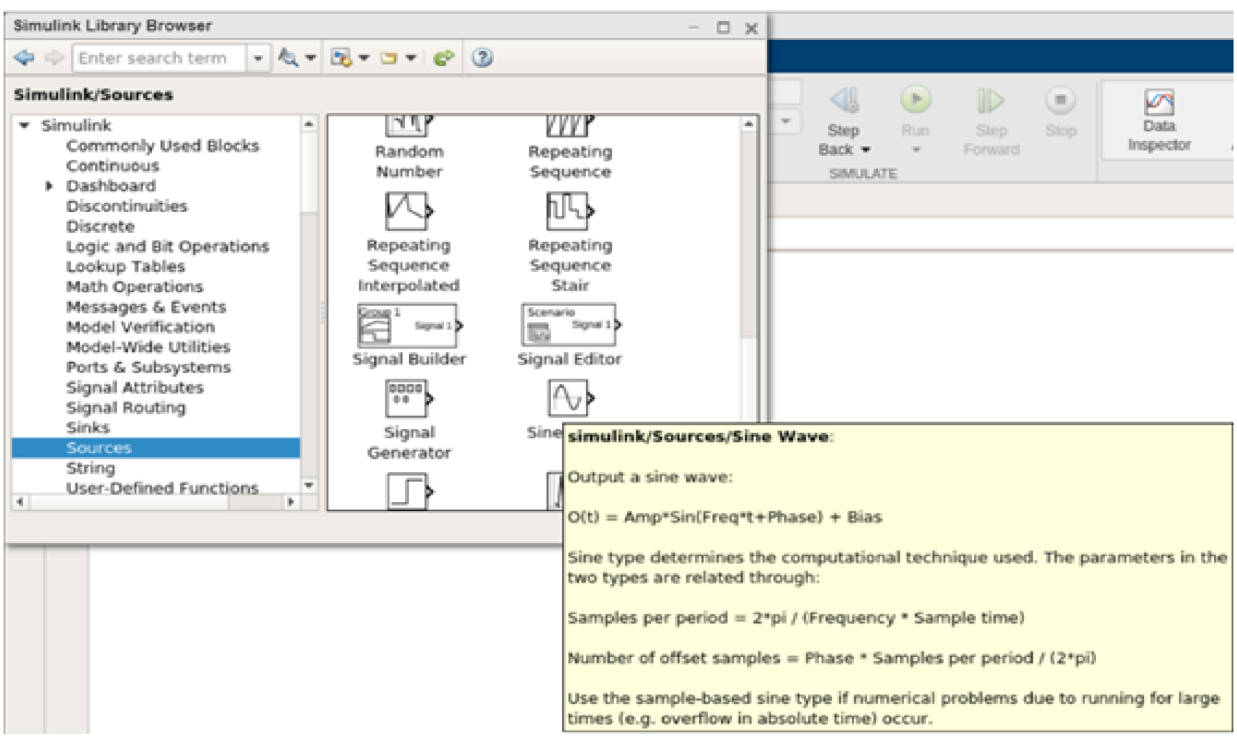
1)Open Simulink online software

2)In new sheet, click on block library

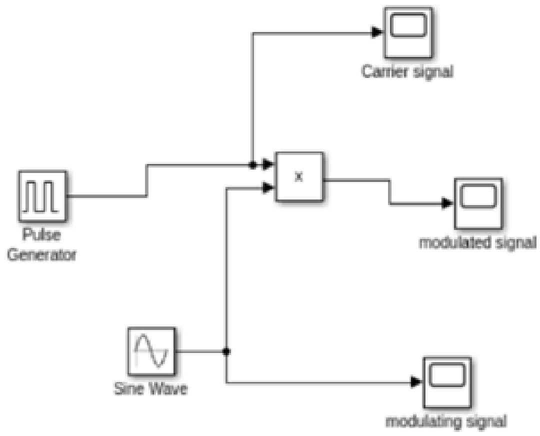


3)Select Pulse generator for carrier wave, sine wave for modulating wave

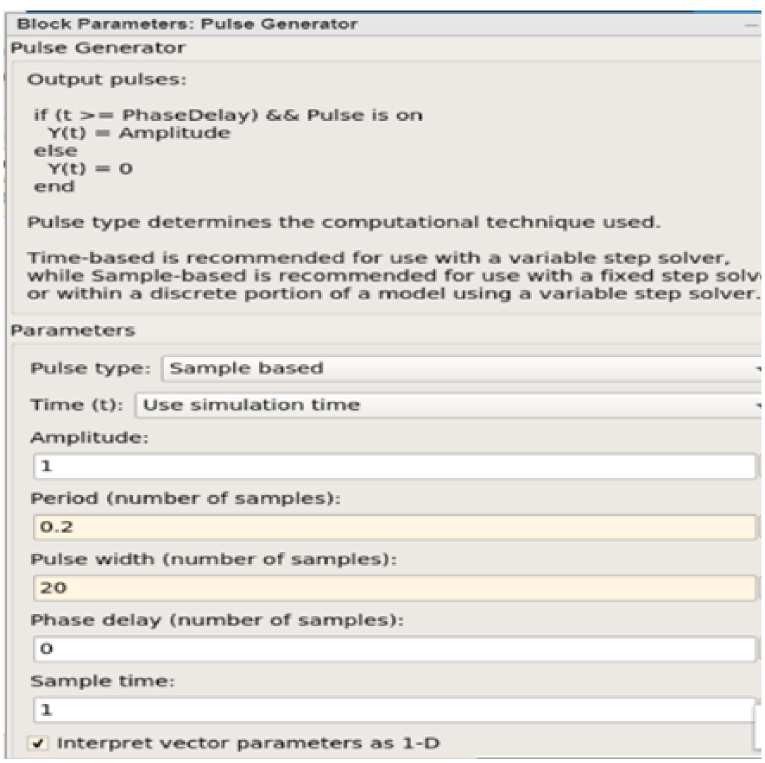




4)Select scope to see the output of the carrier, modulating and modulated wave. Using connectors, connect the input signals to the product and output to scopes



5)Set values for carrier signal (Pulse generator)


Block Parameters: Pulse Generator
Pulse Generator
Output pulses:

```
if (t >= PhaseDelay) && Pulse is on
  Y(t) = Amplitude
else
  Y(t) = 0
end
```

Pulse type determines the computational technique used.

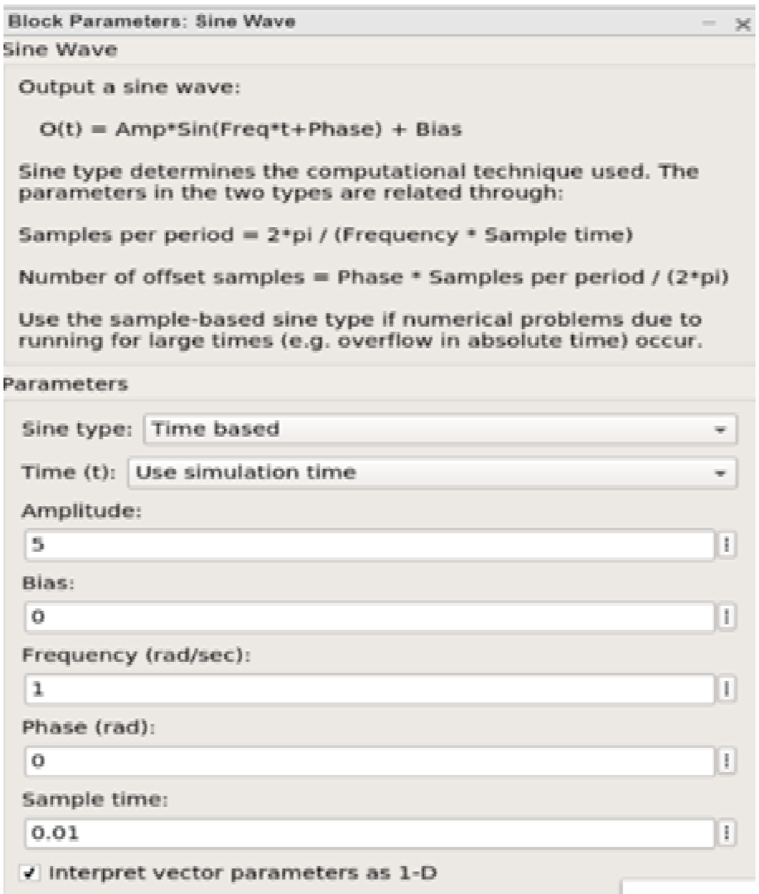
Time-based is recommended for use with a variable step solver, while Sample-based is recommended for use with a fixed step solv or within a discrete portion of a model using a variable step solver.

Parameters

Pulse type: Sample based
Time (t): Use simulation time
Amplitude: 1
Period (number of samples): 0.2
Pulse width (number of samples): 20
Phase delay (number of samples): 0
Sample time: 1
✓ Interpret vector parameters as 1-D

6)Set values for sine wave

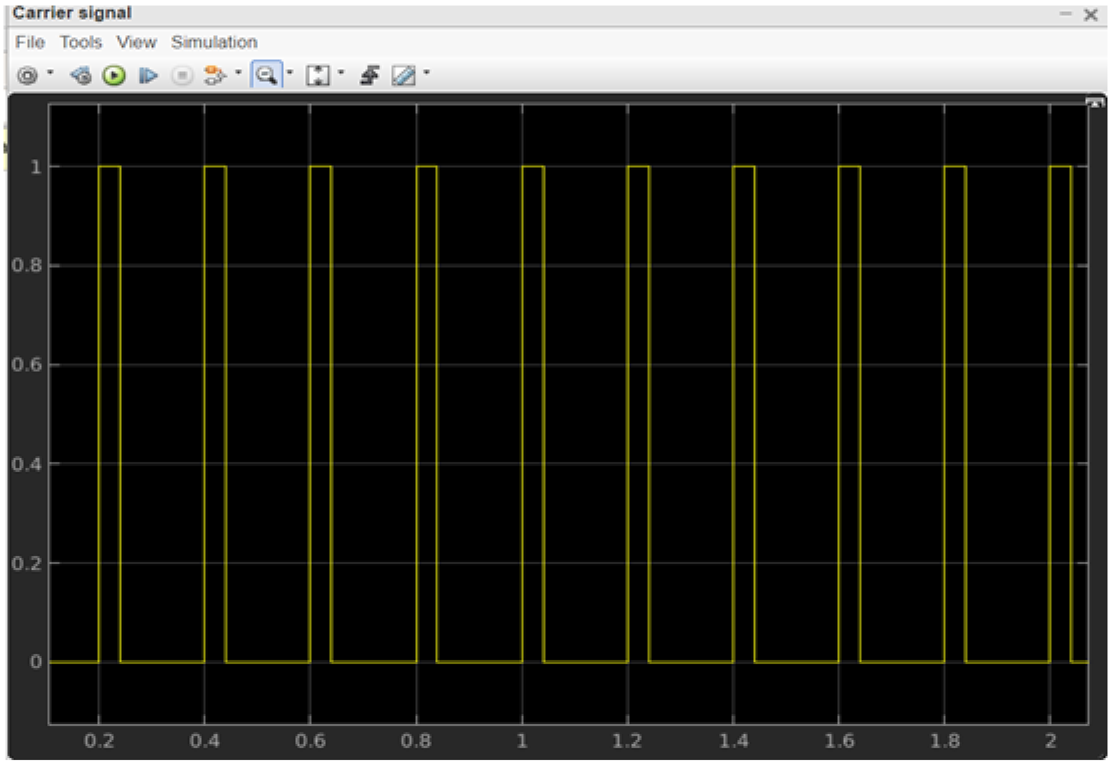
Natural PAM:



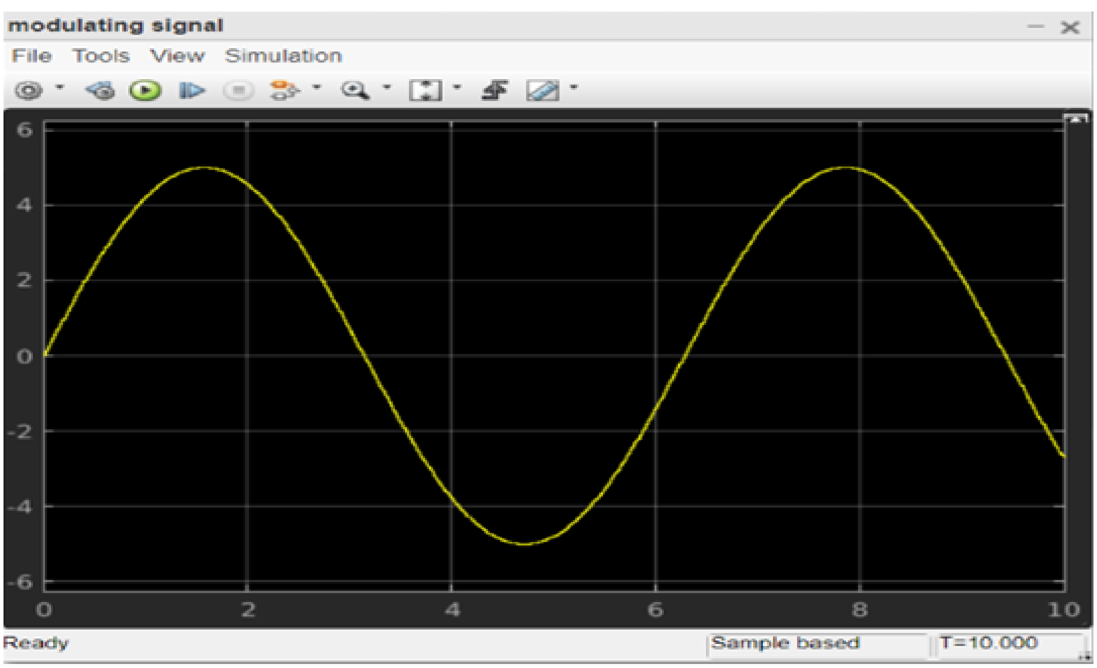
7)Click on Run

8)Click on carrier scope, modulating scope and modulated scope, following signals will be obtained

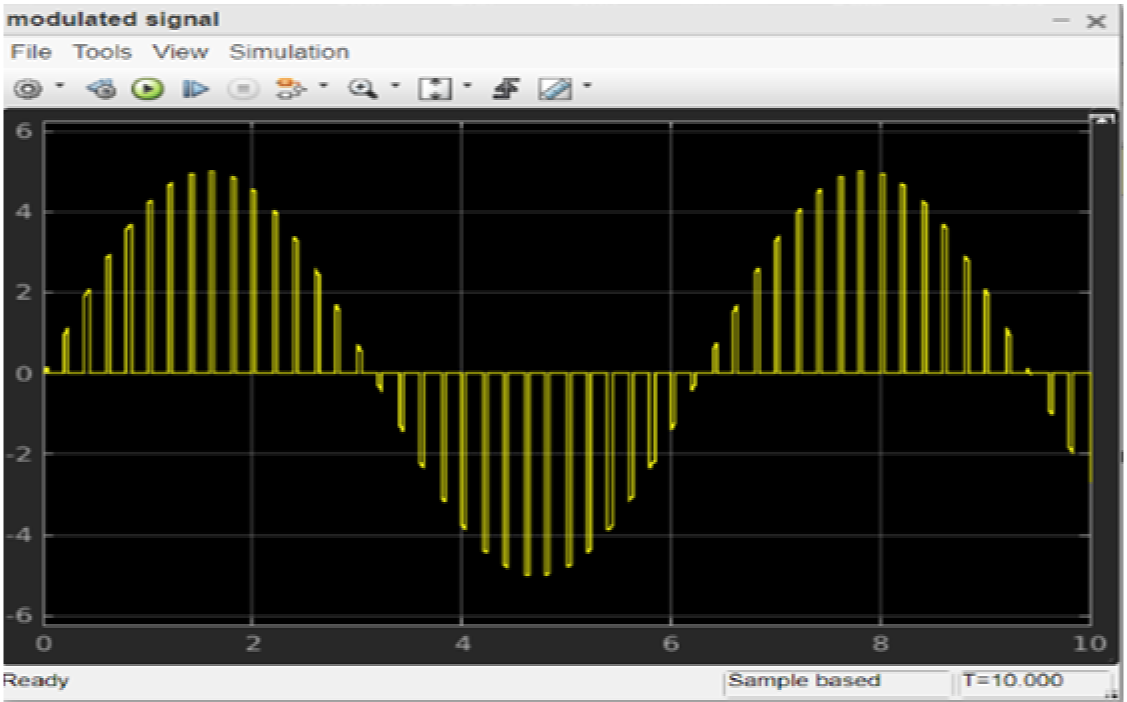
Carrier Signal



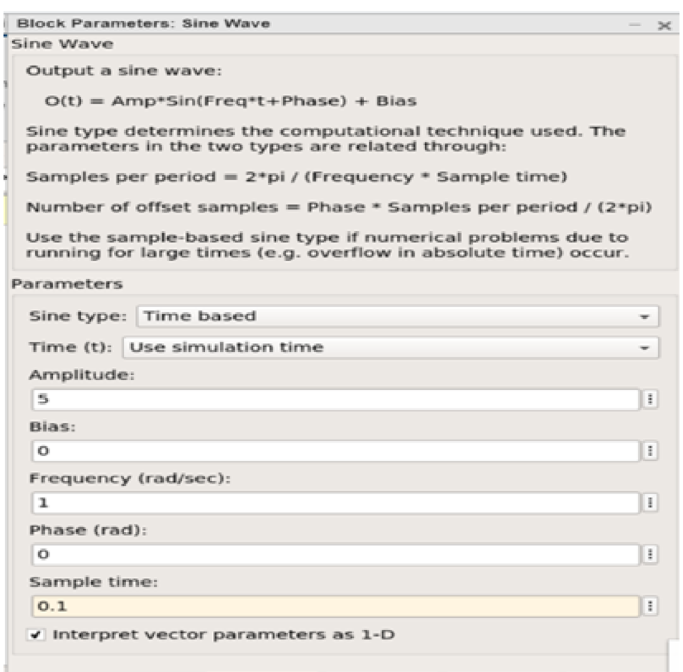
Modulating Signal



Modulated Signal



Flat Top PAM:


Block Parameters: Sine Wave

Sine Wave

Output a sine wave:

O(t) = Amp*Sin(Freq*t+Phase) + Bias

Sine type determines the computational technique used. The parameters in the two types are related through:

Samples per period = 2*pi / (Frequency * Sample time)

Number of offset samples = Phase * Samples per period / (2*pi)

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type: Time based

Time (t): Use simulation time

Amplitude: 5

Bias: 0

Frequency (rad/sec): 1

Phase (rad): 0

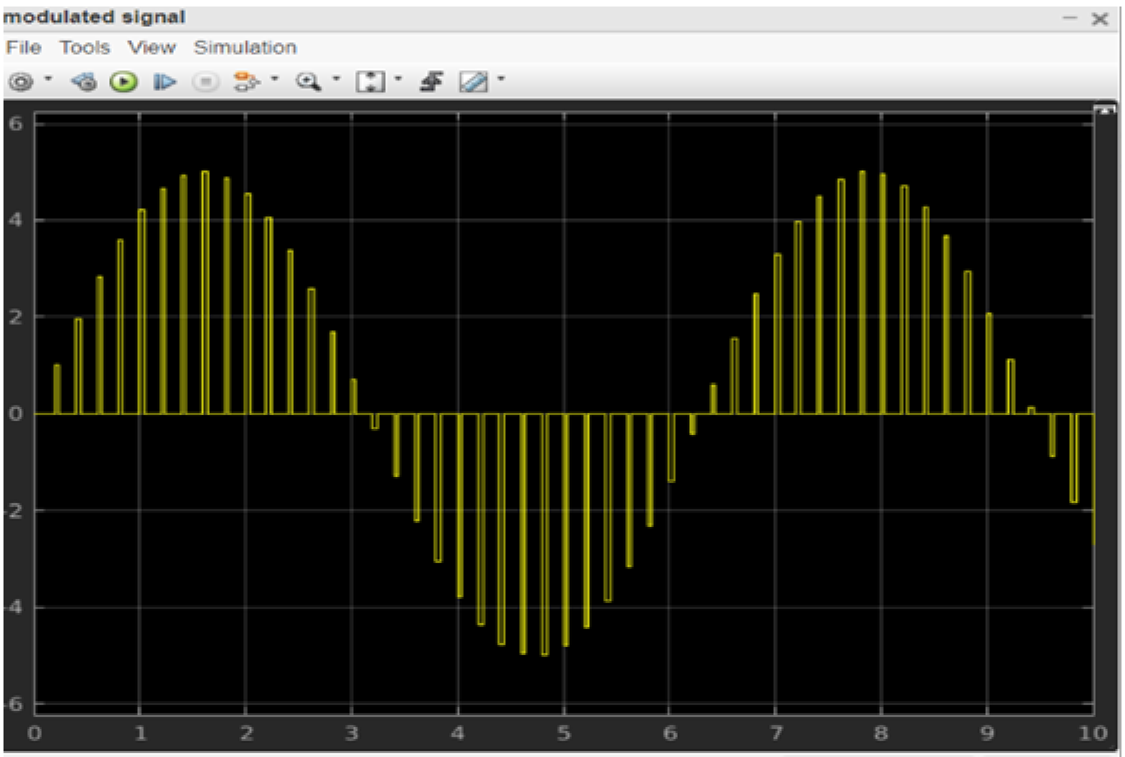
Sample time: 0.1

✓ Interpret vector parameters as 1-D

Carrier Signal remains the same

Sample time of Modulating Signal changed to 0.1

Modulated Signal



<u>Simulation on Matlab:</u>

1) Execution Steps
2) Open Matlab
3) Click on New Script
4) Type the code and then run it
5) Input the frequency values for carrier and message signal and obtain an output waveform in new window

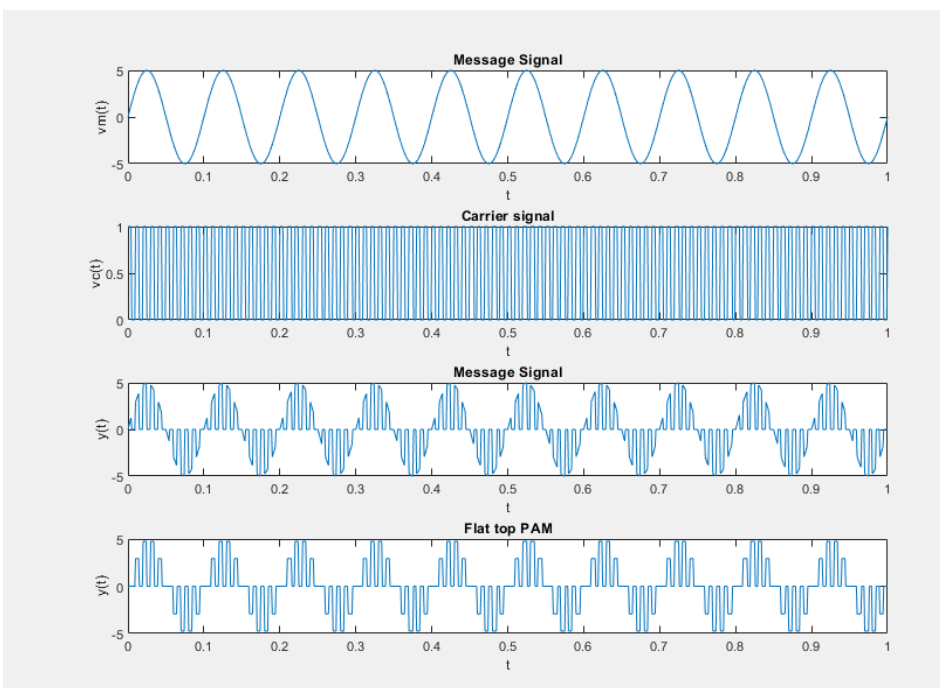
Code

```
clc;
close all;
t = 0:0.001 :1; %time
```

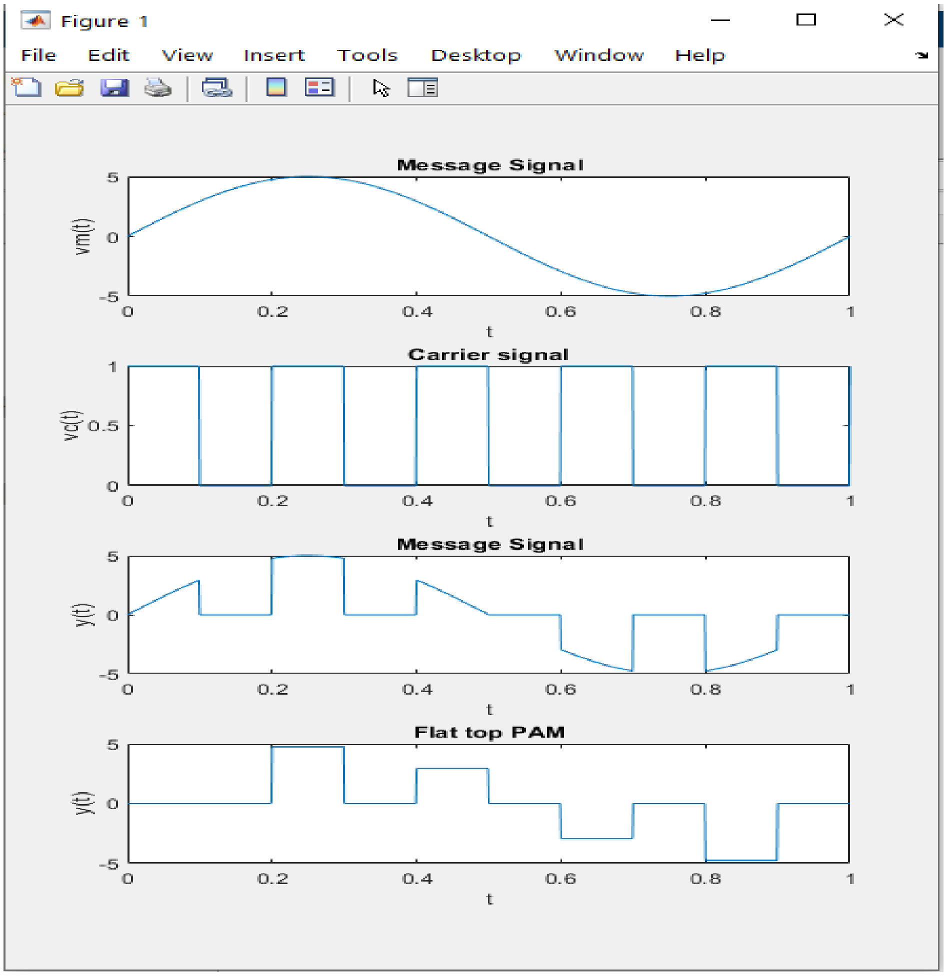
```
%Input values from user
fm = input('Enter the frequency of message signal : ');%10
fc = input('Enter the frequency of carrier signal : ');%50
vm = 5*sin(2*pi*fm*t);%Message Signal
vc = 5*square(2*pi*fc*t);%Carrier Signal consist of square wave
%Flat top requires train of pulses
n = length(vc);%no.of samples in Vc
for i = 1:n
   if vc(i)<=0;%when carrier signal has negative value it will make it zero
   vc(i)=0;%square wave changes to pulse wave
   else
   vc(i)=1;
   end
end
y = vc .*vm;%generation of FTP- Product -Modulation Step
subplot(4,1,1),plot(t,vm);
xlabel('t');
ylabel('vm(t)');
title('Message Signal');
subplot(4,1,2),plot(t,vc);
xlabel('t');
ylabel('vc(t)');
title('Carrier signal');

%Natural PAM
subplot(4,1,3),plot(t,y)
xlabel('t');
ylabel('y(t)');
title('Message Signal');

%Flat Top PAM
for i = 2:length(t)%samples under t
```

```
    if vc(i)== 1&&vc(i-1) ==0 % if the rising edge id detected
        y(i)==vc(i)* vm(i);%sampling occurs
%no change in level
    elseif vc(i)==1 && vc(i-1)==1%and while the carrier signal is 1
        y(i)=y(i-1);% the value of y1 remains constant
    else
        y(i)=0;%otherwise zero
    end
end
subplot(4,1,4),plot(t,y)
xlabel('t');
ylabel('y(t)');
title('Flat top PAM');% Plotting Flat Top PAM
```

Output For Matlab Simulation:



Fc = 5 hz; Fm = 1 hz



Observation and Calculations:

Pulse generator specifications:

Amplitude=1

Time period= 0.2sec

Pulse Width= 20%

Observation Table: (2f m ≤ f s)

	Sampling time	fs=1/Sampling Time	f m	2fm ≤ f s ?
Natural PAM	0.01	1/(0.01)=100	1	YES
Flattop PAM	0.1	1/(0.1)=10	1	YES

Result:

Both the modulating waves are successfully amplitude modulated. In case of both natural and flat top PAM we find that 2fm ≤ f s which verifies the condition of perfect and over sampling.

If we consider values in which fs< fm, then it will be a case of under sampling and we will not get the desired output.

Applications:

PAM is mostly applied in non-based modulating transmission of digital data and applications replaced by pulse-code modulation and pulse-position modulation.

A few common applications of PAM are:

●**Ethernet-** Some versions of the Ethernet communication standard are an example of PAM usage. In particular, 100BASE-T4 and BroadR-Reach Ethernet standard, use three-level PAM modulation (PAM-3), 1000BASE-T Gigabit Ethernet uses five-level PAM-5 modulation.

●**GDDR6X-** developed by Micron and Nvidia and first used in the Nvidia RTX 3080 and 3090 graphics cards, uses PAM4 signaling to transmit 2 bits per clock cycle without having to resort to higher frequencies or two channels or lanes with associated transmitters and receivers, which may increase power or space consumption and cost.

●**Photo biology-** Unlike the traditional dark-adapted chlorophyll fluorescence measurements, pulse amplitude fluorescence devices allow measuring under ambient light conditions, which make measurements significantly more versatile.

●**Electronic drivers for LED lighting-** Pulse-amplitude modulation has also been developed for the control of light-emitting diodes (LEDs), especially for lighting applications.

Advantages:

- PAM allows data to be transmitted more effectively, efficiently and quickly using conventional copper wires in greater volume.
- The frequency modulations available are infinite; hence PAM formulas can be developed continually to allow increased data throughput over existing networks.
- It is the simplest form on base of which all digital or modern modulation techniques work

Disadvantages:

- Amplitude variation occurs in this as the result of which the receiver's peak power varies with it.
- In the transmission of pulse amplitude modulation signals very large bandwidth are required.

Conclusion:

To sum it all up, in this report we have discussed Pulse Amplitude Modulation primarily Natural and Flattop PAM. We have also discussed topics such as Nyquist Rate and Sampling theorem. Pulse amplitude modulation has been demonstrated using- simulink and matlab. In this simulation experiment we observe that the product of carrier wave (pulse wave) and modulating wave (sine wave) gives Pulse Amplitude Modulated wave in the output. Applications, advantages, disadvantages of pulse amplitude modulation are also discussed in the report.

References:

1) https://www.elprocus.com/pulse-amplitude-modulation/
2) https://www.tutorialspoint.com/principles_of_communication/principles_of_communication_analog_pulse_modulation.htm
3) https://jntua.ac.in/gate-online-classes/registration/downloads/material/a159143892914.pdf
4) https://blog.oureducation.in/sampling-techniques/
5) https://byjus.com/physics/pulse-amplitude-modulation/