

DEPARTMENT OF ELECTRONICS ENGINEERING

Madhav Institute of Technology & Science, Gwalior (M. P.)

(A Govt. Aided UGC Autonomous Institute Affiliated to R.G.P.V Bhopal M.P.)

DIGITAL COMMUNICATION

LAB MANUAL

(EC/ET-140513/200513)

DIGITAL COMMUNICATION (140505/200505)

List of Experiments

1. Perform Sampling and Reconstruction of continuous signal.
2. Identify the various line coding schemes for a given data stream.
3. Analyze Pulse Amplitude Modulation.
4. Analyze Pulse Width Modulation.
5. To generate the waveform of Amplitude Shift Keying signal.
6. To generate the waveform of Amplitude Shift Keying signal using MATLAB.
7. To generate the waveform of Phase Shift Keying signal using MATLAB.
8. To generate the waveform of Frequency Shift Keying signal using MATLAB.
9. To generate the waveform of Quadrature Phase Shift Keying signal using MATLAB.

Course Outcomes:

On completion of this Lab the student will be able to:

- CO1.** Understand sampling theorem.
- CO2.** Perform various lines coding techniques.
- CO3.** Construct different analog modulation technique.
- CO4.** Construct different digital modulation technique
- CO5.** Evaluate the performance of the digital communication system using MATLAB.

Experiment 1

Objective:

Perform sampling and reconstruction of continuous signal.

Apparatus Required:

1. Sampling and its reconstruction Kit - DCL 01
2. Digital Storage Oscilloscope (DSO)
3. Power supply
4. Patch cords

Theory:

The analog signal can be converted to a discrete time signal by a process called sampling. The sampling theorem for a band limited signal of finite energy can be stated as, "A band limited signal of finite energy, which has no frequency component higher than W Hz is completely described by specifying the values of the signal at instants of time separated by $1/2W$ seconds." It can be recovered from knowledge of samples taken at the rate of $2W$ per second. Figure 1.1 shows the complete waveforms of sampling process i.e. Input waveform, clock waveform, sampled waveform and reconstructed waveform.

$$f_s \geq 2f_m$$

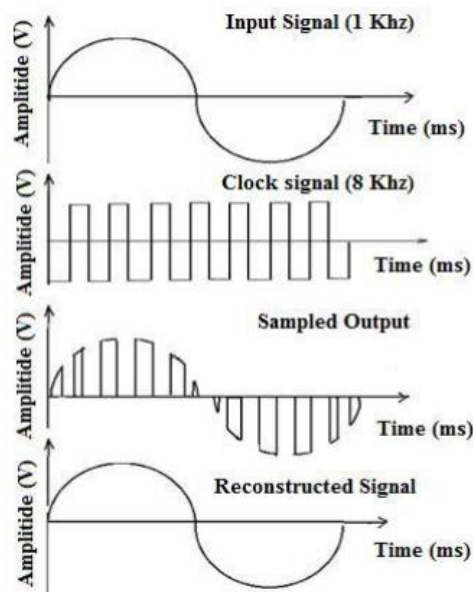


Fig 1.1 Model Graph for Signal samples and reconstruction.

Procedure:

1. The various blocks are connected as shown in figure 1.2.
2. Connect the power supply in proper polarity to the kit and & switch it on.
3. Using the clock selector switch select 8 KHz sampling frequency and using switch SW2 select 50% duty cycle.
4. The input and output waveforms are measured using CRO.
5. The procedure above is repeated for sample & hold and flat top sampling.

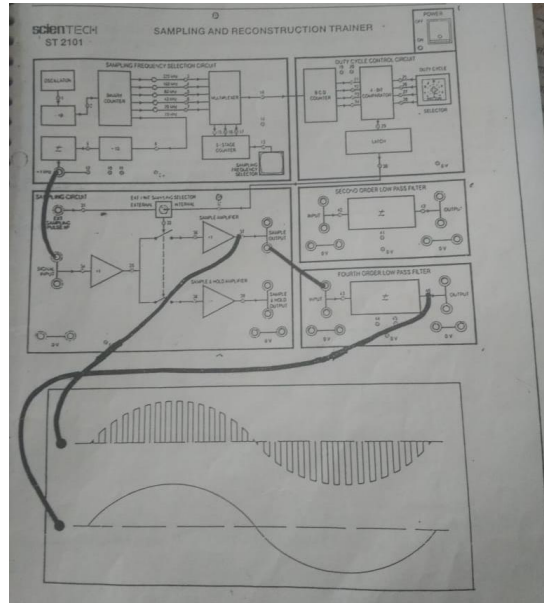


Fig. 1.2 sampling and reconstruction trainer kit

Observation: The different output waveforms shown in figures 1.3 to 1.4 are observed with the help of CRO and are traced with the help of graph paper.

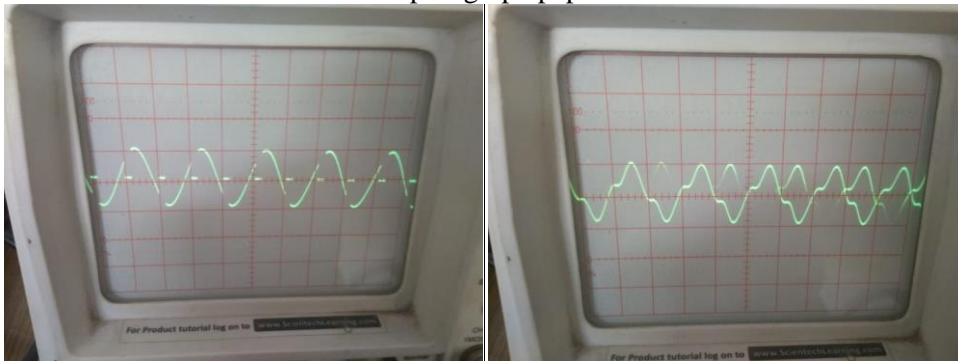


Fig. 1.3 sampled signal and reconstructed signal at 10 KHz

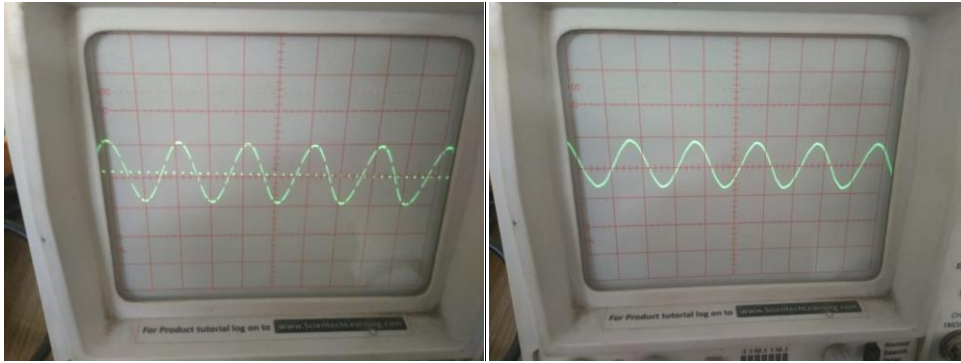


Fig. 1.4 sampled signal and reconstructed signal at 40 KHz

Conclusion:

The sampling of signal has been performed and it satisfies the Nyquist criteria for reconstruction.

Questions:

1. Define Nyquist Rate
2. What is Nyquist interval?
3. What is Aliasing and how it is reduced?
4. Compare Natural sampling and Flat Top sampling.

Precautions:

1. Check the connections before giving the supply.
2. Observations should be done carefully.

Experiment 2

Objective:

Identify the various Line Coding Schemes for a given data stream.

Apparatus Required:

1. Data Formatting kit
2. Cathode Ray Oscilloscope (CRO)
3. Binary Data Generator
4. Power supply
5. Patch cords

Theory:

'1' and '0' can be represented in various formats in different levels and waveforms. The selection of coding technique depends on system band width, system's ability to pass dc level information, error checking facility. Non return to Zero (level): The NRZ(L) waveform simply goes low for one bit time to represent a data '0' and high to represent data '1'. For lengthy data the clock is lost in asynchronous mode. The maximum rate at which NRZ can change is half the data clock when alternate 0's and 1's are there. In Manchester Biphase '0' is encoded low during first half of bit time & high for other half of bit & vice versa for '1'. There is no synchronization problem in the receiver. It is independent of DC levels, since there is a transition occurring in each bit. Its maximum frequency is equal to data clock rate. There is at least one transition per bit. Since there is midway transition, it makes clock regeneration difficult so we use special bi phase clock recovery circuit

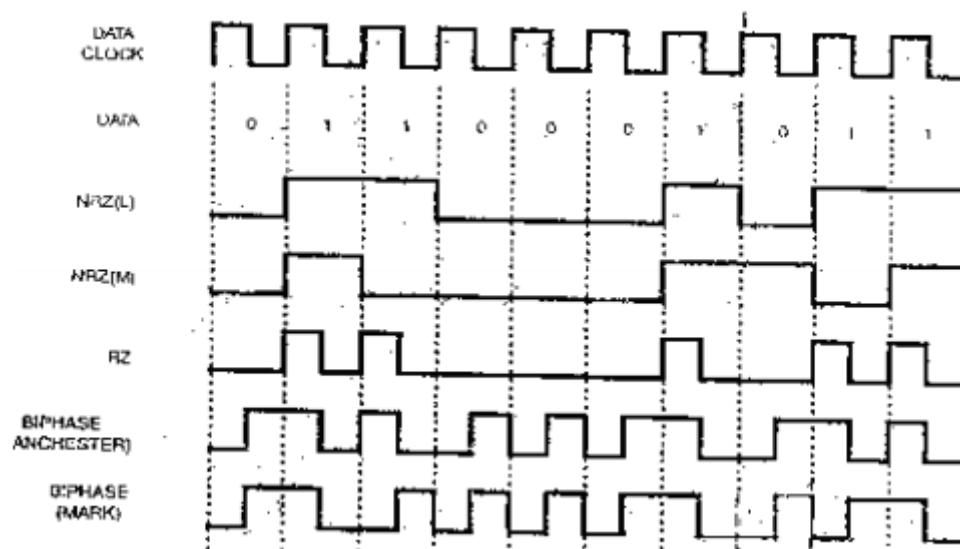


Fig. 2.1 various line coding schemes

Procedure:

1. Make the circuit as shown in figure 2.2.
2. Connect the power supply in proper polarity to the kit and & switch it on.
3. Set the pulse generator output to be 2Vpp at 8 KHz.
4. Observe waveform at output for various encoding scheme and trace on graph paper.

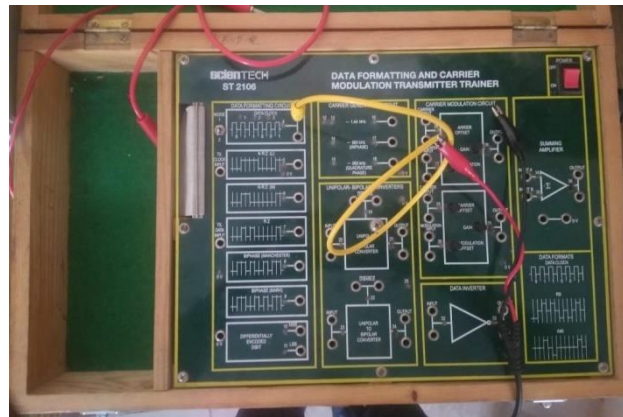


Fig. 2.2 Data formatting kit

Observation:

Figure 2.3 is the data clock. The different output waveforms shown in figures 2.4 (a) to (d) are observed with the help of CRO and are traced with the help of graph paper.

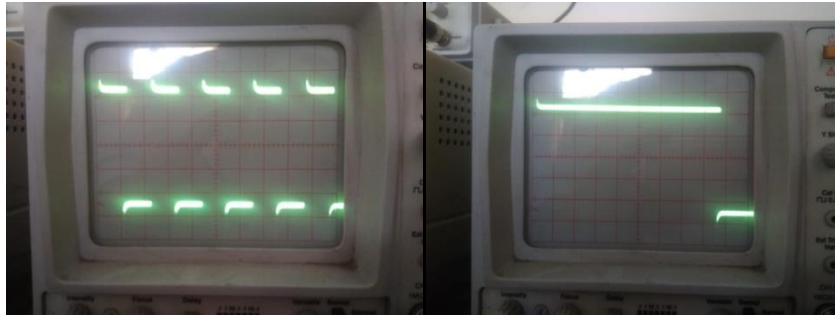


Fig. 2.3 data clock



(a)

(b)



(c)

(d)

Fig. 2.4 various coding scheme (a) NRZ (b) RZ (c) Bi-phase (d) Differentially Encoded

Conclusion:

The study of various encoding scheme has been successfully done.

Questions:

1. What is the use of data formatting?
2. Compare NRZ and biphase encoding.
3. What is the relationship between quantization levels and number of bits in a code word?
4. Give the advantages of Manchester encoding.

Precautions:

1. Check the connections before giving the supply.
2. Observations should be done carefully.

Experiment 3

Objective:

Analyze Pulse Amplitude Modulation (PAM).

Apparatus Required:

1. Pulse Amplitude Modulation Kit
2. Cathode Ray Oscilloscope (CRO)
3. Power supply
4. Patch cords

Theory:

In Pulse Amplitude Modulation (PAM) message information is encoded in the amplitude of a series of signal pulses. It is an analog pulse modulation scheme in which the amplitude of train of carrier pulses is varied according to the sample value of the message signal. A train of very short pulses of constant amplitude and fast repetition rate is chosen the amplitude of these pulse is made to vary in accordance with that of a slower modulating signal the result is that of multiplying the train by the modulating signal the envelope of the pulse height corresponds to the modulating wave. The PAM wave contain upper and lower side band frequencies besides the modulating and pulse signals. Figure 3.1 (a) shows the waveforms for message signal (b) shows the carrier pulse train and (c) shows the PAM signal.

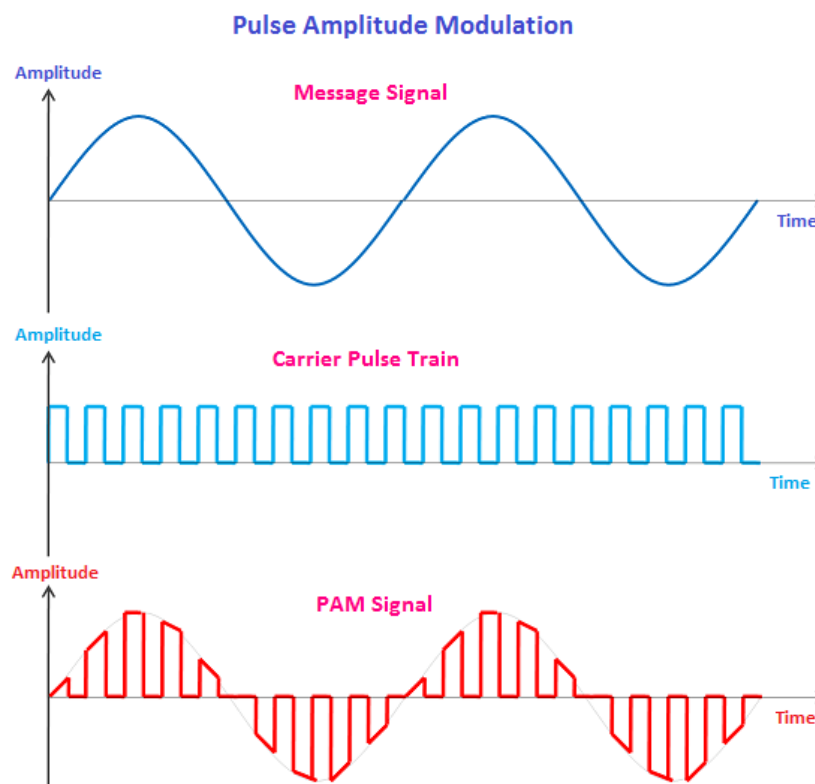


Fig. 3.1 (a) Message Signal (b) Carrier Signal (c) PAM Signal

Procedure:

1. Make the circuit as shown in figure 3.2.
2. Connect the power supply in proper polarity to the kit and & switch it on.
3. Set the pulse generator output to be 2Vpp at 8 KHz.
4. The sampled and reconstructed waveforms are measured using CRO.
5. Repeat for different frequency of pulse generator.

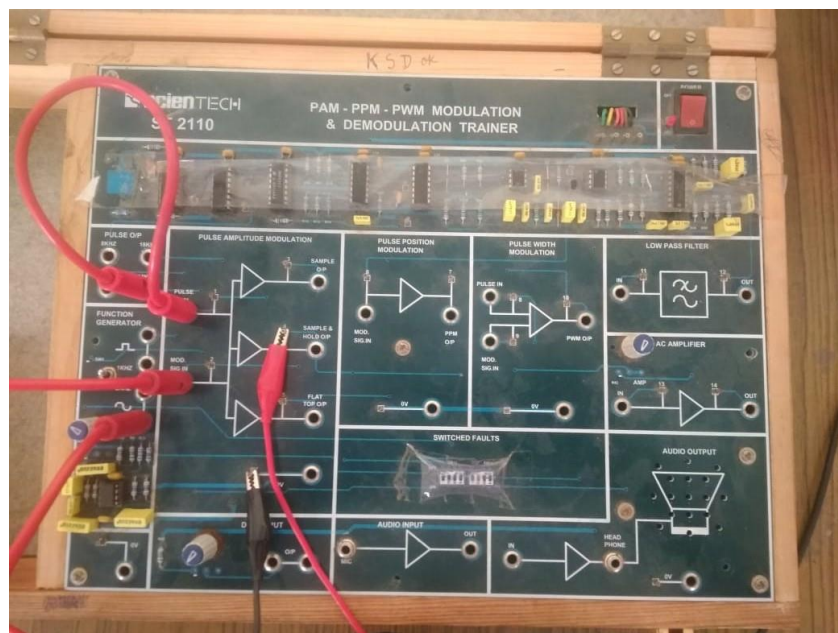


Fig. 3.2 PAM trainer kit

Observation:

The different output waveforms shown in figures 3.3 to 3.6 are observed with the help of CRO and are traced with the help of graph paper.

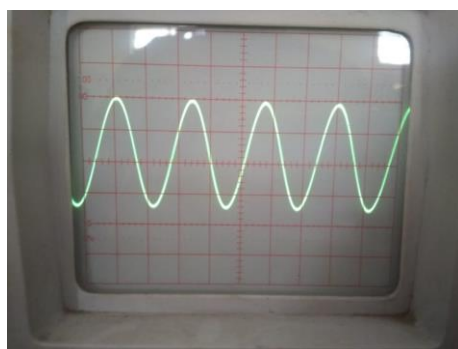


Fig. 3.3 Modulating Signal

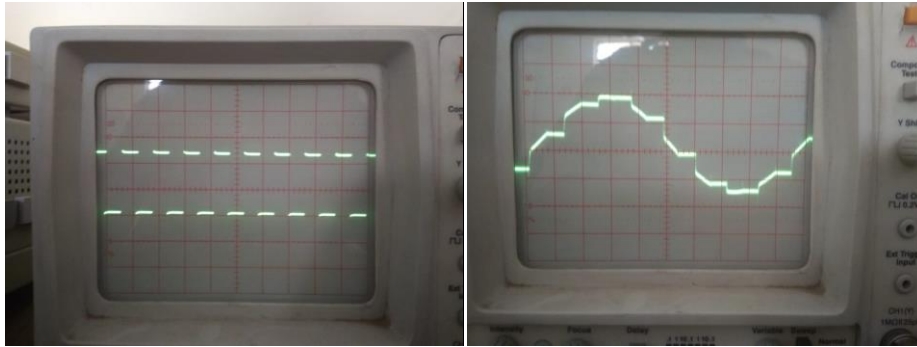


Fig. 3.4 carrier signal (16 khz) and pulse Amplitude modulated Signal

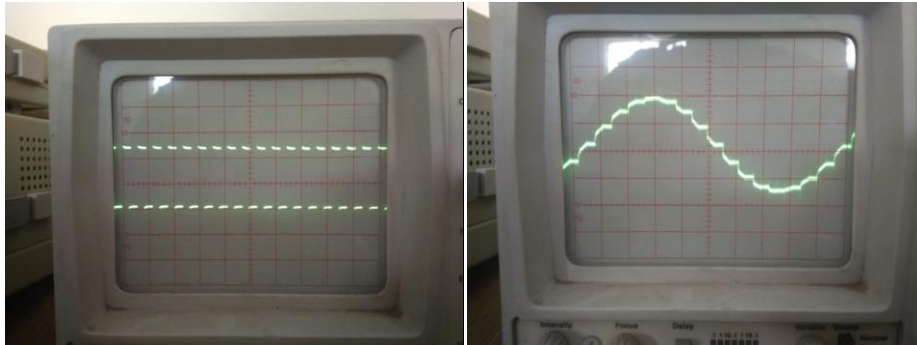


Fig. 3.5 carrier signal at (32 khz) and pulse Amplitude modulated Signal

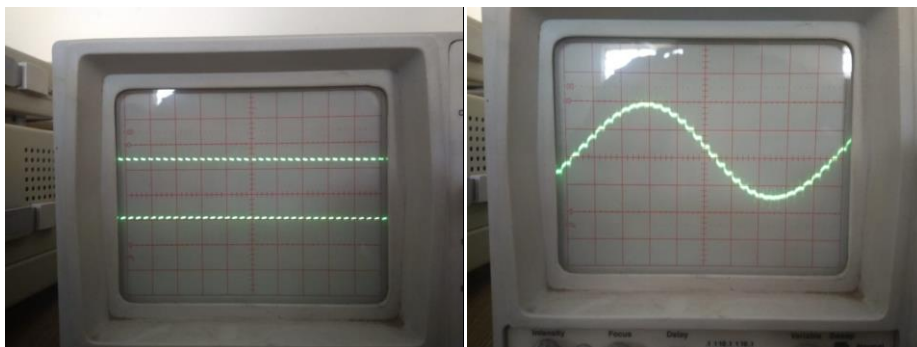


Fig. 3.6 carrier signal at (64 khz) and pulse Amplitude modulated Signal

Conclusion:

The study of pulse amplitude modulation using switching method and by sample and hold circuit has been successfully done.

Question:

1. What is Pulse Amplitude modulation?
2. Why PAM is not preferable in digital transmission?
3. Explain in brief sample and hold method.
4. Write the advantages and disadvantages of PAM.

Precautions:

1. Check the connections before giving the supply.
2. Observations should be done carefully.

Experiment 4

Objective:

Analyze Pulse Width Modulation (PWM).

Apparatus Required:

1. Pulse width modulation kit
2. Cathode Ray Oscilloscope (DSO)
3. Power supply
4. Patch cords

Theory:

In PPM system, the position of the pulses relative to zero reference level is varied in accordance with the instantaneous level of modulating signal as shown in figure 4.1. Amplitude and width of the pulses are kept constant. In this system, the position of each pulse is related to the position of the recurrent reference pulse. The N message bits are encoded by transmitting a single pulse in one of $2N$ possible time shifts. This is repeated every T seconds, such that the transmitted bit rate is N/T bits per second. It is primarily used for radio communication, control of aircrafts, cars etc.

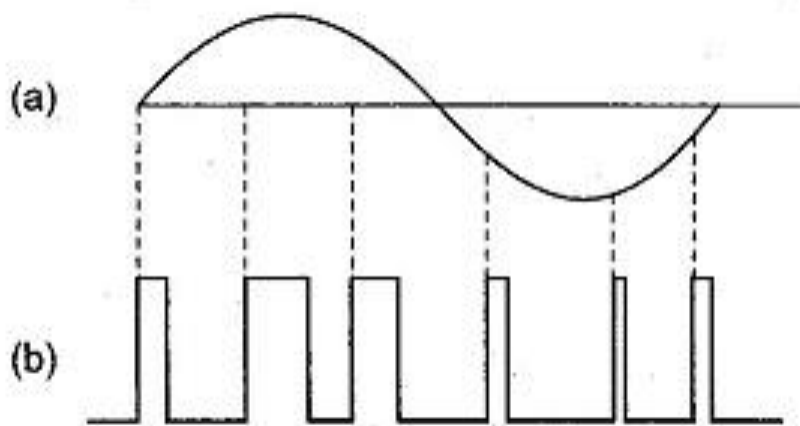


Fig. 4.1 Pulse Width Modulation (a) Signal (b) PWM

Procedure:

1. Make the circuit as shown in figure 4.2.
2. Connect the power supply in proper polarity to the kit and & switch it on.
3. Set the pulse generator output to be $2V_{pp}$ at 8 KHz.
4. The input and output waveforms are measured using CRO.

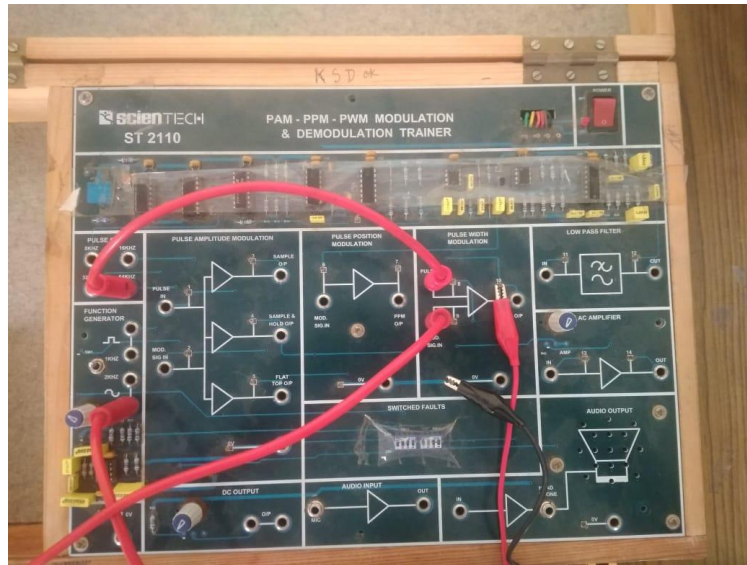


Fig. 4.2 PWM trainer kit

Observation:

The different output waveforms shown in figures 4.3 to 4.4 are observed with the help of CRO and are traced with the help of graph paper.

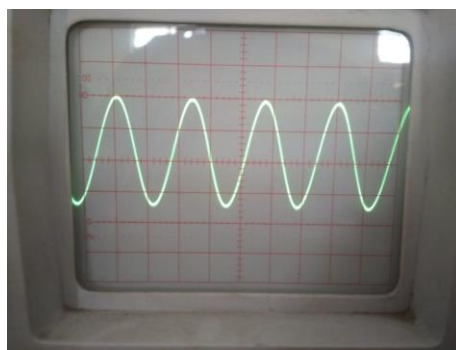


Fig. 4.3 Modulating Signal

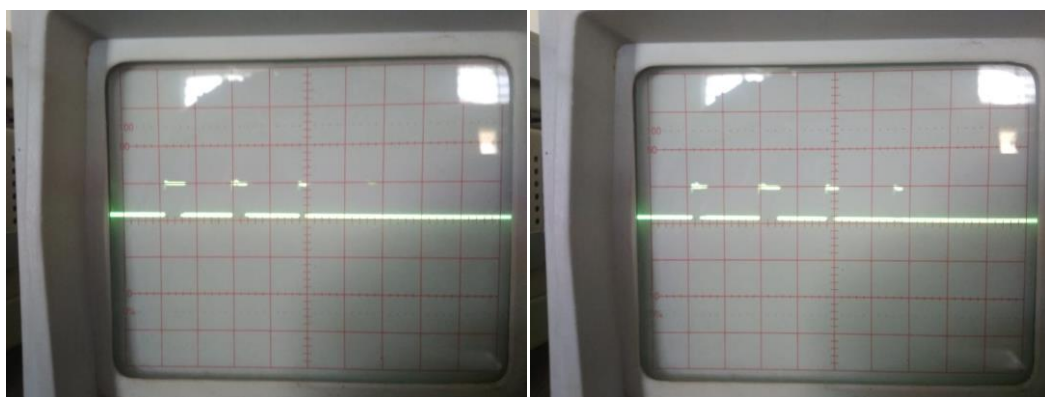


Fig. 4.4 carrier signal and pulse width modulated Signal.

Conclusion:

The study of pulse width modulation has been carried out successfully.

Question:

1. What is PWM?
2. An audio signal consists of frequencies in the range of 100Hz to 5.5KHz. What is the minimum frequency at which it should be sampled in order to transmit it through pulse modulation?
3. What do you infer from the frequency spectrum of a PWM signal?
4. Describe the spectral representation of PWM.

Precautions:

1. Check the connections before giving the supply.
2. Observations should be done carefully.

Experiment 5

Objective:

To generate the waveform of Amplitude Shift Keying (ASK) signal.

Apparatus Required:

1. Amplitude Shifting Key Kit
2. Cathode Ray Oscilloscope (CRO)
3. Power supply
4. Patch cords

Theory:

Amplitude shift keying (ASK) is the simplest digital modulation technique. In this modulation method there is only one carrier which is switched ON/OFF depending upon the input binary sequence to transmit symbol 0 and 1. The binary ASK system was one of the earliest form of digital modulation used in wireless telegraphy. In a binary ASK system binary symbol 1 is represented by transmitting a sinusoidal carrier wave of fixed amplitude A_c and fixed frequency f_c for the bit duration T_b where as binary symbol 0 is represented by switching of the carrier for T_b seconds. This signal can be generated simply by turning the carrier of a sinusoidal oscillator ON and OFF for the prescribed periods indicated by the modulating pulse train. For this reason the scheme is also known as on-off shift testing. The ASK signal can be generated by applying the incoming binary data and the sinusoidal carrier to the two inputs of a product modulator. The resulting output is the ASK wave as shown in figure 5.1.

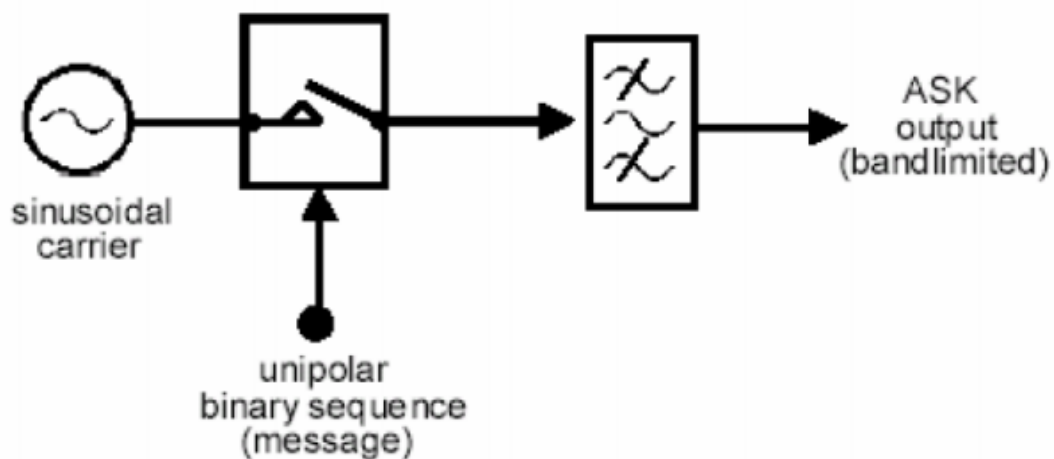


Fig. 5.1 Block diagram for ASK

Procedure:

1. Make the circuit as shown in figure 5.2.
2. Connect the power supply in proper polarity to the kit and & switch it on.
3. The input and output waveforms are measured using CRO.

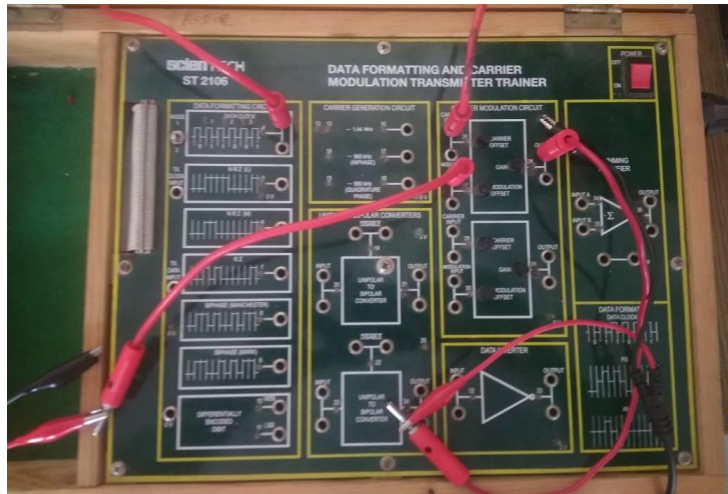


Fig. 5.2 ASK trainer kit

Observation:

The waveforms of CRO shown in figure 5.3 is modulating signal, figure 5.4 (a) is carrier signal and figure 5.4 (b) is PWM signal which are traced with the help of graph paper.

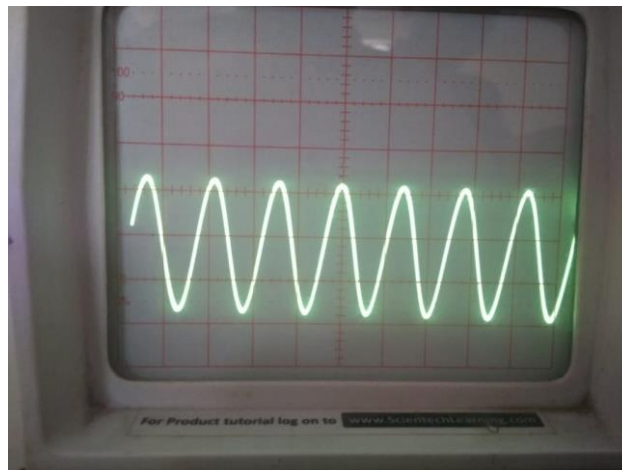


Fig. 5.3 Modulating Signal

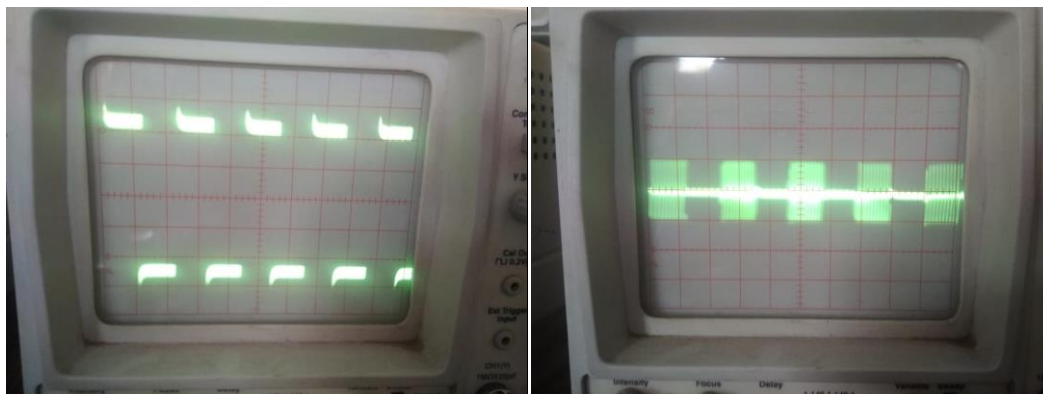


Fig. 5.4 (a) carrier signal and (b) PWM Signal.

Conclusion:

The study of amplitude shifting keying has been carried out successfully.

Question:

1. Define Amplitude Shift Keying.
2. What are the applications of ASK?
3. What is band-limiting?
4. What is the difference between ASK and OOK?

Precautions:

1. Check the connections before giving the supply.
2. Observations should be done carefully.

**SOFTWARE SIMULATION
(MATLAB)**

Experiment 6

Objective:

To generate the waveform of Amplitude Shift Keying (ASK) signal using MATLAB.

Software required:

MATLAB, Computer installed with Windows XP or higher Version.

Theory:

Generation of ASK:

Amplitude shift keying - ASK - is a modulation process, which imparts to a sinusoid two or more discrete amplitude levels. These are related to the number of levels adopted by the digital message. For a binary message sequence there are two levels, one of which is typically zero. The data rate is a sub-multiple of the carrier frequency. Thus the modulated waveform consists of bursts of a sinusoid. The disadvantage of ASK, compared with FSK and PSK, is that it has not a constant envelope. This makes its processing (eg. power amplification) more difficult, since linearity becomes an important factor. However, it does make for ease of demodulation with an envelope detector.

ASK modulation:

1. Generate carrier signal.
2. Start FOR loop
3. Generate binary data and message signal (on-off form)
4. Generate ASK modulated signal.
5. Plot message signal and ASK modulated signal.
6. End FOR loop.
7. Plot the binary data and carrier.

Program:

%ASK Modulation

```
clc;  
clear all;  
close all;
```

%Generate Carrier Signal

```
Tb=1; fc=10;  
t=0:Tb/100:1;  
c=sqrt(2/Tb)*sin(2*pi*fc*t);
```

%Generate Message Signal

```
N=8;  
m=rand(1,N);  
t1=0;t2=Tb  
for i=1:N t=[t1:.01:t2]  
if m(i)>0.5  
m(i)=1;  
m_s=ones(1,length(t));  
else m(i)=0;  
m_s=zeros(1,length(t));
```

```

end
message(i,:)=m_s;

%product of carrier and message
ask_sig(i,:)=c.*m_s;
t1=t1+(Tb+.01);
t2=t2+(Tb+.01);

% Plot the message and ASK signal
subplot(5,1,2);
axis([0 N -2 2]);
plot(t,message(i,:),'r');
title('message signal');
xlabel('t-->');
ylabel('m(t)');
grid on
hold on
subplot(5,1,4);
plot(t,ask_sig(i,:));
title('ASK signal');
xlabel('t-->');
ylabel('s(t)');
grid on
hold on
end
hold off

%Plot the carrier signal and input binary data
subplot(5,1,3);
plot(t,c);
title('carrier signal');
xlabel('t-->');
ylabel('c(t)');
grid on
subplot(5,1,1);
stem(m);
title('binary data bits');
xlabel('n-->');
ylabel('b(n)');
grid on

```

Observation: The desired ASK waveforms i.e. binary data, message signal, carrier signal and output waveforms are shown in figure 6.1.

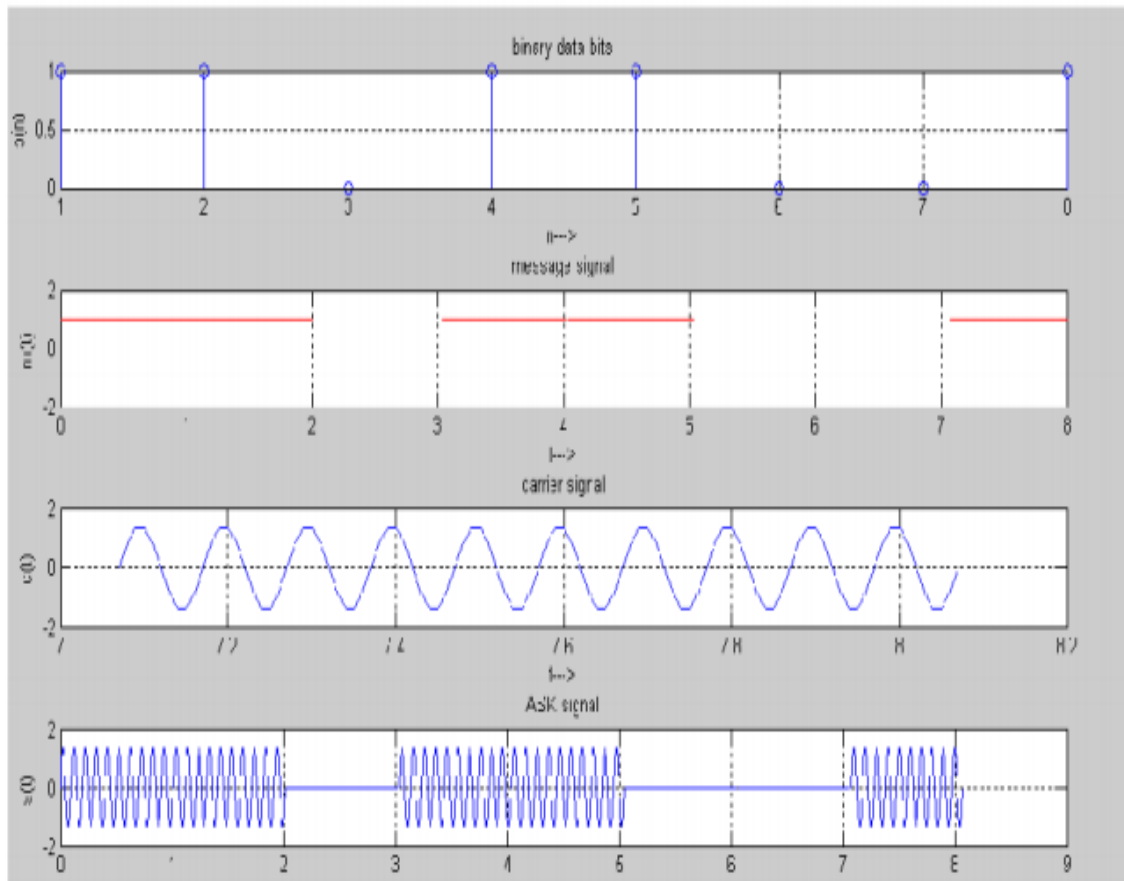


Fig. 6.1 ASK waveform

Conclusion:

The program for ASK modulation has been simulated in MATLAB and observed the desired waveforms.

Question:

1. What is ASK?
2. Write a MATLAB program to generate sinc function
3. Differentiate plot and subplot commands in MATLAB.

Experiment 7

Objective:

To generate the waveform of Phase Shift Keying (PSK) signal using MATLAB

Software required:

MATLAB, Computer installed with Windows XP or higher Version.

Theory:

Generation of PSK

Generation of PSK signal PSK is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data.

In a coherent binary PSK system, the pair of signal $S_1(t)$ and $S_2(t)$ used to represent binary symbols 1 & 0 are defined by

$$S_1(t) = \sqrt{2E_b/T_b} \cos 2\pi f_c t$$

$$S_2(t) = \sqrt{2E_b/T_b} (2\pi f_c t + \pi) = -\sqrt{2E_b/T_b} \cos 2\pi f_c t \quad \text{where } 0 \leq t < T_b \text{ and}$$

E_b = Transmitted signed energy for bit

The carrier frequency $f_c = n/T_b$ for some fixed integer n .

Antipodal Signal:

The pair of sinusoidal waves that differ only in a relative phase shift of 180° are called antipodal signals.

BPSK Transmitter

The input binary symbols are represented in polar form with symbols 1 & 0 represented by constant amplitude levels $\sqrt{E_b}$ & $-\sqrt{E_b}$. This binary wave is multiplied by a sinusoidal carrier in a product modulator. The result is a BPSK signal as shown in figure 7.1.

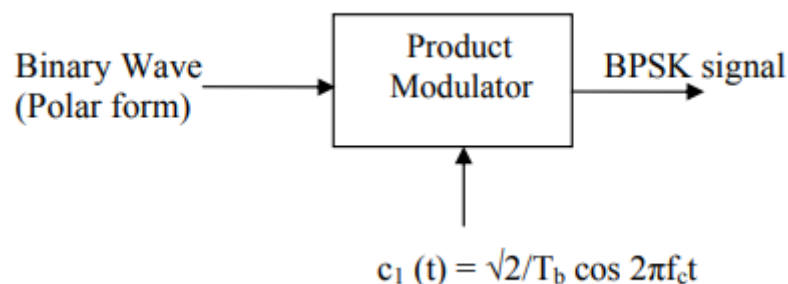


Fig. 7.1 Block Diagram of BPSK Transmitter

PSK modulation:

1. Generate carrier signal.
2. Start FOR loop

3. Generate binary data, message signal in polar form
4. Generate PSK modulated signal.
5. Plot message signal and PSK modulated signal.
6. End FOR loop.
7. Plot the binary data and carrier.

Program:

% PSK modulation

```

clc;
clear all;
close all;

%Generate Carrier Signal
Tb=1;
t=0:Tb/100:Tb;
fc=2;
c=sqrt(2/Tb)*sin(2*pi*fc*t);
% generate message signal
N=8;
m=rand(1,N);
t1=0;t2=Tb
for i=1:N
t=[t1:.01:t2]
if m(i)>0.5
m(i)=1;
m_s=ones(1,length(t));
else
m(i)=0;
m_s=-1*ones(1,length(t));
end
message(i,:)=m_s;

```

%product of carrier and message signal bpsk

```
sig(i,:)=c.*m_s;
```

%Plot the message and BPSK modulated signal

```

subplot(5,1,2);
axis([0 N -2 2]);
plot(t,message(i,:),'r');
title('message signal(POLAR form)');
xlabel('t-->');
ylabel('m(t)');
grid on;
hold on;
subplot(5,1,4);
plot(t,bpsk_sig(i,:));
title('BPSK signal');
xlabel('t-->');
ylabel('s(t)');
grid on;
hold on;
t1=t1+1.01;
t2=t2+1.01;
end
hold off

```

%plot the input binary data and carrier signal

```
subplot(5,1,1);  
stem(m);  
title('binary data bits');  
xlabel('n-->');  
ylabel('b(n)');  
grid on;  
subplot(5,1,3);  
plot(t,c);  
title('carrier signal');  
xlabel('t-->');  
ylabel('c(t)');  
grid on;
```

Observation: The desired BPSK waveforms i.e. binary data, message signal, carrier signal and output waveforms are shown in figure 6.1.

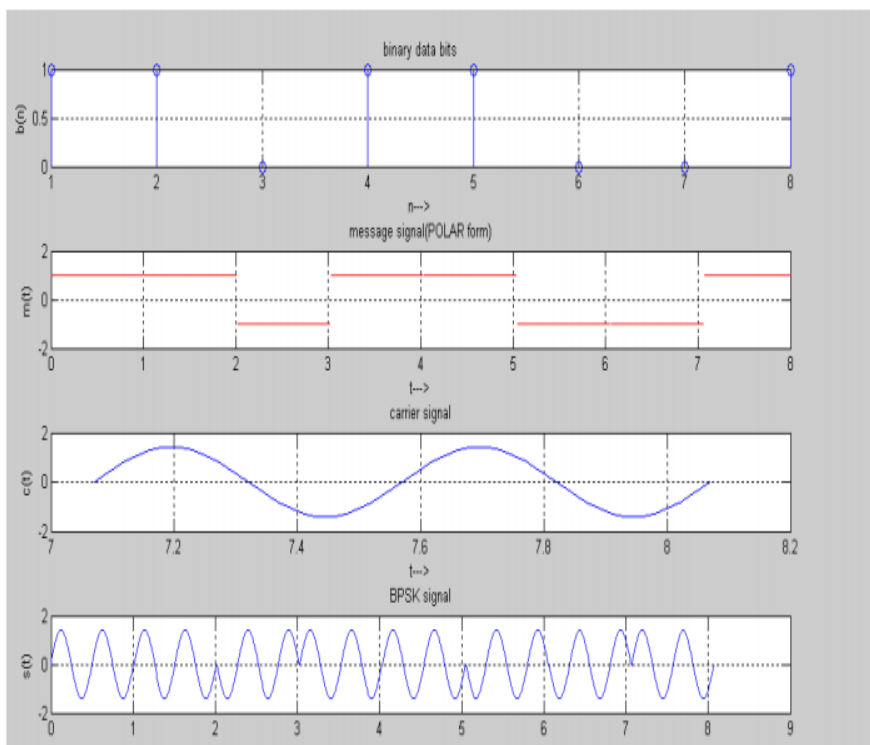


Fig. 7.2 BPSK waveform

Conclusion:

The program for binary PSK modulation has been simulated in MATLAB and observed the desired waveforms.

Question:

1. Write down the drawback of DPSK compared to BPSK?
2. Why do we make 180 degree phase shift in PSK and why not 90 or 270? Comment on this.
3. Compare FSK and PSK.

Experiment 8

Objective:

To generate the waveform of Frequency Shift Keying (FSK) signal using MATLAB.

Software required:

MATLAB, Computer installed with Windows XP or higher Version.

Theory:

Generation of FSK

Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

In binary FSK system, symbol 1 & 0 are distinguished from each other by transmitting one of the two sinusoidal waves that differ in frequency by a fixed amount.

$$S_i(t) = \begin{cases} \sqrt{2E/T_b} \cos 2\pi f_i t & 0 \leq t \leq T_b \\ 0 & \text{elsewhere} \end{cases}$$

where $i=1, 2$ & $E_b = \text{Transmitted energy/bit}$

Transmitted freq = $f_i = (n_c + i)/T_b$, and $n = \text{constant (integer)}$, $T_b = \text{bit interval}$

Symbol 1 is represented by $S_1(t)$ and Symbol 0 is represented by $S_0(t)$

BFSK Transmitter

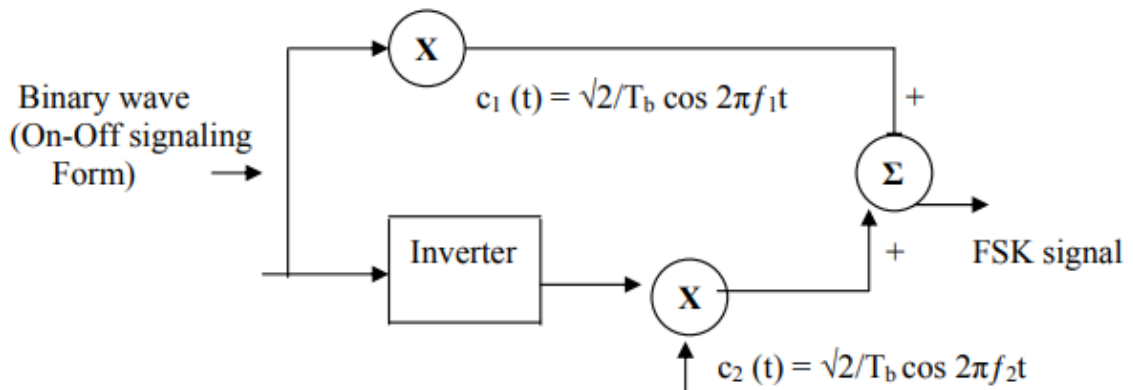


Fig. 8.1 Block Diagram of BFSK Transmitter

The input binary sequence is represented in its ON-OFF form, with symbol 1 represented by constant amplitude of $\sqrt{E_b}$ with & symbol 0 represented by zero volts. By using inverter in the lower channel, we in effect make sure that when symbol 1 is at the input, The two frequency f_1 & f_2 are chosen to be equal integer multiples of the bit rate $1/T_b$. By summing the upper & lower channel outputs, we get BFSK signal as shown in figure 8.1.

FSK modulation

1. Generate two carriers signal.
2. Start FOR loop
3. Generate binary data, message signal and inverted message signal
4. Multiply carrier 1 with message signal and carrier 2 with inverted message signal
5. Perform addition to get the FSK modulated signal
6. Plot message signal and FSK modulated signal.

7. End FOR loop.
8. Plot the binary data and carriers.

Program:

% FSK Modulation

```
clc;
clear all;
close all;
```

%Generate Carrier Signal

```
Tb=1;
fc1=2;fc2=5;
t=0:(Tb/100):Tb;
c1=sqrt(2/Tb)*sin(2*pi*fc1*t);
c2=sqrt(2/Tb)*sin(2*pi*fc2*t);
```

%generate message signal

```
N=8;
m=rand(1,N);
t1=0;t2=Tb
for i=1:N
t=[t1:(Tb/100):t2]
if m(i)>0.5
m(i)=1;
m_s=ones(1,length(t));
inv_m_s=zeros(1,length(t));
else
m(i)=0;
m_s=zeros(1,length(t));
inv_m_s=ones(1,length(t));
end
message(i,:)=m_s;
```

%Multiplier

```
fsk_sig1(i,:)=c1.*m_s;
fsk_sig2(i,:)=c2.*inv_m_s;
fsk=fsk_sig1+fsk_sig2;
```

%plotting the message signal and the modulated signal

```
subplot(3,2,2);
axis([0 N -2 2]);
plot(t,message(i,:),'r');
title('message signal');
xlabel('t---->');
ylabel('m(t)');
grid on;
hold on;
subplot(3,2,5);
plot(t,fsk(i,:));
title('FSK signal');
xlabel('t---->');
ylabel('s(t)');
grid on;
hold on;
```

```

t1=t1+(Tb+.01);
t2=t2+(Tb+.01);
end
hold off

```

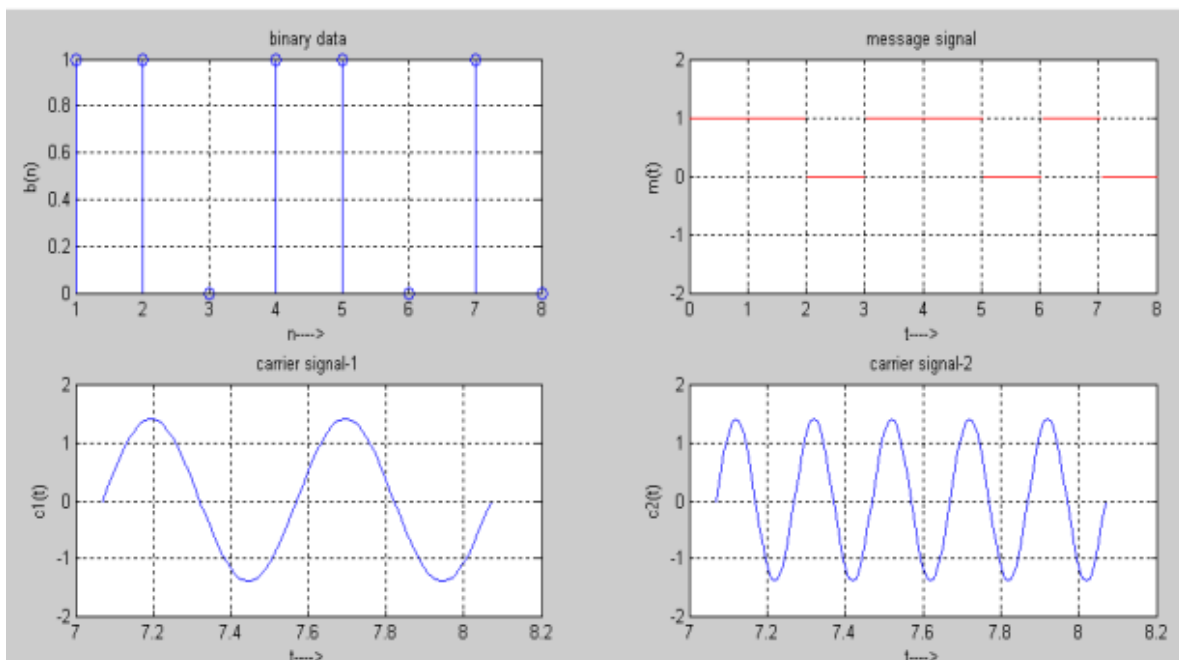
%Plotting binary data bits and carrier signal

```

subplot(3,2,1);
stem(m);
title('binary data');
xlabel('n---->');
ylabel('b(n)');
grid on;
subplot(3,2,3);
plot(t,c1);
title('carrier signal-1');
xlabel('t---->');
ylabel('c1(t)');
grid on;
subplot(3,2,4);
plot(t,c2);
title('carrier signal-2');
xlabel('t---->');
ylabel('c2(t)');
grid on;

```

Observation: The desired BFSK waveforms i.e. binary data, message signal, carrier signal 1&2 and output waveforms are shown in figure 8.2.



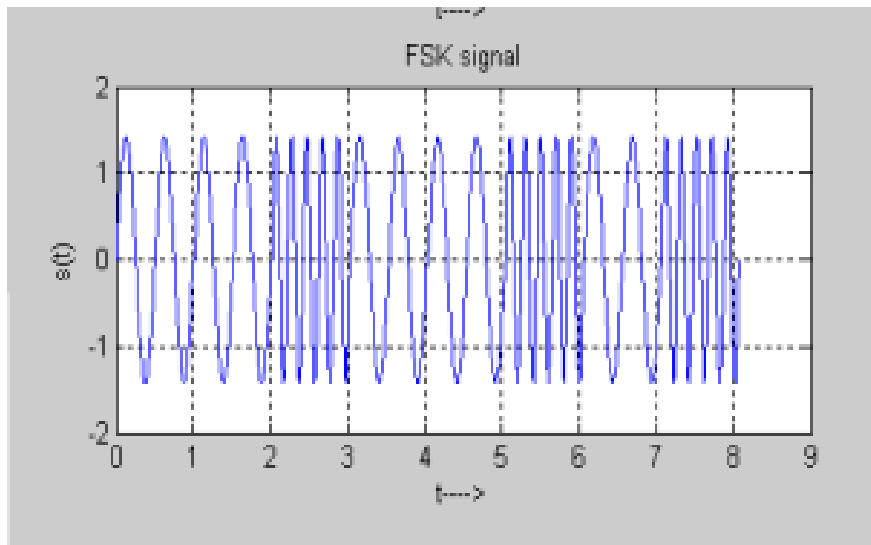


Fig. 8.2 BFSK waveform

Conclusion:

The program for binary FSK modulation has been simulated in MATLAB and observed the desired waveforms.

Question:

1. Determine the bandwidth and baud for BFSK signal with mark frequency of 49 KHz, a space frequency of 51 KHz, and a bit rate of 2 Kbps.
2. Write a MATLAB program for finding the sum of series $1 + 2 + 3 + \dots + N$.
3. Sketch the FSK waveform for the input a) 1010110 b) 1100101.
4. Write the advantages of FSK compared to ASK?

Experiment 9

Objective:

To generate the waveform for Quadrature Phase Shift Keying (QPSK) signal using MATLAB

Software required:

MATLAB, Computer installed with Windows XP or higher Version.

Theory:

Generation of Quadrature phase shift keyed (QPSK) signal:

QPSK is also known as quaternary PSK, quadriphase PSK, 4-PSK, or 4-QAM. It is a phase modulation technique that transmits two bits in four modulation states.

Phase of the carrier takes on one of four equally spaced values such as $\pi/4, 3\pi/4, 5\pi/4$ and $7\pi/4$.

$$S_i(t) = \begin{cases} \sqrt{2E/T} \cos \{ 2\pi f_c t + (2i - 1)\pi/4 \} , & 0 \leq t \leq T \\ 0, & \text{elsewhere} \end{cases}$$

where $i = 1,2,3,4$, E = transmitted signal energy per symbol and T = symbol duration.

Each of the possible value of phase corresponds to a pair of bits called dibits.

Thus the gray encoded set of dibits: 10,00,01,11

$$S_i(t) = \begin{cases} \sqrt{2E/T} \cos [(2i - 1)\pi/4] \cos (2\pi f_c t) - \sqrt{2E/T} \sin [(2i - 1)\pi/4] \sin (2\pi f_c t) , & 0 \leq t \leq T_b \\ 0, & \text{else where} \end{cases}$$

There are two orthonormal basis functions

$$c_1(t) = \sqrt{2/T} \cos 2\pi f_c t, \quad 0 \leq t \leq T_b$$

$$c_2(t) = \sqrt{2/T} \sin 2\pi f_c t, \quad 0 \leq t \leq T_b$$

There are four message points

Block diagram of QPSK Transmitter

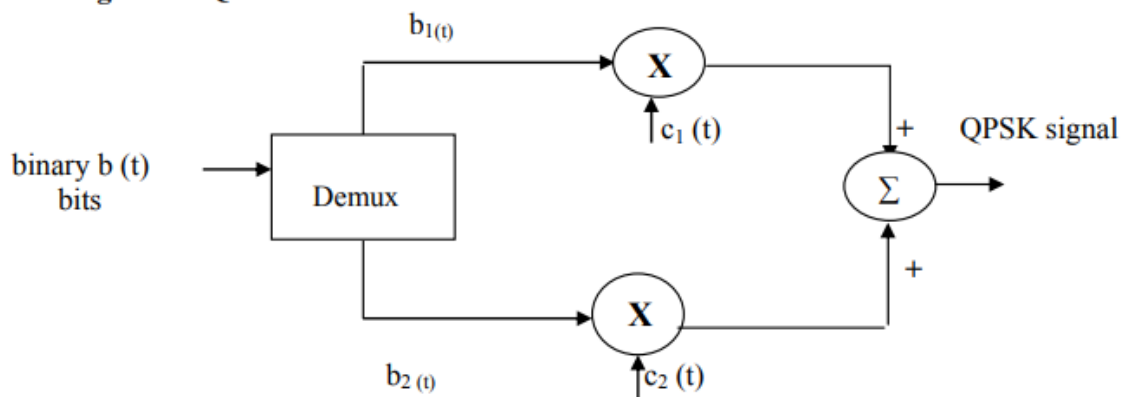


Fig. 9.1 Block Diagram of QPSK Transmitter

The I/p binary sequence $b(t)$ is represented in polar form with symbols 1 & 0 represented as $+\sqrt{E}/2$ and $-\sqrt{E}/2$. This binary wave is demultiplexed into two separate binary waves consisting of odd & even numbered I/P bits denoted by $b_1(t)$ & $b_2(t)$. $b_1(t)$ & $b_2(t)$ are used to modulate a pair of

quadrature carrier. This results two PSK waves .These two binary PSK waves are added to produce the desired QPSK signal as shown in figure 9.1.

QPSK modulation:

1. Generate quadrature carriers.
2. Start FOR loop
3. Generate binary data, message signal(bipolar form)
4. Multiply carrier 1 with odd bits of message signal and carrier 2 with even bits of message signal
5. Perform addition of odd and even modulated signals to get the QPSK modulated signal
6. Plot QPSK modulated signal.
7. End FOR loop.
8. Plot the binary data and carriers.

Program:

% QPSK Modulation

```
clc;
clear all;
close all;
%Generate Quadrature Carrier Signal
Tb=1;
t=0:(Tb/100):Tb;
fc=1;
c1=sqrt(2/Tb)*cos(2*pi*fc*t);
c2=sqrt(2/Tb)*sin(2*pi*fc*t);
%generate message signal
N=8;
m=rand(1,N);
t1=0;t2=Tb
for i=1:2:(N-1)
t=[t1:(Tb/100):t2]
if m(i)>0.5
m(i)=1;
m_s=ones(1,length(t));
else
m(i)=0;
m_s=-1*ones(1,length(t));
end
%odd bits modulated signal
odd_sig(i,:)=c1.*m_s;
if m(i+1)>0.5
m(i+1)=1;
m_s=ones(1,length(t));
else
m(i+1)=0;
m_s=-1*ones(1,length(t));
end
%even bits modulated signal
even_sig(i,:)=c2.*m_s;
%qpsk signal
qpsk=odd_sig+even_sig;
%Plot the QPSK modulated signal
subplot(3,2,4);
plot(t,qpsk(i,:));
title('QPSK signal');
xlabel('t---->');
```

```

ylabel('s(t)');
grid on;
hold on;
t1=t1+(Tb+.01);
t2=t2+(Tb+.01);
end
hold off
%Plot the binary data bits and carrier signal
subplot(3,2,1);
stem(m);
title('binary data bits');
xlabel('n---->');
ylabel('b(n)');
grid on;
subplot(3,2,2);
plot(t,c1);
title('carrier signal-1');
xlabel('t---->');
ylabel('c1(t)');
grid on;
subplot(3,2,3);
plot(t,c2);
title('carrier signal-2');
xlabel('t---->');
ylabel('c2(t)');
grid on;

```

Observation: The desired QPSK waveforms i.e. binary data, message signal, carrier signal 1& 2 and output waveforms are shown in figure 9.2.

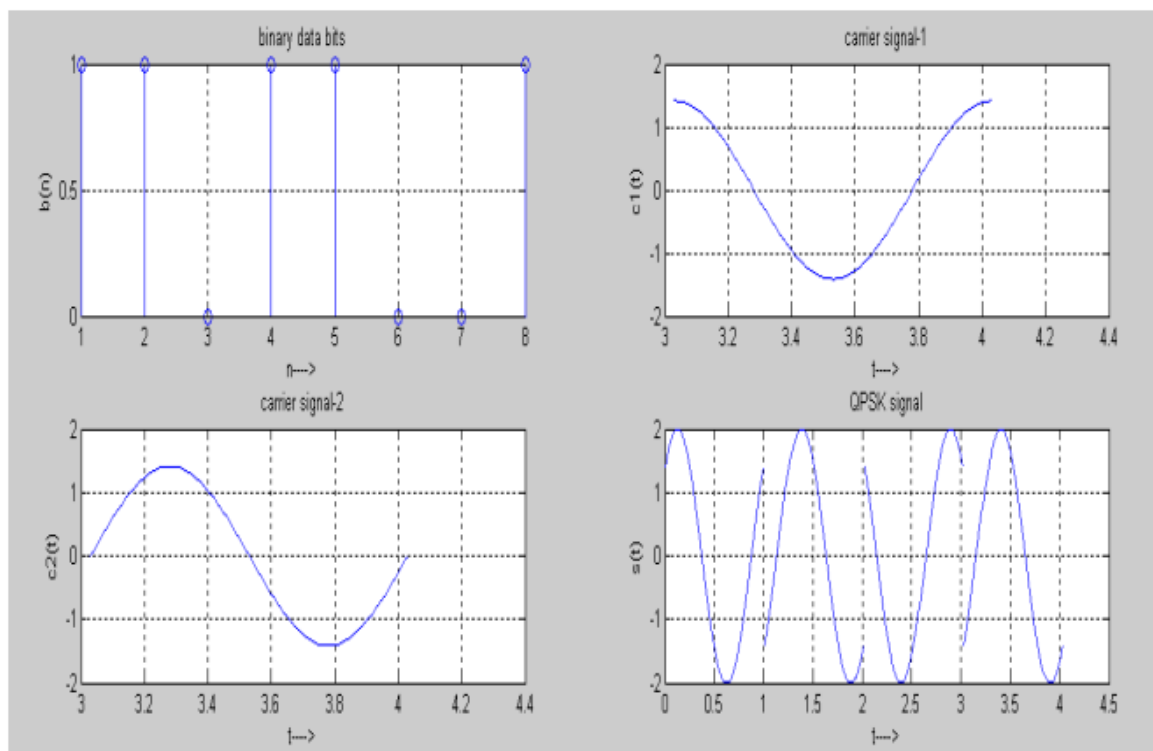


Fig. 8.2 BFSK waveform

Conclusion:

The program for QPSK modulation has been simulated in MATLAB and observed the desired waveforms.

Question:

1. Write a MATLAB program to sample a message signal $m(t)$ and reconstruct it.
2. Draw the constellation diagram of QPSK.
3. Write the applications of QPSK.