MODERN EDUCATION SOCIETY COLLEGE OF ENGINEERING PUNE

ELECTRONICS AND TELECOMMUNICATION DEPARTMENT

DIGITAL COMMUNICATION LIST OF EXPERIMENT

1. **Study of BPSK transmitter & receiver using hardware setup/kit.**

Practical:

Generate BPSK signal and reconstruct original signal using hardware set

Observe waveform and draw on graph paper

Theroy:

Draw transmitter and receiver block diagram

Draw spectrum and show bandwidth

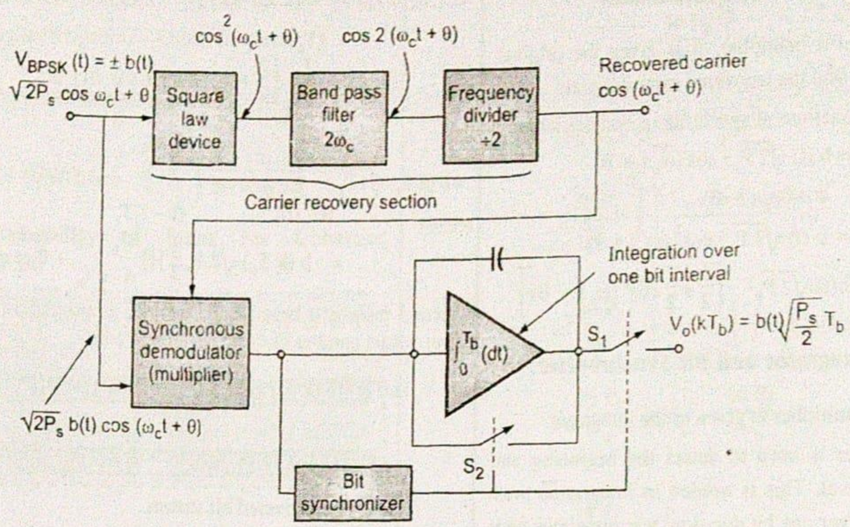
Draw constellation diagram and show euclidean distance.

Write formula of bandwidth, euclidean distance, error probability , bit rate, symbol rate

2.5.2 BPSK Receiver

GQ. Explain coherent BPSK receiver with neat block diagram.

Ans. :



(1E24)Fig. 2.5.2 : Block diagram of BPSK receiver

☑ **Soln. :**

Given :

(1) $x_{01}(T) = +V$

(2) $x_{02}(T) = 0$

$$\text{Decision Threshold} = \frac{x_{01}(T) + x_{02}(T)}{2} = \frac{V+0}{2} = \frac{V}{2}$$

2.5 BINARY PHASE SHIFT KEYING (BPSK)

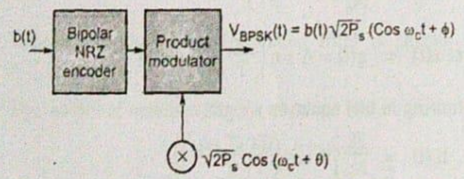
Generation and detection of BPSK

2.5.1 BPSK Transmitter

GQ. Explain BPSK transmitter with neat block diagram.

☑ **Ans. :**

Refer Fig. 2.5.1. It shows block diagram of BPSK generator and coherent BPSK receiver.



(1E32)**Fig. 2.5.1 : Block diagram of BPSK generator**

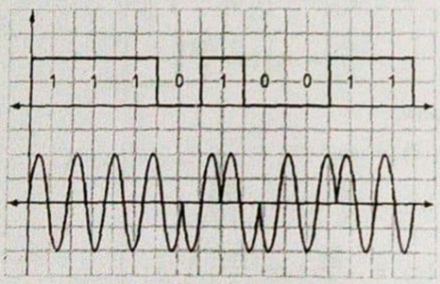


Fig. 2.5.1(a) : Waveforms of BPSK

(1) Polar NRZ encoder

(2) Product modulator

(1) Polar NRZ encoder

- It converts the input binary data sequence into polar NRZ format.
- In this, binary symbols '1' and '0' are represented by $\pm\sqrt{2P_s}$. P_s is the signal power of sinusoidal signal with amplitude 'A'.

$$\therefore P_s = \frac{1}{2} \cdot A^2$$

$$\therefore A = \sqrt{2P_s}$$

$$\therefore \text{Logic 1} \rightarrow +\sqrt{2P_s}$$

$$\text{Logic 0} \rightarrow -\sqrt{2P_s}$$

(2) Product modulator

- The polar NRZ symbols are multiplied with sinusoidal carrier. The desired BPSK output has fixed phase when the data is at one level.
- It changes the phase by 180° for other level change. Thus, the mathematical expression for the output of BPSK signal can be modelled.

Mathematical expression

$$V_{BPSK}(t) = \sqrt{2P_s} \cdot \cos(\omega_c t)$$

0° phase

$$\text{or } V_{BPSK}(t) = \sqrt{2P_s} \cdot \cos(\omega_c t + \pi)$$

π phase

$$= -\sqrt{2P_s} \cdot \cos(\omega_c t)$$

Hence in a general form,

$$V_{BPSK}(t) = b(t)\sqrt{2P_s} \cdot \cos \omega_c t$$

It is the expression for output BPSK.

2.5.4 Bandwidth of BPSK

GQ. State bandwidth of BPSK system.

Ans. :

Bandwidth = Higher frequency – Lower frequency

$$\therefore \quad B = (f_c + f_b) - (f_c - f_b)$$

$$\therefore \quad \mathbf{B = 2\,f_b}$$

$$\text{Where} \quad f_b = \frac{1}{T_b} = \frac{1}{\text{bit interval}}$$

Bit Rate = Total number of Bits per Baud x Baud Rate

$$P_{e(BPSK)} = \frac{1}{2}\,\text{erfc}\left[\sqrt{\frac{E_b}{N_0}}\right]$$

...Error probability of BPSK ...(2.5.10)

2.5.3 Power Spectrum of Binary PSK System

GQ. Describe power spectrum of BPSK system.

Ans. :

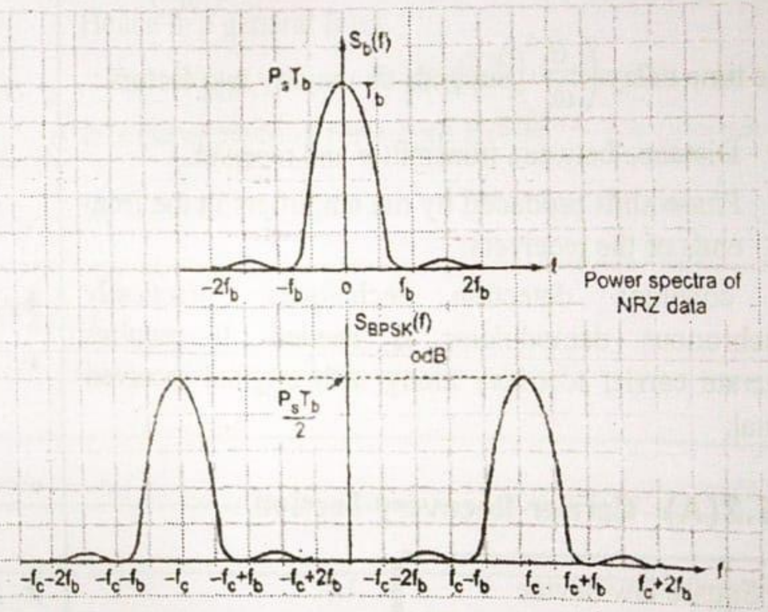
1. The BPSK waveform has b (t) in NRZ binary format. Hence, the binary NRZ waveform has two levels $+\sqrt{P_s}$ and $-\sqrt{P_s}$. Hence, Fourier transform of this waveform is

$$S_b(f) = P_s T_b \left(\frac{\sin \pi f T_b}{\pi f T_b} \right)^2$$

2. The BPSK waveform has NRZ waveform multiplied with carrier $\sqrt{2} \cos \omega_c t$. Hence the power spectral density of BPSK signal is given as,

$$S_{BPSK}(f) = \frac{P_s T_b}{2} \left\{ \left[\frac{\sin \pi (f - f_c) T_b}{\pi (f - f_c) T_b} \right]^2 + \left[\frac{\sin \pi (f + f_c) T_b}{\pi (f + f_c) T_b} \right]^2 \right\}$$

It is plotted in Fig. 2.5.3.



(IE30)**Fig. 2.5.3 : Power spectra of BPSK**

2. Study of QPSK transmitter & receiver using hardware setup/kit.

Practical:

Generate QPSK signal and reconstruct original signal using hardware setup

Observe waveform and draw on graph paper

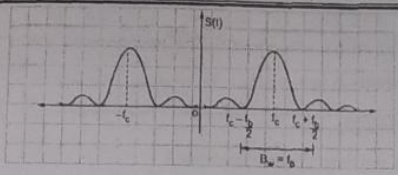
Theory:

Draw transmitter and receiver block diagram

Draw spectrum and show bandwidth

Draw constellation diagram and show euclidean distance.

Write formula of bandwidth, euclidean distance, error probability , bit rate, symbol rate



(1E38)**Fig. 2.8.5(b) : Power spectra of QPSK signal**

1. *Refer Fig. 2.8.5.* It shows power spectrum of QPSK. Power spectral density for QPSK is the sum of individual PSDs of in phase and quadrature components.
2. Hence, $S_n(f) = 2E \operatorname{sinc}^2(T_f)$

$$\therefore \ S_n(f) = 4E_b \operatorname{sinc}^2(2T_b f)$$

2.8.6 Bandwidth of QPSK

GQ. What is the bandwidth of QPSK system?

Ans. :

Bandwidth of QPSK is one half of the BPSK

$$\therefore \ BW = \frac{2f_b}{2} = f_b$$

2.8.7 Error Probability for QPSK System

UQ. Write an expression for its error probability of QPSK system. **SPPU - (E&TC-Sem. 5) Dec. 15, 4 Marks**

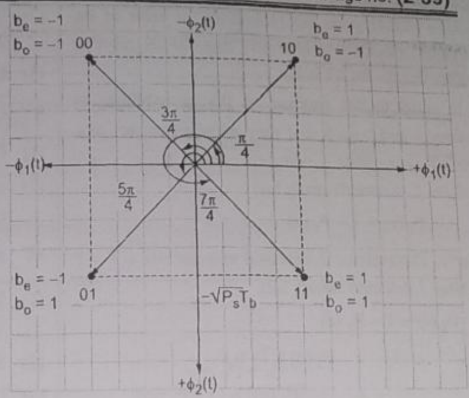
UQ. Draw signal space diagram of QPSK signal. Write the expression of all message points in the diagram. **SPPU - (E&TC-Sem. 5) Dec.-16, May 17, 4 Marks**

Ans. :

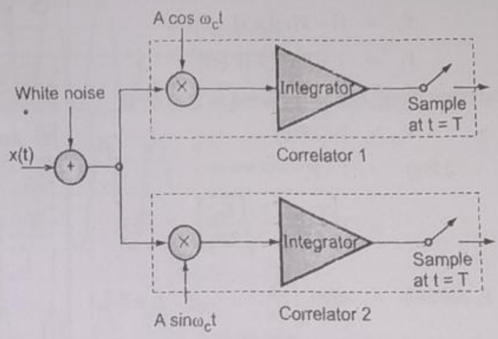
- As we know,

$$V_{QPSK}(t) = A\cos\left(\omega_c t + (2m+1)\frac{\pi}{4}\right),$$
$$m = 0, 1, 2, 3 \quad \text{for} \quad 0 \le t \le T_s = 2T$$

- Refer the signal space diagram drawn in Fig. 2.8.6. Also the receiver system is drawn in Fig. 2.8.7. Receiver diagram shows two correlators. These two correlators are provided with the locally generated carriers.



(1E14)**Fig. 2.8.6 : Signal space diagram for QPSK signal**



(1E36)**Fig. 2.8.7 : Block diagram of QPSK correlation receiver system**

- From the receiver diagram, it is clear that the transmitted signal may be detected with the help of outputs of two correlators.
- There are chances that in presence of noise one of the correlator may give wrong output.
- Reference waveform of correlator 1 is at phase = 45° $= \frac{\pi}{4}$ as shown in Fig. 2.8.6.

Now probability that correlator 1 or 2 make an error is given by,

$$P_1(e) = P_2(e) = \frac{1}{2}\operatorname{erfc}\sqrt{\frac{E_b}{N_o}\cos^2\phi} \qquad \text{...(2.8.3)}$$

Substituting $\phi = 45°$, $\cos^2(45) = \frac{1}{2}$

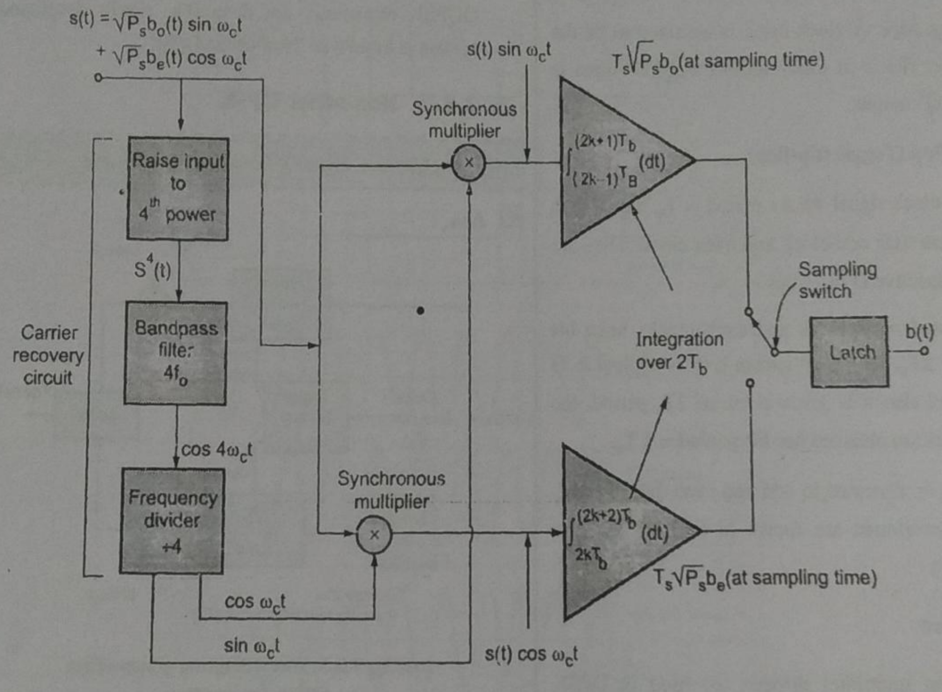
$$\therefore \ P_1(e) = P_2(e) = \frac{1}{2}\operatorname{erfc}\sqrt{\frac{E_b}{2N_o}} \qquad \text{...(2.8.4)}$$

2.8.3 QPSK Receiver/Detection

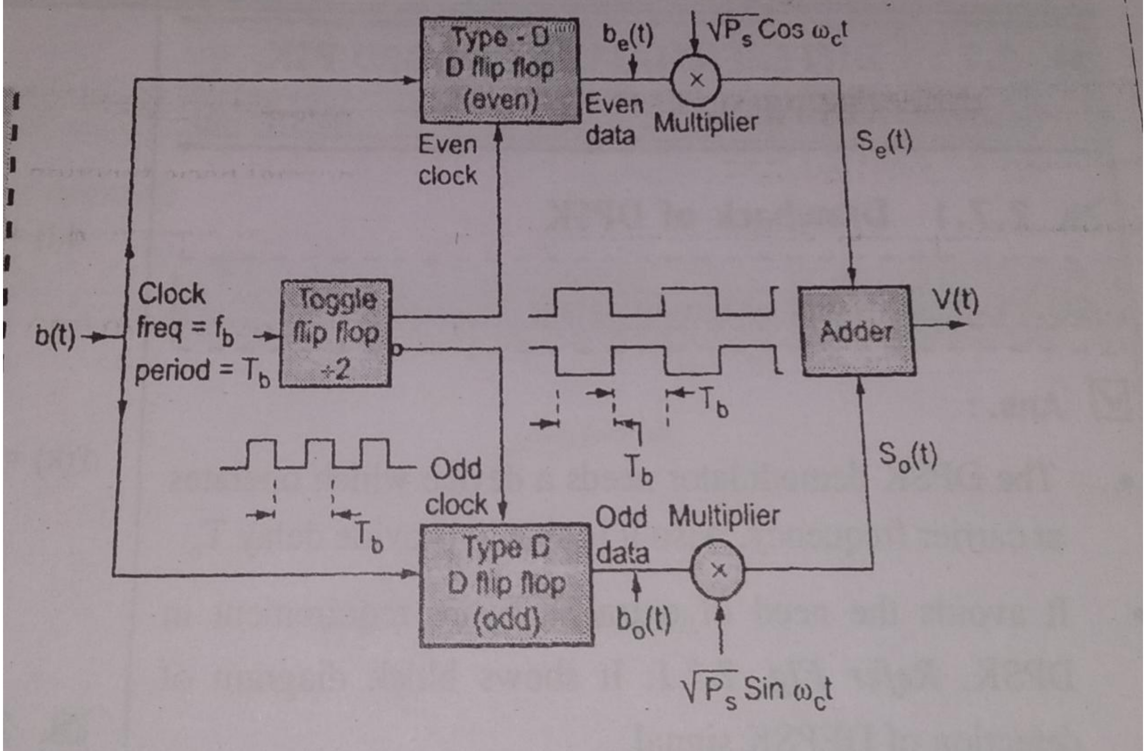
UQ. Explain with block diagram QPSK receives. **SPPU - (E&TC-Sem. 5) Dec. 15, 4 Marks**

Ans. :

- *Refer Fig. 2.8.4.* It shows the block diagram of coherent detection of QPSK.



(1E21)**Fig. 2.8.4 : Coherent detection of QPSK**



(1E26)**Fig. 2.8.1 : Block diagram of QPSK transmitter**

3. Study of DSSS-BPSK transmitter and receiver using hardware setup/kit

Practical:

Generate DSSS-BPSK and reconstruct original signal using hardware setup

Observe waveform and draw on graph paper

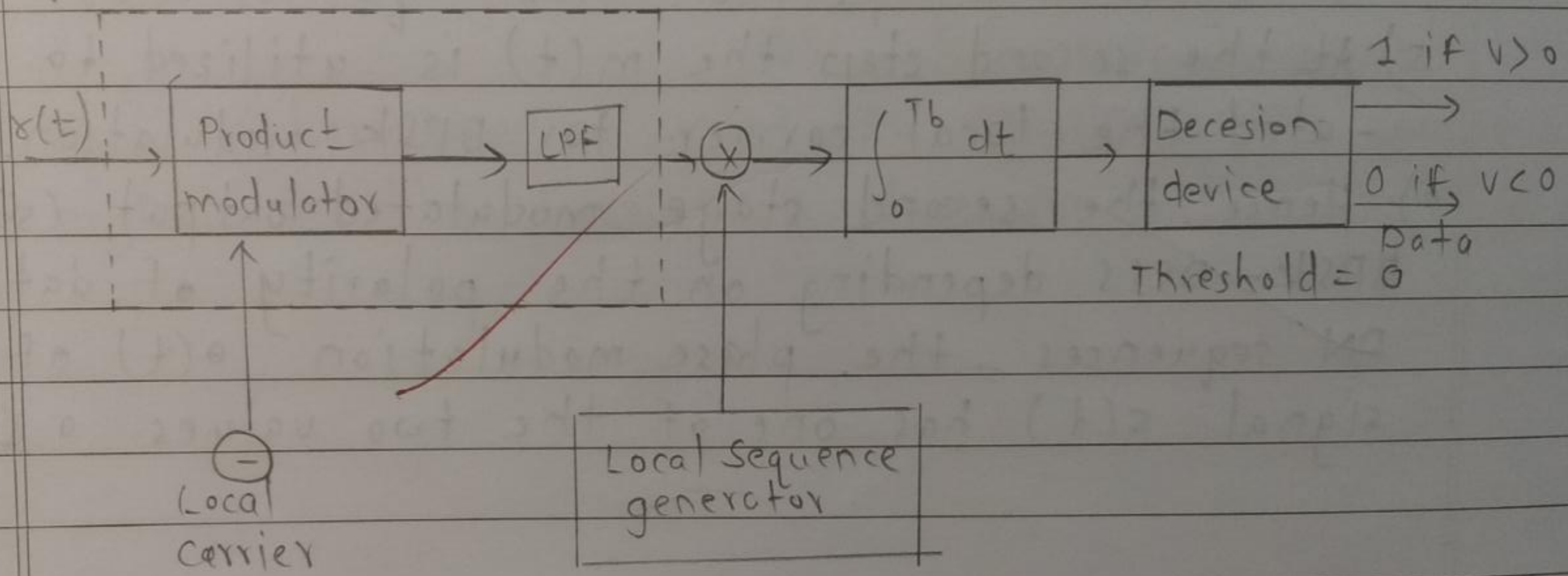
Theory:

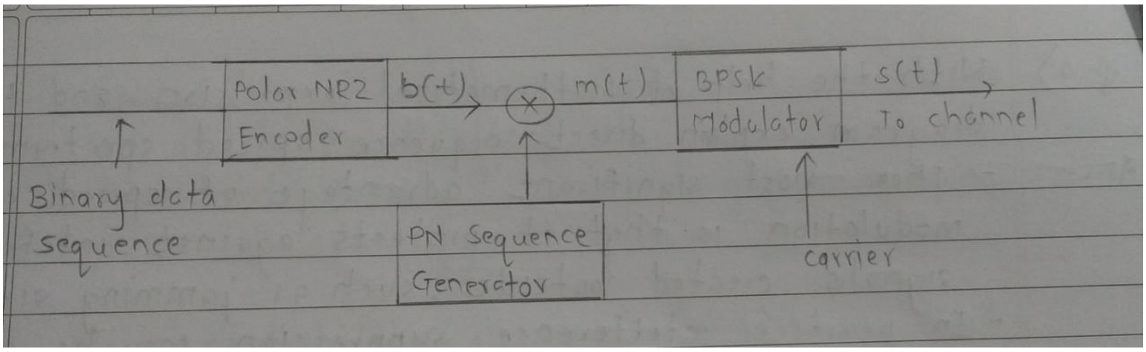
Draw transmitter and receiver block diagram

Draw spectrum and show bandwidth of DSSS -BPSK and BPSK

Write role of PN sequence in DSSS -BPSK

Write bandwidth formula of BPSK and DSSS-BPSK


r(t)
Product modulator
LPF
Local carrier
Local sequence generator
$\int_0^{T_b} dt$
Decesion device
1 if v>0
0 if v<0
Data
Threshold = 0



4. Simulation study of Performance of M-ary PSK .

Program:

Write a program in MATLAB

1. **Generate transmitter constellation of M-PSK of different M=2,4,8,16**
2. **Generate receiver constellation of M-PSK of different M=2,4,8,16 for different SNR.**

Theory:

Explain what is M- ary PSK

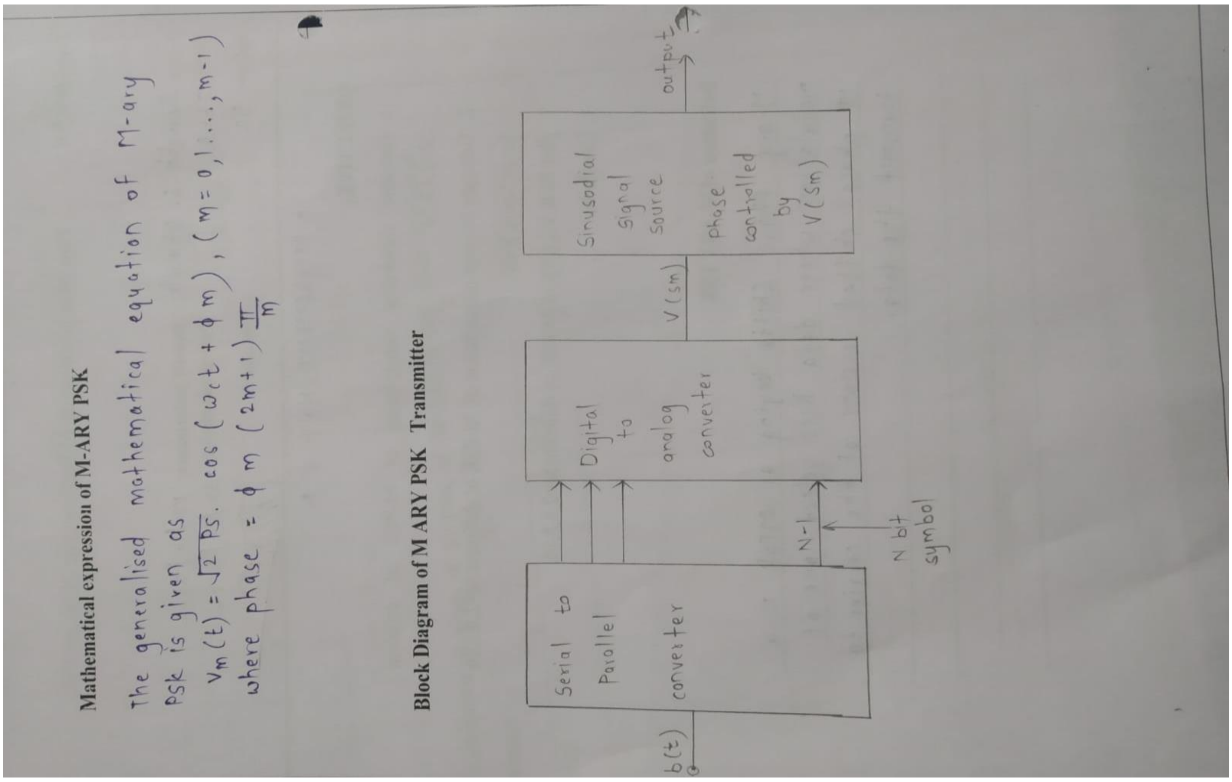
Draw block diagram

Explain constellation diagram of transmitter and receiver of different SNR

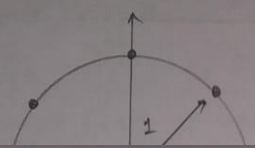
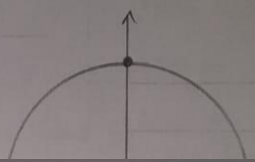
Write bandwidth and error probability of M-ary PSK

Answers:-

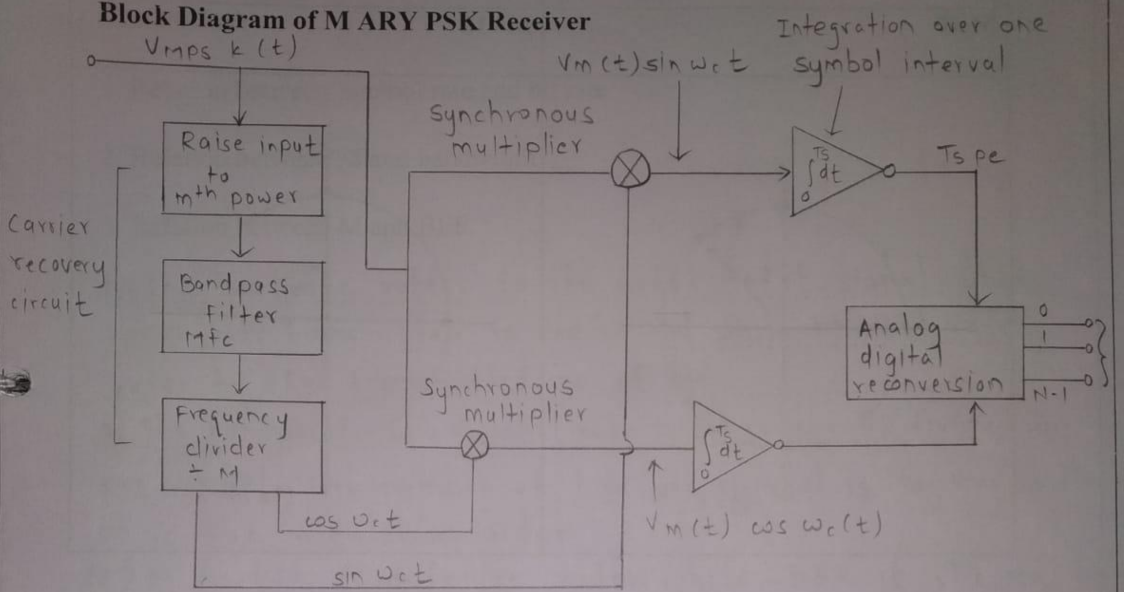
1] Mary phase shift keying or Mpsk is a modulation where data bits select



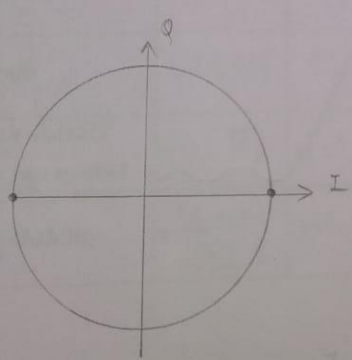
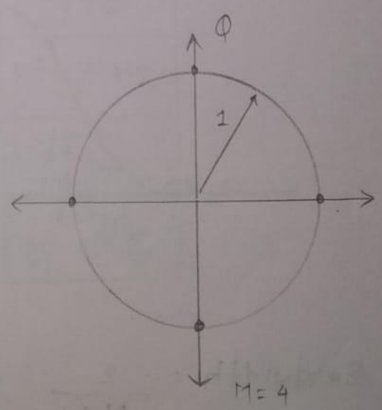
One of M phase shifted versions of the carrier to transmit the data

M=8	M=16
	

Block Diagram of M ARY PSK Receiver



Constellation diagram of M PSK of M=2,4,8,16 and show Euclidean distance

M=2	M=4
	

```
clc;
close all;
clear all;
M = 16;
%generate random data symbols


data = randi([0 M-1],1000,1);
%Modulate the signal using bit inputs, and set it to have unit average power.

txSig = pskmod(data,M);
%Pass the signal through a noisy channel.
scatterplot(txSig)
title('Transmitted signal')
%title('transmitter 64-QAM constellation');
for snr=1:5:30
    rxSig = awgn(txSig,snr);
    %Plot the constellation diagram.
    scatterplot(rxSig);
  title(['Recieved signal with SNR=',num2str(snr),]);
end
```

5. Simulation study of Performance of M-ary PSK .

Program:

Write a program in MATLAB

Plot BER VS SNR of M-PSK of different M=2,4,8,16

Theory:

Explain BER vs SNR plot in detail

Explain what is M- ary PSK

Write bandwidth and error probability of M-ary PSK

What is difference between M-PSK and M-QAM

```
close all;
clear all;
clc;
len = 10000;   %Number of Symbols
M = [2 4 16];  %Size of alphabet

k = 1
for m = 1:3
%Modulate using both PSK and PAM
%to compare the two methods
msg = randi([0 M(m)-1],len,1);  %Original Signal
txpsk = pskmod(msg,M(m));

%Create a scatter plot of the received signals
%scatterplot(txpsk)
i = 1;

for snr = 1:2:50
rxpsk = awgn(txpsk,snr,'measured');

%x = scatterplot(rxpsk);
recovpsk = pskdemod(rxpsk,M(m));
errors = 0;
c = xor(msg,recovpsk);
errors = nnz(c);
BER(k,i) = errors/length(msg); i = i+1;
end
k = k+1;
end
figure
i = 0:2:48;
semilogy(i,BER(1,:),'r',i,BER(2,:),'b',i,BER(3,:),'-*');
legend('BPSK','QPSK','16PSK');
title('BER vs SNR');
ylabel('BER');
xlabel('SNR(db)');
```

Explain BER vs SNR of MPSK Graph.

- Transmitting a symbol take twice as long as a bit (Ts = 2·Tb) which means that the bandwidth efficiency of QPSK is twice that of BPSK. Bit error rate.
- Bit error rate of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific ~~method~~ period.

- SNR Ratio
  - Energy per bit to noise power spectral density ratio is normalized signal to noise ratio (SNR) measure, also known as the "SNR per bits."

Q.1.) Compare M-ARY and M-ARY QAM.

	M-ARY PSK	M-ARY QAM
1.)	PSK stands for Phase shift keying.	QAM stands for Quadrature Amplitude Modulation.
2)	Spectral width is wide.	Spectral width is narrow.
3.)	2 bits are transmitted.	Bits transmission depends on its type.
4)	Performance is better.	Performance is average.
5)	Bit error rate is low.	Bit error rate is high.

6. Simulation study of Performance of M-ary QAM.

Program:

Write a program in MATLAB

1. Generate transmitter constellation of M-QAM of different M=2,4,8,16

2. Generate receiver constellation of M-QAM of different M=2,4,8,16 for different SNR.

Theory:

Explain what is M- ary QAM

Explain constellation diagram of transmitter and receiver of different SNR

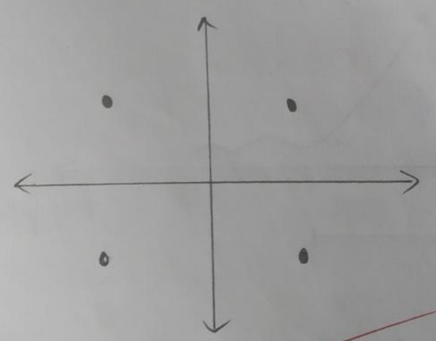
What is difference between M-PSK and M-QAM

Definition of M-ARY QAM

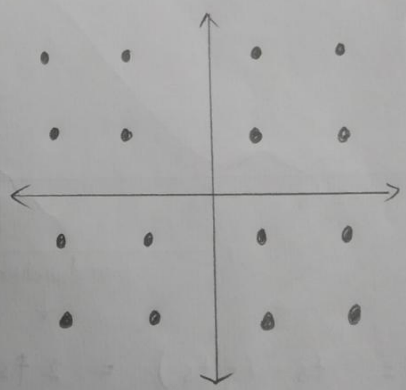
Quadrature Amplitude Modulation can be defined as a modulation technique which can be used to combine two amplitude modulated waves into a single channel to increase the channel Bandwidth.

Constellation diagram of M QAM of M=4,16,64 and show Euclidean distance

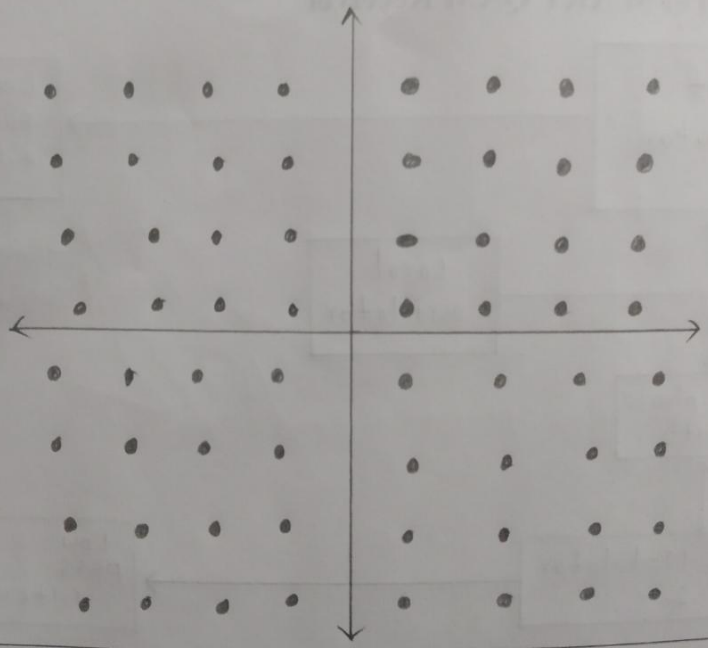
M=4



M=16



M=64



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3.)	2 bits are transmitted.	Bits transmission depends on its type.
4)	Performance is better.	Performance is average.
5)	Bit error rate is low.	Bit error rate is high.

```
M = 4;
k = log2(M);
%Create a binary data sequence. When using binary inputs, the number of rows in the input must be an integer multiple of the number of bits per symbol.

data = randi([0 1],1000*k,1);
%Modulate the signal using bit inputs, and set it to have unit average power.

txSig = qammod(data,M,'InputType','bit','UnitAveragePower',true);
%Pass the signal through a noisy channel.
scatterplot(txSig)
title('transmitter 64-QAM constellation');
for snr=1:5:30
    rxSig = awgn(txSig,snr);
    %Plot the constellation diagram.
    scatterplot(rxSig);
  title(['Recieved signal with SNR=',num2str(snr),]);
end
```

7. Simulation study of Source Coding technique.

Program:

GENERATION AND EVALUATION OF HUFFMAN CODING METHOD in MATLAB

1. Implementation of algorithms for generation and evaluation using Huffman coding
2. Find Entropy of source.
3. Find average codeword length.
4. Check coding efficiency and redundancy.

Apply Huffman Coding for following message ensemble and determine the average length of encoded messages. Find coding efficiency and Redundancy.

[X] = [x1 x2 x3 x4 x5 x6][P]

= [0.3 0.2 0.2 0.15 0.10 0.05]

Verify result theoretical

```
clc;
close all;
clear all;
M=input('Enter the symbols generated by the source');
P=input ('Enter the probablilty ');
H=0;
for i=1:M
H=H+P(i)*log2(1/P(i));
end
disp('The entropy of source is :');
disp(H)
s=1:M;
[dict,avglen] =huffmandict(s,P);
disp('huffman dictionary');
disp(dict);
disp('huffman bitlength');
disp(avglen);
a=dict;
for i=1:length(a)
  a{i,2}=num2str(a{i,2});
end
```

```
disp(a);
tx=input('Enter the transmitted symbol');
x=huffmanenco(tx,dict);
disp(x);
rx=x;
rx=input('Enter the recieved symbol');
y=huffmanenco(rx,dict);
disp(y);
err=isequal(x,y)
if err==1
    disp('The message recieved correctly');
    disp('the efficiency of code is:');
eff=(H/avglen)*100
    disp('The redundancy of code is:');
    Red=100-eff
end
```

```
%output= Enter the symbols generated by the source
6
Enter the probablilty
[0.1 0.1 0.2 0.25 0.25 0.1]
The entropy of source is :
   2.4610

huffman dictionary
   {[1]}    {[0 0 0 1]}
   {[2]}    {[0 0 0 0]}
   {[3]}    {[    1 1]}
   {[4]}    {[    1 0]}
   {[5]}    {[    0 1]}
   {[6]}    {[  0 0 1]}

huffman bitlength
   2.5000

   {[1]}    {'0  0  0  1'}
   {[2]}    {'0  0  0  0'}
   {[3]}    {'1  1'      }
   {[4]}    {'1  0'      }
   {[5]}    {'0  1'      }
   {[6]}    {'0  0  1'   }

Enter the transmitted symbol
[1 2 3 4 5 1 2 3 4]
  Columns 1 through 24

     0     0     0     1     0     0     0     0     1     1     1     0     0     1     0     0     0     1     0     0     0     0     1     1

  Columns 25 through 26

     1     0

Enter the recieved symbol
```

[1 2 3 4 5 1 2 3 4]
Columns 1 through 24

```
0  0  0  1  0  0  0  0  1  1  1  0  0  1  0  0  0  1  0  0  0  0  1  1
```

Columns 25 through 26

```
1  0
```

err =

logical

1

The message recieved correctly
the efficiency of code is:

eff =

98.4386

The redundancy of code is:

Red =

1.5614

8. Simulation study of various Entropies and mutual information in a communication system.

Program :

Implementation of algorithm in MATLAB for determination of various Entropies, Mutual Information of the Binary Symmetrical Channels.

Instruction

Take input from user P(x1)=0.5 and P(X1/Y1)=0.7 of binary symmetrical Channel
Calculate conditional probabilities Matrix P(X/Y)
Calculate joint probability matrix P(X,Y)
Calculate probabilities P(Y)
Calculate Source entropy H(X)
Calculate Source entropy H(Y)
Calculate conditional entropy H(X/Y), H(Y/X)
Calculate joint entropy H(X,Y)
Calculate mutual information I(X,Y).
Display the results.

Theory

Verify result by theoretical calculation
Draw Binary symmetrical Channel, useless channel, noiseless channel and explain
Draw Relation diagram between entropies and Mutual Information :

Relation equation between entropies and Mutual Information :

```
close all;
clc;
clear all;
   px(1)=input('Enter probability of x1');
px(2)=1-px(1);
py=[0 0];
   p=input('Enter conditional probability P(y1/x1)=p= ');
  pygx=[p 1-p;1-p p]
for i=1:2
   for j=1:2
      pxy(i,j)=(px(i)*pygx(i,j));
   end
end
py=[0 0];
for i=1:2
   for j=1:2
      py(i)=py(i)+pxy(j,i);
   end
end
hx=0;
```

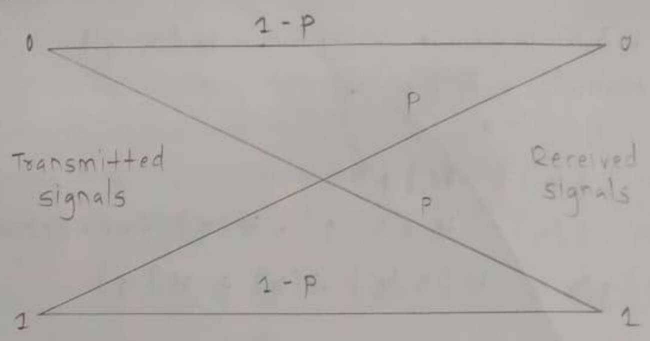
```
for i=1:2
    h=px(i)*(log(1/px(i))/log(2))
    hx=hx+h;
end
hy=0;
for i=1:2
    y=py(i)*(log(1/py(i))/log(2));
    hy=hy+y;
end
Hxy=0;
for i=1:2
    for j=1:2
        if pxy(i,j)==0
            hxy=0;
        else
            hxy=-pxy(i,j)*log2(pxy(i,j));
            Hxy=Hxy+hxy;
        end
    end
end
Hygx=Hxy-hx;
Ixy=hy-Hygx;
Hxgy=Hxy-hy;
if pygx(1,1)~=1
    c=1+[p*log2(p)+(1-p)*log2(1-p)]
elseif p==1
    c=log2(2);
end
z=['Input probabilities are= ',num2str(px)];
disp(z)
disp('Channel conditional probability matrix is= ');
pygx
disp('Channel joint probability matrix is= ');
pxy
z=['Output probabiilties are= ',num2str(py)];
disp(z)
z=['Entropy of source H(X)= ',num2str(hx),'bits/msg'];
disp(z)
z=['Entropy of source H(Y)= ',num2str(hy),'bits/msg'];
disp(z)
z=['Conditional entropy H(Y/X)= ',num2str(Hygx),'bits/msg'];
disp(z)
z=['Joint entropy Hxy= ',num2str(Hxy),'bits/msg'];
disp(z)
z=['Conditional probability H(X/Y)= ',num2str(Hxgy),'bits/msg']
```

```
disp(z)
z=['Mutual information Ixy= ',num2str(Ixy),'bits'];
disp(z)
z=['Channel capacity C is= ',num2str(c),'bits/sec'];
disp(z)
```

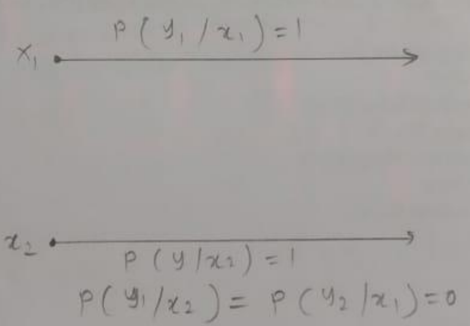
Output=>

```
Enter probability of x1
0.5
Enter conditional probability P(y1/x1)=p=
0.7

pygx =

   0.7000    0.3000
   0.3000    0.7000


h =

   0.5000


h =

   0.5000


c =

   0.1187

Input probabilities are= 0.5        0.5
Channel conditional probability matrix is=

pygx =

   0.7000    0.3000
   0.3000    0.7000

Channel joint probability matrix is=

pxy =

   0.3500    0.1500
   0.1500    0.3500

Output probabiilties are= 0.5        0.5
Entropy of source H(X)= 1bits/msg
Entropy of source H(Y)= 1bits/msg
Conditional entropy H(Y/X)= 0.88129bits/msg
Joint entropy Hxy= 1.8813bits/msg

z =

   'Conditional probability H(X/Y)= 0.88129bits/msg'

Conditional probability H(X/Y)= 0.88129bits/msg
Mutual information Ixy= 0.11871bits
Channel capacity C is= 0.11871bits/sec
```

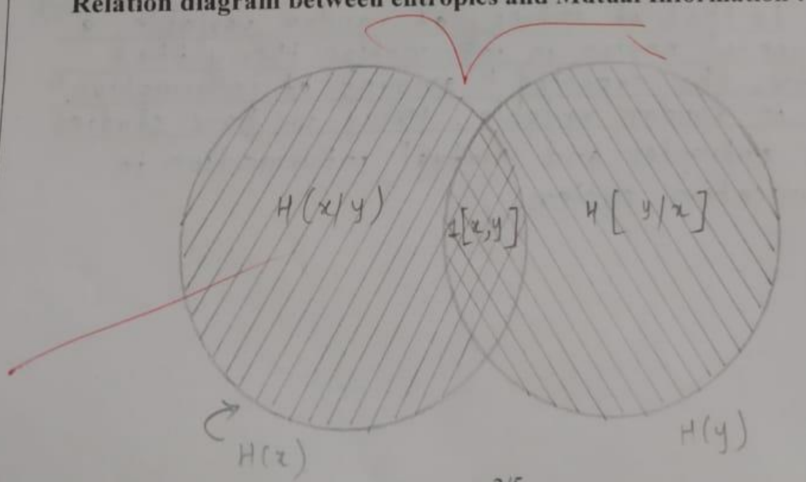
Binary symmetric channel :



Noiseless channel :



Relation diagram between entropies and Mutual Information :



Relation equation between entropies and mutual information :—

$$H(Y/X) = H(X,Y) - H(Y)$$

$$H(X/Y) = H(x,y) - H(x)$$

9. Simulation Study of encoding & decoding of convolutional codes using Viterbi's algorithm.

Write a MATLAB program for encoding & decoding of convolution code
Design (1,1/2) convolutional code using g_1=(111) & g_1=(101)

Verify result theoretically

```
close all;clear all;clc;
msg=input('Enter the message bits:');
l=input('Enter the constraint length:');
n=input('Enter the no. of output:');
for j=1:n
    g(j)=input('Enter the generator polynomial in octal:');
end
trellis=poly2trellis(l,g);
disp(trellis);
[isok,status]=istrellis(trellis);
if(isok==0)
    disp('Trellis is no t valid');

else
code=convenc(msg,trellis);
display(code);

rcode=input('Enter the received code');

tblen = 3; % Traceback length
decoded = vitdec(rcode,trellis,tblen,'trunc','hard'); %Hard
decision
disp('The decoded msg is')
disp(decoded)
```

end

output=>
Enter message bits [1 0 1]
Constraint lenth 3
No. Output 2
Enter the genertator polynomial 7
Enter the genertator polynomial 5
code= 1 1 1 0 0 0

10. Simulation Study of Linear Block codes

Implementation of algorithms for generating and decoding of linear block codes.

1. Encoding and decoding (n,k) LBC algorithm in matlab.
2. Display Generating matrix, parity check matrix.
3. Encode given k bit message and display.
4. Decode given received n bit codeword and display.

Verify result using

k=3

n=6

P=[1 0 1;0 1 1; 1 1 0]

```
clc
clear all
close all
% Use a [7,4] Hamming code.
%k = 3; n = 2^m-1; m = n-k;
%[H, G] = hammgen(k); % Produce parity-check matrix.
k=input('Enter no of message bits k');
n=input('Enter no of code bits n');
G=zeros(k,n);
G(:,1:k)=eye(k);
disp('Enter Parity matrix k x n-k');
for i=1:k
    for j=1:n-k
        G(i,j+k)=input('');
    end
end
d=0:2^k-1;
db=dec2bin(d);
for i=1:2^k
    for j=1:k
        dbb(i,j)=str2num(db(i,j));
    end
end
c(1:2^k,:)=rem(dbb(1:2^k,:)*G,2);
%wt=sum(c,2);
```

```
H=[G(:,k+1:n)' eye(n-k)];

de_table=zeros(n,n);
for i=1:n

    de_table(i,i) = 1;

end

%trt = decodtable(H); % Produce decoding table.
disp('Enter recd vector');
for i=1:n
    recd(1,i)=input('');
end
syndrome = rem(recd * H',2);
Hd=bi2de(H');
syndrome_de = bi2de(syndrome,'left-msb'); % Convert to
decimal.
disp(['Syndrome = ',num2str(syndrome_de),...
    ' (decimal), ',num2str(syndrome),' (binary)']);
    [x,~]=find(kron(syndrome_de,ones(n,1)) == Hd);

error_pattern=de_table(x,:);
correct_codword=xor(recd,error_pattern);
disp('Generator matrix is ');
G
disp('Transpose of Parity matrix is ');
H'
disp('Decoding table is ');
de_table
disp('Recieved code word is ')
recd
disp('Corrected code word is ')
correct_codword
```

output=>
No of message bits k 3
No of code bit 6
Kxn-k
1

0
1
0
1
1
1
1
0
Enter recd
0
1
1
1
1
0