OFDMA System Design.

Basic system+16Qam+2 Users+Channel Estimation

Variables:

```
clear all
close all
clc
Bits =16;
% Symbols = [1,-1];
R = 10^4;
y_c1 = zeros(1,19);
y_c2 = zeros(1,19);
N = 16; % # subcarriers
L = 4;  % # channel taps
cpn = 3;% number of symbols involved with cyclic prefix
```

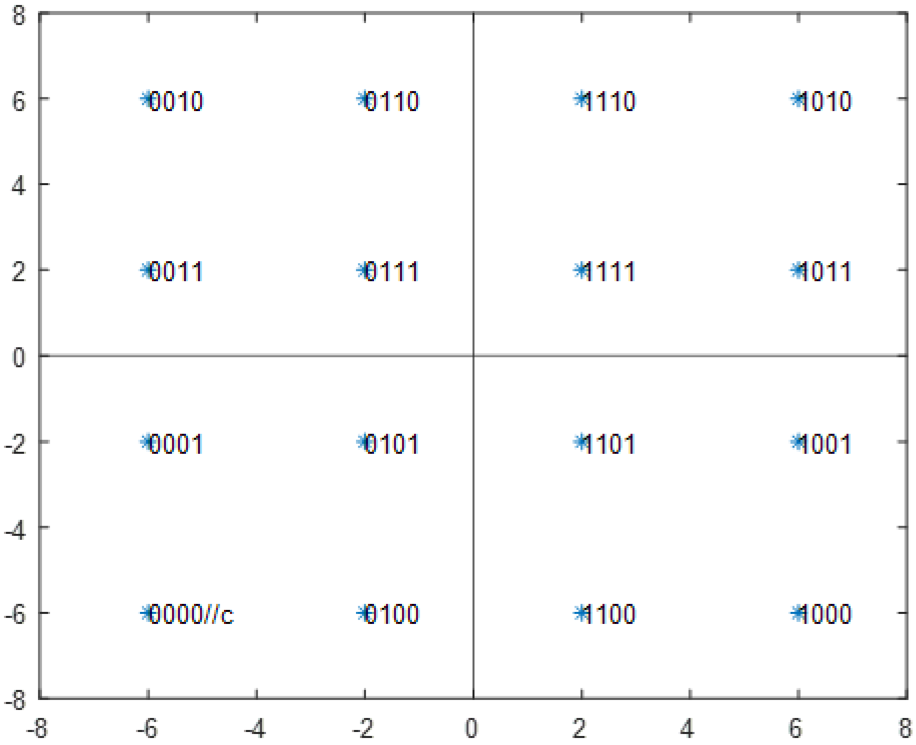
SNR Initialization:

```
SNR_dB = 0:0.5:20;
SNR_linear = 10.^(SNR_dB./10);
for si = 1: length(SNR_linear)
    SNR_samp = SNR_linear(si);
    variance = 10./SNR_samp;

    for ri = 1:R
```

---TRANSMITTER---

Generating Symbols:

- Generating 16 symbols from a 64 bits bit stream.
- The maping is as follows:



- Code to generate the above Plot.

```
ConstPts1 = [-6-6*j -2-6*j 6-6*j 2-6*j -6-2*j -2-2*j 6-2*j 2-2*j -6+6*j -2+6*j 6+6*j 2+6*j -6+2*j -2+2*j 6+2*j
 plot(ConstPts1,'*')
 xline(0)
 yline(0)
axis([-8 8 -8 8 ])
xt = [-6 -6 -6 -6 -2 -2 -2 -2 6 6 6 6 2 2 2 2];
yt = [-6 -2 6 2 -6 -2 6 2 -6 -2 6 2 -6 -2 6 2];
str = {'0000', '0001', '0010', '0011', '0100', '0101', '0110', '0111', '1000', '1001', '1010', '1011', '1100',
text(xt,yt,str,'\leftarrow')
```

- Bit allocation:

$$\begin{bmatrix} 0 & 0 & 0 & 0 & = & -6 & +6i \\ 0 & 0 & 0 & 1 & = & -6 & +2i \\ 0 & 0 & 1 & 0 & = & -6 & -6i \\ 0 & 0 & 1 & 1 & = & -6 & -2i \\ 0 & 1 & 0 & 0 & = & -2 & +6i \\ 0 & 1 & 0 & 1 & = & -2 & +2i \\ 0 & 1 & 1 & 0 & = & -2 & -6i \\ 0 & 1 & 1 & 1 & = & -2 & -2i \end{bmatrix} \& \begin{bmatrix} 1 & 0 & 0 & 0 & = & 6 & +6i \\ 1 & 0 & 0 & 1 & = & 6 & +2i \\ 1 & 0 & 1 & 0 & = & 6 & -6i \\ 1 & 0 & 1 & 1 & = & 6 & -2i \\ 1 & 1 & 0 & 0 & = & 2 & +6i \\ 1 & 1 & 0 & 1 & = & 2 & +2i \\ 1 & 1 & 1 & 0 & = & 2 & -6i \\ 1 & 1 & 1 & 1 & = & 2 & -2i \end{bmatrix}$$

- The Pilot bits for User 1 are assigned to positions, 1,3,5,8,17,19,21,24,33,35,37,40,49,51,53,56. and are mapped to the symbol 6+6i.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & = & 6 & +6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & +6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & 6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & 6i \end{bmatrix} \& \begin{bmatrix} \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \end{bmatrix}$$

- The Pilot bits for User 2 are assigned to positions, 9,11,13,16,25,27,29,32,41,43,45,57,59,61,64 and are mapped to the symbol 6+6i.
- $$\begin{bmatrix} \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & \text{infoSym} \end{bmatrix} \& \begin{bmatrix} 1 & 0 & 0 & 0 & = & 6 & +6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & +6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & 6i \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ \text{infoBit} & \text{infoBit} & \text{infoBit} & \text{infoBit} & = & & \text{infoSym} \\ 1 & 0 & 0 & 0 & = & 6 & 6i \end{bmatrix}$$

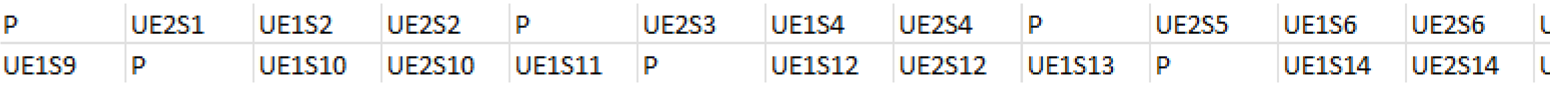
```
     ConstPts1 = [-6-6*j -2-6*j 6-6*j 2-6*j -6-2*j -2-2*j 6-2*j 2-2*j -6+6*j -2+6*j 6+6*j 2-
     BitStream1 = randi(2,1,4*16) - 1;
     bits1_2 = reshape(BitStream1, 16, 4);
     bits1_2(1)=1;
     bits1_2(3)=1;
     bits1_2(5)=1;
     %         bits1_2(12)=1;
     bits1_2(8)=1;
     bits1_2(17)=0;
     bits1_2(19)=0;
     bits1_2(21)=0;
     %         bits1_2(28)=0;
     bits1_2(24)=0;
     bits1_2(33)=0;
     bits1_2(35)=0;
     bits1_2(37)=0;
     %         bits1_2(44)=0;
     bits1_2(40)=0;
     bits1_2(49)=0;
     bits1_2(51)=0;
     bits1_2(53)=0;
     %         bits1_2(60)=0;
     bits1_2(56)=0;

    for i=1:16
```

```
         [ae] = bits1_2(i,:);
         if (ae(1) == 0 & ae(2) == 0)
             x_re1(i) = -6;
         end
         if (ae(1) == 0 & ae(2) == 1)
             x_re1(i) = -2;
         end
         if (ae(1) == 1 & ae(2) == 1)
             x_re1(i) = 2;
         end
         if (ae(1) == 1 & ae(2) == 0)
             x_re1(i) = 6;
         end
         if (ae(3) == 0 & ae(4) == 0)
             x_im1(i) = 6;
         end
         if (ae(3) == 0 & ae(4) == 1)
             x_im1(i) = 2;
         end
         if (ae(3) == 1 & ae(4) == 1)
             x_im1(i) = -2;
         end
         if (ae(3) == 1 & ae(4) == 0)
             x_im1(i) = -6;
         end
         UE1(i) =  x_re1(i) + 1i*x_im1(i);
    end


     ConstPts2 =[-6-6*j -2-6*j 6-6*j 2-6*j -6-2*j -2-2*j 6-2*j 2-2*j -6+6*j -2+6*j 6+6*j 2+6
     BitStream2 = randi(2,1,4*16) - 1;
     bits2_2 = reshape(BitStream2, 16, 4);
     bits2_2(9)=1;
     bits2_2(11)=1;
     bits2_2(13)=1;
     %         bits2_2(12)=1;
     bits2_2(16)=1;
     bits2_2(25)=0;
     bits2_2(27)=0;
     bits2_2(29)=0;
     %         bits2_2(28)=0;
     bits2_2(32)=0;
     bits2_2(41)=0;
     bits2_2(43)=0;
     bits2_2(45)=0;
     %         bits2_2(44)=0;
     bits2_2(57)=0;
     bits2_2(59)=0;
     bits2_2(61)=0;
     bits2_2(61)=0;
     %         bits2_2(60)=0;
     bits2_2(64)=0;

     for i=1:16
```

```
            [ae2] = bits2_2(i,:);
            if (ae2(1) == 0 & ae2(2) == 0)
                x_re2(i) = -6;
            end
            if (ae2(1) == 0 & ae2(2) == 1)
                x_re2(i) = -2;
            end
            if (ae2(1) == 1 & ae2(2) == 1)
                x_re2(i) = 2;
            end
            if (ae2(1) == 1 & ae2(2) == 0)
                x_re2(i) = 6;
            end
            if (ae2(3) == 0 & ae2(4) == 0)
                x_im2(i) = 6;
            end
            if (ae2(3) == 0 & ae2(4) == 1)
                x_im2(i) = 2;
            end
            if (ae2(3) == 1 & ae2(4) == 1)
                x_im2(i) = -2;
            end
            if (ae2(3) == 1 & ae2(4) == 0)
                x_im2(i) = -6;
            end
            UE2(i) =  x_re2(i) + 1i*x_im2(i);
        end
```

Interleaving:

- Generated Symbols are interleaved, so that when the infrmation is split to two users at the reciver, they get their desired bits.



P	UE2S1	UE1S2	UE2S2	P	UE2S3	UE1S4	UE2S4	P	UE2S5	UE1S6	UE2S6	U
UE1S9	P	UE1S10	UE2S10	UE1S11	P	UE1S12	UE2S12	UE1S13	P	UE1S14	UE2S14	U

```
        xiv1 = UE1';
        xiv2 = UE2';
        xx = reshape([xiv1(:) xiv2(:)]',2*size(xiv1,1), [])';%32
        OFDM1 = xx(1:16);%16
        OFDM2 = xx(17:32);%16
```

Applying IDFT:

- Now we perform IDFT from the function that I created, and no the inbuilt function.

```
function X = myidft(x)
N = length(x); %to find the length of the symbols
X = zeros(1,N); % creating an array for the new
for n = 0:N-1
```

```
    for k = 0:N-1
        X(n+1)=X(n+1)+((1/N)*(x(k+1)*exp(((1i)*2*pi*k*n)/N))); %IDFT equation
    end
end
end
```

```
x1_idft = myidft(OFDM1);
x2_idft = myidft(OFDM2);
```

Adding Cyclic Prefix

- Next, we add cyclic prefix, i.e the last three symbols are repeated to the front.

```
for cpi=1:3
    xx1(cpi) =[x1_idft(N-cpn+cpi)];
    xx2(cpi) =[x2_idft(N-cpn+cpi)];
end
xcp1 = [xx1 x1_idft];
xcp2 = [xx2 x2_idft];
```

Generating Channels:

```
for ci = 1:4
    h1(ci) = sqrt(0.25/2)*(randn(1) + 1i*randn(1));
    h2(ci) = sqrt(0.25/2)*(randn(1) + 1i*randn(1));
end
```

Generating Noise:

```
for k = 1:19
    w1(k) = sqrt(variance/2)*(randn(1) + 1i*randn(1));
    w2(k) = sqrt(variance/2)*(randn(1) + 1i*randn(1));
end
```

---RECIVER---

Input at Reciver:

- The channeles are Convoluted with the symbols and recived at the reciver with added noise.

```
y_c1(1) = h1(1)*xcp1(1) + w1(1);
y_c1(2) = h1(1)*xcp1(2) + h1(2)*xcp1(1) + w1(2);
y_c1(3) = h1(1)*xcp1(3) + h1(2)*xcp1(2) + h1(3)*xcp1(1) + w1(3);
for k = 4:19
    y_c1(k) = h1(1)*xcp1(k) + h1(2)*xcp1(k-1) + h1(3)*xcp1(k-2) + h1(4)*xcp1(k-3) + w1(
end

y_c2(1) = h2(1)*xcp2(1) + w2(1);
y_c2(2) = h2(1)*xcp2(2) + h2(2)*xcp2(1) + w2(2);
y_c2(3) = h2(1)*xcp2(3) + h2(2)*xcp2(2) + h2(3)*xcp2(1) + w2(3);
```

```
        for k = 4:19
            y_c2(k) = h2(1)*xcp2(k) + h2(2)*xcp2(k-1) + h2(3)*xcp2(k-2) + h2(4)*xcp2(k-3) + w2(
        end
```

Removing Cyclic Prefix:

```
        y1 = y_c1((cpn+1):length(y_c1));
        y2 = y_c2((cpn+1):length(y_c2));
```

Applying DFT:

- Now we perform DFT from the function that I created, and no the inbuilt function.

```
function Y = mydft(y)
N = length(y); %to find the length of the symbols
Y = zeros(1,N); % creating an array for the new
for k = 0:N-1
    for n = 0:N-1
        Y(k+1)=Y(k+1)+((y(n+1)*exp(((-1i)*2*pi*k*n)/N))); %DFT equation
    end
end
end
```

```
        y1_dft = mydft(y1);
        y2_dft = mydft(y2);
```

Generating Gk:

- Channel estimation is performend by using Maximum likelyhood function:

1. The Z_{4x4} matrx is found by $\begin{bmatrix} \mathrm{Uk}_{1x4}\mathrm{D1} \\ \mathrm{Uk}_{1x4}\mathrm{D2} \\ \mathrm{Uk}_{1x4}\mathrm{D3} \\ \mathrm{Uk}_{1x4}\mathrm{D4} \end{bmatrix}$
2. Then find the estimated chnnel by using this formula $\widehat{h}_{4x1} = \left(Z^*_{4x4} Z_{4x4}\right)^2 Z^*{}_{4x4}\, Y_{4x1}$
3. Once the estimated channel is found, we use it that information to find $\widehat{G}_k = \sum_n^{L-1} e^{-\mathrm{j}2\pi\frac{\mathrm{kn}}{N}} \widehat{h}_n$

```
        z11 = [exp((-1i*2*pi)*((1-1)*(0))/(N)) exp((-1i*2*pi)*((1-1)*(1))/(N)) exp((-1i*2*pi)*(
        z12 = [exp((-1i*2*pi)*((5-1)*(0))/(N)) exp((-1i*2*pi)*((5-1)*(1))/(N)) exp((-1i*2*pi)*(
        z13 = [exp((-1i*2*pi)*((9-1)*(0))/(N)) exp((-1i*2*pi)*((9-1)*(1))/(N)) exp((-1i*2*pi)*(
        z14 = [exp((-1i*2*pi)*((15-1)*(0))/(N)) exp((-1i*2*pi)*((15-1)*(1))/(N)) exp((-1i*2*pi

        z1 = [z11;z12;z13;z14];
        hest1 =  inv(conj(z1)*z1)*conj(z1)*[y1_dft(1);y1_dft(5);y1_dft(9);y1_dft(15)];

        for k = 1:length(y1_dft)
```

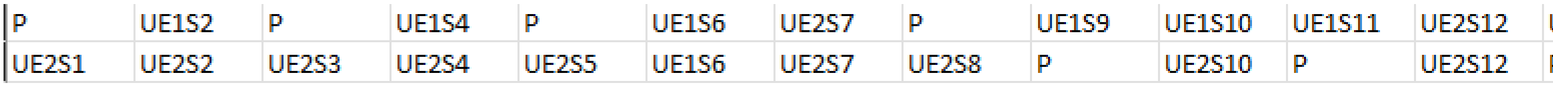
```
            for n = 1:4
                gg1(n) = hest1(n) * exp((-1i*2*pi)*((k-1)*(n-1))/(N));
                G1(k) = sum(gg1);
            end
        end

        z21 = [exp((-1i*2*pi)*((2-1)*(0))/(N)) exp((-1i*2*pi)*((2-1)*(1))/(N)) exp((-1i*2*pi)*(
        z22 = [exp((-1i*2*pi)*((6-1)*(0))/(N)) exp((-1i*2*pi)*((6-1)*(1))/(N)) exp((-1i*2*pi)*(
        z23 = [exp((-1i*2*pi)*((10-1)*(0))/(N)) exp((-1i*2*pi)*((10-1)*(1))/(N)) exp((-1i*2*pi
        z24 = [exp((-1i*2*pi)*((16-1)*(0))/(N)) exp((-1i*2*pi)*((16-1)*(1))/(N)) exp((-1i*2*pi

        z2 = [z21;z22;z23;z24];
        hest2 =  inv(conj(z2)*z2)*conj(z2)*[y2_dft(2);y2_dft(6);y2_dft(10);y2_dft(16)];

        for k = 1:length(y1_dft)
            for n = 1:4
                gg2(n) = hest2(n) * exp((-1i*2*pi)*((k-1)*(n-1))/(N));
                G2(k) = sum(gg2);
            end
        end
```

Decoding using minimum distance decoder:

```
        for di = 1:length(y1_dft)
            dd1 = zeros(1,16);
            for m = 1:16
                dd1(m) = abs((y1_dft(di) - G1(di)*ConstPts1(m))^2);
            end
            [a,b] = min(dd1);
             x1hatofdm(di) = ConstPts1(b);
        end

        for ddi = 1:length(y2_dft)
            dd2 = zeros(1,4);
            for mm = 1:16
                dd2(mm) = abs((y2_dft(ddi) - G2(ddi)*ConstPts2(mm))^2);
            end
            [c,d] = min(dd2);
             x2hatofdm(ddi) = ConstPts2(d);
        end
```

Distributing interleaved subcarriers:

- Getting back the respective symbols of User 1 and User 2.
- The expected UE1 and UE2 symbols would look like:



P	UE1S2	P	UE1S4	P	UE1S6	UE2S7	P	UE1S9	UE1S10	UE1S11	UE2S12	U
UE2S1	UE2S2	UE2S3	UE2S4	UE2S5	UE1S6	UE2S7	UE2S8	P	UE2S10	P	UE2S12	P

```
        for k = 1:8
            x1hat(k)=[x1hatofdm(k*2-1)];
            x1hat(k+8)= [x2hatofdm(k*2-1)];
        end

        for k = 1:8
            x2hat(k)=[x1hatofdm(k*2)];
            x2hat(k+8)=[x2hatofdm(k*2)];
        end
```

Error counting:

- First the Symbols are mapped back to the bits.
- Followed by which, the recived bits are compared with the actual bits and error is calculated.

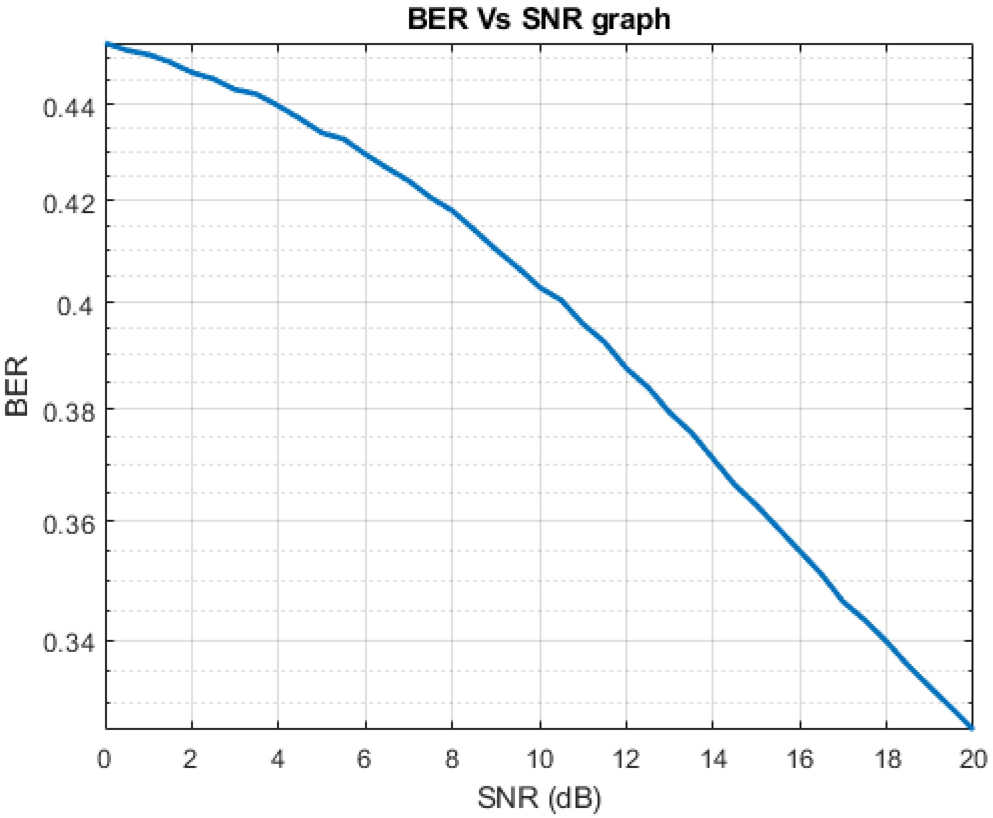
```
        bits_hat1 = zeros(16,4);

        for index = 1:16
            x_hat_re(index)=real(x1hat(index));
            x_hat_im(index)=imag(x1hat(index));

            if x_hat_re(index) == -6
                bits_hat1(index,1) = 0;
                bits_hat1(index,2) = 0;
            end
            if x_hat_re(index) == -2
                bits_hat1(index,1) = 0;
                bits_hat1(index,2) = 1;
            end
            if x_hat_re(index) == 6
                bits_hat1(index,1) = 1;
                bits_hat1(index,2) = 0;
            end
            if x_hat_re(index) == 2
                bits_hat1(index,1) = 1;
                bits_hat1(index,2) = 1;
            end
            if x_hat_im(index) == 6
                bits_hat1(index,3) = 0;
                bits_hat1(index,4) = 0;
            end
            if x_hat_im(index) == 2
                bits_hat1(index,3) = 0;
                bits_hat1(index,4) = 1;
            end
            if x_hat_im(index) == -6
                bits_hat1(index,3) = 1;
                bits_hat1(index,4) = 0;
            end
```

```
    if x_hat_im(index) == -6
        bits_hat1(index,3) = 1;
        bits_hat1(index,4) = 1;
    end
end

bits_hat2 = zeros(16,4);

 for index = 1:16
    x_hat_re2(index)=real(x2hat(index));
    x_hat_im2(index)=imag(x2hat(index));

    if x_hat_re2(index) == -6
        bits_hat2(index,1) = 0;
        bits_hat2(index,2) = 0;
    end
    if x_hat_re2(index) == -2
        bits_hat2(index,1) = 0;
        bits_hat2(index,2) = 1;
    end
    if x_hat_re2(index) == 6
        bits_hat2(index,1) = 1;
        bits_hat2(index,2) = 0;
    end
    if x_hat_re2(index) == 2
        bits_hat2(index,1) = 1;
        bits_hat2(index,2) = 1;
    end
    if x_hat_im2(index) == 6
        bits_hat2(index,3) = 0;
        bits_hat2(index,4) = 0;
    end
    if x_hat_im2(index) == 2
        bits_hat2(index,3) = 0;
        bits_hat2(index,4) = 1;
    end
    if x_hat_im2(index) == -6
        bits_hat2(index,3) = 1;
        bits_hat2(index,4) = 0;
    end
    if x_hat_im2(index) == -2
        bits_hat2(index,3) = 1;
        bits_hat2(index,4) = 1;
    end
 end


for ei = 1:4*16
    error1(ei) = bits1_2(ei) ~= bits_hat1(ei);
end
for eei = 1:4*16
    error2(eei) = bits2_2(eei) ~= bits_hat2(eei);
end
Terror1(ri) = sum(error1);
```

```
        Terror2(ri) = sum(error2);


    end
    finaltotalerror = sum(Terror1) + sum(Terror2);
    BER(si) = (finaltotalerror)/(R*N*4*2);
end
```

---PLOTTING---

```
semilogy(SNR_dB, BER, 'linewidth',2);
grid on;
xlabel('SNR (dB)');
ylabel('BER');
title('BER Vs SNR graph');
```



Final Project.

Basic system.

Variables:

```
% clear all
Bitsb =16;
```

```
Symbolsb = [1,-1];
Rb = 10^4;
y_c1b = zeros(1,19);
y_c2b = zeros(1,19);
Nb = 16; % # subcarriers
Lb= 4;  % # channel taps
cpnb = 3;% number of symbols involved with cyclic prefix
```

SNR Initialization:

```
SNR_dBb = 0:0.5:20;
SNR_linearb = 10.^(SNR_dBb./10);
for sib = 1: length(SNR_linearb)
    SNR_sampb = SNR_linearb(sib);
    varianceb = 4./SNR_sampb;

    for rib = 1:Rb
```

---TRANSMITTER---

Generating Symbols:

```
        ConstPts1b=randi([-1 ,1],1,Bitsb);
        ConstPts1b(~ConstPts1b)=-1;
        x1b=ConstPts1b;

        ConstPts2b=randi([-1 ,1],1,16);
        ConstPts2b(~ConstPts2b)=-1;
        x2b=ConstPts2b;
```

Applying IDFT:

```
        x1_idftb = myidft(x1b);
        x2_idftb = myidft(x2b);
```

Adding Cyclic Prefix

```
        for cpi=1:3
            xx1b(cpi) =[x1_idftb(Nb-cpnb+cpi)];
            xx2b(cpi) =[x2_idftb(Nb-cpnb+cpi)];
        end
        xcp1b = [xx1b x1_idftb];
        xcp2b = [xx2b x2_idftb];
```

Generating Channels:

```
        for cib = 1:4
            h1b(cib) = sqrt(0.25/2)*(randn(1) + 1i*randn(1));
            h2b(cib) = sqrt(0.25/2)*(randn(1) + 1i*randn(1));
        end
```

Generating Noise:

```
        for kb = 1:19
```

```
            w1b(kb) = sqrt(varianceb/2)*(randn(1) + 1i*randn(1));
            w2b(kb) = sqrt(varianceb/2)*(randn(1) + 1i*randn(1));
        end
```

Output at Transmiter:

```
        y_c1b(1) = h1b(1)*xcp1b(1) + w1b(1);
        y_c1b(2) = h1b(1)*xcp1b(2) + h1b(2)*xcp1b(1) + w1b(2);
        y_c1b(3) = h1b(1)*xcp1b(3) + h1b(2)*xcp1b(2) + h1b(3)*xcp1b(1) + w1b(3);
        for kb = 4:19
            y_c1b(kb) = h1b(1)*xcp1b(kb) + h1b(2)*xcp1b(kb-1) + h1b(3)*xcp1b(kb-2) + h1b(4)*xcp
        end

        y_c2b(1) = h2b(1)*xcp2b(1) + w2b(1);
        y_c2b(2) = h2b(1)*xcp2b(2) + h2b(2)*xcp2b(1) + w2b(2);
        y_c2b(3) = h2b(1)*xcp2b(3) + h2b(2)*xcp2b(2) + h2b(3)*xcp2b(1) + w2b(3);
        for kb = 4:19
            y_c2b(kb) = h2b(1)*xcp2b(kb) + h2b(2)*xcp2b(kb-1) + h2b(3)*xcp2b(kb-2) + h2b(4)*xcp
        end
```

---RECIVER---

Removing Cyclic Prefix:

```
        y1b = y_c1b((cpnb+1):length(y_c1b));
        y2b = y_c2b((cpnb+1):length(y_c2b));
```

Applying DFT:

```
        y1_dftb = mydft(y1b);
        y2_dftb = mydft(y2b);
```

Generating Gk:

```
        for kb = 1:length(y1_dftb)
            for nb = 1:4
                gg1b(nb) = h1b(nb) * exp((-1i*2*pi)*((kb-1)*(nb-1))/(Nb));
                G1b(kb) = sum(gg1b);
            end
        end

        for kb = 1:length(y2_dftb)
            for nb = 1:4
                gg2b(nb) = h2b(nb) * exp((-1i*2*pi)*((kb-1)*(nb-1))/(Nb));
                G2b(kb) = sum(gg2b);
            end
        end
```

Decoding using minimum distance decoder:

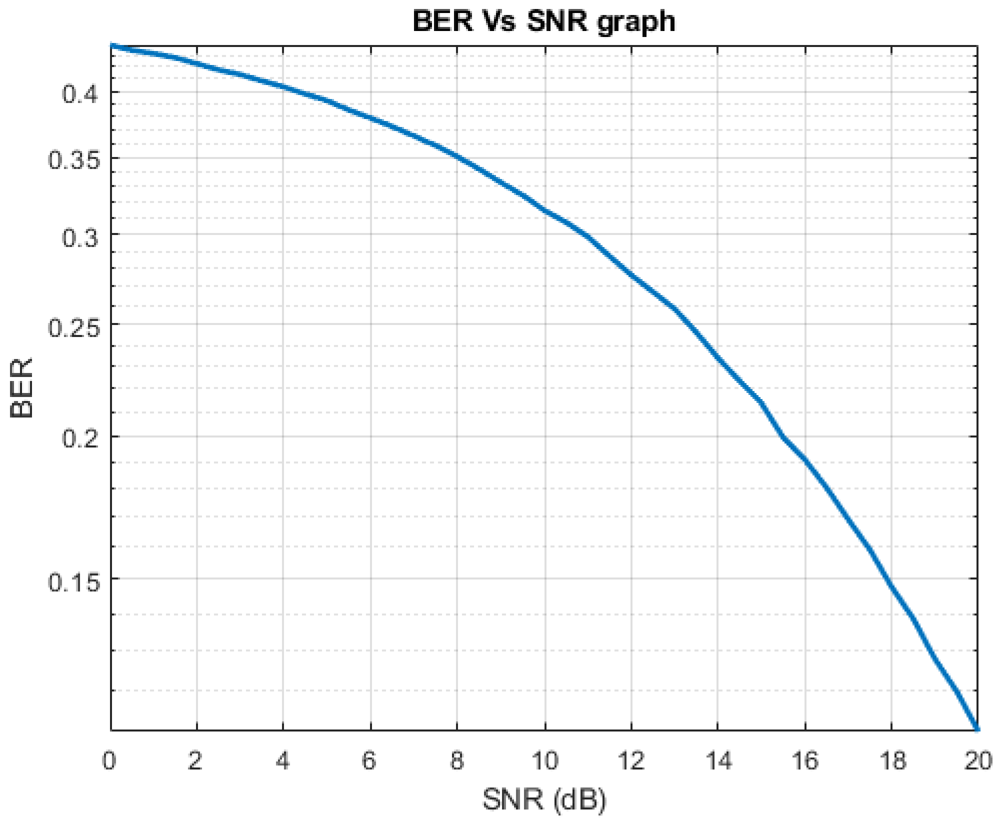
```
        for dib = 1:length(y1_dftb)
            dd1b = zeros(1,2);
            for mb = 1:2
                dd1b(mb) = abs((y1_dftb(dib) - G1b(dib)*Symbolsb(mb))^2);
            end
            [ab,bb] = min(dd1b);
            x1hatb(dib) = Symbolsb(bb);
        end

        for ddib = 1:length(y2_dftb)
            dd2b = zeros(1,2);
            for mmb = 1:2
                dd2b(mmb) = abs((y2_dftb(ddib) - G2b(ddib)*Symbolsb(mmb))^2);
            end
            [cb,db] = min(dd2b);
            x2hatb(ddib) = Symbolsb(db);
        end
```

Error counting:

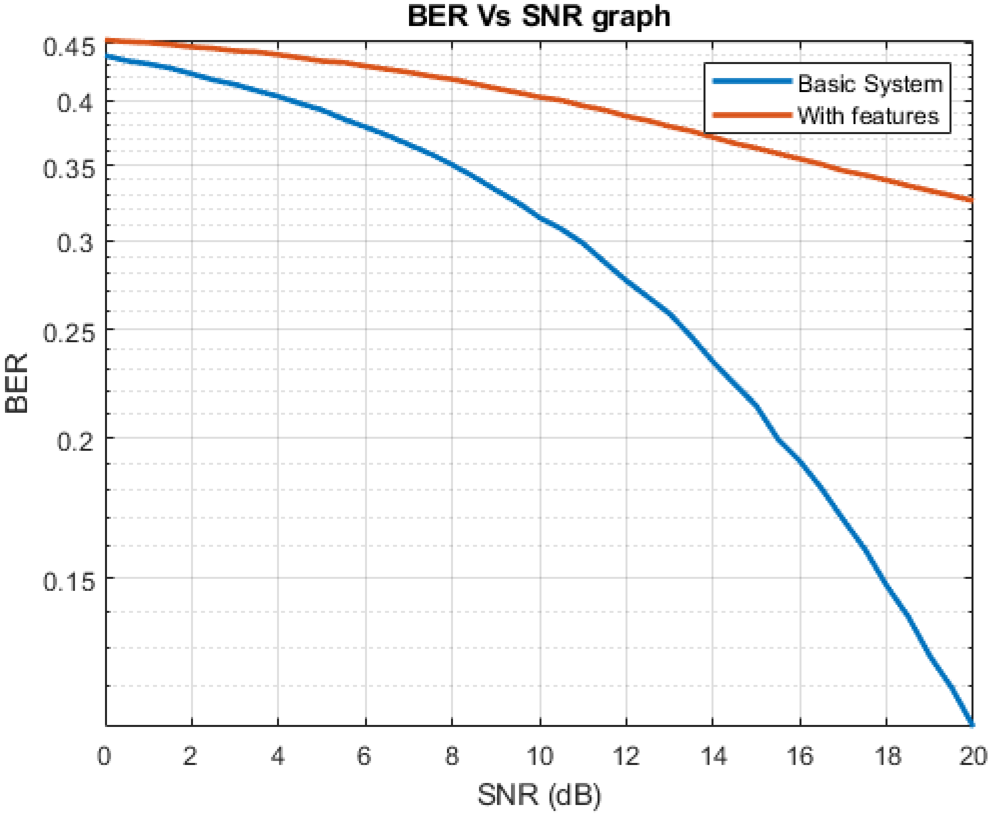
```
        for eib = 1:length(x1hatb)
            error1b(eib) = x1b(eib) ~= x1hatb(eib);
        end
        for eeib = 1:length(x2hatb)
            error2b(eeib) = x2b(eeib) ~= x2hatb(eeib);
        end
        Terror1b(rib) = sum(error1b);

        Terror2b(rib) = sum(error2b);


    end
    finaltotalerrorb = sum(Terror1b) + sum(Terror2b);
    BERb(sib) = (finaltotalerrorb)/(Rb*Nb*2);

end
```

---PLOTTING---

```
semilogy(SNR_dBb, BERb, 'linewidth',2);
grid on;
xlabel('SNR (dB)');
ylabel('BER');
title('BER Vs SNR graph')
```



```
semilogy(SNR_dB, BERb, 'linewidth',2);
hold on
grid on;
semilogy(SNR_dB, BER, 'linewidth',2);

xlabel('SNR (dB)');
ylabel('BER');
title('BER Vs SNR graph');
legend({'Basic System','With features'})
```


BER Vs SNR graph
BER
SNR (dB)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0
2
4
6
8
10
12
14
16
18
20
Basic System
With features