Faculty of Engineering
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OFDM Project

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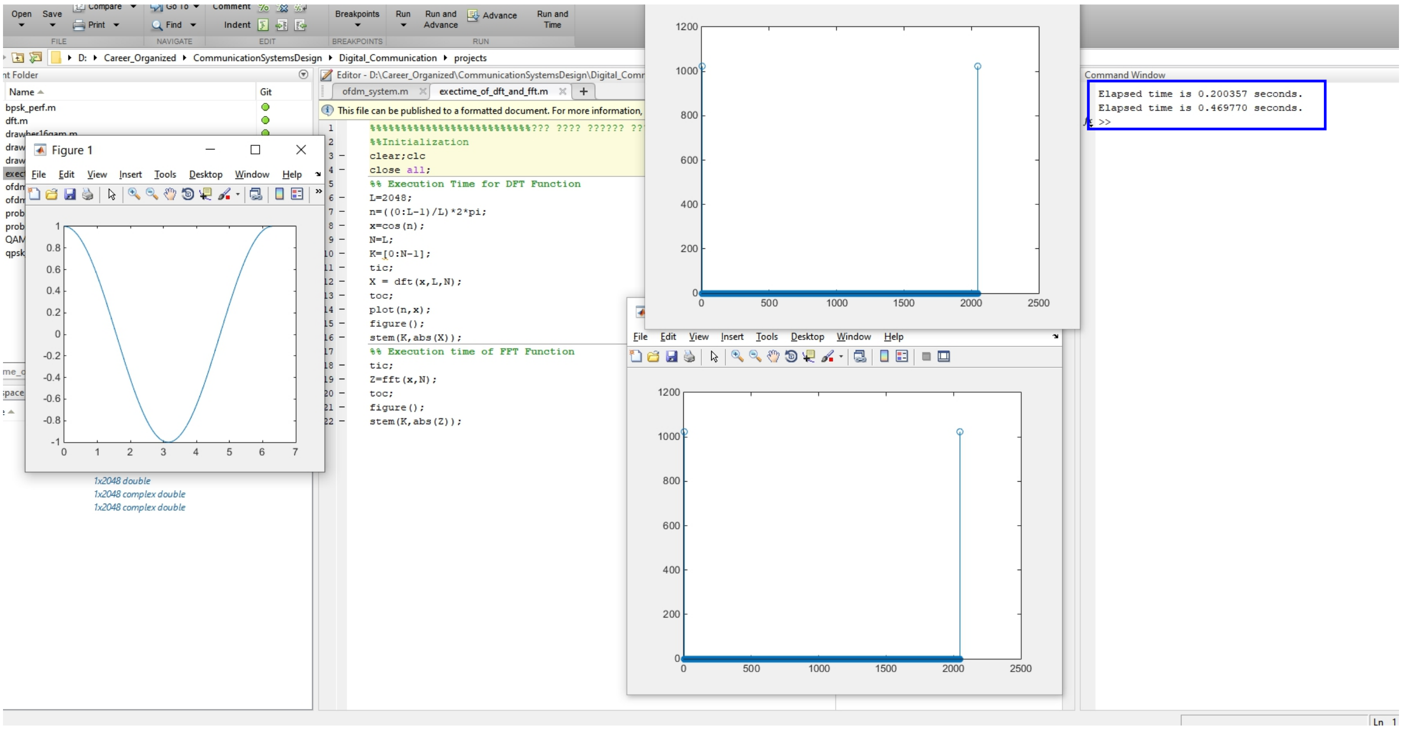
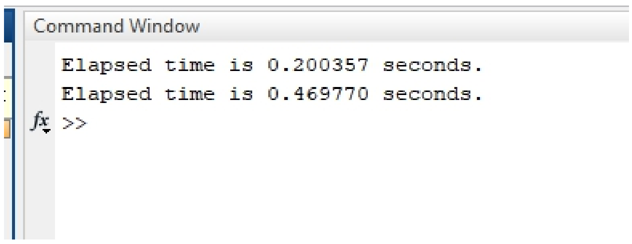
Problem 1:

Elapsed time for DFT: 0.469770 seconds
Elapsed time for FFT: 0.200357 seconds





Problem 2:

Transmitter Model:

Generating BitStream and grey Encode them:

```
%% 16-QAM Transmitter Model
N=100; % Number of Samples
M=16; % Number bits per symbol
%--------------------Data Generation---------------------------%
data=randi([0 M-1],N,1);
%data=[0:M-1];
%-----------Grey Encoding------------%
[datagrey,mapgrey] = bin2gray(data,'qam',M);
```

Mapping Symbols to Constellations:

```
%--------------------16-QAM Modulation----------------------------%
consttable=[-3-3i, -3-1i, -3+3i, -3+1i,...
          -1-3i, -1-1i, -1+3i, -1+1i,...
           3-3i, 3-1i, 3+3i, 3+1i,...
           1-3i, 1-1i, 1+3i, 1+1i];
for k=1:length(datagrey)
    tx(k) = consttable(datagrey(k)+1);
end
tx=tx(:);
scatterplot(tx,1,0,'b*');
for k = 1:16
    text(real(tx(k))-0.3,imag(tx(k))+0.3,...
        dec2base(data(k),2,4));

    text(real(tx(k))-0.3,imag(tx(k))-0.3,...
        dec2base(datagrey(k),2,4),'Color',[1 0 0]);
end
title('Transmitted Symbols');
```

Fading Channel Model:

```
%% Rayleigh-Fading Channel Model
hr=normrnd(0,sqrt(0.5),1);
hi=normrnd(0,sqrt(0.5),1);
h=(hr+1i*hi)*ones(1,N);
h=h(:);
rx=tx.*h;
scatterplot(rx)
title('Rayleigh-Fading Channel Effect');
```

AWGN Channel Model:

```
%% AWGN Channel
%AWGN Noise
mu=0;
No=0.1;
variance=No/2;
sigma=sqrt(variance);
nc=normrnd(mu,sigma,[1,N]);
ns=normrnd(mu,sigma,[1,N]);
n=nc+1i*ns;
n=n(:);
yk=rx+n;
scatterplot(yk);
title('AWGN Channel Effect');
```

Equalizer:

```
%Equalizer assuming channel is known
 yk=yk/h;
```

Correlation and Decision Model:

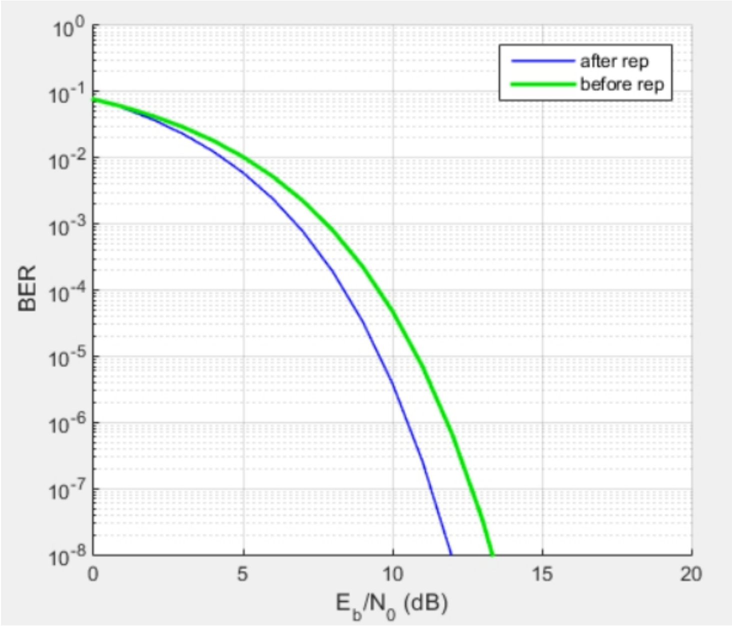
```
%% Correlator & Decision Model
constable=[-3-3i, -3-1i, -3+3i, -3+1i,...
          -1-3i, -1-1i, -1+3i, -1+1i,...
          3-3i, 3-1i, 3+3i, 3+1i,...
          1-3i, 1-1i, 1+3i, 1+1i];
for N = 1:length(yk)
    %compute the minimum distance for each symbol
    [~, idx] = min(abs(yk(N) - consttable));
    datademod(N) = idx-1;
end
[datademodbin,mapbin] = gray2bin(datademod,'qam',M);
datademodbin=datademodbin(:);
```

BitError Rate Estimation:

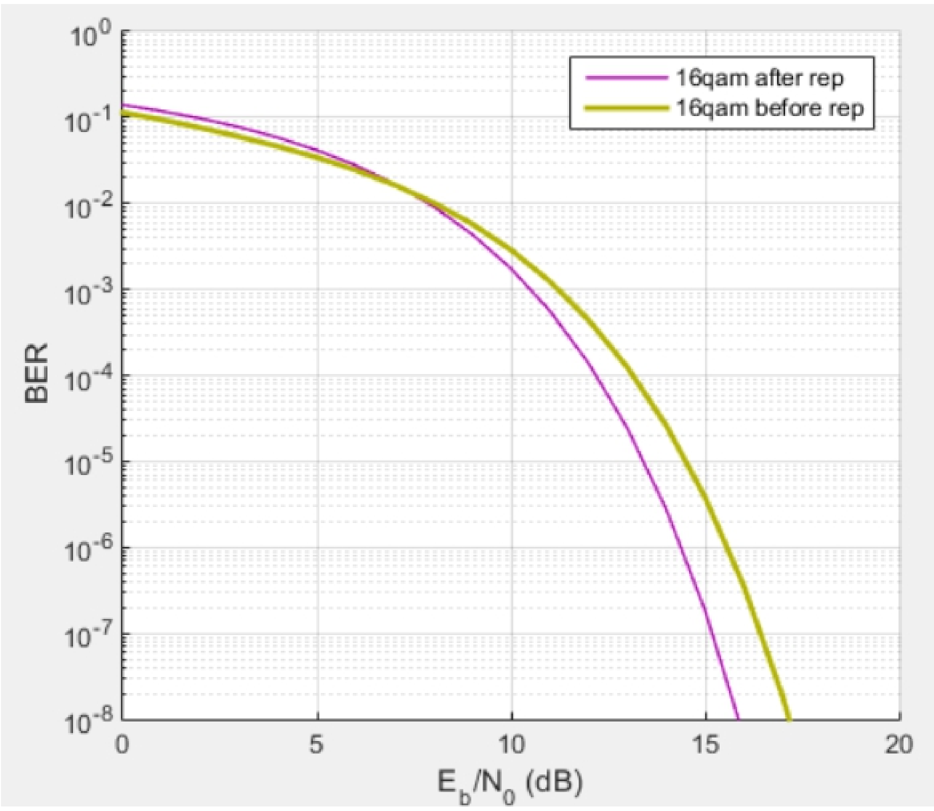
```
%% BER
BER=biterr(datademodbin,data)/(length(data)*log2(M));
```

ALL above procedures are same for different types of modulation we just change params like M for number of levels, constellation tables

BPSK&QPSK BER Before & After Repetition:



16-QAM BER Before & After Repetition:



Problem 3:

1. Coding

```
%% Generating and coding data
N=21;
data=randi([0 3],N,1)';
codeddata=repmat(data,1,3);
codeddata=[0, codeddata];
```

2. Interleaver

```
interleavematrix=reshape(codeddata,8,8);
```

3. Mapper: Same like question 2

4. 32-point IFFT

```
ifft_sig=ifft(y,32);
```

5. Add Cyclic Extension

```
%% Add Cyclic extension
% Cyclic Prefixing
CP_part=serial(:,end-Ncp+1:end); % this is the Cyclic Prefix part to be appended.
cp=[CP_part serial];
```

6. Channel

6.1. Flat Channel

```
%% Rayleigh-Flat Fading Channel
hr=normrnd(0,sqrt(0.5),1);
hi=normrnd(0,sqrt(0.5),1);
h=(hr+1i*hi)*ones(1,N);
h=h(:);
```

6.2. Selective Channel

```
% Selective Channel
selhr=normrnd(0,sqrt(0.5),N);
selhi=normrnd(0,sqrt(0.5),N);
selh=selhr+1i*selhi;
selh=selh(:);
```

6.3. AWGN Channel

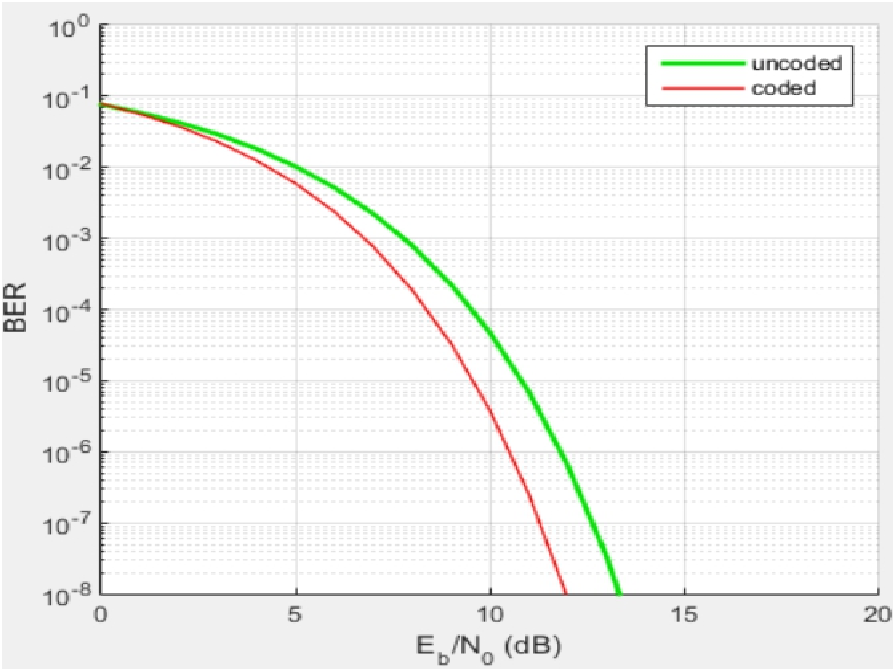
```
%% AWGN Channel
ofdm_sig=awgn(cext_data,snr,'measured'); % Adding white Gaussian Noise
```

7. Receiver

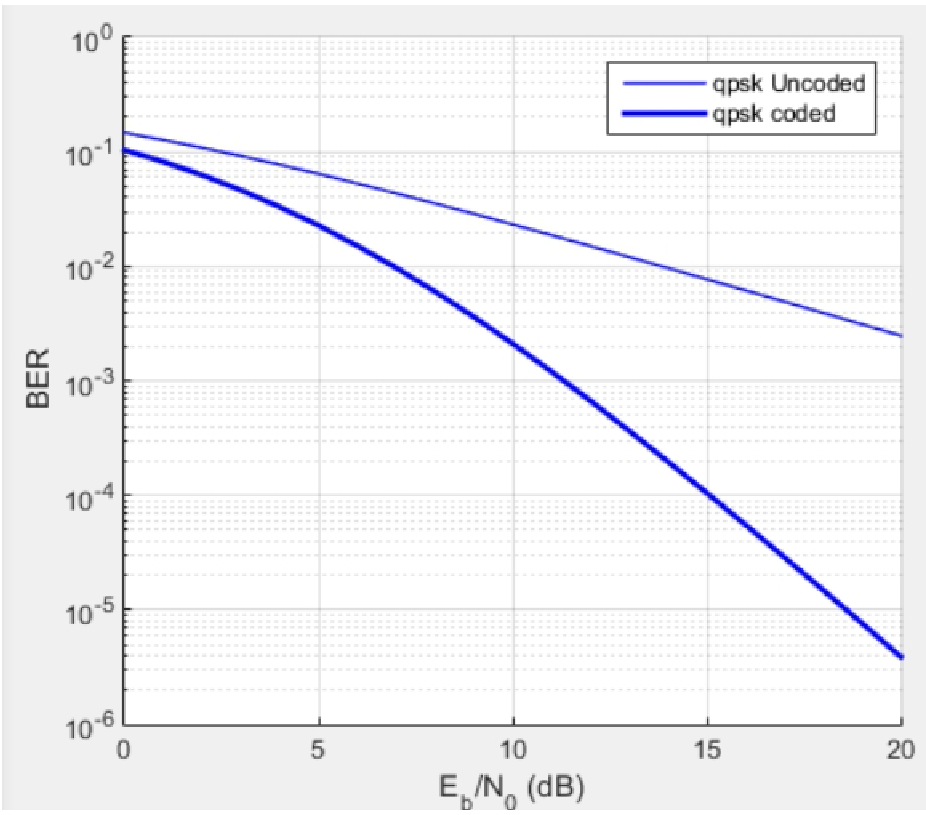
```
% Removing Cyclic Extension

for i=1:32

    rxed_sig(i)=ofdm_sig(i+16);

end

% FFT
ff_sig=fft(rxed_sig,32);


% Demodulation
dem_data= qpskdemod(ff_sig);


% Decimal to binary conversion
bin=de2bi(dem_data','left-msb');
bin=bin';

% De-Interleaving
deintlvddata = matdeintrlv(bin,2,2); % De-Interleave
deintlvddata=deintlvddata';
deintlvddata=deintlvddata(:)';

% Decoding data
n=6;
k=3;
decodedata =vitdec(deintlvddata,trellis,5,'trunc','hard');  % decoding datausing veterbi
decoder
rxed_data=decodedata;

% Calculating BER
rxed_data=rxed_data(:)';
errors=0;
c=xor(data,rxed_data);
errors=nnz(c);
BER=errors/length(data);
```

Results:

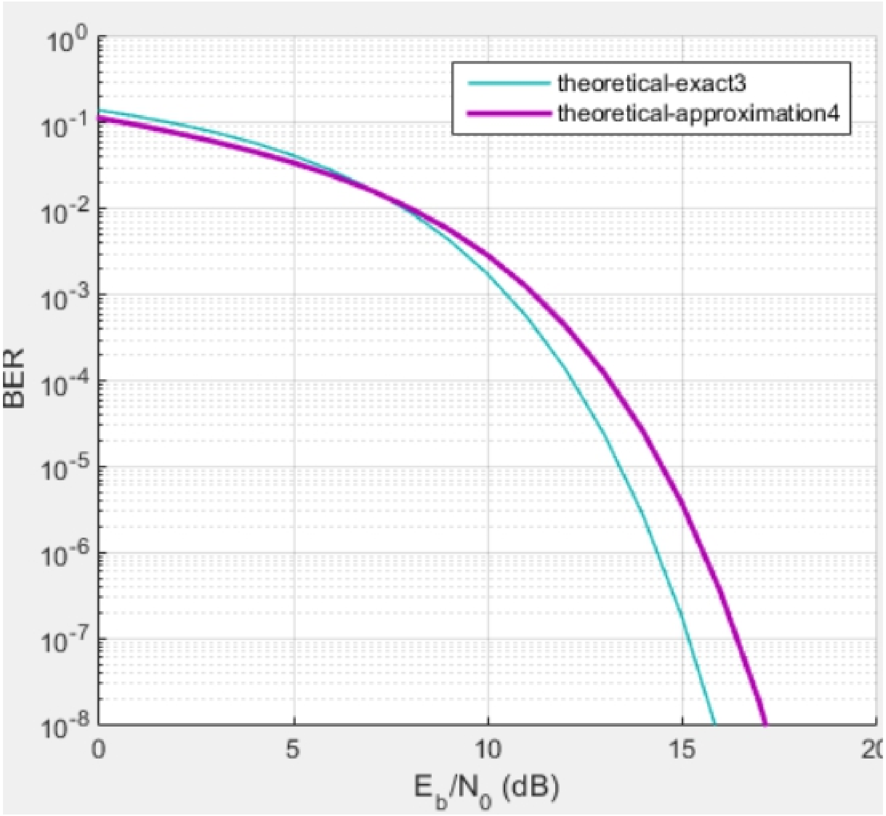
1. QPSK Flat channel & (Coding & NoCoding)



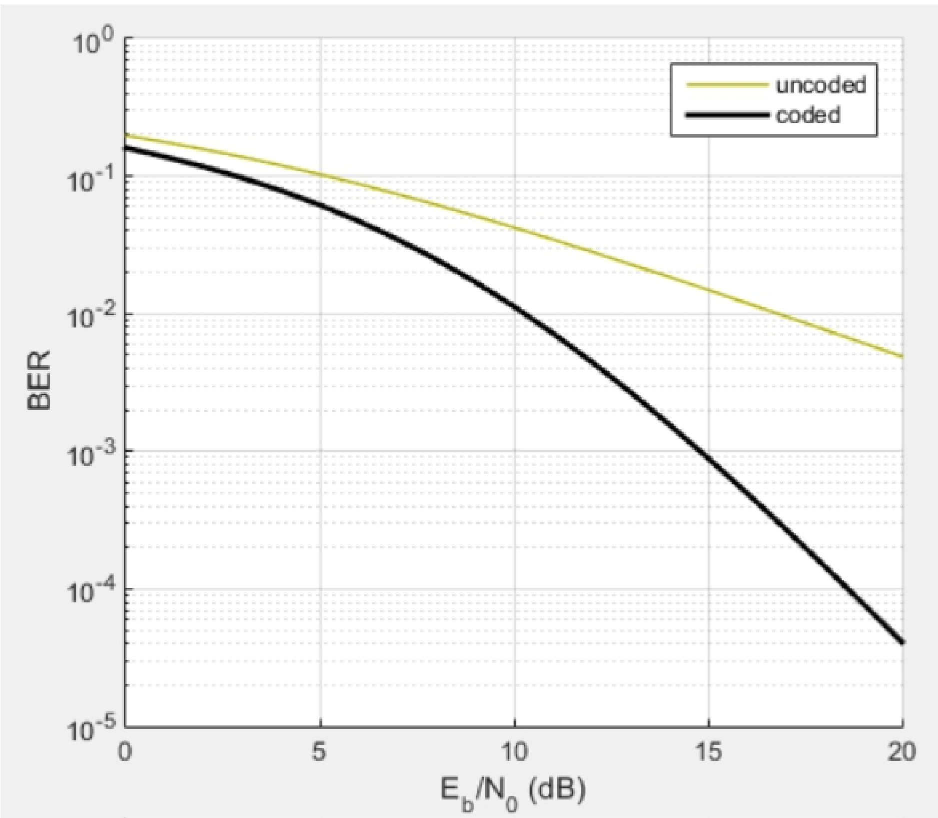
2. QPSK Selective channel & (Coding&No Coding)



3. 16-QAM Flat channel & (Coding & No Coding)



4. 16-QAM Selective channel & (Coding & No Coding)



Full Code:

Problem 1:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%??? ???? ?????? ??????%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%Initialization
clear;clc
close all;
%% Execution Time for DFT Function
L=2048;
n=((0:L-1)/L)*2*pi;
x=cos(n);
N=L;
K=[0:N-1];
tic;
X = dft(x,L,N);
toc;
plot(n,x);
figure();
stem(K,abs(X));
%% Execution time of FFT Function
tic;
Z=fft(x,N);
toc;
figure();
stem(K,abs(Z));

function [X] = dft( x, L, N)
%DFT Summary of this function goes here
%   Detailed explanation goes here%% Implementing DFT Function
n=[0:L-1];
for K=0:N-1
   X(K+1)=sum(x.*exp((-1j*(2*pi*n*K))/N));
end
end
```

Problem 2:

```
function BER=drawber16qam(No)
N=1000; % Number of Samples
M=16; % Number bits per symbol
%--------------------Data Generation---------------------------%
data=randi([0 M-1],N,1);
%------------Grey Encoding------------%
[datagrey,mapgrey] = bin2gray(data,'qam',M);
%--------------------16-QAM Modulation----------------------------%
consttable=[-3-3i, -3-1i, -3+3i, -3+1i,...
          -1-3i, -1-1i, -1+3i, -1+1i,...
           3-3i, 3-1i, 3+3i, 3+1i,...
```

```
           1-3i, 1-1i, 1+3i, 1+1i];
for k=1:length(datagrey)
    tx(k) = consttable(datagrey(k)+1);
end
tx=tx(:);
% Rayleigh-Fading Channel Model
hr=normrnd(0,sqrt(0.5),1);
hi=normrnd(0,sqrt(0.5),1);
h=(hr+1i*hi)*ones(1,N);
h=h(:);
rx=tx.*h;
% AWGN Channel
%AWGN Noise
mu=0;
variance=No/2;
sigma=sqrt(variance);
nc=normrnd(mu,sigma,[1,N]);
ns=normrnd(mu,sigma,[1,N]);
n=nc+1i*ns;
n=n(:);
yk=rx+n;
yk=yk/h;
% Correlator & Decision Model
consttable=[-3-3i, -3-1i, -3+3i, -3+1i, -1-3i, -1-1i, -1+3i, -1+1i, 3-3i, 3-1i, 3+3i, 3+1i,
1-3i, 1-1i, 1+3i, 1+1i];
for N = 1:length(yk)
     %compute the minimum distance for each symbol
     [~, idx] = min(abs(yk(N) - consttable));
     datademod(N) = idx-1;
end
[datademodbin,mapbin] = gray2bin(datademod,'qam',M);
datademodbin=datademodbin(:);
% BER
BER=biterr(datademodbin,data)/(length(data)*log2(M));
end

%% Initialization
clear;clc
close all;
%% 16-QAM Transmitter Model
N=100; % Number of Samples
M=16; % Number bits per symbol
%--------------------Data Generation---------------------------%
data=randi([0 M-1],N,1);
%data=[0:M-1];
%-----------Grey Encoding------------%
[datagrey,mapgrey] = bin2gray(data,'qam',M);
%--------------------16-QAM Modulation---------------------------%
consttable=[-3-3i, -3-1i, -3+3i, -3+1i,...
          -1-3i, -1-1i, -1+3i, -1+1i,...
           3-3i, 3-1i, 3+3i, 3+1i,...
           1-3i, 1-1i, 1+3i, 1+1i];
for k=1:length(datagrey)
    tx(k) = consttable(datagrey(k)+1);
end
tx=tx(:);
scatterplot(tx,1,0,'b*');
for k = 1:16
    text(real(tx(k))-0.3,imag(tx(k))+0.3,...
        dec2base(data(k),2,4));

    text(real(tx(k))-0.3,imag(tx(k))-0.3,...
        dec2base(datagrey(k),2,4),'Color',[1 0 0]);
end
title('Transmitted Symbols');

%% Rayleigh-Fading Channel Model
```

```
hr=normrnd(0,sqrt(0.5),1);
hi=normrnd(0,sqrt(0.5),1);
h=(hr+1i*hi)*ones(1,N);
h=h(:);
rx=tx.*h;
scatterplot(rx)
title('Rayleigh-Fading Channel Effect');

%% AWGN Channel
%AWGN Noise
mu=0;
No=0.1;
variance=No/2;
sigma=sqrt(variance);
nc=normrnd(mu,sigma,[1,N]);
ns=normrnd(mu,sigma,[1,N]);
n=nc+1i*ns;
n=n(:);
yk=rx+n;
scatterplot(yk);
title('AWGN Channel Effect');

%% Correlator & Decision Model
consttable=[-3-3i, -3-1i, -3+3i, -3+1i,...
          -1-3i, -1-1i, -1+3i, -1+1i,...
          3-3i, 3-1i, 3+3i, 3+1i,...
          1-3i, 1-1i, 1+3i, 1+1i];
for N = 1:length(yk)
    %compute the minimum distance for each symbol
    [~, idx] = min(abs(yk(N) - consttable));
    datademod(N) = idx-1;
end
[datademodbin,mapbin] = gray2bin(datademod,'qam',M);
datademodbin=datademodbin(:);

%% BER
BER=biterr(datademodbin,data)/(length(data)*log2(M));
i=1;
for Es_N0_dB = [-4:0.1:16]
   for meannum=1:100
      meanv(meannum)=drawber16qam(10^(-Es_N0_dB/10));
   end
   BER(i)=sum(meanv(:))/100;
   i=i+1;
end
Es_N0_dB = [-4:0.1:16];
plot(Es_N0_dB,1*log10(BER));

%% Repitition Code
 %Repeat by modifying N=N*3 I removed it from here for better explanation
```

Problem 3:

```
%% Initialization
clear;clc
close all;

%% Parameters
N=21;%Size of OFDM Symbol
m=16;%Number of OFDM Symbols
M=4;
L=1;%Up-Sampling Factor
PoQ=1;%Type of Mapping 1 PSK and 2 QAM
```

```
Phase_Offset=0;%Constellation Phase Offset
Symbol_Order=2;%Constellation Symbol Order
Ncp=0;%Size of cyclic prefix samples

%% Coding && InterLeaver && Mapper
% Creating Baseband modems Tx/Rx
% data generation
Data=randi([0 M-1], m, N/L);
% Mapping
Dmap=qpskmod(Data);
% Serial to Parallel
parallel=Dmap.';
% Oversampling
upsampled=upsample(parallel,L);
%% 32-point IFFT
% Amplitude modulation (IDFT using fast version IFFT)
am=ifft(upsampled,N);

% Parallel to serial
serial=am.';

%% Add Cyclic extension
% Cyclic Prefixing
CP_part=serial(:,end-Ncp+1:end); % this is the Cyclic Prefix part to be appended.
cp=[CP_part serial];

%% Channel
% Adding Noise using AWGN
SNRstart=-4;
SNRincrement=2;
SNRend=16;
c=0;
r=zeros(size(SNRstart:SNRincrement:SNRend));
%% Receiver
for snr=SNRstart:SNRincrement:SNRend
    c=c+1;
    noisy=awgn(cp,snr,'measured');
% Remove cyclic prefix part
    cpr=ofdm.noisy(:,Ncp+1:N+Ncp); %remove the Cyclic prefix
% serial to parallel
    parallel=cpr.';
% Amplitude demodulation (DFT using fast version FFT)
    amdemod=fft(parallel,N);
% Down-Sampling
downsampled=downsample(amdemod,L);
% Parallel to serial
    rserial=downsampled.';
% Baseband demodulation (Un-mapping)
    hRx=qpskdemod(rserial);
    Umap=hRx;
% Calculating the Symbol Error Rate
    [n, r(c)]=symerr(DATA,Umap);
    disp(['SNR = ',num2str(snr),' step: ',num2str(c),' of ',num2str(length(r))]);
end
snr=SNRstart:SNRincrement:SNRend;
% Plotting SER vs SNR
semilogy(snr,r,'-ok','linewidth',2,'markerfacecolor','r','markersize',8,'markeredgecolo
r','b');grid;
title('OFDM Symbol Error Rate vs SNR');
ylabel('Symbol Error Rate');
xlabel('SNR [dB]');
```