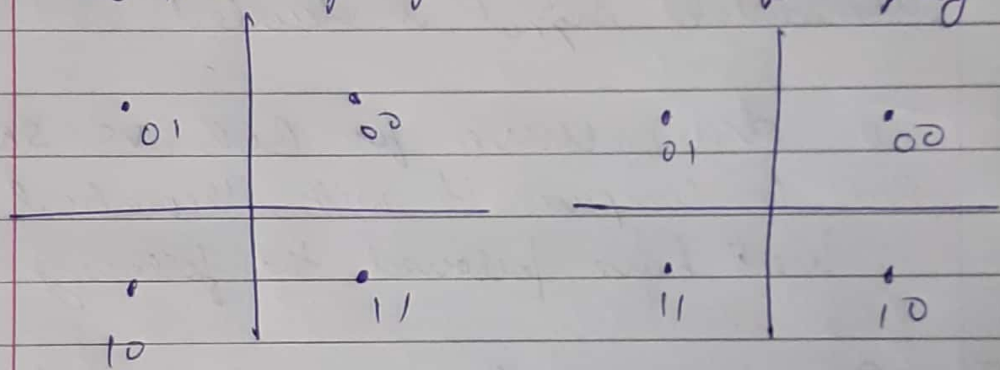
lab 4

Generating 2000 message bits
Symbol.
Complex Symbols are used to map the message bits to gray and without gray code.

without gray | with gray



00 - 1+j1
01 = -1+j1
11 = 1-j1
10 = -~~1~~ -1-j1

~~Aff~~ After mapping ~~it~~ the message bits according to gray and without gray code it is modulated and then awgn is ~~adde~~ added to it using randn function with SNR varying between -10 to 10.
The received signal is message signal plus noise. Then this received ~~signa~~ Signal is compared with message bits and error is calculated for both gray label

and without gray label
Since the message signal is complex a 2D gaussian noise (complex) is added to it.

From the plots it can be said that the BER is more for without gray label. in comparison with ~~with~~ gray label code.

The experimental BER for gray code follows the theoretical plot using Q function.

```
clc;
clear all;
close all;

%generate QPSK constellation as complex numbers
k=double(1.0)/double(sqrt(2)); %The normalizing factor
constellation=k*[1+1i -1+1i -1-1i 1-1i]; %To store constellation points ie. 1+1j ,↙
1-1j ,  -1-1j , -1+1j in complex double
gre=[0 1 3 2]; %This is used to map between non - gray and gray constellation↙
points. %%[00,01,11,10]
%number of symbols in simulation


%———Input Fields—————————%
nsymbols = 2000; %  represents number of bits
%Generating nsymbols random 2 bit symbols  for QPSK
input=zeros(1,nsymbols);
for k=1:nsymbols %Loop to generate 2 bit random inputs symbols.
 input(k)= randi([0, (2^2-1)]); %randomly generates a 2 bit number between 0 and 3↙
including both of them.
end

%%SNR VALUES%%
EbN0dB = -10:1:10;
inputc=constellation(input(:)+1);  %will have the constellation symbols for non↙
gray
input_gray=gre(input(:)+1);        %will get the corresponding gray input for the↙
same constellation input.
inputc=inputc.';  %Taking non conjugate transpose of input signal


%%adding awgn to message bits%%
number_EbN0dBs = length(EbN0dB); %Number of EbN0dB values to check
perr_estimate = zeros(number_EbN0dBs,1); %To estimate error for each EbN0dB value↙
and add it to estimate without gray labelling
perr_estimate_gray = zeros(number_EbN0dBs,1); %To estimate error for each EbN0dB↙
value and add it to estimate for Gray labelling


for k=1:number_EbN0dBs %EbN0dB for loop
    EbN0dB_now = EbN0dB(k); %The current value of EbN0dB being tested for BER.
    ebno=10^(EbN0dB_now/10); %We convert EbN0dB from dB to decimal unit.
    sigma=sqrt(1/(2*ebno)); %The corresponding varience for noise.

    % add 2d Gaussian noise to our symbols.
    received = inputc +sigma*randn(nsymbols,1)+1j*sigma*randn(nsymbols,1); %For↙
adding awgn
    decisions=zeros(nsymbols,1); %We initialize decisions with zeros corresponding↙
to all n symbols for fast execution.
    for n=1:nsymbols
        distances = abs(received(n)-constellation);%Absolute distance from each↙
constellation point.
        [min_dist,decisions(n)] = min(distances); %The minimum of those is choosen↙
```

```
for that recieved point.
    end
    decisions_gray=gre(decisions);%Maps back non gray to gray
    decisions=decisions-1;  %To get it between 0 and 3.


    %To calculate bit errors here, for faster execution.
    num=zeros(nsymbols,1);
    for s=1:nsymbols
        d_bin=de2bi(decisions(s),2); %To get a zero padded 2 bit binary string for
ease of comparing.
        i_bin=de2bi(input(s),2);   %To get a zero padded 2 bit binary string for
ease of comparing.
        biterror=0;    %To count error per bit
        for t=1:2
            if d_bin(t)~=i_bin(t)
                biterror=biterror+1;  %adding error for each incorrectly decieded
bit.
            end
            num(s)=biterror;  %To store the total bit error for each word
        end
    end
    error= num;

    num_gray=zeros(nsymbols,1);
    %For gray encoded
    for s=1:nsymbols
        d_gray=de2bi(decisions_gray(s),2); %To get a zero padded 2 bit binary
string for ease of comparing.
        i_bin=de2bi(input_gray(s),2);   %To get a zero padded 2 bit binary string
for ease of comparing.
        biterror=0;    %To count error per bit
        for t=1:2
            if d_gray~=i_bin(t)
                biterror=biterror+1;  %adding error for each incorrectly decieded
bit.
            end
            num_gray(s)=biterror; %To store the total bit error for each word
        end
    end
    errors_gray= num_gray;

    %BER calculations for that SNR.
    perr_estimate(k) =perr_estimate(k)+ sum(error)/(nsymbols); %This gives BER per
symbol.
    perr_estimate_gray(k) =perr_estimate_gray(k)+ sum(errors_gray)/(nsymbols); %
This gives BER per symbol. as we are adding error for each of the 4 symbols
end



%%plotting the results%%
%%plotting BER vs SNR with graylabelling and without gray labelling%%
```

```
semilogy(EbN0dB,perr_estimate,'o'); %To plot the BER per nsymbols with EbN0dB.
hold on;
semilogy(EbN0dB,perr_estimate_gray,'b*'); %To plot the BER per nsymbols with↙
EbN0dB.
hold on;
semilogy(EbN0dB,qfunc((sqrt(10.^(EbN0dB/10))))); % To plot BER theoretical using Q-↙
function .
legend("Experimental BER without gray ","Experimental BER with gray code","↙
Theoretical using Q function");
grid on;
xlabel("EbN0dB (dB)");
ylabel("BER ");
```

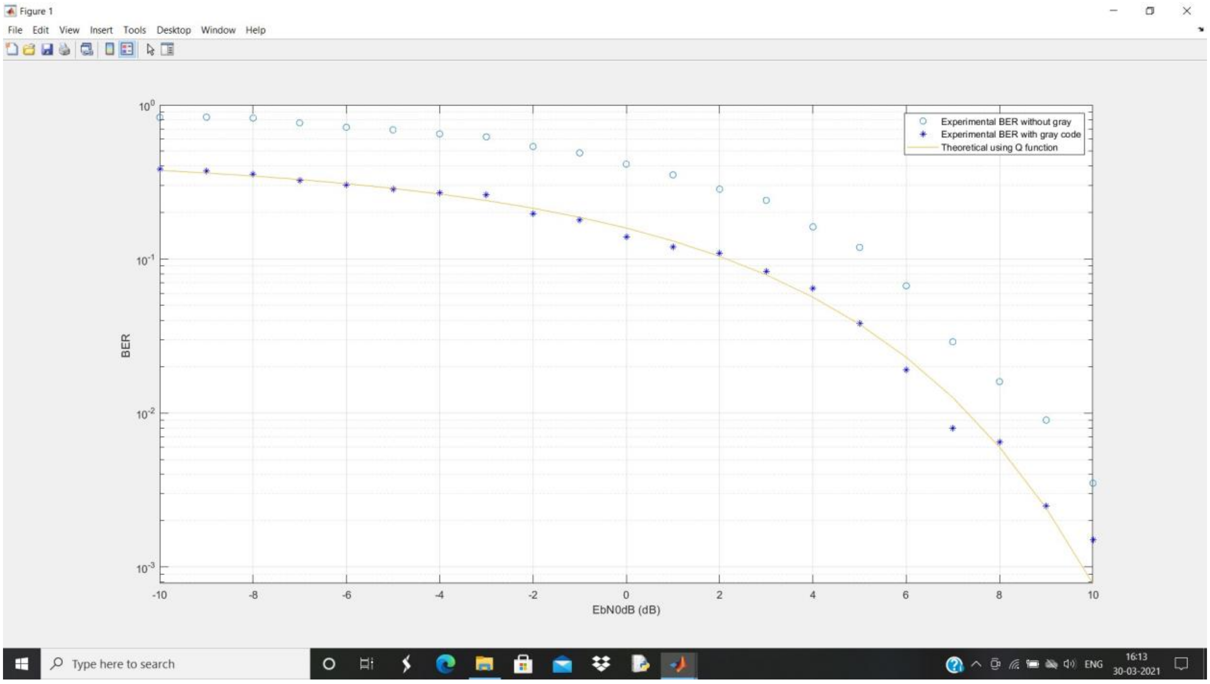


Figure 1
File Edit View Insert Tools Desktop Window Help
Experimental BER without gray
Experimental BER with gray code
Theoretical using Q function
BER
EbN0dB (dB)
10^0
10^{-1}
10^{-2}
10^{-3}
-10 -8 -6 -4 -2 0 2 4 6 8 10
Type here to search
ENG
16:13
30-03-2021