Table of Contents

Hw8 - part II

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```
%Student-Number : [9723042]
% University: Amirkabir University of Technology
```

clear recent data

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

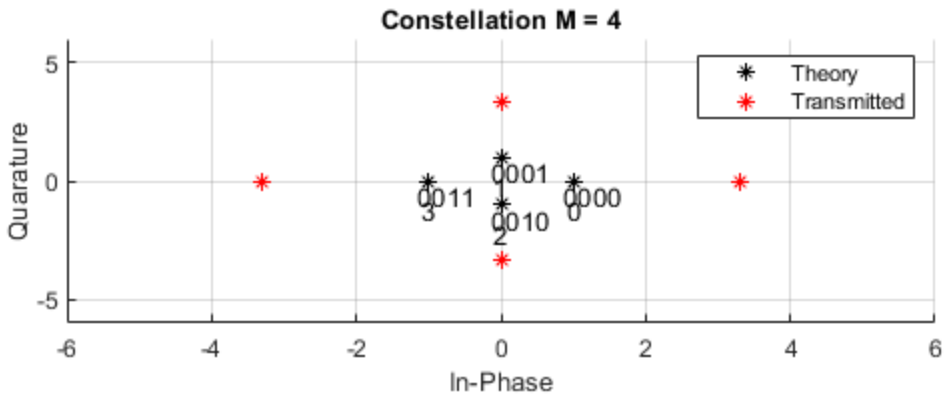
Initialization

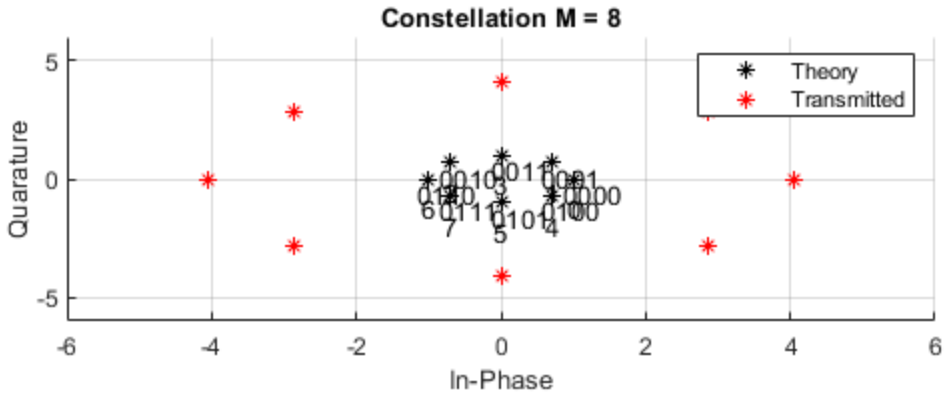
```
clc;
N = 1e3; %Numbers of bits
M =[4 8 16 32 64]; %M or # of symbols
E_b = 0 : 0.1 : 13; % in dB
N_0 = 2; %sigma^2 / 2 = 1 => N0 = 2 = sigma^2
SPS = [ 1, 10]; %Symbol per Sample
```

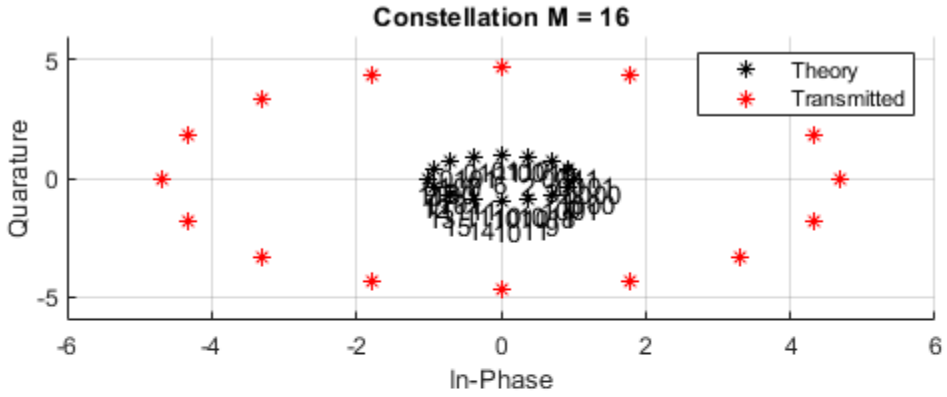
Random bit Generation and scatter plotting

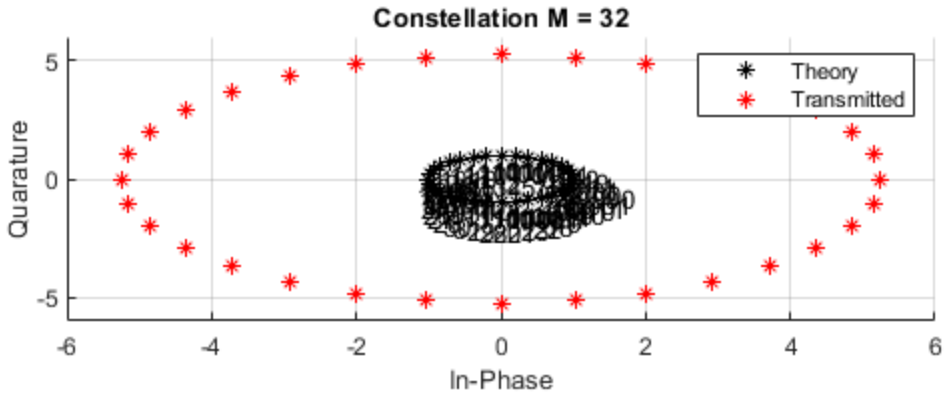
```
clc;
for counter = 1 : length(M)

    data = [0 : M(counter) - 1]; %data generation
    symgray = pskmod(data, M(counter),0, 'gray'); %Modulation by Order
 Gray
    mapgray = pskdemod(symgray, M(counter),0,'gray'); %DeModulation by
 Order Gray
    numbers = symgray(randi(numel(symgray), [1, N]));%Generation of
 Numbers in Order of #symbols * N
    t = numbers / std(numbers);% Transmitted bits : To Normalize: (x -
 u) / sigma
```

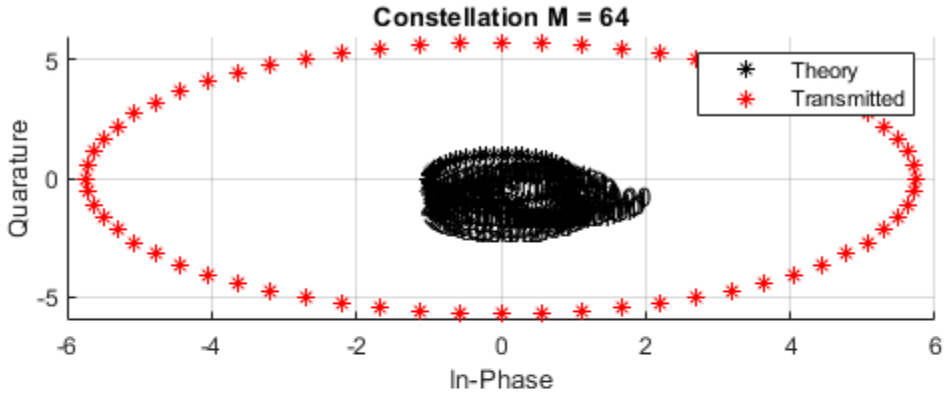
```
   E_s = log2(M(counter)) * 10 .^ (E_b / 10); % Energy of each
symbols
   t = sqrt(E_s)' * t;     % To have Energy E_s all symbols scaled
with sqrt(E_s)
   t_rect = rectpulse(t,SPS(1)); %Repeat symbols
   % Scattering
   figure(counter);
   subplot(2, 1, 1);
   scatter(real(symgray), imag(symgray), '* black');
hold on; %scatter qammod symbols
   scatter(real(t_rect(75, :)), imag(t_rect(75, :)), '*
red');%scatter transmitted symbols
   grid on;
   for k = 1 : M(counter)      % Show the gray code and symbols
sequence #
       text(real(symgray(k)) - 0.15, imag(symgray(k)) - 0.6, ...
           dec2base(mapgray(k), 2, 4));
       text(real(symgray(k)) - 0.1, imag(symgray(k)) - 1.2, ...
           num2str(mapgray(k)));
   end
   axis([-6 6 -6 6])
   legend('Theory', 'Transmitted')
   title(['Constellation M = ', num2str(M(counter))]);
   xlabel('In-Phase');
   ylabel('Quarature');
```




Constellation M = 8
Theory
Transmitted
Quarature
In-Phase
5
0
-5
-6
-4
-2
0
2
4
6

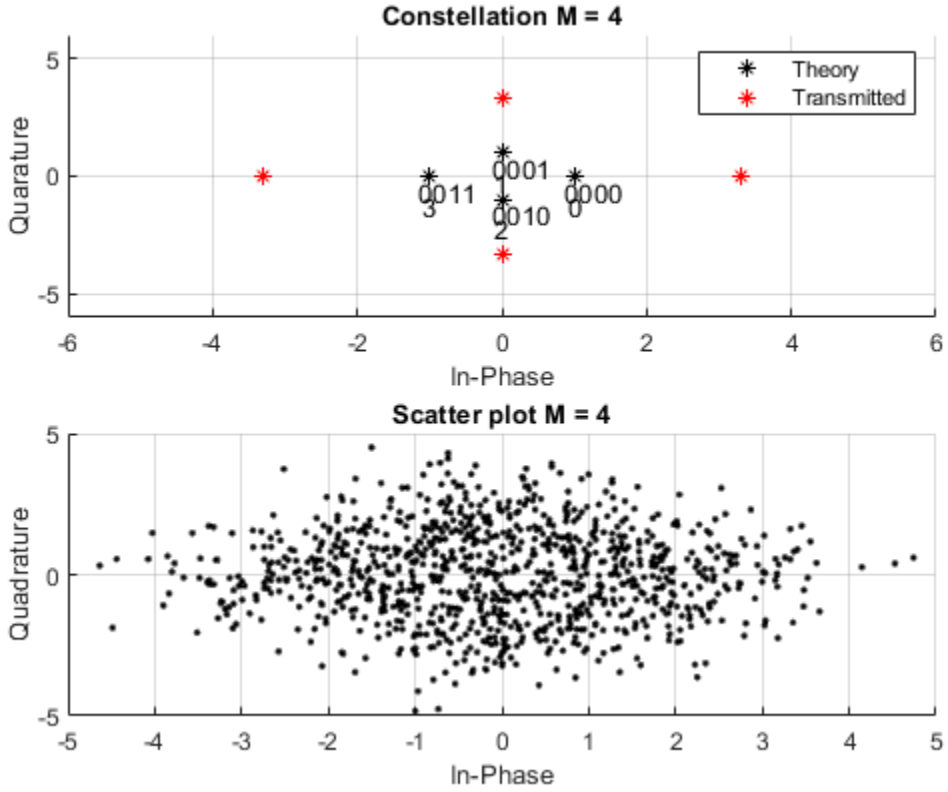

Constellation M = 16
Theory
Transmitted
Quarature
In-Phase
5
0
-5
-6
-4
-2
0
2
4
6

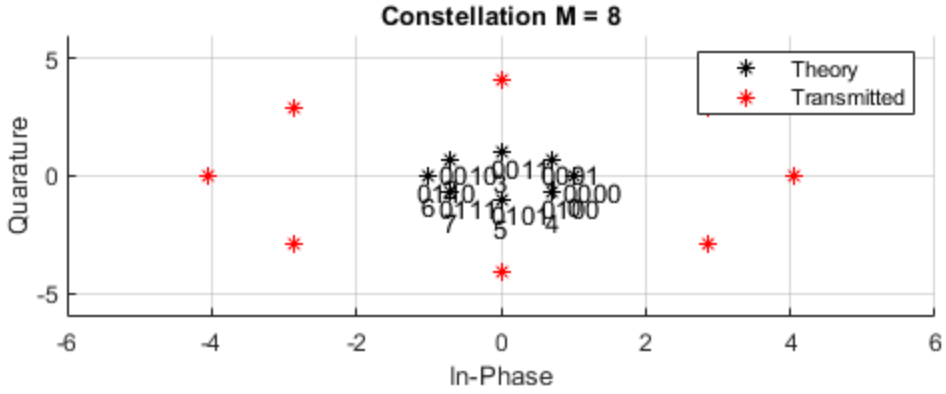

Constellation M = 32
Theory
Transmitted
Quarature
In-Phase
5
0
-5
-6
-4
-2
0
2
4
6

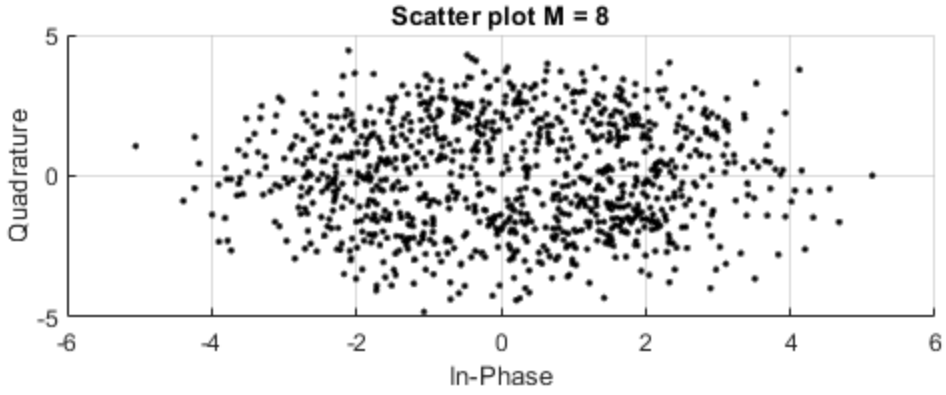

Constellation M = 64
Theory
Transmitted
Quarature
In-Phase
5
0
-5
-6
-4
-2
0
2
4
6

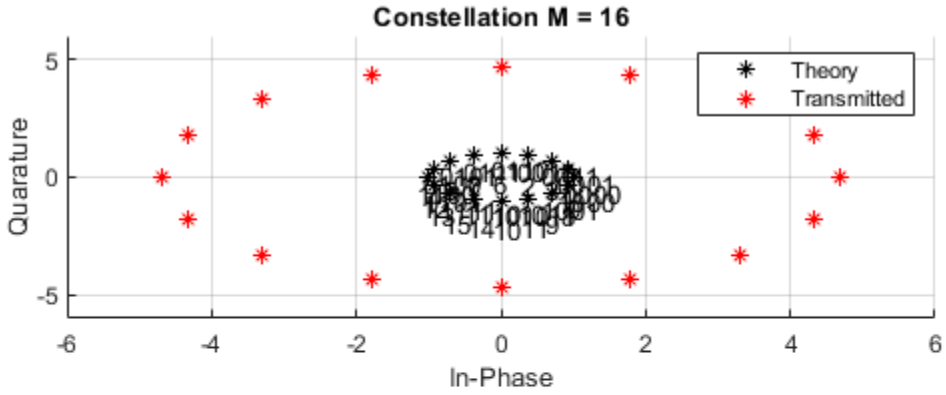
Channel and Noise Generation

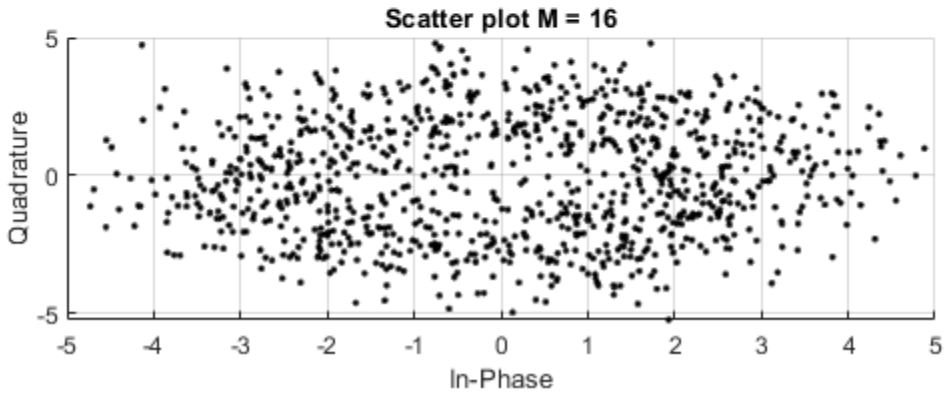
```
    n_i = randn(1, length(t)); %In-Phase noise
    n_q = randn(1, length(t)); %Quadrature noise
    n = sqrt(N_0 / 2) * (n_i / std(n_i) + ...
        1i * n_q / std(n_q));  %Noise generating with variance 1
    r = t_rect + n;       % Recieved Signal
    subplot(2, 1, 2);
    scatter(real(r(25, :)), imag(r(25, :)), '.k'); % Scatter Recieved
signal
    grid on;
    title(['Scatter plot M = ', num2str(M(counter))]);
    xlabel('In-Phase');
    ylabel('Quadrature');
```

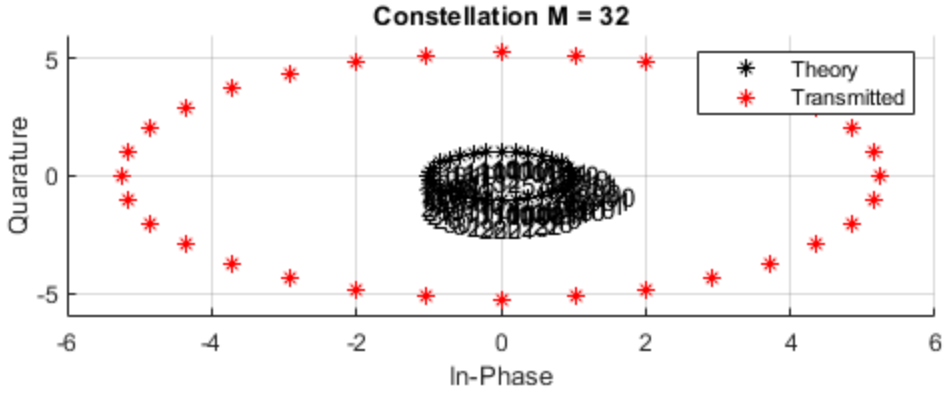


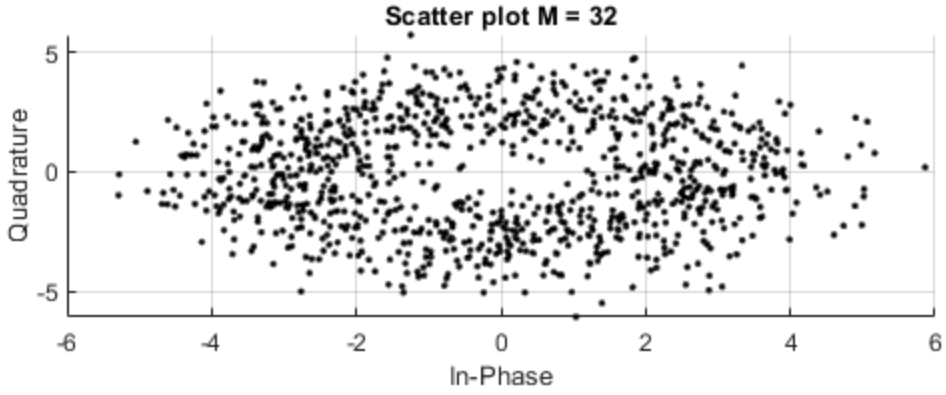

Constellation M = 8
Theory
Transmitted
Quarature
In-Phase

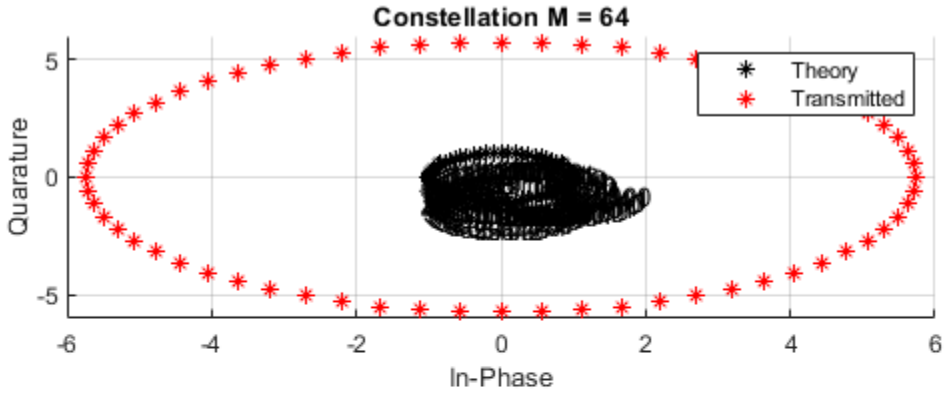

Scatter plot M = 8
Quadrature
In-Phase

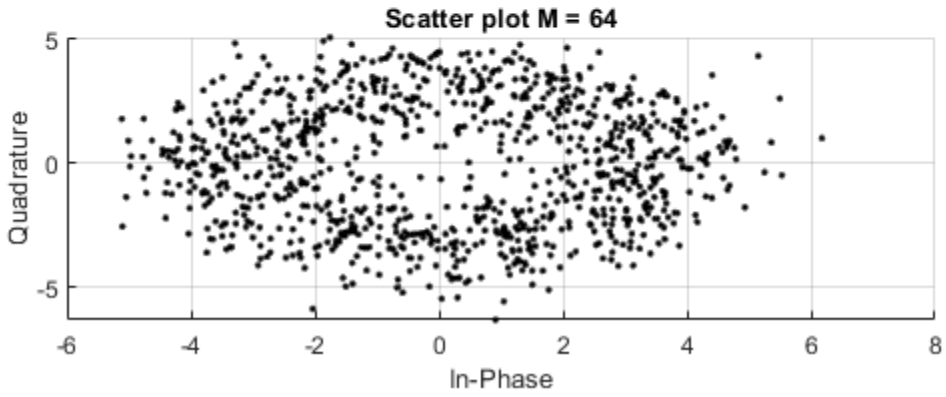

Constellation M = 16
Theory
Transmitted
Quarature
In-Phase


Scatter plot M = 16
Quadrature
In-Phase


Constellation M = 32
Theory
Transmitted
Quarature
In-Phase

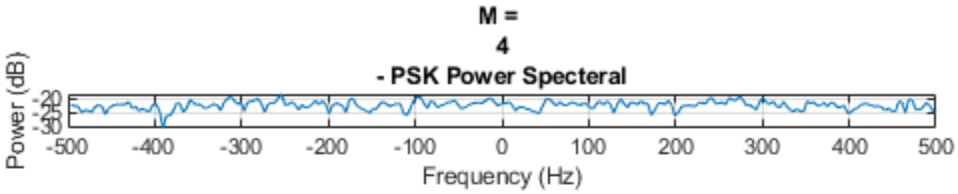

Scatter plot M = 32
Quadrature
In-Phase

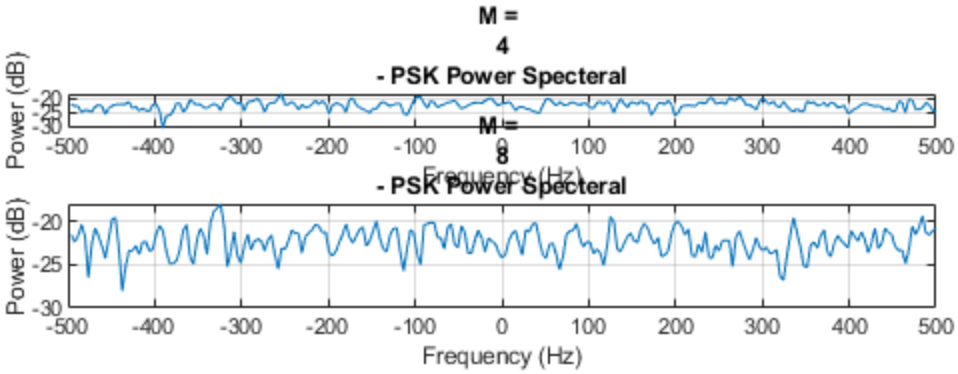

Constellation M = 64
Theory
Transmitted
Quarature
In-Phase

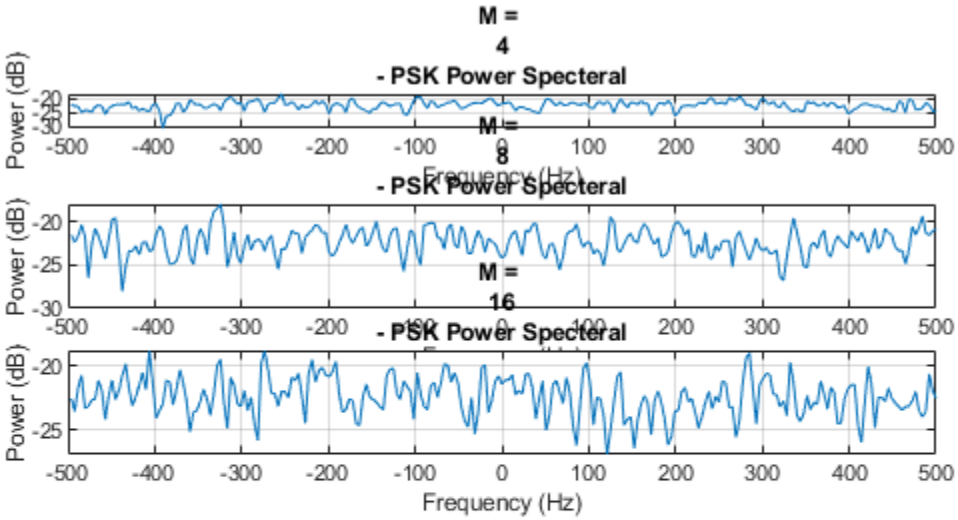

Scatter plot M = 64
Quadrature
In-Phase

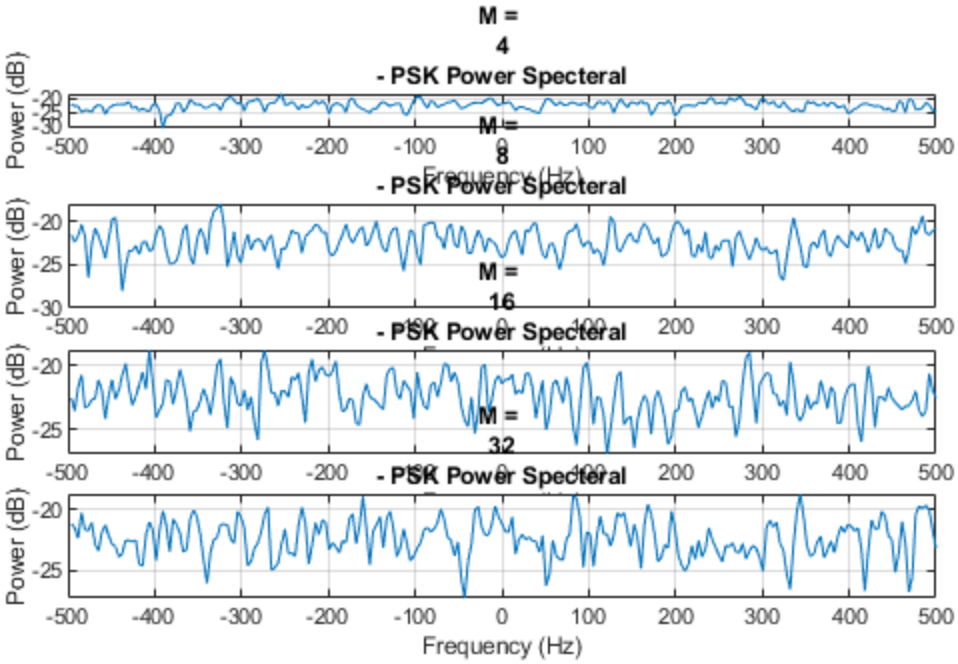
Pwelch

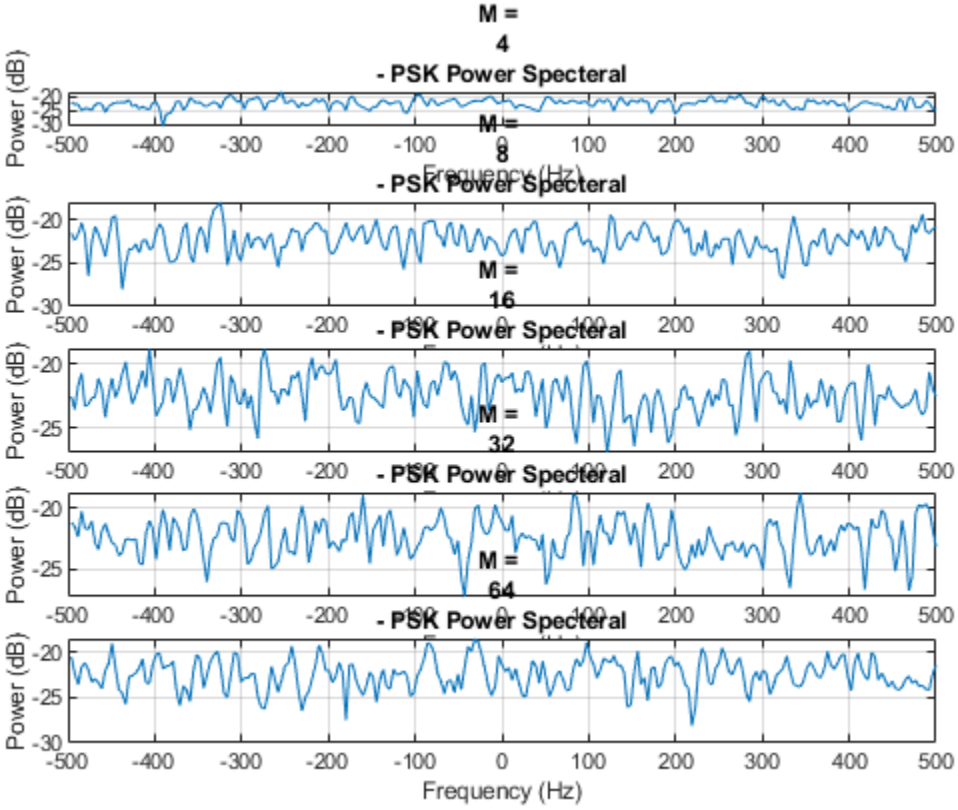
```
clc;
[pxx,f] = pwelch(numbers,[],[],[],1000,'centered','power');
figure(6)
subplot(5,1,counter)
plot(f,pow2db(pxx))
title(["M = ",num2str(M(counter)),"- PSK Power Specteral"])
grid on;
xlabel('Frequency (Hz)')
ylabel('Power (dB)')
```




M =
4
- PSK Power Specteral
Power (dB)
-20
-25
-30
-500
-400
-300
-200
-100
0
100
200
300
400
500
M =
8
- PSK Power Specteral
Power (dB)
-20
-25
-30
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (Hz)


M =
4
- PSK Power Specteral
Power (dB)
-20
-25
-30
-500
-400
-300
-200
-100
0
100
200
300
400
500
M =
8
- PSK Power Specteral
Power (dB)
-20
-25
-30
M =
16
- PSK Power Specteral
Power (dB)
-20
-25
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (Hz)


M =
4
- PSK Power Specteral
M =
8
- PSK Power Specteral
M =
16
- PSK Power Specteral
M =
32
- PSK Power Specteral
Power (dB)
-20
-25
-30
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (Hz)


M =
4
- PSK Power Specteral
M =
8
- PSK Power Specteral
M =
16
- PSK Power Specteral
M =
32
- PSK Power Specteral
M =
64
- PSK Power Specteral
Power (dB)
-20
-25
-30
-500
-400
-300
-200
-100
0
100
200
300
400
500
Frequency (Hz)

Decision Making

```
clc;
   decision = zeros(size(r)); %Preallocating
   pe = zeros(length(E_b), 1); %Preallocating
   R_r = real(r) ; %real part recieved signal
   R_i = imag(r) ; %imag part of Recieved signal
   Dec_angle = myatan(R_i,R_r) ; %Calculating angle in range 0 to
2*pi
   Op_dec = 2*pi ./ M ; %Decision Angle
   symgrayR_sort = sort(real(symgray));
   symgrayI_sort = sort(imag(symgray));
   for i = 1 : size(E_s,2)
       for j = 1 : numel(N)
           for l = 2 : M
               if Dec_angle(i,j) <= Op_dec(l) && Dec_angle(i,j) >
Op_dec(l - 1)
                   decision(i,j) = symgrayR_sort(1,j)...
                       + 1i* symgrayI_sort(1,j);
               end
           end
       end
   end
```

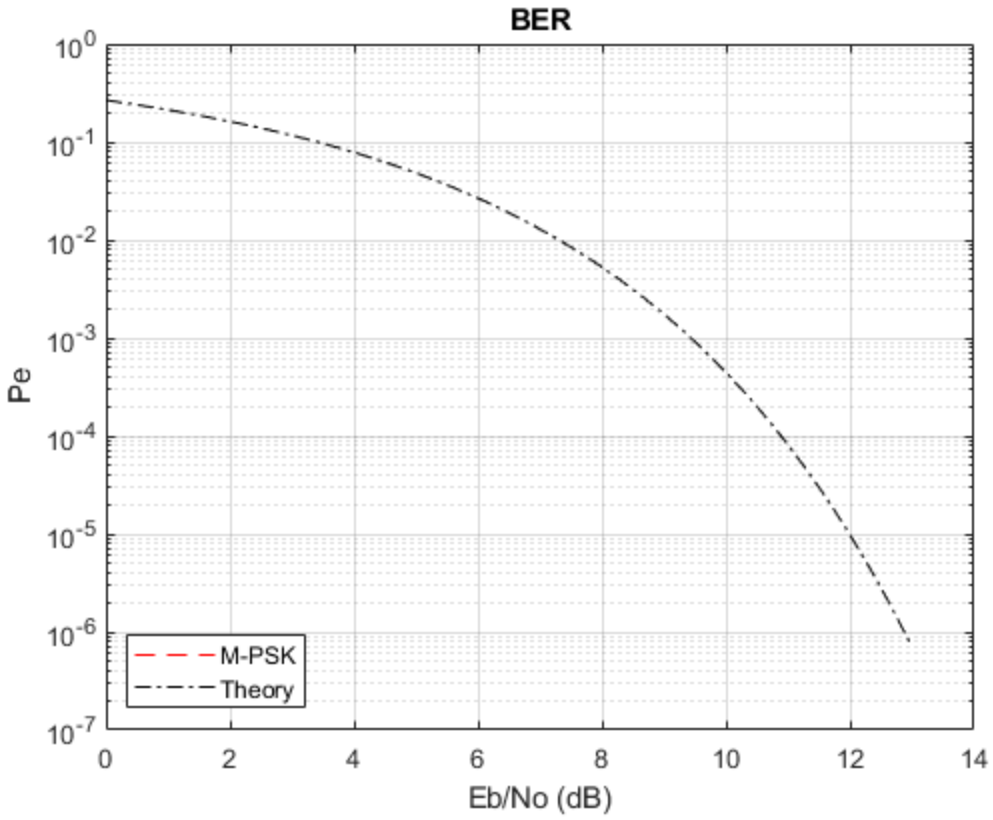
SPS Demodulation

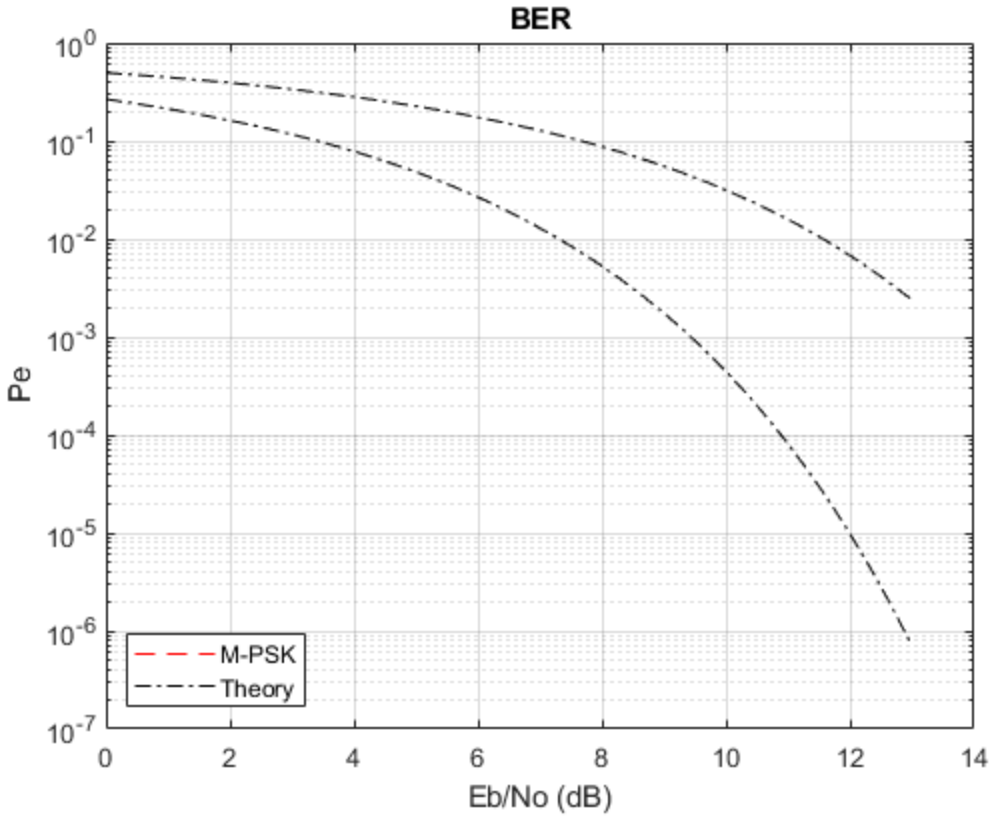
```
h = ones(1, SPS(2)) / SPS(2);
y = zeros(size(E, 1), size(r, 2) + M - 1);
for counter = 1 : size(E, 1)
    y(counter, :) = conv(r(counter, :), h); % Conv for normalized sum c
end
temp_normalized = zeros(size(E_s, 1), N); %preallocation
for row = 1 : size(E_s, 1)
    for column = 1 : num_bit
        temp_normalized(row, column) = y(row, column * SPS(2));   % Opt
    end
end
```

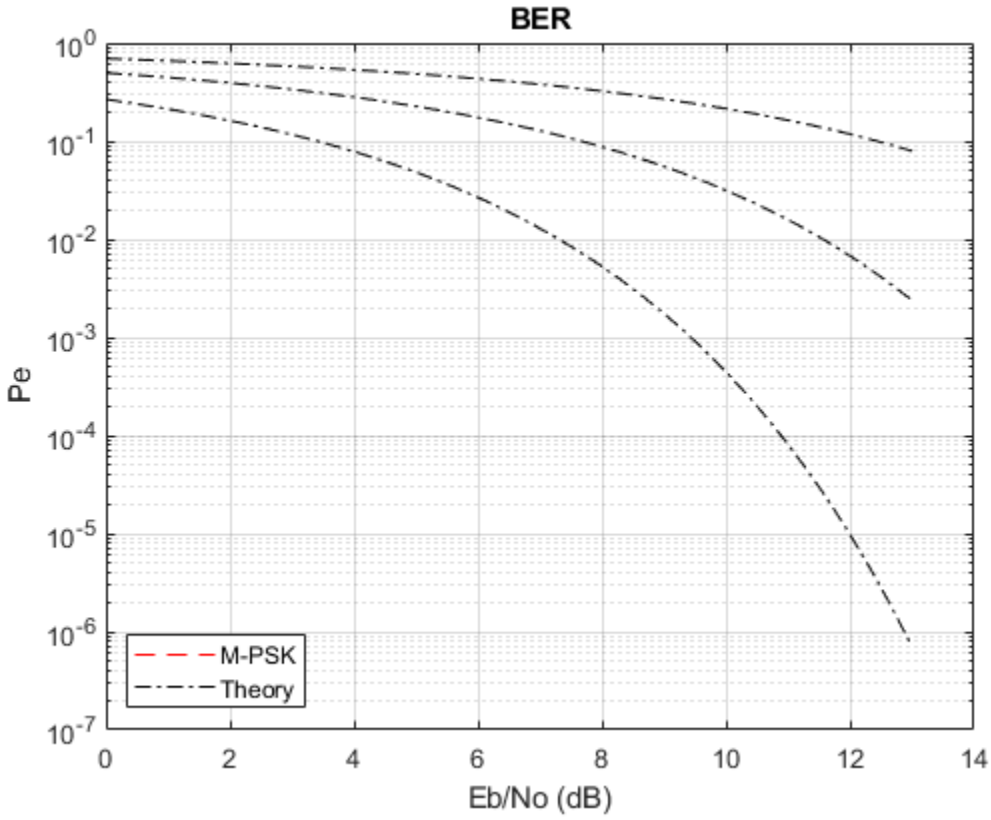
PLOT

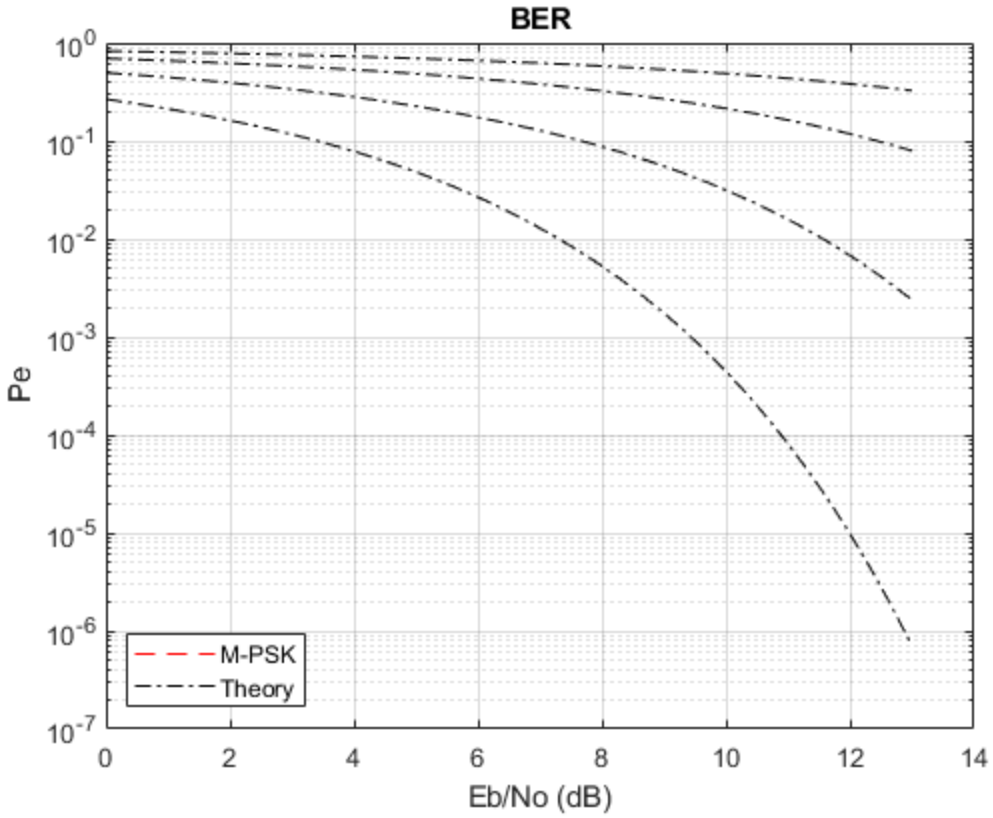
```
   clc;
   pe = pe' / N;     % Normalize the error
   % Plotting BER figure
   figure(7)
   semilogy(E_b, pe, '-- red'); hold on;
   Pe_theory = 2 * qfunc((pi./M(counter)) .*(sqrt((2*E_s)./
N_0))); %sin pi/M =~ pi/M
   semilogy(E_b, Pe_theory, '-. black'); hold on;
   xlabel('Eb/No (dB)');
   ylabel('Pe');
   title('BER');
```

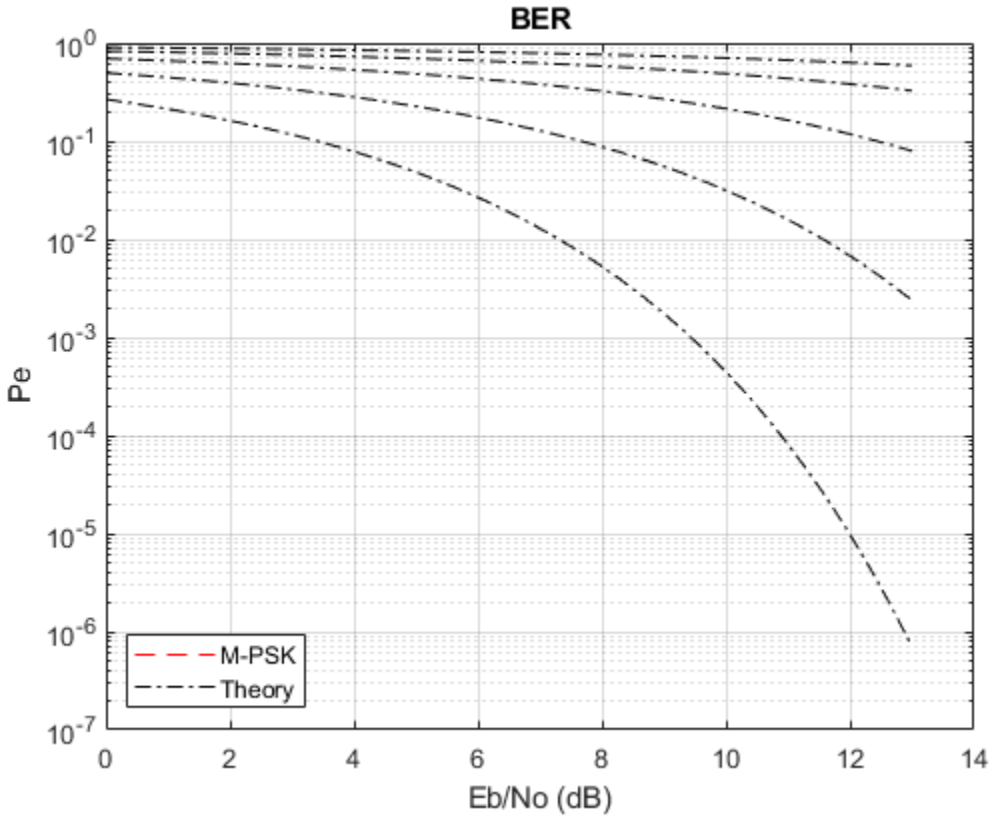
```
grid on;
legend('M-PSK', 'Theory', 'Location', 'SouthWest')
```




BER
Pe
Eb/No (dB)
M-PSK
Theory


BER
Pe
Eb/No (dB)
M-PSK
Theory


BER
Pe
Eb/No (dB)
M-PSK
Theory


BER
Pe
Eb/No (dB)
M-PSK
Theory

```
end
```

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