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ECEN 310 / ENGR 440 Communications Engineering Lab 1 - Bit Error Rate

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

Q1:

```
set(0, 'defaulttextInterpreter','latex')

N = 1e3;

s = zeros(N,1);
n = zeros(N,1);
r = zeros(N,1);
sest = zeros(N,1);

Es = 1;
rng(6) % sets generator seed

SNRdB_axis = 0:5:15;

% init MPSK
```

1b, 1c

Here there are several plotted constellations for BPSK, QPSK, 8PSK, and 16PSK respectively. We see that as there are more points on the constellation, there is less distance between each symbol. This introduces a potential for symbol error.

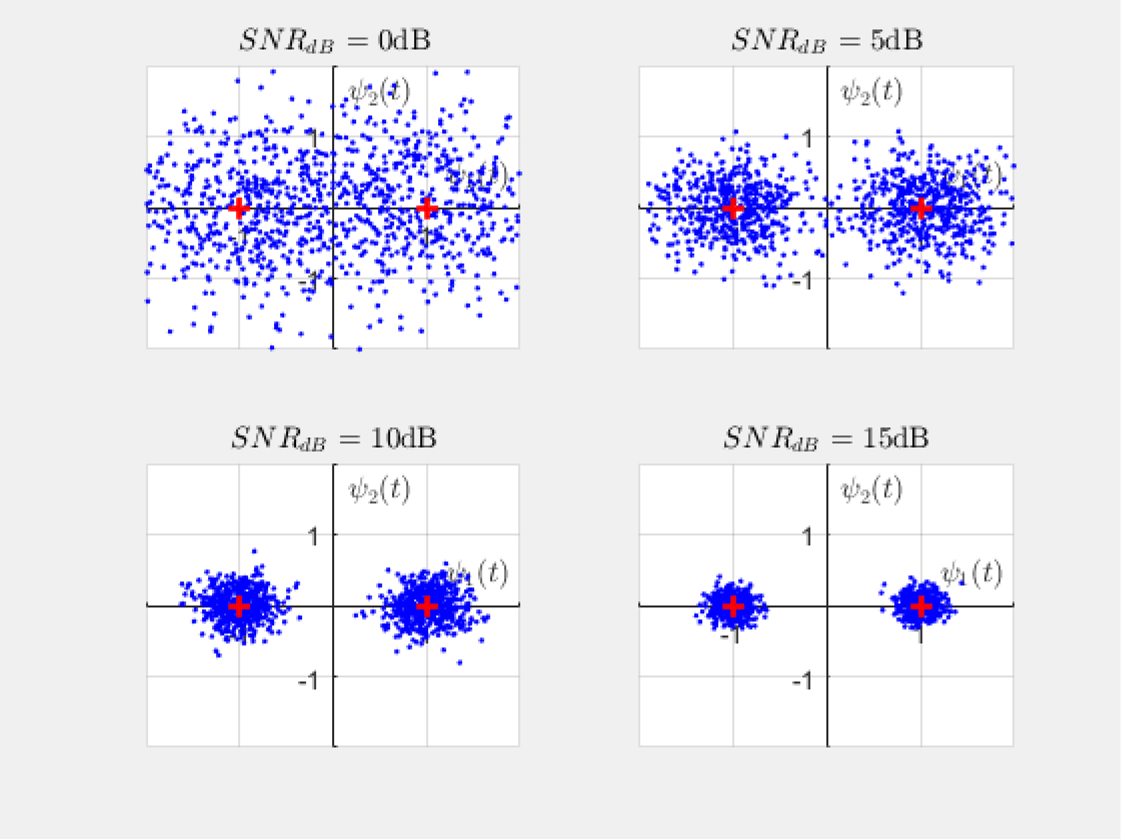
We see that the higher the SNR, the more closely packed the received symbols are to their target decision points. As SNR is reduced, the distribution becomes wider and causes more potential for potential conflict iwht other decision points.

Constellation plots contain $N = 1 \times 10^3$ data points.

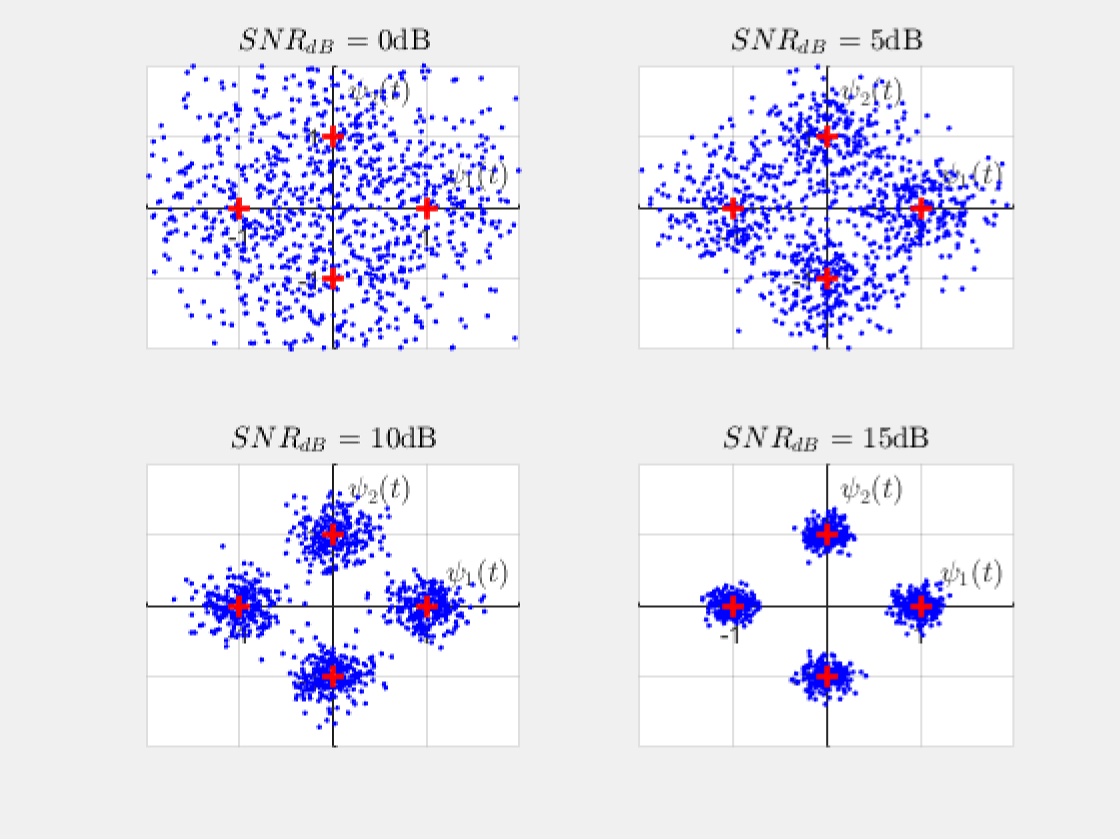
```
M_vect = [2 4 8 16];
for M_indx = 1:length(M_vect)

    M = M_vect(M_indx);
    constel = exp((j * 2* pi * (0:M-1))/ (M));
```

```
   figure(M_indx)
   str = sprintf("This is a constellation plot for a %d PSK system",
M);
   disp(str)

   for SNRdBindx = 1:length(SNRdB_axis);
       SNRdB = SNRdB_axis(SNRdBindx);
       No = Es/db2pow(SNRdB);

       s = randsrc(N,1,constel); % get rnd symbols, tx
       n = sqrt(No/2)*complex(randn(N,1),randn(N,1)); % noise samples
       r = s + n; % rx

       for indx = 1:N
           %returns decision point closest to the received message
           [dmin, const_indx] = min(abs(r(indx) - constel));
           sest(indx) = constel(const_indx);
       end

       subplot(2,2,SNRdBindx)

       hold on
       plot(real(r)', imag(r)', 'b.')
       plot(real(constel)', imag(constel)', 'r+', 'linewidth',
2, 'markersize' , 8)
       hold off

       ax = gca;
       ax.XAxisLocation = 'origin';
       ax.YAxisLocation = 'origin';
       axis([-2 2 -2 2])
       grid on

       xlabel('$ \psi_1 (t)$')
       ylabel('$ \psi_2 (t)$')

       title(['$SNR_{dB}$ = ' num2str(SNRdB) 'dB'])
   end
```

```
This is a constellation plot for a 2 PSK system
```



This is a constellation plot for a 4 PSK system



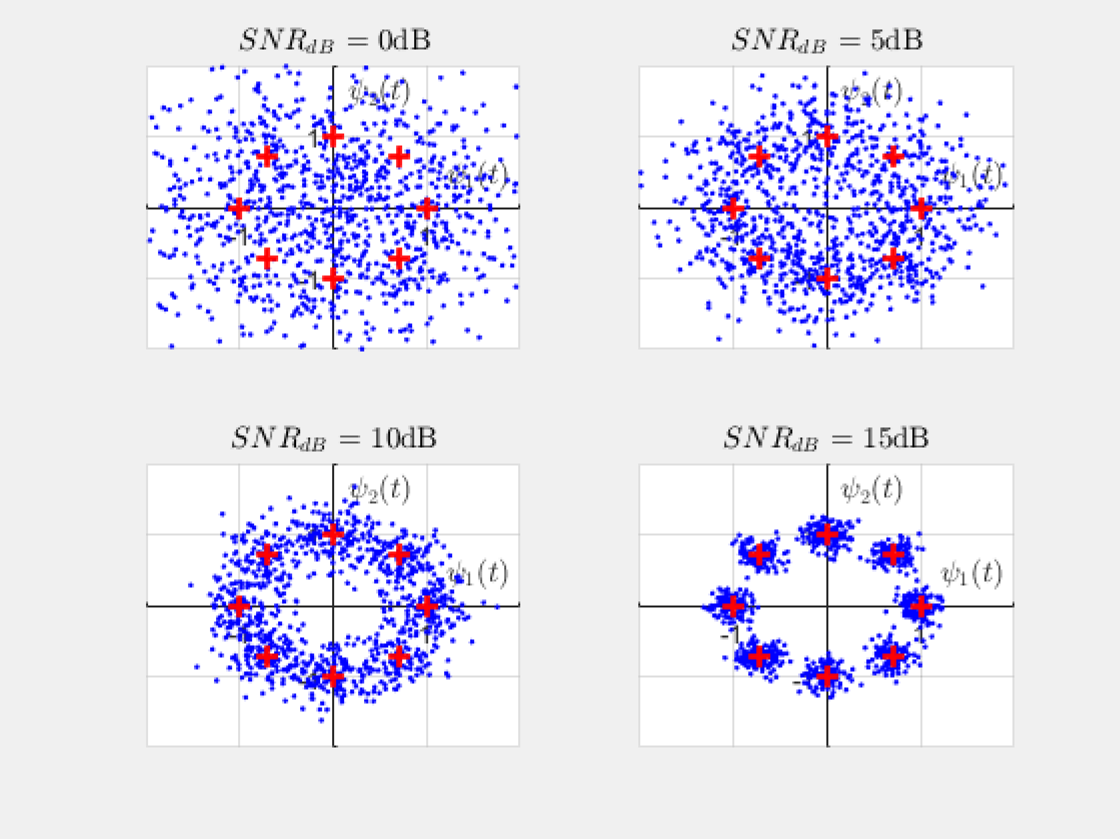
SNR_{dB} = 0dB

SNR_{dB} = 5dB

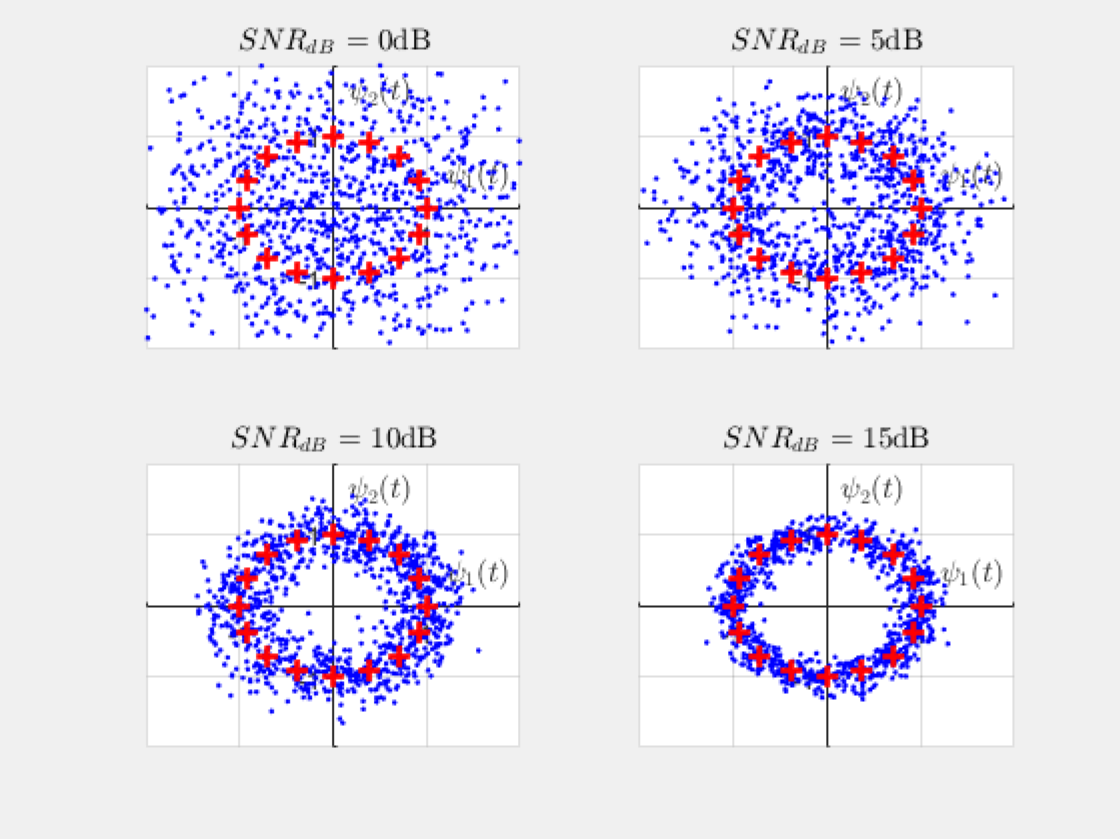
SNR_{dB} = 10dB

SNR_{dB} = 15dB

This is a constellation plot for a 8 PSK system



This is a constellation plot for a 16 PSK system



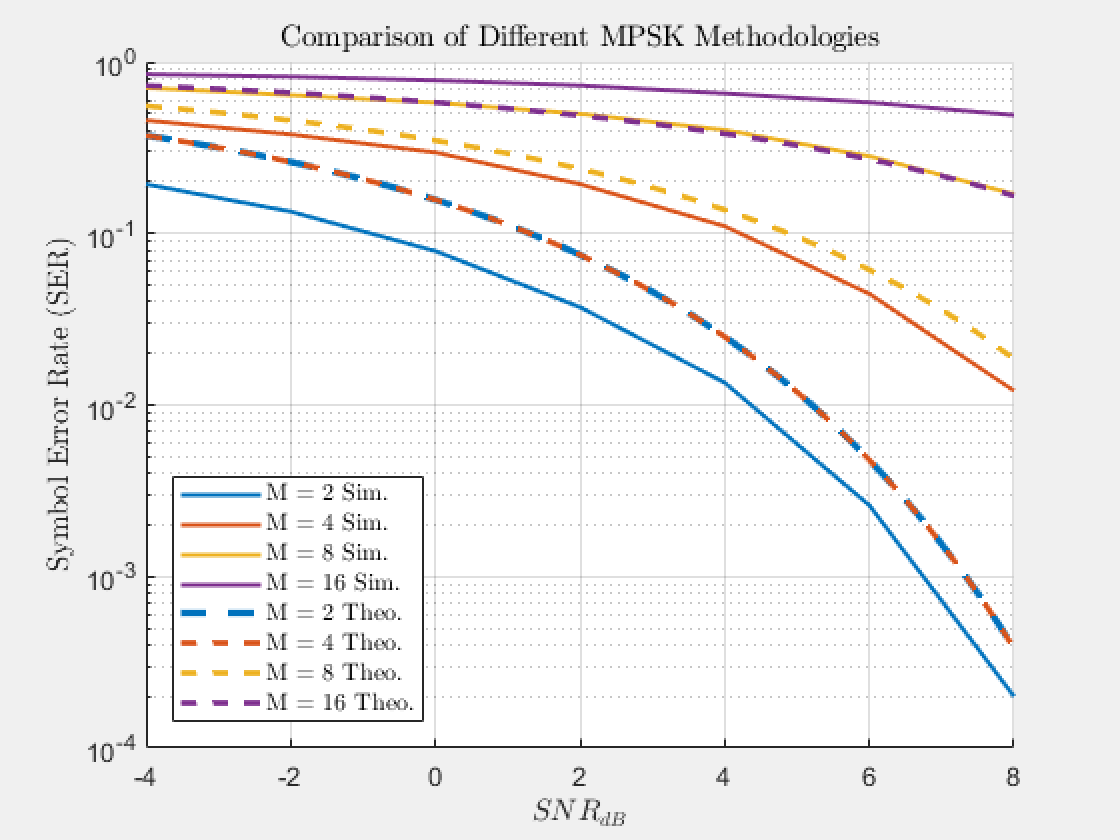
```
end
```

1e-g

Here are the comparisons of the Monte Carlo simulated symbol error rates and the theoretical expressions given. The PSK theoretical expressions given make the smallest distance assumption on the bit error. We see that The difference that becomes apparent. This makes sense as more symbols means that there is less space to place them - reducing the energy difference that may prevent errors. The theorertical lines should act as upper bounds but this is not the case. This may be due to the approximation of the phase error that comes into effect.

```
SNRdBAxis = -4:2:8;
MAxis = [2 4 8 16];

SERresults = zeros(length(SNRdBAxis), length(MAxis));

Ns = 1e4;

% loop through and test different M-ary schemes
for p = 1:length(SNRdBAxis)
    for q = 1:length(MAxis)
        SNRdB_val = SNRdBAxis(p);
        M_val = MAxis(q);
        SERresults(p,q) = getSER(M_val, Ns, SNRdB_val);
    end
end
```

```
SNRdBAxis_theo = -4:0.25:8;
SER_theo = zeros(length(SNRdBAxis_theo), length(MAxis));

% loop through and test different theoretical M-ary schemes
for p = 1:length(SNRdBAxis_theo)
    for q = 1:length(MAxis)
        SNRlin_val = db2pow(SNRdBAxis_theo(p));
        M_val = MAxis(q);
        argu = sqrt( 2 * SNRlin_val * log2(M_val) )*sin(pi/M_val);
        SER_theo(p,q) = 2 * qfunc(argu);
    end
end


% plot SER results

figure(5)
hold on
grid on
ax = gca;
plot(SNRdBAxis ,SERresults,'linewidth', 1.5)
ax.ColorOrderIndex = 1;
plot(SNRdBAxis_theo' ,SER_theo(:,1),'--','linewidth', 2.5)
plot(SNRdBAxis_theo' ,SER_theo(:,2),'--','linewidth', 2)
plot(SNRdBAxis_theo' ,SER_theo(:,3),'--','linewidth', 2)
plot(SNRdBAxis_theo' ,SER_theo(:,4),'--','linewidth', 2)

set(ax,'yscale','log')
hold off

xlabel("$ SNR_{dB} $")
ylabel("Symbol Error Rate (SER)")
title("Comparison of Different MPSK Methodologies")

lgnd = legend('M = 2 Sim.','M = 4 Sim.','M = 8 Sim.','M = 16
 Sim.', ...
    'M = 2 Theo.','M = 4 Theo.','M = 8 Theo.','M = 16 Theo.');
lgnd.Location = 'southwest';
set(lgnd,'Interpreter','latex')


% get SER function
% Inputs: M - number of decision points; Ns - number of data points
% simulated; SNRdB - SNRdB being tested
% Outputs: SER

function SER = getSER(M, Ns, SNRdB);
    constel = exp((j * 2* pi * (0:M-1))/ (M));
    Es = 1;

    No = Es/db2pow(SNRdB);
    s = randsrc(Ns,1,constel); % get rnd symbols, tx
    n = sqrt(No/2)*complex(randn(Ns,1),randn(Ns,1)); % noise samples
    r = s + n; % rx
    sest = zeros(Ns,1);

    for indx = 1:Ns
        %returns decision point closest to the received message
        [dmin, const_indx] = min(abs(r(indx) - constel));
        sest(indx) = constel(const_indx);
    end
    SER = (nnz(s-sest)/Ns);
end
```



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