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

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

# Q2:

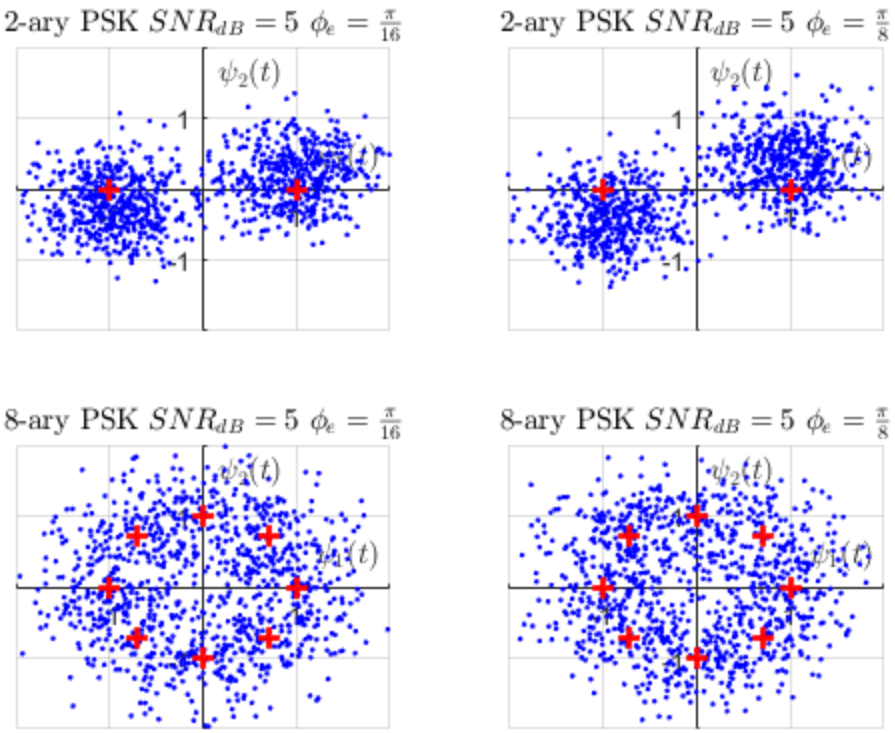
```
set(0, 'defaulttextInterpreter','latex')

M_vect = [2 8];
phi_err = [pi/16 pi/8];
SNRdB = 5;
Es = 1;
N = 1e3;

iter =1;
```

# 2a

Here we examine the performance of a MPSK system to varying amounts of phase error. We see that as the phase error is increased, the distribution of the sent points rotate around the origin. This is exacerbated for 8PSK as the phase error directly pushes the sent symbols to the wrong decision points. This is because PSK only makes the differentation of each received symbol with its phase, not its energy.

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

    for phiIndx = 1:length(phi_err);
        phi = phi_err(phiIndx);
        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 * exp(j*phi) + 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
```

```
        % plotting system

        subplot(2,2,iter)

        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)$')

        if phiIndx == 1
            title([num2str(M)  '-ary PSK $SNR_{dB}=5$ $\phi_e  =
 \frac{\pi}{16} $'])
        end
        if phiIndx == 2
            title([num2str(M)  '-ary PSK $SNR_{dB}=5$ $ \phi_e  =
 \frac{\pi}{8} $'])
        end
        iter = iter + 1;
    end

end
```



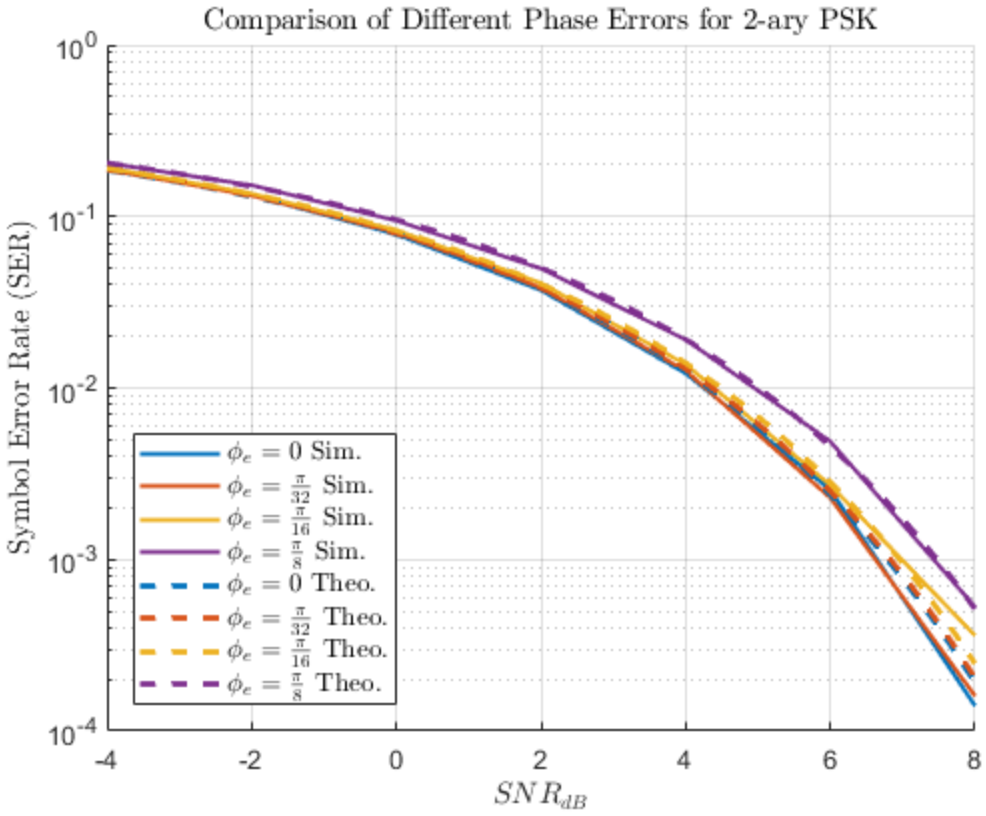

# 2b,2c

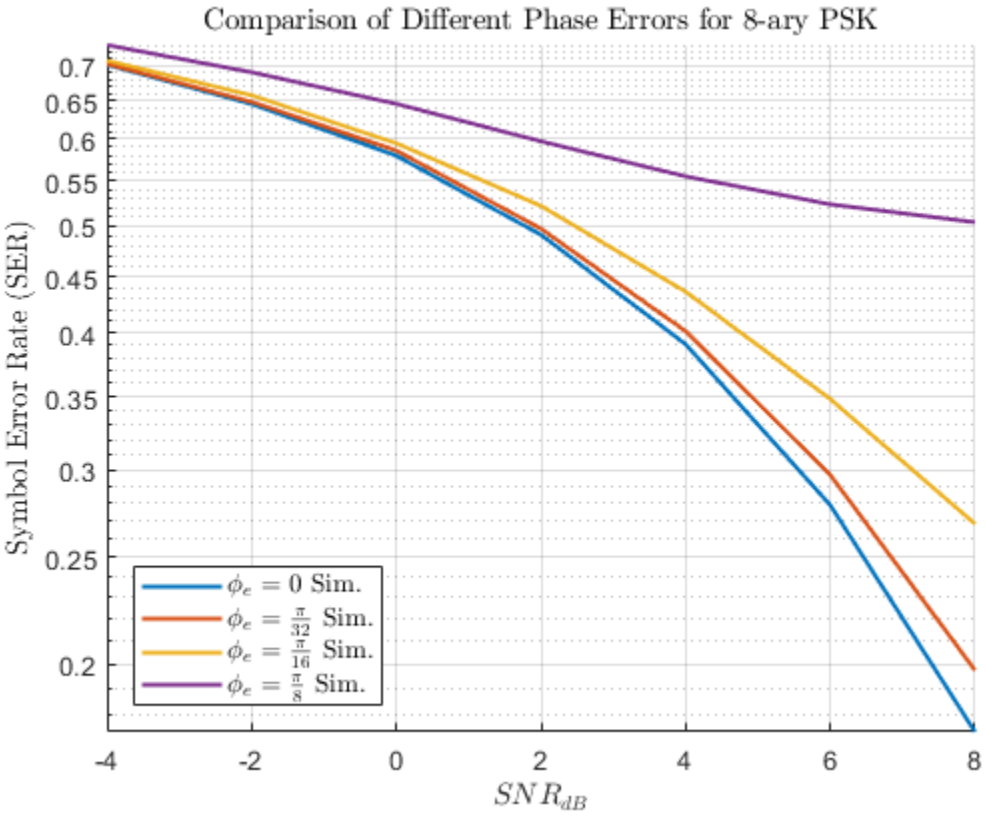
We see with the SER plot that the higher the phase error, the more higher the SER is. This matches closely with the theoretical SER for them. Each Monte Carlo simulation is generated with $N = 10^5$ symbols.

```
% SER error rates:

SNRdBAxis = -4:2:8;
SNRdBAxis_theo = -4:0.25:8;
phiAxis = [0 pi/32 pi/16 pi/8];
Ns = 1e5;
figure(2)

generalSERPlotGen(SNRdBAxis, SNRdBAxis_theo, phiAxis, Ns, 2)

figure(3)
generalSERPlotGen(SNRdBAxis, SNRdBAxis_theo, phiAxis, Ns, 8)


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

function SER = getSER(M, Ns, SNRdB, phaseError);
```

```
    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 * exp(j*phaseError) + 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

%
% Give an SER with a set phase error
% to compare
%
%
function [SERtheo SERresults] = generalSERPlotGen(SNRdBAxis,
 SNRdBtheo_axis, phiAxis, Ns, M);
    SERresults = zeros(length(SNRdBAxis), length(phiAxis));

    % loop through and test different M-ary schemes PSK
    for p = 1:length(SNRdBAxis)
        for q = 1:length(phiAxis)
            SNRdB_val = SNRdBAxis(p);
            phi_val = phiAxis(q);
            SERresults(p,q) = getSER(M, Ns, SNRdB_val, phi_val);
        end
    end
    if M == 2 %only make theoretical for BPSK
        SER_theo = zeros(length(SNRdBtheo_axis), length(phiAxis));

        % loop through and test different theoretical M-ary schemes
 PSK
        for p = 1:length(SNRdBtheo_axis)
            for q = 1:length(phiAxis)
                SNRlin_val = db2pow(SNRdBtheo_axis(p));
                phi_val = phiAxis(q);
                argu = cos(phi_val)*sqrt( ( 2*SNRlin_val));
                SER_theo(p,q) =qfunc(argu);
            end
        end
    end


    % plot SER results

    hold on
```

```
    grid on
    ax = gca;
    semilogy(SNRdBAxis ,SERresults,'linewidth', 1.5)
    ax.ColorOrderIndex = 1;
    if M == 2
        semilogy(SNRdBtheo_axis ,SER_theo,'--','linewidth', 2)
    end

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

    hold off

    xlabel("$ SNR_{dB} $")
    ylabel("Symbol Error Rate (SER)")
    str = sprintf('Comparison of Different Phase Errors for %c-ary
 PSK', (num2str(M)));
    title(str);
    if M == 2
    leg_str  = {'$\phi_e = 0$ Sim.','$\phi_e = \frac{\pi}{32}$
 Sim.', ...
        '$\phi_e = \frac{\pi}{16}$ Sim.','$\phi_e = \frac{\pi}{8}$
 Sim.', ...
        '$\phi_e = 0$ Theo.','$\phi_e = \frac{\pi}{32}$ Theo.', ...
        '$\phi_e = \frac{\pi}{16}$ Theo.','$\phi_e = \frac{\pi}{8}$
 Theo.'};
    else
    leg_str  = {'$\phi_e = 0$ Sim.','$\phi_e = \frac{\pi}{32}$
 Sim.', ...
        '$\phi_e = \frac{\pi}{16}$ Sim.','$\phi_e = \frac{\pi}{8}$
 Sim.'};
    end

    lgnd = legend(leg_str,'FontSize', 10);
    lgnd.Location = 'southwest';
    set(lgnd,'Interpreter','latex')
    return;
end
```


Comparison of Different Phase Errors for 2-ary PSK
Symbol Error Rate (SER)
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
-4
-2
0
2
4
6
8
$SNR_{dB}$
$\phi_e = 0$ Sim.
$\phi_e = \frac{\pi}{32}$ Sim.
$\phi_e = \frac{\pi}{16}$ Sim.
$\phi_e = \frac{\pi}{8}$ Sim.
$\phi_e = 0$ Theo.
$\phi_e = \frac{\pi}{32}$ Theo.
$\phi_e = \frac{\pi}{16}$ Theo.
$\phi_e = \frac{\pi}{8}$ Theo.


Comparison of Different Phase Errors for 8-ary PSK
Symbol Error Rate (SER)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
-4
-2
0
2
4
6
8
$SNR_{dB}$
$\phi_e = 0$ Sim.
$\phi_e = \frac{\pi}{32}$ Sim.
$\phi_e = \frac{\pi}{16}$ Sim.
$\phi_e = \frac{\pi}{8}$ Sim.

# 2d

We see that for 8PSK, the error levels out at a phase error of $\pi/8$. This is due to the phase error being larger than the mid point of each phasdecision point for each ;point. Each point is separated by $\pi/4$ radians. That means if there is a bias of more than $\pi/8$, the mean of the sent symbols will be in the wrong decision area. Increasing SNR will not lead to a decrease in error because of this.

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