EE 482 Spring 2024

Lab 4

By

Tylor Cooks

Date: 04/29/2024

8-PSK

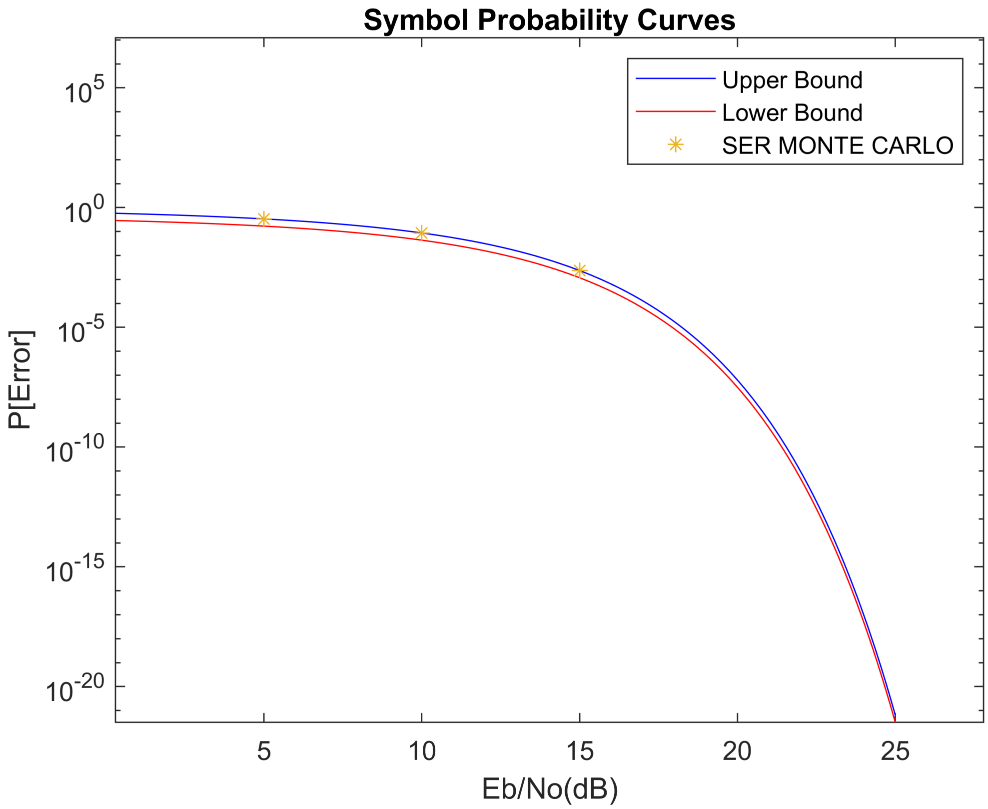
PROJECT 4 MPSK(M-ARY)

```
x_db = 0:0.1:25; % SNR Es/NO
x = 10.^(x_db/10); % db -> linear
M = 8;

low_bound = qfunc(sin(pi/M)*sqrt(2*x));
upper_bound = 2*qfunc(sin(pi/M)*sqrt(2*x));

figure(1)
semilogy(x_db,upper_bound,'b','DisplayName','Upper Bound');
hold on
semilogy(x_db,low_bound,'r','DisplayName','Lower Bound');
title('Symbol Probability Curves')
ylabel('P[Error]')
xlabel('Eb/No(dB)')
legend show

x1 = find(x_db == 5);
x2 = find(x_db == 10);
x3 = find(x_db == 15);
y1U = upper_bound(x1);
y1L = low_bound(x1);
y2U = upper_bound(x2);
y2L = low_bound(x2);
y3U = upper_bound(x3);
y3L = low_bound(x3);

n = 10^5; % number of samples
Es= 1;

si1=zeros(1,M);
si2=zeros(1,M);

for a = 1:M
    si1(a) = sqrt(Es)*cos(((a-1)*2*pi)/M);
    si2(a) = sqrt(Es)*sin(((a-1)*2*pi)/M);
end
figure(2)
SNRs = [5 10 15];
dataTx = randi([1,8],[1,n]);
i = 1;
ser = zeros(1,length(SNRs));
for snr_db = SNRs
    snr = 10^(snr_db/10);
    sigma = sqrt((Es/snr)/2);

    r1 = zeros(1,n);
    r2 = zeros(1,n);
    dataRx = zeros(1,n);
    for v = 1:n
        w1 = normrnd(0,sigma);
        w2 = normrnd(0,sigma);
```

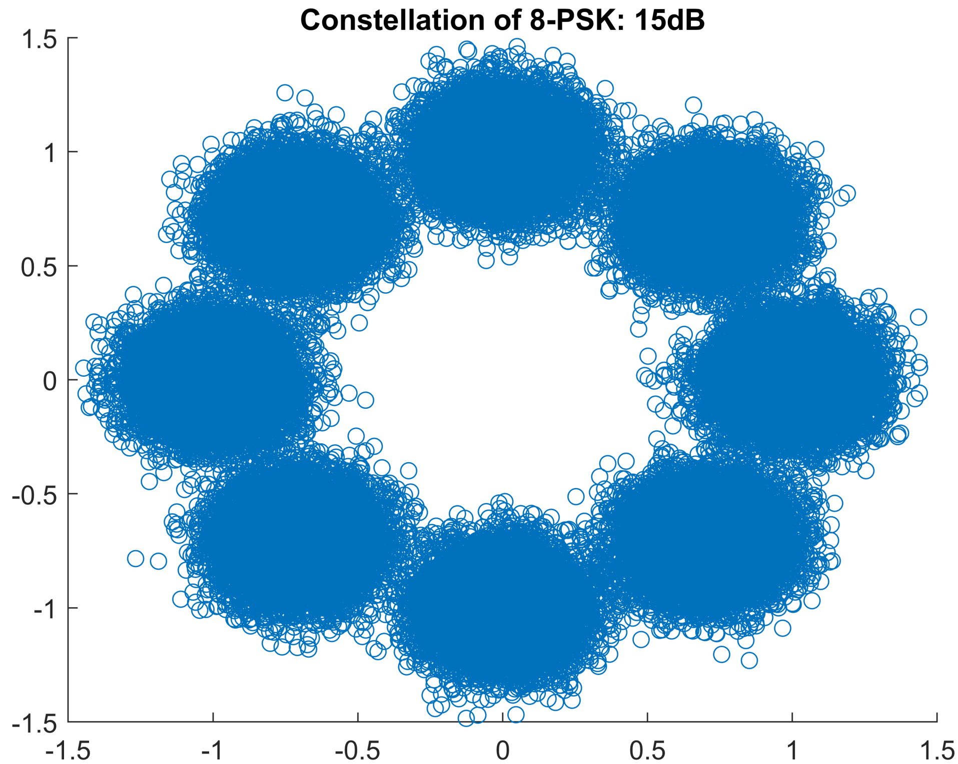
```
        r1(v) = si1(dataTx(v))+w1;
        r2(v) = si2(dataTx(v))+w2;
        d = zeros(1,M); % distance
        for z = 1:M
            d(z) = (r1(v) - si1(z))^2 + (r2(v) - si2(z))^2;
        end
        dataRx(v) = find(min(d)==d);
    end
    nod = length(dataTx); %number of data points
    noe = nnz(abs(dataTx - dataRx)); % number of non-zero elements which are incorrect
    ser(i) = noe/nod % SER, Symbol Error Rate
    i=i+1;
end
```

```
ser = 1×3
    0.3339         0         0
ser = 1×3
    0.3339    0.0875         0
ser = 1×3
    0.3339    0.0875    0.0024
```

```
figure(1)
semilogy(SNRs,ser,'*','DisplayName','SER MONTE CARLO')

xlim([0.3 27.8])
ylim([0 12517258])
hold off
```




```
figure(2)

scatter(r1,r2)
title('Constellation of 8-PSK: 15dB')
```



[Discussion]

The symbol error rate (SER) from the Monte Carlo simulation was in between the bounds of the symbol probability

curve approximated in part 1, however, the symbol errors seem to fall closer to the upper bounds rather than the lower bounds

on the symbol probability curve. This is probably due to the lack of SNRs tested in the Monte Carlo simulations.

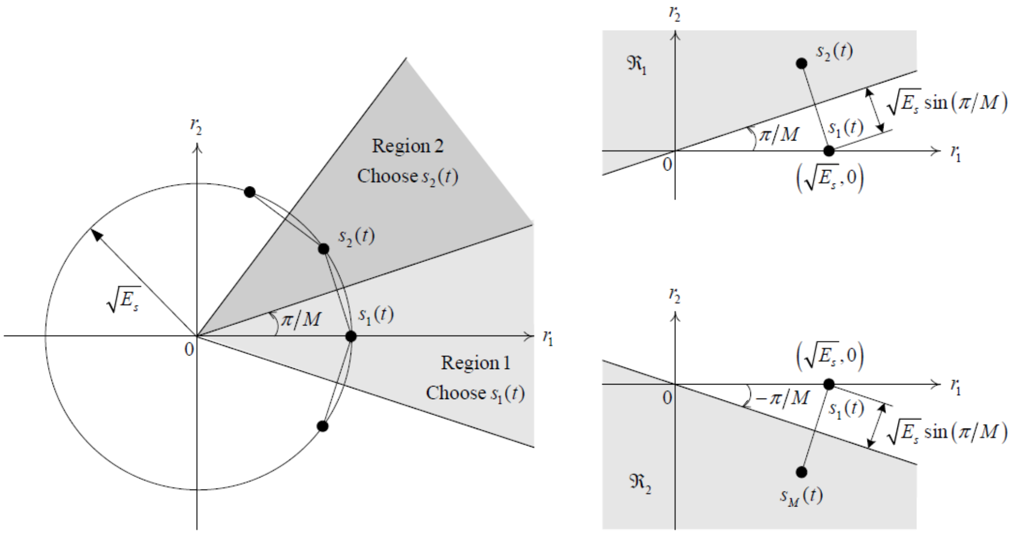
An interesting observation is that the symbol errors form the Monte Carlo simulations somtimes fall above the upper bounds,

I believe this is due to the added noise energy, which increasses the distance from region 1 and 2 which the upper bound takes

into account as shown in the equations below.

$$P[\text{error}] < P[r_1, r_2 \text{ fall in } \Re_1 | s_1(t)] + P[r_1, r_2 \text{ fall in } \Re_2 | s_1(t)], \text{ or}$$

$$P[\text{error}] < 2Q\left(\sin\left(\frac{\pi}{M}\right)\sqrt{2E_s/N_0}\right),$$



From repeated testing if we decrease Es when just calulating sigma, to 90 percent of its

value from when the constellations were caluclated, the SER will fall closer to the lower bounds. However, this is a observation

of a limited number of tests runs, it is more probable that if the test was repeated multiple times the results will be more evenly distributed

between the upper and lower bounds.

Overall, the results from both the symbol probability curve and Monte Carlo simulations seem to be consistant with each other.