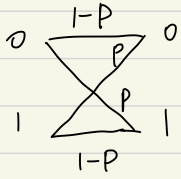
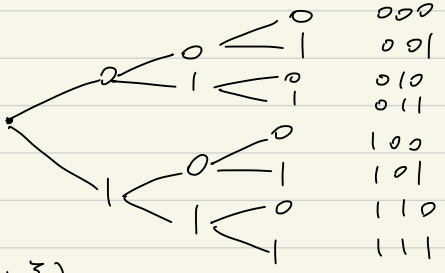
EECS 455 Homework 8 YUZHAN JIAN

P1:

(a)





$$P_{e,0} = P(\{110, 101, 011, 111\})$$

$$= p^2(1-p) + p^2(1-p) + p^2(1-p) + p^3$$

$$= 3p^2(1-p) + p^3$$

$$P_{e,1} = P(\{001, 010, 100, 000\})$$

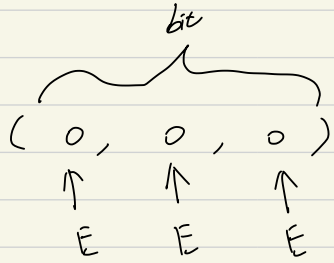
$$= 3p^2(1-p) + p^3$$

(b) The unconditional error probability is

$$P_e = \frac{1}{2} - \frac{1}{2}\sqrt{\frac{E/N_0}{1+E/N_0}}$$

(c) E: energy per transmission

E_b: energy per information bit



Since each bit was transmitted 3 times here,

$$E_b = 3E$$

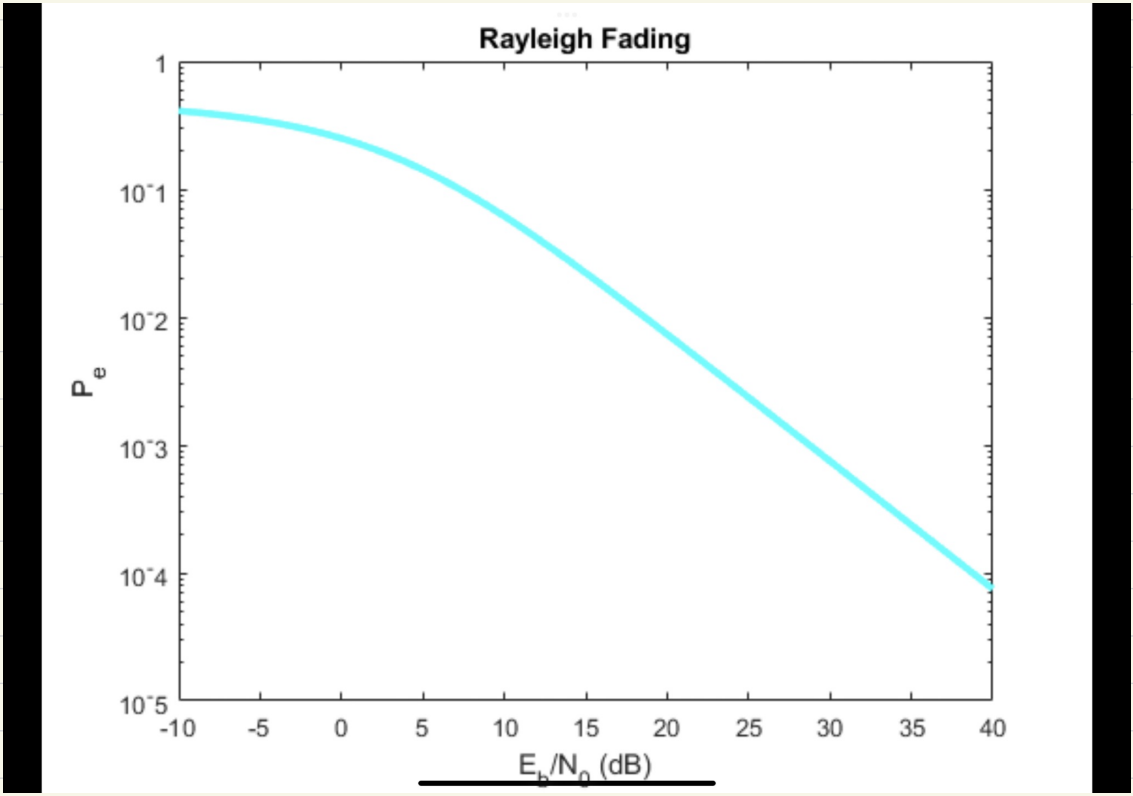
(d) Since $E_b = 3E$, $E = \frac{1}{3}E_b$

Substitute it into part (b) and we get

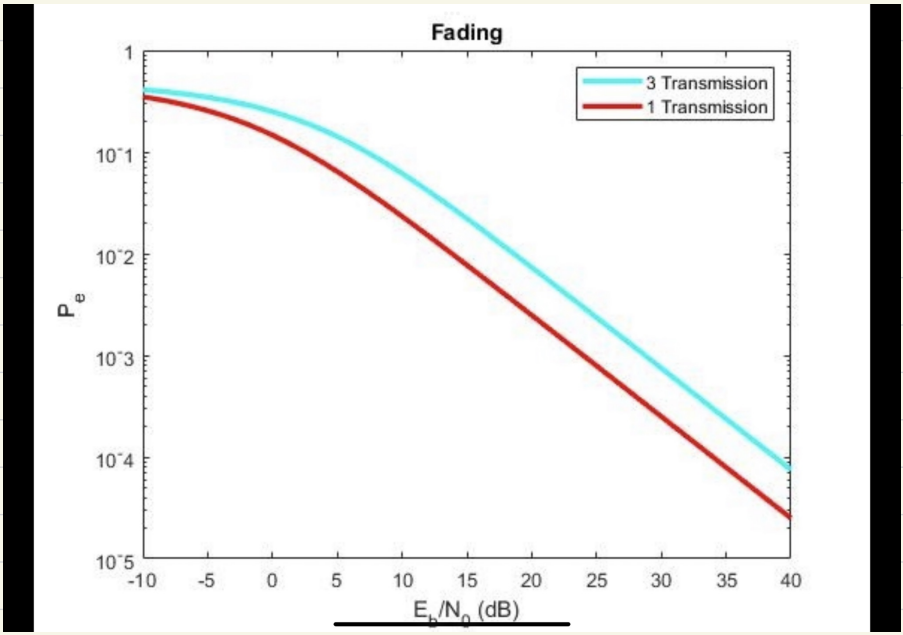
$$P_e = \frac{1}{2} - \frac{1}{2}\sqrt{\frac{E/N_0}{1+E/N_0}}$$

$$= \frac{1}{2} - \frac{1}{2}\sqrt{\frac{\frac{1}{3}E_b/N_0}{1+\frac{E_b}{3N_0}}}$$

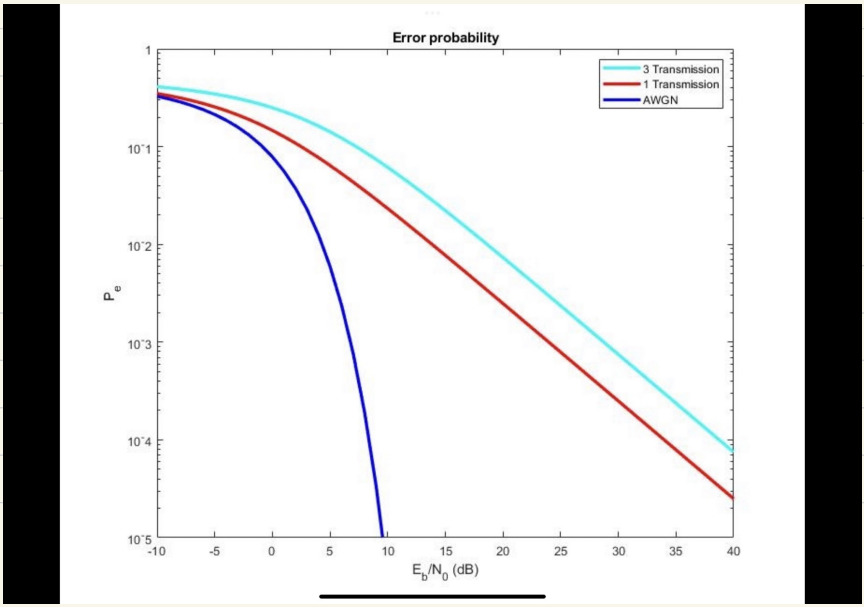
$$= \frac{1}{2} - \frac{1}{2}\sqrt{\frac{E_b/N_0}{3+\frac{E_b}{N_0}}}$$



(e)


Fading
3 Transmission
1 Transmission
P_e
E_b/N_0 (dB)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
-10
-5
0
5
10
15
20
25
30
35
40

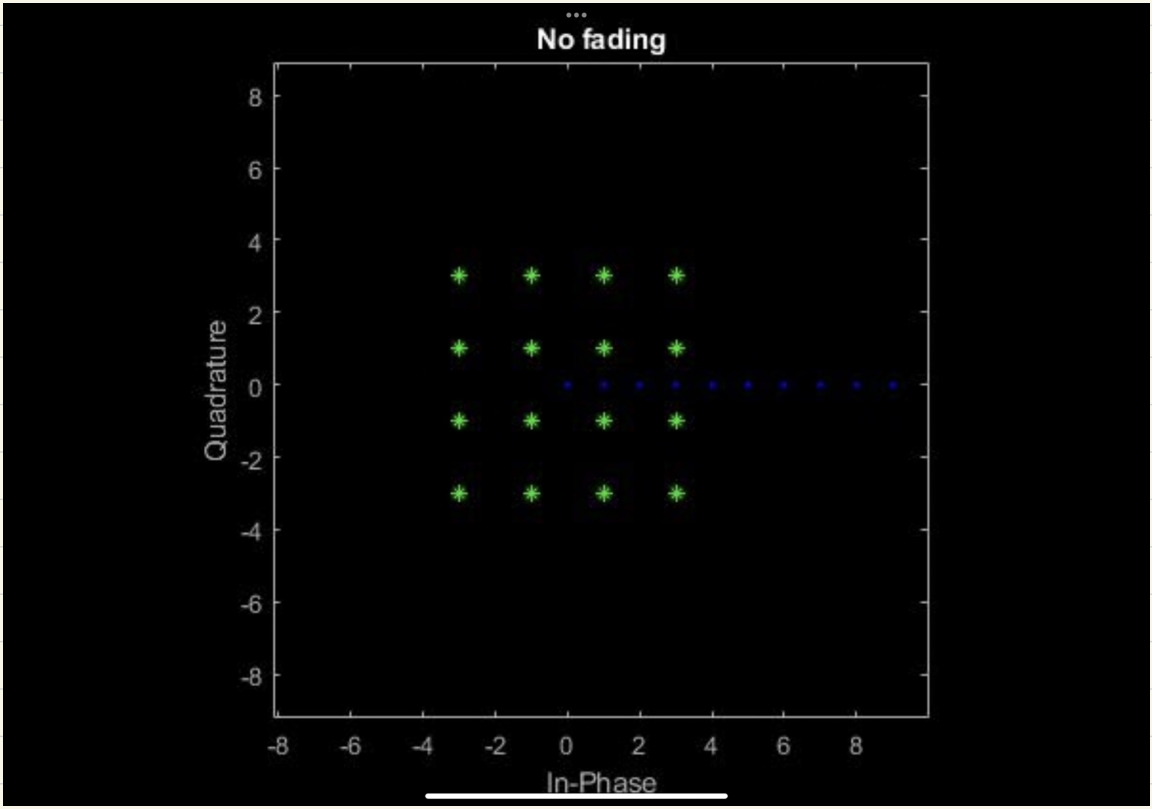
(f)


Error probability
3 Transmission
1 Transmission
AWGN
P_e
E_b/N_0 (dB)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
-10
-5
0
5
10
15
20
25
30
35
40

```
clear all;

x = [-10:40]
y1 = zeros(size(x))
y2 = zeros(size(x))
y3 = zeros(size(x))
 for m = -10:40
    Pe = 0;
    ebnodB = m;
    ebno = 10^(ebnodB/10);
%     Eb= N0*ebno

     Pe1 = 1/2 - 1/2 * (sqrt(ebno / (3 + ebno ) ))
     Pe2 = 1/2 - 1/2 * (sqrt(ebno / (1 + ebno ) ))
     BER = 1/2.*erfc(sqrt(ebno));
    y1(m+11) = Pe1
    y2(m+11) = Pe2
    y3(m+11) = BER

 end



figure
semilogy(x,y1,'c','LineWidth',2.5)
hold on
semilogy(x,y2,'r','LineWidth',2.5 )
hold on
semilogy(x,y3,'b','LineWidth',2.5 )
legend('3 Transmission' , '1 Transmission', 'AWGN')

yticks([10^-5 10^-4 10^-3 10^-2 10^-1 1])
yticklabels({'10^-5','10^-4','10^-3','10^-2', '10^-1', '1'})
axis([-10 40 10^-5 1])
xlabel('E_b/N_0 (dB)')
ylabel('P_{e}')
title('Error probability')
```

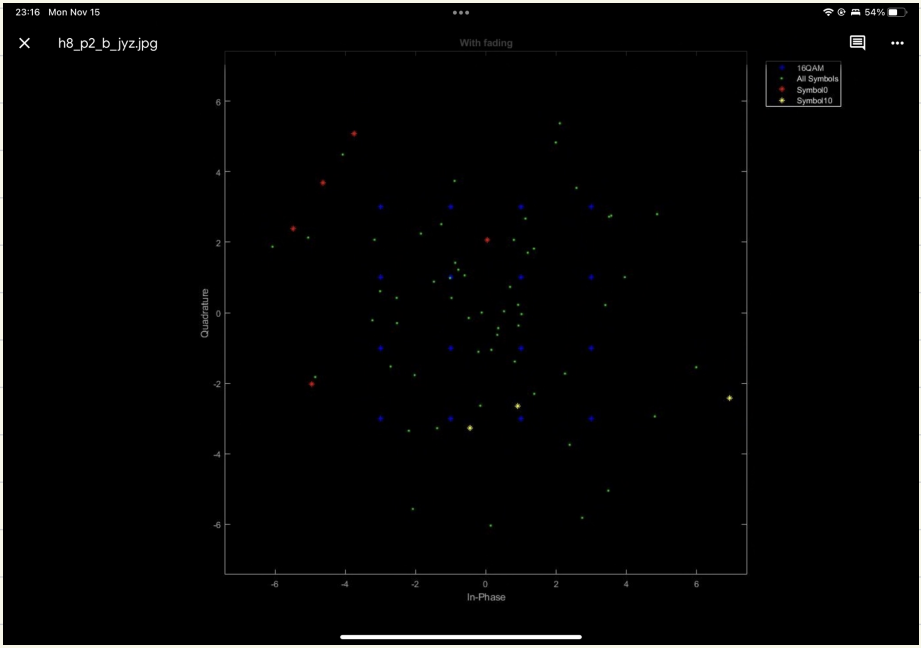
P2.

(a)



(There are some dots in blue)

(b)




```
smallest =

    0.1199


minindex =

    31


largest =

    7.3564


maxindex =

    42
```

```
data=randi([0 15],64,1); %%Generate the vector
data_modu=qammod(data,16); %%Generate a vector of 16QAM modulated symboyls
data_modu_ifft=ifft(data_modu); %% IFFT command
cyclic_prefix=[data_modu_ifft((end-15):end);data_modu_ifft]; %%Add a cyclic prefix
remove_cp=[cyclic_prefix((end-63):end)]; %%remove the cyclic prefix
remove_cp_fft=fft(remove_cp); %% Using FFT regenerate the 16QAM modulated symbols
data_demod=qamdemod(remove_cp_fft,16);

plot1=scatterplot(data_modu,1,0,'g*');
hold on
scatterplot(data_demod,1,0,'b.' ,plot1)
title("No fading")
```

```
%%%%%%%%%%%%%%%%
%   Part b     %
a1=0.9;
a2=0.35;
a3=0.15;
b1=2*pi*0.9051;
b2=2*pi*0.5338;
b3=2*pi*0.1092;

data=randi([0 15],64,1); %%Generate the vector
data_modu=qammod(data,16); %%Generate a vector of 16QAM modulated symboyls
index_s0 = find(data==0)
index_s10 = find(data==10)

data_modu_ifft=ifft(data_modu); %% IFFT command
cyclic_prefix=[data_modu_ifft((end-15):end);data_modu_ifft]; %%Add a cyclic prefix

ht=[1,a1*exp(j*b1),a2*exp(j*b2),a3*exp(j*b3)]

received_signal=conv(cyclic_prefix,ht)%% passing the channel

remove_cp2=[received_signal((end-63):end)]; %%remove the cyclic prefix
remove_cp2_fft=fft(remove_cp2);  %% Using FFT regenerate the 16QAM modulated symbols
amp=abs(remove_cp2_fft)
[smallest, minindex]=min(amp)
[largest, maxindex]=max(amp)

data_demod=qamdemod(remove_cp2_fft,16);
plot2=scatterplot(data_modu,1,0,'b*');
hold on
scatterplot(remove_cp2_fft,1,0,'g.',plot2)
plot(remove_cp2_fft(index_s0),'r*')
plot(remove_cp2_fft(index_s10),'y*')
legend('16QAM', 'All Symbols', 'Symbol0', 'Symbol10')
title("With fading")
```