# EE655 Modem Design Homework Assignment #2

## Task 1)

### a)

clear

close all

theta\_0=2\*pi/25;

eta = sqrt(2)/2;

eta=1.0\*eta;

denom = (1+2\*eta\*theta\_0+theta\_0\*theta\_0)

k\_i = (4\*theta\_0\*theta\_0)/denom;

k\_p = (4\*eta\*theta\_0)/denom;

dphi=[0.05\*ones(1,200) 0.10\*ones(1,200)];

phi\_1=filter(1,[1 -1],dphi);

s\_1 = exp(j\*2\*pi\*phi\_1);

phi\_sv = zeros(1,400);

int\_sv = zeros(1,400);

accum\_sv = zeros(1,400);

dphi\_sv = zeros(1,400);

phi\_2\_sv= zeros(1,400);

int = 0;

accum = 0;

for nn=1:400

% Multiplier

prod = s\_1(nn)\*exp(-j\*2\*pi\*accum);

phi = angle(prod)/(2\*pi);

phi\_sv(nn) = phi;

% Loop filter

int = int + k\_i\*phi;

dphi = k\_p\*phi+int;

dphi\_sv(nn) = dphi;

% DSS

phi\_2\_sv(nn) = accum;

accum = accum+dphi;

end

subplot(4,1,1)

plot(0:length(phi\_sv)-1,phi\_sv)

title('Loop phase error')

subplot(4,1,2)

plot(0:length(phi\_1)-1,phi\_1)

hold on

plot(0:length(phi\_2\_sv)-1,phi\_2\_sv, 'r')

title('Input and output phase')

legend('Input Phase','Output Phase')

ylim([0 max(phi\_1)])

subplot(4,1,3)

plot(0:length(s\_1)-1,real(s\_1))

hold on

plot(0:length(phi\_2\_sv)-1,cos(2\*pi\*phi\_2\_sv))

title('Real Part of input/output signals')

legend('Input', 'Output')

subplot(4,1,4)

plot(0:length(s\_1)-1,imag(s\_1))

hold on

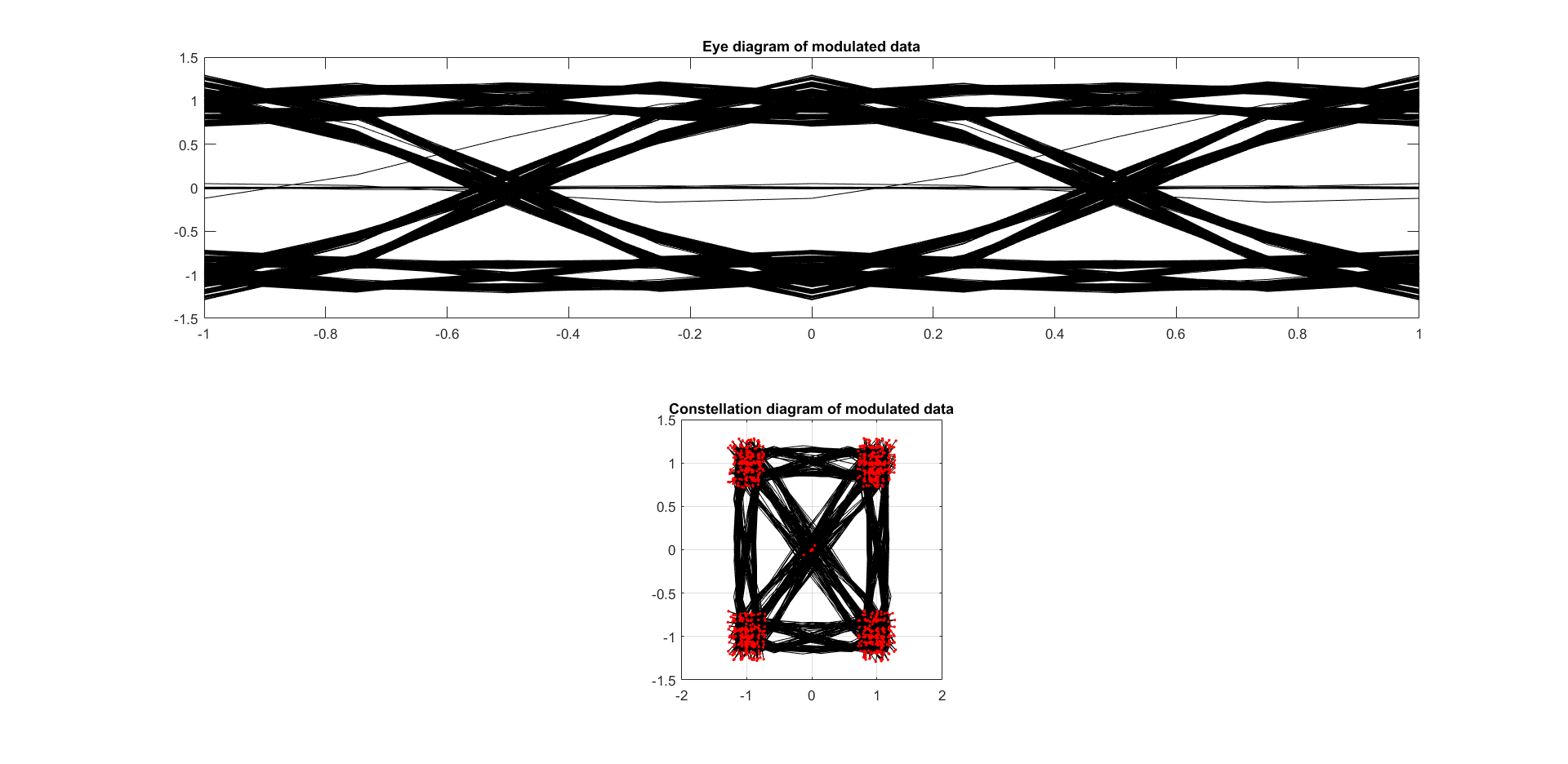
plot(0:length(phi\_2\_sv)-1,sin(2\*pi\*phi\_2\_sv))

title('Imaginary Part of input/output signals')

legend('Input', 'Output')

## Task 2)

### a)



For plotting constellations and eye diagrams, two functions were created, ***plotEyeDiagram()*** and ***plotConstellationDiagram()***. These are used henceforth to create those diagrams. The code can be found below.

function [null] = plotEyeDiagram(x1,fs,str)

%Plots the constellation diagram of a modulated signal

% x1 = modulated signal

% fs = samples per symbol of x1

% str = title of plot

plot(0,0)

hold on

for n=1:fs:fs\*1000-fs\*2

plot(-1:1/fs:1, real(x1(n:n+fs\*2)), 'k')

end

hold off

title(str)

end

function [null] = plotConstellationDiagram(x1,fs,str)

% Plots the constellation diagram of a modulated signal

% x1 = input data

% fs = samples per symbol of x1

% str = title of plot

plot(x1, 'k')

grid on

axis('square')

hold on

plot(x1(1:fs:length(x1)),'r.')

title(str)

end

And the script to solve the problem follows:

clear

close all

%task A

N = 1000

sigma = 0.02

fs = 4

h = rcosine(1, fs, 'sqrt', 0.5, 10);

h = h/max(h);

x0 = ((floor(2\*rand(1,N))-0.5)/0.5)+j\*((floor(2\*rand(1,N))-0.5)/0.5);

x1 = zeros(1, 4\*N);

x1(1:4:4\*N) = x0;

x1 = filter(h,1,x1);

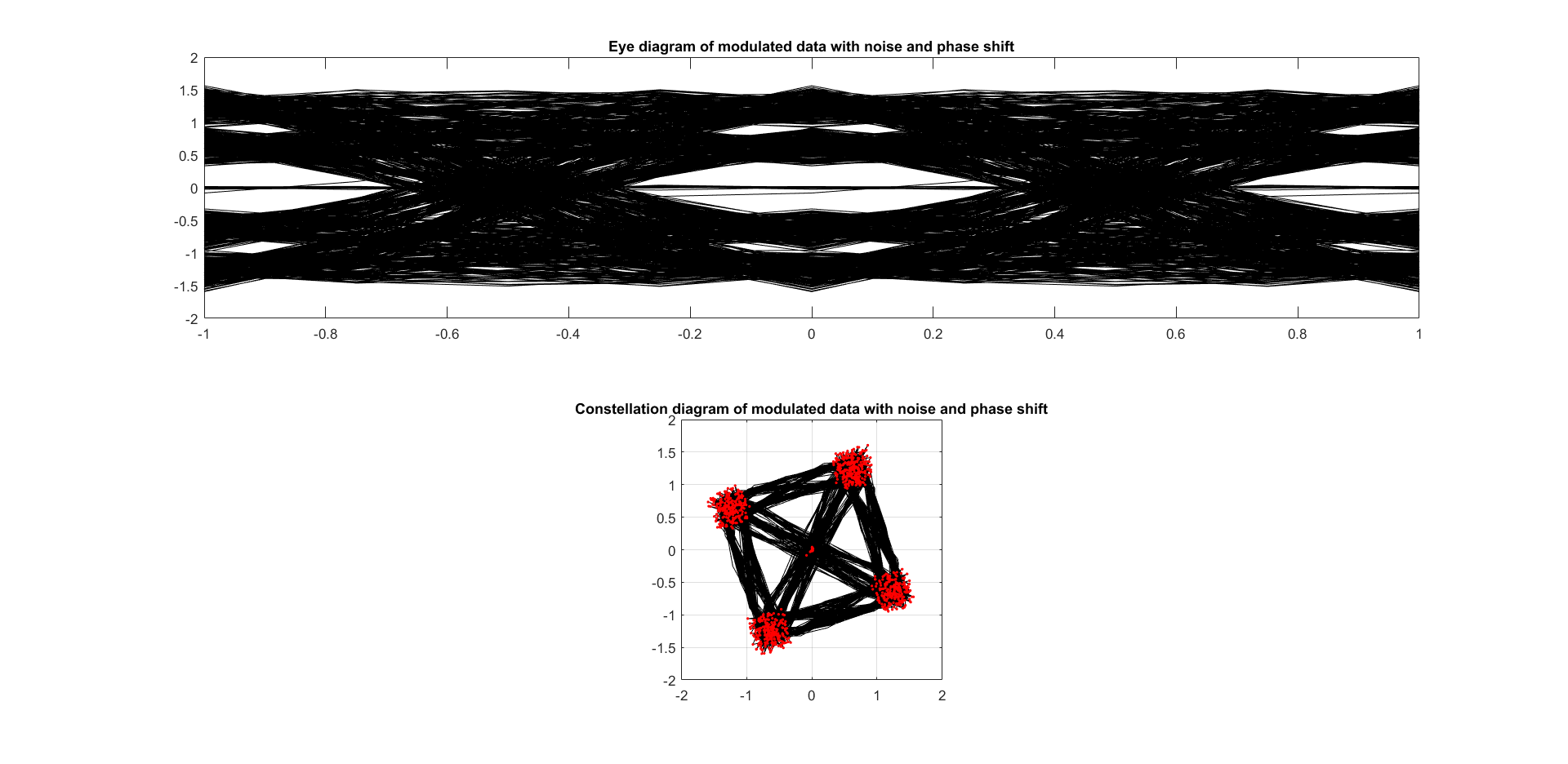
subplot(2,1,1)

plotEyeDiagram(x1,fs,'Eye diagram of modulated data')

subplot(2,1,2)

plotConstellationDiagram(x1,fs,'Constellation diagram of modulated data')

### b)



figure

x2 = x1 + sigma\*(randn(1,length(x1))+j\*randn(1,length(x1)));

x3 = x2 \* exp(j \*2\*pi\*0.05);

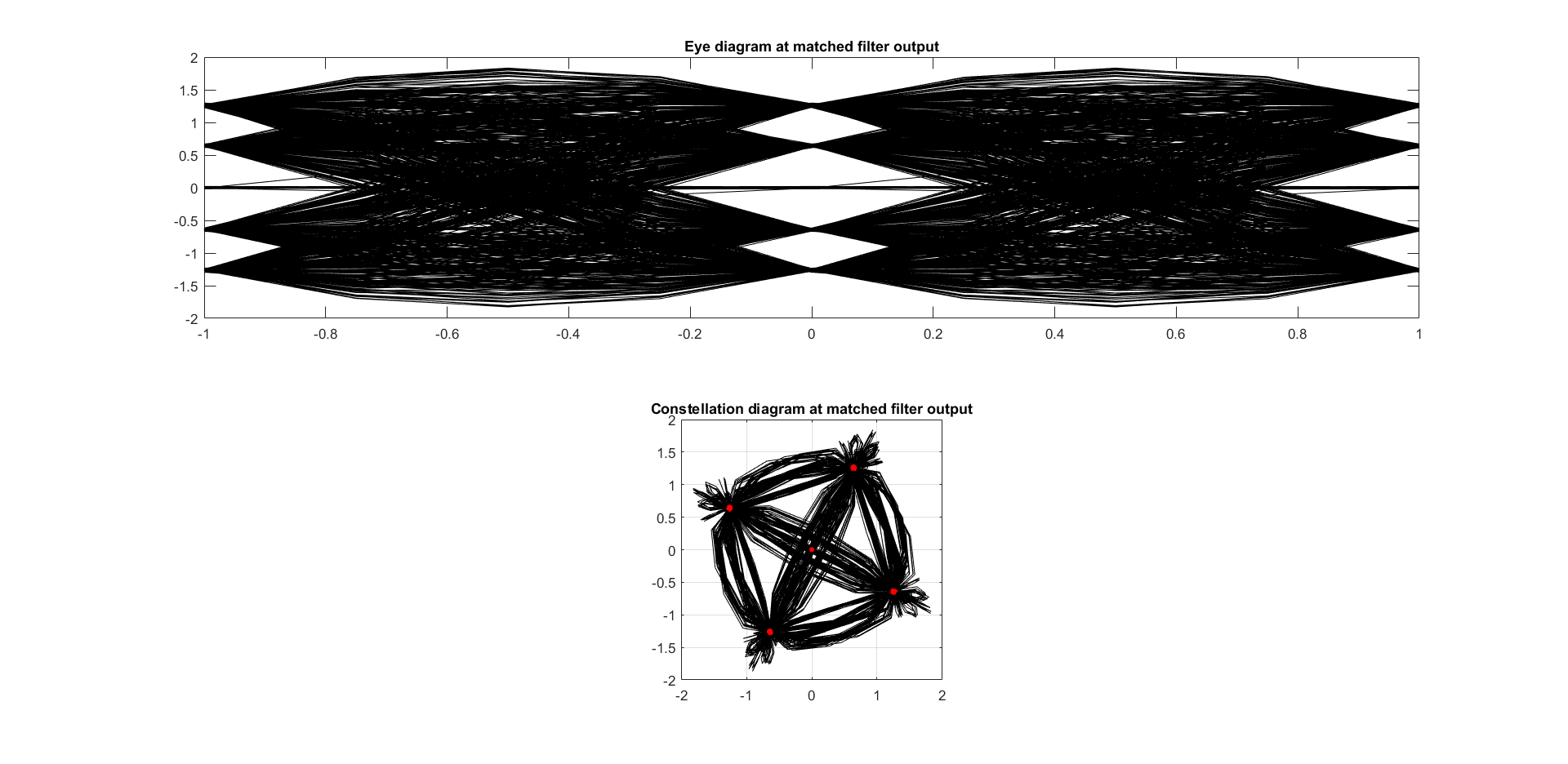
subplot(2,1,1)

plotEyeDiagram(x3,fs,'Eye diagram of modulated data with noise and phase shift')

subplot(2,1,2)

plotConstellationDiagram(x3,fs,'Constellation diagram of modulated data with noise and phase shift')

### c)



hm = h/(h\*h');

y=filter(hm,1,x3);

figure

subplot(2,1,1)

plotEyeDiagram(y,fs,'Eye diagram at matched filter output')

subplot(2,1,2)

plotConstellationDiagram(y,fs,'Constellation diagram at matched filter output')

### d)



x5 = zeros(1,fs\*N);

reg = zeros(1,81);

for n=1:fs\*N

reg=[x3(n) reg(1:80)];

x5(n)=reg\*hm';

if n>20

if rem(n,4)==1;

x5\_d=sign(real(x5(n)));

y5\_d=sign(imag(x5(n)));

i = (n-1)/4;

p2(i) = (x5\_d+j\*y5\_d)\*conj(x5(n));

hold on

end

end

end

figure

subplot(2,1,1)

plot(p2, 'k')

grid on

axis('square')

hold on

plot(p2,'r.')

title('Output of detector')

subplot(2,1,2)

plot(0:length(p2)-1, angle(p2)/(2\*pi))

title('Output of ATAN')

### e)

theta\_0= 2\*pi/1000;

eta=sqrt(2)/2;

eta=1\*eta;

k\_i= (4\*theta\_0\*theta\_0)/(1+2\*eta\*theta\_0+theta\_0\*theta\_0);

k\_p= (4\*eta\*theta\_0)/(1+2\*eta\*theta\_0+theta\_0\*theta\_0);

phs\_accum=0;

int=0;

fltr\_hld=0;

reg=zeros(1,81);

m=1;

p2\_sv = zeros(1,999)

d\_phi\_sv = zeros(1,999);

for n=1:4000

p1=x3(n)\*exp(-j\*2\*pi\*phs\_accum);

reg=[p1 reg(1:80)];

x5(n)=reg\*hm';

if n>20

if rem(n,4)==1;

x5\_d=sign(real(x5(n)));

y5\_d=sign(imag(x5(n)));

i = (n-1)/4;

p2 = (x5\_d+j\*y5\_d)\*conj(x5(n));

p2\_sv(i) = p2;

d\_phi=-angle(p2)/(2\*pi);

d\_phi\_sv(m)=d\_phi;

int=int+d\_phi\*k\_i;

fltr=int+d\_phi\*k\_p;

fltr\_hld=fltr;

m=m+1;

end

phs\_accum\_sv(n)=phs\_accum;

phs\_accum=phs\_accum+fltr\_hld;

end

end

### f)



figure

subplot(3,1,1)

plotConstellationDiagram(x5(1001:end),fs,'Constellation diagram with PLL (last thousand samples)')

subplot(3,1,2)

plot(p2\_sv, 'k')

grid on

axis('square')

hold on

plot(p2\_sv,'r.')

title('Output of detector')

subplot(3,1,3)

plot(0:length(p2\_sv)-1, angle(p2\_sv)/(2\*pi))

title('Output of ATAN')