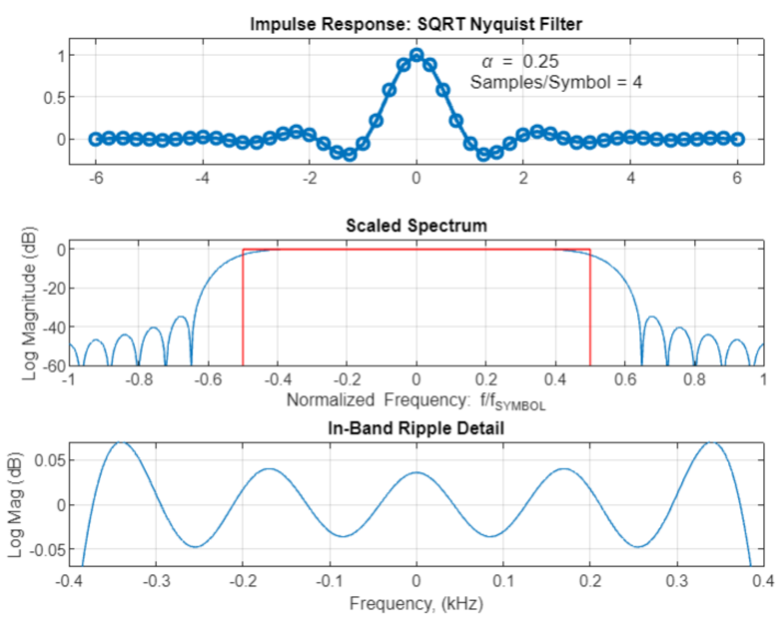
ECE_161B_project_2
Filter Related Distortion

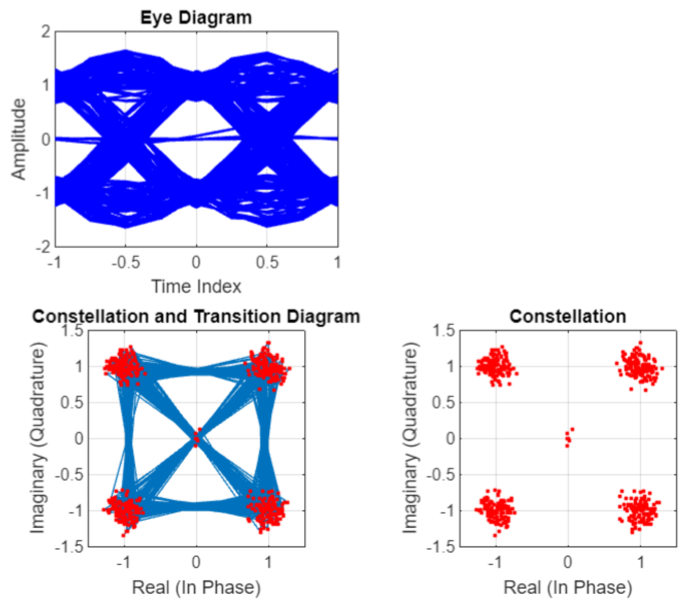
In this project we are going to form 500 symbols of a QPSK modulated communication signal with a sqrt-Nyquist shaping filter, a signal distorting band limiting low pass filter and a sqrt-Nyquist matched filter. Our goal is to compare the distortion levels induced by the low-pass filter and identify the filter with the minimum distortion. The modulation symbol rate is 4-samples per symbol and the excess bandwidth of the shaping filter is 0.25. The filter length is 49 samples.. Use h1=rcosine(1,4,'sqrt',0.25,6) or h1=sqrt_nyq_x(4,0.25,6,0) to form the shaping filter and use the following script to form the symbol sequence.

```
h1=sqrt_nyq_x(4, 0.25, 6, 0);
h1=h1/max(h1);
x0=(floor(2*rand(1,500))-0.5)/0.5+1j*(floor(2*rand(1,500))-0.5)/0.5;

x1=zeros(1,2000);
h2=reshape([h1 zeros(1,7)],4,14);
reg=zeros(1,14);
m=0;
for n=1:500
reg=[x0(n) reg(1:13)];
for k=1:4
   x1(k+m)=reg*h2(k,:)';
end
m=m+4;
end
```

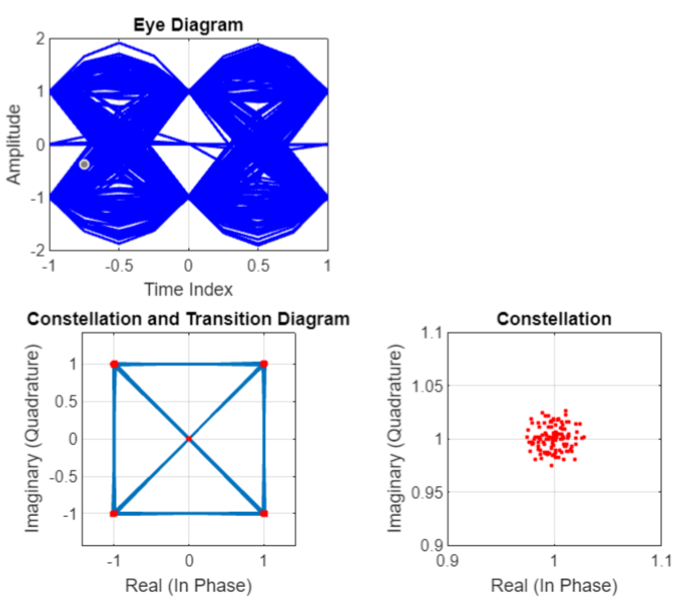
1a. Here we form the time series of the modulated signal using the sqrt Nyquist filter with 25% excess bandwidth and then form in figure(1) on three subplots, the impulse response, the log mag spectrum and zoom to the log mag spectrum passband ripple.



1b. Now we form the figure(2) shaping filter output series eye diagram, the constellation diagram with state transition overlay, and the constellation diagrams in subplots (2,2,1), (2,2,3) and (2,2,4).

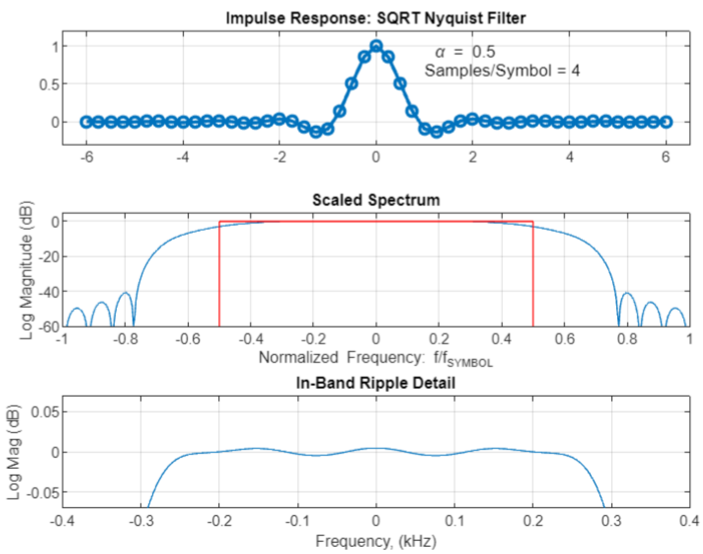


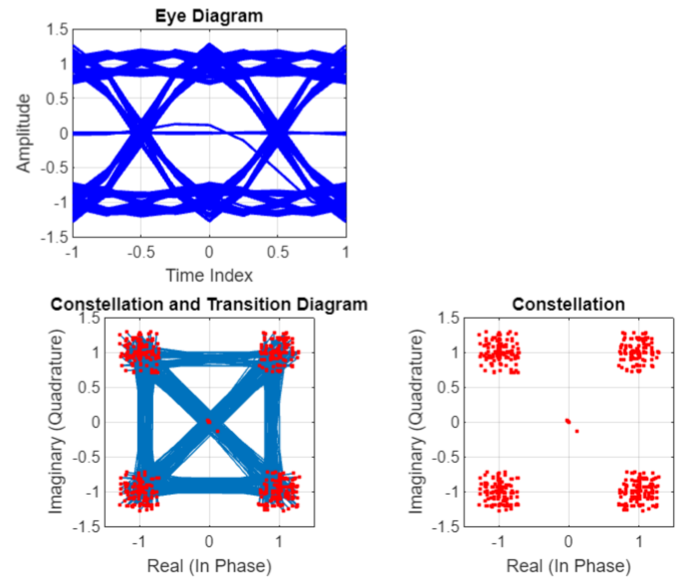
1c. We now pass the output time series from the shaping filter through the properly scaled matched filter. Scaling is h1/(h1*h1'); We plot in figure(3) the matched filter output series eye diagram, the constellation diagram, and the magnitude real versus magnitude imaginary constellation sample point diagrams in subplots (2,2,1), (2,2,3) and (2,2,4). The subplot(2,2,4) constellation point shows the smearing of constellation point due to filter distortion. This is traditionally measured by error vector magnitude (EVM).

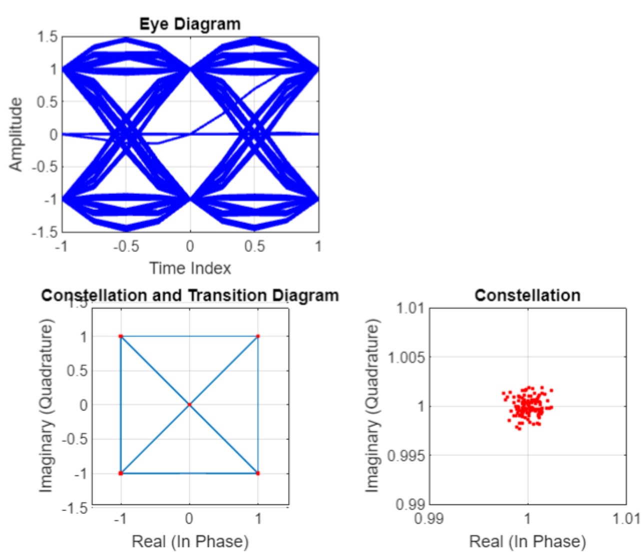



```
h1=sqrt_nyq_x(4, 0.25, 6, 1);
h1=h1/max(h1);
x0=(floor(2*rand(1,500))-0.5)/0.5+1j*(floor(2*rand(1,500))-0.5)/0.5;
x1=zeros(1,2000);
h2=reshape([h1 zeros(1,7)],4,14);
reg=zeros(1,14);

hh= h1/(h1*h1');

m=0;
for n=1:500
reg=[x0(n) reg(1:13)];
for k=1:4
    x1(k+m)=reg*h2(k,:)';
end
m=m+4;
end %1 to 4 interpolated version of x0

x2= conv(x1,hh);
```

1d. We now repeat questions 1a, 1b, and 1c except we now use the shaping filter excess BW to be 0.5 rather than 0.25. We will form figures (4), (5). and (6).



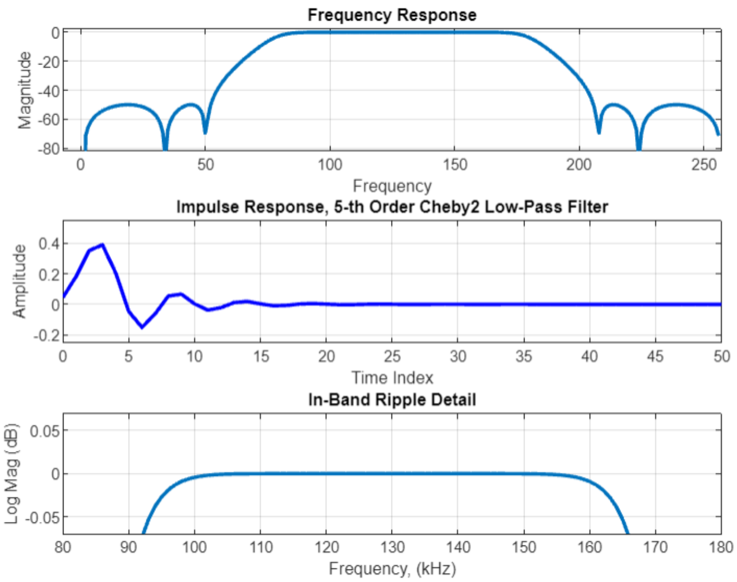


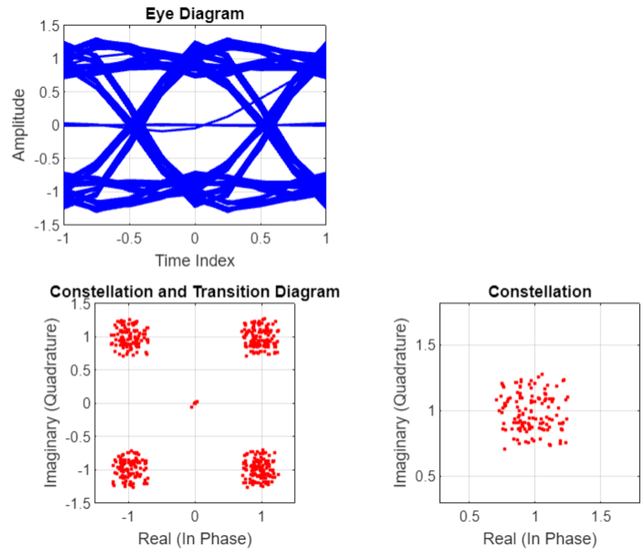



```
h1=sqrt_nyq_x(4, 0.5, 6, 1);
h1=h1/max(h1);
x0=(floor(2*rand(1,500))-0.5)/0.5+1j*(floor(2*rand(1,500))-0.5)/0.5;
x1=zeros(1,2000);
h2=reshape([h1 zeros(1,7)],4,14);
reg=zeros(1,14);

hh= h1/(h1*h1');

m=0;
for n=1:500
reg=[x0(n) reg(1:13)];
for k=1:4
    x1(k+m)=reg*h2(k,:)';
end
m=m+4;
end %1 to 4 interpolated version of x0

x2= conv(x1,hh);
```

1e. For the remainder of these questions, we will use the shaping and the matched filters with excess BW of 0.5.

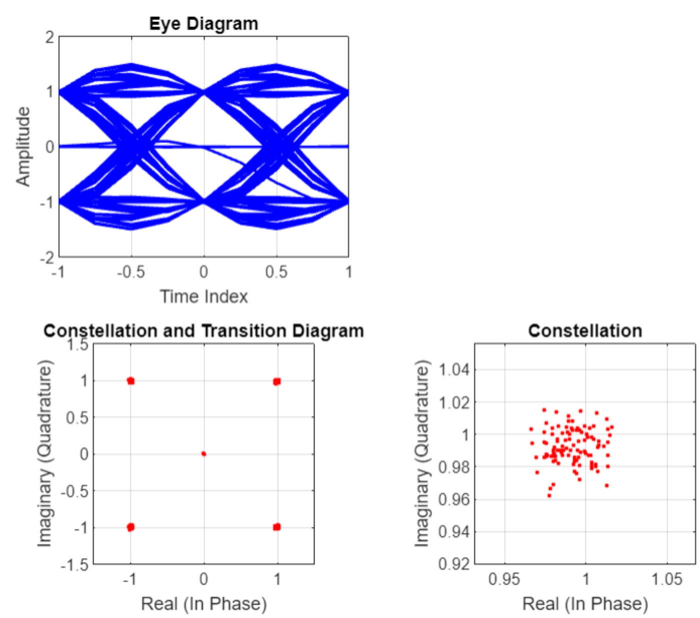
We now insert a 5-th order cheby2 filter with 50 dB stopband attenuation and cutoff frequency of 0.6, cheby2(5,50,0.6) between the shaping and matched filters. Form the filter coefficients and simply plot the impulse response, frequency response and in band ripple response on 3 subplots. Use Matlab filter to obtain impulse response from [bb,aa]. Pass the output of the shaping filter's modulated time series through the cheby2 filter and plot the eye diagram, the constellation, and the magnitude of real and imaginary smeared constellation in the three subplots. You will have to select the starting index for the curves that place the eye opening at index 0 in the eye and in the constellation corners.



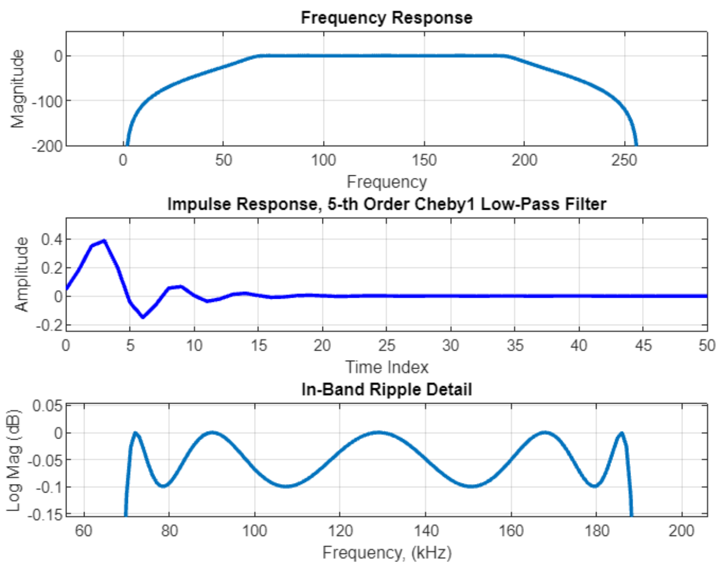


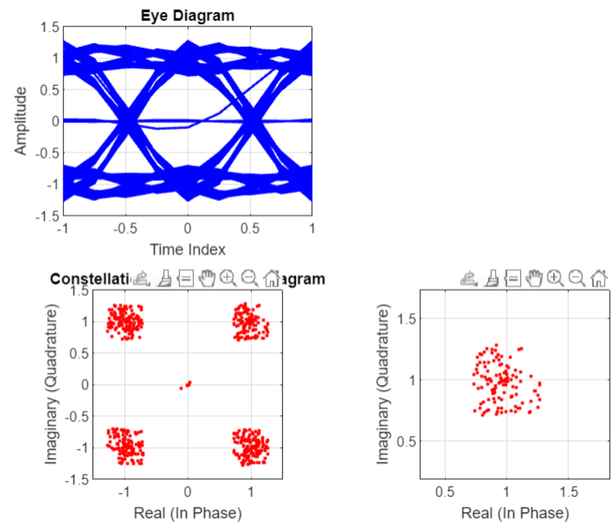
1f. now pass the output of the cheby2 filter through the matched filter and plot the eye diagram, the constellation, and the smeared real and imaginary magnitude constellation point in the three subplots. Surprisingly good constellation points but larger than we would like.

```
[bb,aa] = cheby2(5,50,0.6);
[H,W] = freqz(bb,aa,256,'whole');
fh=fftshift(20*log10(abs(H)));

hh= h1/(h1*h1');
x3= conv(x1,hh);
x2 = filter(bb,aa,x3);

offset = 2;

figure(5)
subplot(2,2,1)
plot(0,0)
hold on
for n=1+offset:8:2000-8
    plot((-1:1/4:+1),real(x2(n:n+8)),'b','linewidth',1.5)
end
hold off
grid on
title('Eye Diagram')
xlabel('Time Index')
ylabel('Amplitude')

subplot(2,2,3)
plot(x2(1+offset:4:2000),'r.')
grid on
axis([-1.5 1.5 -1.5 1.5])
axis('square')
title('Constellation and Transition Diagram')
xlabel('Real (In Phase)')
ylabel('Imaginary (Quadrature)')

subplot(2,2,4)
plot(x2(1+offset:4:2000),'r.')
grid on
axis([0.99 1.01 0.99 1.01])
axis('square')
title('Constellation')
xlabel('Real (In Phase)')
ylabel('Imaginary (Quadrature)')
```

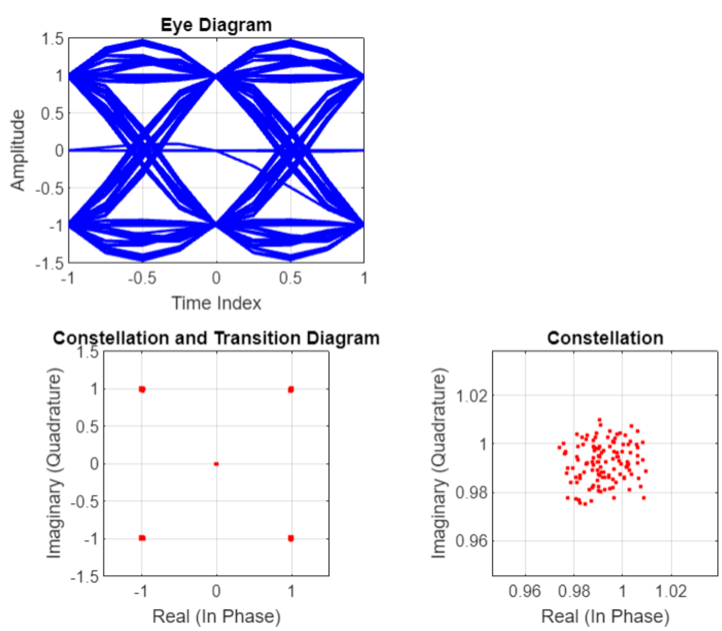


1g. We are now going to use a 5-th order cheby1 filter between the shaping and matched filter. The call to cheby 1 will be [bb2,aa2]=cheby1(5,0.1,0.46); Form the filter coefficients and simply plot the impulse response, frequency response and in band ripple response on 3 subplots. Use matlab filter to obtain impulse response from [bb2,aa2]. Pass the output of the shaping filter's modulated time series through the cheby1 filter and plot the eye diagram, the constellation, and the magnitude of real and imaginary smeared constellation in the three subplots. You will have to select the starting index for the curves that place the eye opening at index 0 in the eye and in the constellation corners.





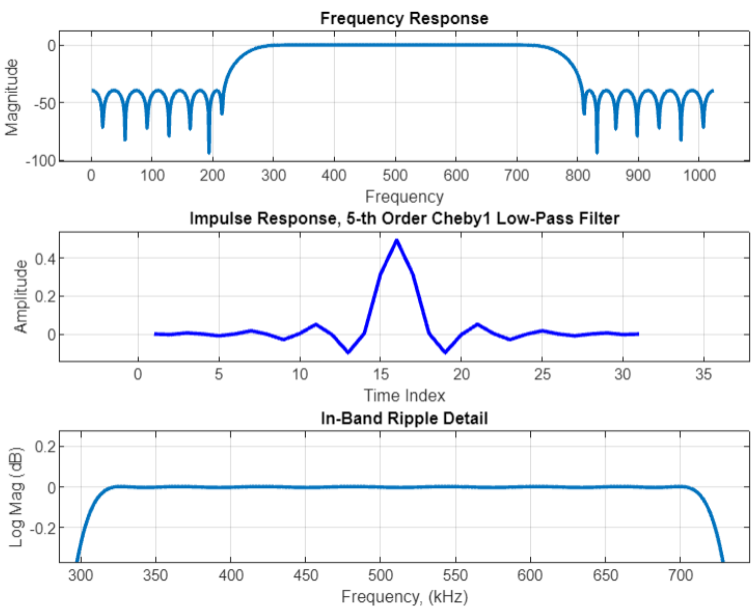
1h. now pass the output of the cheby1 filter through the matched filter and plot the eye diagram, the constellation, and the smeared real and imaginary magnitude constellation point in the three subplots. Again, we have surprisingly good constellation points but larger than we would like.

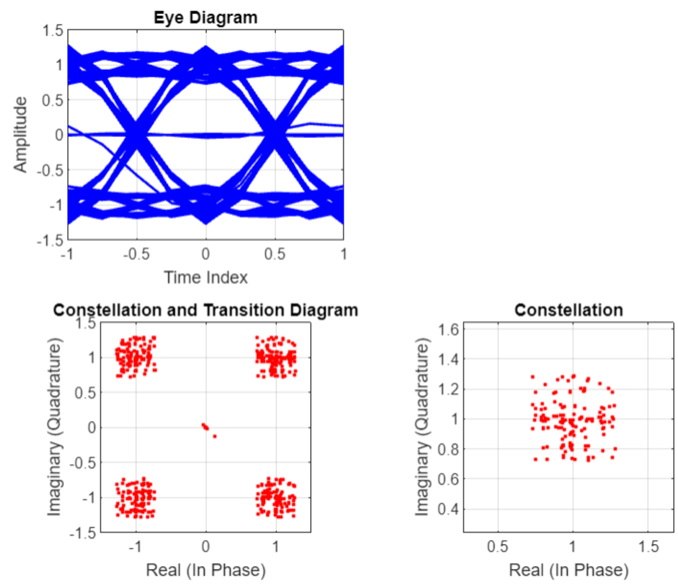



```
offset = 2;

figure(10)
subplot(2,2,1)
plot(0,0)
hold on
for n=1+offset:8:2000-8
    plot((-1:1/4:+1),real(x2(n:n+8)),'b','linewidth',1.5)
end
hold off
grid on
title('Eye Diagram')
xlabel('Time Index')
ylabel('Amplitude')

subplot(2,2,3)
plot(x2(1+offset:4:2000),'r.')
grid on
axis([-1.5 1.5 -1.5 1.5])
axis('square')
title('Constellation and Transition Diagram')
xlabel('Real (In Phase)')
ylabel('Imaginary (Quadrature)')

subplot(2,2,4)
plot(x2(1+offset:4:2000),'r.')
grid on
axis([0.99 1.01 0.99 1.01])
axis('square')
title('Constellation')
xlabel('Real (In Phase)')
ylabel('Imaginary (Quadrature)')
```

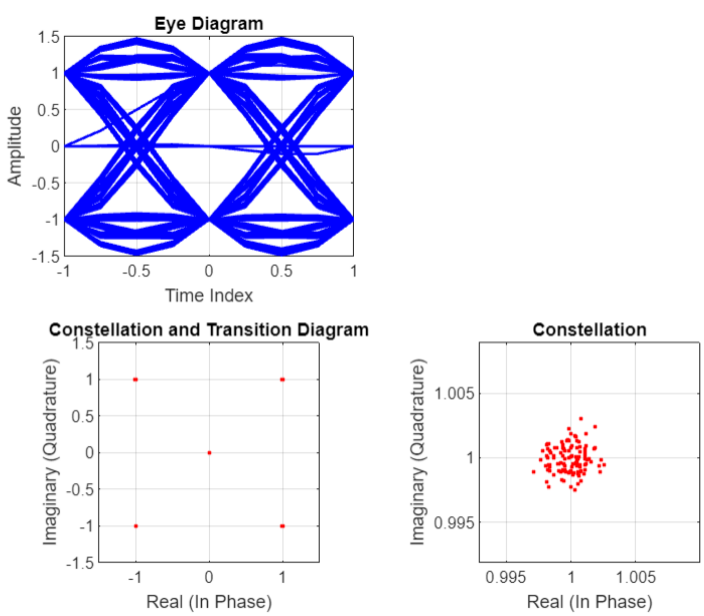
1i. We are now going to use a 30-tap linear phase FIR Filter between the shaping and matched filter. The call to the firpm design script is g3=firpm(30,[0 0.75 1.15 2]/2,[1 1 0 0],[40 1]);

Obtain the filter coefficients and simply plot the impulse response, frequency response and in band ripple response on 3 subplots. Pass the output of the shaping filter's modulated time series through the g3 FIR filter and plot the eye diagram, the constellation, and the magnitude of real and imaginary smeared constellation in the three subplots. You will have to select the starting index for the curves that place the eye opening at index 0 in the eye and in the constellation corners.





1j. Now pass the output of the g3 FIR filter through the matched filter and plot the eye diagram, the constellation, and the smeared real and imaginary magnitude constellation point in the three subplots. Again, we have surprisingly good constellation points very nearly the EVM of the shaping and matched filters without the intermediate filter.




```
g3=firpm(30,[0 0.75 1.15 2]/2,[1 1 0 0],[40 1]);
fh=fftshift(20*log10(abs(fft(g3,1024))));

hh= h1/(h1*h1');
x3= conv(x1,hh);
x2 = conv(x3,g3);

offset = 3;

figure(10)
subplot(2,2,1)
plot(0,0)
hold on
for n=1+offset:8:2000-8
    plot((-1:1/4:+1),real(x2(n:n+8)),'b','linewidth',1.5)
end
hold off
grid on
title('Eye Diagram')
xlabel('Time Index')
ylabel('Amplitude')

subplot(2,2,3)
plot(x2(1+offset:4:2000),'r.')
grid on
axis([-1.5 1.5 -1.5 1.5])
axis('square')
title('Constellation and Transition Diagram')
xlabel('Real (In Phase)')
ylabel('Imaginary (Quadrature)')
```

1k. Compare the performance of the options we have examined in terms of constellation smearing. What can we conclude about the best filters to be placed between the shaping and matched filters in a communication system?

Comparing the constellation smearing at the same scale for the cheby1, cheby2, and firpm:

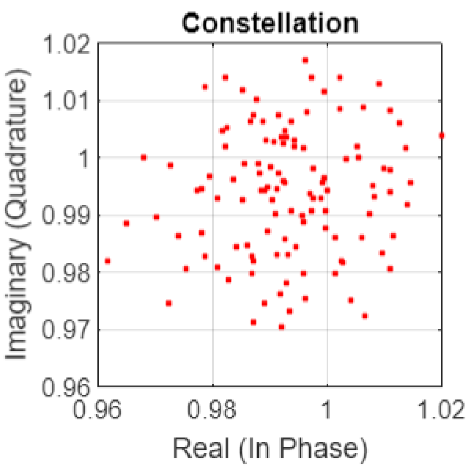


Figure 1: Cheby2

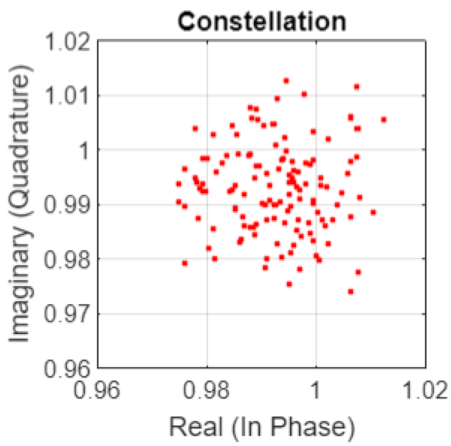


Figure 2: Cheby1

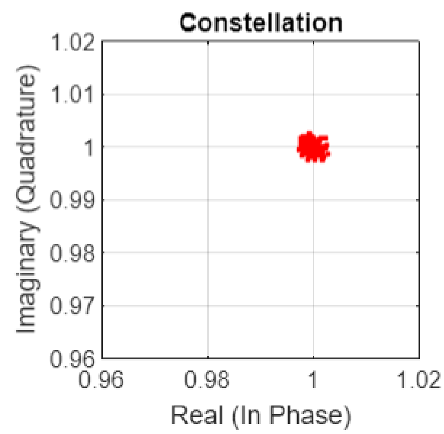


Figure 3: FIRPM

The FIRPM filter seems to have the best performance because it has the least amount of smearing (deviation from the ideal value), which in this case would be 1.