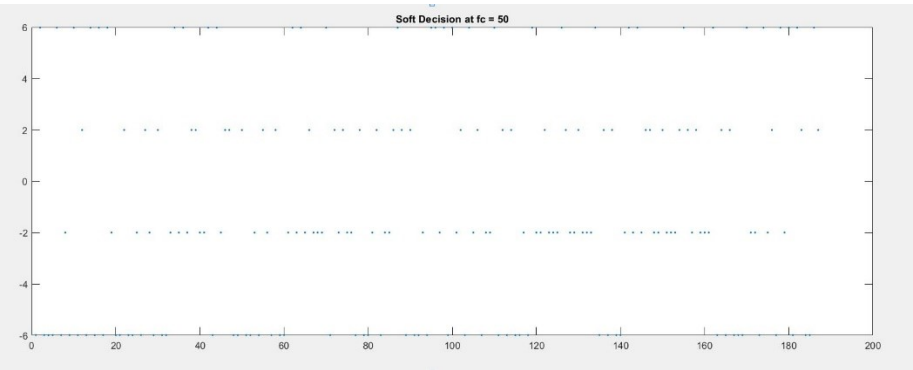
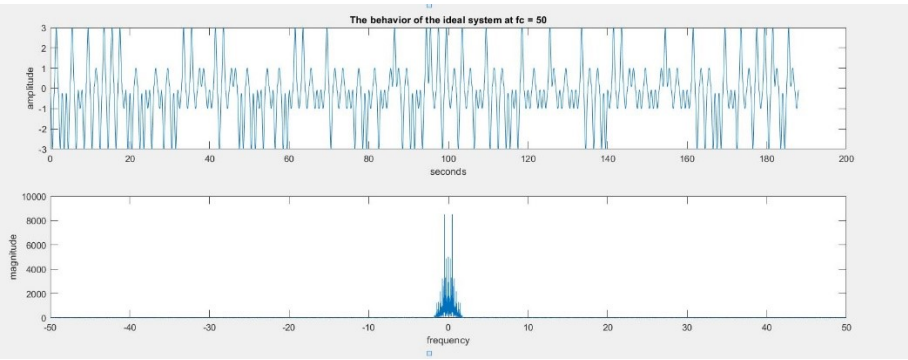
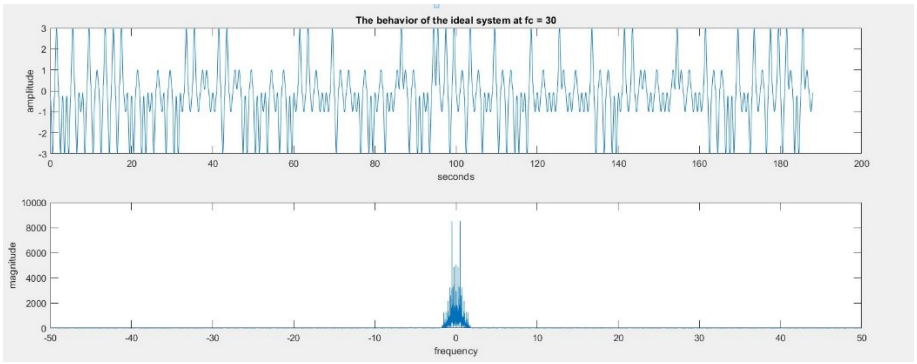
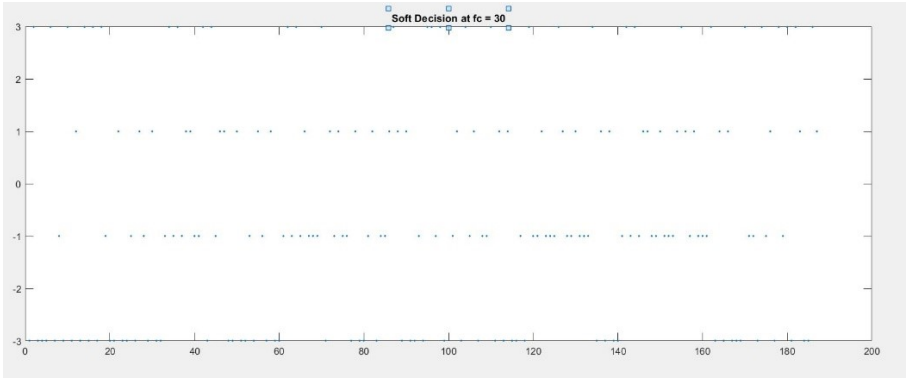
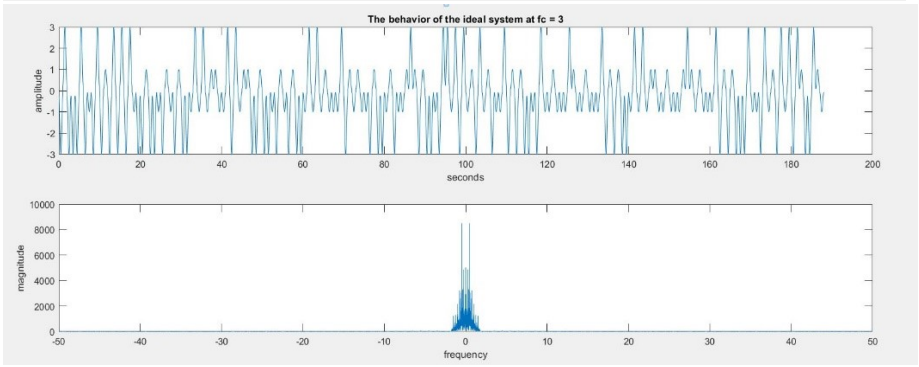
Exercise 9.1

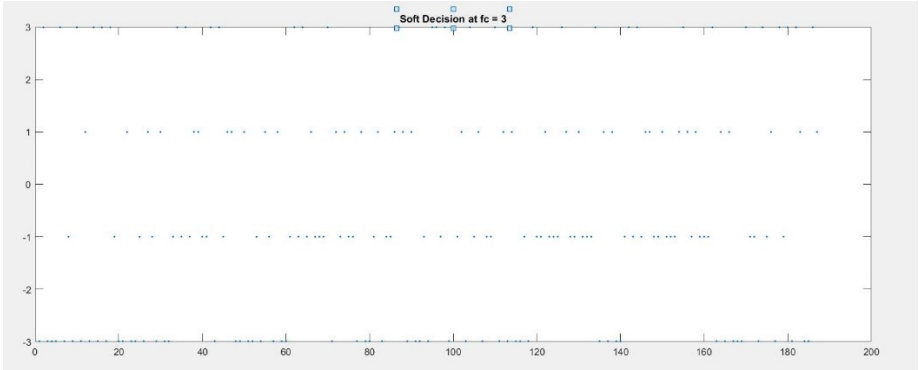

Soft Decision at fc = 50
6
4
2
0
-2
-4
-6
0
20
40
60
80
100
120
140
160
180
200

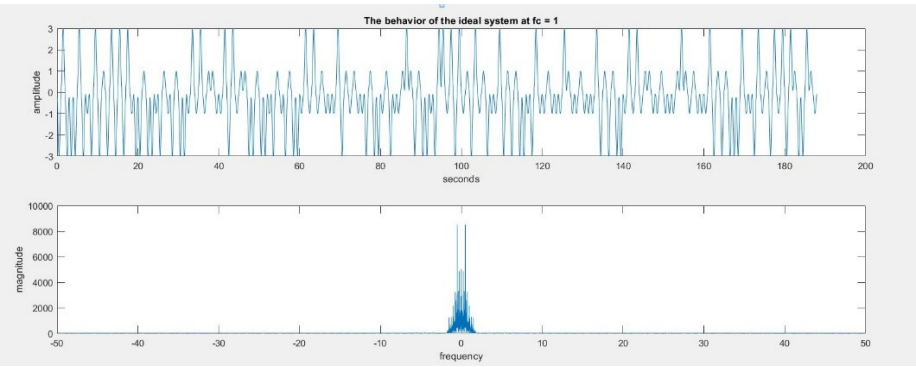

The behavior of the ideal system at fc = 50
amplitude
seconds
magnitude
frequency

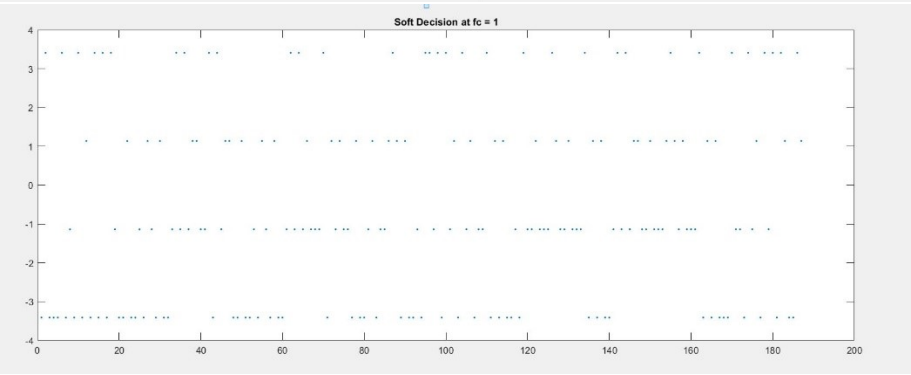

The behavior of the ideal system at fc = 30
amplitude
seconds
magnitude
frequency

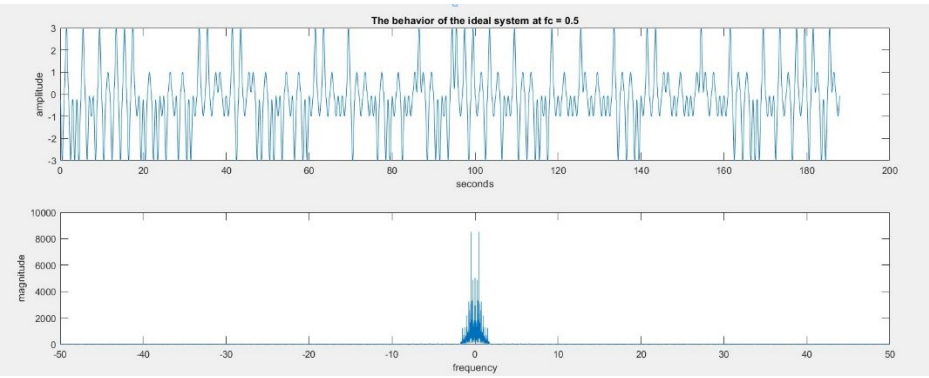

Soft Decision at fc = 30

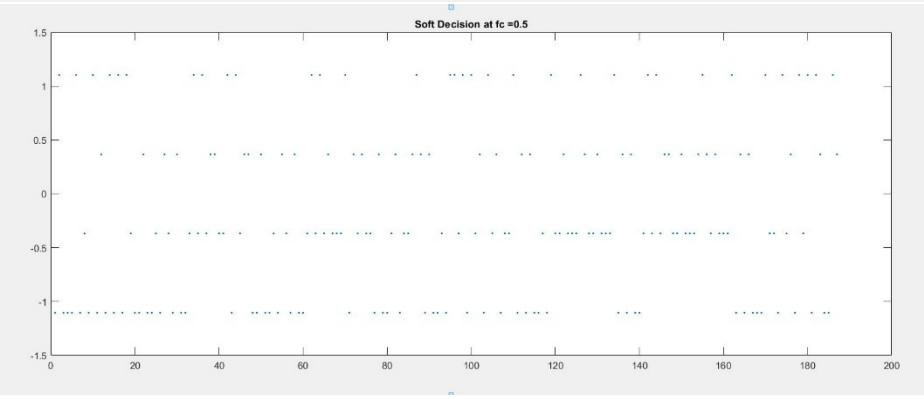

The behavior of the ideal system at fc = 3
amplitude
seconds
magnitude
frequency


Soft Decision at fc = 3


The behavior of the ideal system at fc = 1
amplitude
seconds
magnitude
frequency


Soft Decision at fc = 1

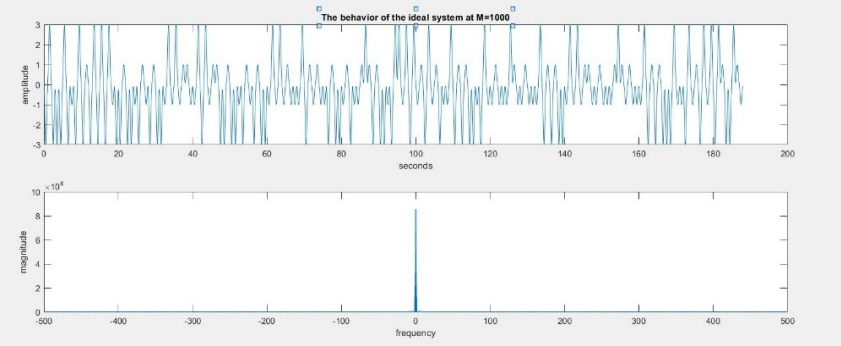


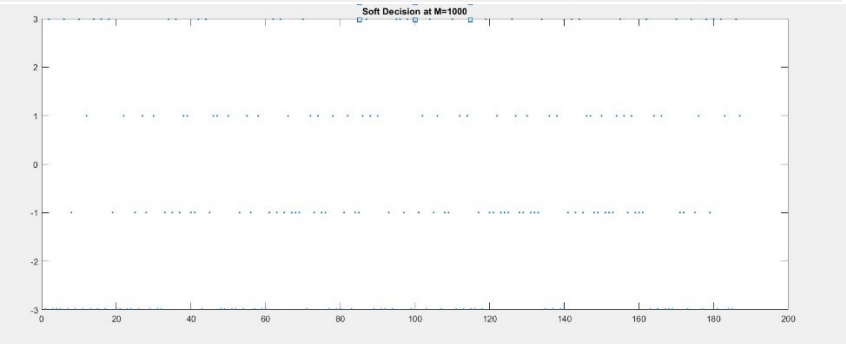


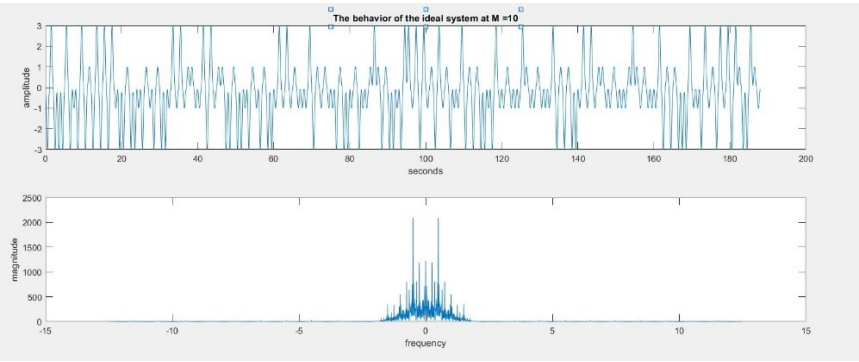

```
cvar =

    0.2104


pererr =

   48.6631


ans =

    'dropping last 3 PAM symbols'


reconstructed_message =

    'eeffeeYefifieYefefeeejeZffefeYeiefefiejefeeffi'

>> when fc = 0.7
```

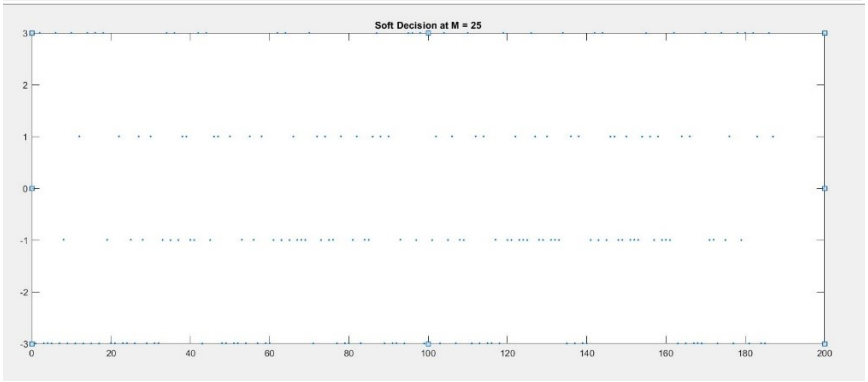
The limiting factors that cause some message to send correctly and some are not depends on fc (carrier frequency) is smaller than sampling frequency.

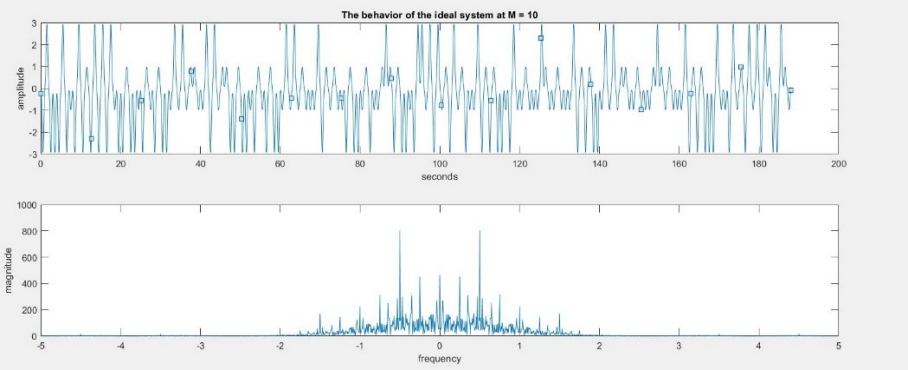
Question 9.2

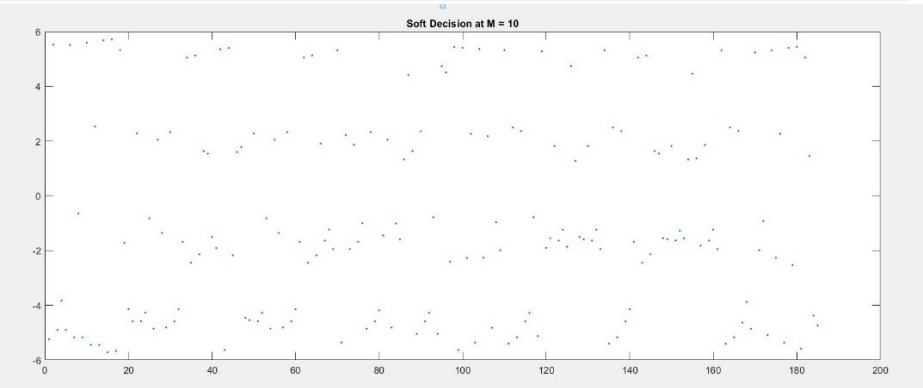

The behavior of the ideal system at M=1000
amplitude
seconds
magnitude
frequency


Soft Decision at M=1000


The behavior of the ideal system at M =10
amplitude
seconds
magnitude
frequency


Soft Decision at M = 25

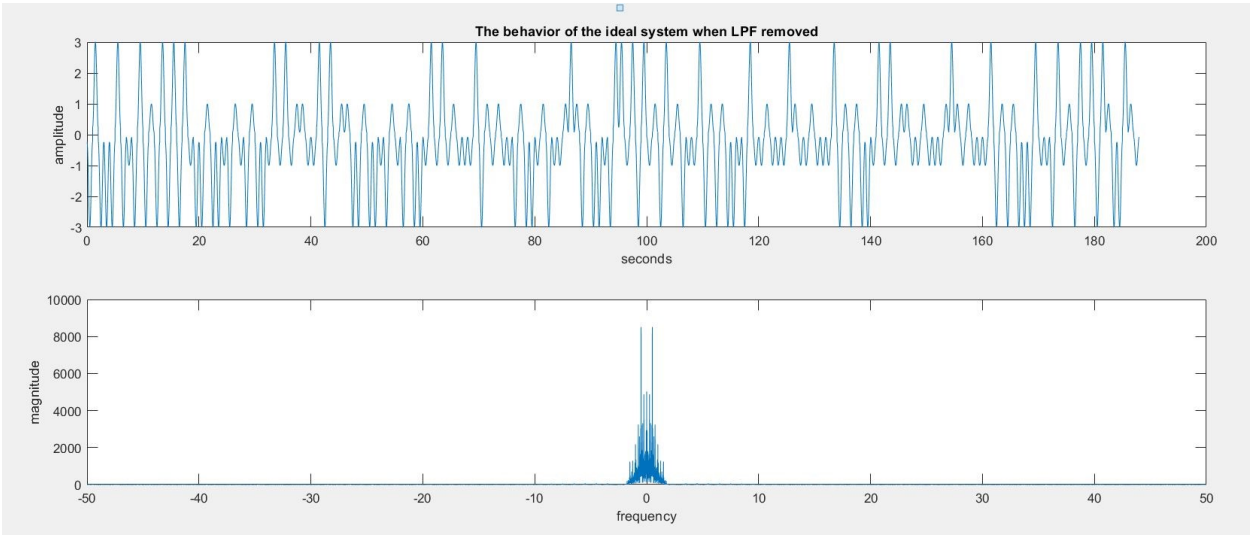


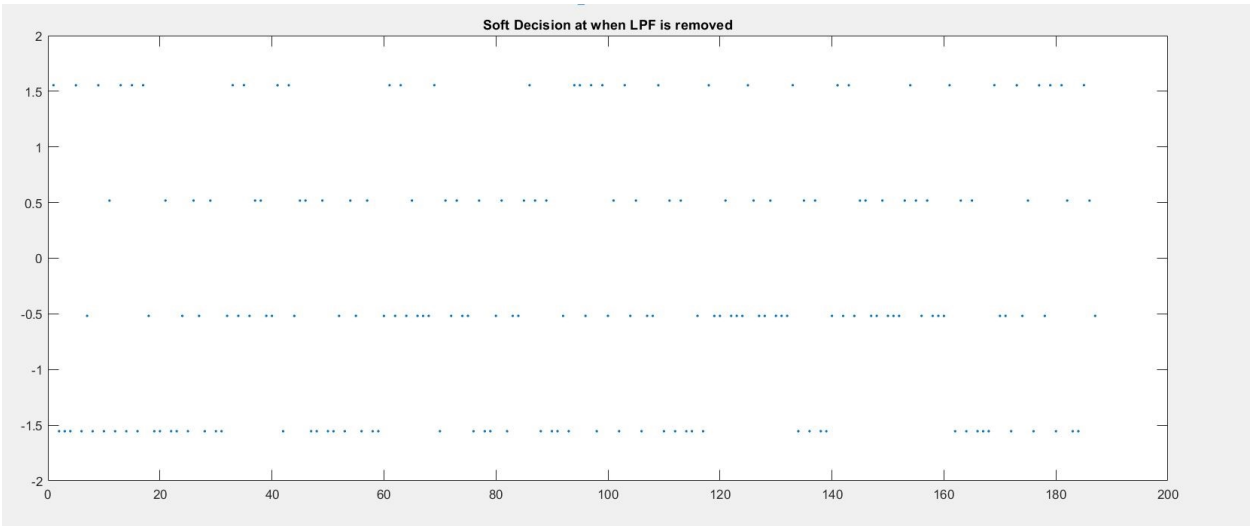



```
cvar =

    2.2154


pererr =

   17.2973


ans =

    'dropping last 1 PAM symbols'


reconstructed_message =

    '013340M0s)s(0M0s%se0qn0O331s0Meyes0s)enes05338'

>> the result when M = 10
```

- M is number of samples in a symbol period and l is 125 in the example code which correlates to half of the symbol period.

Question 9.3


The behavior of the ideal system when LPF removed
amplitude
seconds
magnitude
frequency


Soft Decision at when LPF is removed

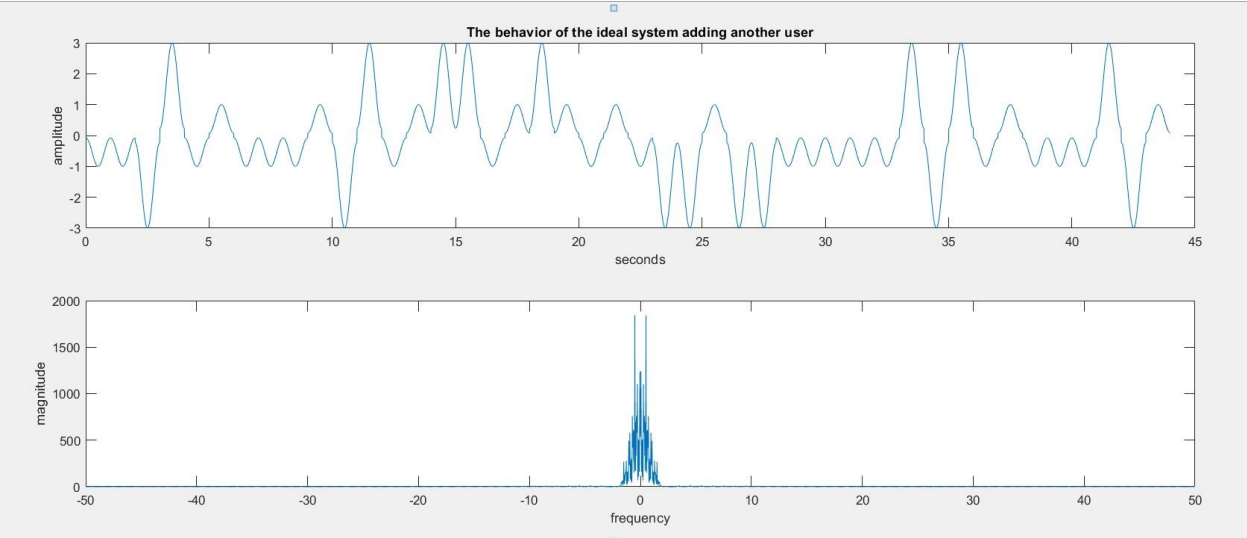
```
cvar =

    0.2683


pererr =

   82.3529


ans =

    'dropping last 3 PAM symbols'


reconstructed_message =

    '□□□□□□e□□¥□¥□e□□□□□□□©□i□□□□□e□¥□□□□¥□©□□□□□□¥'

When LPF is removed, the message is not displayed correctly /n>>
```

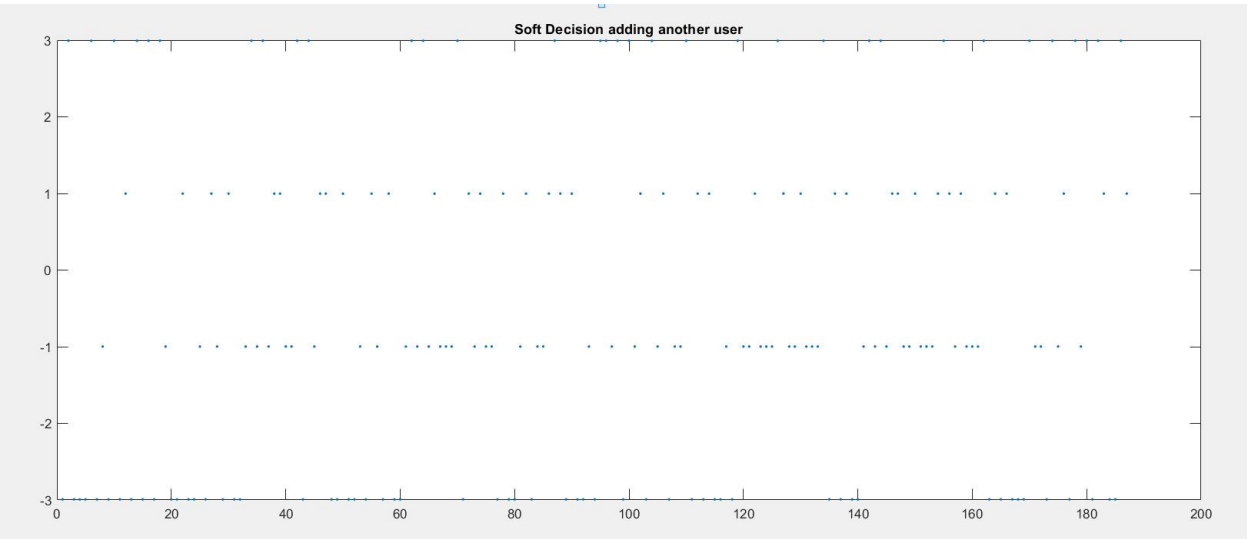
MATLAB

```
%RECEIVER
% am demodulation of received signal sequence r
c2=cos(2*pi*fc*t);                  % synchronized cosine for mixing
x2=r.*c2;                           % demod received signal
fl=50; fbe=[0 0.1 0.2 1];
damps=[1 1 0 0 ];  % design of LPF parameters
b=firpm(fl,fbe,damps);              % create LPF impulse response
%x3=2*filter(b,1,x2);                % LPF and scale downconverted signal
% extract upsampled pulses using correlation implemented as a convolving filter
%y=filter(fliplr(p)/(pow(p)*M),1,x3); % filter rec'd sig with pulse; normalize
% set delay to first symbol-sample and increment by M
z=x2(0.5*fl+M:M:end);               % downsample to symbol rate
figure(2), plot([1:length(z)],z,'.') % soft decisions
title('Soft Decision at fc = 50')
% decision device and symbol matching performance assessment
mprime=quantalph(z,[-3,-1,1,3])';    % quantize to +/-1 and +/-3 alphabet
cvar=(mprime-z)*(mprime-z)'/length(mprime), % cluster variance
lmp=length(mprime);
pererr=100*sum(abs(sign(mprime-m(1:lmp))))/lmp, % symb err
% decode decision device output to text string
reconstructed_message=pam2letters(mprime)      % reconstruct message
fprintf('When LPF is removed, the message is not displayed correctly /n')
```

- When LPF is removed the signals are overlapping
- The extra samples have to be removed with LPF to get the correct message.

Question 9.3 Cont. Add Second User



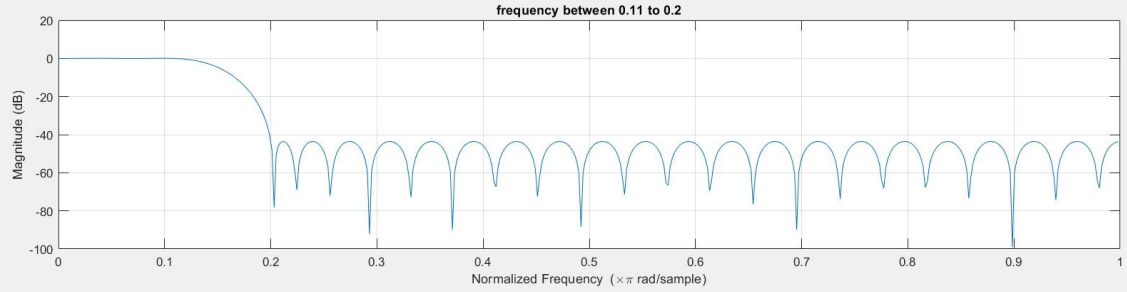


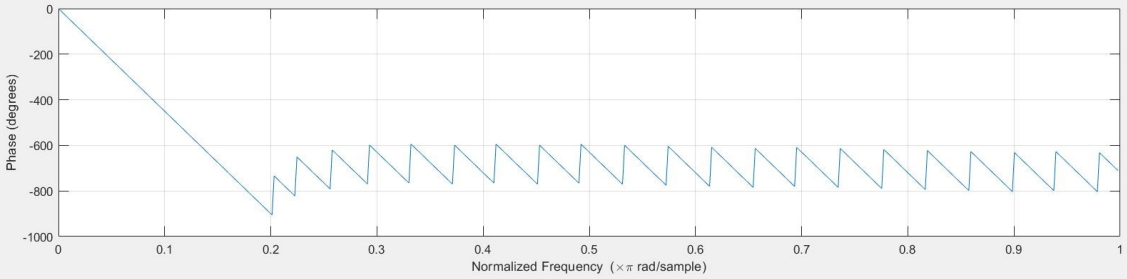

```
cvar =

   2.9259e-05


pererr =

     0


ans =

    'dropping last 3 PAM symbols'

reconstructed_message =

    '01234 I wish I were an Oscar Meyer wiener 5678'
```

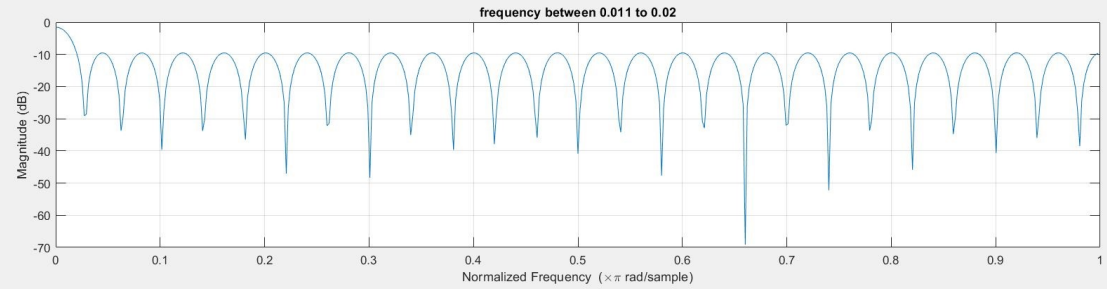
MATLAB

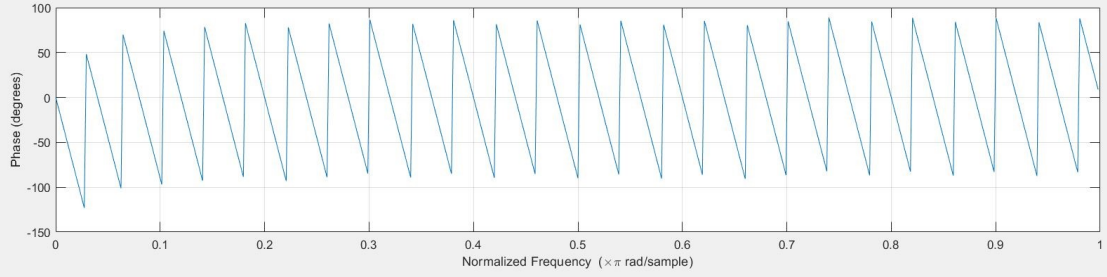
```
%TRANSMITTER
% encode text string as T-spaced PAM (+/-1, +/-3) sequence
str='01234 I wish I were an Oscar Meyer wiener 56789';
m=letters2pam(str); N=length(m);    % 4-level signal of length N
% zero pad T-spaced symbol sequence to create upsampled T/M-spaced
% sequence of scaled T-spaced pulses (with T = 1 time unit)
M=100; mup=zeros(1,N*M); mup(1:M:end)=m; % oversampling factor
% Hamming pulse filter with T/M-spaced impulse response
p=hamming(M);                          % blip pulse of width M
x=filter(p,1,mup);                     % convolve pulse shape with data
figure(1), plotspec(x,1/M)             % baseband signal spectrum
% am modulation
t=1/M:1/M:length(x)/M;                 % T/M-spaced time vector
fc= 20;                                 % carrier frequency
c=cos(2*pi*fc*t);                      % carrier
r=c.*x;                                % modulate message with carrier

%TRANSMITTER_2
str_2= 'Second User';
m_2=letters2pam(str_2); N_2=length(m_2);M_2=100;
mup_2=zeros(1,N_2*M_2); mup_2(1:M_2:end)=m_2; % oversampling factor
% Hamming pulse filter with T/M-spaced impulse response
p_2=hamming(M_2);                       % blip pulse of width M
x_2=filter(p_2,1,mup_2);                  % convolve pulse shape with data
figure(1), plotspec(x_2,1/M_2)          % baseband signal spectrum
% am modulation
t_2=1/M_2:1/M_2:length(x_2)/M_2;              % T/M-spaced time vector
fc_2= 30;                                % carrier frequency
c_2=cos(2*pi*fc_2*t_2);                   % carrier
r_2=c_2.*x_2;                             % modulate message with carrier


%RECEIVER
% am demodulation of received signal sequence r
c2=cos(2*pi*fc*t);                     % synchronized cosine for mixing
x2=r.*c2;                              % demod received signal
c2_2= cos(2*pi*fc_2*t_2);
x2_2 = r_2.*c2_2;

% add signals
x_length = size(x2);
y_length = size(x2_2);
sig = max(x_length(1),y_length(1));
x2 = [[x2;zeros(abs([sig 0]-x_length))],[x2_2;zeros(abs([sig 0]-y_length))]];
fl = 50; fbe=[0 0.1 0.2 1];
damps=[1 1 0 0 ];  % design of LPF parameters
b=firpm(fl,fbe,damps);                 % create LPF impulse response
x3=2*filter(b,1,x2);                   % LPF and scale downconverted signal
% extract upsampled pulses using correlation implemented as a convolving filter
y=filter(fliplr(p)/(pow(p)*M),1,x3); % filter rec'd sig with pulse; normalize
% set delay to first symbol-sample and increment by M
z=y(0.5*fl+M:M:N*M);                   % downsample to symbol rate
figure(2), plot([1:length(z)],z,'.') % soft decisions
title('Soft Decision at fc = 50')
% decision device and symbol matching performance assessment
mprime=quantalph(z,[-3,-1,1,3])';    % quantize to +/-1 and +/-3 alphabet
cvar=(mprime-z)*(mprime-z)'/length(mprime), % cluster variance
lmp=length(mprime);
pererr=100*sum(abs(sign(mprime-m(1:lmp))))/lmp, % symb err
% decode decision device output to text string
reconstructed_message=pam2letters(mprime)      % reconstruct message
```

Question 9.4


frequency between 0.11 to 0.2
Magnitude (dB)
Normalized Frequency (×π rad/sample)


Phase (degrees)
Normalized Frequency (×π rad/sample)


frequency between 0.011 to 0.02
Magnitude (dB)
Normalized Frequency (×π rad/sample)

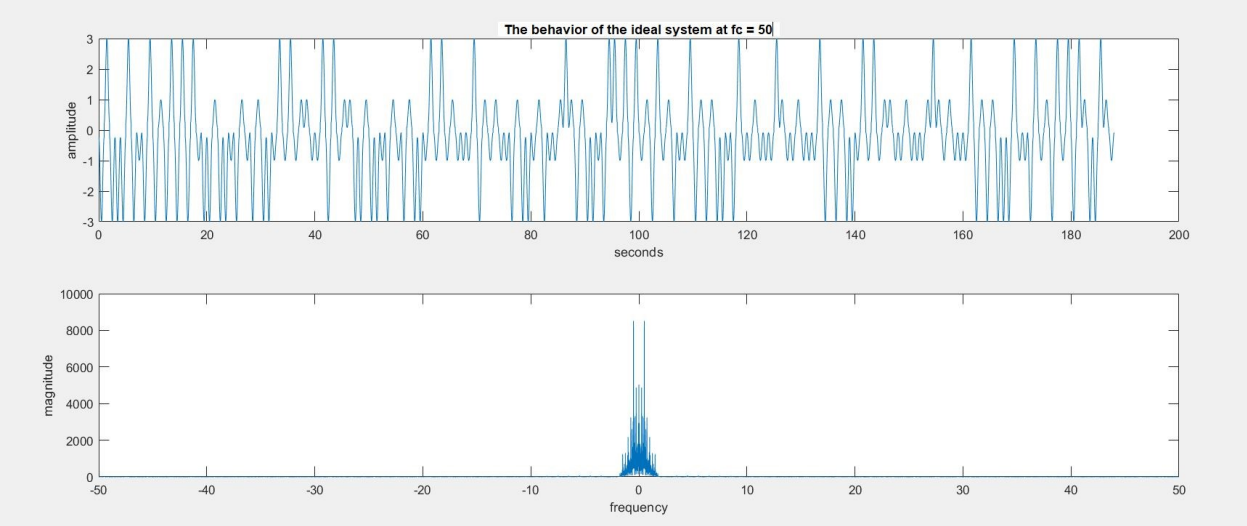

Phase (degrees)
Normalized Frequency (×π rad/sample)

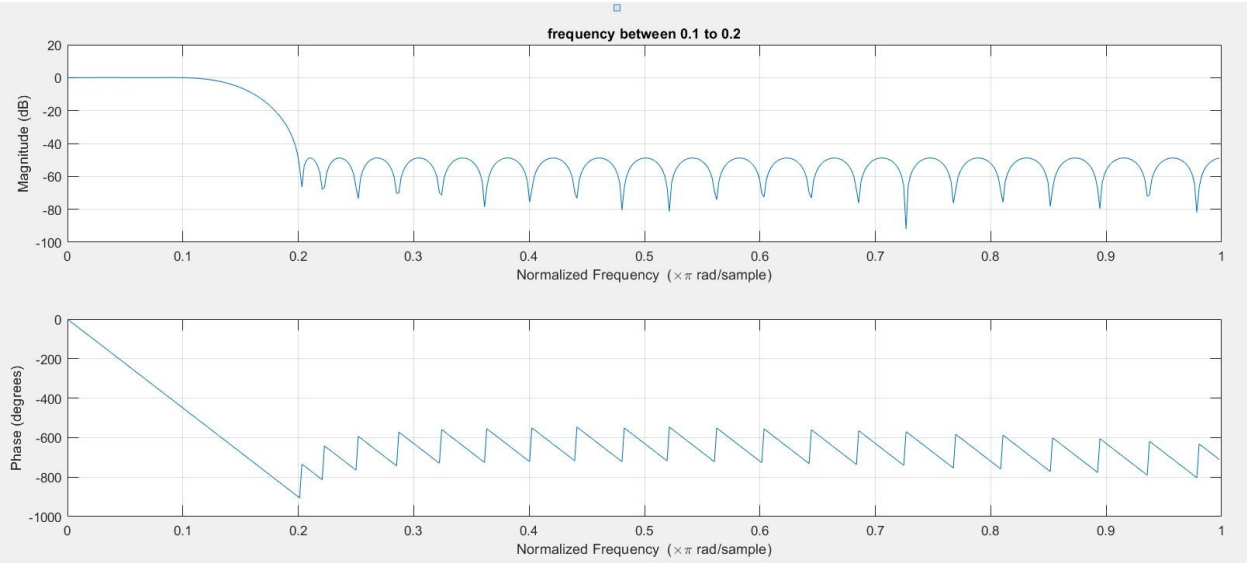
```
cvar =

    0.4789


pererr =

     0


ans =

    'dropping last 3 PAM symbols'


reconstructed_message =

    '01234 I wish I were an Oscar Meyer wiener 5678'
```

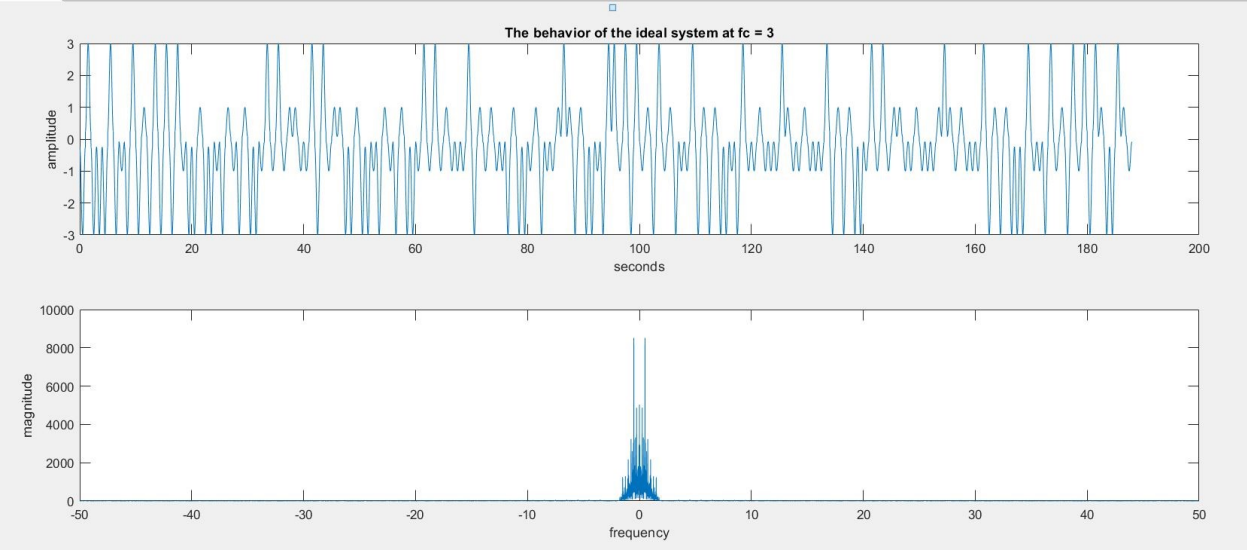
MATLAB CODE

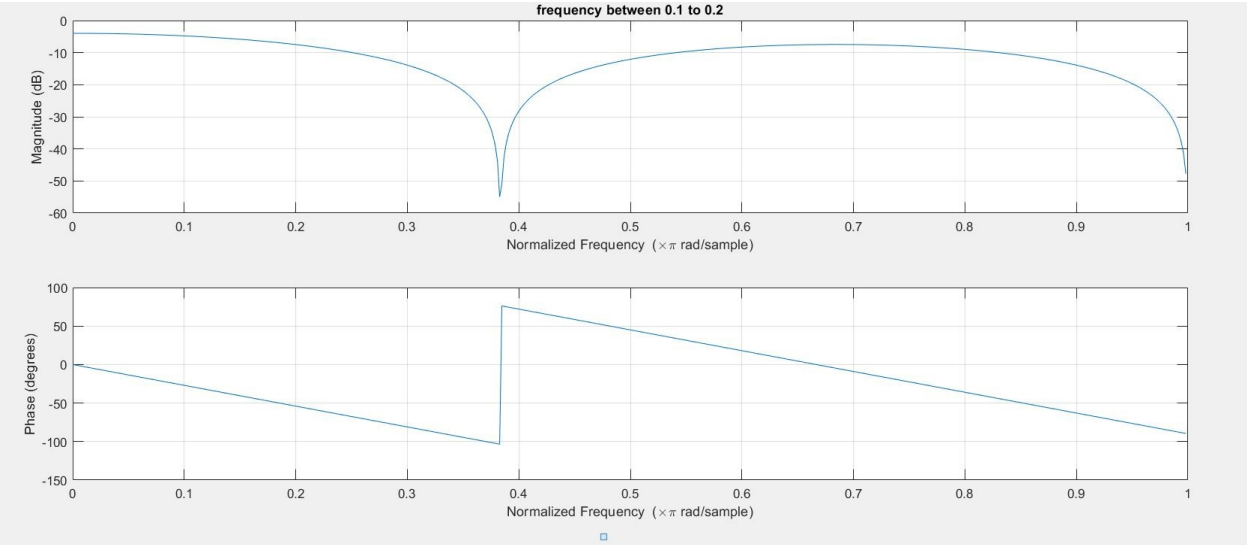
```
%RECEIVER
% am demodulation of received signal sequence r
c2=cos(2*pi*fc*t);                  % synchronized cosine for mixing
x2=r.*c2;                           % demod received signal

fl = 50; fbe=[0 0.011 0.02 1];
damps=[1 1 0 0 ];  % design of LPF parameters
b=firpm(fl,fbe,damps);              % create LPF impulse response
figure
freqz(b)
title('frequency between 0.011 to 0.02')
x3=2*filter(b,1,x2);                % LPF and scale downconverted signal
% extract upsampled pulses using correlation implemented as a convolving filter
y=filter(fliplr(p)/(pow(p)*M),1,x3); % filter rec'd sig with pulse; normalize
% set delay to first symbol-sample and increment by M
z=y(0.5*fl+M:M:end); % downsample to symbol rate

mprime=quantalph(z,[-3,-1,1,3])';    % quantize to +/-1 and +/-3 alphabet
cvar=(mprime-z)*(mprime-z)'/length(mprime), % cluster variance
lmp=length(mprime);
pererr=100*sum(abs(sign(mprime-m(1:lmp))))/lmp, % symb err
% decode decision device output to text string
reconstructed_message=pam2letters(mprime)      % reconstruct message
```

Question 9.5


The behavior of the ideal system at fc = 50
amplitude
seconds
magnitude
frequency


frequency between 0.1 to 0.2
Magnitude (dB)
Normalized Frequency (×π rad/sample)
Phase (degrees)
Normalized Frequency (×π rad/sample)


The behavior of the ideal system at fc = 3
amplitude
seconds
magnitude
frequency




```
cvar =

    0.4597


pererr =

   48.6631


ans =

    'dropping last 3 PAM symbols'


reconstructed_message =

    'eeffeeYefifieYefefeeejeZffefeYeiefefiejefeeffi'

When filter is 3, the message is not correctly displayed>>
```

- ❖ The shortest LPF is 4