

# **EC 415: Homework 5**

Due by Friday 04/23/2021 6:00PM

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## Exercise 8.1

The Matlab code in `naivecode.m`, which is on the website, implements the translation from binary to 4-PAM (and back again) suggested in (8.2). Examine the resiliency of this translation to noise by plotting the number of errors as a function of the noise variance  $v$ . What is the largest variance for which no errors occur? At what variance are the errors near 50%?

### Solution

Using this code

Listing 1: MATLAB code for Exercise 8.1

```

mesLen=1000;                                     %message length
bits=(sign(rand(1,mesLen)-.5)+1)/2; %binary message to send
%index into constl = 1+ bits(i) + 2*bits(i+1)
constl=[-3 1 -1 3];
k=1;
pam4mes=zeros(1,length(bits)/2);
for i=1:2:length(bits)
    pam4mes(k)=constl(1+bits(i)+2*bits(i+1)); %switch to a PAM4 constellation
    k=k+1;
end

n=1000;
indx=1;
percErrs=zeros(1,n/.1);
num_errors=zeros(1,n/.1);
for v=0:.1:n

    %pass the signal through a noisy channel
    noisyPam=sqrt(v)*randn(1,length(pam4mes))+pam4mes;

    %quantize the received signal
    recSig=quantalph(noisyPam,[-3,-1,1,3]);

    k=1;
    recBits=zeros(1,2*length(recSig));
    %decode the signal using the naive code
    for i=1:length(recSig)
        if recSig(i)==3
            recBits(k)=1;
            recBits(k+1)=1;
        elseif recSig(i)==1
            recBits(k)=1;
            recBits(k+1)=0;
        elseif recSig(i)==-1
            recBits(k)=0;
            recBits(k+1)=1;
        elseif recSig(i)==-3
            recBits(k)=0;

```

```
        recBits(k+1)=0;
    end
    k=k+2;
end

%calculate the percentage error
percErrs(indx)=sum((recBits~=bits))/length(recBits);
num_errors(indx)=sum(recBits~=bits);
%length(recBits)

indx=indx+1;
end

% Plot
v=0:1:n;
plot(v, num_errors)
title('number_of_errors_as_a_function_of_variance_for_' + string(length(recBits)) + '_bits')
xlabel('variance')
ylabel('number_of_errors')
```

the following plot was generated.

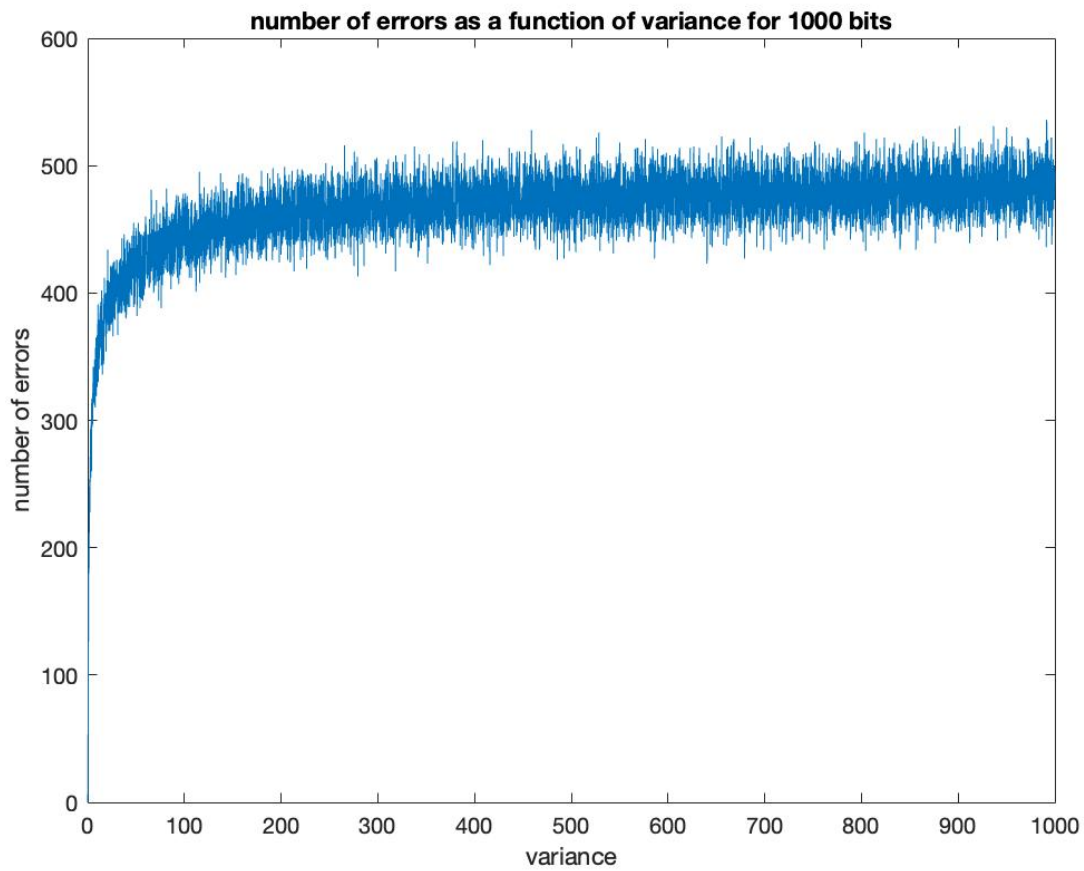


Figure 1: number of errors as a function of the noise variance  $v$

From this we can see that the errors can be greater than 50% as soon as variance reaches about 300, but from the long term trend, the error count only approaches 50% on average.

## Exercise 8.2

A Gray code has the property that the binary representation for each symbol differs from its neighbors by exactly one bit. A Gray code for the translation of binary into 4-PAM is

01  $\rightarrow$  +3

11  $\rightarrow$  +1

10  $\rightarrow$  -1

00  $\rightarrow$  -3

Mimic the code in `naivecode.m` to implement this alternative and plot the number of errors as a function of the noise variance  $v$ . Compare your answer with Exercise 8.1. Which code is better?

## Solution

Using this code:

Listing 2: MATLAB code for Exercise 8.2

```

mesLen=1000;                                     %message length
bits=(sign(rand(1,mesLen)-.5)+1)/2; %binary message to send
%index into constl = 1+ bits(i) + 2*bits(i+1)
constl=[-3 1 -1 3];
k=1;
pam4mes=zeros(1,length(bits)/2);
for i=1:2:length(bits)
    pam4mes(k)=constl(1+bits(i)+2*bits(i+1)); %switch to a PAM4 constellation
    k=k+1;
end

n=1000;
indx=1;
percErrs=zeros(1,n/.1);
num_errors=zeros(1,n/.1);
for v=0:.1:n

    %pass the signal through a noisy channel
    noisyPam=sqrt(v)*randn(1,length(pam4mes))+pam4mes;

    %quantize the received signal
    recSig=quantalph(noisyPam,[-3,-1,1,3]);

    k=1;
    recBits=zeros(1,2*length(recSig));
    %decode the signal using the naive code
    for i=1:length(recSig)
        if recSig(i)==3
            recBits(k)=0;
            recBits(k+1)=1;
        elseif recSig(i)==1
            recBits(k)=1;
            recBits(k+1)=1;
        elseif recSig(i)==-1

```

```
        recBits(k)=1;
        recBits(k+1)=0;
    elseif recSig(i)==-3
        recBits(k)=0;
        recBits(k+1)=0;
    end
    k=k+2;
end

%calculate the percentage error
percErrs(indx)=sum((recBits~=bits))/length(recBits);
num_errors(indx)=sum(recBits~=bits);
indx=indx+1;
end

% Plot
v=0:.1:n;
plot(v, num_errors)
title('number_of_errors_as_a_function_of_variance_for_' + string(length(recBits)) + '_bits')
xlabel('variance')
ylabel('number_of_errors')
```

the following plot was generated.

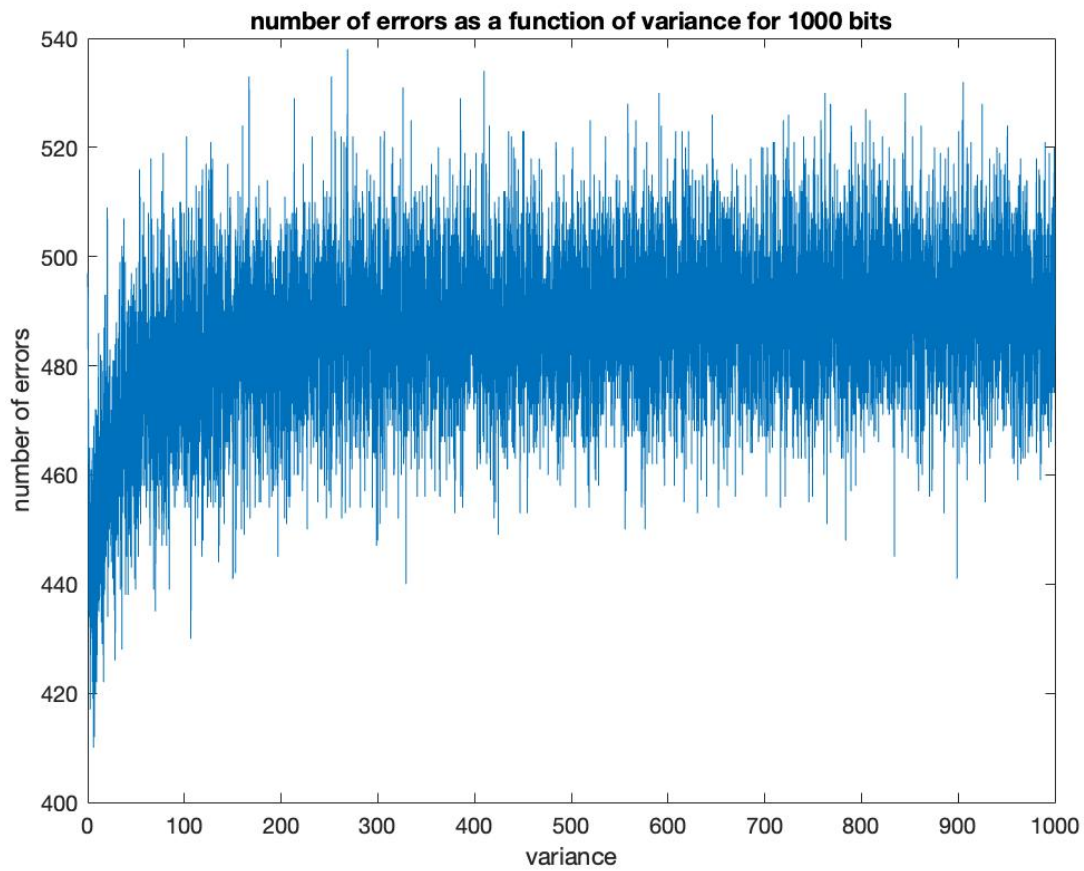


Figure 2: number of errors as a function of the noise variance  $v$

By comparing this plot to the plot generated in Exercise 8.1, we can see that using a Gray code translation reduces the error count. This is to be expected since Gray code sequential transitions are more similar.

## Exercise 8.5

Can you think of a pulse shape that will have a narrower bandwidth than either of the above but that will still be time limited by  $T$ ? Implement it by changing the definition of  $ps$ , and check to see whether you are correct.

### Solution

Using this code:

Listing 3: MATLAB code for Exercise 8.5

```
str='Transmit_this_text_string';           % message to be transmitted
m=letters2pam(str); N=length(m);           % 4-level signal of length N
M=10; mup=zeros(1,N*M); mup(1:M:N*M)=m;    % oversample by M
ps=sinc(linspace(-1,1,10));                 % blip pulse of width M
x=filter(ps,1,mup);                         % convolve pulse shape with data

t=1/M:1/M:length(x)/M;
subplot(2,1,1), plot(0:0.1:0.9,ps)
xlabel('The_pulse_shape')
subplot(2,1,2), plot(t,x)
xlabel('The_waveform_representing_Transmit_this_text')
```

the following plot was generated.



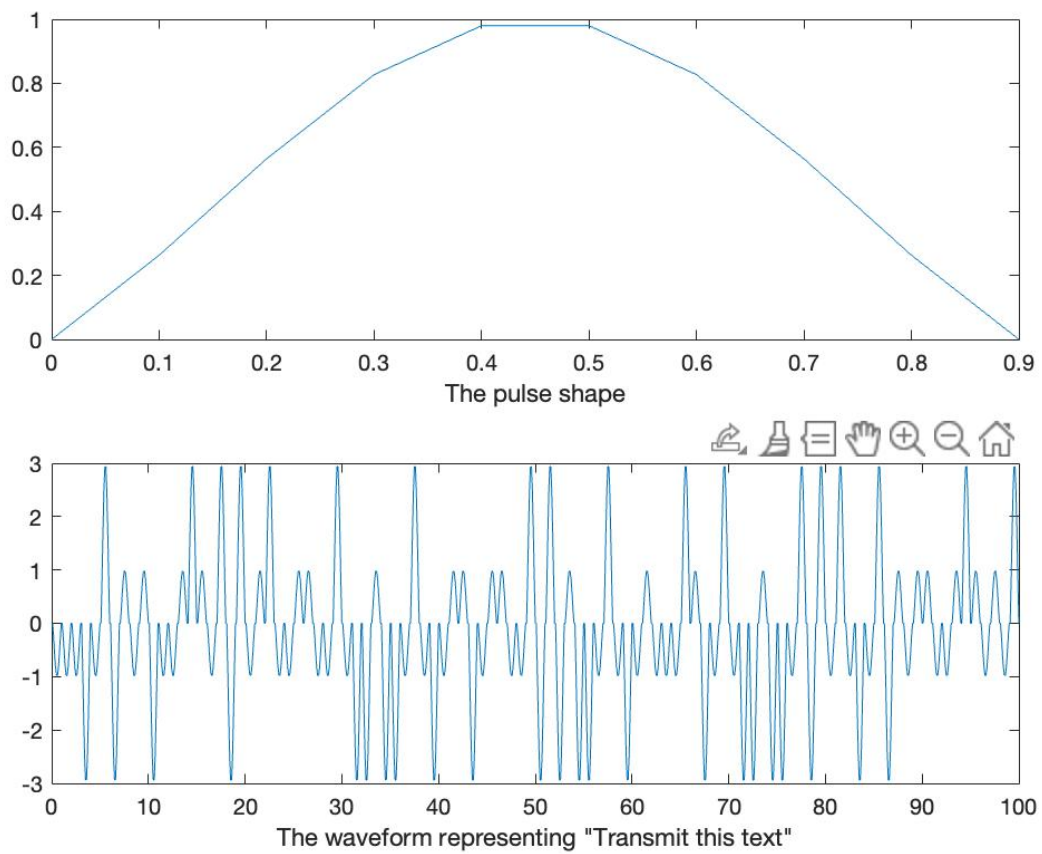


Figure 3: The waveform representing "Transmit this text"

In this solution a sinc pulse shape was used because it is the most efficient pulse shape.

## Exercise 8.8

Rerun `correx.m` with different amounts of noise. Try `sd=0, 0.1, 0.3, 0.5, 1, 2`. How large can the noise be made if the correlation is still to find the true location of the header?

### Solution

Using this code:

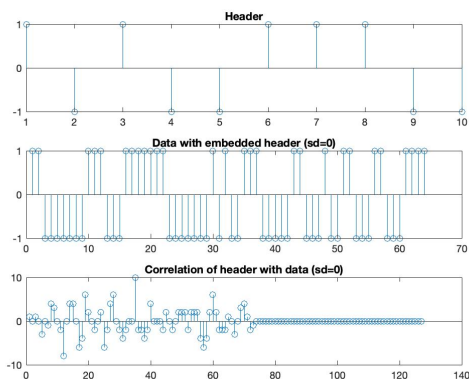
Listing 4: MATLAB code for Exercise 8.8

```
header=[1 -1 1 -1 -1 1 1 1 -1 -1]; % header is a predefined string
loc=30; r=25; % place header in position loc
data=[sign(randn(1,loc-1)) header sign(randn(1,r))]; % generate signal

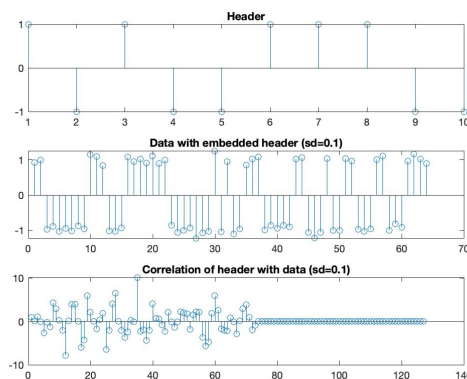
sd=[0 0.1 0.3 0.5 1 2];

for i=1:length(sd)
    data=data+sd(i)*randn(size(data)); % add noise
    y=xcorr(header, data); % do cross correlation
    [m,ind]=max(y); % location of largest correlation
    headstart=length(data)-ind+1; % place where header starts
    figure(i)
    subplot(3,1,1), stem(header) % plot header
    title('Header')
    subplot(3,1,2), stem(data) % plot data sequence
    title('Data with embedded header (sd='+string(sd(i))+')')
    subplot(3,1,3), stem(y) % plot correlation
    title('Correlation of header with data (sd='+string(sd(i))+')')
end
```

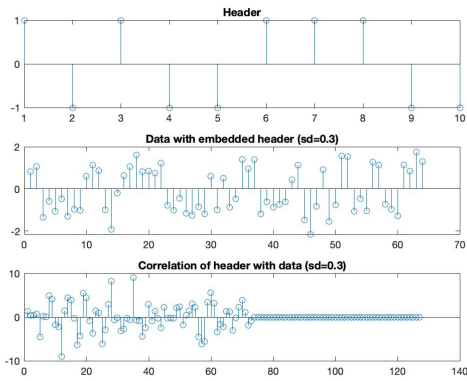
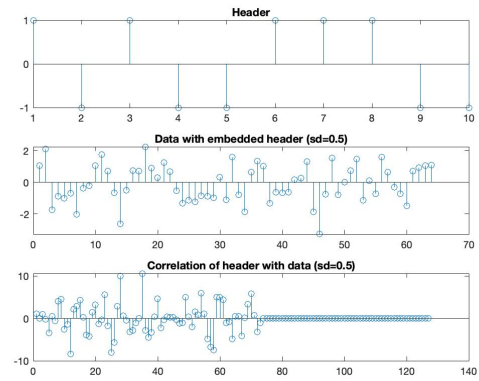
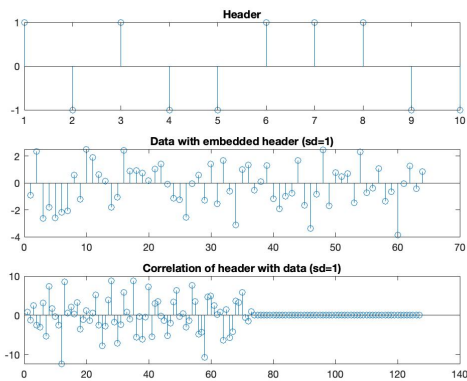
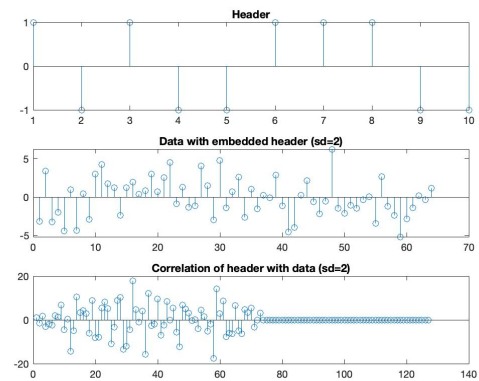
the following plots were generated.



(a) `sd=0`



(b) `sd=0.1`

(a)  $sd=0.3$ (b)  $sd=0.5$ (a)  $sd=1$ (b)  $sd=2$ 

TODO

## Extra Question

### Solution

First, this code was used to convert a given ASCII string into QPSK symbols:

Listing 5: MATLAB code for Problem 5

```
% function complex_out = qpsk_enc(m)
%     M=4;
%     complex_out = exp(j*2*pi*(m-1)/M);
% end

function out = letters2QPSK(str) % call as Matlab function

% Convert ascii to binary string
binary=dec2bin(str);
[l, w] = size(binary);
bin="";
for i=1:l
    row="0"+binary(i:i, :);
    bin=bin+row;
end
bin=char(bin);

% Convert binary string to stuff
out = zeros(1,4*length(str));
M=4;
indx=1;
for i=1:2:length(bin)
    if bin(i) == '0'
        if bin(i+1) == '0'
            m=1;
        else
            m=2;
        end
    else
        if bin(i+1) == '0'
            m=4;
        else
            m=3;
        end
    end
    out(indx)= exp(j*2*pi*(m-1)/M);
    indx=indx+1;
end
```

TODO:EXPLAIN

Then, this code was used to convert a given ASCII string into a QPSK modulated passband signal:

Listing 6: MATLAB code for Problem 5

```

% String for testing
test_str='EC415';

% Get QPSK symbols;
QPSK_symbols=letters2QPSK(test_str);

time=8*length(test_str); Ts=1/1000; % sampling interval & time
t=Ts:Ts:time; lent=length(t);      % define a time vector
w=zeros(1,lent);
start=0;
for i=1:time/2
    w((2*start/Ts)+1:i*2/Ts)=QPSK_symbols(i);
end

fm=1; fc=10; c=exp(j*2*pi*fc*t); % carrier at freq fc

%w=5/lent*(1:lent)+cos(2*pi*fm*t); % create "message"
%w
v=c.*w; % modulate with carrier

% used to plot figure
subplot(2,1,1), plot(t,w)
axis([0,time,-1,3])
ylabel('amplitude'); xlabel('time'); title('(a)_message_signal');
subplot(2,1,2), plot(t,v)
axis([0,time,-2.5,2.5])
ylabel('amplitude'); xlabel('time'); title('(b)_message_after_modulation');
TODO:EXPLAIN

```