EE4440 HW#8 Solution

April 13, 2011

1. What frequency must be used for basis symbols $\phi_1 = \sin(\omega_c t)$ and $\phi_2 = \cos(\omega_c t)$ with a symbol period of 1/(9600Hz) to contain 6 cycles of the sin and cos?
   Solution: The frequency is 6 times the frequency of the symbol frequency= 57,600Hz

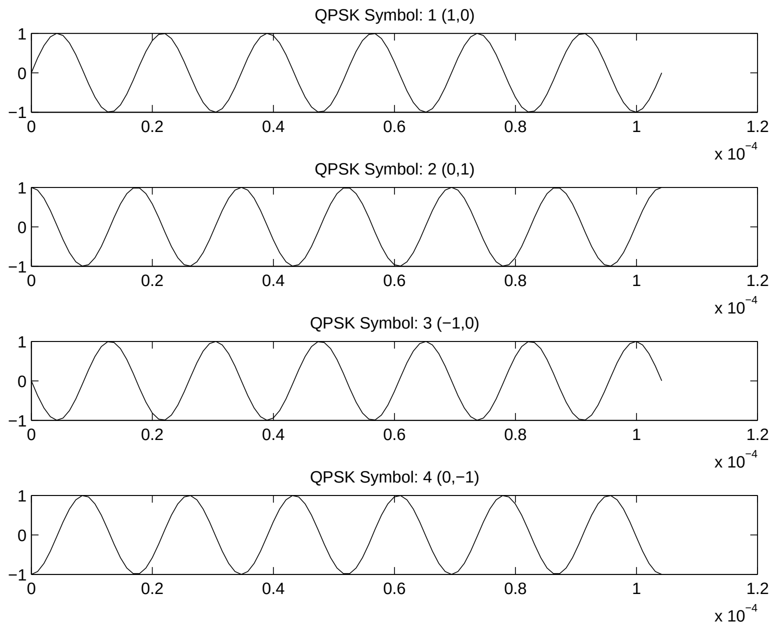
2. Show that the two selected signals are orthogonal to one another over the bit period.
   Solution:The signals are orthogonal because the inner product

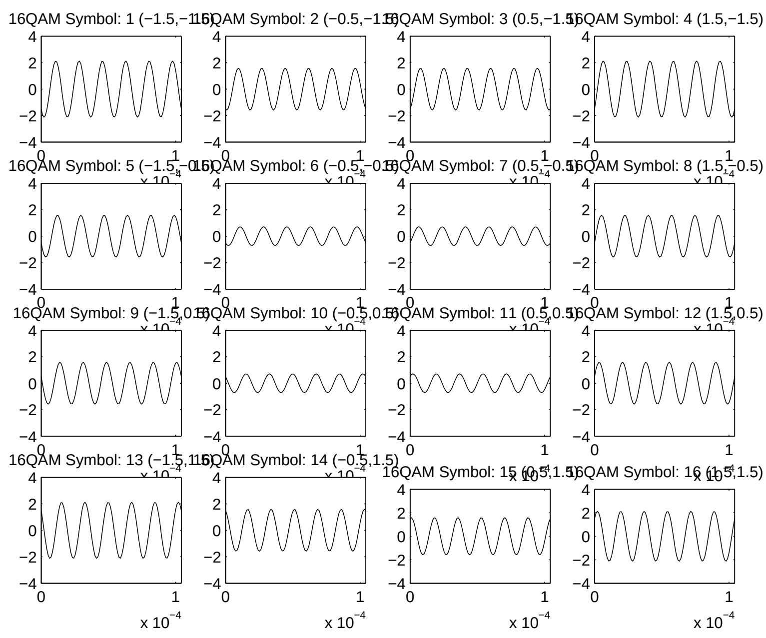
$$\int_0^{1/9600} \cos(2\pi 57600t)\sin(2\pi 57600t) = \frac{-\cos^2(2\pi 57600t)}{4\pi 57600}\Big|_0^{\frac{1}{9600}} = 0$$

3. In MATLAB plot:

   (a) The symbols for Q-PSK using the basis from problem 1

   (b) The symbols for rectangular 16-QAM using the basis from problem 1. Assume one volt horizontal and vertical spacing from symbol to symbol in the constellation diagram.
   Solution:



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%John Davis 4/13/2011 EE4440 Hw8 Problem 3 Soln

T=1/9600;
t=linspace(0,T,100);
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phi1=sin(2*pi*57600*t);
phi2=cos(2*pi*57600*t);

figure(1)
%QPSK Symbols
coeff1=[1 0 -1 0];
coeff2=[0 1 0 -1];
for n=1:4
    subplot(4,1,n);
    plot(t,coeff1(n)*phi1+coeff2(n)*phi2);
    str=sprintf('QPSK Symbol: %d (%d,%d)',n,coeff1(n),coeff2(n));
    title(str);
end

print -deps hw8problem3figure1.eps

%16-QAM symbols
figure(2)
coeff1=[-1.5 -.5 .5 1.5 -1.5 -.5 .5 1.5 -1.5 -.5 .5 1.5 -1.5 -.5 .5 1.5
coeff2=[-1.5 -1.5 -1.5 -1.5 -.5 -.5 -.5 -.5 .5 .5 .5 .5 1.5 1.5 1.5 1.5]
for n=1:16
    subplot(4,4,n);
    plot(t,coeff1(n)*phi1+coeff2(n)*phi2);
    axis([0 t(end) -4 4]);
    str=sprintf('16QAM Symbol: %d (%.1f,%.1f)',n,coeff1(n),coeff2(n));
    title(str);
end

print -deps hw8problem3figure2.eps
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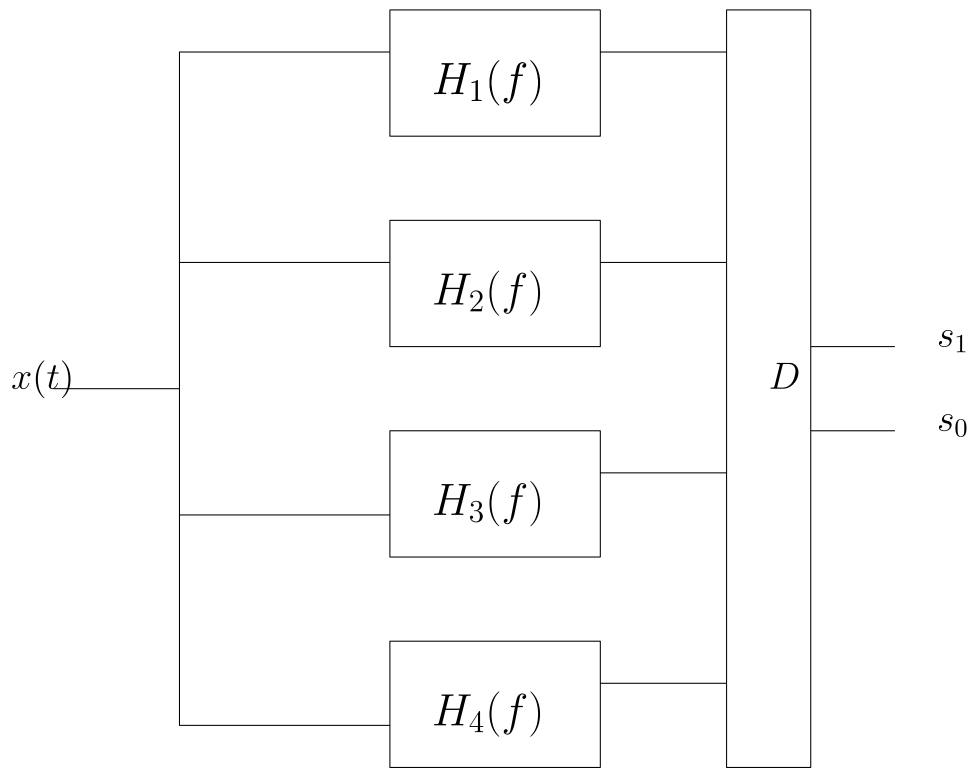
4. Draw the block diagram for a coherent receiver for QPSK using the same basis signals as in problems 1-3. What are the impulse responses for the 4 matched filters?
Solution:



The impulse responses are the time reversed and delayed versions of the basis symbols:

$$h_1(t) = 1\phi_1(T - t)$$
$$h_2(t) = 1\phi_2(T - t)$$
$$h_2(t) = -1\phi_1(T - t)$$
$$h_2(t) = -1\phi_2(T - t)$$

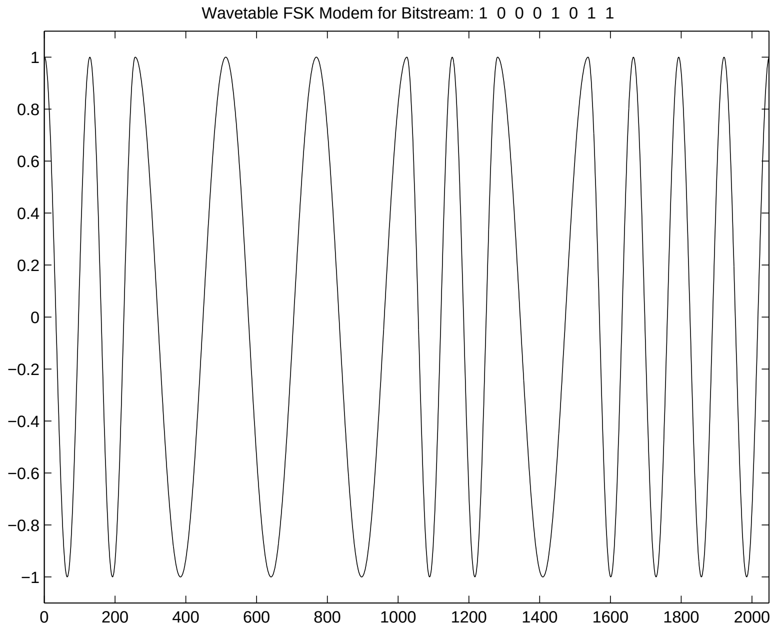
where T is the symbol period.

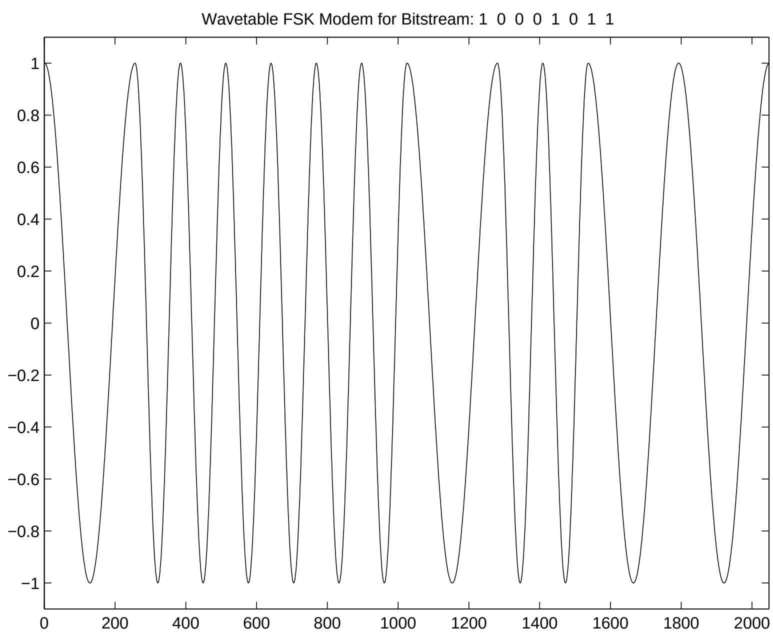
5. Write a MATLAB program that takes a bit stream array (e.g bitStream=[1 0 0 0 1 0 1 1] as input and produces a plot of an FSK waveform as output. Use the wavetable synthesis method discussed in class. Use a 256 entry table built with this command: "table=cos(2*pi*(0:tableLen-1)/tableLen);" where tableLen=256. Produce plots for the example bit stream where the symbols are:

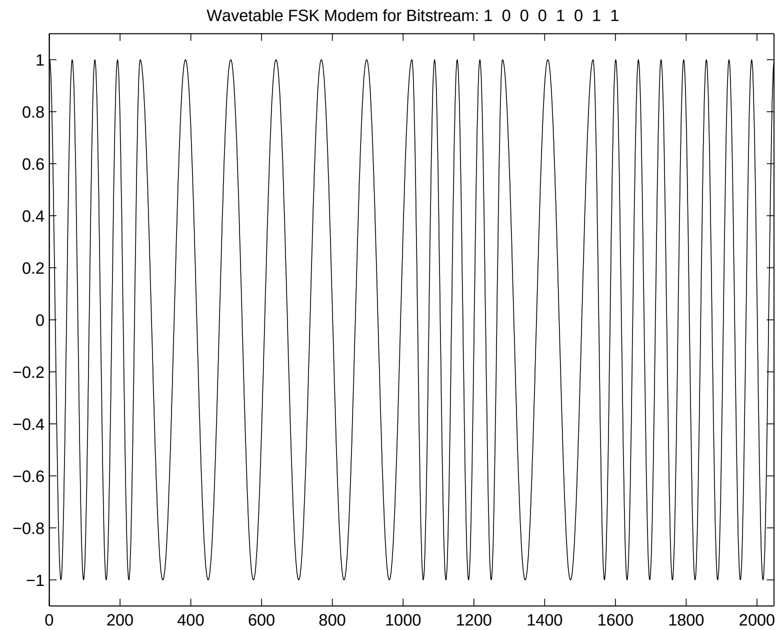
   (a) 0 represented by 1 cycle through the table, 1 represented by twice that frequency

   (b) 1 represented by 1 cycle through the table, 0 represented by twice that frequency

(c) 0 represented by 2 cycles through the table, 1 represented by twice that frequency
Solution:





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%John Davis 4/13/2011 EE4440 Hw8 Problem 5 Soln
function output=fsk(bitStream)

if nargin==0
    bitStream=[1 0 0 0 1 0 1 1];
end

tableLen=256;

table=cos(2*pi*(0:tableLen-1)/tableLen);
output=zeros(1,length(bitStream)*tableLen);
streamNdx=1;
tableNdx=1;
step=1;



for n=1:length(output)

    output(n)=table(tableNdx);

    if bitStream(streamNdx)==0
        %step=1; %Uncomment for part a
        %step=2; %Uncomment for part b
         step=2; %Uncomment for part c
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        elseif bitStream(streamNdx)==1
            %step=2; %Uncomment for part a
            %step=1; %Uncomment for part b
            step=4; %Uncomment for part c
        end

        tableNdx=tableNdx+step;

        if tableNdx>256
            tableNdx=1;
        end

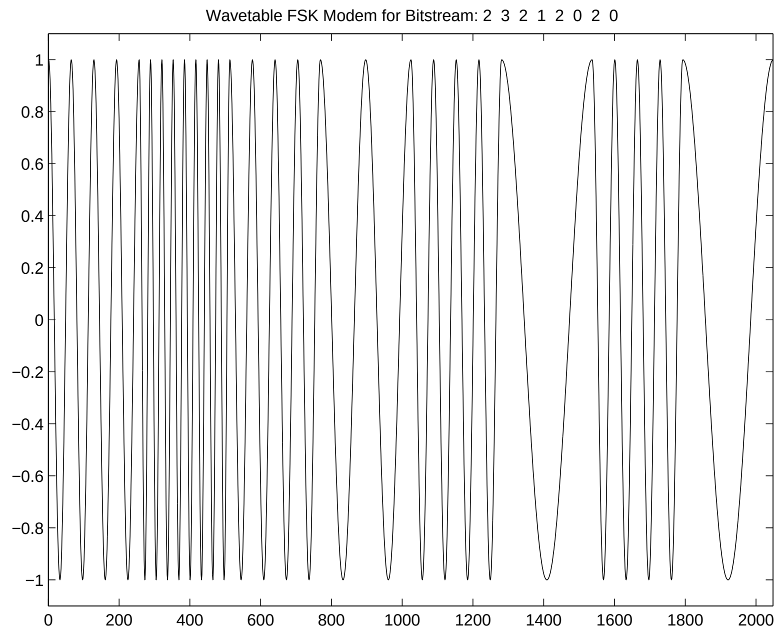
        if mod(n,tableLen)==0
            streamNdx=streamNdx+1;
        end


    end

    figure(1)
    plot(output,'-');
    axis([0 length(output) -1.1 1.1]);
    title(['Wavetable FSK Modem for Bitstream: ', num2str(bitStream)]);

    print -deps hw8problem5figure.eps
```

6. Modify your program from 4 so that it now receives data which is 2 bits per symbol. Choose frequency multiples for your symbols and plot some representative messages.
Solution:

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%John Davis 4/13/2011 EE4440 Hw8 Problem 5 Soln
function output=fsk(bitStream)

if nargin==0
    bitStream=floor(rand(1,8)*4);
end

tableLen=256;

table=cos(2*pi*(0:tableLen-1)/tableLen);
output=zeros(1,length(bitStream)*tableLen);
streamNdx=1;
tableNdx=1;
step=1;



for n=1:length(output)

    output(n)=table(tableNdx);

    if bitStream(streamNdx)==0
        step=1;
    elseif bitStream(streamNdx)==1
        step=2;
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        elseif bitStream(streamNdx)==2
            step=4;
        elseif bitStream(streamNdx)==3
            step=8;
        end

        tableNdx=tableNdx+step;

        if tableNdx>256
            tableNdx=1;
        end

        if mod(n,tableLen)==0
            streamNdx=streamNdx+1;
        end


end

figure(1)
plot(output,'-');
axis([0 length(output) -1.1 1.1]);
title(['Wavetable FSK Modem for Bitstream: ', num2str(bitStream)]);

print -deps hw8problem6figure.eps
```

7. Look up the Bell 103 modem and answer the following questions:

   (a) What year was the modem introduced?

   (b) What baud rate did the modem operate at?

   (c) What is baud rate? How is it different than bit rate?

   (d) The system uses different frequencies for the data coming from the originating station and the answering station. Why?
   Solution:For parts a-b see http://en.wikipedia.org/wiki/Bell_103_modem. The baud rate is the number of symbols for second. In the case of one bit per symbol the rates are equal, other wise the bit rate is bits per symbol times the baud rate. The system uses different frequencies for FDM.