DSP - Homework 2 (HW2)

Reading: Chen micro Doppler Handout
Berwick SVM Tutorial handout
Liland micro Doppler Handout
DSP4 5.3, 5.3 and 5.6

Deliverables:
1. MP2 homework [individual].

Grading Rubric:

Item	Points	Metric
HW2	4	Graded on effort.

1. Explain the Doppler phenomenon in layman's terms using an ambulance driving down the road.
2. Explain the term "microDoppler".
3. A 1 GHz radar sees a moving target with Doppler shift -200 Hz. Determine the direction (away from or towards the radar) and radial velocity in m/s.
4. Explain why we do not calculate the DTFT in a digital signal processing chip.
5. Calculate by hand the 4-point DFT of the following using the DFT definition.
   a) $x = [1, 2,0,0]$
   b) $x = [1, 2,2,1]$
   c) What do you notice about $X[0]$? What electrical engineering circuit term is related to this coefficient?
   d) Using Matlab, calculate the 512-point FFT of x. Plot the magnitude and phase. Is the phase linear?

   Hint: using *fftshift* makes the plots easier to understand.

```
N = 512;
x = % Put values here
X = fft(x, N);         % N-point FFT
Xshift = fftshift(X);  % Place DC in middle of plot

% Calculate magnitude and unwrapped phase
Xshiftmag = abs(Xshift);
Xshiftangle = unwrap(angle(Xshift) * 180 / pi);   % Unwrap angle

% Calculate the normalized frequency (range [-0.5, 0.5])
fnorm = linspace(-0.5, 0.5 * N / (N-1), N);

figure
subplot(2,1,1);
plot(fnorm, Xshiftmag);
xlabel('Normalized frequency (f/f_S)');
ylabel('Magnitude X(f)');
axis([-0.5 0.5 0 20]);
```

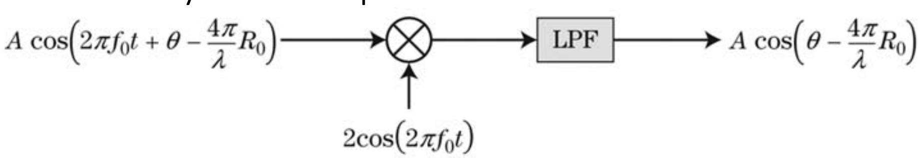
```
subplot(2,1,2);
plot(fnorm, Xshiftangle);
xlabel('Normalized frequency (f/f_S)');
ylabel('Unwrapped phase X(f) in degrees');
axis([-0.5 0.5 -1000 200]);
drawnow;
```

6. What is the main difference between the DFT and an FFT?
7. What parameters control the FFT computational resolution? The FFT physical frequency resolution?
8. Why does a Hamming window have worse physical frequency resolution than the same length boxcar (all ones) filter?
9. Calculate the physical and computational resolution for a *N* = 512-point FFT, a length 128 Hamming, and Rectangular window, with sampling rate 200 MHz.
10. What is the approximate number of complex multiplies to implement a *N* = 2048 point DFT and FFT?
11. Sketch by hand a frequency axis with labels -500,-400,...,400,500 Hz. Label the Nyquist Interval when
    a) The sampling rate is 200 samples / second.
    b) The sampling rate is 400 samples / second.
    c) The sampling interval is 2 ms.
12. State Nyquist's sampling theorem in your own words with a drawing to illustrate. Determine the Nyquist rate for the following signals (give results in ksps = 1000 samples / second) where t is in seconds.
    a) $x(t) = 100cos(2000\pi t + \pi/2)$
    b) $x(t) = 100sin\left(2000\pi t + \frac{\pi}{2}\right)$
    c) $x(t) = 10sin^2(5000\pi t)$
13. Determine the aliased frequencies in MHz for the following signals and sampling rates.
    $f_1 = 0.75\ MHz$, $f_2 = 2.10\ MHz$
    a) $x(t) = -cos(2\pi f_1 t)$, $f_s = 1.25\ MHz$
    b) $x(t) = cos(2\pi f_1 t)$, $f_s = 1.00\ MHz$
    c) $x(t) = -1.5sin(2\pi f_2 t)$, $f_s = 1.00\ MHz$
    d) $x(t) = 3cos(2\pi f_1 t)$, $f_s = 0.50\ MHz$
    e) $x(t) = 4sin(2\pi f_2 t)$, $f_s = 1.25\ MHz$
14. Explain the concept of the STFT in a paragraph and a using a drawing.
15. What are the differences between an FFT and a STFT?
16. Write a Matlab function that takes a frequency f in Hz and a sampling rate fs in Hz and returns the aliased frequency for f in the Nyquist Interval. Calculate the aliased frequencies using your code and by hand for the following parameters:
    $f = 250, \quad f_S = 1000$
    $f = -250, \quad f_S = 1000$
    $f = -4550, \quad f_S = 1000$
    $f = 5900, \quad f_S = 1000$
17. Convert the following numbers to dB without using a calculator: 0.1, 0.01, 2, 20, 50, 100, 500, 1,000, and 100,000.

18. Convert the following dB numbers to natural units: -20, -10, 0, 3, 5, 7, 20, and 100.
19. Determine the locations of the six nulls closest to zero for a length 15 digital sync. Plot the digital sync using Matlab.
20. Calculate and sketch (by hand) the instantaneous frequency for an LFM chirp with bandwidth 100 MHz and pulse length of 10 ms. Plot by hand for -5 ms <= t <= 5 ms.
21. Calculate instantaneous frequency in Hz for the following signals, where the time variable *t* in in seconds.
    a) $2\cos(2000\pi t)$
    b) $\exp(j2\pi 500t)$
    c) $\exp\left(j\pi 500t^2\right)$
22. What happens in a STFT when sigma increases? When it decreases?
23. Explain at a high level how a linear SVM works.
24. What is data normalization and list one way you can do this. Is data normalization important?

Graduates only:

25. For the simple receiver shown below, assume an ideal lowpass filter (LPF). Show mathematically that the output is as shown. Assume the variables are all constants.



26. Find a source (report, paper, etc.) for the kernel SVM and explain it using a few short paragraphs and a drawing.
27. Using MATLAB, recreate this plot. Hint: type ‘help plot’ to get instructions on plotting.