EECS 562
Homework #3

1. Let $m(t) = 1.0\cos(2\pi 100t) + 0.5\cos(2\pi 125t) + 0.25\cos(2\pi 150t)$. This signal is input to an SSB modulator with f_c=5000Hz that uses the upper sideband.
    a. Plot the RF Spectrum.
    b. What is the required RF Bandwidth?
    c. A coherent detector is required to recover m(t) from the RF signal. TRUE or FALSE
    d. Draw the block diagram for a receiver for this SSB signal.

2. The IF frequency of a commercial broadcast FM superheterodyne receiver is 10.7 MHz. Suppose we wish to "tune in" station KANU at 91.5 on the dial.
    a. What are the two possible frequencies for the local oscillator?
    b. For each LO frequency in part a, what is the corresponding image frequency?

3. Draw the block diagram of commercial broadcast AM superheterodyne receiver with $f_{IF=}$ 455 kHz and $f_{RF=}$ 810 kHz (WHB in Kansas City); clearly label LO frequency, the center frequencies, and bandwidths of all filters.

4. Given a set of information bits b_i = {1, 0 ,1, 0}.
    a. Let $x_1(t)$ = +2 for 1 ms for a bit = 0 and $x_1(t)$ = -2 for 1 ms for a bit = 1. A modulated RF signal is $y_1(t) = x_1(t)\cos(2\pi f_c t)$ where f_c=10kHz. Plot $y_1(t)$. [This is an example of Binary Phase shift keying (BPSK) by noting that $-2\cos(2\pi f_c t) = 2\cos(2\pi f_c t - \pi)$
    Thus for bit=0 send $2\cos(2\pi f_c t - 0)$ and bit=1 send $2\cos(2\pi f_c t - \pi)$; the RF spectrum of a BPSK + carrier signal was found in homework #2 problem 3]

    b. An envelope detector can be used to demodulate $y_1(t)$ in part a) to recover the information bits. TRUE or FALSE. Justify

    c. Let $x_2(t)$ = +4 for 1 ms for a bit = 0 and $x_2(t)$ =0 for 1 ms for a bit = 1. A modulated RF signal is $y_2(t) = x_2(t)\cos(2\pi f_c t)$ where f_c=10kHz. Plot $y_2(t)$. [This is an example of On-off shift keying (OOK)]

    d. An envelope detector can be used to demodulate $y_2(t)$ in part c) to recover information bits. TRUE or FALSE. Justify

    e. Let $x_3(t)$ = +5 for 1 ms for a bit = 0 and $x_3(t)$ = 0 for 1 ms for a bit = 1. A modulated RF signal is $y_3(t) = 2\cos(2\pi(x_3(t)*1000 + f_c)t)$ where f_c=10kHz. Plot $y_3(t)$. [This is an example of frequency shift keying (FSK)]

    f. An envelope detector can be used to demodulate $y_3(t)$ in part e) to recover information bits. TRUE or FALSE. Justify [Hint: Consider this modulation as two version of the modulation used in part c, where one carrier frequency 10kHz is used for bit = 1 and another one carrier frequency 15 kHz is used for bit = 0.]

5. A software defined radio (SDR) can be used as an commercial (standard) AM receiver. Here the IF signal is digitized and the IF processing is done entirely in software, i.e., digital signal processing used to demodulate the message signal. What minimum sampling frequency would be needed for this SDR. Do a web search to find a suitable SDR for this application.

6. Coherent (or synchronous) detection required for DSB-SC, TRUE or FALSE.

7. Let z_i be a complex symbol for i=1…4

$z_1 = 1 + j,\ z_2 = 1 - j,\ z_3 = -1 + j,\ z_4 = -1 - j$

Each pair of bits (2 bits) in an information signal is mapped into one complex symbol, e.g., (0,0) $\rightarrow z_1$; so a sequence of information bits is mapped into a sequence of complex symbols. The modulated RF signal $y_i(t) = \mathrm{Re}(z_i e^{j2\pi f_c t})$ for $i = 1...4$ for 1 ms; i.e., a complex symbol is transmitted every symbol time of 1 ms. A modulated RF signal $y_i(t)$ is processed by a quadrature receiver (see figure 3.17 b in Haykin/Moher). [This is an example of QPSK]

a. Find $y_1(t) = \mathrm{Re}(z_1 e^{j2\pi f_c t})$

b. Find the demodulated outputs (one output for demodulating with cos and one output for demodulating with sin) for $y_i(t)$ i=1…4. (See results from Homework 1-Problem 4).

c. What is the transmission bit rate? [Hint: the units of bit rate is bits/sec.]

8. Watch 8VSB, From Transport Stream to RF Signal
http://www.theonlineengineer.org/TheOLEBLOG/8vsb-a-tutorial/

a. What does the 8 refer to in 8VSB?

b. Mathematically explain how shifting the signal by 1.25 V generates the pilot signal.