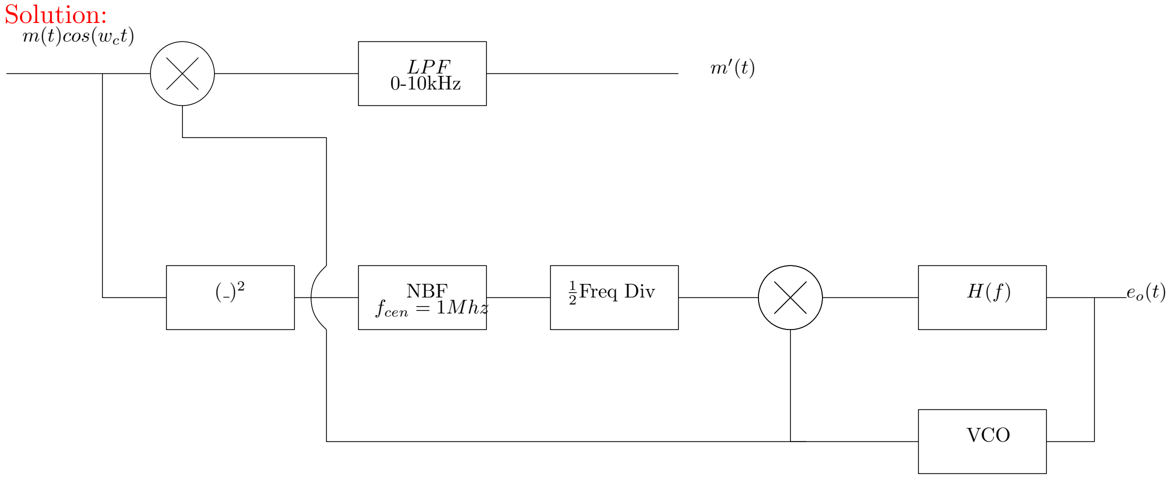
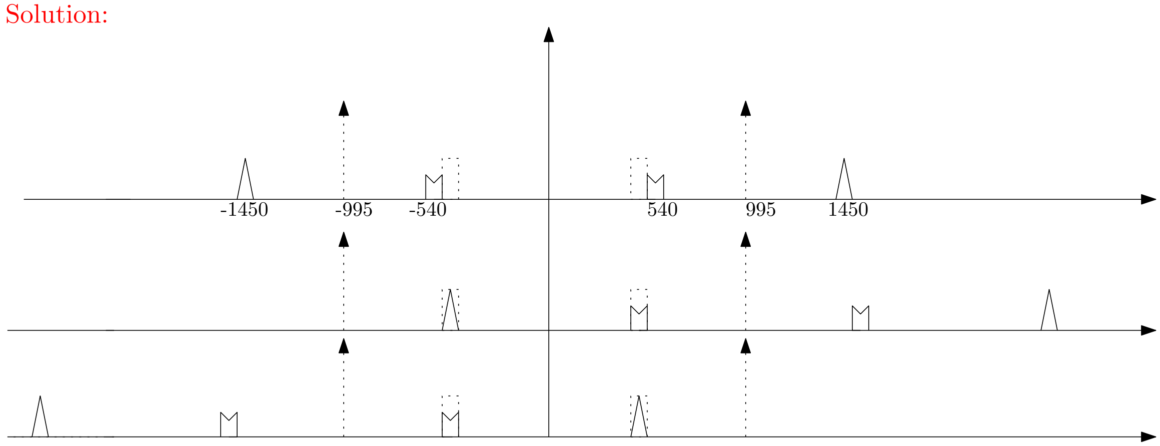
EE4440 HW#4

February 27, 2011

1. Design a direct conversion DSB-SC receiver that uses a PLL for local oscillator sync. Assume that the message signal does not have a pilot carrier embedded, and that you must use signal squaring as discussed in class to provide a reference signal for the PLL. Assume a carrier frequency of 1MHz and a message bandwidth of 10kHz. Document your design with a complete block diagram, include filter specifications for any filters used. Your design should include at least one of each of the following blocks: mixers, squaring blocks, frequency scaling blocks, bandpass filters, lowpass filters.
   Solution:



2. If you wanted to listen to a radio station at 540 kHz with a superhet radio using an IF stage at 455kHz:
   (a) What would be the required LO frequency to translate the station to the IF frequency?
   Solution: $f_{LO} = f_c + f_{IF} = 540 + 455 = 995$kHz.
   (b) At what frequency would the image station for this radio station occur?
   Solution: $f_c' = f_{LO} + f_{IF} = 995 + 455 = 1450$kHz.
   (c) Draw spectrum diagrams showing how the image station would interfere with the desired station if not filtered out with an RF filter stage.
   Solution:



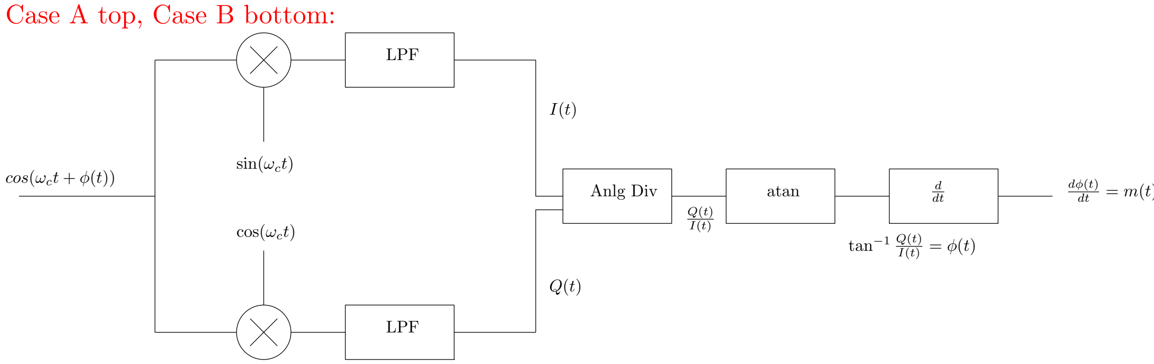
Clearly, there would be corruption here because one copy of each signal lands in the IF band. To prevent this, we must eliminate the image station prior to downconversion to IF. The problem of overlapping spectra after up and down conversion is more general and the potential for a problem like this should ALWAYS be kept in mind when translating frequencies.

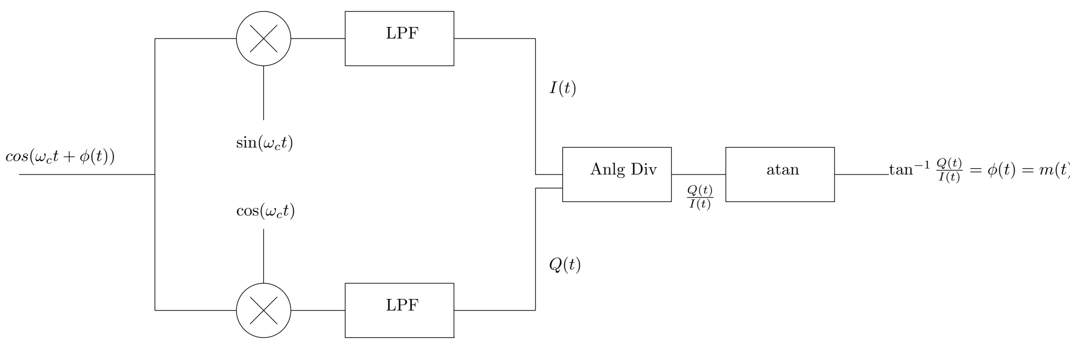
3. In class, we had an extensive discussion about QAM. Suppose that you have a QAM receiver, an analog divider, and an analog circuit that can take trig and inverse trig functions based on a set of selection lines. You also have access to integrator and differentiator circuits.

   (a) How would you use these elements to demodulate an FM signal? Draw a block diagram with each signal line labeled with the function it carries.

   (b) How about a PM signal? Draw a block diagram with each signal line labeled with the function it carries.

   Solution:
   Case A top, Case B bottom:





4. An XOR gate can be used as a phase detector.

   (a) For what kind of signals is this possible, and how? Draw timing diagrams that convince me you know how this would work.
   Solution: It is possible for digital signals, the XOR will output a pulse only when the signals have a phase difference. The pulse duration will be proportional to the phase difference. If the low pass filter cutoff is very low it will essentially be passing the DC value of the pulse train which is a voltage proportional to the phase difference. This will drive the VCO to adjust when the phase is different.

   (b) Assume that you have a VCO that generates a square wave, and that you want to phase lock the square wave to an incoming sine wave. How could you do this? Draw a block diagram that accomplishes this goal.
   Solution: Use a thresholding device, such as a comparator, to make a wave that is high when the sine wave is greater than zero, and low when the sine wave is lower than zero.

(c) Now that you have a square wave synced to your incoming sine wave what could you do if you needed a sin wave at the corresponding frequency?
Solution: Filter the square wave with a filter designed to retain only the fundamental frequency, this will be a sine wave at the corresponding frequency.

5. Given that $x_c(t) = 10\cos[2\pi 10^6 t + .1\sin(10^3\pi t)]$:

(a) If x_c is a PM signal what is $m(t)$?
Solution: In PM, $m(t) = \phi(t)$ so $m(t) = .1\sin(10^3\pi t)$.

(b) If $x_c$is an FM signal what is $m(t)$?
Solution: For FM, $m(t) = \dot{\phi}(t)$ so $m(t) = 10^2\pi\cos(10^3\pi t)$

6. Show that:

(a) DSB-SC modulation is a linear operation
Solution: a function f, is linear if and only if $f(ax + by) = af(x) + bf(y)$. For DSB-SC $f_{DSB}(m(t)) = m(t)\cos(w_c t)$. If we have some scalars a and b and two messages $m_1(t)$ and $m_2(t)$ then

$$f_{DSB}(am_1(t) + bm_2(t)) = [am_1(t) + bm_2(t)]\cos(\omega_c t)$$

and

$$af_{DSB}(m_1(t)) + bf_{DSB}(m_2(t)) = am_1(t)\cos(\omega_c t) + bm_2(t)\cos(\omega_c t)$$

so the function is linear by the property of distribution of multiplication.

(b) PM is a non-linear operation
Solution:Using the same definition of linearity as in Part a, and noting that

$$f_{PM}(m(t)) = \cos(\omega_c t + \phi(t))$$

we see that

$$f_{PM}(am_1(t) + bm_2(t)) = \cos(\omega_c t + [am_1(t) + bm_2(t)]$$

and that

$$af_{PM}(m_1(t)) + bf_{PM}(m_2(t)) = a\cos(\omega_c t + m_1(t)) + b\cos(\omega_c t + m_2(t))$$

There is no algebraic method of manipulating these two expressions into one another, therefore PM is a nonlinear operation.