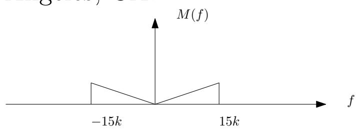
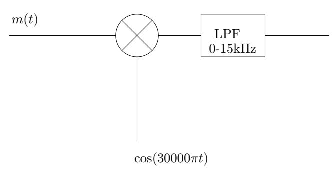
EE4440 HW#3 Solution

February 27, 2011

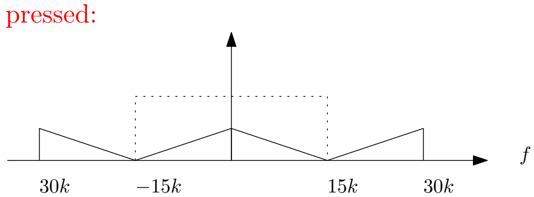
1. For what class of signals can a Fourier Series be computed?
   Solution: Periodic!

2. The block diagram below is a very rudimentary scrambling system for analog communications. In ancient times it was used to secure the radio-telephone link from Santa Catalina Island, CA to Los Angeles, CA.





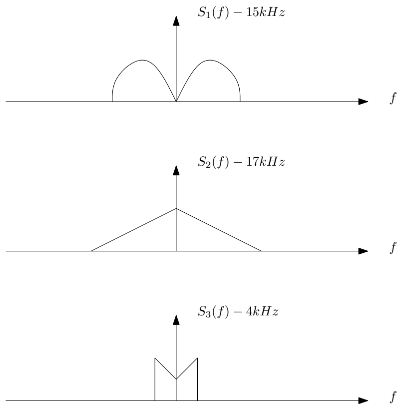
   (a) Draw a sketch of the spectrum of the system output, be careful to label all frequencies.
   Solution, the dotted line indicates an ideal low pass filter, anything outside is completely suppressed:



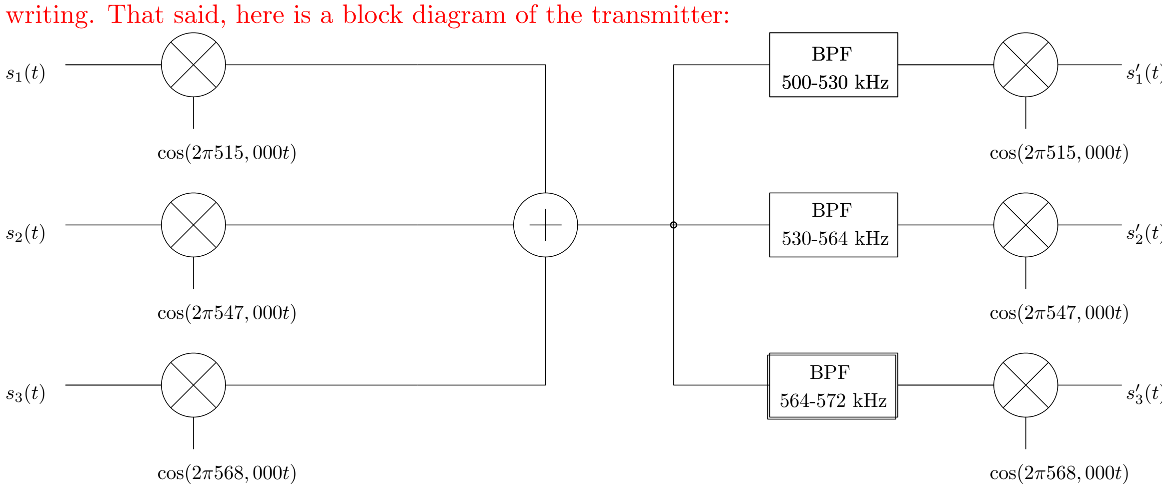
   (b) What is actually getting "scrambled here"?
   Solution: The spectrum is being scrambled by inversion.

   (c) If you were the LAPD police technician who was responsible for being able to tap this scrambled phone system what kind of system could you use? Produce a system block diagram along with spectral diagrams that prove your descrambler would work.
   Solution: The descrambler is identical to the scrambler.

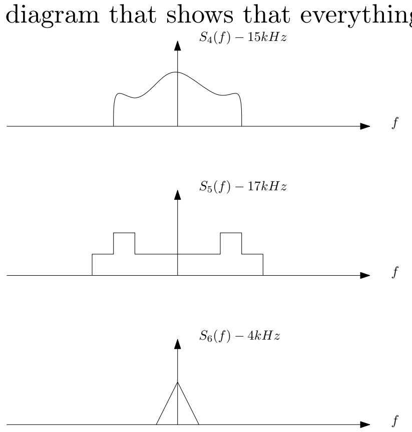
3. This May you are offered a job by Telemetry Systems 'R Us, Inc. The first week you are on the job your boss tells you that a current project requires a telemetry system that can transmit the three instrumentation signals shown below, and that you have 100kHz to transmit the data within. The available band runs from 500kHz to 600kHz.



(a) Choose appropriate carriers to transmit the instrumentation signals using DSB-SC draw a block diagram of the transmitter.
Solution: Due to brain cramps I told some people that the bandwidths involved in this problem were half of what I intended, so solutions with either sets of bandwidths will be accepted. However, IN GENERAL, if someone tells you the bandwidth of a baseband signal they only mean the positive half. When in doubt, ask. Hopefully they'll give you the right answer. Try to get it in writing. That said, here is a block diagram of the transmitter:

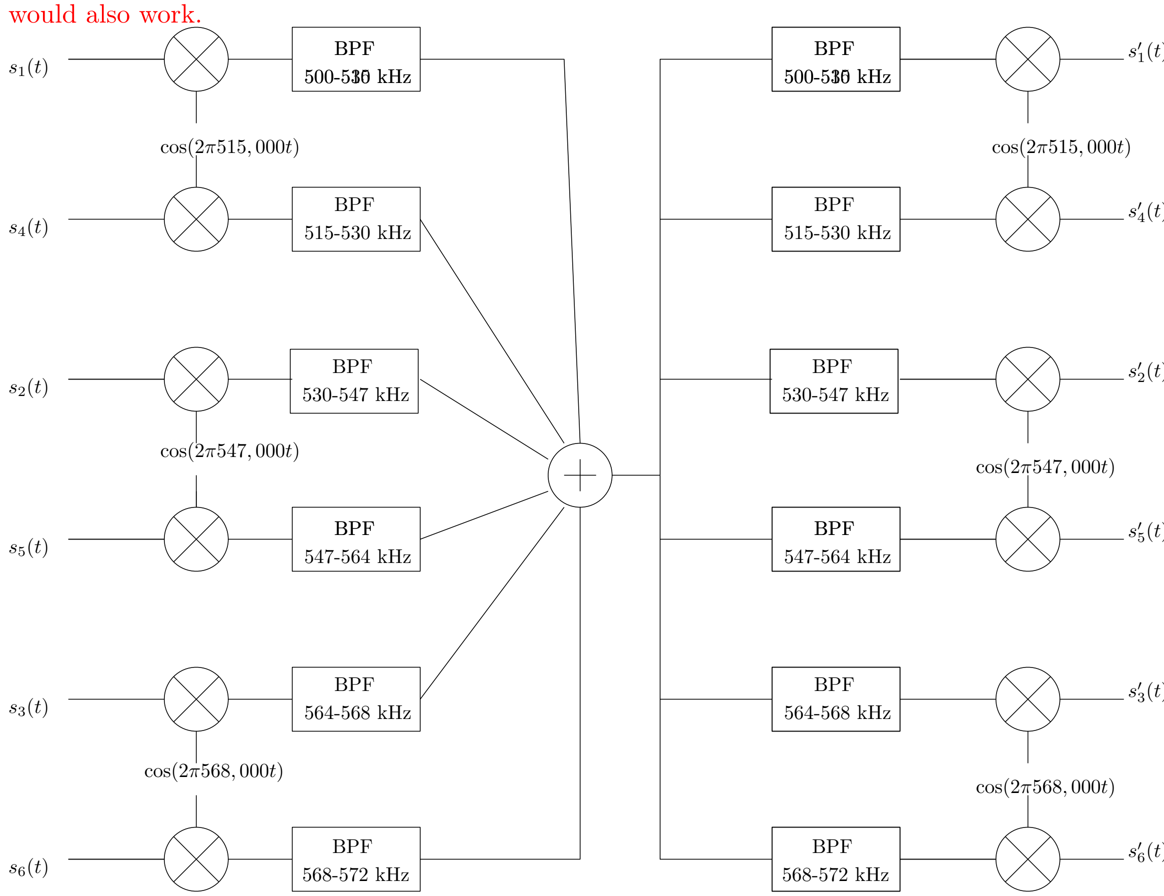


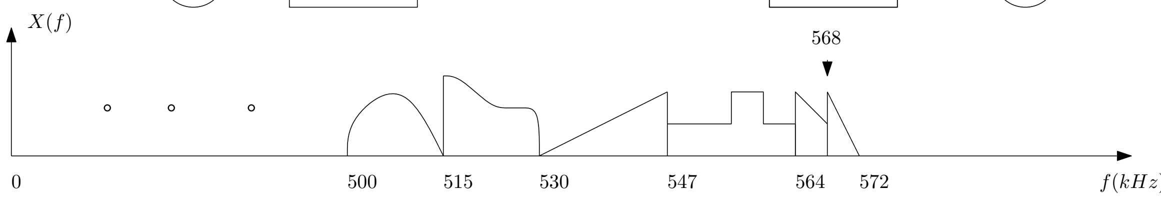
(b) Your second week on the job, you new boss comes back to you and says, "oh, by the way, we now need to send twice as much data through the channel you were allocated." The new signals are stereo channels of the original set, i.e. they have identical bandwidths 4,17 and 15 kHz. Luckily you know about SSB. Design an appropriate transmitter system complete with BPF specifications for each of the six channels, as well as carrier frequencies for each channel. Provide a spectral diagram that shows that everything will fit.



(c) Design a receiver system that can recover the transmitted signal from part b, include a block diagram.

Solution: This diagram and spectrum is for both parts b and c. I have used the lower sidebands of 1-3 and the upper sidebands of 4-6. Solutions using all upper, all lower, or some other combination would also work.

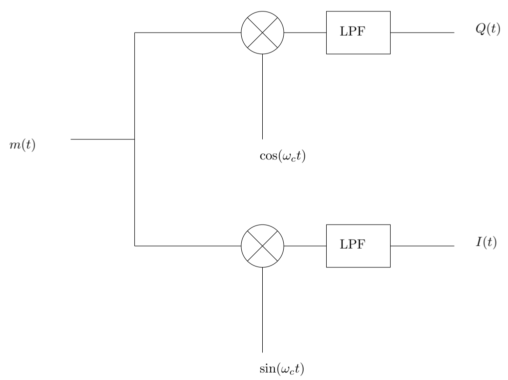




(d) Look in your book and identify another method of generating and demodulating SSB signals. Include a block diagram for this system.

Solution: the other method is the Hilbert Transform or Phase Shift method, see figure 4.17 of your text for a diagram.

4. In class we derived the output for a quadrature receiver using the expression $x(t) = a(t)\sin(\omega_c t + \phi(t))$. Verify that the output is identical if we instead use the expression $x(t) = I(t)\sin(\omega_c t) + Q(t)\cos(\omega_c t)$. (You will find the product-to-sum trig identities very helpful for this exercise, you can get them from a trig table or you can derive them yourself from Euler's identities.)



Solution: For the in-phase (lower) branch:

$$x_{out}(t) = [I(t)\sin(w_c t) + Q(t)\cos(w_c t)]\sin(w_c t)$$
$$= I(t)[\cos(0) - \cos(2w_c t)] + Q(t)[\sin(2w_c t) - \sin(0)]$$

so, after the low pass filter this is $I(t)$.Similarly for the upper branch:

$$x_{out} = [I(t)sin(w_c t) + Q(t)cos(w_c t)]cos(w_c t)$$
$$= I(t)[sin(2w_c t) + sin(0)] + Q(t)[cos(0) + cos(2w_c t)]$$

and so, after the low pass filter this will be $Q(t)$.

5. For the case of a QAM system such as the one described on page 205 of your text, what are $I(t)$ and $Q(t)$? QAM is widely applied in consumer, industrial, and military systems. Find a system that uses QAM and cite your source.
Solution: $m_2(t) = I(t)$ and $m_1(t) = Q(t)$ per our definition in class. Digital cable tuners are an example of a product using QAM, source: the Hauppauge Digital, Inc homepage.

6. Use the Interwebs to find the data sheet for a mixer and answer the following:
Solution: if these aren't clear to you from the feedback in graded homework, come see me.

   (a) What physical interface does the mixer use (SMA, BNC, DIP, SMT, etc.) ?
   (b) What is the RF range? What does the RF input do?
   (c) What is the IF range? What does the IF input do? What does IF stand for?
   (d) What is the LO range? What does LO stand for?
   (e) What is the cost of the mixer you have found?
   (f) What mixer configuration or topology does the mixer you found use?
   (g) Can your mixer be used in the broadcast AM frequency range?
   (h) Can it be used in the FM frequency range?
   (i) Can it be used in the 802.11 WiFi frequency range?
   (j) Circle the parts of the data sheet you used to come to your conclusions.

7. For the DSB-SC system we discussed in class please analyze the effect on $m'(t)$ of:

   (a) A phase error in the receiver's oscillator, i.e. instead of generating $\cos(\omega_c t)$ it generates $\cos(\omega_c t+\theta)$.
   Solution:

$$x_{mixout} = m(t)\cos(\omega_c t)\cos(\omega_c t + \theta)$$
$$x_{mixout} = m(t)[\cos(\omega_c t + \omega_c t + \theta) + \cos(\omega_c t - \omega_c t - \theta)]$$

   the high frequency term is elimnated by the low pass filter leaving us with:

$$m'(t) = m(t)\cos(\theta)$$

   which is a constant gain and only a problem if $\theta = \frac{\pi}{2}$ It's probably a little inconvenient as you approach $\frac{\pi}{2}$ as well. Note, cosine is even so the sign of θ is irrelevant.

(b) A small frequency error in the receiver's oscillator, i.e. instead of generating $\cos(\omega_c t)$ it generates $\cos((\omega_c + \Delta\omega)t)$.
Solution: Here

$$\begin{aligned} x_{LO}(t) &= \cos((\omega_c + \Delta\omega)t) \\ &= \cos(\omega_c t + \Delta\omega t) \end{aligned}$$

which is the same as we had above, except that now

$$\theta = \Delta\omega t$$

so the result will be:

$$m'(t) = m(t)\cos(\Delta\omega t)$$

which is a far worse distortion because it translates the spectrum. At very small frequency errors this will sound like a time varying gain, so if you ever had a younger sibling turn the radion up and down repeatedly you know that this can drive you to physical violence.

8. Show that a DSB-SC receiver can receive AM. What additional block will be required at the receiver output to allow recovery of $m(t)$ without an offset?
Solution: Here, the only change is that now $m(t)$ has a constant added, the receiver will pass this constant through just fine. To remove it, use a high pass filter or AC coupling capacitor.