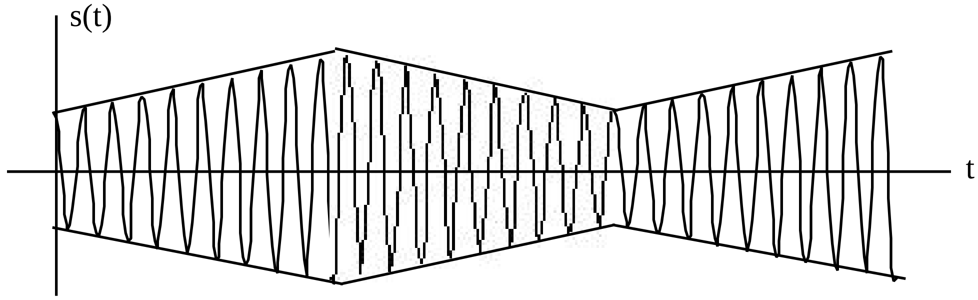
ECE 405 - ANALOG COMMUNICATIONS - INVESTIGATION 7
INTRODUCTION TO AMPLITUDE MODULATION - PART II

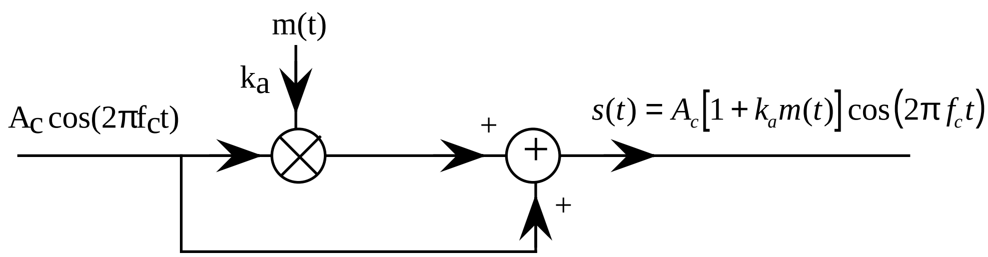
FALL 2005 **A.P. FELZER**

To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

From the last Investigation we know that amplitude modulated signals s(t) like the following



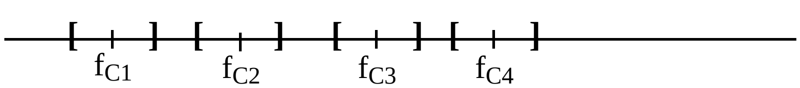
are generated as follows



with $-1 \le m(t) \le 1$; $0 < k_a \le 1$; $f_c >>$ bandwidth of m(t).

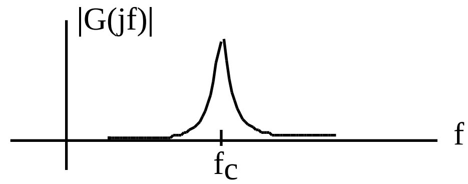
The main objectives of this Investigations are to show how multiple AM stations can transmit at the same time without interfering with each other and to show how a receiver can detect and then demodulate the station we want to listen to.

1. From the last Investigation we know that one of the main reasons for modulating signals is that antennas are practical only at the higher frequencies of the carriers. The other big advantage of modulation is that it allows us to transmit many different signals at the same time by using different center frequencies f_c as indicated in the following diagram

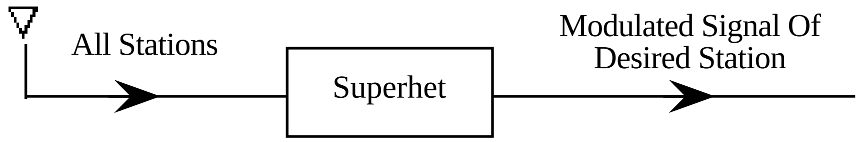


   We call this **frequency division multiplexing (FDM)**. **Memorize** this term. Then find how many AM radio stations can be transmitted in the frequency range 1MHz to 1.1MHz if each station is allotted 10KHz of spectrum.

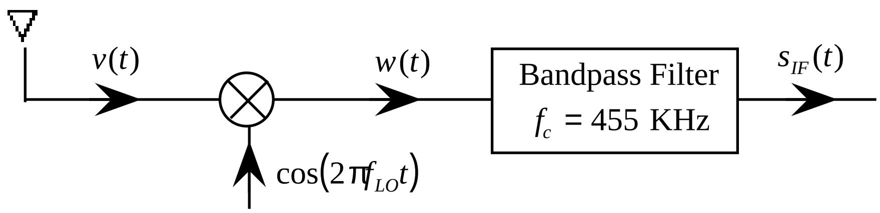
2. From the last problem we see that to recover the baseband signal of a given radio station we first have to separate it from all the others. One way to do this is to build a bandpass filter as follows



with an adjustable center frequency f_c. But this is hard to do. A more practical circuit is a **superheterodyne** - or **superhet** as follows



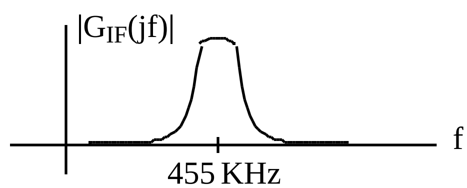
consisting of a *local oscillator* with an adjustable frequency f_{LO} together with a fixed bandpass filter as follows



The basic operation of a superhet is as follows

(1) The signal v(t) from the antenna is first multiplied by a sinusoid of frequency f_{LO} from the *local oscillator LO*. The value of f_{LO} is controlled by the user as he or she turns a knob or pushes a button on the radio

(2) The resulting product $w(t)$ is then passed through a fixed bandpass filter with a center frequency of 455 KHz as follows



with a passband that is wide enough for only one radio station. Note that we refer to $f_c = f_I = 455$ KHz as the **intermediate frequency (IF)** and the passband filter as the **IF Filter**. Note that the "carrier frequency" of the radio station that makes it through the bandpass filter has been shifted to $f_c = 455$ KHz

From this we see that for a user to tune a particular station he or she needs to adjust the local oscillator to a frequency that puts the desired station in the passband of the IF filter. **Memorize** this result.

Now suppose the sum of signals $v(t)$ received by the antenna is as follows

$$v(t) = v_1(t) + v_2(t) = 2\cos(2\pi 9x10^5 t) + 2\cos(2\pi 1.045x10^6 t)$$

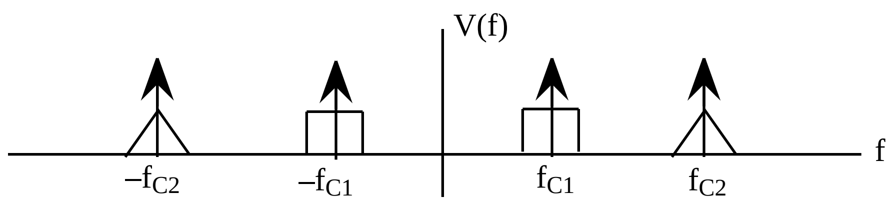
and that $f_{LO} = 1.5$ MHz

a. Sketch the spectral plot of $v(t)$
b. Find and sketch the spectral plot of $w(t)$. Hint - make use of the fact that

$$\cos(x)\cos(y) = 0.5\cos(x+y) + 0.5\cos(x-y)$$

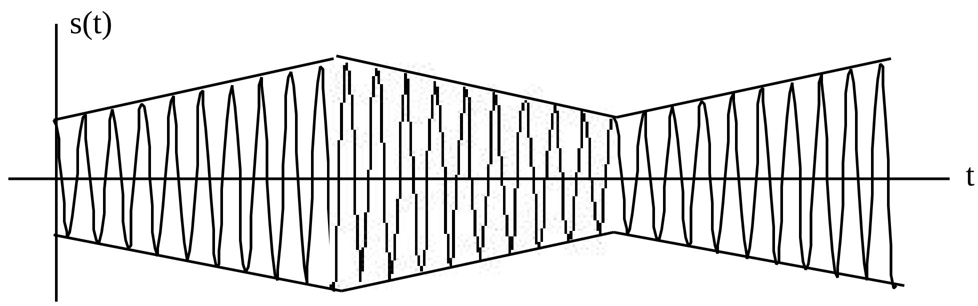
c. Find and sketch the spectral plot of $s(t)$
d. Which station is the radio tuned to
e. What is f_{LO} when we're listening to $v_1(t)$

3. Suppose the signal v(t) being received by the antenna of the AM radio in Problem (2) is equal to the sum of two radio stations. And that its spectrum $V(f)$ is as follows

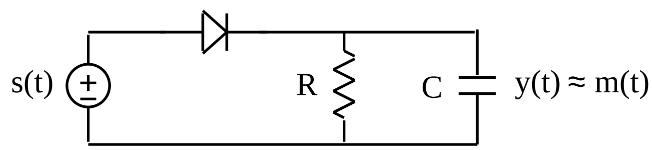


with $f_{C1} = 600$ KHz and $f_{C2} = 700$ KHz and that $f_{LO} = 1.155$ MHz
a. Sketch the spectrum of $w(t)$ in the circuit of Problem (2)
b. Sketch the spectrum of $s(t)$ in the circuit of Problem (2). Which station is being tuned in

4. Once we have separated out a desired AM signal $s(t)$ like the following



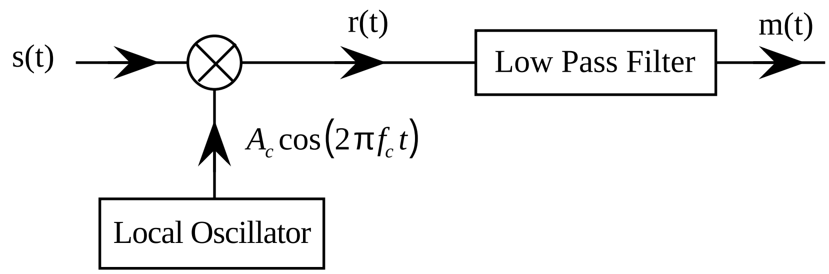
from all those being received by the antenna we need to demodulate it - recover the baseband signal $m(t)$. One relatively simple way to do this is with an **envelope detector** as follows



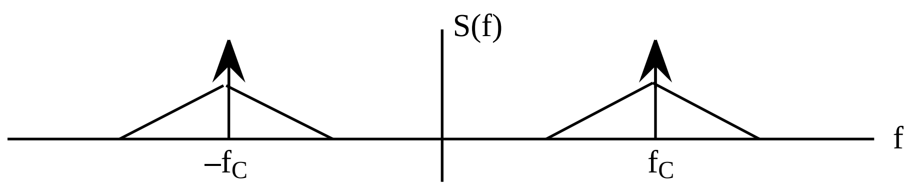
a. Describe and draw equivalent circuits of what's going on when $s(t) > y(t)$
b. Describe and draw equivalent circuits of what's going on when $s(t) < y(t)$
c. Describe in words the constraints on the RC time constant $\tau = RC$ required for the circuit to work properly
d. Make use of your results in parts (a) and (b) to sketch the circuit's response $y(t)$ to the signal above

e. Why do we call such circuits envelope detectors

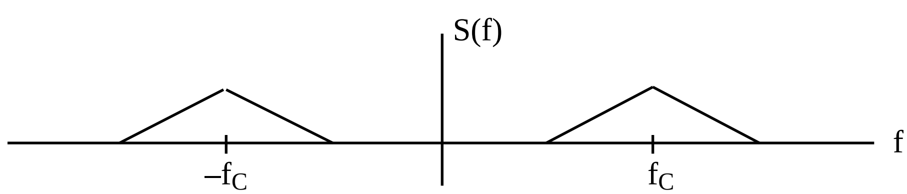
5. Demodulation schemes like those in Problem (4) are examples of what we refer to as **noncoherent detection** because the receiver does not require its own copy of the carrier $\cos(2\pi f_c t)$. **Coherent detectors** on the other hand make use of the carrier. **Memorize** these terms. And then sketch the spectrums to illustrate the operation of the following coherent AM detector



for s(t) with the following spectrum



6. The objective of this and the rest of the problems of this Investigation is to introduce some variations on amplitude modulation that reduce the power and bandwidth of the modulated signal at the expense of circuit complexity. The first is Double Side Band–Suppressed Carrier modulation which is referred to as DSB-SC. DSB-SC is just like AM except that the carrier sinusoid is not transmitted as indicated in the following spectrum of a DSB-SC signal



In particular $s(t)$ for an AM signal is given by

$$s(t) = A_c\left[1 + k_a m(t)\right]\cos\left(2\pi f_c t\right)$$

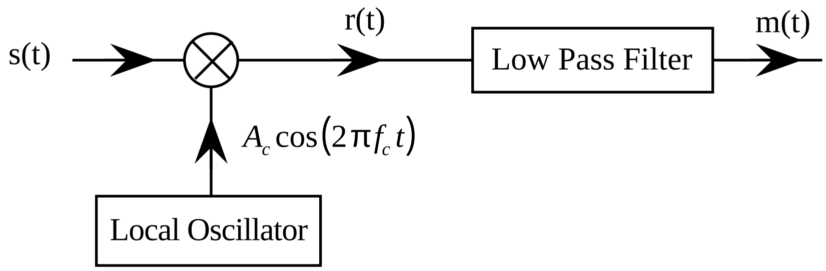
while for a DSB-SC signal we have simply

$$s(t) = A_c m(t)\cos\left(2\pi f_c t\right)$$

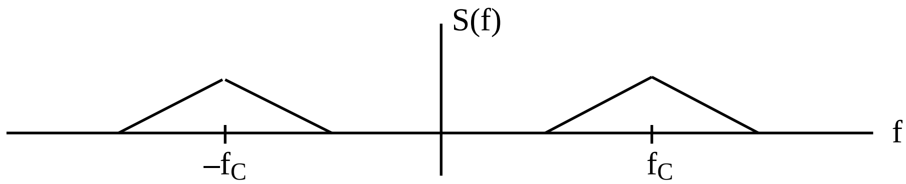
a. Sketch the spectrum of the DSB-SC signal with $m(t) = \cos(2\pi 1000 t)$ and carrier frequency $f_c = 1$ MHz

b. How much power does a DSB-SC signal $s(t) = A_c m(t)\cos\left(2\pi f_c t\right)$ save over an AM signal when $A_c = 5$, $k_a = 0.8$ and $m(t) = \cos(2\pi 1000 t)$

c. Verify that the following coherent detector

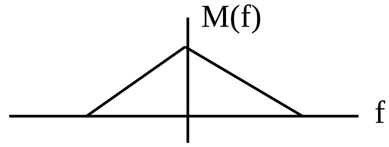


with a local oscillator generating a carrier frequency at the same phase as the transmitter will demodulate the DSB-SC signal with the following spectrum



by finding and sketching the spectrums $R(f)$ and $M(f)$ as $s(t)$ passes through the demodulator

7. Single-Sideband (SSB) modulation is just like DSB-SC except that only one of the sidebands is transmitted instead of both. Suppose in particular that the spectrum of a given message signal $m(t)$ is as follows



a. Sketch the spectrum of the corresponding DSB-SC signal
b. Sketch the spectrum of the lower sideband
c. Sketch the frequency response of a filter for obtaining SSB from DSB-SC
d. What are advantages of single-sideband over DSB-SC