RUTGERS
THE STATE UNIVERSITY OF NEW JERSEY

Department of Electrical and Computer Engineering

332:427 | Communications Systems Design | Fall 2008

PRELAB EXERCISES #4: AMPLITUDE MODULATION AND DEMODULATION

1. Consider the block diagram of the mixer, shown in Fig. 1, which consists of a product modulator with a local oscillator of variable frequency f_l, followed by a bandpass filter. The input signal is an AM wave of bandwidth 10 kHz and carrier frequency that may lie anywhere in the range 535 kHz to 1.605 MHz; these parameters are typical of AM radio broadcasting. It is required to translate this signal to a frequency band centered at a fixed intermediate frequency (IF) of 455 kHz. Find the range of tuning that must be provided in the local oscillator in order to achieve this requirement.

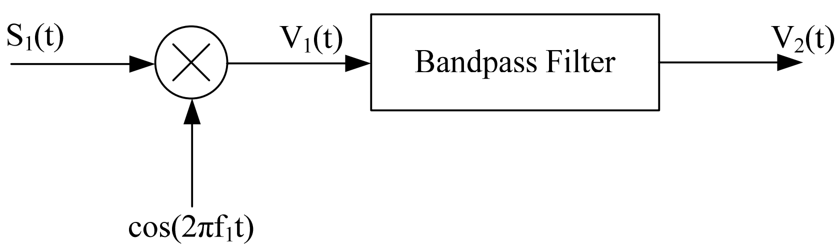

Fig. 1. Block diagram of a mixer.

2. Suppose you have a good quality AM radio receiver that tunes from 540 kHz to 1600 kHz. You wish to add some circuitry external to the receiver so that you can listen to the AM short-wave broadcast band 6000-6200 kHz by tuning the receiver only from 1000 kHz to 1200 kHz. No modifications are to be made internal to the receiver because it is still under warranty. Draw a block diagram showing how you could do this. Name all blocks and carefully label all the required frequencies.

3. The spectrum of a voice signal $m(t)$ is zero outside the interval $f_a\ |f|\ f_b$. In order to ensure communication privacy, this signal is applied to a scrambler that consists of the following cascade of components: a product modulator, a high-pass filter, a second product modulator, and a low-pass filter. The carrier wave applied to the first product modulator has a frequency equal to f_c, whereas that applied to the second product modulator has a frequency equal to $f_b + f_c$; both of them have unit amplitude. The high-pass and low-pass filters have the same cutoff frequency at f_c. Assume that $f_c > f_b$.
   a) Derive an expression for the scrambler output s(t), and sketch its spectrum.

b) Briefly describe a system that a receiver can use to unscramble the scrambled signal.

4. In SSB-SC modulation exact $90°$ phase shifts are assumed, this is difficult to achieve in practice. Assume that the input signal is shifted by $(90-\alpha)°$ and the carrier is shifted by $90°$. Show that the ratio of the undesired output sideband magnitude to the desired sideband magnitude is $\tan(\alpha/2)$.

5. Using block diagrams, develop a way to place two information signals each of bandwidth B on to a carrier of frequency F. The bandwidth of the output must not be greater than 2B.

6. An alternative method of SSB generation is shown in the system diagram in Fig. 2(a). Here ω_c is the final carrier frequency and $\omega_c >> \omega_n$. This technique for SSB generation is known as Weaver's method.

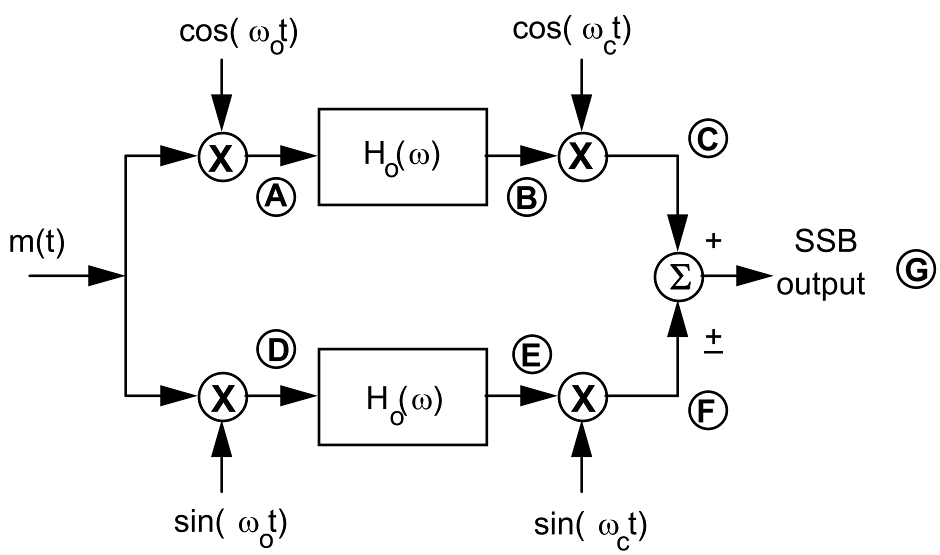

Fig. 2(a). System implementation of Weaver's method.

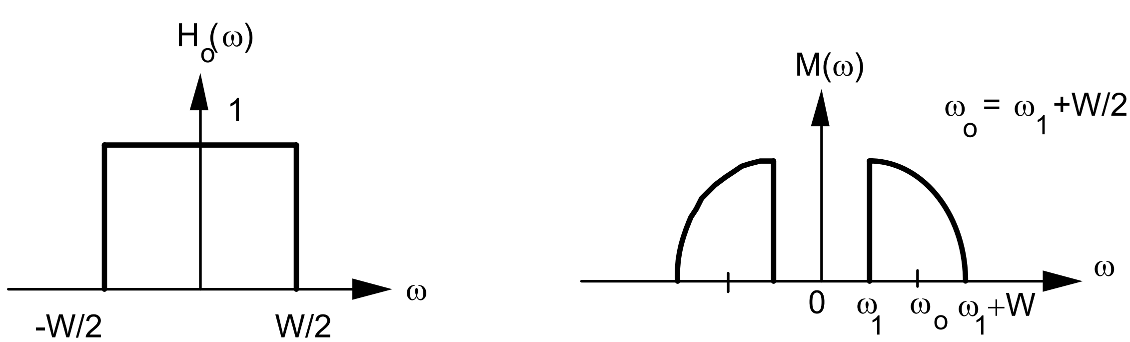

Fig. 2(b). Filter frequency response and the message spectrum.

a) Analyze this system and show that the output is an SSB signal.
(Hint: Use the fact that the message signal $m(t)$ can be expressed as the sum of two components $m_+(t)$ and $m_-(t)$, where $m_+(t)$ is the inverse Fourier transform of $M(\omega)U(\omega)$ while the function $m_-(t)$ is the inverse Fourier transform of $M(\omega)U(-\omega)$. Note that $U(\omega)$ is the unit step function defined in the frequency domain.)

b) In the diagram above the message spectrum, *M(ω),* is shown containing a notch at the origin. Show that the system works even without such a notch if ideal filters are used for $H_0(\omega)$.

c) Show that if the notch at the origin is present, the filters $H_0(\omega)$ do not have to be ideal.

d) What is the advantage of this scheme over SSB modulator implementation using the selective (direct sideband) filtering method?