EE 3640 Communication Systems I Chi-chao Chao
Spring 2023

Homework Assignment No. 2
Due 1:20pm, March 27, 2023

Reading: Haykin & Moher, Chapter 3.

Problems for Solution:

1. The output signal from an AM modulator is

$$s(t) = 5\cos(1800\pi t) + 20\cos(2000\pi t) + 5\cos(2200\pi t).$$

   (a) Determine the percentage modulation.

   (b) Determine the ratio of the power in the sidebands to the total power.

2. Below shows the circuit diagram of a *square-law modulator* for AM. The signal applied to the nonlinear device is relatively weak, such that it can be represented by a square law:

$$v_2(t) = a_1 v_1(t) + a_2 v_1^2(t)$$

   where a_1 and a_2 are constants, $v_1(t)$ is the input, and $v_2(t)$ is the output. The input is given by

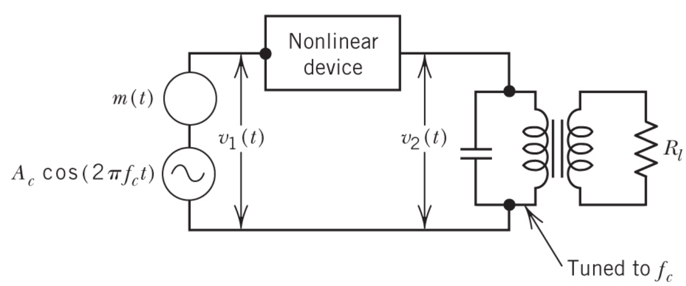
$$v_1(t) = A_c \cos(2\pi f_c t) + m(t)$$

   where $m(t)$ is the message signal and $A_c \cos(2\pi f_c t)$ is the carrier wave.

   (a) Find the output $v_2(t)$.

   (b) Specify the frequency response that the tunned circuit in the diagram must satisfy in order to generate an AM signal with f_c as the carrier frequency.

   (c) What is the amplitude sensivitity k_a of this AM signal?



3. A DSB-SC signal is modulated by the message signal

$$m(t) = 2\cos(2000\pi t) + \cos(6000\pi t).$$

   The modulated signal is

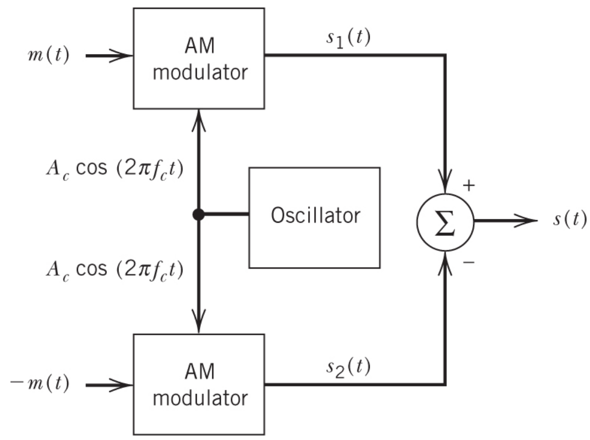
$$s(t) = 100m(t)\cos(2\pi f_c t)$$

   where $f_c = 1$ MHz.

(a) Determine the Fourier transform $S(f)$ of $s(t)$.

(b) Determine the average power of $s(t)$.

4. Below shows the circuit diagram of a *balanced modulator*. The input to the top AM modulator is $m(t)$, whereas that applied to the lower AM modulator is $-m(t)$; these two modulators have the same amplitude sensitivity. Show that the output $s(t)$ of the balanced modulator represents a DSB-SC modulated signal.



5. Suppose that in the receiver of the quadrature-carrier multiplexing system discussed in class the local carrier available for demodulation has a phase error ϕ with respect to the carrier source used in the transmitter. Assuming a distortionless communication channel between the transmitter and receiver, show that this phase error will cause *cross-talk* to arise between the two demodulated signals at the receiver outputs. By cross-talk we mean that a portion of one message signal appears at the receiver output belonging to the other message signal, and vice versa.

6. Assume that a message signal is given by

$$m(t) = 2\cos(2\pi f_m t) + \cos(4\pi f_m t).$$

(a) Calculate an expression for

$$s(t) = \frac{A_c}{2} m(t)\cos(2\pi f_c t) - \frac{A_c}{2}\hat{m}(t)\sin(2\pi f_c t)$$

where $\hat{m}(t)$ is the Hilbert of transform of $m(t)$, $f_m \ll f_c$, and $A_c = 4$.

(b) Find the Fourier transform $S(f)$ of $s(t)$. Is this an upper-sideband SSB signal or a lower-sideband SSB signal?

7. The single-tone modulating signal $m(t) = A_m\cos(2\pi f_m t)$ is used to generate the VSB signal

$$s(t) = \frac{1}{2} a A_m A_c \cos\left[2\pi(f_c + f_m)t\right] + \frac{1}{2} A_m A_c (1-a)\cos\left[2\pi(f_c - f_m)t\right]$$

where a is a constant, less than unity, representing the attention of the upper side frequency.

(a) Find the quadrature component $s_Q(t)$ of the VSB signal $s(t)$.

(b) The VSB signal, plus the carrier $A_c \cos(2\pi f_c t)$, is passed through an envelope detector. Let the output of the envelope detector be $A_c [1 + km(t)] \cdot d(t)$, where k is some constant. Determine the distortion $d(t)$ produced by the quadrature component. (*Hint:* The output of the envelope detector is given by $\sqrt{x_I^2(t) + x_Q^2(t)}$ when the input is $x_I(t)\cos(2\pi f_c t) - x_Q(t)\sin(2\pi f_c t)$.)

(c) What is the value of the constant a for which this distortion reaches its worst possible condition?

8. In this problem we study the idea of mixing in a superheterodyne receiver. To be specific, consider the block diagram of the mixer discussed in class, that consists of a product modulator with a local oscillator of *variable frequency* f_l, followed by a band-pass filter. The input signal is an AM wave of bandwidth 10 kHz and carrier frequency that may lie anywhere in the range of 0.535 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 0.455 MHz. Find the range of tuning that must be provided in the local oscillator to achieve this requirement.

Homework Collaboration Policy: I allow and encourage discussion or collaboration on the homework. However, you are expected to write up your own solution and understand what you turn in. Late homework is subject to a penalty of 5% to 40% of your total points.