University of Illinois at Urbana-Champaign
Department of Electrical and Computer Engineering

ECE 359: Communications I

Fall 2001

Problem Set 4

Amplitude Modulation Schemes

Issued: Thursday, September 20th. **Due:** Never.

Reading from Haykin: Chapter 2, Sections 2.1–2.6.

Announcement: The first Mid-Semester Exam will be held on Thursday, September 27th, from 1:30pm to 2:50pm in 161 Everitt. The exam will cover all material from the beginning of the term *up to and including* the lecture on Thursday, September 20th. The corresponding material includes Problem Sets 1 through 4 and the following material from Haykin: Appendix A.2, Background and Preview and Chapter 2 (Sections 2.1–2.6).
During the exam, you can bring an 8.5 × 11-inch double-sided sheet of *handwritten* notes. Calculators are allowed but will not be necessary.
A copy of an old exam can be downloaded from `http://www.ece.uiuc.edu/ece359`. This exam does not necessarily resemble this year's exam (also notice that the material covered in this old exam is slightly different from the material covered in this year's exam).

Problem 4.1

The complex envelope $\widetilde{x}(t)$ of a real signal $x(t)$ is generally complex and can be written in the form

$$\widetilde{x}(t) = x_I(t) + jx_Q(t) ,$$

where $x_I(t)$ and $x_Q(t)$ are the in-phase and quadrature-phase components of $x(t)$.
Find the expressions for $x_I(t)$ and $x_Q(t)$ of the following signals:

(a) DSB-SC signal $x(t) = m(t)\cos(2\pi f_c t + \phi)$.

(b) DSB-TC signal $x(t) = [A + m(t)]\cos(2\pi f_c t + \phi)$.

Problem 4.2

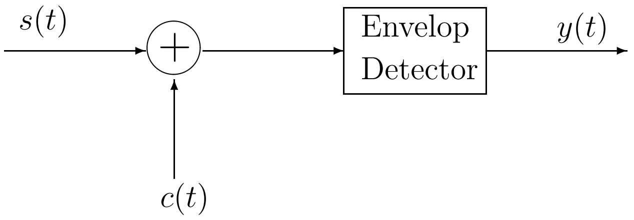
Problem 2.11 from Haykin, p. 169.

Problem 4.3

Problem 2.16 from Haykin, pp. 170–171.

Problem 4.4

Show that a DSB-SC signal can be demodulated by an envelope detector if a sufficient amount of carrier is inserted at the receiver as shown below.



In particular, show that if the carrier $c(t) = A\cos[2\pi(f_c + \Delta f)t + \phi]$ is inserted in the received DSB-SC signal $s(t) = m(t)\cos 2\pi f_c t$ and the resulting signal is envelope-detected, then the output (after DC blocking) will be $y(t) = m(t)\cos(2\pi\Delta f t + \phi)$.

Problem 4.5

An SSB signal is generated by modulating an 800 kHz carrier by the signal $m(t) = \cos(2000\pi t) + 2\sin(2000\pi t)$. The amplitude of the carrier is $A_c = 100$.

(a) Determine the signal $\widehat{m}(t)$.

(b) Determine the time domain expression for the lower sideband SSB signal.

(c) Determine the spectrum of the lower sideband SSB signal.

Problem 4.6

Consider the SSB modulated waveform

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

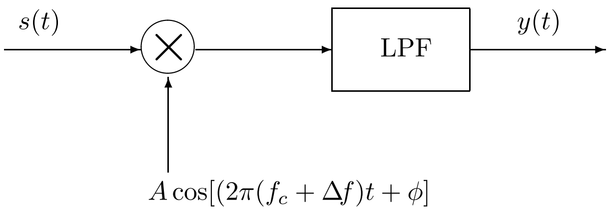
where $m(t)$ is the message signal and $\hat{m}(t)$ is its Hilbert transform. Suppose that $s(t)$ is the input to a square-law device whose output $y(t)$ is then given by

$$y(t) = s^2(t) \ .$$

Show that $y(t)$ contains a frequency component at twice the modulation frequency f_c. Do you think it would be practical to try and recover the message signal $m(t)$ from this component?

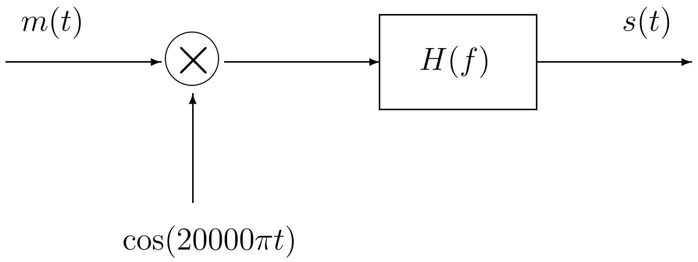
Problem 4.7

A VSB-SC signal $s(t) = m(t)\cos 2\pi f_c t - m'(t)\sin 2\pi f_c t$ is coherently demodulated by a locally generated carrier $A\cos[2\pi(f_c + \Delta f)t + \phi]$ as shown below. Find the output signal $y(t)$.

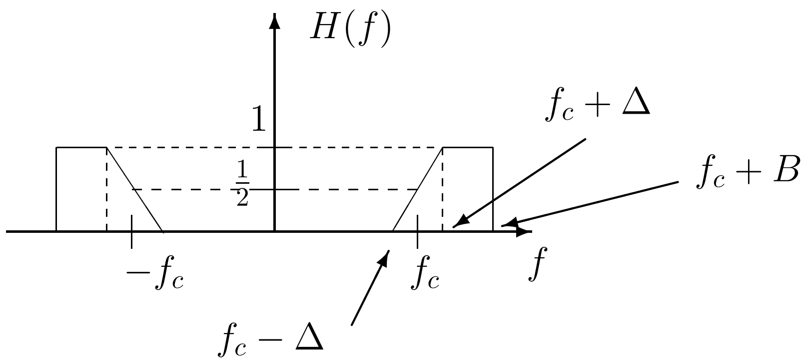


Problem 4.8

Consider the following VSB modulation scheme.



The frequency response of the VSB filter $H(f)$ is shown below, where $f_c = 10000$, $B = 250$, and $\Delta = 100$.



Let $m(t) = \cos(300\pi t) + \cos(100\pi t)$.

(a) Find the transmitted VSB-modulated waveform $s(t)$.

(b) Describe a coherent demodulator for $s(t)$ so that its output $y(t)$ equals $m(t)$.