Also $A_c = 20$ V and $f_c = 300$ Hz. Determine the expression for the upper-sideband SSB signal and the lower-sideband SSB signal. Write these in a way that shows the amplitude and frequency of all transmitted components.

3.7 Equation (3.63) gives the amplitude and phase for the VSB signal components centered about $f = +f_c$. Give the amplitude and phase of the signal comonents centered about $f = -f_c$. Using these values show that the VSB signal is real.

3.8 An AM radio uses the standard IF frequency of 455 kHz and is tuned to receive a signal having a carrier frequency of 1020 kHz. Determine the frequency of the local oscillator for both low-side tuning and high-side tuning. Give the image frequencies for each.

3.9 The input to an AM receiver input consists of both modulated carrier (the message signal is a single tone) and interference terms. Assuming that $A_i = 100$ V, $A_m = 0.2$ V, $A_c = 1$ V, $f_m = 10$ Hz, $f_c = 300$ Hz, and $f_i = 320$ Hz, approximate the envelope detector output by giving the amplitudes and frequencies of all components at the envelope detector output.

3.10 A PAM signal is formed by sampling an analog signal at 5 kHz. The duty cycle of the generated PAM pulses is to be 5%. Define the transfer function of the holding circuit by giving the value of τ in (3.92). Define the transfer function of the equalizing filter.

3.11 Rewrite (3.100) to show that relationship between δ_0/A and $T_s f_1$. A signal defined by

$$m(t) = A\cos(40\pi t)$$

is sampled at 1000 Hz to form a DM signal. Give the minium value of δ_0/A to prevent slope overload.

3.12 A TDM signal consists of four signals having bandwidths of 1000, 2000, 4000, and 6000 Hz. What is the total bandwidth of the composite TDM signal. What is the lowest possible sampling frequency for the TDM signal?

Problems

Section 3.1

3.1 Assume that a DSB signal

$$x_c(t) = A_c m(t)\cos(2\pi f_c t + \phi_0)$$

is demodulated using the demodulation carrier $2\cos[2\pi f_c t + \theta(t)]$. Determine, in general, the demodulated output $y_D(t)$. Let $A_c = 1$ and $\theta(t) = \theta_0$, where θ_0 is a constant, and determine the mean-square error between $m(t)$ and the demodulated output as a function of ϕ_0 and θ_0. Now let $\theta_0 = 2\pi f_0 t$ and compute the mean-square error between $m(t)$ and the demodulated output.

3.2 A message signal is given by

$$m(t) = \sum_{k=1}^{5} \frac{10}{k}\sin(2\pi k f_m t)$$

and the carrier is given by

$$c(t) = 100\cos(200\pi t)$$

Write the transmitted signal as a Fourier series and determine the transmitted power.

Section 3.2

3.3 Design an envelope detector that uses a full-wave rectifier rather than the half-wave rectifier shown in Figure 3.3. Sketch the resulting waveforms, as was done in for a half-wave rectifier. What are the advantages of the full-wave rectifier?

3.4 Three message signals are periodic with period T, as shown in Figure 3.32. Each of the three message signals is applied to an AM modulator. For each message signal, determine the modulation efficiency for $a = 0.2$, $a = 0.3$, $a = 0.4$, $a = 0.7$, and $a = 1$.

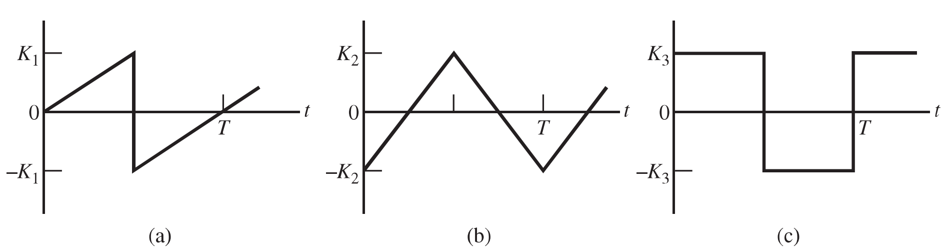

Figure 3.32

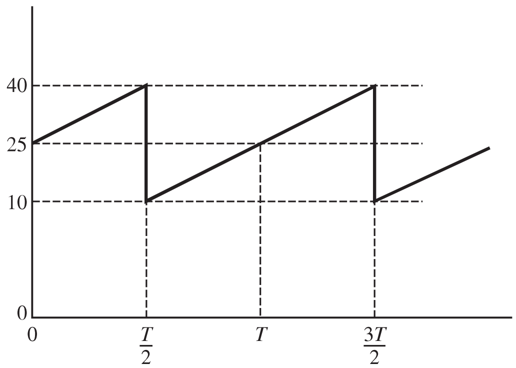

Figure 3.33

3.5 The positive portion of the envelope of the output of an AM modulator is shown in Figure 3.33. The message signal is a waveform having zero DC value. Determine the modulation index, the carrier power, the efficiency, and the power in the sidebands.

3.6 A message signal is a square wave with maximum and minimum values of 8 and -8 V, respectively. The modulation index $a = 0.7$ and the carrier amplitude $A_c = 100$ V. Determine the power in the sidebands and the efficiency. Sketch the modulation trapezoid.

3.7 In this problem we examine the efficiency of AM for the case in which the message signal does not have symmetrical maximum and minimum values. Two message signals are shown in Figure 3.34. Each is periodic with period T, and τ is chosen such that the DC value of $m(t)$ is zero. Calculate the efficiency for each $m(t)$ for $a = 0.7$ and $a = 1$.

3.8 An AM modulator operates with the message signal

$$m(t) = 9\cos(20\pi t) - 8\cos(60\pi t)$$

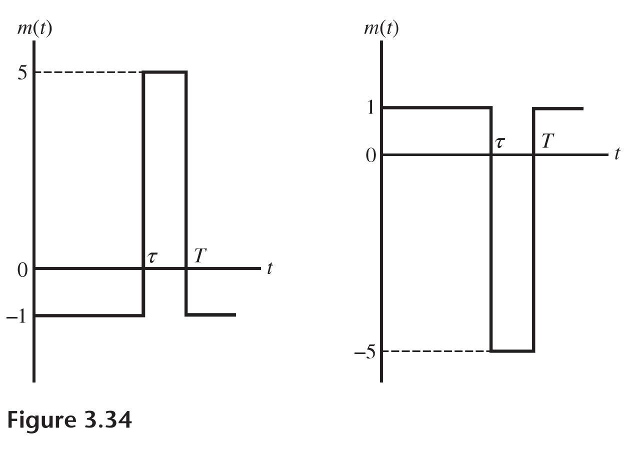

Figure 3.34

The unmodulated carrier is given by $110\cos(200\pi t)$, and the system operates with an index of 0.8.

(a) Write the equation for $m_n(t)$, the normalized signal with a minimum value of -1.

(b) Determine $\langle m_n^2(t)\rangle$, the power in $m_n(t)$.

(c) Determine the efficiency of the modulator.

(d) Sketch the double-sided spectrum of $x_c(t)$, the modulator output, giving the weights and frequencies of all components.

3.9 Rework Problem 3.8 for the message signal

$$m(t) = 9\cos(20\pi t) + 8\cos(60\pi t)$$

3.10 An AM modulator has output

$$x_c(t) = 40\cos[2\pi(200)t] + 5\cos[2\pi(180)t] + 5\cos[2\pi(220)t]$$

Determine the modulation index and the efficiency.

3.11 An AM modulator has output

$$x_c(t) = A\cos[2\pi(200)t] + B\cos[2\pi(180)t] + B\cos[2\pi(220)t]$$

The carrier power is P_0 and the efficiency is E_{ff}. Derive an expression for E_{ff} in terms of P_0, A, and B. Determine A, B, and the modulation index for $P_0 = 200\ W$ and $E_{ff} = 30\%$.

3.12 An AM modulator has output

$$x_c(t) = 25\cos[2\pi(150)t] + 5\cos[2\pi(160)t] + 5\cos[2\pi(140)t]$$

Determine the modulation index and the efficiency.

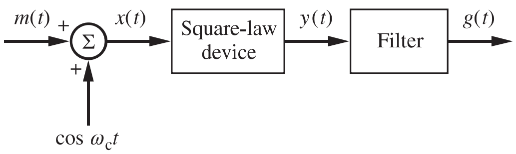

Figure 3.35

3.13 An AM modulator is operating with an index of 0.8. The modulating signal is

$$m(t) = 2\cos(2\pi f_m t) + \cos(4\pi f_m t)$$
$$+2\cos(10\pi f_m t)$$

(a) Sketch the spectrum of the modulator output showing the weights of all impulse functions.

(b) What is the efficiency of the modulation process?

3.14 Consider the system shown in Figure 3.35. Assume that the average value of $m(t)$ is zero and that the maximum value of $|m(t)|$ is M. Also assume that the square-law device is defined by $y(t) = 4x(t) + 2x^2(t)$.

(a) Write the equation for $y(t)$.

(b) Describe the filter that yields an AM signal for $g(t)$. Give the necessary filter type and the frequencies of interest.

(c) What value of M yields a modulation index of 0.1?

(d) What is an advantage of this method of modulation?

Section 3.3

3.15 Assume that a message signal is given by

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

Calculate an expression for

$$x_c(t) = \frac{1}{2}A_c m(t)\cos(2\pi f_c t) \pm \frac{1}{2}A_c \widehat{m}(t)\sin(2\pi f_c t)$$

for $A_c = 10$. Show, by sketching the spectra, that the result is upper-sideband or lower-sideband SSB depending upon the choice of the algebraic sign.

3.16 Redraw Figure 3.10 to illustrate the generation of upper-sideband SSB. Give the equation defining the upper-sideband filter. Complete the analysis by deriving the expression for the output of an upper-sideband SSB modulator.

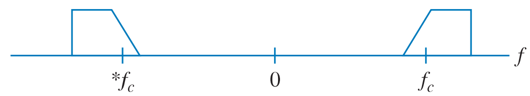

Figure 3.36

3.17 Squaring a DSB or AM signal generates a frequency component at twice the carrier frequency. Is this also true for SSB signals? Show that it is or is not.

Section 3.4

3.18 Prove analytically that carrier reinsertion with envelope detection can be used for demodulation of VSB.

3.19 Figure 3.36 shows the spectrum of a VSB signal. The amplitude and phase characteristics are the same as described in Example 3.3. Show that upon coherent demodulation, the output of the demodulator is real.

Section 3.5

3.20 Sketch Figure 3.20 for the case where $f_{LO} = f_c - f_{IF}$.

3.21 A mixer is used in a short-wave superheterodyne receiver. The receiver is designed to receive transmitted signals between 10 and 30 MHz. High-side tuning is to be used. Determine an acceptable IF frequency and the tuning range of the local oscillator. Strive to generate a design that yields the minimum tuning range.

3.22 A superheterodyne receiver uses an IF frequency of 455 kHz. The receiver is tuned to a transmitter having a carrier frequency of 1100 kHz. Give two permissible frequencies of the local oscillator and the image frequency for each. Repeat assuming that the IF frequency is 2500 kHz.

Section 3.6

3.23 A DSB signal is squared to generate a carrier component that may then be used for demodulation. (A technique for doing this, namely the phase-locked loop, will be studied in the next chapter.) Derive an expression that illustrates the impact of interference on this technique.

Section 3.7

3.24 A continuous-time signal is sampled and input to a holding circuit. The product of the holding time and the sampling frequency is τf_s. Plot the amplitude response of the required equalizer as a function of τf_s. What problem, or problems, arise if a large value of τ is used while the sampling frequency is held constant?