- Complex Exponential & Sinusoidal
  Amplitude Modulation & Demodulation
- Frequency-Division Multiplexing
- Single-Sideband Sinusoidal Amplitude Modulation
- Amplitude Modulation with a Pulse-Train Carrier
  - Time-Division Multiplexing
- Pulse-Amplitude Modulation
- Sinusoidal Frequency Modulation
- Discrete-Time Modulation

8.4: Amplitude Modulation with Sinusoidal Carrier

8.4. Suppose

$$x(t) = \sin 200\pi t + 2\sin 400\pi t$$

and

$$g(t) = x(t)\sin 400\pi t.$$

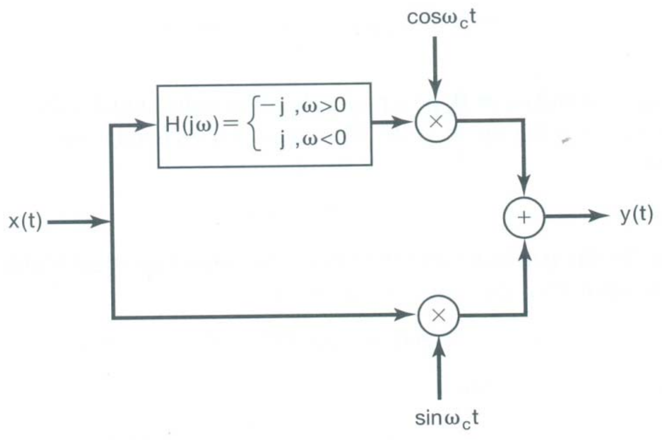
If the product $g(t)(\sin 400\pi t)$ is passed through an ideal lowpass filter with cutoff frequency 400π and passband gain of 2, determine the signal obtained at the output of the lowpass filter.

8.8: Retain Sidebands Using Phase-Shift Network

8.8. Consider the modulation system shown in Figure P8.8. The input signal $x(t)$ has a Fourier transform $X(j\omega)$ that is zero for $|\omega| > \omega_M$. Assuming that $\omega_c > \omega_M$, answer the following questions:

(a) Is $y(t)$ guaranteed to be real if $x(t)$ is real?

(b) Can $x(t)$ be recovered from $y(t)$?



8.25: Speech Scrambler

8.25. A commonly used system to maintain privacy in voice communication is a *speech scrambler*. As illustrated in Figure P8.25(a), the input to the system is a normal speech signal $x(t)$ and the output is the scrambled version $y(t)$. The signal $y(t)$ is transmitted and then unscrambled at the receiver.

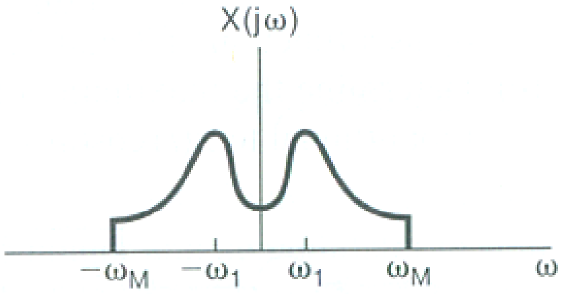
We assume that all inputs to the scrambler are real and band limited to the frequency ω_M; that is, $X(j\omega) = 0$ for $|\omega| > \omega_M$. Given any such input, our proposed scrambler permutes different bands of the spectrum of the input signal. In addition, the output signal is real and band limited to the same frequency band; that is, $Y(j\omega) = 0$ for $|\omega| > \omega_M$. The specific algorithm for the scrambler is

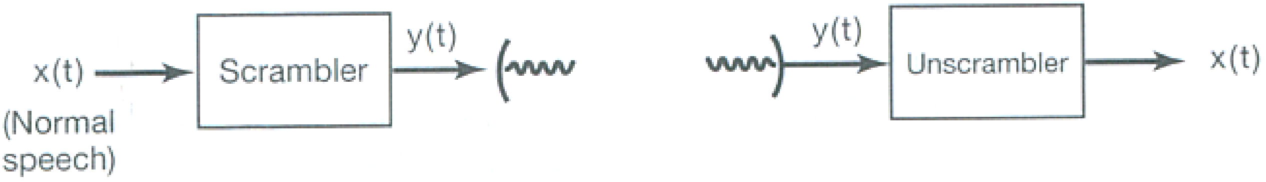
$$Y(j\omega) = X(j(\omega - \omega_M)), \quad \omega > 0,$$
$$Y(j\omega) = X(j(\omega + \omega_M)), \quad \omega < 0.$$

(a) If $X(j\omega)$ is given by the spectrum shown in Figure P8.25(b), sketch the spectrum of the scrambled signal $y(t)$.

(b) Using amplifiers, multipliers, adders, oscillators, and whatever ideal filters you find necessary, draw the block diagram for such an ideal scrambler.

(c) Again using amplifiers, multipliers, adders, oscillators, and ideal filters, draw a block diagram for the associated unscrambler.

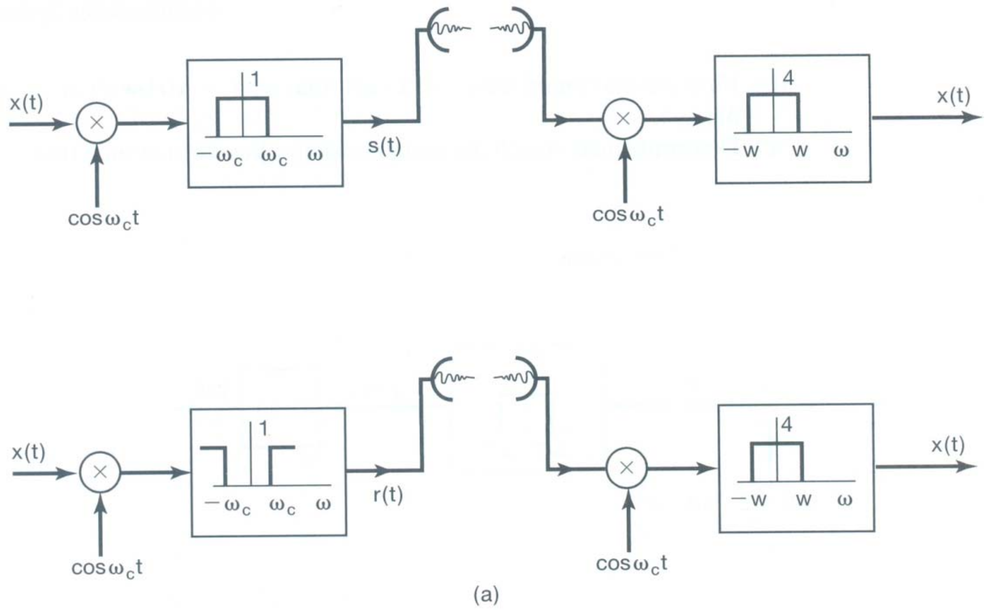




8.29: Double-Sideband Suppressed Carrier, Phase-Shift Method

8.29. Single-sideband modulation is commonly used in point-to-point voice communication. It offers many advantages, including effective use of available power, conservation of bandwidth, and insensitivity to some forms of random fading in the channel. In double-sideband suppressed carrier (DSB/SC) systems the spectrum of the modulating signal appears in its entirety in two places in the transmitted spectrum. Single-sideband modulation eliminates this redundancy, thus conserving bandwidth and increasing the signal-to-noise ratio within the remaining portion of the spectrum that is transmitted.

In Figure P8.29(a), two systems for generating an amplitude-modulated single-sideband signal are shown. The system on the top can be used to generate a single-sideband signal for which the lower sideband is retained, and the system on the bottom can produce a single-sideband signal for which the upper sideband is retained.



(a)

8.29: Double-Sideband Suppressed Carrier, Phase-Shift Method

(a) For $X(j\omega)$ as shown in Figure P8.29(b), determine and sketch $S(j\omega)$, the Fourier transform of the lower sideband modulated signal, and $R(j\omega)$, the Fourier transform of the upper sideband modulated signal. Assume that $\omega_c > \omega_3$.

The upper sideband modulation scheme is particularly useful with voice communication, as any real filter has a finite transition region for the cutoff (i.e., near ω_c). This region can be accommodated with negligible distortion, since the voice signal does not have any significant energy near $\omega = 0$ (i.e., for $|\omega| < \omega_1 = 2\pi \times 40$ Hz).

(b) Another procedure for generating a single-sideband signal is termed the *phase-shift method* and is illustrated in Figure P8.29(c). Show that the single-sideband signal generated is proportional to that generated by the lower sideband modulation scheme of Figure P8.29(a) [i.e., $p(t)$ is proportional to $s(t)$].

(c) All three AM-SSB signals can be demodulated using the scheme shown on the right-hand side of Figure P8.29(a). Show that, whether the received signal is $s(t)$, $r(t)$, or $p(t)$, as long as the oscillator at the receiver is in phase with oscillators at the transmitter, and $w = \omega_c$, the output of the demodulator is $x(t)$.

The distortion that results when the oscillator is not in phase with the transmitter, called *quadrature distortion*, can be particularly troublesome in data communication.