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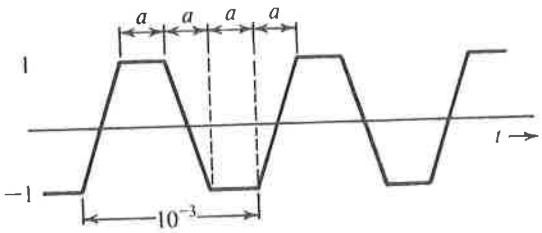
PROBLEMS

5.1-1 Sketch $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$ for the modulating signal $m(t)$ shown in Fig. P5.1-1, given $\omega_c = 10^8$, $k_f = 10^5$, and $k_p = 25$.

Figure P.5.1-1

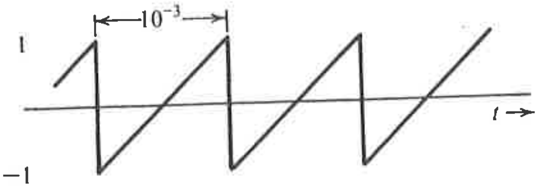


5.1-2 A baseband signal $m(t)$ is the periodic sawtooth signal shown in Fig. P5.1-2.

(a) Sketch $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$ for this signal $m(t)$ if $\omega_c = 2\pi \times 10^6$, $k_f = 2000\pi$, and $k_p = \pi/2$.

(b) Show that the PM signal is equivalent to a PM signal modulated by a rectangular periodic message. Explain why it is necessary to use $k_p < \pi$ in this case. [Note that the PM signal has a constant frequency but has phase discontinuities corresponding to the discontinuities of $m(t)$.]

Figure P.5.1-2



5.1-3 Over an interval $|t| \le 1$, an angle-modulated signal is given by

$$\varphi_{EM}(t) = 10 \cos 13{,}000\pi t$$

It is known that the carrier frequency $\omega_c = 10{,}000\pi$.

(a) If this were a PM signal with $k_p = 1000$, determine $m(t)$ over the interval $|t| \le 1$.

(b) If this were an FM signal with $k_f = 1000$, determine $m(t)$ over the interval $|t| \le 1$.

5.2-1 For a message signal

$$m(t) = 2\cos 100t + 18\cos 2000\pi t$$

(a) Write expressions (do not sketch) for $\varphi_{PM}(t)$ and $\varphi_{FM}(t)$ when $A = 10$, $\omega_c = 10^6$, $k_f = 1000\pi$, and $k_p = 1$. For determining $\varphi_{FM}(t)$, use the indefinite integral of $m(t)$; that is, take the value of the integral at $t = -\infty$ to be 0.

(b) Estimate the bandwidths of $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$.

5.2-2 An angle-modulated signal with carrier frequency $\omega_c = 2\pi \times 10^6$ is described by the equation

$$\varphi_{EM}(t) = 10\cos(\omega_c t + 0.1\sin 2000\pi t)$$

(a) Find the power of the modulated signal.

(b) Find the frequency deviation Δf.

(c) Find the phase deviation $\Delta\phi$.

(d) Estimate the bandwidth of $\varphi_{EM}(t)$.

5.2-3 Repeat Prob. 5.2-2 if

$$\varphi_{EM}(t) = 5\cos(\omega_c t + 20\sin 1000\pi t + 10\sin 2000\pi t)$$

5.2-4 Estimate the bandwidth for $\varphi_{PM}(t)$ and $\varphi_{FM}(t)$ in Prob. 5.1-1. Assume the bandwidth of $m(t)$ in Fig. P5.1-1 to be the third-harmonic frequency of $m(t)$.

5.2-5 Estimate the bandwidth for $\varphi_{PM}(t)$ and $\varphi_{FM}(t)$ in Prob. 5.1-2. Assume the bandwidth of $m(t)$ in Fig. P5.1-1 to be the fifth-harmonic frequency of $m(t)$.

5.2-6 Given $m(t) = \sin 2000\pi t$, $k_f = 200{,}000\pi$, and $k_p = 10$.

(a) Estimate the bandwidths of $\varphi_{FM}(t)$ and $\varphi_{PM}(t)$.

(b) Repeat part **(a)** if the message signal amplitude is doubled.

(c) Repeat part **(a)** if the message signal frequency is doubled.

(d) Comment on the sensitivity of FM and PM bandwidths to the spectrum of $m(t)$.

5.2-7 Given $m(t) = e^{-t^2}$, $f_c = 10^4$ Hz, $k_f = 6000\pi$, and $k_p = 8000\pi$:

(a) Find Δf, the frequency deviation for FM and PM.

(b) Estimate the bandwidths of the FM and PM waves.
Hint: Find $M(f)$ and find its 3 dB bandwidth ($B \ll \Delta f$).

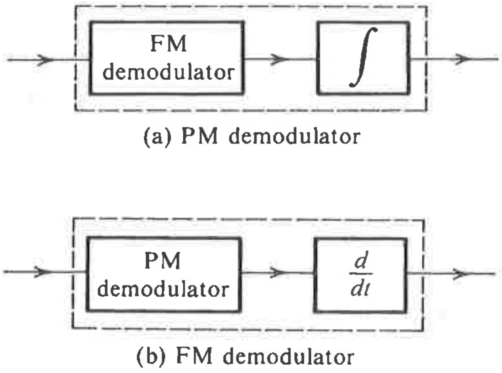
5.3-1 Design (only the block diagram) an Armstrong indirect FM modulator to generate an FM carrier with a carrier frequency of 98.1 MHz and $\Delta f = 75$ kHz. A narrowband FM generator is available at a carrier frequency of 100 kHz and a frequency deviation $\Delta f = 10$ Hz. The stock room also has an oscillator with an adjustable frequency in the range of 10 to 11 MHz. There are also plenty of frequency doublers, triplers, and quintuplers.

5.3-2 Design (only the block diagram) an Armstrong indirect FM modulator to generate an FM carrier with a carrier frequency of 96 MHz and $\Delta f = 20$ kHz. A narrowband FM generator with $f_c = 200$ kHz and adjustable Δf in the range of 9 to 10 Hz is available. The stock room also has an oscillator with adjustable frequency in the range of 9 to 10 MHz. There is a bandpass filter with any center frequency, and only frequency doublers are available.

5.4-1 (a) Show that when $m(t)$ has no jump discontinuities, an FM demodulator followed by an integrator (Fig. P5.4-1a) forms a PM demodulator. Explain why it is necessary for the FM demodulator to remove any dc offset before the integrator.

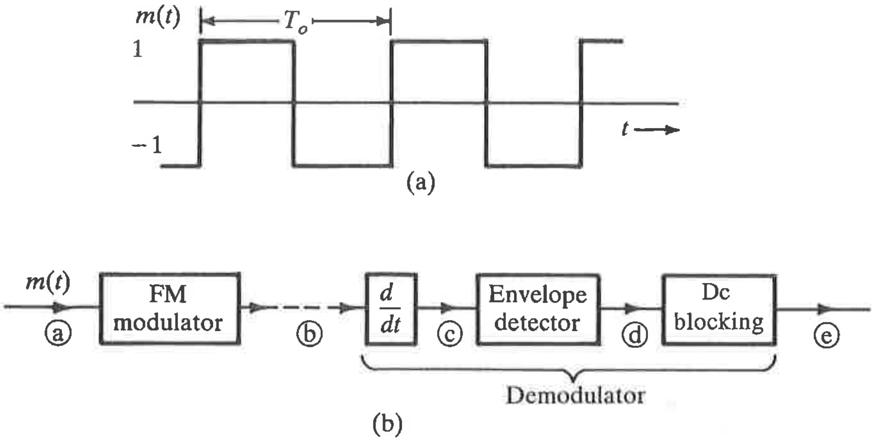
(b) Show that a PM demodulator followed by a differentiator (Fig. P5.4-1b) serves as an FM demodulator even if $m(t)$ has jump discontinuities or if the PM demodulator output has dc offset.

Figure P.5.4-1



5.4-2 A periodic square wave $m(t)$ (Fig. P5.4-2a) frequency-modulates a carrier of frequency f_c = 10 kHz with Δf = 1 kHz. The carrier amplitude is A. The resulting FM signal is demodulated, as shown in Fig. P5.4-2b by the method discussed in Sec. 5.4 (Fig. 5.12). Sketch the waveforms at points b, c, d, and e.

Figure P.5.4-2



5.4-3 Use small-error PLL analysis to show that a first-order loop [$H(s) = 1$] cannot track an incoming signal whose instantaneous frequency is varying linearly with time [$\theta_i(t) = kt^2$]. This signal can be tracked within a constant phase if $H(s) = (s + a)/s$. It can be tracked with a zero phase error if $H(s) = (s^2 + as + b)/s^2$.

5.6-1 A transmitter transmits an AM signal with a carrier frequency of 1500 kHz. When an inexpensive radio receiver (which has a poor selectivity in its RF-stage bandpass filter) is tuned to 1500 kHz, the signal is heard loud and clear. This same signal is also heard (not as well) at another dial setting. State, with reasons, at what frequency you will hear this station. The IF frequency is 455 kHz.

5.6-2 Consider a superheterodyne FM receiver designed to receive the frequency band of 1 to 30 MHz with an IF frequency 8 MHz. What is the range of frequencies generated by the local oscillator for this receiver? An incoming signal with a carrier frequency of 10 MHz is received at the 10 MHz setting. At this setting of the receiver, we also get interference from a signal with some other carrier frequency if the receiver RF-stage bandpass filter has poor selectivity. What is the carrier frequency of the interfering signal?