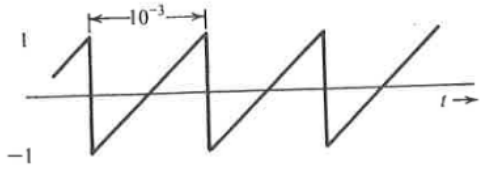
**5.1-2** A baseband signal $m(t)$ is the periodic sawtooth signal shown in Fig. P5.1-2.

**(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 $|t| \leq 1$, 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 $|t| \leq 1$.

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

**5.2-1** For a message signal

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

**(a)** Write expressions (do not sketch) for $\varphi_{\text{PM}}(t)$ and $\varphi_{\text{FM}}(t)$ when $A = 10$, $\omega_c = 10^6$, $k_f = 1000\pi$, and $k_p = 1$. For determining $\varphi_{\text{FM}}(t)$, 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 $\varphi_{\text{FM}}(t)$ and $\varphi_{\text{PM}}(t)$.

**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 $\Delta f$.

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

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

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

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

**(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 $m(t)$.

**5.3-1** 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 $\Delta f$ 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.

**5.6-1** 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.