

## Homework 5

### 1. FM Modulation/Bandwidth (15 points)

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

$$s(t) = 10 \cos(\omega_c t + 0.1 \sin 2000\pi t)$$

- Determine the power of the modulated signal.
- Find the frequency deviation  $\Delta f$ .
- Estimate the bandwidth of  $s(t)$ .

### 2. FM Modulation/Bandwidth (25 points)

Given  $m(t) = \sin 2000\pi t$ ,  $k_f = 200,000\pi$ , and  $k_p = 10$ ,

- Express  $s_{FM}(t)$  and  $s_{PM}(t)$ .
- Estimate the bandwidth of  $s_{FM}(t)$  and  $s_{PM}(t)$ .
- Repeat part (b) if the message signal amplitude is doubled.
- Repeat part (b) if the message signal frequency is doubled.
- Comment on the sensitivity of FM and PM bandwidths to the spectrum of  $m(t)$ .

### 3. Armstrong indirect FM (20 points)

Design the block diagram of an Armstrong indirect FM modulator to generate an FM signal with carrier 96.3 MHz and  $\Delta f = 20.48$  kHz. A narrowband FM generator with  $f_c = 150$  kHz and  $\Delta f = 10$  Hz is available. Only a limited number of frequency doublers are available as frequency multipliers. In addition, an oscillator with adjustable frequency from 13 to 14 MHz is also available for mixing, along with bandpass filters of any specification.

### 4. FM Modulation/Demodulation (20 points)

A periodic square wave  $m(t)$  (see Figure 2) frequency-modulated a carrier of  $f_c = 10$  kHz with  $\Delta f = 1$  kHz, and amplitude  $A$ . The resulting FM signal is demodulated as shown in the figure. Sketch the waveform at the points (b), (c), (d), and (e).

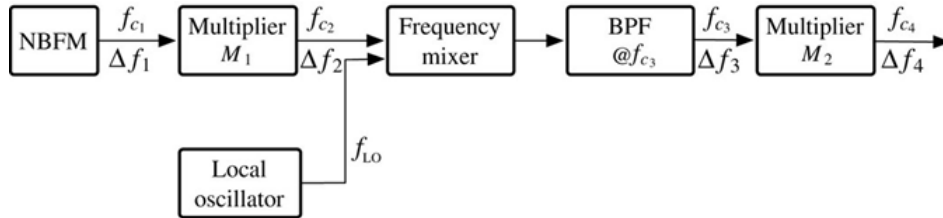


Figure 1: Problem 3

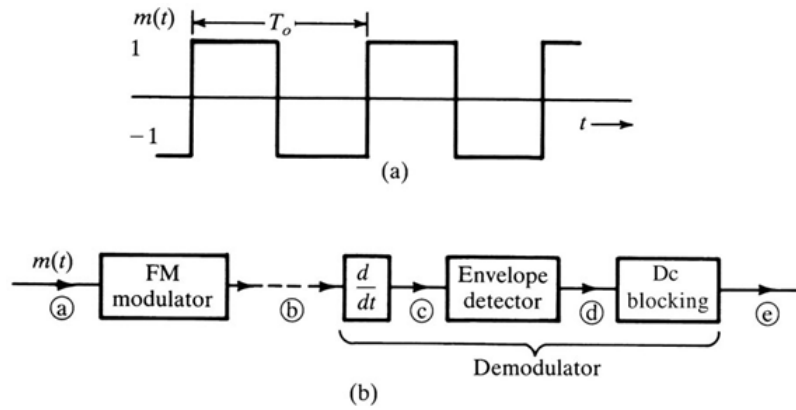


Figure 2: Problem 4

**5. Superheterodyne Receiver** (20 points)

In shortwave AM radio the IF is 455 kHz. A receiver is designed to receive shortwave broadcasting of 31-meter band between 9.4 and 9.9 MHz. Find

- (a) the local oscillator tuning range for this receiver,
- (b) analyze and explain whether it is possible for this receiver to receive both a desired AM station and an image station within the same 31-meter band.