## Homework 5 (Due on Oct. 23)

1. (Definition of FM) (10pts)

An FM modulator has output $x_c(t) = 10\cos[2\pi f_c t + 2\pi f_d \int_0^t m(\tau)d\tau]$, where $f_d = 20$ Hz/Volt. Assume that $m(t) = 3\Lambda(\frac{1}{3}(t-3))$, as shown in Figure 1.

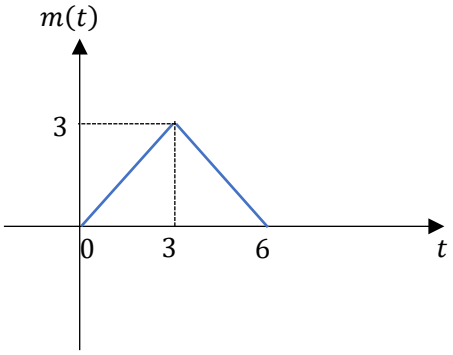


Figure 1

1) Determine the phase deviation in radians.
2) Determine the frequency deviation in hertz.
3) Determine the peak frequency deviation in hertz.
4) Determine the peak phase deviation in in radians.

2. (Definition of PM) (10pts)

A PM modulator has output $x_c(t) = 10\cos[2\pi f_c t + k_p m(t)]$, where $k_p = 20$ radians/Volt. Assume that $m(t) = 3\Lambda(\frac{1}{3}(t-3))$, as shown in Figure 1.

1) Determine the phase deviation in radians.
2) Determine the frequency deviation in hertz.
3) Determine the peak frequency deviation in hertz.
4) Determine the peak phase deviation in in radians.

3. (Parameters of FM: modulation index, spectrum and bandwidth) (40pts)

An FM modulator has $f_c = 2000$ Hz and $f_d = 20$ Hz/Volt. The modulating message signal is $m(t) = 5\cos 20\pi t$.

1) What's the peak frequency deviation?
2) What's the modulation index?
3) Is this narrowband FM? Why?
4) If the same $m(t)$ is used for a phase modulator, what must $k_p$ be to yield the modulation index given in 1)?
5) Determine the approximate bandwidth of the FM signal, using Carson's rule.
6) Determine the bandwidth by transmitting only those side frequencies whose amplitudes exceed 1 percent of the unmodulated carrier amplitude. Use the Table

from Page 163 for this calculation. (Hint: find $n_{max}$, which is the largest value of the integer that satisfies the requirement $J_n(\beta) > 0.01$. Then $B = 2n_{max}f_m$.)

7) Repeat your calculations in 5), assuming that the amplitude of the modulating signal $m(t)$ is doubled. (Hint: $m(t) = 10\cos 20\pi t$.)
8) Repeat your calculations in 5), assuming that the frequency of the modulating signal $m(t)$ is doubled. (Hint: $m(t) = 5\cos 40\pi t$.)

## 4. (Bandwidth of Wideband PM) (20pts)

Consider a PM signal produced by a sinusoidal modulating wave $m(t) = A_m \cos 2\pi f_m t$ using a modulator with a phase deviation constant equal to $k_p$ radians per volt. The unmodulated carrier wave has frequency $f_c$ and amplitude $A_c$.

1) Show that if the maximum phase deviation of the PM signal is much larger than 1 radian, the bandwidth of the PM signal varies linearly with the modulation frequency $f_m$.
2) Compare this characteristic of a wideband PM signal with that of the corresponding wideband FM signal.

## 5. (Generation of Wideband FM Signal) (20pts)

A narrowband FM has a carrier frequency of 110 kHz and a deviation ratio of 0.05. The bandwidth of the modulating message signal is 10 kHz. This narrowband FM signal is used to generate a wideband FM signal with a deviation ratio of 20 and a carrier frequency of 100 MHz. We use the Armstrong indirect FM transmitter in Figure 2 to accomplish this. Give the required value of frequency multiplication n. Also, fully define the mixer by giving two permissible frequencies for the local oscillator, and define the required bandpass filter (the center frequency and the bandwidth using Carson's rule).

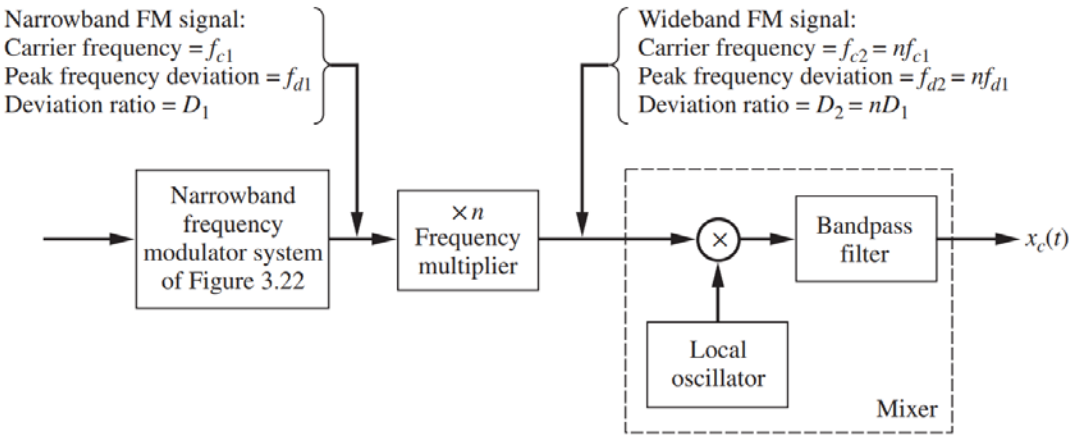


Figure 2