

Homework 5

ECE 340A: Introduction to Communications

Fall 2025

- Date Assigned: Thursday, October 30, 5:00 pm MST
 - Due Date and Time: Thursday, November 13, 11:59 pm MST (**submit on D2L**)
 - Maximum Credit: 100 points
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1. [20 points] An angle modulated signal is given as

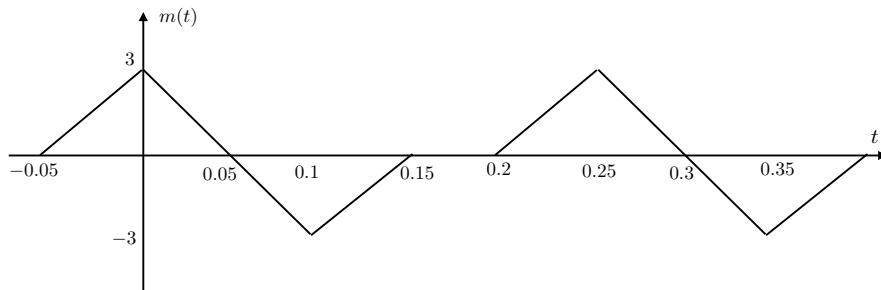
$$\phi(t) = 8 \cos(\omega_c t + 2 \sin(5000\pi t))$$

with carrier frequency 1 MHz.

- (a) Find the power of the modulated signal.
- (b) Find the frequency deviation and the phase deviation.
- (c) Find the bandwidth of the modulated signal.
- (d) Repeat the above parts when the signal is

$$\phi(t) = 7 \cos(\omega_c t + 10 \sin(1300\pi t) + 12 \cos(6000t)).$$

2. [20 points] A periodic message signal $m(t)$ shown in the figure below is transmitted as an angle-modulated signal. The carrier frequency is 1 kHz and the bandwidth of the message signal is approximated by its own 5th harmonic frequency.



- (a) To generate an FM signal, we are given $k_f = 15\pi$. Sketch the resulting time-domain FM signal and find its bandwidth.
 - (b) If instead a PM signal is generated from $m(t)$ with $k_p = \pi/2$, sketch the time-domain PM signal and find its bandwidth.
 - (c) Repeat parts (a) and (b) if the signal amplitude is doubled, i.e., $m(t)$ is changed to $2m(t)$.
 - (d) Repeat parts (a) and (b) if the signal bandwidth is instead approximated by the 3rd harmonic.
 - (e) Comment upon the differences between the resulting FM and PM signals when the signal bandwidth is changed vs the signal amplitude is changed.
3. [20 points] Consider the following pair of modulating signals:

$$m_1(t) = \begin{cases} a_1 t + a_0 & \text{if } t \geq 0, \\ 0 & \text{if } t = 0, \end{cases} \quad (1)$$

and

$$m_2(t) = \begin{cases} b_2 t^2 + b_1 t + b_0 & \text{if } t \geq 0, \\ 0 & \text{if } t = 0, \end{cases} \quad (2)$$

where the a 's and b 's are constant parameters.

Signal $m_1(t)$ is applied to a frequency modulator, whereas signal $m_2(t)$ is applied to a phase modulator. Determine the conditions (in terms of the constants) for which the outputs of these two angle modulators are exactly the same.

4. [20 points] Consider an FM system where the modulated signal is

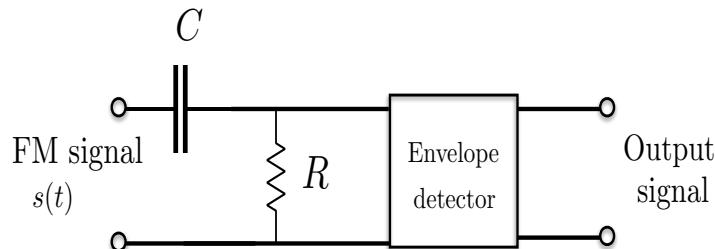
$$s(t) = 10 \cos \left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau \right)$$

with the carrier frequency being $f_c = 100$ MHz. The modulating signal is $m(t) = 10 \cos(2\pi f_m t)$, where $f_m = 3$ kHz.

- (a) What is the maximum value of k_f such that $s(t)$ can be demodulated using an ideal differentiator followed by an envelope detector?
 - (b) Assuming that $k_f = 10$, what is the approximate bandwidth of $s(t)$? Would you classify this as a narrow-band (NBFM) or a wide-band (WBFM) signal?
 - (c) Find the instantaneous frequency $f_i(t)$ of $s(t)$. What are the maximum and minimum values of $f_i(t)$?
5. [20 points] The FM signal

$$s(t) = A_c \cos \left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau) d\tau \right)$$

is applied to the system shown below,



which consists of an RC filter and an envelope detector. Assuming that RC is much smaller compared to the significant frequency components in $m(t)$, determine the resulting signal at the envelope detector, assuming that $k_f|m(t)| < f_c$ for all t .