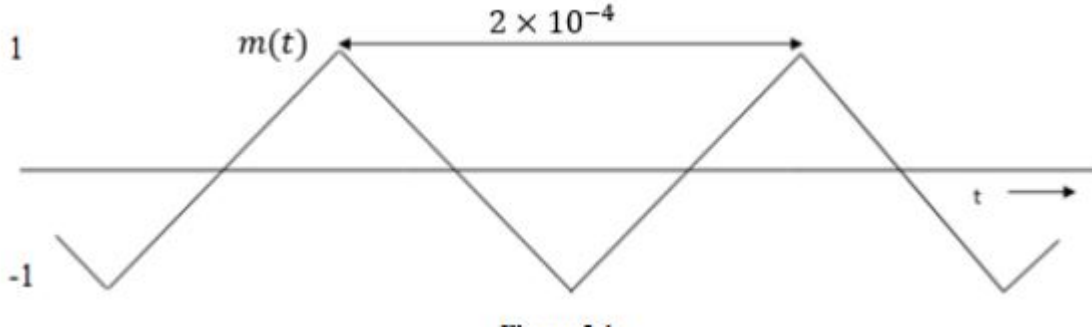# Homework 3

Communication Systems I (EE 341), Autumn 2021

1) The following problems from "Communication Systems" by Haykin and Moher, Fifth edition, Chapter 4: 4.1, 4.3, part (a) of 4.5, 4.6 to 4.12 on pp. 140-141.

2) Sketch PM and FM wave for the modulating signal shown below. The constant k_f and k_p are 10^5 and 10π, respectively, and the carrier frequency f_c is 100 MHz.

3) Consider a narrowband FM signal approximately defined by

$$s(t) \approx A_c cos(2\pi f_c t) - \beta A_c sin(2\pi f_c t) sin(2\pi f_m t) \tag{1}$$

   a) Determine the envelope of this modulated signal. What is the ratio of the maximum to the minimum value of this envelope?

   b) Determine the average power of the narrowband FM signal, expressed as a percentage of the average power of the unmodulated carrier wave.

   c) By expanding the angle $\theta_i(t)$ of the narrowband FM signal $s(t)$ in the form a power series, and restricting the modulation index β to a maximum value of 0.3 radians, show that

$$\theta_i(t) \approx 2\pi f_c t + \beta sin(2\pi f_m t) - \frac{\beta^3}{3} sin^3(2\pi f_m t) \tag{2}$$

   What is the power ratio of third harmonic to fundamental component for $\beta = 0.3$?

   Hint: For small x, the power series approximation $tan^{-1}(x) = x - \frac{1}{3}x^3$ holds.

4) A carrier wave of frequency 100MHz is frequency-modulated by a sinusoidal wave of amplitude 20 Volts and frequency 100kHz. The frequency sensitivity of the modulator is 25kHz per Volt.

   a) Determine the approximate bandwidth of the FM signal.

   b) Repeat the part (a) above, assuming that the amplitude of the modulated signal is doubled.

   c) Repeat the part (a) above, assuming the modulation frequency is doubled.

5) Consider an FM signal of carrier frequency f_c, which is produced by a modulating signal $m(t)$. Assume that f_c is large enough to justify treating this FM signal as a narrowband signal. Find an approximate expression for its Hilbert Transform.

6) Design (only the block diagram) an Armstrong indirect FM Modulator to generate an FM carrier with a carrier frequency of 98.1 MHz and $\triangle$ f = 75 KHz. A narrow band FM generator is available at a carrier frequency of 100 KHz and a frequency deviation $\triangle$f = 25 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 and triplers.