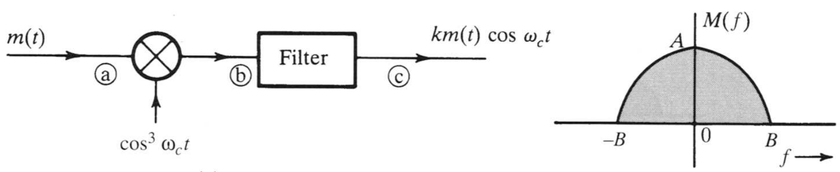
EE 179 | October 20, 2017
Digital and Analog Communication Systems | Handout #2

Homework #2

Due Monday, October 30

1. *DSB-SC modulator* (Lathi & Ding 4.2-3). You are asked to design a DSB-SC modulator to generate a modulated signal $km(t)\cos(\omega_c t + \theta)$, where $m(t)$ is a signal bandlimited to B Hz. Figure P4.2-3 shows a DSB-SC modulator available in the stockroom. The carrier generator available generates not $\cos\omega_c t$ but $\cos^3\omega_c t$. Explain whether you would be able to generate the design using only this equipment. You may use any kind of filter you like.



(a) (b)

   a. What kind of filter is required in Fig. P4.2.3?

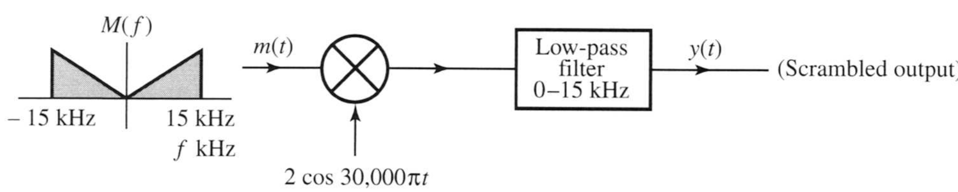
   b. Determine the signal spectra at points b and c, and indicate the frequency bands occupied by these spectra.

   c. What is the minimum usable value of ω_c?

   d. Would this scheme work in the carrier generator output were $\sin^3\omega_c t$? Explain.

   e. Would this scheme work in the carrier generator output were $\cos^n\omega_c t$ for any integer $n \geq 2$?

2. *Audio scrambler* (Lathi & Ding 4.2-8). The system shown in Fig. P4.2-8 is used for scrambling audio signals. The output $y(t)$ is the scrambled version of the input $m(t)$.

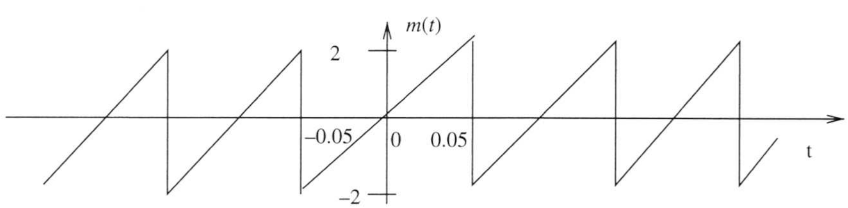


   a. Find the spectrum of the scrambled signal $y(t)$.

   b. Suggest a method for descrambling $y(t)$ to obtain $m(t)$.

3. *AM signal* (Lathi & Ding 4.3-1). In an amplitude modulation system, the message signal is given by Fig. P4.3-1 and the carrier frequency is 1 KHz. The modulator output is

$$s_{\mathrm{AM}}(t) = 2(b + 0.5m(t))\cos\omega_c t\,.$$



   a. Determine the average message power.

b. If $b = 1$, determine the modulation index and the modulation power efficiency.

c. Sketch the modulated signal of part (a) in the time domain.

d. If $b = 0.5$, repeat parts (a) and (b).

4. *Hilbert transform* (Lathi & Ding 4.4-5). Given that $m_h(t)$ is the Hilbert transform of $m(t)$, do the following.

   a. Show that the Hilbert transform of $m_h(t)$ is $-m(t)$.

   b. Show that the energies of $m(t)$ and $m_h(t)$ are identical.

5. *FM detection.*

   This problem illustrates design choices and limitations for certain FM detector designs. Consider an FM system where the modulated signal is

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

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

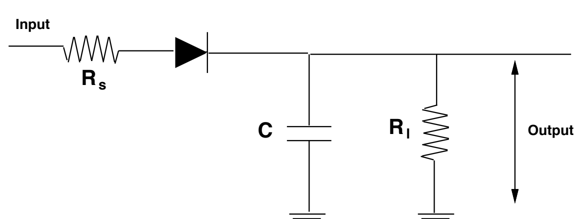
   a. What is the maximum value of k_f such that $s(t)$ can be demodulated using an ideal differentiator followed by an envelope detector?

   For the remainder of the problem assume that $k_f = 10$.

   b. What is the approximate bandwidth of $s(t)$? Is this NBFM or WBFM?

   c. Find the instantaneous frequency $f_i(t)$ of $s(t)$. What are the maximum and minimum values of $f_i(t)$?

   d. Suppose that you demodulate $s(t)$ using an ideal differentiator followed by an envelope detector. Assume a standard envelope detector as shown below, where the capacitor has capacitance $C = 10^{-9}$ F. Propose values for the source resistance R_s and load resistance R_l such that the output of the envelope detector is approximately equal to $c_1 + c_2 m(t)$ for some constants c_1 and c_2. Is it possible to use this detection method if $f_c \approx f_m$? Why or why not?



   e. Suppose that you use a zero-crossing detector for $s(t)$. Find an expression for the minimum interval T for a zero-crossing detector such that there are at least four zero crossings in every interval T. Evaluate this expression.