

EECS 562  
Homework 7

1. (Concept: DSB-LC)

A DSB-LC signal can be defined as  $y_{RF}(t) = A_c(1 + k_a x_{bb}(t)) \cos(2\pi f_c t)$ .  $k_a$  is the amplitude sensitivity of the modulator. For a message signal of  $x_{bb}(t) = 8 \cos(2\pi f_m t)$  volts where  $f_m = 25$  Hz and the unmodulated RF signal of is  $1000 \cos(2\pi f_c t)$  volts where  $f_c = 1$  kHz and a the percent modulation (sometimes called modulation index or modulation factor) of 50%, 75%, 100% and answer the following questions.

- Find  $A_c$  and  $k_a$ .
- Plot the RF signal in the time domain to scale.
- What is the total RF transmitted power for a modulation index=1, assume a 1 ohm load.
- What is the power in the carrier wave modulation index=1, assume a 1 ohm load.
- What is the RF bandwidth?
- Plot the one-sided power spectral density of the RF signal modulation index=1.
- What is the impact of overmodulation, e.g., a modulation index of 125%, on the RF signal in the time domain?

2. (Concept: Digital Modulation using DSB-LC: Amplitude Shift Keying)

For a sequence of information bits  $b_i = \{1, 1, 0, 1, 1, 0\}$ ;  $i=1..6$ , the baseband message signal is formed as

$$m(t) = \sum_{i=1}^6 b_i \text{rect}(t - (i-1) - 0.5)$$

- Plot  $m(t)$
- The baseband message signal is transmitted with DSB-LC with 25% percent modulation plot the RF time-domain signal (use  $f_c = 10$  Hz)
- For 100% AM percent modulation plot the RF time-domain signal (use  $f_c = 10$  Hz)
- Can an envelope detector be used to recover the transmitted bits?

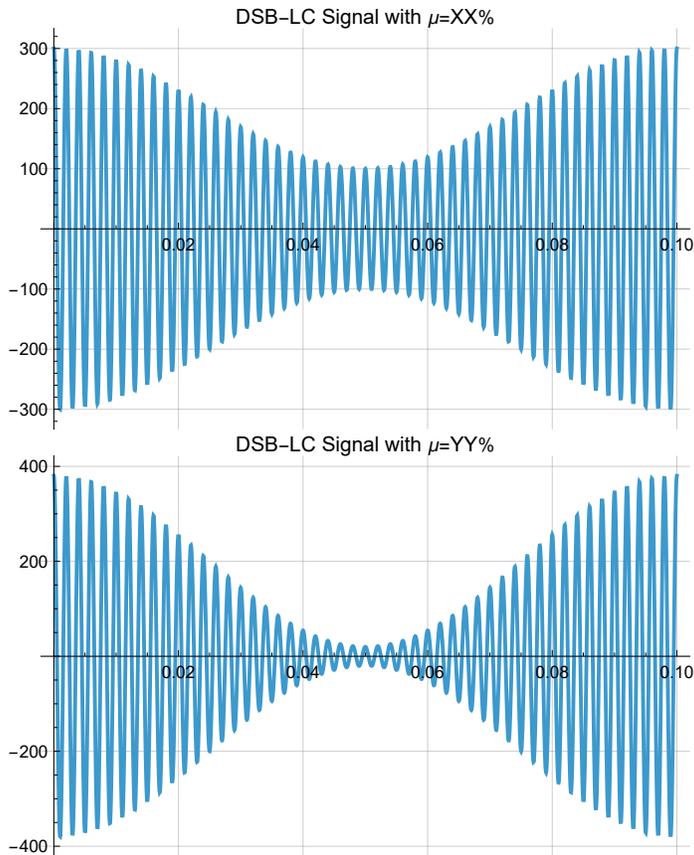
3. (Concept: Power in DSB-LC signals)

Let  $s(t)$  be an DSB-LC (AM) signal. The unmodulated transmitted power is 300 KW. The message signal is  $x_{bb}(t) = \cos(2\pi f_m t)$ . The power in the sidebands is 100 KW.

- Find the corresponding carrier amplitude,  $A_c$
- What is the modulation factor?
- What is the power efficiency?
- What is the RF bandwidth?

4. (Concept: Measuring the modulation index)

An DSB-LC RF signals are plotted in the time domain below. What is the modulation index (modulation factor) for each signal?



**5. (Concept: Spectrum of Digital Modulation using DSB-LC: Amplitude Shift Keying)**

Consider a sequence of information bits  $b_i \{ \dots, 0, 1, 0, 1, 0, 1, 0, 1, \dots \}$ , That is, alternating 0's and 1's. A baseband analog message signal is formed using the following mapping:

$$a_i = -1 \text{ if } b_i = 0$$

$$a_i = +1 \text{ if } b_i = 1,$$

The baseband signal is

$$x_{bb}(t) = \sum_{k=-\infty}^{\infty} a_k \text{rect}\left(\frac{t - kT_b/2}{T_b}\right)$$

Set the bit rate to 100 bits/sec,  $T_b = 10\text{ms}$ .

- Plot  $x_{bb}(t)$ .
- What is the DC (or average value) of  $m(t)$ ?
- Find the Fourier Series of  $x_{bb}(t)$  and plot its one sided amplitude spectrum.
- DSB-LC (AM) modulation is used to transmit  $x_{bb}(t)$  with a unmodulated carrier  $100 \cos(2\pi f_c t)$  with  $f_c = 10\text{kHz}$ . Plot the RF amplitude spectrum for 90% AM percent modulation.

**6. (Concept: DSB-LC modulator using a square-law device)**

A square-law modulator for generating an DSB-LC signals relies on the use of a nonlinear device (e.g., diode). Ignoring higher order terms, the input-output characteristic of the diode-load resistor circuit is represented by a square law, i.e.,  $v_{out}(t) = a_1 v_{in}(t) + a_2 v_{in}^2(t)$

- With  $x_{in}(t) = A \cos(2\pi f_c t) + x_{bb}(t)$  where  $x_{bb}(t)$  has a bandwidth  $B_{bb}$ . Find  $v_{out}(t)$  and identify the terms that represent a DSB-LC signal.
- Draw the block diagram of a DSB-LC modulator that uses a square law device as defined in this problem.

7. (Concept: Role of DC blocking capacitor in an envelope detector)
  - a. Explain why a DC blocking capacitor is required in an envelope detector.
  - b. What is the impact of the DC blocking capacitor is required in an envelope detector on the performance of commercial AM radio receivers.