Communication Theory
Spring-2025

Assignment 2 **Deadline: February 20th 11:59 PM**

Instructions:

- All questions are compulsory.
- Clearly state the assumptions *(if any)* made that are not specified in the questions.
- MATLAB Submission Format : Attach the MATLAB code along with the figures and zip it.
- Submission format: `Rollnumber.pdf`

Cautions:

(a) One late homework assignment is allowed without penalty.

(b) 2 marks will be deducted on other late assignments.

Questions

1. For the baseband signal $m(t) = \cos(1000\pi t)\cos(3000\pi t)$ do the following:

   (a) Sketch the spectrum of $m(t)$.

   (b) Sketch the spectrum of the DSB-SC signal $m(t)\cos(10,000\pi t)$.

   (c) Identify the upper sideband (USB) and the lower sideband (LSB) spectra.

   (d) Identify the frequencies in the baseband and the corresponding frequencies in the DSB-SC, USB, and LSB spectra. Explain the nature of frequency shifting in each case.

2. The message signal $m(t) = 2 * \cos 400t + 4 * \sin(500t + \pi/3)$ modulates the carrier signal $c(t) = A * \cos(8000\pi * t)$ using DSB amplitude modulation. Find the time-domain and frequency-domain representations of the modulated signal and plot the spectrum (Fourier transform) of the modulated signal. What is the power content of the modulated signal?

3. Two signals $m_1(t)$ and $m_2(t)$, both band-limited to 5000 Hz, are to be transmitted simultaneously over a channel by the multiplexing scheme shown in the below figure. The signal at point b is the multiplexed signal, which now modulates a carrier of frequency 20,000 Hz. The modulated signal at point c is transmitted over a channel.

   (a) Sketch signal spectra at points a, b, and c.

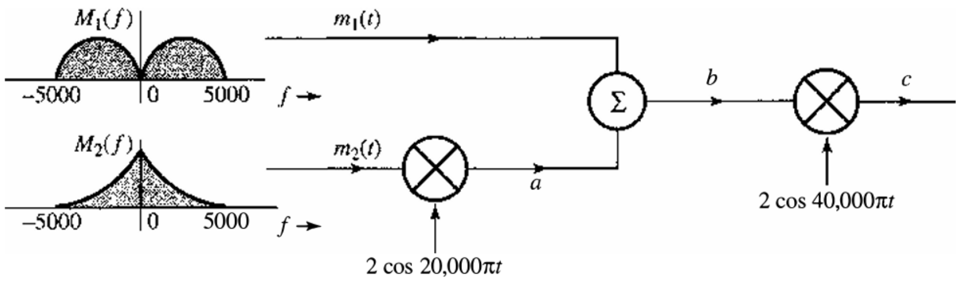

Figure 1

(b) What must be the bandwidth of the channel?

(c) Design a receiver to recover signals $m_1(t)$ and $m_2(t)$ from the modulated signal at point c.

4. In a DSB system, the carrier is $c(t) = A * \cos 2\pi f_c t$ and the message signal is given by $m(t) = sinc(t) + sinc^2(t)$. Find the frequency-domain representation and the bandwidth of the modulated signal.

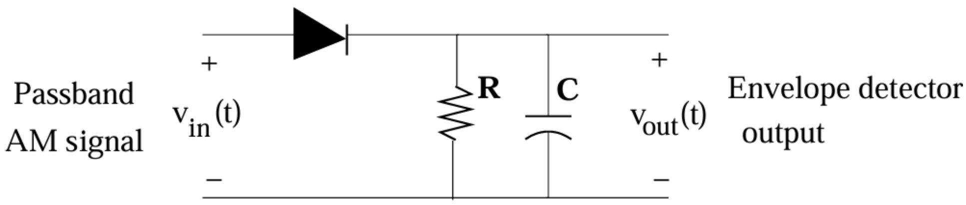

Figure 2

5. A message to be transmitted using AM is given by $m(t) = 3\cos 2\pi t + 4\sin 6\pi t$ where the **unit of time is milliseconds**. It is to be sent using a carrier frequency of 600 KHz.

(a) What is the message bandwidth? Sketch its magnitude spectrum, clearly specifying the units used on the frequency axis.

(b) Find an expression for the normalized message $m_n(t)$

(c) For a modulation index of 50%, write an explicit time domain expression for the AM signal.

(d) What is the power efficiency of the AM signal?

(e) Sketch the magnitude spectrum for the AM signal, again clearly specifying the units used on the frequency axis.

(f) The AM signal is to be detected using an envelope detector (as shown in the above figure), with $R = 50\Omega$. What is a good range of choices for the capacitance C?

6. Consider the modulation system shown in fig. 1 and message signal shown in fig. 2. The bandpass filter has a bandwidth of 2W centered at f_0 and the lowpass filter has a bandwidth of W. Plot the spectra of the signals x(t), y1(t), y2(t), y3(t) and y4(t). Determine the bandwidths of these signals.

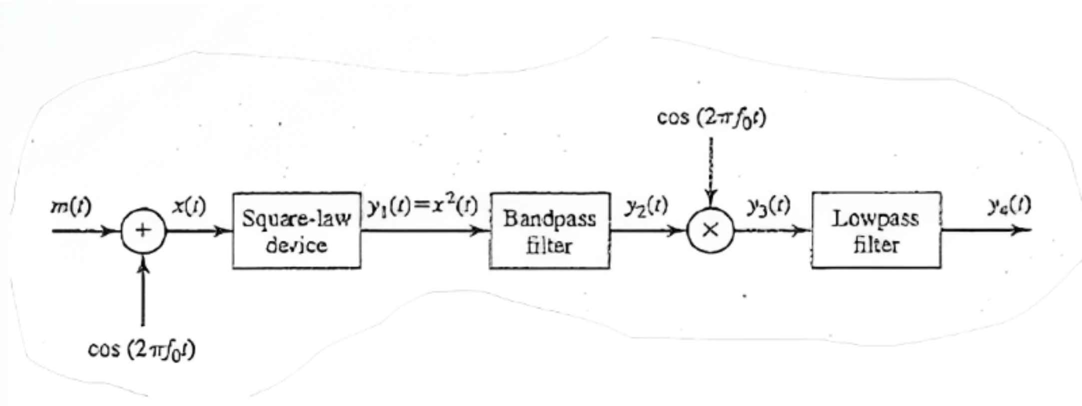

Figure 3: Modulation system

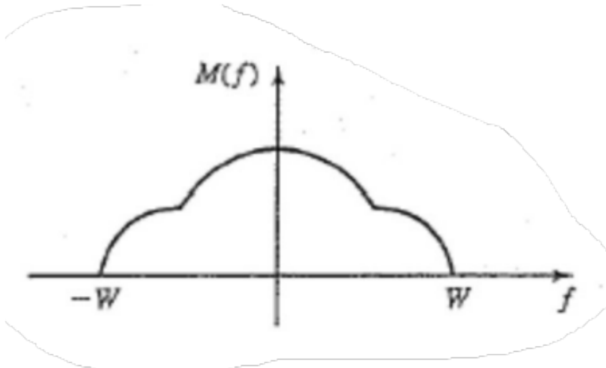

Figure 4: Message signal

MATLAB

7. In this question, you will implement DSB-SC modulation and then perform demodulation, using a few different methods.

   You will use the following signals:

   Message signal:

   $$m(t) = A_m \sin(2\pi f_m t) \tag{1}$$

   Carrier signal:

   $$c(t) = A_c \cos(2\pi f_c t) \tag{2}$$

   with carrier amplitude $A_c = 1$, message amplitude $A_m = 1$, frequency $f_m = 10$ KHz. and frequency $f_c = 100$ MHz.

   It is advised to make separate functions for each of the schemes, and one for demodulation, so that they can be called from the main script.

   Modulation:

   (a) **Multiplier modulator:** This is the simplest modulation scheme (in code, not in hardware, that's why it is not very commonly used), where an analog multiplier is used to produce an output signal that is proportional to the product of the message and carrier. This is very easy in MATLAB. Just multiply the two signals. This is a good warm-up for the following schemes.

(b) **Switching modulation:** Here, we use a periodic square pulse to get a high-bandwidth signal, and then use a low-pass filter to get only the desired first harmonic AM component. Use a square pulse with no DC offset so that you do not get a message signal component at zero frequency.

Plot the message signal, and the above modulated signals in a 2×2 subplot. For parts (b) and (c) you can perform frequency domain filtering (using in-built functions FFT and IFFT).

Demodulation:

You can use the transmitted signals obtained using any of the above schemes for this task (as long as the output is correct). Use a switching demodulator, which involves multiplying by the same square pulse, then using a low-pass filter to get the message signal $m(t)$.

Plot in a 1×2 subplot, the original message signal and the demodulated signal.

Phase shift effects: One of the main problems with DSB-SC modulation schemes is coherent detection. Here we will analyze the effect of phase shifts in the received signals w.r.t. the carrier on demodulation.

Repeat the demodulation performed prior to this, but use a carrier with the following frequency and phase offsets:

(a) $\Delta f = 0$ and $\Delta\theta = \frac{\pi}{3}$

(b) $\Delta f = 5$ Hz and $\Delta\theta = 0$

(c) $\Delta f = 5$ Hz and $\Delta\theta = \frac{\pi}{3}$

Frequency spectrum: Now plot the frequency spectrum of the message signal, modulated signal, and demodulated signal in a 3×1 plot.

8. Generate a triangular message signal of frequency 500 Hz and peak amplitude 1, along with a sinusoidal carrier signal of frequency 15 kHz and peak amplitude 10. Implement Amplitude Modulation (AM) without using built-in functions.

   (a) Plot the message signal, carrier signal, and AM waveforms using subplots.

   (b) Demodulate the AM wave using an envelope detector for three different modulation index (μ) values: 0.5, 1, and 1.2. Compare the recovered message signals corresponding to different μ values by plotting them together with the original message signal in a single figure. Observe and discuss the effect of different modulation index on signal recovery.

   (c) Plot the spectrum of the message signal, modulated AM signal, and the recovered message signal on a single figure.