Lab 4

Introduction to Modulation

4.1 Pre-Lab

1. For the amplitude modulation system shown in Equations (4.1) and (4.2) and Figure 4.1, sketch the spectra $X(\omega)$, $C(\omega)$, and $Y(\omega)$ of $x(t)$, $c(t)$, and $y(t)$ respectively, where

$$x(t) = A\cos(\omega_m t) \tag{4.1}$$
$$c(t) = A\cos(\omega_c t), \qquad \omega_c \gg \omega_m \tag{4.2}$$

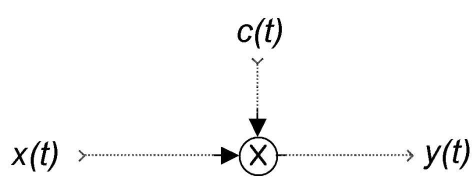

Figure 4.1: Modulation system for Problem 1

2. Design a demodulator for the system in Problem 1 to regain $x(t)$ from $y(t)$.

3. Now let $c(t) = A\cos(\omega_c t + \theta_c)$. Angle modulation (which includes frequency and phase modulation) uses $x(t)$ to vary the angle $\omega_c t + \theta_c$ of $c(t)$. For <u>phase modulation</u>, we have

$$y(t) = A\cos(\omega_c t + \theta(t)) \qquad \text{where } \theta(t) = \theta_0 + k_p x(t) \tag{4.3}$$

For <u>frequency modulation</u>, we have

$$y(t) = A\cos(\theta(t)) \qquad \text{where } \frac{d\theta(t)}{dt} = \omega_c + k_p x(t) \tag{4.4}$$

Let $x(t) = B$ (a constant). Determine the expression for $y(t)$ for both phase and frequency modulation in this case.

4.2 Overview

In general, a modulation system is one in which one signal is used to control parameters of another signal. In the field of communications, modulation systems paly a key role and are used primarily to:

- Move the frequency of an information signal from baseband to a higher frequency that is more compatible with realizable antennas
- Multiplex signals in frequency to increase the capacity of a given channel with a specified bandwidth

In this lab we will observe the time and frequency domains of output signals of various types of modulation systems. We hope to confirm the results of the Pre-Lab exercise.

4.3 Procedure

1. Use the function generator to create an amplitude modulated signal. To do this, select the **AM** button. Select the sine wave as both the message and carrier signals. Set the message frequency to 10 kHz and the carrier to any frequency you like over 100 kHz.

2. On the oscilloscope observe both the message signal and modulated signals from the signal generator. After you have adjusted the peak-to-peak voltage to a sufficiently low value, observe the modulated signal on the spectrum analyzer. Record your observations.

3. Now vary the frequency of the carrier signal. What happens as you increase this frequency? What happens as you decrease it?
Now adjust the Percent Modulation. This is the parameter that changes the modulation index. Describe your observations as the modulation index increases or decreases.

4. As you look at the AM waveform, what changes do you notice when you select the message signal to be a square wave? Note and explain any changes in both the time and frequency domains.

5. Create a frequency modulation signal using the function generator. To do this, select the **FM** button. Again use sine waves for both the carrier and message signals.

6. On the oscilloscope observe both the message signal and the modulated signal from the signal generator. You should see a "ribbon-like" waveform

as the modulated signal. If you do not see this, adjust the **frequency deviation** in the signal generator. Also make sure that the **store** function on the oscilloscope is turned **off** at this time.

7. After you have adjusted the peak-to-peak voltage to a sufficiently low value, observe the modulated signal on the spectrum analyzer. Record your observations. Now adjust the frequency deviation and observe what happens to the bandwidth.