In the Name of God

Communication Systems (25751-4)

Python Assignment 02

Fall Semester 1402-03

Department of Electrical Engineering

Sharif University of Technology

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Due on Dey 1, 1402 at 23:59

($*$) starred problems are optional and have a bonus mark!

1 Amplitude Modulation

Consider the following signal

$$m(t) = e^{-6t}\big(u(t-4) - u(t-8)\big) + e^{6t}\big(u(-t-4) - u(-t-8)\big). \tag{1}$$

1.1

First, plot the signal in the time and frequency domains and declare its bandwidth; Then sample the signal at an appropriate rate. Explain how this rate is obtained.

1.2

By defining suitable parameters, modulate this signal with AM modulation. Plot the modulated signal and its spectrum.

1.3

The circuit shown in figure 1 is the simplest circuit to detect the signal envelope. Introduce the time constant and explain its effect on the output corresponding to this circuit. What effect do you think putting a resistor in series with a diode has on the output?

1.4

Write a function that takes the input signal, the time constant and the initial value of the output and gives the corresponding output. (for the detector in the previous part)

1.5

Demodulate the modulated signal with a coherent detector shown in figure 2.

1.6

Compare the output of these two methods together and with the original signal. Which of these 2 demodulation methods perform more accurate?

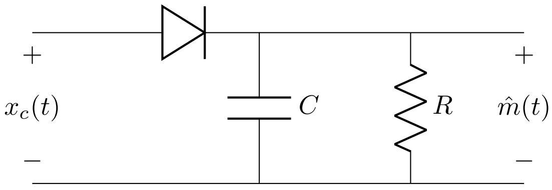

Figure 1: Envelope Detector

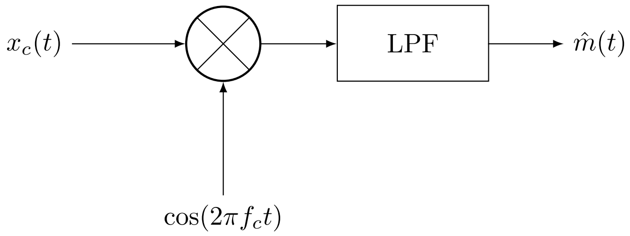

Figure 2: Coherent Detector

1.7

Modulate the primary signal using the Upper Single Side Band (USSB) method and create time and frequency domain plots. Then, demodulate the signal using the coherence demodulation method and generate time and frequency domain plots for the demodulated signal.

1.8

Repeat the previous part for LSSB modulation.

1.9

Compare the original message with the AM, USSB, and LSSB output and explain the reason for the difference. Also, compare the advantages and disadvantages of these three modulation methods.

1.10 $(*)$

Use a microphone to record your voice (Useful link). Then, apply the AM modulation method that you used in the second part of this question to your speech signal and plot the spectrum of the modulated signal. Next, use the two demodulation methods that you studied in the question to recover your speech signal and compare the outputs.

2 Frequency Modulation

In this section, we want to obtain the sent message from its FM modulated signal with three methods. We call the sent message $m(t)$ and we have:

$$m(t) = \sin(25\pi t) \qquad (0 \le t \le 1) \tag{2}$$

2.1

Sample this message at $f_s = 10$ kHz and obtain the FM signal with the following values.

$$x_c(t) = A_c \cos\left(2\pi f_c t + 2\pi f_\Delta \int_0^t m(\tau)d\tau\right) \qquad (A_c = 1,\ f_c = 200\text{Hz},\ f_\Delta = 30\text{Hz/V}) \tag{3}$$

2.2

With the help of `scipy.signal.detrend` and `scipy.signal.hilbert` command, restore the message signal ideally.

2.3

Taking the derivative of the signal $x_c(t)$ we will have:

$$x_d(t) = \frac{dx_c(t)}{dt} = -A_c\big(2\pi f_c t + 2\pi f_\Delta m(t)\big)\sin(2\pi f_c t + 2\pi f_\Delta \int_0^t m(\tau)d\tau) \tag{4}$$

If the frequency changes $\sin(2\pi f_c t + 2\pi f_\Delta \int_0^t m(\tau)d\tau)$ of the signal due to the message $m(t)$ are ignored compared to the frequency f_c, $(\frac{f_\Delta m(t)}{f_c} \approx 0)$ we can consider the x_d signal as an AM signal whose envelope contains the desired message. Restore the message using the Envelope Detector made in the first problem with new values for the resistor and capacitor.

2.4

We can also extract the message from the FM signal by using a **Zero Crossing Detector**. This method is based on the fact that the message value influences the instantaneous frequency of the FM signal. When the message value is high, the instantaneous frequency is also high, and when the message value is low, the instantaneous frequency is low. Therefore, we can estimate the frequency of the signal by counting the number of times it crosses zero. A high frequency signal will have more zero crossings than a low frequency signal. The block diagram in Figure 3 shows how we can use a Zero Crossing Detector to reveal the message from the FM signal

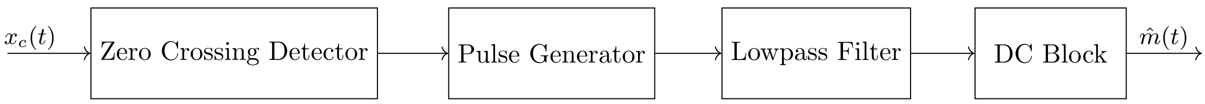

Figure 3: Zero Crossing Detector

A Zero Crossing Detector block can be implemented by taking the derivative of the signal $\text{sign}(x_c(t))$ and then finding the absolute value of the result. This will give us the locations where the signal crossed zero. The output of this block should be one only when a zero crossing occurs and zero otherwise. A Pulse Generator block can then produce a rectangular pulse for a short duration for each zero crossing. This way, we can recover the message from the FM signal.

2.5

On a graph, plot the message, the FM signal of the message, and the messages retrieved in the three methods.