Experiment
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Frequency Modulation (FM)
MATLAB Simulation

Objectives

The main objectives of this experiment are:

1) To gain a good understanding of Frequency Modulation.

2) To learn how to implement FM modulation & demodulation in software.

3) To demodulate an FM signal using the Differentiation (or Slope) technique.

Pre-Lab Work

1) Integration can be used to find the area under a given curve defined by some function f(u). Our concern in this experiment is to learn how to numerically integrate a function f(u) up to some point t (i.e. to get a function of t, say m(t)). To do so consider the following formula (i: is the index in MATLAB):

$$m = \frac{1}{length(f)} \sum_{i=1}^{length(f)} f(i)$$

Generate **f** = cos(2*pi*t) for **t** = 0:0.001:1. Find m? In order to speed up the time of computation, avoid using *for*-loops. Think of the functions: sum or cumsum. You also need to plot **f** vs. **t** and **m** vs. **t**.

2) How to differentiate a function in MATLAB? First, generate a function f in MATLAB like the one in Part 1. Use the function **diff(f)** and store it as a vector called **df**. Now plot **f** vs. **t** and **df** vs. **t**. What will happen? Type **whos** in the MATLAB command window to see the dimensions of **t**, **f**, and **df**, what do you notice? What do you need to be able to plot **df** vs. **t**? Think about the length of the **t** and **df** vectors. Read carefully how **diff(f)** works by typing ***help diff*** in the MATLAB command window.

Overview

Angle modulation includes both Frequency and Phase modulation schemes (FM and PM), which are characterized by their superior performance (compared to AM) in the presence of noise at the expense of higher bandwidth requirements. As you studied in class, FM and PM are very similar. In fact, an FM signal can be interpreted as PM signal and vice-versa (refer to your textbooks). As such, our focus in this lab will be on FM modulation exclusively.

An FM-modulated signal has its instantaneous frequency that varies linearly with the amplitude the message signal. For example, a message signal $x(t)$ causes the frequency of the FM signal $y(t)$ to vary linearly around a central carrier frequency f_c. The following formula describes this relationship:

$$y(t) = A_c \cos(2\pi f_c t + k_f \int_0^t x(\tau) d\tau)$$

Here, k_f is known as the sensitivity factor, and represents the frequency deviation rate as a result of message amplitude change. In practice, FM modulation is implemented by controlling the instantaneous frequency of a voltage-controlled oscillator (VCO). The amplitude of the input signal voltage controls the oscillation frequency of the VCO output signal.

FM signals can be demodulated using different techniques (refer to your textbook for details). Our focus in this experiment will be on the Slope Method, which uses a cascaded differentiator with an envelope detector circuit as illustrated in the diagram below The differentiator basically produces an AM-like signal that is then demodulated by the envelope detector block. Refer to your textbooks for the mathematical details of this method.
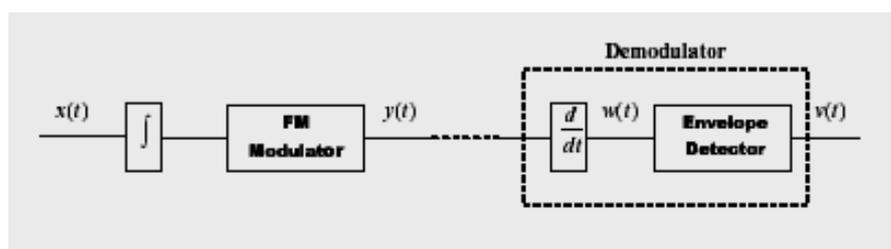
Lab Work

1) Implement the FM Modulator function for the message signal $x(t) = \sin(2\pi t)$. Use a carrier frequency of $f_c = 100$ Hz and a frequency sensitivity factor $k_f = 160\pi$.

2) Plot $x(t)$ and $y(t)$. Also, plot the magnitude spectrum for *y(t)*.

3) Next, implement the FM demodulator part.

4) Plot $w(t)$, and $v(t)$ both in Figure 3. You need to present only one period of the message signal with $t_s = 1/(10 f_c)$.

Useful MATLAB Functions: fftshift(fft( )), cumsum, diff, plot, subplot, figure, xlabel, ylabel, title.

5) Repeat the above for a sinc message signal $x(t) = \mathrm{sinc}(100\pi\, t)$ with f$_c$=250Hz and $k_f = 200\pi$, and where t = -0.1:ts:0.1.

What is the bandwidth of $x(t)$ and $y(t)$?

Homework Questions

Q1. What is the effect of changing the value of the sensitivity factor k_f ?

Q2. List and compare all the other methods you know about for demodulating an FM signal?