1 Preliminaries

In the previous weeks, we have considered amplitude modulation (AM) and its variants. We now consider angle modulation. To generate angle modulation, the amplitude of the modulated carrier is held constant and either the phase or the time derivative of the phase of the carrier is varied linearly with the message signal, $m(t)$. These lead to phase modulation (PM) or frequency modulation (FM), respectively. In this week, we focus on FM.

FM is a system in which the amplitude of the carrier wave c(t) is kept constant, while its frequency and the rate of changes are varied by the message signal.

The time-domain representation of FM signal, when the carrier is $c(t) = A_c \cos(2\pi f_c\, t)$ and the message signal is $m(t)$, is given by

$$s(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau\right) \tag{1}$$

where k_f represents the frequency sensitivity factor.

Frequency demodulation is the process that enables us to recover the original modulating signal from a frequency modulated signal. Here, we apply fmdemod(.) function to recover the original modulating signal.

In this week, our objectives are

a. to generate FM waveforms,

b. to consider the effect of different frequency sensitivity factors,

c. to observe and analyze the FM modulated waveforms in both time and frequency domains.

It is also useful to learn about the Matlab functions *cumsum(.)* and *fmdemod(.)* by using **Matlab Help** before performing the labwork given below.

2 Labwork

Read the preliminaries given above carefully before doing the experiment given below.

2.1 Modulation

a. Assume that the sampling frequency $F_s = 2$kHz and the durations of carrier signal $c(t)$ and message signal $m(t)$ are 0.2s.

b. Construct the carrier signal $c(t)$ which is $c(t) = A_c \cos(2\pi f_c\, t)$ with carrier frequency $f_c = 200$Hz and $A_c = 1$.

c. Construct the message signal $m(t)$ which is $m(t) = A_m \cos(2\pi f_m\, t)$ with message frequency $f_m = 50$Hz and $A_m = 2$.

d. Construct the frequency modulated signal, $s(t)$ as given in Equation 1, for each following frequency sensitivity factor k_f such as $k_f = [5,\ 25,\ 50]$. (i.e. $s_1(t)$, $s_2(t)$, $s_3(t)$)

   Hint: Use MATLAB command cumsum() for the integration.

e. Plot $m(t)$ and the time domain frequency modulated signals, $s_1(t)$, $s_2(t)$, $s_3(t)$, with $k_f = [5,\ 25,\ 50]$ in the same figure using 4×1 subplot.

f. Compare and comment on the obtained frequency modulated signals in 2.1(e).

2.2 Signals in Frequency Domain

a. Obtain the Fourier transforms of $m(t)$, $c(t)$ and $s_1(t)$, $s_2(t)$, $s_3(t)$ for each $k_f = [5,\ 25,\ 50]$ where the number of DFT points (N) is the length of the signal.

b. Plot the magnitude of the frequency spectrum of $m(t)$ and $c(t)$ i.e., $|M(f)|$ and $|C(f)|$, respectively in the same figure using 2×1 subplot.

c. Plot the magnitude of the frequency spectrum of $s_1(t)$, $s_2(t)$, $s_3(t)$ for each $k_f = [5,\ 25,\ 50]$ i.e. $|S_1(f)|$, $|S_2(f)|$, $|S_3(f)|$, in the same figure using 3×1 subplot.

d. Comment on the effect of the different k_f values to the frequency modulation.

2.3 Demodulation

a. Demodulate the each modulated signal $s_1(t)$, $s_2(t)$, $s_3(t)$ using **fmdemod(.)** function when $k_f = [5,\ 25,\ 50]$.

b. Plot the three demodulated signals and the message signal in the time domain on the same figure using 3×1 subplot.

   Note: Use hold on command to plot the message and the corresponding demodulated signal.

c. Comment on the results that you obtain in 2.3(b).

Note: All comments will be written in your reports. Please do not add the comments to the Matlab file.