1 Preliminaries

Phase modulation (PM) is a modulation pattern that encodes information as variations in the instantaneous phase of a carrier wave. The phase of the carrier wave is varied according to the message signal, whereas the amplitude and frequency are kept constant.

We studied the Frequency Modulation (FM) you implemented in the last experiment. We can obtain PM from a frequency modulator by passing the modulating signal through a differentiator, as in the following figure:

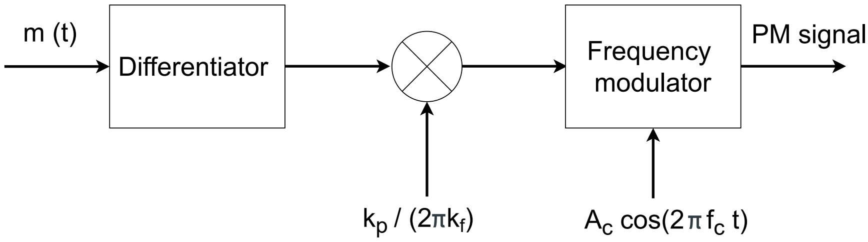

Figure 1: Phase modulated signal.

Thus, a phase-modulated signal, when the carrier is $c(t) = A_c \cos(2\pi f_c\, t)$ and the message signal is $m(t)$, is represented by

$$s(t) = A_c \cos(2\pi f_c t + \phi(t)) \tag{1}$$

The instantaneous phase is defined by

$$\theta_i(t) = 2\pi f_c t + \phi(t) \tag{2}$$

where the function $\phi(t)$ is known as the phase deviation. The PM implies that the phase deviation of the carrier is proportional to the message signal. Thus,

$$\phi(t) = k_p m(t) \tag{3}$$

where k_p represents the phase deviation constant. If $m(t)$ is a voltage, k_p has units of radians/volt.

Accordingly, the transmitted signal $m(t)$ can be retrieved from the PM modulated signal by forming an analytic signal with Hilbert transform and then extracting the instantaneous phase. Then, accomplish a differentiation operation on the phase of the low pass equivalent signal and divide the results by the phase deviation constant, k_p.

It is also useful to learn about the Matlab functions *hilbert(.)*, *angle(.)*, *unwrap(.)* and *phase(.)* by using **Matlab Help** before performing the labwork given below.

2 Homework

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

2.1 Modulation *(20 pts)*

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 signals $m_1(t)$, $m_2(t)$ which are $m_1(t) = \cos(2\pi 50\, t)$ and $m_2(t) = \cos(2\pi 10\, t)$.

d. Construct the phase modulated signal, $s_1(t)$ and $s_2(t)$ for the corresponding message signals $m_1(t)$, $m_2(t)$, respectively with $k_p = \frac{\pi}{4}$ rad/V.

e. Construct the phase modulated signal, $s_3(t)$ for the message signal $m_3(t) = m_1(t) + m_2(t)$ with $k_p = \frac{\pi}{4}$ rad/V.

f. Plot the time domain phase modulated signals, $s_3(t)$ and the signal $\{s_1(t) + s_2(t)\}$ in the same figure using 2×1 subplot.

g. Compare and comment on the obtained phase modulated signals in 2.1(f). Are they the same or not? Explain the reason and the property **in your reports**.

2.2 The effect of the different k_p values *(30 pts)*

Call $s_{PM}(t)$ for the previous modulated signal $s_1(t)$ with $k_p = \frac{\pi}{4}$ rad/V. Considering the message signal $m_1(t)$:

a. Construct $s_{PM1}(t)$ for $k_p = \frac{2\pi}{4}$ rad/V and $s_{PM2}(t)$ for $k_p = \frac{3\pi}{4}$ rad/V.

b. Plot $m_1(t)$, $s_{PM}(t)$, $s_{PM1}(t)$ and $s_{PM2}(t)$ on the same figure by using 4×1 subplot.

c. Comment on the effect of the different k_p values to phase modulation **in your reports**.

2.3 Demodulation *(50 pts)*

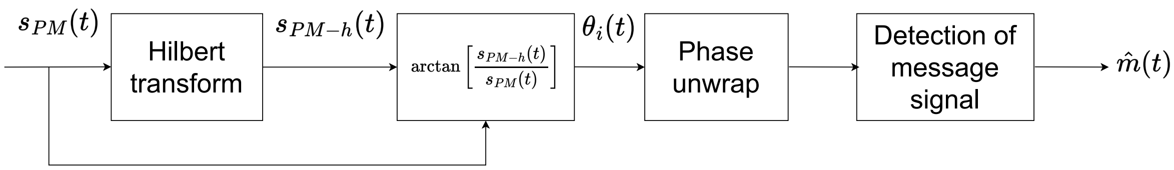

Figure 2: Demodulation of PM signal.

a. Demodulate the each modulated signal $s_{PM}(t)$, $s_{PM1}(t)$, $s_{PM2}(t)$ using Figure 2.

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 for 2.3(b) **in your reports**.

d. Please explain the usage of *phase unwrap* in the demodulation process **in your reports**.

Note: All comments will be written in your reports. Please do not add the comments to the Matlab file. Add a title/legend/label to your figures to get full credit.