International Institute of Information Technology
Bangalore

Principles of Communication Systems Lab

ECE 303P

Angle Modulation and Demodulation

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October 18, 2021

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Abstract

In this lab report, we study angle modulation and demodulation of multi-tone signals. Specifically, we study frequency modulation and phase modulation. We plot the message and carrier signal followed by the phase and frequency modulated signal along with its spectrum. We also demodulate the signal and understand its various properties.

1 Introduction

1.1 Question 1

Consider an information signal $m(t) = A_{m1}cos(2\pi f_{m1}t) + A_{m2}cos(2\pi f_{m2}t)$ with A_{m1} = 1 V, A_{m2} = 2 V, f_{m1} = 25 and f_{m2} = 50 Hz, and a carrier signal $c(t) = A_c cos(2\pi f_c t)$ with A_c = 2 V and f_c = 250 Hz.

(a) Plot m(t) for 3 complete cycles, and plot c(t) over the duration of m(t).

(b) Consider frequency sensitivity k_f = 12.5 Hz/Volt and plot the frequency modulated signal $\phi_{FM}(t) = A_c cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(\alpha)d\alpha)$ and its spectrum. Also calculate the bandwidth of the modulated signal.

(c) Consider frequency sensitivity k_f = 100 Hz/Volt and plot the frequency modulated signal $\phi_{FM}(t) = A_c cos(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(\alpha)d\alpha)$ and its spectrum. Also calculate the bandwidth of the modulated signal.

(d) Demodulate the frequency modulated signal and plot the demodulated signal (take k_f = 125 Hz/Volt).

1.2 Question 2

Consider an information signal $m(t) = A_{m1}cos(2\pi f_{m1}t) + A_{m2}cos(2\pi f_{m2}t)$ with A_{m1} = 1 V, A_{m2} = 2 V, f_{m1} = 25 and f_{m2} = 50 Hz, and a carrier signal $c(t) = A_c cos(2\pi f_c t)$ with A_c = 2 V and f_c = 250 Hz.

(a) Plot m(t) for 3 complete cycles, and plot c(t) over the duration of m(t).

(b) Consider phase sensitivity k_p = 0.25 rad/Volt and plot phase modulated signal $\phi_{PM}(t) = A_c cos(2\pi f_c t + 2\pi k_p m(t))$ and its spectrum. Also calculate the bandwidth of the modulated signal.

(c) Demodulate the phase modulated signal and plot the demodulated signal (take k_p = 0.25 rad/Volt).

2 Method

2.1 Question 1

First we create message signal and carrier signal vector and plot it using `plot` command. To modulate the signal we use `fmmod` command. Similarly to demodulate the signal we use `fmdemod` command.

2.2 Question 2

Same as question 1. However, here we use `pmmod` and `pmdemod` for modulating and demodulating the signal.

3 Results and Analysis

3.1 Question 1

The MATLAB code to solve this question is as follows:

```
clear all; close all; clc;

Am1 = 1;     Am2 = 2;
fm1 = 25;    fm2 = 50;    fc = 250;    fs = 50000;
Ac = 2;      %Parameters
t = 0:1/fs:1;            %Time vector

m_t = Am1*cos(2*pi*fm1*t) + Am2*cos(2*pi*fm2*t);
c_t = Ac*cos(2*pi*fc*t);

%≤===== 1(a) ======>
subplot(2, 1, 1);            %Plot the message signal
plot(t, m_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('1(a) Message Signal: A_{m1}cos(2\pif_{m1}t) + A_{m2}cos(2\pif_{m2}t)');
xlim([0 0.12]);  ylim([-4 4]);
grid on;

subplot(2, 1, 2);            %Plot the carrier signal
plot(t, c_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> c(t)');
title('1(a) Carrier Signal: A_ccos(2\pif_ct)');
xlim([0 0.12]);  ylim([-3 3]);
grid on;


%≤===== 1(b) ======>
kf = 12.5;
freqDev = kf*(Am1 + Am2);
phi_t = Ac*fmmod(mt, fc, fs, freqDev);

subplot(2, 1, 1);            %Plot the frequency modulated signal
plot(t, phi_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> \phi_{FM}(t)');
title('1(b) Frequency modulated signal \phi_{FM}(t)');
xlim([0 0.12]);  ylim([-3 3]);
```

```
    grid on;

    f = -fs/2:1:fs/2;
    fftphi = fftshift(fft(phi_t))/length(phi_t);

    subplot(2,1,2);             %Plot spectrum of frequency modulated signal
    plot(f, real(fftphi), 'LineWidth', 1.7);
    xlabel('---> Frequency(Hz)');    ylabel('---> \phi_{FM}(f)');
    title('1(b) Frequency spectrum of \phi_{FM}(t)');
    xlim([-600 600]); ylim([-0.8 0.5]);
    xticks(-1000:100:1000);    yticks(-1:0.2:1);
    grid on;

    %≤===== 1(c) ======>
    kf = 100;
    freqDev = kf*(Am1 + Am2);
    phi_t = Ac*fmmod(mt, fc, fs, freqDev);

    subplot(2, 1, 1);            %Plot the frequency modulated signal
    plot(t, phi_t, 'LineWidth', 1.5);
    xlabel('---> time(s)');    ylabel('---> \phi_{FM}(t)');
    title('1(c) Frequency modulated signal \phi_{FM}(t)');
    xlim([0 0.12]);
    ylim([-3 3]);
    grid on;

    f = -fs/2:1:fs/2
    fftphi = fftshift(fft(phi_t))/length(phi_t);

    subplot(2,1,2);
    plot(f, real(fftphi), 'LineWidth', 1.7);
    xlabel('---> Frequency(Hz)');    ylabel('---> \phi_{FM}(f)');
    title('1(c) Frequency spectrum of \phi_{FM}(t)');
    xlim([-1600 1600]); ylim([-0.7 0.7]);
    xticks(-2000:200:2000); yticks(-1:0.2:1);
    grid on;

    %≤===== 1(d) ======>
    kf = 125;
    freqDev = kf*(Am1 + Am2);
    phi_t = Ac*fmmod(mt, fc, fs, freqDev);
    mt = fmdemod(phi_t, fc, fs, freqDev);

    plot(t, mt, 'LineWidth', 1.7);
    xlabel('---> time(s)');    ylabel('---> m(t)');
    title('1(d) Demodulated signal');
    xlim([0 0.12]);  %ylim([-2 4]);
    grid on;
```

The plots obtained for this question is shown below:

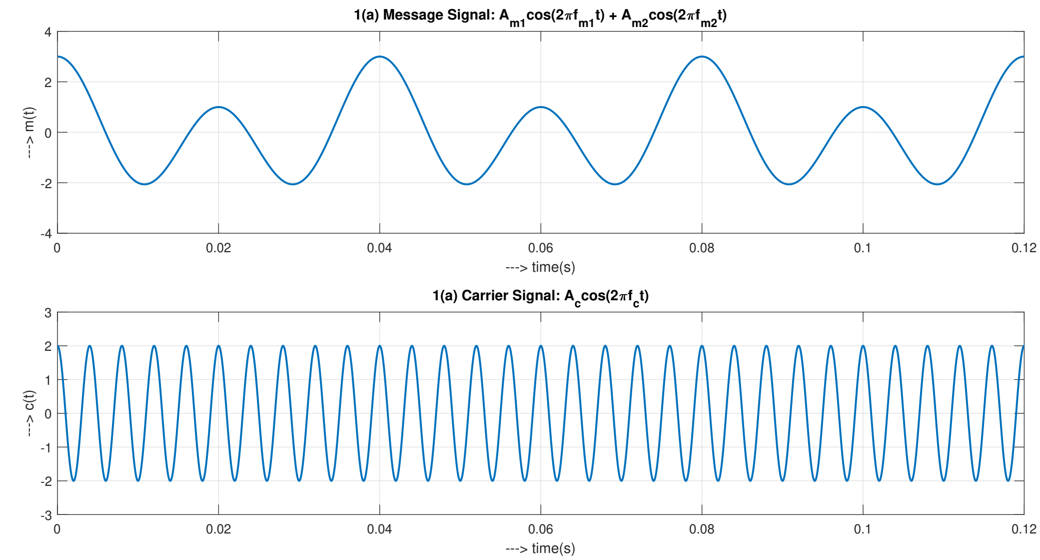

Figure 1: 1(a) Message signal and carrier signal

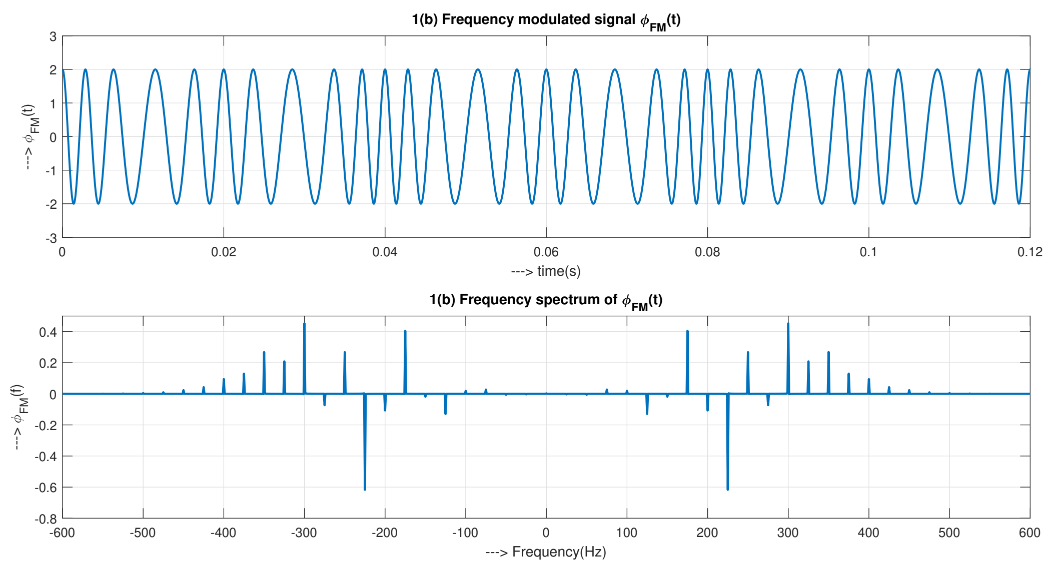

Figure 2: 1(b) Frequency modulated signal and its spectrum for $k_f = 12.5$ Hz/Volt

Here (in fig 2) we see that the bandwidth of the signal is 450 Hz for $k_f = 12.5$ Hz/Volt.

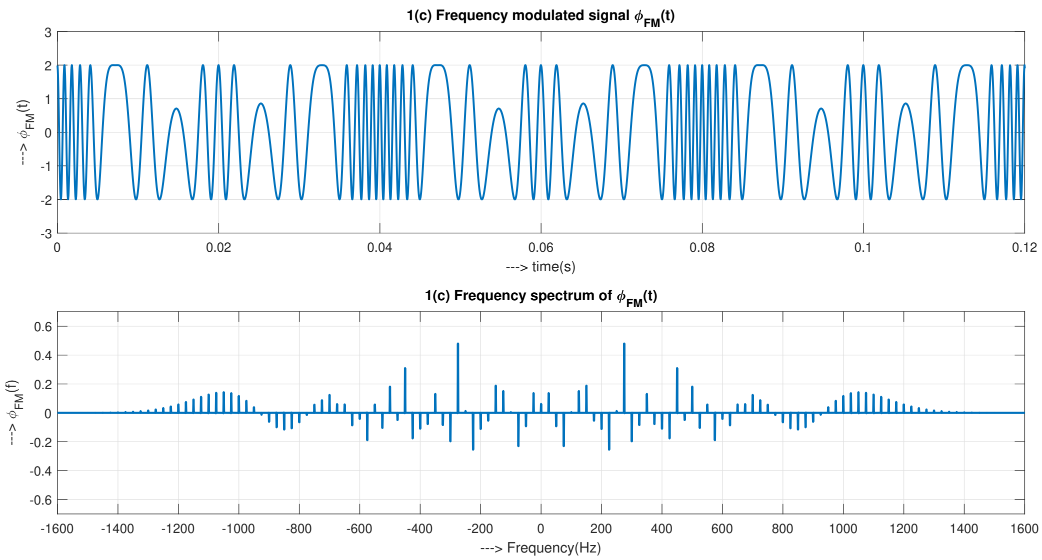

Figure 3: 1(c) Frequency modulated signal and its spectrum for $k_f = 100$ Hz/Volt

Here (in fig 3) we see that the bandwidth of the signal is 1400 Hz for $k_f = 100$ Hz/Volt.

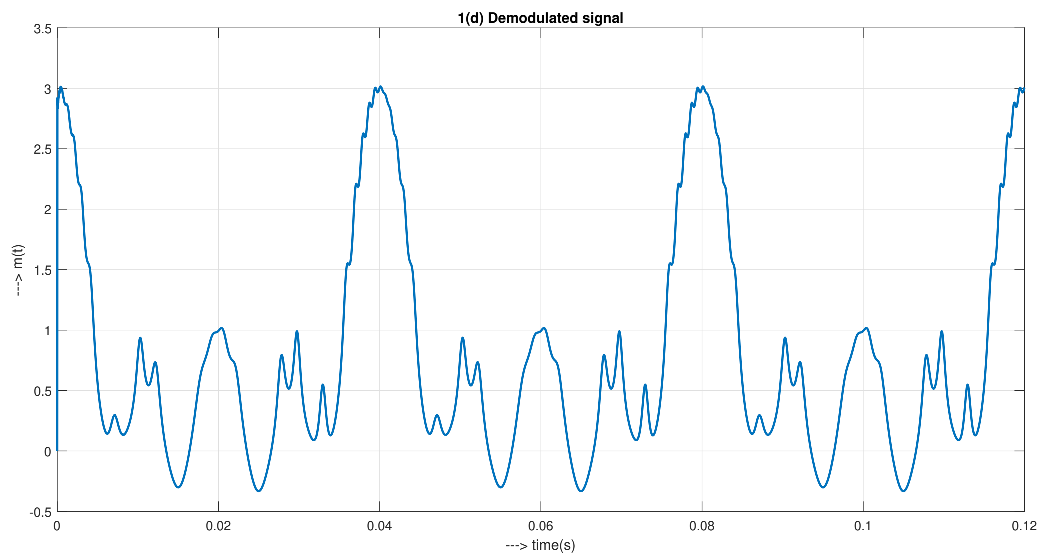

Figure 4: 1(d) Demodulated signal for $k_f = 125$ Hz/Volt

3.2 Question 2

The MATLAB code for this question is shown below:

```
clear all; close all; clc;
Am1 = 1;    Am2 = 2;
fm1 = 25;   fm2 = 50;   fc = 250;   fs = 50000;
Ac = 2;     %Parameters
t = 0:1/fs:1;           %Time vector

m_t = Am1*cos(2*pi*fm1*t) + Am2*cos(2*pi*fm2*t);
c_t = Ac*cos(2*pi*fc*t);

%≤===== 2(a) ======>
subplot(2, 1, 1);           %Plot the message signal
plot(t, m_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('2(a) Message Signal: A_{m1}cos(2\pif_{m1}t) + A_{m2}cos(2\pif_{m2}t)');
xlim([0 0.12]);
ylim([-4 4]);
grid on;

subplot(2, 1, 2);           %Plot the carrier signal
plot(t, c_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> c(t)');
title('2(a) Carrier Signal: A_ccos(2\pif_ct)');
xlim([0 0.12]);
ylim([-3 3]);
grid on;

%≤===== 2(b) ======>
kp = 0.25;
phi_t = Ac*pmmod(m_t, fc, fs, kp*(Am1+Am2));
subplot(2, 1, 1);           %Plot the phase modulated signal signal
plot(t, phi_t, 'LineWidth', 1.5);
xlabel('---> time(s)');    ylabel('---> \phi_{PM}(t)');
title('2(b) Phase modulated signal \phi_{PM}(t)');
xlim([0 0.12]);
ylim([-3 3]);
grid on;

f = -fs/2:1:fs/2;
fftphi = fftshift(fft(phi_t))/length(phi_t);
subplot(2,1,2);             %Plot spectrum of phase modulated signal
plot(f, real(fftphi), 'LineWidth', 1.7);
xlabel('---> Frequency(Hz)');    ylabel('---> \phi_{PM}(f)');
title('2(b) Frequency spectrum of \phi_{PM}(t)');
xlim([-500 500]); ylim([-0.5 0.5]); yticks(-1:0.2:1);
grid on;

%≤===== 2(d) ======>
mt = pmdemod(phi_t, fc, fs, kp*(Am1+Am2));
plot(t, mt, 'LineWidth', 1.7);
xlabel('---> time(s)');    ylabel('---> m(t)');
title('2(d) Demodulated signal');
xlim([0 0.12]);  %ylim([-0.5 0.5]);
grid on;
```

The plots obtained for this question is shown below:

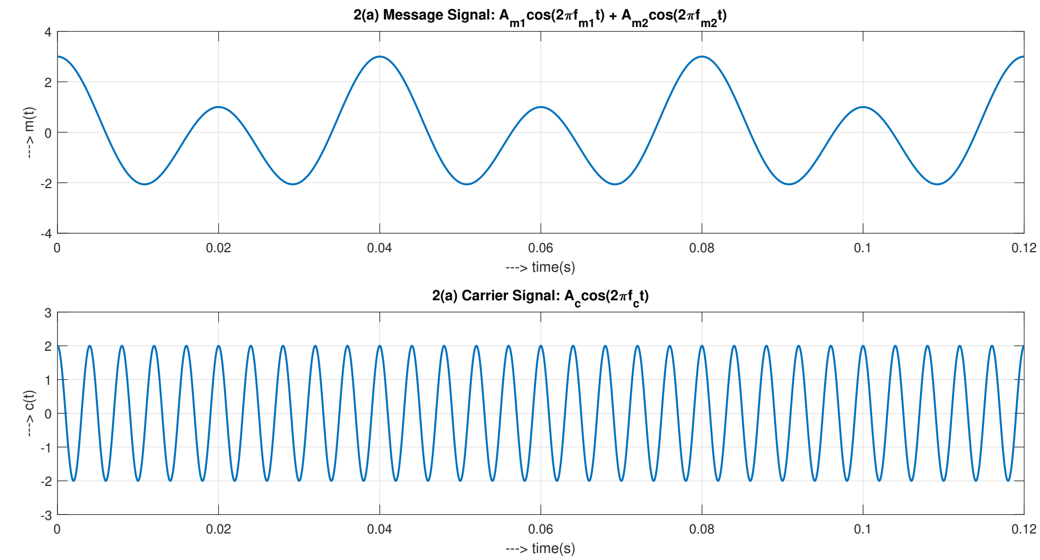

Figure 5: 2(a) Message signal and carrier signal

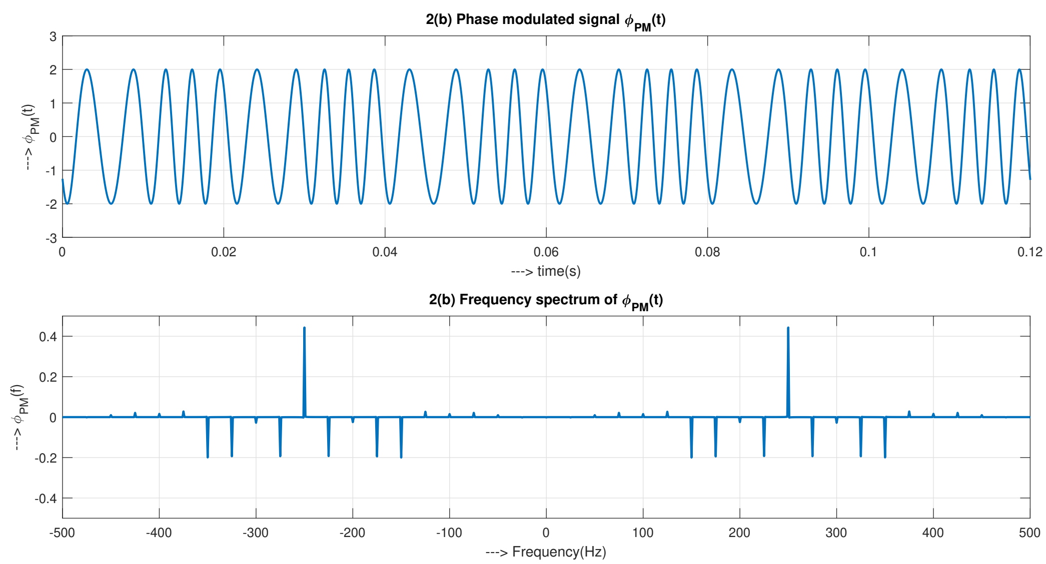

Figure 6: 2(b) Phase modulated signal for $k_f = 0.25$ rad/Volt

Here (in fig 6) we see that the bandwidth of the signal is 400 Hz for $k_p = 0.25$ rad/Volt.

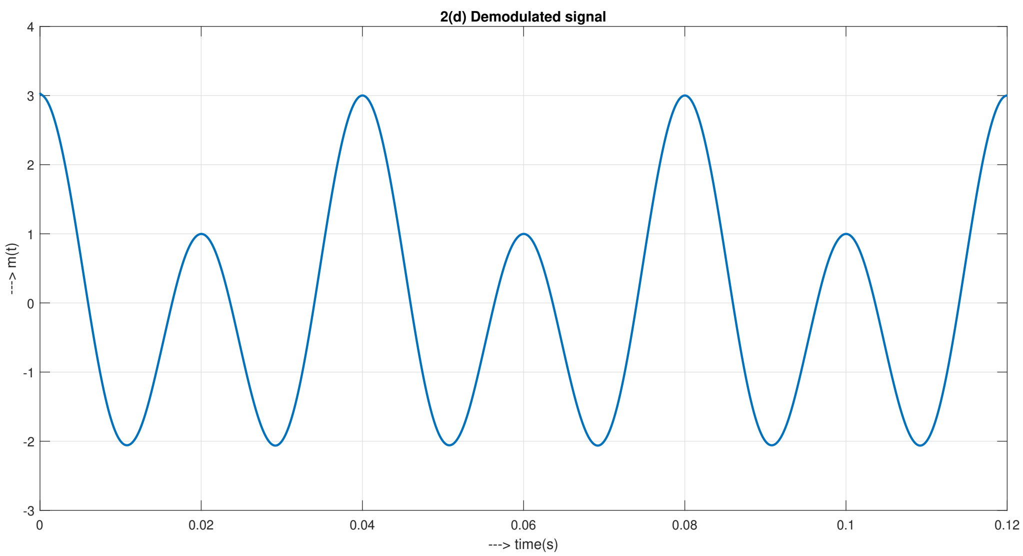

Figure 7: 2(d) Demodulated signal for $k_p = 0.25$ rad/Volt