International Institute of Information Technology Bangalore

Principles of Communication Systems Lab ECE 303P

Angle Modulation and Demodulation

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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 $c(t) = A_ccos(2\pi f_c t)$ 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 $c(t) = A_ccos(2\pi f_c t)$ 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 $k_p = 0.25 \text{ rad/Volt}$ 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:

```
1
       clear all; close all; clc;
2
3
       Am1 = 1;
                    Am2 = 2;
       fm1 = 25;
                    fm2 = 50;
                                 fc = 250;
                                              fs = 50000;
5
       Ac = 2;
                   %Parameters
       t = 0:1/fs:1;
                                %Time vector
6
       m_t = Am1*cos(2*pi*fm1*t) + Am2*cos(2*pi*fm2*t);
       c_t = Ac*cos(2*pi*fc*t);
9
10
11
       % \le = = = 1 (a) = = = = >
       subplot(2, 1, 1);
12
                                     %Plot the message signal
13
       plot(t, m_t, 'LineWidth', 1.5);
                                   ylabel('---> m(t)');
       xlabel('---> time(s)');
14
       title('1(a) Message Signal: A_{m1}\cos(2\pi_{m1}) + A_{m2}\cos(2\pi_{m2})');
15
16
       xlim([0 \ 0.12]); ylim([-4 \ 4]);
17
       grid on;
18
       subplot(2, 1, 2);
                                     %Plot the carrier signal
19
       plot(t, c_t, 'LineWidth', 1.5);
20
       xlabel('---> time(s)');
                                   ylabel('---> c(t)');
21
       title('1(a) Carrier Signal: A_ccos(2\pif_ct)');
22
       xlim([0 \ 0.12]); ylim([-3 \ 3]);
23
24
       grid on;
25
26
       %<===== 1 (b) =====>
27
       kf = 12.5;
28
       freqDev = kf*(Am1 + Am2);
29
       phi_t = Ac*fmmod(mt, fc, fs, freqDev);
30
31
       subplot(2, 1, 1);
                                     %Plot the frequency modulated signal
32
       plot(t, phi_t, 'LineWidth', 1.5);
33
       xlabel('---> time(s)');
                                    ylabel('---> \phi_{FM}(t)');
34
       title('1(b) Frequency modulated signal \phi_{FM}(t)');
35
       xlim([0 \ 0.12]); ylim([-3 \ 3]);
36
```

```
37
       grid on;
38
       f = -fs/2:1:fs/2;
39
40
       fftphi = fftshift(fft(phi_t))/length(phi_t);
41
                                    %Plot spectrum of frequency modulated signal
       subplot (2,1,2);
42
       plot(f, real(fftphi), 'LineWidth', 1.7);
43
       xlabel('---> Frequency(Hz)');
                                         ylabel('---> \phi_{FM}(f)');
44
       title('1(b) Frequency spectrum of \phi_{FM}(t)');
45
46
       xlim([-600 600]); ylim([-0.8 0.5]);
47
       xticks(-1000:100:1000);
                                  yticks(-1:0.2:1);
48
       grid on;
49
       %<===== 1(c) =====>
50
       kf = 100;
51
52
       freqDev = kf*(Am1 + Am2);
       phi_t = Ac*fmmod(mt, fc, fs, freqDev);
53
54
       subplot(2, 1, 1);
                                     %Plot the frequency modulated signal
55
       plot(t, phi_t, 'LineWidth', 1.5);
56
       xlabel('---> time(s)');
                                   ylabel('---> \phi_{FM}(t)');
57
       title('1(c) Frequency modulated signal \phi_{FM}(t)');
58
       xlim([0 0.12]);
59
60
       ylim([-3 \ 3]);
61
       grid on;
62
       f = -fs/2:1:fs/2
63
       fftphi = fftshift(fft(phi_t))/length(phi_t);
64
65
       subplot (2,1,2);
66
       plot(f, real(fftphi), 'LineWidth', 1.7);
67
       xlabel('---> Frequency(Hz)');
                                         ylabel('---> \phi_{FM}(f)');
68
       title('1(c) Frequency spectrum of \phi_{FM}(t)');
69
       xlim([-1600 1600]); ylim([-0.7 0.7]);
70
       xticks(-2000:200:2000); yticks(-1:0.2:1);
71
72
       grid on;
73
       %<===== 1 (d) =====>
74
       kf = 125;
75
       freqDev = kf*(Am1 + Am2);
76
       phi_t = Ac*fmmod(mt, fc, fs, freqDev);
77
       mt = fmdemod(phi_t, fc, fs, freqDev);
78
79
       plot(t, mt, 'LineWidth', 1.7);
80
       xlabel('---> time(s)');
                                   ylabel('---> m(t)');
81
       title('1(d) Demodulated signal');
82
       xlim([0 \ 0.12]); \ %ylim([-2 \ 4]);
83
       grid on;
84
```

The plots obtained for this question is shown below:

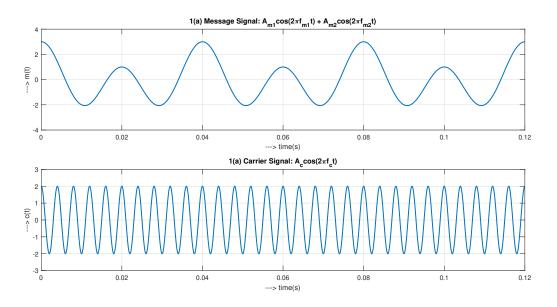


Figure 1: 1(a) Message signal and carrier signal

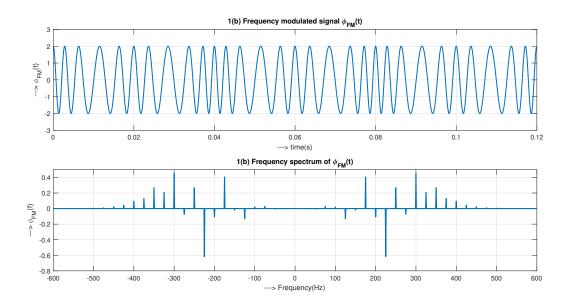


Figure 2: 1(b) Frequency modulated signal and its spectrum for $k_f = 12.5$ Hz/Volt. Here (in fig 2) we see that the bandwidth of the signal is 450 Hz for $k_f = 12.5$ Hz/Volt.

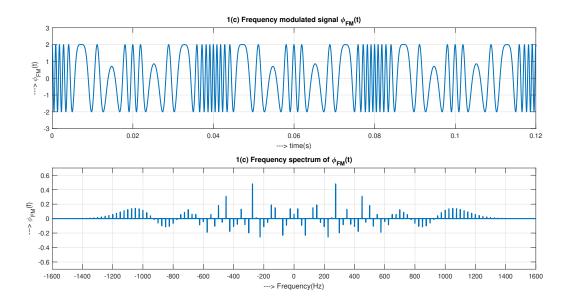


Figure 3: 1(c) Frequency modulated signal and its spectrum for $k_f = 100$ Hz/Volt. Here (in fig 3) we see that the bandwidth of the signal is 1400 Hz for $k_f = 100$ Hz/Volt.

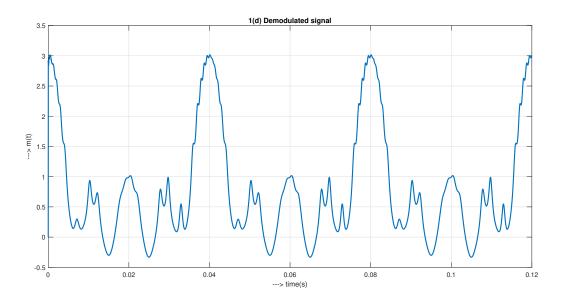


Figure 4: 1(d) Demodulated signal for $k_f=125~\mathrm{Hz/Volt}$

3.2 Question 2

The MATLAB code for this question is shown below:

```
clear all; close all; clc;
1
       Am1 = 1;
2
                    Am2 = 2;
       fm1 = 25;
                    fm2 = 50;
                                 fc = 250;
                                             fs = 50000;
       Ac = 2;
                    %Parameters
       t = 0:1/fs:1;
                                %Time vector
5
6
       m_t = Am1*cos(2*pi*fm1*t) + Am2*cos(2*pi*fm2*t);
7
       c_t = Ac*cos(2*pi*fc*t);
8
       %<===== 2 (a) =====>
10
       subplot(2, 1, 1);
                                     %Plot the message signal
11
12
       plot(t, m_t, 'LineWidth', 1.5);
       xlabel('---> time(s)');
                                   ylabel('---> m(t)');
13
       title('2(a) Message Signal: A_{m1}\cos(2\pi_{m1}t) + A_{m2}\cos(2\pi_{m2}t)');
14
       xlim([0 0.12]);
15
       ylim([-4 \ 4]);
16
       grid on;
17
18
       subplot(2, 1, 2);
                                     %Plot the carrier signal
19
       plot(t, c_t, 'LineWidth', 1.5);
20
       xlabel('---> time(s)');
                                   ylabel('---> c(t)');
21
       title('2(a) Carrier Signal: A_ccos(2\pif_ct)');
22
       xlim([0 0.12]);
23
24
       ylim([-3 \ 3]);
25
       grid on;
26
       %<===== 2 (b) =====>
27
       kp = 0.25;
28
29
       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);
31
                                   ylabel('---> \phi_{PM}(t)');
32
       xlabel('---> time(s)');
       title('2(b) Phase modulated signal \phi_{PM}(t)');
33
       xlim([0 0.12]);
34
       ylim([-3 \ 3]);
35
       grid on;
36
37
       f = -fs/2:1:fs/2;
38
       fftphi = fftshift(fft(phi_t))/length(phi_t);
39
                                     %Plot spectrum of phase modulated signal
       subplot(2,1,2);
40
       plot(f, real(fftphi), 'LineWidth', 1.7);
41
       xlabel('---> Frequency(Hz)');
                                         ylabel('---> \phi_{PM}(f)');
42
       title('2(b) Frequency spectrum of \phi_{PM}(t)');
43
       xlim([-500 500]); ylim([-0.5 0.5]); yticks(-1:0.2:1);
44
       grid on;
45
46
       %<===== 2 (d) =====>
47
       mt = pmdemod(phi_t, fc, fs, kp*(Am1+Am2));
48
       plot(t, mt, 'LineWidth', 1.7);
49
       xlabel('---> time(s)');
                                    ylabel('---> m(t)');
       title('2(d) Demodulated signal');
51
       xlim([0 \ 0.12]); \ %ylim([-0.5 \ 0.5]);
52
       grid on;
53
```

The plots obtained for this question is shown below:

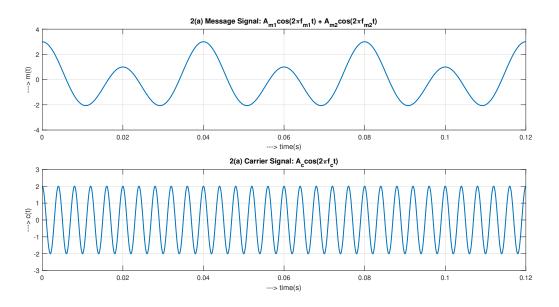


Figure 5: 2(a) Message signal and carrier signal

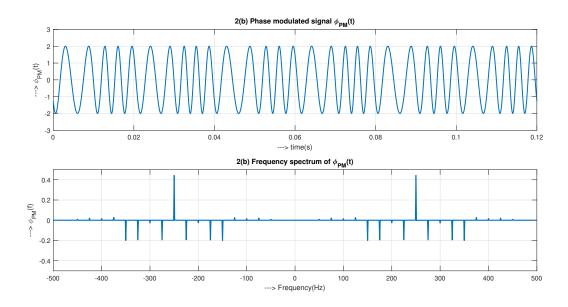


Figure 6: 2(b) Phase modulated signal for $k_f=0.25~\mathrm{rad/Volt}$

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

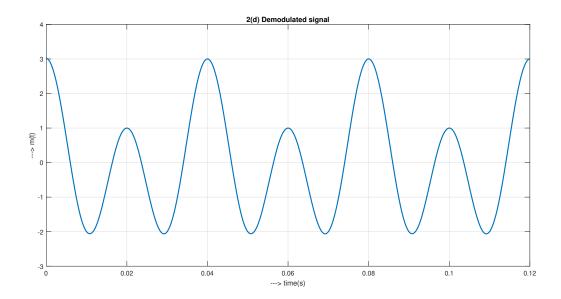


Figure 7: 2(d) Demodulated signal for $k_p = 0.25 \text{ rad/Volt}$