Communication Theory Lab Report

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Communication Theory Lab
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Lab Assignment # 3

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Phase modulation

Abstract

In this experiment, we have tried to understand the concept of Phase Modulation (PM) in time domain by giving both a sinusoidal and a square wave as input. We analysed them by plotting their graphs in MATLAB. In phase modulation, we observed the effect of increasing the amplitude of message signal. We also compared the above two phase modulated signals. We also tried to analyze the modulated signal when a square wave is provided for better understanding.

1 Theory

In carrier modulation, we have a message signal and a carrier signal. Message signal is usually of low frequency and the carrier signal is of very high frequency. The carrier signal acts as an. envelop as it does not carry any information but helps in transmitting the same. carrier signal is given by this formula `C(t) = Ac*cos(2*pi*`f_c`*t)` and here f_c is very high. If you look carefully, it has three components :

1. Amplitude
2. Phase
3. Frequency

In phase modulation, phase of the carrier signal is changed according to that of the message signal. It is a part of angle modulation. Here the amplitude of the message signal is kept constant.

Consider m(t) as the message signal and c(t) as carrier signal. So m(t) = Am*cos(ω_m*t). Also c(t) = Ac*cos(ω_c*t). In PM, the phase at an instant t is given by -

$$s(t) = Ac * cos(\theta(t)) \tag{1}$$

$$\theta(t) = 2 * pi * f_c * t + k_p * m(t) \tag{2}$$

$$\theta(t) = 2 * pi * f_c * t + k_p * Am * cos(\omega m * t) \tag{3}$$

$$\theta(t) = 2 * pi * f_c * t + mu * cos(\omega m * t) \tag{4}$$

$$s(t) = Ac * cos(2 * pi * f_c * t + mu * cos(\omega m * t)) \tag{5}$$

1.1 Block Diagram

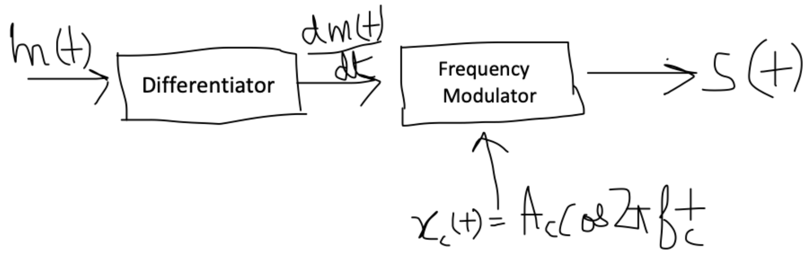

Figure 1: PM block diagram

1.2 Expected Outcome

The figures below are not drawn to scale.

1.2.1 Answer 1

This question was taken directly from what was taught in the lectures.

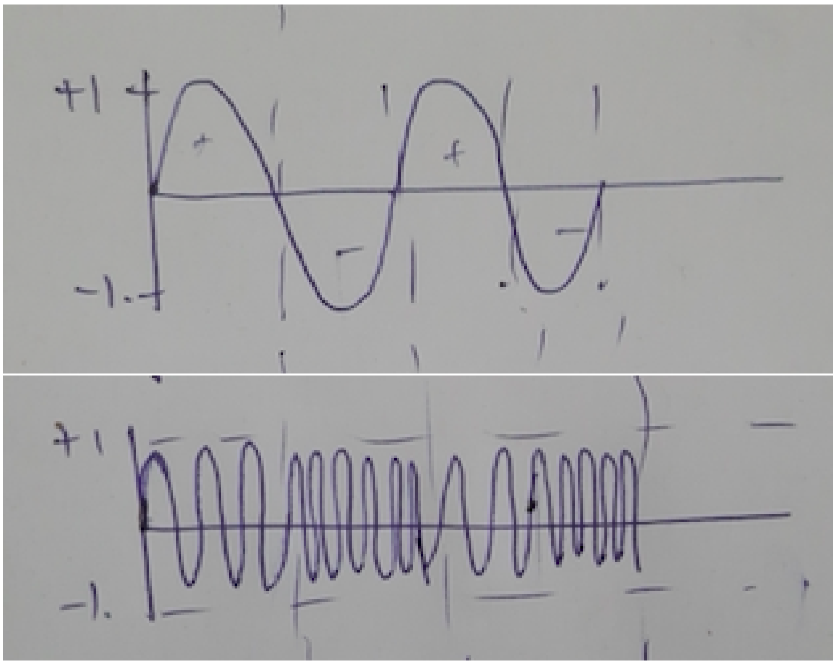

Figure 2: Answer 1

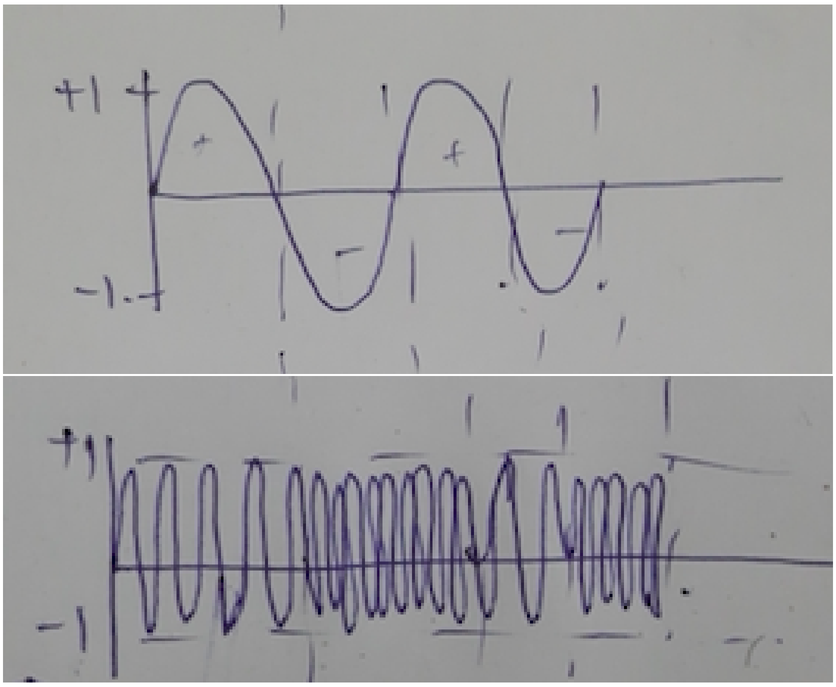

Figure 3: Answer 2

1.2.2 Answer 2

This is directly taken from the lecture.

1.2.3 Answer 3

This question was taking inference from what was taught in the lectures. In lectures, FM was taught with mostly sinusoidal waves. Here it was about square waves, so one has to just infer it from what was taught.

1.3 Application

Applications of PM signal :

1. `Wave synthesizers:` It is widely used in synthesizing waves or music as in Casio and Yamaha.

2. `Radio waves transmission:` PM also finds its usage in transmitting radio waves and used in a number of wireless technologies such as Wifi and GSM.

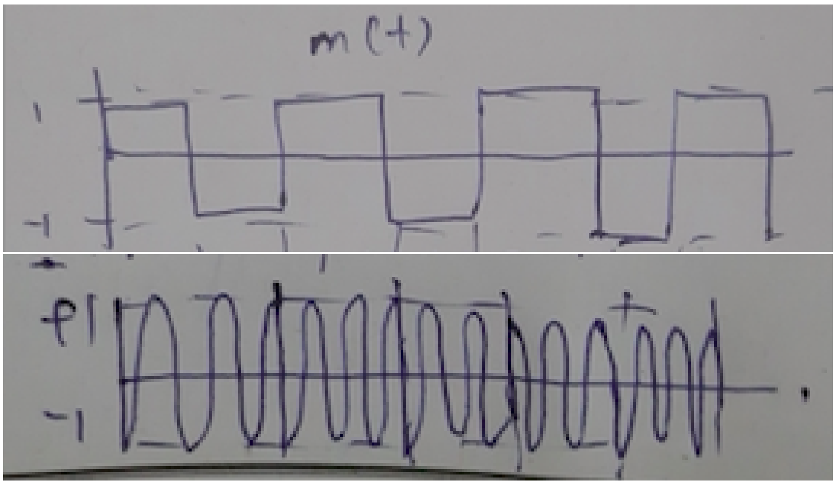

Figure 4: Answer 3

2 Results and Inferences

2.1 Answer 1

We have - Φ_{pm}(t) = Ac*cos(2*π*f_c*t + k_p*m(t)) Here instantaneous frequency is -

$$f_i(t) = f_c + 1/2 * pi * k_p * \frac{dm(t)}{dt} \tag{6}$$

It's given that m(t) = Am×sin(2π×fm ×t), so

$$\frac{dm(t)}{dt} = (Am/2\pi f_m)sin(2\pi f_m t) \tag{7}$$

Thus plugging the above differentiation into the earlier equation gives the instantaneous frequency of the modulated signal. As mentioned in theory section, amplitude will remain same as carrier signal. From the earlier equation, one can say that frequency increases as $\frac{dm(t)}{dt}$ increases. It reaches its peak value when $\frac{dm(t)}{dt}$ reaches its peak. And as $\frac{dm(t)}{dt}$ decreases, the frequency also decreases. One can see this in the plot as well.

Inferences are:

1. phase is being modulated by the equation : 2π f_c t + k_p*Am*cos(ω_m*t).
2. Amplitude of modulated signal is same as carrier signal.

3. Frequency is given by this equation $f_i(t) = f_c + 1/2 * pi * k_p * \frac{dm(t)}{dt}$. Thus wherever the message signal is high, the frequency of the modulated signal will decrease and vice-versa.

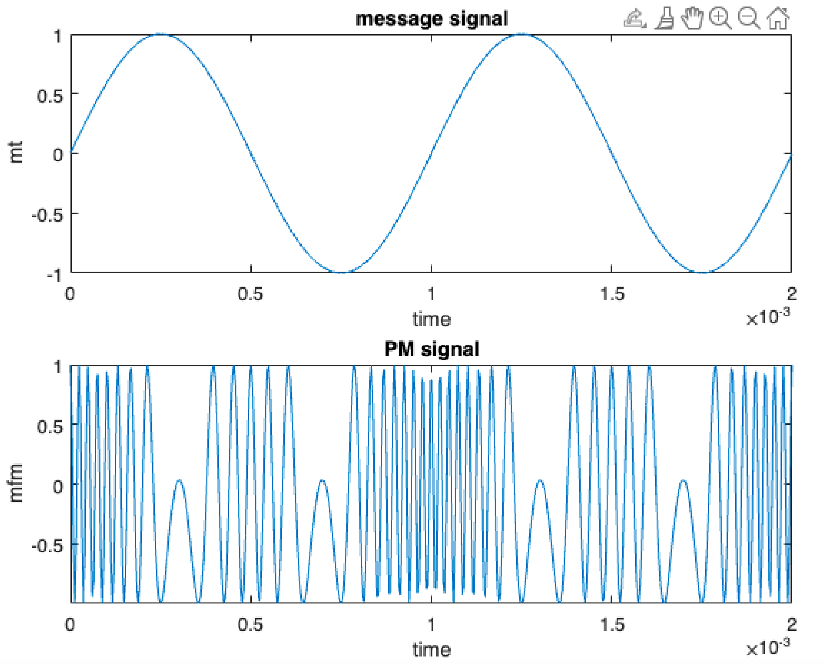

Figure 5: Answer 1

2.2 Answer 2

We have - Φ_{pm}(t) = Ac*cos(2*π*f_c*t + k_p*m(t)) Here instantaneous frequency is -

$$f_i(t) = f_c + 1/2 * pi * k_p * \frac{dm(t)}{dt} \tag{8}$$

It's given that m(t) = Am×sin(2π×fm ×t), so

$$\frac{dm(t)}{dt} = (Am/2\pi f_m)sin(2\pi f_m t) \tag{9}$$

Thus plugging the above differentiation into the earlier equation gives the instantaneous frequency of the modulated signal. As mentioned in theory section, amplitude will remain same as carrier signal. From the earlier equation, one can say that frequency increases as $\frac{dm(t)}{dt}$ increases. It reaches its peak value when $\frac{dm(t)}{dt}$ reaches its peak. And as $\frac{dm(t)}{dt}$ decreases, the frequency also decreases. One can see this in the plot as well.

Difference from 1a : Yes, it is different from the 1a plot because as mentioned above, the instantaneous frequency for PM signal is directly proportional to the amplitude of the message signal. In part b, the amplitude Am is three times as that of the amplitude given in 1a. So the frequency of PM signal should be higher than that of 1a. One can also notice the closeness of the signal lines in modulated signal.

Inferences are :

1. phase is being modulated by the equation : 2π f_c t + k_p*Am*cos(ω_m*t).
2. Amplitude of modulated signal is same as carrier signal.
3. Frequency is given by this equation $f_i(t) = f_c + 1/2 * pi * k_p * \frac{dm(t)}{dt}$. Thus wherever the message signal is high, the frequency of the modulated signal will decrease and vice-versa.
4. Frequency of PM signal should be higher than that of 1a because it is directly proportional to amplitude. And amplitude is more in the part b.

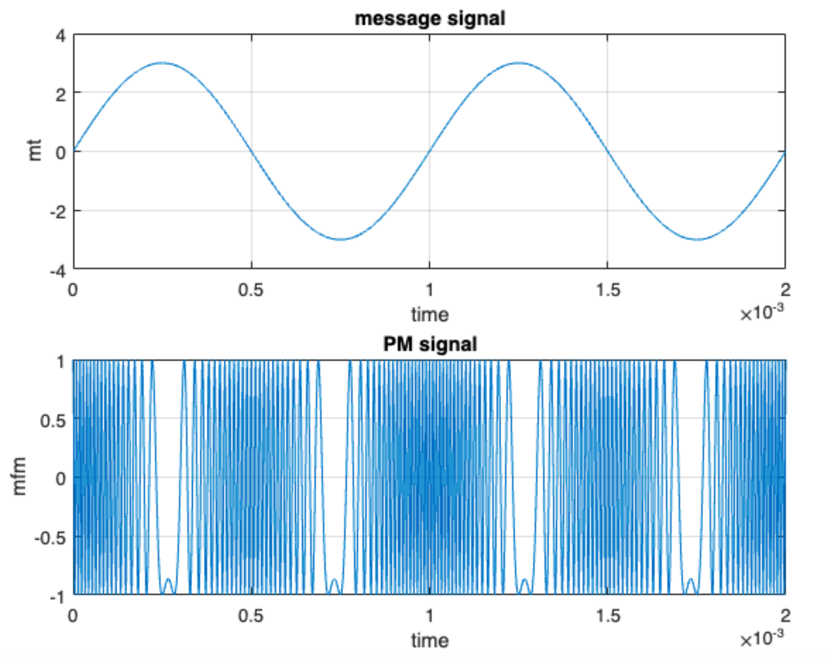

Figure 6: Answer 2

2.3 Answer 3

The message signal is a square wave in this question. We have -

$$f_i(t) = f_c + 1/2 * pi * k_p * \frac{dm(t)}{dt} \tag{10}$$

Here $\frac{dm(t)}{dt}$ is not a continuous function. $\frac{dm(t)}{dt}$ is 1 at corner points, elsewhere it is 0. These corner points are points of discontinuity. Hence the PM signal will have the same frequency as the carrier signal. Also their amplitudes will also be same.

The value of m will be wither +1 or -1, so the phase can be -
Θ_1(t) = $2\pi * f_c * t$ + k_p
Θ_2(t) = $2\pi * f_c * t$ - k_p.

To conclude, at the points which are continuous, the modulated signal will go with either of the phases mentioned above. But where there are discontinuities, there is an abrupt change of phase in the phase. These abrupt changes can be seen in the plot.

Inferences are :

1. Abrupt changes in the modulated signal at points where message changes from +1 to -1 or vice-versa. Reason is stated above.

2. Frequency of the modulated signal will be same as frequency of the carrier signal.

3. Amplitude of the modulated signal will be same as amplitude of the carrier signal.

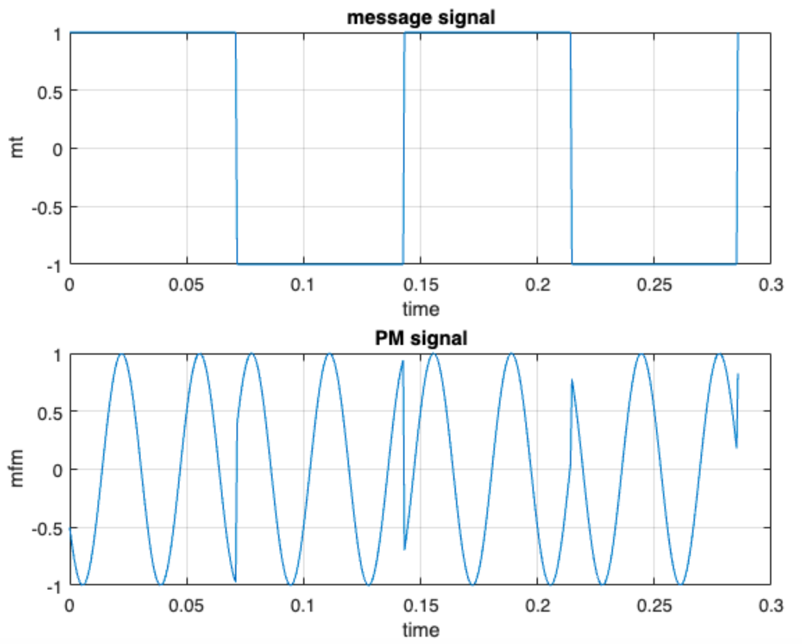

Figure 7: Answer 3

Appendix

A Matlab Commands

Table 1: Matlab commands used in this lab.

Matlab Command	**Function**
`plot(`x,y`)`	plots values of the simulation series y along the y-axis, with values of the simulation series x along the x-axis.
`figure()`	creates a new figure in MATLAB.
`title(x)`	adds a title x to the plot
`xlabel(x)`	adds a horizontal label x (along x axis) to the plot
`ylabel(x)`	adds a vertical label x (along y axis) to the plot
`grid on`	adds a grid to the plot.
`clc`	clears everything from the matlab command line window.
`linspace(x1,x2,p)`	generates p equally distant points between x1 and x2.
`subplot(abc)`	generates a subplot of size a x b, and the current image is of index c
`sawtooth`	generates a sawtooth wave.
`square`	generates a square wave.

B Matlab Code

Matlab codes for each part.

B.1 Q1(a)

```
fm =1000;
fc = 10*1000;
```

```
Am =1;
Ac = 1;

Tm = 1/fm;
t = linspace(0,2*Tm,500);

kp = 2*pi*5;

% message signal
figure();
subplot(211);
mt = Am*sin(2*pi*fm*t);
plot(t,mt);
xlabel("time");
ylabel("mt");
title("message signal");
grid on;

% PM signal
subplot(212);
mfm = Ac*cos(2*pi*fc*t + kp*mt);
plot(t,mfm);
xlabel("time");
ylabel("mfm");
title("PM signal");
grid on;
```

B.2 Q1(b)

```
fm =1000;
fc = 10*1000;

Am =3;
Ac = 1;

Tm = 1/fm;
t = linspace(0,2*Tm,50000);

kp = 2*pi*5;
```

```
% message signal
figure();
subplot(211);
mt = Am*sin(2*pi*fm*t);
plot(t,mt);
xlabel("time");
ylabel("mt");
title("message signal");
grid on;

% PM signal
subplot(212);
mfm = Ac*cos(2*pi*fc*t + kp*mt);
plot(t,mfm);
xlabel("time");
ylabel("mfm");
title("PM signal");
grid on;
```

B.3 Q1(c)

```
fm =7;
fc = 30;

Am =1;
Ac = 1;

Tm = 1/fm;
t = linspace(0,2*Tm,500);

kp = 2*pi*0.333;

% message signal
figure();
subplot(211);
mt = Am*square(2*pi*fm*t);
plot(t,mt);
xlabel("time");
ylabel("mt");
title("message signal");
```

```
grid on;

% PM signal
subplot(212);
mfm = Ac*cos(2*pi*fc*t + kp*mt);
plot(t,mfm);
xlabel("time");
ylabel("mfm");
title("PM signal");
grid on;
```

References

[1] IIT Mandi lectures on EE304 offered by Dr Adarsh https://cloud.iitmandi.ac.in/d/4bb3a5f304334160ab67/

[2] Electronic notes lectures on PM signal https://www.electronics-notes.com/articles/radio/modulation/phase-modulation-what-is-pm-tutorial.php

[3] PM by All About Circuits https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/radio-frequency-modulation/phase-modulation-theory-time-domain-frequency-domain/