Communication Theory Lab Report

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Communication Theory Lab
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Lab Assignment # 2

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Frequency modulation

Abstract

In this experiment, we have tried to understand the concept of Frequency Modulation (FM) in time domain by giving both a sinusoidal and a square wave as input. We analysed them by plotting their graphs in MATLAB. In frequency modulation, we observed the effect of increasing the amplitude of message signal. We also compared the above two frequency 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 frequency modulation, frequency 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 carrier signal is kept constant.

Consider m(t) as the message signal and c(t) as carrier signal. So m(t) = Am*cos(m*t + θ). Also c(t) = Ac*cos(c*t + θ). In FM, the frequency at an instant t is given by -

$$f_i(t) = f_c(t) + k_f * m(t)$$

We know that -

$\omega_i = \frac{d\theta_i}{dt}$
$2 * pi * f_i(t) = \frac{d\theta_i}{dt}$

$\theta_i(t) = 2 * pi * \int f_i dt.$

On putting the value of$f_i(t)$, one can get $-$

$\theta_i(t) = 2 * pi * f_c * t + 2 * pi * k_f * \int m(t)dt.$
$s(t) = Am * cos(2 * pi * f_c * t + 2 * pi * k_f * \int m(t)dt)(1)$

1.1 Block Diagram

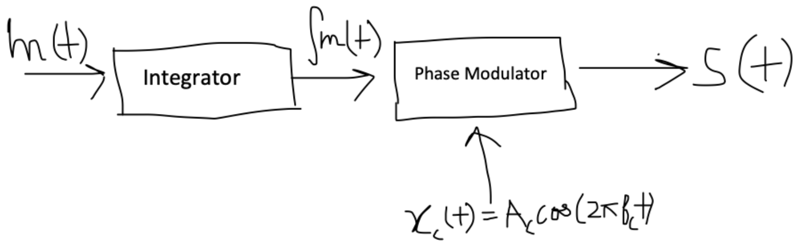

Figure 1: FM block diagram

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.

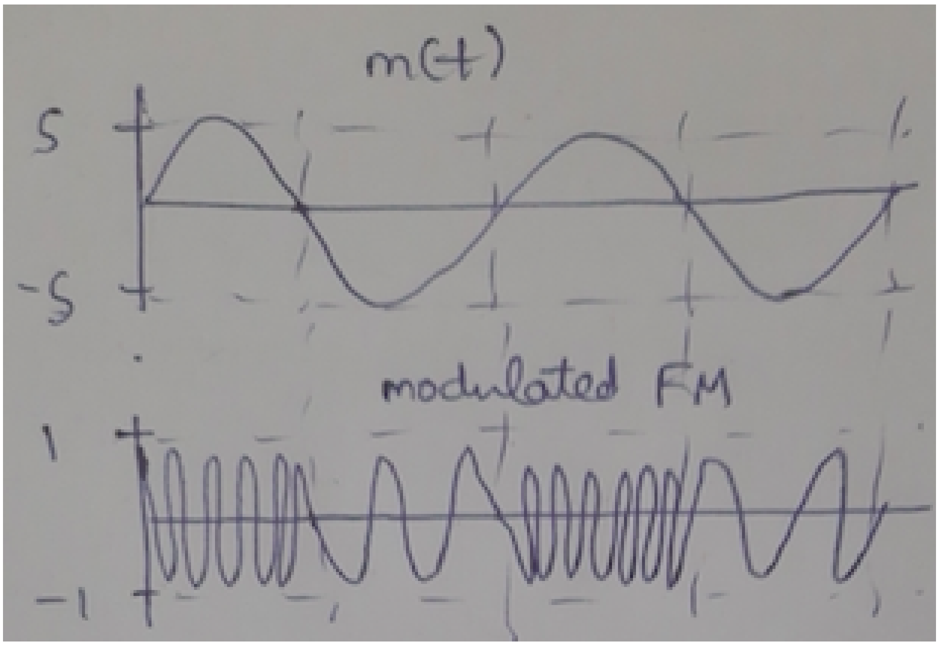

Figure 2: Figure for part A

1.2.2 Answer 2

This is directly taken from the lecture. And it will be almost similar to what is drawn in answer 1.

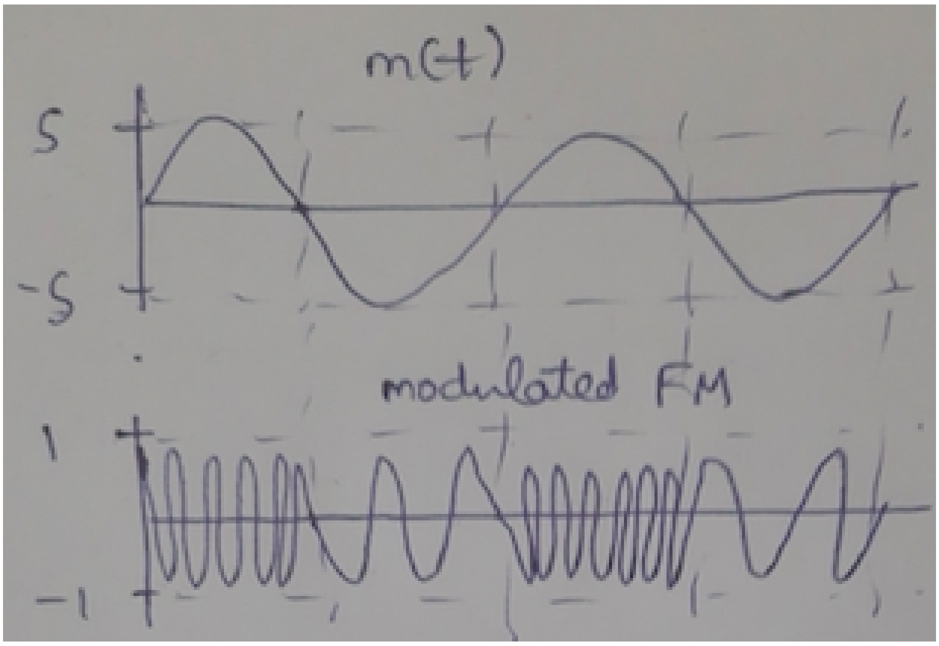

Figure 3: Figure for part B

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 FM signal :

1. `Radio broadcasting:` It is widely used in radio transmission as it has a larger SNR (signal to noise ratio), because of which it has low radio frequency interference. This is one of the main reasons that many radio stations broadcast music over the radio using FM.

2. `Radar, telemetry, EEG:` FM also finds its usage in radar, telemetry, seismic prospecting and in EEG. It is also used in different ra-

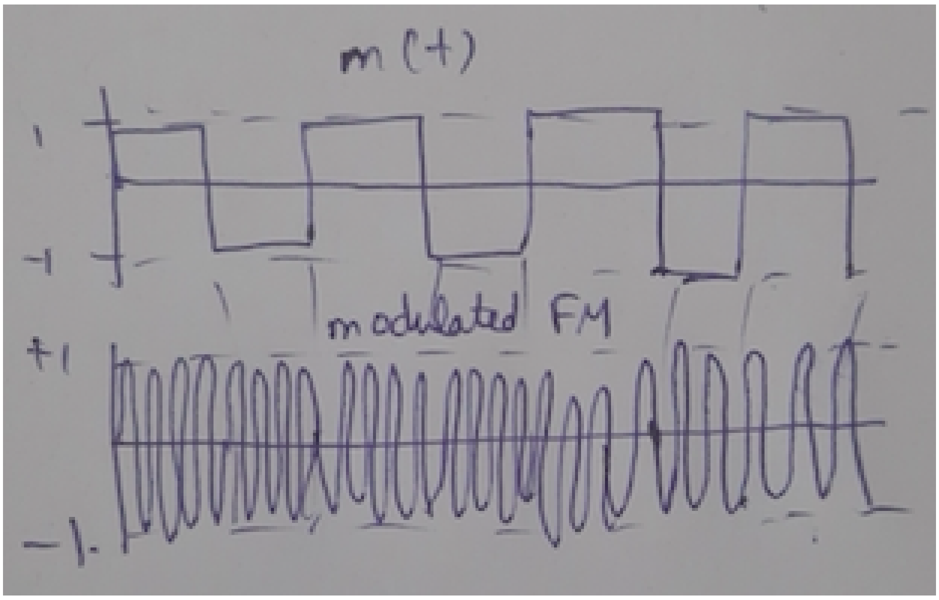

Figure 4: Figure for part C

dio systems where different musics are synthesized, and also in video-transmission instruments.

2 Results and Inferences

2.1 Answer 1

We have,

$$f_i = f_c + (1/(2 * \pi)) * K_f * m(t) \tag{2}$$

Inferences are :

1. The instantaneous frequency of FM Signal varies accordingly with the message signal. That is as message signal increases, the frequency of FM signal increases. And as m(t) starts to decrease, the frequency of FM signal also starts to decrease. It reaches its maximum/minimum when m(t) is at its highest/lowest point.

2. The amplitude of the modulated signal is same as the carrier signal.

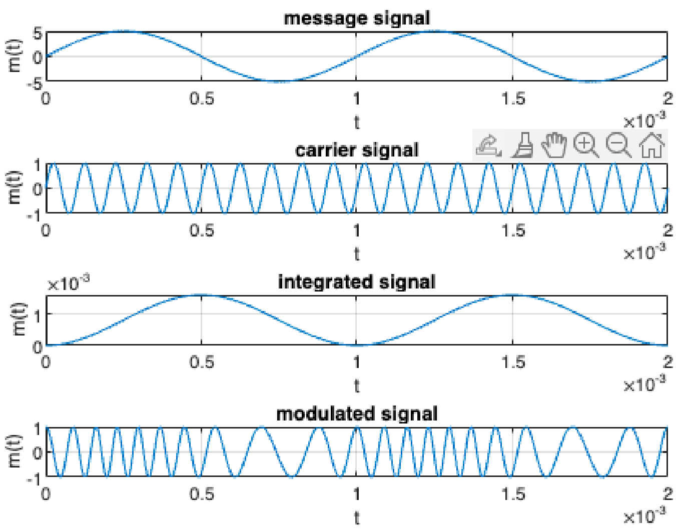

Figure 5: Figure for part A

2.2 Answer 2

We have,

$$f_i = f_c + (1/(2 * \pi)) * K_f * m(t) \tag{3}$$

Also Kf*m(t) (for 1a) = Kf*m(t) (for 1b).
It means that the difference between maximum and minimum instantaneous frequency for 1a and 1b would be same.

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1. The instantaneous frequency of FM Signal varies accordingly with the message signal. That is as message signal increases, the frequency of FM signal increases. And as m(t) starts to decrease, the frequency of FM signal also starts to decrease. It reaches its maximum/minimum when m(t) is at its highest/lowest point.
2. The amplitude of the modulated signal is same as the carrier signal.
3. difference between maximum and minimum instantaneous frequency for 1a and 1b is same.

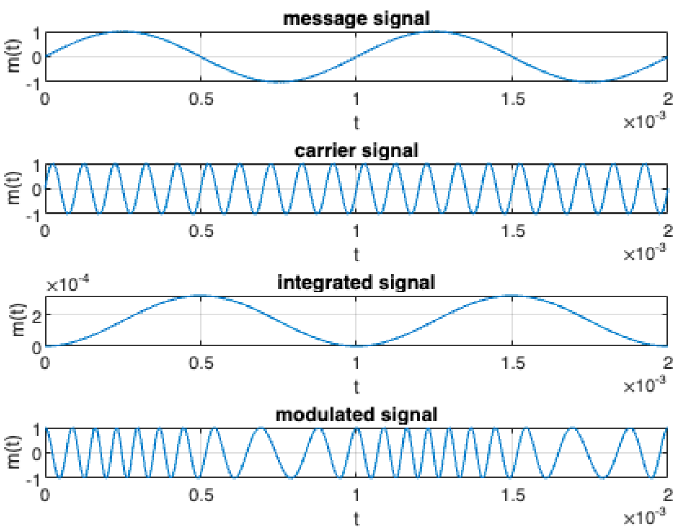

Figure 6: Figure for part B

2.3 Answer 3

Inferences are :

1. In the FM signal, one can observe two types of frequencies. One frequency is present when the square wave is continuous and the pther one is present when the message square wave changes from -1 to 1.

2. Frequency of carrier wave is 5 times of the message signal. Hence the frequency of FM signal will be around 10 times of the message signal.

3. The message signal is given to be a square wave. On integration, it will result into sawtooth wave which will act as an offset to phase for the FM wave.

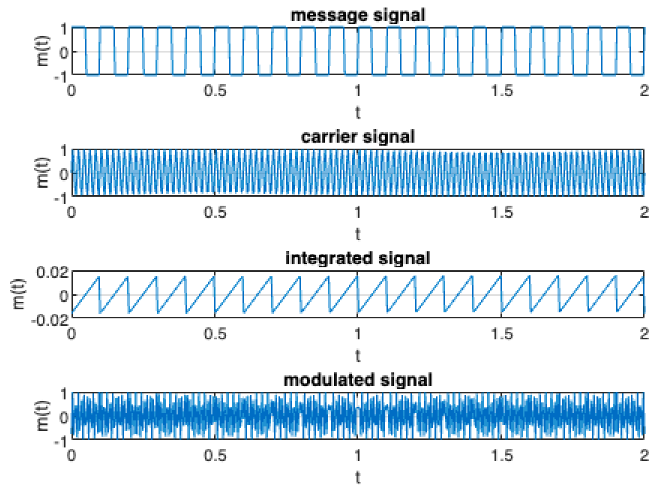

Figure 7: Figure for part C

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)

```
clc;

Am = 5;
```

```
Ac = 1;
fm =1000;
fc = 10^7;

T = 1/fm;
t = (0:T/999:2*T);
kf = 2*pi*1000;

% message signal
figure();
subplot(411);
mt = Am*sin(2*pi*fm*t);
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("message signal");
grid on;

% carrier signal
subplot(412);
mt = Ac*sin(2*pi*fc*t);
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("carrier signal");
grid on;

% modulated signal
subplot(413);
imt = Am*(1-cos(2*pi*fm*t))/(2*pi*fm);
plot(t,imt);
xlabel("t");
ylabel("m(t)");
title("integrated signal");
grid on;

% FM signal
subplot(414);
fm = Ac*cos(2*pi*fc*t + kf*imt);
plot(t,fm);
xlabel("t");
```

```
ylabel("m(t)");
title("modulated signal");
grid on;
```

B.2 Q1(b)

```
clc;

Am = 1;
Ac = 1;
fm =1000;
fc = 10^7;

T = 1/fm;
t = (0:T/999:2*T);
kf = 2*pi*5000;

% message signal
figure();
subplot(411);
mt = Am*sin(2*pi*fm*t);
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("message signal");
grid on;

% carrier signal
subplot(412);
mt = Ac*sin(2*pi*fc*t);
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("carrier signal");
grid on;

% modulated signal
subplot(413);
imt = Am*(1-cos(2*pi*fm*t))/(2*pi*fm);
plot(t,imt);
```

```
xlabel("t");
ylabel("m(t)");
title("integrated signal");
grid on;

% FM signal
subplot(414);
fm = Ac*cos(2*pi*fc*t + kf*imt);
plot(t,fm);
xlabel("t");
ylabel("m(t)");
title("modulated signal");
grid on;
```

B.3 Q1(c)

```
clc;

Am = 1;
Ac = 1;
fm =10;
fc = 50;

T = 1/fm;
t = linspace(0,2,500);
kf = 2*pi*150;

% message signal
figure();
subplot(411);
mt = Am*square(2*pi*fm*t);
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("message signal");
grid on;

% carrier signal
subplot(412);
mt = Ac*sin(2*pi*fc*t);
```

```
plot(t,mt);
xlabel("t");
ylabel("m(t)");
title("carrier signal");
grid on;

% modulated signal
subplot(413);
imt = Am*sawtooth(2*pi*fm*t)/(2*pi*fm);
plot(t,imt);
xlabel("t");
ylabel("m(t)");
title("integrated signal");
grid on;

% FM signal
subplot(414);
fm = Ac*cos(2*pi*fc*t + kf*imt);
plot(t,fm);
xlabel("t");
ylabel("m(t)");
title("modulated 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 FM signal https://www.electronics-notes.com/articles/radio/modulation/frequency-modulation-fm.php

[3] FM by Byjus https://byjus.com/jee/frequency-modulation/