CIE 337 Project I Report (Part I)

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Introduction

Frequency Modulation (FM) is a technique used to change the instantaneous frequency of a sinusoidal carrier signal $c(t)$ by means of a message signal $m(t)$, which one desires to transmit [1]. The instantaneous frequency of the carrier signal in this case is the time derivative of the carrier's angle. If one assumes that the carrier's angle is $\omega_c t$, then the instantaneous frequency of the carrier is ω_c. To apply FM, one adds the term $k_m m(t)$, where k_m is the frequency sensitivity, to the instantaneous frequency of the carrier (i.e. ω_c). To get the angle of the frequency-modulated signal $s(t)$, the expression $\omega_c + k_m m(t)$ is integrated with respect to t. Accordingly, one obtains the mathematical expression of the frequency-modulated signal $s(t)$ as

$$s(t) = A_c cos(\omega_c t + k_m \int_0^t m(u)du)$$

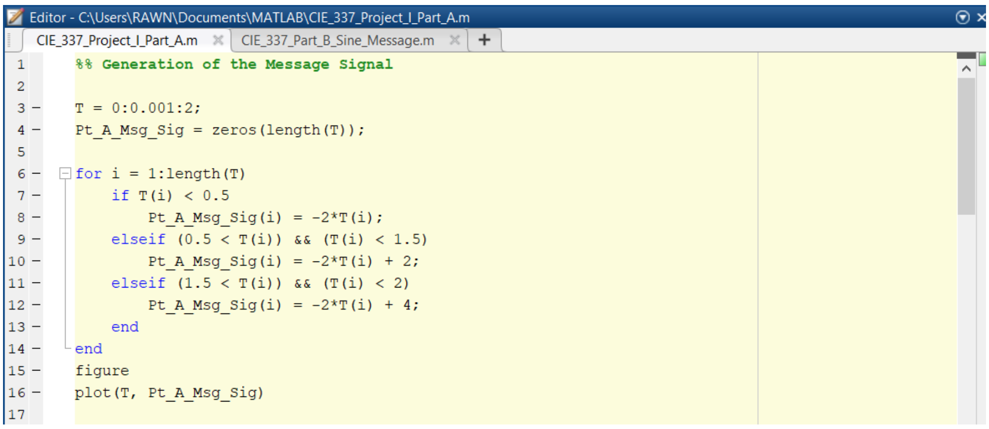
Part I: Generation of a Frequency-modulated Signal with a Sawtooth Message Signal Using Matlab®

Generation of the Sawtooth Message Signal

The message signal in **Fig. 1** in the project description document is a piece-wise function that can be expressed as

$$m(t) = \begin{cases} -2t & 0 < t < 0.5 \\ -2t + 2 & 0.5 < t < 1.5 \\ -2t + 4 & 1.5 < t < 2 \end{cases}$$

The source code that generate $m(t)$ is shown in **Figure 1**.




```
%% Generation of the Message Signal

T = 0:0.001:2;
Pt_A_Msg_Sig = zeros(length(T));

for i = 1:length(T)
    if T(i) < 0.5
        Pt_A_Msg_Sig(i) = -2*T(i);
    elseif (0.5 < T(i)) && (T(i) < 1.5)
        Pt_A_Msg_Sig(i) = -2*T(i) + 2;
    elseif (1.5 < T(i)) && (T(i) < 2)
        Pt_A_Msg_Sig(i) = -2*T(i) + 4;
    end
end
figure
plot(T, Pt_A_Msg_Sig)
```

Figure 1: Matlab Source Code that generate part-A's Message Signal

A plot of the message signal vs time is prompted, as soon as the **Run** button is clicked; it is shown in **Figure 2**.

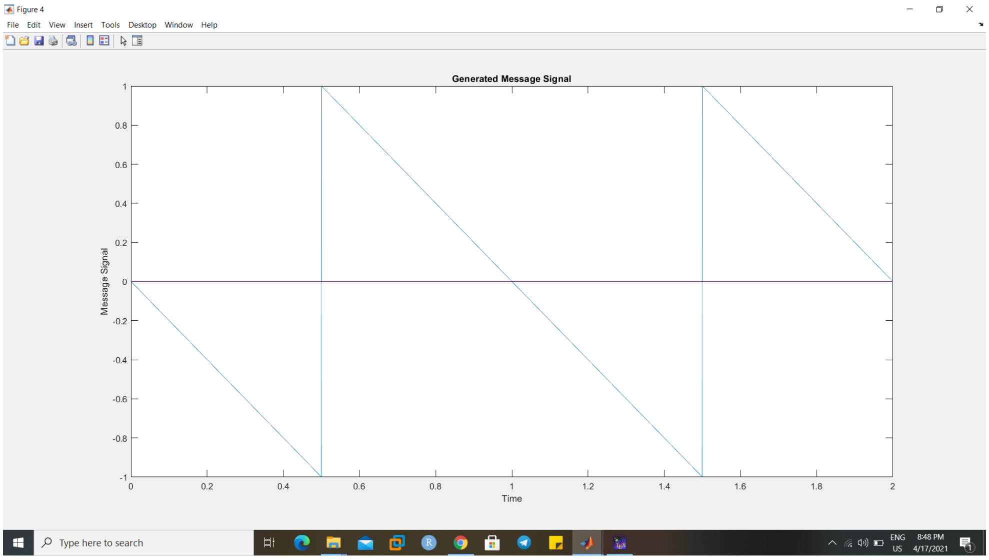


Figure 2: Matlab Plot of Part-A's Message Signal

Generation of the Phase Deviation Signal

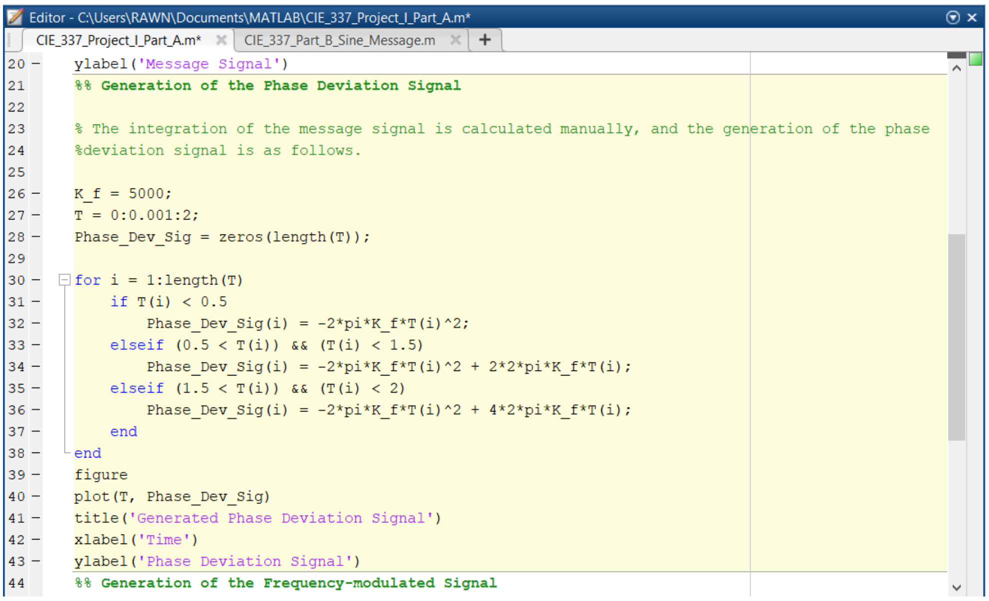
In the previous subsection, one obtained the message signal function; this help us obtaining the integral of the message signal, where it can be expressed as

$$M(t) = \begin{cases} -t^2 & 0 < t < 0.5 \\ -t^2 + 2t & 0.5 < t < 1.5 \\ -t^2 + 4t & 1.5 < t < 2 \end{cases}$$

One knows that the phase deviation $\theta(t)$ is equal to $2\pi K_f M(t)$, accordingly $\theta(t)$ can be expressed as

$$\theta(t) = \begin{cases} -4\pi K_f t^2 & 0 < t < 0.5 \\ -4\pi K_f t^2 + 2t & 0.5 < t < 1.5 \\ -4\pi K_f t^2 + 4t & 1.5 < t < 2 \end{cases}$$

The source code that generate $\theta(t)$ is shown in **Figure 3**.



Editor - C:\Users\RAWN\Documents\MATLAB\CIE_337_Project_I_Part_A.m*

CIE_337_Project_I_Part_A.m* | CIE_337_Part_B_Sine_Message.m

```
ylabel('Message Signal')
%% Generation of the Phase Deviation Signal

% The integration of the message signal is calculated manually, and the generation of the phase
%deviation signal is as follows.

K_f = 5000;
T = 0:0.001:2;
Phase_Dev_Sig = zeros(length(T));

for i = 1:length(T)
    if T(i) < 0.5
        Phase_Dev_Sig(i) = -2*pi*K_f*T(i)^2;
    elseif (0.5 < T(i)) && (T(i) < 1.5)
        Phase_Dev_Sig(i) = -2*pi*K_f*T(i)^2 + 2*2*pi*K_f*T(i);
    elseif (1.5 < T(i)) && (T(i) < 2)
        Phase_Dev_Sig(i) = -2*pi*K_f*T(i)^2 + 4*2*pi*K_f*T(i);
    end
end
figure
plot(T, Phase_Dev_Sig)
title('Generated Phase Deviation Signal')
xlabel('Time')
ylabel('Phase Deviation Signal')
%% Generation of the Frequency-modulated Signal
```

Figure 3: Matlab Source Code that generate the Phase Deviation Signal

the resulting plot of $\theta(t)$ is shown in **Figure 4**

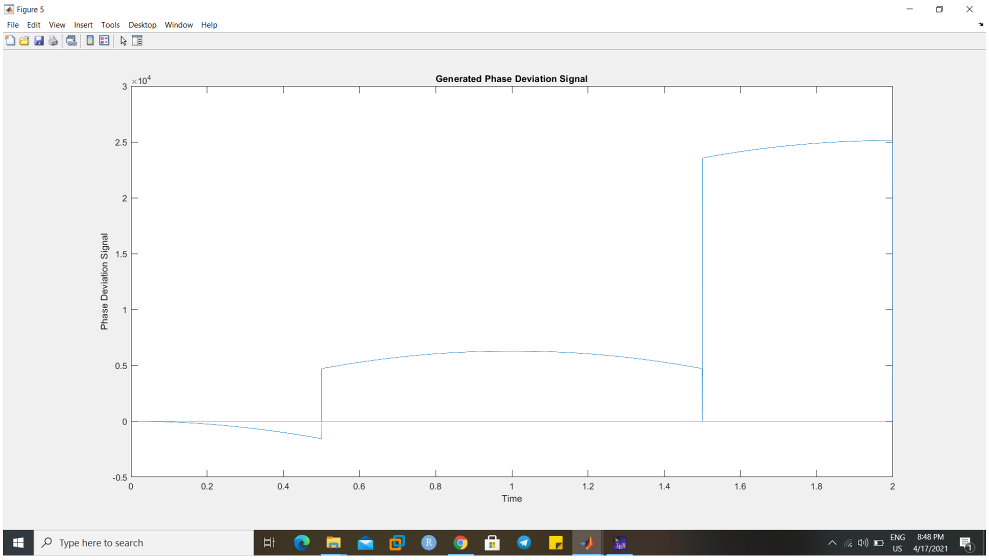
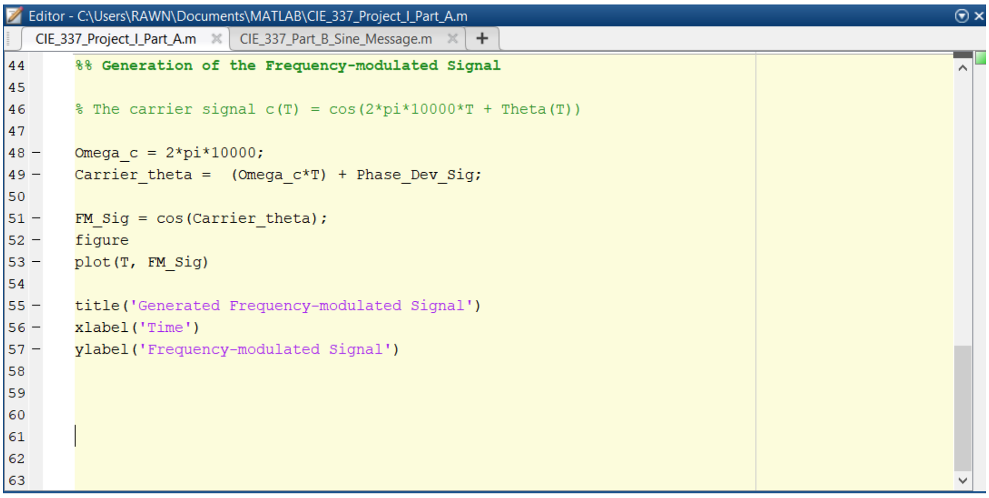


Figure 4: Matlab Plot of the Phase Deviation Signal

Generation of the Frequency-modulated Signal

In the previous section, one obtained the mathematical formula of $s(t)$; the formula needed to generate the FM signal after obtaining the phase deviation signal. In **Figure 5**, the source code that generate the FM signal is shown.


Editor - C:\Users\RAWN\Documents\MATLAB\CIE_337_Project_I_Part_A.m

CIE_337_Project_I_Part_A.m | CIE_337_Part_B_Sine_Message.m

```
%% Generation of the Frequency-modulated Signal

% The carrier signal c(T) = cos(2*pi*10000*T + Theta(T))

Omega_c = 2*pi*10000;
Carrier_theta =  (Omega_c*T) + Phase_Dev_Sig;

FM_Sig = cos(Carrier_theta);
figure
plot(T, FM_Sig)

title('Generated Frequency-modulated Signal')
xlabel('Time')
ylabel('Frequency-modulated Signal')
```

Figure 5: Matlab Source Code that generate the FM Signal

The result of running the code in **Figure 5** is shown in **Figure 6**

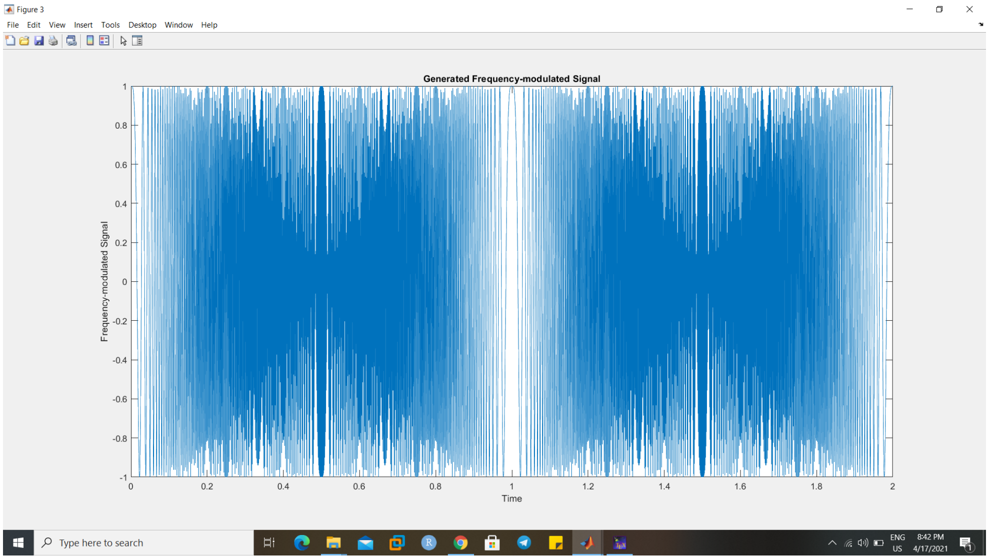


Figure 6: Matlab Plot of the FM Signal

The Resulting Frequency-modulated Signal for different K_f values

The former results one's obtained is when the $K_f = 1000$; now, one desires the plots of the FM signals for $K_f = 3000$ and $K_f = 5000$. In **Figure 7**, the plot of the FM signal for $K_f = 3000$ is shown, while the plot of the FM signal for $K_f = 5000$ is shown in **Figure 8**.

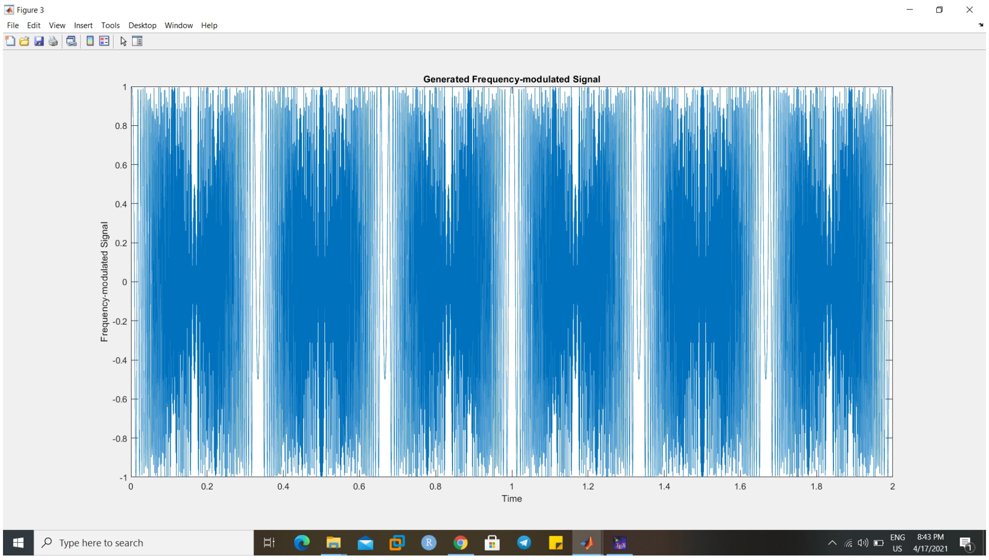


Figure 7: Matlab Plot of the FM Signal for $K_f = 3000$

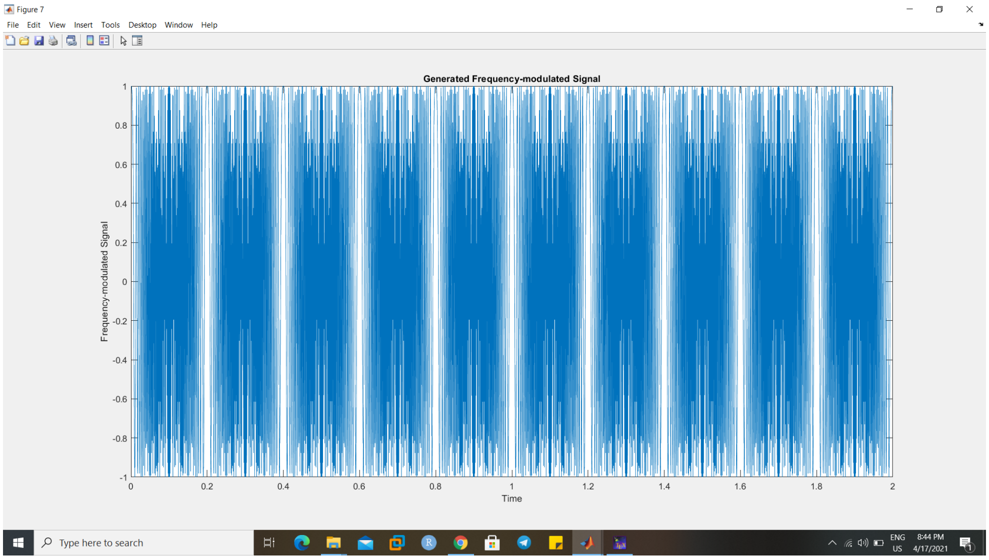


Figure 8: Matlab Plot of the FM Signal for $K_f = 5000$

At this point, one notices that when K_f **increases**, number of carrier's frequency change occurrences **increases** in the same time interval as well.