Faculty of Engineering and Technology

Electrical and Computer Engineering Department

ENEE 3309

Communication Systems

Course Project

Amplitude modulation and demodulation

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Section: 1.

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Abstract

This aim of this project is to know how to use Matlab software to write codes for plotting modulated and demodulated signal in time domain using envlope detector circiut for a normal amplitude waveform. In additon, to evalute the optimum value of the time constant that minimizes the mean square error between the modulated signal s(t) and the output signal of the envelope detector.

Procedure and discussion

Question 1 and Question 2:

Consider the AM signal

$$s(t) = A_c[1 + \mu\cos(2\pi f_m t)]\cos(2\pi f_c t)$$

1. Use Matlab (m-file commands) to plot $s(t)$ assuming $\mu = 0.25$, $A_c = 1$, $f_m = 1\text{Hz}$, $f_c = 25\text{Hz}$ over two cycles of the message $m(t) = \cos(2\pi f_m t)$
2. If $s(t)$ is passed through an ideal envelope detector, plot the demodulated signal over two cycles of the message $m(t)$.

- **Implementation in Matlab:**

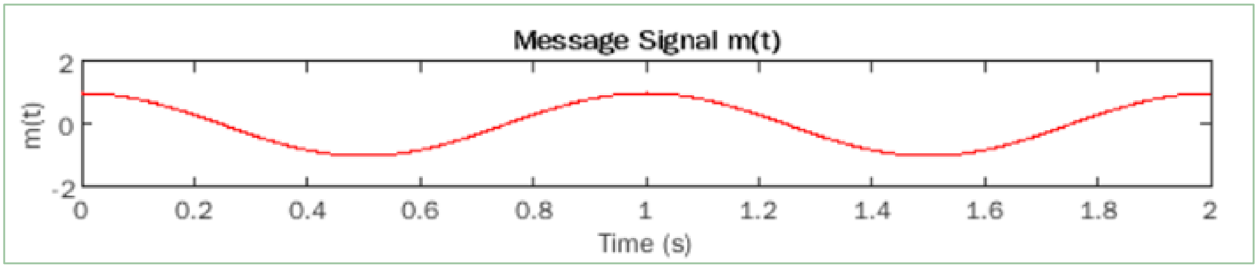
```
%% 1190707-Lojain Abdalrazaq-Sec 1
%% Question 1+2
% Plotting the modualted signal s(t) = Ac[1 + μ cos(2πfmt)]cos(2πfct)
% Plotting the demodulated signal y(t)
M=0.25;      % μ
Ac=1;        % Carrier Amplitude
Fm=1;        % The frequncy of the message signal--> m(t)
Fc=25;       % The frequncy of the carrier signal-->c(t)
t=0:0.001:2; % 2 cycles
%---------------------*Message Signal*-----------------------------------
axis([0 2 -2 2]);
subplot(4,1,1);
m=cos(2*pi*Fm*t);  % message signal m(t)
plot(t,m,'red');     % Plotting the message signal m(t)
title('Message Signal m(t)');
xlabel('Time (s)');
ylabel('m(t)');
%---------------------*Carrier Signal*-----------------------------------
axis([0 2 -2 2]);
subplot(4,1,2);
c=cos(2*pi*Fc*t);  % carrier signal c(t)
plot(t,c,'blue');     % Plotting the carrier signal c(t)
title('Carrier Signal c(t)');
xlabel('Time (s)');
ylabel('c(t)');
```

```
%---------------------*Modulated Signal*--------------------------------
axis([0 2 -2 2]);
subplot(4,1,3);
s=Ac*(1+ M*m).*c;  % modualted signal s(t)
plot(t,s,'green');
title('Modulated Signal s(t)');
xlabel('Time (s)');
ylabel('s(t)');
%---------------------*Demodulated Signal*------------------------------
axis([0 2 -2 2]);
subplot(4,1,4);
y=abs(Ac*(1+ M*cos(2*pi*Fm*t)));  % Demodulated signal
plot(t,y,'black');
title('Demodulated Signal y(t)');
xlabel('Time (s)');
ylabel('y(t)');
%----------------------------------------------------------------------
```

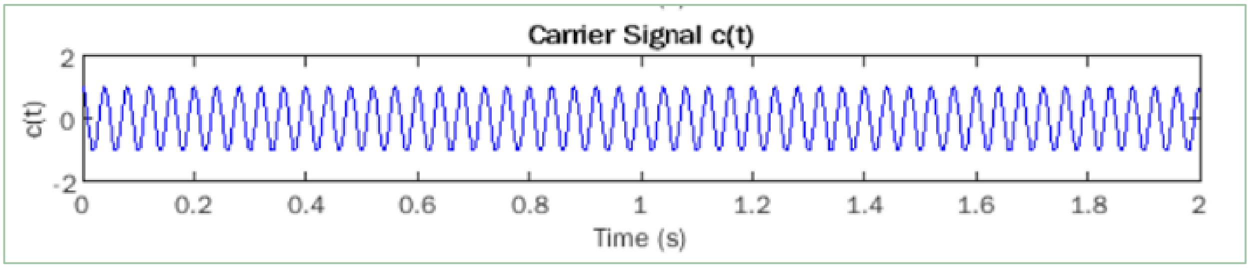
Fig(1): The implementation of Q1 and Q2 using matlab.

- **The plot:**

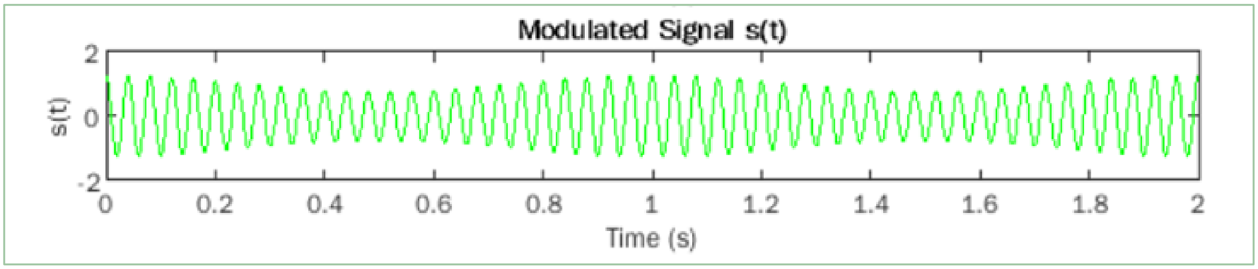
The following figures represent the plot of the signals using Matlab:



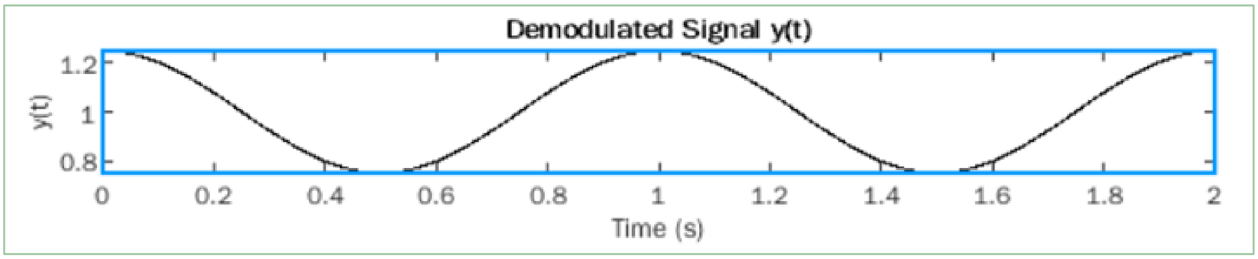
Fig(2): The plot of message signal m(t).



Fig(3): The plot of Carrier Signal c(t).



Fig(4): The plot of the modulated signal s(t).



Fig(5): The plot of the demodulated signal y(t).

<u>Question 3:</u>

3. Assume that $s(t)$ is passed through the envelope detector shown in the figure to produce the waveform $y(t)$, where $R_s = 0$ and the diode is ideal ($V_D = 0$). In class, we put the following condition on the time constant of the circuit for best performance

$$\frac{1}{f_c} \ll \tau = R_L C \ll \frac{1}{f_m}$$

Define the mean squared error between $s(t)$ and $y(t)$ as:

$$D = \frac{1}{T_m} \int_0^{T_m} (y(t) - m(t))^2 dt$$

a. Plot D versus $\frac{1}{f_c} \leq \tau \leq \frac{1}{f_m}$

b. From the figure, determine the optimum value of the time constant that minimizes D.

c. Plot $y(t)$ that corresponds to the minimum D

- **Implementation in Matlab:**

```matlab
%% 1190707-Lojain Abdalrazaq-Sec 1
%% Q3:
M=0.25;        % µ
Ac=1;          % Carrier Amplitude
Fm=1;          % The frequncy of the message signal--> m(t)
Fc=25;         % The frequncy of the carrier signal-->c(t)
T = 10 ;
MinVal = 1/Fc;               % 1/25=0.04  --> Lower bound of tau
MaxVal = 1/Fm;               % 1/1=1      --> Upper bound of tau
tau = MinVal:0.001:MaxVal;   % MinVal << tau << MaxVal
num_tau=length(tau);         % Return the length of the array of tau
Ts=MinVal/100;               % Sampling time
t=0: Ts :2*MaxVal;          % time
% Ideal Envelope equation:
ideal_envelope  =Ac*(1 + M*cos(2*pi*Fm*t));
% Modulated signal s(t) equation:
S = ideal_envelope.*cos(2*pi*Fc*t);  %s(t)--> modulated signal
%-------------------------------------------------------------------------
```

```matlab
% At the 1st time,the Actual Envelope will be the same as Modulated signal
for i=1:num_tau
    % In this for loop, we will cover the values of the tau
    actual_envelope(1,1)=1+M;
    for n=1:length(t)-1
           if actual_envelope(1,n) < S(1,n)
            % When the modualted signal more then the exponential, then
            % The Actual Envelope will be the same as S(t)
            % The capacitor is charging
            % The diode is ON
           actual_envelope(1,n+1)= S(1,n);
           else
            % As long as the modulated signal s(t) less than the product of
            % the value of previous Actual Envelope and the exponential
            % e^-t/ta, the capacitor is discharging
            % The diode is OFF
            actual_envelope(1,n+1)=actual_envelope(1,n)*exp(-Ts/tau(1,i));
        end
```

```
    % Calculating the mean square error Cal_MSE
    % The norm function returns the sum of the diffrence between the ideal
    % envelope detector and the practical envelop detector divided by the
    % the length of the time
    Cal_MSE(1,i)=(sum((actual_envelope-ideal_envelope).^2))/length(t);
end
 [~,T]=min(Cal_MSE);
 actual_envelope(1,1)=1+M;
 for n=1:length(t)-1
     if actual_envelope(1,n) < S(1,n)
         actual_envelope(1,n+1)=S(1,n+1);
     else
        actual_envelope(1,n+1)=actual_envelope(1,n)*exp(-Ts/tau(1,T));
     end
 end
%----------------------------*Plotting MSE*-------------------------------
plot(tau,Cal_MSE,'green');
grid;
xlabel('tau (s)');
ylabel('MSE');
title('Mean Square Function');
figure;
```

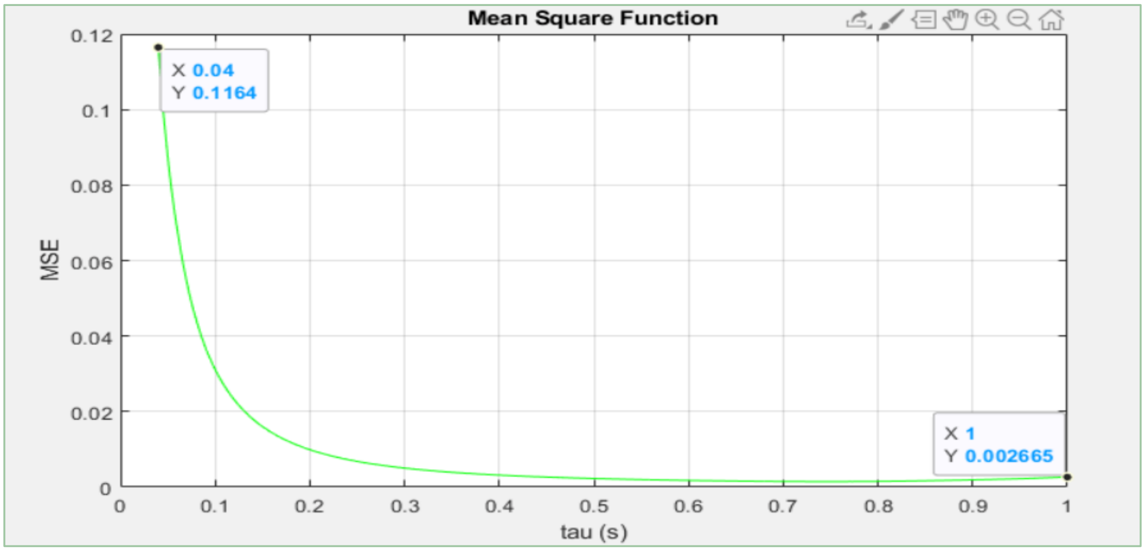
```
  end
%----------------------------*Plotting MSE*------------------------------
plot(tau,Cal_MSE,'green');
grid;
xlabel('tau (s)');
ylabel('MSE');
title('Mean Square Function');
figure;
%-----------------------*Plotting Actual Envelope*-----------------------
% Modulated signal and output signal for optimum value of Tau
plot(t,actual_envelope,'black','linewidth',2.0);
title('AM waveform and envelope detector')
xlabel('Time (s)');
ylabel('Amplitude');
figure;
%---------------*Plotting Actual Envelope and Modulated Signal*----------
plot(t,S,'Blue');
hold on
plot(t,actual_envelope,'m','linewidth',1.5);
title('AM waveform and envelope detector')
xlabel('Time (s)');
ylabel('Amplitude');
```

Fig(6): The implementation of Q3 using matlab.

- ## The plot of Mean Square Error :

The following figure represents the plot of the Mean square function between s(t) and y(t) versus $1/fc \leq \tau \leq 1/fm$:

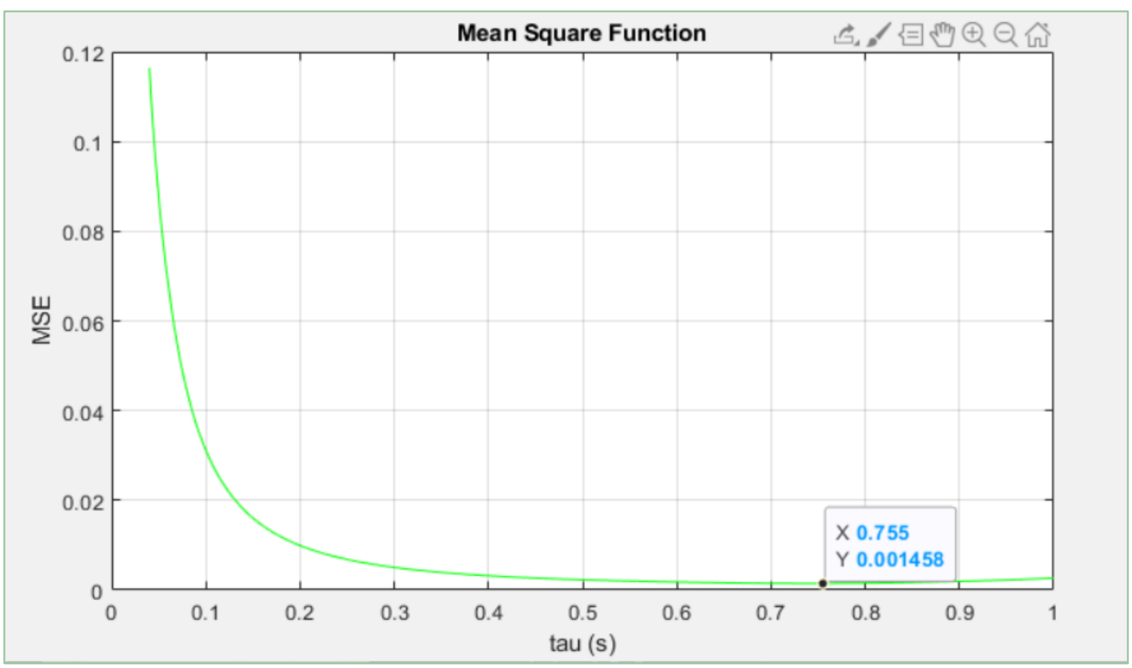
Note that the value of 1/fc= 0.04, and 1/fm=1.



Fig(7): The plot of MSE function.

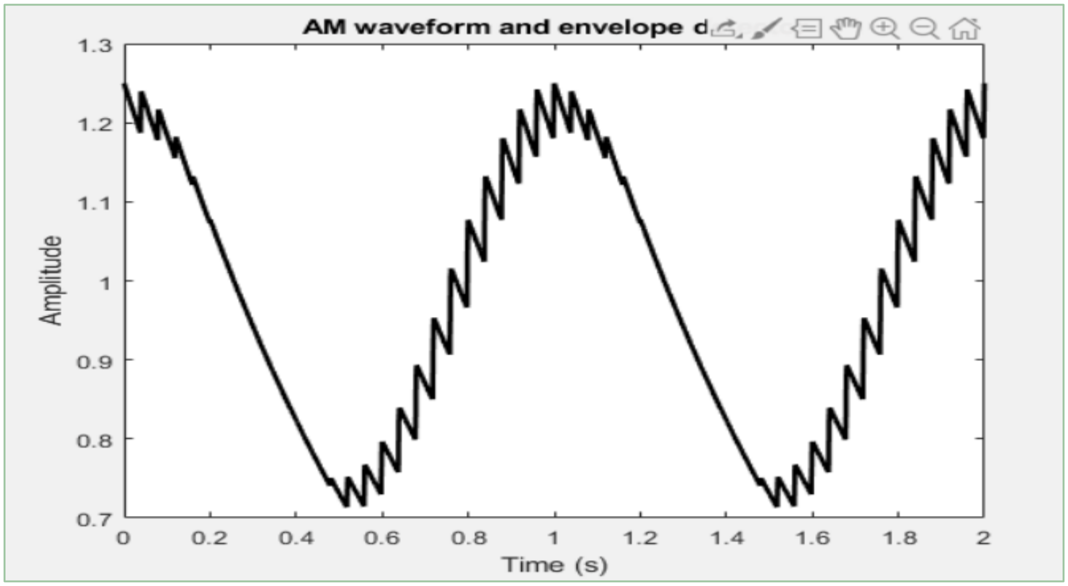
- ## The value that minimize D:

The value of tau= 0.775.

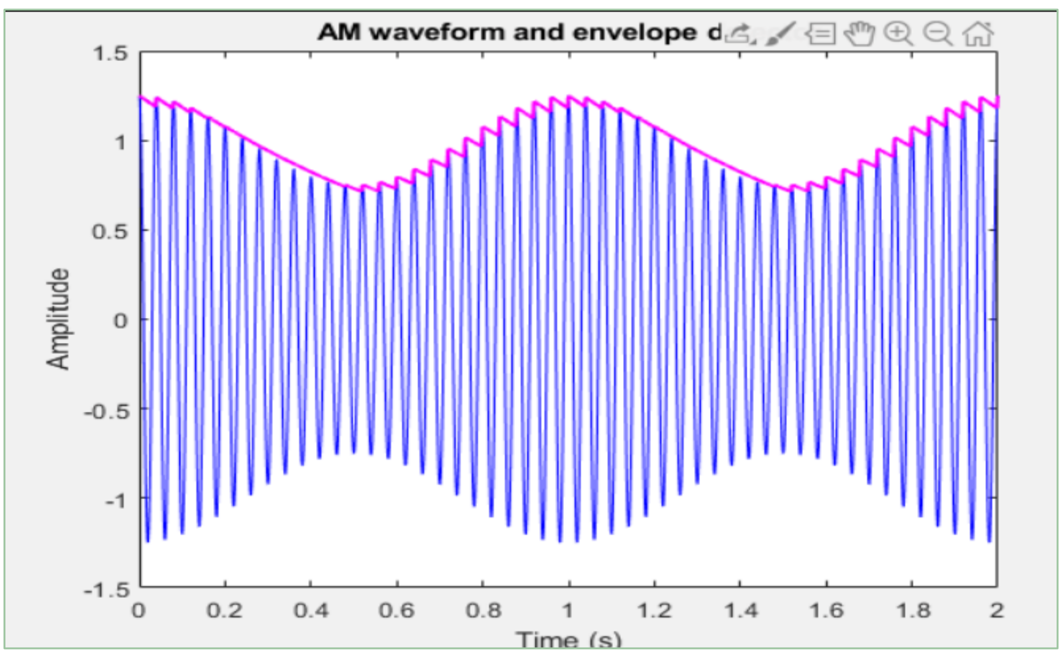


Fig(8): The plot of MSE function with the value that minimize D.

- **Plot $y(t)$ that corresponds to the minimum D:**



Fig(9): The plot of Actual envelope detector.



Fig(10): The plot of modulated signal and Actual Envelope detector.

Appendixes:

- **Q1+Q2 Matlab Code:**

```
%% 1190707-Lojain Abdalrazaq-Sec 1
%% Question 1 + 2
% Plotting the modualted signal s(t) = Ac[1 + μ cos(2πfmt)]cos(2πfct)
% Plotting the demodulated signal y(t)
M=0.25;      % μ
Ac=1;        % Carrier Amplitude
Fm=1;        % The frequncy of the message signal--> m(t)
Fc=25;       % The frequncy of the carrier signal-->c(t)
t=0:0.001:2; % 2 cycles
%----------------------*Message Signal*-----------------------------------
axis([0 2 -2 2]);
subplot(4,1,1);
m=cos(2*pi*Fm*t);  % message signal m(t)
plot(t,m,'red');   % Plotting the message signal m(t)
title('Message Signal m(t)');
xlabel('Time (s)');
ylabel('m(t)');
%----------------------*Carrier Signal*-----------------------------------
axis([0 2 -2 2]);
subplot(4,1,2);
c=cos(2*pi*Fc*t);  % carrier signal c(t)
plot(t,c,'blue');     % Plotting the carrier signal c(t)
title('Carrier Signal c(t)');
xlabel('Time (s)');
ylabel('c(t)');
%----------------------*Modulated Signal*---------------------------------
axis([0 2 -2 2]);
subplot(4,1,3);
s=Ac*(1+ M*m).*c;  % modualted signal s(t)
plot(t,s,'green');
title('Modulated Signal s(t)');
xlabel('Time (s)');
ylabel('s(t)');
%----------------------*Demodulated Signal*-------------------------------
axis([0 2 -2 2]);
subplot(4,1,4);
y=abs(Ac*(1+ M*cos(2*pi*Fm*t)));  % Demodulated signal
plot(t,y,'black');
title('Demodulated Signal y(t)');
xlabel('Time (s)');
```

- **Q3 Matlab Code:**

```
%% 1190707-Lojain Abdalrazaq-Sec 1
%% Q3:
M=0.25;        % μ
Ac=1;          % Carrier Amplitude
Fm=1;          % The frequncy of the message signal--> m(t)
Fc=25;         % The frequncy of the carrier signal-->c(t)
T = 10 ;
MinVal = 1/Fc;               % 1/25=0.04  --> Lower bound of tau
MaxVal = 1/Fm;               % 1/1=1      --> Upper bound of tau
tau = MinVal:0.001:MaxVal;   % MinVal << tau << MaxVal
num_tau=length(tau);         % Return the length of the array of tau
Ts=MinVal/100;               % Sampling time
t=0: Ts :2*MaxVal;          % time
% Ideal Envelope equation:
ideal_envelope  =Ac*(1 + M*cos(2*pi*Fm*t));
% Modulated signal s(t) equation:
S = ideal_envelope.*cos(2*pi*Fc*t);  %s(t)--> modulated signal
%---------------------------------------------------------------------------
% At the 1st time,the Actual Envelope will be the same as Modulated signal
for i=1:num_tau
    % In this for loop, we will get over all the values of the tau
    actual_envelope(1,1)=1+M;
    for n=1:length(t)-1
           if actual_envelope(1,n) < S(1,n)
            % When the modualted signal more then the exponential, then
            % The Actual Envelope will be the same as S(t)
            % The capacitor is charging
            % The diode is ON
           actual_envelope(1,n+1)= S(1,n);
           else
            % As long as the modulated signal s(t) less than the product of
            % the value of previous Actual Envelope and the exponential
            % e^-t/ta, the capacitor is discharging
            % The diode is OFF
            actual_envelope(1,n+1)=actual_envelope(1,n)*exp(-Ts/tau(1,i));
        end
    end
    % Calculating the mean square error Cal_MSE
    % The norm function returns the sum of the diffrence between the ideal
    % envelupe detector and the practical envelop detector divided by the
    % the length of the time
    Cal_MSE(1,i)=(sum((actual_envelope-ideal_envelope).^2))/length(t);
end
```

```
 [~,T]=min(Cal_MSE);
 actual_envelope(1,1)=1+M;
 for n=1:length(t)-1
     if actual_envelope(1,n) < S(1,n)
         actual_envelope(1,n+1)=S(1,n+1);
     else
        actual_envelope(1,n+1)=actual_envelope(1,n)*exp(-Ts/tau(1,T));
     end
 end
%-----------------------------*Plotting MSE*------------------------------
plot(tau,Cal_MSE,'green');
grid;
xlabel('tau (s)');
ylabel('MSE');
title('Mean Square Function');
figure;
%------------------------*Plotting Actual Envelope*------------------------
% Modulated signal and output signal for optimum value of Tau
plot(t,actual_envelope,'black','linewidth',2.0);
title('AM waveform and envelope detector')
xlabel('Time (s)');
ylabel('Amplitude');
figure;
%----------------*Plotting Actual Envelope and Modulated Signal*-----------
plot(t,S,'Blue');
hold on
plot(t,actual_envelope,'m','linewidth',1.5);
title('AM waveform and envelope detector')
xlabel('Time (s)');
ylabel('Amplitude');
ylabel('y(t)');
```