BERZIET UNIVERSITY

FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF COMPUTER ENGINEERING

ENEE3309 COMMUNICATION SYSTEMS

Course Project

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Section

1

Instructor

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Abstract:

This project studies amplitude modulation and demodulation.

s(t) A normal AM modulation on message m(t) is produced.

Then s(t) is demodulated using an envelope detector circuit.

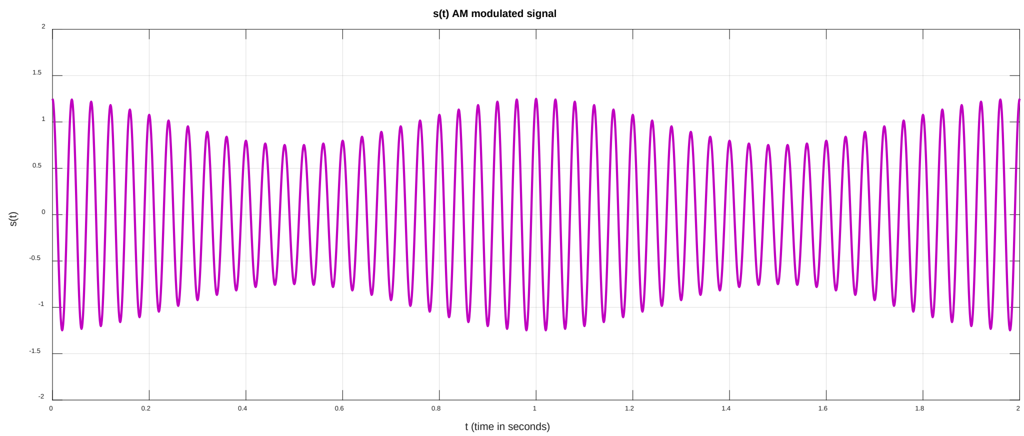
Procedure:

S(t) = Ac(1+mu*cos(2pi*fm*t)) cos(2pi*fc*t)

1. plot s(t) assuming mu=0.25, Ac=1, fm=1Hz, fc=25Hz over two cycles of the message m(t)=cos(2πfmt):

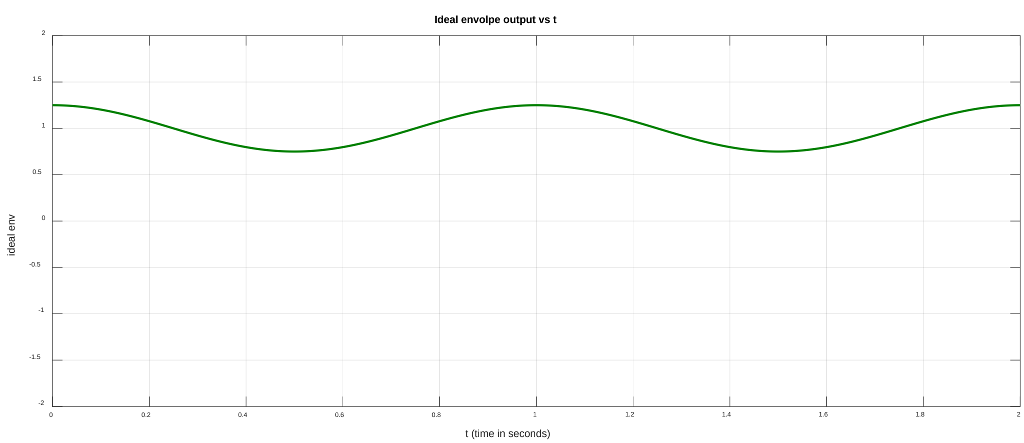
project.m

```
mu= 0.25;
Ac= 1;
fc= 25;
fm= 1;
t= 0:0.001:2;

m = cos(2*pi*fm*t);      % m(t) message signal
c = cos(2*pi*fc*t);      % c(t) carrier signal
s = Ac*(1+(mu*m)).*c;    % s(t) AM modulated signal

plot(t,s)
axis([0 2 -2 2]);
title("s(t) AM modulated signal");
xlabel("t (time in seconds)");
ylabel("s(t)");
grid on;
```



2. If $s(t)$ is passed through an ideal envelope detector, plot the demodulated signal over two cycles of the message m(t):

```
ideal_env = abs(Ac*(1+(mu*m)));      % ideal envelope detector output signal

```



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

   1/fc << tau=RC << 1/fm

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

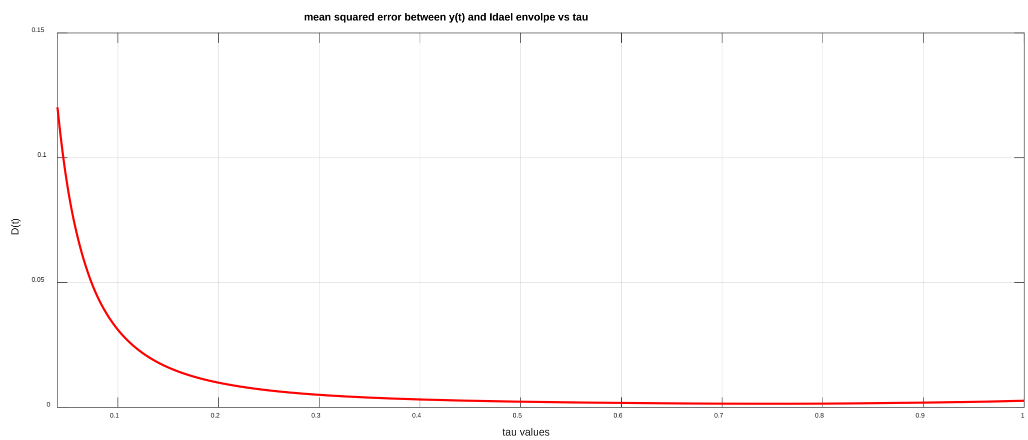
   $$D = 1/Tm \sum_{t=0}^{Tm} (\mathrm{y(t)} - \mathrm{ideal\_env\ (t)})^2$$

   a) Plot D versus 1/fc <= tau <= 1/fm:

```
max_tau =1/fm;
min_tau = 1/fc;
tau = min_tau:0.001:max_tau;

tlength =length(t);          %time lentgh
taulength =length(tau);      %tau lentgh

D(1,1) = 0;      %mean squared error between ideal env and y(t)
for i=1 :taulength
    y(1,1)=s(1,1);        %envelope detector output signal for tau(i)
    T0(1,1) =1;           %the time value just before the diode turns off
    V0 = s(1,1);          %the value of s(t) just before the diode turns off
    for n=1: tlength-1
        if y(1,n) < s(1,n+1)     %diode is on
            y(1,n+1)= s(1,n+1);
            T0 = n;
            V0 = s(1,n+1);
        else                     %diode is off
            y(1,n+1)= V0*exp( -(t(1,n)- t(1,T0)) /tau(1,i));
        end
    end
    D(1,i)= sum((y - ideal_env).^2) / tlength;
end

```

For each tau value, we find the output y(t) that corresponds to that value, Then we find the mean square error between y(t) and the ideal envelope and add the result to D(tau).

```
plot(tau,D)
title("mean squared error between y(t) and Idael envolpe vs tau");
axis([0.04 1 0 0.15]);
xlabel("tau values");
ylabel("D(t)");
grid on;
```



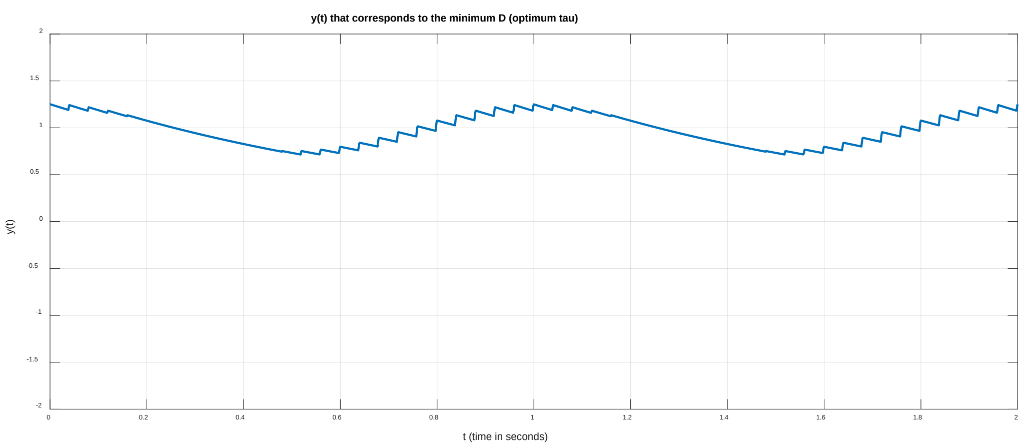
b) From the figure, determine the optimum value of the time constant that minimizes D:

```
[~,optimum_tau] = min(D);    %the optimum value of the tau that minimizes D
fprintf("optimum value of tau = %0.4f \n",tau(1,optimum_tau));
```

```
Command Window
New to MATLAB? See resources for Getting Started.
>> project
optimum value of tau = 0.7610
>>
```

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

```
y(1,1)=s(1,1);      %envelope detector output signal for optimum tau
T0(1,1) =1;
V0 = s(1,1);
for n=1: tlength-1
    if y(1,n) < s(1,n+1)
        y(1,n+1)= s(1,n+1);
        T0 = n;
        V0= s(1,n+1);
    else
        y(1,n+1)=V0*exp(-(t(1,n)- t(1,T0))/tau(1,optimum_tau));
    end
end
```



How we find the output y(t):
We initall y(0) = s(0) , T0 =0 and V0 = s(0).
For each time value we compare y(t) with s(t+1) .
If s(t+1) is bigger (diode is on): the the next value y(t+1) = s(t+1) ,and we save the time and value in (T0,V0).

If y(t) is bigger than the next value (diode is off) :
y(t+1) = V0 * $e^{\frac{-(t-T0)}{tau}}$.

Source Code:

```
mu= 0.25;
Ac= 1;
fc= 25;
fm= 1;
t= 0:0.001:2;

m = cos(2*pi*fm*t);    % m(t) message signal
c = cos(2*pi*fc*t);    % c(t) carrier signal
s = Ac*(1+(mu*m)).*c;  % s(t) AM modulated signal
ideal_env = abs(Ac*(1+(mu*m)));    % ideal envelope detector output signal

max_tau =1/fm;
min_tau = 1/fc;
tau = min_tau:0.001:max_tau;

tlength =length(t);       %time lentgh
taulength =length(tau);    %tau lentgh

D(1,1) = 0;    %mean squared error between ideal env and ?(?)
for i=1 :taulength
  y(1,1)=s(1,1);     %envelope detector output signal for tau(i)
  T0(1,1) =1;        %the time value just before the diode turns off
  V0 = s(1,1);       %the value of s(t) just before the diode turns off
  for n=1: tlength-1
    if y(1,n) < s(1,n+1)    %diode is on
      y(1,n+1)= s(1,n+1);
      T0 = n;
      V0 = s(1,n+1);
    else                %diode is off
      y(1,n+1)= V0*exp( -(t(1,n)- t(1,T0)) /tau(1,i));
```

```
        end
    end
    D(1,i)= sum((y - ideal_env).^2) / tlength;
end

[~,optimum_tau] = min(D);   %the optimum value of the tau that minimizes D
fprintf("optimum value of tau = %0.4f \n",tau(1,optimum_tau));

 y(1,1)=s(1,1);     %envelope detector output signal for optimum tau
 T0(1,1) =1;
 V0 = s(1,1);
 for n=1: tlength-1
    if y(1,n) < s(1,n+1)
        y(1,n+1)= s(1,n+1);
        T0 = n;
        V0= s(1,n+1);
    else
        y(1,n+1)=V0*exp(-(t(1,n)- t(1,T0))/tau(1,optimum_tau));
    end
 end

 %Plots
subplot(2,2,1);
plot(t,s)
axis([0 2 -2 2]);
title("s(t) AM modulated signal");
xlabel("t (time in seconds)");
ylabel("s(t)");
grid on;

subplot(2,2,2);
plot(t,ideal_env)
axis([0 2 -2 2]);
```

```
title("Ideal envolpe output vs t");

xlabel("t (time in seconds)");

ylabel("ideal env");

grid on;


subplot(2,2,3);

plot(tau,D)

title("mean squared error between y(t) and Idael envolpe vs tau");

axis([0.04 1 0 0.15]);

xlabel("tau values");

ylabel("D(t)");

grid on;


subplot(2,2,4);

plot(t,y)

axis([0 2 -2 2]);

title("y(t) that corresponds to the minimum D (optimum tau)");

xlabel("t (time in seconds)");

ylabel("y(t)");

grid on;
```