Faculty of Engineering & Technology – Electrical & Computer Engineering Department

First Semester 2021 – 2022

Communication Systems – ENEE3309.

MATLAB Project

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Section: 4

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Project Description

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 $m(t)$.
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

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

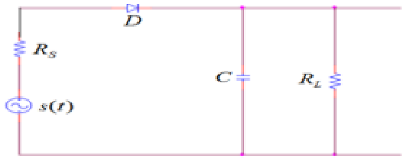
Define the mean squared error between $s(t)$ and $y(t)$ as:

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

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



HINT:

$$V_{out} = \begin{cases} V_o e^{-\frac{t}{\tau}} & \text{Diode is off} \\ s(t) & \text{Diode is on} \end{cases}$$

where

V_{out} is the voltage at the output of the envelop detector

Vo is the value of s(t) just before the diode turns off

The time constant $\tau = RC$.

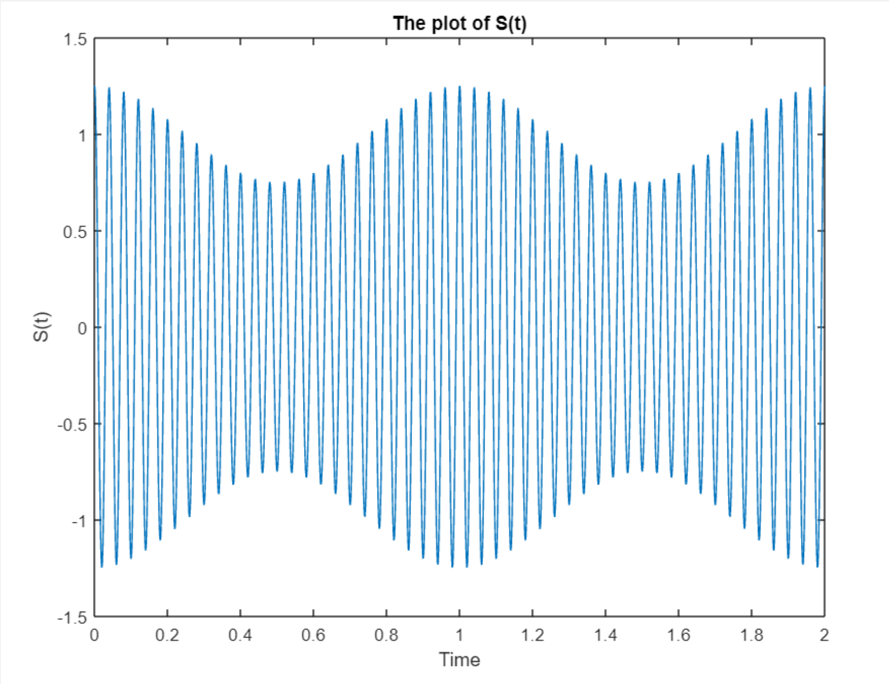
First Question

1. Use Matlab (m-file commands) to plot $s(t)$ assuming $\mu = 0.25$, $Ac = 1$, fm = 1Hz, fc = 25Hz over two cycles of the message m(t) = cos(2πfmt)

The Code:

```
fm=1
fc=25
k=0.25
Ac=1
Am=1
u=k.*Am
t=0:0.000001:2;
s=(1 + u.*cos(2.*pi.*fm.*t)).*cos(2.*pi.*fc.*t)
plot(t,s)
xlabel("Time")
ylabel("S(t)")
title("The plot of S(t)")
```

The Graph:



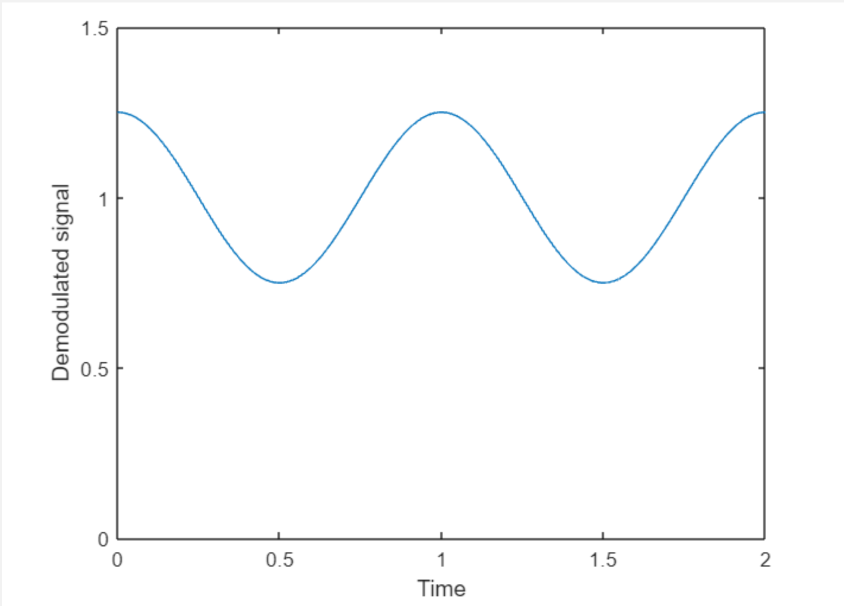
Second Question

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

The Code:

```
fm=1
k=0.25
Am=1
u=k.*Am
t=0:0.000001:2;
de=(1 + u.*cos(2.*pi.*fm.*t))
y=abs(de)
plot(t,y)
ylim([0 1.5])
xlabel("Time")
ylabel("Demodulated Signal")
title("Message passed throught an envelope detector")
```

The Graph:



Third Question

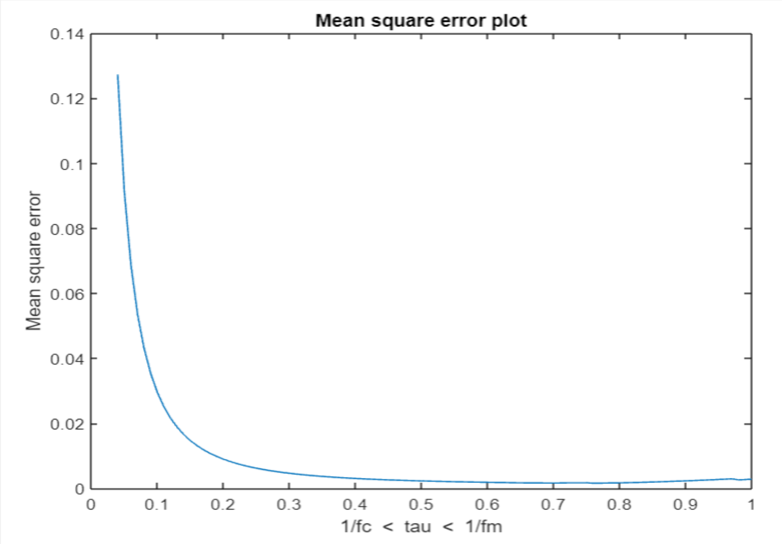
3. Assume that $s(t)$ is passed through the envelope detector shown in the figure to produce the waveform $y(t)$, where $Rs = 0$ and the diode is ideal ($VD = 0$). In class, we put the following condition on the time constant of the circuit for best performance.

Finding tau Code:

```
fm = 1;
fc = 25;
Ka = 0.25;
tau_min =1/fc;  % tau >= 1/fc
tau_max =1/fm;  % tau <= 1/fm
tau = tau_min:0.01:tau_max;
Ptau=length(tau);  % number of tau points
t = 0:0.01:2;
Pt=length(t) ;    % number of signal points
ideEnv=1 + Ka*cos(2*pi*fm*t);   % Theoratical envelop
S=ideEnv.*cos(2*pi*fc*t);    % Modulated signal

%% This loop will go on all values of tau
%% And calculate the mean square error
for i=1:Ptau
  pracEnv(1,1)=1+Ka;
  %% This loop will go on each practical envolope
  %% For each value of tau
  for n=1:Pt-1
    %% Diode is on
    if pracEnv(1,n)<S(1,n)
      pracEnv(1,n+1)= S(1,n);
     %% Diode is off
    else
      pracEnv(1,n+1)=pracEnv(1,n)*exp(-0.01/tau(1,i));
    end
  end
  %% The calculation of the mean square error (d)
  d(1,i)=(norm((pracEnv-ideEnv)).^2)/Pt;
end
[~,minError]=min(d);
%% Getting the value of tau
%% That has the least mean square error
bestValue = tau(1, minError);
plot(tau,d);
xlabel('1/fc  <  tau  <  1/fm');
ylabel('Mean square error');
title('Mean square error plot');
```

Finding tau Graph:



Best value of tau = 0.7600

Practical Envelop detector Code:

```
n=500;
fm=1
fc=25
Ka=0.25
tau=0.76;
so=1+0.25;
to=0;
for i=1:n
  t(i)=i/250;
  ideEnv(i)=(1 + Ka.*cos(2.*pi.*fm.*t(i)));
  s(i)=ideEnv(i).*cos(2.*pi.*fc.*t(i));
  if s(i)==ideEnv(i)
    to=t(i);
    so=s(i);
  end
  d=so.*exp(-(t(i)-to) / 0.6);
  pracEnv(i)=0;
  if d>s(i)
    pracEnv(i)=d;
  else
    pracEnv(i)=ideEnv(i);
  end
end
plot(t,pracEnv,'-',t,s,'-',t,ideEnv,'-');
xlabel("Time");
ylabel("Final Signal");
title("practical and ideal envelope dectector outputs");
```

Practical Envelop detector with ideal graph: