BERZIET UNIVERSITY
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF COMPUTER ENGINEERING
COMPUTER DESIGN LABORATORY

Communication Systems

ENEE 3309

Course Project

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Abstract:

The aim of this project will cover amplitude modulation and demodulation. A normal AM waveform is produced using a simple switching modulator circuit. The resulting AM waveform is then demodulated using an envelope detector circuit. Finally, Evaluating the optimum value of the time constant that minimizes the mean square error between modulated signal and the output signal of the envelope detector.

Table of Contents:

List Of Figures:

1. Procedure and Discussion:

Consider the AM signal:

$$s(t) = Ac\,[1 + \mu \cos(2\pi \text{fmt})]\cos(2\pi \text{fc } t)$$

NOTE: $\mu = 0.25$, $Ac = 1$, fm = 1Hz, fc = 25Hz, m(t) = cos(2πfmt).

1. The code to plot m(t), c(t) and $s(t)$:

```
% Question I, the AM signal s(t) = Ac [1 + M cos(2.pi.Fm.t)]cos(2.pi.Fc.t)
clear all % to remove all variables from workspace.
close all % to close all previous codes.
clc % clears the command window
t = 0:0.001:2; % seconds
Fm = 1; % hertz (Hz)
Am = 1;
Fc = 25; % hertz (Hz)
ka = 0.25;
Ac = 1;
m = Am.*cos(2*pi*Fm*t); % m(t) = cos(2πFmt)
carrier = Ac.*cos(2*pi*Fc*t); % c(t) = Ac.cos(2πFct)
s=(1+ka.*m).*carrier; % s(t) = Ac [1 + M cos(2πFmt)]cos(2πFct)
figure % figure NO.1
plot(t, m), xlabel ('t(sec)'), ylabel('m(t) = cos(2.pi.Fm.t)') % to plot m(t)
title('Message signal (Modulating signal)');
axis([0 2 -2 2]); % x axis from 0 to 2, and y axis from -2 to 2
grid on
figure % figure NO.2
plot(t, carrier), xlabel ('t(sec)'), ylabel('c(t) = Ac.cos(2.pi.Fc.t)') % to plot
c(t)
title('Carrier signal');
axis([0 2 -2 2]) % x axis from 0 to 2, and y axis from -2 to 2
grid on
figure % figure NO.3
plot(t, s), xlabel ('t(sec)'), ylabel('s(t) = Ac[1 + M
cos(2.pi.Fm.t)]cos(2.pi.Fc.t)') % to plot s(t)
title('Modulated signal (AM signal)');
axis([0 2 -2 2]) % x axis from 0 to 2, and y axis from -2 to 2
grid on
```

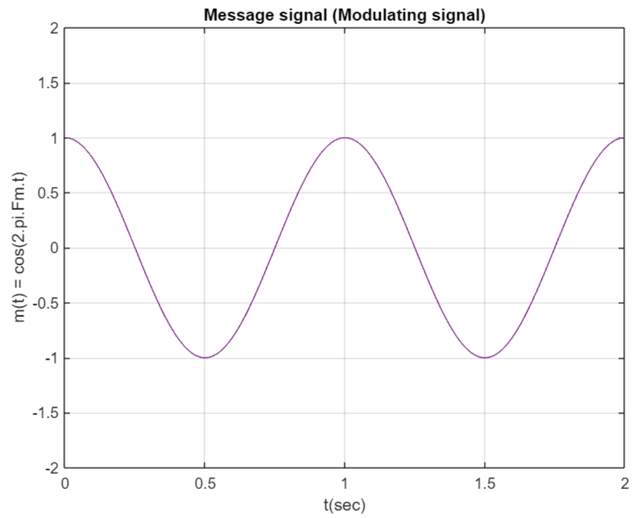


Figure NO.1: Message signal (Modulating signal): m(t)

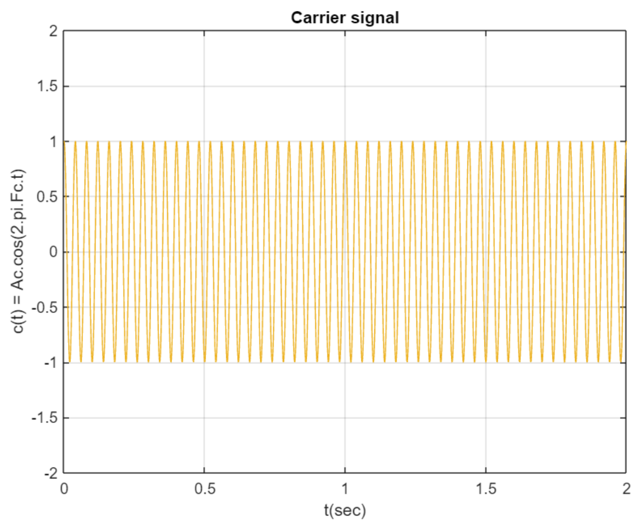


Figure NO.2: Carrier signal: c(t)

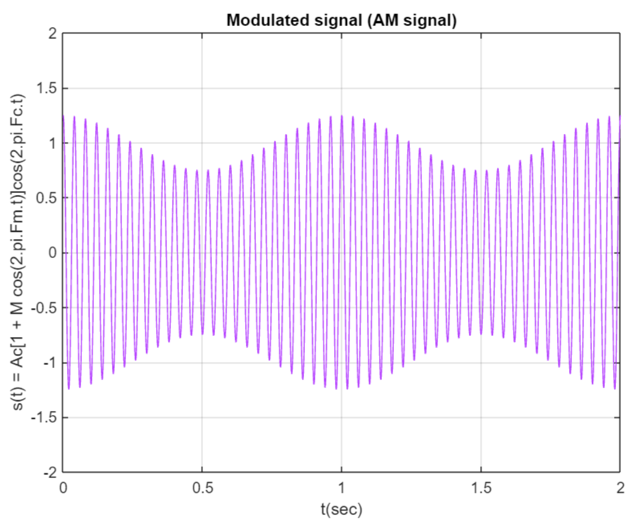


Figure NO.3: AM signal (Modulated signal): s(t)

2. The code to plot demodulation signal y(t):

```
% Question II, demodulated signal is output from ideal envelope detector
y(t) = |Ac [1 + M cos(2πfmt)]|
clear all % to remove all variables from workspace.
close all % to close all previous codes.
clc % clears the command window
t = 0:0.001:2; % seconds
Fm = 1; % hertz (Hz)
Am = 1;
Fc = 25; % hertz (Hz)
ka = 0.25;
Ac = 1;
m = Am.*cos(2*pi*Fm*t); % m(t) = cos(2πFmt)
carrier = Ac.*cos(2*pi*Fc*t); % c(t) = Ac.cos(2πFct)
s=(1+ka.*m).*carrier; % s(t) = Ac [1 + M cos(2πFmt)]cos(2πFct)
y = abs(Ac.*(1 + ka.*m));
plot(t,y) % plot the demodulated signal y(t)
title('Demodulated signal')
xlabel (' t(sec) ') % to put t(sec) under x axis
ylabel (' y(t) = |Ac [1 + M cos(2πfmt)]|') %to put y(t) = |Ac [1 + M
cos(2πfmt)]| next to y axis
axis([0 2 -2 2]); % x axis from 0 to 2, and y axis from -2 to 2
grid on
```

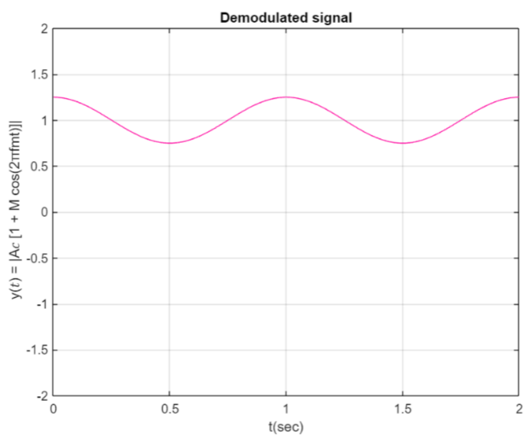


Figure NO.4: demodulation signal: y(t)

3. The code to plot D and $y(t)$ that corresponds to the minimum D:

a. Plot D versus $\frac{1}{fc} \ll \tau = R_L C \ll \frac{1}{fm}$:

```
% Question III, Plot D versus tau_o
clear all % to remove all variables from workspace.
close all % to close all previous codes.
clc % clears the command window
Fm = 1; % Message Signal Frequency in hertz (Hz)
Am = 1;
Fc = 25; % Carrier Frequency in hertz (Hz)
ka = 0.25; % Sensitivity Factor
Ac = 1;

%Lower bound of time constant is 0.04 AND Upper bound of time constant is 1
Tc = 10^(-6); %Sampling time of tau, Note: The tau value is in microseconds
tau = 0.04:Tc:1;
number_tau = length(tau);
Ts = 0.04/100; %Sampling time=Lower bound of time constant/100
```

```
t = 0:Ts:2;  % seconds
number_pts = length(t);
m = Am.*cos(2*pi*Fm*t);
carrier = Ac.*cos(2*pi*Fc*t);
s =(1+ka.*m).*carrier;    % Modulated Signal(AM signal)
y = abs(Ac.*(1 + ka.*m)); % Ideal Envelope Signal

for i=1:number_tau    % All values of tau
    ActualEnvelope(1,1)=1+ka;
    for n=1:number_pts-1
        if ActualEnvelope(1,n)<s(1,n)
            ActualEnvelope(1,n+1)= s(1,n);
        else
            ActualEnvelope(1,n+1)=ActualEnvelope(1,n)*exp(-Ts/tau(1,i));
        end
    end
    D(1,i)=(norm((ActualEnvelope-y).^2))/number_pts; %D Calculation (norm:
to calculate the magnitude of (Actual Envelope - y))
End

[~,Tau]=min(D); % to select a tau value from index value of minimum D
disp(Tau); % Display function to print tau value
plot(tau,D) % Plot D versus tau_o
grid on, xlabel('\tau_o (sec)'), ylabel('D'), title('D versus  \tau_o');
```

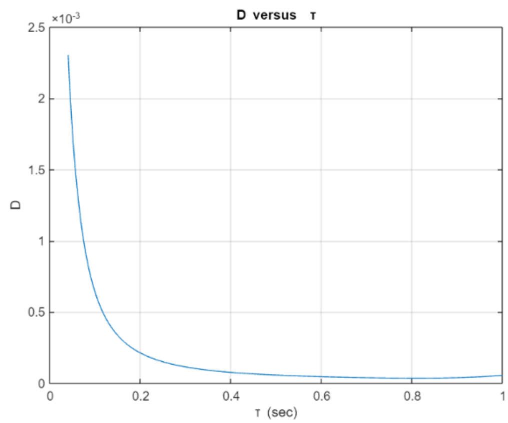
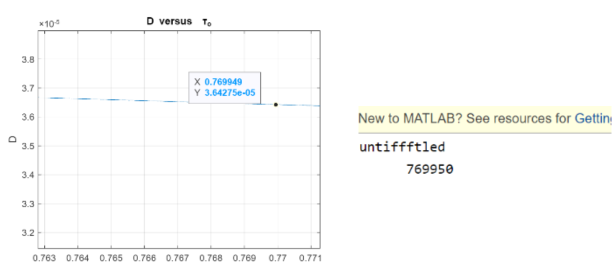


Figure NO.5: D versus τ

b. From the Figure NO.5, determine the optimum value of the time constant that minimizes D:

   Optimum value of the time constant that minimizes D = τo = 769950 microsec = 0.769950 sec.



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

```
% Question III,  Define the mean squared error between s(t) and y(t)
clear all % to remove all variables from workspace.
close all % to close all previous codes.
clc % clears the command window
Fm = 1; % Message Signal Frequency in hertz (Hz)
Am = 1;
Fc = 25; % Carrier Frequency in hertz (Hz)
ka = 0.25; % Sensitivity Factor
Ac = 1;

%Lower bound of time constant is 0.04 AND Upper bound of time constant is 1
Tc = 0.000001; %Sampling time of tau=10^(-6)
tau = 0.04:Tc:1;
Tau = 769950; %microseconds
Ts = 0.04/100; %Sampling time=Lower bound of time constant/100
t = 0:Ts:2;  % seconds
number_pts = length(t);

m = Am.*cos(2*pi*Fm*t);
carrier = Ac.*cos(2*pi*Fc*t);
s =(1+ka.*m).*carrier;    % Modulated Signal(AM signal)
y = abs(Ac.*(1 + ka.*m)); % Ideal Envelope Signal

ActualEnvelope(1,1)=1+ka; % actual OR practical envelope detector
for n=1:number_pts-1 % By using HINT from project
    if ActualEnvelope(1,n)<s(1,n)
        ActualEnvelope(1,n+1)=s(1,n+1);
    else
        ActualEnvelope(1,n+1)=ActualEnvelope(1,n)*exp(-Ts/tau(1,Tau));
    end
end

% Modulated signal and output signal for optimum value of Tau
plot(t, s); % to plot s(t) versus t
hold on
plot(t,ActualEnvelope,'g','linewidth',0.5); % The curve is drawn with a
straight line of width 0,5 cm
hold on
plot(t, y); % to plot y(t) versus t
grid on, title('A Simple Practical Envelope Detector: Effect of \tau_o');
xlabel('t(sec)'); ylabel('Amplitude');
```

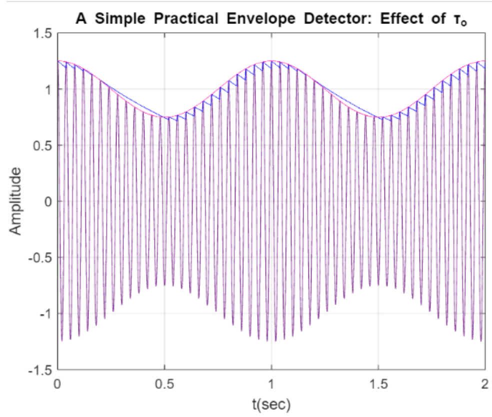


Figure NO.6: A Simple Practical Envelope Detector

Define the mean squared error between $s(t)$ and $y(t)$ as: $D = \frac{1}{Tm} \int_0^{Tm} (y(t) - m(t))^2 \, dt$

$V_{out} = \{ Vo\, e^{-t/\tau} \quad ,Diode\ is\ off$

$\qquad s(t) \qquad ,Diode\ is\ on$

Where:

Vout is the voltage at the output of the envelop detector (Actual/practical envelop detector).

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

The time constant $\tau = RC$.

2. References:

1. 3 DEC 2021. [Online]. Available: https://birzeit-edu.zoom.us/rec/share/5Hyf57SEnZzSJLxD7KcGd2ijlCX6KAZQ7ngG1UuFbTEbpYrRyc1rki0XCYyIJlMm.ioZAGJgjMfUogLtm.
2. "Envelope Detector," 4 DEC 2021. [Online]. Available: https://www.mathworks.com/matlabcentral/fileexchange/43966-envelope-detector?s_tid=FX_rc2_behav.
3. "Display value of variable," 6 DEC 2021. [Online]. Available: https://www.mathworks.com/help/matlab/ref/disp.html.
4. "Specify Line Style," 6 DEC 2021. [Online]. Available: https://www.mathworks.com/help/matlab/ref/plot.html.