ENEE3309 Communication Systems

2023-2024-1st semester Project

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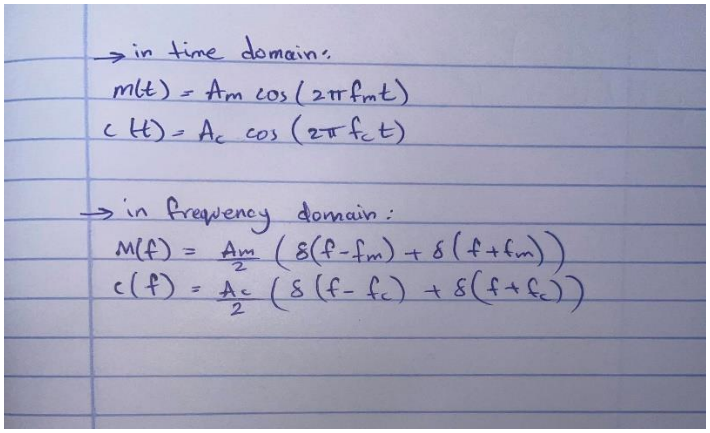
Section: 2

Introduction

This project is all about learning how to generate a normal AM signal, which are used in things like radio by using message and carrier signals with filtering. and learn about demodulation process, where the modulated signal goes through a circuit to recover the message signal.

Problem Specification

1.1 Express modulating signal m(t) and carrier signal c(t) in time domain, and frequency domain.



→ in time domain:

$m(t) = A_m \cos(2\pi f_m t)$

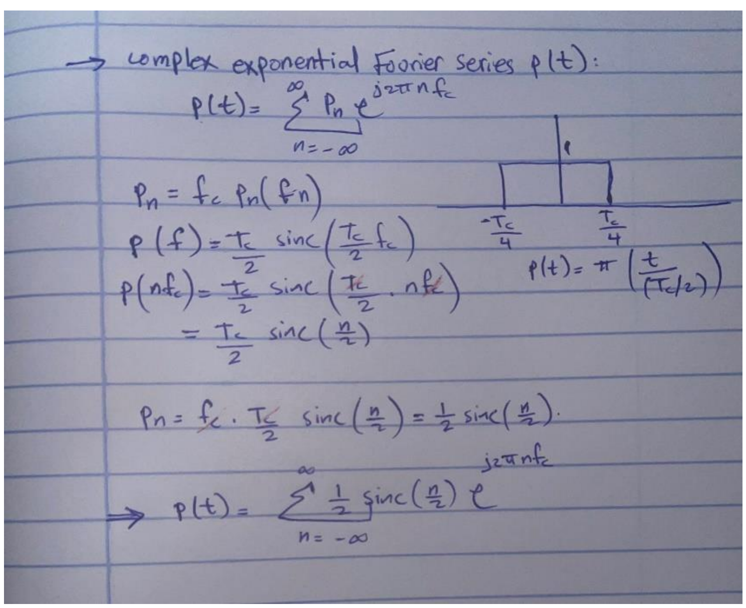
$c(t) = A_c \cos(2\pi f_c t)$

→ in frequency domain:

$M(f) = \frac{A_m}{2}\left(\delta(f-f_m) + \delta(f+f_m)\right)$

$C(f) = \frac{A_c}{2}\left(\delta(f-f_c) + \delta(f+f_c)\right)$

1.2 Determine the complex exponential Fourier series of the signal $p(t)$.



→ complex exponential Fourier series $p(t)$:

$p(t) = \sum_{n=-\infty}^{\infty} P_n e^{j2\pi n f_c}$

$P_n = f_c P_n(fn)$

$P(f) = \frac{T_c}{2} \operatorname{sinc}\left(\frac{T_c}{2} f_c\right)$

$P(nf_c) = \frac{T_c}{2} \operatorname{sinc}\left(\frac{T_c}{2} \cdot n\cancel{f_c}\right)$

$= \frac{T_c}{2} \operatorname{sinc}\left(\frac{n}{2}\right)$

$P_n = f_c \cdot \frac{T_c}{2} \operatorname{sinc}\left(\frac{n}{2}\right) = \frac{1}{2} \operatorname{sinc}\left(\frac{n}{2}\right).$

→ $p(t) = \sum_{n=-\infty}^{\infty} \frac{1}{2} \operatorname{sinc}\left(\frac{n}{2}\right) e^{j2\pi n f_c}$

1.3 Evaluate the output modulated signal $s(t)$

$\rightarrow$ $a_0 = g_0 = \frac{1}{2}$

$\rightarrow$ $a_n = 2R_e\{g_n\} = 2 \cdot \frac{1}{2}\,\text{sinc}\left(\frac{n}{2}\right) = \dfrac{\sin\left(\frac{n\pi}{2}\right)}{\frac{n\pi}{2}}$

$\rightarrow$ $a_1 = \frac{2}{\pi}$, $a_2 = 0$, $a_3 = \frac{-2}{3\pi}$

$\rightarrow$ $b_n = 0 \rightarrow$ even function.

$$g(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega_0 t + \sum_{n=1}^{\infty} b_n \sin n\omega_0 t$$

$$g(t) = \frac{1}{2} + \frac{2}{\pi}\left(\cos(\omega_0 t) - \frac{1}{3}\cos(3\omega_c t) + \cdots\right)$$

$$v(t) = (m(t) + c(t)) \cdot g(t)$$

$$= \frac{1}{2}m(t) + \frac{2}{\pi}m(t)\cos(\omega_c t) + \frac{2}{\pi}m(t) - \frac{1}{3}\cos(3\omega_c t) + \cdots$$

$$+ \frac{1}{2}c(t) + \frac{2}{\pi}m(t)\cos(\omega_c t) - \frac{1}{3} \cdot \frac{2}{\pi}c(t)\cos(3\omega_c t) + \cdots$$

$$\Downarrow$$

$$\boxed{B.P.F}$$

$$y(t) = \frac{2}{\pi}\cos(\omega_c t)\cancel{m(t)} + \frac{1}{2}c(t), \quad c(t) = A_c\cos(\omega_c t).$$

$$y(t) = \frac{1}{2}A_c\cos(\omega_c t) + \frac{2}{\pi}m(t)\cos(\omega_c t)$$

$$y(t) = \frac{A_c}{2}\cos(\omega_c t)\left[1 + \frac{4}{\pi A_c}m(t)\right] = \text{modulated signal}$$

Evaluate the output of the demodulated signal

To demodulate the signal:

$$S_{AM}(t) = A_c(1 + k_a m(t))\cos(2\pi f_c t).$$

$$v(t) = S_{AM}(t) \cdot \acute{c}(t) = A_c(1 + k_a m(t))\cos(2\pi f_c t) \cdot \acute{A}_c\cos(2\pi f_c t)$$

$$= A_c\acute{A}_c(1 + k_a m(t))\left(\frac{1}{2} + \frac{1}{2}\cos(4\pi f_c t)\right)$$

$$v(t) = A_c\acute{A}_c(1 + k_a m(t)) \cdot \frac{1}{2} + \frac{A_c\acute{A}_c}{2}(1 + k_a m(t))\cos(4\pi f_c t)$$

$$\Downarrow$$

$$\boxed{LPF}$$

$$y(t) = \frac{1}{2}A_c\acute{A}_c(1 + k_a m(t))$$

$$\Downarrow$$

$$r(t) = \frac{1}{2}A_c\acute{A}_c k_a m(t)$$

Data

We used these signals to evaluate our work

$$s(t) = 2\,[1 + 0.8\cos(2\pi 10^3\, t)]\cos(2\pi 10^4\, t)$$

$$m(t) = 2.51\cos(2\pi 10^3\, t)$$

$$c(t) = 4\cos(2\pi 10^4\, t)$$

Evaluation Criteria

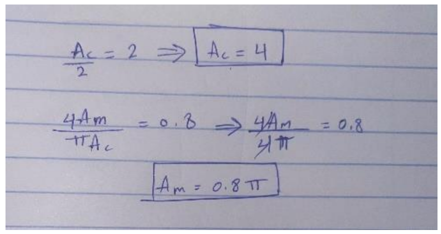
To measure the performance of our project, we may evaluate key matric such as signal-to-noise ratio as known as (SNR) which is a measure of the strength of a signal compared to the background noise in a communication channel, we also plan to use simulations and real-world experiments to assess system behavior under various conditions

Approach

To achieve the desired AM signal $\boldsymbol{s(t)} = \mathbf{2}\ [\mathbf{1} + \mathbf{0.8}\ \mathbf{cos}\ (\mathbf{2\pi}1000\ \boldsymbol{t})]\ \mathbf{cos}\ (\mathbf{2\pi}10000\ \boldsymbol{t})$, the general expression of the AM signal that we reach in the switching modulator circuit is

$\boldsymbol{s(t)}$ = (Ac/2) [$\mathbf{1}$ + (4Am/$\boldsymbol{\pi}$Ac) cos(2$\boldsymbol{\pi}$fmt)] $\mathbf{cos}$ ($\mathbf{2\pi}$fc $\boldsymbol{t}$),

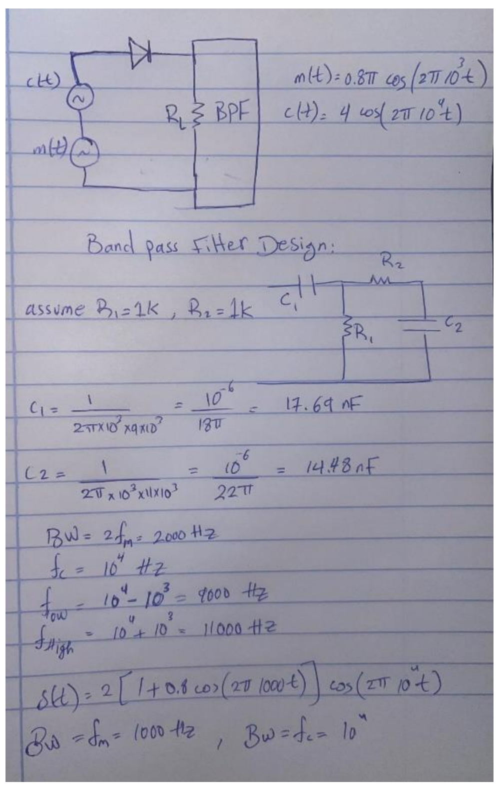
comparing the two expressions we use Ka=4/($\boldsymbol{\pi}$Ac), and achieve the values of Ac and Am



values obtained:

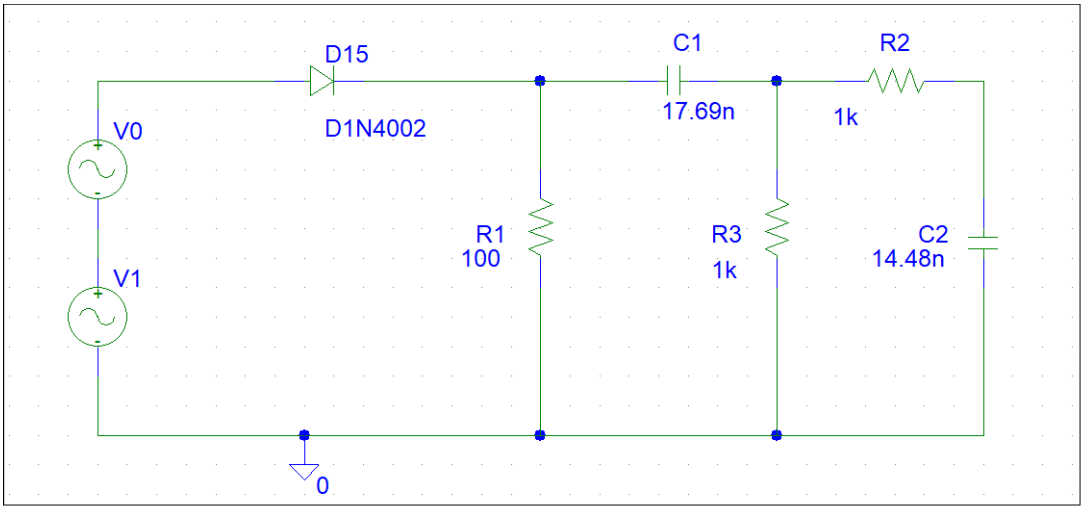
Ka=0.3, Ac=4, Am=2.51

We build a circuit to generate a normal AM signal using bandpass filter



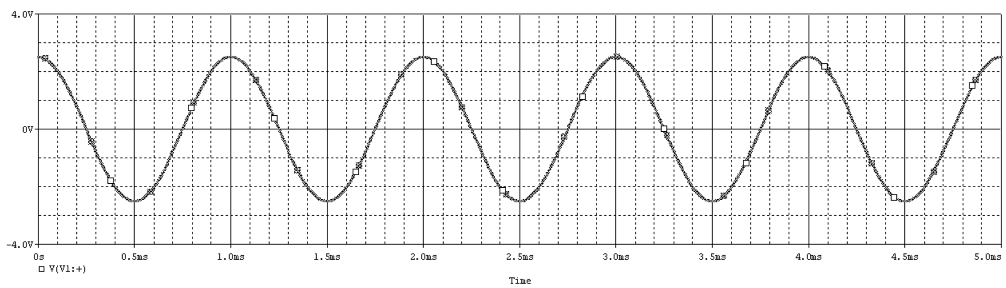
Results and Analysis

Generating normal AM using PSpice (Modulation):

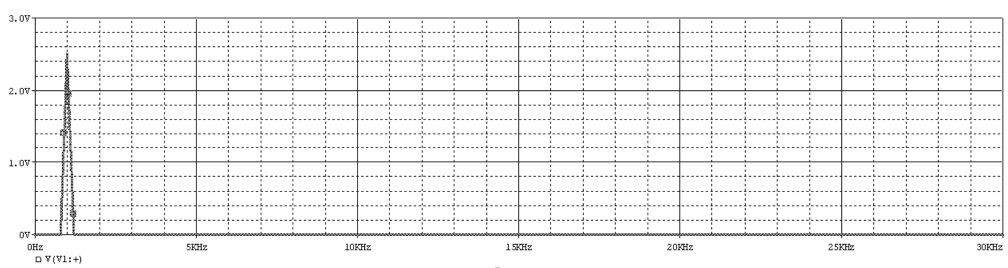


m(t)

In Time Domain:

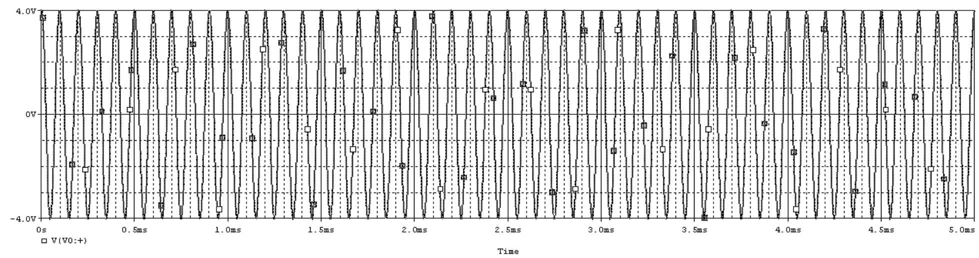


In Frequency Domain:

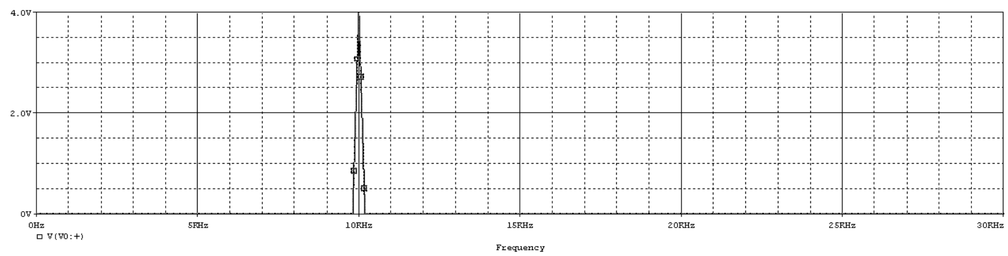


C(t)

In Time Domain:

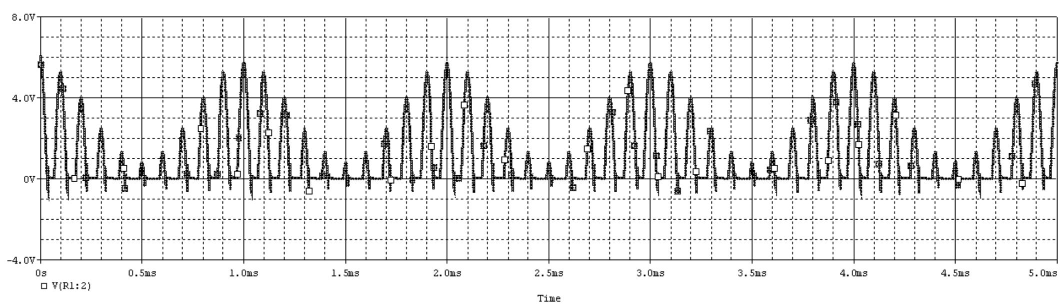


In Frequency Domain:

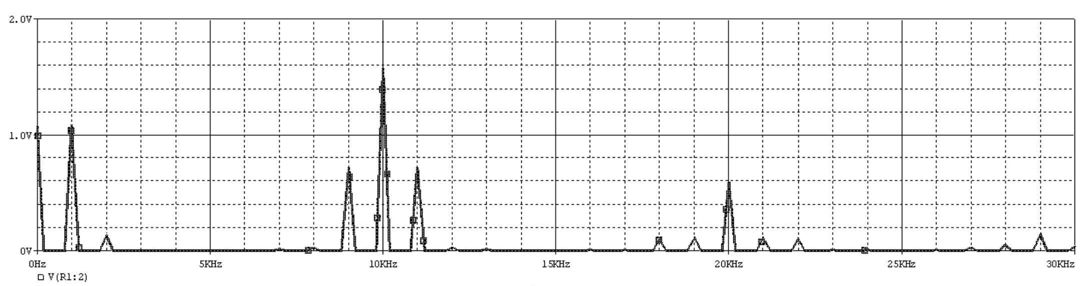


P(t)

In Time Domain:

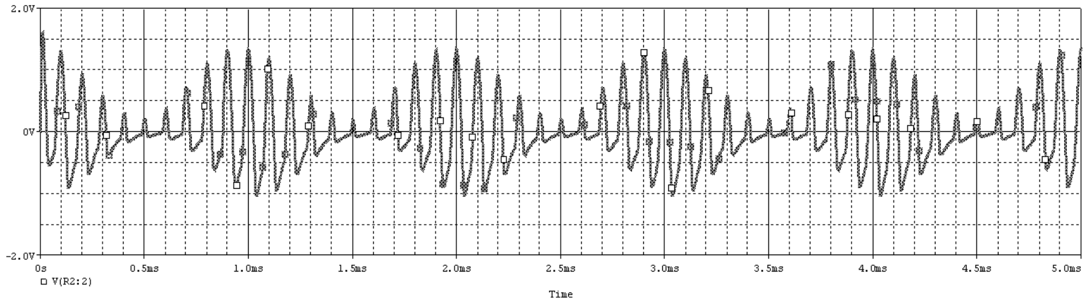


In Frequency Domain:

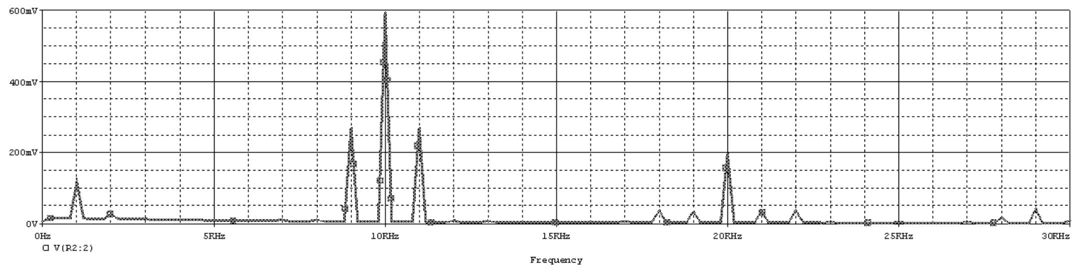


S(t)

In Time Domain:

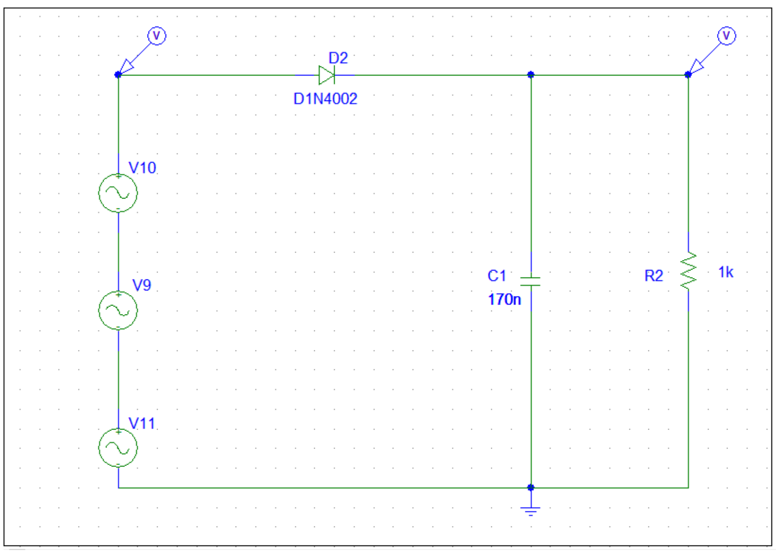


In Frequency Domain:

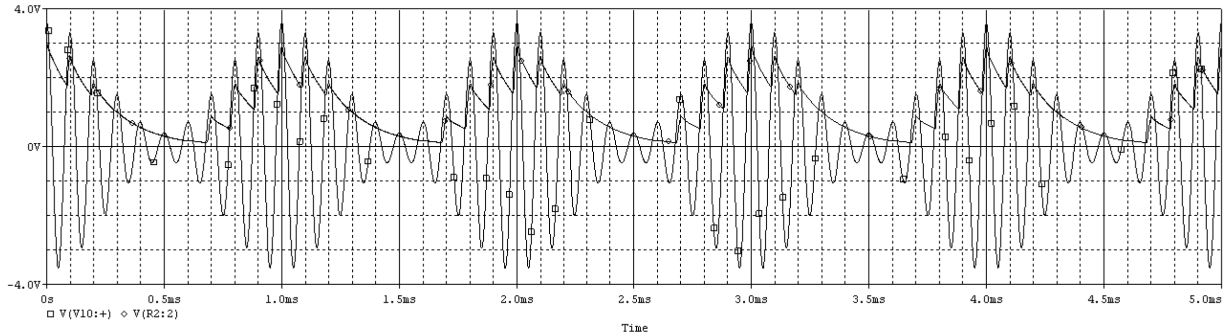


(Demodulation):

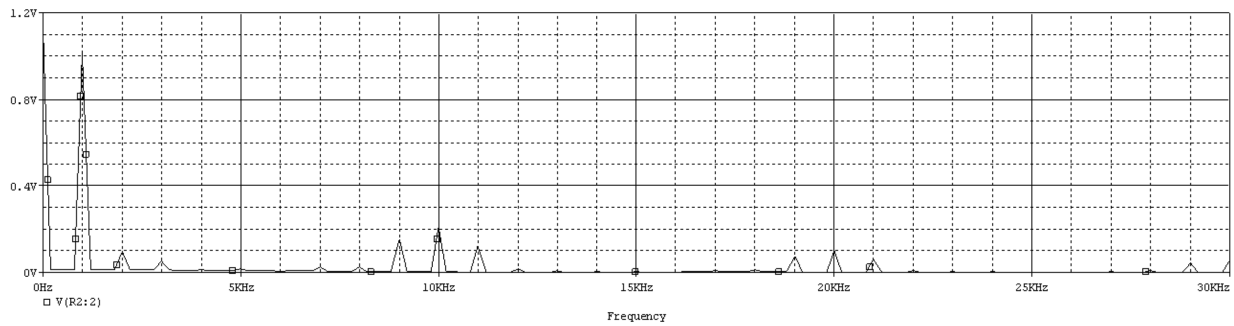
We designed this envelop detector with c= 170nF and R(load)= 1k ohm to recover the message signal



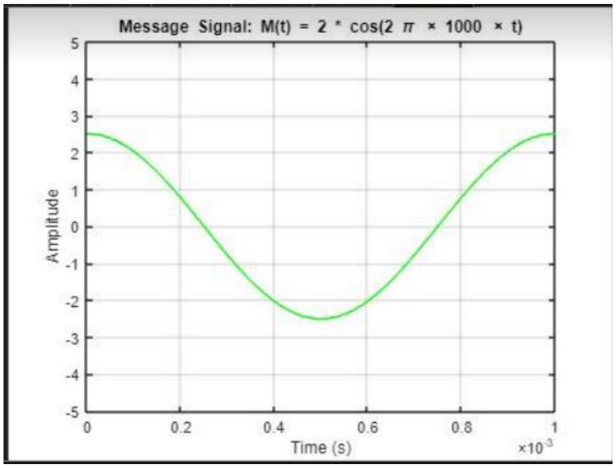
Time Domain

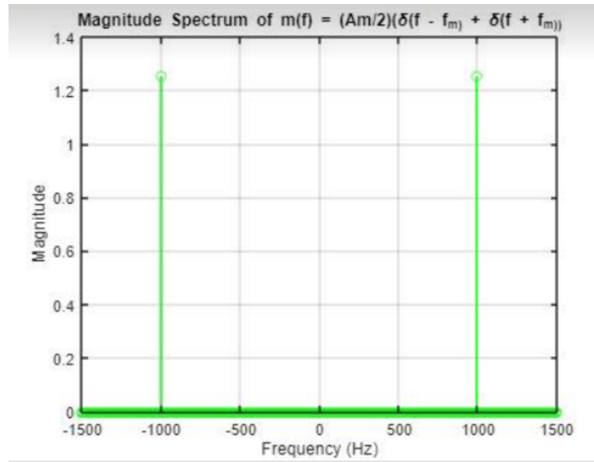


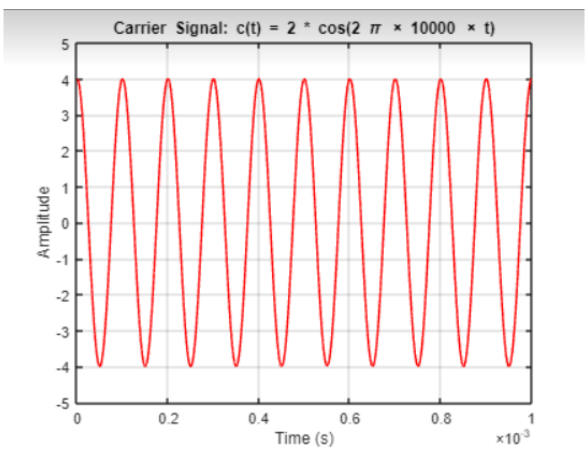
Frequency Domain

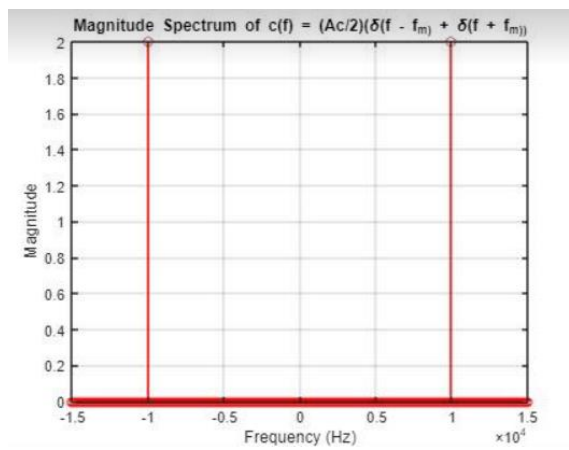


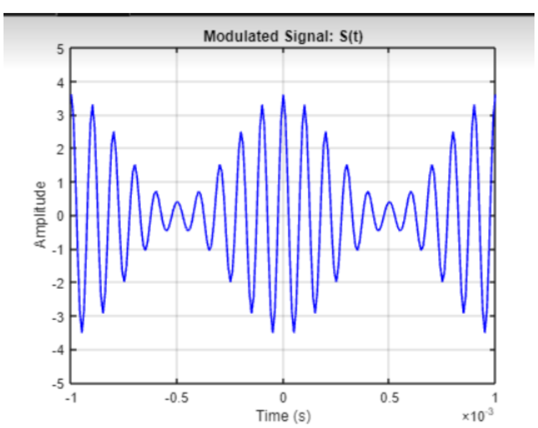
MATLAB solution:

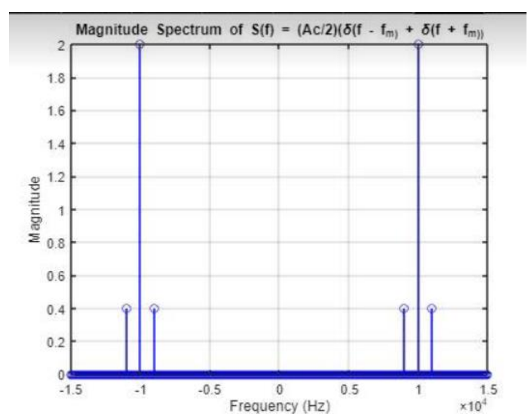












```
t = -0.001:0.00001:0.001;  % Time vector with increased resolution
s=2*cos(2*pi*10000*t).*(1+0.8*cos(2*pi*1000*t));

% Plot the modulated signal
figure;
plot(t, s, 'b');
title('Modulated Signal: S(t)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
ylim([-5, 5]);
```

```
Ac=4;
fc = 10000;
t = 0:0.0000001:0.001;  % Time vector with increased resolution

                        % Carrier signal generation
C = Ac*cos(2 * pi * fc * t);

% Plot the Carrier signal
figure;
plot(t, C, 'r');
title('Carrier Signal: c(t) = 2 * cos(2 \pi \times 10000 \times t)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
ylim([-5, 5]);
```

```
Am=2.51;
fm = 1000;
t = 0:0.00001:0.001;  % Time vector with increased resolution

                        % message signal generation
M = Am*cos(2 * pi * fm * t);

% Plot the message signal
figure;
plot(t, M, 'g');
title('Message Signal: M(t) = 2 * cos(2 \pi \times 1000 \times t)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
ylim([-5, 5]);
```

```
syms m f
Am = 2.51;
fm = 1000;
% Frequency vector
f = (-1500:1500);
% Signal in the frequency domain
m = ((Am/2)* del_me(1000,-1500,1500))+ ((Am/2)*del_me(-1000,-1500,1500));
% Plot the magnitude spectrum with a line
stem(f, m, 'g');
title('Magnitude Spectrum of m(f) = (Am/2)(\delta(f - f_m) + \delta(f + f_m))');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;
function [m,f]= del_me(f0,f1,f2)
f=f1:f2;
m= (f-f0) ==0;
end
```

```
syms m f
Ac = 4;
fc = 10000;
% Frequency vector
f = (-15000:15000);
% Signal in the frequency domain
c = ((Ac/2)* del_me(10000,-15000,15000))+ ((Ac/2)*del_me(-10000,-15000,15000));
% Plot the magnitude spectrum with a line
stem(f, c, 'r');
title('Magnitude Spectrum of c(f) = (Ac/2)(\delta(f - f_m) + \delta(f + f_m))');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;
function [m,f]= del_me(f0,f1,f2) %Function for the delta function
f=f1:f2;
m= (f-f0) ==0;
end
```

```
syms m f
Ac = 4;
fc = 10000;
% Frequency vector
f = (-15000:15000);
% Signal in the frequency domain
s = ((Ac/2)* del_me(10000,-15000,15000))+ ((Ac/2)*del_me(-10000,-15000,15000)) + (0.4*
% Plot the magnitude spectrum with a line
stem(f, s, 'b');
title('Magnitude Spectrum of S(f) = (Ac/2)(\delta(f - f_m) + \delta(f + f_m))');
xlabel('Frequency (Hz)');
ylabel('Magnitude');
grid on;
function [m,f]= del_me(f0,f1,f2) %Function for the delta function
f=f1:f2;
m= (f-f0) ==0;
end
```

We used MATLAB to implement each of the carrier, message, and modulated signal in both time and frequency domain. to make sure our results obtained previously are correct and identical.

Conclusion:

In conclusion, this project aimed to explore and implement Normal AM modulation and demodulation techniques using a switching modulator and an envelope detector, respectively. It was a successful process simulating the transmitted signal, carrier signal, switching signal and the message signal. We learnt deeply about the normal AM signals and understood the modulation and the demodulation of the signal and how it is done. This project helped us to search more in communication systems and learn the main keys about normal AM.

References

1. https://www.etti.unibw.de/labalive/experiment/amtransmissionenvelopedetector/?fbclid=IwAR3t4ApQuOBc_vuoDvK17AbiplBRuun0bidWKlMBsQIfImFq3fyfXCN1UXk#:~:text=An%20easy%20way%20to%20recover,Simple%20hardware%20envelope%20demodulator

   We used this website and took an idea of how we can build the circuit. Additionally, we ensured that our plot of the message signal is correct.

2. https://www.winlab.rutgers.edu/~crose/322_html/envelope_detector.html