CIE-227: Signals and Systems
Frequency Modulation/Demodulation Project

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introduction

Frequency modulation (FM) is a modulation process wherein the instantaneous frequency of a carrier signal is varied according to the message signal amplitude. In this modulation the modulated FM signal has changing frequency relating to the message amplitude but the amplitude of the FM signal remains constant. This form of FM modulation is analog modulation wherein the frequency of the carrier signal continuously changes with the message signal.

Discussions

FM modulation:

If we want to discuss what do we mean by Modulation we say that modulation is the process by which information is encoded from a message signal for optimization to signal. So, it needs medium to be transmitted and that wave is called carrier wave which is electromagnetic wave that is modulated in amplitude or frequency to carry a signa so because of its electromagnetic properties, it travels with the velocity of light and with constant amplitude. So, frequency modulation is a modulation that encode information into the carrier wave by varying the frequency so FM modulation use the constant amplitude to control the frequency of the carrier signal to be transmitted as information.

FM Demodulation:

it is the process to extract the original modulation signal form modulated signal so it recovers the information encoded to use it in various purposes.
- it allows high-fidelity transmission of audio signals.

Am Modulation

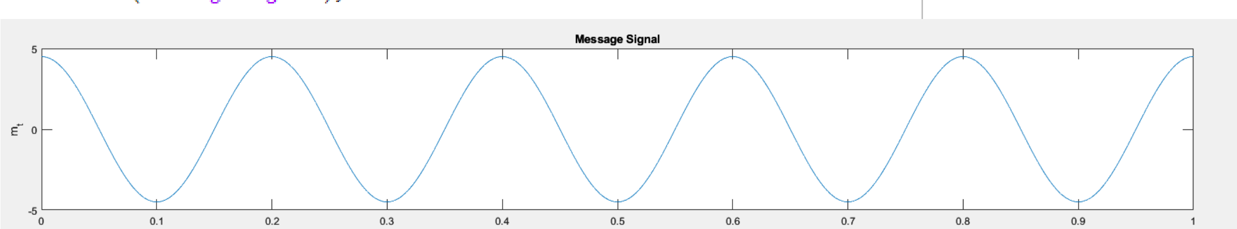
Amplitude modulation is a modulation that encode information into the carrier wave by varying the amplitude so AM modulation use the constant frequency to control the Amplitude of the carrier signal to be transmitted as information.
- It allows audio signal to transmit over long distance.

After explaining the concept if we go to the first Task
FM Modulation 1. Generate a sinusoidal signal from 0 to 1 s with sample rate f_s=1 kHz and the frequency of the sinusoidal signal f_m= 5 Hz.

$$m(t)=0.5\cos[(2\pi f\_m\ t)]+\cos[(2\pi f\_m\ t)]+3\cos[(2\pi f\_m\ t)]$$

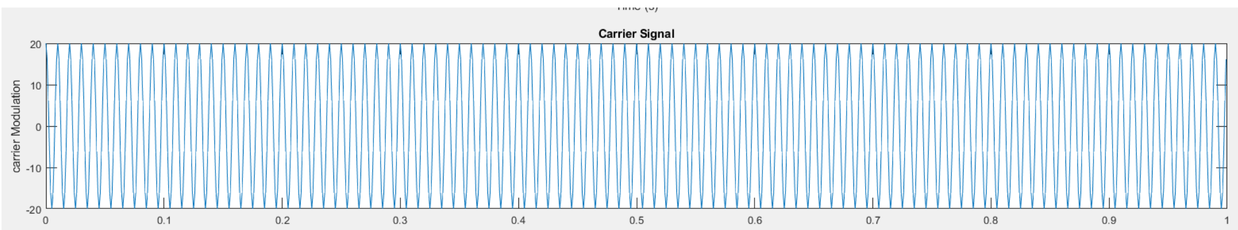
this is the message signal with time 1 seconds and sample rate is 1000 Hz and the frequency so using matlab

```
%Question (1) FM Modulation
%1. Generate a sinusoidal signal from 0 to 1 s with sample rate f_s=1 kHz and the frequency
%5of the sinusoidal signal f_m= 5 Hz. (1 point)
%m(t)=0.5 cos[(2πf_m t)]+ cos[(2πf_m t)]+ 3 cos[(2πf_m t)]


f_s=1000 ;  % sample rate in Hz
f_m= 5 ; % frequency of sinusoidal signal
f_c = 100 ;
t = 0 : 1/f_s : 1;
Ac = 20 ;  % Ac is 20 volt



% (.5+1+3)cos[(2πf_m t)] = 4.5 cos[(2πf_m t)]
% generate the message signal
m_t = 0.5* cos(2*pi*f_m *t)+ cos(2*pi*f_m *t)+ 3 *cos(2*pi*f_m* t);


% Plot the signals
figure(1);
subplot(3, 1, 1);
plot(t, m_t);
xlabel('Time (s)');
ylabel('m_t');
title('Message Signal');
```



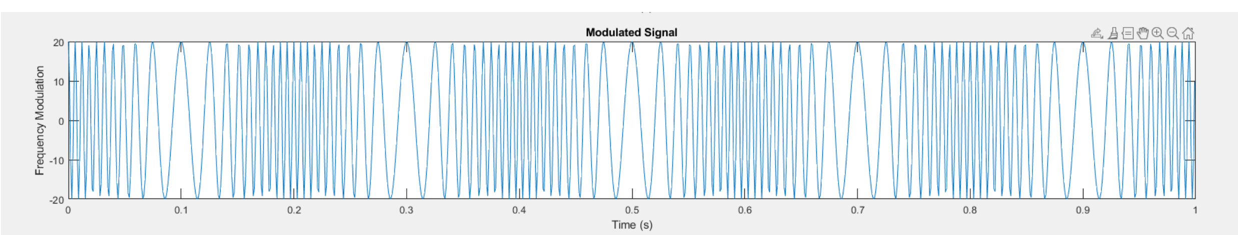
2. Generate a Carrier signal from 0 to 1 s with sample rate f_s=1 kHz. The frequency of the sine signal f_c=100 Hz and its amplitude Ac=20 V. (1 point) c(t)=Ac cos(2πf_c t)

```
% % generate the carrier signal
c_t = Ac *cos(2 * pi*f_c* t);  %carrier signal

subplot(3, 1, 2);
plot(t, c_t);
xlabel('Time (s)');
ylabel('carrier Modulation');
title('Carrier Signal');
```



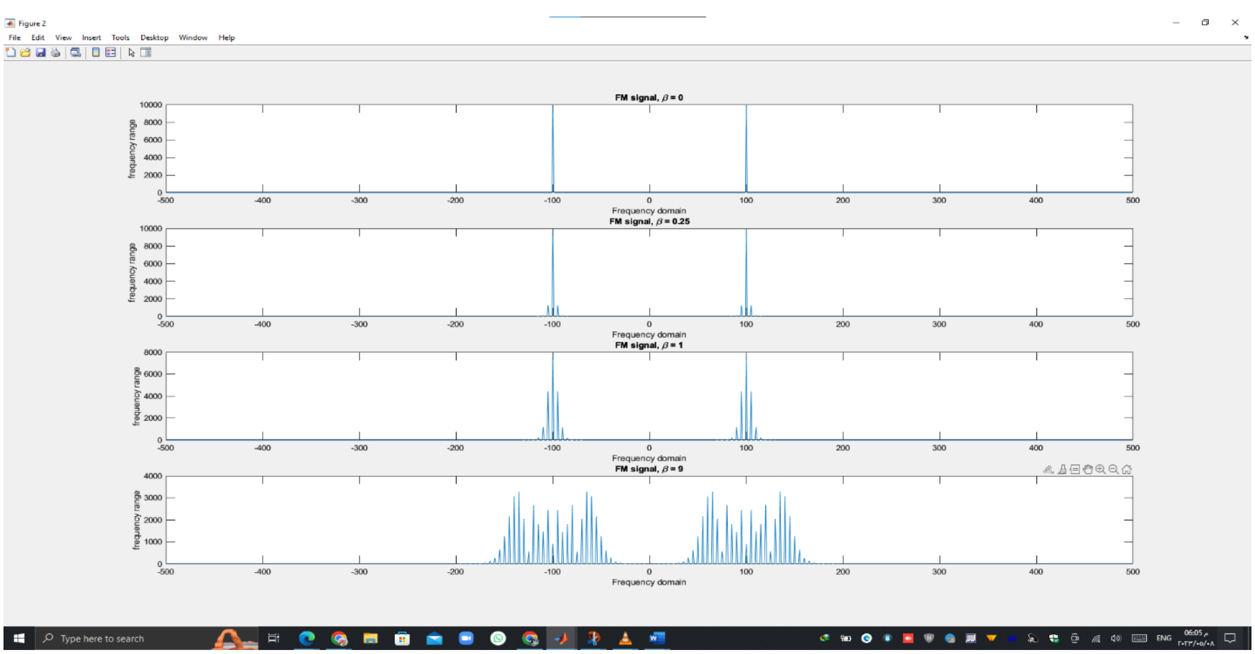
3. Plotting the FM signal in the time domain. K_f=15 V/Hz sinusoidal signal, carrier and FM signal in one figure. (1 point) P_FM (t)=Ac cos(2πf_c t+ β sin2π f_m t)

```
%Am = [0,0.25,1,9]*f_m/k_f;
%Am = [0,0.25,1,9]*5/15;
%k_f = 15;
Ac = 20;
f_m= 5 ; % frequency of sinusoidal signal
m = [0,0.25,1,9];
%mod_index = (k_f*Am/f_m);
f_s=1000 ;  % sample rate in Hz
f_c = 100 ;
%t = 0 : 1/f_s : 1-(1/f_s);
t = 0 : 1/f_s : 1-1/f_s;
figure(2);
for i = 1:length(m)

        P_FM = Ac * cos(2 * pi * f_c * t + m(i) * sin(2 * pi * f_m * t));
        n =length(P_FM);

        ffshift = (-n/2:n/2-1)*(1000/n);

        fn =fft(P_FM);
        fo = fftshift(fn);
        fd = abs(fo);
        subplot(length(m), 1, i);
        %f = linspace(-100, 100, length(fd)); % frequency range
        plot(ffshift,fd);
        xlabel('Frequency domain');
        ylabel('frequency range');
        title(['FM Signal with Modulation Index  = ', i]);
        %xlim([0 300]);
end
```



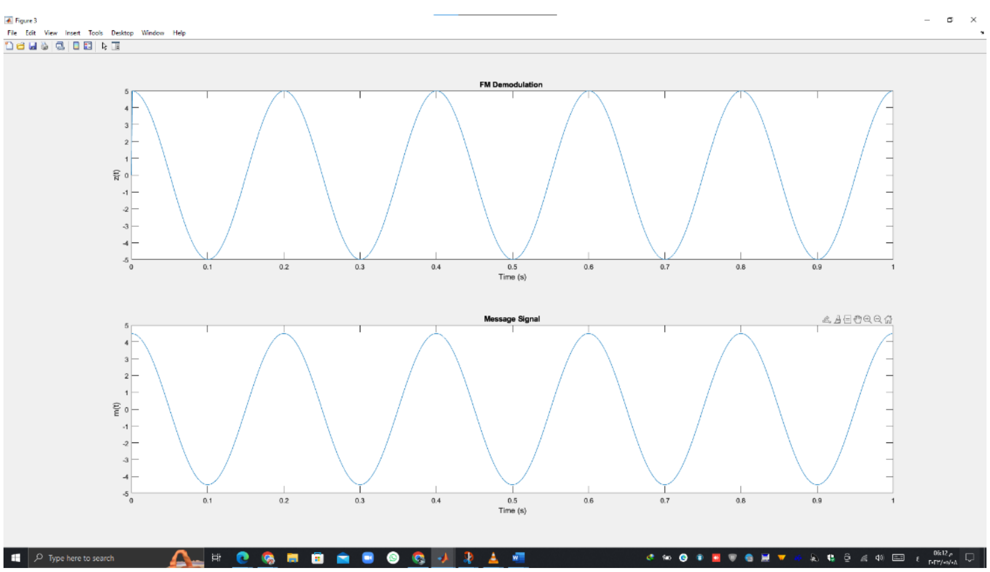
4. Vary the amplitude of the message signal such that the modulation index is equal to 0,0.25,1,9. Plotting the FM signal in frequency domain and observe how the FM signal bandwidth and power (carrier + sidebands) changes as modulation index changes

```
%Am = [0,0.25,1,9]*f_m/k_f;
%Am = [0,0.25,1,9]*5/15;
%k_f = 15;
Ac = 20;
f_m= 5 ; % frequency of sinusoidal signal
m = [0,0.25,1,9];
%mod_index = (k_f*Am/f_m);
f_s=1000 ;  % sample rate in Hz
f_c = 100 ;
%t = 0 : 1/f_s : 1-(1/f_s);
t = 0 : 1/f_s : 1-1/f_s;
figure(2);
for i = 1:length(m)

        P_FM = Ac * cos(2 * pi * f_c * t + m(i) * sin(2 * pi * f_m * t));
        n =length(P_FM);

        ffshift = (-n/2:n/2-1)*(1000/n);

        fn =fft(P_FM);
        fo = fftshift(fn);
        fd = abs(fo);
        subplot(length(m), 1, i);
        %f = linspace(-100, 100, length(fd)); % frequency range
        plot(ffshift,fd);
        xlabel('Frequency domain');
        ylabel('frequency range');
        title(['FM signal, \beta = ' num2str(m(i))]);
       % title(['FM Signal with Modulation Index  = ', i]);
        %xlim([0 300]);
end
```



FM Demodulation 5. Plot in the time domain and compare it to the original message signal

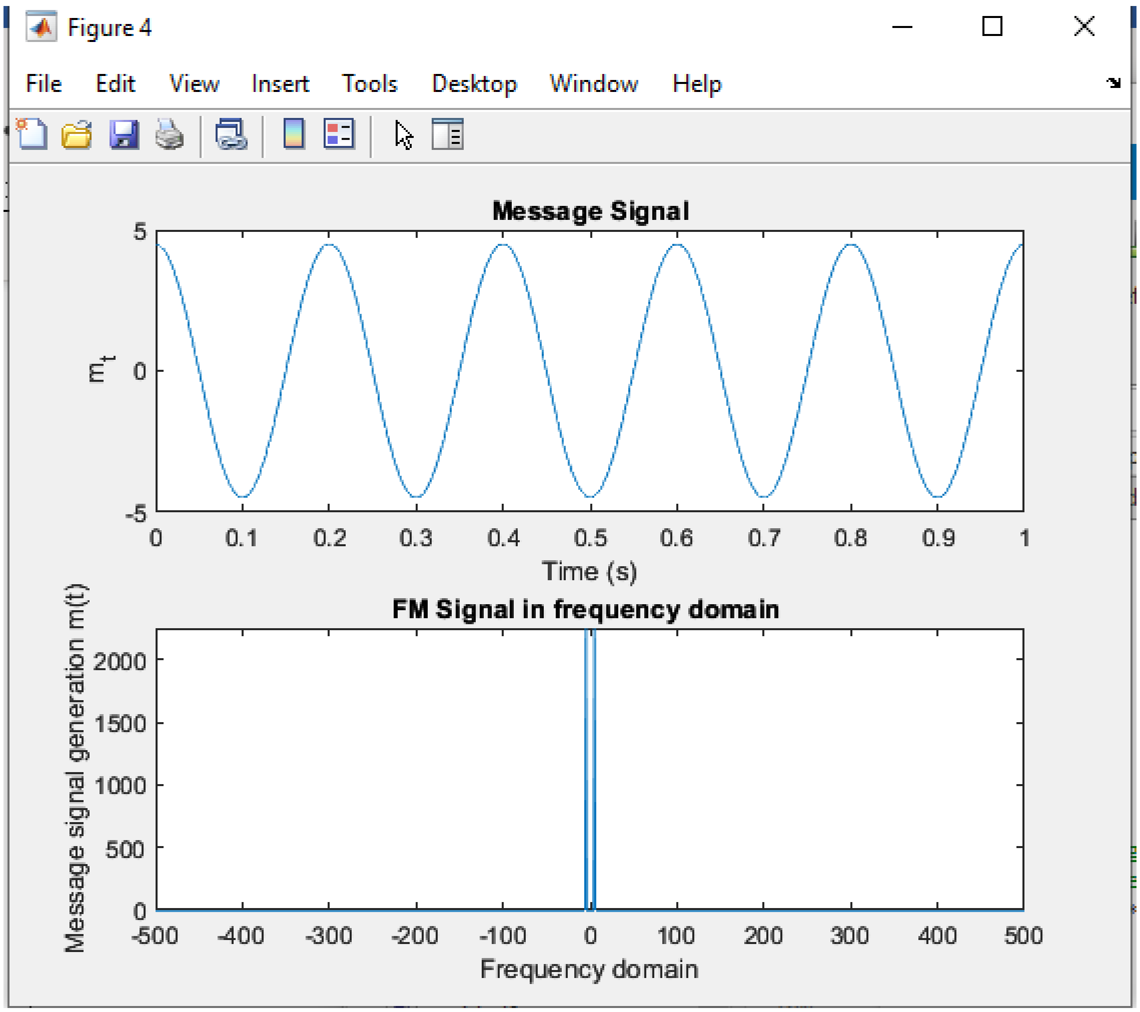
```
  %demodulation
% Plot the signals
m_t = 0.5* cos(2*pi*f_m *t)+ cos(2*pi*f_m *t)+ 3 *cos(2*pi*f_m* t);

f_s=1000 ;  % sample rate in Hz
f_m= 5 ; % frequency of sinusoidal signal
f_c = 100 ;
%t = 0 : 1/f_s : 1;
Ac = 20 ;  % Ac is 20 volt
k_f = 15;
w_c = 2*pi*f_c;
%z_t=Ac * (w_c+2*pi*k_f *m_t);
P_FM = Ac * cos(2 * pi * f_c * t + beta * sin(2 * pi * f_m * t));
%m = modulate(z_t,f_c,f_s,"fm");
d = fmdemod(P_FM,f_c,f_s,beta);

figure(3);
subplot(2, 1, 1);
plot(t, d);
xlabel('Time (s)');
ylabel('z(t)');
title('FM Demodulation ');


subplot(2,1,2);
plot(t, m_t);
subplot(2,1,2);
xlabel('Time (s)');
ylabel('m(t)');
title(' Message Signal ');
```



Bonus Part

Message signal generation: Generating a sinusoidal signal from 0 to 1 s with sample rate fs=1 kHz and The frequency of the sinusoidal signal fm=5 Hz .

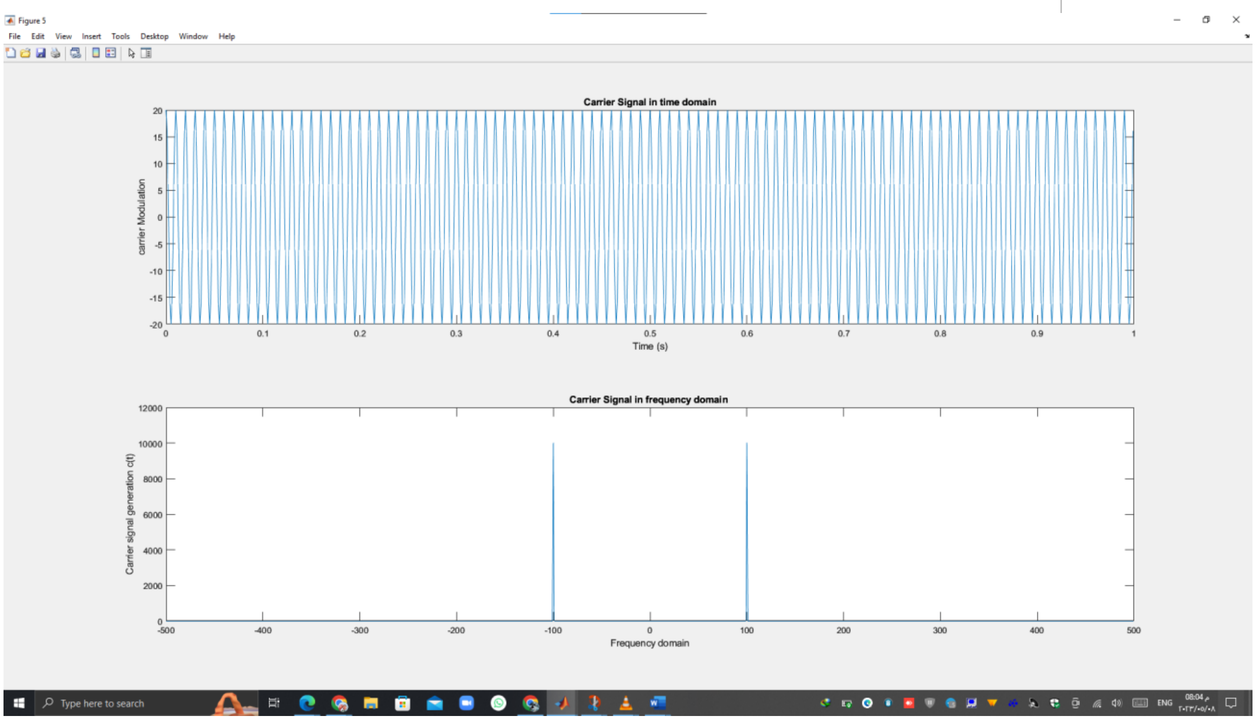
$$m(t)=0.5 \cos[(2\pi f\_m\ t)]+ \cos[(2\pi f\_m\ t)]+ 3 \cos[(2\pi f\_m\ t)]$$



Carrier signal generation: Generate a sine signal from 0 to 1 s with sample rate fs=1 kHz. The frequency of the sine signal fc =100 Hz and its amplitude Ac=20 V.

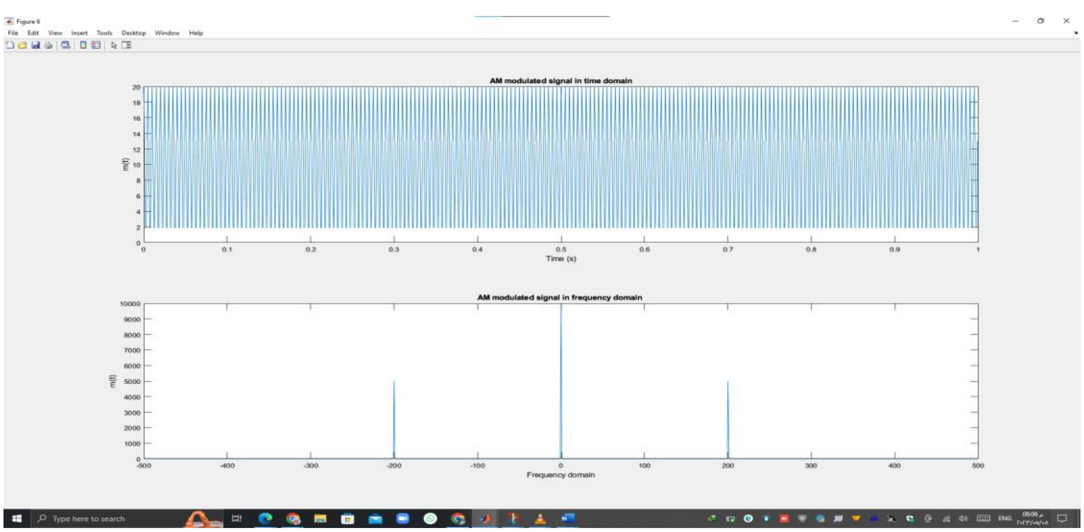
$$c(t)=Ac\cos(2\pi f\_c\ t)$$

```
%%% 2) Plot the carrier signal in the time domain and frequency domain

% % generate the carrier signal
c_t = Ac *cos(2 * pi*f_c* t);  %carrier signal
figure (5);
subplot(2, 1, 1);
plot(t, c_t);
xlabel('Time (s)');
ylabel('carrier Modulation');
title('Carrier Signal in time domain');


q =length(c_t);

ffshift = (-q/2:q/2-1)*(1000/q);

fa =fft(c_t);
fb = fftshift(fa);
fc = abs(fb);
subplot(2,1,2);
%f = linspace(-100, 100, length(fd)); % frequency range
plot(ffshift,fc);
xlabel('Frequency domain');
ylabel('Carrier signal generation c(t)');
title('Carrier Signal in frequency domain ');
%xlim([0 300]);
```



AM modulation (DSB-LC and DSB-SC): Modulate the carrier signal. To generate the modulated signal, you can either multiply the carrier signal by the message signal (which is called modulating signal) or use ammod() built-in function (Communications Toolbox) 3) Plot the AM modulated signal in time and frequency domain. Observe the spectrum of the modulated signal. What is the bandwidth of the modulated signal? (using subplot)

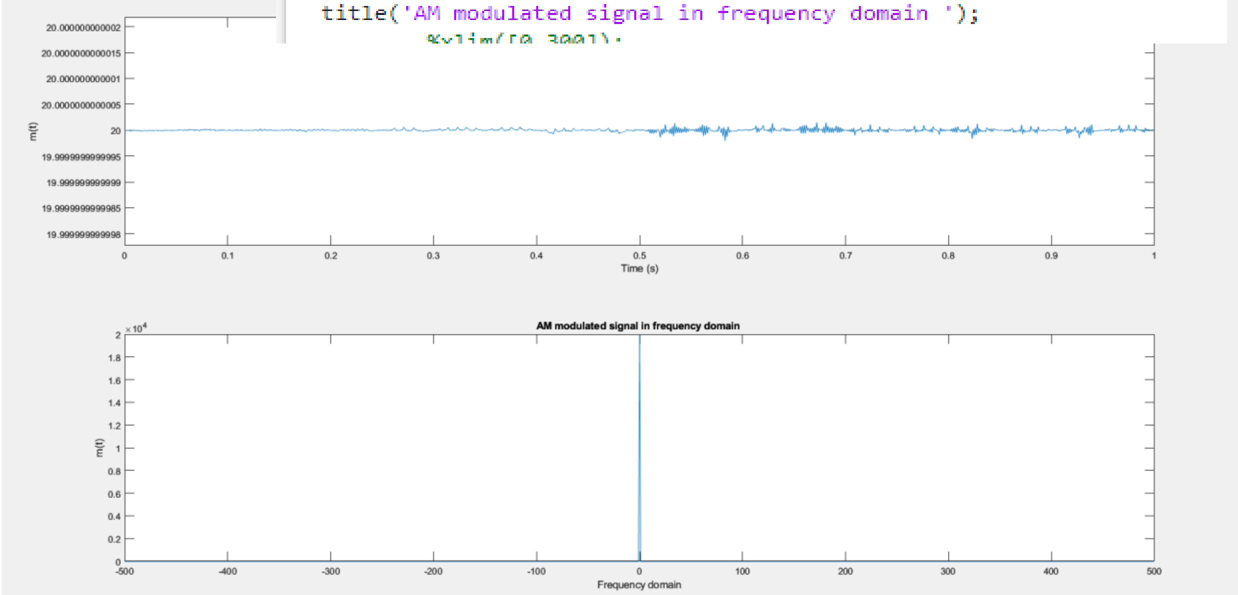
```
%AM modulation (DSB-LC and DSB-SC):
%Frequency

% sampling frequency
f_s= 1000;
% time Duration
time = 0 : 1/fs : 1-1/fs;
 c_t = Ac *cos(2 * pi*f_c* t);  %carrier signal
A_mmod = ammod(c_t,f_c,f_s);
figure(6);
subplot(2, 1, 1);
plot(time, A_mmod);
xlabel('Time (s)');
ylabel('m(t)');
title('AM modulated signal in time domain');


%AM modulated signal in frequency domain ');
p =length(c_t);
ffshift = (-p/2:p/2-1)*(1000/p);
fa =fft(A_mmod);
fb = fftshift(fa);
fc = abs(fb);
subplot(2,1,2);
%f = linspace(-100, 100, length(fd)); % frequency range
plot(ffshift,fc);
xlabel('Frequency domain');
ylabel('m(t)');
title('AM modulated signal in frequency domain ');
        %xlim([0 300]);
```



SSB

SSB modulation,you can using ssbmod() built-in function, which does DSB-SC modulation, then uses a passband filter to get rid of either lower sideband or upper sideband. The carrier frequency fc =10 Hz. 4) Plot the SSB modulated signal (both USB and LSB) in time domain and frequency domain. 5) Please compare between AM and FM in time and frequency domain, also indicating the advantages and disadvantages of both.

```
%SSB modulation

%Frequency
f_m = 10;
% sampling frequency
f_s= 1000;
f_c=10;
% time Duration
time = 0 : 1/fs : 1-1/fs;
 c_t = Ac *cos(2 * pi*f_c* t);  %carrier signal
S_mmod = ssbmod(c_t,f_c,f_s);
figure(7);
subplot(2, 1, 1);
plot(time, S_mmod);
xlabel('Time (s)');
ylabel('m(t)');
title('AM modulated signal in time domain');


%AM modulated signal in frequency domain ');
p =length(c_t);
ffshift = (-p/2:p/2-1)*(1000/p);
fa =fft(S_mmod);
fb = fftshift(fa);
fc = abs(fb);
subplot(2,1,2);
%f = linspace(-100, 100, length(fd)); % frequency range
plot(ffshift,fc);
xlabel('Frequency domain');
ylabel('m(t)');
title('AM modulated signal in frequency domain ');
        %xlim([0 300]);
```



the difference between AM and FM

AM in time domain amplitude of the carrier with modulating signal varies with time

FM in time domain frequency of the carrier with modulated signal varies with time

AM and Fm in frequency domain
AM appears as sidebands around the carrier frequency
so the spectrum with single peak at the carrier frequency and two smaller on each side
FM: the carrier shift up and sown so it spreads around the carrier frequency

Am **Advantages**	**FM**
Low cost	High quality
Long distance	Stereo signal
Disadvantages	
Poor sound quality because of limited frequency	High complexity
Limited capacity for transmission	expensive
Suitable for transmistion like music	Not suitable for short distance

results :

AM and Fm in frequency domain
AM appears as sidebands around the carrier frequency
so the spectrum with single peak at the carrier frequency and two smaller on each side
FM: the carrier shift up and sown so it spreads around the carrier frequency

conclusion

-This project discussed the analysis of frequency and amplitude modulation and also the demodulation of frequency domain and compare between them and the analysis indicates that
- frequency modulation is a modulation that encode information into the carrier wave by varying the frequency so FM modulation use the constant amplitude to control the frequency of the carrier signal to be transmitted as information.
- Amplitude modulation is a modulation that encode information into the carrier wave by varying the amplitude so AM modulation use the constant frequency to control the Amplitude of the carrier signal to be transmitted as information.
- It allows audio signal to transmit over long distance
- AM in time domain amplitude of the carrier with modulating signal varies with time

FM in time domain frequency of the carrier with modulated signal varies with time

AM and Fm in frequency domain
AM appears as sidebands around the carrier frequency
so the spectrum with single peak at the carrier frequency and two smaller on each side
FM: the carrier shift up and sown so it spreads around the carrier frequency
Single sideband (ssB) transmite information more efficiently over long distance
In AM, the entire signal is trasmiitted including the carrier and the sidebands so it a waste of bandwidth as almost half of transmitted power is used to transmitted which carry no information so SSB overcome this issue by transmitting one of sidebands so reducing time

consuming .

References

[1] "Difference between time domain and frequency domain," *Polytechnic Hub*, 13-May-2017. [Online]. Available: https://www.polytechnichub.com/difference-time-domain-frequency-domain/. [Accessed: 08-May-2023].

[2] *Electronics-notes.com*. [Online]. Available: https://www.electronics-notes.com/articles/radio/modulation/fm-frequency-demodulation-detection-discrimination.p. [Accessed: 08-May-2023].

[3] M. Rouse, "Frequency Modulation," *Techopedia*, 13-Nov-2015. [Online]. Available: https://www.techopedia.com/definition/7244/frequency-modulation-fm. [Accessed: 08-May-2023].

[4] "Frequency Modulation," *Heavy.ai*. [Online]. Available: https://www.heavy.ai/technical-glossary/frequency-modulation. [Accessed: 08-May-2023].