C0E 472: DIGITAL SIGNAL PROCESSING

Lab 1: Introduction to MATLAB

INDEX NUMBER: 3050420

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COURSE: BSc. Biomedical Engineering

Year 4

1. INTRODUCTION

This report focuses on section 3 of this lab labelled "**Lab Exercise: Manipulating Sinusoids with MATLAB**". In this lab exercise, we manipulate sinusoids using MATLAB to understand the properties of signals, specifically focusing on generating, summing, and analyzing sinusoidal signals.

2. MANIPULATING SINUSOIDS WITH MATLAB

Generating Sinusoids

a. Time Vector

A time vector, tt, was generated to cover a range of time, t, which will exhibit approximately two cycles of three 4000 Hz sinusoids that will be later generated.

```
% Parameters
Freq = 4000;            % Frequency of the sinusoids in Hz
T = 1/Freq;             % Period of the sinusoid
samples = 25;           % Number of samples per period
step = T/samples;


% Generate time vector tt from -T to T with sufficient samples
tt = -T : step : T;
```

b. Sinusoids with Arbitrary Amplitude and Time-Shift

Two 4000 Hz sinusoids, $x_1(t)$, and $x_2(t)$, were generated with arbitrary amplitude and time-shift. The third sinusoid $x_3(t)$, is the sum of $x_1(t)$, and $x_2(t)$.

$$x_1(t) = A_1 \cos(2\pi(4000)(t - t_{m_1})) \qquad x_2(t) = A_2 \cos(2\pi(4000)(t - t_{m_2}))$$

Using the day and month of my birth (April 19) to calculate the amplitudes and time shifts

```
% Amplitudes
A1 = 22;               % My Age, amplitude of x1
A2 = 1.2 * A1;         % 1.2 times age = 26.4, amplitude of x2


% Time shifts
D = 19;                     % Day of birth
M = 4;                      % Month of birth
tm1 = (37.2 / M) * T;       % Time shift for x1, 0.0023
```

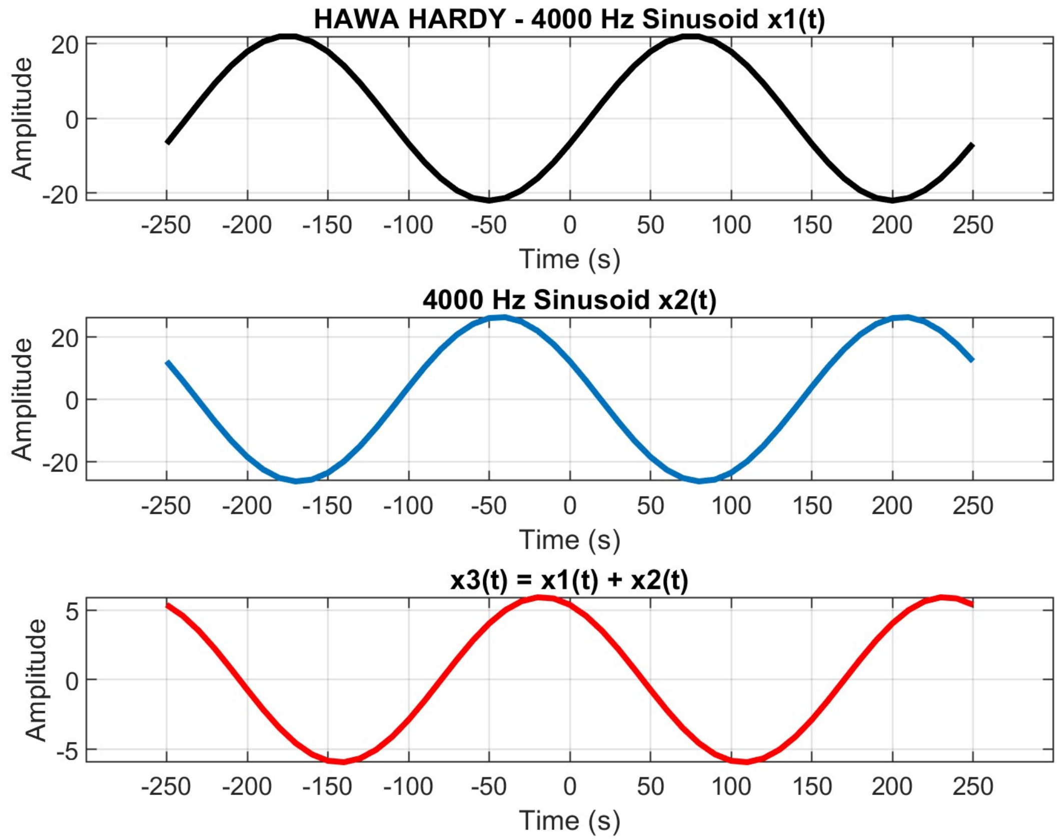
```
tm2 = -(41.3 / D) * T;      % Time shift for x2. -5.4342e-04


% Generate the two sinusoids
x1 = A1 * cos(2 * pi * Freq * (tt - tm1));
x2 = A2 * cos(2 * pi * Freq * (tt - tm2));

% Third sinusoid
x3 = x1 + x2;
```

d. Plotting the Signals

The signals were plotted in a single figure with three subplots for better visualization.

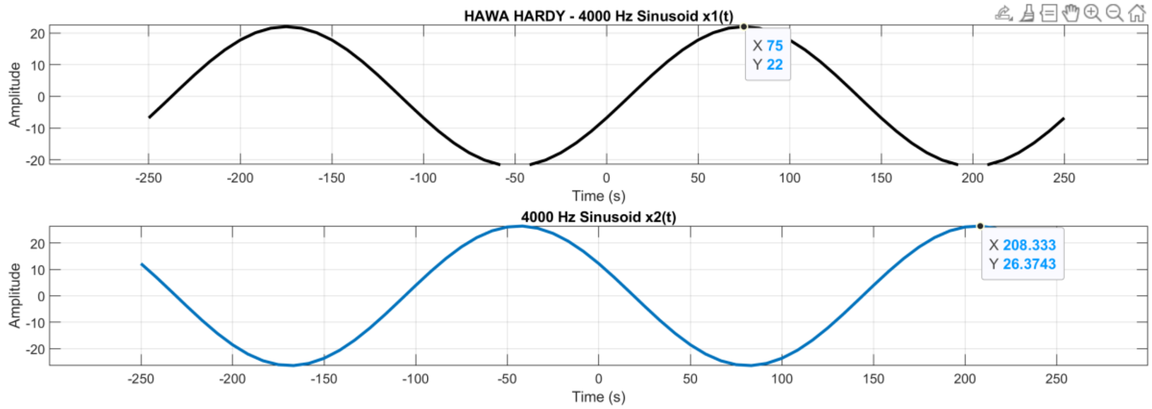
```
% Plotting
figure; % Creating new figure window


% Plot x1(t)
subplot(3,1,1);
plot(tt/1e-6, x1, 'k', LineWidth=2); grid on;
title('HAWA HARDY - 4000 Hz Sinusoid x1(t)');
xlabel('Time (s)');
ylabel('Amplitude');
xticks([-T/1e-6 : 50 : T/1e-6]) %set x-axis ticks to every 50
microseconds


% Plot x2(t)
subplot(3, 1, 2);
plot(tt/1e-6, x2, 'LineWidth',2);
title('4000 Hz Sinusoid x2(t)');
xticks([-T/1e-6 : 50 : T/1e-6])
xlabel('Time (s)');
ylabel('Amplitude');
grid on;


% Plot x3(t)
subplot(3, 1, 3);
plot(tt/1e-6, x3, 'r', LineWidth=2);
title('x3(t) = x1(t) + x2(t)');
xlabel('Time (s)'); ylabel('Amplitude');
grid on; xticks([-T/1e-6 : 50 : T/1e-6])
```

OUTPUT



3. Theoretical Calculations

a. Phase Calculation For $x_1(t)$ and $x_2(t)$ using measurements from graph
   $x_1(t)$: A_1= 22 and t_{m1} = 75 μsecs
   $x_2(t)$: A_2= 26.37 and t_{m2} = 208.33 μsecs



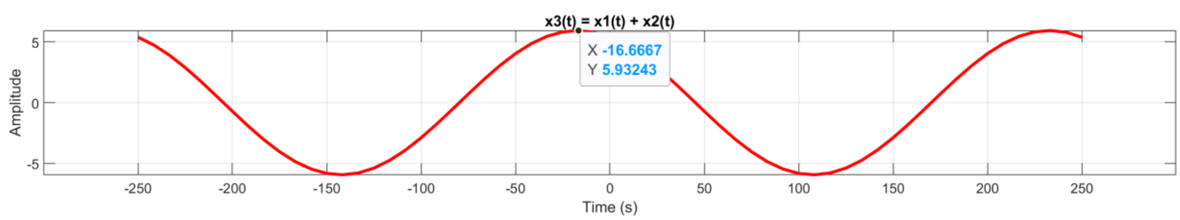
Phase Calculations ; $\phi = 2\pi \frac{t_m}{T}$

$\phi_1 = -2\pi \frac{(75\mu secs)}{250\mu secs} = -1.88 \text{ rad}$

$\phi_2 = -2\pi \frac{(208.33\mu sec)}{250\mu secs} = -5.24 \text{ rad}$

- Φ_1 = -1.88 rads and Φ_3 = -5.24 rads

(b) Amplitude and time-shift of $x_3(t)$ were measured directly from the plot, and the phase was calculated.



$x_3(t)$: A_3= 5.93 and t_{m1} = -16.67 μsecs

$\phi_3 = -2\pi \frac{(-16.67\mu secs)}{250\mu secs} = 0.42 \text{ rad}$

Φ_3 = 0.42rads

(c) Phasor addition was performed to determine the complex amplitude for $x_3(t)$

This method is done to verify if the previous calculations of Φ_3 and A_3 were correct.5

$$x(t) = A e^{j\phi}$$

$$x_1(t) = 22e^{-1.88j}$$

$$x_1(t) = 22[\cos(-1.88) + j\sin(-1.88)]$$

$$x_1(t) = -6.6946 - 20.9567j$$

$$x_2(t) = 26.37e^{-5.24j}$$

$$x_2(t) = 26.37[\cos(-5.24) + j\sin(-5.24)]$$

$$x_2(t) = 13.2765 + 22.7840j$$

$$x_3(t) = x_1(t) + x_2(t)$$

$$x_3(t) = (-6.6946 - 20.9567j) + (13.2765 + 22.7840j)$$

$$x_3(t) = 6.5819 + 1.8273j$$

$$A_3 = \sqrt{(6.5819)^2 + (1.8273)^2}$$

$$A_3 = 6.8308$$

$$\phi_3 = \tan^{-1}\left(\frac{1.8273}{6.5819}\right)$$

$$\phi_3 = 15.52 \text{ rad}$$

$$t_{m3} = -\frac{\phi_3 T}{2\pi} = -\frac{15.52(250M)}{2\pi}$$

$$t_{m3} = 617.52 \text{ M secs}$$

3.2 COMPLEX AMPLITUDES

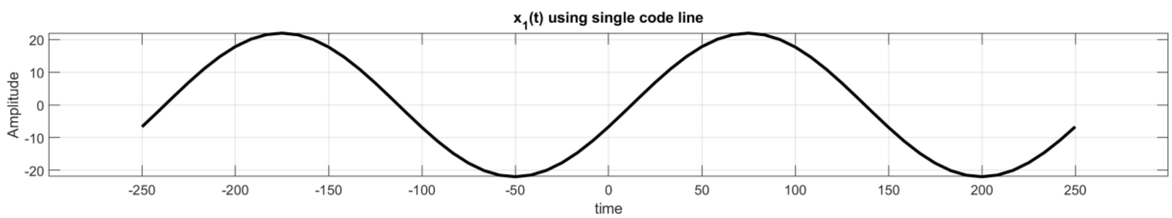
A code to generate the values of using the complex amplitude representation:

$$x_1(t) = \Re e\{Xe^{j\omega t}\}$$

A_1 = 22 and Φ_1 = -1.88 rads

```
phi1 = -1.88
x1 = real(A1*exp(1j*phi1).*exp(1j*2*pi*4000*tt)); %single code line


subplot(3,1,1);
plot(tt/1e-6, x1, 'k','Linewidth', 2); grid on
ylabel('x_1(t)')
title('x_1(t)', 'FontWeight', 'Bold')
xticks([-T/1e-6 : 50 : T/1e-6])  % Sets x-axis ticks to every 50 microseconds
```

OUTPUT



4. Conclusion

This lab exercise provided hands-on experience with manipulating and analyzing sinusoidal signals using MATLAB. Through generating, summing, and plotting sinusoids, as well as performing theoretical calculations, we gained a deeper understanding of the properties and behavior of these signals. The complex amplitude representation further enhanced our ability to work with sinusoids in MATLAB.

5. APPENDICE

```
% Parameters
Freq = 4000;            % Frequency of the sinusoids in Hz
T = 1/Freq;             % Period of the sinusoid
samples = 30;           % Number of samples per period
step = T/samples;


% Generate time vector tt from -T to T with sufficient samples
tt = -T : step : T;


% Amplitudes
A1 = 22;                % My Age
A2 = 1.2 * A1;          % 1.2 times age


% Time shifts
D = 19;                 % Day of birth
M = 4;                  % Month of birth
tm1 = (37.2 / M) * T; % Time shift for x1
tm2 = -(41.3 / D) * T;% Time shift for x2


% Generate the sinusoids
x1 = A1 * cos(2 * pi * Freq * (tt - tm1));
x2 = A2 * cos(2 * pi * Freq * (tt - tm2));
% Third Sinusoid
x3 = x1 + x2;


% Plotting
figure; % Creating new figure window


% Plot x1(t)
subplot(3,1,1);
plot(tt/1e-6, x1, 'k', 'LineWidth', 2); grid on;
title('HAWA HARDY - 4000 Hz Sinusoid x1(t)');
xlabel('Time (s)');
ylabel('Amplitude');
xticks([-T/1e-6 : 50 : T/1e-6]) % set x-axis ticks to every 50
microseconds
```

```
% Plot x2(t)
subplot(3, 1, 2);
plot(tt/1e-6, x2, 'LineWidth', 2);
title('4000 Hz Sinusoid x2(t)');
xticks([-T/1e-6 : 50 : T/1e-6])
xlabel('Time (s)');
ylabel('Amplitude');
grid on;


% Plot x3(t)
subplot(3, 1, 3);
plot(tt/1e-6, x3, 'r', 'LineWidth', 2);
title('x3(t) = x1(t) + x2(t)');
xlabel('Time (s)');
ylabel('Amplitude');
grid on;
xticks([-T/1e-6 : 50 : T/1e-6])


%----- Complex Amplitude
phi1 = -1.88;                       % phase in radians
x1 = real(A1*exp(1j*phi1).*exp(1j*2*pi*4000*tt)); %single code line


figure;
subplot(3,1,1);
plot(tt/1e-6, x1, 'k','Linewidth', 2); grid on
ylabel('Amplitude'); xlabel('time');
title('x_1(t) using single code line', 'FontWeight', 'Bold')
xticks([-T/1e-6 : 50 : T/1e-6])  % Sets x-axis ticks to every 50
microseconds
```