SIGNALS AND SYSTEMS LAB (CSE-301L)

Spring 2024, 4^{th} Semester

Lab Report 10

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Section: **A**

"On my honor, as a student at the University of Engineering and Technology Peshawar, I have neither given nor received unauthorized assistance on this academic work."

Signature: Hassan

Submitted To: Dr. Safdar Nawaz Khan Marwat

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Task 01:

Problem Analysis:

In this problem ak’s are chosen to be symmetric about the index k=0, i.e. ak = a-k. Select new ak’s on your own to alter this symmetry and form the new signal.

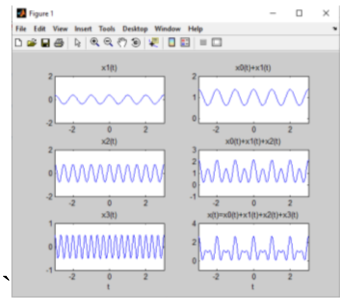
Algorithm:

1. Choose asymmetric ak coefficients.
2. Form the new signal $x(t)$ x(t) using these coefficients.
3. Observe the resulting signal.
4. Check if $x(t)$x(t) is real-valued.

Code Screenshot:

```
t = -3:0.01:3;                                   % duration of signa,    % dc component for k=0
x0 = 1;                                          % first harmonic components for k=-1 and k=1
x1 = (1/4)*exp(j*(-1)*2*pi*t)+(1/8)*exp(j*(1)*2*pi*t);
y1 = x0 + x1;                                     % sum of dc component and first harmonic
                                                  % second harmonic components for k=-2 and k=2
x2 = (1/2)*exp(j*(-2)*2*pi*t)+(1/4)*exp(j*(2)*2*pi*t);
y2 = y1 + x2;                                     % sum of all components until second harmonic
                                                  % third harmonic components for k=-3 and k=3
x3 = (1/3)*exp(j*(-3)*2*pi*t)+(1/6)*exp(j*(3)*2*pi*t);
x = x0 + x1 + x2 + x3;                            % sum of all components until third harmonic
figure;
subplot(3,2,1);
plot(t,x1);
axis([-3 3 -2 2]);
title('x1(t)');
subplot(3,2,2);
plot(t,y1);
axis([-3 3 -0.2 2]);
title('x0(t)+x1(t)');
subplot(3,2,3);
plot(t,x2);
axis([-3 3 -2 2]);
title('x2(t)');
subplot(3,2,4);
plot(t,y2);
axis([-3 3 -1 3]);
title('x0(t)+x1(t)+x2(t)');
subplot(3,2,5);
plot(t,x3);
xlabel('t');
axis([-3 3 -1 1]);
title('x3(t)');
subplot(3,2,6);
plot(t,x);
xlabel('t');
axis([-3 3 -1 4]);
```

Output:



Conclusion:

When the coefficients ak are not symmetric about k=0, the reconstructed signal $x(t)$, $x(t)$ may not be real. The symmetry of the Fourier coefficients is crucial for ensuring that the resulting signal is real.

Task 02:

Problem Statement:

Express the continuous-time periodic signal $x(t)x(t)$ as a sum of exponential terms derived from its non-zero Fourier Series coefficients.

Algorithm:

1. Identify the non-zero Fourier coefficients $a1$, $a{-}1$, $a3$, $a1$, $a{-}1$, $a3$, and $a{-}3$.
2. Use the Fourier series formula to express $x(t)x(t)$ as a linear combination of these coefficients:

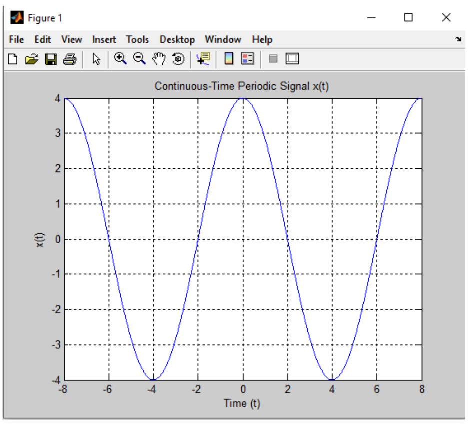
$$x(t)=\sum k=-\infty\infty akej2\pi kTtx(t)=k=-\infty\sum\infty akejT2\pi kt$$

3. Substitute the given coefficients and simplify the expression to obtain $x(t)x(t)$.

Code Screenshot:

```
% Define the time vector
t = -8:0.01:8; % duration of signal
% Given Fourier series coefficients
a1 = 2;
a_neg1 = 2;
a3 = 4j;
a_neg3 = 4j;
% Compute the signal using the Fourier series formula
x1 = a1 * exp(1j * (2*pi/8) * t) + a_neg1 * exp(-1j * (2*pi/8) * t); % k = 1 term
x3 = a3 * exp(1j * (6*pi/8) * t) + a_neg3 * exp(-1j * (6*pi/8) * t); % k = 3 term

% Combine the components to get the signal x(t)
x = x1 + x3;

% Plot the signal
figure;
plot(t, real(x));
xlabel('Time (t)');
ylabel('x(t)');
title('Continuous-Time Periodic Signal x(t)');
grid on;

```

Output:



Conclusion:

The continuous-time periodic signal $x(t)x(t)$ can be expressed as a linear combination of its non-zero Fourier Series coefficients. This representation helps in understanding the signal in the frequency domain.

Task 03:

Problem Statement:

A discrete-time periodic signal $x[n]x[n]$ is real-valued and has a fundamental period of $N=5N=5$. The non-zero Fourier Series coefficients for $x[n]x[n]$ are: $a0=1a0=1$, $a2=a-2*=ej\pi/4a2=a-2*=ej\pi/4$, $a4=a-4*=2ej\pi/3a4=a-4*=2ej\pi/3$.
Express $x[n]x[n]$ as the linear combination of these coefficients.

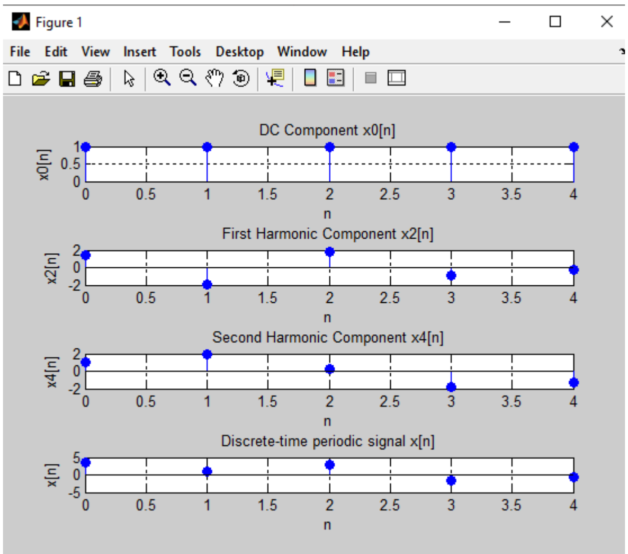
Algorithm:

1. Identify the non-zero Fourier coefficients $a0,a2,a-2,a4,a0,a2,a-2,a4$, and $a-4a-4$.
2. Use the inverse discrete Fourier series formula to express $x[n]x[n]$ as a linear combination of these coefficients:
   $$x[n]=\sum k=0N-1akej2\pi kNnx[n]=k=0\sum N-1akejN2\pi kn$$
3. Substitute the given coefficients and simplify the expression to obtain $x[n]x[n]$.

Code Screenshot:

```
a2 = exp(1j * pi / 4);
a_neg2 = conj(a2);
a4 = exp(1j * pi / 3);
a_neg4 = conj(a4);
N = 5;                          % Fundamental period
n = 0:N-1;                      % Time indices for one period
x0 = a0 * ones(size(n));        % Compute each component separately
x2 = a2 * exp(1j * 2 * pi * 2 / N * n) + a_neg2 * exp(-1j * 2 * pi * 2 / N * n);
x4 = a4 * exp(1j * 2 * pi * 4 / N * n) + a_neg4 * exp(-1j * 2 * pi * 4 / N * n);
x = x0 + x2 + x4;               % Sum all components to get the final signal x[n]
figure;                         % Plot the components and the final signal using subplot
subplot(4, 1, 1);
stem(n, real(x0), 'filled');
xlabel('n');
ylabel('x0[n]');
title('DC Component x0[n]');
grid on;
subplot(4, 1, 2);
stem(n, real(x2), 'filled');
xlabel('n');
ylabel('x2[n]');
title('First Harmonic Component x2[n]');
grid on;
subplot(4, 1, 3);
stem(n, real(x4), 'filled');
xlabel('n');
ylabel('x4[n]');
title('Second Harmonic Component x4[n]');
grid on;
subplot(4, 1, 4);
stem(n, real(x), 'filled');
xlabel('n');
ylabel('x[n]');
title('Discrete-time periodic signal x[n]');
grid on;
```

Output:



Conclusion:

The discrete-time periodic signal $x[n]x[n]$ can be expressed as a linear combination of its non-zero Fourier Series coefficients. This helps in analyzing the signal in the frequency domain.

Task 04:

Problem Statement:

In this task considering the FS coefficients plot given below, and observe happens to the envelope of the coefficients when T1 is reduced from 1/4 to 1/16 with constant period T.

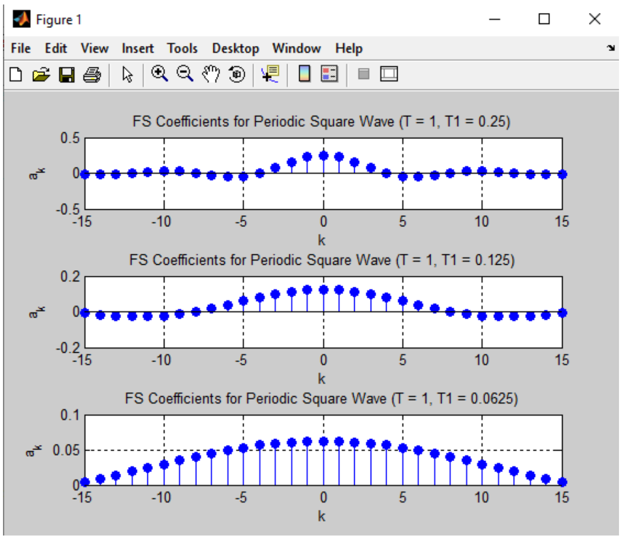
Algorithm:

1. Observe the given Fourier Series coefficients plot.
2. Analyze the changes in the envelope of the coefficients when $T1T1$ is reduced from ¼ 1/4 to 1/16 1/16 while keeping T constant.
3. Note and describe the observed changes in the envelope.

Code Screenshot:

```
% MATLAB code to plot Fourier Series coefficients for different T1 values

% Parameters
T = 1; % Fundamental period
N = 31; % Number of coefficients to compute (odd number for symmetry)
k = -(N-1)/2:(N-1)/2; % Range of k values

% Define the pulse widths (T1 values)
T1_values = [1/4, 1/8, 1/16];

% Prepare the figure
figure;

% Loop over different T1 values
for i = 1:length(T1_values)
    T1 = T1_values(i);
    D = T1 / T; % Duty cycle

    % Compute Fourier Series coefficients
    a_k = sin(pi * k * D) ./ (pi * k);
    a_k((N-1)/2 + 1) = D; % Handle k=0 term separately

    % Plot the coefficients
    subplot(length(T1_values), 1, i);
    stem(k, a_k, 'filled');
    title(['FS Coefficients for Periodic Square Wave (T = ', num2str(T), ', T1 = ', num2str(T1), ')']);
    xlabel('k');
    ylabel('a_k');
    grid on;
end
```

Output:



Conclusion:

We considering the FS coefficients plot given below, and observe happens to the envelope of the coefficients when T1 is reduced from 1/4 to 1/16 with constant time period T.

Task 05:

Problem Statement:

In this task we have to create the plots of square wave reconstructed using M = 10, 20, & 100 terms above,

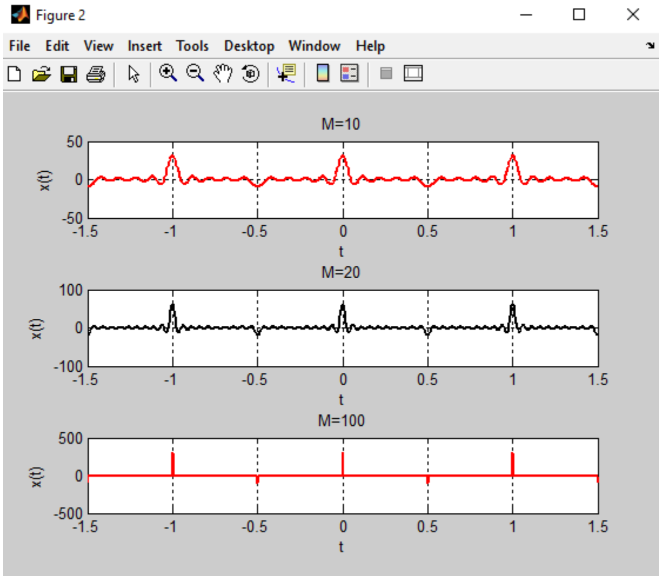
Algorithm:

1. Examine the plots of the square wave reconstructed using M=10,20, M=10,20, and 100 terms.
2. Observe the overshoot and ringing near the discontinuities in the reconstructed square wave.
3. Compare the amplitude of the overshoot and the width of the ringing for different MM values.
4. Describe the behavior and characteristics of Gibb's phenomena observed in these plots.

Code Screenshot:

```
t = -1.5:0.005:1.5;
T = 1;
T1 = 1/4;
w0 = 2*pi/T;
M = 10;
k = -M:M;
x = zeros(1,length(t));
for k = -M:M
    x=x+((mod(k,2)~=0)+1)*exp(1i*k*w0*t);
end
figure;
subplot(3,1,1)
plot(t,real(x),'r','lineWidth',2);
grid;
xlabel('t');
ylabel('x(t)') ;
title('M=10');
M = 20;
k = -M:M;
x = zeros(1,length(t));
for k = -M:M
    x=x+((mod(k,2)~=0)+1)*exp(1i*k*w0*t);
end
hold on;
subplot(3,1,2)
plot(t,real(x),'k','lineWidth',2);
grid;
xlabel('t');
ylabel('x(t)') ;
title('M=20');
M = 100;
k = -M:M;
x = zeros(1,length(t));
for k = -M:M
    x=x+((mod(k,2)~=0)+1)*exp(1i*k*w0*t);
end
subplot(3,1,3)
plot(t,real(x),'r','lineWidth',2);
grid;
xlabel('t');
ylabel('x(t)') ;
title('M=100');
```


Output:



Conclusion:

We have to create the plots of square wave reconstructed using M = 10, 20, & 100 terms above

Task 06:

Problem Statement:

In this task we have to plot given the following FS coefficients & reconstructed signal. Take the terms for reconstructed signal to be M = 10, 20, & 50.

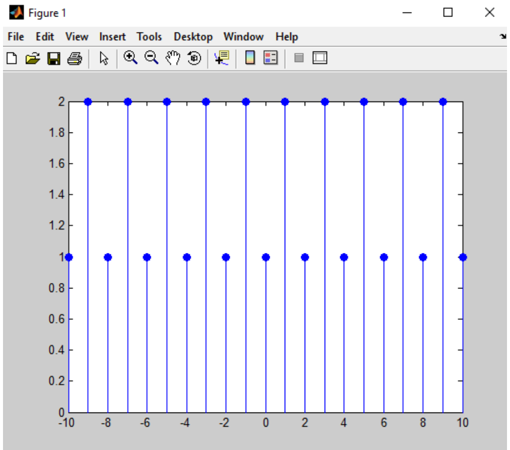
Algorithm:

1. Define the Fourier Series coefficients ak based on the given conditions.
2. Plot the coefficients for visualization.
3. Reconstruct the signal $x(t)x(t)$ using M=10, 20, M=10,20, and 5050 terms.
4. Plot the reconstructed signals for each MM.
5. Observe and describe the changes in the reconstructed signal as MM is varied.

Code Screenshot:

```
t = -1.5:0.005:1.5;
T = 1;
T1 = 1/4;
w0 = 2*pi/T;
M = 10;
k = -M:M;
x=zeros(1, length(t));
figure
for k = -M:M
    if (mod(k,2)==0)
        ak=1;
x = x + ak*exp(j*k*w0*t);
stem(k,ak,'filled');
axis([-10 10 0 2]);
hold on
    else
   ak=2
  x = x + ak*exp(j*k*w0*t);
stem(k,ak,'filled');
axis([-10 10 0 2]);
hold on
    end
end
```

Output:



Conclusion:

We plot given the following FS coefficients & reconstructed signal. Take the terms for reconstructed signal to be M = 10, 20, & 50.

Task 07:

Problem Statement:

In this task we have given the following FS coefficients, we have to plot the coefficients and reconstructed signal. Take 10 terms for reconstructed signal.

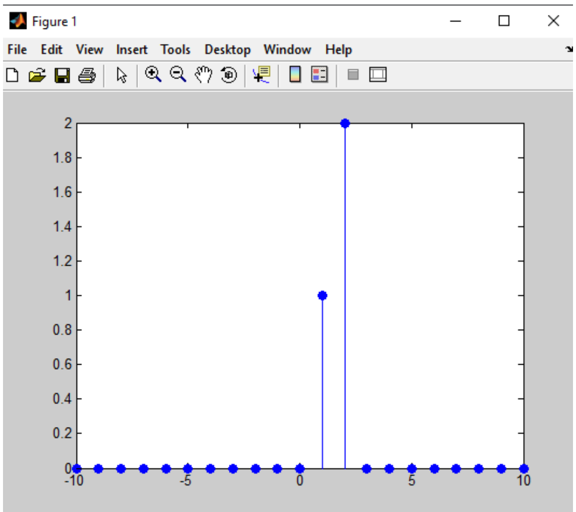
Algorithm:

1. Define the Fourier Series coefficients $akak$ based on the given conditions.
2. Plot the coefficients for visualization.
3. Reconstruct the signal $x(t)x(t)$ using 10 terms (M=10M=10).
4. Plot the reconstructed signal.
5. Observe and describe the characteristics of the reconstructed signal.

Code Screenshot:

```
T = 1;
T1 = 1/4;
w0 = 2*pi/T;
M = 10;
k = -M:M;
x=zeros(1, length(t));
figure
for k = -M:M
    if (k>0 && k<3)
        ak=k;
x = x + ak*exp(j*k*w0*t);
stem(k,ak,'filled');
axis([-10 10 0 2]);
hold on
    else
   ak=0;
  x = x + ak*exp(j*k*w0*t);
stem(k,ak,'filled');
axis([-10 10 0 2]);
hold on
    end
end
```

Output:



Conclusion:

We have given the following FS coefficients; we plot the coefficients and reconstructed signal. Take 10 terms for reconstructed signal.