Name: Rameen **Roll No:** 2023-EE-03

EE-322L Analog and Digital Communication Marks Obtained: ________

Lab Report

Experiment No. 2

Relationship between DFT and DTFT

Note:

- **Don’t forget to include the rubrics table (available at the end in this document), otherwise reports will not be graded.**
- **Copy-pasted and plagiarized reports will get zero marks**

Ensure proper comments are there in the source code of each task

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1) Objective

To verify that the Discrete Fourier Transform (DFT) corresponds to a sampled version of the Discrete-Time Fourier Transform (DTFT) in the frequency domain using a finite discrete rectangular pulse.

2) Technical Background

The DTFT represents the frequency spectrum of a discrete-time signal over a continuous frequency range, while the DFT provides frequency samples at discrete points. When the number of DFT points NNN is sufficiently large, the DFT samples approximate the DTFT. This relationship is fundamental in digital signal processing where finite-length signals are analyzed in the frequency domain.

3) Task-1

3.1. ***Description of Task-1***

Consider the following rectangular pulse in MATLAB

$$\boldsymbol{u[n] = [1,1,1,1,1]} \text{ where } n = [0,1,2,3,4]$$

Find its Discrete Fourier Transform (DFT) by

$$U(k) = \sum_{n=0}^{n=N-1} u[n]\, e^{-j\frac{2\pi}{N}kn}$$

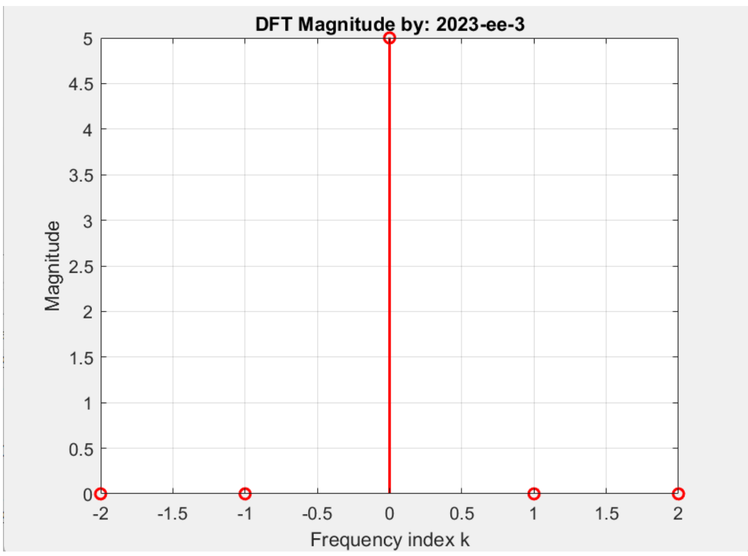
Here N is any length greater than or equal to $N = 5$. Choose $N = 5$ and plot phase and amplitude of $U(k)$ with respect to ω_k , where k goes from 0 to 4.

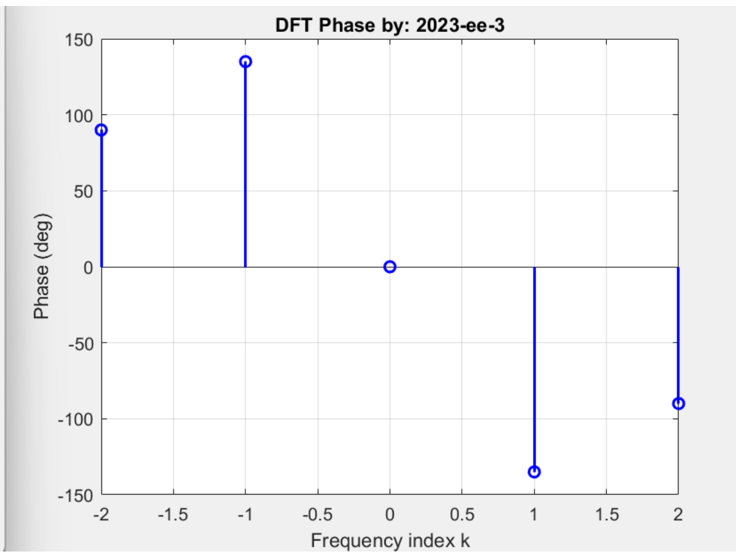
3.2. ***Source Code for Task-1***

```
u = [1,1,1,1,1];        % input rectangular pulse
N = 5;                  % DFT length
n = 0:1:4;              % time index

% ---- DFT ----
k = -floor(N/2) :1: floor(N/2);   % frequency index for symmetric view
w_dft = (2*pi*k)/N;               % angular frequencies of DFT

Un_dft = zeros(size(k));          % accumulator initialized

for n = 0:4                      % compute DFT using definition
    Un_dft = Un_dft + (u(n+1) * exp(-1j * 2 * pi * k * n / N));
end

phase_dft = angle(Un_dft) * (180/pi);   % convert rad to deg
magnitude_dft = abs(Un_dft);            % magnitude of DFT

% ---- Plot DFT Magnitude ----
figure;
stem(k, magnitude_dft, 'r', LineWidth=1.5);
title('DFT Magnitude by: 2023-ee-3');
xlabel('Frequency index k');
ylabel('Magnitude');
grid on;

% ---- Plot DFT Phase ----
figure;
stem(k, phase_dft, 'b', LineWidth=1.5);
title('DFT Phase by: 2023-ee-3');
xlabel('Frequency index k');
ylabel('Phase (deg)');
grid on;
```

3.3. ***Results and Discussions for Task-1***

This plot shows the magnitude and phase of DFT respectively for N=5





The sampling frequency is low, due to which the DFT obtained does not give a lot of information about the frequency spectrum of the signal.

4) Task-2

4.1. ***Description of Task-2***

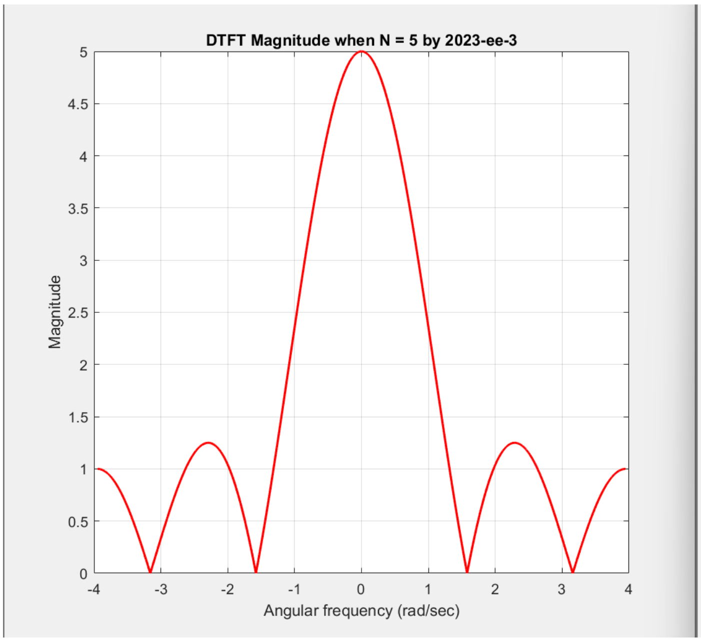
Plot the DTFT of the same signal and compare it with the DFT.

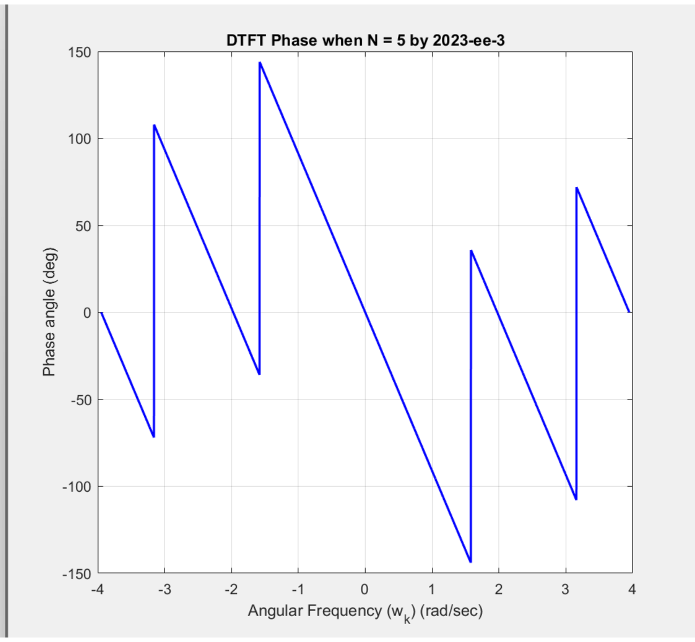
4.2. ***Source Code for Task-2***

```
N = 5;                              % length reference for normalization
u = [1,1,1,1,1];                    % input rectangular pulse
w = -pi:0.001:pi;                   % continuous frequency vector for DTFT
w_k = (2*pi*w)/N;                   % normalized angular frequency axis
Un = 0;                             % initialize DTFT accumulator

for n = 0:4                         % DTFT definition
    Un = Un + u(n+1) * exp(-1j * w * n);
end

% ---- DTFT Magnitude ----
figure;
plot(w_k, abs(Un), 'r', LineWidth=1.5);
title('DTFT Magnitude when N = 5 by 2023-ee-3');
xlabel('Angular frequency (rad/sec)');
ylabel('Magnitude');
grid on;

% ---- DTFT Phase ----
figure;
plot(w_k, angle(Un) * (180/pi), 'b', LineWidth=1.5);
title('DTFT Phase when N = 5 by 2023-ee-3');
xlabel('Angular Frequency (w_k) (rad/sec)');
ylabel('Phase angle (deg)');
grid on;

```

4.3. ***Results and Discussions for Task-2***

This plot shows the magnitude and phase of DTFT respectively.





Comparing the DFT with the DTFT shows that the amplitude and phase values at the DFT's sampled frequency points coincide with the corresponding values of the DTFT. However, the DFT appears as a low-resolution, discretely sampled representation of the continuous DTFT spectrum.

5) Task-3

5.1. ***Description of Task-3***

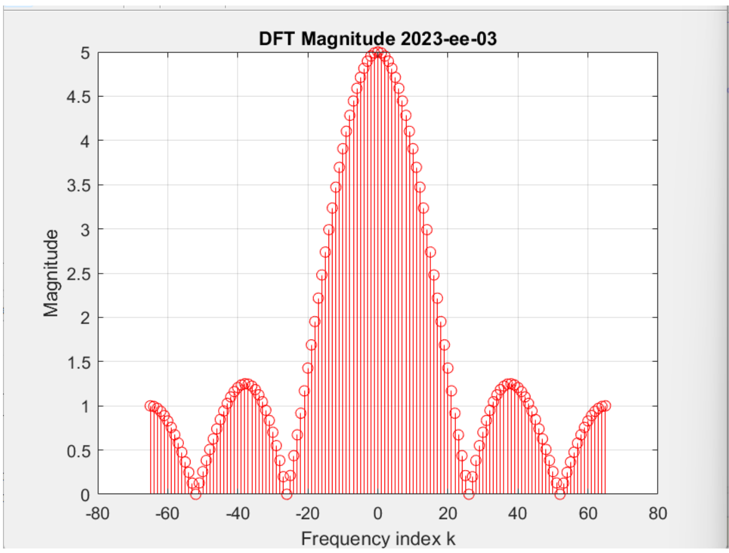
Now set the number of discrete samples N to your roll number, and then compare the resulting DFT with the previous DFT and DTFT.

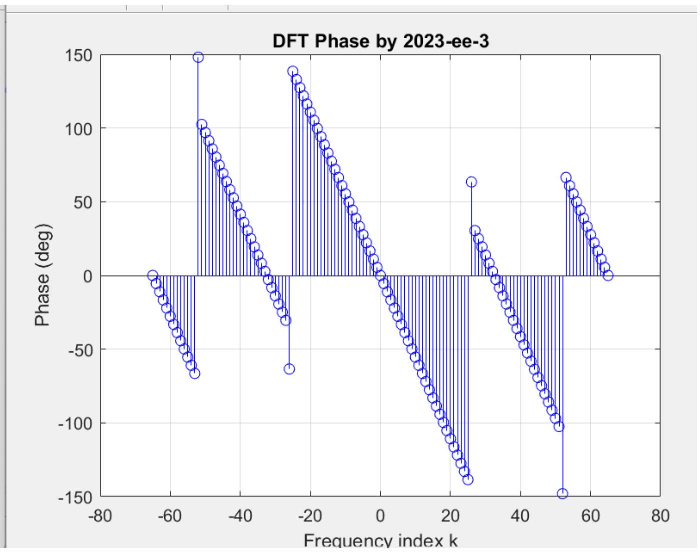
5.2. ***Source Code for Task-3***

```
u = [1,1,1,1,1];              % input rectangular sequence
N = 130;                      % DFT length (chosen = roll no.)
n = 0:1:4;                    % time index for the signal

% ---- DFT ----
k = -floor(N/2) : 1 : floor(N/2);   % symmetric frequency indices

w_dft = (2*pi*k)/N;                  % angular frequency points of DFT

Un_dft = zeros(size(k));             % initialize accumulator

for n = 0:4                          % compute DFT using definition
    Un_dft = Un_dft + (u(n+1) * exp(-1j * 2 * pi * k * n / N));
end

phase_dft = angle(Un_dft) * (180/pi);   % phase in degrees
magnitude_dft = abs(Un_dft);            % magnitude of DFT


% DFT Magnitude
figure;
stem(k, magnitude_dft, 'r');
title('DFT Magnitude 2023-ee-03');
xlabel('Frequency index k');
ylabel('Magnitude');
grid on;

% DFT Phase
figure;
stem(k, phase_dft, 'b');
title('DFT Phase by 2023-ee-3');
xlabel('Frequency index k');
ylabel('Phase (deg)');
grid on;
```

5.3. ***Results and Discussions for Task-3***

This plot shows the magnitude and phase of DFT respectively for N= 130





This DFT shows a closer resemblance to the DTFT compared to the result in Task-1. The improvement comes from using a larger number of frequency samples, which effectively increases the sampling resolution in the frequency domain. As a result, the DFT captures more detail of the spectrum and represents the DTFT more accurately than before.

6) Conclusion

The results confirm that the DFT is a sampled form of the DTFT. When the length N is small, the frequency resolution is poor and the DFT does not represent the spectral content accurately. Increasing N improves resolution but also increases computational cost. Therefore, an appropriate choice of N is essential when analyzing signals in the frequency domain using the DFT.
With the availability of efficient algorithms like the Fast Fourier Transform (FFT) and advancements in hardware, the computational burden has become less significant in practical applications.

Rubrics for Experiment No.

Performance	Exceeds expectation (2)	Meets expectation (1)	Does not meet expectation (0.5)	Marks
R1: Knowledge of required functions for code design. **Marks: 0-2**	Has required knowledge for code	Has partial knowledge for code	Has no knowledge for code	
R2: Simulation of experiment **Marks: 0-2**	Simulates all the tasks correctly by himself	Needs guidance to simulate the tasks correctly	Incapable to simulate the tasks correctly by himself even with guidance	
R3: Demonstrate proper results with justification **Marks: 0-2**	Correct results are provided with required justification	Results are provided with minor errors and/or with little justification	Results are provided with major errors and/or with no justification	

Rubrics for Lab Manual No.

Performance	Exceeds expectation (0.5)/(0.25)	Meets expectation (-)/(-)	Does not meet expectation (0)/(0)	Marks
R1: Timely submission **Marks: 0-0.5**	The submission is on time	---	Late submission	
R2: Report completeness **Marks: 0-0.25**	All relevant calculations, specifications, code, graphs, and results are provided with proper explanation.	All the relevant calculations, specifications, code, graphs and results are provided but with little explanation and justification.	Most of the relevant graphs, results, calculations, specifications, and code are missing, as well as their proper explanation and justification is also missing.	
R3: Error-free writeup **Marks: 0-0.25**	The submitted assignment is without any plagiarism and formatting errors.	Some parts of the submitted assignment contain formatting errors and plagiarized material.	The submitted assignment is mostly plagiarized and contain formatting errors.	