LAB 4: Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT)

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Aim:

To perform the Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT).

Requirements: MATLAB Software was used to perform the practical

Theory:

Discrete Fourier Transform (DFT)

Definition

The Discrete Fourier Transform (DFT) is a mathematical operation that transforms a finite sequence of equally spaced samples of a function into a sequence of coefficients of the discrete frequencies of the function.

Formula

The DFT of a sequence x[n] of length N is defined by:

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-j\frac{2\pi}{N}kn}$$

Inverse Discrete Fourier Transform (IDFT)

Definition

The Inverse Discrete Fourier Transform (IDFT) is the process of converting the frequency-domain representation back to the time-domain signal.

Formula

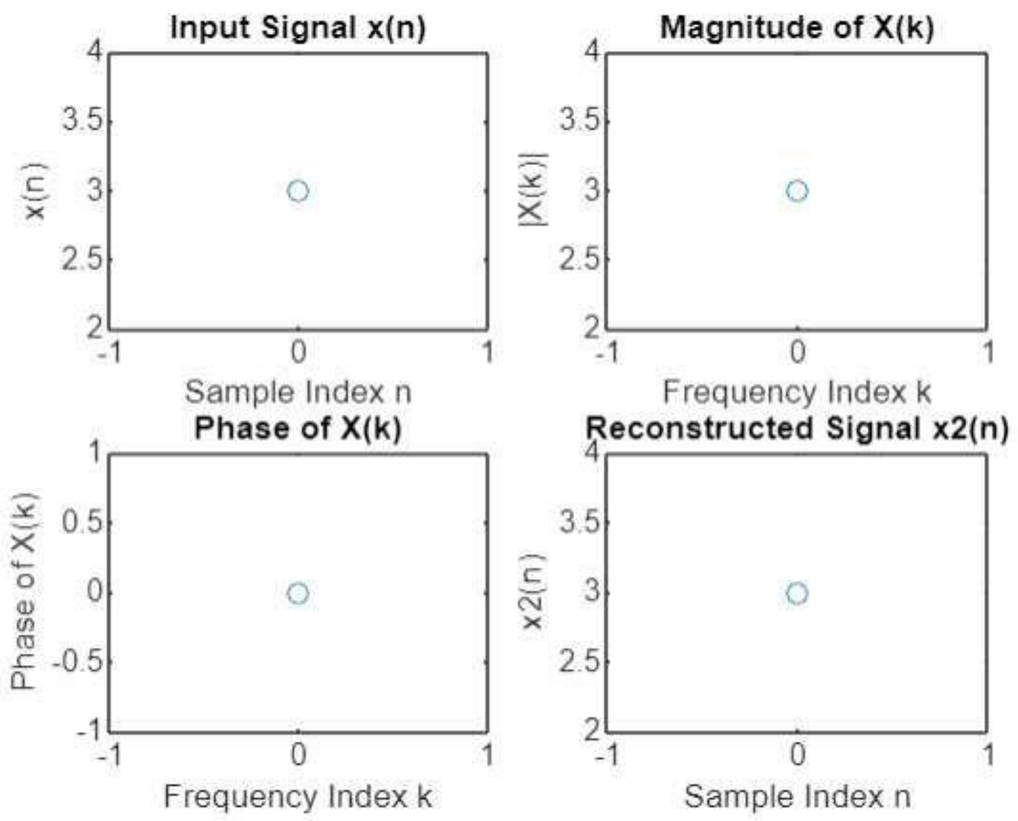
$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} X[k] e^{j \frac{2\pi}{N} kn}$$

The IDFT is given by:

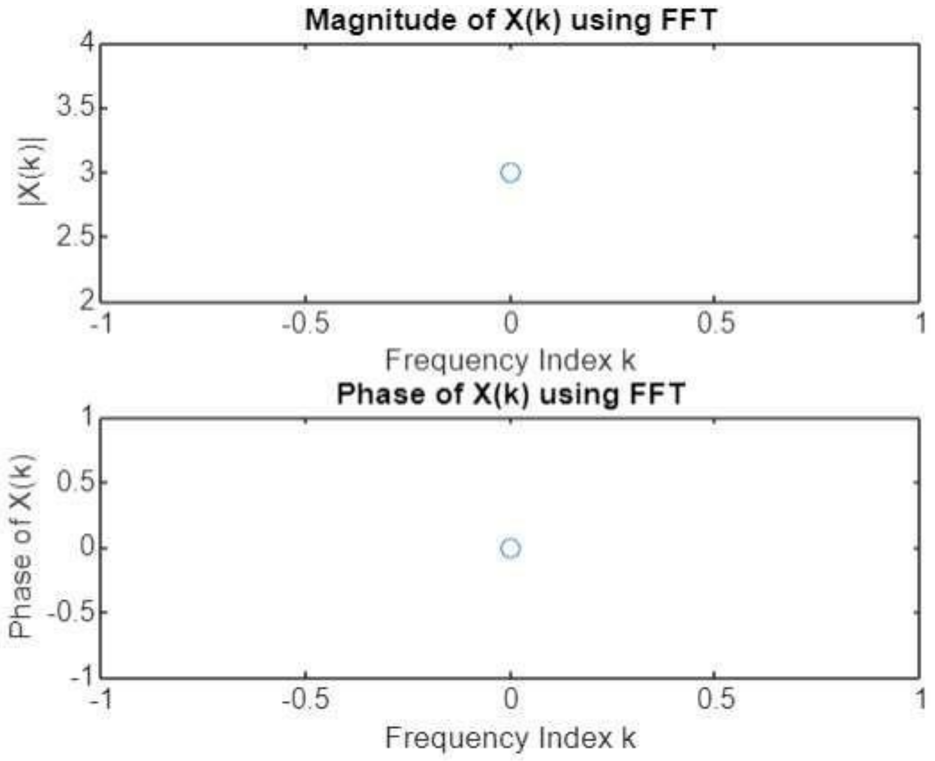
```
Program: close
all;

% Define the input signal x =
input('Enter the input x = ');

% Length of the input signal
N = length(x);

% Time indices n
= 0:N-1;

% Frequency indices k
= 0:N-1;

% Compute DFT manually
% DFT matrix
W = exp(-1i * 2 * pi * (n' * k) / N);
```

```
% DFT calculation
Xk = x * W;

% Display DFT results disp('N
point DFT:'); disp(Xk);


% Magnitude and Phase of DFT
mag = abs(Xk); phase = angle(Xk);

% Plotting the results
subplot(2, 2, 1); plot(n, x,
'-o'); title('Input Signal
x(n)'); xlabel('Sample
Index n'); ylabel('x(n)');

subplot(2, 2, 2); plot(k, mag,
'-o'); title('Magnitude of
X(k)'); xlabel('Frequency
Index k'); ylabel('|X(k)|');

subplot(2, 2, 3); plot(k, phase,
'-o'); title('Phase of X(k)');
xlabel('Frequency Index k');
ylabel('Phase of X(k)');

% Compute IDFT manually
% IDFT matrix
W1 = exp(1i * 2 * pi * (n' * k) / N);
```

```
% IDFT calculation
x2 = (1 / N) * (Xk * W1);

%  Display  IDFT  results
disp('IDFT    of    X(k):');
disp(x2);

% Plotting the IDFT result subplot(2,
2, 4); plot(n, x2, '-o');
title('Reconstructed Signal x2(n)');
xlabel('Sample Index n');
ylabel('x2(n)');

% Verification using MATLAB's FFT function
Xk1 = fft(x); disp('Verification by FFT
function:'); disp(Xk1);

% Plotting FFT results for comparison
figure; subplot(2, 1, 1); plot(k, abs(Xk1),
'-o'); title('Magnitude of X(k) using
FFT'); xlabel('Frequency Index k');
ylabel('|X(k)|');

subplot(2,       1,       2);      plot(k,
angle(Xk1),   '-o');   title('Phase   of
X(k)              using              FFT');
xlabel('Frequency      Index      k');
ylabel('Phase of X(k)');
```


Input Signal x(n)
x(n)
Sample Index n
Magnitude of X(k)
|X(k)|
Frequency Index k
Phase of X(k)
Phase of X(k)
Frequency Index k
Reconstructed Signal x2(n)
x2(n)
Sample Index n

Result:


Magnitude of X(k) using FFT
|X(k)|
4
3.5
3
2.5
2
-1
-0.5
0
0.5
1
Frequency Index k
Phase of X(k) using FFT
Phase of X(k)
1
0.5
0
-0.5
-1
-1
-0.5
0
0.5
1
Frequency Index k

Observations:

- DFT Results: The DFT output provides a frequency-domain representation of the input signal, with visible peaks corresponding to the dominant frequencies.
- IDFT Results: The reconstructed signal from the IDFT should closely match the original input signal, verifying that the DFT and IDFT processes are accurate.
- FFT Verification: The results from MATLAB's built-in FFT function can be used to verify the manual DFT implementation, confirming the validity of the DFT computation.

Conculsion:

From the experiment:

- The DFT and IDFT provide a comprehensive method to analyze and reconstruct signals in the frequency domain.
- The implementation shows that the calculated DFT accurately reflects the frequency content of the input signal.
- The reconstruction using IDFT confirms that the original signal can be recovered from its frequency representation.
- The agreement between manual DFT/IDFT and MATLAB’s FFT functions highlights the reliability of the computations performed.

This experimentation emphasizes the importance of DFT and IDFT in signal processing applications, illustrating how they facilitate frequency analysis and signal reconstruction.