Institute of Information Technology (IIT)

Jahangirnagar University

Lab Report: 05

Course Code: ICT-4104

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EXP.NO: 05

Name Of the Experiment: Determination of power spectrum of a given signal

AIM: Determination of Power Spectrum of a given signal.

Software: MATLAB

Theory:
The power spectrum describes the distribution of signal power over a frequency spectrum. The most common way of generating a power spectrum is by using a discrete Fourier transform, but other techniques such as the maximum entropy method can also be used. The power spectrum can also be defined as the Fourier transform of auto correlation function.

Methodology

Algorithm:

Step 1 : Give input sequence x.

Step 2 : Give sampling frequency, input frequency and length of the spectrum.

Step 3 : Find power spectrum of input sequence using matlab command spectrum.

Step 4 : Plot power spectrum using specplot.

Flow Chart:

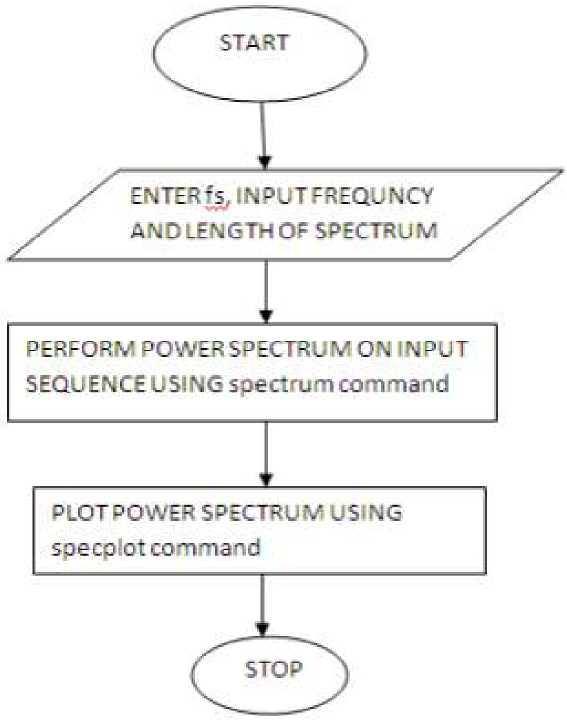

Fig-01: Flowchart

PROGRAM:

```
clear all;

close all;

N = 1024;

fs = 8000;

f = input('Enter the frequency [1 to 5000]: ');

n = 0:N-1;

x = sin(2 * pi * (f / fs) * n);

[Pxx, frequencies] = periodogram(x, [], N, fs);

figure; plot(frequencies, 10 * log10(Pxx));
```

```
grid on;

xlabel('Frequency (Hz)');

ylabel('Magnitude (dB)');

title('Power Spectrum of x(n)');
```

Output:

Enter the frequency [1 to 5000]: 3000

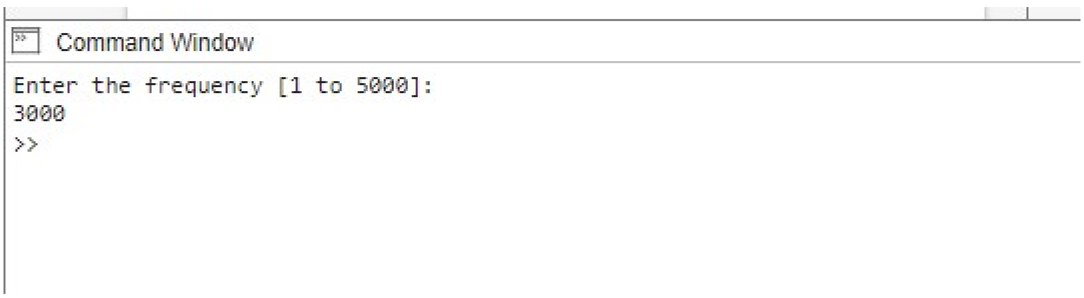

Fig 02: command window

Output Waveforms:

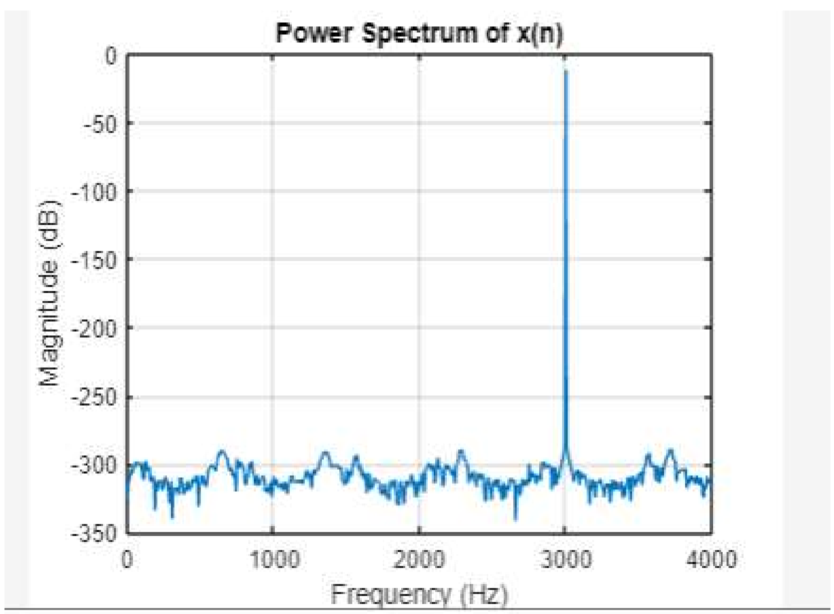

Fig 03: wavelength

Exercise:

1. Find power spectrum of the signal x(n)=cos(2*pi*50*n)

Program:

```
clc;
clear all;
close all;
N = 1024;
fs = 8000;
f = input('Enter the frequency [1 to 5000]: ');
n = 0:N-1;
x = cos(2 * pi *50* (f / fs) * n);
[Pxx, frequencies] = periodogram(x, [], N, fs);
figure;
plot(frequencies, 10 * log10(Pxx));
grid on;
xlabel('Frequency (Hz)');
ylabel('Magnitude (dB)');
title('Power Spectrum of x(n)');
```

Output:

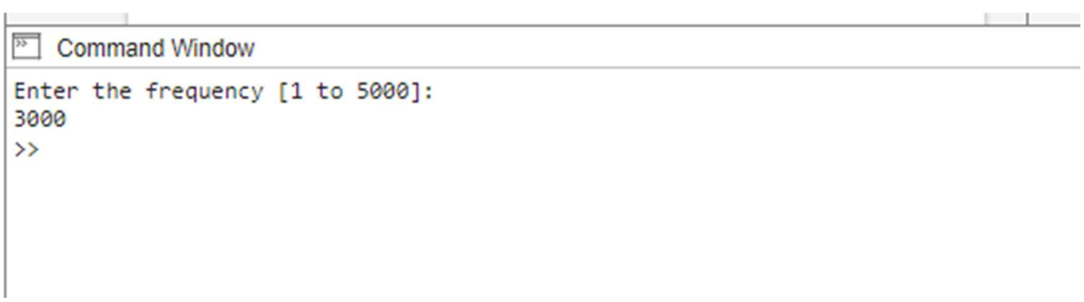

Fig 04: Command window

Output Waveforms:

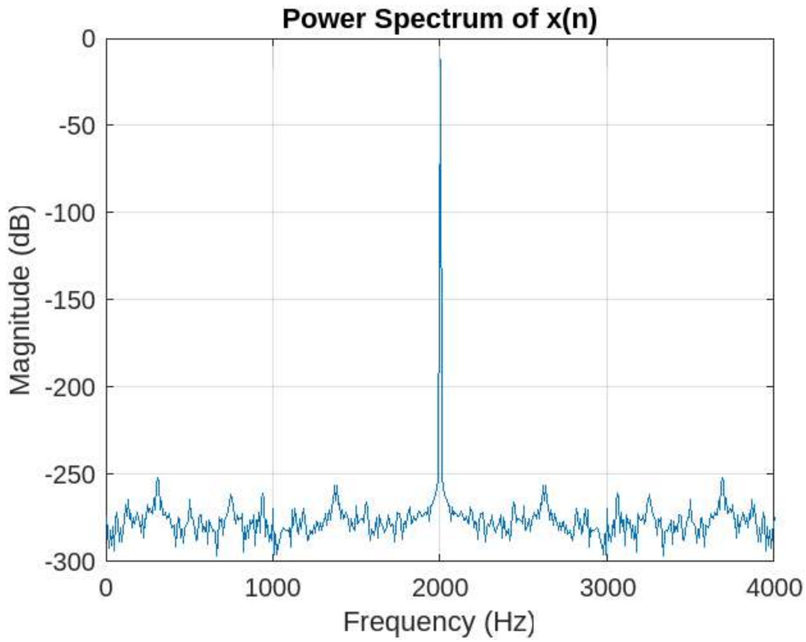

Fig 05: Waveforms

DISCUSSION:

This experiment illustrates a straightforward but crucial procedure for figuring out a signal's power spectrum. The code permits the investigation of various frequency components in the power spectrum by enabling user input for the signal frequency. Understanding the frequency content of the signal and identifying dominant frequency components are made easier with the help of power spectrum visualization.

CONCLUSION:

A signal's power spectrum analysis offers vital information about the frequency distribution and components of the signal. Understanding signal properties, noise sources, and prospective applications in diverse fields are all aided by this technique. Researchers and engineers can make wise choices for signal processing, communication systems, and other areas by analyzing frequency-domain data.

VIVA QUESTIONS:

1. **Define power signal.**

A power signal refers to a signal whose samples have a non-zero average power over an infinite number of samples. Mathematically, for a discrete signal $x[n]$ the power is calculated as:

$$P = \lim_{N \to \infty} \frac{1}{N} \sum_{n=-\infty}^{\infty} |x[n]|^2$$

Where:

- P is the power of the signal.
- N is the number of samples considered for power calculation.
- $x[n]$ is the signal in the discrete domain.

2. **Define the energy signal.**

An energy signal in the discrete domain refers to a signal whose samples have finite energy over a specific, often finite, number of samples. The mathematical definition for a discrete energy signal $x[n]$ is:

$$E = \sum_{n=-\infty}^{\infty} |x[n]|^2$$

Where:

- E is the energy of the signal.
- $x[n]$ is the signal in the discrete domain.

3. **Define power spectral density of a signal.**

The power spectral density (PSD) of a signal is a fundamental concept in signal processing that describes how the power of a signal is distributed across different frequency components.For a discrete-time signal $x[n]$, the power spectral density $S(f)$ can be estimated using the discrete Fourier transform (DFT) of the autocorrelation sequence $r[k]$ of the signal:

$$S(f) = \sum_{k=-\infty}^{\infty} r[k]\, e^{-j2\pi fk}$$

Where:

- $S(f)$ is the power spectral density of the signal.
- $r[k]$ is the autocorrelation sequence of the signal.

4. How the energy of a signal can be calculated?

The energy of a signal can be calculated by summing the squared magnitudes of its samples over a specified interval. For a discrete-time signal $x[n]$ defined over a finite number of samples N, the energy E is calculated as the sum of the squared magnitudes of the samples:

$$E = \sum_{n=-\infty}^{\infty} |x[n]|^2$$

However, since most signals have finite support (a finite number of non-zero samples), the summation is limited to the range where the signal is non-zero:

$$E = \sum_{n} |x[n]|^2$$

Where:

- E is the energy of the signal.
- $x[n]$ is the signal in the discrete domain.

5. Explain difference between energy spectral density and power spectral density.

Energy Spectral Density (ESD): Describes how the energy of a signal is distributed across frequencies. Used for finite-energy signals.

Power Spectral Density (PSD): Describes how the power of a signal is distributed across frequencies. Used for signals with constant power over time. This is the key difference between energy spectral density and power spectral density.

6. Explain the PSD plot.

The PSD plot is a graphic depiction of a signal's power spectral density (PSD). It displays the signal's strength at each frequency. The PSD plot is typically a line graph with the frequency on the x-axis and the power spectral density on the y-axis.

A signal's PSD is a measurement of how the signal's power is distributed over frequency. It is defined as the average power of the signal at each frequency. The power spectral density is often used to characterize the frequency content of a signal.

7. What is the importance of PSD?

The importance of PSD lies in its ability to characterize the frequency content of a signal. This information can be used for a variety of tasks, such as noise filtering, signal detection, and system identification.

Here are some of the importance of PSD:

- **Noise filtering**: PSD can be used to identify and remove noise from signals. Noise is often characterized by having a wide bandwidth and low power at all frequencies. PSD can be used to identify the frequencies that are associated with the noise and then remove those frequencies from the signal.

- **Signal detection:** PSD can be used to detect signals in noisy environments. The signal can be identified by looking for a peak in the PSD plot that is above the noise level.

- **System identification:** PSD can be used to identify the characteristics of a system, such as its resonant frequencies. The resonant frequencies are the frequencies at which the system vibrates with maximum amplitude. PSD can be used to identify the frequencies that are associated with the resonant frequencies.

- **Audio engineering:** PSD can be used to analyze and improve the quality of audio signals. PSD can be used to identify the frequencies that are present in the signal and to remove unwanted frequencies.

8. What are the applications of PSD?

The Power Spectral Density (PSD) is a versatile tool with a wide range of applications across various fields. Here are some of the key applications of PSD:

Signal Analysis and Processing: PSD is extensively used in signal analysis and processing to understand the frequency composition of signals. It helps in identifying dominant frequency components, harmonics, modulation, and noise levels.

Communication Systems: In communication systems, PSD analysis is crucial for designing modulation schemes, understanding channel capacity, and optimizing frequency allocation for efficient data transmission.

Vibration Analysis: PSD is used in mechanical engineering to analyze vibrations in structures, machinery, and vehicles. It helps in identifying resonances, natural frequencies, and potential sources of structural failure.

Audio Processing: In audio applications, PSD analysis is used to analyze and equalize audio signals. It aids in tasks like noise reduction, audio effects, and improving audio quality.

9. Explain MATLAB function randn(size(n)).

The MATLAB function randn(size(n)) generates an array of random numbers from a standard normal distribution (also known as a Gaussian distribution). Let's break down the function and its components:

randn: This is the MATLAB function used to generate random numbers from a standard normal distribution.

size(n): size(n) returns the dimensions (size) of the array or matrix n. In the context of the function call, it is used to determine the size of the output random array based on the size of array n.

When you use randn(size(n)), MATLAB generates random numbers from a standard normal distribution to match the dimensions of the array n. The standard normal distribution has a mean of 0 and a standard deviation of 1. The resulting array will have the same dimensions as n, and its elements will be random values drawn from the standard normal distribution.

10. What is the need to represent the signal in frequency domain?

There are several reasons why it is useful to represent a signal in the frequency domain.

Frequency analysis: The frequency domain representation of a signal can be used to analyze its frequency content. This information can be used for a variety of tasks, such as noise filtering, signal detection, and system identification.

Compression: The frequency domain representation of a signal can be used to compress the signal without losing important information. This is because the frequency domain representation can be represented with fewer numbers than the time domain representation.

Filtering: The frequency domain representation of a signal can be used to filter the signal. This is because filters can be designed to operate in the frequency domain.

Computation: Some operations are easier to perform in the frequency domain than in the time domain. For example, convolution is easier to perform in the frequency domain than in the time domain.

References:

[1]Wikipedia Contributors, “Spectral density,” Wikipedia, Aug. 01, 2023. Available: https://en.wikipedia.org/wiki/Spectral_density?fbclid=IwAR1iMVx_kvvjG4CHA7BADjM44SvFiZx0nX2ncUB5W-QqHXPbP3p1edGXWfU. [Accessed: Aug. 15, 2023]