Minnesota State University, Mankato

Electrical and Computer Engineering Department

Lab Assignment 5 – Fourier Transform of an Energy Signal

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Fourier Transform of an Energy Signal

*Abstract*

This lab investigates the **Fourier Transform of a Gaussian-shaped energy signal** using **numerical integration**, avoiding built-in Fast Fourier Transform (FFT) functions. The objective is to analyze how a time-domain energy signal behaves in the frequency domain. The experiment includes computing the **magnitude and phase spectra**, along with the **Energy Spectrum Density** (ESD). Additionally, we examine how time-shifting x(t−3T) and time-scaling x(2t) affect the Fourier Transform. The results validate the fundamental properties of the Fourier Transform, such as time-frequency duality and shift invariance.

*Materials*

**Equipment Needed                                        Quantity.**

Laptop (Visual Studio Code)                                 1

**Methods (Procedure, Data Collection, and Analysis)**

**Part A: Computing the Fourier Transform of an Energy Signal**

1. Define an energy-limited signal:



where T=0.1ms and t ranges from **0 to 10T**.

1. Implement numerical integration to compute its **Fourier Transform**:

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1. Compute and plot:
   * **Magnitude Spectrum ∣X(f)∣**
   * **Phase Spectrum ∠X(f)**
   * **Energy Spectrum Density ∣X(f)∣2**

**Part B: Fourier Transform of Time-Shifted Signal x(t−3T)**

1. Compute the signal **shifted by 3T**:

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1. Compute and plot:
   * **Magnitude Spectrum ∣Xshifted(f)∣**
   * **Phase Spectrum ∠Xshifted(f)**
2. Compare the **phase shift** with the original spectrum.

**Part C: Fourier Transform of Scaled Signal x(2t)**

1. Compute the **time-scaled signal**:

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1. Compute and plot:
   * **Magnitude Spectrum ∣Xscaled(f)∣**
   * **Phase Spectrum ∠Xscaled(f)**
2. Compare the **spectral compression/stretching** with the original spectrum.

*Results*

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A graph with a blue line

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A graph with a line

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A graph with a red line

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A graph of lines with red and blue lines

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A graph with a line

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A graph with a blue line

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A graph with lines and numbers

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A diagram of a normal distribution

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*Conclusion*

In this lab, we successfully implemented the **Fourier Transform of an energy signal** using **numerical integration** and analyzed its behavior in the frequency domain.

Our key observations include:

* **Magnitude spectra remain unchanged** under **time shifts**, but phase shifts occur as expected.
* **Time scaling compresses the signal in time** while **stretching it in the frequency domain**, confirming **time-frequency duality**.
* The computed **Energy Spectrum Density ∣X(f)∣2** shows how the signal distributes its energy over frequencies.

Challenges in this lab included handling **numerical integration accuracy** and ensuring a **sufficiently large frequency range** to capture the signal’s spectral characteristics. Overall, this experiment reinforced core Fourier Transform concepts and their applications in signal processing.

*Appendices*

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*References*

1. <https://rodzah.files.wordpress.com/2011/07/how-to-write-lab-report.pdf>
2. EE343- LAB Assignment 5.pdf