Digital Communication Lab

Rectangular Pulse, Sinc Function, ESD, and Autocorrelation

Name: Sachin Kumar
Roll No: 220104026
Section: D
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Objective

The objective of this lab is to analyze the rectangular pulse in both the time and frequency domains, compute the Energy Spectral Density (ESD), and derive the autocorrelation function. These concepts are essential in signal processing, particularly in understanding how signals behave in time and frequency.

Introduction

In signal processing, a rectangular pulse has a well-known relationship to the sinc function in the frequency domain. The Energy Spectral Density (ESD) represents the distribution of energy as a function of frequency. Autocorrelation measures the similarity between a signal and a delayed version of itself, and it's useful for analyzing the time-domain characteristics of a signal.

Code Implementation

Below is the Python code that simulates the rectangular pulse, sinc function, ESD, and autocorrelation function.

```
import numpy as np
import matplotlib.pyplot as plt

# Time and frequency parameters
T = 2
t = np.linspace(-T, T, 1000)
f = np.linspace(-2, 2, 1000)
tau = np.linspace(-T, T, 1000)

# Time domain: rectangular pulse p_T(t)
pT_t = (np.abs(t) <= T / 2)

# Plot time domain signal
plt.subplot(321)
plt.plot(t, pT_t)
plt.title('Time Domain: p_T(t)')
plt.xlabel('Time t')
plt.ylabel('p_T(t)')
plt.grid(True)
plt.axis([-T, T, -0.1, 1.1])

# Frequency domain: sinc function p_T(f)
pT_f = T * np.sinc(T * f)

# Plot frequency domain signal
plt.subplot(322)
plt.plot(f, pT_f)
plt.title('Frequency Domain: p_T(f)')
plt.xlabel('Frequency f')
plt.ylabel('p_T(f)')
plt.grid(True)

# Energy Spectral Density (ESD)
ESD_f = np.abs(pT_f) ** 2

# Plot Energy Spectral Density
plt.subplot(323)
plt.plot(f, ESD_f)
plt.title('Energy Spectral Density: |P_T(f)|^2')
plt.xlabel('Frequency f')
plt.ylabel('ESD(f)')
```

```
plt.grid(True)

# Autocorrelation function: R_{p_Tp_T}(\tau)
RpTpT_tau = np.convolve(pT_t, np.flip(pT_t), mode='same') * (T / 1000)
RpTpT_tau = RpTpT_tau / np.max(RpTpT_tau) * T

# Plot autocorrelation function
plt.subplot(324)
plt.plot(t, RpTpT_tau)
plt.title('Autocorrelation Function: R_{p_Tp_T}(   )')
plt.xlabel('Time Shift    ')
plt.ylabel('R_{p_Tp_T}(   )')
plt.grid(True)

# Display plots
plt.tight_layout()
plt.show()
```

Results

The following plots represent the rectangular pulse in the time and frequency domains, the Energy Spectral Density (ESD), and the autocorrelation function.

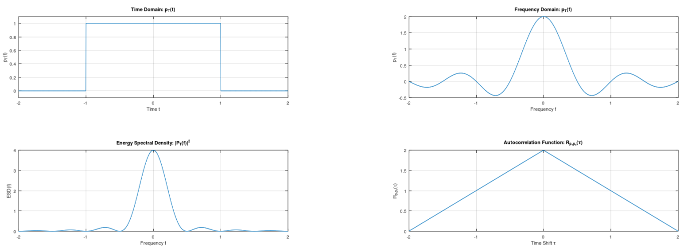

Figure 1: Time Domain Signal: $p_T(t)$

Conclusion

In this lab, we successfully analyzed the rectangular pulse, its corresponding sinc function in the frequency domain, the Energy Spectral Density, and the autocorrelation function. These fundamental concepts are crucial in understanding the behavior of signals in both time and frequency domains.