Digital Communication Lab

Pulse Amplitude Modulation (PAM) and FFT Analysis

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Objective

The objective of this lab is to generate and analyze a Pulse Amplitude Modulation (PAM) signal. The PAM signal is created by sampling a message signal with an impulse train and applying a pulse shaping function. Additionally, we perform FFT analysis to examine the frequency spectrum of the PAM signal and the pulse shape function.

Introduction

Pulse Amplitude Modulation (PAM) is a form of modulation where the amplitude of each pulse in the signal is proportional to the instantaneous value of the modulating signal (message signal). It is widely used in digital communications and serves as a foundation for more advanced modulation techniques.

In this experiment, we will generate a cosine wave as the message signal, sample it using an impulse train, and then modulate the sampled signal using a pulse shaping function. Finally, we will perform a Fast Fourier Transform (FFT) to analyze the frequency components of the pulse and the PAM signal.

Code Implementation

The following code in Python using the NumPy and Matplotlib libraries implements the generation and analysis of the PAM signal.

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

fs = 100  # Sampling frequency
fm = 5    # Message signal frequency
Ts = 1/fs # Sampling interval
T = 0.005 # Pulse width
t = np.linspace(0, 1, 1000)  # Time axis
mt = np.cos(2 * np.pi * fm * t)  # Message signal

# Plotting the message signal
plt.figure(1)
plt.subplot(4, 1, 1)
plt.plot(t, mt)
plt.title("Message Signal")
plt.grid()

# Impulse train (sampling)
impulse_train = np.ones_like(t)
sampled_signal = mt * impulse_train
n = np.arange(0, 1 + Ts, Ts)  # Sampling instances
m_sampled = np.cos(2 * np.pi * fm * n)  # Sampled message signal

# Plotting the sampled signal
plt.subplot(4, 1, 2)
plt.stem(n, m_sampled, basefmt=" ")
plt.title("Sampled Signal")
plt.grid()

# Pulse shape function
def p_t(t):
    return np.where((t >= 0) & (t < T), 1, 0)

# PAM signal generation
m_pam = np.zeros_like(t)
for i in range(len(n)):
    m_pam += m_sampled[i] * p_t(t - n[i])
```

```
# Plotting the pulse shape function
plt.subplot(4, 1, 3)
plt.plot(t, p_t(t))
plt.title("Pulse Shape Function")
plt.xlim([0, 0.05])
plt.ylim([-0.5, 1.5])
plt.grid()

# Plotting the PAM signal
plt.subplot(4, 1, 4)
plt.plot(t, m_pam)
plt.title("PAM Signal")
plt.grid()

# FFT Analysis
N = len(t)  # FFT length
f_axis = np.fft.fftshift(np.fft.fftfreq(N, d=1/fs)) * 10
# Frequency axis

fft_pt = np.abs(np.fft.fftshift(np.fft.fft(p_t(t)) / N))
# FFT of pulse shape
fft_pam = np.abs(np.fft.fftshift(np.fft.fft(m_pam) / N))
# FFT of PAM signal

# Plotting FFT results
plt.figure(2)
plt.subplot(3, 1, 1)
plt.plot(f_axis, fft_pt)
plt.title("FFT of Pulse Shape Function")
plt.grid()

plt.subplot(3, 1, 2)
plt.plot(f_axis, fft_pam)
plt.title("FFT of PAM Signal")
plt.grid()

plt.show()
```

Results and Discussion

Message Signal

The message signal is a simple cosine wave with a frequency of 5 Hz. The time-domain representation of the message signal is shown below:

Sampled Signal

The message signal is sampled using an impulse train with a sampling frequency of 100 Hz. The sampled signal is displayed below:

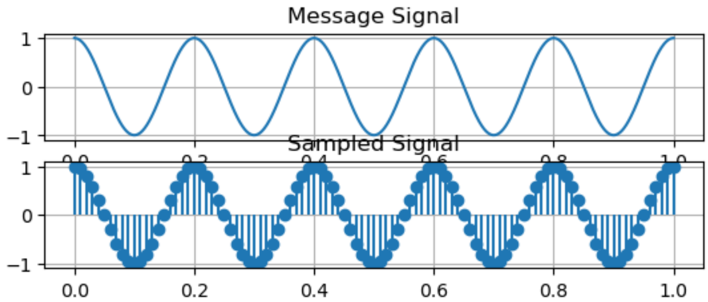

Figure 1: Sampled Signal

Pulse Shape Function

A rectangular pulse is used for the modulation process. The pulse width is 0.005 seconds. The pulse shape function is illustrated below:

PAM Signal

The PAM signal is generated by modulating the sampled message signal with the pulse shape function. The resulting PAM signal is shown below:

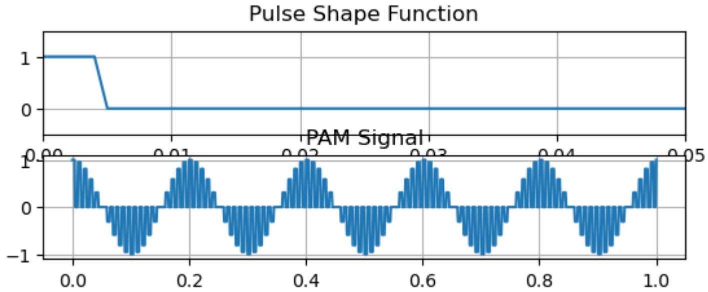

Figure 2: Pulse Shape Function

FFT Analysis

To analyze the frequency content of the signals, we perform FFT on both the pulse shape function and the PAM signal. The FFT plots are displayed below:

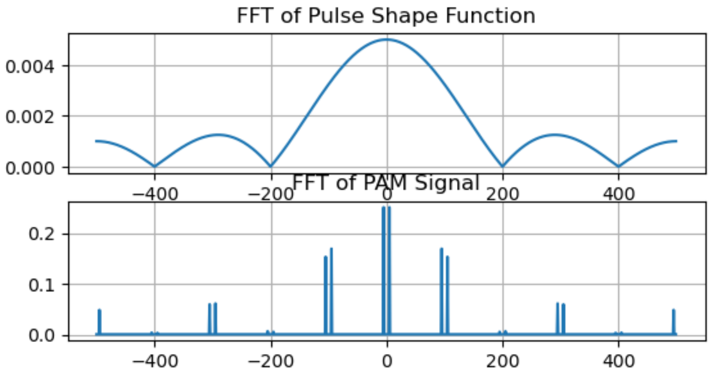

Figure 3: FFT of Pulse Shape Function

Conclusion

In this lab, we successfully generated a Pulse Amplitude Modulation (PAM) signal by sampling a message signal and applying a rectangular pulse shaping function. We also performed FFT analysis to examine the frequency components of the pulse shape and the PAM signal. This experiment provides insight into the time-domain and frequency-domain characteristics of PAM systems.