Fourier Decomposition and DSP Analysis

A Comprehensive Study Using DFT and DCT

Submitted to:
Dr. Pushpendra Singh
Associate Professor
School of Engineering , JNU

Submitted by :
Kartikay Dubey EE/034
Ayush Anand EE/031
Aditya Mishra EE/033
Prayagraj Singh EE/036

Introduction

This project investigates signal processing techniques, specifically focusing on the Fourier Decomposition Method (FDM). The FDM function, provided by Dr. Pushpendra Singh, was extended in this project to analyze both synthetic signals (such as sine waves) and real-world audio signals using the Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT).

The main objectives of this project are:

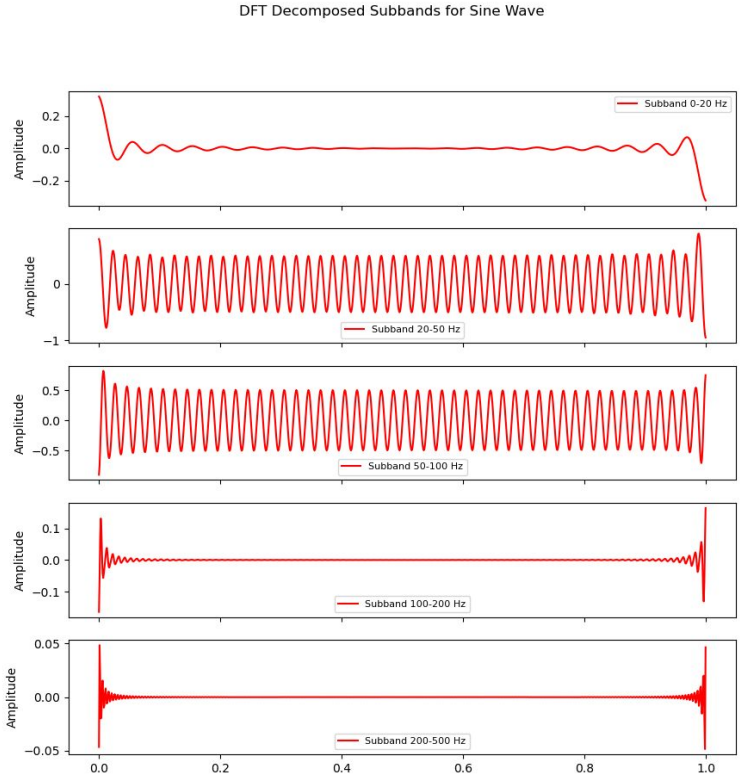
- To analyze the energy distribution of both synthetic sine wave signals and real-world audio signals across subbands using DFT and DCT.
- To compare the effectiveness of DFT and DCT in decomposing signals into frequency subbands.
- To demonstrate the application of FDM on both synthetic and real-world audio signals.

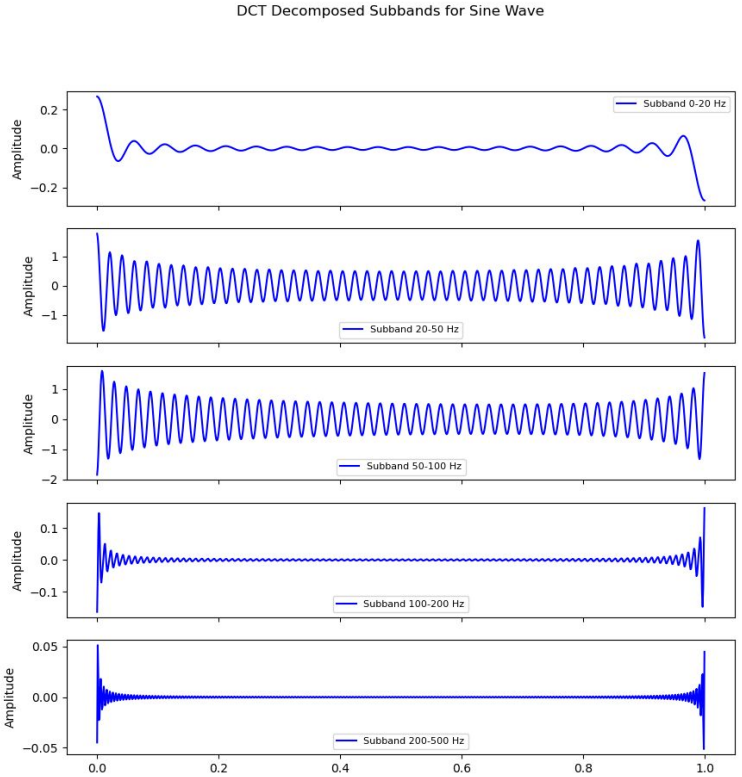
Input Section

This project uses two types of input signals: a synthetic 50 Hz sine wave and a real-world audio signal. The sine wave is generated with a frequency of 50 Hz, sampled at 1000 Hz for 1 second. The audio signal is a real-world recording processed similarly.

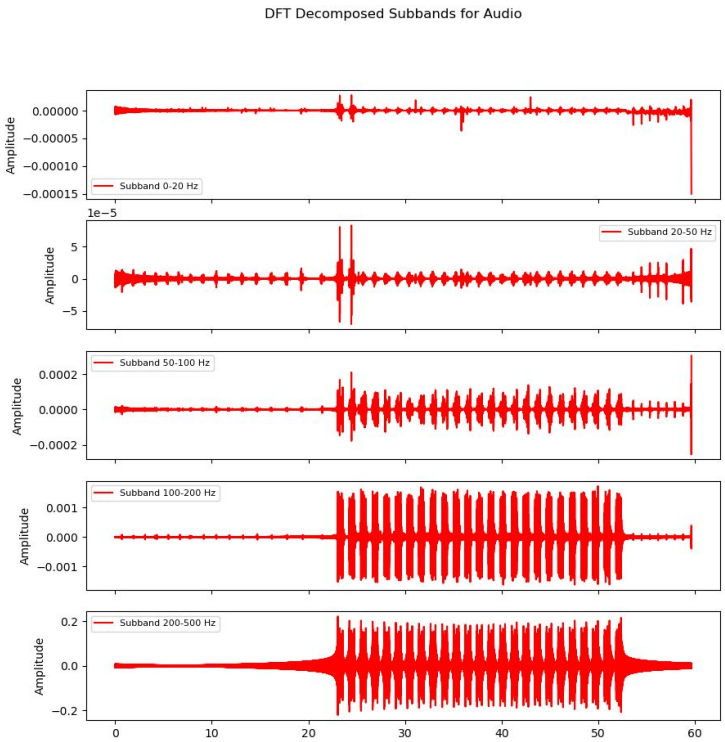
- **Sampling Frequency**: 1000 Hz for both signals.
- **Frequency Cutoffs**: fc=[0,20,50,100,200,500]fc = [0, 20, 50, 100, 200, 500]fc=[0,20,50,100,200,500] Hz for signal decomposition.
- **Methods**: The Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT) were applied using the fdm function, with options to sort cutoffs in ascending order and remove the mean of the signals

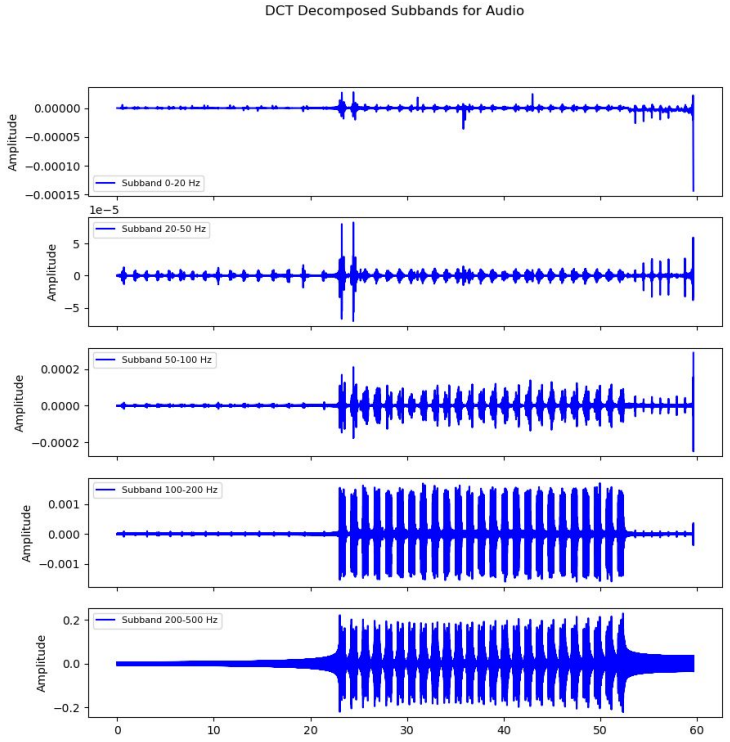
Output for SINE wave





OUTPUT for Audio





CONCLUSION

1. **Sine Wave (50 Hz)**:
   - Energy is concentrated in the **20-50 Hz** and **50-100 Hz** subbands.
   - Higher subbands show negligible energy, as expected for a pure sine wave.
   - **DCT** compacts energy smoothly, while **DFT** retains oscillatory components.
2. **Audio Signal**:
   - Energy is distributed across **all subbands**, indicating the presence of multiple frequency components.
3. **DCT vs DFT**:
   - **DCT**: Better energy compaction, smoother representation.
   - **DFT**: Highlights periodic components but spreads energy more.

Conclusion:

DCT is efficient for energy concentration (useful for compression), while DFT is better for detailed frequency analysis.

REFERENCES

- **Python Code of Fourier Decomposition Method (FDM)**
  Udawat, A. S., & Singh, P. (December 2023). *Fourier Decomposition Method (FDM)*. DOI: 10.13140/RG.2.2.21491.30240. Licensed under **CC BY-NC-SA 4.0**.
- **Python Libraries**: NumPy, Matplotlib, Librosa for implementation.

GITHUB LINK OF CODE :

https://github.com/aldol07/FDM-Implementatiom