

Zewail City of Science and Technology

CIE-442

CIE 442 Project Part 1

FFT Spectrum Analyzer

1.1 Objectives

- Understand the operation of Spectrum Analyzer.
- Understand the need of Discrete convolution.
- Understand the effect of Windowing, averaging and so forth on both the time domain and frequency domain signals.
- Use MATLAB as a simulation software.

1.2 Introduction

Fourier transform is one of the most important tools, if not the most important, in communications. It is used to transform the time domain signals to their frequency counterparts which helps in analyzing the spectrum of the information signals. Knowing the spectrum of the signal is crucial to be able to apply the correct digital signal processing algorithms without wrongly affecting the information signal and keep the info intact.

One of the devices used in real-life to visualize the signal's frequency contents is the Spectrum analyzer which is the main topic of this project. One of the signal types of interest is audio files. Audio files are analog in their nature; hence, they require an analog to digital converter to be able to process it digitally. In this project, the audio signal is given to you sampled or in other words, it is ready for signal processing in the digital domain (No ADC is required in this project). The spectrum analyzer, then, takes the sampled audio file and perform all the necessary measurements to visualize the different frequency components and the effect of windowing and averaging on such signal.

This project aims at understanding the need for spectrum analyzers and their use in real-life applications. Furthermore, it will help you understand the DFT process, windowing and the leakage concept. In addition, it will help in looking at different methods in visualizing your signal and compare different methods against each other. You will implement an N-point Radix 2 FFT by yourself, so this will give you an option to understand the FFT processing in a better manner. Moreover, the discrete convolution feature will be of an asset to understand how convolution works and can aid you in understanding the channel effects on signal transmission.

1.3 Project statement

This part of the project is divided into two main sections

- Discrete Convolution.
- Spectrum Analyzer.

It is required to implement a GUI in MATLAB to mimic the operation of real-life spectrum analyzer with the Discrete Convolution being an additional feature.

1.3.1 Layout

- Your GUI should start by giving two choices for the user to either perform Discrete Convolution or use Spectrum Analyzer.
- In the FFT spectrum analyzer, you should **implement your own code to perform Radix-2 Fast Fourier Transform (FFT) as explained in the lecture** and use it in your project. You should verify your code by making sure that it performs the correct FFT and can be compared to the built-in function in MATLAB.
- If the choice is Discrete Convolution, then a new GUI window will open and:
 - You Should give the user a drop-down list of your available functions to perform convolution with.
 - It is expected to have two drop-down lists to allow the user to choose the two functions that will be convolved together.
 - Additional features can be added to allow the user to choose different parameters like the signal amplitude, the signal width or period, the exponential power and so forth.
 - You should provide at least four plots on your GUI in this section, the main signal, the signal to be convolved with, the result of the convolution.
 - Hint: You must include at least three different functions in this section.
- If the choice is Spectrum Analyzer, then a new GUI window will open and:
 - The Layout should be as follows:
 - **Inputs:**
 1. An input file option should be available to allow the user to choose an audio file (any file of your choice).
 2. Built-in functions to try them as examples or for the purpose of demonstration (two functions will be enough).
 - Two plots to plot the time domain signal and the frequency domain signal.
 - A comparison mode tab.
 - Display options for the plots (linear and logarithmic, magnitude and phase, real and imaginary).
 - Calculation Tab.
 - Window choice and window length.

- N-FFT choice (Maximum is 64K, one of your choices should be the maximum and you can choose any other three values of the form 2^n).
- Markers.
- Option to choose the frequency bands (Spans).
- The frequency plots should be drawn versus your actual frequency not the frequency bins ($f_{analysis}(m) = \frac{mf_s}{N}$).
- The windowing option:
 - You should try Rectangular, Triangular, Hanning and Hamming windows.
 - You should give the user different choices for the window's length.
- The Calculation mode:
 - Calculate the power (within a certain span).
 - Perform RMS averaging.
 - Find the maximum point in your spectrum (Peak).
- N-FFTchoice:
 - You should give the user valid N-FFT choices or allow the user to enter it with a maximum value of 64K.
 - The N is related to RBW and f_s . You should view your RBW.
- Comparison mode:
 - You should have at least four plots in this mode (It is recommended that this mode opens up in a new a GUI). The four plots are two for the time domain comparisons and two for the frequency domain comparisons.
 - The idea of this mode is to compare the same signal under different windowing and show the results side by side for both the time domain and the frequency domain.
 - The effect of the window length and the N should be also available in the comparison mode. In other words, you should be able to compare the same window but with different length on the same signal and same wise for the N.

1.3.2 Features:

- Time and Frequency domain analysis.
- Discrete time convolution.
- Windowing effect.
- Comparison mode.
- Calculation mode.
- RMS averaging.
- Peak finding.
- Different display options.
- Markers.
- Frequency band choices.
- Different input options.

1.4 Requirements

- Implement the MATLAB code for all the above tasks and include all the MATLAB files in your online submission.
- Write a report that explains the operation theory and includes your code and documentation within your report.

1.5 Important notes

- The code should be readable and all the variable names are meaningful.
- The code should be commented to explain the functionality of your code.
- The report should be formatted in an organized way (i.e: it should include table of contents, introduction, theory, results and discussions, conclusion, code section and so forth).
- The pages should be numbered.
- Don't forget to include your references.
- The quality of your report will be assessed.
- Documentation should be clear and any used variables within the theory should reflect on your code.