REPORT 2

Digital Signal Processing

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Lab 2

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Topic: "Windowing"

Variant 1

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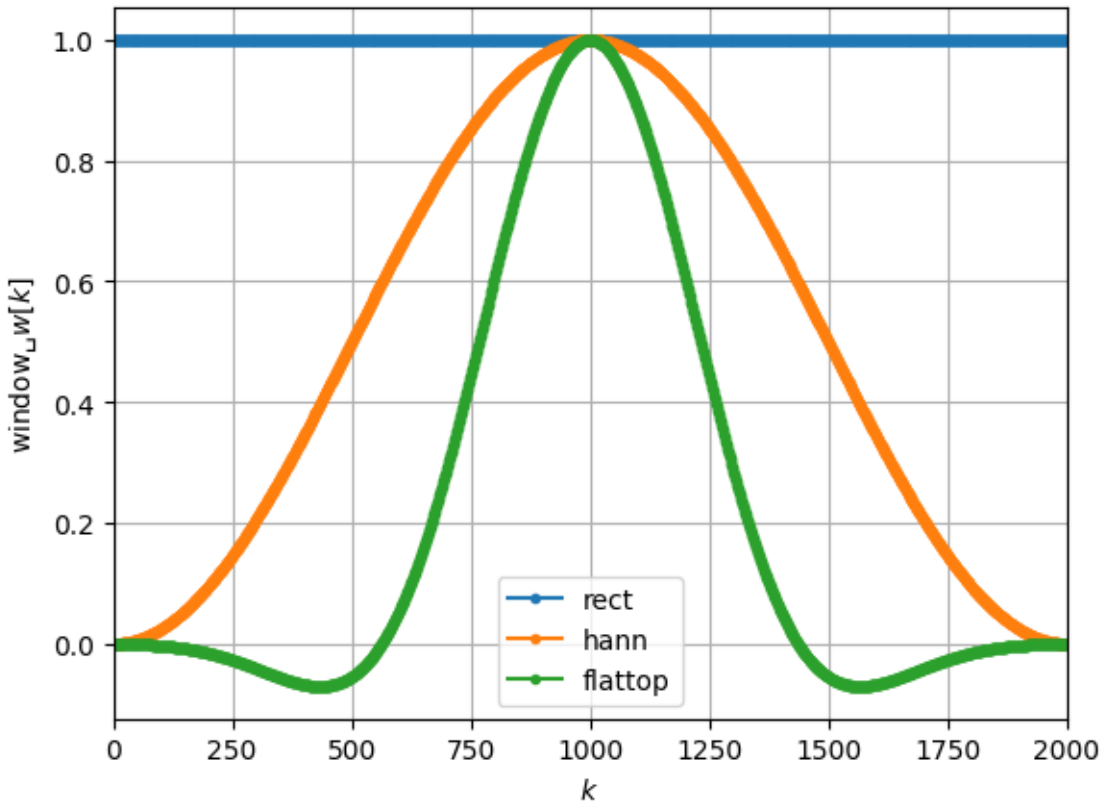
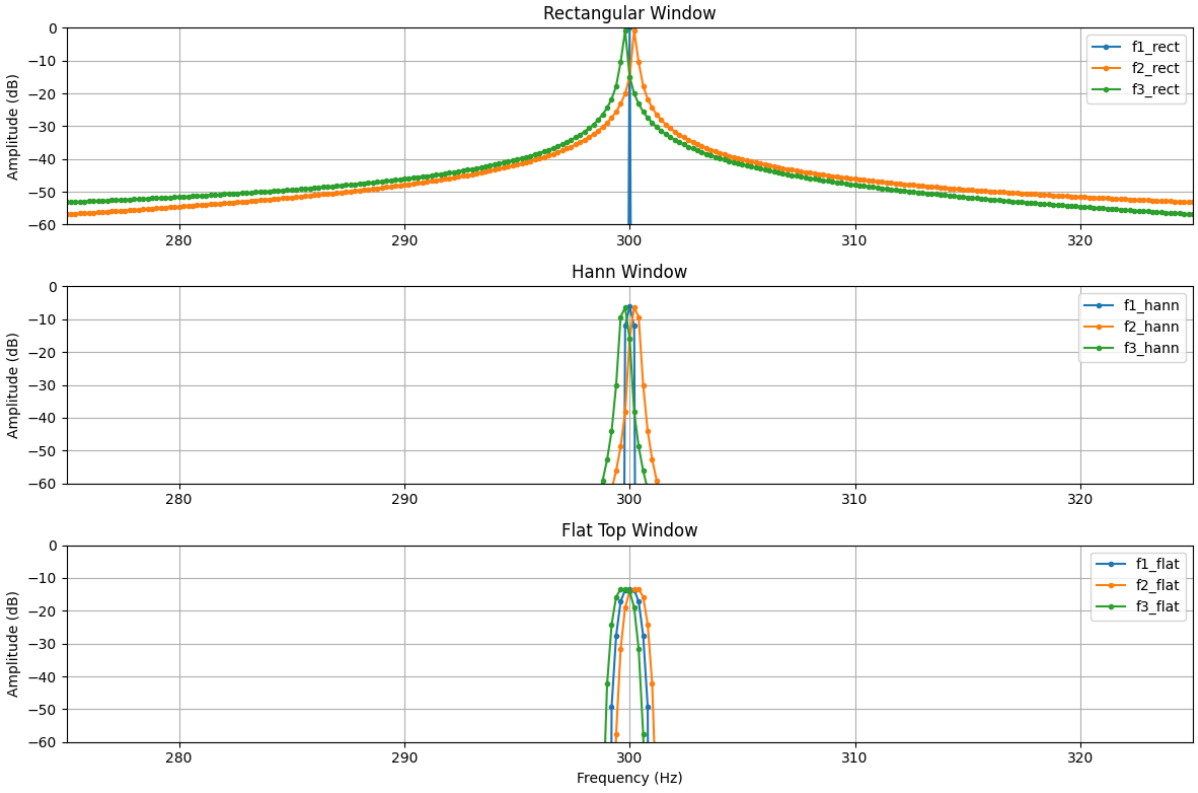
1. Generate three sine signals of given f1, f2, and f3 and amplitude |x[k]|max for the sampling frequency fs in the range of 0 ≤ k < N. Plot: 1 1. the "normalized" level of the DFT spectra. 2. the window DTFT spectra normalized to their mainlobe maximum. The intervals for f, Ω, and amplitudes should be chosen by yourself for the best interpretation purposes. Interpret the results of the figures obtained regarding the best and worst case for the different windows. Why do the results for the signals with frequencies f1 and f2 differ?

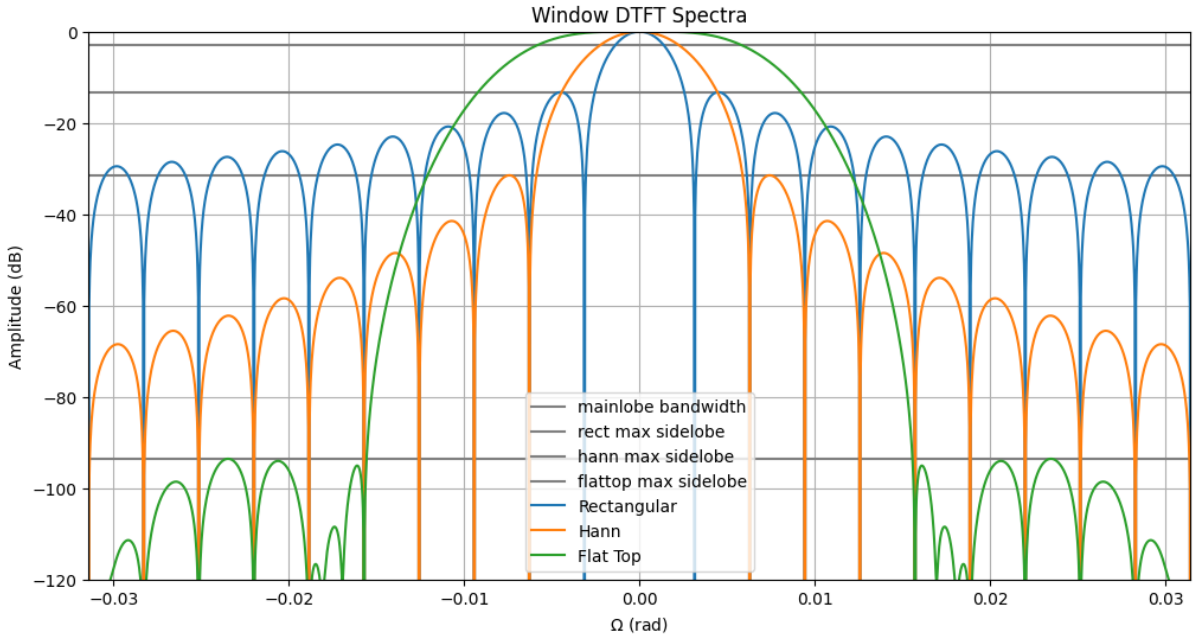
2. Input data:
No f1 f2 f3 |x[k]|max fs N
1 300 300.25 299.75 2 400 2000
3. Commands used (or GUI):

a) The source code has been put into the repository under [unibb/Digital signal processing/Task2 at main · mariuszjagosz/unibb]

4. Outcomes:




Rectangular Window
Amplitude (dB)
f1_rect
f2_rect
f3_rect
Hann Window
f1_hann
f2_hann
f3_hann
Flat Top Window
f1_flat
f2_flat
f3_flat
Frequency (Hz)


Window DTFT Spectra
Amplitude (dB)
mainlobe bandwidth
rect max sidelobe
hann max sidelobe
flattop max sidelobe
Rectangular
Hann
Flat Top
Ω (rad)

5. Conclusions:

Effect of Windowing:

- **Rectangular Window**: Offers the narrowest mainlobe, but the sidelobes are high in amplitude. This makes it less effective at distinguishing closely spaced frequencies due to spectral leakage.
- **Hann Window**: Reduces sidelobe amplitudes significantly, resulting in better frequency resolution for closely spaced signals. However, the mainlobe is wider compared to the rectangular window, which may cause some blurring.
- **Flat Top Window**: Exhibits the lowest sidelobe levels, providing excellent suppression of spectral leakage. However, it has the widest mainlobe, which limits frequency resolution.

Comparison of Signals:

- Signals with closely spaced frequencies (f1 = 300 Hz, f2 = 300.25 Hz) are difficult to resolve with the rectangular window due to high sidelobes. The Hann and Flat Top windows perform better, with the Flat Top window showing the clearest separation.

Normalized DFT Levels:

- The DFT spectra normalized to sine amplitudes reveal that the Rectangular Window exaggerates leakage into nearby frequencies, whereas the Hann and Flat Top Windows provide a smoother, more localized response around the main frequency components.

Best and Worst Case Scenarios:

- The best case for frequency resolution occurs with the Hann or Flat Top windows for signals f1 and f2, where their frequency spacing is preserved with minimal leakage.
- The worst case occurs with the rectangular window, where high sidelobe amplitudes obscure the ability to distinguish closely spaced frequencies.

Impact of Frequency Differences:

- The slight difference between f1 and f2 is emphasized more clearly with low-sidelobe windows (Hann and Flat Top). This difference is harder to discern with the rectangular window due to spectral leakage overpowering the subtle variations.