CAMBRIDGE UNIVERSITY ENGINEERING TRIPOS PART IB

IB INTEGRATED COURSEWORK: EXTENDED EXERCISE REPORT

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Date submitted for marking: ..... 2/12/20 ..... Lab Group: 124

Title: ..... Effect of windowing on removing artifacts in DFTs .....

Main topic area(s): *(delete as appropriate)* ~~Vibration / Soils / Structures /~~ Signals

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Marker: ..... Date: .....

Please highlight one mark in each row:

Technical content mark:	8	7	6	5	4	3	2	1	0
Report quality mark:	8	7	6	5	4	3	2	1	0

Marker's Comments:

Effect of windowing on removing artifacts in DFTs
— A4 SIGNAL PROCESSING —

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November 25, 12020 — Downing College — Lab Group: 124

1 Introduction

DFTs of signals can experience artifacting via spectral leakage and scalloping due to sampling imperfection:

- noise
- frequencies not appearing for an integer number of cycles

Windows aim to reduce this effect. There is a resolution - range trade-off between different window functions.

2 Aims

- Understand the purpose of windowing
- Research different types of windows
- Comment on how signal properties affect choice of window

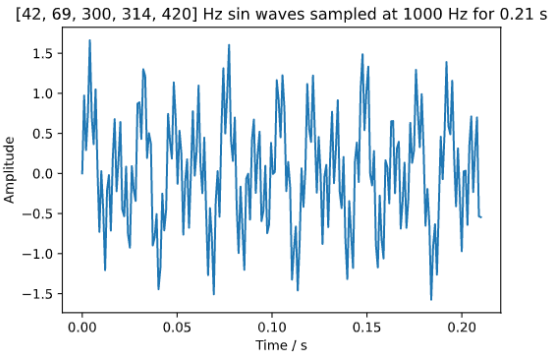
3 Method

- To investigate the effect of windowing, we used a sum of 5 sine waves with different frequencies and amplitudes as shown in Table 1. The frequencies were chosen to see how windowing effects the range and resolution picked up by the DFT.
- The signal was produced for 0.21 s so that the frequencies don't appear for an integer number of cycles. A very short time frame was used, because the advantages of windowing decrease as the time increases.
- We applied the most suitable window to an earthquake simulation
- We used Python and the *numpy* library to simulate the signal, apply a window, and perform the DFT.

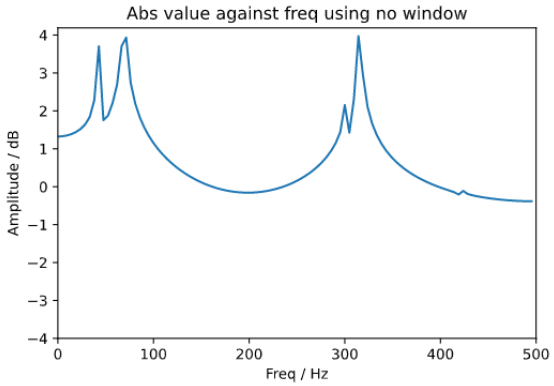
f / Hz	Amplitude
42	0.42
69	0.69
300	0.05
314	0.57
420	0.001

Table 1: Table showing the range of frequencies and amplitudes of each in the signal.

4 Results

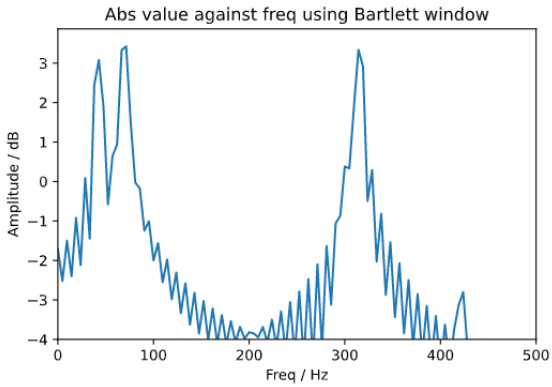


(a) Signal in the time domain for 0.21 s

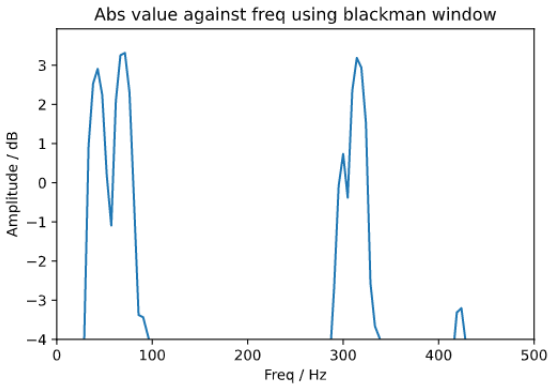


(b) DFT of signal without a window produces a lot of leakage

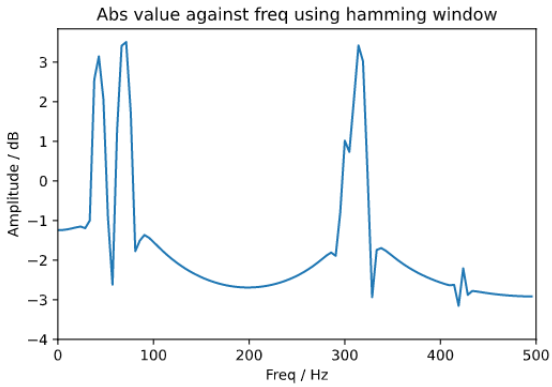
Figure 1: Signal and DFT



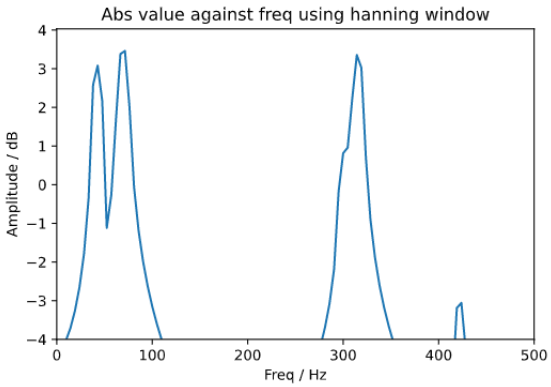
(a) DFT with Bartlett Window



(b) DFT with Blackman Window



(c) DFT with Hamming Window

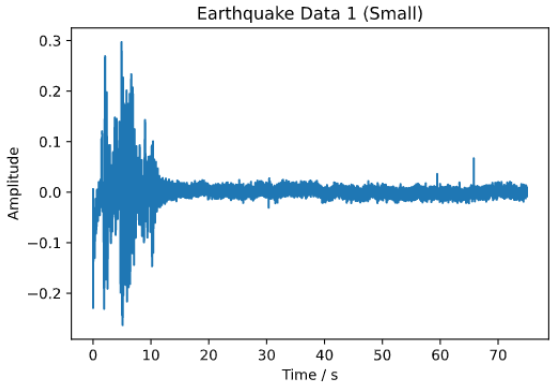


(d) DFT with Hanning Window

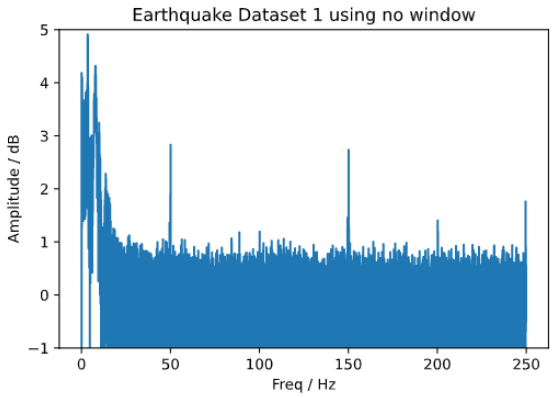
Figure 2: DFT with different window functions

Window	Attenuated Frequencies (Hz)					Range vs Resolution
	42	69	300	314	420	
None					x	Max Resolution
Bartlett			x			High Range
Blackman						High Resolution
Hamming				∼		Good balance
Hanning			x			More Range

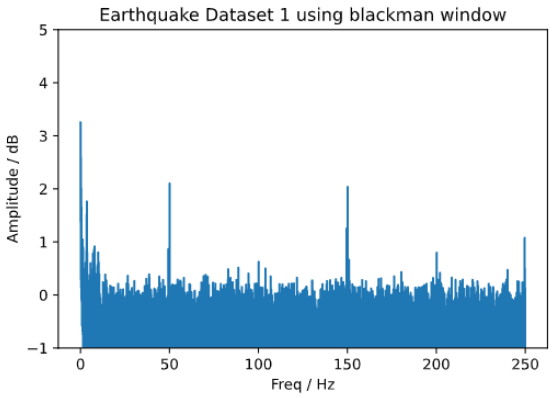
Table 2: Summary table of results



(a) Earthquake signal in time domain



(b) DFT with no window



(c) DFT with blackman window

Figure 3: Analysis of Earthquake Dataset 1 (small)

5 Conclusion

- Windowing helps identify peaks by reducing leakage from noise, but at the expense of resolution due to a broader peak
- Blackman window identified the peaks most clearly
- Bartlett window was the worst
- When applied to real earthquake data windowing has little effect. This is because the sampling time was very long hence giving enough time for distinct frequencies to appear without the need for windowing.

6 Further Research

- Quantify range - resolution trade-off (e.g. Amplitude x Bandwidth)
- Investigate window overlapping
- Investigate zero-padding to remove spectral leakage