Questionnaire 3 - Short Time Fourier Transform

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Exercise 1

Draw (sketch) the corresponding waveforms of the following spectrograms.

For each spectrogram, we will plot computationally the signal $x(t)$ to have originated the spectrogram, and then plot a spectrogram for simple checking. We observe that the duration is the same for all signals: 5s. Furthermore, sampling rate is also the same and equal to $2 \times 2000 = 4000$ Hz. All code created for the solution of this exercise is appended to the end of the document.

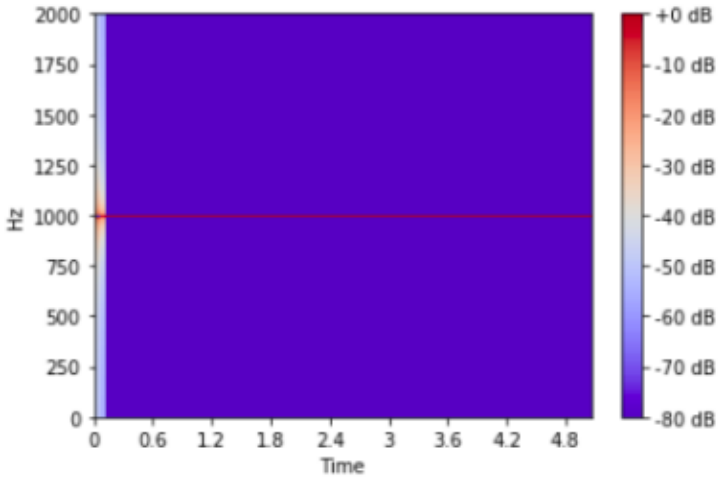

Figure 1: Provided spectrogram for exercise 1a.

(a)

$$x(t) = \sin(2\pi 1000t)$$

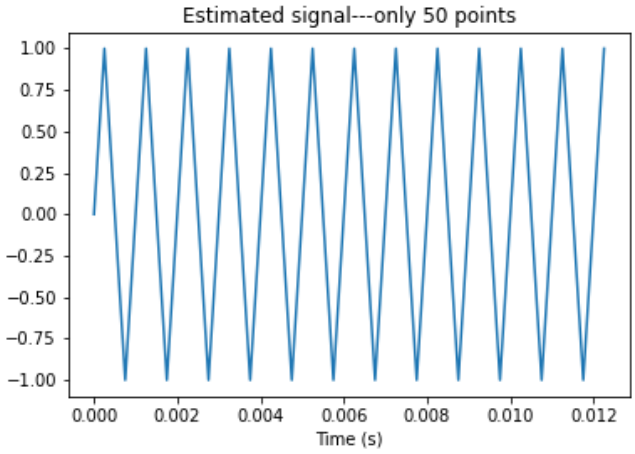

Figure 2: Corresponding signal for exercise 1a.

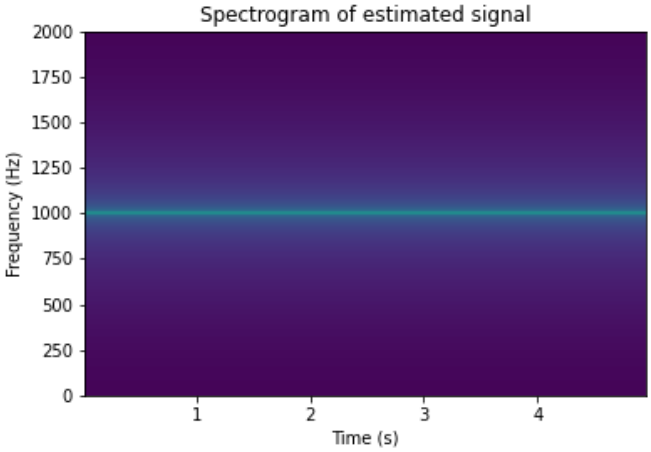

Figure 3: Plotted spectrogram for exercise 1a.

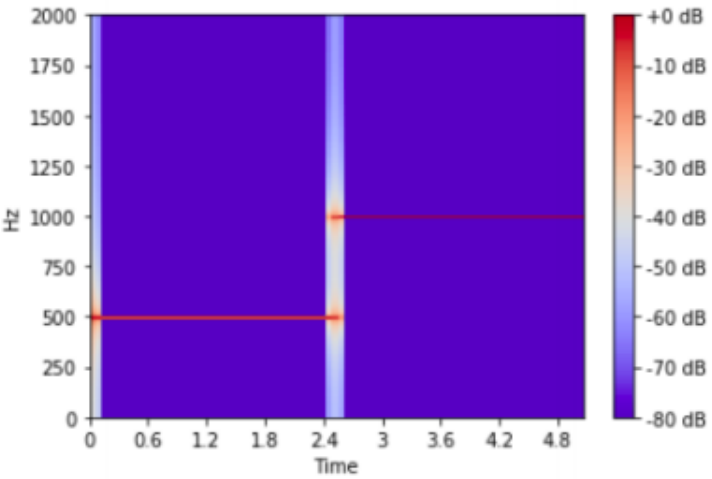

Figure 4: Provided spectrogram for exercise 1b.

(b)

$$x(t) = \begin{cases} \sin(2\pi 500t), & t \leq 2,4 \\ \sin(2\pi 1000t), & t > 2,5 \end{cases}$$

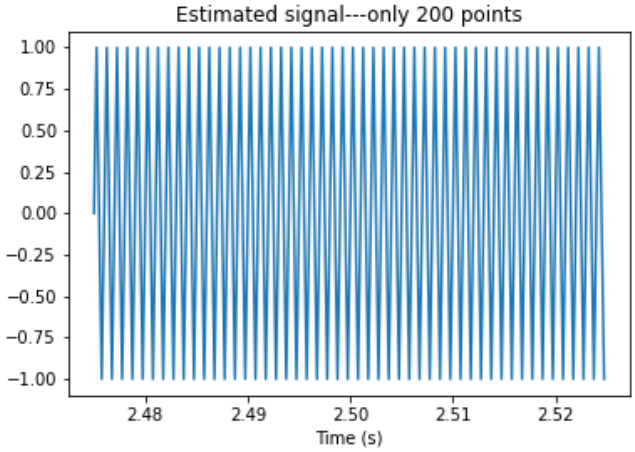

Figure 5: Corresponding signal for exercise 1b.

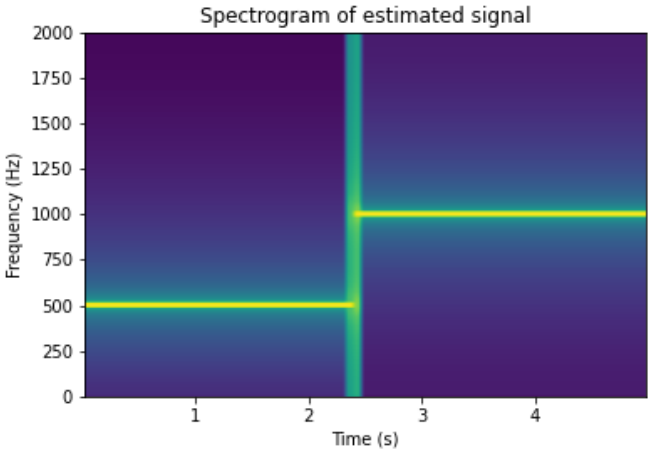

Figure 6: Plotted spectrogram for exercise 1b.

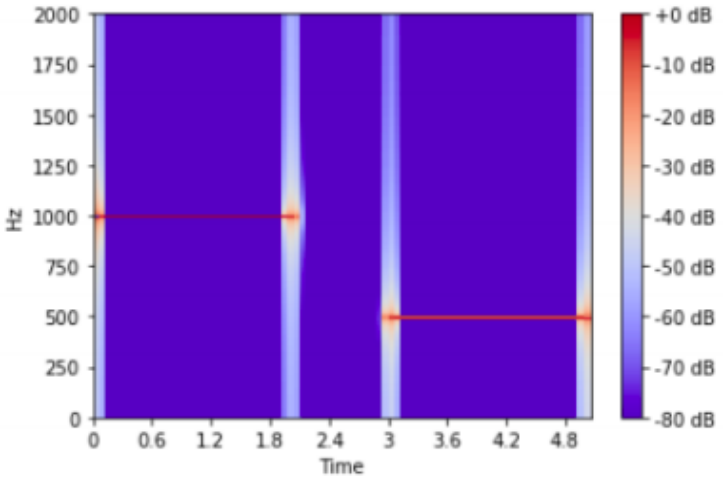

Figure 7: Provided spectrogram for exercise 1c.

(c)

$$x(t) = \begin{cases} \sin(2\pi 500t), & t \leq 2 \\ 0, & 2 < t < 3 \\ \sin(2\pi 1000t), & t \geq 3 \end{cases}$$

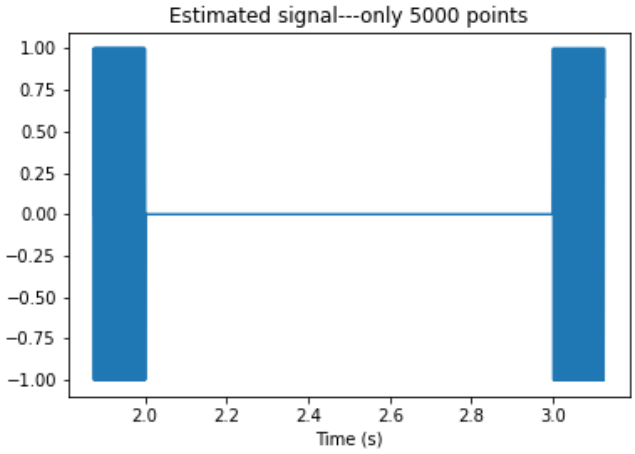

Figure 8: Corresponding signal for exercise 1c.

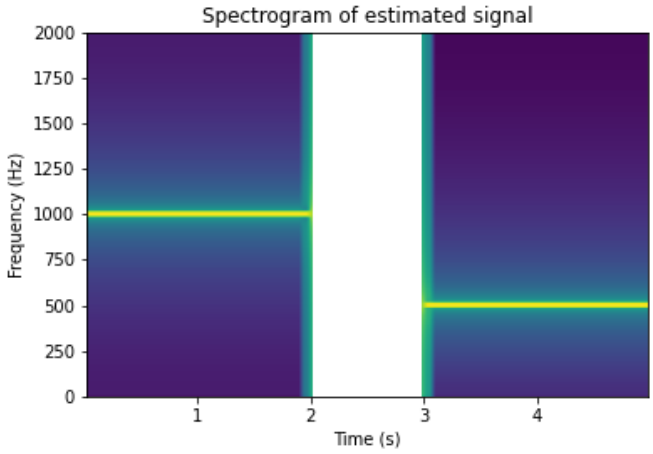

Figure 9: Plotted spectrogram for exercise 1c.

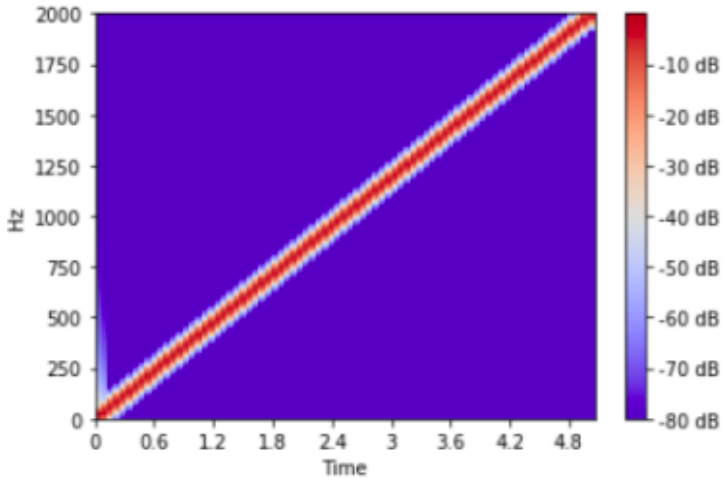

Figure 10: Provided spectrogram for exercise 1d.

(d)

$$\sin\left(2\pi\left(\frac{400t}{2}\right)t\right)$$

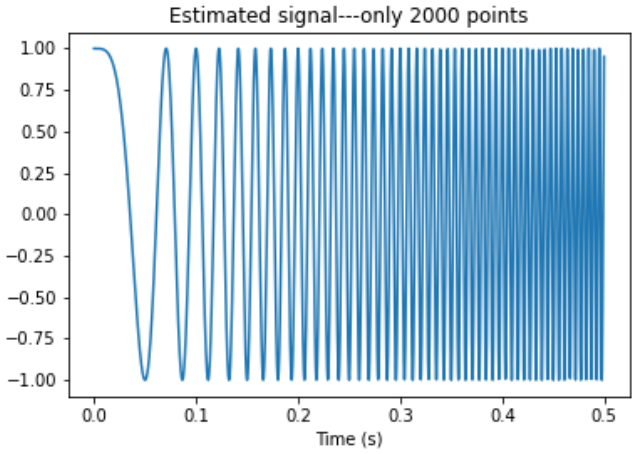

Figure 11: Corresponding signal for exercise 1d.

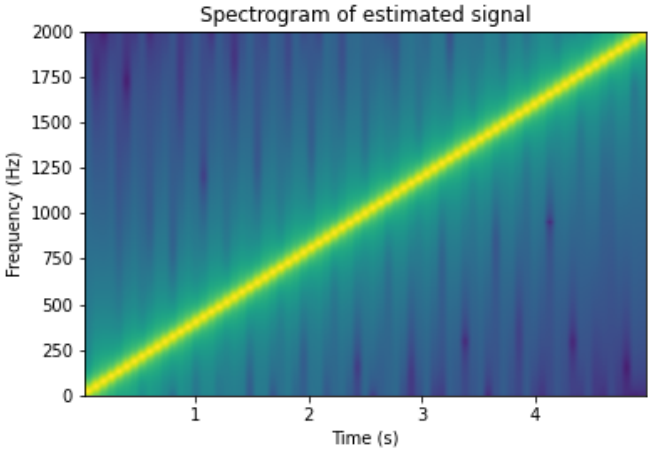

Figure 12: Plotted spectrogram for exercise 1d.

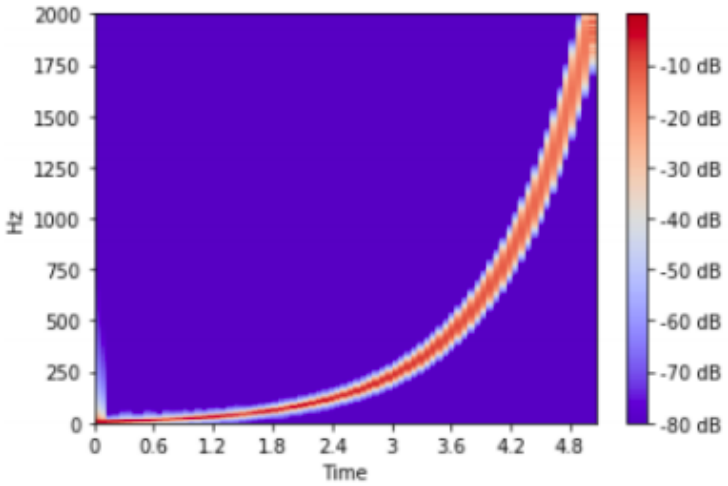

Figure 13: Provided spectrogram for exercise 1e.

(e) Exponential chirp with initial frequency at $t = 0$ s of approximately 1 Hz and frequency at $t = 5$ s of approximately 2000 Hz.

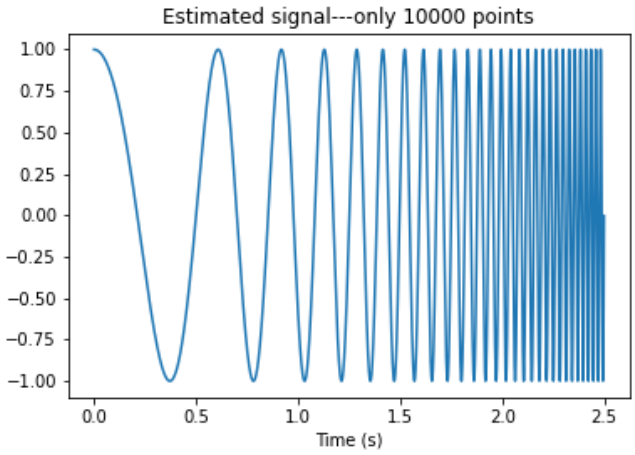

Figure 14: Corresponding signal for exercise 1e.

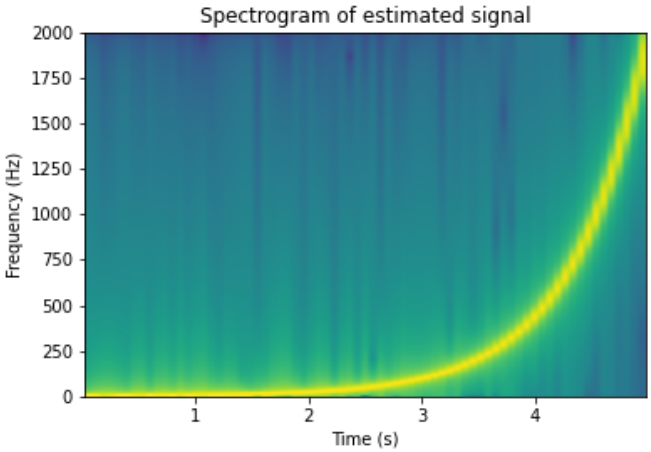

Figure 15: Plotted spectrogram for exercise 1e.

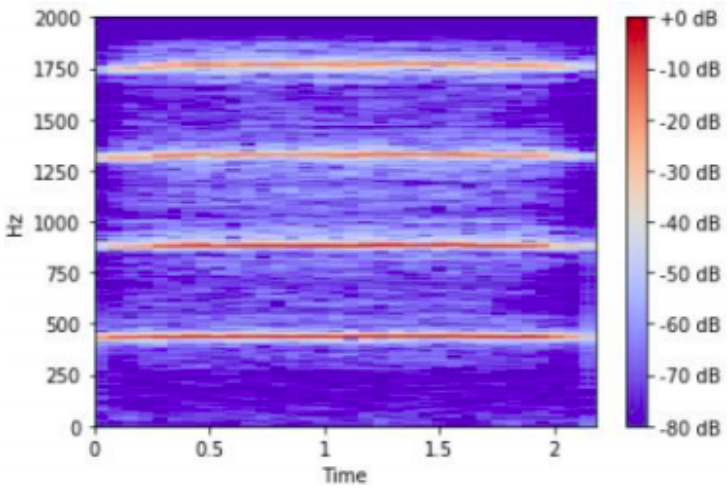

Figure 16: Provided spectrogram for exercise 1f.

(f)

$$x(t) = \sum_{k=1}^{4} \sin(2\pi k f_0 t)$$

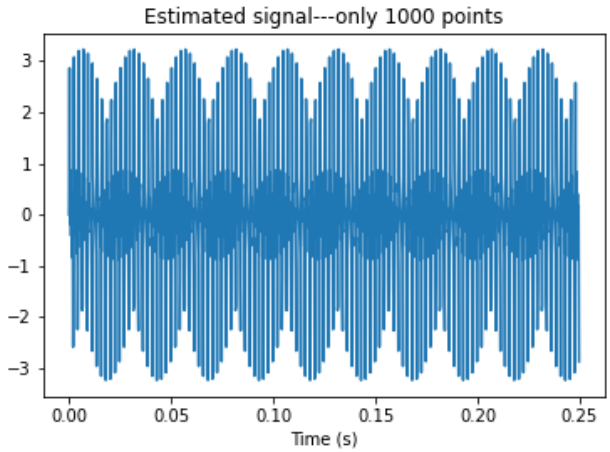

Figure 17: Corresponding signal for exercise 1f.

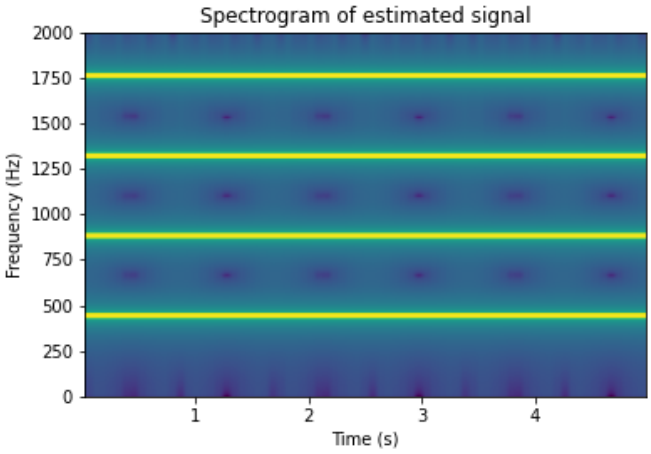

Figure 18: Plotted spectrogram for exercise 1f.

Exercise 2

- The following figure is the spectrogram of a speech signal. What is the sampling rate of this signal?

The sampling rate corresponds to 2 times the Nyquist frequency. That is, the sampling rate of this signal is approximately $2 \times 4000 =$ 8000 Hz.

Exercise 3

The following figure is a zoom-in of the above spectrogram. Calculate the frequency resolution and the window size (in samples)?

The frequency resolution is 10 Hz. With a sample rate of 8000 Hz, we need a window of size 800 samples to get that resolution.

Exercise 4

Estimate the temporal resolution and calculate the hop size (in samples).

The temporal resolution is of 0,05 s. With a sample rate of 8000 Hz, the hop size that corresponds to 0,05 s is of 400 samples.