Date: 25.04.2022 8:15 - 12:00
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EDISP Lab 3
Short-Time Fourier Transform (STFT)

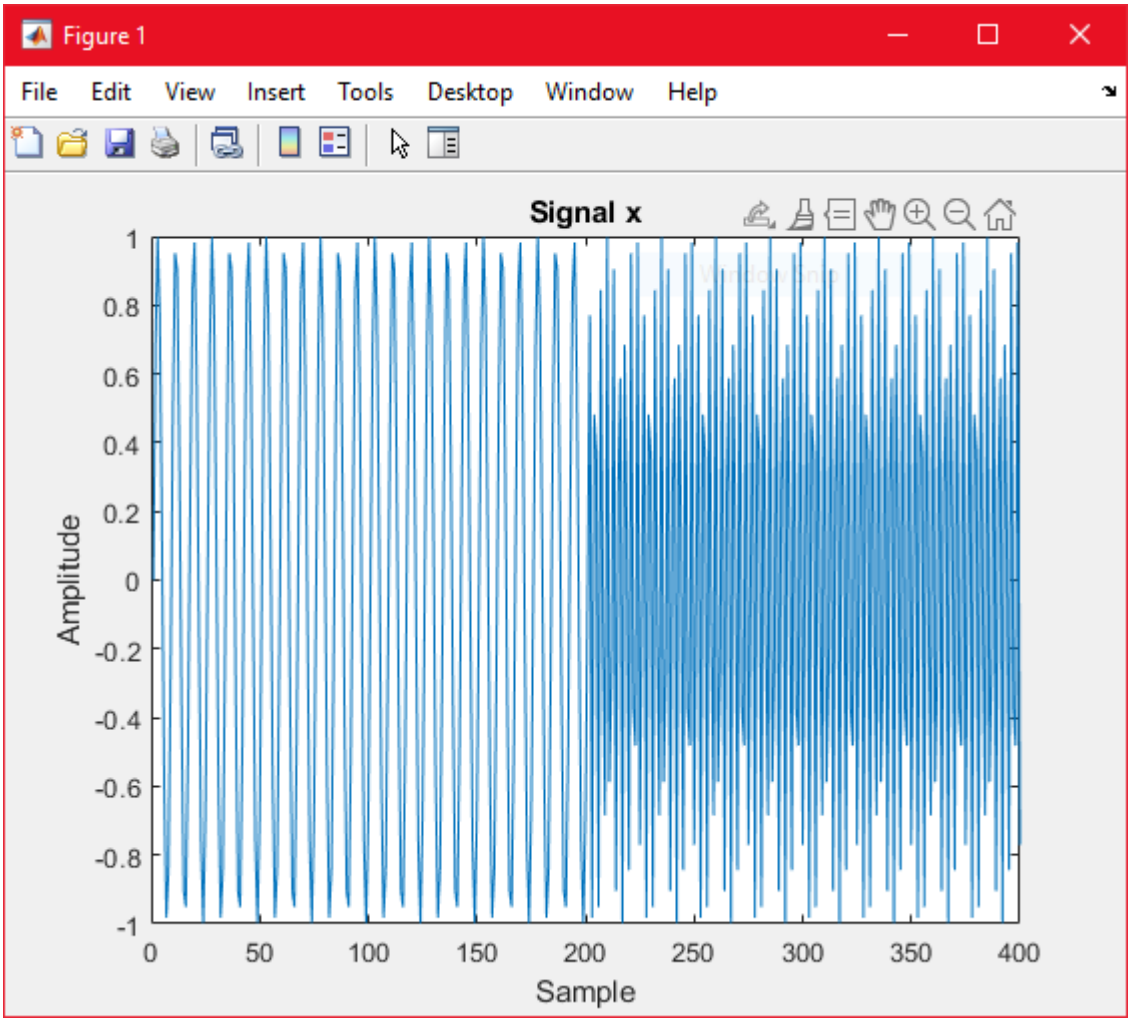
Task 1 & 2

Amplitude spectrum and spectrogram analysis of a MATLAB signal.

The following signal will be analyzed:

```
x1 = sin(0.24 * pi * [0:199]);
x2 = sin(0.72 * pi * [200:399]);
x = [x1 x2];
```

Its plot:



Better quality on the next page.

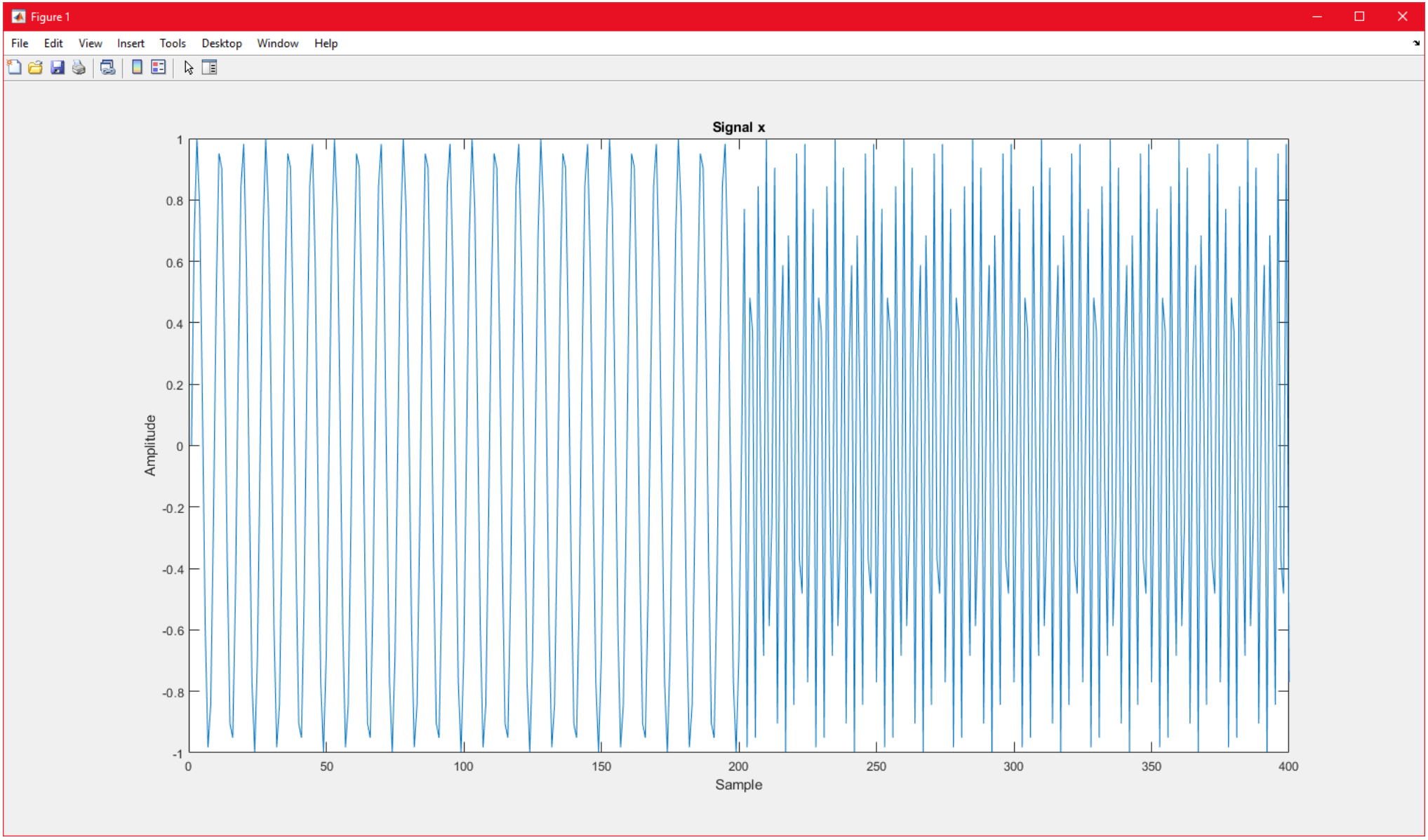


Figure 1
File Edit View Insert Tools Desktop Window Help
Signal x
Amplitude
Sample
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
50
100
150
200
250
300
350
400

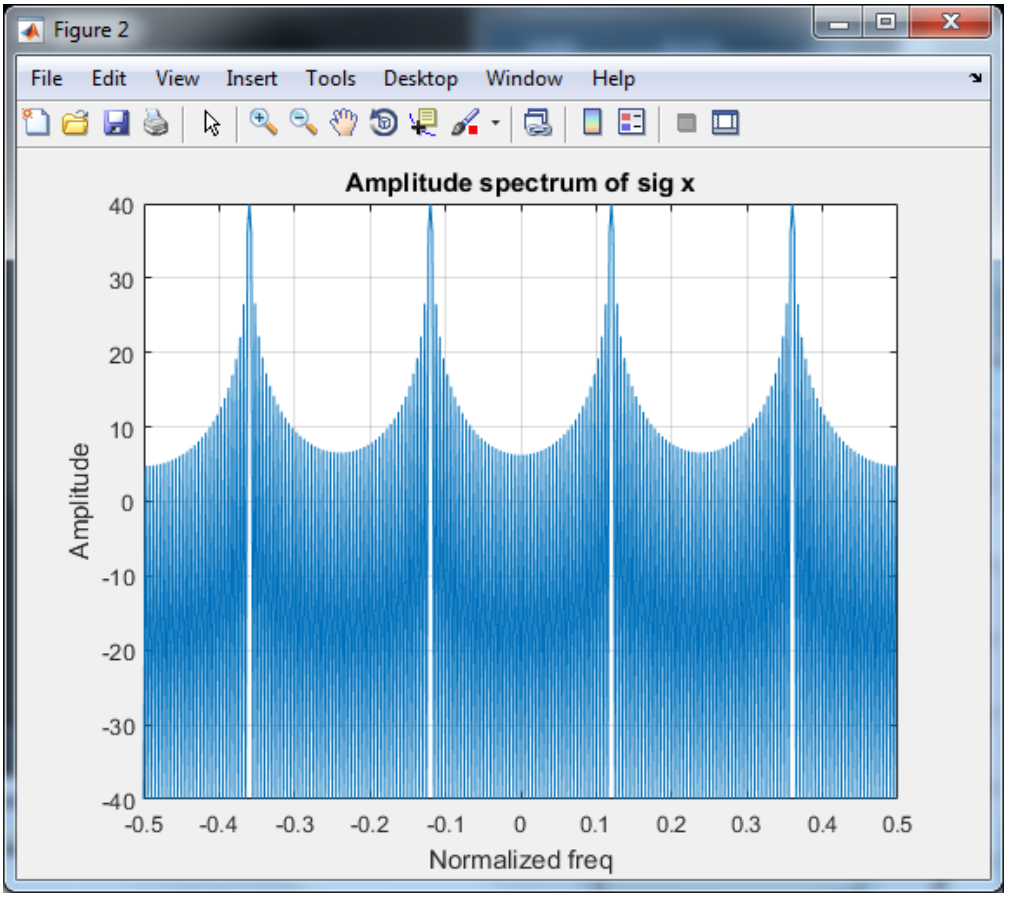


Figure 2
File Edit View Insert Tools Desktop Window Help
Amplitude spectrum of sig x
Amplitude
Normalized freq
40
30
20
10
0
-10
-20
-30
-40
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

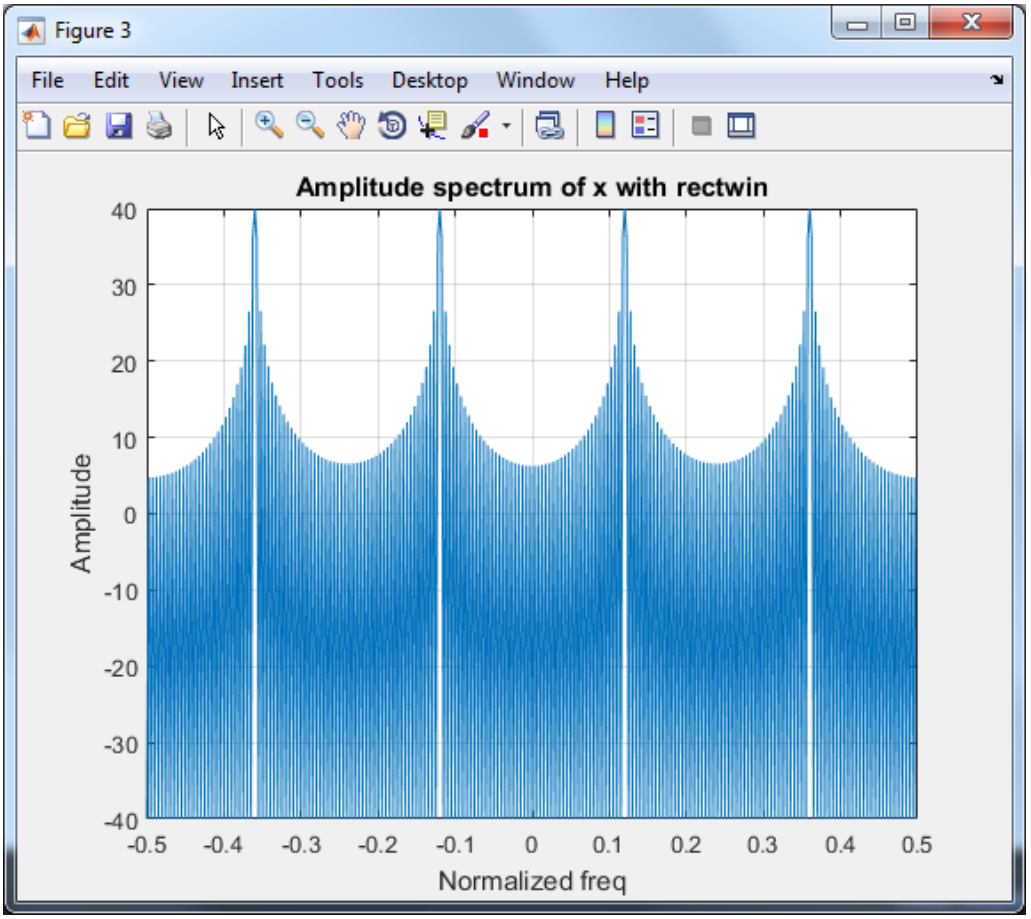


Figure 3
File Edit View Insert Tools Desktop Window Help
Amplitude spectrum of x with rectwin
Amplitude
Normalized freq
40
30
20
10
0
-10
-20
-30
-40
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5

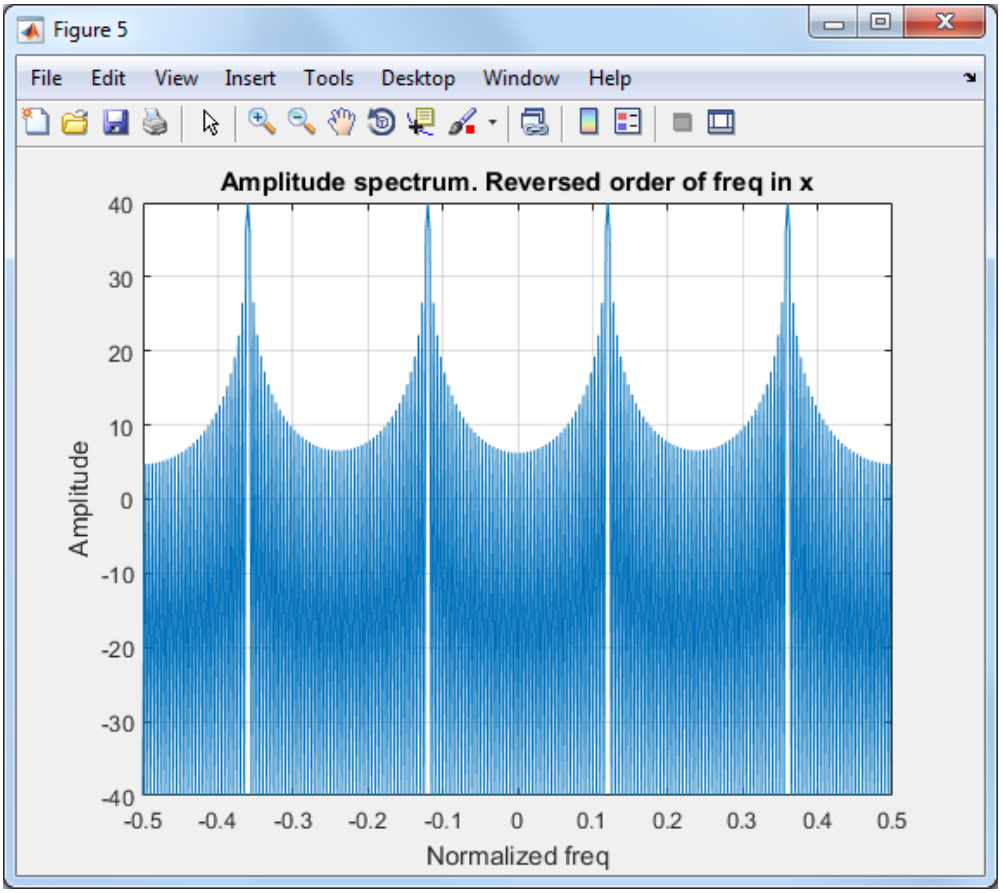


Figure 5
File Edit View Insert Tools Desktop Window Help
Amplitude spectrum. Reversed order of freq in x
Amplitude
40
30
20
10
0
-10
-20
-30
-40
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
Normalized freq

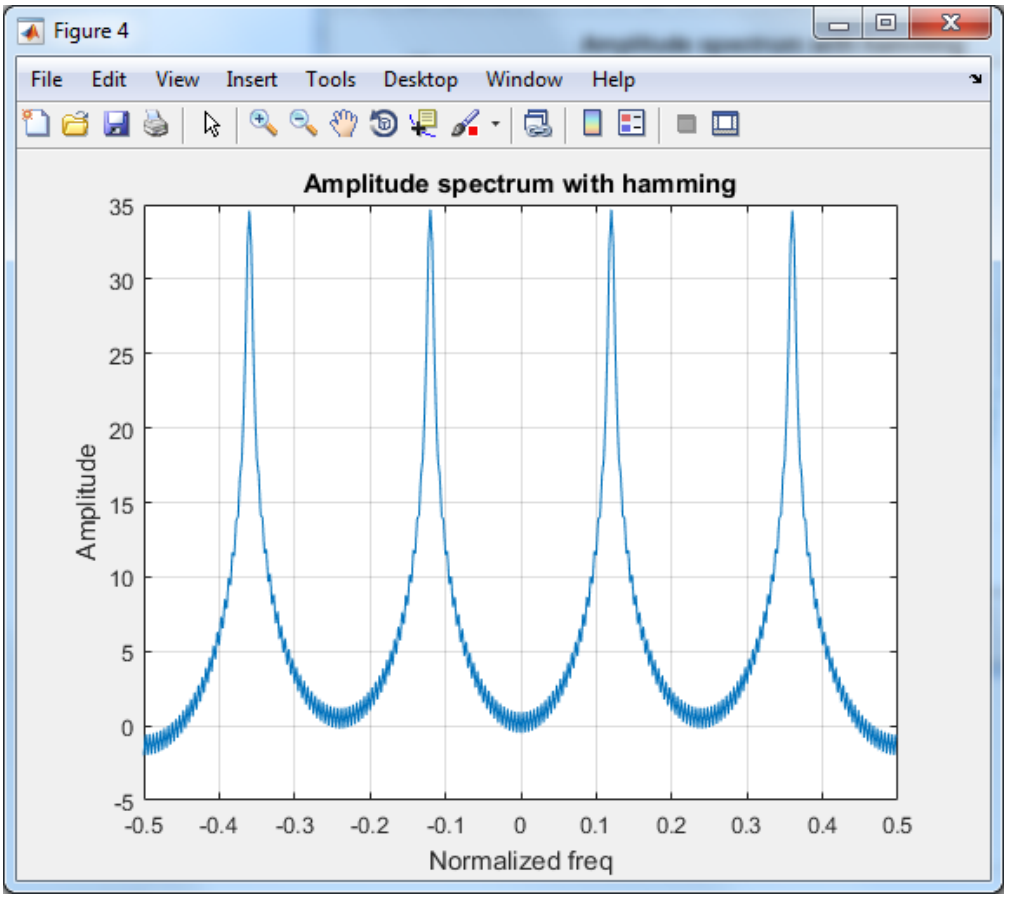


Figure 4
File Edit View Insert Tools Desktop Window Help
Amplitude spectrum with hamming
Amplitude
35
30
25
20
15
10
5
0
-5
-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
Normalized freq

What is the difference between your plots: without window, with rectangular or hamming window?

Rectangular window and no window plots are the same (because rectangular window is applied “by default”). Using the hamming window, the frequency spectrum is easier to read and is more clear. There are no ‘sudden jumps’ every two samples, but also the amplitudes are more distinct i.e. the high/low amplitudes are more easily noticeable, so the frequency spikes are more noticeable.

Can you tell anything about the properties of signal changing vs. time from this spectrum?

No, we can’t tell anything. If we look at the figures provided above we can notice that the spectrum for reversed order of frequencies is the same as for non-reversed. The plot only shows what frequencies are present and ‘how strong’ they are in the signal, but not the order of them. To see the order, STFT is more appropriate for this.

Describe the shape of the spectrum at the transition between segments.

Looking back at the provided figure showing the spectrogram, we can see how it looks.

As we get near 200th sample, we see the bars at normalized frequency of 0.24 “fade” and then appear at a higher normalized freq. of 0.72 instead (because 2nd half of signal x is a higher frequency sine)

Describe the differences between plots with different window lengths.

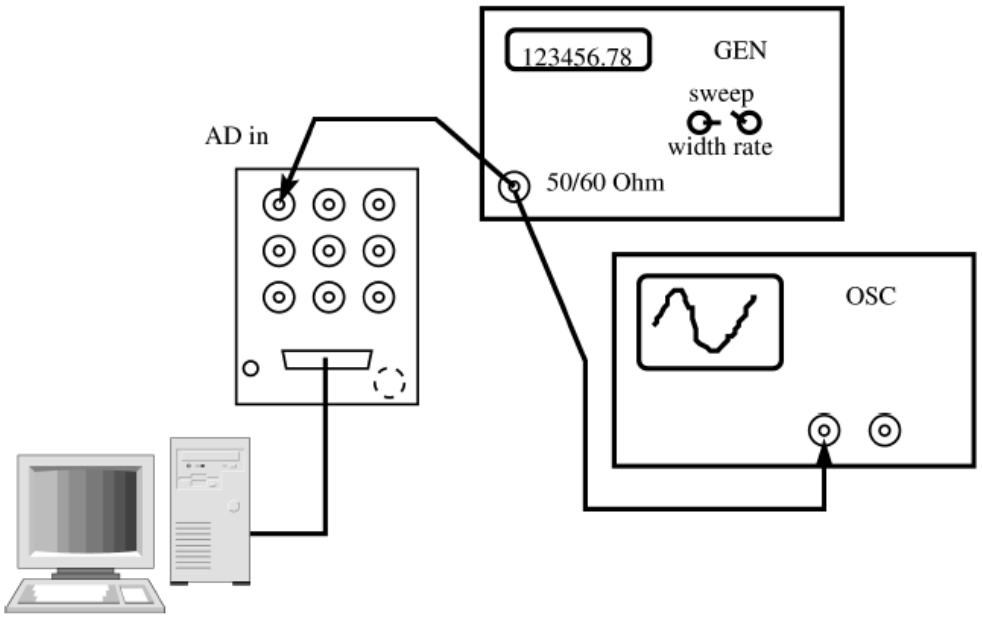
To say shortly - lower window width means better time (sample) resolution, but worse frequency resolution.

It can be described that the transition between 0.24 and 0.72 normalized freq. is narrower (takes less samples to show, better sample/time resolution) for a smaller window, but instead the “bars” for 0.24 and 0.72 normalized frequencies are wider (smaller freq. resolution).

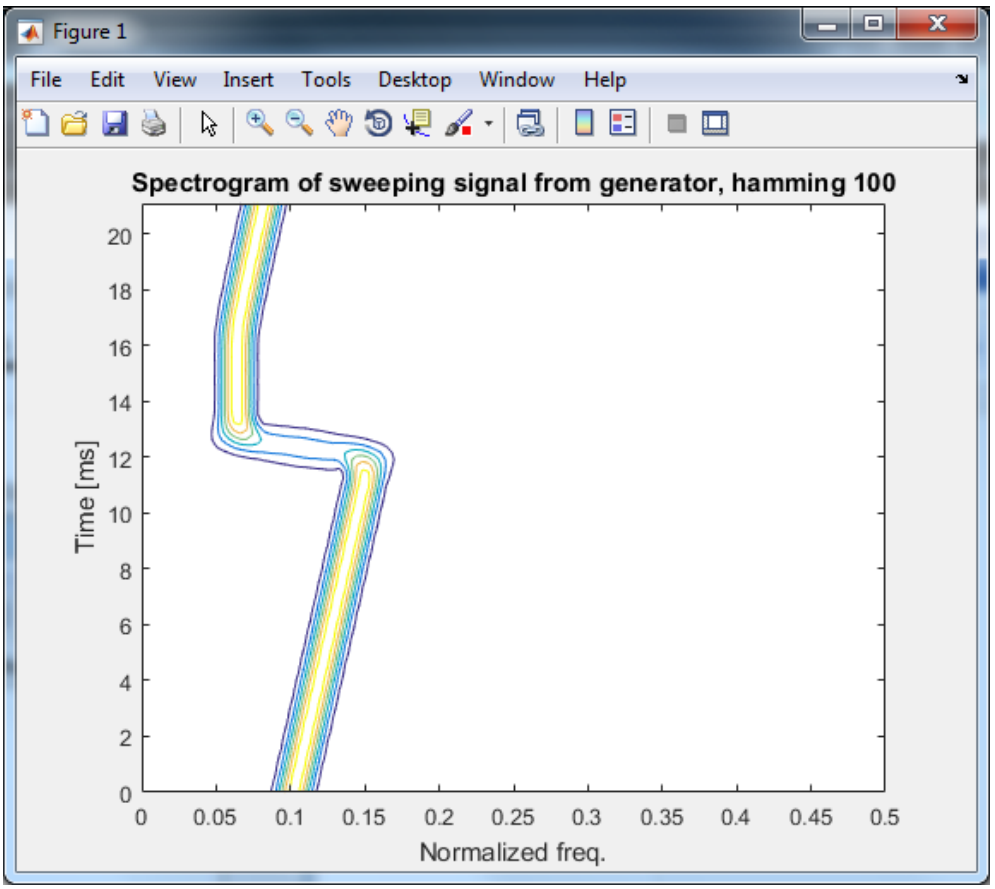
Task 3

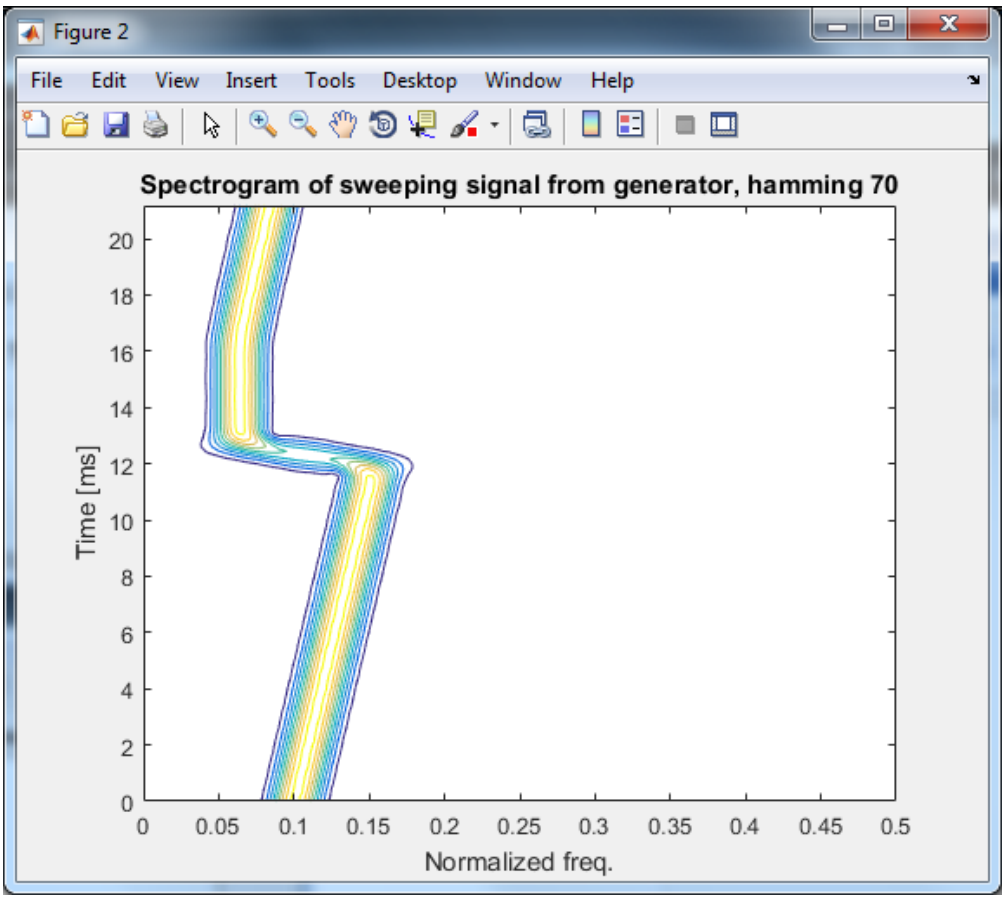
Linear Frequency Modulation signal spectrogram analysis

Connection setup:



This is the obtained spectrogram plot after proper configuration of the axis:





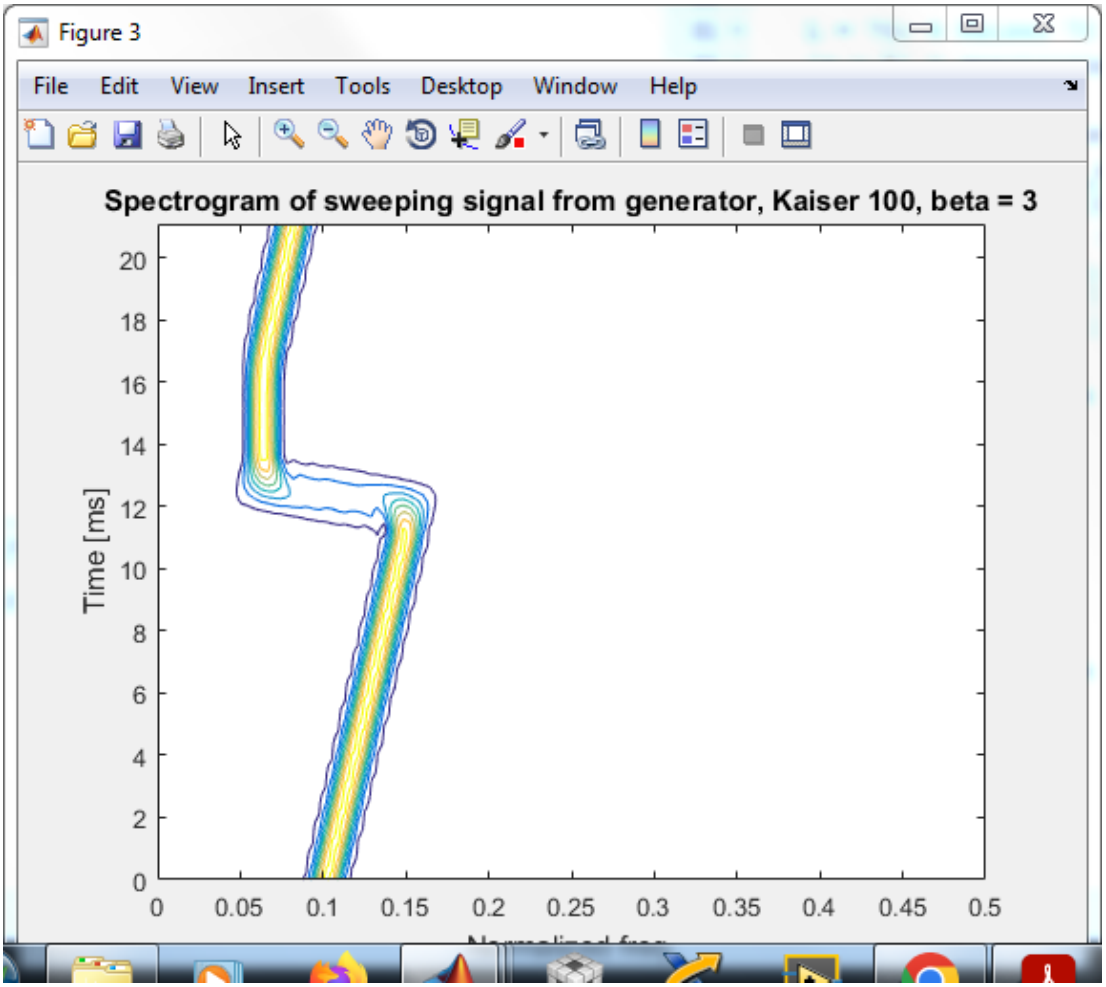
We can clearly see the moment on the contour plot when the generator stops to change the frequency. The generator was set to 4.8 kHz. From that we can see this frequency is the bottom frequency, as the bottom normalized frequency is 0.1. Since our fs = 48 kHz, then fn indeed is 0,1 for fa = 4.8 kHz. 4.8 kHz / 48 kHz = 0.1

Task 4

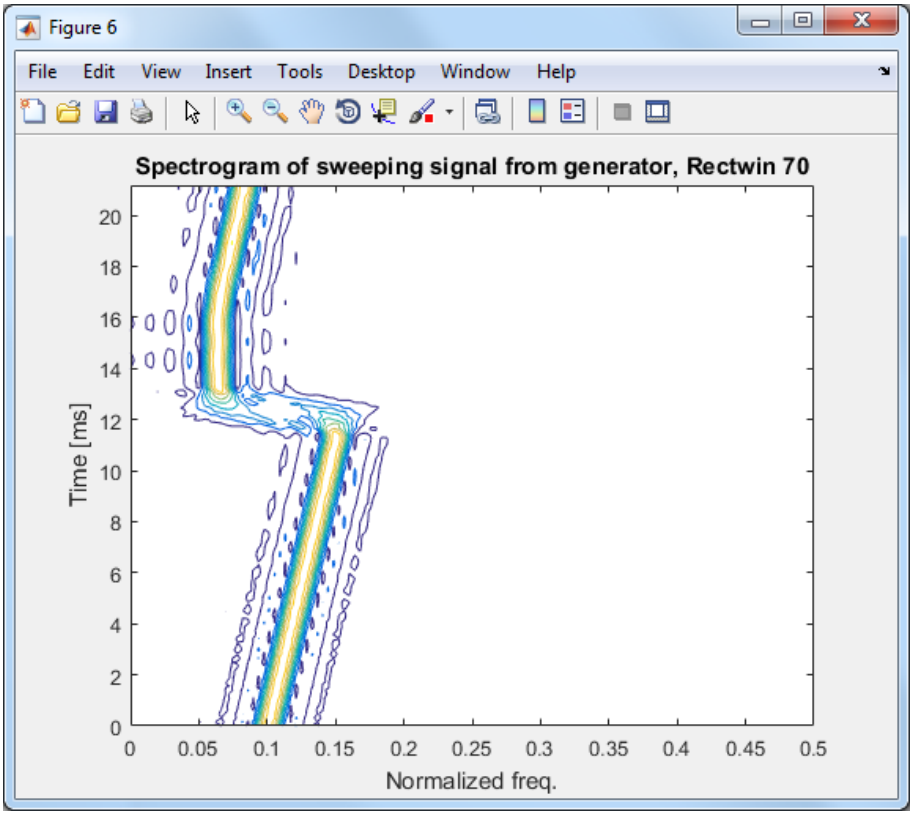
LFM signal spectrogram analysis with different window settings

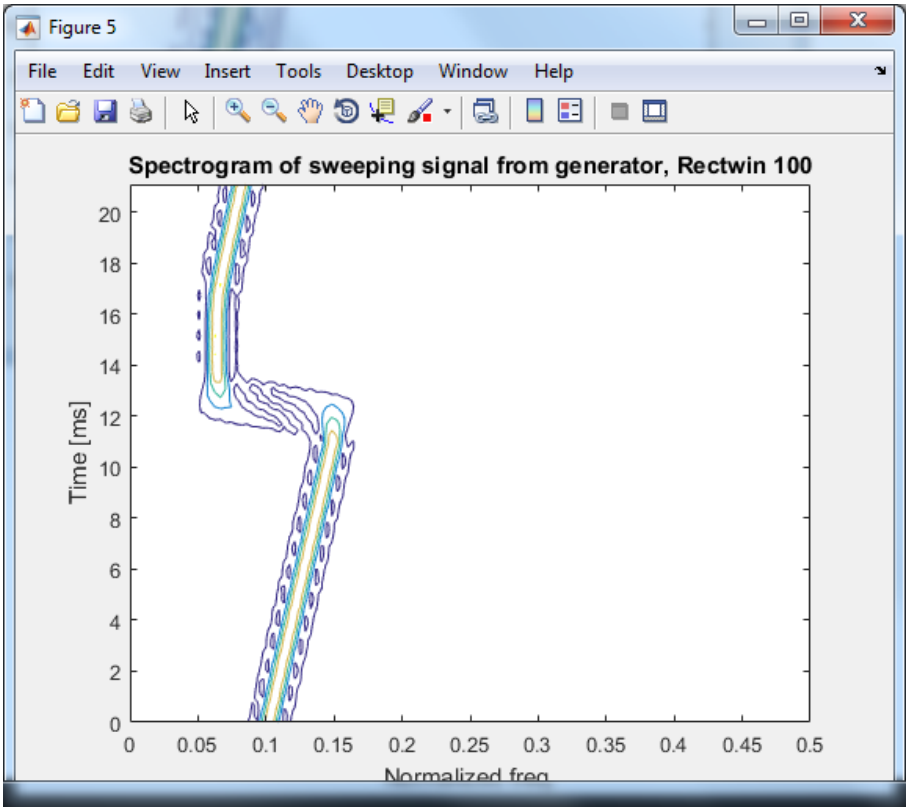
Same as task 3, but with different window settings in spectrogram computation.
Computed spectrograms were for following windows:
hamming (prev. task), Kaiser beta = 3, rectangular, blackman.
Each window was computed for two lengths: 100, 70.

Notable results:

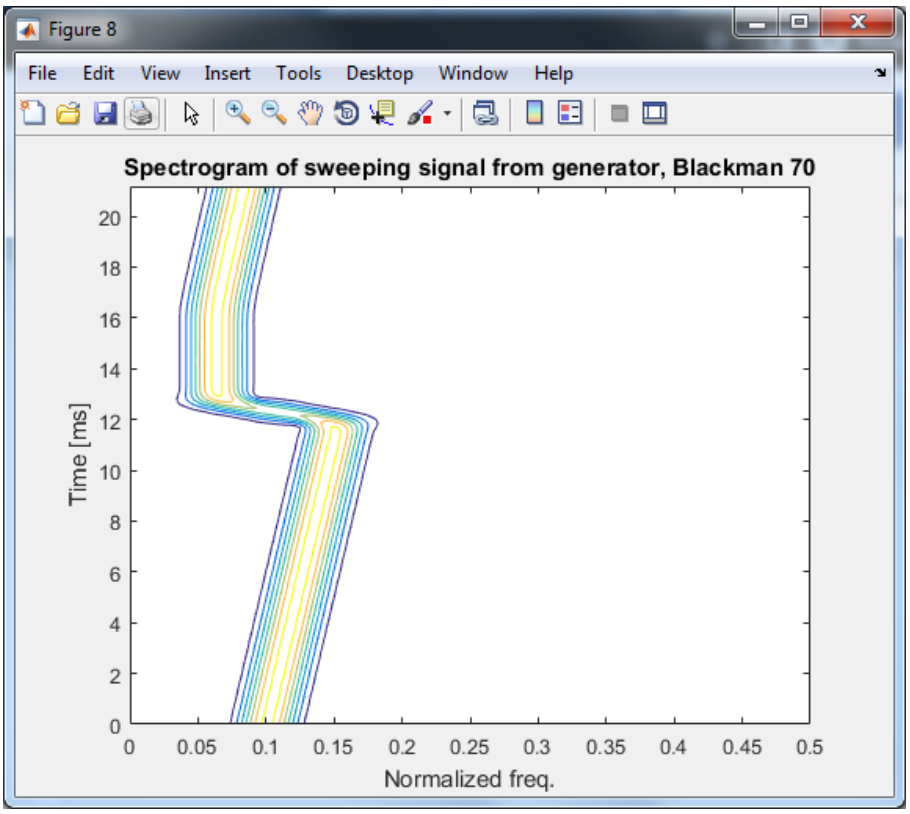


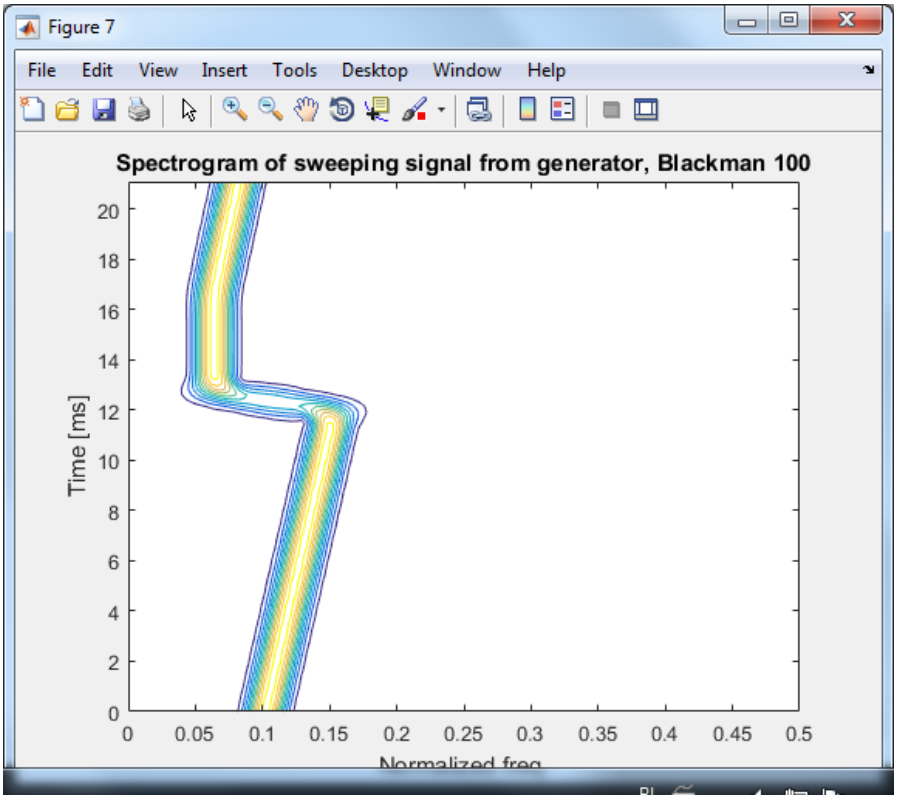
Note: very good frequency resolution, but time resolution is worse compared to other (the transition width is high, but the width of normalized frequency component is low)





Very strange results. Rectwin is not a good window for spectrogram analysis, the transition between frequencies is abnormal compared to other spectrograms



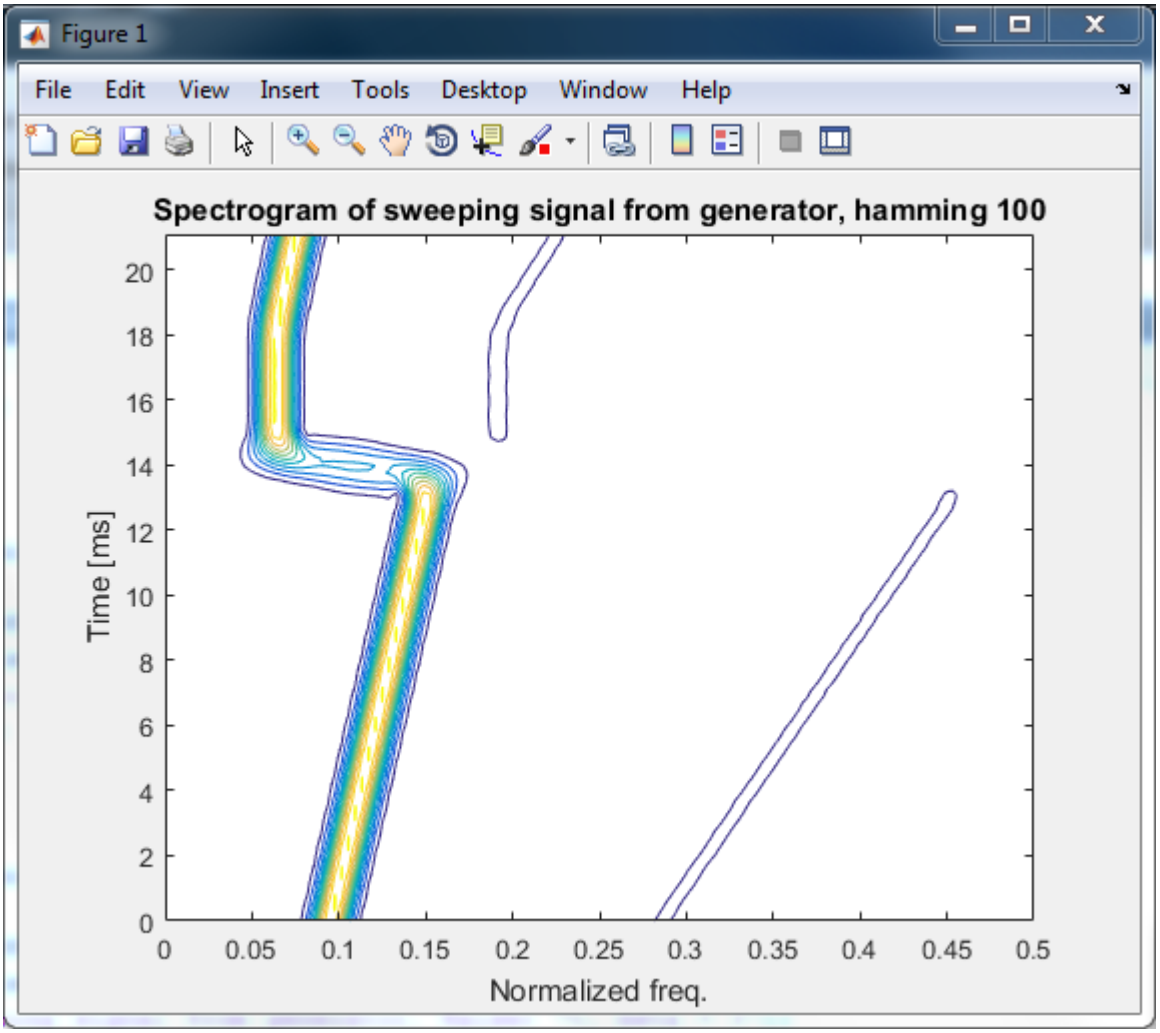


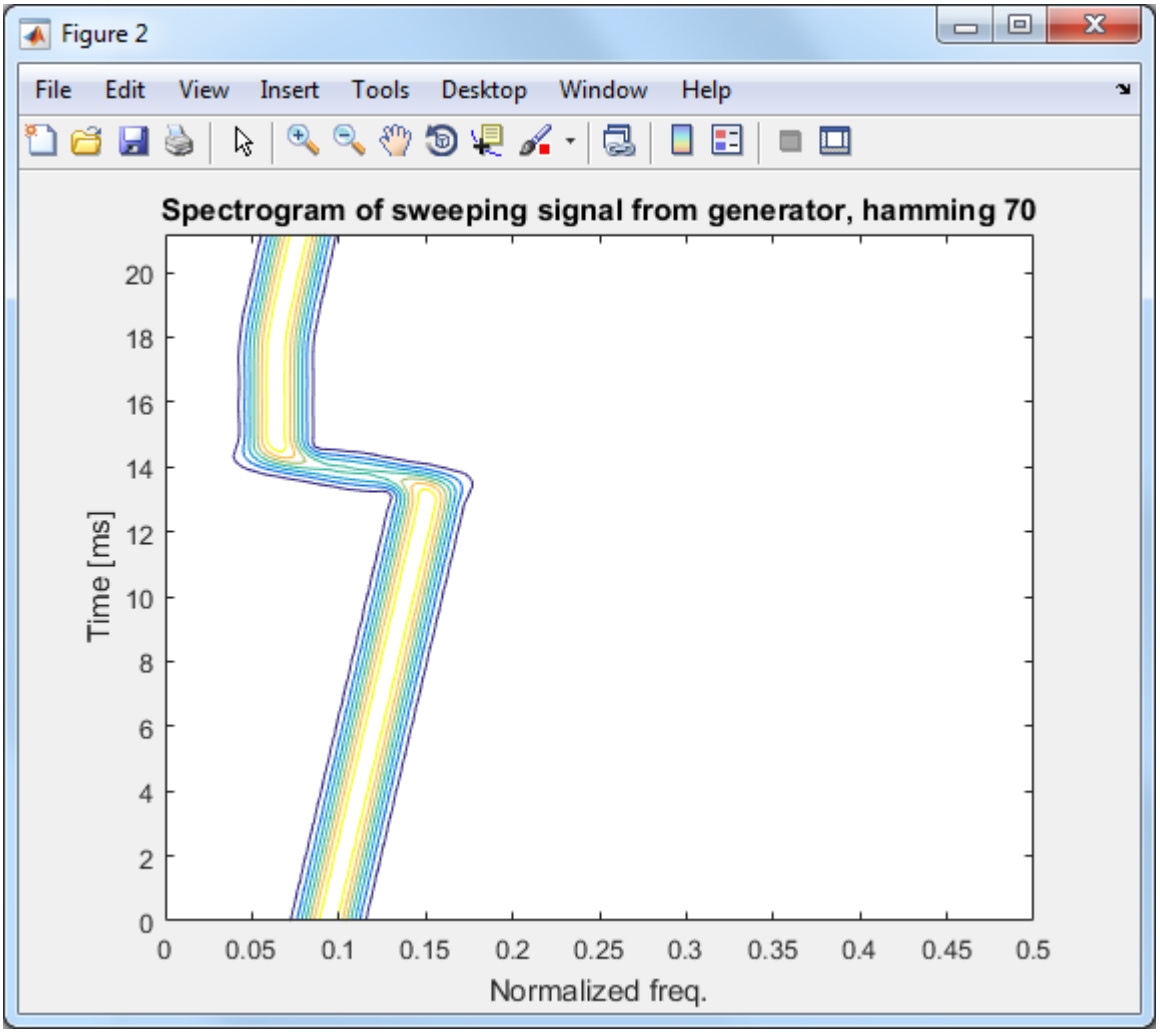
Blackman 100 might have the best balance between frequency and time resolution. It seems like a more balanced version of Hamming 70. The frequency resolution looks better, but also the time resolution is not much worse compared to Hamming 70. For Blackman 70 we have very good time resolution, but worse freq. resolution.

Task 5

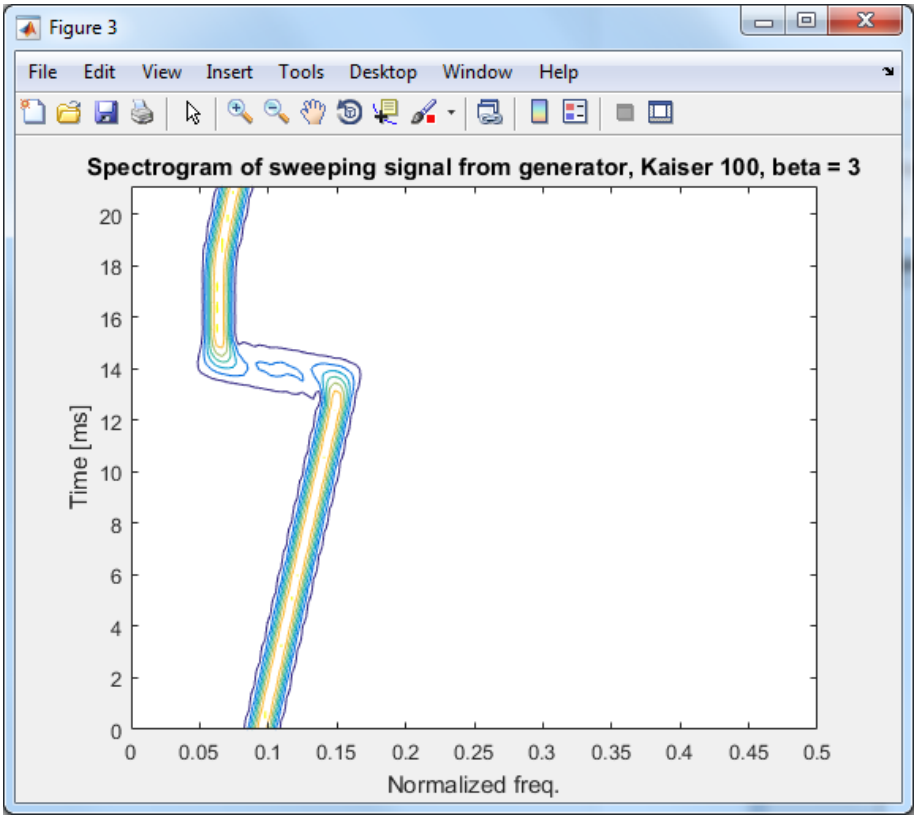
LFM signal spectrogram analysis with different window settings for triangular (sawtooth) wave

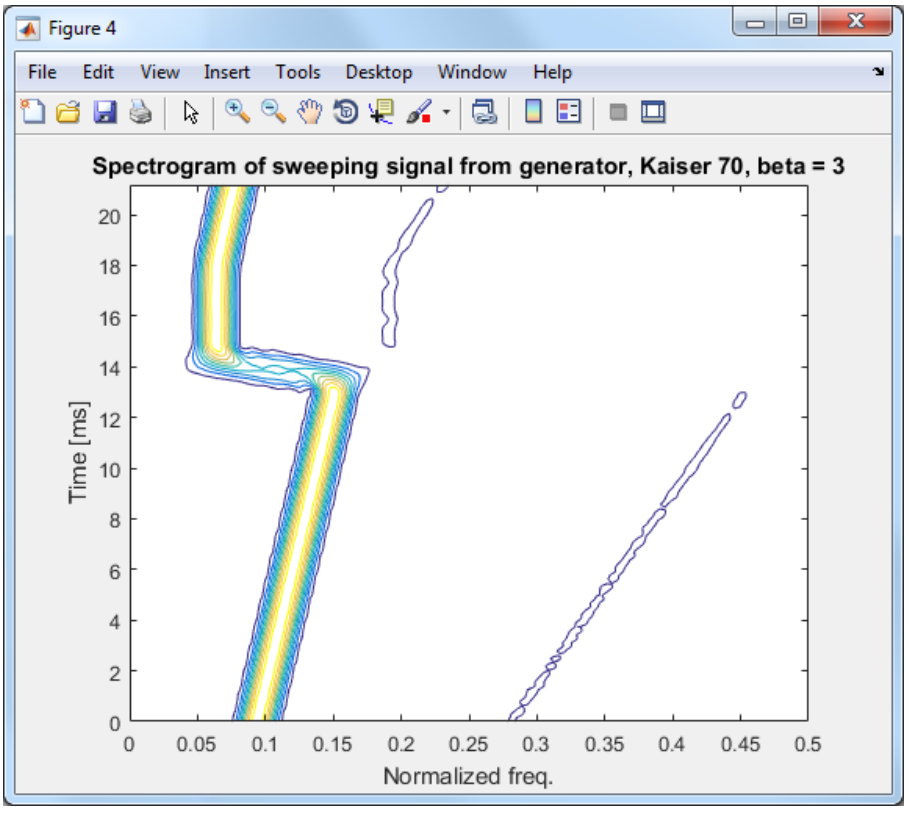
Same settings as for task 4, but we change the function generator to sawtooth wave.



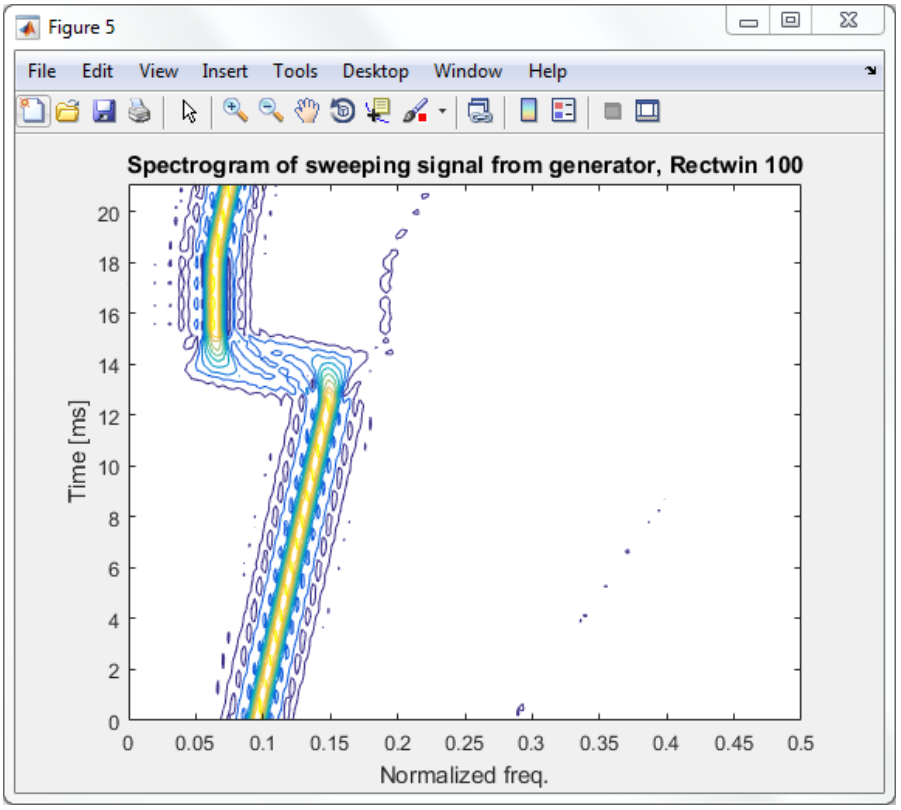


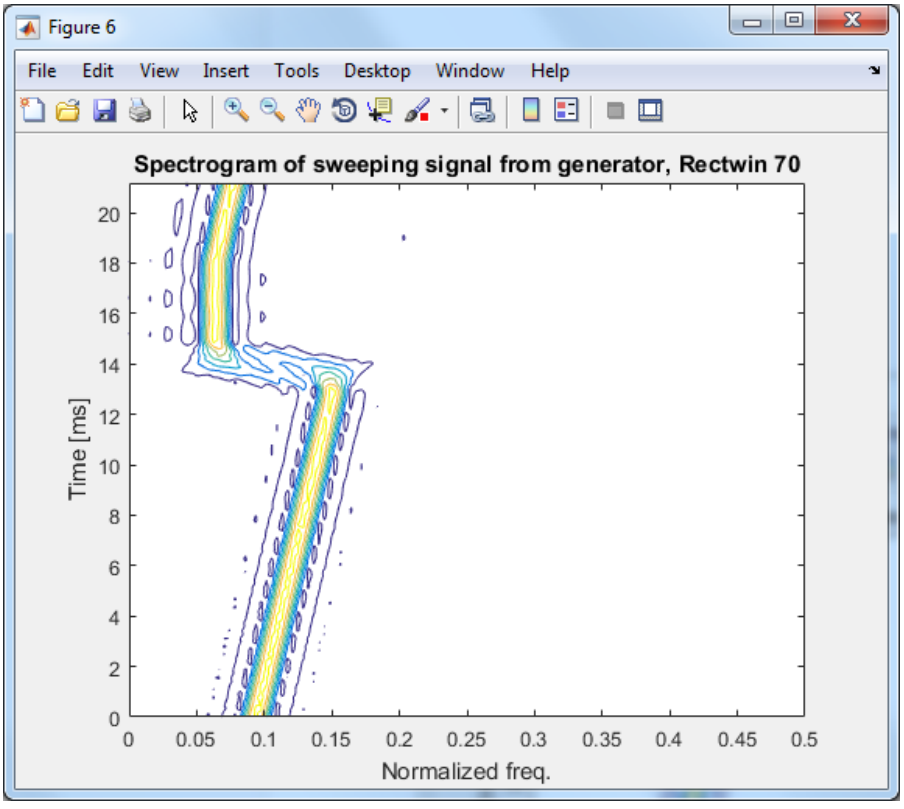
Hamming 70 works ok. Good time and freq. resolution. For hamming 100 we clearly see some issues, there are incorrect frequency components shown on the spectrogram. This window is incorrect for sawtooth wave type analysis.





Kaiser 70 also shows incorrect behavior, similar to Hamming 100. Kaiser 100 has very good frequency resolution, but a bit worse time resolution





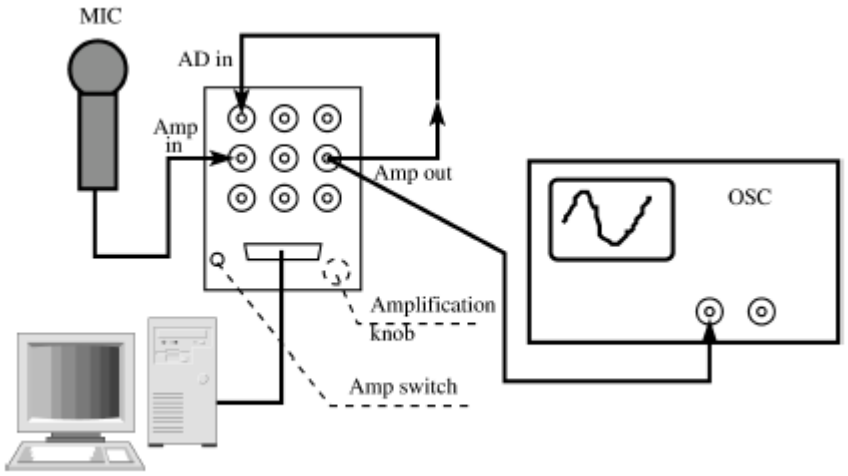
Rectwin shows even bigger problems for sawtooth than for sinusoidal waves. Rectwin 70 has similar behavior in sawtooth as in sinusoidal, but rectwin 100 has also incorrect frequency components shown.

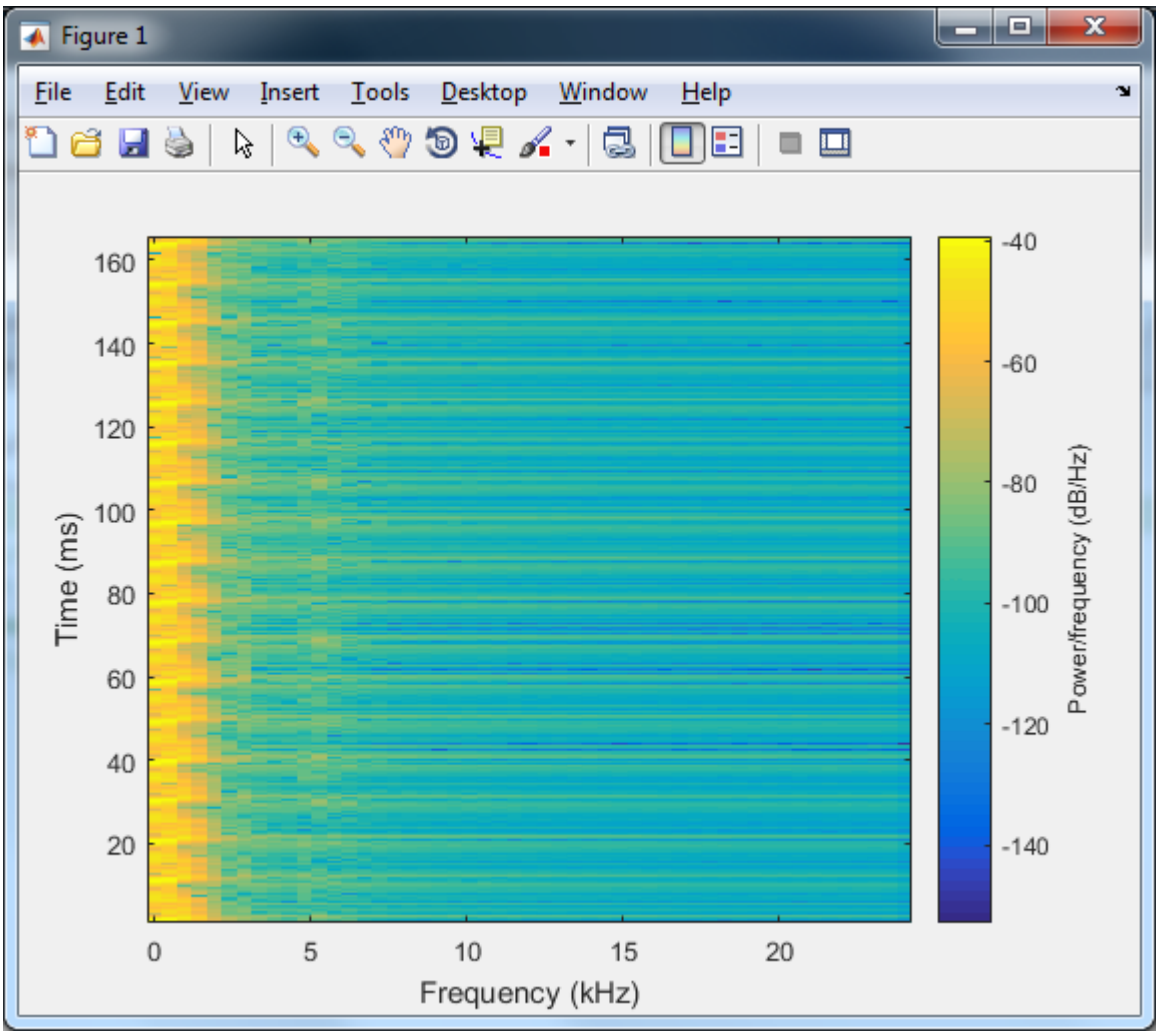
Blackman windows worked properly for sawtooth. Normal output was observed.

Task 6

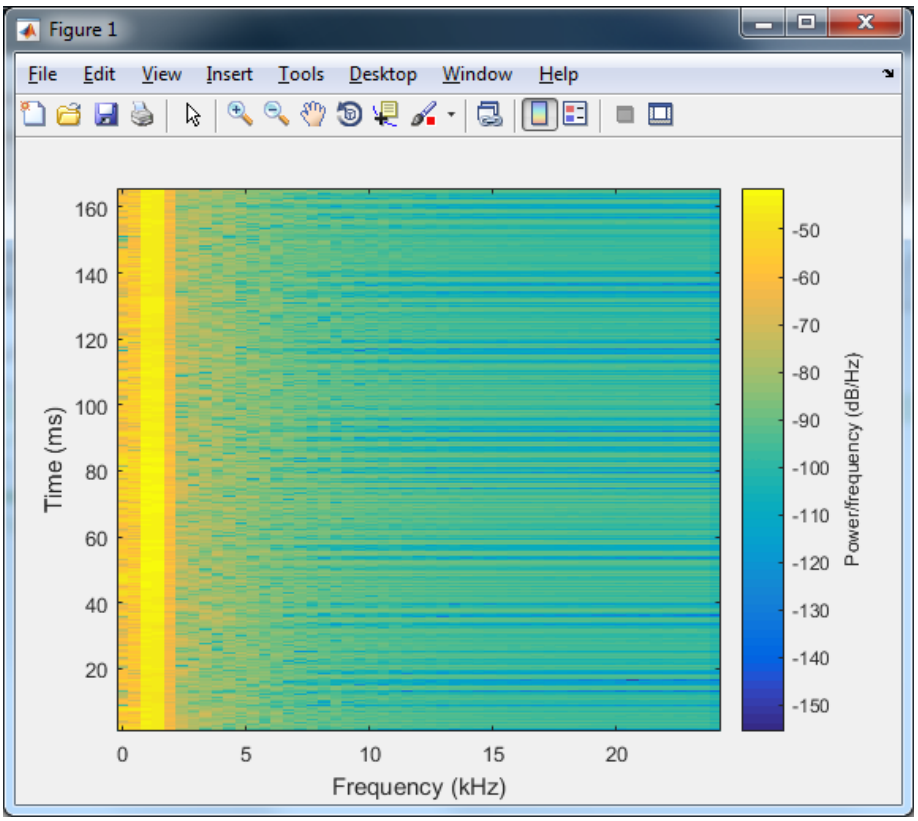
Voice signal spectrogram analysis

Stand setup:

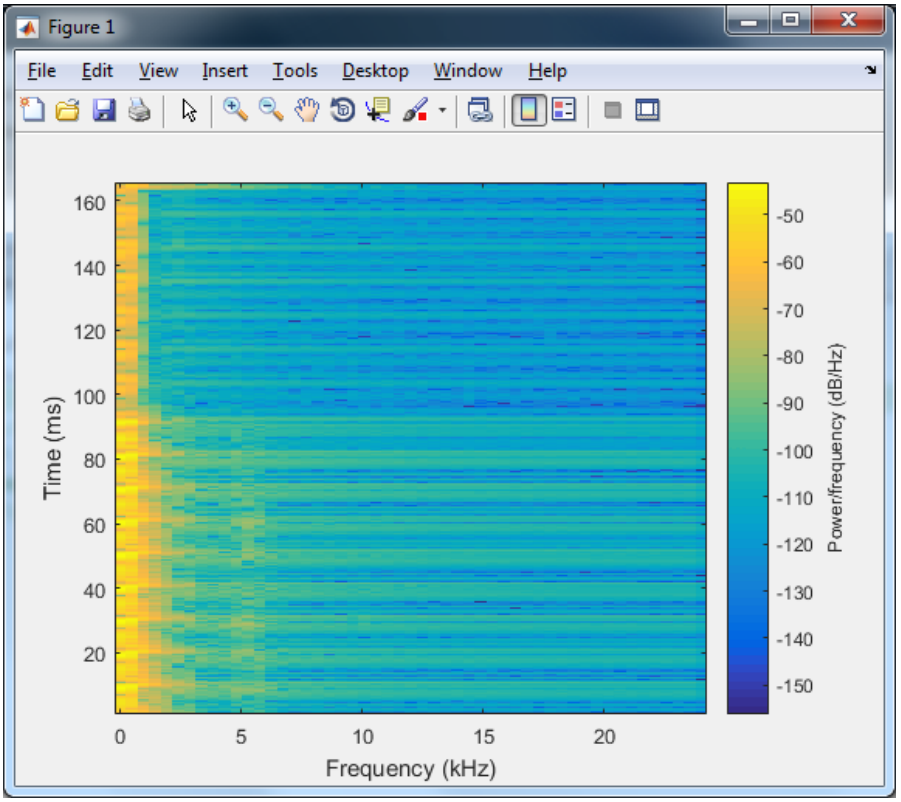




Saying ‘aaaa’



A whistle. We see consistent frequency in spectrum



Saying repeatedly ‘abababab’, we see a difference at around 100 ms