Lab Report

FOURIER ANALYSIS OF DIGITAL SIGNALS

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Introduction

In this Lab, we will be focusing on the following point:

Four assignments where we have to analyze recordings and other real-life data with the methods and theory that we learn in Lectures 1 to 3.

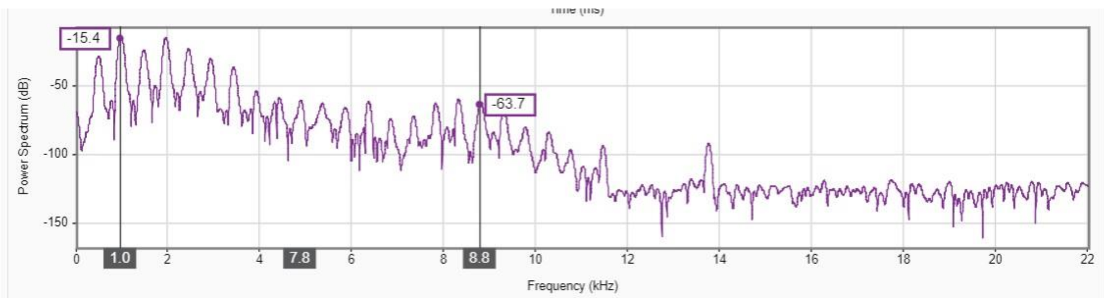
So, the purpose of this Lab is to apply our theoretical knowledge in the field of signal processing into real life cases.

Spectral analysis of trumpet sounds

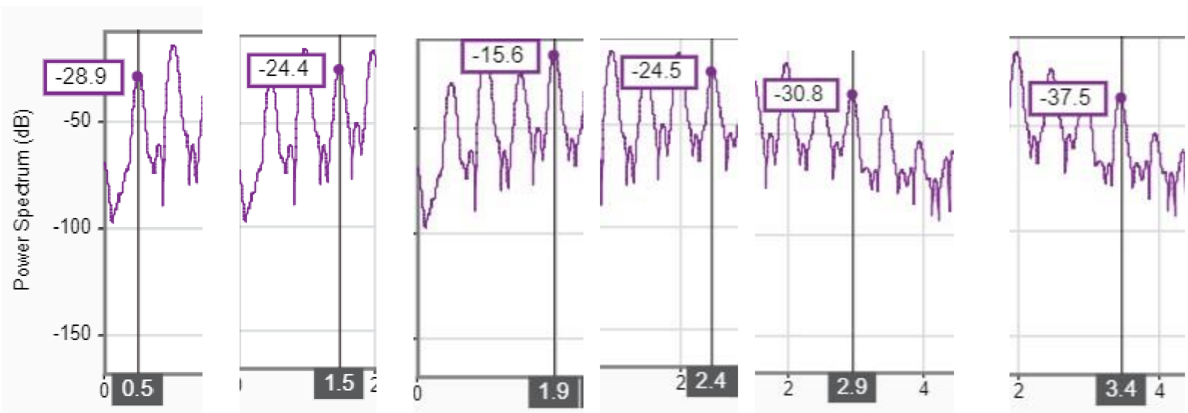
This assignment aims at determining the fundamental frequency of actual trumpet sounds by Fourier analysis. Also, it's planned to do analyze the sound of trumpet while an interfering or spurious signal is added to it.

We expect to see a difference between the two sounds and get more information about dealing with interfering or spurious signal in the background of our signal.

1. The fundamental frequency of this trumpet sound:
   After writing the script provided in the question sheet and using signal Analyzer, we get the following spectrum:



   Using the spectrum, we may notice that the fundamental of the trumpet is 1kHZ, where the power is equal to -15,4 dB.
   We may conclude that the sound of the trumpet is medium (1000HZ).
2. The number of non-negligible harmonics and their frequencies:
   There are 6 harmonics:



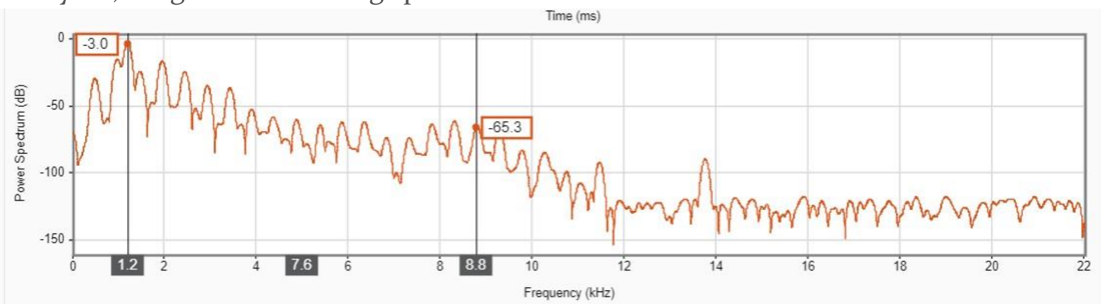
F = 0,5 kHZ F=1.5kHZ F=1.9kHZ F=2.4kHZ F=2.9kHZ F=3.4kHZ

All of the previous harmonics are higher the -40dB, because as it's mentioned in the question sheet, those attenuations of a harmonic in comparison with the fundamental or with the harmonic having the largest power will be considered here as the threshold of audibility. Indeed, the sounds below this value are of little interest because they are often masked by louder sounds, and therefore can be considered as uninformative sounds.

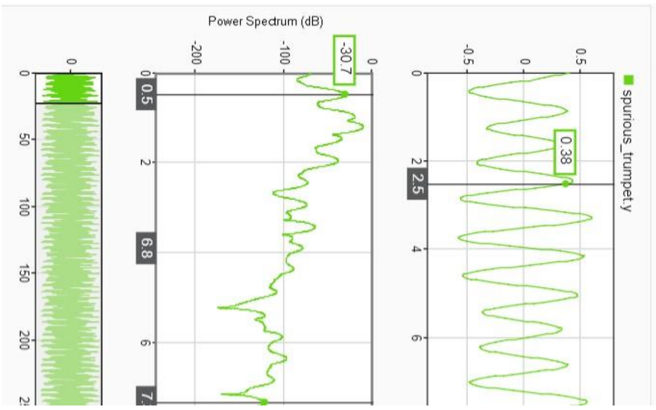
REPEATING THE ANALYSIS WITH SPURIOUS TRUMPET SOUND

This part is aiming to help us see the effect of spurious signals.

1. The fundamental frequency of the spurious sound:
   After writing the script provided in the question sheet and using signal Analyzer, we get the following spectrum:



   Using the spectrum, we may notice that the fundamental of the trumpet is 1.2kHZ, where the power is equal to -3 dB.
   We may conclude that the sound of the trumpet got a little bit higher (1200HZ).
2. The first idea that comes to mind to get rid of the spurious sound is to add a filter, because it can eliminate and smoothen our signal.
   We kind find different type of filters on Signal Analyzer such as: High-pass, Low-pass and Smooth.
   When applying the smooth filter, we get the following result:



   Where we can notice the number of harmonics is only 4.

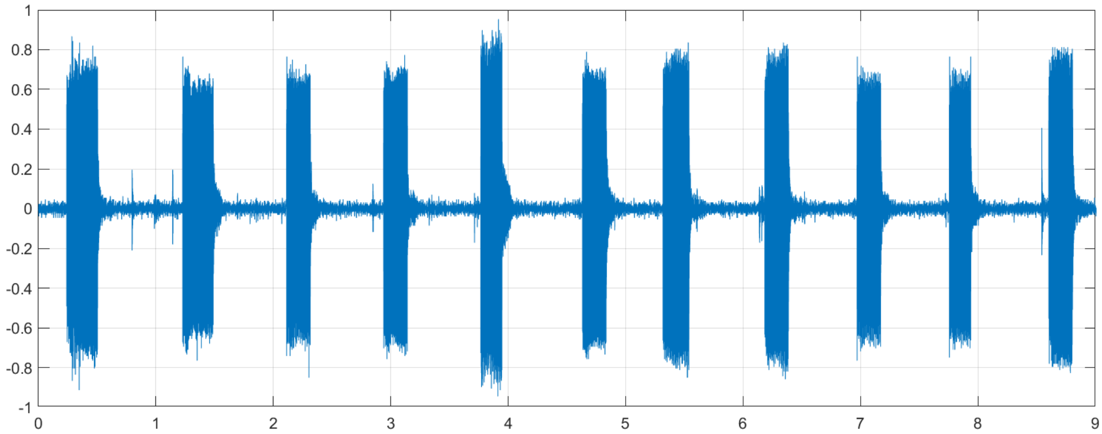
<u>Conclusion:</u> Adding spurious and interfering signals may make the signal higher and we would need a filter to adjust it properly. Also, the number of important harmonics may increase.

Decoding of a dual-tone multi-frequency tone

This assignment aims at decoding a phone number from dual-tone multi-frequency (DTMF) signaling tone data by Fourier analysis. We are expecting to find a real number at the end using only the tone of each digit.

A dual-tone multi-frequency (DTMF) or VF (Voice Frequency) is a telecommunication signaling system using the voice-frequency band over telephone lines between telephone equipment and other communication devices and switching centers. These codes are emitted when pressing a key on the telephone keypad and are used for dialing phone. Technically, each key on a telephone corresponds to a pair of two audible frequencies that are transmitted simultaneously. Here we look at the DTMF code used in the United States which uses seven distinct frequencies that can encode the twelve-telephone keypad.

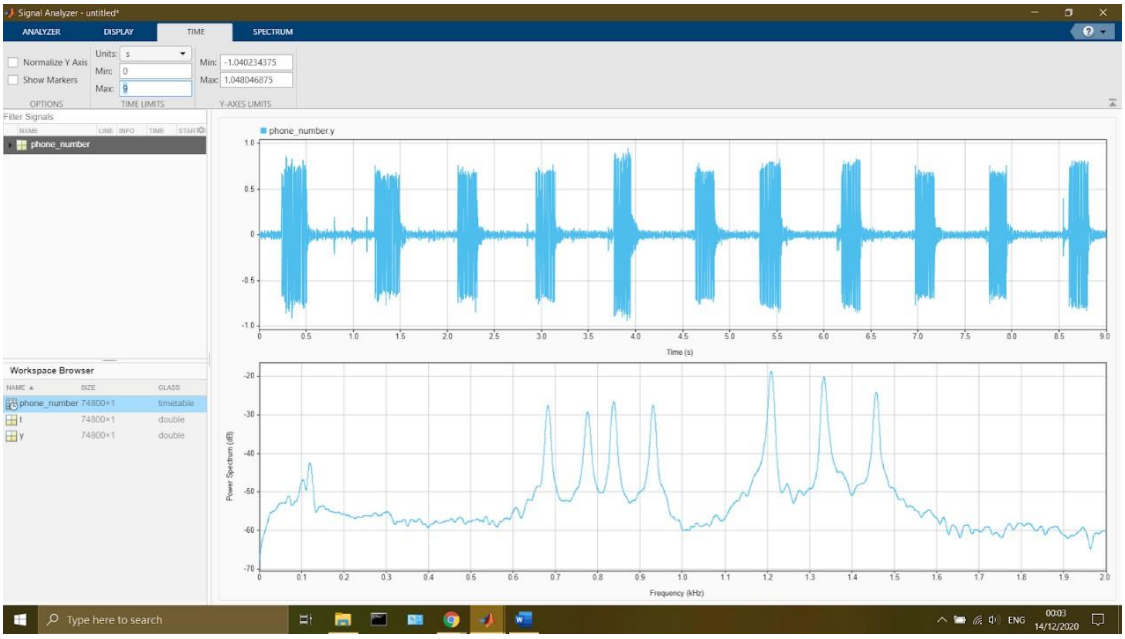
1. The plot we're going to be using is the following:



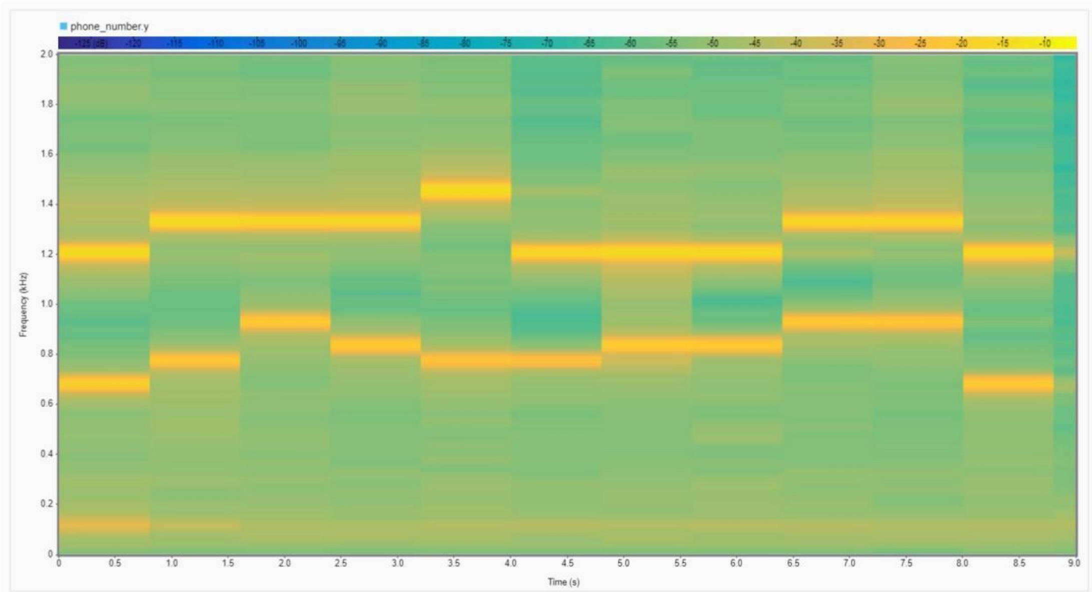
   There are 11 digits in this number, indicated by the number of spikes in the plot.

2. it is not possible to determine the phone number from the time evolution of the composite signal, but it will be possible after analyzing the signal.

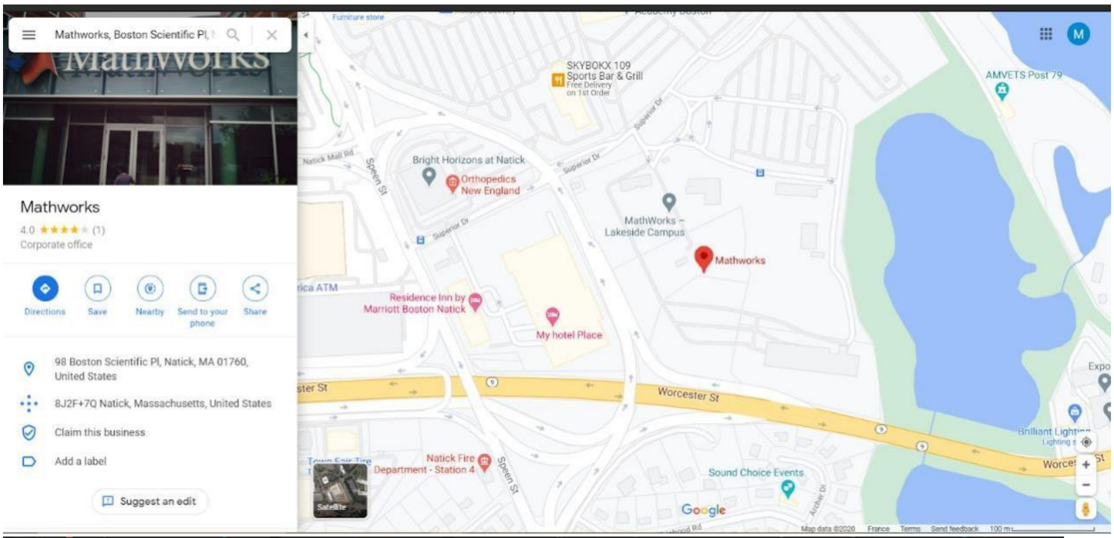
3. By analyzing the spectogram and matching the frequencies shown on it to the ones on the number pad we find that the hidden number is: 15086477001

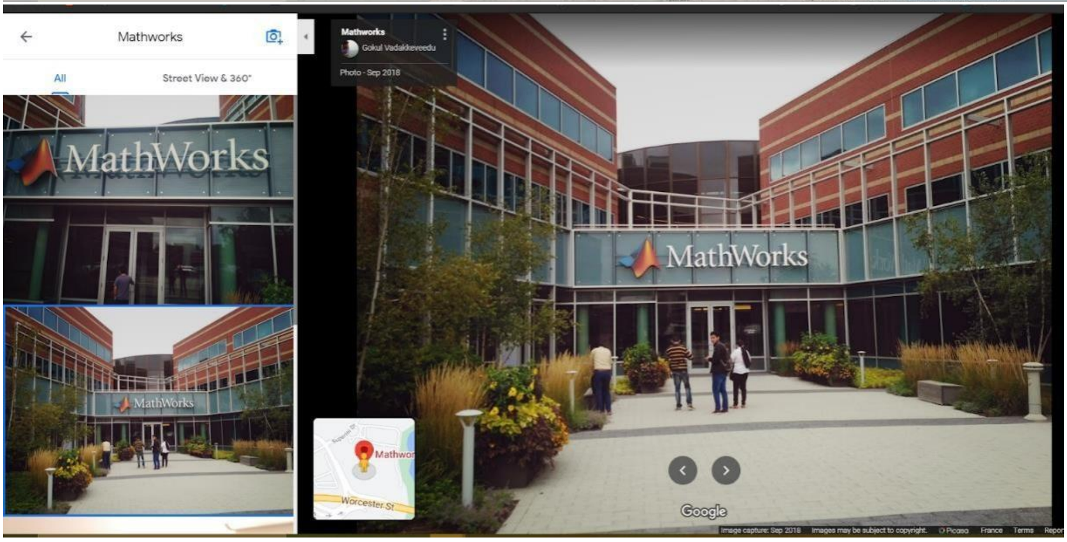


Spectrogram view (time-frequency representation)



4. The hidden number is the number of MathWorks headquarter in Massachusetts, USA.
5. The Address is: 98 Boston Scientific Pl, Natick, MA 01760, United States





<u>Conclusion:</u> It's possible to find out a phone number using only the dual-tone multi-frequency.

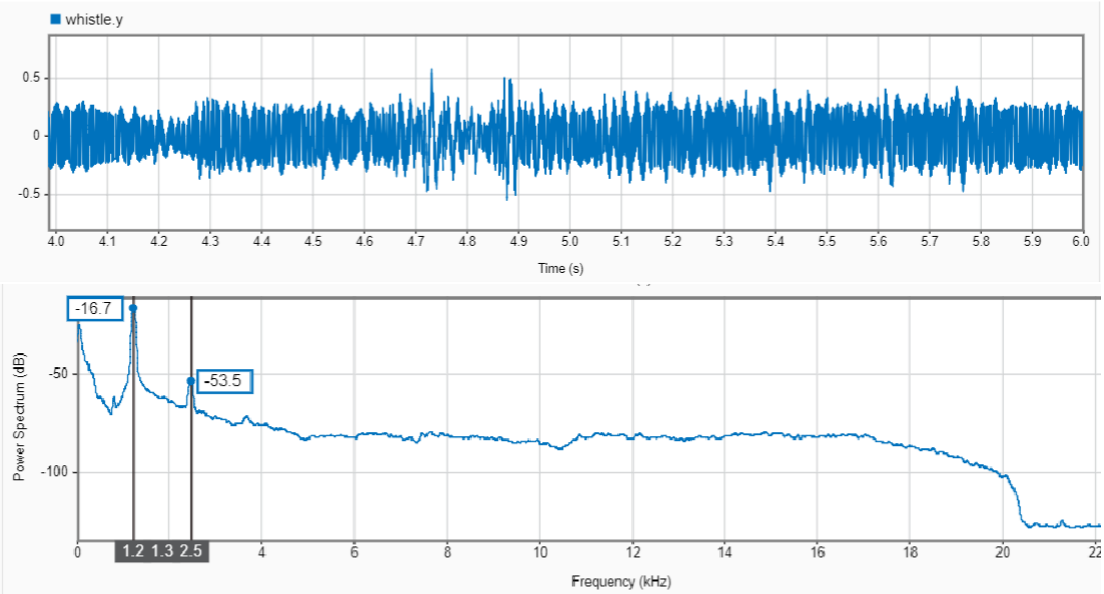
Determination of the type of sounds produced by your whistle

This part consists of analyzing a whistle and tying to find in which range its frequency might be.

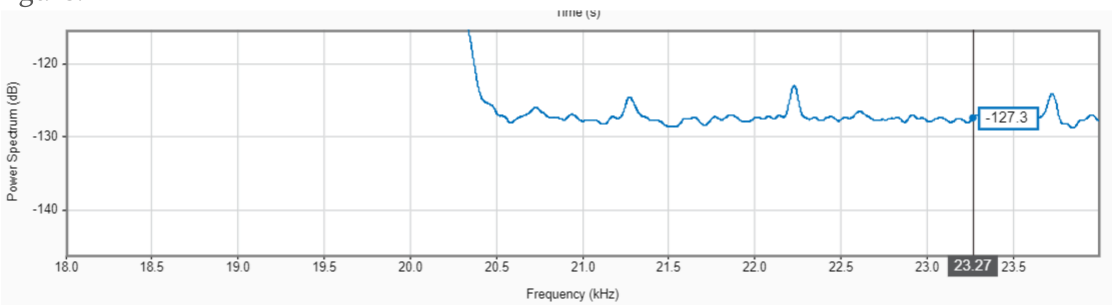
As neither me nor my lab partner can whistle, we are using the audio provided in the Lab file, and we are thankful for the help given by our teacher.

We are expecting a high pitch sound and trying to find whether or not the iPhone 7 used by the teacher had an anti-aliasing filter applied to the analogue signal before digitizing it.

1. After writing the script provided in the question sheet and using signal Analyzer, we get the following spectrum:



2. The native sampling frequency of iOS devices is 44100 Hz
3. As we may notice from the spectrum from the question 1, the fundamental is equal to 1.2 kHZ where the power is -16.7 dB, and we can ignore all the other harmonics. Also, we notice a that when the pour got to -100 dB and the frequency was equal to 20kHZ, the power reduced dramatically, which makes us conclude that the phone used had e an anti-aliasing filter applied to the analogue signal before digitizing it, with a cut-off frequency equal to 20kHZ because it is the maximum that the human being can hear.
4. The dominating frequency is 1.2 kHZ as we may see in the spectrum.
5. There are no significant harmonics because the one right after the fundamental is equal to -53.5 dB, so we can ignore it.
6. The sound is high pitched (1000<1200<15000).
7. After zooming on the low-frequency part of the spectrum, we get the following figure:



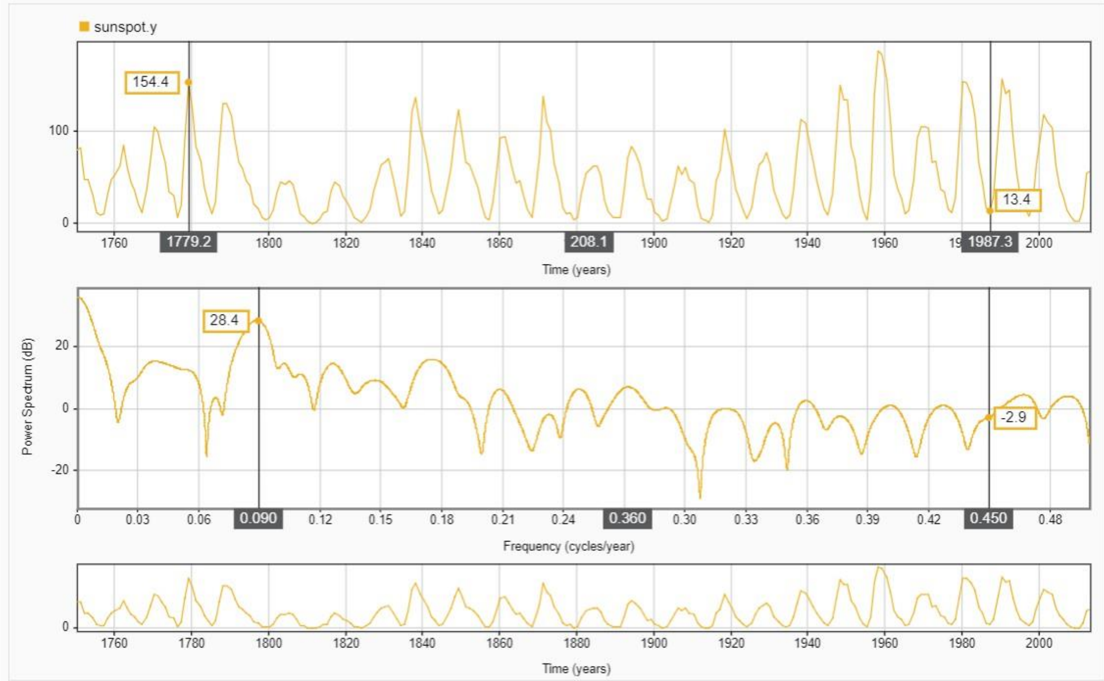
the nominal frequency of the electrical supply voltage?

<u>Conclusion</u>: whistling causes a high-pitched sound, that has no significant harmonics.

Prediction of the Sun's activity over the coming decade:

This assignment aims at analyzing sunspot data which is available from NASA for the years 1749-2012, and hopefully in the end of it we can get to know when we will be hitting the new maximum sunspot number.

1. After writing the script provided in the question sheet and using signal Analyzer, we get the following s time and frequency contents of the sunspots since 1749:



   We may notice that the result is a periodic signal, with a spectrum that has a lot of harmonics.

2. Steps to the determination of the main cycle/period in years of the sunspot activity:
   - Finding the year of each peak.
   - Calculating the difference between each 2 years
   - Calculating the mean of those differences.

   We finally find that the main cycle in years is 11.13 years, so each 11 years and 1 month and 16 days in average.

3. Predicting in which year we should reach a new maximum sunspot number:
   Based on what we found on the question number 2, the cycle after the one happening in 2001, was in 2013, and using the average we calculated the one after it is in 2023,57 (11.13 x 2 x 2001,3).
   So, if we can guess an exact date based on this, it would be the 26th of July 2023.

   Conclusion: Signal processing is involved in many kinds and fields of research.

General conclusion:

Signal processing is involved in many activities that we do in a daily bases, Signal Analyzer is an easy and an effective tool to use in order to understand more about signals.