

UNIVERSITY OLDENBURG

WIND PHYSICS MEASUREMENT PROJECT

Exercise 4 - Lidar measurements

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Introduction

The fourth and last exercise deals with Lidar measurements. The exercise itself was separated into three sub tasks. First we received 312 frequency spectra which span a vertical plane in front of the SpinnerLidar. For each spectra we calculated the peak and the corresponding line-of-sight velocity.

1 Task 1: Spectral analysis: from backscatter spectrum to line-of-sight velocity

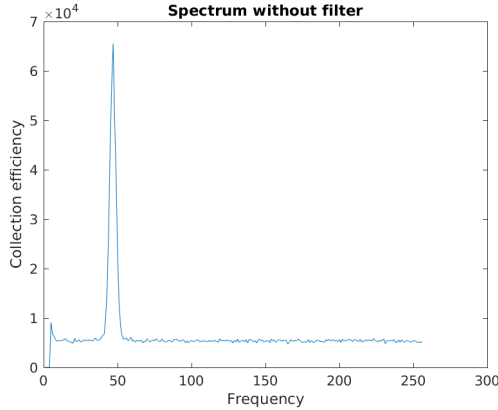
1.1 Clean the spectra from their background noise

In order to clean the 312 different spectra from their individual background noise we calculated the mean values of each spectra. Keeping in mind that the goal of this exercise is to identify the peak location, we defined 1.5 multiplied with the mean of the spectrum as noise. Therefore we subtracted $1.5 \cdot \text{mean}$ and discarded all values below zero.

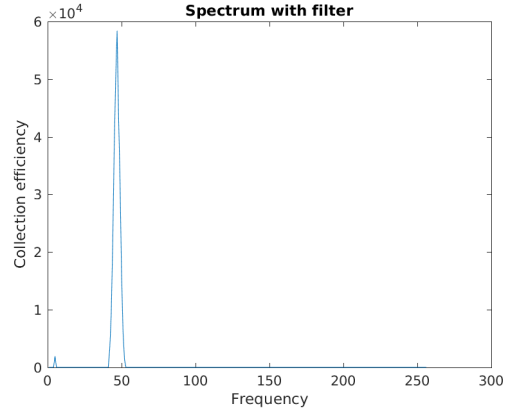
The following code-snippet shows this procedure in Matlab:

```
1 for pos = 1:312
    spinner_noiseCancelled(pos,:) = spinnerlidar_spectra(pos,:) - 1.5*mean(
        spinnerlidar_spectra(pos,:));
3    spinner_noiseCancelled(spinner_noiseCancelled < 0) = 0;
end;
```

The following figure shows on the left the raw spectrum and on the right the noise cleaned spectrum. As one can easily see we obtain different values for the collection efficiency, but since it is only important to find the corresponding frequency and subsequently the line-of-sight velocity of the peak, the peak value itself is not relevant for further calculations.



(a) Raw spectrum



(b) Spectrum cleaned from background noise

1.2 Calculate the Doppler frequency that each bin of the spectra corresponds to

We received the spectra as histograms which are separated in 256 bins. The measured bandwidth is $25 \cdot 10^6$ Hz. Therefore each bin represents a frequency of

$$frequency = x * \frac{25 \cdot 10^6 Hz}{256}$$

where x is the bin number. With the equations provided during the lecture we were also able to calculate the line-of-sight velocity. The implementation in Matlab is shown in the following.

```

for bin=1:256
    f_d(bin,1) = (bin-1)/bins*bandwidth;
    v(bin,1) = f_d(bin,1) * lambda_0;
end;

```

1.3 For each spectrum, define the peak location with the centroid method

The centroid method was introduced during the lecture and is defined as:

$$f_{peak} = \frac{\int f_d \cdot p(f) df}{\int p(f) df}$$

Before we calculated the peak values we normalized our data to get a PDF instead of absolute values. Since we are dealing with discrete values, we summed over all values in order to identify the peak

value. In order to check all 312 f_{peak} values, we first calculated the index of the maximum collection efficiency for each spectra. The maximum should always represent the peak of the spectrum. Next we determined the corresponding index of f_{peak} . Now we were able to compare the distance of the calculated indices. The results are shown in figure 2.

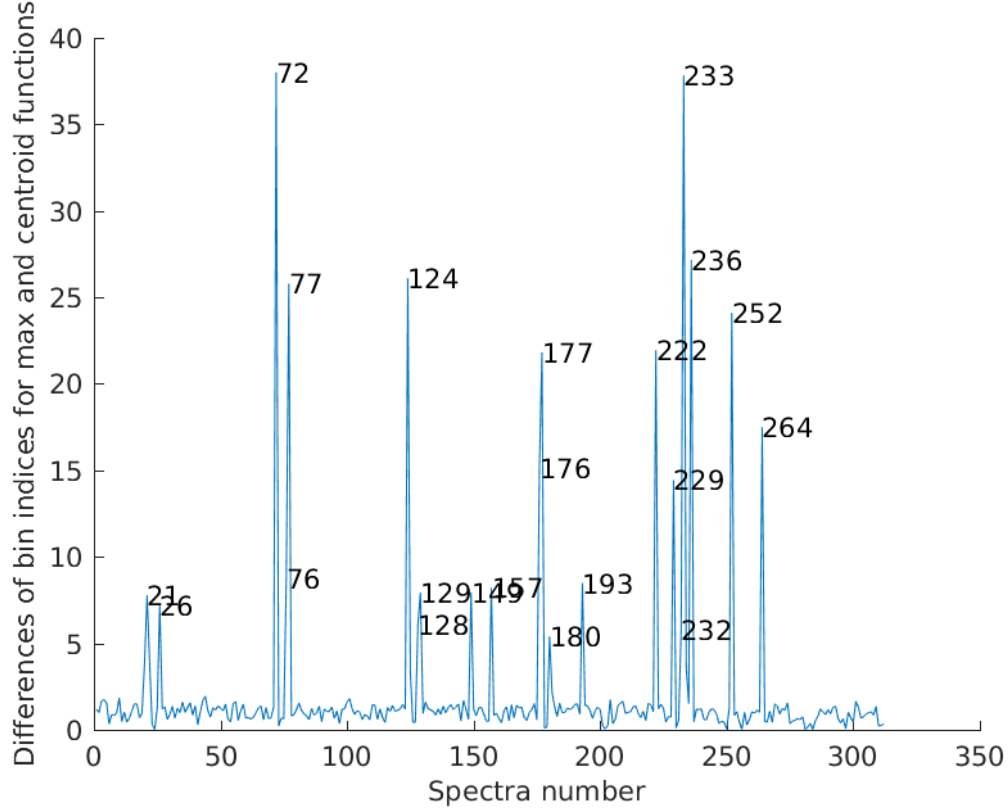


Figure 2: Centroid Errors in bin distance

The figure shows that there are several errors. The reason why the centroid method fails for some spectra is due to a measurement error. As stated in the exercise sheet the lidar was placed on the nacelle of a wind turbine. Therefore for some measurements the lidar might be blocked by the rotating blades which would result in a second frequency peak. If the spectrum contains two peaks, the centroid method returns the middle of these two peaks and is not applicable for this case. One of those cases is shown in figure 3.

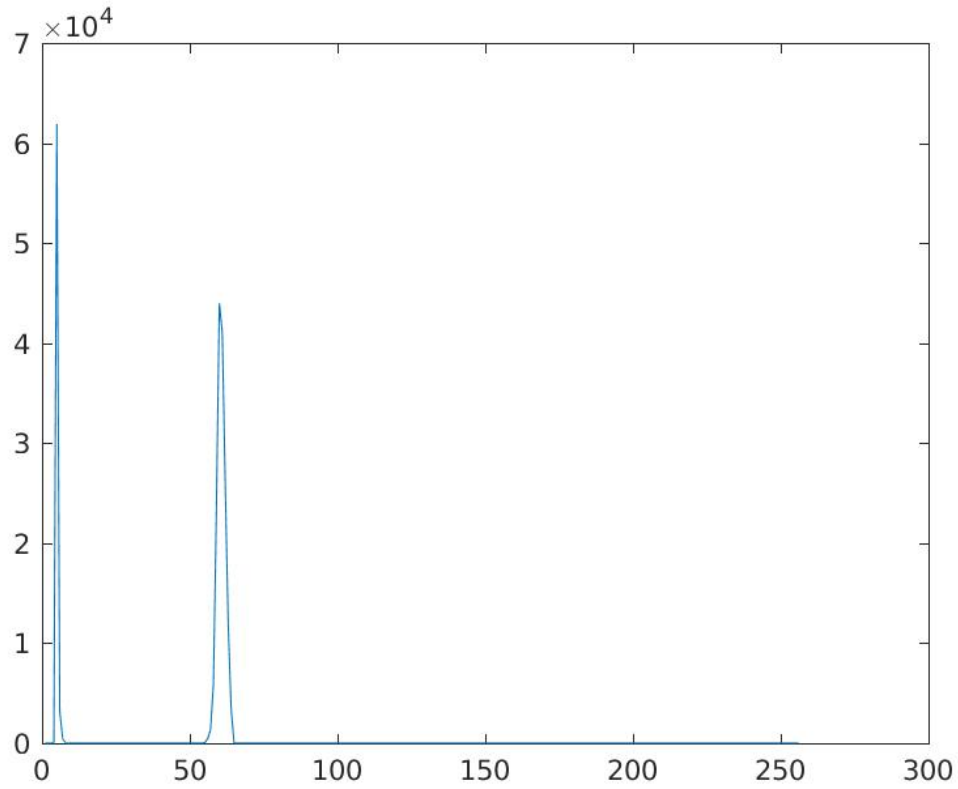


Figure 3: Measurement error in spectrum 72

1.4 Correlate your calculated line-of-sight speeds

In step 4 we were asked to correlate the calculated line-of-sight speeds with the lidar data itself. The correlation method was already provided. Therefore we only needed to calculate the line-of-sight velocity by multiplying f_{peak} with λ_0 . The resulting plot is shown in figure 4.

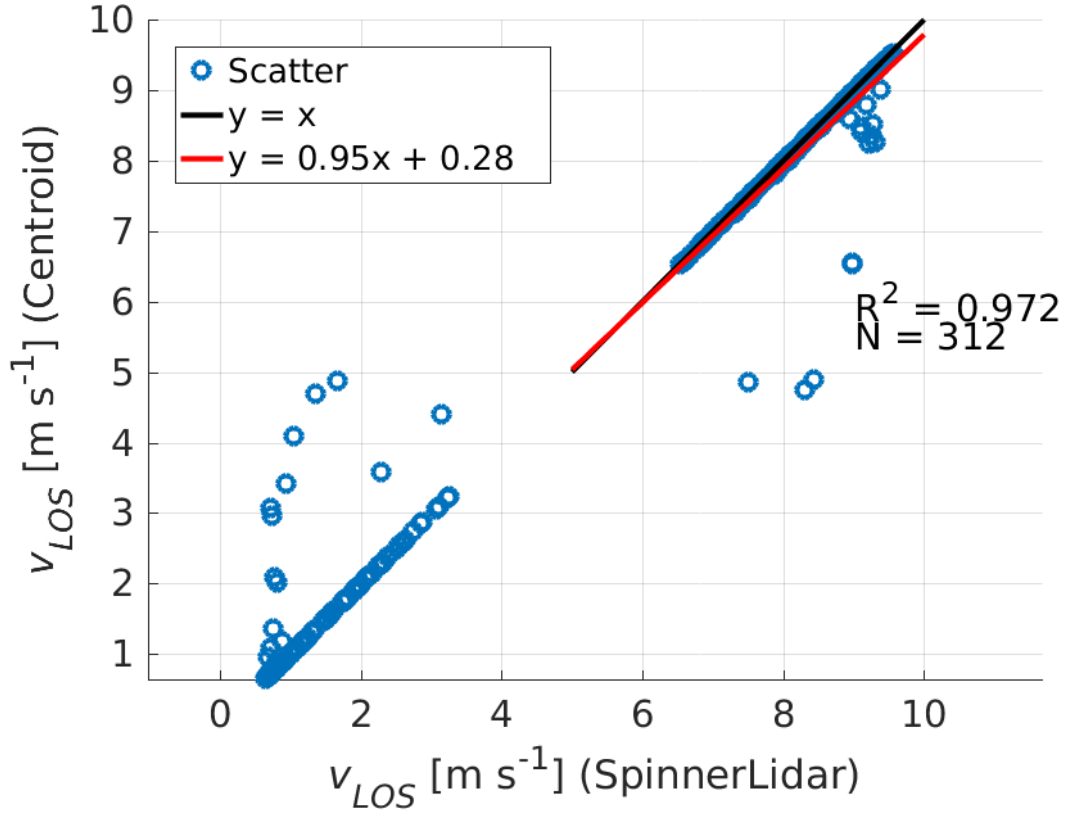


Figure 4: Correlation of the calculated line-of sight-speed and the lidar data

Figure 4 shows a strong correlation of $R^2 = 0.972$. As discussed in section 1.3 there are measurement errors due to the position of the lidar. Some measurements are blocked by the moving blades.