Lidar-Assisted Control for Wind Turbines I

Exercise to Lecture #10
"Controller Design for Wind Turbines and Wind Farms"

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Wind Field Reconstruction and Spectra Estimation

A two-beam lidar is scanning a turbulent wind field in $x = 80\,\mathrm{m}$ distance. The measurements are taken at hub height $z = 0\,\mathrm{m}$ and $y = \pm 20\,\mathrm{m}$, see Figure 1. Coordinates are given in the lidar coordinate system. The analytic auto- and cross-spectra of the rotor effective wind speed from rotor and lidar are necessary to optimize the scan positions and to design an appropriate filter.

The wind field reconstruction and spectra estimation is done with the script SpectraEstimationTwoBeamLidar.m. The lidar is simulated in section 2 using the lidar point measurement model. Only section 3, 6-9 need to be modified.

a) Please estimate the rotor-effective wind speed $v_{0\mathrm{L}}$ in Section 3 of the code from the two line-of-sight wind speeds $v_{\mathrm{los},1}$ and $v_{\mathrm{los},2}$. The signals and coordinates are already given. The resulting rotor-effective wind speed estimate is plotted in Figure 2. Please assume for the wind field reconstruction that the turbine is perfectly aligned with the mean wind direction, so the lateral and vertical wind velocity component are assumed to be zero.
b) Please calculate the analytic spectrum S_{LL} of the rotor effective wind speed estimate from the lidar system in Section 6. It should be close to its frequency estimate $S_{\mathrm{LL,est}}$, see Figure 3. Please consider that the lateral and vertical wind velocity component are not zero in reality.
c) Please calculate the analytic spectrum S_{RR} of the rotor effective wind speed in Section 7.
d) Please calculate the measurement coherence via the cross-spectrum S_{RL} in Section 8 and 9. What is then the measurement coherence bandwidth and the smallest detectable eddy size?

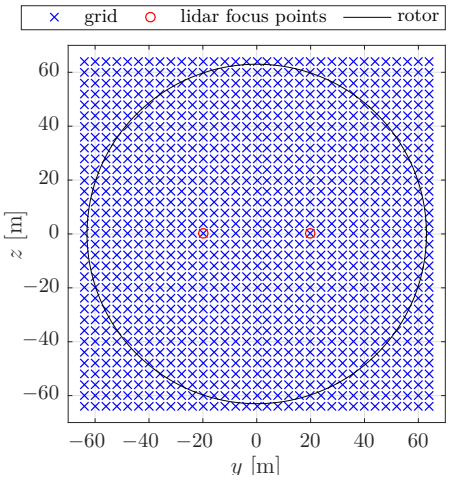

Figure 1: Lidar focus points for a two-beam lidar system on a the 5 MW reference turbine.

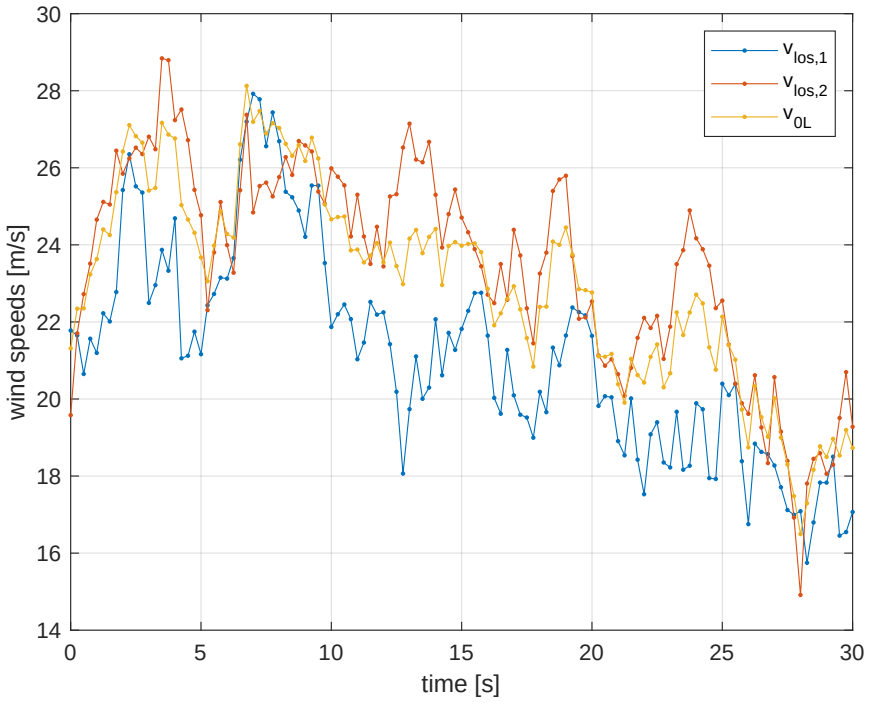

Figure 2: Line-of-sight wind speeds and rotor effective wind speed estimate from lidar $v_{0\mathrm{L}}$.

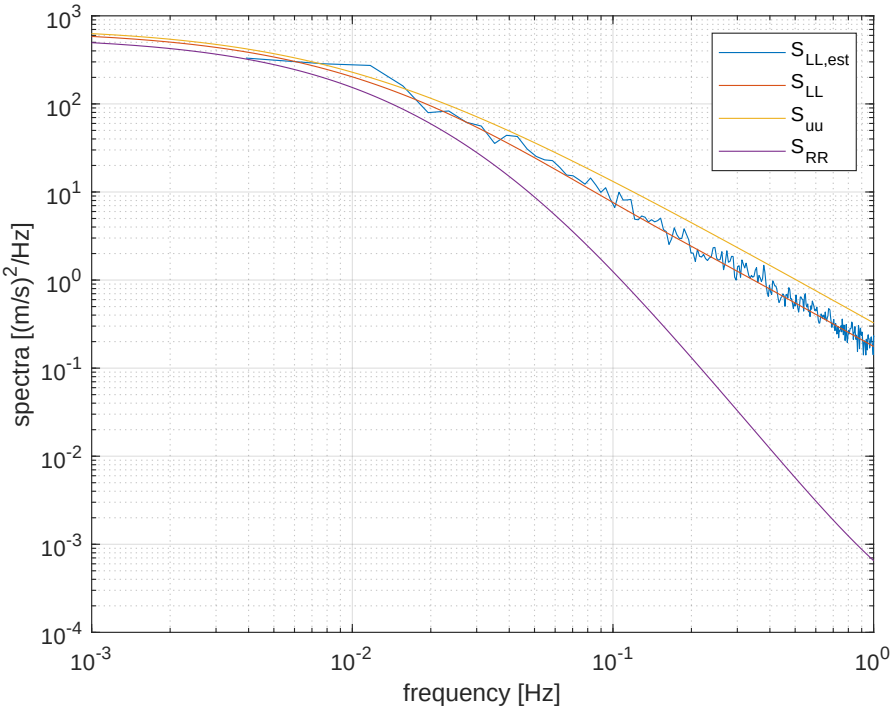

Figure 3: Analytic auto spectrum of longitudinal wind component S_{uu}, analytic spectrum of rotor effective wind speed estimate from lidar S_{LL}, and its frequency estimate $S_{\mathrm{LL,est}}$.