Chapter 11

11.1 The file “turbsigs.mat” that accompanies this problem set contains velocity signals measured in a turbulent boundary flow. Specifically, the file contains two arrays “ue_time_series”, “ve_time_series” containing simultaneously measured samples of 2 velocity components in meters per second. Each array has a dimension of 8192 x 50 and contains 50 records of 8192 consecutive samples measured at a rate of 50kHz. (a) Estimate and plot the autospectral density of wall normal velocity fluctuations $G_{vv}(f)$, where f is the frequency in Hz. Your plot should be on a log-log scale from 5Hz to 50kHz. Use axes scaled so that one decade on the horizontal axis and one on the vertical axis cover the same length on the paper (this ensures that the physical slope of the spectrum on the paper gives its power law dependency). Be careful to plot only physically meaningful results. Estimate the percentage uncertainty in your spectral estimates $100\% \times \delta[G_{vv}]/G_{vv}$. Show curves calculated both with a square window and a Hanning window and, assuming you find the differences to be small, explain why this is. (b) Estimate the spectra of coherence and phase between the u and v velocity components over the same frequency range using a square window. Plot the spectra using logarithmic frequency axes and a linear coherence axis (from zero to 1) and linear phase axis (from -180 to 180 degrees). Include a curve showing the coherence uncertainty on the coherence plot.

11.2 An engineer is tasked with performing a detailed measurement of the sound produced by a vehicle when it is producing broadband noise over a frequency range from 10 Hz to 2kHz, in addition to 150Hz and 200Hz tones.

(a) What minimum sampling frequency and record length should the engineer use to measure the full frequency range of the sound? What will be the frequency resolution of the resulting measured spectrum in Hz?

(b) In this specific case what will be the dominant effects in the measured spectrum of applying a Hanning window to the measured records in this case, once the appropriate scaling has been accounted for?

(c) How many records would you suggest the engineer measure if the uncertainty in the spectrum due to averaging is to be reduced to 1dB?

(d) The engineer simultaneously records the signal from a sensor mounted on the vehicle, and processes this along with the acoustic signal to obtain the coherence between the two, averaging for 50 records. The coherence at 150Hz is 0.07. Is this significant?