Homework #1

Signal processing

Turbulent velocity signals in a round subsonic jet have been measured using a x-hot-wire anemometer. These signals have been recorded in data files, refer to Table 1, and to the zip file *hwa.zip* to be downloaded.

$u_1 \& u_2$	$u_1 \& u_2$	$u_1 \& u_3$	$u_1 \& u_3$
$x_2 = 0, x_3 = 0$	$x_2 = D/2, x_3 = 0$	$x_2 = 0, x_3 = 0$	$x_2 = 0, x_3 = D/2$
data1.dat	data2.dat	data3.dat	data4.dat

Matlab script to read the data

```
load data1.m
t = data1( :,1);
u1 = data1( :,2);
u2 = data1( :,3);
```

Table 1 – Turbulent velocity signals for a free round jet of diameter $D = 50$ mm and exit velocity $U_j = 30$ m.s^{-1}, yielding a Reynolds number value of $\mathrm{Re}_D \simeq 10^5$. The Cartesian coordinates are denoted by (x_1, x_2, x_3) where x_1 is associated with the jet axis, and (u_1, u_2, u_3) are the velocity components. The hot-wire probe is located at $x_1 = 2D$.

You can conduct your study fairly freely ; the following points may be considered :

1. For the point located at $x_3 = D/2$ in the jet shear layer, extract the time signature of $u_1'(t)$, calculate $u'_{1\mathrm{rms}} = (\overline{u_1'^2})^{1/2}$, the skewness S_1 and the flatness T_1 coefficients defined respectively by

$$S_1 \equiv \frac{\overline{u_1'^3}}{(\overline{u_1'^2})^{3/2}} \qquad T_1 \equiv \frac{\overline{u_1'^4}}{(\overline{u_1'^2})^2}$$

2. Compare your results with a Gaussian distribution for the longitudinal velocity u_1' and comment.
3. What does the following quantity $\left(\overline{u_1^2} - \overline{u_1}^2\right)^{1/2}$ correspond to ?
4. Repeat the calculation of the previous statistical quantities for the time derivative of the longitudinal velocity component, that is $\partial u_1'/\partial t$.
5. Calculate the Reynolds tensor components $\overline{u_i' u_j'}$ on the jet axis and in the shear layer where possible. Comment your results, what is expected ?
6. By splitting the time signal $u_1'(t)$ into n segments, that are considered as n statistically independent realizations, verify that turbulence is stationary. What is the appropriate time length of each segment ? Compute the time autocorrelation $R(\tau)$ (refer to slide 11 of the course)
7. Calculate and plot the power spectral density of u_1' and u_2' measured at $x_2 = D/2$ (hint : there is a short introduction to Matlab for signal processing on the website)