

The Difference Between Data Rate and Data Density

LDV Systems

With laser Doppler velocimetry (LDV), a velocity measurement is made only when a scattering center (a particle that scatters sufficient light for the signal processor to make a measurement) passes through the measuring volume. Data rate is simply the number of measurements per unit of time made by the signal processor, usually expressed as samples per second.

If the dominant frequency in the flow is 1 Hz, a data rate of 100 samples per second would follow the dominant frequency quite well. However, if the dominant frequency in the flow is 1 kHz, 100 samples per second would not follow the flow well at all. Obviously, a better descriptor than data rate is necessary to describe how well the signal processor output represents the time history of the flow. This descriptor is referred to as data density.

Data density is represented by:

$$\text{Data Density} = \dot{N} T = \dot{N} \frac{\sigma_u}{\sqrt{(du/dt)^2}}$$

where: \dot{N} = data rate in samples/second
 T = Taylor microscale of $u(t)$
 σ_u = variance of $u(t)$

We define:

Low Data Density $\dot{N} T \ll 1$

High Data Density $\dot{N} T \gg 1$

With the above definition, data density is a good representation of how well the signal processor output is following the large scale fluctuations in the flow.



Why is data density important? First, a high data density is required to represent the time history of the flow (Figure 1). But there is perhaps velocity fluctuations that are a significant percentage of the mean flow (e.g., over 30%), even the mean velocity measured by simply averaging the particle velocities will be in error. This error occurs because, per unit of time, more measurements are made at high velocity than at low velocity. While this can be corrected, the assumptions required for accurate correction are, themselves, often invalid.

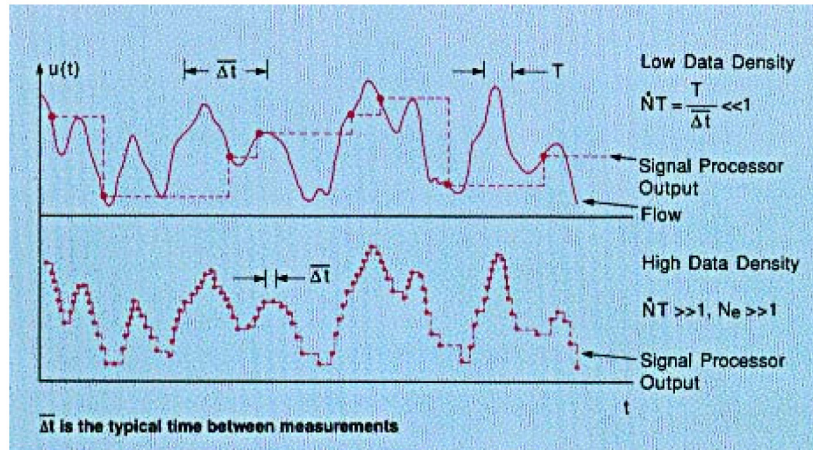


Figure 1. Low data density and high data density signals.

If the data density is high, this problem can be avoided simply by sampling at uniform time increments. The velocity sampled will be the most recent measurement of the signal processor. While it may be shifted slightly in time, the answer will be correct if the data density is high. Not only the mean velocity, but also the amplitude probability statistics will be correct.

In summary, it is very difficult to get accurate measurements when the turbulence intensity is high and the data density low. At high data density, however, uniform time sampling can be used to get accurate flow statistics. Both high seed rates and a signal processor that maximizes the number of accurate measurements are helpful in maintaining a high data density.

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