# NOVEL TECHNIQUE FOR LDV BURST SIGNAL FREQUENCY ESTIMATION

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The accuracy of velocity measurements with the LDV technique is not only limited by the accuracy of the fringe spacing and the signal-to-noise ratio of the detected signal, but also by the signal processing technique used. While a large variety of different techniques have been employed successfully for frequency estimation of LDV-signals, most of today's processors employ at some point the Fourier transform. This transform covers a range of frequency with a constant resolution Δf by using a constant time window for its data, e.g. when using a 1024 point FFT for the frequency estimation, Δf is about 1 kHz when f is 1 MHz. However, since the resolution Δf is constant over the full frequency range, a burst with 1 kHz frequency will only be resolved with 1 kHz accuracy, resulting in 100 % uncertainty. Frequencies below this point can't be measured at all. So far this problem is solved by either lowering the sampling rate or increasing the number of data points in the FFT. The first approach would make measuring the high frequencies impossible, while the later approach is also not feasible, as there are likely to be several if not thousands of bursts within the same data-range in the case of high velocities. In effect, this severely limits the range of frequencies that can be analysed at the same time without re-adjusting the measurement system. For this task of analyzing transient events like LDV bursts the wavelet transform is much better suited, as it scales its time and frequency resolution relatively to the signal frequency and duration. However, the discrete wavelet transform (DWT) alone will not provide sufficient resolution for accurate frequency estimation. While it could be adapted for this, e.g. by using so called over-complete DWT or wavelet package trees, we propose a different and simpler technique for LDV burst-signal processing, which is suited to cover a wide range of transient signals. For this we combine the scaling and re-sampling properties of the DWT with the high resolution frequency estimation powers of the FFT. Here the DWT is used to continuously filter the signal into a dyadic cascade of non-overlapping frequency bands with sampling rates appropriate to the frequencies they contain. Measuring the signal power in those bands provides a reliable way to establish if and when a burst event occurs, which otherwise would need a separate algorithm. Additionally, the DWT also improves the SNR of the signal by suppressing the frequency bands, which do not contribute to the burst. The significant part of the signal is then analyzed by standard FFT. A typical LDV signal with an SNR of 20 dB and a sampling rate that is 100 times the burst-frequency is once analyzed only by using a 1024 point FFT (fig. a) and by utilizing a combination of DWT and a 1024 point FFT (fig. b). As can be seen in fig. a) the high-frequency noise is still present in the signal and only a few points in the power-spectrum define the peak of the burst-frequency. Fig. b) shows the 4th approximation level of the DWT. Here, most of the high-frequency noise has been removed from the signal. Due to the dyadic down-sampling with every level of the DWT, the burst frequency is now well centred in the power-spectrum of the FFT and has an excellent representation in the frequency domain. In using this combined technique, high resolution measurement of LDV signal frequencies over the whole range from DC to Nyquist frequency becomes possible.
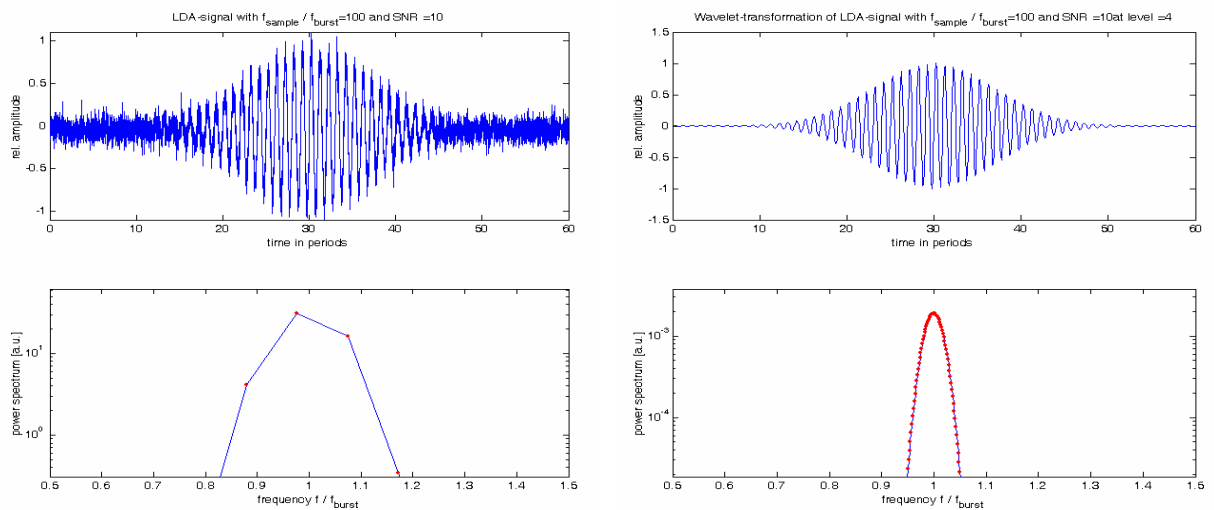
LDV Signal and power-spectrum derived by a) 1024 point FFT and b) combination of DWT and 1024 point FFT.