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Title: Vectrino – Micro ADV comparison

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Vectrino – Micro ADV Comparison

Overview

This brief report describes some results from a recent comparison between a Nortek “Vectrino” 3D Velocimeter and a Sontek “MicroADV” Velocimeter. The data were collected at the O.H. Hinsdale wave tank in Corvallis, Oregon on September 9th, 2004

The Vectrino is a new Velocimeter developed by Nortek in 2004. The unit used for this test is the property of Nortek and was manufactured for demonstration/evaluation. It was among the first 25 Vectrino manufactured by Nortek and can best be characterized as a “manufacturing prototype”. The MicroADV was developed by Sontek in 1997 and the particular unit used in the test was purchased by the O.H. Hinsdale Wave Laboratory at Oregon State University.

1) The Vectrino and the MicroADV

The two instruments employ the same acoustic Doppler principle and the same basic processing schemes for deriving the Doppler shift. However, the hardware implementation is quite different.

A) The operating frequency is not the same.

The MicroADV operates at an acoustic frequency of 16 MHz whereas the Vectrino operates at 10 MHz. The advantage of operating at a higher frequency is that the sampling volume – for the same processing bandwidth – is smaller by a factor of 1.6. This corresponds to an improvement of $1.6^2 = 2.56$ in variance. This would mean, for example, that if all of the other sampling variables remain the same, a 16 MHz system could sample 2.56 faster than a 10 MHz system. Because the acoustic signal attenuates faster at 16 MHz, it is also possible to increase the internal ping rate. The downside of operating at 16 MHz is a reduction in the SNR because of the smaller transmit pulse and because of the of the increased receiver bandwidth. Earlier comparisons between 10 MHz and 16 MHz systems have indicated a difference in about 10 dB. However, this was not an issue in this experiment because of the large number of suspended particles in the wave tank.

B) The Vectrino is not multiplexing

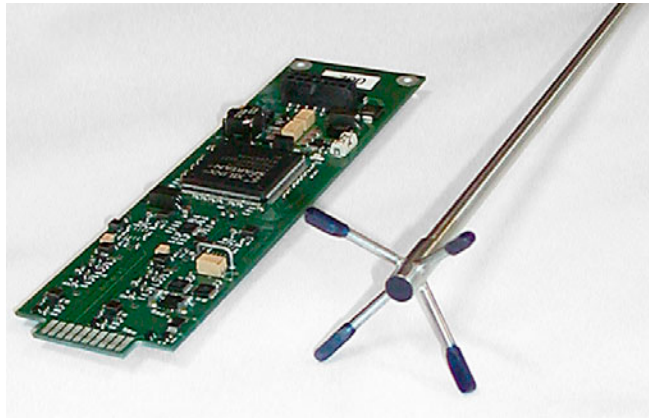
For the test, the Vectrino was configured to use the ‘plus’ firmware, where four receiver channels are processed in parallel. The MicroADV operates in “multiplexing mode”, where only one of the three receiver channels is active at a time. This gives the

Vectrino a factor of 4 advantage relative to the MicroADV if all other sampling variables remain the same.

Disregarding issues such as the exact processing bandwidth and the exact internal sampling rate (which are both quite complex issues), the difference in frequency and parallel processing give the Vectrino an advantage of 1.56 in variance. This is not insignificant but it also not a huge advantage for instruments that measure motions over many orders of magnitude. To the first order, we should thus expect the two instruments to perform quite similarly when using the same size sampling volume and the same output rate.

C) *New versus older electronics*

The MicroADV is a derivative of the original ADV developed in 1993 and the electronics are divided between a receiver board mounted inside the “signal conditioning module” and a separate unit for the processing electronics. As such, it is a two-part system. The Vectrino (right) was designed in 2003-04 to fit all of the electronics onto a single board which in turn is mounted directly onto the probe. This allows for less hassle with analog signal cables and reduces production costs. It also simplifies the task of running long cables to the data logger.



D) *The little things*

As part of the new design, several useful features were introduced with the Vectrino

- A fourth receiver arm was introduced to give two independent estimates of the vertical velocity. This provides a direct estimate of the instrument noise level and it also reduces the noise level in the vertical velocity spectrum.
- The probe was minimized to reduce the interference of the probe onto the flow inside the sampling volume (see above). The reduced flow interference is documented in tow tank tests.
- The maximum velocity range was increased by 66% (from 0.9 m/s to 1.5 m/s in the along-beam directions)
- A temperature sensor was embedded in the probe to remove the need to measure the temperature independently.

2) **Comparison in the wave tank**

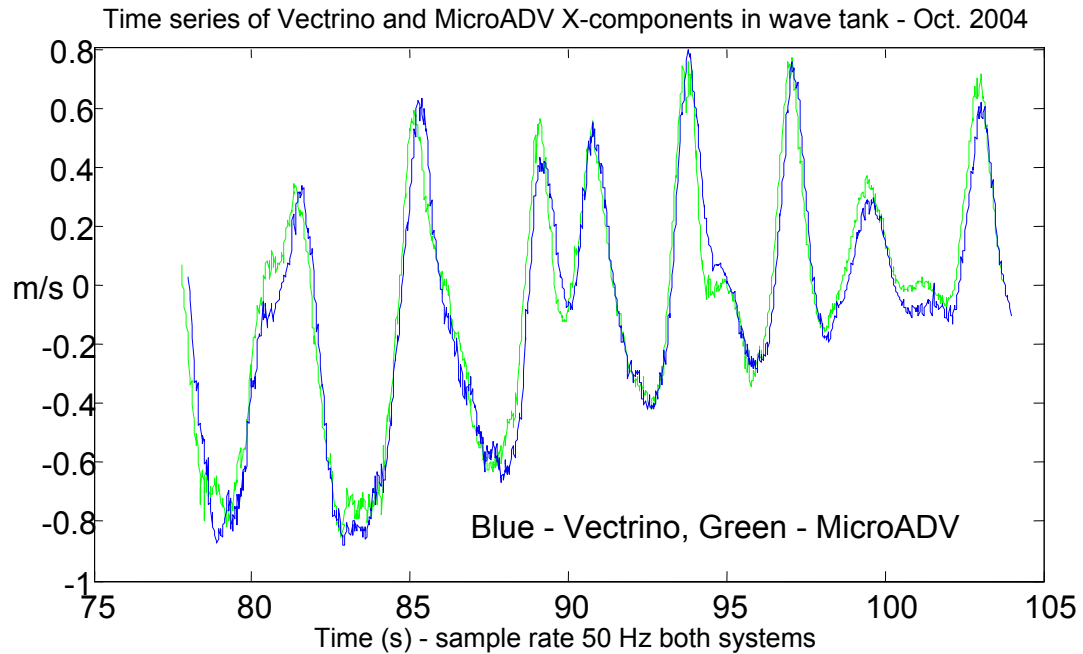
A series of experiments were conducted in the wave tank but only one times series is described here. This particular test was conducted with irregular waves and the data

were collected for about 20 minutes. The configuration of both systems was set as identical as possible:

- Output rate was 50 Hz
- The vertical extent of the sampling volume was 6 mm
- The horizontal extent of the sampling volume is defined by the ceramic size, which is the same for both instruments (about 6 mm)

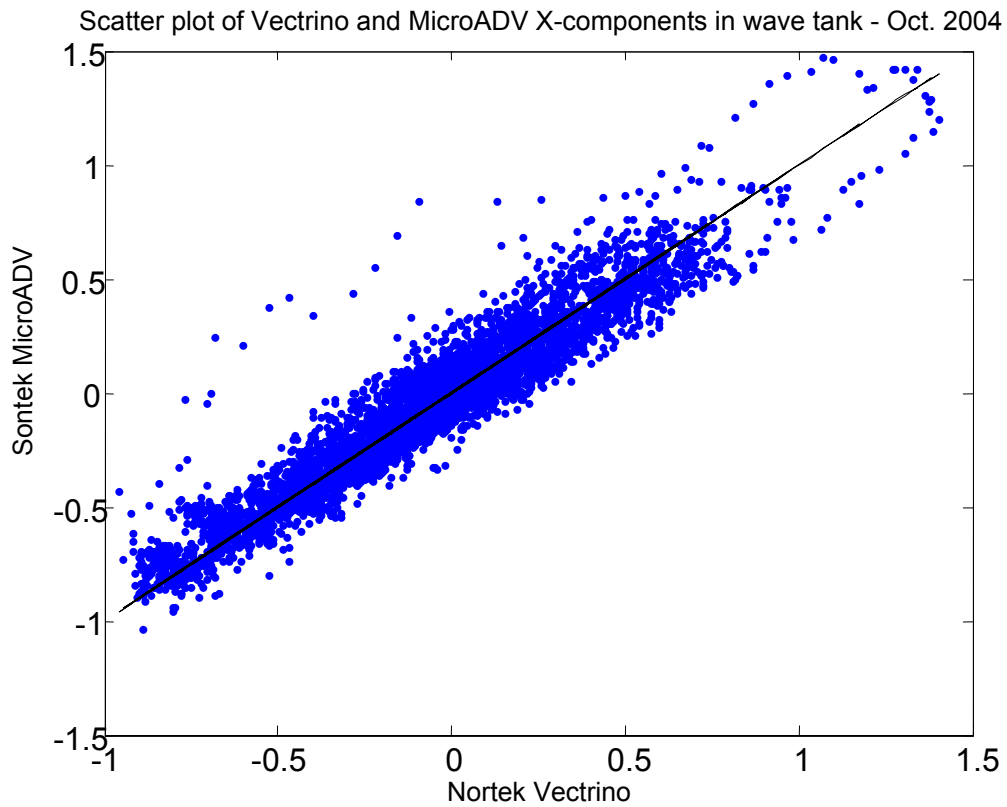
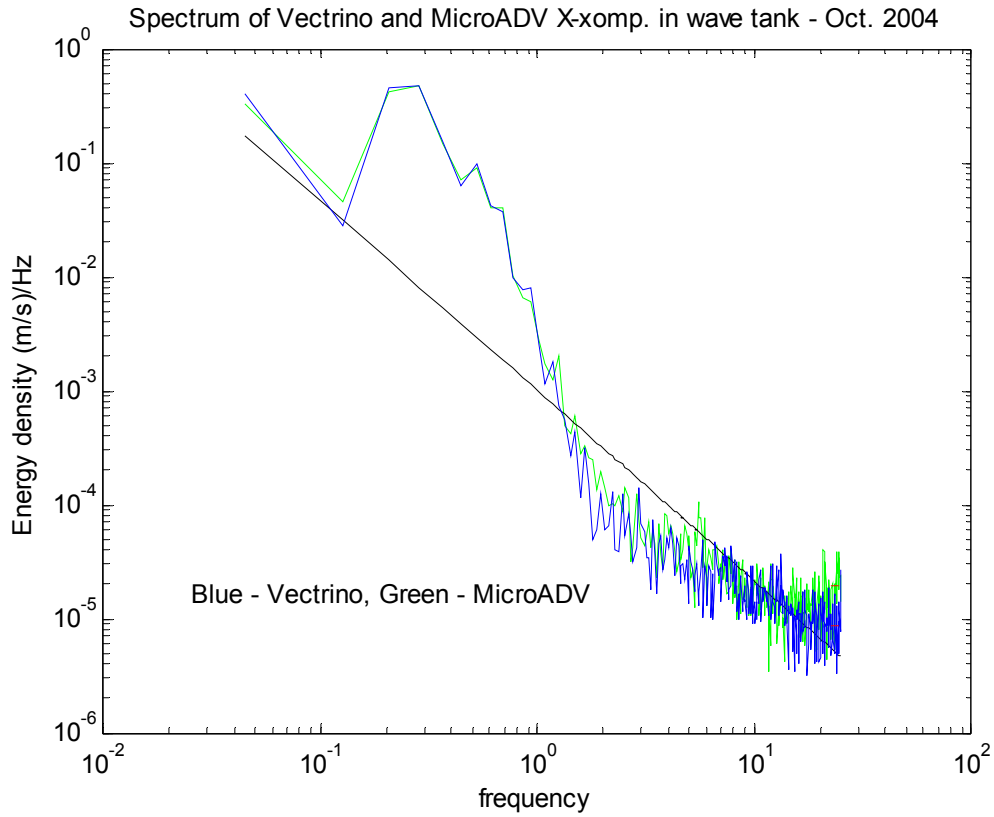


Both instruments were placed on the same horizontal line in the tank (above) and they were started at the same time with a “start on sync” trigger pulse. The data from the two sensors stayed synchronous only for a short period of time and it is clear that the internal clocks in both systems are not good enough for data collection periods extending beyond 1-2 minutes. For this reason, the function “sample on sync” (where an external sync pulse is used to control the sampling) must be used when several instruments need to sample synchronously for long durations.



From the first figure – showing the along tank velocity for both instrument - it is evident that the velocity data is almost the same, although there are small difference in crests, troughs and phased-coupled harmonics. Most likely, this is due to small horizontal variations in the wave field, although it cannot be ruled out that probe interference plays a role. This latter issue can be analyzed by placing the probes horizontally but this was not done during this test period.

Since the timing between the two instruments was off after a couple of minutes, a direct comparison of the velocity data is difficult. A scatter plot (below) was developed based on the best possible timing adjustments. The plot still shows quite a bit of variability due to the variable timing but the regression offset is close to zero and the slope is between 0.93 – 0.98, depending on the method used. It is a little surprising that the slope is not quite 1:1 but it is possible that the MicroADV probe was mounted a little closer to the bottom than the Vectrino.

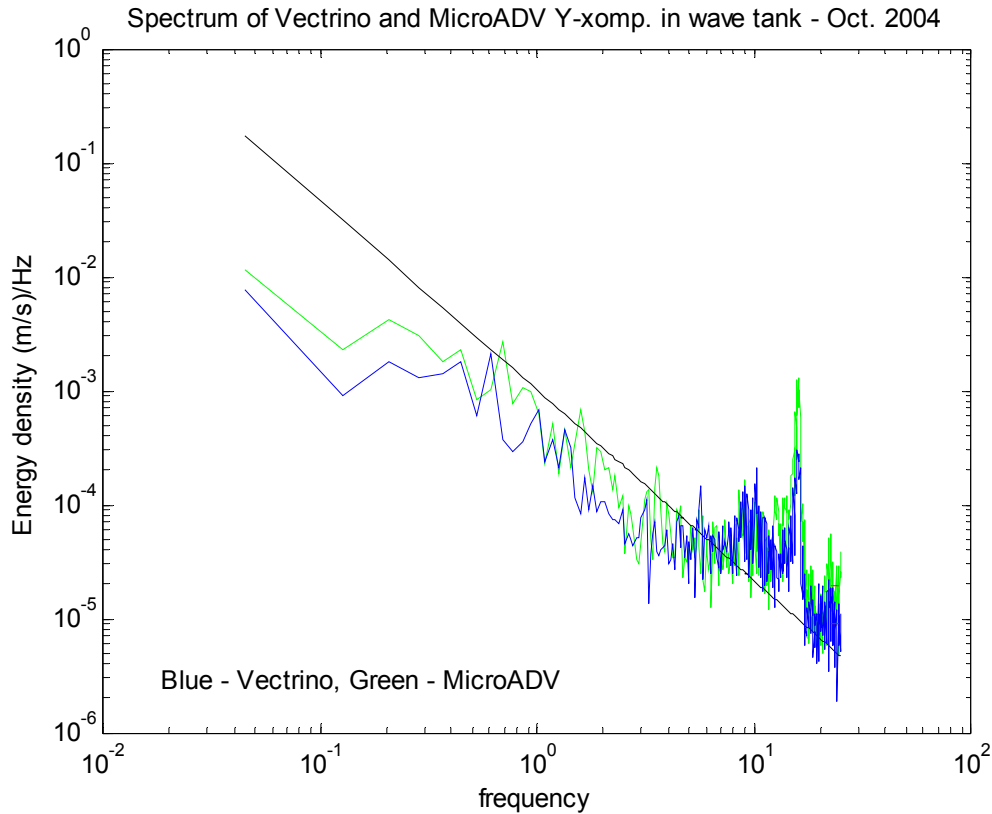


In the 20-minute time series, there are periods where one or both sensors show excessive noise in the velocity signal. This is thought to be caused by bubbles induced by breaking waves, which will disturb the acoustic signal. These events were about evenly distributed between the two instruments.

The plot above shows the spectrum based on 5000 data points collected during a period with a very clean velocity signal from both instruments. The data series is taken from the along-tank velocity and both instruments show similar signal levels at the wave frequency (about 0.25 Hz or 4-s periods). Beyond the wave peak, the signal level drops off quickly before it seems to approach an instrument noise level around 20-25 Hz. The spectra are very similar but a little different at the very highest frequencies, where the MicroADV seems to have more energy than the Vectrino. The reason for this is not quite clear; perhaps the MicroADV velocity contains high-frequency signals (generated from the mounting structure or from the probe stem) that are aliased into the spectrum.

If we assume that the end of the spectrum (from 20-25 Hz) constitutes the instrument's noise level, it would indicate that the MicroADV noise level is higher by a factor of 1.2-1.3, which is close to the theoretical factor calculated by simply looking at the difference in acoustic frequency and the parallel processing implemented in the Vectrino.

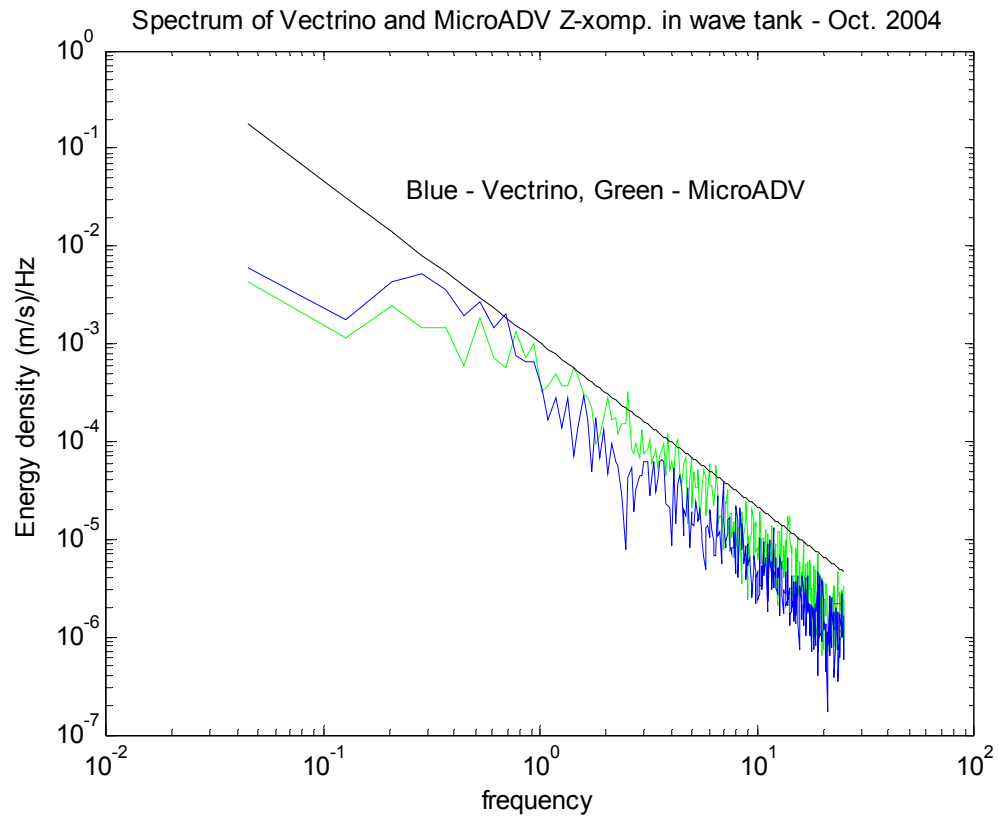
The cross-component of the velocity has very little energy but shows clear resonance around 15 Hz. This peak is seen in both instruments and indicates that the mounting frame is oscillating. While not a serious problem (....as long as the oscillations are in the direction perpendicular to the wave direction), it illustrates the importance of a firm mounting structure for velocity instruments that are sampling this fast.



The final plot (next page) shows the spectrum of the vertical velocity component. The straight black line depicts the $-5/3$ line, normally corresponding to the turbulent energy cascade. The Vectrino and the MicroADV show almost the same feature but not quite – there is more energy in the Vectrino around the wave frequency but less turbulent energy. Again, the reason is not quite clear but the vertical position of the sampling volume is critical for both issues. Further tests are required to determine the exact nature of these relatively small but still important differences.

3) Conclusions

A new Vectrino Velocimeter from Nortek and a MicroADV from Sontek have been tested and compared in a 2D wave tank under irregular waves. Both instruments collected data at 50 Hz and show similar results. Some smaller differences exist both in the velocity time series and in the spectra, encouraging further studies into the exact performance characteristics of the two instruments.



Acknowledgements

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