The Evolution of a Deep Water Current Meter, The Argonaut-MD

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***Abstract* – The Argonaut-MD (mooring deployed) is a single-point, vector-averaging, current meter that measures three-dimensional velocities. The MD, released in 1996, was the first of SonTek's line of low-power Argonaut acoustic Doppler current meters. The design allows for a relatively small and light package that can be used on mooring deployments of over one year.**

Doppler current meters typically have difficulty in low-scattering conditions. Insufficient scatterers results in backscatter signals that are near or below a system's noise levels; however, the MD's short-range one-cell design provides robust velocity measurements in some of the weakest scattering conditions.

In this paper we will show how significant increases in sensitivity for the MD have been accomplished. Acoustic signal to noise ratios have been improved 6 to 12 dB by shifting the acoustic pulse frequency, enhancing the systems analogue electronics and altering transducers. Notably, these modifications have little impact on deployment durations.

I. Background

Research and environmental monitoring require velocity measurements in virtually all oceanographic conditions, from high sediment loaded waters to extremely-clear deep oceans. While acoustic Doppler current meters have had over 20 years of successful application, some limitations have been found, especially in regions with few scatterers.

Doppler current meters measure water velocity by using acoustic pulses (also known as pings). The acoustic pulses reflect from scatterers (backscattered) and are received by the current meter's transducers. The measured Doppler or phase shifts of the backscattered pulses are directly proportional to the speed which the scatterers are moving towards or away from the transducer. The water velocity is determined, by assuming that the scatterers are being advected by the water.

The strength of the backscattered signal is dependent on a number of variables. Transmission losses along the sound beam's path are due to reflection, refraction, absorption and scattering [1]. Thus, some acoustic energy is attenuated before the acoustic pulses reflect from scatterers. The scatterers can be everything from sand, to air bubbles, to temperature microstructures [2,3,4]. The amount of energy that is reflected depends on the shape, size, distribution, composition, surface characteristics, concentration and other properties of the scatterers [5]. In certain conditions, particularly regions of low scatterer concentrations or high transmission losses, the backscattered acoustic signal can be below the detection threshold of the current meter.

The Argonaut-MD (Mooring Deployed) was designed as a single point current meter that can be used in the deep oceans. These regions characteristically have low-scattering conditions that significantly reduce the effective range of profiling acoustic Doppler current meters. However, the MD's short-range single-cell design works robustly in low-scattering conditions because of limited transmission losses. Though the MD has a history of proven performance, SonTek continues to improve the MD's sensitivity for enhanced performance in low-scattering conditions.

II. The Argonaut-MD

The Argonaut-MD (Fig. 1), acoustic Doppler current meter, was developed in 1996 by SonTek. It is the first of a family of current meters that are based on the compact, low-power, CMOS Argonaut set of electronics. The MD is designed as a low-power, self-contained, long-deployment, vector-averaging current meter that is capable of working on moorings in the deep oceans and in low-scattering conditions. Its design allows the MD to be deployed for durations of over one year with a standard alkaline battery pack.

The MD's pressure housing is manufactured with two different materials. The Delrin pressure housing has a maximum depth of 600 m and the fully Titanium pressure housing has a maximum depth rating of 6000 m. Both materials are highly resistant to corrosion.

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Fig. 1. Argonaut-MD with a Titanium pressure case.

The Argonaut-MD is a relatively small current meter. Both Delrin and Titanium MDs have a 10.2 cm diameter but they are produced in three lengths. The standard length (67.5 cm) housing has sufficient alkaline battery capacity for deployments of more than a year. The shorter 44.5 cm pressure case is useful for short term deployments of a few weeks. The real-time system at 35.6 cm contains no batteries at all. The MDs are also relatively light. Standard sized systems in Delrin and Titanium are respectively 1.4 kg and 7.7 kg in water.

The MD is a complete package with standard internal batteries, 4 MB recorder, compass, tilt and temperature sensors. The 4 MB recorder will outlast the battery packs under most circumstances. The compass and tilt sensors are sampled to produce vector averaged currents relative to magnetic north or true north with a user input magnetic declination. The measured temperature and user input salinity are used to estimate the *in-situ* sound speed. This assures that the accuracy of the MD's measured velocities is within 1% because the velocities depend on the sound speed.

Other optional sensors can be integrated with the MD. A strain gauge pressure sensor can be installed internally. The electronics of SeaBird's inductive modem, for long range communications along mooring lines, can be integrated internally; while a SeaBird MicroCat that measures conductivity and temperature can be integrated externally with its data being logged on the MD's recorder.

Two different acoustic frequencies are used with Argonaut-MDs. Classically, the Delrin systems used 3.0 MHz pulses and the Titanium systems used 1.5 MHz pulses. This was because of the respective advantages of the two frequencies. The 3.0 MHz system requires a cell size and pulse length that is half that of the 1.5 MHz system to get the same velocity precision. However, the transmission losses of the 1.5 MHz pulses is significantly less; thus, a 1.5 MHz system is preferable in the low-scattering conditions of the deep oceans where the Titanium systems are typically used.

III. Deployment and Results

The Argonaut-MD has been deployed in diverse environments. A deep deployment on Endeavour Ridge by the Institute of Ocean Sciences in Victoria, Canada demonstrates that the MD can successfully operate in low scattering conditions.

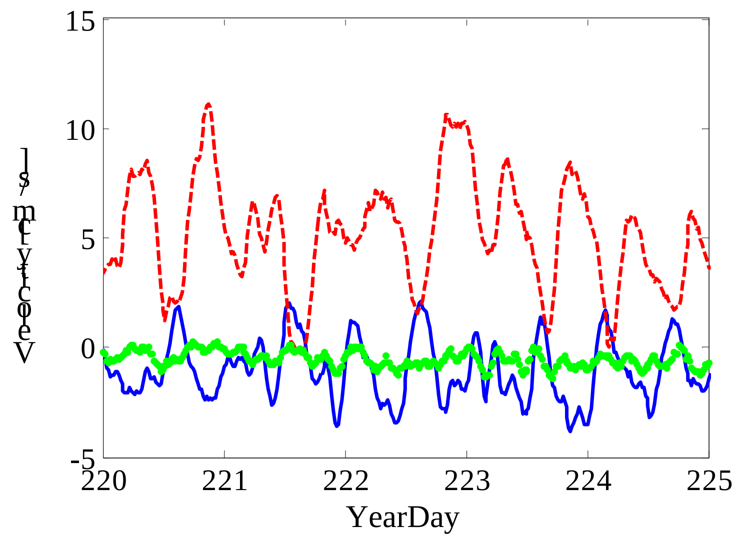

Fig. 2. A section of the low-passed filtered velocity data from Endeavour Ridge. Easting velocity is the solid, blue line, Northing is dashed, red line and the vertical velocity is the dotted, green line.

The Argonaut-MD was at a depth of about 2000 m and in a region of low-scattering conditions. The ocean currents were sampled every 20 minutes for over 83 days. A short section of the velocity data is shown in figure 2. The mean current speed during the 83 days was approximately 5 cm/s and the maximum speed was about 15 cm/s. According to the Institute of Ocean Sciences, the velocities measured by the MD were highly correlated to those observed by two other co-located current meters.

The velocity data's precision is given by the per-sample, mean, standard error of the three velocity components (Fig. 3). For the entire deployment, the standard error was on average 0.38 cm/s and was always below 1 cm/s. These numbers are quite acceptable but might have been improved with longer averaging intervals for each sample.

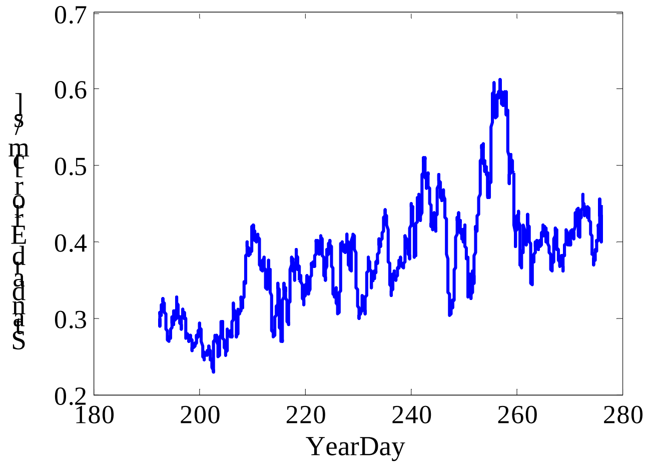

Fig. 3. The standard error of the velocity data. The standard error of the three velocity components was averaged together and the resultant was filtered with a 51 point running mean.

While the velocity data was excellent during the deployment, the backscatter signal was relatively weak. During the entire 83 days, the backscatter signal strength was above the system's noise level of about 9.9 dB (Fig. 4). However, at times the difference between signal and noise was as small as 2.7 dB. The MD provided robust velocity data in the poor scattering conditions of Endeavour Ridge; however, SonTek was concerned that in regions of significantly weaker scattering conditions the MD might fail.

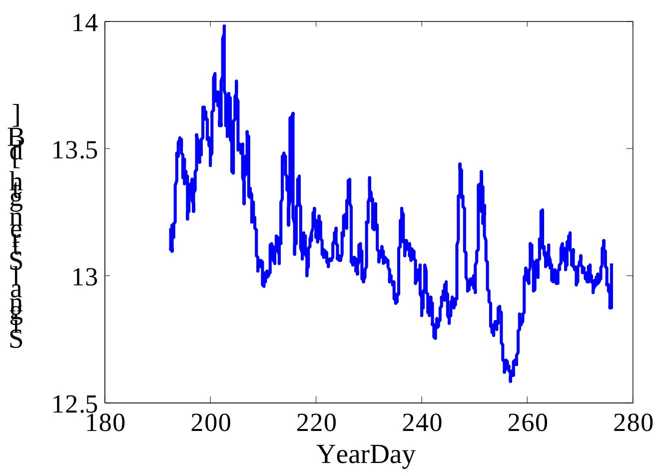

Fig. 4. The average signal strength from the three beams of the MD.

SonTek has decided to solve this potential problem by improving the sensitivity of the MD. A simple solution is to increase the amplitude of the acoustic pulse. However, this would produce an unacceptable increase in the power usage and consequently a decrease of the deployment duration. Instead, improvements have to increase the sensitivity of the MD without significant impacts on the power usage.

IV. Sensitivity Improvements

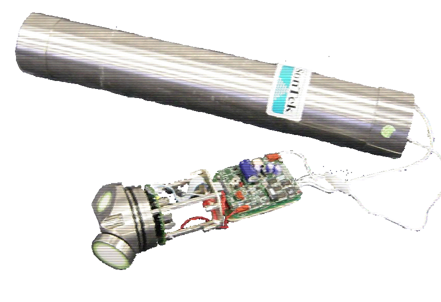

Fig. 5. Argonaut-MD test unit. Both the standard 20 mm transducer and a larger 40 mm transducer are visible.

SonTek uses three approaches to improving the sensitivity of the Argonaut-MD. The first and simplest is to build the 1.5 MHz system with Delrin housings and not just Titanium. The second is an enhancement of the analogue electronics for both 3.0 and 1.5 MHz systems. The most significant development is the use of larger transducers on 1.5 MHz systems.

The simplest improvement of the MD impacts only the Delrin systems. By using 1.5 MHz pulses with Delrin systems, the improved low-scattering characteristics of the lower frequency is now available on all systems and not just the deep-deployable Titanium systems. SonTek has one other sensitivity improvement for the 3.0 MHz systems and two improvements for the 1.5 MHz systems.

A test unit has been built to evaluate the developments of the 1.5 MHz deep-deployable Argonaut-MD (Fig. 5). The test MD has three different beams – there is one standard 20 mm transducer with the classic analogue electronics, the second beam also has a 20 mm transducer but the analogue electronics have been improved and the last beam has a 40 mm transducer and improved electronics. All other parts are the same as a normal production unit.

Laboratory and ocean tests were run to evaluate the improvements in sensitivity. Typical results from one of the shallow ocean tests (Fig. 6) indicate large increases in signal strengths for the modified beams. The signal from the 20 mm transducer with the standard electronics starts at 40 dB and drops to below 15 dB by the time the acoustic pulse travels 3.5

m from the head. The 20 mm transducer with the modified analogue electronics starts at 40 dB but only drops to 22 dB after traveling 3.5 m. The signal from the 40 mm transducer has the least reduction with range. Even at 5 m, the signal strength stays above 20 dB. At 3.5 m the signal is approximately 27 dB – about 12 dB greater than the 20 mm transducer with unmodified electronics and about 5 to 6 dB above the 20 mm transducer with improved electronics.

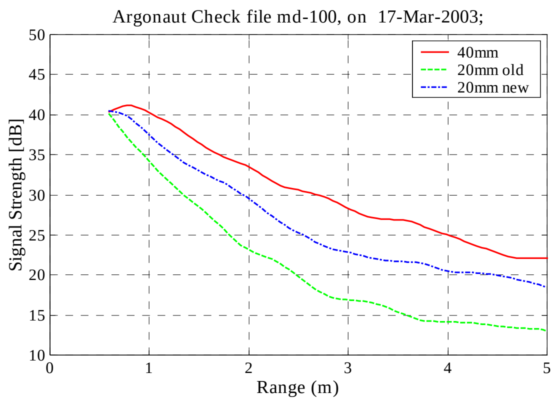

Fig. 6. Argonaut-MD test results. The lower line is the standard 20 mm, the middle line is the improved electronics with 20 mm transducer, and the upper line is improved electronics with 40 mm transducer.

From multiple tests, the average increase in signal strength by improving the analogue electronics is approximately 3 dB. By converting to a 40 mm transducer, the signal strengths improve by about 9 dB over the 20 mm transducer with unmodified electronics. If we consider the results from figure 4, a 9 dB increase in signal strength is greater than the entire variability of the signal strength during the deployment at Endeavour Ridge. Thus an improved Argonaut-MD with 40 mm transducers can be expected to work in significantly more demanding scattering conditions than those observed at Endeavour Ridge.

V. Conclusions

SonTek developed the Argonaut-MD into a small, complete package for measuring currents within the oceans. While it has been a proven vector-averaging current meter, there has been some room for improvements in the system's sensitivity. SonTek has addressed this by three proven methods.

- The simplest is to use the lowest MD frequency, 1.5 MHz, for both the Titanium and Delrin systems. Hence, taking advantage of the lower transmission losses of the 1.5MHz pulses for shallower deployments.
- Analogue electronic modifications of both 3.0 and 1.5 MHz systems provide improvements of at least 2 to 3 dB in sensitivity. This is the only modification that affects systems of either frequency.
- Increasing the transducer size from 20 mm to 40 mm has made a dramatic impact on the 1.5 MHz systems. This increase of four times in transducer surface area increases the sensitivity by 6 dB.

Thus, a new 1.5 MHz MD with 40 mm transducers can have signal strengths of at least 4 to 8 times greater than older MD systems. Importantly, these enhancements do not degrade deployment durations.

The improvements in sensitivity will allow Argonaut-MDs to work in much more demanding low-scattering conditions than observed at Endeavour Ridge. Further tests will evaluate the enhanced MDs within other low-scattering areas of the deep-ocean. Future developments in hardware and downloadable firmware will continue to improve the Argonaut-MD's capabilities.

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Acknowledgments

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