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1. Can the AquaTrak™ be used as an altimeter and velocity log?

Yes. AquaTrak™ does not need to know the speed of sound to estimate the velocity, as it uses an advanced spatial cross correlation technique, where it measures the displacement between two very closely spaced adjacent pulses as seen by two or more receive elements.

The difference in observed position is therefore a function of the difference in the positions at which the two pulses were transmitted. The velocity estimate is then calculated by dividing the known distance between the receiver elements by the correlation time delay between the measured return of the two pulses.

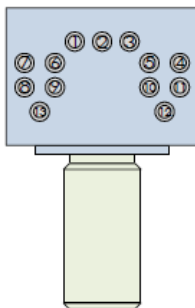
The altitude is estimated during the first stage of this calculation process using the cross correlations between all channels for two adjacent pulses. This assumes a speed of sound of 1500 m/s unless an external speed of sound value is provided.

2. What are the data output formats?

AquaTrak™ provides outputs in PD4, PD6 and PD11 formats across both Ethernet and serial (RS232) as standard. Units can be factory configured to output RS485 instead of RS232 if required.

3. What connector does AquaTrak™ use?

AquaTrak™ is supplied as standard with a Subconn power Ethernet right angled connector Model DLPBH13M.



SUBCONN DLPBH13M	
PIN #	SIGNAL
1	GND
2	SHIELD
3	TRIGGER-
4	RS485 TX+ / RS232 TX
5	RS485 TX- / RS232 RX
6	RS485 RX+ / RS232 GND
7	RS485 RX-
8	ETH TX-
9	ETH TX+
10	ETH RX-
11	ETH RX+
12	PWR (18 - 75VDC)
13	TRIGGER+

AquaTrak™ is also available with a 7 pin, serial only connector as a direct drop in replacement for an RDI DVL. Please contact Trittech for further details.

4. How does the AquaTrak™ CVL differ from a DVL?

All DVLs work by measuring the Doppler Effect, which relies on accurately knowing the speed of sound. This creates a number of issues, which are overcome by a CVL which calculates velocity independent from the speed of sound.

The Doppler shift is a function of seabed incidence angle, so in the presence of a rapidly changing topography the scatter in the estimates will be higher due to mismatched topography between forward and aft beams of a DVL, and in the presence of a seabed slope or DVL array head orientation error, there will be a bias that is not accounted for. In other words at high altitudes with 4 beams transmitting at a 30° offset, there will be a large distance between the returns from each beam, which could mean that the forward beam get a return from 200m range and the aft beam from 100m, resulting in an inaccurate altitude estimate, as it is averaged across the returns from the 4 beams.

Also, the finite beam width of the DVL gives rise to a range of incidence angles and hence Doppler shifts. A DVL needs a narrow beam to provide a more accurate estimate, which in a small unit means using a high frequency. As the frequency increases, the acoustic absorption increases, so there is a contradicting requirement; in order to limit the physical size a high frequency is required for a narrow beam, but the absorption is high at that frequency.

By comparison the CVL uses a single downward looking wide beam and transmits two or more pulses at a calculated transmit separation in time. As the beam is down looking and the pulses follow the same path through the water they both see the same speed of sound profile and there is no error from sound speed mismatch.

To calculate velocity, instead of using Doppler, the CVL uses the spatial cross correlation coefficient between two identical pulses whose transmit times are close together (a pair of pulses makes up a ping).

The CVL therefore doesn't need to know the speed of sound, as it is not measuring the Doppler Effect. The CVL is measuring the displacement between 2 adjacent pulses as seen by two or more receive elements. If you know the spacing between the receive elements, you know the distance travelled between the two pulses and can therefore calculate the velocity. A perfect correlation is 1 and then goes down to 0.999, 0.998 etc.

The maximum distance between the two furthest spaced receive elements in the CVL limits the speed and ping rate at which you can operate, however the time interval between the two pulses is very short and is determined by the largest separation between the receive elements. The time interval varies according to speed, and the length of the pulses varies according to the depth of the seabed.

Thus if the CVL is not moving at all, the signals look identical from the same position, and all receiver elements correlate with themselves with high correlation coefficient, hence why the CVL performs particularly well in hover mode. If the head is moving forwards with a given speed, then cross

correlation of all channels with the first pulse, with all channels with the adjacent pulse, performs a search for the maximum cross correlation coefficient.

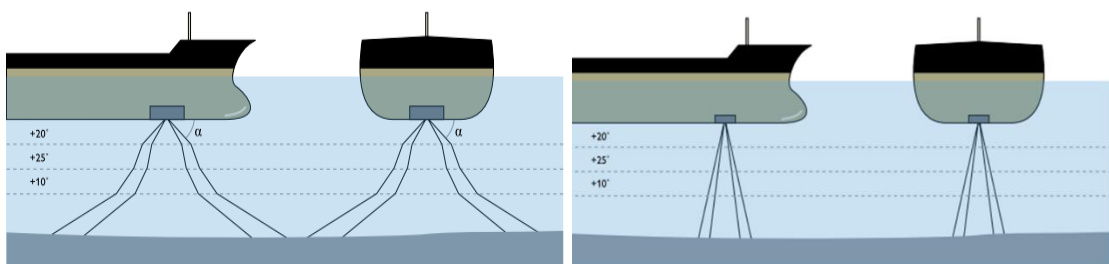
The displacement of the unit is determined from the position of a 2D spatial correlation function. The position of the peak indicates the direction of travel relative to the main axis of the array, and its distance from the centre of the array indicates the speed.

The correlation coefficient is proportional to the similarity between the two pulses and is thus unaffected by speed of sound, seabed topography, and array head orientation (the receive elements must be able to see both pulses however). Also as the speed of the head approaches zero the number of correlating elements increases, and so the unit is very sensitive to motion near to zero speed, i.e. in hover operations.

AquaTrak™ therefore offers a simpler solution which is also capable of achieving a lower bias in the speed estimates. The use of a single down looking beam, with vertical incidence, also means that the seabed backscatter is considerably higher than a tilted beam, and thus that the source level requirement is reduced. Also the elements are flush with the front face, so there is no protrusion into the current flow.

5. What benefits does AquaTrak™ CVL provide over a DVL?

- Robust tracking solution even in rapidly changing topography, unlike a DVL where the Doppler shift is a function of the seabed incidence angle.
- Unaffected by the speed of sound as the CVL uses a vertical beam and therefore there is no error from speed of sound mismatch per the figures that follow. The CVL is a spatial estimate based on the distance moved between the two adjacent pulses and is not reliant on the Doppler Effect.



- Unaffected by array head orientation or misalignment – as long as both pulses transmitted a few ms apart insonify the same patch of seabed as viewed from two correlating receive elements. The CVL is unaffected by pitch and roll as the interval between the pulse pairs is so small that there is no measurable motion between the pulses and where there is, it does not exceed the footprint of the transmit beam.
- Unaffected by vehicles/vessels speed, provides high accuracy even at zero speed as it does not rely on measuring the Doppler shift to calculate velocity.
- Requires reduced source level as the single downward looking beam means the seabed backscatter is considerably higher than a tilted beam used by standard DVLs with a Janus beam configuration, i.e. the majority of the energy is returned from the seabed rather than being scattered out the sides.
- Unaffected by cavitation/turbulence across the sensor face (same as phased array DVL) as the CVL has a flat planar array.
- Offer same performance irrespective of altitude by using spatial correlation to derive altitude estimates. In addition as the CVL uses a vertical beam and is calculating the velocity based on the time delay between two adjacent pulses, the transmit beam and the return signal are from the same patch of seabed, as opposed to a DVL where the forward beam may insonify a patch of seabed with a significantly different altitude to the aft beam, resulting in a large bias.

6. What benefits does an AquaTrak™ CVL provide for ROV and AUV use?

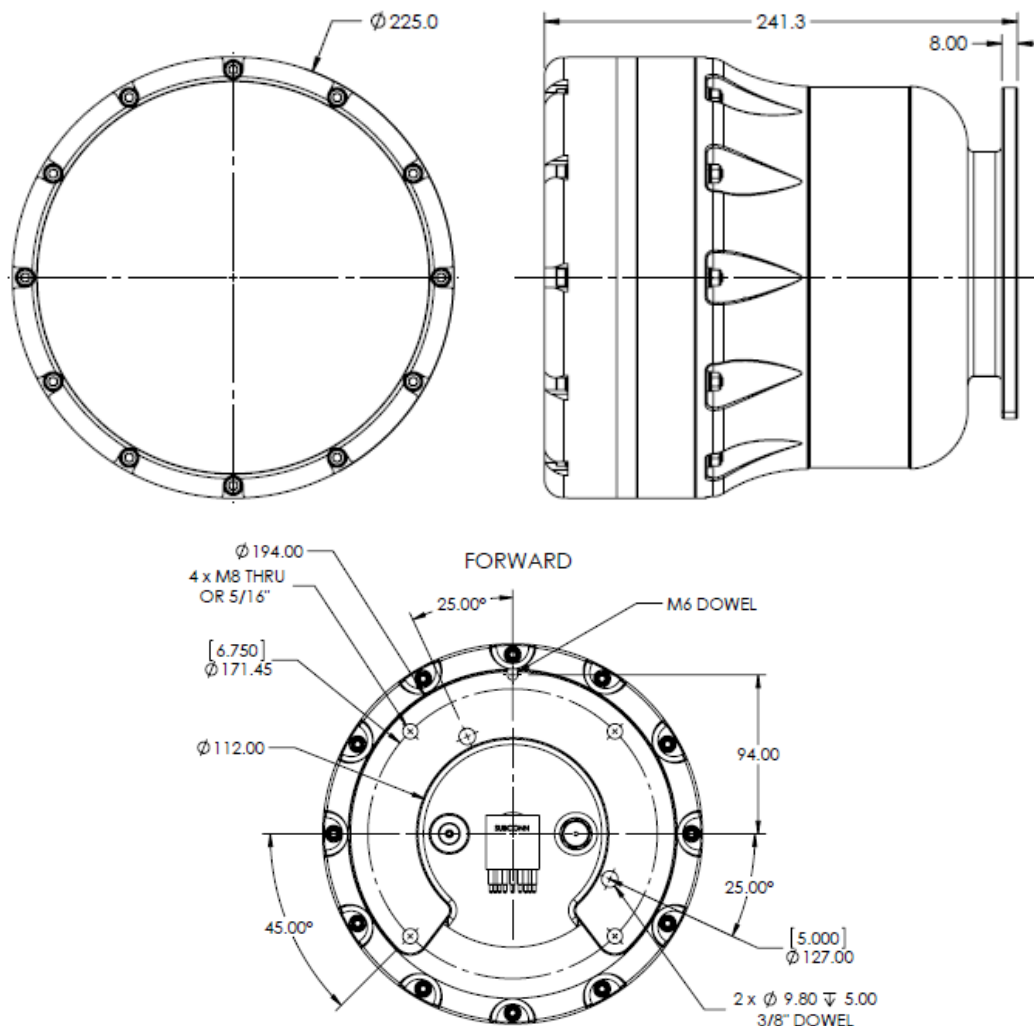
For ROV use	For AUV use
Near hover performance	Bottom lock/high altitude bottom lock
Independence from sound velocity	Independence from sound velocity
Long term accuracy (improved overall drift with or without USBL aiding)	Long term accuracy (improved overall drift with or without USBL aiding)
Less dependence on USBL	Lower power requirements for increased range
Lower noise at high velocities due to reduced cavitation	Lower noise at high velocities due to reduced cavitation

A CVL or DVL are just one component in an overall navigation solution for both ROVs and AUVs. Central to all navigation solutions is a Kalman filter with the overall accuracy of the navigation system being affected by all the inputs. If you can improve the solution by using a CVL instead of a DVL and therefore remove the reliance on the speed of sound input to improve the overall accuracy, you improve the overall velocity solution. In addition if you can obtain bottom lock quicker by having a longer range/high altitude bottom lock, you are less dependent on the USBL system.

7. How is AquaTrak™ configured?

AquaTrak™ is configured via a set of registers. These are programmed over the Ethernet or RS232, using a basic terminal-like interface such as PuTTY which Trittech can supply.

8. What are the dimensions of AquaTrak™?



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9. What is the weight of AquaTrak™?

Weight in air: 14.5kg, Weight in Seawater; 6.9kg (density 1025 kg/m³)

10. What material is the AquaTrak™ housing?

6061-T6 Aluminum, Hard Anodized

11. Is the update rate set by the user?

No. Each ping is made up of pulse pairs and triplets, or pulse groups. The pulse separation in a group is a function of speed. The unit will operate with as many pulse groups as possible to maximise the sample rate and hence maintain the speed accuracy, while avoiding multipath interference. The precise timing of the pulse pairs and associated blanking zones around them, which are to prevent interference between pulse pairs, is a function of seabed type and altitude. The timing will be updated dynamically as the unit processes data.

The pulses will be transmitted in closely spaced groups of up to three pulses per group. The PRI is the interval between repetitions of the pulse sequence, defined by the altitude above seabed. The minimum number of pulses per second, bearing in mind they will be transmitted in bursts, is 10. The maximum is approximately 30.

12. Is CVL technology new?

No. CVL technology has been around for a number of decades, but previous generations of CVL technology had the following issues:

- Size – large low frequency transducers
- Precision – low bandwidth
- Power – long pulses and wide beams
- Processing – limited electronics
- Costs – similar to the large low frequency DVLs
- Design – large arrays for spatial redundancy

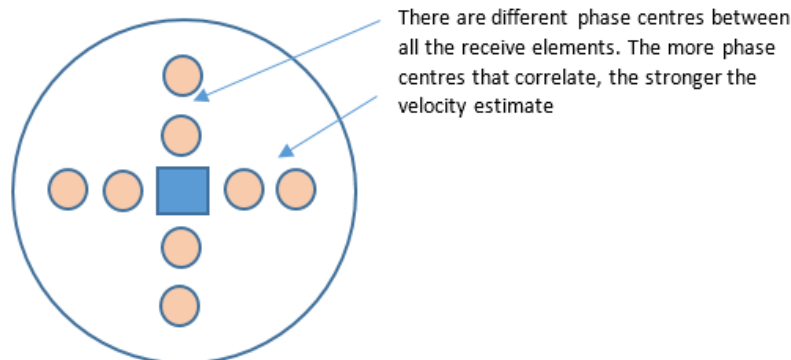
The speed and robustness of motion compensation algorithms, and complexity of minimum redundancy transducer designs have been barriers to entry for most sonar manufacturers.

13. AquaTrak™ uses Synthetic Aperture Sonars (SAS) processing, can you explain?

AquaTrak™ relies on the same theory as the SAS motion compensation, which is that the phase centre position defined by a transmitter and receiver pair remains stationary if the positions of the transmitter and receiver are swapped. Aquatrak™ performs a spatial search for the phase centre position that is common between two pulses. This is the same as for SAS, with the only difference being geometry.

14. How many transmit and receive elements does AquaTrak™ have?

AquaTrak™ uses 8 receiver elements and 1 transmitter. The receive elements are arranged in a pattern that fully samples the displacement of the correlation function over the area of the array head, with no redundancy. Using more than 8 would give an oversampled array head. Using less than 8 would reduce the along track and / or across track speed envelope and reduce the accuracy with which we estimate the displacement of the correlation function.



The design of the AquaTrak™ array is optimised to ensure full redundancy, with the receive elements uniquely spaced to generate as many phase centres as possible, to achieve the highest correlation possible.

15. Is there any internal data logging and if so what is the storage capacity?

No, there is no internal data logging.

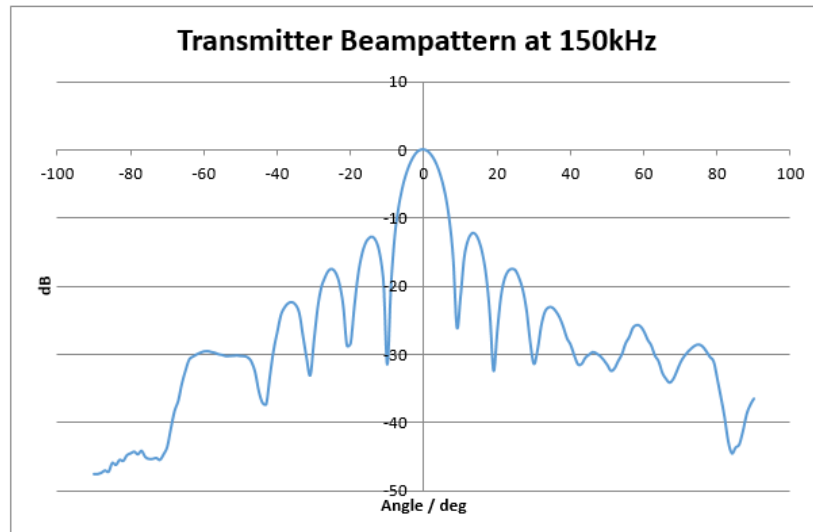
16. What type of ping trigger can the system use?

AquaTrak™ accepts a trigger input on RS422.

The separation between pulses in a pulse train, equivalent to a single ping cannot be externally controlled, however this separation is very short, so the pulse train can be compared to a typical sonar ping e.g. if each pulse is 1ms, and there are three pulses used in the current pulse train, then with a pulse spacing of 10ms, then effective pulse train length or ping is 23ms. This train or ping would be transmitted each time an external pulse trigger is received.

17. What is the transmit beam width and shape?

The transmit beam width is $8.3^\circ \pm 1^\circ$ and is designed to give enough scatterers for a good spatial correlation function. The receiver elements have a wider beam width, such that the response of the system is dominated by the transmit beam, and the spatial correlation function is well sampled by the separation of the receiver element phase centres.



18. Why does AquaTrak™ not need a narrow beam width to achieve accuracy?

Unlike a traditional sidescan, AquaTrak™ uses the spatial dependence of the backscatter time series. A wide transmit beam is used to insonify a large patch on the seabed so that the receive elements see returns from the same ping, to allow cross correlation between the pulses that make up each ping. The wider the patch of seabed, the quicker it de-correlates as the sonar head is displaced.

In other words, the time series changes more quickly as a function of the movement between two pulses being transmitted and received.

19. What is the minimum altitude/range?

0.5m.

20. What is the long term velocity accuracy?

0.1% +/- 0.1cm/s.

21. What is the input voltage range?

18-75 VDC.

22. Does AquaTrak™ have a pitch and roll sensor and if not why not?

No, AquaTrak™ does not have an internal pitch and roll sensor.

Because the CVL has a broad transmit beam, it is less affected by pitch and roll of the vehicle and it is not reliant on a narrow beam. The wide seabed footprint de-correlates more quickly. The CVL is therefore relatively insensitive to the effects of pitch and roll, we can detect it, but the correlation

does not break down, whereas with a DVL you only want to insonify a small patch on the seabed to get an accurate measurement, therefore it is very sensitive to roll and pitch.

23. What is the operating temperature?

-5° to +45°C.

24. Is AquaTrak™ export restricted?

Yes. AquaTrak™ is a licensable product and falls under the dual use code 6A001B1B and can be exported outside the EU with an export license with an end user undertaking.

AquaTrak™ is not subject to USA re-export restrictions.

25. What is the commodity code for the AquaTrak™?

The commodity code is 9015809100.

26. Do you need to align AquaTrak™ with the vehicle it is deployed on?

Yes. The direction of travel of the CVL needs to be aligned to the platform. This is so that the displacement reported by the CVL can be related to that of the platform. The array design of the CVL is also optimised to measure the surge movement.

27. Are the min/max acoustic ping rate and the data output rate aligned?

Yes. The output rate matches the ping rate, but from that ping you have multiple displacement estimates, so the accuracy is vastly improved.

28. Does AquaTrak™ generate any significant harmonics?

Harmonics are generated but as AquaTrak™ is not a Continuous Wave systems, the harmonics are not significant and there is a frequency range of +/- 30kHz across which the transmit pulse is swept.

29. What is the power consumption?

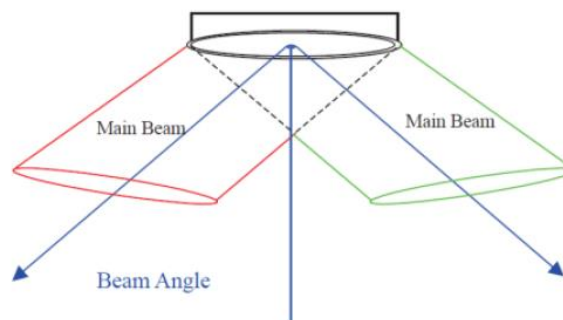
The average power consumption is currently 10-12W. The maximum power consumption is 23W at maximum altitude (300m) and maximum ping rate.

30. Is there a correlation between input power voltage and range?

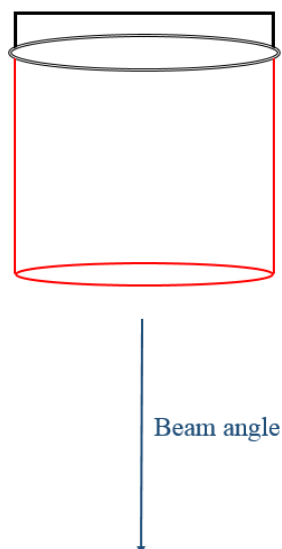
No there is no correlation. Full range can be achieved across the whole 18-75 VDC supply voltage input range.

31. Where can the CVL be mounted on an ROV and what clearance do I need to provide around the unit?

Unlike a traditional DVL which uses tilted beams, the CVL uses a single vertical beam. As such the CVL can be mounted flush with the ROV skid or slightly recessed into the body of the vehicle, away from any impact zone.



The diagram above shows the typical tilted beams of a DVL, hence clearance is required around the DVL to avoid interference with the beams, however this results in a requirement for the DVL to be mounted in an area of the ROV subject to regular impact, e.g. the bottom of the skid.



The diagram above shows the single wide vertical beam of the CVL. Minimal clearance is required around the transducer face and the sonar head can be recessed into the skid or body of the ROV or AUV so as to avoid impact damage.