NORTEK MANUALS

Principles of Operation High-resolution

NORTEK

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1 Introduction

This manual is designed to give an overview of the principles of operation of High-Resolution acoustic Doppler velocity systems. Most information found here is general, for instrument specific details related to operation and configuration, please refer to the Nortek Deployment software. For information about wave, current, ice, echosounder measurements, please refer to the principle of operation manuals on the website, www.nortekgroup.com, within the support section.

Nortek online

At our website, www.nortekgroup.com, you will find technical support, user manuals, FAQs, and the latest software and firmware. General information, technical notes, and user experience can also be found here. On our products page you can find technical specifications and software and firmware relevant for your specific instrument.

Your feedback is appreciated

If you find errors, omissions or sections insufficiently explained, please do not hesitate to contact us. We appreciate your comments and your fellow users will as well.

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2 Measurement principles

This section outlines the shared measurement concepts and processing principles used in Nortek instruments operating in High Resolution (HR) mode, including the Signature 1 MHz, Aquadopp (1 MHz and 2 MHz), and both generations of Vector instruments. While these systems differ in geometry and function, the underlying physics of HR mode remains consistent, primarily leveraging pulse-coherent Doppler processing.

2.1 Beam geometry

All HR instruments measure water velocity by detecting Doppler shifts from particles in the water (refer to Principles of Operation: Currents for a detailed explanation on the Doppler principle). However, their sampling geometry can vary from having an divergent (profiler) or convergent beam (velocimeter) configuration:

- Signature 1 MHz & Aquadopp 1/2 MHz (Profiler): These instruments use slanted, monostatic acoustic beams to generate vertical profiles of water velocity. Each beam captures multiple velocity measurements at different depths along its path, enabling detailed, depth-resolved flow data. When operating in HR mode, the profiling range is reduced, but vertical resolution is significantly enhanced - often down to the centimeter scale - making it ideal for capturing fine-scale flow structures. See ADCP Profiler Specific Section for more details.
- Vector (Velocimeter): This instrument features a bistatic acoustic geometry (a configuration where the acoustic transmitter and receivers are in separate locations, reducing flow disturbance and enhancing velocity measurement accuracy), with a central transmitter and three angled receivers arranged symmetrically around it. The beams converge on a fixed point located just a few centimeters above the sensor, enabling high-precision, single-point measurements of all three velocity components. This configuration provides exceptionally fine spatial resolution, ideal for capturing rapid fluctuations and turbulence at a specific location. See Vector Specific Section for more details.

Figure 1: Instruments that operate with high resolution mode and relay on the pulse-coherent methodology.

2.2 Pulse-coherent measuring methodology

The pulse-coherent Doppler technique is a high-precision method used in several Nortek instruments, available as a HR mode for specific profiler instruments or as the standard measuring technique for the velocimeter, which measure water velocity with exceptional accuracy.

Pulse-coherent processing determines velocity by analyzing the phase shift between two closely spaced acoustic pulses.
The key steps are:

- The instrument transmits two short identical acoustic pulses separated by a known time lag (Δt).
- These pulses reflect off suspended particles (scatterers) moving with the water.
- The returning echoes are received, and the phase shift (Δφ) between the returning pulses is measured.
- This phase shift is used to calculate the along-beam velocity (V) of the water.

The velocity along the beam is given by:

$$V = \frac{\Delta\phi C}{4\pi F_{source}\Delta t}$$

Here, V is the current velocity, $\Delta\varphi$ is the phase difference, F_{source} is the transmitted frequency and Δt is the time difference between two consecutive pulses ("Lag"). V is scaled with the speed of sound in the liquid (C).

Figure 2 below demonstrates the principle of pulse-coherent Doppler processing by comparing the timing of echoes received after a transmitted acoustic pulse. In both plots, the same transmitted signal (black) is reflected by particles in the water and received by three transducers. In the upper plot, the echoes from the receivers are only slightly delayed, indicating a stationary or slowly moving particle. In contrast, the lower plot shows greater delays between the transmitted signal and the received echoes, consistent with a particle moving away from the instrument. This delay appears as a phase shift, which is used by the system to calculate particle velocity, which is assumed to be the same velocity as the current.

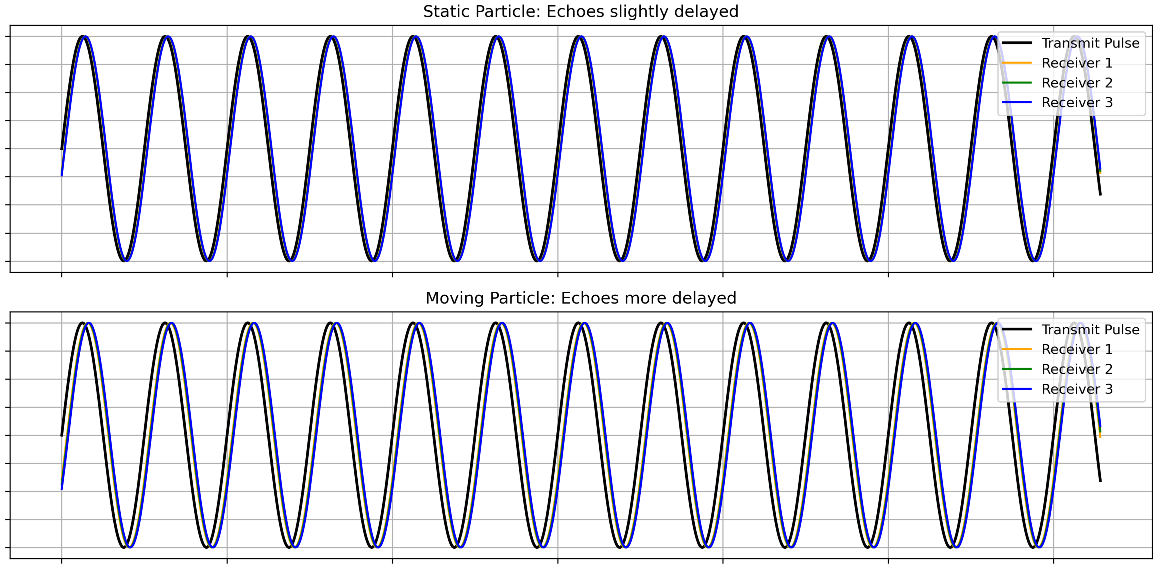

Figure 2: The black waveform represents the transmitted acoustic pulse. The orange, green, and blue waveforms show the echoes received by three sensors after interacting with a particle. In the upper plot, the echoes are only slightly delayed, indicating a stationary or slow-moving particle. In the lower plot, increased delays in the echoes illustrate a particle moving away from the instrument. This phase shift is the basis of velocity estimation in Norteks pulse-coherent Doppler processing.

This phase-based approach allows for highly accurate velocity measurements over short ranges. However, it introduces limitations such as velocity ambiguity, where phase shifts exceeding ±π radians become indistinguishable, leading to potential measurement errors. To mitigate this, the system's maximum measurable velocity (Vmax) is constrained by the chosen time lag, calculated as:

$$V_{max} = \frac{C}{4F\Delta t}$$

Selecting an appropriate time lag is critical in pulse-coherent Doppler processing, as it balances the trade-off between measurable velocity range and precision. This method offers exceptional temporal resolution, low noise, and high precision, making it ideal for capturing fine-scale turbulence, rapidly varying flows, and near-boundary measurements, particularly in low-energy environments. However, its effectiveness is constrained by a short profiling range due to pulse separation and phase coherence limits. In high-velocity or highly turbulent conditions, the risk of velocity ambiguity increases, and phase unwrapping techniques may be required to maintain measurement accuracy.

2.3 Velocity ambiguity and Phase wrapping

In pulse-coherent Doppler systems, phase wrapping and velocity ambiguities are critical challenges that can affect the accuracy of velocity measurements. Phase-wrapped velocities appear as sudden discontinuities in the recorded velocity time series, typically showing abrupt jumps between maximum and minimum values. In coordinate transformations, phase wrapping can be more evident in XYZ or ENU coordinate systems when velocities are converted from the beam coordinate system.

Phase wrapping occurs when the phase difference between successive pulses exceeds ±π radians, causing the measured phase to "wrap around" and leading to incorrect velocity estimations. This typically happens when the actual velocity surpasses the system's configured velocity range, known as the ambiguity velocity. In such cases, a sine wave with phase -π appears identical to one with phase +π, resulting in ambiguous measurements.

Velocity ambiguity refers to the inability to distinguish between true and aliased velocities when the measured phase shift exceeds the unambiguous range. This is particularly problematic in pure coherent systems due to large pulse separations. The phase difference between two reflected pulses directly measures velocity. However, if this difference goes beyond ±π, the measurement uniqueness is lost, leading to velocity ambiguity, this can been seen in Figure 3.

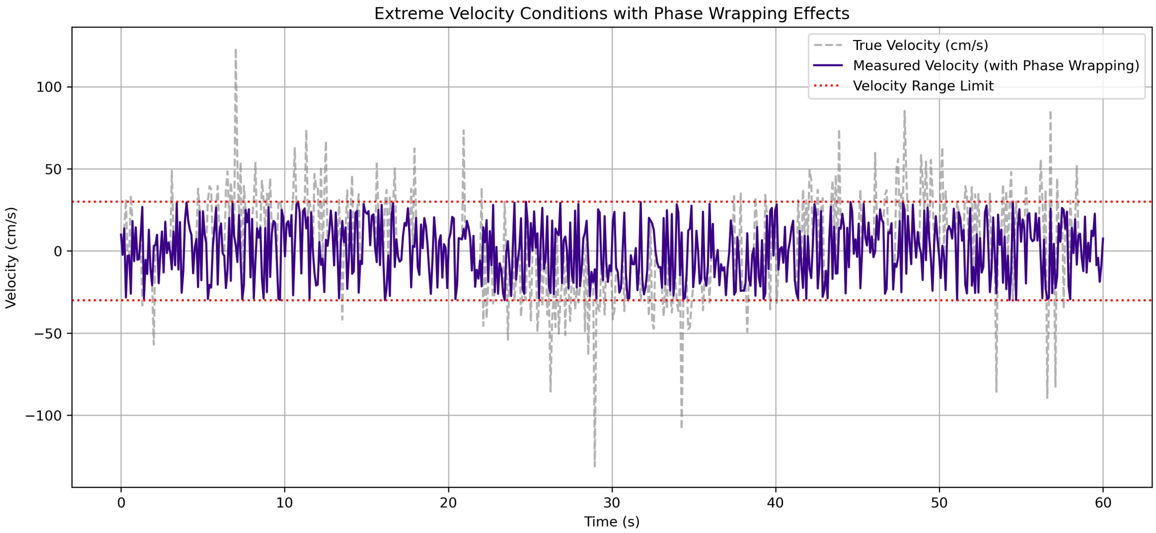

Figure 3: An example of phase wrapping showing an abrupt change from negative to postivie velocity. The nominal velocity range was set to 30 cm/s, yeilding a horizontal velocity range of 142 cm/s. Note: Example data set.

Phase wrapping is most prevalent in highly turbulent environments, such as surf zones and rivers, where rapid velocity fluctuations increase the likelihood of exceeding the instrument's ambiguity velocity. However, it can also occur if the instrument is not properly configured for the deployment conditions, leading to phase aliasing even in moderate flow environments. To minimize phase wrapping, it is essential to assess expected flow conditions and configure the instrument accordingly. Increasing the velocity range above the anticipated maximum flow speed helps prevent wrapping by reducing pulse separation, which in turn raises the ambiguity velocity, allowing the system to measure higher speeds before aliasing occurs.

2.4 Extended velocity range

Adjusting pulse separation may not always be feasible. In such cases, the Extended Velocity Range (EVR) method is used to enhance the ambiguity velocity. The EVR is a technique used in pulse-coherent Doppler systems to extend the maximum measurable velocity while maintaining high precision. It works by introducing an additional pulse pair with two distinct time lags, allowing the system to resolve phase ambiguity that occurs when velocities exceed the unambiguous range.

How EVR improves velocity measurements:

1. The standard lag (longer pulse separation) provides high precision velocity measurements but is limited by phase wrapping (Figure 4 - blue line).
2. The EVR lag (shorter pulse separation) provides a coarse velocity estimate with a velocity range approximately three to five times greater than the standard lag (Figure 4 - red line).

3. By comparing the phase shift from both lags, the system determines which ambiguity branch the velocity measurement belongs to, effectively unwrapping the phase and extending the measurable velocity range.

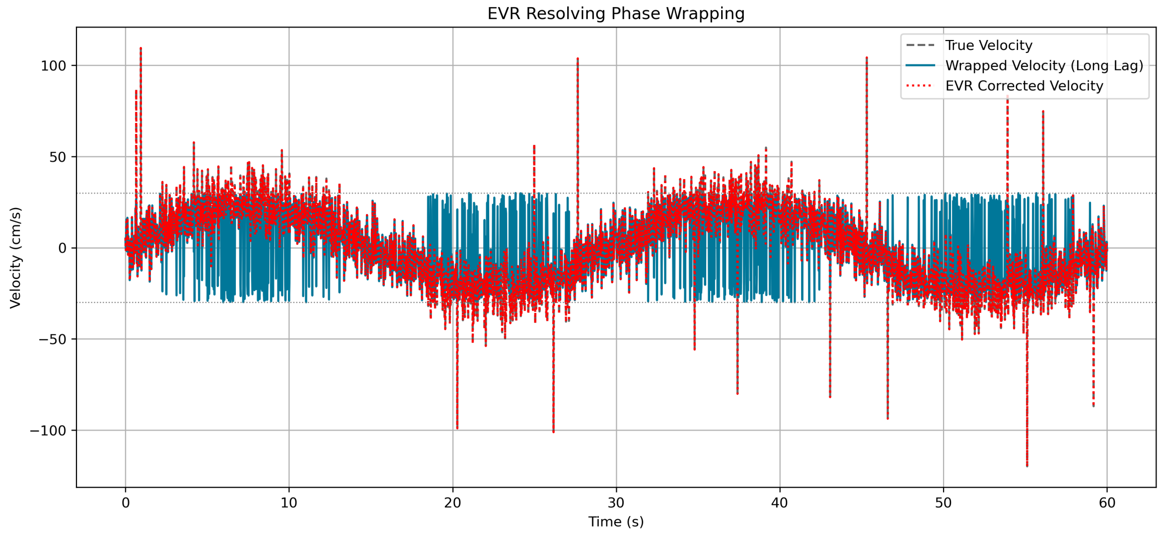

Figure 4: EVR resolving phase wrapping in complex flow. The flow measurements (blue) wrap under conditions where the velocity exceeds the configured ±30 cm/s limit. EVR is enabled to unwrap and recover the full velocity signal (red), even in the presence of turbulence and extreme flow bursts. Note: Example data set.

The first lag is used to get a high resolution estimate of the velocity, the second and larger lag aims to provide a coarse estimate. The first lag defines the ambiguity range of the setting and the second is the one that is actually reported after we have used the first estimate to determine what ambiguity branch we are on. The actual lags change with the velocity setting. The velocity calculated using this technique is:

$$V = \frac{c}{4}\pi f(\Delta_{\phi 2} - \Delta_{\phi 1})(\Delta_{t2} - \Delta_{t1})$$

The ambiguity velocity then becomes:

$$V = \frac{c}{4} f(\Delta_{t2} - \Delta_{t1})$$

Here, V represents the measured velocity along the beam axis, while c is the speed of sound in water, and f is the acoustic transmit frequency. The phase shift of the first and second pulse lag is $\Delta\phi 1$ and $\Delta\phi 2$, respectively. Similarly, $\Delta t1$ and $\Delta t2$ denote the time lags for the first and second measurements, respectively. This technique has the advantage of producing an extended velocity measurement for all cells in the profile. Signal noise effectively limits the minimum usable time difference.

When enabling EVR, two main trade-offs must be considered. First, the internal ping rate is halved compared to non-EVR operation, since the same pulse pairs used for velocity profiling are also applied in phase unwrapping. Second, the introduction of an additional pulse increases the potential for boundary echo interference. While these constraints can lead to lower sample rates and added complexity in noisy environments, EVR significantly improves performance in high-energy conditions - such as surf zones - by extending the usable velocity range and reducing phase wrapping. Lastly, EVR does not eliminate the possibility of ambiguity problems if the measured velocities exceed the specified velocity range set by the user.

However, setting the velocity range too high can degrade data quality. A shorter pulse separation, necessary for higher velocity limits, increases noise and reduces measurement precision, especially in low-energy flows where resolving fine-scale motion is critical. Excessive velocity range settings may also result in lower correlation, unstable readings, and inefficient instrument performance. For optimal results, the velocity range should be carefully tuned: high enough to avoid phase wrapping, but not so high that it compromises accuracy.

2.5 Acoustic Interference: Weak spots and boundary reflections

HR instruments that transmit two pings per measurement cycle are susceptible to pulse interference when deployed near boundaries. This interference, known as a "weak spot," appears in the data as low Signal-to-Noise Ratio (SNR), reduced correlation values, and noisy velocity traces, making the affected measurements unreliable.

Weak spots occur due to the spatial separation between pulse pairs in pulse-coherent Doppler systems. They form when the first pulse reflects off the bottom, and its echo reaches the sampling volume at the same time as the second pulse passes through it. This overlapping signal causes interference, reducing data quality and often resulting in unusable measurements.

The pulse-to-pulse interference is demonstrated in Figure 5 where the transmit pulse reflects of the sea surface back in to the measurement volume. This overlap impairs the instrument’s ability to accurately resolve phase information, leading to reduced correlation and a higher rate of data rejection. For upward-looking instruments, pulse-to-pulse interference is not a concern when the profiling range is less than half the total water depth. For example, an instrument deployed at a depth of 10 meters in HR mode - accounting for tidal variations, wave action, or surface reflections - should be configured to profile up to a maximum range of 5 meters.

The water/air interface can act as a strong acoustic reflector, unlike the more absorptive water/sediment boundary. Surface echoes may persist and introduce noise into the data. In shallow, upward-looking deployments, tidal variations further complicate this by altering the distance to the surface. To reduce the risk of interference, the deployment software conservatively sets the pulse distance to half the water depth.

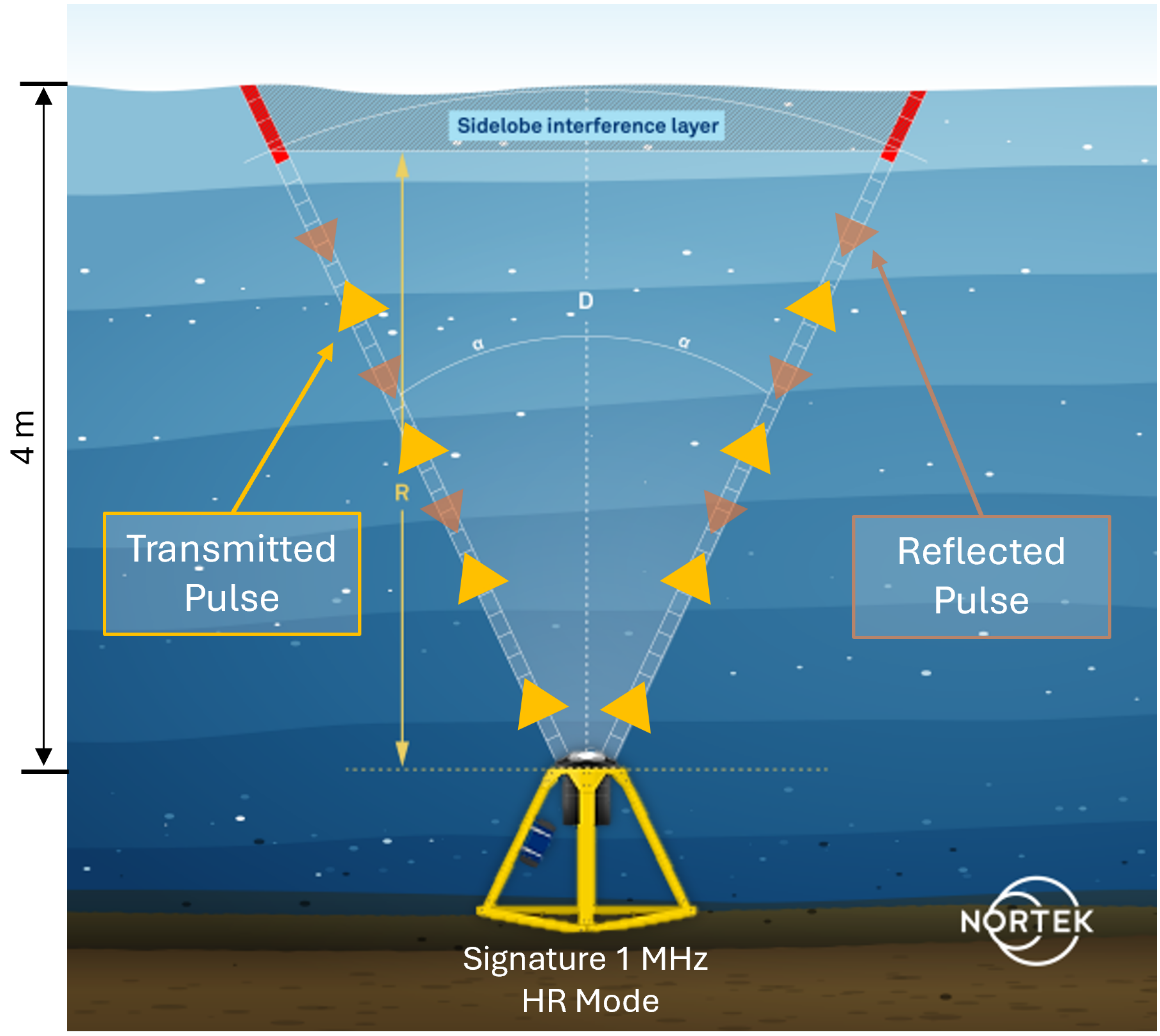

Figure 5: Sketch of an upward looking Signature 1 MHz measuring in HR mode in shallow water where reflection from the sea surface is present.

Downward-looking configurations are typically less prone to pulse interference, especially when the distance to the bottom is known and stable (e.g., mounted on a fixed frame above the seabed). Sediment beds—particularly sandy or silty bottoms—tend to absorb acoustic energy, helping dissipate echoes. However, hard bottoms like rock or coral may produce stronger reflections, increasing the risk of interference.

The vertical extent of a weak spot depends on bottom conditions:

- Well-defined bottoms (e.g., sand) typically cause minimal interference, confined to the transmit pulse length (~1 cm).
- High water scattering (e.g., in turbid conditions) can reduce or eliminate weak spots by overpowering the bottom reflection.
- Rough or irregular bottoms can increase the vertical extent of interference.

The bottom material in a laboratory or field setting can significantly impact data quality. Highly reflective surfaces, such as metal-bottomed flumes, produce strong return signals that can interfere with velocity measurements, especially in profiles stepped up from the bottom. To assess reflection strength, check the bottom return signal in the data. If reflections are too strong, they may create weak spots and introduce noise into velocity readings.

To reduce weak spot interference, the instrument should be set up with the velocity range as low as possible while ensuring that it still accommodates expected water velocities at the desired deployment site. The velocity range determines the pulse separation time and can be adjusted in the configuration dialog. In addition, avoiding settings that result in overlapping pulse reflections, especially in shallow or boundary-affected regions should be considered.

Figure 6 shows how a weak spot may show up in the data, in the X direction more specifically.

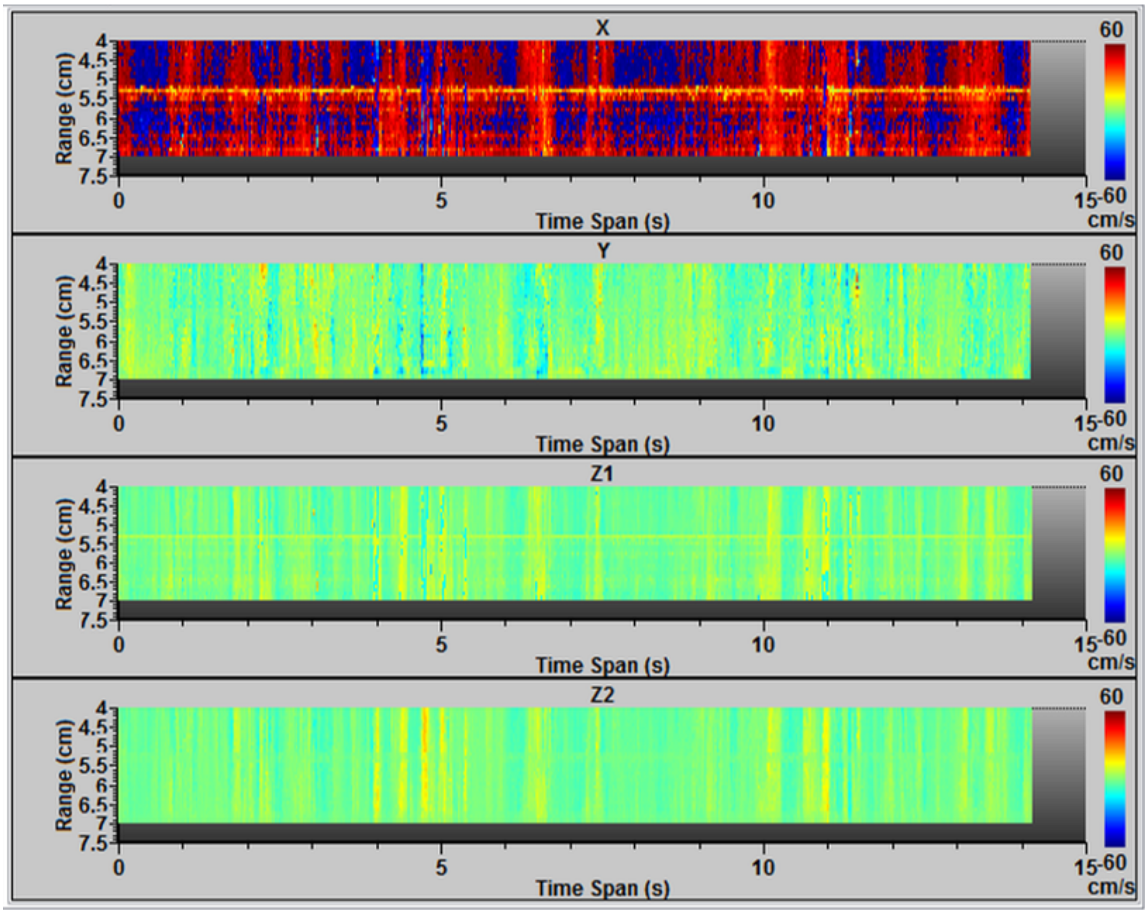

Figure 6: X, Y, Z1 and Z2 velocity plots. The upper plot shows X velocity, which is subject to interference due to a weak spot

Weak spots are an inherent limitation when measuring near boundaries with high resolution pulse-coherent instruments. Understanding their causes and mitigation strategies, such as adjusting the velocity range and considering bottom composition, helps improve data quality and minimize unusable measurements. When operating in a controlled environment, the user can minimize interference in highly reflective settings by placing absorptive materials beneath the probe. Effective options include thick plexiglass, acrylic or rubber layers or concrete blocks. These materials dampen reflections, improving data quality and reducing measurement errors.

2.6 Correlation and data quality

Correlation in pulse-coherent Doppler instruments reflects the signal quality used to compute velocity from the phase shift between successive acoustic pulses. High correlation indicates reliable velocity tracking, while low correlation suggests signal degradation due to factors such as turbulence, weak scatterers, or boundary interference. Because velocity estimation relies directly on these phase shifts, maintaining strong correlation is essential for accuracy. While both profilers (in HR mode) and the Vector's are based on the same underlying principles, their differing geometries and sampling strategies result in distinct correlation behavior across their respective measurement volumes.

In HR profilers, each acoustic beam samples a sequence of range cells along its slanted path. As range increases, the returned signal typically weakens due to beam spreading, attenuation, and reduced scatterer density. This results in a progressive decline in correlation with distance from the instrument. Lower correlation at far range cells can introduce uncertainty in phase interpretation, reduce data reliability, and complicate phase unwrapping. The correlation for both a Vector and profiler in HR mode is demonstrated in Figure 7.

By contrast, the Generation 2 Vector samples at a fixed, tightly focused point, located approximately 15 centimeters from the central transducer. Its bistatic beam configuration ensures that all three receiver beams converge on the same location, producing consistently high correlation values across all measurements. The short acoustic travel distance and compact sampling volume minimize signal loss and reflection complexity, resulting in stable and strong phase. The figure below illustrates how correlation varies with depth for the two instrument types. The profiler shows individual correlation values across multiple range bins, while the Vector samples the same volume and thus provides correlation at a fixed depth for all measurements.

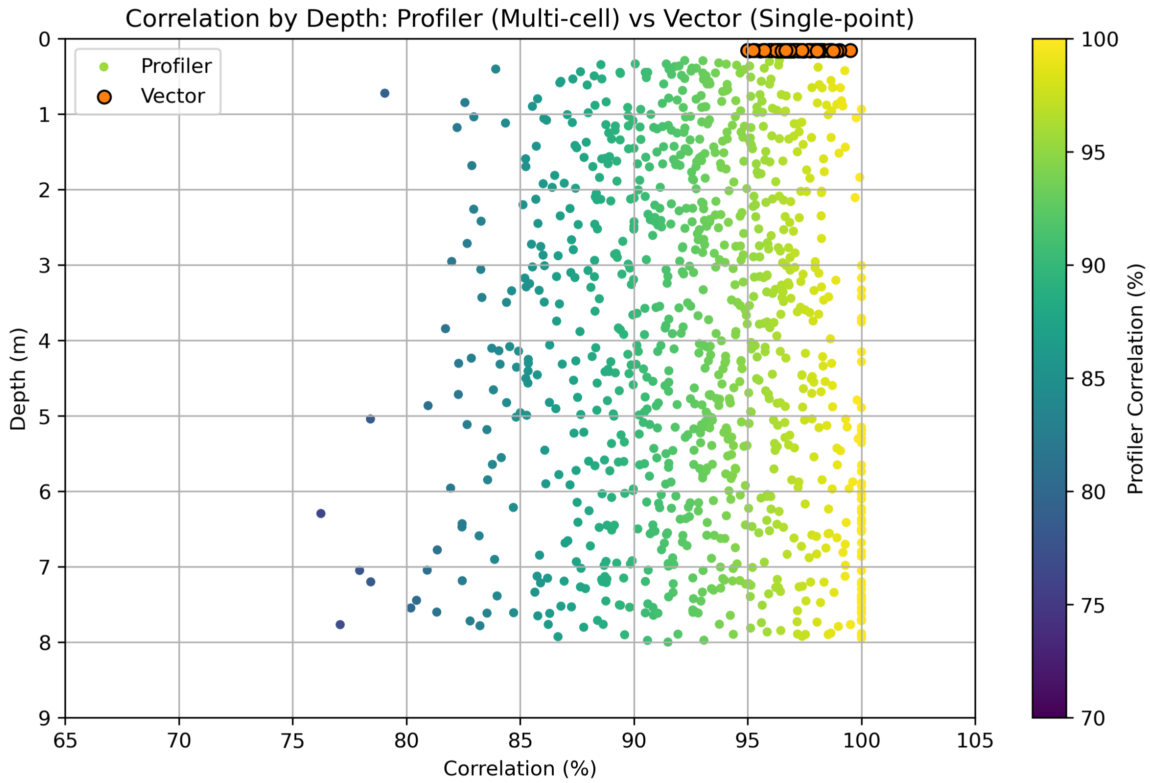

Figure 7: Correlation with depth. Note: The example data shown here is for illustrative purposes only and is intended to highlight the differences in correlation patterns between instrument types.

Note: While typical correlation patterns differ between profiling instruments and the Vector, it’s important to recognize that low correlation can occur at any point within the measurement volume, often as a result of poor scattering conditions such as low particle density, stratification, or signal absorption.

3 ADCP Profiler Specific

This section focuses on how High Resolution mode is used in Nortek's profiler instruments. These profiler-class systems are designed to produce detailed vertical profiles of water velocity and turbulence using slanted acoustic beams.

3.1 Slanted beam geometry and high-resolution profiling

Profiler instruments operating in HR mode share a common architectural principle, they use slanted acoustic beams, arranged to create detailed vertical profiles of water velocity. These systems typically employ a monostatic configuration, where each transducer both transmits and receives along the same acoustic path. Beams are slanted, most often at 25° from vertical, and evenly distributed around the instrument, typically using three or four beams to enable three-dimensional velocity vector reconstruction.

Instruments with an optional vertical beam can perform additional tasks such as wave tracking or monitoring echo strength along the central axis. The slanted beam arrangement allows the profiler to collect a column of range-based velocity measurements (depth cells) along each beam, which are then merged into a vertical velocity profile. HR mode enhances this capability by using pulse-coherent Doppler processing, enabling much finer spatial resolution and lower measurement noise, particularly in the near field. The signature 1 MHz and Aquadopp profiler 1 MHz both have a central transducer, these instruments can be configured to just function with HR mode on the central transducers.

When operating in HR mode, profiler instruments transform from general-purpose current meters into fine-scale diagnostic tools. They can resolve subtle gradients in flow, such as shear layers, boundary turbulence, or stratified microstructures, that would otherwise be lost in coarser sampling. Figure 8 illustrates this dual-function beam configuration, highlighting how the HR mode significantly enhances measurement detail within a shorter range, enabling the capture of fine-scale flow structures that would otherwise go unresolved in standard mode.

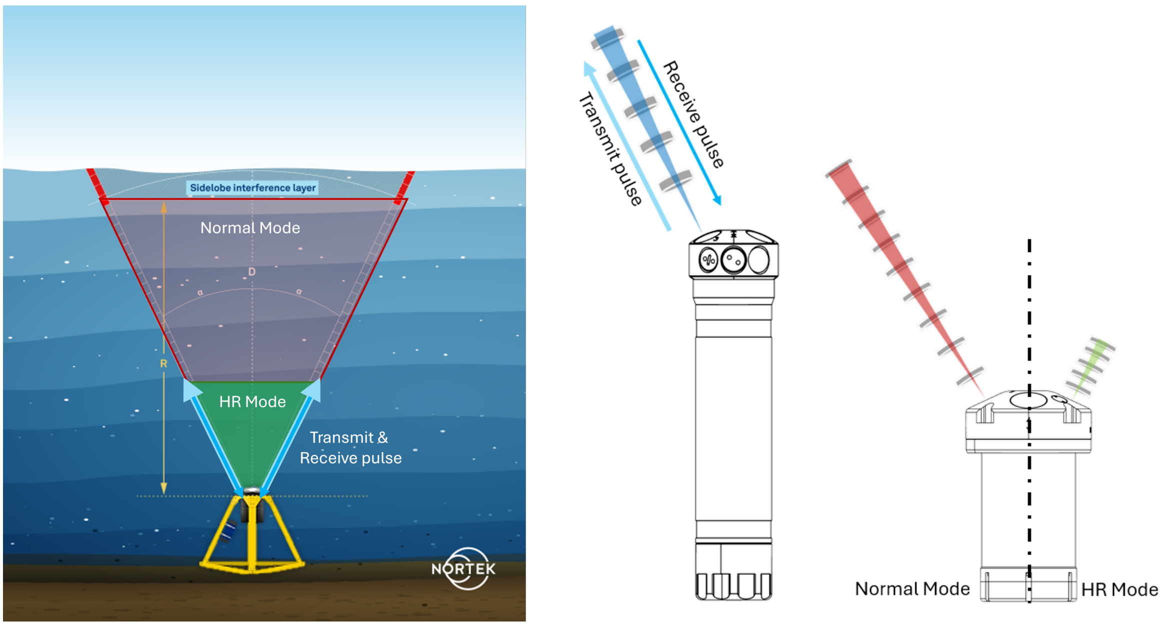

Figure 8: Illustration of transmit and receive pulse pairs from profiler systems. On the left, both transmission and reception occur on the same transducer, with the signal traveling outward and then returning. On the right, the effective range of each pulse is shown for both Normal and High-Resolution (HR) modes. Range difference in normal (up to 35 m) and HR (up to 8 m) mode. Note: Diagram not to scale.

Performance Characteristics of HR Mode

HR mode is designed for short-range, high-resolution profiling, generally achieving vertical coverage between 0.3 and 8 meters depending on frequency and environmental scatter. Through pulse-to-pulse phase analysis, profilers can resolve:

- Cell sizes as small as 7 mm (2 MHz) or ~20 mm (1 MHz).
- Velocity-range products typically limited to <0.25–0.5 m^2/s to avoid phase ambiguity.
- Sampling rates up to 16 Hz, depending on beam count, cell size, and range.

Cell size defines vertical resolution, but it also directly affects data quality. Smaller cells produce finer detail but contain fewer scatterers, increasing measurement noise. Larger cells, in contrast, return stronger signals and reduce variance, but at the cost of resolution. Therefore, cell size must be carefully selected based on deployment goals, fine detail for near-boundary or flume studies, broader coverage for deeper or energy-limited settings.

The precision of a Doppler measurement is inversely proportional to the cell size, making this a critical factor in configuring the instrument. Additionally, a wider velocity range shortens the lag between pulses, which can degrade phase sensitivity. The configuration must stay within system-specific velocity range thresholds to preserve accuracy, approximately 0.5 m^2/s for 2 MHz systems and 1.0 m^2/s for 1 MHz. This makes it difficult to assign a fixed precision value for HR measurements, as precision depends on the interplay between flow velocity, deployment depth, and the configured pulse lag.

Profiler instruments with HR mode

- Signature 1 MHz profilers feature four slanted beams (plus an optional vertical beam), and can achieve cell sizes as small as 2 cm over profiling ranges up to 8 meters. With maximum sampling rates of 16 Hz, they're ideal for open-water turbulence studies, moored tripod deployments, and structured marine environments. The wider beam footprint requires careful placement to avoid weak spots caused by reflections.
- Aquadopp HR (1 MHz and 2 MHz) profilers, in contrast, are compact systems optimized for near-bed and confined deployments, such as in flumes, tanks, and shallow estuaries. The 2 MHz version achieves finer vertical resolution (down to 7 mm), while the 1 MHz model offers a broader range. Both support configurable HR settings, and sample at 4–8 Hz, depending on the configuration.

3.2 ADCP Profiler specific phase wrapping

Since the ADCP profilers measure across multiple range cells, each with potentially varying signal strength and flow conditions, phase wrapping can manifest inconsistently throughout the water column. The challenge lies in maintaining sufficient correlation and appropriate lag settings across the entire profile, particularly near boundaries or in high-turbulence zones. EVR is commonly used to resolve ambiguity, but its effectiveness depends on maintaining adequate correlation throughout the beam path.

Figure <%HMFIGURENUMBER%> shows the impact of phase wrapping in ADCP profiler instruments. The velocities range between 1.5–2.0 m/s, with sharp spikes exceeding the instrument's maximum unambiguous velocity. These spikes cause wrapping artifacts, seen as sudden drops in the measured signal. While the true velocity remains smooth, the wrapped velocity misrepresents rapid changes due to phase ambiguity. This highlights the need for phase unwrapping in post-processing, especially in turbulent or boundary-affected flows.

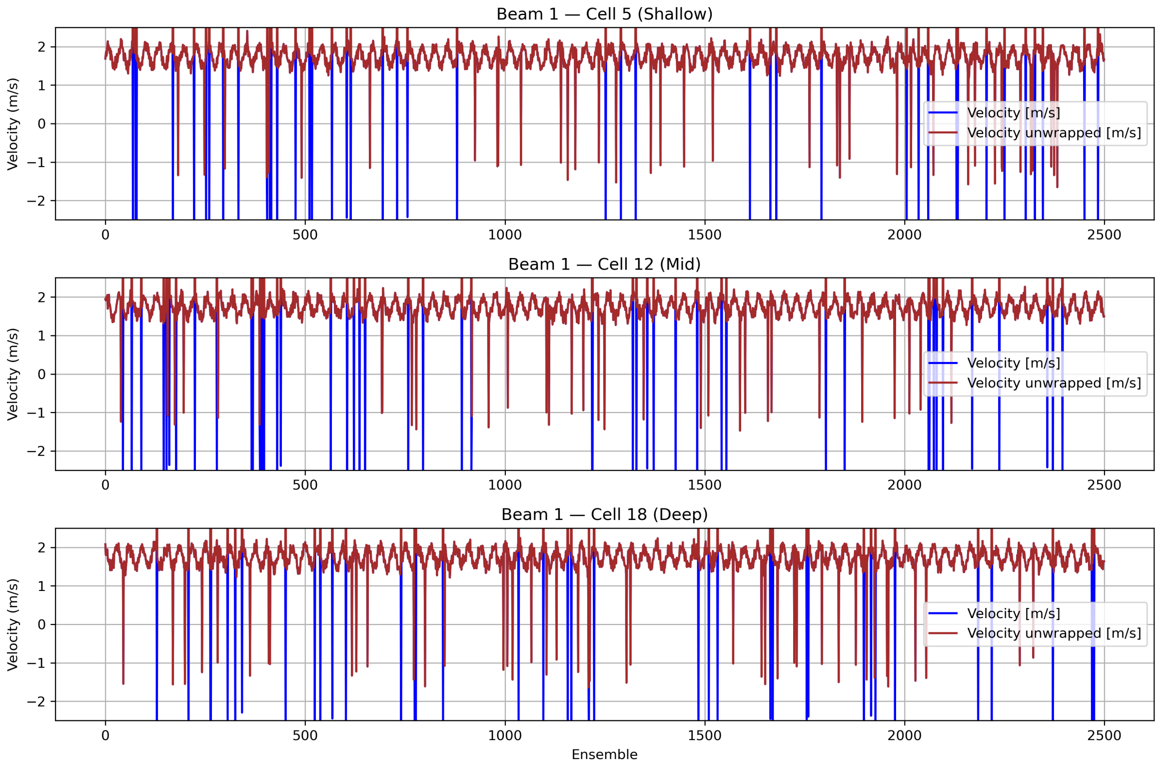

Figure 9: Time series of velocity measurements from three depth cells (Cell 5 – Shallow, Cell 12 – Mid, and Cell 18 – Deep) along Beam 1 of a Doppler profiler. Each subplot shows both the wrapped velocity (as measured, blue line) and the true unwrapped velocity (reference signal, brown line) over 2500 ensembles. Phase wrapping is evident as sudden discontinuities or negative spikes in the wrapped signal when the true velocity exceeds the instrument's maximum unambiguous velocity

4 Vector Specific

This section explores how the Vector 2 applies the same high-resolution pulse-coherent processing principles in a single-point velocimeter format. Rather than providing vertical profiles, it offers highly localized, three-component velocity data at an extremely high temporal resolution. The following sections describe its unique architecture, performance characteristics, and common use cases.

4.1 Bistatic geometry: central transmitter with angled receivers

The Vector employs a bistatic acoustic design. A central vertical transmitter emits acoustic pulses while three symmetrically spaced angled receivers detect echoes from a converging point located approximately 15.7 cm above the sensor. This differs from profiler instruments, which transmit and receive along the same slanted beams. The Vector's geometry is optimized to capture water velocity at a single, fixed location with high directional accuracy.

This tightly constrained beam intersection forms the basis of its fixed-volume measurement approach, allowing reliable three-dimensional velocity reconstruction within a defined region near the sensor as shown in Figure 10.

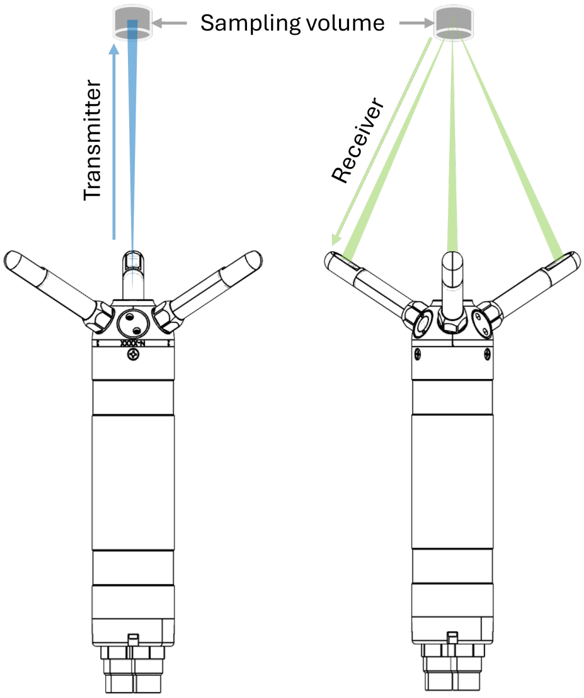

Figure 10: Generation 2 Vector, transmitter and receivers.

4.2 High-resolution point samping methodolgy

Unlike profiling systems, the Vector samples velocity at a fixed point, with spatial resolution determined by the convergence of its bistatic beams just centimeters above the sensor. This approach makes it an excellent companion to profiler instruments by offering detailed temporal data where spatial profiling is not required or feasible.

Additionally, the Generation 2 Vector uses a simultaneous pinging scheme (updated from the legacy Vector using the multiplexing pinging scheme) across all three receivers, enabling synchronized 3D velocity measurements without temporal skew between components, as shown in Figure 11. This is especially beneficial in rapidly evolving flow conditions, such as boundary layers, breaking waves, or turbulent shear, where accurate time alignment is critical for capturing transient flow structures and computing reliable turbulence metrics.

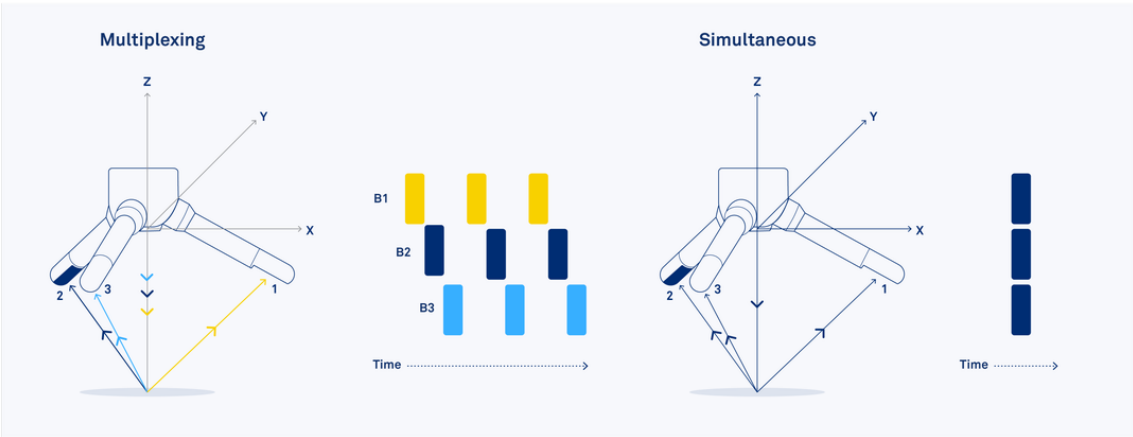

Figure 11: Comparison of multiplexed (sequential) and simultaneous (parallel) pinging schemes. Left: in the legacy Vector, each beam transmits and receives in sequence, a method known as multiplexed (or sequential) pinging. Right: The Generation 2 Vector with simultaneous (parallel) pinging, where all beams receive the transmit pulse at the same time. This allows true synchronous 3D velocity sampling, improving temporal resolution and data coherence.

Figure 12 below visualizes how a sound wave transmitted through the central transducer (shown in blue), hits a particle (red), which in next turn reflects parts of the sound (Doppler shifted - shown in black) back to the receiver arm, which will detect the reflected sound wave.

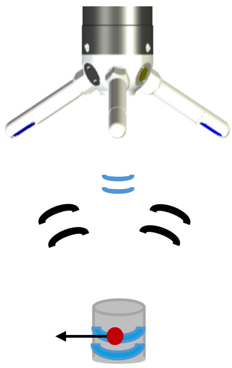

Figure 12: Transmit pulse pair (blue), a moving particle (red), and the reflected, Doppler shifted pulse (black).

Processing Technique

Figure 13 below illustrates how the Vector measures velocity using the pulse-coherent Doppler technique. The central transducer transmits two acoustic pulses (P1 and P2), separated by a time lag (Δt). As these pulses travel, they reflect off a moving particle (red dot), which shifts position over time. The phase difference (φ1 and φ2) between the received echoes of the two pulses is then used to calculate the particle's velocity. This method allows the instrument to precisely measure water movement by detecting small changes in phase.

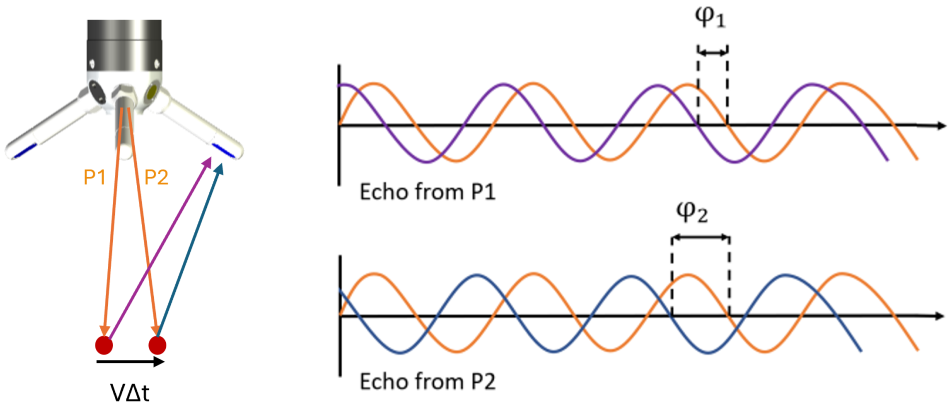

Figure 13: Two pulses are transmitted by the central transducer, with a time lag. The difference in phase between the two transmit pulses is used to calculate velocity. The reflecting particle can be seen in red, with a vector indicating its speed and direction.

The Vector is capable of sampling at rates up to 64 Hz, with the option to reduce this frequency depending on deployment configuration, experimental objectives, and prevailing scattering conditions.

4.3 Phase unwrapping in velocimeters instruments

Phase wrapping in the Vector is governed by the same fundamental limit as in profilers, but its correction is more straightforward. Because the Vector samples at a single fixed location with consistently high correlation and minimal geometric variation, velocity ambiguity can be more reliably detected and resolved. EVR is also available in the Generation 2 Vector, but is generally more effective due to the stable acoustic conditions and reduced complexity of applying corrections across only one measurement point rather than an entire profile.

4.4 Acoustic Streaming

Acoustic streaming, also known as secondary flow, occurs when the instrument’s transmitted pulses generate a steady fluid motion in the surrounding water. This effect becomes significant when ambient flow velocities are low, particularly when they are below 8 cm/s, where streaming can introduce a measurable velocity bias.

The effect of acoustic streaming can be observed by placing the instrument in still water and monitoring velocity readings over time. In stationary water, induced flows of 2–3 cm/s have been recorded when the power level is set to HIGH, as shown in Figure 14. This effect is more pronounced in small, confined spaces such as laboratory tanks or flumes, where natural flow is minimal, allowing the acoustic energy to generate movement in the water.

Lowering the transmission power reduces the magnitude of transducer-induced flow. However, this comes at the expense of a lower SNR in the return signal. Deploying the instrument in open water or larger tanks helps minimize the effects of acoustic streaming by allowing natural ambient currents to dominate. When streaming cannot be avoided, it can be accounted for by measuring and subtracting the induced flow from velocity readings using background subtraction techniques.

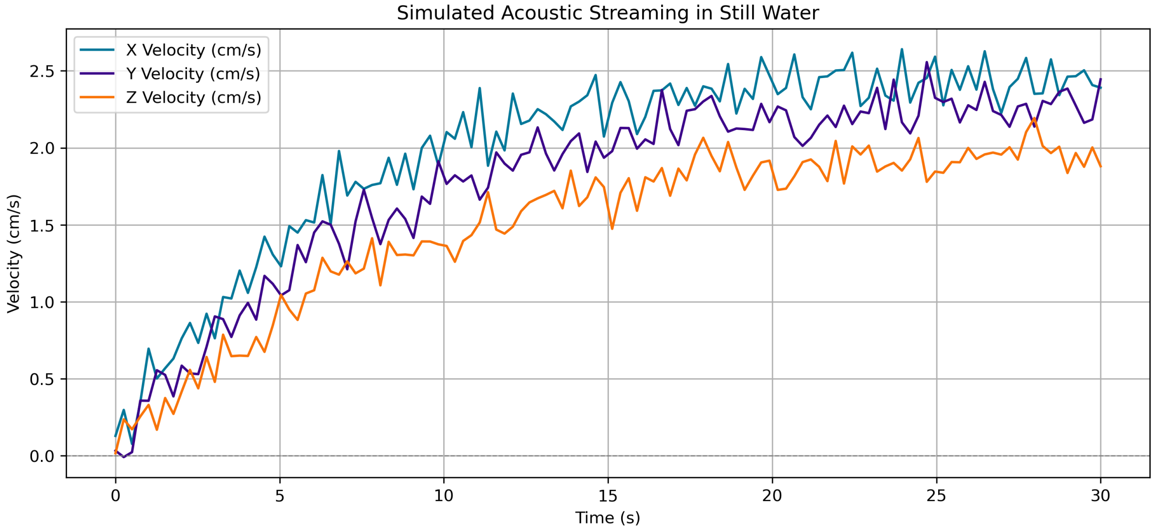

Figure 14: This plot represents how transducer-induced flow builds up gradually in a no-flow environment. All three components (X, Y, Z) show similar velocity trends, stabilizing between 2–2.5 cm/s after about 15 seconds.

4.5 Minimizing boundary interference with Vector measurements

Due to its proximity-based measurement zone and lack of profiling beams, the Vector is less prone to pulse overlap or weak spots seen in near-boundary profiler deployments. However, deployment setup remains critical:

- If positioned too close to solid boundaries (e.g., tank walls or seabeds), reflections and echoes may distort signal quality.
- In lab or flume conditions, acoustic dampening materials (e.g., rubber mats, plexiglass) are recommended to reduce unwanted reflections.
- In natural environments, soft sediment and flow variability usually help minimize boundary echo artifacts.

While less vulnerable than a profiler instrument, the Vector's precision requires a stable acoustic environment to ensure consistent measurements. Figure 15 below shows how the Generation 2 Vector can be mounted. Note: For side-looking applications, the Vector should be mounted perpendicular to the flow. Current flow traveling directly toward the transmitter, the maximum measurable velocity will be the lowest it can be, while flow toward the connector end can cause housing-induced flow disturbance at the sampling volume.

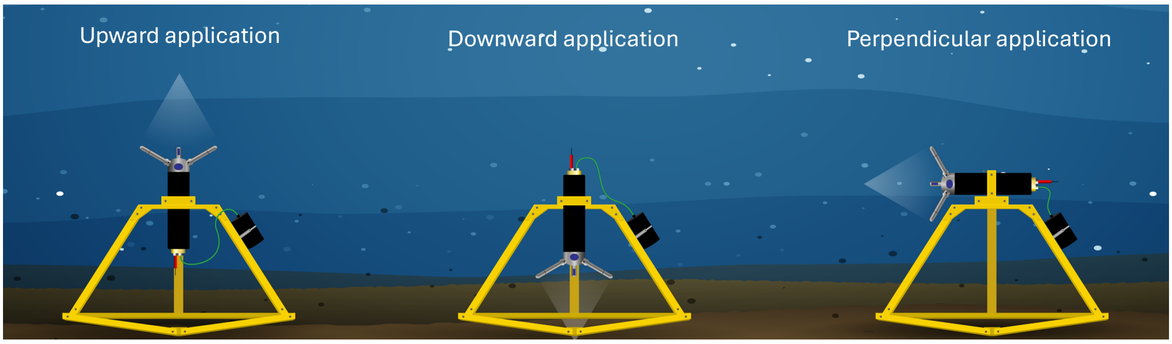

Figure 15: Examples of the Generation 2 Vector deployment configurations. The instrument is mounted on a bottom frame in various orientations, including upward-facing, downward-facing, and side-facing positions. Each setup is designed to optimize flow measurement depending on the surrounding environment and target observation zone.

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