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Triton Principles of Operation

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Section 1. Introduction

The SonTek/YSI Triton is a single-point, 3D Doppler current meter designed for shallow water flow monitoring. Triton Doppler processing provides several advantages.

- Accurate, 3D velocity measurements in a remote sampling volume
- No periodic re-calibration needed
- Simple operation
- Excellent low-flow performance
- A wide variety of system configurations and integrated sensors

This document presents the operating principles the Triton. It does not attempt to provide a detailed discussion of all technical issues, nor a detailed description of Triton operation. To learn more about specific applications, please contact SonTek.

Section 2. The Doppler Shift

The Triton measures the velocity of water using a physical principle called the Doppler effect. If a source of sound is moving relative to the receiver, the frequency of the sound at the receiver is shifted from the transmit frequency.

$$F_{doppler} = -F_{source} (V / C)$$

where

$F_{doppler}$ = Change in received frequency (Doppler shift)
F_{source} = Frequency of transmitted sound
V = Velocity of source relative to receiver
C = Speed of sound

The velocity (**V**) represents the relative speed between source and receiver (motion that changes the distance between the two).

- If the distance between the two objects is decreasing, frequency increases.
- If the distance is increasing, frequency decreases.
- Motion perpendicular to the line connecting source and receiver does not introduce a Doppler shift.

2.1. Bistatic Doppler Current Meters

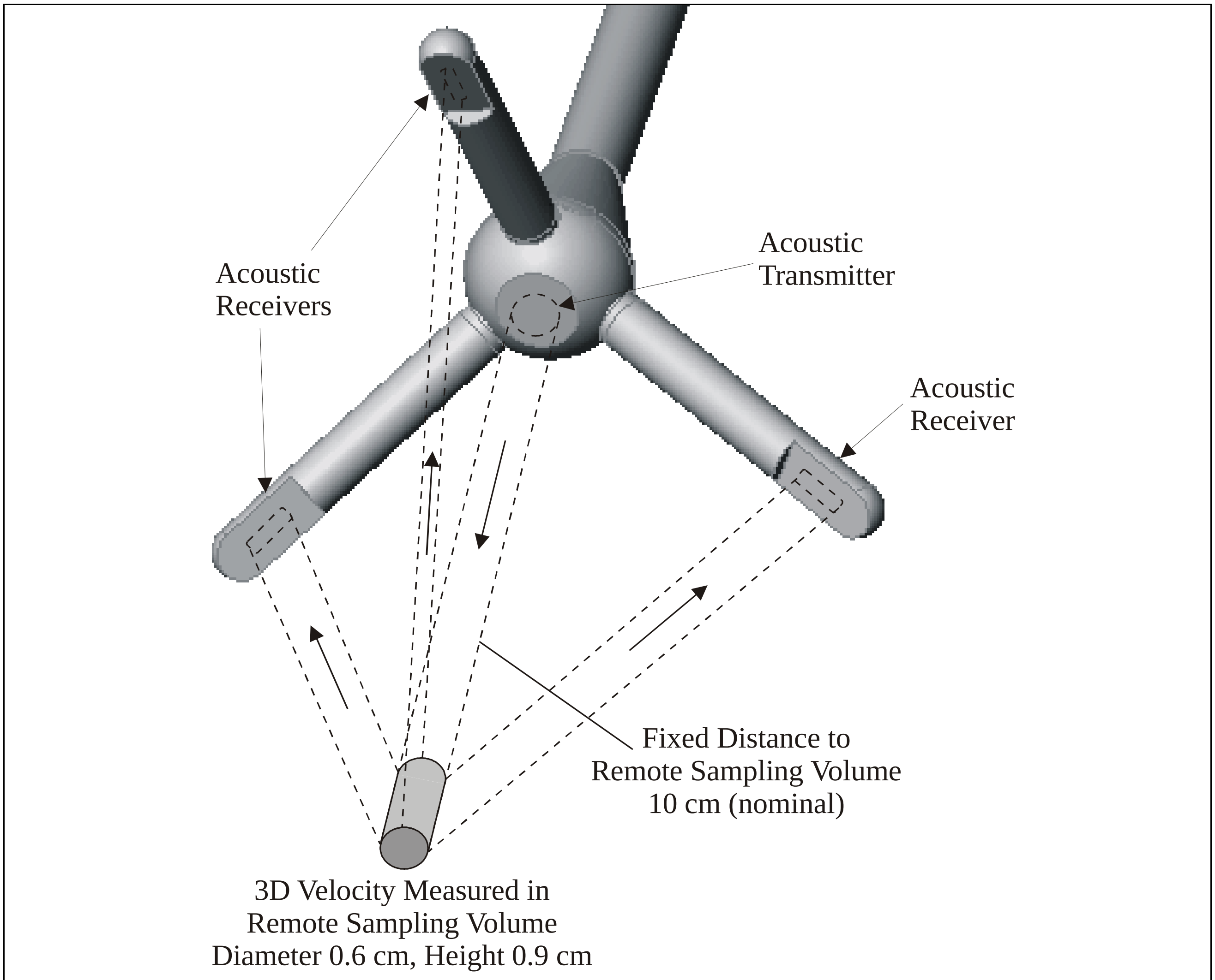


Figure 1 – Triton Probe and Sampling Volume

Figure 1 shows the basic operation of the Triton probe. The Triton is a **bistatic** Doppler current meter.

- Bistatic means separate acoustic transducers are used for transmitter and receiver.
- The transmitter generates sound concentrated in a narrow beam.
- The receivers are sensitive to sound coming from a narrow beam.
- The receivers are mounted such that the beams intersect at a volume of water located a fixed distance from the tip of the probe, typically 10 cm (4 in).
- The beam intersection determines the location of the **sampling volume**, which is the volume of water in which measurements are made.

The Triton measures velocity as follows.

- The transmitter generates a short pulse of sound at a known frequency.
- The sound travels through the water along the transmitter beam axis.
- As the pulse passes through the sampling volume, sound is reflected in all directions by particulate matter (sediment, small organisms, bubbles).
- Some portion of the reflected energy travels back along the receiver beam axes.
- The reflected signal is sampled by the acoustic receivers.
- The Triton processor measures the change in frequency for each receiver.
- The Doppler shift is proportional to the velocity of the particles along the bistatic axis of the receiver and transmitter. The bistatic axis is located halfway between the transmit and receive axes.
- Knowing the relative orientation of the bistatic axes of all receivers allows the Triton to calculate 3D water velocity in the sampling volume.

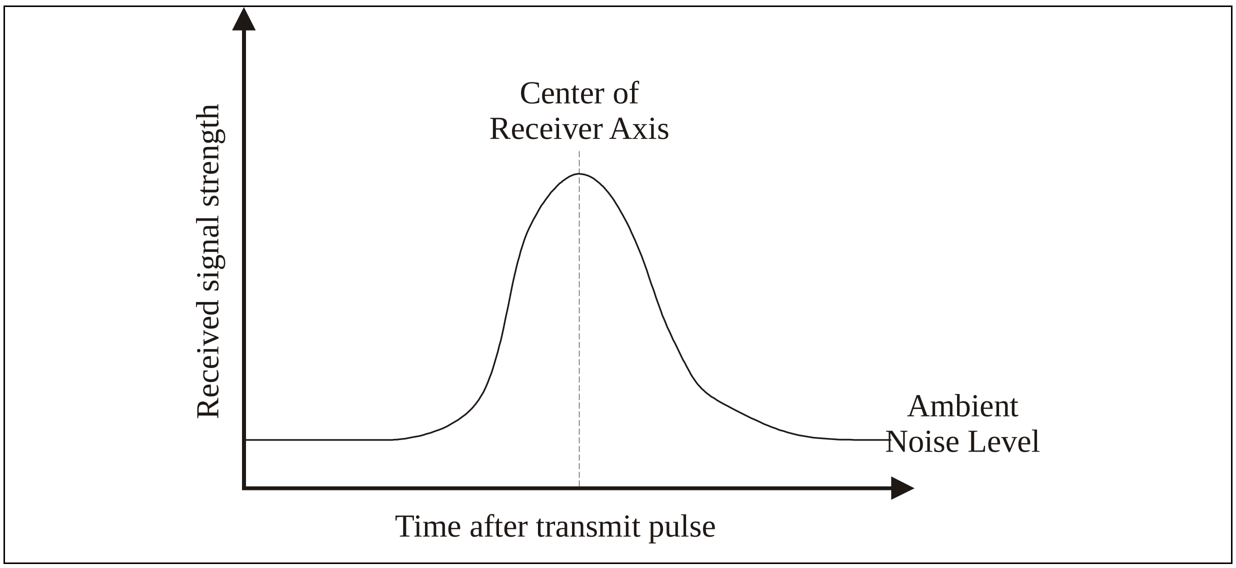


Figure 2 – Triton Signal Strength Profile

Figure 2 shows the profile of signal strength versus time for the Triton.

- The horizontal axis shows time after the transmit pulse
- The vertical axis shows the returned signal strength measured by one receiver.
- As the transmit pulse travels through the water, sound is reflected in all directions.
- Immediately following the transmit pulse, reflections come from outside the receiver beam; the receiver measures only the ambient noise level.
- As the pulse propagates along the transmit axis, it moves closer to the receiver beam; the receiver sees an increase in signal strength.
- Signal strength reaches a maximum at the intersection of the transmit and receive beams.
- By sampling the return signal at its peak, the Triton makes measurements in the sampling volume defined by the intersection of transmit and receive beams.

Section 3. Beam Geometry and 3D Velocity Measurements

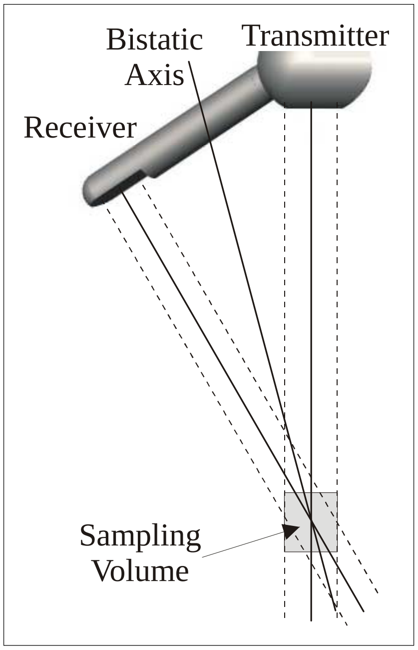


Figure 3 – Bistatic Axis

A single transmit/receive pair measures the projection of the 3D velocity onto the bistatic axis.

- The bistatic axis is halfway between the transmit and receive beam axes (Figure 3).
- The velocity measured by each receiver is called the bistatic velocity.
- The Triton uses one transmitter and two or three receivers (for 2D or 3D probes).
- Receivers intersect with the transmit beam pattern at a common sampling volume.
- Bistatic velocities are converted to Cartesian (XYZ) velocities using the probe geometry (the relative angles of transmit and receive beams).
- During the manufacturing process, probe geometry is precisely determined by a calibration procedure.
- The calibration only needs to be performed once.
- No periodic re-calibration is required.

Cartesian (XYZ) velocities give the 3D velocity relative of the Triton probe.

- The Triton can include a compass/tilt sensor to measure probe orientation.
- Knowing instrument orientation allows the Triton to report velocity data in an Earth (East-North-Up or ENU) coordinate system.
- Using the ENU coordinate system allows the Triton to report accurate velocity data even when probe orientation is unknown or varies with time.

3.1. Velocity Sensitivity

When analyzing Triton velocity data, it is helpful to understand the effect of the probe geometry.

- We define the vertical direction as the axis of the transmitter, and the horizontal direction as perpendicular to this axis.
- The Triton measures bistatic velocities (about 15° off the vertical axis) and converts these to Cartesian (XYZ) velocities using the probe geometry.
- Bistatic velocities are more sensitive to vertical velocity than to horizontal velocity by a factor of four (tan (15°) = 0.27).
- The maximum horizontal velocity that can be measured is four times larger than the maximum vertical velocity (§6.1.1).
- Noise in horizontal measurements is four times larger than in vertical measurements (§6.1.3).

Section 4. Sampling Volume Definition

The Triton sampling volume location is specified as follows.

- The sampling volume is nominally 10 cm (4 in) from the tip of the probe (Figure 1).
- The exact location varies ±0.5 cm (±0.2 in) from probe to probe.
- Precise sampling volume location is fixed for any given probe.
- Precise sampling volume location, ±0.1 cm (±0.04 in), is determined by the probe calibration procedure and is reported by the Triton software.
- The sampling volume location is specified at the vertical center of the sampling volume.

The physical size of the sampling volume is approximated as follows.

- A cylinder 0.6 cm (0.24 in) in diameter by 0.9 cm (0.35 in) long (Figure 1)

A complete definition of the Triton sampling volume size is more complicated. The size is determined by four factors.

- Transmit beam pattern
- Receive beam pattern
- Acoustic pulse length
- Receive window (the period of time over which the return signal is sampled)

The horizontal boundaries of the Triton sampling volume are determined by the intersection of the transmit and receive beam patterns.

- The precise definition of the beam pattern intersection is not easily modeled.
- It is approximated from the transmit beam pattern as a cylinder. The diameter of the transmit ceramic is typically 0.6 cm (0.24 in).
- The approximation is reasonably accurate since the vertical limits of the sampling volume are typically most important.

The vertical extent of the sampling volume is defined by the acoustic pulse length and the receive window over which the return signal is sampled.

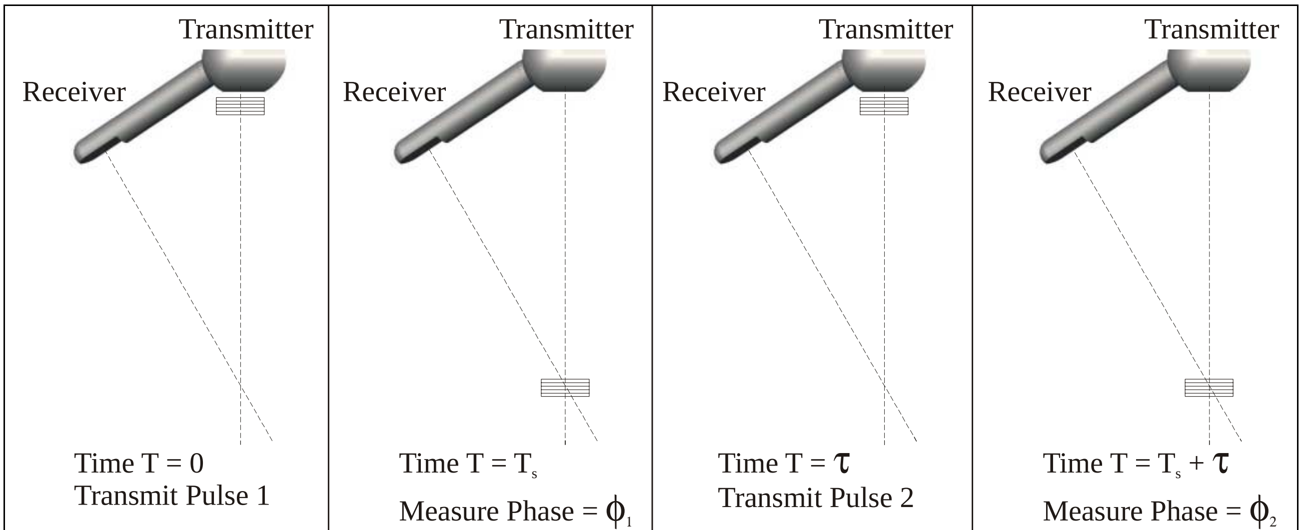
- These parameters are controlled by the Triton software.
- The height of the sampling volume is 0.9 cm (0.35 in).
- The vertical edges are defined to ±0.05 cm (±0.02 in).

Section 5. Pulse-Coherent Processing

This section does not attempt to provide a detailed description of pulse-coherent processing. It presents a general overview with a focus on how this affects Triton operation. SonTek can provide additional references on request.

The description of Triton operation given in Section 2 is a simplification.

- Section 2 describes incoherent Doppler processing: the transducer sends a single pulse of sound and measures the frequency change of the returned signal.
- The Triton uses pulse-coherent processing (Figure 4).



$$V = \frac{\lambda\,(\phi_2 - \phi_1)}{\tau} \qquad \lambda = \text{Wavelength}$$

Figure 4 – Pulse-Coherent Processing

Pulse-coherent processing works as follows.

- The Triton sends two pulses of sound separated by a time lag, τ.
- Each receiver measures the phase (ϕ) of the return signal from each pulse.
- The change in phase ($\phi_2 - \phi_1$) divided by the time lag (τ) is proportional to velocity.

Pulse-coherent processing provides the best possible spatial and temporal resolution of any Doppler processing technique. There are several aspects of pulse-coherent processing that affect Triton operation.

One aspect is the limitation on the maximum velocity that can be measured.

- Pulse-coherent processing measures the phase of return signals.
- Phase measurements are limited to a range of [$-\pi$, π].
- If the phase exceeds these limits, it will “wrap around” (i.e., if phase increases above π, the Triton measures a phase of $-\pi$).
- This is known as an ambiguity jump, where (for example) the Triton will measure a negative velocity rather than the true, larger positive velocity.

The maximum velocity is a function of the time lag (τ) between the two pulses. The Triton can be operated in two different ways regarding the maximum velocity range.

- In the Auto velocity range, the Triton sends pulses at a number of lags and automatically determines the best lag based on the measured water velocity. In this mode, the Triton gives the best performance possible for any velocity within its measurement range of 0.01 to 600 cm/s (0.0003 to 19 ft/s).
- The Triton offers you a choice of several preset velocity ranges, each of which corresponds to a particular pulse lag. If the velocity exceeds the maximum velocity for the specified range, an ambiguity error will result and velocity data will be corrupted.

For most applications, the Auto velocity range is the preferred choice.

- The Auto velocity range offers the best performance with no risk of ambiguity errors.
- The Auto velocity range increases power consumption by about a factor of two.
- The only reason to use the preset velocity ranges is for power-limited applications (e.g., extended deployments on battery power).
- Even when using the Auto velocity range, the Triton only consumes 0.5 W, so the use of the preset velocity ranges is rarely required.

Pulse-coherent processing affects Triton operation in two other situations.

- When making near-boundary measurements, there is a possibility that the reflection of the first pulse from the boundary could interfere with the second pulse. This is discussed in Section 7.3.
- The ability to adjust the time lag between pulses gives the Triton excellent performance for applications with low flows. This is discussed in Section 7.4.

Section 6. Triton Data

The Triton records the following data with each sample.

- Date and time from the Triton internal clock
- Three velocity values, one for each 3D component (§6.1)
- Three signal strength values, one for each receiver (§6.2)
- Three standard error values, one for each velocity component (§6.3)
- Boundary range data (§7.3, §7.5)
- Temperature sensor data
- Compass/tilt sensor data, if installed (§Section 3)
- Pressure sensor data, if installed (§7.6.1)
- SeaBird MicroCat sensor data, if installed (§7.6.2)
- YSI Multiprobe sensor data, if installed (§7.6.3)

6.1. Velocity

The Doppler processing techniques used by the Triton provide several important performance advantages.

- It can measure 3D water velocities from 0.01 to 600 cm/s (0.0003 to 19 ft/s).
- For most applications, velocity data can be used immediately without any postprocessing corrections.
- Velocity data is typically output in Cartesian coordinates (XYZ) relative to probe orientation.
- For systems with the optional compass/tilt sensor, velocity data can be output in Earth coordinates (East-North-Up or ENU) independent of probe orientation.
- The Triton calibration does not change unless the probe has been physically damaged.
- The only time postprocessing corrections are needed is when sound speed has been incorrectly specified (§7.2).

Several aspects of Triton operation affect the quality of velocity data.

- Velocity range setting (§6.1.1)
- Sampling rate (§6.1.2)
- Short term uncertainty (§6.1.3)
- Accuracy (§6.1.4)

6.1.1. Velocity Range Setting

The maximum velocity that can be measured by the Triton varies with velocity range setting (a user-specified parameter).

- For most applications, the Auto velocity range setting is preferred as it provides the best performance over the widest range.
- For power-limited applications, a preset velocity range will reduce power consumption and extend deployment length.
- Triton power consumption using the Auto velocity range is very low (0.5 W), so the use of preset velocity ranges is rarely required.
- See Section 5 to learn more about maximum velocity limitations.

Velocity range settings for the Triton are shown in the table below.

- The Auto velocity range gives the best performance for the widest range of velocities.
- When using a preset velocity range (for power-limited applications), select the lowest range setting that exceeds the maximum velocity expected.
- Doppler noise in velocity data is proportional to the velocity range setting; higher velocity ranges have higher noise levels (§6.1.3).

The velocity range settings are nominal values.

- The Triton measures velocities along the bistatic axis of each receiver.
- Since the bistatic axes are 15° off the probe vertical axis, the Triton is more sensitive to vertical flow and has a lower maximum velocity for vertical flow.
- The table below shows the maximum velocities that can be measured in each Triton velocity range for purely vertical or purely horizontal flow.

Velocity Range Setting	Max. Horizontal Velocity	Max. Vertical Velocity
±3 cm/s	±20 cm/s (0.65 ft/s)	±5 cm/s (0.16 ft/s)
±15 cm/s	±35 cm/s (1.1 ft/s)	±10 cm/s (0.32 ft/s)
±50 cm/s	±80 cm/s (2.6 ft/s)	±20 cm/s (0.65 ft/s)
±200 cm/s	±225 cm/s (7.4 ft/s)	±60 cm/s (2.0 ft/s)
±600 cm/s	±600 cm/s (19 ft/s)	±160 cm/s (5.2 ft/s)
Auto	±600 cm/s (19 ft/s)	±160 cm/s (5.2 ft/s)

6.1.2. Sampling

The following describes the basic Triton sampling strategy.

- An individual measurement of the 3D velocity is referred to as a ping.
- The Triton pings 10 times per second.
- Pings are averaged over the user-specified averaging interval to produce a mean 3D velocity value.
- The mean 3D velocity is referred to as a sample.
- An important result of the Triton sampling strategy is that increasing the averaging interval decreases the uncertainty in each sample (by increasing the number of pings averaged).

6.1.3. Short Term Uncertainty (Noise)

The Triton, like all Doppler velocity systems, has an inherent measurement noise.

- The noise is a result of the physical process by which the sound waves are scattered from particles in the water, and is referred to as Doppler noise.
- Doppler noise is random and can be assumed to follow a Gaussian distribution
- Averaging multiple data points converges to the true value without introducing bias.
- Noise decreases with the square root of the averaging interval. (e.g., data using a 60-s averaging interval has half the noise of a 15-s averaging interval [$0.5 = \sqrt{(15/60)}$]).

The table below gives an estimate of noise levels for different velocity range settings and averaging times (assuming good operating conditions, see Section 6.2).

Velocity Range Setting	Noise – 1-second Averaging Interval	Noise – 15-second Averaging Interval	Noise – 60-second Averaging Interval
±3 cm/s	±0.1 cm/s (0.003 ft/s)	±0.03 cm/s (0.001 ft/s)	±0.01 cm/s (0.0003 ft/s)
±15 cm/s	±0.2 cm/s (0.007 ft/s)	±0.05 cm/s (0.002 ft/s)	±0.03 cm/s (0.001 ft/s)
±50 cm/s	±0.5 cm/s (0.016 ft/s)	±0.1 cm/s (0.003 ft/s)	±0.06 cm/s (0.002 ft/s)
±200 cm/s	±2.0 cm/s (0.07 ft/s)	±05 cm/s (0.016 ft/)	±0.3 cm/s (0.01 ft/s)
±600 cm/s	±6.0 cm/s (0.2 ft/)	±1.5 cm/s (0.05 ft/s)	±0.8 cm/s (0.025 ft/s)
Auto	±1% of measured velocity	±0.25% of measured velocity	±0.1% of measured velocity

- The values above are for horizontal velocities; because of probe geometry, noise in vertical velocity data is lower by a factor of four.
- The values here reflect only instrument generated noise, and do not account for real variations in water motion.
- In most applications, real variations in water motion will be much larger than instrument generated noise.

6.1.4. Accuracy

Triton accuracy is specified as follows.

- Accuracy refers to bias in velocity measurements after removing noise (§6.1.3).
- There are two main factors that influence the accuracy of the Triton: sound speed and probe geometry.
- The effect of sound speed on velocity measurements is discussed in Section 7.2. Sound speed errors are typically negligible (less than 0.25%); larger errors (which are uncommon) can be corrected in postprocessing.
- Probe geometry is calibrated at the factory for each Triton; no recalibration is required unless the probe has been physically damaged.
- The Triton calibration procedure is specified to ±1.0% of the measured velocity.
- For the Triton, there is no potential for zero offset in velocity measurements; it is extremely well suited to low flow applications. See Section 7.4 for additional information about using the Triton to measure low flow velocities.

6.2. Signal Strength

Signal strength is a measure of the intensity of the reflected acoustic signal received by the Triton.

- Signal strength is recorded in internal logarithmic units called counts; one count equals 0.72 dB.
- Signal strength is typically compared to the system noise level, which is measured directly using the Triton software.
- For good operation, signal strength should be at least 20 counts (15 dB) higher than the noise level.
- Accurate velocity data can be obtained with only 10 counts (7 dB) above the noise level, although there will be more uncertainty (Doppler noise) in individual measurements.
- Low signal strength indicates a lack of particulate matter (scatterers) in the water. For very clear water, seeding material can be introduced to increase signal strength.
- Seeding is typically only required in large, quiescent laboratory basins. Most field applications have sufficient scattering material naturally.

Signal strength is a function of the amount and type of particulate matter in the water.

- Signal strength can be used as a measure of sediment concentration.
- While Triton signal strength data cannot be immediately converted to sediment concentration, it provides an excellent qualitative picture of sediment fluctuations and, with proper calibration, can be used to estimate sediment concentration.
- For more information about this application, contact SonTek.

6.3. Standard Error of Velocity

Standard error of Triton velocity data is provided as a direct measure of the quality of velocity data.

- One standard error value is reported for each velocity component (in the user-specified coordinate system, XYZ or ENU).
- The standard error value can be directly interpreted as an estimate of the accuracy of the mean velocity value reported for a sample.
- Standard error data reflects both instrument-generated uncertainty (Doppler noise) and real variations in water velocity. In many applications, real variations in water velocity will dominate.

The standard error is calculated as follows.

- A number of pings are averaged during the user-specified averaging interval.
- A mean velocity value is reported.
- The standard deviation of velocity is divided by the square root of the number of pings to compute standard error.
- Standard error values are a direct statistical measure of the accuracy of the mean velocity data.
- Standard error data reflects both instrument-generated uncertainty (Doppler noise) and real variations in water velocity. In many applications, real variations in water velocity will dominate.
- Predicted Doppler noise values (§6.1.3) reflect only instrument-generated uncertainty.

Section 7. Special Considerations

7.1. Alternate Probe Configurations

The Triton probe is available in several configurations for different measurement needs. Probes can be configured with almost any combination of these options.

<u>Probe mounting</u>. Three mounting options are available.

- 15-cm (6-in) long stainless steel stem (standard)
- 25-cm (10-in) long stainless steel stem
- 100-cm (40-in) flexible cable (this increases flexibility in probe orientation, but requires special mounting arrangements)

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<u>Probe type</u>. Three different probe types are available.

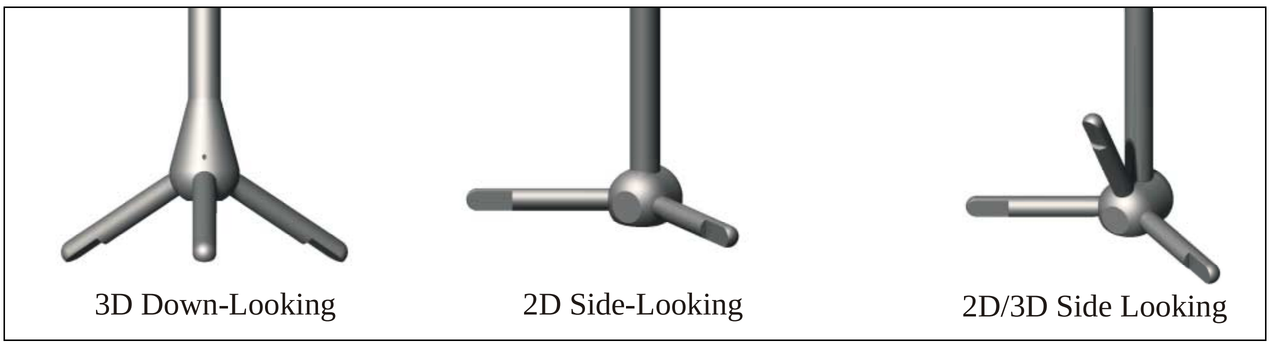

Figure 5 – Triton Probe Configurations

- The standard Triton uses a 3D down-looking probe, where the sampling volume is located 10 cm (4 in) below the probe.
- For shallow water, a 2D side looking probe can be used. This has a sampling volume located 10 cm (4 in) to the side of the probe, and can operate in as little as 2 cm (1 in) of water.
- To work in both shallow and deeper water, a combination 2D/3D side looking probe is available. This has a sampling volume located 10 cm (4 in) to the side of the probe, and can operate in as little as 2 cm (1 in) of water. The system automatically switches between 2D and 3D operation depending on water depth.

7.2. Sound Speed

The Triton uses sound speed to compute velocity from the measured Doppler shift. This section discusses how to correct Triton velocity data for errors in the sound speed value used during data collection. Sound speed errors are typically very small; postprocessing corrections are rarely required.

The speed of sound in water is primarily a function of temperature and salinity.

- The Triton includes a temperature sensor (±0.1°C; ±0.2°F) for automatic sound speed corrections.
- A user-entered value of salinity is used for sound speed calculations.

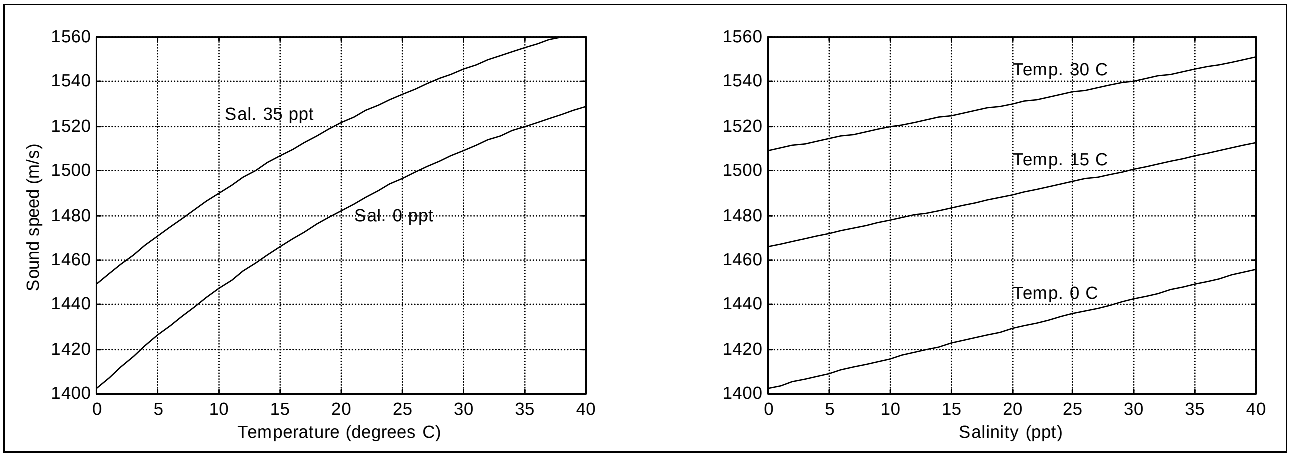

Figure 6 – Sound Speed as a Function of Temperature and Salinity

Figure 6 shows sound speed as a function of temperature at two different salinity levels (left) and salinity at three temperature levels (right). As a general rule:

- A temperature change of 5°C (9°F) results in a sound speed change of one percent.
- A salinity change of 12 ppt results in a change in sound speed of one percent.
- The full range of typical temperature levels (-2 to 40°C; 28 to 105°F) and salinity levels (0 to 35 ppt) gives a sound speed range of 1400 to 1560 m/s (4590 to 5120 ft/s) – total change of 11%.

Sound speed affects Triton velocity data in two ways.

- Conversion of the Doppler shift to velocity, which scales directly with sound speed.
- Measurement geometry as determined by the location of the sampling volume. A geometry change can occur since the Triton sampling time is determined by sound speed. If sound speed is incorrect, the physical location of the sampling volume will differ from the location in the probe calibration file.

Correcting Triton velocity for sound speed errors can be done two ways. The first method uses a best-fit approximation of the geometry change. This correction, shown below, is accurate to about 0.5% for sound speed errors up to about 5%.

<u>Horizontal velocity correction</u> (Vx and Vy for the 3D down-looking probe; Vx for the 2D side-looking probes; Vx and Vz for the 2D/3D side looking probe):

$$V_{true} = V_{orig} * (1 + 1.93 * ([C_{true} / C_{orig}] - 1))$$

<u>Vertical velocity correction</u> (Vz for the 3D down-looking probe; Vy for the 2D side-looking probes and the 2D/3D side-looking probe):

$$V_{true} = V_{orig} * (1 + 0.94 * ([C_{true} / C_{orig}] - 1))$$

where:

V_{true} = Corrected velocity value
V_{orig} = Uncorrected (original) velocity value
C_{true} = True speed of sound
C_{orig} = Speed of sound used in original calculations

A more precise method to correct Triton velocity involves calculating the exact geometry change and recomputing the Cartesian velocity values. This is done in four steps.

1. Transform Cartesian (XYZ) velocities back to bistatic velocities.
2. Scale bistatic velocities for correct sound speed.
3. Compute corrected transformation matrix for geometry change.
4. Transform bistatic velocities to Cartesian (XYZ) velocities using corrected matrix.

This algorithm uses the transformation matrix and bistatic angles unique to each Triton probe. Further details are available upon request.

7.3. Near-Boundary Measurements

Thanks to its remote, 3D velocity measurements, the Triton is well suited to boundary layer studies. However, making accurate measurements near a boundary requires some additional care. This section describes the potential sources for error and the overall system performance.

The primary source of interference is when the sampling volume includes the boundary.

- In this case, the Triton measures the Doppler shift of the boundary reflection rather than particles in the water. This will typically bias velocities towards zero.
- Under good operating conditions, the leading edge of the Triton sampling volume can be placed within about 1 mm of a boundary without interference.
- When making near-boundary measurements, it is important that the distance from the probe to the boundary be constant. If making measurements where the height of the boundary can change with time (e.g., near the surface or near a moving bed), this will typically be the limiting factor in how close measurements can be made.

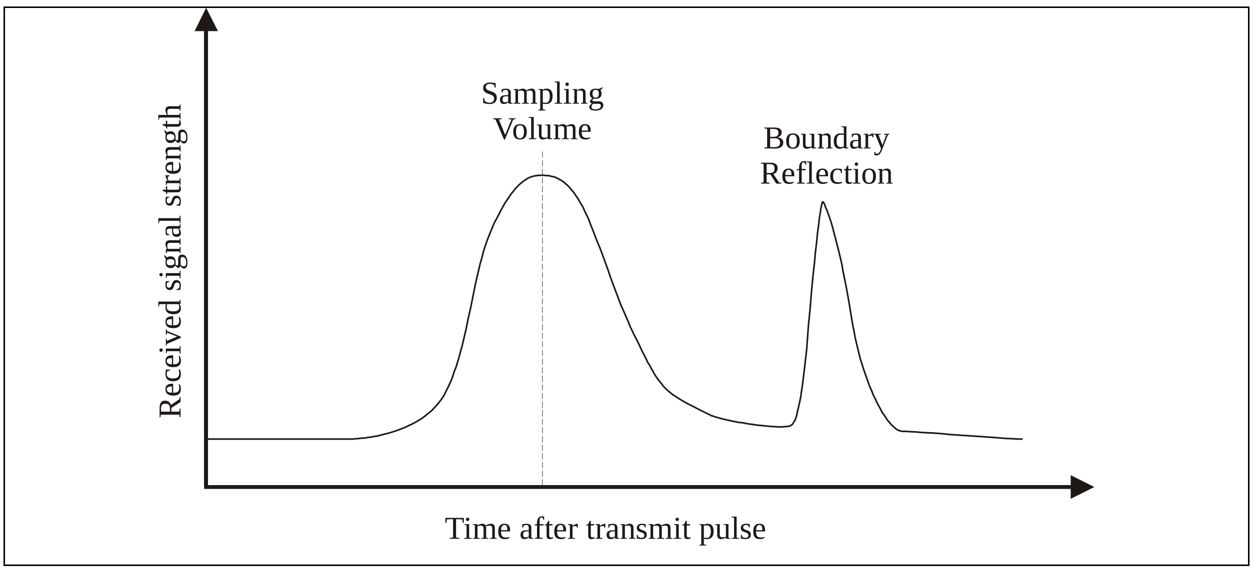

Figure 7 – Triton Signal Strength Profile with Boundary Reflection

Figure 7 shows the profile of signal strength for one Triton receiver when operating near a boundary.

- This is the same as Figure 2, but with a spike corresponding to the boundary reflection.
- The size and shape of the boundary reflection will vary with range, the type of boundary, and the orientation of the probe.
- Although the boundary reflection comes from outside the peak receiver sensitivity, the strength of the reflection is far stronger than the return signal from the water so its return can be as strong (or stronger) than the return from the sampling volume.
- The distance between the sampling volume peak and the bottom reflection peak is used by the Triton to mea%sure the distance from the sampling volume to the boundary.

When working close to a boundary, measuring the distance from the sampling volume to the boundary becomes extremely important.

- The Triton measures the distance to the boundary, accurate to about ±0.1 cm.
- This accuracy is valid only if the center of the sampling volume is more than 2 cm (1 in) from the boundary. At closer ranges, the Triton cannot distinguish the boundary from the sampling volume.
- To position the Triton sampling volume very close to a boundary, use the Triton measured distance at a greater range and move the probe a controlled distance to achieve the desired measurement location.

There is a second, less obvious, source of boundary interference.

- The Triton sends two pulses for each velocity measurement (Section 5).
- If the distance between the two pulses matches the distance from the sampling volume to the boundary, this can cause interference in velocity measurements.

The Triton is designed to look for this type of interference.

- At the start of each sample (if the averaging interval is 10 seconds or more), the Triton measures the distance to the boundary (if present).
- If the averaging interval is less than 10 seconds, the Triton measures the distance to the boundary only once at the start of data collection.
- If that boundary distance matches the pulse lag, the Triton adjusts the pulse lag to avoid interference.
- In most cases, the adjustments can be made with no effect on instrument performance.
- The most significant limitations occur when trying to measure high flows very close to the boundary. These measurements can typically be made, but require careful adjustment and monitoring.

There is one important result of this second type of potential boundary interference.

- If moving the probe with the respect to the boundary (i.e., making a profile), data collection should be restarted at each depth that is less than about 20 cm from the boundary **if the averaging interval is less than 10 seconds**. This allows the Triton to check for interference and adapts its operation to avoid it. If the averaging interval is 10 seconds or more, the Triton will look for boundary interference with each sample.
- When working more than 30 cm (12 in) from the boundary, interference is not a concern.
- Care should be taken when working near moving beds or near the surface, where the height of the boundary can change with time.

7.4. Low Flow Measurements

A significant advantage of the Triton is that there is no minimum detectable velocity, and no potential for zero offset or zero drift.

- Under normal operating conditions, the Triton will yield good results to below 0.1 cm/s (0.003 ft/s).
- In laboratory experiments, the Triton has been used to measure calibrated flows as low as 0.04 cm/s (0.001 ft/s).
- For more information about low flow applications, please contact SonTek.

7.5. Acoustic Altimetry

An added feature of the boundary detection routines discussed is Section 7.3 is that the Triton measures and records the range to the boundary with each sample.

- Boundary range is recorded with each sample if the averaging interval is 10 seconds or more.
- The Triton can detect the boundary to a range of about 30 cm (12 in).
- The boundary measurement is stored as a standard part of the Triton data.
- Boundary range can be used as a measure of evolving bed height for boundary layer studies.

7.6. External Sensor Integration

The Triton is designed to allow integration of other sensors and to store all data in a single, synchronized file. Three primary sensor types are available (a temperature sensor is included standard with all systems).

- Pressure (strain gage or RPT)
- Conductivity-temperature (SeaBird Microcat)
- Multiparameter environmental probe (YSI).

7.6.1. Pressure Sensor – Surface Level

Two types of pressure sensors can be added to the Triton for deployment depth/surface level measurements.

- Strain gage pressure sensor: 10 to 60-m (33 to 200-ft) depth ranges; ±0.1% of full scale
- Resonant pressure transducer (RPT) sensor: 20-m (66-ft) depth range; ±0.01% of full scale

7.6.2. SeaBird MicroCat Conductivity-Temperature

SeaBird is the recognized leader in high-precision temperature and conductivity measurements.

- SonTek has integrated the MicroCat with the Triton to provide the best velocity, temperature, and conductivity measurements in a single, integrated package.
- The MicroCat offers temperature accuracy of 0.002°C and conductivity accuracy of 0.0003 S/m.
- The Triton controls MicroCat operation (using a built-in RS232 serial interface) and collects one synchronized CT sample with each velocity sample.
- The data is stored in the same file as the Triton velocity data for easy analysis.
- With the integrated Microcat, an averaging interval of at least 10 seconds must be used.

7.6.3. YSI Multiprobe

The YSI 6820 Multiprobe offers the following parameters in a single package.

- Ammonium-nitrogen, dissolved oxygen, nitrate-nitrogen, temperature, ammonia, turbidity, chloride, salinity, ORP, and pH

Combined with the Triton, the Multiprobe lets you directly calculate the flux of pollutants.

- The Triton controls Multiprobe operation (using a built-in RS232 serial interface) and collects one synchronized sample with each velocity sample.
- The data is stored in the same file as the Triton velocity data for easy analysis.
- With the integrated SeaBird Multiprobe, an averaging interval of at least 10 seconds must be used.

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