PDF version of USGS Office of Surface Water Hydroacoustics Web page:
http://hydroacoustics.usgs.gov/indexvelocity/instruments.shtml

Index-velocity and Other Fixed-deployment Instruments

Instruments commonly used for index-velocity and other fixed-deployment current profiling applications are hydroacoustic current meters that use sound transmitted through the water to measure water velocities. For index-velocity applications, the water velocity measured by a hydroacoustic current meter can be used as an estimator or "index" of the mean velocity in a stream or river channel. Other fixed-deployment applications measure a profile of the water-column to determine current patterns in bays, harbors, estuaries, lakes and rivers.

Hydroacoustic current meters used by the USGS for index-velocity and fixed-deployment current profiling applications include:

- Acoustic Doppler Velocity Meters
- Acoustic Doppler Profilers
- Acoustic Velocity Meters

Acoustic Doppler Velocity Meters

Acoustic Doppler Velocity Meters (ADVMs) are acoustic current meters that use the Doppler principle to measure water velocities in a two-dimensional plane. These instruments are currently (2006) the most commonly used velocity meter for index velocity stations. Each ADVM transducer transmits sound pulses of a known frequency along a narrow acoustic beam (fig 1). As the pulses travel along the acoustic beam, they strike particulate matter (scatterers) suspended in the water. When the pulses strike scatterers some of the sound is reflected along the acoustic beam to the transducer. The reflected pulses have a frequency (Doppler) shift proportional to the velocities of the scatterers they are traveling in along the acoustic beam:

$$V = (Fd/2F0)*C$$

where,

Fd is the Doppler shifted frequency received at the transducer,

F0 is the transducer transmit frequency,

C is the sound speed, and

V is the scatterer (water) velocity.

ADVMs have two acoustic beams set at a known angle (beam angle) in a two-dimensional plane that is parallel to the water surface so if seen from above they would be in a "V" configuration (fig 1). From the beam radial velocities (velocities measured along the acoustic beams) the ADVM uses trigonometry to compute velocities in a user-set sample volume (fig 1). Velocities are output in cartesian coordinatates; in a typical installation where the ADVM is mounted on the side of the river, the x-component is the component of velocity parallel to the main flow direction of the river ("along flow") and the y-component of velocity is perpendicular to the main flow direction ("across flow") (fig 1). ADVMs can have one, three, or five sample volumes.

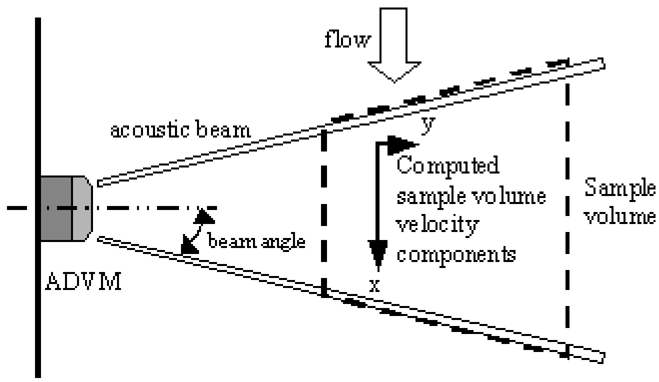

Figure 1. ADVM Schematic

The ADVM-measured velocity used to index mean velocity is usually the sample volume x-component of velocity. If an ADVM is equipped with multiple sample volumes, the average x-component of velocity from more than one sample volumes can be used as the index mean velocity.

ADVM transducer frequency, maximum and minimum sample volume sizes, and features vary by manufacturer and model. AVM features can include:

- multiple sample volumes
- "upward-looking" transducers to measure water stage
- internal data storage capability
- SDI-12 data communications specification
- internal tilt and roll sensors

The following is a brief description of some common ADVM models along with links to manufacturer specifications:

Sontek Argonaunt SL – A 2D side-looking velocity meter intended for side-looking current or flow measurement operations from bridge piers or pilings;

Sontek Argonaunt SW - Typically mounted on the bottom of a channel, stream, or pipe, and measures water level and vertically-integrated velocity in small channels from 0.5 to 16 ft (0.3-5 m) deep;

RD Instruments Channel Master - A 2D side-looking velocity meter intended for side-looking current or flow measurement operations from bridge piers or pilings;

Nortek Easy-Q - A 2D side-looking velocity meter intended for side-looking current or flow measurement operations from bridge piers or pilings.

Acoustic Profilers

Acoustic profilers use the Doppler frequency shift of acoustic pulses reflected from particles in the water to measure water velocities in multiple sample cells. Profilers can be mounted in a horizontal orientation (fig. 1a) to measure velocity profiles across a channel or mounted in a vertical orientation (fig. 1b) to measure vertical velocity profiles. A profiler uses two to four transducers set at a known orientation to measure water velocities. Each transducer transmits sound pulses of a known frequency along a narrow acoustic beam (fig 1). As the pulses travel along the acoustic beam, they strike particulate matter (scatterers) suspended in the water. When the pulses strike scatterers some of the sound is reflected along the acoustic beam to the transducer. The reflected pulses have a frequency (Doppler) shift proportional to the velocities of the scatterers they are traveling in along the acoustic beam:

$$V = (Fd/2F0)*C$$

where,

Fd is the Doppler shifted frequency received at the transducer,

F0 is the transducer transmit frequency,

C is the sound speed, and

V is the scatterer (water) velocity.

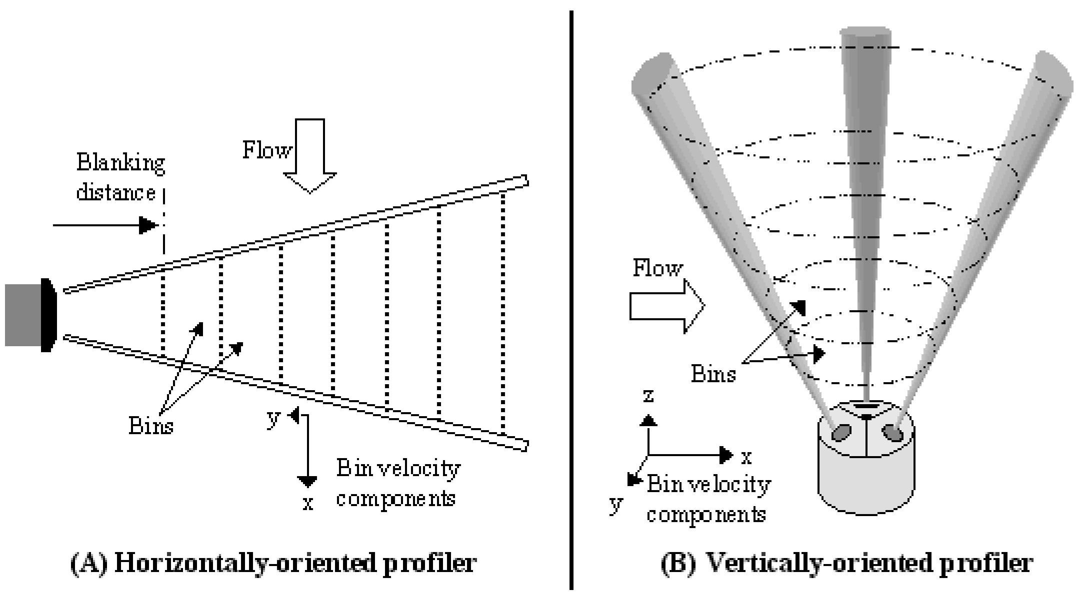

Figure 1. Examples of acoustic profiler orientations

Profilers measure velocities in uniformly-sized cells or bins along the acoustic beams (fig 1). By measuring velocities in a number of bins across a channel or vertically through the water column, these instruments produce horizontal or vertical water velocity profiles, hence the designation "profiler."

Profilers have varying acoustic beam geometries and can be installed in several different orientations. Profilers with two acoustic beams are usually used for horizontal orientations; the beams are set in a two-dimensional plane that is parallel to the water surface so if seen from above they would be in a "V" configuration. In the example orientation shown in figure 1a, the profiler is mounted on the side of the river and velocities are output in cartesion coordiates; the x-component is the component of velocity parallel to the main flow direction of the river ("along flow") and the y-component of velocity is perpendicular to the main flow direction ("across flow"). The profiler outputs an x-component and y-component of velocity for each bin (the number and size of the bins is programmable). An x-component and y-component velocity can be output for each bin.

Profilers with three acoustic beams are usually used for vertical orientations with the the three beams traversing the water column from the bottom up for a profiler mounted on the channel bottom (fig 1b), or from the top down if the profiler mounted on a floating buoy. Profilers with three beams can output velocities in three dimensions. In the example shown in fig. 1b, the profiler outputs velocities in cartesian coordinates; with the x-component is along flow, the y-component is cross flow, and the z-component is the vertical-velocity component (up or down). All three components can be output for each bin.

The profiler-measured velocity used to index mean velocity can be the velocity measured in one or multiple bins.

Profiler transducer frequency, maximum and minimum range, maximum and minimum bin size, and features vary by manufacturer and model. Profiler features can include:

- internal tilt and roll sensor
- internal compass
- dynamic ranging, a feature that adjusts the range to uppermost bin based on the distance to the water surface
- internal data storage capability
- a fourth beam that produces a redundant vertical velocity to test the assumption of homogenous flow in all beams
- a pressure transducer for estimating water stage

The following is a brief description of some common models of acoustic Doppler profilers along with links to manufacturer specifications:

Sontek Argonaunt XR - A 3D low-profile velocity profiler with adjustable sampling volume size and location

Sontek ADP - A 3-beam current profiler available in various frequencies

Teledyne RD Instruments Monitor – A 4-beam direct-reading ADCP that is typically bottom frame-mounted and hard-wired to shore to provide real-time monitoring of coastal currents.

Teledyne RD Instruments Rio Grande – A 4-beam ADCP primarily used as a rapid-sampling current profiler designed to operate from a moving boat but have also been used in upward and downward-looking fixed applications.

Acoustic Velocity Meters

Acoustic Velocity Meters (AVMs) are time-of-travel devices that measure water velocities along an acoustic path between pairs of transducers located on a diagonal line across a channel. The transducers are connected to a central processors by cables (figure 1). Acoustic pulses are transmitted along the acoustic path; the upstream-moving (against current) pulses travel slower than the downstream-moving (with current) pulses. The difference in travel times between the upstream and downstream moving pulses is proportional to the water velocity.

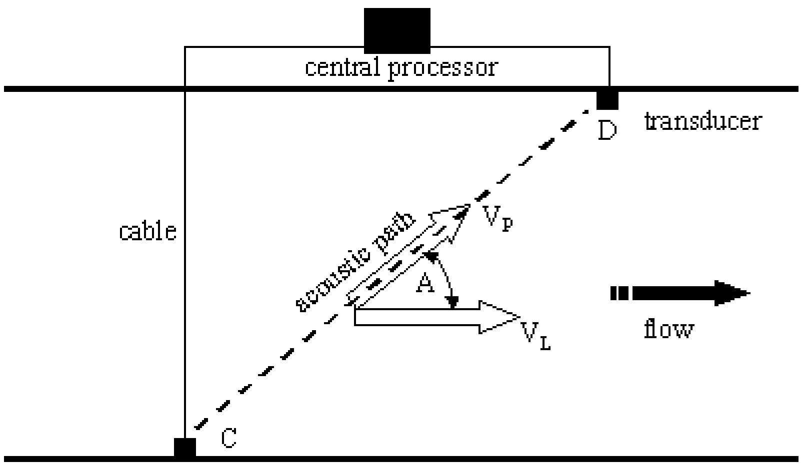

Figure 1. AVM Schematic

The AVM measures the average water velocity along the acoustic path (VP, figure 1); then computes the "line velocity," the velocity component parallel with the average downstream flow line (VL):

VL = (B/2cosA)(1/TDC-1TCD)

Where,

VL is the AVM line velocity,

B is the length of the acoustic path (figure 1),

A is the angle between acoustic path and VL (figure 1),

TDC is the travel time from transducer D to transducer C (figure 1), and

TCD is the travel time from transducer C to transducer D (figure 1).

AVMs can have multiple configurations, including:

- Multiple paths in the horizontal; the "cross-path" configuration (figure 2a) is commonly used. Multiple paths in the horizontal; the "cross-path" configuration (figure 2a) is commonly used.

* Multiple paths in the vertical (figure 2b). Multiple paths in the vertical can define vertical velocity profiles and can identify flow stratification.
* Reflector configuration (figure 2c). For sites where running cables to the far-bank transducers is impractical, it is possible to have both acoustic path transducers on one side of the channel. The acoustic pulses are bounce off of a reflector mounted on the opposite side. Reflectors are typically constructed of metal plates welded together so that the angle between plates is 90 degrees.
* Responder configuration (figure 2d). Another alternative for sites where running cables to the far-bank transducers is impractical is to have a responder mounted on the side of the channel opposite to the transducers. A responder is connected to two transducers; signals transmitted from transducer A are received at transducer B and immediately replicated and transmitted by the responder from transducer C to transducer D figure 2d). The total upstream travel time is computed for signals traveling along path ABCD and the downstream travel time is computed for signals traveling along path DCBA.

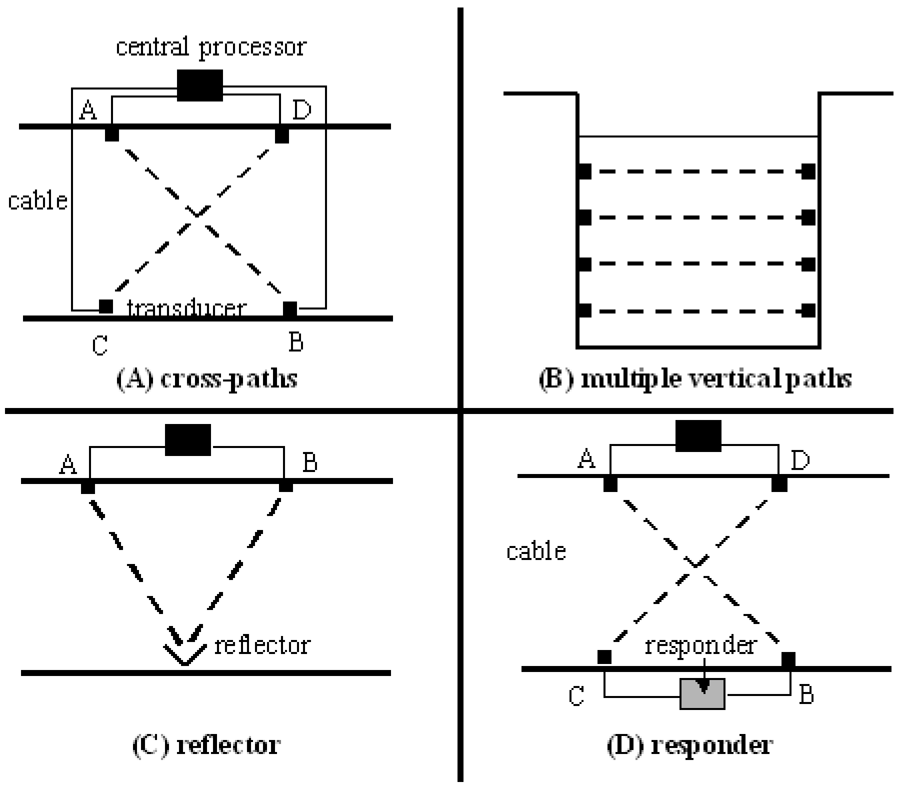

Figure 2. AVM configurations

The AVM-measured velocity used to index mean velocity can be the line velocity from one acoustic path or from multiple acoustic paths. For example, if the horizontal angle of flow in the channel is constant, the AVM line velocity from one acoustic path may be sufficient to accurately index mean velocity. If the horizontal angle of flow in the channel changes over time, using the average of AVM line velocities from both acoustic paths of a cross-path configuration (fig 1a) may be a more accurate index of mean velocity than the velocity from a single path.

AVM transducer frequency, maximum number of acoustic paths, maximum and minimum acoustic path lengths, and features vary by manufacturer and model. AVM features can include:

- "upward-looking" transducers to measure water stage
- internal data storage capability
- SDI-12 (serial digital interface) data communications specification (allows interface with many types of electronic data loggers)