SLOVENSKI STANDARD
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Hidrometrija - Smernice za uporabo akustičnih merilnikov hitrosti s pomočjo Dopplerjeve in korelacijske metode z odmevom

Hydrometry - Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods

Hydrométrie - Lignes directrices pour l'application des compteurs de vitesse ultrasoniques fixes utilisant l'effet Doppler et la corrélation d'échos

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Hydrometry — Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods

Hydrométrie — Lignes directrices pour l'application des compteurs de vitesse ultrasoniques fixes utilisant l'effet Doppler et la corrélation d'échos

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ISO copyright office
Case postale 56 CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15769 was prepared by Technical Committee ISO/TC 113, *Hydrometry*, Subcommittee SC 1, *Velocity area methods*.

This first edition of ISO 15769 cancels and replaces ISO/TS 15769:2000, which has been technically revised.

Hydrometry — Guidelines for the application of acoustic velocity meters using the Doppler and echo correlation methods

1 Scope

This International Standard provides guidelines on the principles of operation and the selection and use of Doppler-based and echo correlation velocity meters for continuous-flow gauging.

This International Standard is applicable to channel flow determination in open channels and partially filled pipes using one or more meters located at fixed points in the cross-section.

NOTE A limitation of the techniques is that measurement is made of the velocity of particles, other reflectors or disturbances.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies.

ISO/TS 25377:2007, *Hydrometric uncertainty guidance (HUG)*

ISO 772, *Hydrometry — Vocabulary and symbols*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 772 and the following apply.

3.1.1
beam angle
mounting angle of the acoustic transducer relative to the normalized profiling direction

NOTE Different beam angles will be suitable for different applications.

3.1.2
beam width
width of the acoustic signal transmitted, in degrees (°), from the centre of the transducer

NOTE This, coupled with the side lobe of the acoustic signal, will affect the suitability of a particular instrument for its application, based on the mounting location and the distance of the water volume measured from the sensor.

3.1.3
bed-mounted device
upward-looking Doppler or echo correlation device that measures velocities within a beam looking upwards at an angle through the water column

3.1.4
bin
depth cell
portion of the water sampled by the instrument at a known distance and orientation from the transducers

NOTE The instrument determines the velocity in each cell.

3.1.5
blanking distance
portion of water close to the instrument that is not sampled by Doppler technology

NOTE 1 This is left blank to allow the transducer to stop "ringing" before it receives reflected signals.

NOTE 2 It is also used to avoid the instrument sampling velocity in the zone of flow interference created close to, and by, the instrument.

3.1.6
broad-band Doppler
instrument that records velocity at set distances from the sensor (see range-gated Doppler, 3.1.11) using coded acoustic pulses to make multiple velocity measurements from a single pulse pair (ping)

3.1.7
continuous Doppler
simple type of Doppler instrument that measures the Doppler shift of all the particles within the range of the beam, taking the frequency with the largest peak as the average

3.1.8
downward-looking device
instrument that can be deployed floating on the water surface looking down into the water column

3.1.9
echo (cross) correlation
acoustic technique for recognizing echo images that can be used to determine the velocity of particles moving in the flowing water

3.1.10
profiling Doppler
Doppler instrument that discriminates between signals from reflectors at different distances from the sensor and uses this information to moderate the estimate of average velocity

3.1.11
range-gated Doppler
sophisticated Doppler instrument that records particle velocities at pre-set distances from the sensor

NOTE Some instruments can produce velocity profiles along the length of the beam, while others just log measurements from one or more pre-defined cells.

3.1.12
side lobe
most transducers that are developed using current technology have parasitic side lobes that are emitted off the main acoustic beam

NOTE The side-lobe effect needs to be allowed for in the design and operation of the instrument.

3.1.13
side-looker
Doppler usually mounted on the side of the channel

3.1.14
stage
water level measured relative to a fixed datum

EXAMPLE The level of the lowest point in the channel.

3.1.15
upward-looking device
bed-mounted instrument that looks up through the water column

3.2 Abbreviated terms

Abbreviation	Meaning	Notes
ADCP	acoustic Doppler current profiler	
ADP	acoustic Doppler profiler	This is a registered trademark of Sontek/YSI.[1)]
ADVM instrument	acoustic Doppler velocity meter	Term used to describe a profiling acoustic Doppler velocity.
ADVP	acoustic Doppler velocity profiler	Alternative acronym and name for ADCP.
H-ADCP	horizontal ADCP	Side/bank-mounted acoustic Doppler velocity profiler.
H-ADVM	horizontal ADVM	Side/bank-mounted acoustic Doppler velocity meter.

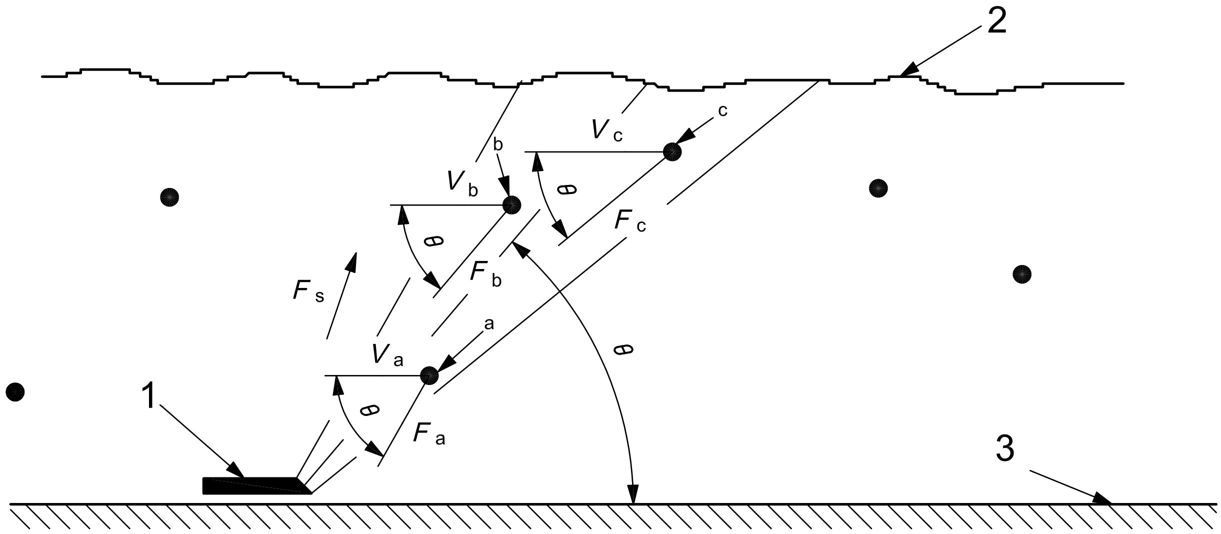
4 Principles of operation of the techniques

4.1 Ultrasonic Doppler

The method of velocity measurement used is based upon a phenomenon first identified by Christian Doppler in 1843. The principle of “Doppler shift” describes the difference, or shift, which occurs in the frequency of emitted sound waves as they are reflected back from a moving body.

The sensors of Doppler systems normally contain a transmitting and a receiving device (see Figure 1). A sound wave of high frequency (F_s) is transmitted into the flow of water and intercepted and reflected back at a different frequency by tiny particles or air bubbles (reflectors). A typical reflector n produces a frequency shift F_{dn}. The “shift” between transmitted and reflected frequencies is proportional to the movement of particles relative to the position of the sound source (i.e. the sensor).

1) Sontek/YSI is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.



Key

1	Doppler sensor
2	water surface
3	channel bed
a, b and c	particulates
F_s	frequency of transmitted sound pulse
F_a, F_b and F_c	frequency of sound pulses reflected from particulates a, b and c
V_a, V_b and V_c	velocity of particulates a, b and c
.	angle between the horizontal and the angle of the sound beam

Figure 1 — Principle of Doppler ultrasonic flow measurement

Doppler shift only occurs if there is relative movement between the transmitted sound source and the reflected sound source along the acoustic beam (but not if it is perpendicular to it). The velocity of the moving reflector n can be calculated from

a) the magnitude of the Doppler shift,

b) the angle between the transmitted beam and the direction of movement, and

c) the velocity of sound in water.

It can be shown that

$$v_n = F_{dn} \bullet c/2F_s \cos ._n$$

where

F_{dn} is the Doppler frequency shift produced by reflector n;

F_s is the frequency of sound with no movement;

v_n is the relative velocity between the transmitted sound source and reflector n;

c is the velocity of sound in water;

$._n$ is the angle between the reflector's line of motion (the assumed flow path) and the direction of the acoustic beam.

A Doppler velocity meter measures the resultant frequency shift produced by a large number of reflectors, of which reflector n is typical, and from that computes a mean velocity. It is the velocity of moving particles, and not water velocity, which is measured. By including the velocity of many particles, it aims to make an estimate of the mean water velocity of the volume sampled by the acoustic beam. Although the particles, if small, will travel at almost the same speed as the water, sampling errors may occur depending on the spatial and velocity distribution of the particles.

The cross-sectional area is also required to apply the velocity-area calculation of discharge. Most systems incorporate a water-level sensor, and combining the water depth with knowledge of the cross-sectional profile allows the flow to be calculated.

4.2 Operating techniques

4.2.1 Introduction

All Dopplers fit into one of four general categories, based upon the method by which the measurements are made:

a) continuous wave Dopplers;

b) pulsed incoherent profiling Dopplers (including narrow band);

c) pulse-to-pulse coherent;

d) spread spectrum or broad band.

The last three of these four categories are all range gated. Range gating breaks the signal into successive segments and processes each segment independently of the others. This allows the instrument to measure the profile of the velocity at different distances from the instrument, with precise knowledge of the location of each velocity measurement. Reference should be made to the manufacturer's instrument manual to determine the type of instrument in use.

4.2.2 Continuous wave Dopplers

Pulse incoherent or continuous Dopplers are the simplest type of Doppler system. A continuous Doppler transmits a continuous signal with one transducer, while receiving the reflected signal with a separate transducer. The instrument measures the Doppler shift, which is used to calculate the velocity of the particles along the path of the acoustic beam. The instrument takes an average of the measured velocities calculated from the frequency and the strength of the loudest reflected signals. The instrument cannot determine the precise location within the water column. In some situations, this simplicity does not cause any problems but, in channels where the sediment distribution is uneven, the loudest signal may not represent the average velocity in the channel. In addition, in channels with a heavy sediment load, most of the signal would be reflected back before fully penetrating the water column. Thus, the loudest signal would be from close to the instrument and would not be representative of the average velocity in the channel.

4.2.3 Pulse incoherent

Incoherent Doppler or profiling systems are more sophisticated than continuous wave Dopplers, in that they take into account the distance travelled by the reflected signals when calculating the average velocity. An incoherent Doppler transmits a single pulse of sound and measures the Doppler shift, which is used to determine the velocity of the particles along the path of the acoustic beam. Based upon the elapsed time since the pulse was transmitted, and the speed of sound in water, the exact location of the velocity measurement is known. By range gating the return signal at different times, the profile of velocity with the distance away from the instrument can be determined.

4.2.4 Pulse-to-pulse coherent

Coherent Doppler systems follow many of the same measurement principles as incoherent Doppler systems, but use a different method for determining the Doppler shift. Coherent systems transmit one relatively short pulse, record the return signal and then transmit a second short pulse, when the return from the first pulse is no longer detectable. The instrument measures the phase differences between the two returns and uses this to calculate the Doppler shift. Signals too close to the instrument are rejected.

4.2.5 Spread spectrum (broad band)

Like coherent systems, broad-band Dopplers transmit two pulses and look at the phase change of the return from successive pulses. However, with broad-band systems, both acoustic pulses are within the profiling range at the same time. The broad-band acoustic pulse is complex, it has a code superimposed on the wave form. The code is imposed on the wave form by reversing the phase and creating a pseudo-random code within the wave form. This pseudo-random code allows many independent samples to be collected from a single sound pulse. Because of the complexity of the pulse, the processing is slower than in a narrow-band system. However, multiple independent samples are obtained from each ping.

4.2.6 Range gating

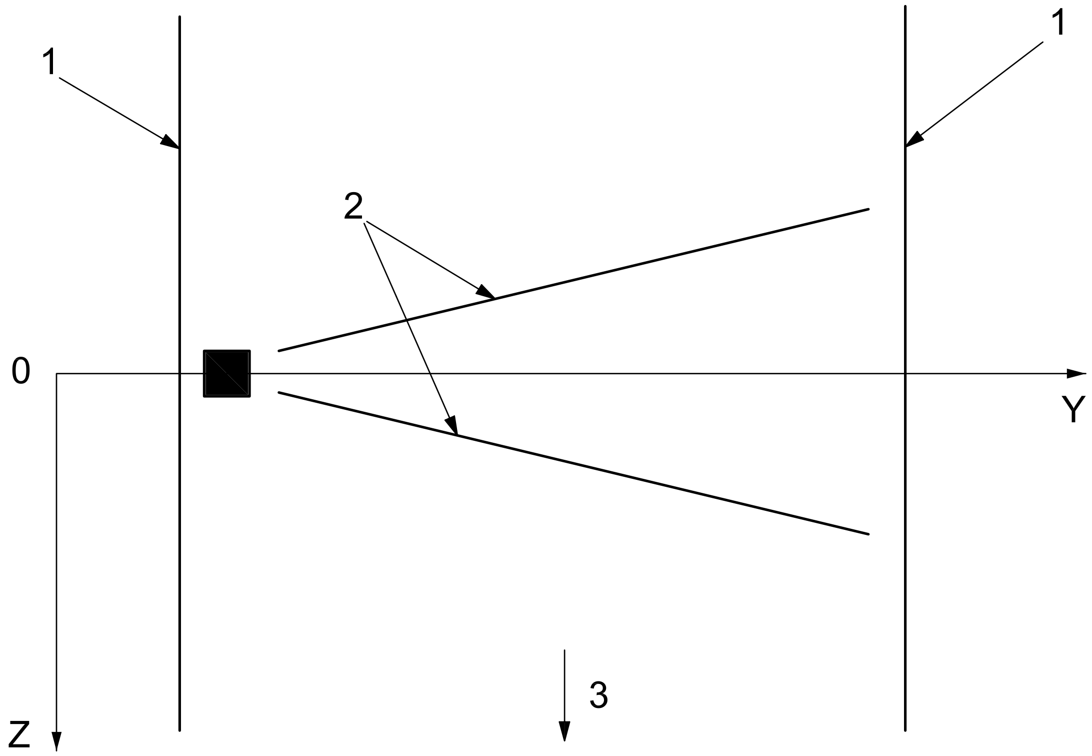
The range gating method breaks the signal into successive segments and processes each segment independently of the others. Side-looking/horizontal ADCPs use this approach, as do several of the more sophisticated bed-mounted devices.

4.3 Bed-mounted Doppler systems

Bed-mounted Doppler systems include all four types of Doppler instrument. They are normally used in smaller channels, for example up to 5 m wide and 5 m deep, where they are often practical and easy to install. However, this does not mean they cannot be used in larger channels, even though it may be difficult to install bed-mounted instruments in particularly deep channels. If siltation is a problem, it may be possible to mount such devices on a raised platform or on the channel sides.

4.4 Side-looking/horizontal ADCPs

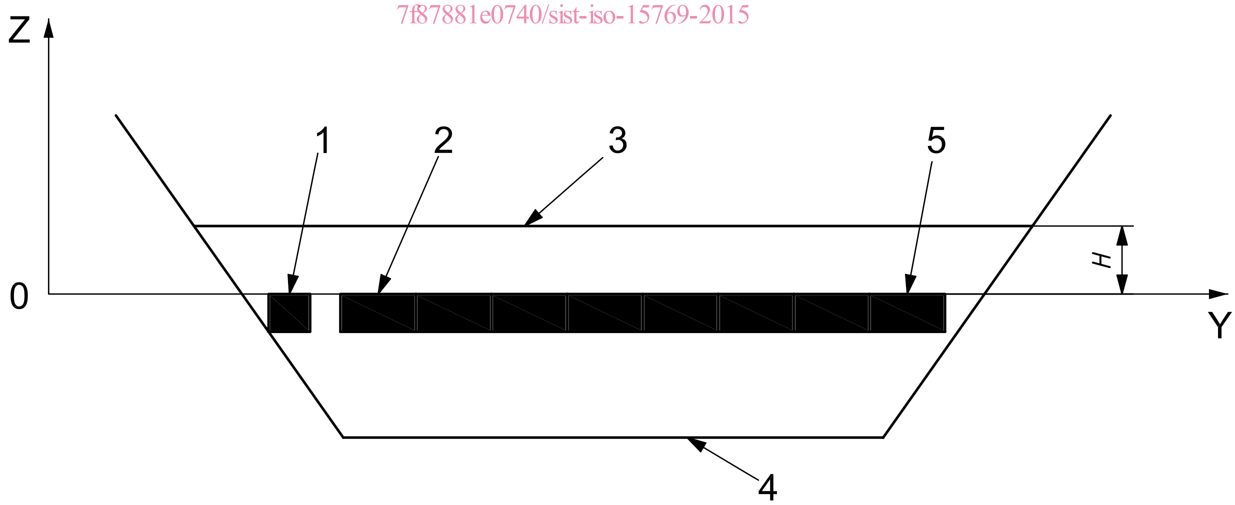
These instruments are usually fixed to the side of the channel and look across the channel to determine velocities in one horizontal layer across the full width, or a portion of the width, of the cross-section (excluding the blanking distance). Most systems consist of two transducers, one sending a beam diagonally across the channel in an upstream direction and the other diagonally across the channel in a downstream direction [see Figures 2 a) and 2 b)]. A fixed, side-looking ADCP does not estimate velocity throughout the full channel cross-section. With a known orientation of the transducers, each beam can be divided into an equal number of cells or bins and the component average velocity in the x-, y- and resultant directions can be determined for each cell. An integrated cell will give an average velocity, or individual cell velocities can then be averaged to determine the index velocity/measured velocity for the sampled length for the full distance sampled, or by selecting cells for a portion of the length. The mean velocity in the x-direction, i.e. at right angles to the measuring cross-section or parallel with the assumed direction of flow, is usually used to derive the velocity-index rating. Effectively, the instrument looks at a single horizontal layer across the channel (see-Figure 3). This layer is divided into one or more sample cells or bins and the average velocity is computed for each. The operator can usually select the size and position of these measurement cells.



Key

1 bank of channel
2 beams
3 direction of flow

a) Plan view



b) Side view

Key

1 instrument
2 first cell
3 water surface
4 channel bed
5 last cell
H height of water above cell

Figure 2 — Diagram illustrating a typical H-ADCP/side-looker beam and cell arrangement