# Acoustic Doppler Curent Profiler to Measure Current Velocity

## AUTHOR

***Abstract: -*** *Doppler speed log, an instrument that measures the speed of ships through the water or over the sea bottom was used before adcp. The first ADCP which was commercial, was based on concept of a commercial speed log . The speed log was refabricated to measure water velocity more precisely and to allow measurement in range cells over a depth profile. Henceforth, the first vessel-mounted ADCP was made. TRDI produced its first ADCP, a self-contained instrument designed for use in long-term in 1982. TRDI produced its first vessel-mounted ADCP In 1983. By 1986, TRDI had made five different frequencies (75-1200 kHz) and three different ADCP models (self-contained, vessel-mounted, and direct-reading). The concept of Doppler signal processing has established itself with the instruments afterwards. Speed logs used relatively simple processing with phase locked loops. The first generation of ADCPs used a narrow-bandwidth, single-pulse, autocorrelation method that computes the first moment of the Doppler frequency spectrum. This method was the first to produce water velocity measurements with sufficient quality for use by oceanographers.*
*Measurements of current velocity of streams, rivers, oceans are very important for:*
- *Study of biological life*
- *Transportation*
- *Weather Study*
- *Ecological Study*
- *Pattern of seasons.*

*Some examples of adcps are:*
*a) Sea PROFILER ADCP's are designed for real-time current profiling applications.*
*b) Sea WATCH ADCP's are well suited for deployments on buoys, moorings, or sea-floor structures.*
*c) The Sea WAVE vertical beam and standard pressure sensor provide accurate, higher frequency wave measurements that interfaces seamlessly.*
*PRINCIPLES: - Doppler effect is the effect of change in frequency or pitch of the sound which occurs due to the motion of the object with respect to the listener when both of them is in motion or stand still.*
*Doppler shift means the difference between the frequencies between the one when object is still in reference to source and when object is in motion. This only measures relative or radial motion.*
*$\Delta F=Fs(V/C)$*

---------------------------------------------------------------------------------------------------------------------------------

Date of Submission: 14-12-2020          Date of Acceptance: 28-12-2020

---------------------------------------------------------------------------------------------------------------------------------

## I. Introduction

ADCPs(Acoustic Doppler Current Profiler) consist piezoelectric transducers to send and get back sound signals. The time to travel of sound waves gives us the rough idea of the distance.

Adcp measurements can be assumed as chain of current meters where the width of the cell corresponds to the distance between them.

Now this effect is used by the ADCPS for the measurement of the radial current velocities.

Ocean current is continuous movement of sea water generated by various forces acting on water like Coriolis force, wind, gravitation force etc.

The frequency of the ultrasonic sound transmitted by commercially available ADCPs ranges from 30 kHz to 3000 Khz whereas human ear can hear frequencies up to 20kHz moreover dolphins can only hear frequencies up to 120kHz. So, the wavelength at such high frequencies is very less about 6 mm to 0.5mm.

To understand the concept of adcps it is important to understand the concept of sound and its relation with ocean along with its use in shallow water ocean waves.

Terms related to the term SOUND: -

Waves – Water wave crests and troughs are high and low water elevations.
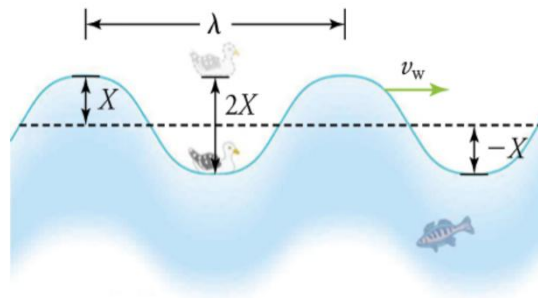
Sound wave ―crests‖ and ―troughs‖ consist of bands of high and low air pressure
. Wavelength – The distance between successive wave crests.
 Frequency – The number of wave crests that pass per unit time.
Speed of sound = frequency × wavelength: C = f·λ
v(w)-velocity of wave at which disturbances move
Although the sound waves are scattered in all directions the one which are reflected back represents Doppler shift here.

## II.    Detailed Description:

*For finding the current velocities we assume that these particles move at the same velocity horizontally as same as the water*

Adcp use doppler effect by transmitting sound signals of same frequencies and capturing the echoes which are returned and collected from the scattered particles in the water.
The factors on which the measurements rely are :-
1.        When there is change in density of water the sound is scattered or reflected.
2.        the frequency of the reflected sound is increased or decreased in direct proportion to the rate at which the reflectors are approaching the instrument.
3.        The particles which can reflect back the sound signals are "clouds of planktonic organisms-
❖        Fish without swim bladders
❖        Gellies
❖        Copepods
❖        Euphausiids
The ADCP works by listening  hydrophone for the sound that bounce offs the small particles.
        Sound reflects back after coming in contact with small particles like mentioned above due to high frequencies
        Structure: - Adcps are multi-beamed structures having 3-9 beams which radiates acoustic energy at a fixed frequency but the choice of frequency is subject to use for any particular application and then the frequency of the acoustic energy of the backscattered particles in the water column is noted and calculated. The position of this is either downward or upward as this machine words on (column data)
        The ADCP transducer configuration is called the Janus configuration, in reference to Roman god who looks both forward and backward. The Janus configuration is particularly good for rejecting errors in horizontal velocity caused by tilting (pitch and roll) of the ADCP
        The standard narrow-band ADCPs has 4 different transducers structured in a manner with beams pointing at an angle of  20 -30° to the plane of the transducers.
Since the transducers on an ADCP are at angles,
 the slant range (R) is calculated using the equation:
            (where φ is the transducer angle in degrees.)     $R_i = \dfrac{Z_i}{\phi \cdot \frac{180}{\pi}}$

COMPONENTS:

| components | Usage |
|---|---|
| temperature sensor | To note the temperature |
| electronic amplifier | To transmit sound signals |
| a receiver | To receive sound signals |
| a clock to measure the traveling time | To estimate the sound velocity |
| compass |  To know the heading |
| and a pitch/roll sensor | To know the orientation |
| analog-to-digital converter digital signal processor | To sample the returning for determining the Doppler shift. |

Now through calculations of trigonomatry,3D velocity the components are calculated by Doppler shifts measured with three to four sonar beams. Sometimes fourth beam is used to calculate error velocity also.

**Working: -**
The velocity of the current will be equal to the change in frequency: -
We know, velocity is defined as amount of distance covered in a unit time period in a particular direction.

$$\text{Velocity} = \text{distance} / \text{time}$$

Here,
$v_w = \lambda/T$
$v_w = f\lambda$                                     $[f=1/T]$

On move away from the ADCP , the sound they hear of the scattered particles is Doppler-shifted to a lower frequency which is proportional to the relative velocity between the scattered and ADCP the sound of the back scarred later appears to the ADCP as if the scatterers were the same as the sound source .Hence, the ADCP hears the backscattered sound Doppler-shifted a twice. So, as the ADCP both transmits and receives sound, the Doppler shift is doubled

$$F_d = 2\,F_s(V/C)$$

Therefore, velocity is proportional to the doppler shift. So if we know the actual frequency ,speed of sound in water we can easily calculate the velocity of current.

Now ,each beam can measure only the velocity of water column along its axis. So, minimum 4 beams having transducers are projected in the water in 3 axis (x,y,z)

Each velocity will have two components namely $\cos\theta$ and $\sin\theta$ having conditions:-
a)        assumes current Homogeneity in a Horizontal Layer
b)        two pairs of opposing acoustic beams, and that each beam measures a velocity that is actually a weighted sum of the local horizontal and vertical velocities

| $u1 = v\sin\theta + w\cos\theta$ | $u2 = -v\sin\theta + w\cos\theta$ |
|---|---|

Now where $\theta$ is the angle of the acoustic beam from the vertical (20° in this case) and *u*, *v* and *w* are the horizontal and vertical velocity components. So that:
- $u = u3 - u42\sin\theta$
- $v = u1 - u22\sin\theta$
- $w = u1 + u22\cos\theta = u3 + u42\cos\theta$

<u>Sound Speed Corrections</u>: – ADCP automatically computes sound speed and corrects velocity based on measured temperature and assumed salinity

<u>Measured velocity correction</u>: The difference between a velocity measured by one set of three beams and a velocity measured by another set of three beams at the same time

**Vcorrected=Vuncorrected(Creal/CADCP )**

        ADCP which is of narrow band having transmission of pulse of length which is fixed and ranging few milliseconds then the frequency shift, denoted as (Δf ) of the backscattered signal is directly proportional to the relative velocity (vcosθ) component  along the axis of the acoustic beam between the transmitted signals and backscattered particles. We calculate for a given source

$$v_k = \frac{(\Delta f_k / f)c}{\cos\theta_k}$$

vk - the relative current velocity for bin k at depth
Dk - depth range and is for
θk - the angle between the relative velocity vector and the line between the scatters and the ADCP beam
c - speed of sound at the transducer
Δf - frequency shift measured by the instrument
This velocity is for the velocity forward or backward as cos component resolves the horizontal component

## PARAMETERS AFFECTING ADCP SETUP:-

### A-Resolution
1-Resolution (Depth) vs. Random Noise – when depth resolution is developed the random noise will also be developed.
2- Resolution: Depth vs. Time – depth resolution when doubled without any increment the random noise will require 4 x the measuring period
3- Resolution vs. Deployment Length – when number of depth is doubled the cells doubles the power
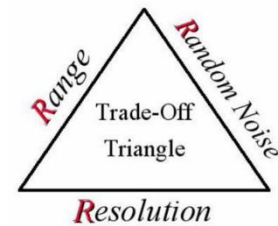
### B-Range
1-Range vs. Frequency – Twice the acoustic frequency will reach about half as far distance
2- Resolution vs. Range – Doubling cell size injects more energy into the water
3-Range: external factors – Cold and fresh water can support more precise profiling along with suspended materials.

### C-Random Noise-
1-Dynamic Conditions – When there is much turbulence, great change in velocity across the depth cell, pitch and also roll of the ADCP mounting the velocity precision gets affected.
Data Reading: -

i.  ADCP.dll:
o  Support for DVL.
o  Supports Rowe and Nortek devices
ii.  autolines.dll: Used for generating planned lines based on multibeam coverage.

The ADCP system usually uses a downward-looking profiler which broadcasts a forward, right- and left-lateral acoustic signals. In order to calculate discharge, the cross-product velocities are integrated over the water depth and, then, integrated, by time, over the width of the cross-section. The general equation for calculating water discharge through a surface, s, is modified as:

$$Q_t = \int\limits^{T} \int\limits^{d} \left( \left( V_f \times V_b \right) k \right) dz \cdot dt$$

where

* $Q_t$ = total river discharge (cms)
* $Vf$ = mean water-velocity vector, in meters/second
* $V_b$ = mean vessel-velocity vector, in meters/second
* $k$ = a unit vector in the vertical direction
* $d_z$ = vertical differential depth (meters)
* $d_t$ = differential time (seconds)

### Advantages:
* To measure the current depth profile required the use of long strings of current meters which is no longer needed.
* Measures small scale currents
* ADCPs measure the absolute speed of the water
* Measures a water column up to 1000m long

### Disadvantages:
* High frequency pings yield more precise data, but low frequency pings travel farther in the water
* ADCPs set to "ping" rapidly also run out of batteries rapidly
* Bubbles in turbulent water or schools of swimming marine life can cause the instrument to miscalculate the current
* Users must take precautions to keep barnacles and algae from growing on the transducers.

## III.  Conclusion
The use of this instrument has broadened the usage of the water bodies and its properties to a higher and more précised manner. This has helped the mankind to calculate the complex quantities and large data value easily and swiftly. This can also help as an alert system in case of heavy or extreme turbulences in the water bodies .So that people may get conscious and help themselves well in time.

## Acknowledgement:

## References

[1].    Frank Bahr, research specialist in the Physical Oceanography Department at WHOI
[2].    Jim Culter, program manager of the Benthic Ecology Department at Mote Marine Laboratory
[3].    SonTek
[4].    RD Instruments - particularly the ADCP (BroadBand) Practical Primer
[5].    Adler, M. (1993) Messungen von durchflüssen und strömungsprofilen mit einem ultraschall-Doppler gerät (ADCP)
[6].     Wasserwirtschaft, 83, 192-196. Appell, G. and P. Bass (1990) Near-surface measurements with a Doppler current profiler
[7].    Proceedings of the IEEE Fourth Working Conference on Current Measurement, April 3-5, 1990
[8].    Sontek, 2004. *PC-ADP Read me first*. Sonetek, San Diego, USA
[9].    Deacon, EL, 1959.The measurements of turbulent transfer in the lower atmosphere. *Advances in Geophysiscs*, 6, Acad. Press, 211-228.
[10].   *"Federal Standard 1037C"*. (in support of MIL-STD-188)
[11].   Author: OpenStax College
[12].   Agrawal, Y.C. and Pottsmith, H.C., 2000. Instruments for particle size