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New Design of Acoustic Doppler Current Profiler

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Abstract: This paper gives a new design of Acoustic Doppler Current Profiler (ADCP). It basically works on the principle of Doppler Effect. Development of Acoustic Doppler Current Profiler is given. Types of ADCP's are depending on mounting are horizontally mounted ADCP's and vertically mounted ADCP's. Frequency shift measurement is the basic thing in ADCP. There are various algorithms available for frequency measurement of ADCP. Some are given in this paper. So this paper gives a detailed study of Acoustic Doppler Current Profiler. Only some components are required for the design. Further range of penetration is dependent on the type of ultrasonic sensor used. As we go on changing the sensor performance parametric will also change.

Keywords: Acoustic**,** ADCP, Frequency shift, Phase array**.**

1. Introduction

Acoustic Doppler current profilers are the instruments used for measuring the velocity of water not just at a bottom but at an equal intervals across the entire water column. ADCPs with waterproof sensors can be placed inside the water or they can be placed outside the water. Basic principle used in this ADCP is Doppler Effect which is related to the frequency change of sound wave. Acoustic field is important field in research from past years. Various processing are done on acoustic signals for various applications like finding defects in metal, medical fields etc. Mathematical modeling of acoustic signals, various processing are done on these signals to use it for further different applications. Basic aim of this design is to find velocity of water which will be useful in dam, rivers, canal etc. It is useful to study advantages of Acoustic Doppler Current Profiler over other velocity measurement techniques. Due to less hardware, less complexity, and accurate performance Acoustic Doppler Current Profilers are of greater interest and use. By using different ultrasonic sensors it is possible to vary range according to the applications. Acoustic signal processing is widely used technology nowadays. There are various techniques by which velocity of the water can be measured like positive displacement method, piston method etc. The instruments based on above method are heavy in nature and fitting these instruments is a difficult task. So an acoustic Doppler technology can be used to measure the flow velocity.
An Acoustic Doppler Current Profiler is the instrument used to measure how fast water is moving across an entire water column. An Acoustic Doppler Current Profiler is the instrument used to measure how fast water is moving across an entire water column. An ADCP anchored to the seafloor can measure current speed not just at the bottom, but also at equal intervals up to the surface. The instrument can also be mounted horizontally on seawalls or on bridge in rivers. It also can be used in canals to measure the current profile from shore to shore. When placed at the bottoms of ships it take constant velocity measurements as the boats move. In very deep areas, they can be lowered on a cable from the surface. ADCP can also be used to avoid flood conditions.

2. Doppler Effect Principle

Doppler's principle relates the change in frequency of a source to the relative velocities of the source and the observer. According to Doppler Effect principle sound wave has a higher frequency, or pitch, when it moves to you than when it moves away. So this shift is Doppler shift. Difference in frequency between the waves the source sends out and the waves it receives is called the Doppler shift. If the sound source and receiver move, relative to the Earth, but stay at a fixed distance from one another, there is no Doppler shift. The Doppler shift exists only when sound sources and receivers move in relation to when sound sources and receivers move in relation to each other. It is shown in fig 1. F_0 is frequency of transmitted pulse and F_D is frequency of received pulse. SO this gives Doppler Effect principle which can be related to the frequency shift principle used in acoustic Doppler Current Profiler.

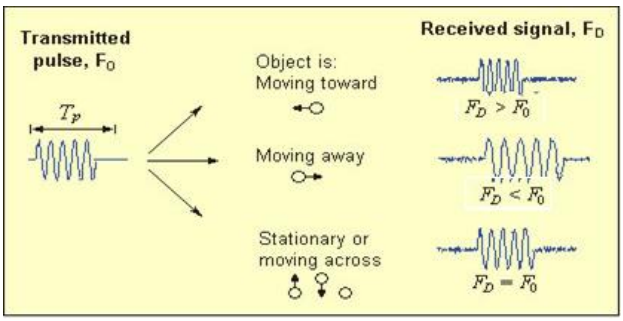

Fig 1: Frequency changes due to particle movement

3. Literature Survey

Horizontally mounted ADCP's are compared with vessel mounted and frame mounted vertical ADCP's [1]. They give 0.15 m/s. 10 transducers were used for his purpose. At the bottom and at the surface ADCP results are more difficult to interpret. 150 KHz ADCP was mounted 7 m below the water. Two acoustic beams has had been used with 5 transducers for each beam. So beam width is vertically 0.4 degrees and horizontally 1.5 degrees. Lack of accuracy is because of not having mathematical model of scattering. Then phase array

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technology for ADCP was used. It reduces physical size of low frequency ADCP. Phased array transducer is built by assembling individual acoustic elements. By using proper electronics four distinct transducers are generated rather than using separate transducer for each acoustic beam. The phased array transducer used is of frequency 600 KHz. It is approximately 7.3 degrees in diameter. This transducer produces acoustic beams with 3 degrees. The acoustic beams are slanted 30 degrees outward from the central axis of the transducer face. One advantage of a phased array transducer is that measurement of velocity components parallel to the transducer face is independent of the actual speed of sound in the water. A second advantage is reduced flow distortion around the instrument. Single phased array transducer replaces four tilted piston transducers. So smaller instrument obtains a flat transducer face.

4. Frequency shift algorithms of ADCP

There are several classification methods of ADCP. In reference with the acoustic signal transmitting and processing methods, ADCP can be divided into narrow-band ADCP and broadband ADCP [6]. Narrowband ADCP transmits a single pulse. This type of ADCP has very large estimation variance. It is not possible to improve spatial resolution. It is also called as pulse non-coherent. Broadband ADCP transmits two or more sets of pulses. Each pulse sequence consists of many encoded pulses. So ADCP calculates echo autocorrelation function. It also calculates the phase difference. Depending on autocorrelation function and phase difference velocity is calculated. There are some algorithms for ADCP carrier frequency.

4.1 Fast and accurate frequency shift algorithm

This algorithm is based on Fourier transform and variable sampling rate method. Suppose encoded carrier signal of ADCP is phase modulated sine wave which has single frequency component. When ADCP transmits an acoustic signal, the data of two adjacent cycles are sampled. Suppose number of sampling data per cycle is N. In this algorithm current sampling frequency is adjusted based on the latest calculated frequency fn-1. So the sampling rate is close to an integer multiple of the real carrier frequency f. So it reduces the Fourier transform error. This is shown in Figure 2. Here £ is the value of the frequency error to be set in the calculation. Using the loop iterative calculation can estimate the actual carrier frequency.

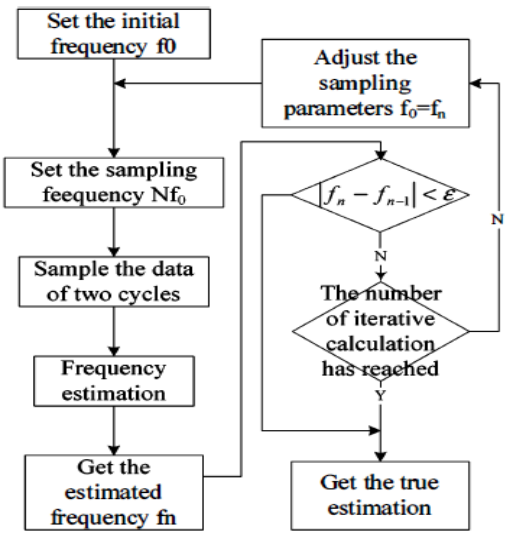

Fig 2: Fast and accurate frequency shift algorithm

4.2 Coded pulse Complex Correlation algorithm

The estimation methods of Doppler shift are FFT, complex covariance method and other methods. Coded pulse complex correlation algorithm is mainly based on the principle of Complex correlation. Steps of this algorithm are as below-

1. It transmits pseudorandom codes. These codes include a pair of phase modulated pulse.
2. Calculates the complex autocorrelation function of echoes.
3. Doppler shift is the phase variation of complex autocorrelation function.

5. Block diagram of ADCP

This is having components as ultrasonic transmitter, ultrasonic receiver, amplifier, display and microcontroller. Firstly microcontroller gives trigger pulse to ultrasonic transmitter. So after triggering ultrasonic transmitter generates an ultrasonic wave. Now when wave strikes to particles in the water it is reflected back. It is received by receiver. It has small amplitude, so it is given to amplifier. There is frequency shift between transmitted and received wave. This frequency shift is measured by the microcontroller. This frequency shift is used to calculate velocity of water. It is displayed on the LCD display. It is shown in fig 3.

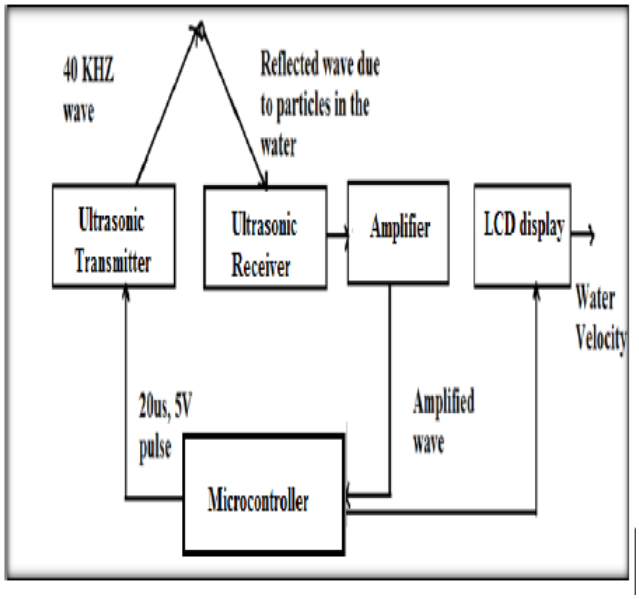

Fig 3: Block diagram of Acoustic Doppler Current Profiler

6. Results

Results are observed as against a physical sensor which is available. Ultrasonic sensor of 40 KHz is used. Range is 2 centimeters to 4 meters. Further range and accuracy can be increased by using waterproof sensor and by including further noise removal circuitry. Readings are given in the table 1.

Table1: Comparison of physical sensor and ADCP values

Physical sensor(m/s)	Measured on ADCP	Error
0.30 m/s	0.35 m/s	0.05
0.3 m/s	0.35 m/s	0.05
0.309 m/s	0.408 m/s	0.099
0.031 m/s	0.038 m/s	0.017
0.32 m/s	0.4 m/s	0.21
0.31 m/s	0.35 m/s	0.17
0.306 m/s	0.317 m/s	0.116
0.98 m/s	1.09 m/s	0.26
0.0315 m/s	0.0365 m/s	0.0175
0.0312 m/s	0.034 m/s	0.0168
0.0285 m/s	0.0291 m/s	0.0086
5 m/s	5.045 m/s	0.28
0.0282 m/s	0.031 m/s	0.0035
0.0293 m/s	0.031 m/s	0.0021
0.31 m/s	0.306 m/s	0.12
0.9 m/s	1.04 m/s	0.3
10 m/s	10.104 m/s	1.5

Conclusion and future scope

New design of Acoustic Doppler Current Profiler is given in this paper. Further range and accuracy can be increased by using new waterproof sensors. AD620 N is an instrumentation amplifier which is very useful in this design. Its gain can be adjusted between 1 and 10K using single variable pot. Further At mega 8 series used takes less space on the chip. Timers used for design are sufficient from At mega 8. An ultrasonic sensor used is on frequency 40 KHz. As the frequency is less, faster will be the operation time.

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