Ultrasonic Underwater Depth Measurement

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Abstract. It is required a precise, linear indication of the depth of water in a specific part of the sea. This demands a continuous level measurement. There are a wide variety of ways to produce a signal that tracks the depth of water in a specific part of the sea. Ultrasonic detectors find the distance between seabed to the surface of the water. To measure level, depth, with an ultrasonic range detector, the module is mounted at the bottom of the sea, seabed, looking up the surface. We must measure the time between the transmit pulse and the echo received pulses. Since the ultrasonic signal is traveling at the speed of sound, the time between transmission and echo received is a measure of the distance to the surface ,water depth.

A micro-controller sends a pulse to the ultrasonic module. The module is transmitting an ultrasonic wave for a short period of time and wait for receiving its echo. As soon as echo received to ultrasonic module, is sent a pulse to micro-controller, which measures the time between two pulses.

There are two modes of operation, program mode and run mode. When the unit is powered, it is programmed to start up in the run mode, to detect the distance from the transducer face to a target, depth, in meter. The unit can be placed into program mode at any time by pressing the menu key to alter a value of parameters in order to better suit the application or user preferences. Unit of measurement, type of measurement, set point of alarms and factory setting are some of its parameters.

The working time of transition and receiver part of the module is specifies by micro-controller normally for each second 10 ultrasonic pulses are transmitted. The measuring error is approximately 1.25%. Such an error value is acceptable with reception to wavelength of ultrasonic waves. For so many application that the precision of Cm is sufficient ultrasonic level measurement is suitable. The system protected from virtual echoed by using threshold and counting number of echo pulses.

KEYWORDS-Depth Measurement, Ultrasonic Instrument, Automatic Measurement

I.INTRODUCTION

Measurment of the depth of a sea bed or a river bed represent an application of ultrasonic techniques. The principle of operation of an echo sounder is explained here. An ultrasonic pulse was emitted in an upward direction from the emitter. After reflection, the echo was detected and processed in an electronic block. It was recorded on an X-Y recorder as a time interval that was proportional to the measured distance, or it was depicated on the screen of CRT, usually in polar coordinates, in order to obtain a sufficiently long circumferentail, time-coordinate[1,12].

Modern equipment evaluates the distance in a straightforward way, showing depth units of the display, or the reading is stored directly into computer memory and drawn on a plotter as a chart. Ultrasonic depth measurements have a service range from 0-50 m up to 0-10 km, according to their design and specification. the working frequency is in the range from 20 kHz to 500 kHz.

The instruments are usually equipped with an adjustable length scale in order to compensate for fluctuations of temperature, and propagation velosity of ultrasound, due to flactuation in the water composition, sea/river water.

Ultrasonic depth measurement are widely used thanks to their useful characteristics. The physical phenomenon that the transducers radiate well into the water is used, which enables low- power operation, and relatively low amplification at the receiver [5,10].

Measurement of water depth can also be carried out on the basis of measuring the propagation time of an ultrasonic wave to the water level and, after reflection, back to the receiver. The propagation time of the wave is proportional to the depth of water.

Ultrasonic transducers (transmitter / receiver) are mounted at the bottom of the sea, seabed, looking up to the surface.

II.REFLECTION AND TRANSMISSOIN OF ULTRASONIC WAVE

The transfer of the wave motion into the medium, its reflection and its reception are affected by the following factors:

-the transducer- medium coupling

-the transfer of ultrasonic through the medium above the water level

-the condition of the reflecting surface

Upon transfer of an ultrasonic wave from one medium into another, the ratio of acoustic waves impedance play a critical role. The wave impedance is expressed as a product of the density of the medium and the velocity of wave, and

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it represents a characteristic feature of a particular material [5].

$$Z=\rho C \quad (1)$$

At the interface of two media with different acoustic impedance, Z1 and Z2, part of the wave motion is reflected back and another part transfer into the second medium. The coefficient of reflection, R, i.e. the ratio of the intensity of the reflected wave over the total intensity of the primary wave, is given by:

$$R=((Z2-Z1)/(Z2-Z1))^2 \quad (2)$$

The coefficient of transmission, D, i.e. the ratio of the intensity of the transmitted wave over the total intensity of the primary wave, is:

$$D=4*Z1*Z2/(Z2-Z1)^2 \quad (3)$$

Thus, for a wave to be transferred from transducer into water efficiency, it is necessary to choose the physical properties of a transducer so that the expression for R is as small, and for D as high as possible. It means that the acoustic wave impedance of the transducer should be as close as possible to the acoustic wave impedance of water [7,8].

Suppose water is a first medium and air is second one as shown in Fig. 1. Since the wave impedance of air is 430 kg $m^{-2} s^{-1}$ and that of water from $1.49*10^6$ up to 10^7 kg $m^{-2} s^{-1}$, the coefficient of reflection, R, and the coefficient of transmission, D, could be calculated:

R=0.998 D=0.0012

Therefore, most of the incident wave reflected back to the water. Due to this total reflection, practically all the acoustic energy is reflected back to the acoustic emitter inside the sea. Thus for this application a lower level emitted energy is sufficient.

III.VELOCITY OF ULTRASOUND IN WATER

The velocity of ultrasound propagation increases with increasing temperature until it reaches a maximum 74 °C and then decreases. This dependence is expressed as [5]:

$$C(\theta)=Cmax-0.0245\ (\theta max-\theta)^2 \quad (4)$$

Where

Cmax: the maximum velocity of ultrasound in water, 1557 m/s

θmax: temperature of water at maximum velocity, 74 °C

θ: is the medium temperature, °C

Then

$$C(\theta)=1557-0.0245\ (74-\theta)^2 \quad (5)$$

Therefore, the propagation velocity of ultrasound is temperature dependence, and the medium temperature should be measured. The temperature is defined as an input parameter to the system which will be entered by user at the time of measurement [6].

IV.PRINCIPLE OF DEPTH MEASUREMENT

The transducers are mounted at the bottom of the sea, seabed, looking up to the water level. The elapsed time, t, that an ultrasonic pulse take to travel from a transmitter transducer to the water level and back to a receiver transducer must be measured [4]. This is shown in Fig. 2. Hence, the water depth, D, is give by:

$$D=0.5*C(\theta)*t \quad (6)$$

Regarding the temperature dependence of the propagation velocity, equation 5, after substituting C(θ) in D, we obtain

$$D=0.5*t*[1557-0.0245*(74-\theta)^2] \quad (7)$$

Where

- t is the propagation time of the ultrasonic pulse(s^{-1})
- θ is the medium temperature (°C)
- D is depth of sea, water (m)

By adding k, high of the transducer module, the real depth, i.e. Dr, could be found as shown in Fig.3.

$$Dr=D+k \quad (8)$$

V.TRANSMITTER/RECEIVER TRANSDUCER

A transducer converts electronic energy to ultrasonic pulses and vice versa. The type of transducer used is a major determining factor in depth measurement. Lower frequency transducer tends to have longer beam widths, which can cause distortion but less attenuation and allow greater depth measurement. High frequency transducers will provide move precise depth measurement and narrow beam widths with more attenuation.

Although greater depth measurements not required, frequency ranging between 20 kHz and 50 kHz are typically employed [12].

Transmission frequency is highly synthesized and based on the stable frequency characteristic of crystal controlled clock oscillator that is used for micro-controller. A 40 kHz oscillation is generated by micro-controller, which is amplified and sent to the water level through ultrasonic transducer [2,8].

Echo is received by the same transducer and passed through amplifier and schmit-trigger and sent to the micro-controller. A threshold level is considered in receiver to prevent virtual echoes. In spite of this the specific number of transducer pulses, ten, is transmitted for each measuring period (T=1 sec) and at the receiver, number of echo pulses is counted first and if it is 10, the echo assumed to be real echo [3].

Transducer should be waterproof itself or it should be put inside the waterproof housing.

VI.MODES OF OPERATIONS AND PARAMETERS

There are two made of operation, program mode and run mode. When the unit is powered, it is started up in run mode, to detect the water depth in meter.

The unit can be placed into program mode at any time by pressing the menu key, to alter the values of parameters in order to suit the application on user s preferences. This could be done via the local keypad.

Parameters of the unit are listed here:

1- Unit of measurement: (Centimeter, Meter).
2- Medium temperature: (°C).
3- High of the transducer: (k in Centimeter).
4- Set point of relay A: (in Centimeter).

5- Set point of relay B: (in Centimeter).
6- Default setting.
7- Software version.

Keypad includes 4 keys, Menu, Up, Down and Enter. Normally, Menu key should be pressed to access program mode and display shows P1. By using Up or Down key one of parameter from P1 to P7 is selected and by pressing Enter it is confirmed. After pressing Enter the value of selected parameter is displayed. Now, by pressing Up or Down key desired value of parameters is adjusted and finally by pressing Enter key again validates the value. All of the parameters are selected and their values are adjusted as above. At the end Menu key is pressed to return to run operation mode [3,9].

VI.RESULTS AND CONCLUSION

The travel time of the ultrasonic pulse is measured electrically by micro-controller. The accuracy of the absolute time measurement is less than one µsec (1.5 mm).

Normally, the water temperature is measured separately and the actual temperature value is entered as a parameter to the unit. It is possible to add temperature sensor to the unit and do this automatically in future work.

The unit includes transducer module, micro-controller, keypad and LCD display [11]. It could measure depth between 20 cm to 750 m with accuracy around 3-4 cm, according to the working frequency and measuring period. This accuracy seems to be sufficient for such an application. Anyway by increasing ultrasonic transducer frequency, accuracy could be increased.

There are some methods to increase measuring accuracy. As illustrated in Fig. 6, a pool could be made and connected to the sea through a channel or pipe. Therefore, transducer should be mounted at the bottom of the pool and small modification should be done in formula to calculate real depth of the sea.

$$Dr=D+k+h \quad (9)$$

where

-D is depth of water in the pool.

-k is high of the transducer.

-h is the level difference between the pool and specific part of the sea.

In the other hand, a big full of holes cylindrical steal or hard plastic with some holes could be fixed around the measuring area to filter fluctuation in level of the sea. It is shown in Fig. 7. However, the instrument could be used to measure the ebb and flow of the sea. Some facilities should be provided to connect the instrument to computer and store all measured data during day and night in future work.

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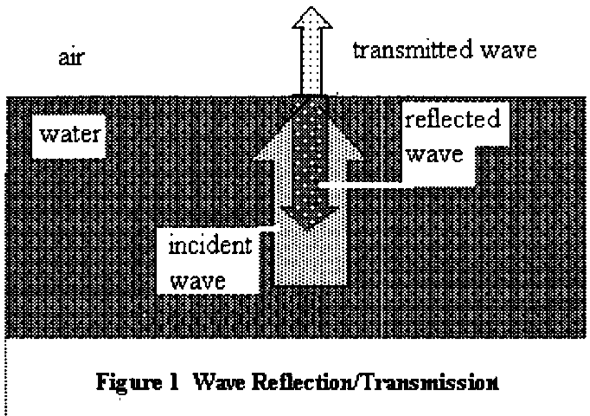

Figure 1 Wave Reflection/Transmission

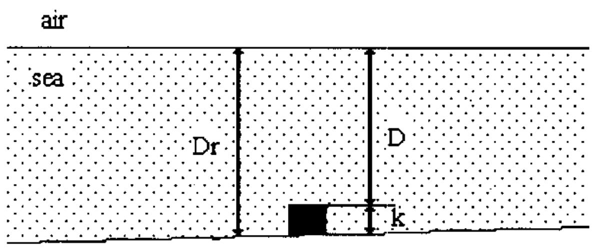

Figure 2 Real Deapth, Dr=D+k

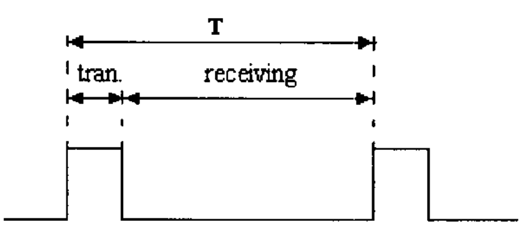

Figure 3 Measuring Period, T

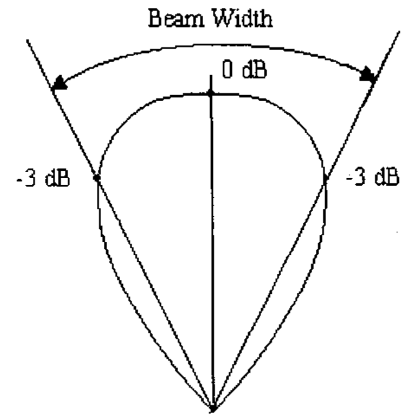

Figure 4 Transducer Beam Width

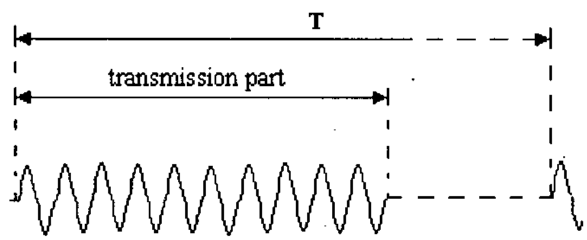

Figure 5 Ten Pulses in Each Measuring Period

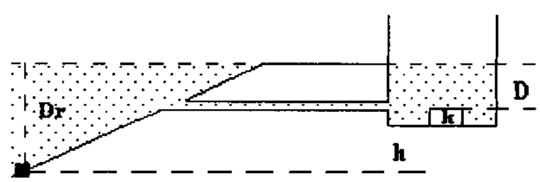

Figure 6 Using Connected Pool to the Sea
Dr=D+k+h

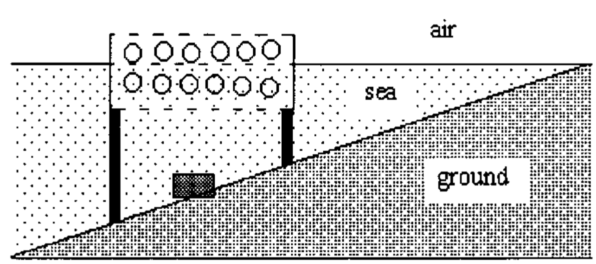

Figure 7 Filtering Fluctuation of Water