Target Strength Identification Using Commercial Echo Sounder

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Abstract— **This research proposes the acoustic measurement by using commercial echo sounder JMC V1082 model to detect the object underwater. The acoustic scattering is depends on shape, size, and material properties An envelope echo signal produced using 50 KHz and 200 KHz echo sounder receiver. Various spheres and cylinder are used in this experiment. Cylinder is used for detection of diver underwater. The transducer was positioned about 1, 2, 3, 4, 5 meter from the target (sphere and air-filled). The commercial echo sounder was modified to obtain the echo/output signal from transducer and transmit the signal through high speed analog input USB to be record and analyze using a computer or laptop. MATLAB software was used to analyze the output/echo signal of the commercial echo sounder and the echo observation is in time and frequency domain. The modification of signal output presentation is needed for target strength identification. The target strength of object is depends on size of the object. The bigger size of object will have bigger target strength value. Although the structure signal without any object are different compare to the signal from the object, the reflected signal from the tank floor increase linearly with the object size.**

Index Terms—Echo sounder, echo power, target strength

I. INTRODUCTION

Sonar is well known as (Sound Navigation and Ranging) system which is the technique that had many similarities to radar and electro-optical systems which using sound propagation to communicate or navigate with detected objects on or under the surface of water. The sonar operation is based on the propagation of waves between a target and also the receiver [1]. There are two types of sonar system which is active and passive. In fisheries technology, echo sounder is used as the sonar device. The device is widely used to observe marine animal. This device has proven to be a suitable and perfect tool in studying the spatial and temporal distribution of fish. In addition, echo sounder have operates at ten to hundreds kilohertz frequency and two commonly used frequency are 38 and 120 kHz [2] [11]. For this experiment, 50 KHz and 200 KHz echo sounder is used.

Generally target strength (TS) is refers to the ability of a target to return an echo and it is widely uses a sonar for active acoustic measurement applications [3]. The acoustic scattering properties of the target are defined by the target strength [4]. In sonar equation, target strength is defined as 10 times the logarithm to the base 10 of the ratio of the intensity of the sound returned by a target at a various distance. In this study, the target strength of object is measure using echo sounder which is used to transmit the acoustic pulse that generated by a transducer. The transducer emits an acoustic pulse and it will return back the signals to be recorded and then the output signal is analyze using software such as MATLAB [1][5].

Echo sounder is a device used to determine the depth of water [7]. Instead to determine the depth of water, it is also can be used to detect the object underwater. Echo sounder itself can be a radar to navigate the fish, mammals, and so on. Basically there are two types of echo sounder which is scientific and another one is commercial. In this study we use the commercial echo sounder. For scientific echo sounder it is actually listen to the pulse of sound that have been created electronically using a sonar projector consisting of transducer and then listen back for reflections (echo) of the pulse. Once the signal is transmit back, then the echo sounder will calculate and show the value of target strength.

In this research, the commercial echo sounder have been used and the device is modify so that it can transmit the output/echo signal along through the high speed analog input USB to the computer or laptop. Next, the data can be collected by using Matlab software where the program is created to analyze the signal. The output signals need to be analyzes so that the target strength can be calculate. Once all the signal have been analyze, so that the GUI program can be create. The calculation of target strength is needed in the program so that the value of TS for each object can be calculated and show in the program. All the calculation of TS is based in the result get earlier. The problem statement is that how to differentiate the between the sphere and cylinder object underwater. It may be difficult to identify the object (sphere and cylinder) underwater. So with the help of this program, hence we can identify the objects.

In this study, the objective is to differentiate the echo signal from both sphere and cylinder. Next is to identify the target strength of the sphere and cylinder with a various distance. Besides that, we need to identify the target strength of sphere and cylinder for various sizes. The other objective is to develop a program that can measure the value of target strength of each object.

The scope of the study is focus on to identify the target strength of object. In this study we only focus on solid sphere and air-filled shape object. The sphere use as reference target and calculation of target strength will

base on standard expression for the target strength of rigid sphere. The study conducted in reservoir tank with the object is place with fix position while the transducer is position with various distances from 1m, 2m, 3m, 5m, 7m. Different object with various diameter and distance will have different target strength. By using MATLAB, the output signal is taken to be analyzes and the echo observation is in time and frequency domain.

II. TARGET STRENGTH FOR VARIOUS OBJECTS

Echo sounder is widely used in submarine navigation, fisheries technology and under water object clarification. In fisheries technology, echo sounder is use to catch fish. Every type of fish will have different target strength. Information on the size of the recorded fish can be obtained from knowledge of target strength which may be found by an analysis of the received echo signals (Gushing 1968, Craig and Forbes 1969) [9]. Sonar is also used as navigation which it is likely same as radar. In this study, the use of cylinder as object is important to navigate diver. The target strength of diver with tanks, buoyancy control, wet or dry suit, etc. is a complicated function of aspect angle and frequency. The tanks behind the body in cylinder shape, so that's how we need to determine the diver, swimmer underwater by focus on this study. By doing experiment of target strength of sphere and cylinder, the result can be applied and implication to navigate, detect the diver.

There are basically two types of echo sunder which is scientific and commercial. In this study we focus on using commercial echo sounder because we want to take out the signal. This signal is transmit from the transducer, then the use of high speed analog input USB convert the signal and transfer it to the laptop or computer. The main reason to collect the data is because we want to identify the target strength of each object. The target strength calculation is based on Urick formula which is $TS=10\log (a^2/4)$ [8]. Target strength of objects can be calculated manually. For more complicated geometric objects, Urick principle which is Principles of Underwater Sound gives the formula to calculate the target strength for many other shaped objects [9]. So this formula can be apply for TS calculation of cylinder object. The target strength (TS) is one of the ingredients of the sonar equation for active acoustic detection applications [10]. Target strength is the acoustic size of a target in form of decibels (dB). The TS measurement suggested using echo signal observation from the transducer output [11]. For this study, various sphere and cylinder has been used.

a. Sphere as reference target

In this study, sphere is use as a reference target/object because of the sphere echo voltage measurement is the best method in calculating target strength. Besides that, the echo characteristic of the object can be observe easily. This technique also can facilitate us to design sounder device for many application. The aim of this experiment is to obtain envelope echo signal structure of the sphere. There are two types of cylinder used in this experiment which is air-filled sphere and solid sphere.

Acoustic is the most effective tool for monitoring object under surface of water because of the ability of the sound to propagate long distance in water. Acoustic scattering by spherical objects has been investigated by Rayleigh [6]. Target strength measurement using commercial echo sounder is one challenging method in studying the underwater living (animal). There is a technique that can apply in echo sounder calibration which is using an object whose acoustic properties are known. So that, sphere have been used as calibration and reference target in sonar equation and the sphere which is steel ball. Although the TS value of object are known, but it necessary and important that the theoretical predictions should be tested by an experiment. Sphere echo voltage measurement is mostly used in calculating target strength so that the echo can be observed. The target strength for the object is measured and it depends on shape, size, and material properties. The object is place fix and not moving while the transducer was positioned in various distances from the target. The distance is measure by 1, 2, 3, 5, 7 meter from the target. In this study, we use commercial echo sounder to obtain the echogram.

Below are the standard expression for the target strength of rigid sphere that have been introduced by Urick,1983.

$$TS = 10 \log_{10} (a^2/4)$$

"a" is denote as radius of the sphere. The above formula comes from $P_i=I_i\pi a^2$, where $\sigma=\pi a^2$. Since the power of the incident wave is all reflected back, we find that power reflected = power incident [9];

$$P_r = P_i$$
$$I_r\, 4\pi r^2 = I_i\, \pi a^2$$
$$I_r / I_i = a^2 / 4r^2$$

By using the definition of target strength, we find that;

$$TS = 10\log (I_r / I_i) = 10\log (a^2 / 4r^2)$$

since r = 1yd or 1m

$$TS = 10\log (a^2 / 4)$$

b. Cylinder as object/target

In this study, cylinder is used as object is basically to detect the diver underwater. There are two types of cylinder used in this experiment which is air-filled cylinder and solid cylinder. For the cylinder, here is the formula of calculating target strength by Urick.

$$TS=10\log [(aL^2 / 2\lambda)(\sin \alpha / \alpha)^2(\cos^2 \theta / (1yd^2))]$$

Since the angle, θ is 0, and $a = (2\pi L / \lambda)$;

$$TS= 10\log [(aL^2 / 2\lambda)(1 / (1yd^2))]$$

λ is the acoustic wavelength and a is denote as radius of the cylinder, L is the length of cylinder

III. METHODOLOGY

This project uses a standard target needed whose acoustic scattering properties are known. The echo sounder type JMC V1082 model is using to transmit the signal and transducer (radar sonic) act as generate and emit the acoustic pulse.

At the beginning of the project, one program has been created to record all the data. By using Matlab software, the program is needed during the experiment. Experiment have been conducted at TUMEC, Terengganu, Malaysia. Figure 1 shows and Table I the setup of the experiment.

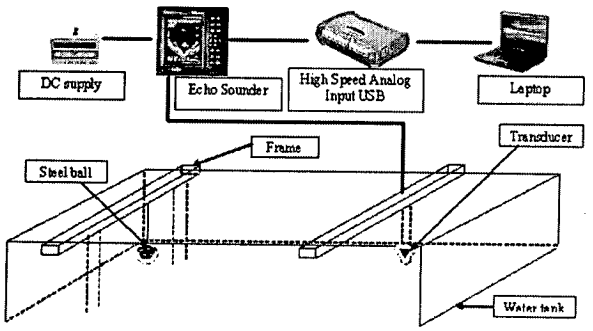

Figure 1. Experiment setup

Table I: Echo sounder setting

Frequency	50 kHz /200 kHz
Echo Threshold Level	3 Levels (Red, Orange, Yellow)
Echogram Feed Rate (PF)	1/1
Sensitivity Time Control (STC)	4
Gain	45dB
Noise Reduction Level (NR)	High
Echo Dynamic Range (D. RNG)	5dB
Sound Speed	1500 m/s

IV. RESULT AND ANALYSIS

The data for first and second experiment have been collected.. There are difference in target strength of sphere and cylinder. The sphere (steel ball) is use as reference target so that the value of target strength of cylinder require data from reference target to be solve in equation that have been made by Urick (1983). For this experiment, we just analyze data to calculate the echo power and voltage of object. The result of experiment aslisted in Table II to Table X.

Table II: Echo power of steel ball using 50 KHz

Distance of object from transducer (m)	Steel ball (1.8cm)	Steel ball (2.2cm)	Steel ball (3.1cm)
1.0	0.2390	0.2663	0.2275
2.0	0.2570	0.2493	0.2426
3.0	0.2202	0.2058	0.2347
5.0	0.2417	0.2034	0.2222

Table III: Echo power of steel ball using 200 KHz

Distance (m)	Steel ball (1.8cm)	Steel ball (2.2cm)	Steel ball (3.1cm)
1.0	0.2741	0.2700	0.3121
2.0	0.2549	0.2733	0.2727
3.0	0.2566	0.2301	0.2674
5.0	0.2795	0.2545	0.2634

Table IV: Echo power without object (frame only)

Distance (m)	using 50 kHz	using 200 kHz
1.0	0.2771	0.3334
2.0	0.2899	0.3074
3.0	0.2671	0.2955
5.0	0.2873	0.3109

Table V: Power of solid sphere and air-filled sphere for 50 kHz

Distance	Small	Medium	Big
Solid sphere			
1M	1.9678 k	2.0292 k	2.4042 k
2M	1.7573 k	1.8646 k	1.7557 k
3M	1.5920 k	1.5393 k	1.6894 k
4M	1.5586 k	1.3984 k	1.4585 k
5M	1.5386 k	1.2821 k	1.3361 k
Air-filled sphere			
1M	2.2198 k	1.9865 k	2.8818 k
2M	1.9800 k	1.7678 k	1.7542 k
3M	1.8340 k	1.6561 k	1.5750 k
4M	1.6962 k	1.5243 k	1.5061 k
5M	1.5237 k	1.3752 k	1.3230 k

Table VI: Power of solid sphere and air-filled for 200 kHz

Distance	Small	Medium	Big
Solid sphere			
1M	1.7813 k	2.2355 k	3.1478 k
2M	1.7498 k	1.7907 k	2.4518 k
3M	1.6685 k	1.9083 k	2.1166 k
4M	2.2253 k	2.4322 k	2.7805 k
5M	2.3677 k	2.4843 k	2.8525 k
Air-filled sphere			
1M	2.8330 k	3.2466 k	3.2597 k
2M	2.1227 k	2.3101 k	2.3624 k
3M	1.6203 k	1.7385 k	1.9899 k
4M	2.3113 k	2.3200 k	2.3286 k
5M	2.2671 k	2.2752 k	2.4961 k

Table VII: Power of solid cylinder 50 kHz

Distance	BIG		Small
	Short	Long	
1M	1.6386 k	2.1991 k	1.8608 k
2M	2.4859 k	2.4822 k	2.6449 k
3M	1.7802 k	1.4749 k	1.6101 k
4M	1.6855 k	1.6144 k	1.4223 k
5M	1.1552 k	1.3675 k	1.1604 k

Table VIII: Power of air-filled cylinder 50 kHz

Distance	Big		Small	
	Short	Long	Short	Long
1M	1.5208 k	2.4900 k	1.6768 k	2.0616 k
2M	2.0777 k	1.8949 k	2.1572 k	2.3720 k
3M	1.6129 k	1.9905 k	1.5740 k	1.8776 k
4M	1.2650 k	1.8538 k	1.5636 k	2.0815 k
5M	1.5504 k	1.5249 k	1.2179 k	1.3819 k

Table IX: Power of solid cylinder for 200 kHz

Distance	Big		Small
	Short	Long	
1M	1.6460 k	5.2497 k	4.4541 k
2M	2.4623 k	1.8021 k	4.5308 k
3M	1.7806 k	1.5527 k	2.5999 k
4M	1.6456 k	2.1935 k	2.1386 k
5M	1.1788 k	2.1734 k	2.1620 k

Table X: Power of air-filled cylinder for 200 kHz

Distance	Big		Small	
	Short	Long	Short	Long
1M	4.5110 k	4.0138 k	4.3420 k	4.2528 k
2M	3.6052 k	5.1156 k	3.1759 k	4.1035 k
3M	1.9793 k	4.1292 k	1.9227 k	3.4298 k
4M	2.2228 k	2.7330 k	2.2182 k	2.4200 k
5M	2.4667 k	2.3229 k	1.9628 k	2.1761 k

From the result collected, size of object effect the value of target strength. Means that the value of target strength become bigger if the size of object increases. From the calculation on measuring the echo power and voltage of object, the value suppose decrease as the target or object is place in increasing distance.

Calculation of echo power and voltage for 200 kHz echo sounder setting shows that the value is decreasing in order from a distance 1meter up until 3 meter. However the value start increase back when set the distance to 4 meter and 5 meter. Same goes to 50 kHz echo sounder setting where the some of the result not too correct as well as theoretical.

There are several problem or issues how this result happen:

1) The target/object was placed not exactly parallel with the transducer.
2) The setup of echo sounder. Might be the gain, echo threshold level and etc.
3) The beam of 50 Khz and 200 Khz frequency of echo sounder.

From the problem state above, the object and transducer must be place parallel to each other so that the transducer will emit pulse directly to the object and transmit back precisely. Besides that, the setup of echo sounder also becoming one of the factor. There are 7 echo threshold level for the echo sounder but we only use 3 of that. Last but not least, the beam of signal also might be the factor how the result is not too correctly. For 50 kHz frequency, the signal beam is actually 45° while for 200 kHz frequency, the signal beam is only 10°. During the analyzing of data, especially for 50 kHz, the signal appears on matlab is too small compare to 200 kHz. Hence it will effect the calculation of echo power and voltage of object.

V. CONCLUSIONS

The target strength can be obtain and analyze with commercial echo sounder that have been modified by obtain the signal and analyze it with MATLAB. By using sphere and cylinder with various diameters and distance in underwater, we can differentiate the echo signal and also can identify the target strength of objects. Hence, the objective of project can be achieve as well.

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