Target Strength of Underwater Objects Using Echo Voltage Reference

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***Abstract*—A target strength measurement is proposed in this paper using echo voltage reference from steel ball. The echo signal and target strength of the object observed using modified echo sounder model JMC V1082 operated at 200kHz. Sphere echo voltage reference is the best practical way in calculating target strength, especially when to quantify object at certain distance from the sound source. The goal of this experiment is to obtain target strength of the underwater object in fresh water using echo voltage reference technique and its variability for use in acoustic surveys of the shell animal. Underwater object (stainless steel ball, rock and tortoise) were positioned about 1 meter from the transducer face using nylon rope. Three objects selected in this experiment considered base on hard body and hard shell which is can give high backscattering strength. Target strength was calculated using echo voltage comparison between reference targets and underwater object. Two solid steel with different diameter (3.1 cm & 2.2 cm) used in measurement to confirm target strength value. The envelope echo signal of three underwater object was recorded using high speed analog input USB1208HS and analyzed in matlab program. From echo observation in time domain, it is obviously shown that echo signal structure are different between the three underwater object. The higher echo voltage is from rock with TS value equal to -44.163 dB. Amplitude voltage from air filled stainless steel equal to 34.1 mV and contributed -46.357 dB. The lowest TS value in this experiment is from Tortoise shell which is recorded -49.229 dB.**

***Index Terms*—Echo sounder, Target Strength, Sphere, Tortoise**

I. Introduction

The Target strength (TS) refers to the ability of a target to return an echo. Depending on the interest of the observer, the target may be a submarine, mine, whale or sunken ship [1]. In the context of sonar equations, target strength is defined as the ratio of the intensity sound returned to the incident intensity from a distance source, at 1 yd from its acoustic centre [2]. An acoustic method for the detection of fish was first reported in the scientific literature in 1929. Continuous waves (CW) at a frequency of 200 kHz were directed across ponds containing goldfish. As the number of fish intercepted by the acoustic beam changed, so the amplitude of the signal can record using an oscillograph [3].

Acoustic waves or sound waves provide the best mean of exploration in the underwater environment and propagate well compared than others. In the turbid, saline water of the sea, both light and radio waves are attenuated far more in the water and their working ranges are greatly reduced [2]. The sonar device used to observe marine animal called echo sounder. This device has proven to be a powerful tool in studying the spatial and temporal distributions of fish. Traditionally, acoustic echo sounders operated at frequencies of 38 and 120 kHz [4]. The measurement of TS can be conducted both in situ and ex situ. In situ measurement technique involved independent target. The experiment will be conduct at the natural animal habitat. Ex situ is one technique to measure TS for specific fish with known length in which tilt and depth are controlled [5].

TS is a complex function of several factors including fish size, shape, orientation, swimbladder and so on [6]. Aquatic organisms are complicated scatter by nature of their shape (cylindrical or spheroid). The important factor is the size of the animal, smaller animals have lower target strengths and larger animals have higher target strengths [7][8]. Most recently, the deformed cylinder model has been applied to zooplankton using Distorted Wave Born Approximation (DWBA). The function for the DWBA based deformed cylinder model was derived under the assumption that the body is weakly scattering which is properties similar to the surrounding water [9]. DWBA model can predict the scattering from a more real shape because the shape of the animal is composed as contiguous cylinder slices [10].

Scattering from elastic shelled animal is characterized by a very strong echo secularly reflected by their hard shell [11]. Study on acoustic scattering by a shell covered seafloor by Stanton [12] discovered that shellfish played an important role scattering seafloor. There are many approaches to modeling the scattering of sound by objects. The particular approach depends upon the shape and material properties of the body as well as conditions such as frequency range [13]. The acoustic scattering is a complex function and depends on animal size, shape, orientation and material properties [14].

Target strength measurement using echo sounder is one challenging method in studying the underwater object and animal. The estimation of underwater object by the echo integrator method requires a sonar that has been accurately calibrated [15]. The easy technique can apply in echo sounder calibration is using an object whose acoustic properties are known. Several types of Sphere have been used as calibration and reference target in acoustic equation, in particularly, ping pong ball [16], cooper, tungsten [17], [18] and steel ball [7], [19]. Although, the TS value of the object are known, but it is important that theoretical predictions should be tested by experiment. Most target strength measurements have been made by conventional method, in which measurements of the peak or average intensity of the irregular echo envelope are made at some

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long range and then reduced to 1 yd [2]. Generally, envelope voltage target will be measure and compare with the envelope voltage reference target (TS sphere). The goal of this experiment is to obtain target strength of the underwater object in fresh water using echo voltage reference technique and its variability for use in acoustic surveys of the shell animal.

II. Methodology

This method of measurement used a standard target whose acoustic scattering properties are known. Two diameter size steel ball (3.1 cm & 2.2 cm) used in this experiment as reference target. The underwater object as shown in Fig. 1 (rock, air filled stainless steel and tortoise) were positioned about 1 m from the transducer face. The object were suspended by nylon rope in reservoir tank containing fresh water as shown in Fig. 2.

Fig. 1. Underwater object tested in the experiment.

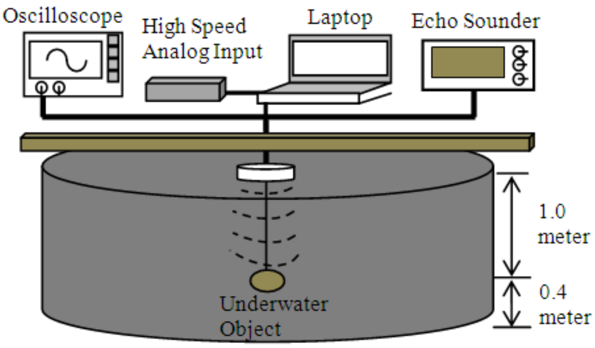

Fig. 2. The object were positioned about 1 m from the transducer face.

Modified dual frequency commercial echo sounder model JMC V1082 used in this research. The experiment used frequency 200kHz to observe structure signal from the object. Six hundred sample echo signal from the transducer will read directly into digital oscilloscope and computer using high speed analog input USB 1208HS. The velocity of sound set up at 1480 m/s which is for fresh water. The envelope of the echo was digitized at a sampling rate 100 Hz and the echo will be analyze in Matlab program.

Target strength of the object will calculate using an indirect calibration procedure incorporating reference targets. Calibration of the experimental setup will substituting a solid steel ball and comparing the echo level of the object. Two solid steel with different diameter (3.1 cm & 2.2 cm) will use in this calibration to confirm TS value. The target strength of the object equation [7][19] represented by

$$TS_{Object} = 20 \log (V_{envelope} / V_{calibrated}) + TS_{sphere} \quad (1)$$

where Venvelope is the voltage received by the echo sounder from the object, Vcalibrated is the voltage received from a sphere at the same range, and TS sphere is the known target strength of the sphere.

III. Result and Discussion

Data recordings were classified base on amplitude signal in time domain. The echo signal for different type of sphere are located at 1 meter distance from transducer face shown in Fig. 3. The envelope for each echo represented by the dashed curve.

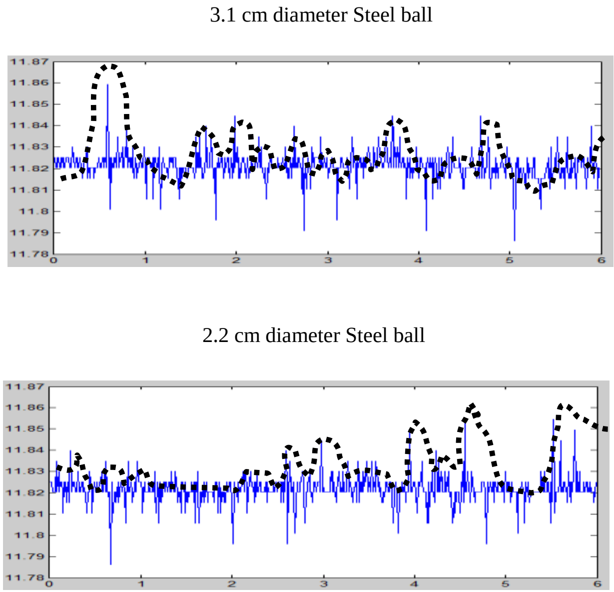

Fig. 3. Echo signal for steel ball representation in time domain.

Theoretical target strength was compared with measurement using echo voltage reference technique as shown in Table I. Base on the result, we found that the measurement value approximately to the theoretical value. TS value for 3.1 cm diameter steel ball is about -43.244 dB which is less 1.032 from theoretical value. Meanwhile 2.2 cm diameter steel ball produced TS value equal to -44.160 dB and less 1.031 from theoretical value. We confirm that both of the sphere can be use as a reference target in calculating TS for underwater object.

TABLE I: TS Value Comparison Between Theoretical and Measurement

Sphere		TS Value	
Size	V-peak	Theoretical	Measurement
2.2 cm	39.0mV	-45.192dB	-44.160dB
3.1 cm	48.8mV	-42.213dB	-43.244dB

The echo signal for three objects (rock, stainless steel ball and tortoise) was analysis in matlab program. An echo signal for three object at 1 meter distance are shown in Fig. 4. Three objects selected in this experiment considered base on hard body and hard shell which is can give high backscattering strength. From the echo observation in time domain, it is obviously shown that echo signal structure are different between the three underwater object. The peak value for each object are shown in Table II. The higher echo voltage is from rock with TS value equal to -44.163 dB. Amplitude voltage from air filled stainless steel equal to 34.1 mV and contributed -46.357 dB. The lowest TS value in this experiment is from Tortoise shell which is recorded -49.229 dB.

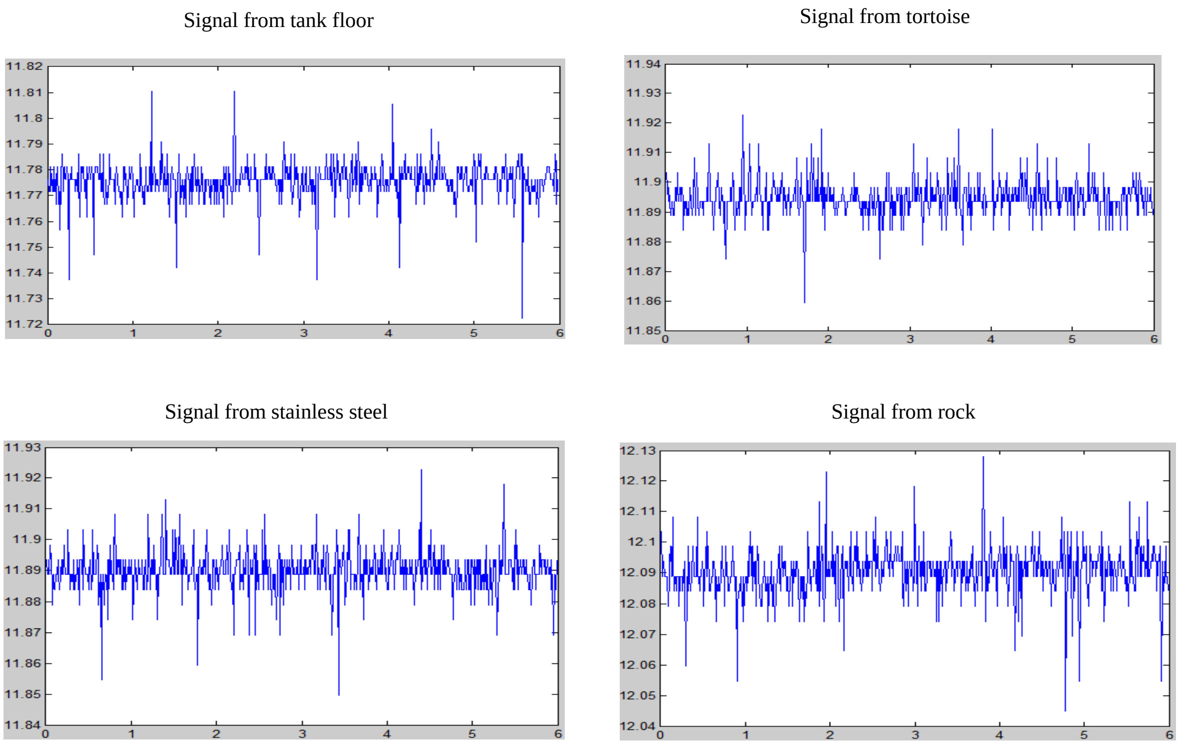

Fig. 4. Echo signal using 200kHz frequency mode.

TABLE II: PEAK VALUE AND CALCULATED TS USING 200 KHZ

Object	V-peak	TS Value
Stainless steel ball	34.1 mV	-46.357 dB
Rock	43.9 mV	-44.163 dB
Tortoise	24.5 mV	-49.229 dB

IV. CONCLUSION

The envelope echo signal of three underwater objects was measured using high speed analog input USB1280HS and analyzed in matlab program. Base on the result we can differentiate the echo structure and the target strength value for each object for 200kHz frequency. Although the result show echo signal from the object is different but the peak value still not consistent. Therefore, further observation must be conduct in frequency domain using FFT analysis and signal must be record for long period of time, in order to get accurate value.

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