Developing signal processing of echo sounder for measuring acoustic backscatter

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Abstract. The method used to determine the condition of marine biological resources is still conventional, not systematic and not comprehensive. So far, the methods used include divers where the depth of observation is very limited. Another method using sonar for which the acquisition of data is still qualitative. For this reason, it is necessary to strive for new methods that can guarantee careful and accurate observation. This study proposes the detection, classification and quantification of underwater target algorithms using Intelligent Biomass Active Sonar Transducer (IBAST) using a microcontroller unit. IBAST uses acoustic pulses and features that are narrow spectral so as to provide the ability to detect underwater targets (underwater targets) accurately and be able to classify such targets as fish, zooplankton, marine mammals, coral reefs, and other targets. IBAST uses a tracking algorithm and output detector which reduces errors in target detection. The application of the algorithm will be carried out to test the classification method and quantification of underwater targets. This research is very useful in the aspects of quantification of marine life, protection of fishery resources and seabed habitat.

1. Introduction

Indonesia is one of the countries that have great maritime resource potential. Maritime resources consist of marine and non-biological resources. Maritime resources such as fish besides having good taste also have nutritional content that is very useful for humans. Until now, the method of detection, classification, and quantification of underwater targets has not met scientific requirements such as the use of a single beam acoustics fish finder instrument with a single beam system that only detects targets in narrow waters. The use of a single beam sensor is limited to only detecting objects in a narrow beam, the information obtained is still qualitative, and is operated at a limited water depth, so the data obtained is not accurate. Another method is to use divers and use nets to capture underwater targets. This requires a lot of time, money and labor. Another problem is the need for knowledge of the environmental conditions as the place where the detected targets [1]. For this reason, research needs to be done using methods that meet the requirements in terms of accuracy, comprehensive, up-to-date and ongoing.

One of the latest methods that can be applied is the utilization of the Intelligent Biomass Active Sonar Transducer (IBAST) algorithm. The use of IBAST technology in Indonesia for marine resource
exploration and quantification of underwater targets has never been done. For this reason, it is necessary to develop an IBAST algorithm for the detection, classification and quantification of underwater targets. With the development of these technologies, monitoring and quantification of underwater targets such as marine resources and the environment can be carried out continuously, in situ, real time, low cost, and does not require a large amount of labor.

This study aims to develop an Intelligent Biomass Active Sonar Transducer (IBAST) algorithm in the detection, classification, and quantification of marine biota acoustic backscattering. The application of the results of activities is the increased utilization of Intelligent Biomass Active Sonar Transducer (IBAST) Technology in the provision of data, information, and knowledge in the management of marine biota resources.

2. Materials and methods
The stages of the research are as follows:
1. Development of the Intelligent Biomass Active Sonar Transducer (IBAST) Algorithm.
   Development of the Intelligent Biomass Active Sonar Transducer (IBAST) algorithm in the form of sonar equations will be carried out. The Intelligent Biomass Active Sonar Transducer (IBAST) instrument operates using simple principles. Transducer sensor will emit waves or sound signals. When the wave propagates about an object, for example a fish in a water column or bottom of the water, a part of the wave energy will be reflected or scattered again.
2. Development of an Intelligent Biomass Active Sonar Transducer (IBAST) Transmitting and Receiving System.
   The design of the Broadband Sonar transmitting and receiving system is planned to be carried out in the acoustic laboratory and marine instrumentation of the Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB (Fig. 1). The next step is to run terminal software, select COM port, and setup serial port, and log data to file (Fig. 2).

3. Result and discussion
3.1. Transducer characteristics
   The measurement of transducer directivity is shown in Fig. 2. The directivity depends on the transducer frequency and its size. For circular transducer, the beam width (deg) can be estimated approximately by [3].

\[
B_w = \frac{43.50}{fr} 
\]

(1)
Where $f$ (kHz) is frequency and $r$ (cm) is the radius of transducer. The $B_\psi$ from the above equation is 17.4 ° for 50 kHz and 4.35 ° for 200 kHz and show in good agreement with Fig 3. The function of directivity function for circular piston is shown below [4]

$$D(\theta) = \frac{2J_1(\kappa \sin \theta)}{\kappa \sin \theta}$$

(2)

![Figure 2. Computed directivity pattern.](image)

3.2. Sonar equation for fish finder

Quantification methods using a scientific echo sounder are classified into two types: (1) the individual fish estimation for single echoes, which includes the echo counting and TS measurement in situ; (2) individual school estimation for multiple echoes, which includes estimations of the volume of fish schools and of distribution density in schools or layers.

$$TS = EL - KTR + 40 \log R + 2 \alpha R - 120$$

(3)

$$SV = EL - KTR + 20 \log R - 10 \log \left( \frac{\psi \cdot \tau}{2} \right) - 120$$

(4)

$$KTR = EL + 40 \log R + 2 \alpha R - 120 - TS$$

(5)

$EL$ : Echo level [dBμV], $KTR$ : Factor of Transmit and Receive [dBV], $R$ : Water depth [m], $\alpha$ : Absorption coefficients [dB/km], $\psi$ : Equivalent Beam Width, $c$ : Sound Speed, $\tau$ : Pulse Width. The specification of echo sounder was shown in Table 1.

| Specifications | Values |
|----------------|--------|
| Frequency $f$ | 50 kHz and 200 kHz |
| Output Power W | 600 W |
| Basic Range $r$ | 2 m – 1200 m |
| Power Supply W | A 5.0-1.1: VDC 24-1 |
| Diameter of transducer $d$ | 10 cm |
| Beam width $Bw$ | 17.4 ° for 50 kHz and 4.35 ° for 200 kHz |
| Transceiver coefficient $KTR$ | 17.9 dB (50 kHz); 20.5 dB (200 kHz) |
The calculation of Signal to Noise Ratio (SNR) of a single target echo is shown by [5]:

\[
SNR = \frac{4\pi^3 \rho \eta W d^4 f_{\text{max}}^2 \exp\left[-2\left(\frac{\pi \alpha f}{c}\right)^2\right]}{c^3 r^4 N_p \Delta f \cdot T_s}
\]

Where \(\Delta f\) is the band width of the receiving system, \(r\) is the radius of the transducer, \(\lambda\) is the wavelength, \(\eta\) is the electroacoustic efficiency of transmission, \(W\) is the transmitter electric power, \(\alpha\) is the absorption coefficient, \(r\) is the distance to the target, and \(\theta\) is the position angle. The maximum detectable range is 220 m and the maximum detectable breadth is 16 m (Fig. 3).

Calculate theoretical TS for tungsten carbide sphere WC38.1 mm gained TS using temperature 27 °C, Salinity 34.8 PSU, Pressure 5dbar were -39.7 dB and -40.0 dB for 50 kHz and 200 kHz, respectively. The absorption coefficient \(\alpha\) [6] with Temp 27 °C, Salinity 34.8 PSU, pH 8.5, obtained 15.0 dB/km and 87.9 dB/km for 50 kHz and 200 kHz, respectively. Transceiver coefficient was 17.9 dB and 20.5 dB for 50 kHz and 200 kHz using this formula.

![Figure 3. Detection range of echo sounder.](image)

### 3.3. Output data of fish finder

The example of data output was in Fig 4 - 6.

![Figure 4. Example of data output of fish finder.](image)
Figure 5. Data format for SDes1.

Figure 6. Data format for SDes2.

Acoustic calibrations are fundamental to gain accuracy and precision of results when estimating the backscatter signal. For this purpose, we calibrate our echosounder using a standard target [7]. Theoretical TS of sphere was given by [8]

$$TS = 10 \log \frac{a^2}{4}$$  \hspace{1cm} (7)

where $a$ is radius of sphere (cm).

Bottom backscattering strength (SS) was computed using this formula [9]

$$SS = \frac{1}{2} c \tau SV_B$$  \hspace{1cm} (8)

where $c$ is sound speed, $\tau$ is pulse width, and $SV_B$ is volume backscattering of sea bottom.
Target strength of sphere using this formula was \(-40.1\) dB and from acoustic calibration was \(-41.0\) dB (Fig. 8), show a good agreement between theory and measurement. Application of this sounder for several underwater targets such as fish, seagrass, and seabed was shown in Fig. 8. Target strength of fish was \(-45.5\) dB, acoustic backscattering volume of seagrass (SV) was \(-50.5\) dB and \(-60.0\) dB, and bottom backscattering strength (SS) for sand was \(-22.2\) dB and \(-43.2\) dB for mud bottom. This results were nearly equal using scientific echosounder [8].

4. Conclusions
We introduce the method of fisheries resources investigation using fish finder. Calibration method using standard sphere was applied for this sounder. The echogram from output data reproduces well the features of original echo sounder image. Simple echo sounder Furuno FCV 628 was able to measure TS, SV, and SS of underwater objects such as fish, seagrass, and sea bottom. Future research will be addressed to data validation to offer higher accuracy of this sounder.
5. References

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