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Review : Acoustic systems (split beam echo sounder) to determine abundance of fish in marine fisheries

Muhammad Zainuddin Lubis[1,*], Henry M Manik [2]

[1]Department of Informatics Engineering, Geomatics Engineering Batam Polytechnic, Batam Kepulauan Riau, 29461Indonesia
2 Department of Marine Science and Technology Faculty of Fisheries and Marine Sciences Bogor Agricultural University Kampus IPB Dramaga Bogor, Indonesia

* Corresponding author : zainuddinlubis@polibatam.ac.id
Tel+62-778-469856 ext : 2510; fax: +62-778-463620
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Abstract

Acoustic waves are transmitted into the subsurface ocean will experience scattering (scattering) caused by marine organisms, material distributed in the ocean, the structure is not homogeneous in seawater, as well as reflections from the surface and the seabed. Estimation of fish stocks in the waters wide as in Indonesia have a lot of them are using the acoustic method. The acoustic method has high speed in predicting the size of fish stocks so as to allow acquiring data in real time, accurate and high speed so as to contribute fairly high for the provision of data and information of fishery resources. Split beam echo sounder comprises two aspects, and a transducer. The first aspect is the high-resolution color display for displaying echogram at some observations and also serves as a controller in the operation of the echo sounder. The second aspect is transceiver consisting of transmitter and receiver. The Echosounder divided beam first inserted into the ES3800 by SIMRAD beginning of the 1980s and in 1985 was introduced to fishermen in Japan as a tool for catching up. Split beam transducer is divided into four quadrants. Factors that contribute affect the value of Target Strength (TS) fish Strength target can generally be influenced by three factors: a target factor itself, environmental factors, and factors acoustic instrument. Factors include the size of the target, the anatomy of fish, swim bladder, the behavior of orientation.

Keywords: Acoustic systems, Estimation of fish stocks, Split beam echo sounder, Simrad, Target strength

1. Introduction

Acoustic waves are transmitted into the subsurface ocean will experience scattering (scattering) caused by marine organisms, the material distributed in the ocean, the structure is not homogeneous in seawater, as well as reflections from the surface and the seabed. Part of the initial acoustic energy on an object and is reflected back to the source called backscattering (Maisonhaute et al., 2002). According to (Benoit-Bird and Whitlow, 2001), a good fisheries resource management must control the number of catches in conjunction with the number of stocks that can be exploited. It required an estimate of the number of fish stocks at the time and acoustic survey techniques can be used to estimate the abundance of fish at a time and under certain conditions. The use of echo sounder and echo integrator for the purposes of exploration of fishery resources today are growing rapidly.

Hardware echo integrator aims to get the echo signal integration. The accuracy of this method is very high so it can be applied to estimate the abundance of fish in the waters (Benoit-Bird and Whitlow, 2001),. According to (Lubis and Pujiyati, 2016), the hydroacoustic method with detection backscatter value of mangrove crab (scylla sp.) using cruzpro fishfinder pcff-80 hydroacoustic instrument. According to (Pujiyati, 2008) hydroacoustic method is an underwater detection method that use acoustic devices, among others: echosounder, fish finder, sonar, and Acoustic Doppler Current Profiler (ADCP).

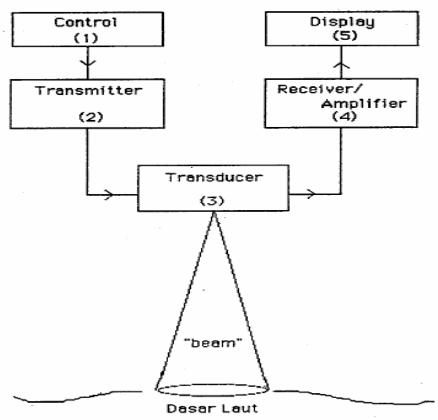

Fig 1. Working mode of hydroacoustic tool

According to (MacLennan and Simmonds, 1992) a good fisheries resource management must control the number of catches in conjunction with the number of stocks that can be exploited. It required an estimate of the number of fish stocks at the time and acoustic survey techniques can be used to estimate the abundance of fish at a time and under certain conditions.

The use of echo sounder and echo integrator for the purposes of exploration of fishery resources today are growing rapidly. Hardware echo integrator aims to get the echo signal integration. The accuracy of this method is very high so it can be applied as an estimate abundance of fish in the waters (Benoit-Bird and Whitlow, 2001).

Estimation of fish stocks in the waters wide as in Indonesia have a lot of them are using the acoustic method. The Acoustic method has high speed in predicting the size of fish stocks so as to allow acquiring data in real time, accurate and high speed so as to contribute fairly high for the provision of data and information of fishery resources (MacLennan and Simmonds, 1992) in Fig 3 and 4.

The second aspect is transceivers consisting of transmitter and receiver. The echosounder divided beam first inserted into the ES 3800 by SIMRAD beginning of the 1980s and in 1985 was introduced to fishermen in Japan as a tool for catching up. Split beam transducer is divided into four quadrants (Foote, 1987) in which the transmitting wave conducted by the merger of four full beam. The signal reflected by the target is received by each quadrant and reassembled to form a full beam. The direction on the ship split beam is divided into four (4) ie Fore, Aft, Port, and Starboard. While in principle Split Beam is divided into four quadrants that FP.FS.AP and AS in Fig 2.

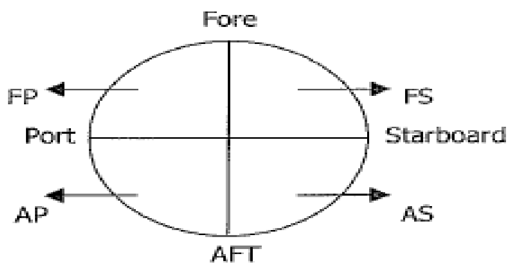

Fig 2. Split beam transducer, Source in (MacLennan and Simmonds, 1992).

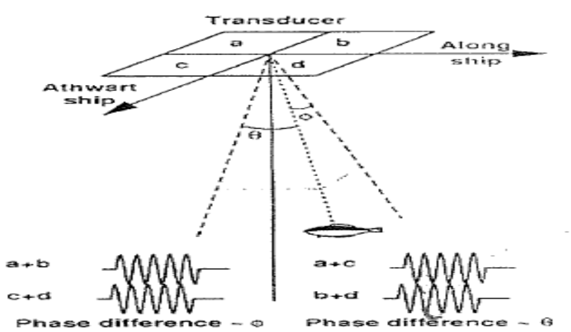

Fig 3 Split beam shape and a full beam transducer, Source in (MacLennan and Simmonds, 1992)

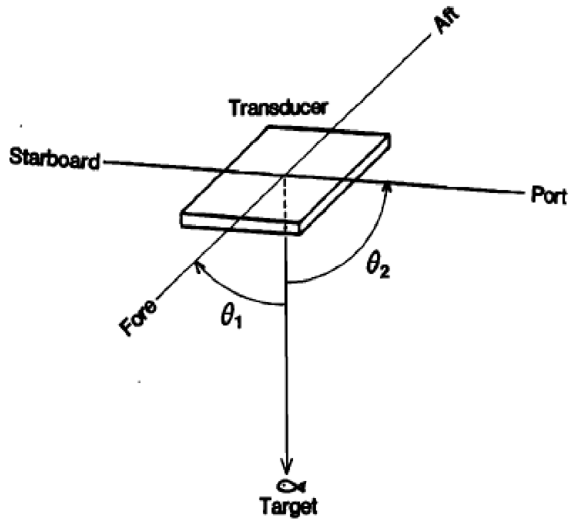

Fig 4. Geometry targets in Split Beam transducer. Towards the target defined by the θ1 and θ2 angle, Source in (MacLennan and Simmonds, 1992).

In Fig 3, Split beam echo sounder has the function of Time Varied Gain (TVG) in acoustic data acquisition system serves as a reliever TVG attenuation (Amplifier) whether caused by geometrical spreading and absorbs noise as it propagates into the water. There are two types of functions, namely TVG function that works to echo a single fish called TVG 40 log R and a function for a group of fish that TVG 20 log R.

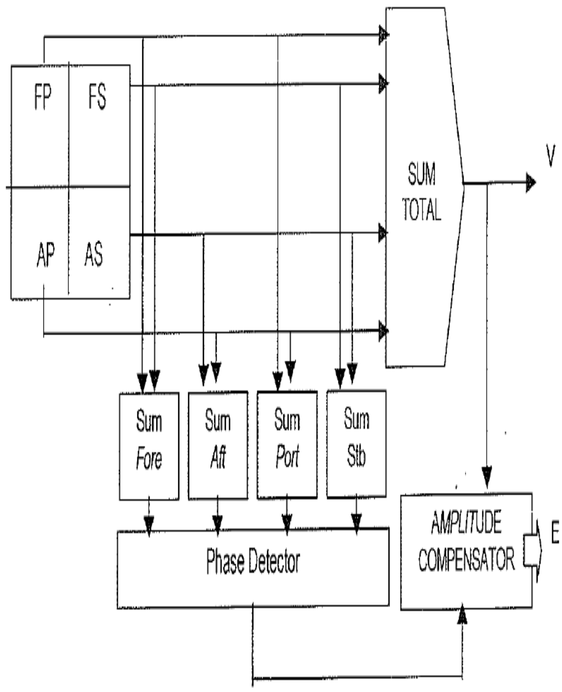

Fig 5. Block diagram of the receiver split beam echo sounder, Source in (Arnaya, 1991).

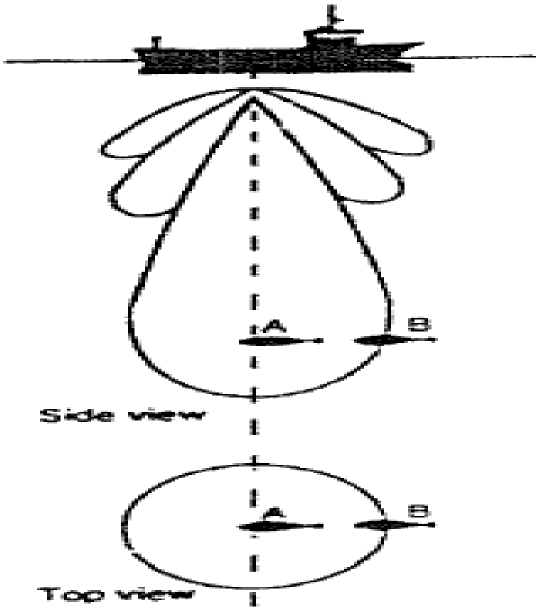

Fig 6. The working principle of Split Beam on detecting fish echo sounder, Source in (Arnaya,1991).

In (Figure 6) by SIMRAD, fish axis A located right above the maximum transducer gain, while fish B is located at the end (edge) transducer beam where the gain is lower. A fish echo thus more likely to result stronger than the backscattered echo in fish B. Although both of these fish are at the same depth and the same size. To determine the size of the fish from the echo strength alone is not enough, however, knowledge about the pattern beam transducer and the fish in the beam position is very important to correct transducer gain strength and determining the target value of real fish. An estimate obtained approximate angle of incidence and factors beam pattern in the acoustic signals can be obtained by using a processor of the split beam which has a signal source X leads to Phase detection and will produce energy or power by means of calculating the results of input and will generate output waveform display in Fig 8.

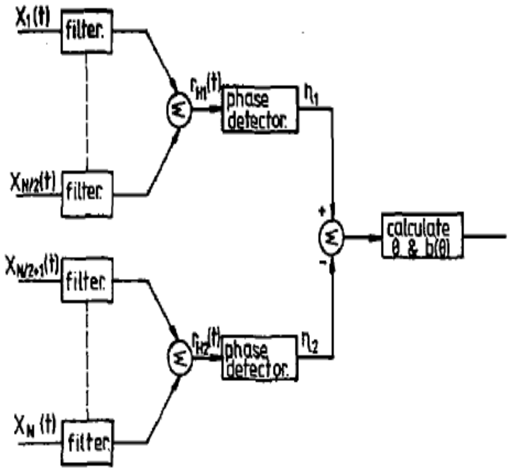

Fig 7. Split Beam Processor to obtain estimates of the incidence angle and the beam pattern factor, Source in (Ehrenberg, 1979)

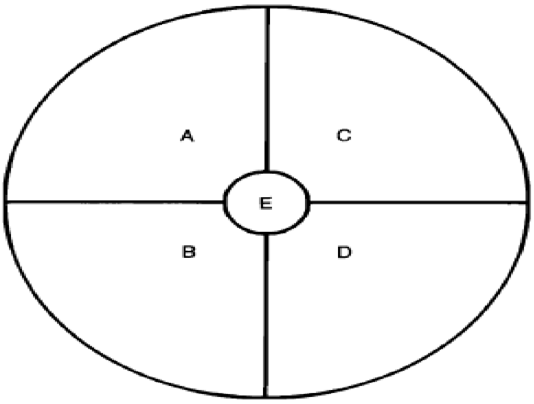

Fig 8. Diagram of a dual beam transducer / split beam, showing the location of the various segments described in the text and the shape of each beam used in the split reception beam or dual beam, Source in (Foote, K.G & Traynor, 1988)

Table 1. Beam descriptiont, TVG, Used, and signal in split beam echo sounder

Beam descriptions	TVG	Used	Signal
A+C	40 logR+2 αR	Split-beam phase measurements	10 kHz
B+D	40 logR+2 αR	Split-beam phase measurements	10 kHz
A+B	40 logR+2 αR	Split-beam phase measurements	10 kHz
C+D	40 logR+2 αR	Split-beam phase measurements	10 kHz
E	40 logR+2 αR	Amplitude *Dual Beam, Split Beam*	Detected
A + B + C + D +E	40 logR+2 αR	Integration echo	Detected

2. Target Strength

Target strength (TS) is the ability of the target to reflect a sound about it. Based domain is used, the target strength is defined into two, namely in the form of Target Strength Intensity (TSi) and Energy Target Strength (TSE). Target strength (TS) can be defined as the quotient between the value of the intensity of the noise coming about the target and multiplied by the number of ten (10) in (Maclennan *et al.,* 2002) is :

$$TSi = 10 \log \frac{Ir}{Ii} \quad (1)$$

$$TSe = 10 \log \frac{Er}{Ei} \quad (2)$$

Information :
TSi : Intensity target of strength
Ii : Intensity of sound on targets
Ir : Reflected sound intensity targets

TSE : Energy Target Strength
Ei : Energy sound on targets
Er : Energy reflection sound at a distance of 1 meter from the target

According to (Maclennan *et al.,* 2002) stated that the target strength (TS) is a measure decibel sound that is returned by the target as measured by a standard distance of 1 meter from the acoustic center of the target is located, relative to the intensity of sound that hit the target. A simple model to estimate the backscattering cross section based on the size of fish referred by (MacLennan and Simmonds,1992):

$$\sigma_{bs} = b_0 L^2 \quad (3)$$

$$TS = 20 \text{ Log } L + b_0 \quad (4)$$

Then according in (Love, 1997) introduced the equation which connects the backscattering cross section (σ_{bs}), fish length (L) and wavelength (λ) by the following equation: $\sigma_{bs} / \lambda^2 = a(L/\lambda)^b$ (dB) where a and b are constants that depend on the anatomy, fish size, and wavelength. Equation (4) can be converted into a logarithmic form becomes:

$$TS = a \text{ Log}(L) + b \text{ Log}(f) + b_0 \quad (5)$$

Information :
TS = Target strength (TS)
F = Sound frequency
A, b = Constant

Then obtained the possibility of the average best performing measurements on the measurement of the target strength of the dorsal aspect:

$$TS_D = 19{,}1 \log (L) - 0{,}9 (f) - 62 \quad (6)$$

But according to (Natsir *et al.,* 2005) explains more about the similarities that show no difference in the comparison of results of different frequencies. Furthermore, the equation (Foote and Traynor , 1988) to formulate relationships TS (Target Strength) to the length of the fish, namely:

$$TS = 20 \text{ Log } (L) - 68 \text{ (dB)} \quad (7)$$

Conversions strength target value into a length (L) for pelagic fish used equation TS = 20 log L-73.97 (Natsir *et al.,* 2005). Relations targets strength and OBS (backscattering cross-section, m^2) is calculated based in [6] with equation:

$$TS = 10 \log óbs \quad (8)$$

Equation for densitas ikan (ñA, ind./nmi^2) is :

$$ñA = sA / óbs \quad (9)$$

Fish length (L) associated with óbsis:

$$óbs = aL^b \quad (10)$$

Associated of *target strength* and L is:

$$TS = 20 \log L + A \quad (11)$$

Where :
A = the value of the target strength to 1 cm long fish (normalized target of strength)

Conversions strength target value into a length (L) for pelagic fish used equation: TS = 20 log L-73.97 (Natsir *et al.,* 2005) . According in (Effendie, 2001) the relationship length (L) and weight (W) of a species of fish that is:

$$W = aL^b \quad (12)$$

In addition (Natsir *et al.,* 2005) has a long and weighs equation to convert length into weight alleged allegations are as follows:

$$Wt = a\{\textstyle\sum_1^{i1}.ni(Li+ÄL/2).^{b+1} - (Li-ÄL/2).^{b+1}\}/\{(b+1)ÄL\}\} \quad (13)$$

Information :
Wt : Total weight (g)
Al : Class interval length (cm)
Li : The midpoint of the long-th grade (cm)
Ni : Number of individuals in the i-th grade
a, b : Constants for certain species

Factors that contribute affect the value of target Strength (TS) fish Strength target can generally be influenced by three factors: a target factor itself, environmental factors, and factors acoustic instrument. Factors include the size of the target, the anatomy of fish, swim bladder, the behavior of orientation (Priatna. A & Wijopriono, 2011). Factors such targets are:

1. **Size of fish:** There is a relationship between the size of the fish with a value of TS, but the relationship varies greatly depending on the species. Generally, for fish species, the larger the fish the greater its value TS. This is especially true for the region of the graph geometrical relationship between the size of the target and TS, for the region, resonance, resonance region and the transition region, the

tendency of the relationship is not valid (Maclennan *et al.,* 2002). Anatomy such as the head, body, tail and fins have different sound reflections. Likewise, stomach, intestine, liver, bones, flesh and gills have a specific gravity = (ρ) and the speed of sound = (c) different so acoustically will have the ability to reflect a different sound.

2. **Swim bladder of fish**: Acoustically fish and marine organisms are divided into two major groups, namely bladder fish (have a swim bladder). Fish that have a swim bladder generally do not have the right maximum TS on the dorsal aspect, while fish that do not have a swim bladder with a maximum value of TS is generally right on the dorsal aspect. TS value of fish that have a swim bladder (Furusawa, 1998 in Manik *et al.,* 2006). With deformed-cylinder model (DCM) with Approximation of> 5 and the value of Tilt Angle was not until (<40 °) according to (Yasuma *et al.,* 2003). results from the resultant corner of a fish that has swim bladder that is:

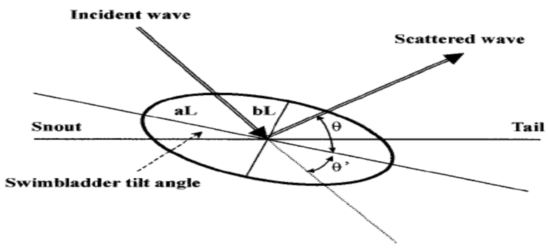

Fig 9. Swim bladder Geometry for Soft spheroid models, Source in to (Yasuma et al., 2003).

3. **Behavior / orientation fish**: Results of a previous study conducted by (Henderson *et al.,* 2008 and Fässler *et al.,* 2008) states that the value of Target Strength (TS) is determined by the orientation of the fish, especially the slope of the body to a line connecting between the head and tail. Fish orientation will include tilting, yawing and rolling along. Yawing no effect because generally spherical transducer position so that the fish does not cause changes in the angle when viewed from the transducer, for Rolling no real effect because the fish have a swim bladder due partly reflected energy is derived from the swim bladder did not come from the dorsal aspect. Tilting lead to a change in angle-position transducer is good for fish that have a swim bladder or not (Arnaya, 1991).
4. **Instrumental factor**: The small big factor value Beam pattern depending on the extent of the transducer will be greater the beam angle of the transducer, and vice versa. Large beam angle changes cause TS great value, separately it is better to use a relatively narrow beam.

Acoustic reflections of fish and plankton that are returned in the form of echo are detected by the receiver has an appeal. Estimation of biomass can be seen from how much force the target and how to interpret it. TS plankton is numbers that indicate the size of the echo. The larger the value, the greater echo energy is returned to the receiver by the target. Unit of measure Standard International (SI) for the TS expressed in decibels (dB). A decibel is a logarithmic form of a comparison or ratio of the two intensities due to the values involved can be very large or very small. According to (Lurton, 2002) TS formulated as backscattering cross-section of the target which returns a signal and is expressed in the equation:

$$TS = 10 \log (\sigma / 4\pi) \qquad (14)$$

Then the value of TS theoretical spherical object is:

$$TS = 10 \text{ Log } \frac{a^2}{4} \qquad (15)$$

Where σ = T*arget strength* individual or *backscattering cross-section* (σ_{bs}) with TS according to (DeCino and Willette, 2014 in Lurton, 2002) with equation :

$$TS = 10 \log \sigma_{bs} \qquad (16)$$

3. Volume Backscattering Strength (SV)

Volume Backscattering Strength (SV) is defined as the ratio between the intensity reflected by a group of single targets (target located at a water volume of certain invocation of instantaneously measured at a distance of 1 m from a target with the intensity of sound that hit the target. Definition Volume Backscattering Strength (SV) has the same meaning as the target strength for a single target, while Volume Backscattering strength (SV) for a group of fish.

Each individual targets is the source of the reflected sound wave, so that the output of the integration will be proportional to the quantity of fish in the group. Echo integration methods used to measure Volume Backscattering Strength (SV) based on the measurement of the total power backscattered on the transducer (Arnaya 1991).

Volume Backscattering Strength (SV) is the ratio between the intensity reflected by a single group target where the target is located at a water volume (Xie and Jones, 2009). This is similar to the definition of TS where TS value is the result of the detection of a single organism, while SV is the value for detection organism groups in (Kaartvedt and Aksnes, 2012) states SV is defined as the equation:

$$SV = 10 \log (I_s / I_i) \qquad (17)$$

Information :

I_s : Intensity scattering volume measured 1 m from the center of the acoustic waves.

I_i : Scattering intensity emitted

4. Fish density (Abundance Fish)

To date research on fish stock estimates done by cruise track using a SIMRAD EK 60 Scientific split beam echo sounder system with a frequency of 70 kHz and acoustic data acquisition is performed continuously during the day and night during the period boat cruise at speeds ranging between 7- 8 knots. Trails include a data acquisition area of an area that allows the analysis of spatially made with the zig-zag shape according to (MacLennan and Simmonds, 1992 in (Diez *et al*., 2016, Jurvelius *et al*., 2016) with the length of each transect approximately 12 nmi of bounds islands outwards. Density values for fish processing performed on Ms. Excel. The treatment may be carried out after the integration process SV and TS. Density is generated by using the formula (Lubis and Anurogo, 2016).

$$SV\,(\mathrm{dB}) = 10 \log (N \tau bs) = 10 \log N + TS \quad (18)$$

Assuming the numerical density is proportional to the density of individuals, then the equation (1) can be rewritten as follows:

$$SV\,(\mathrm{dB}) = 10 \log \rho + A \quad (19)$$

Where:
SV : Volume strength (dB)
ρ : Abundance / density of organisms (ind / m3)
A : Target average strength (dB)

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