Chapter 15

Acoustic Fish Detection and Gear Monitoring Devices

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15.1 Introduction

Introduction of acoustic fish detection devices is one of the most significant developments in modern fishing. It has greatly reduced the element of chance and the dependence on fisherman's intuition in fishing and has enhanced the effective fishing time by reducing the time spent for searching. Important fish detection devices are echo sounder and sonar. Acoustic devices such as *trawl eye* and *net sonde* are used for monitoring of gear performance and improving capture efficiency in aimed midwater trawling and purse seining.

Leonardo da Vinci is credited with the earliest known reference to underwater sound (Urick, 1983; Fernandes et al., 2002). He observed in 1490 that it is possible to hear ships at great distance, as sound is transmitted through seawater. The first reported application of acoustics to detect fish was by Kimura (1929) who measured fish movement in an aquaculture pond. Sund (1935) made the first echogramme recording of cod (*Gadus morhua*), in Norway. Electronic echo sounders were first developed in 1930s as a navigational aid. Since Second World War, there has been intensive development of the technique and its application in fish detection (Hodgson, 1950; Hodgson and Fridriksson, 1981; Johannesson and Mitson, 1983; Urick, 1983; MacLennan, 1990; MacLennan and Simmonds, 1992; Fernandes et al., 2002 and Simmonds and MacLennan, 2005).

15.2 Basic principles of acoustic fish detection

All acoustic fish detection devices are based on echo-sounding or echo-ranging techniques in which a pulse of sound energy is transmitted through water and received back from a reflecting object. The duration of time between the original pulse and the received echo is proportional to the distance of the target.

$$T = 2d / V$$

where T is time delay; d denotes distance travelled by the sound pulse from the source to the target; and V is the velocity of sound in water.

Sound is transmitted through seawater at a nominal speed of 1500 m per second. While the speed of 1500 $m.s^{-1}$ is exact for 13°C and 35 ppt salinity, the speed ranges from 1450 to 1570 m per second depending on salinity, temperature and pressure. The speed increases with temperature at the rate of 4.5 $m.s^{-1}$ per degree Celsius; with salinity at the rate of 1.3 $m.s^{-1}$ per ppt; and with pressure at the rate of 1.7 $m.s^{-1}$ per 100 m depth. Speed in seawater is about 3% higher than in freshwater.

The signal-to-noise ratio determines whether or not an echosounder or sonar will be able to detect a signal in the presence of background noise in the ocean. It takes into account the source level, sound spreading, sound absorption, reflection losses, ambient noise, and receiver characteristics. The sonar equation is used to estimate the expected signal-to-noise ratios for echo sounder and sonar systems.

$$EL = SL + TS - 2TL$$

where EL is the level of reflected sound (echo level), SL is the level of incident sound (source level), TS is the target strength and 2TL is the two-way loss due to spreading and absorption.

15.3 Echo sounder

The most well known and widely used instrument for fish detection is echo sounder. The echo sounder transmits sound signals vertically in water and shows their echo return on a display unit. Echo sounders are used for (i) depth recording for navigation purposes and position fixing, (ii) ground or sea bed discrimination i.e., to distinguish soft mud, sand, gravel and rock bottom conditions, (iii) determination of sea bed contour, (iv) location of wrecks and hazardous areas and (v) location of fish and determination of its depth of occurrence.

15.4 Basic components of echo sounder

The echo sounder comprises of four main units *viz.,* the transmitter, the transducer, the receiver amplifier and the recording and display unit and a time base (Fig. 15.1).

15.4.1 Transmitter

The transmitter generates an electrical pulse of the required frequency and duration. Each pulse will have a specific duration in milliseconds (1/1000 second) and contains a number of vibrations or oscillations measured in cycles per second or Hertz (Hz) (1 cycle per second = 1 Hz; 1000 Hz = 1 kHz). The pulse will also have a power rating in watts.

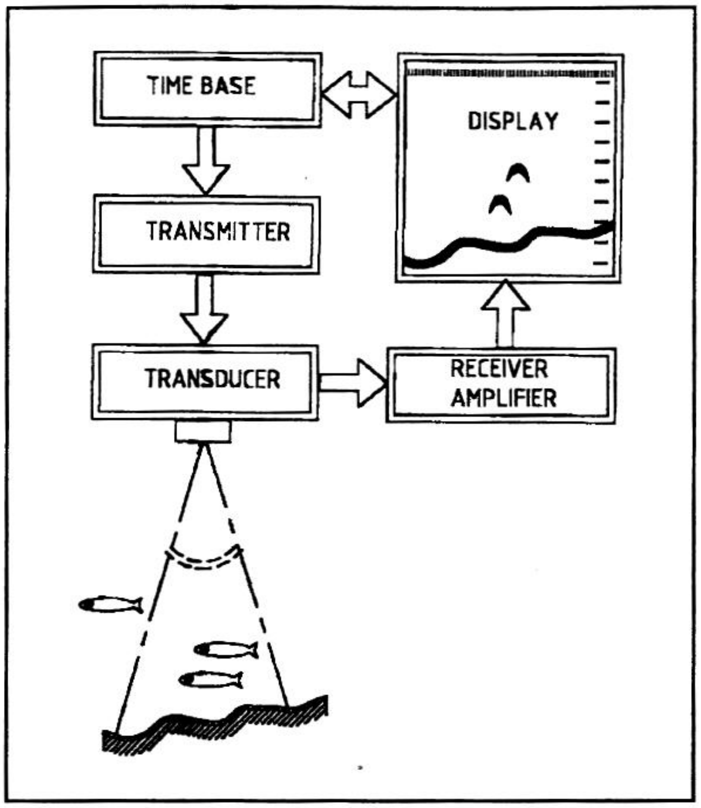

Fig. 15.1 Basic components of echo sounder

15.4.2 Transducer

The transducer coverts electrical energy from the transmitter into mechanical energy or sound of corresponding frequency and duration. It also performs the reverse function of converting the received echo signals into the corresponding electrical signals.

Transducer types

Underwater transducers makes use of an effect whereby the actual dimension of a piece of material change under the influence of either a magnetic field (magneto-striction; e.g., nickel, nickel-cobalt alloys, ferrite) or electric field (electro-striction; e.g., polycrystalline ceramics such as barium titanate and lead zirconate-titanate. If the field follows electrically applied oscillations, the resulting changes in the dimensions will generate acoustic pressure variations in the same frequency. The opposite effect occurs when an acoustic echo acts on the transducer - the dimensions change producing a voltage across the terminals which varies in sympathy with the echo. Electro-strictive ceramic transducers are widely used in modern echo sounders due to their advantages in terms of cost and efficiency.

The transducer installation

The transducer installation is the single most critical factor involved in achieving optimum performance of echo sounder. The transducer should be installed in such way that its working face is parallel to the water line when the boat is in its normal upright position, and well submerged when the boat is underway. It is always desirable to mount the transducer unit on the vessel's hull at a point where acoustic disturbances are minimum, free of air bubble streams and other impediments. Normally it is installed in a fishing vessel in the region which is between one-third from the vessel's stern post and not greater than half the vessel's length from stern post. The transducer should never be mounted immediately below the main engine, auxiliary engines or gear box. It is best mounted under fish storage area. The transmitting/ receiving face of the transducer should never be painted, but must be periodically cleaned to remove any fouling accretions.

15.4.3 Receiver amplification unit

The basic function of the receiver is to amplify the electric signals from the transducer so that they can be used to mark the paper in the paper recorder or displayed in the monitor. In modern fish finding echosounders, various signal processing controls are built into the receiver section. The echoes from nearer targets are stronger than those from distant targets. Time Varied Gain (TVG) function is incorporated in modern echo sounders to proportionately compensate for sound propagation losses.

15.4.4 Recording and display unit

The amplified echo signals are recorded in a recording paper or displayed in a cathode ray tube (CRT) or liquid crystal display (LCD) monitor. From the echogramme or display one can understand the relative abundance of fish at a particular depth. In order to read the depth of occurrence of the fish or sea bed directly from the echogramme or display, the time delay is calibrated to a scale marked in meters or fathoms or both.

15.5 Echo sounder specifications

15.5.1 Frequency

Frequency is selected according to the operating depth, fish species and fishing methods. The frequencies used range from 10 kHz to 1 MHz, but is generally in the range of 10 kHz to 400 kHz. Low frequency sounders (10-40 kHz) give good ground discrimination, can detect schools of fish but cannot detect the fishes without air bladders such as mackerel, tuna and squid so well. They are usually selected for bottom trawlers. High frequency sounders (80 - 200 kHz) are very good at detecting fish without air bladders but they do not give good ground discrimination and are usually chosen by tuna and mackerel purse seiners, squid jigging vessels and liners. Mid-frequency sounders (40-80 kHz) have good performance some what in between the other two and may be preferred by gillnetters and handliners. Dual frequency sounders combining low and high frequency, for instance 50 and 200 kHz, are also in popular use in fishing vessels.

Table 1: Characteristics of low and high frequency echo sounders

Characteristics	Frequency of sound pulse	
	Low	High
Beam angle	Wide	Narrow
Sounding range	Deep	Shallow
Resolution	Poor	Good
Effect air bubbles	Susceptible	Not susceptible
Advantages	Deep sounding; good bottom discrimination	Good resolution; little interference

15.5.2 Transducer beam angle

In the ultrasonic sound beam, energy is concentrated at its centre and weakens towards the edges. The beam angle is defined as the angle at which the sound energy at the edge is half of the energy at the centre (Fig. 15.2). The beam angle is determined by the frequency and the size of transducer. For any given frequency, the larger the transducers, the sharper will be the beam angle. A sharper beam angle gives excellent horizontal resolution but is poor for effective bottom discrimination or wide range searching. Beam angle varies from 4 and 40°. Beam angle chosen can directly affect the shape of the fish echoes in the recorder, the quality of ground discrimination and the ability of small targets to be located at greater depth. A general rule is to select a wide beam angle for shallow waters (<100 m) and narrow beam angle for deep waters (>100 m).

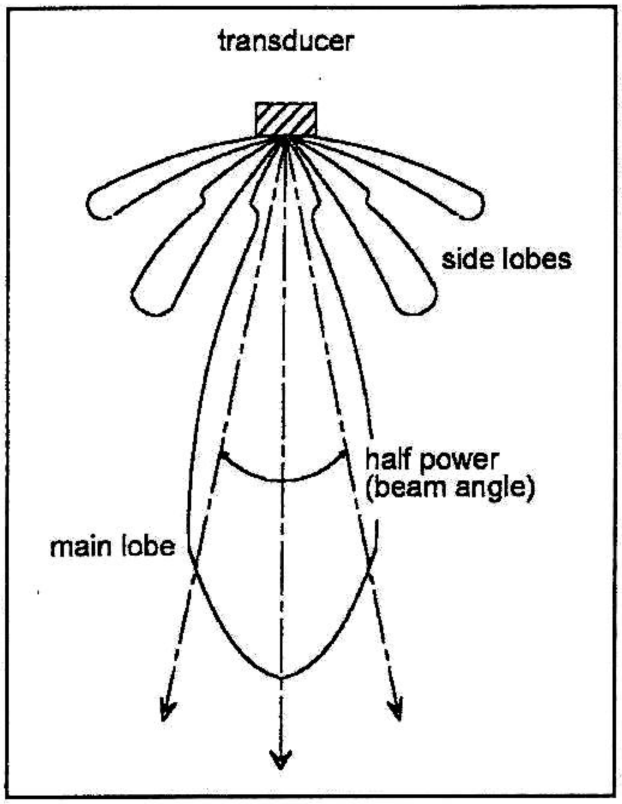

Fig. 15.2 Transducer beam angle

15.5.3 Pulse length

Pulse length is the distance a pulse extends in meters. Pulse duration is the time for which pulse continues (in milliseconds). In general long pulse lengths are best for deep sounding. The shorter the pulse the better will be the vertical (range) discrimination.

15.6 Methods of presentation

Early types of display used mechanically operated pens which marked paper to provide recording. The recording paper is either moist or dry type. The moist type is cheaper and has a larger dynamic range i.e., higher number of discernible shades between no marking and full saturation, but shorter shelf life. The reduced dynamic range of dry recording paper is partly compensated by greater ease of handling and long shelf life. White line or grey line effect is available in most of the modern echo sounders in order to help detect fish schools lying close to the sea bed (Fig. 15.3). Modern echo sounders use CRT and LCD colour display in which bottom fish and sea bed echoes are represented in easily distinguishable colours. Strong echoes are represented as red whereas weak signals are blue. In the monochrome display, high amplitude signals appear as dark marks in white background.

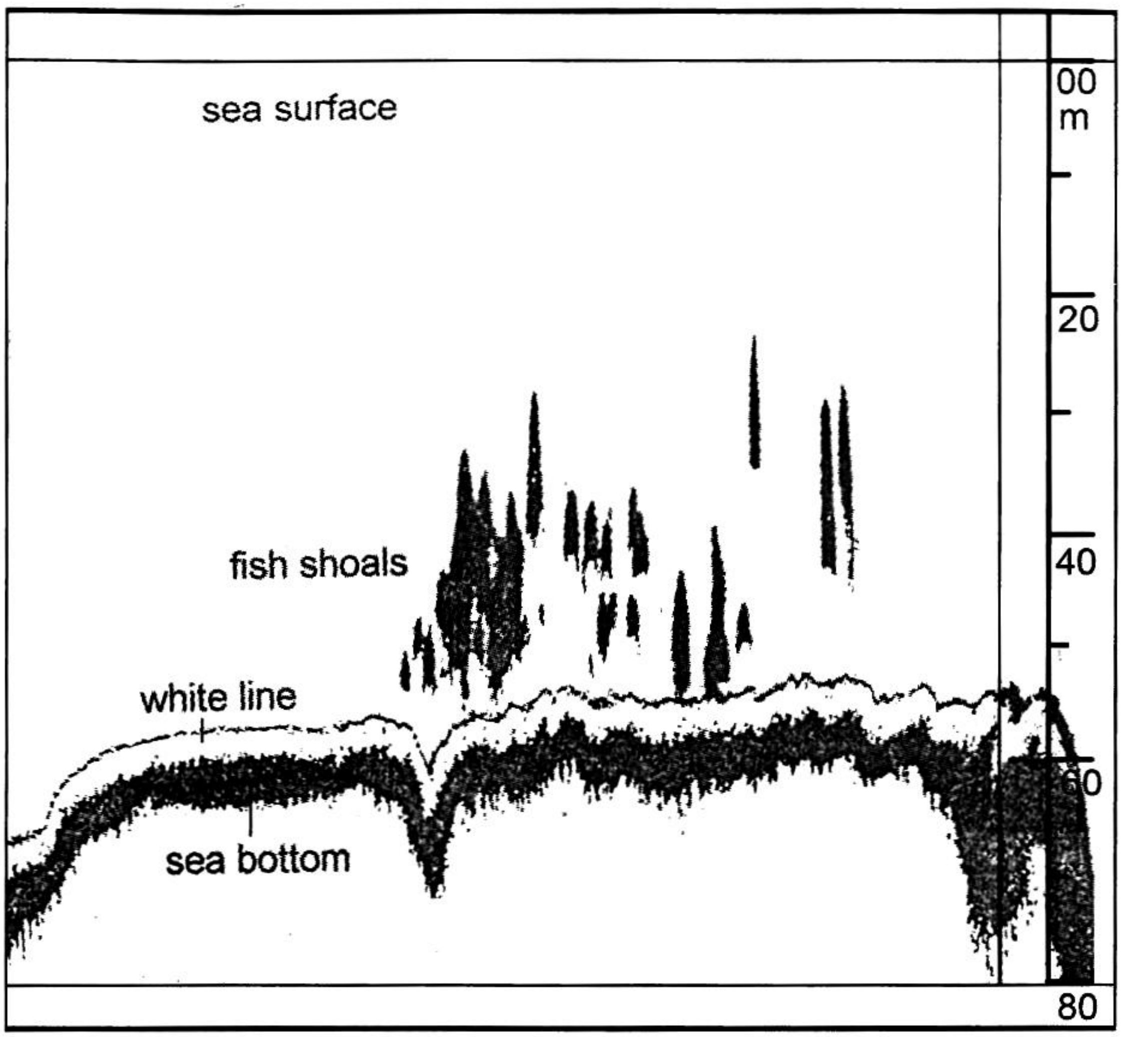

Fig. 15.3 Echogram

15.7 Sonar

Sonar is an indispensable tool for aimed trawling and purse seining operations. Sonar is the acronym for **SO**und **NA**vigation and **R**anging. Basic components of sonar are represented in Fig. 15.4. Sonar can be described as a horizontally scanning echo sounder. Its transducer is fixed to a pipe which can be lowered or raised from within a larger cylinder located below the hull and can be scanned to either side of the vessel or through 360° with free sight in all directions. Sonar transducer can be tilted up and down from +10 to -90°. The train and the tilt are remotely controlled from the bridge. Information is displayed in Plan Position Indicator (PPI) display as in radar or in Cathode Ray Tube (CRT); or recorded in paper recorder and/or played in audible form for 'eyes free' operation of the equipment.

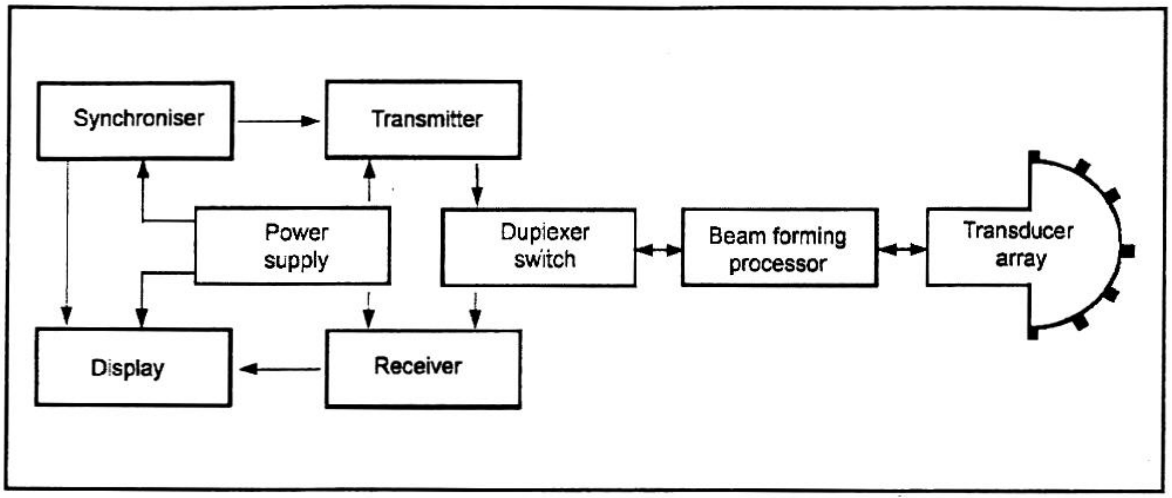

Fig. 15.4 Basic components of sonar

15.7.1 Types of Sonar

There are two distinct types of equipment available for use in fishing operations. They are search light sonar and omnisonar.

Search light sonar

Search light sonars, as the name implies are designed to transmit a sound pulse on a selected sector bearing, listen to the echoes and on completion step to a new bearing before transmitting again (Fig. 15.5).

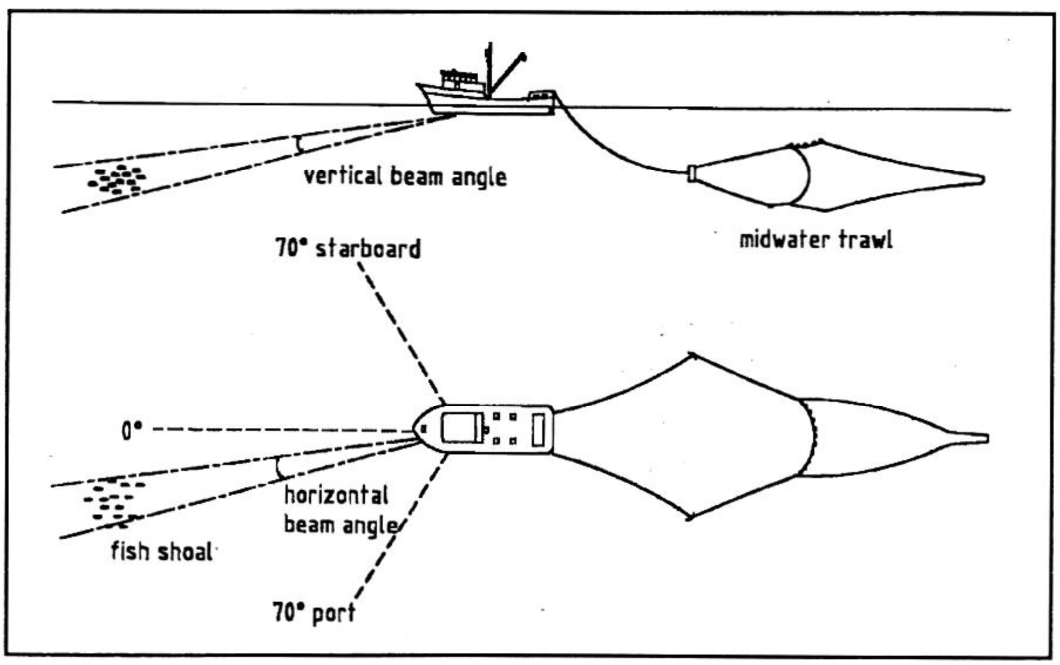

Fig. 15.5 Searchlight sonar

Omnisonar

Omnisonar transmit one sound pulse which effectively radiates from the transducer through a complete 360° and electronically scan the entire area while listening for echoes. The display shows a complete picture around the vessel for each transmission.

15.7.2 Sonar specifications

Frequency and detection range

As in vertical echo sounders, the frequency determines the maximum detection ranges. High frequency sonars of 60 kHz and above usually have an effective range limitation between 800 and 1200 m, depending on the target strength, density and depth of water. Lower frequency sonars between 20 and 60 kHz can detect up to 2000 m, once again depending on target type, density and water depth. Sonar performance is affected by refraction of sound (thermocline; density gradients) and by the pitching and rolling of vessels.

Pulse length and power

Typical small sonar specifications for pulse duration and power are 1-4 milliseconds and 1 kW, respectively. Larger range sonars may have variable pulse duration up to 30 milliseconds and 5 kW of transmitted power.

Audio output

A facility on sonar which is not usually found in the echo sounder is audio output through a loud speaker. This is normally provided for operator's convenience as he can work his equipment continuously without watching the display ("eyes free" operation). A skilled sonar operator can detect in the sound from the loud speaker, potential fish targets, sea bed echoes including pinnacles or wrecks and other echo returns caused by vessel wakes.

15.8 Conclusion

Technological advances in electronics and research into underwater acoustics have led to tremendous improvements in echo sounder and sonar and made them more reliable and affordable. Microcomputer-based menu-driven user-friendly control interfaces are now in common use. Double and triple frequency capabilities recently introduced into echo sounders have greatly improved both detection and differentiation of individual fish species and shoal volumes.

Common features in modern echo sounders include features such as scale expansion, bottom lock and pelagic lock modes, selectable display shift speeds, time marks, digital indications, roll stabilisation feature and interfaces for GPS, speed log and temperature sensor. Systems are now available with 3-D graphic presentation features based on stored and real time data giving details of bottom topography and resources abundance distribution. Long range sonars of up to 8000 m range, with automatic search programmes and capabilities to read fish concentrations, depth range, bearing and movement of a number of schools simultaneously giving real time presentation of the vessel, net and fish shoals are increasingly used in recent times.

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