Marine Information Technology
Curriculum Report

APPLICATION OF SONAR IN BATHYMETRIC MAPPING

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Marine Science

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Date: 08/06/2020

Abstract

The oceans covers about 75 percent of the earth surface. The study of ocean bottom has evolve over the last decade and of all the advancement in ocean science, sonar technology has been one of the most ground breaking. The earliest form of ocean parameter measurements involved the use of weighted lines to explore the ocean bottom for bathymetric measurements, charting maps, and ancient ruins before underwater wireless communications were introduced. Because of the expenses on cables and other inconveniences associated with the cable method, high-speed communication between the remote end and the surface became a necessity. Underwater wireless networking has come into being to address these impediments. The ocean is greatly underexplored due to challenges associated with varying and extreme conditions found with the ocean and the advent of sonar technology which involve the use of acoustic wave has advanced the study of ocean science.

Introduction

Akyildiz et al. (2005) defined underwater acoustic communication as a technique of sending and receiving messages below water. The choice of energy to be used for underwater detection is determined by three factors; range of penetration, ability to differentiate between various objects in the medium and the speed of propagation (FAS). Of all the known physical phenomena, light has excellent differentiation ability and high speed of transmission, but its range in water is very limited, on the order of tens of meters, thereby restricting its operational usefulness. Radio frequency waves also are

propagated with extreme rapidity and to great distances through certain mediums, but sea water is essentially impervious to them for most frequencies. Very Low Frequency (VLF) signals will penetrate only about 10 meters, whereas higher frequency penetration depths can be measured in millimeters. Magnetic and gravitational field distortions are detectable only at very short ranges because the anomaly diminishes proportionally with the inverse of the range cubed. While their detection range is greater than either light or radio frequency, it is only of the magnitude of several hundred meters and therefore is insufficient for normal surveillance.

Acoustic energy, while lacking the propagation speed of electromagnetic waves, is capable of being transmitted through the sea to distances that are operationally significant. Because of this, sound is the physical phenomenon used for underwater communications such as bathymetric mapping, sounding, and underwater navigation. It must not be inferred, however, that sound is a panacea as it equally has significant limitations to its effective employment. The optimum use of sound requires a thorough understanding of its limitations so that these effects can be minimized. For example, sea water is not uniform in pressure, temperature, or salinity, and all these characteristics have important effects on sound propagation through the sea. The requirement for predicting these effects on sonar performance has become a necessity.

Marine Acoustic

Marine acoustics is the study and application of sound in water. Marine acoustics, using sound navigation ranging (sonar) technology, is most commonly used for monitoring

of underwater physical and biological characteristics. Marine acoustics can be used to detect the depth of a water body (bathymetry), as well as the presence or absence, abundance, distribution, size, and behavior of underwater plants and animals. Marine acoustic sensing involves "passive acoustics" (listening for sounds) or active acoustics making a sound and listening for the echo, hence the common name for the device, echo sounder or echo sounder. The advent of underwater wireless communication (UWC) has brought about ease and improvement in the various underwater investigations in the field of marine sciences such as mapping the seafloor, marine monitoring and surveillance, exploration for oil and gas. For decades, the trained people classified and recognized the class of marine vessels by listening to their radiated noise. Substituting these people with intelligent systems for classifying marine vessels based on their acoustic radiated noise is one of the hot topics in signal processing and artificial intelligence.

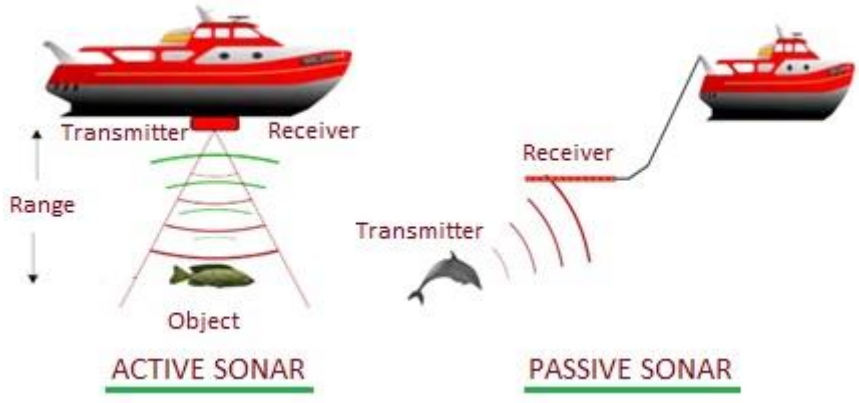
Fundamental concepts

All sound, whether produced by a cowbell or a complicated electronic device, behaves in much the same manner. Sound originates as a wave motion by a vibrating source and requires for its transmission an elastic medium such as air or water. For example, consider a piston suspended in a medium. As the piston is forced to move forward and backward, compressing the medium on the forward stroke and decompressed or rarefied on the return stroke. Thus, a wave motion or series of compressions and rarefactions is caused to move from the source out through the medium. In the fluid

medium the molecular motion is back and forth, parallel to the direction of the piston's movement. Because the fluid is compressible, this motion results in a series of detectable pressure changes. This series of compressions and rarefactions, such as is produced by the piston, constitutes a compressional wave train (Cohen, 1970).

Another way of explaining the phenomenon of acoustic wave propagation is to consider the medium of transmission as a loosely packed collection of mass elements connected by springy bumpers. A disturbance of the elements at some point (e.g., piston motion) moves along in the fluid by the successive extension and compression of the springs as the elements swing back and forth, each communicating its motion to its neighbor through the connecting bumpers. In this way, the agitation of a cluster of elements is propagated through the medium even though the individual elements do no more than move about their equilibrium positions without actually migrating. The sound wave propagates parallel to the source resulting in a longitudinal wave.

Types of sonar



Types of Sonar (Source: rfwireless online)

Sonar signal can be classified to wide range of applications according to the sonar mode, i.e. active or passive sonar system, and the nature of received signal, i.e. radiated

acoustic noise of marine vessels, received active sonar ping's echo from ships, bats' echo or marine mammals' sound, and so on.

Passive sonar system provides monitoring the undersea environment without sending energy through the water. On the other hand, active sonar system can act same as Radar using responses from signals sent towards targets. Underwater signals obtained from passive sonar contain valuable clues for source identification even in high noisy environments. Attempts on detection/classification of acoustic signals based on spectral characteristics met little success in early era of sonar system development (Urick, 1963). In addition, finding the rules to classify objects in underwater is more difficult than those for surface vessels. Understanding the nature and characteristics of ambient noise and the acoustic radiated noise of vessels is of great importance in selecting the discriminating features and the classification algorithms.

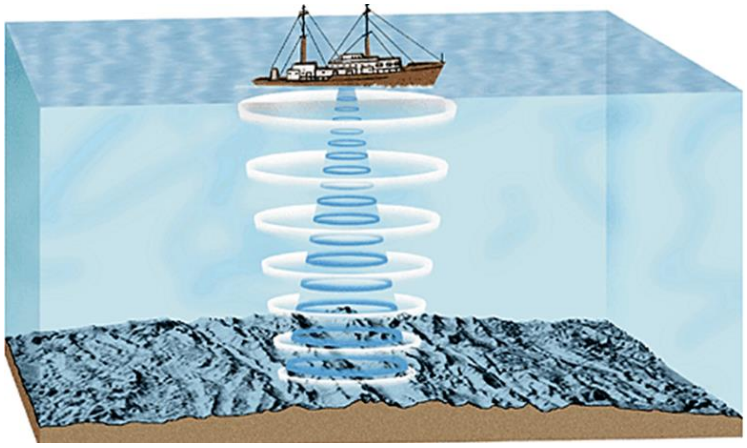
The passive sonar plays an important role in the modern naval battles. In addition to the long range detection, this mode of sonar systems works covertly so the underwater surveillance systems utilize these two advantages of passive sonar to stealthily monitor the surface and sub-surface marine vessels.

Characteristic features of sonar

The following are the features of Sonar;

- It uses sound waves in the frequency range from 20 KHz to 10 MHz for its operation.
- The sonar transmits waves at about 343 meters/second into the sea.

- Sonar supports a lower range in comparison to radar. This is due to the fact that sound waves are affected by various layers of temperature/salinity/depth of the Sea.
- Sonar is unaffected by any countermeasures, but it can be affected because of attenuation of sound waves by marine life.



Echo sounder determines water depth by measuring the time required for sonic wave to travel from the ship to the sea floor and back

Our knowledge of the diverse topography of the ocean floor grew rapidly after the development of the echo sounder.

Depth = (speed*time)/2

Speed of sound in saline water = 1530 meter per second

This method of calculation of speed is called Echo Ranging.

The application of Active Sonar is more than passive Sonar.

The Transmitter in Sonar System:

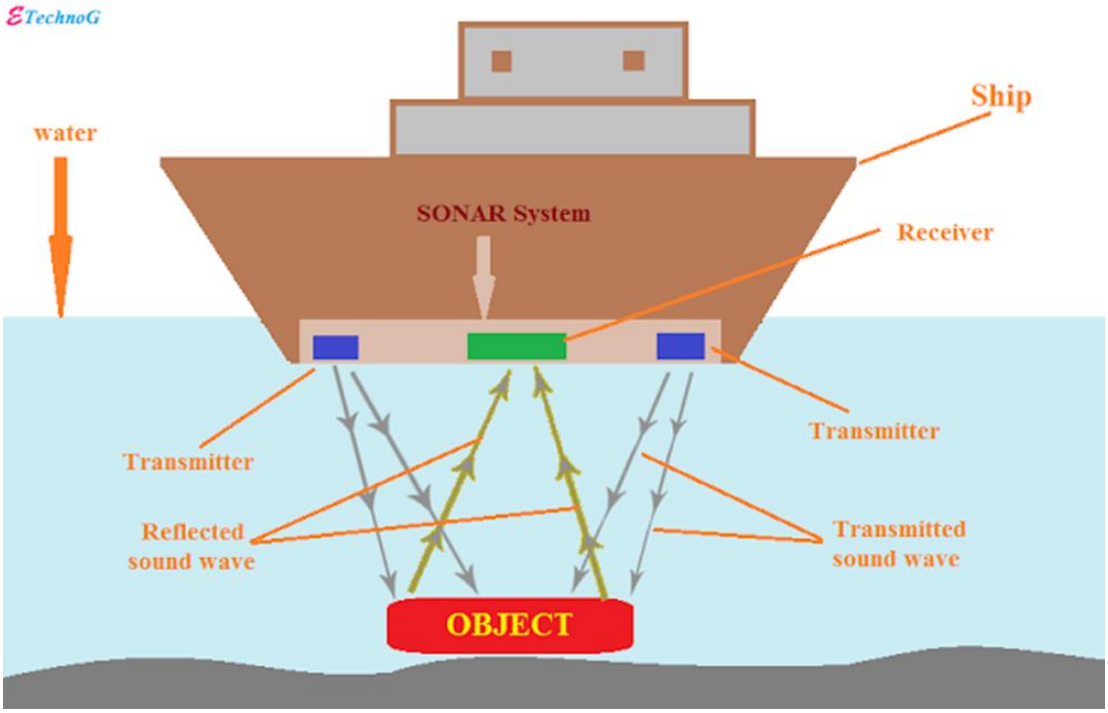
Sonar system uses the Piezoelectric Transducer. The Piezoelectric material has a property that when we apply an electric power supply to it then it creates a sound wave or vibration. So the in this time the Piezoelectric material works as sound waves or ultrasonic waves transmitter.

The Receiver or detector in Sonar System:

The Piezoelectric material also has a property that when sound is applied, it can produce an electric signal according to the sound nature. In this case, the piezoelectric material works as sound waves or ultrasonic wave's receiver.

Important applications of SONAR Technology:

i. The Sonar Technique is used to determine the depth of the sea.
ii. The Sonar technique is installed in every ship to locate underwater hills, valleys, submarines, icebergs, and sunken ships e.t.c to avoid a disaster.
iii. The Sonar system is also used in Military.
iv. The fishermen have used Sonar technology to find fish.
v. The Sonar technology also used in the medical industry like Sonography.
vi. The Sonar technology is used in the navigation system.



A typical Sonar System (Farrokhrooz, 2011)

SCATTERING

When active sonar is used, scattering occurs from small objects in the sea as well as from the bottom and surface. This can be a major source of interference. This acoustic scattering is analogous to the scattering of the light from a car's headlights in fog: a high-intensity pencil beam will penetrate the fog to some extent, but broader-beam headlights emit much light in unwanted directions, much of which is scattered back to the observer, overwhelming that reflected from the target ("white-out"). For analogous reasons active sonar needs to transmit in a narrow beam to minimize scattering.

According to Woolf and Thorpe, (1991), the scattering of sonar from objects (mines, pipelines, zooplankton, geological features, fish etc.) is how active sonar detects them, but this ability can be masked by strong scattering from false targets, or 'clutter'. Where they occur (under breaking waves; in ship wakes; in gas emitted from seabed seeps and

leaks e.t.c, (Westbrook et. al, 2009)), gas bubbles are powerful sources of clutter, and can readily hide targets. TWIPS (Twin Inverted Pulse Sonar) is currently the only sonar that can overcome this clutter problem (Leighton et. al, 2010). This is important as many recent conflicts have occurred in coastal waters, and the inability to detect whether mines are present or not present hazards and delays to military vessels, and also to aid convoys and merchant shipping trying to support the region long after the conflict has ceased (Leighton et. al, 2010).

Target characteristics

The sound reflection characteristics of the target of an active sonar, such as a rock, are known as its target strength. A complication is that echoes are also obtained from other objects in the sea such as submarine, whales, wakes, schools of fish and rocks.

Conclusion

The advances in underwater communication systems; sonar system, has led to high to higher resolution mapping of seafloor features and this has greatly improved the understanding of this hidden environment. This records of safety over the sea has improved immensely due to easier detection of obstacles in the course of ocean navigation.

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