Introduction to Sonar

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Date:

Objective:

An introduction to the history of Sonar and how it uses sound for detection and targeting of underwater targets.

Vocabulary Words:

Sonar - SOundingNavigationAnd Ranging - A device, or an organ in animals, that uses sound in water to detect objects. Sonar has two modes of operation: Active and Passive modes that will be discussed later

Sonobuoy - a device deployed from aircraft, either helicopter or low flying plane, in a pattern to aid in the detection of submarine targets.

Nixie - A defensive device used by ships without Sonar, like the USS IOWA, as a decoy to attract enemy torpedoes.

Echo location - the term given to the act of bouncing sound off of a target using Sonar to determine bearing and depth.

Relative Bearing - the direction, in degrees, from the ship to a target. There are 360 clockwise degrees in a horizontal circle from the ship's bow.

True Bearing - the direction, in degrees, from magnetic North to a target. There are 360 degrees in a horizontal circle from magnetic North.

Thermal layer - a layer of cold, dense water used by submarines to hides from suface ships. Thermal layers affect the way sound travels in the ocean.

ASW - AntiSubmarine Warfare

Materials:

See activities

Background Information:

Development of the modern sonar began in the 1920s when advancements in applying underwater sound to practical needs became abundantly clear. During this time and with advances in electronics, depth sounding by ships and echo ranging on submarines was developed. Thomas Edison and other scientists became involved in the research of passive listening devices. Other researchers explored the physics of oceanography in which later work would be based.

Work rapidly began on the development of sonar at the onset of World War II due to the German U-boat threat. German submarines torpedoed Navy-escorted convoys at a record pace. At one point during the war, ships were being sunk faster than the U.S. could replace them. Some of the ships were sunk within view of the U.S. eastern seaboard. The mobilization of the U.S. workforce turned the tide of the war. Without the development of sonar, the U-boat threat would probably have never been contained.

After the war, development of underwater detection devices continued. In 1949, the Naval Research Laboratory reported they could detect submarines at ranges of 10–15 nautical miles using SOFAR (Sound Fixing and Ranging) hydrophones. By the end of the year, submarines could be detected several hundred miles away.

The two most important factors in the development of sonar was the discovery that low-frequency sounds could travel great distances in the ocean, and the realization that submarines radiate identifiable low-frequency energy. The work of Bell Laboratories was also an important element.

Anti-submarine warfare (ASW) usually, but not always, involves the use of sonar. Although the vagaries of the environment make it difficult to predict and use, there is no other type of energy propagation that travels so far in the ocean without significant losses as acoustics waves. In this section, we describe the principles of operation of the major types of sonar systems and one non-acoustic system - magnetic anomaly detection or MAD.

We will only cover the two most common Sonar systems, Active and Passive.

Active Sonar.

Transmitter. The transmitter generates the outgoing pulse. It determines pulse width, PRF, modulation (optional), and carrier frequency. The output power can be controlled by the operator.

Transducer array. The individual transducers are simple elements with little or no directionality. They are arranged in an array to improve the directivity index, which improves the figure-ofmerit by noise reduction. The array of transducers reduces the beamwidth in the horizontal (or azimuthal) direction, and is usually circular in order to give more or less complete coverage, with the exception of the region directly behind the array (where the ship is). The array is protected from noise by own ship by discontinuing the array in the after regions, and also by putting in sound attenuating material. This region aft of a hull-mounted array, from which the sonar system cannot detect is called the baffles.

Receiver. Collects the received energy. The receiver compares the power level to noise with a threshold SNR (DT) in order to determine if the signal will be displayed in a particular beam. If the DT is set too low, there will many false alarms. If it is too high, some detection capability will be lost.

Display. Puts all of the detection information into a visual format.

Passive Sonar

Passive Sonar Systems do not use sound generated by an active transducer array. Instead, passive sonar "listens" to the sounds generated by other ships, submarines, and sea life. Some passive sonar systems utilize hydrophone arrays such as sonobuoys.

Hydrophone array. These are the sensitive elements which detect the acoustic energy emitted from the target. Again, they are arranged into an array to improve the beamwidth. Common configurations are cylindrical or spherical. The cylindrical array operates at a fixed vertical angle, usually downward. The spherical array, which is common on submarines, has a much wider vertical field-of-view. Since the submarine may be below what it is tracking, the array must be able to look upwards to some extent. The large downward angles are only used for bottom bounce detection. Using a beamforming processor (described below) the field-of-view is broken down into individual beams in the vertical and azimuthal directions.

A sonobuoy (a portmanteau of sonar and buoy) is a relatively small buoy (typically 13 cm or 5 in, in diameter and 91 cm or 3 ft long) expendable sonar system that is dropped/ejected from aircraft or ships conducting anti-submarine warfare or underwater acoustic research.

Sonobuoys are ejected from aircraft in canisters and deploy upon water impact. An inflatable surface float with a radio transmitter remains on the surface for communication with the aircraft, while one or more hydrophone sensors and stabilizing equipment descend below the surface to a selected depth that is variable, depending on environmental conditions and the search pattern. The buoy relays acoustic information from its hydrophone(s) via UHF/VHF radio to operators on board the aircraft.

Activity Instructions:

There are seveal activities that accompany this lesson. You may choose any or all of them to further your knowledge of how sound travels in water.

Conclusion/wrap up:

The reader should have a good basic understanding of the operation of Sonar. If further knowledge is desired there are several online resources that go into depth about the physic involved with sound propagation in seawater.

Further Investigations:

Suggested Readings

For a more indepth understanding of Sonar and ASW operations please refer to:

https://fas.org/man/dod-101/navy/docs/es310/asw_sys/asw_sys.htm

Sources:

https://www.history.navy.mil/browse-by-topic/exploration-and-innovation/radar-sonar.html