Bistatic Sonar, explained

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Abstract: Monostatic sonar is one for which the transmitter (projector) and receiver are at the same location. Bistatic sonar has the transmitter (projector) and receiver at separate locations. This paper outlines the differences between monostatic and bistatic sonar and the challenges to be considered.

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Introduction

Sonar (SOund Navigation and Ranging) is an acoustic device used to find underwater objects (*targets*). Sonar can be passive (listen only) or active (transmit sound pulse and listen to echo).

The part of sonar which transmits the pulse (or *ping*) is usually called the "projector". The part of the sonar which receives the sound is often not the single sensor, but an array of sound sensors – or hydrophones.

Bistatic sonar is an active sonar in which the projector and receiver(s) are separated by a distance large enough to be comparable to distances from the projector to the target and from the target to the receiver. In monostatic sonars the projector and receiver(s) are at the same place.

Bistatic vs monostatic

Propagation (transmission) loss

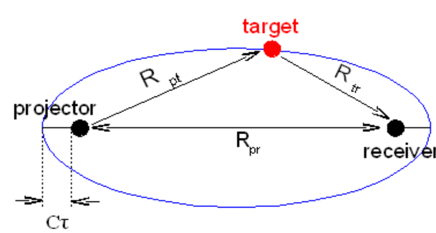
This is a loss in sound level which happens while the sound pulse travels from projector to target and from target to receiver. There are 3 different mechanisms causing transmission loss: spherical (or cylindrical in shallow water) spreading, absorbing and scattering by ocean media inhomogeneities. Transmission loss (TL) is proportional to range, (the longer the sound travels the more the loss), and to sound frequency.

In monostatic sonar the sound first travels from projector to target, then the same way back from target to receiver, so two-way loss is just 2TL, where TL is one-way loss.
In bistatic sonar the total loss (in decibels) is a sum of TL_{pt} (from projector to target) and TL_{tr} (from target to receiver).

Dead zone

In monostatic sonar, the first thing the receiver can hear is the sound of the transmitted ping. This sound level is very high, and it is impossible to detect the echo during the ping duration τ. That means targets are undetectable within the circle of $C\tau/2$ radius, where C is sound speed in water. This area is usually referred to as "dead zone". If the sonar is close to the surface, bottom or both, (which may happen in shallow water), the dead zone may be greater than $C\tau/2$ due to a high level of reverberation.

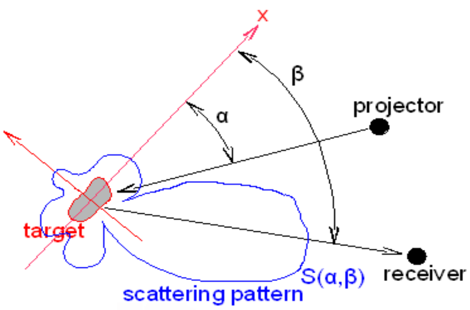
In bistatic sonar, the travel distance from projector to target and from target to receiver is $R = R_{pt} + R_{tr}$. As the projector is separated from receiver by R_{pr} distance, first R_{pr}/C seconds after the ping starts, the receiver is just waiting. After that time, it receives direct signal from the projector (often referred to as "direct blast"[1]), which lasts $C\tau$ seconds. So the sonar cannot detect targets within the ellipse $R = R_{pr} + C\tau$, as shown at the picture. High level reverberation in the projector area does not effect the dead zone.



Bistatic sonar dead zone

Target scattering pattern

Targets do not reflect the sound omni-directionally. The mechanism of sound reflection (or scattering by the target) is complicated, because the target is not just a rigid sphere. Scattered sound level depends on the angle β from which the target is ensonified by the projector, and it also varies with angle scattering direction α (refer to local target axes {x,y}). These angles are often referred to as aspects. This scattered sound level vs (α, β) function is called the scattering pattern S(α, β). Direction of maximum echo (maximum of S(α, β)) also depends on target shape and inner structure. So sometimes the best ensonifying aspect is not the same as the best receive aspect.



Target scattering pattern

This leads to the bistatic solution. Target scattering becomes even more complicated if the target is buried (or semi-buried) into sea bottom sediments. (That happens to sea mines, waste containers, shipwrecks, etc.) In that case, the scattering mechanism is effected not by target features only, but also by sound wave interaction between the target and surrounding bottom.

Installation limitations

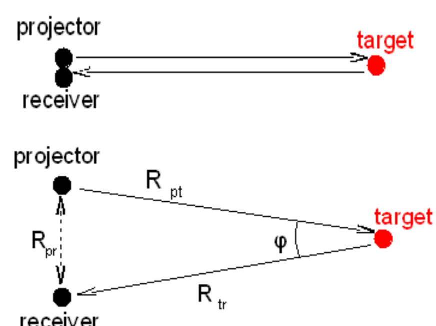
Sometimes simple technical reasons may require to separate the projector from the receiver, and so the system becomes bistatic naturally.
a) An extremely high sound transmission level is required. It can be so high that it can break the sensitive receive hydrophones if the projector is installed close to the receiver.
b) High projector directivity is required. That, in turn, requires a large projector size. For example, in low frequency sonars, directional projectors could be of some meters in size. So the projector and receive arrays can not be spatially co-located.
c) Limited space for sonar installation. In some platforms, like small boats or small autonomous underwater vehicles, it is hard to find a suitable position for a co-located projector and receiver.

Types of bistatic sonar

Backscattering and forward scattering

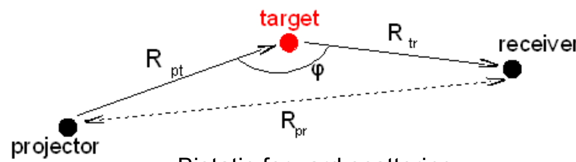
In monostatic sonar the receiver is listening to the echo which is reflected (scattered) right back from the target.

Bistatic sonar can work in two ways: by utilizing either the target backscattering or forward scattering. Backscattering bistatic sonar is the sonar in which the bistatic angle φ is less than 90º.



Bistatic backscattering

Forward scattering is the physical phenomena based on Babinet's principle. Forward scattering bistatic sonar is the sonar in which the bistatic angle φ is greater than 90º.



Bistatic forward scattering

Pseudo-monostatic sonar

This is the sonar with a small bistatic angle. In other words, both the range from projector to target R_{pt} and from target to receiver R_{tr} is much greater than the distance from projector to receiver R_{pr}.

Multistatic sonar

This is the multi-node system with more than one projector, receiver or both.

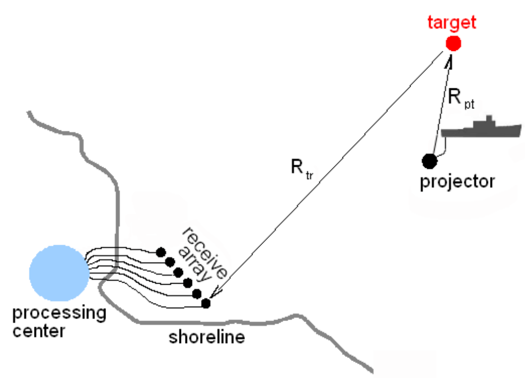
Applications

Long range surveillance

For coastal surveillance, a large receive array of hydrophones is usually deployed close to the shore and connected with cables to a land-based processing center. To enable long range target detection (far away from the shore), one can use a powerful mobile projector, deployable from the ship.

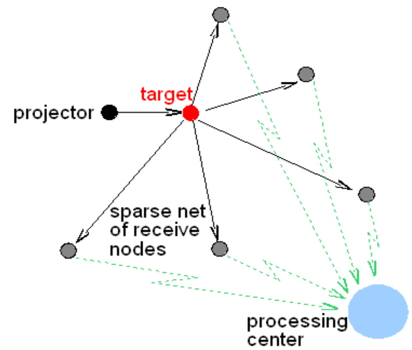
A system of this kind exploits the idea of "bringing the projector closer to area of interest and getting the transmission loss down".

The examples are:
US Navy stationary system Artemis and Russian system Dnestr. The early prototype deployable projector for the Artemis sonar was of 400 ton weight. The receive array in the Dnestr sonar is 750 square meters in size[2].



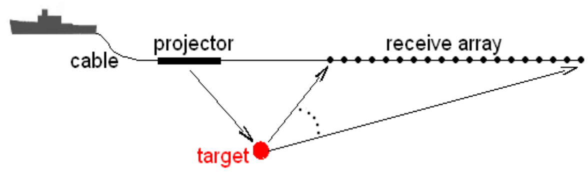
Large area surveillance with a single projector and a net of receivers

A system of this type is multistatic. It exploits the idea of "cover the area of interest with a sparse net of receivers and ensonify the whole area with a powerful projector". Receive nodes may be sonobuoys (with radio communication link to a processing center) or autonomous underwater vehicles (AUVs) with an acoustic communication link[3]. The example is GOATS project[4], using AUVs as receive nodes.



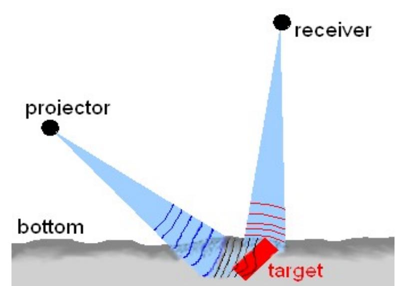
Low frequency towed sonar

The lower the frequency, the less the transmission loss absorbing and scattering components. On the other hand, the lower the frequency, the larger the size of directional projector and receive array. So the ship-deployable long range sonar is a low frequency bistatic towed array sonar with spatially separated projector and receive array. The example is LFATS towed sonar[5].



Buried objects detection

To detect a buried object, the transmit ping must penetrate into the bottom. That requires a powerful and highly directional projector. Next, a directional receiver should be placed at the point where the "target + surrounding bottom" reflection is the best. This is a bistatic system. The example is SITAR project[6], developed to find objects like toxic waste containers and mines.



See also

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Endnotes

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