How to find a submarine (no, it’s not just a case of flicking the sonar on)

By Bruce Drinkwater, The Conversation on 12.04.17
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The Virginia-class attack submarine USS Hawaii. Photo from U.S. Navy.

"Das Boot," "The Hunt for Red October," "The Bedford Incident," "We Dive At Dawn": films based on submariners’ experiences reflect the tense and unusual nature of undersea warfare – where it is often not how well-armed or armored a boat is that counts, but how quiet.

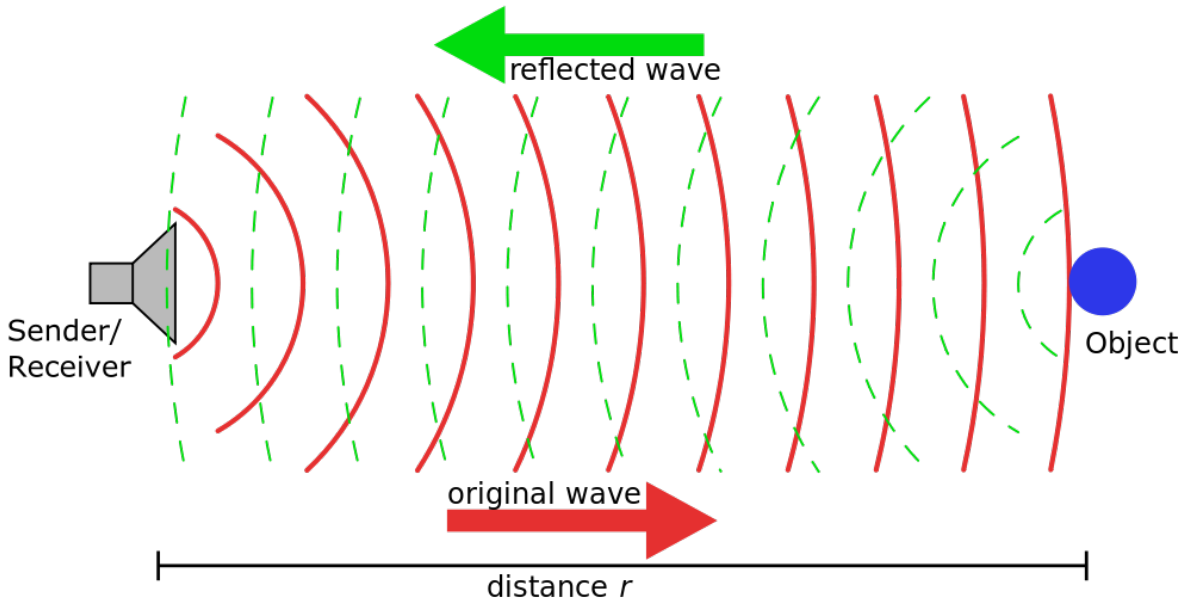
Submarines generate sound from their machinery and crew, and sound waves from other submarines or surface ships are used to find them. But of course, submarines don’t want to be found. In 2014, the Swedish Navy unsuccessfully searched for what they believed to be a Russian mini-submarine in Swedish Baltic waters. The question remains, though, how can unseen boats below the water be detected?

Echolocation

Sonar devices reveal objects below the surface by directing sound waves into the ocean and recording the sound waves reflected back. This is called active sonar – a form of echolocation much like that used by bats. Radar is also similar, but uses radio waves instead of sound.

Active sonar sources and receivers – essentially underwater loudspeakers and microphones – are usually distributed along a rope in an array and towed behind a ship. The length of the array is the equivalent to the aperture of a lens in optics: the longer the array, the more sound it will receive, resulting in a higher definition and better-quality sonar image.

Sonar works well if the submarine has a highly reflective steel surface and is surrounded by water at a constant temperature. But in the deep ocean, the water temperature varies, which causes the water density to vary. This changing density creates an effect called the thermocline, which acts as a barrier, causing sound energy to bend away. A canny submarine captain can use the thermocline to good effect, effectively shielding the submarine from view.

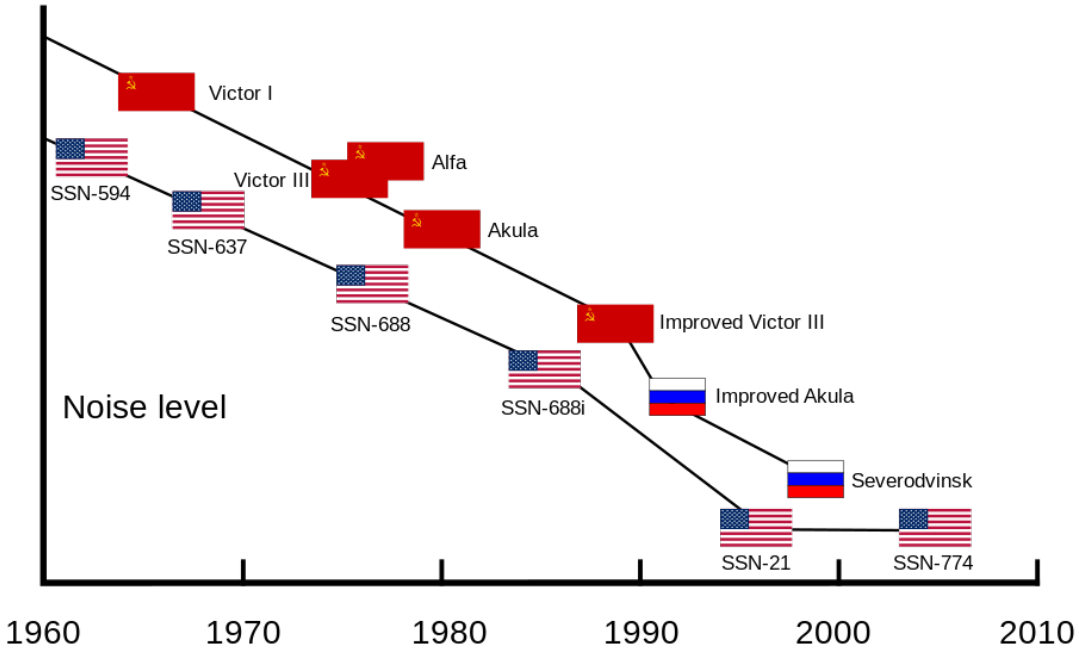


Another ruse (one often seen in the films) is for a submarine to hide itself by coming to rest on the ocean floor, or near ocean cliffs and trenches. Here it's difficult for the sonar to distinguish between echoes from rocks and from the submarine. If this wasn't enough, modern submarines are shaped in such a way to minimise reflections and are covered in coated tiles to absorb sound and minimise the boat's profile even further.

Listening In

While sonar is well known, it's rarely actually used to hunt submarines as it's too easy to hide from the incoming sound waves. Instead modern anti-submarine warfare systems are actually extremely sensitive listening devices that rely on the submarine giving away its position by the sounds it makes. This is known as passive sonar.

Surviving below the ocean without making any sound is pretty much impossible. Keeping the submariners quiet is the easy part. Much harder is keeping the submarine's complex systems quiet – such as the machinery used to circulate air for the crew, or the boat's engines.



So the first thing a submarine wishing to hide does is to shut down all unnecessary systems and, most importantly, come to a stop. This is important – a moving submarine disturbs the water, and the sound of the moving water leaves an imprint of sound waves that can be detected by the pursuer's highly sensitive microphones.

Countermeasures

Given how hard it is to remain silent, submarine designers have spent a lot of time thinking of ways to minimise the sounds their systems make. For example, naval nuclear power plants not only allow long missions at sea between refueling but can also be cooled without using pumps, a source of noise. The final protection is the outer layer of tiles, which both reduce echoes from incoming sound waves and also reduce transmission of sound from within the submarine out into the ocean.

To find a submarine like the Swedish Navy attempted to do in the Baltic Sea is a challenge. This area of relatively shallow waters is strewn with lots of small islands. To get the highest resolution images with active and passive sensors would require large arrays, often kilometers in length, to be towed behind quite large ships. But the complex ocean terrain makes doing so really tricky. In all probability, Sweden used relatively small arrays, and while these are still effective for detection, they are less able to discriminate between objects and pretty poor at an accurate location.

All of which explains why Sweden failed to find the Russian submarine: the navy knew there was a submarine out there, but they just didn't know where. Ultimately there are just too many good places for a submarine to hide in this region.

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Quiz

1 Read the selection from the section "Echolocation."

> *Another ruse (one often seen in the films) is for a submarine to hide itself by coming to rest on the ocean floor, or near ocean cliffs and trenches. Here it's difficult for the sonar to distinguish between echoes from rocks and from the submarine.*

Which phrase from the selection BEST emphasizes what the author means by "ruse"?

(A) seen in the films

(B) to hide itself

(C) coming to rest

(D) difficult for the sonar

2 Read the sentence from the section "Countermeasures."

> *This area of relatively shallow waters is strewn with lots of small islands.*

What does the verb "strewn" convey in the sentence?

(A) the sense that the islands appear isolated and abandoned

(B) the sense that the water looks muddled and cloudy because of the islands

(C) the sense that the islands are widely dispersed over a vast area

(D) the sense that the water is cluttered haphazardly with islands

3 Examine the chart in the section "Listening In" and read the selection below.

> *Surviving below the ocean without making any sound is pretty much impossible. Keeping the submariners quiet is the easy part. Much harder is keeping the submarine's complex systems quiet – such as the machinery used to circulate air for the crew, or the boat's engines.*

Based on the information in the chart and the selection, which of the following predictions is MOST reasonable?

(A) Submarine noise levels are not likely to become much lower than they have been since about 1995.

(B) Submarine noise levels are likely to undergo another drastic dip like the one seen around 1990.

(C) Submarine designers are not likely to continue using the same designs they have tried in recent years.

(D) Submarine designers are likely to design much simpler systems to circulate air in the future.

4 What limitations do the images included with the article have that the text does NOT?

(A) The images do not illustrate how improvements in Russian submarines allowed them to evade Swedish sonar.

(B) The images do not provide specifics about the relationship between U.S. and Russian submarine noise levels.

(C) The images illustrate ideas related to active and passive sonar without context for their significance.

(D) The images provide information about active and passive sonar without information about their past.