

Identification underwater with towed array sonar

Dr Carlo Kopp

Since their introduction, towed array sonars have become one of the most important if not the most important sensor used by submarines and anti-submarine warfare surface combatants in ASW. Unlike active sonars which betray the location of the boat or combatant using them, towed arrays are passive and don't betray the location or identity of the user.

The capabilities of a towed array vary widely, with the design of the array itself, the manner of deployment and the capability of the signal processing system, which analyses the acoustic signals the array collects. Advances in digital processing will continue as Moore's Law sees ever increasing computational power at ever decreasing costs.

The idea behind a towed array is simple in concept but complex in implementation. At the most basic level the towed array is a cable arrangement up to kilometres in length, to which hydrophones are attached with regular spacing. The acoustic signals collected by these hydrophones are collected and routed back to the towing vessel where they are combined by a signal processing system and analysed. A good towed array can detect propeller noises and other acoustic 'indiscretions' from distances of up to hundreds of kilometres, and measure bearing with high accuracy, but limited by the acoustic propagation characteristics of the ocean between the listening array and emitting vessel.

Surface warships and submarines produce noises as an inevitable byproduct of propelling themselves through water and operating their internal systems and any subsurface weapons. The propulsion system is typically the biggest single source in an acoustic signature, comprising the noise produced by the propeller and the machinery driving it. Cavitation noises, arising when gas bubbles form and collapse on the blades of propellers, have been the principal signature of interest with propellers, especially since these are modulated by the revolution of the propeller and thus provide a signature which is typically unique for a class of vessel, a specific hull, and the power setting of the engine driving the propeller. The machinery driving the propeller, specifically the engine, gears and bearings, will also produce noise coupled into the surrounding water through the skin of the vessel. Propulsion noises are of particular interest since they tend to be continuous and thus permit tracking and identification of the target.

Other acoustic signature components of interest are hydrodynamic displacement noises produced by the vessel forcing itself through the water and, in the case of submarines, weapon launch signatures such as torpedo tube door openings and torpedo launches or missile launches via dedicated tubes. Missiles, which typically use boost rockets to rise



RAN Collin class SSK.

to the surface and climb before the cruise engine is started, can be particularly problematic from a signature perspective. Torpedo screws are also frequently loud, alerting the victim to an attack. The noisiest known torpedo is the Russian VA-111 Shkval rocket propelled super-cavitating torpedo, which travels at 200 knots in a bubble of gas. Acoustic signature reduction, defacto 'underwater stealth', rose to prominence during the latter half of the Cold War, as advancing sonar and guided torpedo technology reduced the survivability of more conventional submarine designs. Technology for reducing acoustic signatures is today as jealously guarded as stealth technology for reducing radar signatures in aircraft.

Passive detection performance of a submarine depends on three primary factors. The first is the target's acoustic signature, the second is the subsurface acoustic propagation environment, and the third is the performance of the sonar trying to detect and track the submarine.

Oceans are 'ugly' acoustic propagation environments, and in many respects much more severe than atmospheres are as radio propagation environments. Sound waves will be refracted or 'bent' by variations in water density arising from temperature and salinity changes. Sound waves reflect off the surface of the ocean, and in the littorals and near continental shelves, they will also reflect off the ocean floor. Marine life and turbulent flow in littorals often add severe background clutter. An effective sonar must be capable of detecting and tracking the signatures of many targets in this environment, filtering the targets from the background and compensating as well as possible for refractive effects.

The invention of towed array sonar is most often credited to US Navy physicist Harvey Hayes who in the latter phase of the Great War developed the 'Electric Eel' generally considered the first towed array design. This design employed a pair of towed arrays each with twelve hydrophones, capable of

detecting a submarine from around two kilometres distance.

Towed array technology lay dormant until the early 1960s, when the US Navy resurrected the idea in a drive to counter the increasing number and quality of Soviet submarines, and Gorshkov's doctrine of crippling NATO by sea lane interdiction. Conventional bow sonars in period submarines were effective, but blind in the 70 to 90 degree sector aft of the submarine, in part due to the hull obstructing coverage and in part due to the propeller and perturbed flow behind the vessel. An opposing submarine could thus approach undetected in the 'baffles' and position for a torpedo shot from close range.

Through the early 1960s the US Navy conducted a series of experiments with two SSNs and a surface vessel, with tests culminating in 1964-1965 with the detection of a snorkeling submarine at 60 nautical miles. These led to the tender for the AN/SQR-14 towed array in 1967, and the deployment in 1970 of three systems on Dealey class destroyers operating in the Mediterranean. The success of these systems – and the appearance of much quieter Soviet Charlie, Victor and Yankee class submarines – led to the development of the TB-16, eventually deployed across the US Navy submarine fleet, and the interim STASS (Submarine Towed Array Sonar System). The subsequent TB-23 deployed during the mid 1980s, and the TB-29 during the mid 1990s.

The technology in these early arrays relied on bundles of twisted-pair cables to connect the hydrophones to the processing equipment in the ship or submarine – essentially equivalent to analogue telephone technology of the ear. This was problematic if the number of hydrophones reached fifty or more, as the girth of the cables became unmanageable. The subsequent generation of towed arrays employed a single coaxial cable, with multiple taps, and analogue or digital signals multiplexed on multiple carrier waves – a technology comparable to that used during the period in digital telephony and cable television. This technology has since been superceded by the use of optical fibres rather than copper cables, a technology inherently more suitable for operation underwater.

Evolution in cable technology has been paralleled by evolution in hydrophones, the demand being for increasing numbers in each array, increasing dynamic range – the difference between the faintest and loudest signals that can be handled. The evolution of this technology has seen dynamic range advance from 60 decibels up to 120 decibels over several decades.

Several techniques are in use for the deployment of towed arrays. Surface ships typically carry the arrays stowed on drums, not unlike a winch, and the arrays are spooled out for use. A common arrangement is to attach a finned buoyancy device or a remotely operated vehicle at the end of the array to permit some control over its deployed geometry.

Deployment from submarines is more challenging, to ensure clearance from the propeller and to avoid unwanted drag and acoustic noise. Soviet submarines typically stow the towed array in a large streamlined pod carried at the top of the vertical rudder on the tail of the boat. The preferred deployment method in more recent US submarine designs is via a tube in the leading and outboard edges of the submarine's starboard horizontal tail surface, such that the array is trailed from the tip



LM TB-16 Towed Array.



LM TB-29 Towed Array.

of the surface. This arrangement is less likely to foul the propeller in comparison with the Russian design.

The most recent US towed array to enter volume production is the TB-29A, a COTS technology upgrade to the TB-29, and it is to be installed across the improved Los Angeles class and the Virginia class. Australia's Collins class boats are equipped with either the Thales Karriwara or Namara towed arrays.

The outlook for towed array technology is very bright longer term, as it is the only technology available with the capability to detect faint acoustic targets at long ranges. Current trends indicate that nascent optical fibre technology will dominate the market in future decades, resulting in longer arrays with more hydrophones, and better sensitivity and accuracy. Signal processing subsystems in newer array designs are dominated by COTS computing equipment, which is likely to dominate the market in the future. With Moore's Law driving the computational end of the towed array business, increasing powerful processing techniques will become possible and economical.

Further reading:

Stanley G. Lemon, Towed-Array History, 1917–2003, IEEE JOURNAL OF OCEANIC ENGINEERING, VOL. 29, NO. 2, APRIL 2004