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FISH RAGU (FISH, RADIO-RECEIVING AND GENERALLY USEFUL)

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STRATEGIC SUBMARINE COMMUNICATIONS
VLF COMMUNICATIONS
SUBMARINE VLF RECEIVERS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The concept of using a 50kg self-propelled body as a receiver for VLF signals is presented. This "fish" would operate a few meters below the surface and communicate to a submarine via high frequency acoustics. Zinc oxide batteries provide sufficient power for all of the "fish's" operations including a 24 hour endurance at a 4 knot speed. The "fish" could also be used as a sonar receiver, a sensor of submarine radiated noise and as a VHF or UHF receiver.

19. KEY WORDS (Continued)

20 ABSTRACT (Continued)

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I INTRODUCTION

Blue-green lasers and ELF are massive technological approaches to improving a single link in the chain for one-way communication to submarines. In both cases, the submarine (or at least the communications receiver) would still be restricted in operating depth, but less severely than by the few-meter limitation imposed by skin depth of VLF. There should be interest in another approach to improving the communications link to the submarines, which seems far cheaper, better, and more generally useful than either BGL or ELF.

The concept is simply to employ a relay contained in a small "fish" which patrols directly above the submarine, submerged a few meters in the water and containing ferrite-rod antennas for receiving the normal VLF signal. The VLF band is simply translated in frequency and modulated as FM or AM onto a megahertz acoustic signal ($\lambda = 1.5$ mm) radiated to the submarine from a transducer on the belly of the fish. The attenuation of megahertz sound in the ocean is such that the transmission cannot be heard at long range, and the acoustic power output required for excellent signal to noise ratio over a kilohertz band to a receiver 10 cm diam at 400 m is less than a microwatt.

At least two such fish (and probably many more) would be housed in a module attached to the submarine, which would provide recharging facilities for their batteries. A fish would weigh about 50 kg and could travel for about an hour at 10-knot or all day at 4-knot speed.

A fish would normally swim at constant speed and heading unless commanded by the host submarine (via the megahertz acoustic link) to change heading, translate sideways by a specified amount, translate longitudinally by a specified amount, change speed, or return to its housing (change mode). The fish would be tracked by a 10-cm diam transducer on the submarine, which would also serve for 2-way communication.

Assuming zinc-nickel oxide (Zn-NiO) batteries at 50 w-h/kg (as produced in large quantities by General Motors on its Delco-Remy pilot line for electric vehicles) we assume 20 kg of the total fish weight of 50 kg is batteries. Thus the energy available is 1 kwh.

Such a fish would have an endurance of only about 7 min at 20- knot (and 2 min at 30-knot) speed. For very-high-speed, long-endurance traverse, it might be better to equip one of the fish with an optional tow line, but the line could be a simple mechanical attachment, since the intelligence would be transmitted via the acoustic link, and the electronics supplied forever by the batteries.

Additional functions for such a fish could be a quiet sonar receiver, a fish to sense submarine radiated noise as a function of direction, and the like. It could also be equipped with a body-mounted whip antenna (or low-gain array) for deployment in case the VLF signal disappears and VHF or UHF communciation (via satellite) is desired with satellites.

II RADIO-LINK FUNCTION

Since the VLF band is so noisy, only modest frequency selectivity and gain need be provided in the fish to receive the signal. It is amplified slightly and modulated onto the megahertz acoustic transducer, with an antenna pattern limited to the downward quarter sphere. The acoustic signal could be wide-band FM, with the deviation maintained by the received VLF signal or by noise if no VLF signal is received.

III STATIONKEEPING

The fish should remain directly above the submarine (or at some convenient [small] angle offset to the vertical. This prevents the normal variation in sound velocity with depth from causing significant signal refraction or shadowing.

3.1 Normal Stationkeeping

Ordinarily the stationkeeping is maintained by error signals derived from the high-gain megahertz acoustic antenna on the submarine. This 10-cm diam antenna has a beamwidth of about 1 degree, and is to be used to derive fish velocity and position. The comparison of the fish velocity and position with those desired should result in the transmission of commands from the submarine to the fish to correct its position, velocity, or heading. In order to minimize the consequences of a loss of transmmission, the fish should have sufficient intelligence (via a microprocessor) so that position modification could be accomplished by a position-change command, rather than by a command to change velocity (which would have to be paired with a later compensation of that velocity change in order to result in a net change of position only).

3.2 Fall-back Stationkeeping

When the submarine is at the surface, it obviously cannot communicate from a transducer atop the submarine to the belly of the fish. Under these circumstances, the fish should patrol, submerged, at some distance abeam the submarine. A few-meter offset can be maintained by reference to a 4-element megahertz transducer mounted abeam the submarine.

Launching and recovery of the fish should be done largely open loop. The fish would be commanded by the megahertz link and tracked to within a few feet of its housing. At that point, a "home" command would be issued, which would result in the fish dropping down and forging ahead into its housing, where it would be retained by a clamp, valve, or the like. It would then be recharged through electrical connections to the battery. Launching the fish is simpler, since it need only drift out of the housing, climb and advance to a point at which it can be picked up by the acoustic link.

IV SKETCH

The power source would be a Zn-NiO battery of about 1 kwh capacity. Scaling required-power as velocity cubed and displacement to the 2/3 power gives a requirement of about 0.4 kw for operation at 10-knot and about a 0.03 kw for operation at 4-knot. The battery voltage would be converted by an efficient solid-state converter to operate a variable-speed motor connected to the propeller.

4.1 Propulsion Train

At 10-knot speed, the Brenouilli pressure is about 1.2×10^5 dyne/cm^2, about equal to the hydrostatic pressure at 1 m depth. A required propulsive power of 500 w (at 10-knot speed) corresponds to a propulsion force of about 10^7 dyne or 10^4 gm force. Thus, a propeller area exceeding 100 cm^2 would reduce the propulsion pressure to below the Brenouilli pressure and should allow propeller operation without cavitation at depth exceeding 1 m. At 10-knot speed, a propeller rotation rate on the order of 600 rpm seems suitable.

4.2 Radio Subsystem

The radio subsystem should consist of two ferrite-core antenna coils for VLF reception independent of VLF polarization and propagation direction, and appropriate deployable satellite antennas for use when VLF is down or for transmission from the submarine to satellite via a burst low-probability-of-intercept (LPI) system. The electronics should be fed from the main battery, constituting a negligible drain.

4.3 Acoustic Subsystem

For the radio-link function, the acoustic subsystem is a low-gain antenna on the belly of the fish, transmitting signals to the submarine and receiving signals from the submarine. The two signals may be multiplexed onto the same transducer, since only a modest bandwidth is required for each at the megahertz frequency.

V SUBMARINE MODIFICATIONS

The submarine must be provided with a housing for several RAGU fish, probably two acoustic tracking antennas in order that constant coverage by a fish at the surface may be obtained (and to allow for failures), power supply to the housing, and communications through the hull for the signal and recharging power of a few kw (peak). Only small hull penetrations are required.

The modifications are best accomplished via a single, consolidated housing and electronics subsection, faired to the submarine surface. The size is that required to accommodate three or four 50-kg fish--about a meter long, 30-cm high, and perhaps a meter broad.

VI DETECTABILITY

Naturally one does not want to add to the detectability of the bare submarine, and one wants to reduce the potential detection possibilities by the trailing wire or the towed buoy now used for receiving VLF communications.

6.1 Acoustic-Link Detectability

The tracking antenna on the submarine has more than 40 dB gain and operates at a distance not exceeding some 400 m. If desired, the signal can be broad-band so as to reduce the probability of intercept by a submarine hunter.

6.2 Kelvin Wake

A body about 30-cm diam travelling at 10-knot produces a flow velocity which falls off as the inverse cube of the radius from the body in the plane perpendicular to the axis. At 1 m distance, this flow amounts to only about 0.1-knot and is limited to a region about 1 meter in extent. It would correspond to an elevation of the water surface by 0.01 cm--difficult to detect among the normal disturbances.

6.3 Propulsion Noise

At a maximum turn rate of 10 rps (and with a three-bladed propeller combined with bilateral symmetry of the fish and propeller shroud), the alternating forces should be exceedingly small compared with those on a submarine. Furthermore, since the structure is so small compared with the wave length of sound waves in this frequency range, the radiation efficiency is much further reduced. By holding the water surface speed over the propeller below cavitation speed at the operating depth, one can avoid high-frequency noise. These are design constraints on the propulsion system, and seem readily satisfied. Any problems can be solved by increasing the diameter of the propeller.

VII OTHER USES

Such a fish operated from submarines could be used to provide a displaced listening post, far from the internal noise of the submarine. It would be even more valuable if deployed from surface ships, because of the much higher noise level of the ship and the ocean surface. Naturally, the fish could be used for a submarine at great depth to detect blue-green laser radiation or ELF! It could also be used to map accurately the radiated acoustic field from a submarine, to intercept active sonar signals before they reach the submarine, and the like.

VIII SUMMARY

By the use of consumer technology in the propulsion system, structure, and electronics of such a fish, it would seem possible to replicate it for $1,000. Naturally the housing, tracking system, command generator, and the like on the submarine would be more costly. The fish RAGU would be a major aid to the flexibility and covertness of submarine operations, while maintaining excellent receive capability on VLF signals. If the fixed-base VLF transmitters were destroyed, TACAMO aircraft would take over. If all U.S. VLF signals disappeared, a VHF or UHF antenna could be deployed from the fish RAGU at appointed times to listen to dark satellites.

In view of the modest entry cost and substantial potential benefits, the characterization and development of such a fish should be undertaken now.

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