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SOME PROPOSED EXPERIMENTS FOR DETECTION OF SUBMARINES

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ABSTRACT

This is a speculative report in which a mechanism is proposed as a working hypothesis to explain a possibly observed coupling between acoustic energy in water and electromagnetic energy in air. An approach is suggested for exploitation of this mechanism, if it exists, for detection of submerged submarines. A series of tests is proposed for checking the hypothesis.

PROBLEM STATUS

This is an interim report on a recently established problem; work is continuing.

AUTHORIZATION

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SOME PROPOSED EXPERIMENTS FOR DETECTION OF SUBMARINES

It has been suggested that the detection of submerged submarines by microwave radar may be possible through interaction between acoustic energy in the water and electromagnetic energy above the water. One form of this interaction may be in the nature of reflection of radio waves from distortion in the water surface caused by acoustic waves from below the surface. Such distortion would be very slight in magnitude, and probably could be detected only by very short radio wavelengths. The radar reflection at near grazing incidence from a single element of surface of wavelength dimensions would of course be infinitesimally small. A noticeable effect would require coherent or in-phase reflection from a surface area very large relative to a wavelength. A large coherently reflecting area might result if acoustic energy were concentrated in one frequency whose wavelength in water was comparable to the radio wavelength in air. The surface distortion might then form a diffraction grating which could possibly interact with the radio wave.

The wavelength of X-band radar is about 3 cm. In water this wavelength corresponds to an acoustic frequency of about 50 kc. Therefore, 50 kc, or any one of a few of its near multiples and submultiples, should provide a resonant grating for X-band radar if the acoustic wavefront in water is vertical. Figure 1 illustrates the geometry for a 3-cm wavelength in air, corresponding to X-band radar, and a 9-cm wavelength in water, corresponding to about 17-kc sound in water.

If the source of sound is appreciably below the water surface, the angle at which the sonic wavefront intercepts the surface will be a function of the distance from the source. The apparent wavelength at the surface will then also be a function of the distance from the source. Specifically, the surface phase-front spacing would equal the acoustic wavelength in water times the cosecant of the angle between the surface and the acoustic phase-front below the surface,

$$a = \lambda \csc \alpha$$

where a is the phase-front spacing on the surface, λ is the acoustic wavelength in water, and α is the angle between the water surface and the acoustic phase-front in water. The

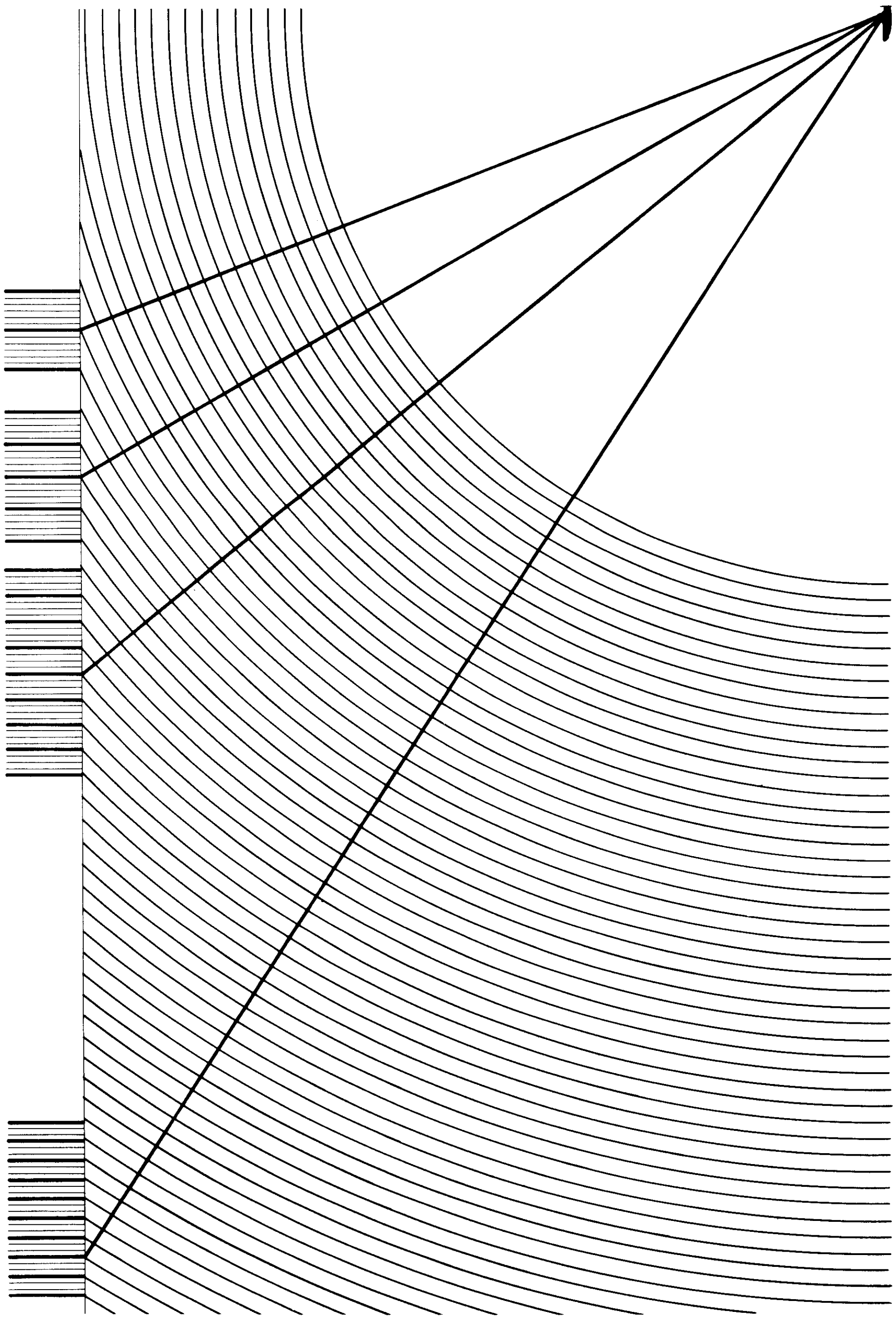

Fig. 1 - Juxtaposition at the water surface of 17-kc sound in water and 10-kMc radio in air

relationship is explained in greater detail in Fig. 2. It might therefore be possible with a single acoustic frequency to observe several different orders in the diffraction pattern simultaneously with one radar, each order appearing at a range different from that of other orders.

In Fig. 1 the X-band radar is shown to be coherent with 17-kc sound at four different ranges from the vertical over the source. The ranges correspond to surface phase-front spacings of 3, 4, 5, and 6 radar wavelengths, respectively. Likewise, different acoustic frequencies would produce echoes at different distances from the source, all with the same radar frequency. Since the angle between the acoustic phase-front in water and the water surface decreases from 90 degrees far from the source to 0 degree directly over the source, it will at one point be 30 degrees, where the cosecant of the angle is 2. Thus, from 90 to 30 degrees, the surface phase-front spacing will double. Resonance with X-band radar might then exist at one or more points for any acoustic frequency from some low value such as 6 or 7 kc to some high value such as 350 to 400 kc. It follows that a wide spectrum of noise generated in the water will give rise randomly to some resonant coupling at the surface with any one of a wide spectrum of radar frequencies.

The acoustic energy just below the surface may exist as standing waves or as traveling waves. If standing waves, the phase velocity of the surface distortion would be zero, and echoes would exhibit the characteristics of stationary targets. However, if the distortion were due to traveling waves, the phase-front would advance with a velocity equal to or greater than the velocity of sound in water, and the echoes should exhibit the characteristics of moving targets. At 3-cm radar wavelength, a target having a range rate equal to the velocity of sound in water would generate a doppler shift of approximately 100 kc. The doppler shift should be relatively independent of acoustic frequency.

If a doppler shift is in fact produced by the mechanism here described, its value would be proportional to the secant of the angle formed with the surface by the radius vector from the position of the echo to the submerged source of acoustic energy. This is explained in Fig. 3, where v_s is the velocity of the sound in water, v_ϕ is the velocity of the surface phase-front, and β is the angle between the velocity vectors. Observing the doppler shift at two different ranges would therefore enable determination of the position of the sound source in both range and depth. This also may be seen in Fig. 1. If high acoustic frequencies in water do in fact produce the observed effects through the mechanism here described, then low-frequency modulation of the high-frequency acoustic energy, if present, would appear as modulation on the echo received, and might be audible in phones connected in on the range-gated echo.

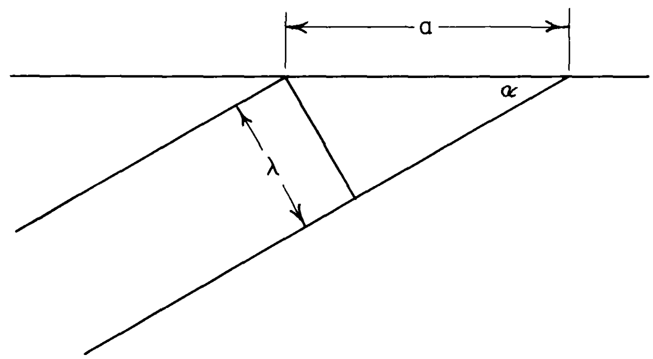

Fig. 2 - Relationship between phase-front spacing on the surface and acoustic wavelength in water at oblique incidence

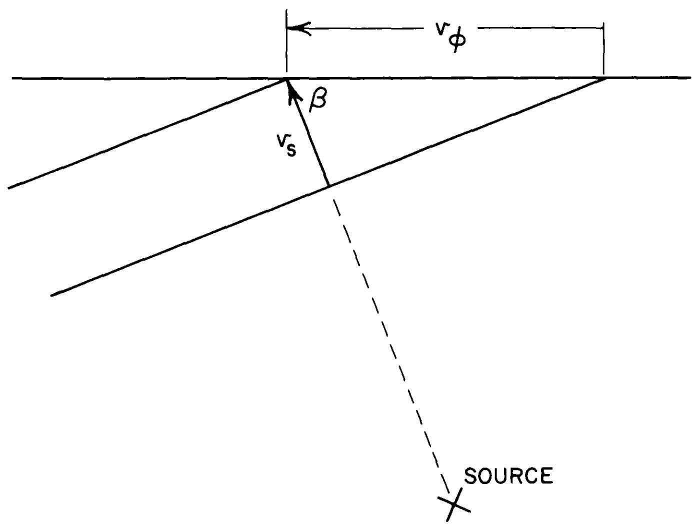

Fig. 3 - Velocity relationship between surface phase-front and sound in water

Submerged submarines in motion are known to radiate acoustic energy over a wide spectrum of frequencies. The existence of strong "spectrum" lines is not uncommon. A slight modulation of the high frequencies by low frequencies might reasonably exist. If the mechanism here described is operative, it might account for all the phenomena thus far reported, as well as the additional ones here predicted. Should the predicted results be realized, ocean surveillance against submerged submarines by fixed-wing aircraft might become practical.

It is proposed that a series of carefully controlled experiments be conducted to explore this mechanism. The following tests should be performed:

1. Using radars at Chesapeake Bay Annex of NRL and acoustic generators suspended from a boat in the Bay, determine whether the predicted effect can be observed. If so, study its characteristics, and the relationship between range, doppler shift and source depth, acoustic frequency and radar frequency.

2. Perform a similar experiment at sea using radars that have proven effective in previous tests, but modified for coherent operation and doppler integration, and a second surface ship <u>or</u> submarine to carry acoustic generators.

3. Conduct a "live" test with one surface ship and one submarine, using coherent radar with a high gain-high resolution doppler indicator, low-frequency modulation detector on range and doppler gated signals, precise range indicator for observed echoes, and several sonic listening devices located close to the submarine with sensitivity extended to high frequencies. Record all data with precision adequate for subsequent exhaustive analysis in the laboratory. Recorded data must include automatic time synchronism for all records, including records of submarine depth.

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