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DETECTION OF UNDERWATER SOUND SOURCES BY MICROWAVE RADIATION REFLECTED FROM THE WATER SURFACE

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A series of experiments have been conducted to investigate the feasibility of detecting a low-frequency low-power underwater sound source. The accompanying Figure shows an example of one of them. Generally, the underwater sound source has been a submerged diaphragm set in a horizontal square plate and vibrates at frequencies centered around $f_0 = 30$ Hz, producing plate displacements of amplitudes of either 0.16 cm or 0.08 cm. The water surface can be subjected to a wind blower so as to produce a turbulent water surface in which is superimposed the vibration due to the frequency source, f_0. A small portion of the water surface is illuminated by an unmodulated beam of 8 mm wavelength microwave radiation. The angular positions of the transmitting and receiving antennas with respect to the surface normal to the water are adjustable over wide ranges in one of the experiments.

The received microwave radiation which has been phase modulated by the turbulence is detected by a synchronous phase detector. The detection system includes a component of the transmitted signal which is fed to the crystal detector. This component has a constant amplitude, T, and a phase, ϕ_0, initially set at $\pi \pm \pi/4$ radians as a reference. The received signal, R(t), is the amplitude modulation caused by motion of the water surface and, $\theta(t)$, is the phase modulation also produced by motion of the water surface. The system is adjusted to be sensitive to $\theta(t)$, but relatively insensitive to R(R(t). The output of the detector and filter system is approximately

$$4g = -\sqrt{2}\,TR + 2R^2 \mp \sqrt{2}\,TR\theta .$$

After amplification, g(t) is sent to the computer for processing. The quantity $\theta(t)$ contains the information components due to the submerged source as well as other extraneous sources. It is possible to minimize the contribution of the other terms in g(t) through a proper choice of detector system elements.

The detected signal is led via a shielded cable to an IBM 1800 analog/digital system for processing. The signal is sampled at a rate of about 166 points/second for a total of either 1024 or 2048 points, depending on the type of processing used. The basic program consists of two points, ANN and FANN, which are tied together by CALL LINK statements. With these programs, it is possible to:

(a) Sample 1024 data points and calculate the 1024 point Fast Fourier Transform (FFT) of the data. OR
(b) Sample 2048 points, calculate the 1024 point autocorrelation function (ACF) of the data, and compute the FFT of the ACF AND
(c) Plot the FFT

In one experiment results are obtained for the case of specular reflection in which the angles of incidence and reflection each varied from 5 degrees to 50 degrees with respect to the surface normal. These results include the case of "wind" superposed by blowers intended to disturb the water surface with "noise".

Results indicate that a submerged source vibrating at a frequency above the characteristic "frequencies" of the surface roughness spectrum may be detected readily for angles of incidence and reflection up to about 35 degrees from the normal. The source may be

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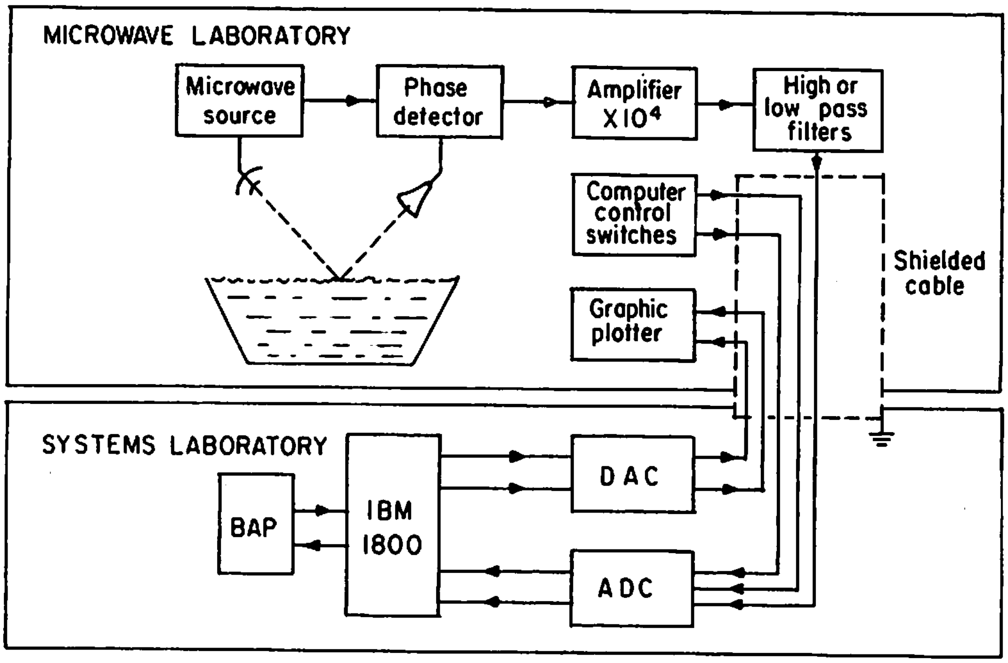
detected for angles of incidence and reflection as large as between 40 degrees and 50 degrees only if two or three transforms are averaged. Generally, detection is more difficult for angles in this range. A number of cases of back-scattering have been investigated as well. Only for the case of back-scattering along the normal to the water surface was detection possible without an undue amount of signal processing.



Microwave scattering from water.