Bubble Clouds and Surface Reverberation of Underwater Noise

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Abstract: In a paper presented in 1985 at the Nashville meeting of the Acoustical Society of America we suggested that bubble **clouds** could oscillate in collective modes that would have a significant effect on underwater sound. For example, bubble **clouds** form structures capable of oscillating at frequencies as low as a few tens of Hz, even though the constituent bubbles, in isolation, might have natural frequencies of tens of kHz or more. Similarly, the large contrast between the index of refraction of pure liquid and bubbly liquid gives rise to strong reflection and scattering processes that might well explain the unexpectedly large backscattering data at low grazing angles. The work carried out under this grant has developed these ideas with particular emphasis on the backscattering from bubble **clouds**. We have studied the acoustic excitation of bubble cloud as a whole by adapting tools developed for non-homogeneous media in which the bubbly liquid is treated, in an average sense, as a continuum and the individuality of the bubbles lost. The bubble cloud is modelled as a region filled of a complex fluid having a dispersion relation different from the one prevailing in the surrounding pure water. The Helmholtz equation is solved in the bubble region and in the pure water and the two solutions are matched by suitable boundary conditions. In this way it is possible to simulate noise emission as well as scattering processes. This mathematical model has been very precisely validated by comparison with laboratory experiments conducted with artificial bubble **clouds**. The results of the work are documented in a series of papers.

Limitations:	✔ APPROVED FOR PUBLIC RELEASE DOCUMENT PARTIALLY ILLEGIBLE
Description:	Final rept. 1 Mar 89-3 Jan 94
Pages:	18
Report Date:	03 JAN 94
Contract Number:	N00014-89-J-1922
Report Number:	A190903

Keywords relating to this report:
- ACOUSTIC SCATTERING
- ACOUSTIC WAVES
- BACKSCATTERING
- BUBBLES
- CLOUDS
- GRAZING ANGLES
- HELMHOLTZ EQUATIONS
- OCEAN SURFACE
- OSCILLATION
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- REVERBERATION
- UNDERWATER SOUND

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