SEA SURFACE SCATTERING

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ABSTRACT

It has been known for some time that sea surface scattering is due to two mechanisms: that due to the interfacial roughness, and that due to microbubbles within a metre or so of the surface, respectively. It is now generally agreed that interfacial scattering has relatively weak windspeed and frequency dependence, whereas that due to bubbles is much more highly dependent on these parameters. It also tends to be the dominant mechanism; in almost all sea states at ultrasonic frequencies, but also in higher sea states even at frequencies as low as 500Hz, when windspeeds are greater than typically 6 m/s.

A principal aim of this paper is to examine the extent to which bubble-induced scattering can be explained quantitatively by measured bubble concentrations, and how these in turn can be modelled as processes of dynamic equilibrium, governed by an appropriate partial differential equation in depth and bubble radius. Experimental measurements of bubble concentrations made by the present author using a bottom-mounted high resolution echo sounder, working over 30 kHz to 200 kHz are presented, and compared with those due to Thorpe, Farmer and Vagle and others, using similar echo-sounding techniques. Comparison is also made with data gathered by in-situ probes, photographic and acoustic. It is found that the present measurements are consistent with previously reported echo-sounder data in comparable sea states, but that in-situ techniques give bubble densities between one and two factors of ten greater. It is also shown that the present data are consistent with solutions obtained from the partial differential equations for bubble concentration in depth and radius, together with a dimensionally correct form of bubble injection rate spectrum. Two variants of the differential equation are solved, one where diffusion coefficient is independent of depth, and one where it is proportional to depth, $K_v = \beta . Z$, where β is found to be typically 0.04m/s at windspeed 10 m/s. The latter variant is found to give a slightly better fit to experiment.

It is also shown that the resulting data and models for bubble concentrations are consistent with observed ultrasonic back scattering from the sea surface, as a function of windspeed and grazing angle, on the assumption that each bubble scatters separately and incoherently with respect to other bubbles. The same mechanism and model is shown to indicate a plausible extension of agreement with experiment down to frequencies of about 3 kHz. Reference is also made to another bubble mechanism, namely collective or coherent scattering of bubbles. A recent paper [K.E. Gilbert, J. Acoust Soc. America 94, 3325-3335 (1993)], has put this mechanism on a quantitative basis. It appears likely that it must account for scattering at frequencies of a few hundred Hertz up to perhaps 1-2 kHz, with a transition to incoherent scatter at an as yet not well determined frequency. It is found, however, that bubble concentrations postulated for this mechanism are of order ten to one hundred times greater than are reported in the present paper.