ACOUSTIC MEASUREMENTS OF BUBBLE DENSITIES AT 15-50 kHz

S. O. McConnell
Applied Physics Laboratory
College of Ocean and Fishery Sciences
University of Washington
1013 N.E. 40th Street
Seattle, WA 98105

ABSTRACT. Acoustic measurements of near-surface bubbles generated by breaking waves were made off Whidbey Island, Puget Sound, Washington. A limited amount of data was also gathered in the open ocean off the coast of Washington. The intent of these measurements was to delineate the role of near-surface bubbles in surface backscattering, forward loss, and ambient noise at high frequencies. High resolution vertical incidence backscatter was the principal method used for determining the near-surface volume scattering strength profile attributable to bubbles. For one of the data sets low grazing angle forward loss measurements were interspersed with the vertical incidence measurements. It was clear from the vertical incidence measurements that bubbles are acoustically observable at wind speeds as low as 3 m/s and that for wind speeds greater than about 5-6 m/s the surface forward loss can become quite large (>10 dB).

1. INTRODUCTION

The research presented at this meeting is focused on the role of near-surface bubbles generated by breaking waves in acoustic scattering and noise processes. Whether surface roughness or a near-surface bubble layer is the dominant source of high-frequency surface backscatter at low grazing angles is a controversial issue\textsuperscript{1,2,3} that the present measurements were intended to address. Perhaps more controversial is whether observed high surface forward losses can be attributed to these near-surface bubbles.\textsuperscript{4,5} Thirdly, an issue directly related to the purpose of this meeting is the role of bubbles in ambient noise generation and propagation. Presently, the ambient noise effect of greatest importance to us is the absorbing effect of bubbles that serves to reduce the noise levels generated at or very near the air-sea interface because the noise must propagate through the bubble layer to be detected. Recent work has clearly implicated bubbles as the cause of the dramatic reduction in the noise level at 25 kHz at wind speeds above 12 m/s.\textsuperscript{6} Presumably this effect would be even more pronounced at higher
frequencies since bubble density measurements have shown increasing numbers of acoustically resonant bubbles up to frequencies of 60 kHz and beyond. The expected dipole radiation pattern for ambient noise should be affected as well since the path length through the bubbles varies with grazing angle as $1/\sin \theta$. For noise generation, knowledge of the bubble population is essential to determination of the relative strength of certain contributory mechanisms such as bubble oscillations excited by near-surface turbulence and bubbles bursting at the air-sea interface.

The principal type of measurement was narrow-beam, short pulse length vertical incidence backscatter measurements at 15-50 kHz that permitted determination of the near-surface volume scattering strength profile attributable to bubbles. From this profile it is possible to specify the scattering strength for any arbitrary bistatic geometry. It is also possible to infer the surface forward loss. To ascertain the accuracy of this inference, low grazing forward loss measurements were taken in conjunction with vertical incidence measurements. Measurements of low angle backscatter and ambient noise (contaminated by other noise interference) were also made but are not reported here. The data reported here represent only a small portion (10%) of the total data set but nearly all of the data digitized in the field. The remainder was recorded on analog tape after the digitizing computer was damaged by several power outages resulting from storms (the very storms we hoped to observe acoustically!).

2. EXPERIMENTAL DESCRIPTION

Figure 1 shows the measurement locations off Whidbey Island, Puget Sound, Washington, and off the coast of Washington. The Whidbey Island location was chosen such that fairly open exposure to passing storms was common at varying fetches up to 50 km (winds from the west). Mile long cables connected the acoustic and environmental instrumentation to a shore site trailer containing the electronic systems, computer, and recorders. For the open ocean measurements a 500 m steel-armored cable connected the acoustic transducers to the surface support vessel placed in a 1-point moor. The water depth was about 50 m in the open ocean and 35 m at Whidbey Island.

The measurement geometry at Whidbey Island is shown in Figure 2. The principal acoustic measurement system was a suite of transducers placed atop a 5 m tripod tower on the sea bed. For the vertical incidence measurements two linear arrays 1.3 m in length and arranged perpendicular to each other were used. The acoustic pulses were transmitted on one of the arrays and received on the adjacent array, thus producing a very narrow combined beam with a 3 dB beamwidth ranging from $1.2^\circ$ at 50 kHz to $4.1^\circ$ at 15 kHz. An omnidirectional broadband hydrophone was also placed next to the line arrays. The frame on which all the transducers were mounted could be varied in both elevation ($0^\circ$ to $90^\circ$) and azimuth (300$^\circ$ total). In contrast, the open ocean vertical incidence measurements were gathered with a $20^\circ$ wide transmitter and an omnidirectional receiver. The system in that case was placed in a three-point moor 25 m below the sea surface.