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The Wide Band Sonar: An experimental tool for measuring low frequency scattering in littoral waters

by
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Abstract -Defence Research Establishment Atlantic has developed a wide-band sonar (WBS) for collecting acoustic data in the open ocean The system employs a parametric array transmitter which enables direct measurement of seabed parameters in shallow water. To complement the parametric transmitter, a pair of 6-channel receivers have been developed for the system; a 6-channel superdirective line array is used as the principle receiver and a tri-axial intensity array is used to localize the platform and measure ambient noise directionality In this paper the attributes of the WBS will be outlined, the typical experimental geometries will be described, and a sample of the measurements made with the system during the Boundary 2001 trial will be presented.

I. Introduction

Defence Research Establishment Atlantic has developed a wide-band sonar (WBS) for collecting environmental acoustic data in the open ocean [1]. The sonar's direction is remotely controlled from a research ship via an RF radio link fixed to the system's surface float. This minimizes the risk of acoustic interference from the ship and prevents ship motion from compromising array stability. In addition to acoustic sensors, the array is instrumented with a range of non-acoustic sensors to assist in the evaluation of the data. The non-acoustic sensors include depth, tilt, roll, and heading sensors to monitor array position and direction, as well as accelerometers to monitor platform vibration The sonar head can be panned through 360° azimuth. The array can be configured to be either bottom-tethered (Fig. 1a) or bottom-mounted (Fig. 1b). In bottom-tethered mode the sonar support arm rotates 180° vertically so that the sonar can be positioned above or below the space frame. This enables measurements through 4π steradians. Platform stability is achieved by de-coupling the space frame from the surface float through a weighted cable and streaming the space frame into the prevailing shear current. In bottom-mounted mode a remote command is sent from the ship to the surface float to flood the sub-surface floats on the space frame to set the system on the seabed. This offers an extremely stable platform that permits coherent averaging of multiple pings. This is used in low SNR conditions such as measurements of backscattering strength at very shallow grazing angles; however, physical constraints limit the vertical range of angles to -30° from the horizontal up to+90°. Prior to recovery compressed air is forced into the sub-surface floats to evacuate the water.

The acoustic sensor suite consists of a parametric array transmitter (PATS), a superdirective endfire line array receiver (SIREM), and a tri-axial intensity array receiver (SIRA). The parametric array offers three advantages: First and foremost, due to the nature of signal generation in the parametric array, no sidelobes are formed. This feature avoids the added complexities of boundary interactions when making measurements in shallow water Second, one can obtain a wider bandwidth than that obtained using a conventional source. In the present case a usable bandwidth of 1 kHz to 10 kHz is realized from a single transducer. Third, the beamwidth of the parametric array is only 3° thereby allowing measurements of backscatter as a function of azimuth as well as out of plane bistatic scatter. The principle receiver for measuring acoustic backscatter is the SIREM line array mounted on the PATS head. The array yields gains of up to 15 dB across the sonar's frequency band from an array aperture only 0.8 m long The SIRA intensity array is a secondary receiver and is used to measure ambient noise directionality. The superdirective array weights can then be optimized for the specific ambient noise field. SIRA is also used to localize the platform during bistatic experiments It's bearing accuracy is better than ±0.5° Following the introduction, a sample of the measurements made with each of these systems during Boundary 2001 will be presented Space constraints will limit discussion of the results significantly

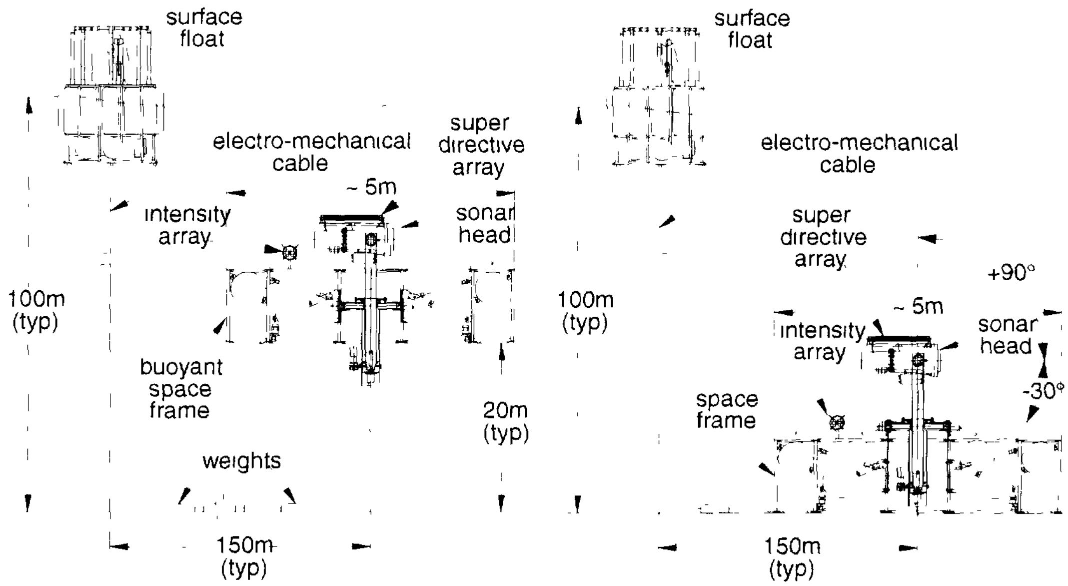

Figure 1: Schematic of Wide Band Sonar bottom-tethered (left), bottom-mounted (right). Note that the pivot point for the sonar support arm is different for the two configurations.

II. The measurements

Figure 2 compares the beam pattern for a 4 kHz difference frequency made at DREA's calibration barge with one taken at sea during Boundary 2001 when the WBS was bottom mounted. This figure serves to show a typical beam width as well as the stability of the platform during the sea experiment to allow such a measurement. The source level at 4 kHz is 183 dB//1 $\mu Pa^2/Hz$@1m. Figure 3 compares the measured gain against ambient noise for a 3^{rd} order superdirective array with modeled results. The model assumes a 3-dimensionally isotropic ambient noise field and a system noise floor 30 dB below ambient. The system is designed as a 5th order superdirective array which would provide an additional 5 dB increase in gain against ambient noise; however, a phase mismatch between the two National Instruments data acquisition boards prevented this during the experiment. The error has since been corrected.

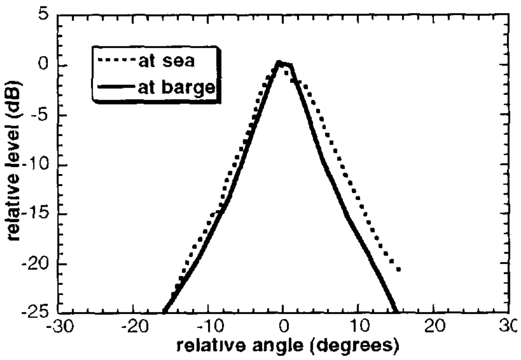

Figure 2: Comparison of beam calibration results collected at sea with those taken at DREA's acoustic calibration barge. The data is for a difference frequency of 4 kHz.

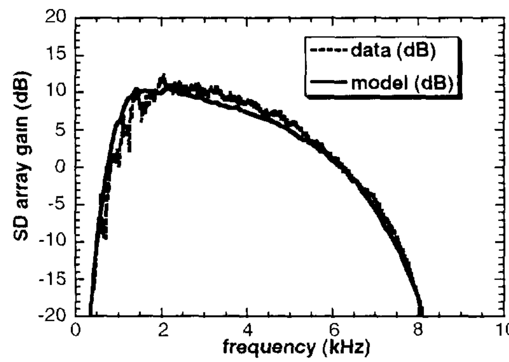

Figure 3: Model-data comparison of gain against a 3-dimensionally isotropic ambient noise field using a 3rd order superdirective array.

A sample of the bearing estimation obtained by SIRA is shown in Figure 4 A series of fifty 4 kHz pulses, 0.5 ms in duration were projected from a source located 160 m away on the UAT vertical line array. The vector intensity is displayed as vertical and horizontal slices to ease interpretation. The solid line is the average of the 50 pings and the length of the line gives the magnitude of the intensity. The points along the line are the individual pings. The close packing of the points reflects the stability of the WBS and UAT during the bistatic experiment.

Figure 5 contains an energy time series from a bottom backscattering experiment performed at 4 kHz and 8 kHz with the transmit array directed at 3.5° and 10° grazing. The initial returns from the seabed are circled. The displacement of the 4 and 8 kHz peaks from one another in the 3.5° data corresponds to a ±0.1° uncertainty in angle, this is within the mechanical tolerances of the array.

III. Concluding remarks

The Wide Band Sonar is an effective tool for interrogating the seabed. It permits a wide range of experimental geometries, minimizes the risk of acoustic interference from the ship and prevents ship motion from compromising array stability. Measurements made during the Boundary 2001 trial include low-grazing angle backscatter, bistatic scatter, and ambient noise directionality.

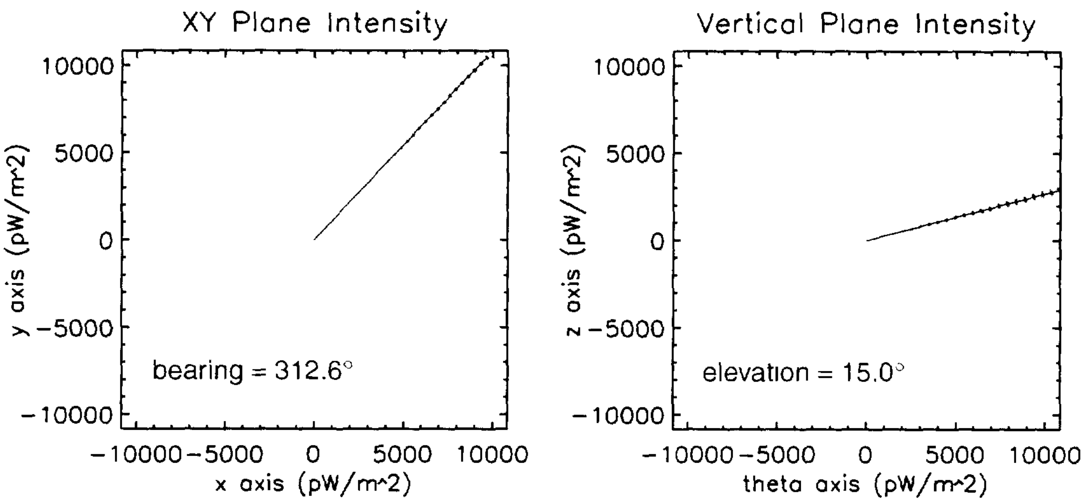

Figure 4: Sample plot of the horizontal (left) and vertical (right) slices of the intensity vector collected using SIRA during a localization experiment

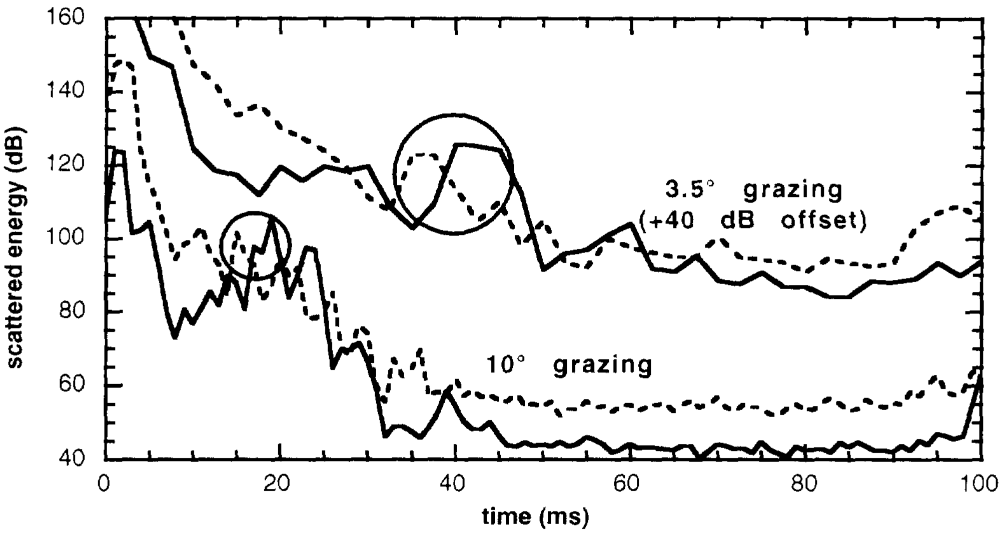

Figure 5: Time series of bottom backscattered returns at 4 kHz (dash) and 8 kHz (solid), for grazing angles of 10° and 3.5°. Initial returns from the seabed are circled.

IV. References

1 Paul C. Hines, W. Cary Risley, and Martin P. O'Connor, "A Wide-Band Sonar for Underwater Acoustics Measurements in Shallow Water," Proceedings: Oceans'98, Nice, France, Sept. 29-Nov. 1, 1998.