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TITLE

Interrogating Seabeds in Coastal Waters Using a Parametric Sonar

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Interrogating Seabeds in Coastal Waters Using a Parametric Sonar

Parametric Array—Principles Are Outlined in this Feature—Offers Three Advantages: First & Foremost, Due to the Nature of Signal Generation in the Parametric Array, No Sidelobes Formed

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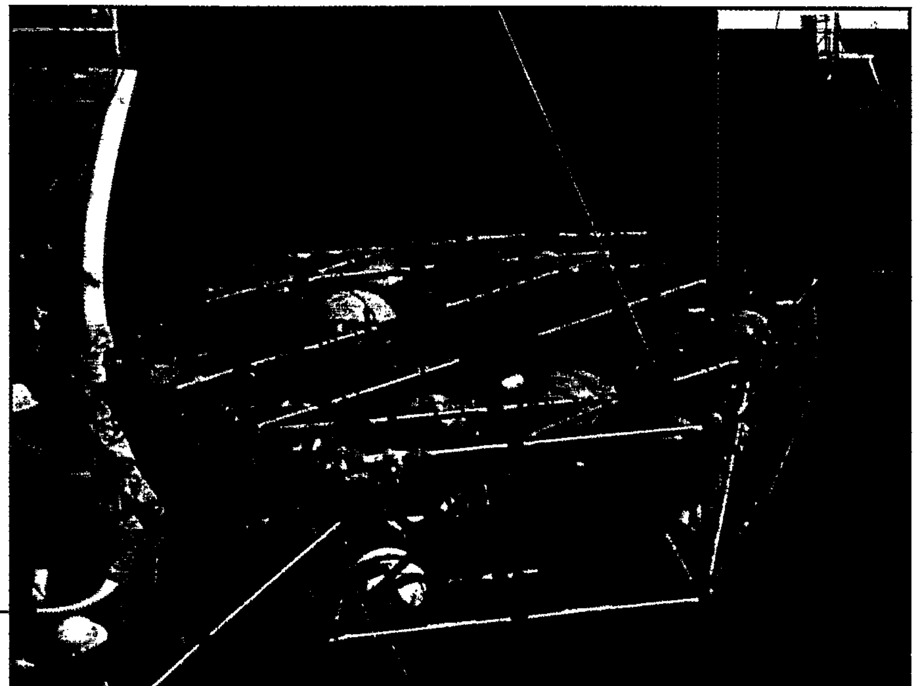
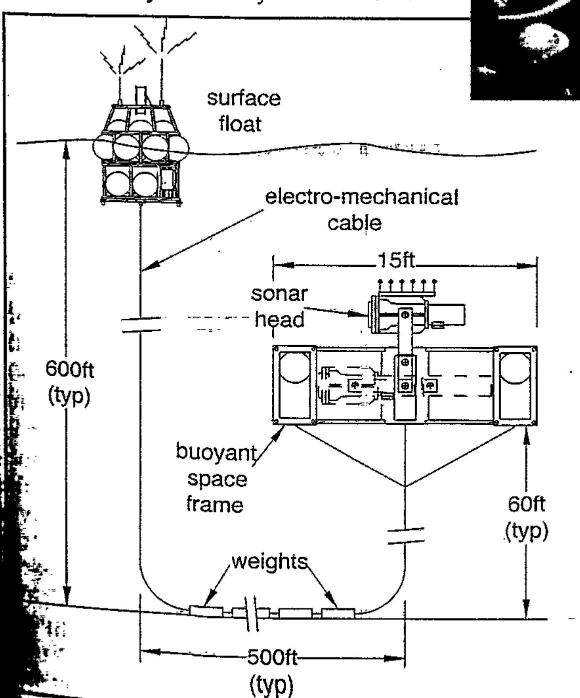
Quantifying the effect that the seabed has on an acoustic wave is crucial if we are to assess the performance of current sonar systems. Furthermore, advances in sonar technology require that we clearly understand how sound interacts with the seabed. This includes reflection and scattering from, as well as penetration into, the seabed. We require direct measurements of these parameters that are unhindered by vertically directed sidelobes that generate unwelcome fathometer returns. In deep water this is accomplished by locating the sonar sufficiently near the seabed to temporally separate signals of interest from the fathometer returns; however, in shallow coastal water at low kiloHertz frequencies this is not possible. This is because the size of a conventional sonar is roughly proportional to its acoustic wavelength and in order to project a narrow-enough acoustic beam the sonar must be many wavelengths long. In this circumstance, one cannot place the sonar near-enough to the seabed.





Schematic of wide band sonar (WBS) in a typical deployment.

Above, launch of sub-surface space frame from fore deck of CFAV* Endeavour. *Insert at top right of the figure shows launch of the surface buoy.

The Underwater Acoustics Section of the Defence Research Establishment Atlantic (DREA), to address this deficiency, is developing a bottom-tethered, wide-band active sonar for collecting environmental acoustic data in the open ocean. A parametric array was chosen for the acoustic source. The parametric array—the principles of which are outlined later in this feasurface float via 2,000 foot armored *electro-mechanical cable*—with ancillary weights over part of its length. The weighted portion, which lies along the bottom, serves two purposes: It sets the height to which the buoyant platform will rise (typically around 60 feet) and it isolates the platform from motions of the surface float. The surface float supports the upper end of the electro-mechanical cable and houses battery packs and electronics that enable RF communication between the research vessel and the sonar.

Deployment. The WBS system is stored and deployed from the aft deck of a research vessel. The sub-surface platform is first lifted over the side and released from the crane, then, as the vessel drifts away downwind the electromechanical cable attached to the bottom of the structure is paid off a large cable reeler. (Given the size of the sub-surface platform—15 feet across the flats by 4 feet high and weighing nearly 9,000 lbs.—this is not a trivial evolution!) The weight of the cable loop between the ship and the platform slowly sinks the platform. Finally, the surface float is affixed and released over the side—armored cable is used because there is a short period during which the cable is dragged across the bottom while the surface float is being attached.

Acoustic Design

The Parametric Transmitter. Guigné International Ltd. (GIL) of St. John's Newfoundland, in conjunction with the Defence Research Establishment Atlantic (DREA), designed and constructed a high-power, low-frequency parametric array. This parametric array, referred to as PATS (Parametric Array Transmit System), serves as the transmit head in the WBS. The basis of operation of the parametric array can be understood as follows: in linear acoustics we make the approximation that the acoustic wave speed is unaffected by the presence of an acoustic wave. However, if the acoustic wave is sufficiently intense, this assumption is no longer valid. In essence, the increased ambient pressure at the crest of the wave speeds-up the wave whereas the decreased ambient pressure at the trough slows the wave. This allows the crest to "catch-up" to the trough so that what started as a simple sinusoidal wave eventually transforms into a saw-toothed wave. Mathematically, this equates to a transfer of energy from the fundamental frequency to higher order harmonics. This phenomenon is analogous to harmonic distortion in electronic amplifiers.

Continuing with this analogue, a parametric sonar operates on the principle of inter-modulation distortion (IMD)—that is to say, if two intense sound beams with slightly different frequencies are transmitted from the same transducer, the non-linearity of the water medium generates secondary frequencies which are the sum- and difference-frequencies of the sound beams originally transmitted. In practical applications, the sum frequency attenuates at small distances from the transmitter and it is the difference frequency that is of principle interest. The considerable advantages of the parametric array are highlighted in the introduction. The disadvantage is low acoustic efficiency—typically 0.1 to 1 percent across the difference frequency band—but this is acceptable within the present application.

Superdirective/Intensity Receiver

"The difference between superdirective and intensity arrays lies in how one processes the received signals. One obtains the intensity by multiplying pressure and pressure gradient signals."

Evaluation Module (SIREM). Given the acoustical inefficiency of parametric arrays, a relatively high gain receiver is needed for the WBS; however, conventional receive arrays— like conventional transmit arrays—are too large for the present requirement. In contrast, superdirective and intensity hydrophone arrays are much more compact than a conventional array. Since they are designed to measure the gradient of the acoustic field, the inter-sensor spacing must be much less than a wavelength.

The difference between superdirective and intensity arrays lies in how one processes the received signals. One obtains the intensity by multiplying pressure and pressure gradient signals. The superdirective solution is obtained by summing the pressure and the pressure gradient. To achieve maximum gain from these so-called "difference arrays" one must ensure that pre-amplifier voltage noise, inter-channel gain and phase errors, etc. are kept to a minimum. The SIREM is a six-channel line array 80 centimeters long designed to measure the processing gains of the two methods in a variety of experimental conditions. The hydrophones are ITC model 1042D (International Transducer Corp.) with custom-built pre-amplifiers designed by GIL. SIREM can provide up to 15 dB gain against three-dimensionally isotropic ambient noise.

Electrical Design

The electrical design can be loosely categorized into five sub-systems: the command and control system (inside the dashed box) which oversees all tasks performed by the WBS, the transmit electronics (in PATS) which conditions the transmit signal, the acoustic receiver (SIREM) which conditions acoustic and non-acoustic data in preparation for RF transmission, the telemetry system (contained in the surface float) which transmits data bi-directionally between the WBS and the ship, and the power supply system that distributes power throughout the WBS.

Command and Control System. System control is maintained using a single board computer operated remotely from the research ship using PC Anywhere™ communication software. The command software is written in modular form in labVIEW™ to simplify modification to the code as and when additional requirements are identified. Generic pulse types are stored in the command computer with the user selecting pulse frequency and duration, receiver gain settings, etc. To reduce the workload of the command computer, a series of job-specific microcontrollers are used to control the hydraulic positioning unit, handle NAS data collection, etc. Communication throughout the system is accomplished using a series of ASCII-controlled, sensor-to-computer interface modules. The modules perform signal conditioning, analogue-to-digital conversion, etc.

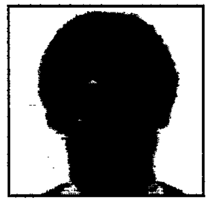
Transmit and Receive Systems. The transmit head (PATS) contains four 2 kW rms power amplifiers designed to operate at 100 kHz. The amplifiers connect to the projectors through a transformer-based power combiner unit. In this arrangement up to 8 kW rms is available to the transducers. The output of the power combiner goes to all nine projectors wired in parallel. The six acoustic hydro-phone channels are sampled simultaneously at a rate of 24 kHz using a pair of 4-channel AT-2150 dynamic signal acquisition cards (National Instruments). These delta-sigma analogue-to-digital converters provide linear-phase response, minimal phase error, and 16 bit resolution. The digitized signals are serialized, interleaved with the NAS data, and randomized using custom electronics. The resulting 4 Mbits/s serial bit stream is driven up the cable to the data transmitter situated on the surface buoy.

Telemetry System. There are two RF links between the ship and the WBS. A 900 MHz bi-directional command link employing spread-spectrum communication protocol is used to steer the array, set amplifier gains, etc. A uni-directional UHF data link that is used to transmit the acoustic and NAS data collected with the WBS, back to the ship. The data are fed into a shipboard decommutator, separated into acoustic and non-acoustic streams and recorded for processing. The NAS data are displayed (as well as recorded) to facilitate monitoring of the WBS system.

Power System. Inherent in the electronic block diagram is the power supply distribution for the WBS. Each supply consists of sets of 55 A-h batteries with the voltages as labeled in the figure. Each of the primary systems is on its own isolated power supply to optimize the efficiency of the dc-dc converters and prevent the high current draw of the parametric transmitter and the hydraulics unit from damaging the command computer or contaminating the receiver system. A sleep mode is available to extend battery life thereby allowing periodic measurements during deployments up to a week in length. A sleep mode is available in which non-essential systems are shut down reducing power consumption to less than 50 watts rms. For typical experimental scenarios, the system is designed to operate for approximately 12 hours during deployments of up to five days.

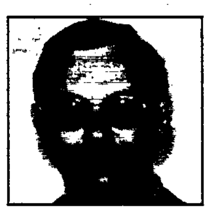
Summary

The wide band sonar has been designed to provide a versatile platform from which to interrogate the seabed. Using a parametric array provides a wide bandwidth and avoids boundary interactions from sidelobes, making the system ideal for measurements in coastal waters. Another key feature of the system is that the sonar is remotely controlled from a research ship via an RF radio link. This permits a wide range of experimental geometries, minimizes the risk of acoustic interference from the ship and prevents ship motion from compromising array stability. /st/



Dr. Paul C. Hines was born in Glace Bay, Nova Scotia, Canada. He received his B.S. (Hon.) in Engineering-Physics in 1981 from Dalhousie University, Halifax, Canada. He received his Ph.D. in Physics in 1989 from the University of Bath, U.K. From 1981-1985 he was a scientist in the Sonar Projects Group at DREA working in the field of towed array self-noise. Upon returning from the University of Bath in 1989, he joined the Acoustic Countermeasures Group at DREA to work on scattering and time spreading. Presently, he is Leader of the Environmental Acoustics Group at DREA. His principle research interests include acoustic scattering and frequency and time spreading.

W. Cary Risley is a native of Halifax, Nova Scotia, and received an MSc in Mechanical Engineering from the University of Saskatchewan in 1968. At DREA he has been responsible for the development of numerous experimental systems used for undersea acoustics research, including DREA's Omega acoustic research system (Sea Technology, vol. 35, no. 8, 1994). He currently acts as Leader of the Airborne Sensors Group, a team tasked to carry out studies in air deployable active and passive sonar systems.



*Martin P. O'Connor was born in Riverside, New Brunswick, Canada. He received a diploma in Electronic Technology from the New Brunswick Institute of Technology in 1975, before joining the Service Projects Unit at DREA. He has worked in mixed signal circuit design and embedded controllers for Canadian Forces projects and DREA research systems including DREA's Omega acoustic research system (*Sea Technology, *vol. 35, no. 8, 1994). He currently works in the Environmental Acoustics Group where he is leading the electrical design of the WBS system.*

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