

Acoustic Communications and Navigation for Mobile Under-Ice Sensors

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LONG-TERM GOALS

The long-term goals of this project are to create a new capability for under-ice acoustic navigation and communication, specifically in support of the ONR Marginal Ice Zone (MIZ) Departmental Research Initiative (DRI). The MIZ DRI field program will occur in 2014, with trials starting this year. The MIZ DRI will include a large array of sensors deployed on the surface of the ice, as well as Sea Gliders and drifters operating below. The project seeks to answer a number of important science questions, and will investigate surface forcing, both mechanical and solar, on the ice and the upper water column. The response of the upper ocean will be established using data collected sub-sea by the autonomous vehicles operating under the ice, and then assimilated into oceanographic models.

OBJECTIVES

The objectives of the portion of the ONR MIZ project described in this report include development of the communications and navigation system, plus integration and testing with the target platforms. The goal for navigation performance is to achieve better than 1 km accuracy at 100 km range, and 100 m at closer ranges (less than 20-50 km). Because the navigation sources will drift with the ice, we will also develop a communication capability that will allow transmission of source locations. The communications will be one-way, and allow control of the sea gliders, albeit with a very few number of bits per command. However, simple instructions to tell the gliders how to move as the MIZ evolves will be possible.

APPROACH

The proposed system consists of an array of sources suspended from the surface, each equipped with GPS receiver, Iridium terminal and acoustic source. The proposed layout is as shown in Figure 1. The notional spacing of the navigation sources is 100 km for the initial layout because the separation between sources may grow as the ice moves and the array deforms.

Each source is operated on a fixed schedule, transmitting 4-8 times per day, and transmissions are synchronized to GPS time. Each transmission consists of a navigation signal, telemetry with location

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information (quantized to approximately a 100 m grid), and an optional command. On order 24-32 bits are required to convey the current location of an individual source, depending on the size of the study area. On the under-ice platforms a derivative of the WHOI Micro-Modem will be used. The modem is turned on by the platform controller according to the schedule, and it operates for the short time required to acquire and process the incoming signal. The time base on the remote systems is a SeaScan clock (drift of less than 1 msec/day), and the receiver computes the one-way time-of-flight and its position using multiple range estimates from the different receivers. All of the relevant data is logged by the platform controller and in the case of the glider, used to update its internally-reckoned position.

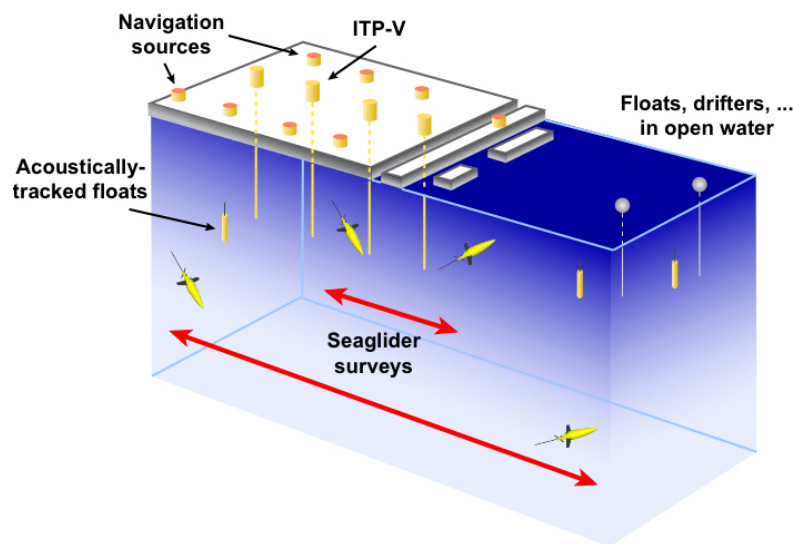


Figure 1. Proposed experimental layout showing navigation sources, ice-tethered profilers, floats and Seagliders. Source spacing is approximately 100 km, and thus 8 sources cover at least 60,000 square km. (Courtesy Lee and Rainville, APL-UW).

WORK COMPLETED

Major work completed in 2012 included:

1. Analysis of the data from the Alaskan Arctic (the Canadian Basin) collected during ICEX 2011 was completed.
2. Evaluation of acoustic sources and receiver hardware for use during the experiment was also completed.
3. System architecture and design discussions were held with APL-UW (Seagliders) and WHOI (SOLO II floats).

Major work items for 2013 include the following:

1. The proposed layout for the sources was developed in conjunction with APL-UW.
2. Design of source buoy mechanical and electrical components was completed and fabrication of the majority of the parts was done.

3. Physical layer communications software that encoded and decodes the source position information and commands was developed and written. The transmit software was implemented on the Micro-Modem 2, and the receiver software prototyped on the existing floating-point co-processor.
4. Trials in the marginal ice zone of the Fram Strait were performed in September in conjunction with an experiment organized by the Nansen Center in Bergen, and utilized the Norwegian Ice Breaker the KV Svalbard.

RESULTS

The results are summarized below for each of the work areas described above.

Navigation Network Layout. The proposed layout is as shown in Figure 2. The sensor clusters, shown in four groups, will be deployed 1 degree of latitude apart. A total of eight sources will be deployed with the first phase of ice-based installations. There will be two additional sources that can be deployed from the Araon, filling gaps that appear as the sensor array deforms between April and mid-summer. Two Wave Gliders from Liquid Robotics will be positioned outside the MIZ during the launch of the UW Seagliders and the deployment of the UW wave measurement buoys in June. These two will provide navigation for the Seagliders as they enter the MIZ and go from open to ice-covered waters.

The selected separation distance for each pair of sources is 40 km. This is very conservative, and was selected because two travel times are required to compute a position, and because it is possible that the sources may move apart during drift across the Canada Basin. The nominal distance from the baseline of the source pair to the sensor cluster is 55 km. An exception is for the southern pair, which if placed 55 km south of the sensor, would melt out well before the sensor, and thus not be available for navigation between the MIZ edge and the sensor. Thus those are placed closer: the baseline will be only 20 km from the sensor, and the sources on the Wave Gliders will be used to guide the Seagliders north into the ice-covered areas.

Source Buoy Design and Construction. The buoy design is new but based on several generations of ITP designs that have been very successful. It consists of a shaped foam collar with aluminum pressure housing with a radome on top to protect the GPS and Iridium antennas, plus a urethane-filled hose with spiral conductors for the through-ice transition where a cable would be vulnerable. The buoy is designed to float after melting out of the ice floe that it is installed on, so that it will continue to provide navigation information in the MIZ, and constructed for easy recovery when drifting. The source is mounted into a cage at the bottom of 100 m of cable, and requires a ten inch diameter hole. A 70 pound weight on the bottom provides a compromise between deployment ease and keeping the cable as vertical as possible when the ice is drifting fast.

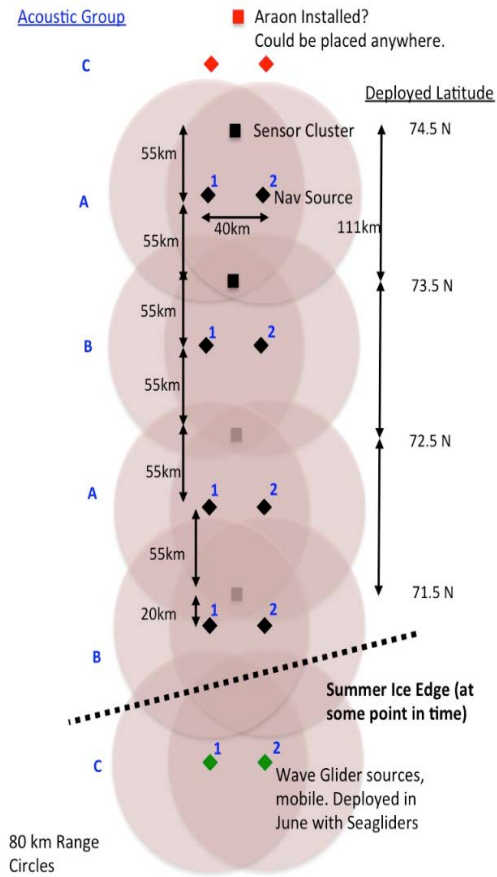


Figure 2. Navigation network layout.

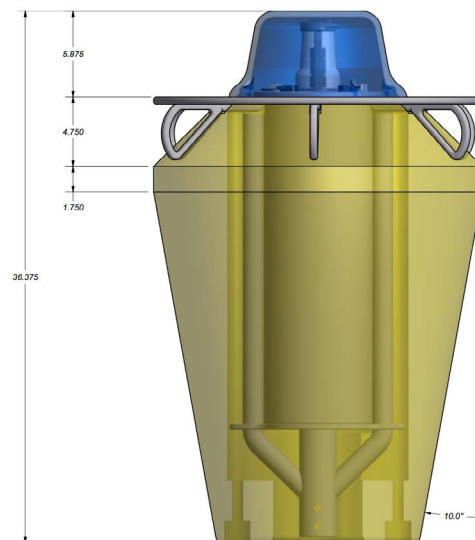


Figure 3. Communications and navigation buoy.

Real-Time Firmware. The transit-receive and controller functions for the buoy are based on the WHOI Micro-Modem 2.0. While much of the core software is similar to that used for other applications, the data rate and the number of bits used are nearly two orders of magnitude lower than typically used. This necessitated creating a new packet format that is efficient for transmissions that are as small as 6-8 bytes, and a two-pass decimation scheme for receiving data at 10-100 Hz symbol rate. This work has been successfully completed, with the currently receiver running on a floating-point co-processor board. Remaining work in the program includes porting this software to run on the fixed-point Micro-Modem 2 DSP to avoid the extra power and expense of the co-processor.

Fram Strait Trials. Two of the buoys were deployed for several days during a cruise on the Norwegian Ice Breaker the KV Svalbard at 82 degrees North, near the center of the Fram Strait as shown in Figure 4. Access to the KV Svalbard for two WHOI engineers to take part was made possible by an on-going collaboration with Hanne Sagen at the Nansen Centre in Bergen, Norway. This year's cruise was called UNDER-ICE 13, and included both the acoustic measurements described here and an extensive series of XBT and XCTD profiles. The ship mobilized from the port of Longyearbyen on Svalbard, and took place during September 11-24. In addition to the pair of MIZ buoys deployed approximately 65 km apart, several acoustic recorders were deployed as backups. Further, to provide additional source-receiver ranges several transmissions were made from the ship. Real-time results sent back over Iridium demonstrated reliable communications between the two buoys, and evaluation of the travel-time accuracy and the data collected at the longer ranges at the recorders is just beginning as of the submission of this report.

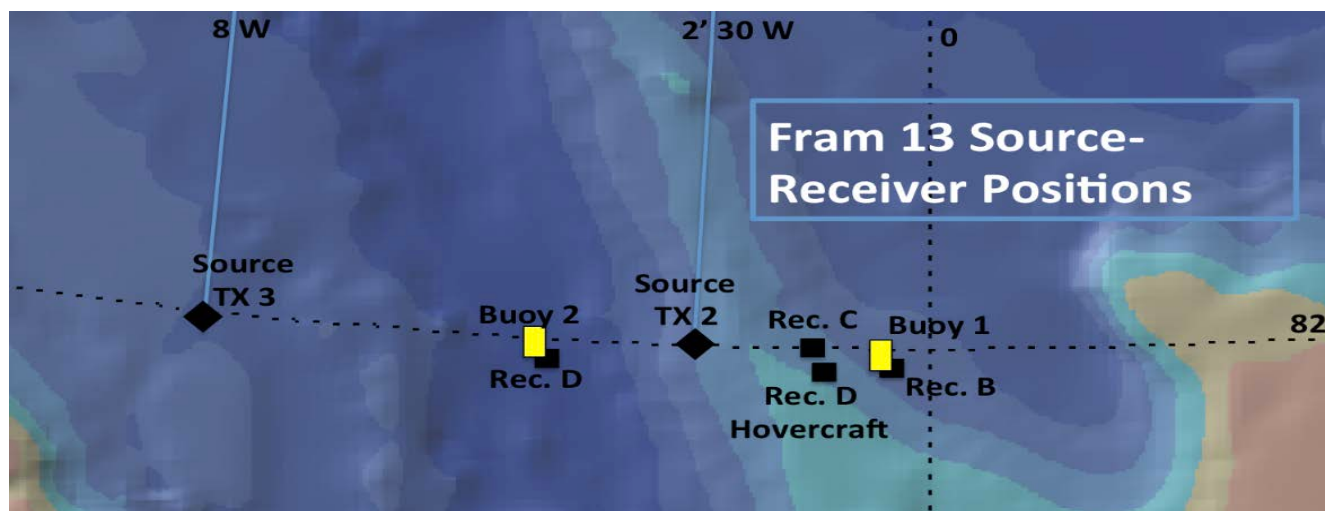


Figure 4. Locations of sources and receivers during the September 2013 UNDER-ICE Fram Strait experiment.

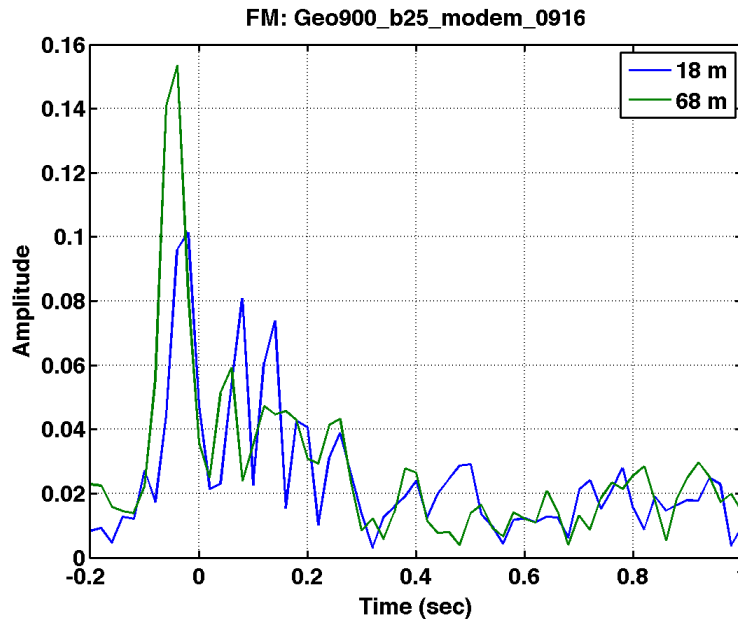


Figure 5. Impulse response from a 900 Hz carrier, 25 Hz bandwidth communications-navigation signal from the Fram 13 experiment.

While acoustic propagation in the Fram has differences from the Beaufort, the results have implications for navigation performance in 2014. An example impulse response (Figure 5) shows a spread of approximately 0.050 s, which corresponds to 75 meters in travel time. A second note is that of the two different hydrophone depths that were measured, the signal amplitude on both is adequate for detection, and though the deeper receiver often had a matched-filter output that was up to 50% higher, the two were often equal as well.

IMPACT/APPLICATIONS

The potential impact of this project is that it allows a drifting, ice-tethered navigation and communications system to be employed in the Arctic during times when it is not possible for UUVs to safely surface.

TRANSITIONS

While no transitions are currently planned, clearly the technology is applicable to Navy UUVs performing tactical missions under Arctic ice. Potential programs for transition include LD-UUV if an Arctic version is fielded in the future.

RELATED PROJECTS

WHOI is working with a small business, OASIS (Lexington, MA) on an ONR STTR focused on acoustic modeling and system design for a next generation of even longer range acoustic navigation and communications. PI: Kevin Heaney (OASIS). Grant Number: N00014-12-M-0353. ONR Program Manager: Scott Harper.

PUBLICATION

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