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 in 2013. 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 development 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 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.

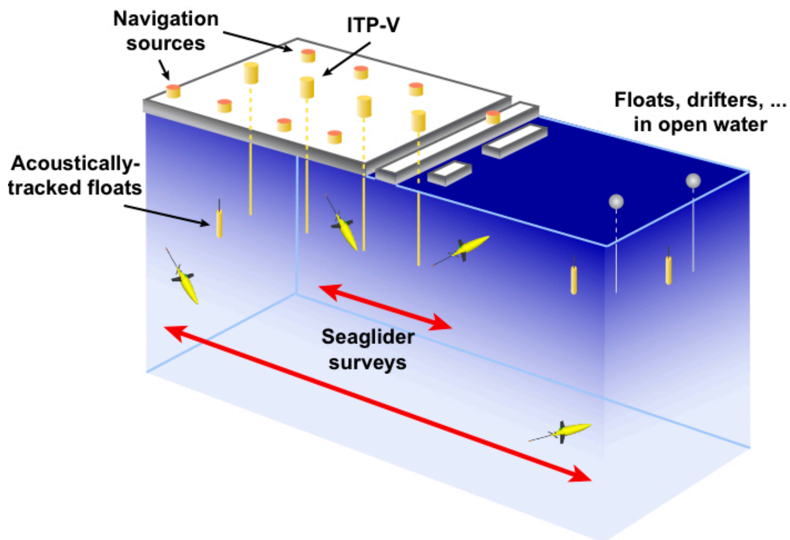

Figure 1. Proposed experimental layout showing navigation sources, ice-tethered profilers, floats and Seagliders. Source spacing is approximately 100 km, and thus 8 sources cover at least 60,000 square km. (Courtesy Lee and Rainville, APL-UW).

WORK COMPLETED

Our initial work has included system design and analysis of alternatives, plus additional work to understand acoustic propagation in the Arctic using data collected during two previous exercises in 2010 and 2011. Specific items include:

1. Interaction with the APL-UW Sea Glider team and the drifter group at WHOI on interfaces and system integration. An interface control document will be written and distributed to ensure that specifications for the equipment are clear and that the users have the information they need to install and operate the receivers.
2. Additional analysis of data from the Alaskan Arctic (the Canadian Basin) that was collected during ICEX 2011.
3. Evaluation of acoustic sources and receiver hardware for use during the experiment has also been performed. The acoustic source selection is critical because the cost per unit is relatively high and at least ten are necessary to cover the test area. Selection of receiver hardware is important because it must be integrated into the two types of sub-sea platforms, both of which have severe space, weight and power limitations.

RESULTS

The results are summarized below for each of the items listed above.

System Integration. The integration effort has begun with defining the critical interfaces, such as power, data and mechanical mounting. In conversations with APL-UW (Craig Lee) and the WHOI drifter group (Breck Owens), the installation of the on-board electronics appears to be the lowest risk, with power and data interfaces being more important, at least initially. Use of power will be minimized by leaving the receiver off except when being used, and also by use of an asynchronous interface to the receiver that allows the host on the glider to be powered off as much as possible. Thus the operation of the receiver will be as follows: (a) Host turns on receiver at scheduled time, provides any configuration information necessary. The host can then go to sleep if desired to save power. (b) The receiver runs for a specified amount of time, stores reception data, and then goes to sleep. (c) At any time in the future the host wakes the receiver and queries for previous results. This approach maximizes flexibility for the host controllers on the two platforms, both of which are relatively simple and have other tasks to perform.

Analysis of data from ICEX 2011. Additional processing of the data collected during the 2011 Navy Arctic Submarine Lab exercise north of Alaska has been performed with the goal of establishing the best depth for the acoustic source. The processing uses an adaptive equalizer operating on the phase-shift keying (PSK) data, with SNR at its output being the relevant reliability metric. In the figures below the results at 10 , 20, 30 and 40 nmi (19, 37, 56 and 75 km) are shown. Each point corresponds to the average of three received packets for each of four different signal bandwidths (and thus data rates). At 56 km the 12 and 24 Hz cases are still more than high enough for reliable acoustic communications at approximately 12 and 24 bps respectively, while at the longest range all of the packets have some bit errors.

In the 2nd case the receiver was at 75 m, and the results at 75 km are significantly better. While the output SNR was 1-2 dB in the 25 m case, at 75 m the output SNR is 8 dB for the 12 Hz bandwidth and 6 dB for 24 Hz. The 8 dB level would provide approximately 6 bits per second throughput using 12 Hz bandwidth, and 6 dB at 24 Hz would provide 6-10 bps, depending on the type of error correction code that is used.

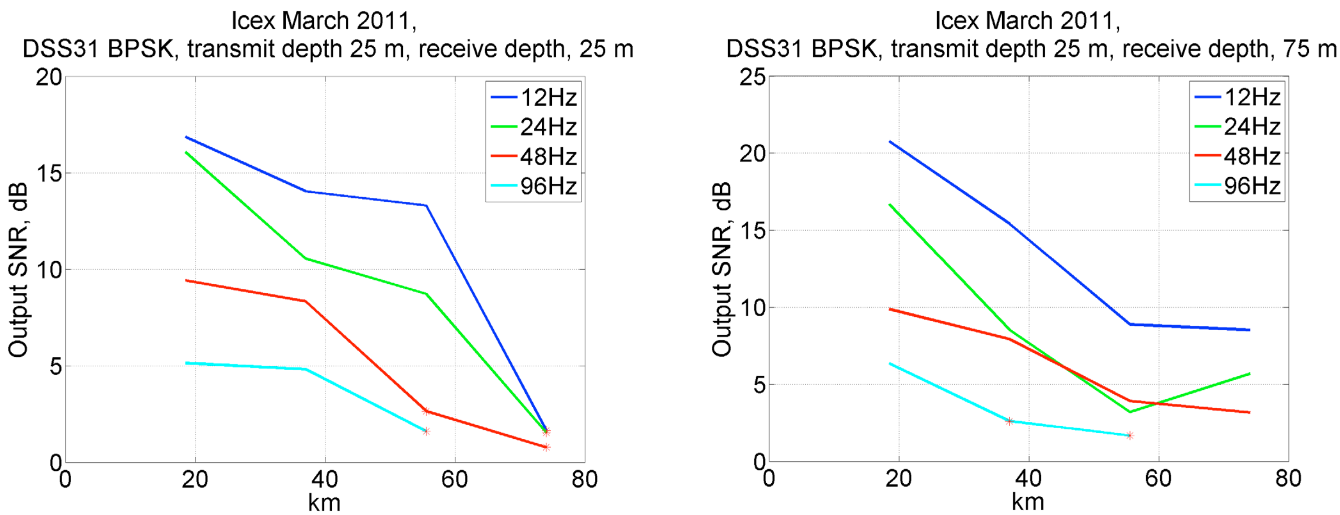

Figure 2. SNR at the output of the adaptive equalizer for the 25m-25m and 25m-75 m transmit-receiver depth cases.

Source-Receiver Hardware Evaluation.

A. Acoustic Source. An important feature of acoustic propagation in the deep Arctic ocean is that a shallow source can provide long-range navigation nearly continuously in range because the sound refracts on layers within the water column or simply due to the increasing sound speed with depth, and then it returns to the surface where it reflects from the ice. Thus there is no advantage to placing the source deep as would typically be the case in temperate water, and a shallow source can be used. A review of different source technologies highlighted the flexural disk as the best candidate for this program due to size, weight and cost. The selected source is made by Geospectrum Technologies, and it has the specifications shown below. Its maximum depth of 160 m is more than adequate.

Flexural Disk Specifications (Geospectrum)	
Dimensions	19 by 3.1 cm
Weight	2.8 kg
Max power	1000 W
Bandwidth	90 Hz
Carrier	890 Hz
Max. Depth	160 m

Figure 3. Flexural disk acoustic source manufactured by Geospectrum Technologies, Canada.

B. Receive Hydrophone. In winter the Arctic is a very quiet acoustic environment most of the time, though with periods that are noisy during ice movement and when floes break up. To maximize receiver performance during quiet periods a low-noise transducer is needed. Initial section has focused on the HTI-90-U because its equivalent self-noise is approximately sea state 0 at 800 Hz. This will allow the receiver to take advantage of quiet periods and not be self-noise limited. The receiver is 1.5 by 4 inches, still small enough for both Sea Glider and the drifter.

Figure 4. The HTI-90-U low-noise hydrophone.

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 company, 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

Freitag, L., P. Koski, A. Morozov, S. Singh, J. Partan, "Acoustic Communications and Navigation Under Arctic Ice", *OCEANS, 2012 MTS/IEEE Conference*, Hampton Roads, VA, October 2012.