The factors that influence the design of an underwater acoustic modem for Arctic missions

Andy Smerdon, CEng, MIET
Aquatec Group Ltd, High Street, RG27 8NY Hartley Wintney, United Kingdom

Observation of the Arctic ice-ocean interface

As summer Arctic sea ice cover continues to reduce, there is a growing need to monitor the Arctic ice-ocean interface. DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies) is an EU 6th Framework programme that sets out to establish an integrated atmosphere-ice-ocean monitoring system intended to observe and quantify Arctic climate change.

As part of this system, several subsea elements of a new Arctic Ocean observing system will be deployed in the Arctic Ocean during 2008. These include:

- ≈ Free-drifting Upward-Looking Sonar (ULS) floats, used to measure ice thickness from a depth of around 50 m.
- ≈ Ice-Tethered Profilers (ITP) that drift with the ice and gather data on water column temperature, salinity and current profiles.
- ≈ Acoustic tomography moorings, used to measure ocean temperature in the Fram Strait.
- ≈ Autonomous subsea gliders carrying out oceanographic data acquisition tasks.

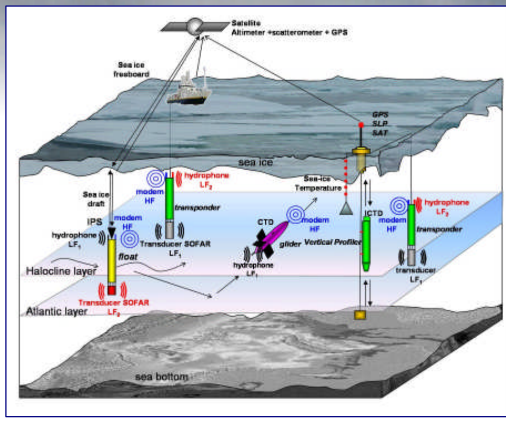

Fig 1: The DAMOCLES under-ice instrumentation

The need for acoustics

For an effective observing system, measured data from the ocean environment must be delivered in a timely fashion for assimilation with data sets from the ice surface and atmosphere. As several of the observing platforms are drifting freely in the water below the ice, or are located on inaccessible subsea moorings, they must communicate their data to the surface using underwater acoustic techniques. However, the environment imposes a number of restrictions on how to achieve this.

Arctic under-ice modem requirements and limiting factors

Several commercially available acoustic modems are well suited to short range or vertical transmission applications. However, the requirements for communication of data between under-ice platforms differ in several respects.

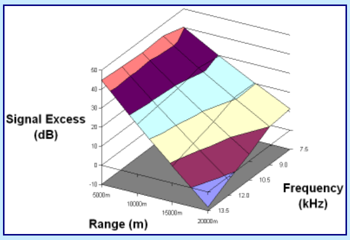

Fig 2: Frequency dependent attenuation

Range: The spatial scale of under-ice operations means that achieving close approaches between the two ends of a communication link may be extremely difficult. Apart from the fixed moorings, all other platforms will be mobile, and with the exception of ice-tethered platforms, their position will be difficult to predict accurately. Chance encounters are highly improbable with the initial small population of instruments. To optimize any interaction, the maximum range of the system should be as large as possible consistent with other constraints. Signal attenuation increases with frequency, but at lower frequencies, available bandwidth is lower, transducer cost and size increase, and environmental noise is generally higher.

Data storage: The difficulty of collocating two ends of a communication link, combined with the general inaccessibility of the Arctic environment mean that data transmissions will seldom occur without considerable planning. It is essential therefore that the modem can store data that need to be transmitted until a suitable opportunity arises. The stored data can be forwarded across a communication link once it has been established.

Power conservation: Power is a very limited resource – large battery packs contribute weight to subsea components, which then introduces buoyancy problems and raises manufacturing and running costs. Available power can limit maximum range. However, over long deployments, it is not only the energy used to transmit data that must be optimized, but also the standby power consumption, when the modem is awaiting interactions with its host or another acoustic unit. Signal processing capability must also be traded against power consumption.

Low temperature operation: In upper Arctic waters, temperatures can fall to -2°C, and in the air prior to immersion, they can be substantially lower. Most batteries suffer from reduced capacity at these temperatures. Some devices, such as hard disk drives typically used for data storage, will not function below 5°C and therefore cannot be specified. Acoustic attenuation also increases as the temperature drops, which means more transmit power is needed to achieve a given range.

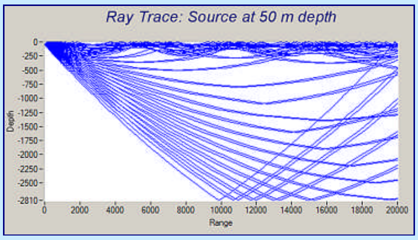

Fig 3: Upper Arctic sound channel

Acoustic channel: Much of the under-ice communication will take place in the shallow, upward-refractive sound channel, where under-ice measurements are typically made in the upper 50 m. Sound that reaches the ice interface will scatter according to the age-dependent roughness of the ice. The multiple paths taken by signals, including bottom and surface bounces may lead to signal spreads of several seconds, and introduce significant fading. A modulation and coding scheme must be chosen that is sufficiently robust to accommodate these characteristics.

Interoperability: One of the most challenging requirements is that of interoperability, which the Acoustic Navigation and Communications for High-latitude Ocean Research (ANCHOR) Workshop at the University of Washington discussed in spring 2006. The workshop concluded that "Given the number of countries and funding sources, a successful basin scale system requires that components from multiple vendors must be interoperable" … "The common protocol needs to be open and transparent, so that a wide range of users and vendors can design components to operate within the network."

Navigation: Although not a specific requirement of the modem, navigation is an essential system consideration in establishing any communication between two subsea platforms. The subsea floats used in the DAMOCLES array incorporate low frequency beacons operating typically once to three times daily. Any ice-tethered platforms within a few hundred kilometres range can detect their transmissions for position fixing and drift speed estimation. Knowledge of position and drift velocity allows an airborne team above ice to choose a suitable landing point to drill through and lower a modem to interrogate. It also provides navigational information for underwater gliders, which can harvest data during their subsea missions by seeking out subsea floats and downloading their stored information payload.


Fig 4: Prototype modem

Modem specification

Taking all the above factors into account, a specification for a prototype modem was developed. The characteristics described below were implemented in the AQUA*modem* 1000 prototype pictured right. Over twenty modems have now been built and are undergoing testing or are in their initial field deployments.

Environmental	Operating Depth	Up to full ocean depth, depending on requirements
	Temperature	Operating: -5°C to 40°C Storage: -40°C to 65°C
Telemetry	Frequency band	7.5 – 11 kHz
	Operating Range	Up to 20 km depending on environment
	Transmission type	FSK and DPSK Spread spectrum
	Bit rate	300 bps → 2 kbps
Data storage	Capacity	2 Gb SD Card for Store and Forward capability
Power requirements	Timed / triggered wakeup	1 mW (waiting for communications from host instrument, or waiting until an internal alarm wakes the modem up)
	Acoustic wakeup mode	5 mW (listening to acoustic signals from up to 5 km away, wakes up when received)
	Receiving mode	0.6 W (full power receiving mode, decoding acoustic data as it arrives)
	Transmitting mode	20 W (transmitting continuously at full power – reduced power operation possible)
	External power, transmitter	10.8 → 20 V, max current 3 A
	External power, digital	6 → 20 V, max current 500 mA
Interface	Electrical	TTL or RS232 levels
	Protocol	NMEA 0183, ASCII interface standard Aquatec binary format
	Debug	USB 2.0


Fig 5: Through-ice Arctic deployment

Testing and deployment

Initial testing has been carried out in shallow water in UK and Norwegian coastal waters. However, weather conditions and lack of ship availability have so far prevented substantial data gathering in the Arctic environment. However, in April this year, several ULS floats were deployed with modems attached, and additional modems will be deployed as part of an acoustic tomography array in the Fram Strait in August this year.

Further work

The Arctic work has only just begun, so there will be substantial acoustic data sets to analyse over the remainder of the DAMOCLES project. The initial modem implementations have concentrated on robust frequency-hopping FSK signals with non-coherent detection, but more advanced algorithms are now under test, and will be implemented in future deployments.

Acknowledgments

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