Acoustic Localization of Hydrophone Array Elements in the Arctic Ocean

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BACKGROUND

In the Spring of 1996, the Esquimalt Defence Research Detachment of the Defence Research Establishment Atlantic and the US Naval Research and Development laboratory deployed an acoustic research array (ARA) through 4 m of polar pack ice near the edge of the continental shelf of the Arctic Basin, north of Ellesmere Island [1]. The ARA is configured as a 2.4-km horizontal line array (HLA) of 80 hydrophones on the seafloor, and two vertical line arrays (VLA's) of 20 hydrophones which span the water column (~560 m), one located at each end of the HLA. A 240-m secondary horizontal array of 8 hydrophones is also included perpendicular to the main HLA to resolve ambiguities about the main array axis. Acoustic data from the ARA are transferred 180 km via a seafloor fibre optic cable to a land-based recording recording facility at CFS Alert. Data are to be recorded continuously for the battery life of the system (approximately five years).

The three-dimensional nature of the ARA is ideally suited to advanced acoustic signal processing methods such as matched-field inversion. These methods require precise knowledge of the location of individual sensors in the arrays. This paper describes and analyzes a series of acoustic measurements carried out shortly after deployment of the ARA to localize the VLA and HLA sensors. Because of the difficulty of making acoustic measurements through the pack ice and the continual possibility of ice motion, only a minimal data set was recorded. Inversion methods are applied to obtain the most precise localization possible from this limited data.

VLA ELEMENT LOCALIZATION

Due to the effects of ocean tides and currents, the shape of a VLA suspended in the water column is not fixed but can change with time. The shape of each VLA of the ARA is continuously monitored using three high-frequency engineering hydrophones positioned at intervals along the VLA cable. The engineering hydrophones are localized acoustically using travel-time measurements from four transceivers (acoustic receive/transmit units) located on the seafloor, one in each quadrant about the VLA. For optimum array-processing performance, the position of the engineering sensors are required to a precision of 1 m. To meet this requirement, the position of the transceivers must be known to within < 1 m. The transceivers themselves were localized by recording their signals on hydrophones deployed just below the ice in the VLA and transceiver deployment holes. The transceivers were activated from a control transducer co-located with one of the surface hydrophones to provide a reference for absolute timing. Ideally, transponder localizations are based on a vastly over-determined data set from a symmetric set of source-receiver configurations to minimize the effect of experimental errors, e.g., [2]. In the present case, only five independent (non-symmetric) travel-time measurements were available to determine three spatial coordinates for each transceiver. A numerical sensitivity study was carried out prior to the experiment to appraise possible sources of error, and care was taken to minimize these errors in the field.

HLA ELEMENT LOCALIZATION

A simple experiment was carried out to localize the HLA hdyrophones based on deploying small impulsive sources (imploding glass light bulbs) at a series of locations surrounding the HLA. Shot instants were not independently measured, so the recordings represent relative rather than absolute travel times. Hence, shot instants must be included as unknowns in the inverse problem; this results in a coupled problem which must be solved for multiple hydrophone locations and shot instants simultaneously. Since refraction effects due to variations in ocean sound speed with depth are significant over the maximum propagation ranges, these coupled equations are non-linear. The system is solved using linearization and iteration, with ray tracing methods employed to calculate numerical partial derivatives.

REFERENCES

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