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KAIYO Cruise Report

KY10-05

Izu-Ogasawara

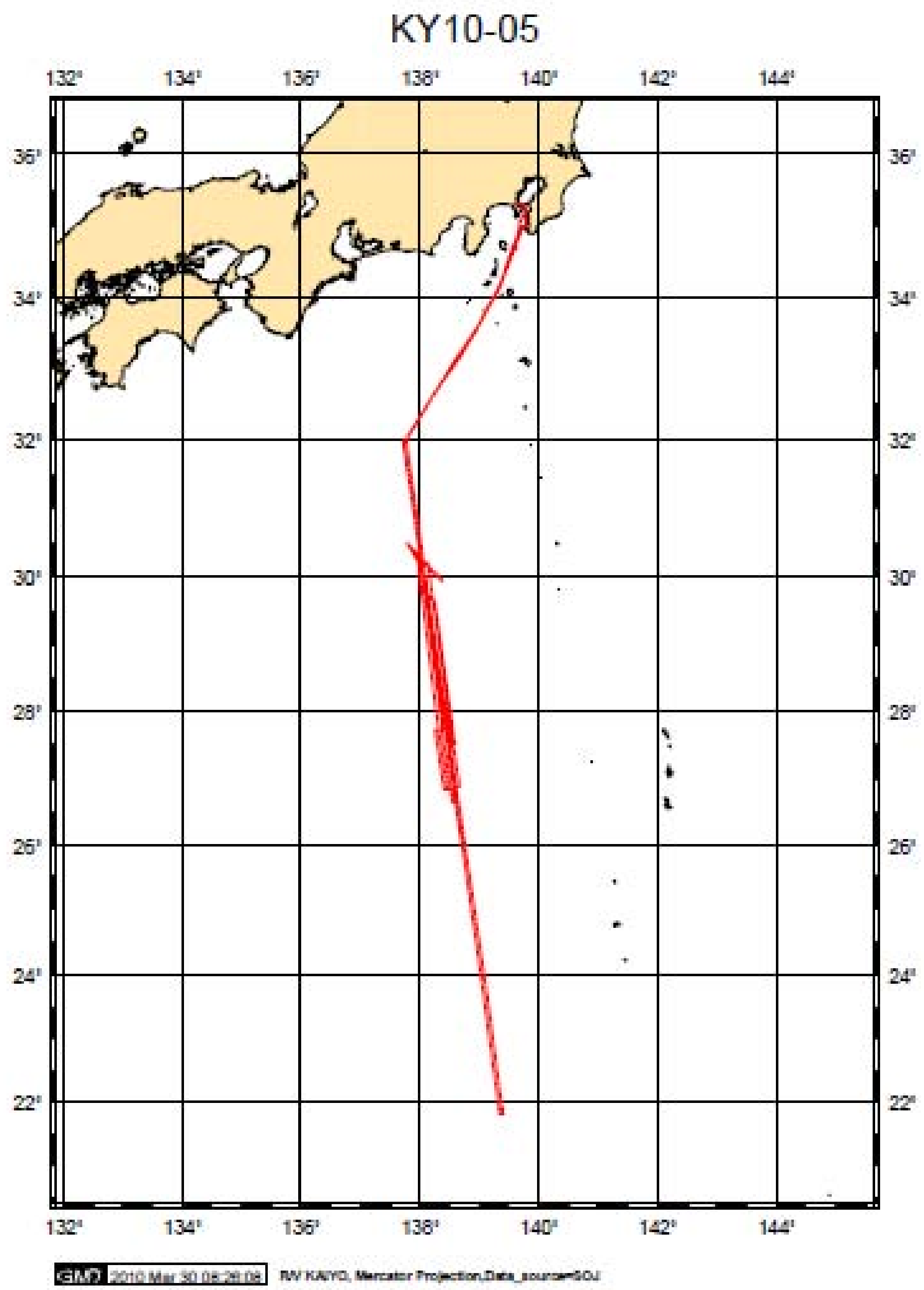
12/March/2010 – 30/March/2010

Japan Agency for Marine-Earth Science and Technology
(JAMSTEC)

Contents

1. Cruise Information

Cruise number:	KY10-05
Cruise ship:	“KAIYO”
Title of the cruise:	Experimental research on underwater acoustic technology
Cruise period:	12/March/2010 – 30/ March/2010
Port call:	JAMSTEC (Yokosuka)
Research area:	Izu-Ogasawara
Research map:	



2. Researchers

Chief scientist: Hiroshi Ochi (JAMSTEC)

Science party: Takuya Shimura, Yoshitaka Watanabe (JAMSTEC)
Takehito Hattori (Nippon Marine Enterprises LTD.)
Keisuke Matsumoto, Shinsuke Toyoda, Syungo Oshitani (Marine Works Japan LTD.)

3. Overview of experiments

In this cruise, these two kinds of experiments are conducted.
1) Experiments for “long range underwater acoustic communication by time reversal wave”.
2) Experiments for “long range acoustic positioning system”.

Mooring list

Name of mooring point	Mooring point		Water depth [m]	Depth of top buoy [m]	Mooring period	
NAV01	35-03.0085N	138-40.0733E	1,061	980	01/13	01/14
COM01	35-02.9008N	138-40.1008E	1,045	975	01/15	01/16
COM02	35-02.9172N	138-40.0213E	1,042	972	01/17	01/17
NAV02	35-03.0673N	138-40.0390E	1,032	942	01/18	01/18
COM03	34-49.0923N	138-37.2654E	1,634	1,575	01/19	01/20
NAV03	35-03.1188N	138-40.0284E	1,029	939	01/21	01/21

COMxx: mooring for experiment 1).
NAVxx: mooring for experiment 2).

3-1. Experiments for “long range underwater acoustic communication by time reversal wave”.

3-1-1. Introduction

In Advanced Marine Technology Research and Development Program, the project of developing a new autonomous underwater vehicle (AUV) is being planned which has a long cruising capability up to several hundred kilometers. Our research group is promoting the research to realize acoustic communication with such an AUV by time reversal. In the ocean, many multipath waves cause inter-symbol interferences (ISI) that make it difficult to achieve communication as known well. Time reversal (TR) has a possibility to solve this problem. Because TR converge and utilize multipath signals so that ISI are removed.

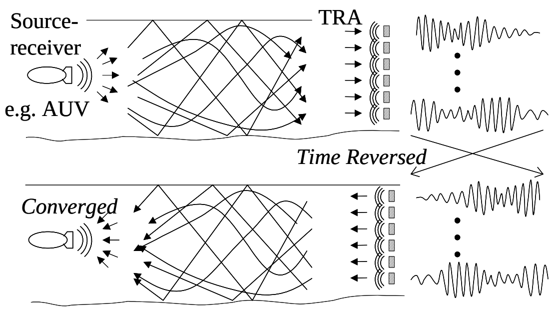


Fig. 1 Schematic of time-reversal communication

3-1-2. Experimental setup

In this cruise, experiments for passive time-reversal (PTR) communication, that is, single-input-multiple-output (SIMO) time-reversal communication, were executed. The experiment site is shown in Fig. 2. The center frequency and bandwidth of the source was 500 ± 50 Hz and the source level was 186 dB. The receiver array was composed of 20 receiver systems. The intervals between the receivers were 6.0 m approximately. Then, the array length was 114 m approximately. The source and the receiver array were moored at the ranges of 500, 600, 700 and 900 km on the red line as shown in Fig. 2. The sound velocity profiles at some points on the line are also shown in Fig. 2. The source and receivers were installed at the depth of 1,000 m approximately.

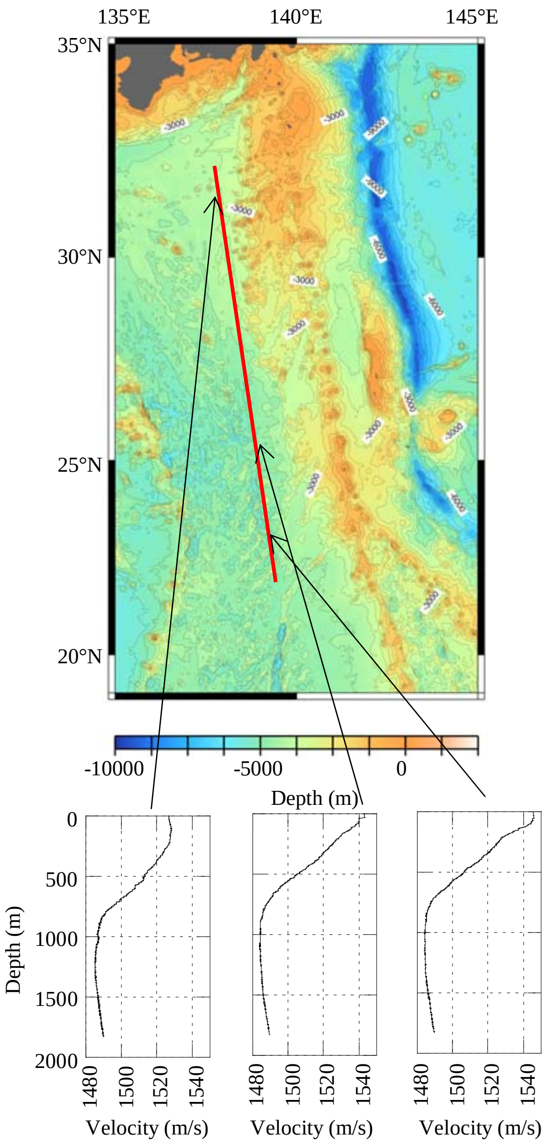


Fig. 2 The bathymetry of the experiment site and the sound velocity profiles on the survey line.

3-1-3. Results

Some of results are shown here as a flash report.

In the measurement of 700-km-range, M-sequence signals were transmitted as a probe signal. The data rate was 100 bps. The probe signal was processed with the fourth root raised-cosine filter and the data signal was processed with the root raised-cosine filter. The received probe signal was correlated with the original M-sequence signal, and correlated with the received data signal as PTR process.

One of the demodulated results is shown in Fig. 3.. In this figure, "TR only" indicates using only time reversal, and "TR+AE" indicates the proposed method of combining time reversal and adaptive equalization (AE). In this result, the demodulated symbols are rotated in the case of TR due to the ship drifting similarly as in the previous experiments. Such phase rotation is compensated well in the case of

TR+AE. Thus, it is performed that communication at the range of 700 km is accomplished.

In the measurements of 900-km-range, the same probe and data signals were transmitted. However, it was impossible to realize demodulations. Thus, the technique of combining spread spectrum (SS) additionally was introduced. Such results will be summarized and published in future.

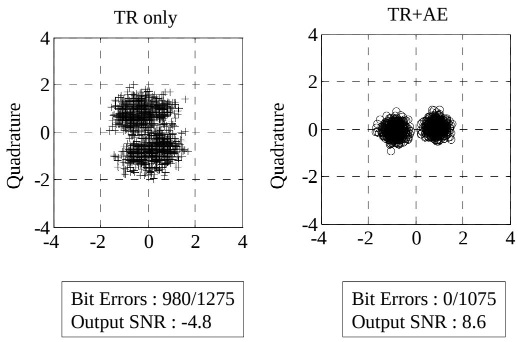


Fig. 3 Demodulation results at the range of 700 km.

3-2. Experiments for "long range acoustic positioning system".

3-2-1. Introduction

In this cruise, experiments were conducted to acquire data to consider long range acoustic positioning for cruising AUV. Positioning method is considered as that AUV receives acoustic signal from acoustic reference, measures propagation time and arrival direction of the acoustic signal, and compute its own position. The AUV is equipped with receiver array on the body side, and the array is horizontally long. The depth can be measured by a depth sensor which is typically on the AUV. The horizontal position, latitude and longitude, should be estimated by the received acoustic signal.

3-2-2. Experiment

Fig.4 shows experimental configuration. Transmitter and receiver devices are shown in Fig. 5. The transmitter device were equipped with a transducer, and moored on sea bottom. The depth of transmitter device was set at about 1,100m depth which is near the axis of sound fixing and ranging channel (SOFAR).

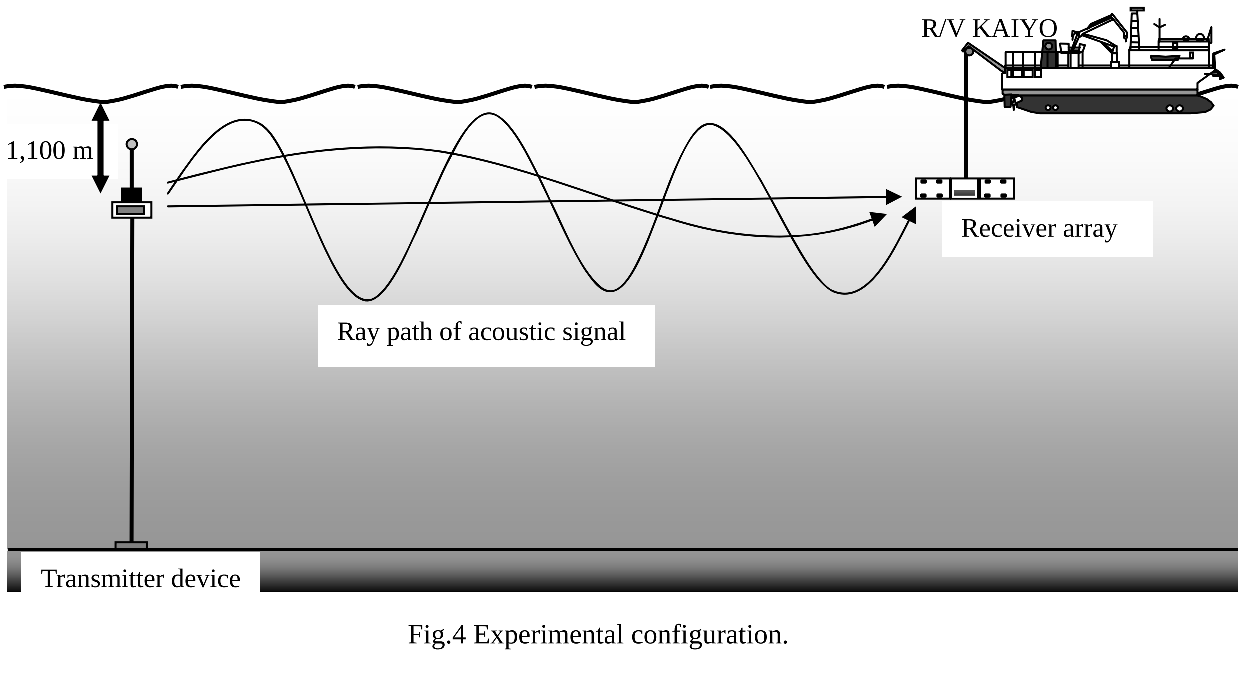
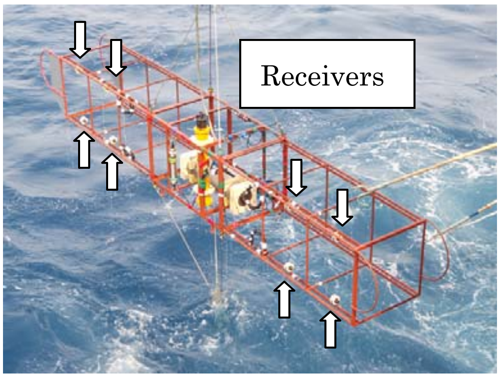
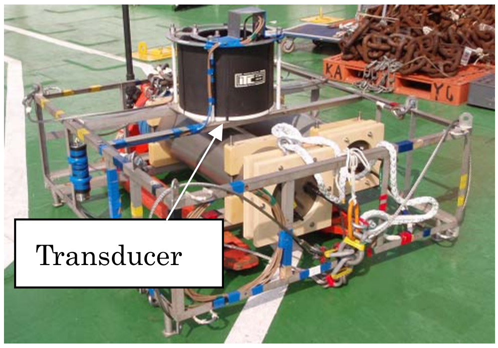


Fig.4 Experimental configuration.



Receiver device.



Transmitter device.

Fig. 5 Experimental devices

The receiver device were equipped with 8 hydrophones, which were allocated as planer array, suspended from the ship. The white arrows on the left-side figure of Fig. 5 indicate the receivers. The size of the receiver array is H 0.7 m and L 4.9 m. Acoustic signals transmitted by the transmitter device were received by the receiver device and recorded as digital signal data for post-processing and consideration. Frequency band of the transmitted signal was 1 kHz± 100Hz, and was coded by a pseudo noise (PN) code. The 8-th and 9-the M-sequence codes were used as PN codes, and the pulse width of the acoustic signal were 1.275s and 2.555s. The acoustic pulses were not single but with multiple pulses transmitted at regular intervals. The received pulses are synthesized at post-processing.

Fig. 6 shows event points in the cruise. The yellow plots show the points where the sound speed profile was measured. The green plot show the position where the transmitter device was moored, and the red plots show the position where the receiver device was suspended from the ship.

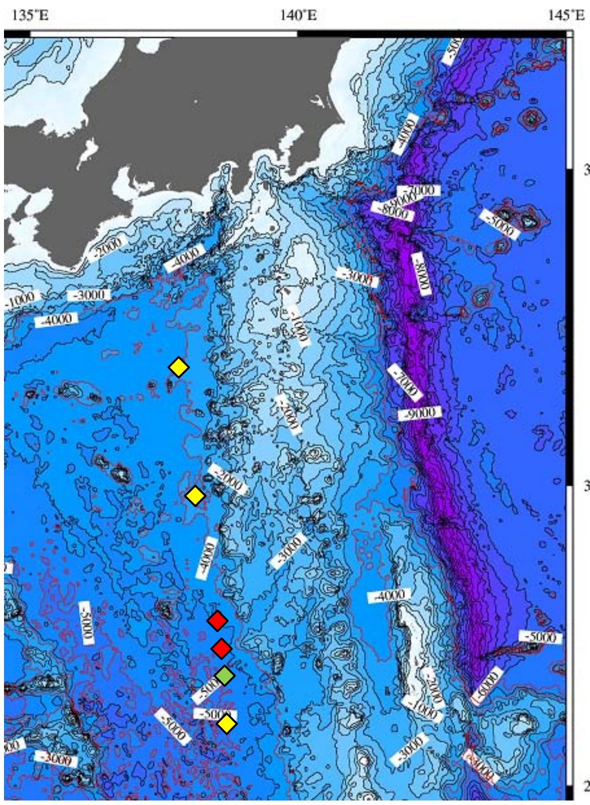


Fig. 6 Position where some events were conducted.

The experiments were conducted three times. The data of the three experiments are shown in Table 1. Fig. 8 shows the sound speed profile at three experiments. In experiments, the ship with the receiver device drifted at 0.5 knot in order to obtain signal data of multiple pulses with moving receiver array. Fig. 9 shows tracks of the ship at three experiments. In the two experiments of 100 km range, the tracks were northward-long, which is along the line between transmitter and receiver, and eastward-long, which is across the line between transmitter and receiver.

Table 1. Experimental configuration.

	Date	Horizontal range between Tx and Rx	Track of the ship
Ex.1	18th May AM	50 km	Toward north-east at 0.5 knot
Ex.2	18th May PM	100 km	Toward north at 0.5 knot
Ex.3	19th May	100 km	Toward east at 0.5 knot

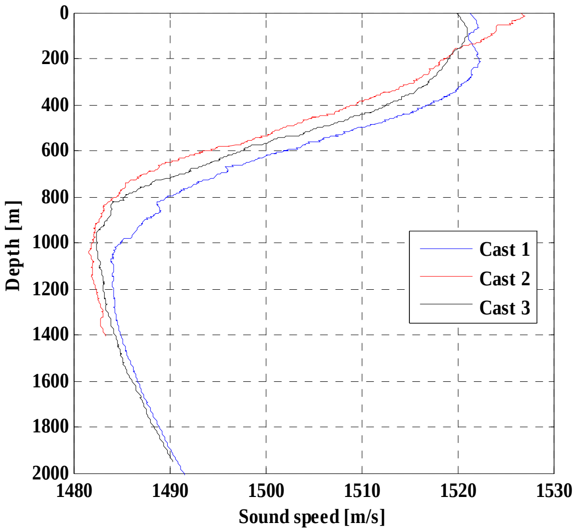


Fig. 7 Sound speed profiles at yellow points.

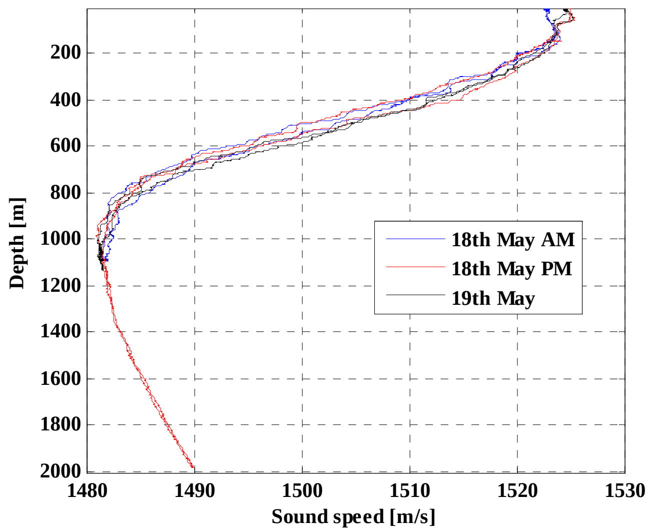
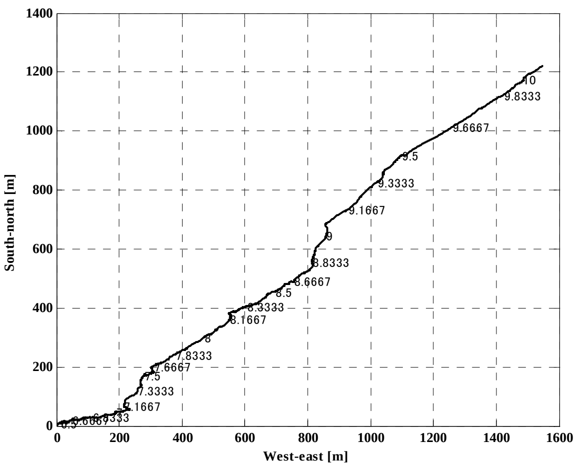
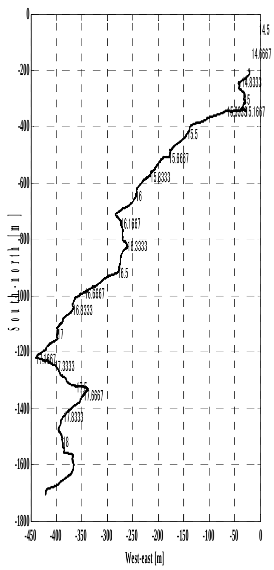


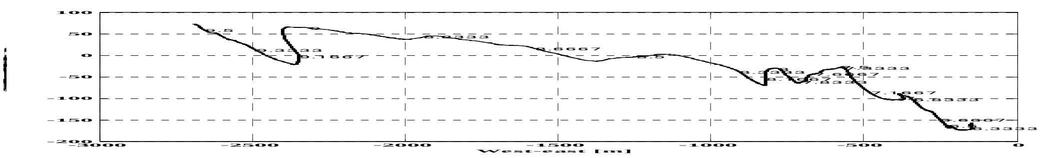
Fig. 8 Sound speed profiles at three experiments.



Ex. 1



Ex. 2



Ex. 3

Fig. 9 Tracks of ship in experiments.