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Japan Agency for Marine-Earth Science and Technology

JAMSTEC Researchers Achieve 300km-Horizontal Acoustic Communication in Deep Ocean

1. Overview

Takuya Shimura and his team from the Advanced Marine Technology Research Program, the Marine Technology Center (MARITEC), the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Yasuhiro Kato, President), successfully achieved horizontal time-reversal communication over a range of 300 kilometers at a depth of about 4,000 meters in the ocean. The distance set the new world record in experiments designed for underwater acoustic communication.

It is well known that horizontal acoustic communication in the sea is difficult to establish due to interference by a large number of multipath waves caused by reflection or refraction in water. By use of time-reversal communication techniques, in contrast, these multipath signals are converged in time and space, enabling efficient and reliable communications (Fig.1).

JAMSTEC plans to refine the time-reversal techniques and apply them to the development of a remote control system for autonomous underwear vehicles (AUVs), to contribute to advances in marine science and technology.

The study will be reported in the 3rd International Conference and Exhibition on Underwater Acoustic Measurements (UAM 2009): Technologies and Results, scheduled in Greece from June 21 to 26, 2009.

2. Results

Time-reversal communication tests were conducted in the waters around the Izu-Bonin islands at a depth of approximately 4,000 meters (Fig. 2). An array of 20 time-reversal receivers was deployed at Point B, toward which sound signals were transmitted from a source device that was lowered from the JAMSTEC research vessel KAIYO at Point A.

In the mid-latitude pelagic waters, acoustic communications over a range of several hundreds kilometers is difficult to establish due to multipath signals from underwater refractions. The time-reversal communication techniques employed in this study has overcome these obstacles, achieving accurate communications without error (Fig. 3).

3. Future perspectives

JAMSTEC has been involved in technological innovation for long-distance cruising AUVs as part of the “Next-Generation Deep-sea Exploration Technology.” one of the national critical technologies of Japan. Time-reversal

techniques are being developed to allow for a wireless communication with such AUVs. Following the basic tests of a time-reversal system in a bay, lead scientist Shimura and his colleagues attempted an experiment in outer seas, achieving the horizontal underwater communication over a distance of 300 kilometers. The team will continue to test the time-reversal techniques with moving source-receivers and over longer distances, to bring them into practical use.

Note: Time-reversal communication

Time-reversal communication is a technique using time-reversal signal processing (Fig. 4).
Time-reversal is a phenomenon in which a sequence of events happens as if it went back in time. For instance, when you videotape a sequence of events and run the tape backward, you will see the images being played backward in time. Time-reversal processing is a method taking advantage of this phenomenon for wave propagation.

In the ocean, time-reversal processing is applied using a system as illustrated in Figure 4. Acoustic signals are transmitted from the point source to the time-reversal array. The signals are then transmitted back from the array and take the same route back to the original source. In other words, they converge in time and space, reconstructing the original signals. Scattered waves by reflection or refraction also travel back and converge to the original source.

It is well known that horizontally transmitted acoustic signals are interfered by multipath signals from the surface and seafloor reflection, as well as refraction attributed to changes in sound velocity that depends on water temperature, salinity and pressure (Fig. 5a). These multipath signals make the data unrecognizable at the receiver, especially in long-distance communication links (Fig. 5b). In conventional methods, these multipath signals are removed by digital signal processing; but it is sometimes hard to do so when a large number of reflected/refracted waves are produced. Time-reversal processing can converge these multipath signals at the original source location, reconstructing the original signal and allowing robust and reliable acoustic communication (Fig. 5c).

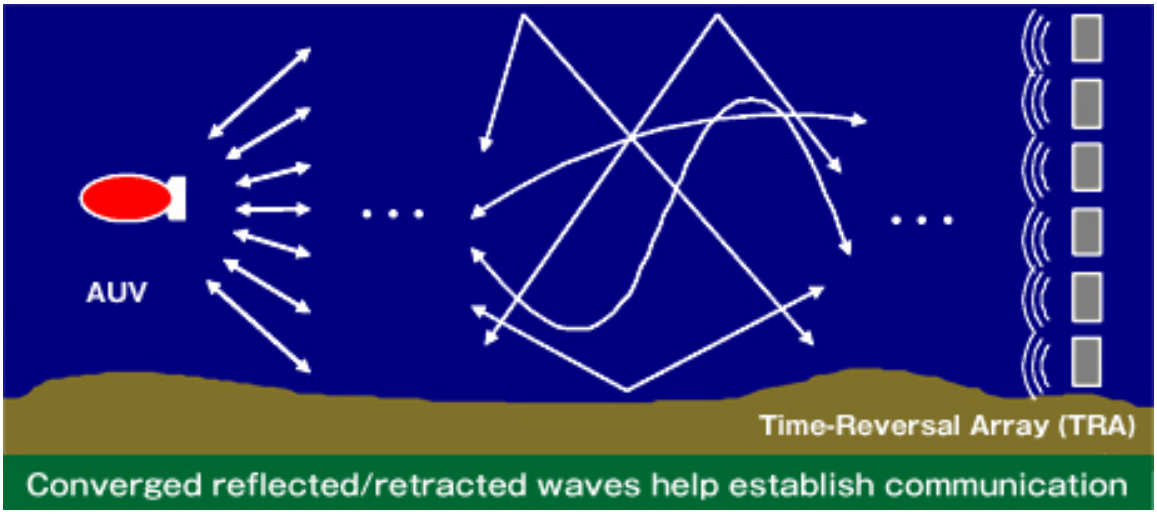

Figure 1: Schematic sketch of time-reversal communication

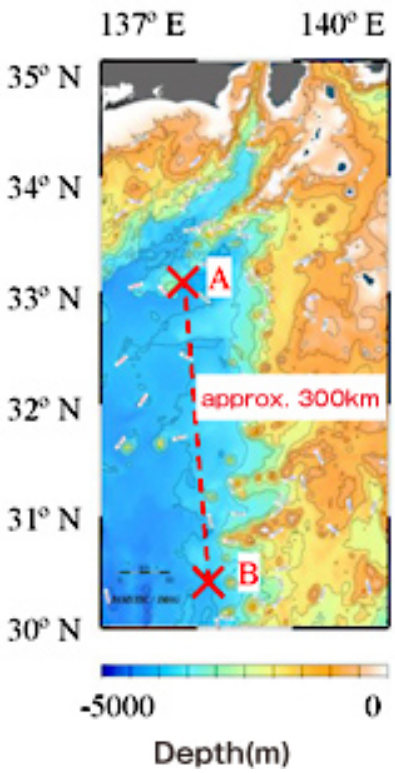

Figure 2: Experiment site

Waters around the Izu-Bonin Islands (depth: approx. 4,000m)

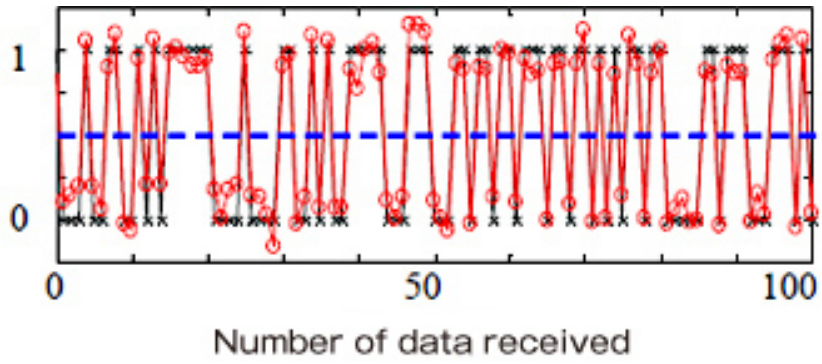

Figure 3: Results of time-reversal communication

"0" and "1" on the vertical axis represent binary digital data. Black crosses denote the correct answers. Red circles show the results of time-reversal communication. The area below the dotted blue line represents "0" and the area above it represents "1". The graph shows that time-reversed signals were clearly recognized as either "0" or "1", indicating a successful communication without error.

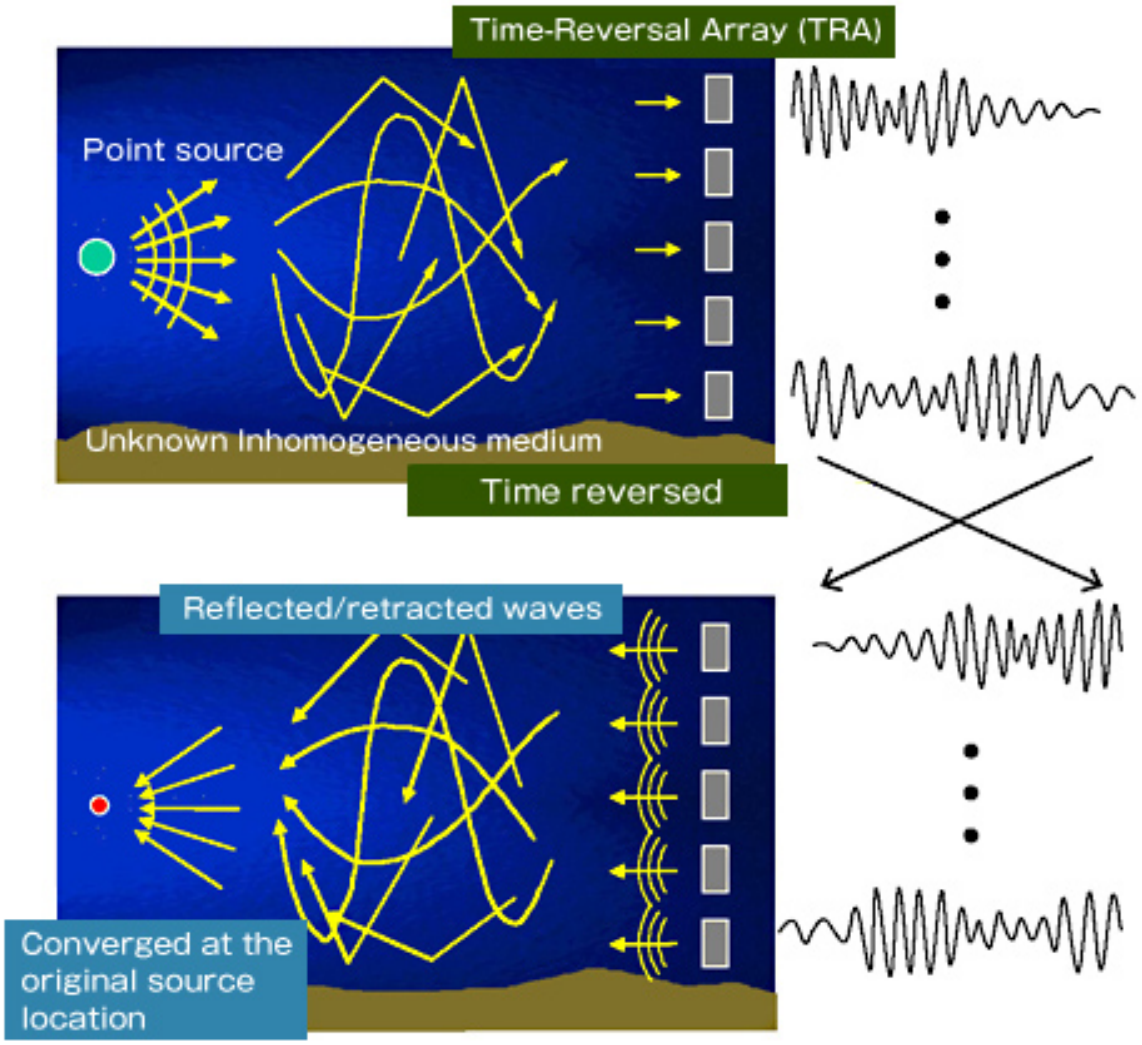

Figure 4: Principle of time-reversal communication

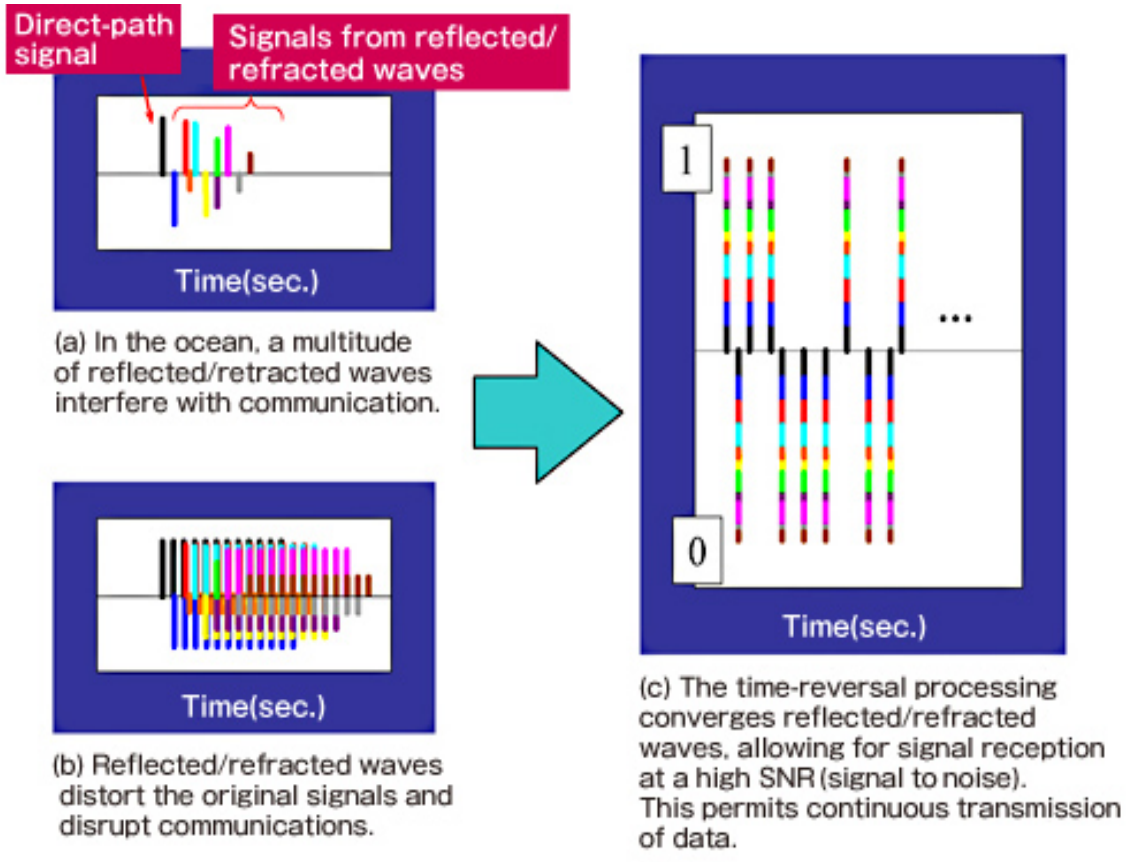

Figure 5: Time-reversal Communication

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