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Sonar Mapping with Synthetic Aperture Sonar at Sanrikukaigan Coast

合成開口ソナーを用いた三陸海岸沿岸の音響探査

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1. Introduction

Synthetic aperture technique has been developed in a radar field, and is adapted to sonar field in background of development of autonomous underwater vehicles and computers. The sonar called a synthetic aperture sonar (SAS) increases its resolution and sensitivity keeping its size, and reached into practical use now. A report of SAS has been published from Marine Acoustic Society Japan in 2001[1], and from Marine Technology Society, which is the one of major society, again in 2009[2]. The most important technique for SAS is a motion compensation of the sonar [3]. An inertial navigation system and a precise navigation using received echo are the key techniques of the motion compensation.

JAMSTEC continues to develop SAS. First survey with the SAS was carried out in Kagoshima bay in 2011. We captured acoustical images of hydro-thermal-vents on the bottom in the survey, and confirmed the high performance of SAS[4]. But some improvement are needed to achieve its original potential or performance. For example, ambiguity of sonar's altitude causes deterioration of sonar's focus. Large gap between the course and the heading also causes target going outside of the projection beam. Wide projection beam for SAS system leads to low projection power. To clear those problem, we develop new SAS (Fig. 1).

In this report, we show sonar mapping with the SAS at Sanrikukaigan coast in June, 2014 and study the effectiveness of the improvement from the results.

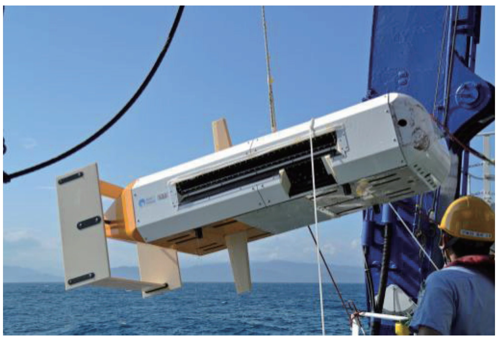

Fig. 1 The tow-fish specially made for the Synthetic Aperture Sonar.

2. Feature of the Synthetic Aperture Sonar

Our conventional SAS which was used in the survey in 2011 have been adapted motion compensation algorithm specially made for the SAS so as to synthesize aperture effectively. The algorithm can do below; It changes the directivity of the receiver array with sonar motions and keep focusing the target, decodes FM modulated pulses (or process range compression) faster by linear approximated process, and filters sonar motions in frequency domain. The synthetic aperture process is done fast and reduced affection from the sonar motion. The inertial measurement unit (IMU) is in the underwater vessel, and a recorder for all acoustic signal and position data are also in the vessel. In other words, we can use the SAS easily without other underwater devices and just load it on the platform such as tow-fish. But as mentioned above, a lack of the altitude and the course and a low power of the projection deteriorated the sonar performance.

Therefore we try to acquire the altitudes by interferometry with multi-channel arrayed acoustic transducers. The course is calculated roughly from a course of mother ship through FFT process which pass low frequency and keep small error in time domain between both course. The projection power of the transducer is improved by controlling delay time in all elements in the multi-channel receiver keeping the directivity.

The new SAS can be loaded on the same tow-fish but is converted a little to adjust the new SAS, and need simple operation to enlarge its utility. In addition, post-process software which overlay the sonar image to google-earth are developed, on purpose to show many users the sonar images as a final result.

3. Sonar Mapping at off Sanriku

1. The earthquake and tsunami of the Great East Japan Earthquake caused drastic changes to the marine ecosystems. It is necessary to investigate

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marine ecosystems to reconstruct fishery grounds. Aiming to provide scientific findings and information that contribute to determine the fishery grounds and to estimate the existing marine resources, we survey Sanrikukaigan coast with the SAS which is high performance and can detect unknown object clearly.

2. In June 2014, we carried out acoustic survey totally for 40 hours over 5 days near border of Miyagi and Iwate prefecture. Depth at the area is form 100 to 250m, but the area is gently undulations and an easy slope. The SAS was loaded on the small neutral buoyancy tow-fish and towed by mother ship "Kaiyou" from astern left. The towing speed is around 2kt. Towing depth is around 7m by means of upper and lower a depressor at a middle of tow-cable.

3. Fig.2 shows the results of the sonar mapping where off the coast of Rikuzentakata and Ofunato city. The mapping is shown by GoogleEarth with standard desktop PC. The coverage area is 6.8 km from north to south, 4.5 km from east to west and 20 km^2 approximately. These are measured with ruler tool on GoogleEarth. Many white blocks that are similar shape and indicate existence of underwater reefs, can be seen in lines on the sonar image. We confirmed the reefs had been deployed by the prefecture, the city and fisheries cooperative ago by a data book they has. The white block concentrate in green and yellow squares, and the shape of the blocks in the same color squares are similar with each other. These facts are also confirmed by the book. We decide that The earthquake and the tunami didn't affect the reefs strongly. A yellow pin on sonar image in Fig. 2 shows a point where unknown object is. We improve a sonar image around the object by synthetic aperture process, and the image is Fig. 3. A shape like a ship is clearly shown in the image. After we generated the sonar image, a remotely operated vehicle was launched to watch the sunk ship to identify the ship, and it was confirmed that the ship is a few decade old and no relation with the earthquake.

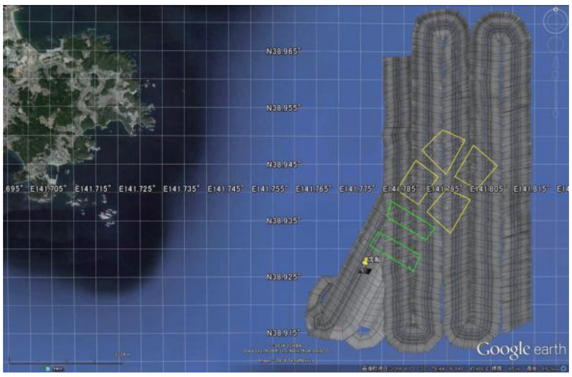

Fig. 2 A sonar mapping image overlaid on Google-Earth map.

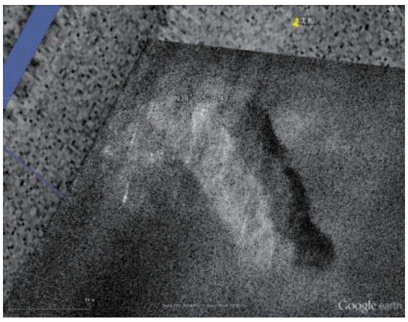

Fig. 3 A zoomed image of the sunk-ship after the synthetic aperture process.

4. Future Works

Through this survey, we show a performance of the SAS on a tow-fish which needs easy operation and show the results can be utilize by many users with standard PC. Our Next development of the SAS must be considered to apply the SAS to practical or commercial survey.

But the results of the SAS in this reports is limited. The resolution of the SAS imaged is limited or deteriorated by the resolution of IMU and errors of a course of the SAS which is generated from mother ship course substitutionally. These will be solved by loading on Yumeiruka, an autonomous underwater vehicle (AUV) developed by JAMSTEC. We plan to evaluate differences of performance between the SAS on tow-fish and on AUV. In addition, interferometric process for altitude calculation isn't tuned properly and autofocus process isn't implemented yet. We are analyzing the data from the survey and develop the synthetic aperture process. These are to be ready for next survey that the SAS is on Ymeiruka.

Acknowledgment

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