Development of the Underwater Search Supporting Technique Using the High-resolution Imaging Sonar

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***Abstract*—When marine disasters occur, it is sometimes necessary for search and rescue dive teams to begin rescue and recovery efforts, even before a complete assessment of the underwater safety situation can be conducted. This makes the job of the Coast Guard personnel in charge of these types of operations very risky. In order to alleviate this type of risk and to be able to operate safely in affected areas, it is desirable for the divers to have as much prior knowledge of the physical and spatial aspects of the area as possible. Furthermore, being able to present this information rapidly in a visual manner is critical for the divers in order to able to clearly understand and quickly interpret the information being presented. This paper will discuss a newly developed optimized search and diver support technique, which utilizes high-resolution forward-looking sonar to allow Coast Guard personnel to improve the accuracy of the search operation, while also increasing the efficiency and safety factors involved in these types of operations.**

Keywords— forward-looking sonar; sonar imaging; underwater search operation; diver support technique

I. INTRODUCTION

Once marine accidents or tsunami disasters occur, Japan Coast Guard promptly send search and rescue teams to the accident scene or the stricken area and begin rescue and recovery effort. Particularly, underwater search and rescue are required the emergency in terms of lifesaving. This operation is very severe and risky since divers cannot help carrying out diving search even if the underwater situation is uncertainty. In order to reduce this type of risk and to be able to operate safely in affected areas, it is desirable for the divers to have as much prior knowledge of the physical and spatial aspects of the area as possible. Furthermore, it is a key point to provide the above information quickly and visually at the scene. In this paper, we develop a newly optimized underwater search supporting technique using the high-resolution imaging sonar [1] (forward-looking sonar; indicates FLS in the following) to allow Coast Guard personnel to improve the accuracy of the underwater search operation, while also increasing the efficiency and safety factors involved in these types of operations.

In recent years, Model Sonic 2024/2022 have been developed by R2Sonic as a multibeam echo-sounder for measurements of depth and seafloor topography in shallow water and becoming the mainstream for hydrographic survey. These models have the features of high resolution, small size and lightweight, thus easily portable. The R2Sonic multibeam echo-sounder have also very unique capability that is switchable between multibeam and FLS mode. The FLS is basically the same theory of operation as the multibeam echo-sounder though the direction of the transmission beam and measurement procedure is somewhat different. Recently each of Regional Coast Guard Headquarters of Japan Coast Guard has been equipped with the R2Sonic 2024 and 2022 as multibeam echo-sounders. Sonic 2024 cannot use as FLS because they were installed on the bottom of the survey vessels. However, Sonic 2022 which were installed with over side mounting on the small launches or chartered boats is easy to change the direction of the sonar head from downward to forward. And it works as FLS once its FLS option lock is released. Specifications of R2 Sonic model 2024/2022 deployed in each of 11 regional headquarters of Japan Coast Guard is shown in Table I.

On March 11, 2011, we Japanese experienced the tsunami disaster accompanied with East Japan great earthquake [2, 3]. Japan Coast Guard immediately carried out the search and rescue of the missing persons with utmost effort and 360 people were saved by them. Afterwards, a number of rescue teams have been put around the coastal area where there were many missing people, and 395 corpses were contained by concentrative and continuous diving search. However, according to the divers engaged in diving search, these operations were greatly hampered by the following reasons; 1) Vastness of the search area, 2) Muddy sea water, 3) Enormous

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TABLE I. SPECIFICATIONS OF R2 SONIC MODEL 2024/2022 DEPLOYED IN EACH OF 11 REGIONAL HEADQUARTERS OF JAPAN COAST GUARD.

	SONIC 2024	***SONIC 2022***
Frequency	200 - 400 kHz	200 - 400 kHz
Max. range	500 m	500 m
Max. swath angle	160 °	160 °
Beam number	256	256
Horizontal beam width	0.5 °	1.0 °
Vertical beam width	1.0 °	1.0 °
Pulse width	10 µs - 500 µs	10 µs - 500 µs
Deployment place	7 survey vessels (twin type)	Each of 11 regional headquarters
Equipment condition	Installed beforehand on the bottom of the vessels	Installed on the board of launches with the mounting hardware
FLS Mode	Unavailable	Available when FLS option lock is released
Total amount	7	11

amounts of debris, 4) Fatigue from long diving. The best way to solve these problems would be to realize an underwater search and rescue operation by utilizing the high-resolution imaging sonar (FLS) effectively. In addition, large-scale tsunami disaster such as the East Japan great earthquake simultaneously arises in the wide area. In case of such a great disaster, it is required to work on underwater search and rescue at the same time in many disaster areas. For meeting this kind of situation, it is necessary to set up several equipments beforehand with the prediction of the emergency. But it is not realistic to prepare the expensive equipments for the great disaster that is unpredictable. It is the most rational to get ready for disaster from the equipments which use regularly.

From the deployment circumstances of the R2Sonic multibeam echo-sounder in Japan Coast Guard mentioned above and lessons learned from the East Japan great earthquake disaster, we have decided to develop the underwater search supporting technique by using the R2Sonic 2022 effectively as FLS newly delivered to the 11 district headquarters.

II. WHAT IS THE SUPPORT TECHNIQUE TO BE REQUIRED FOR UNDERWATER SEARCH OPERATION?

In the operation of underwater searching, it is considered that the following input of advance information and support function to divers will link to the underwater diving activity with safety and certainty.

- The certain information whether the target really exists or not in the water
- The correct position information of the target in the water
- The true image of the target in the water and the information of entire situation
- The wide area topographic image of the search area
- The logistic support function for diving search with safety and certainty

As the first stage, therefore, we have decided to develop the special mounting hardware for survey launches to install the R2Sonic multibeam echo-sounder and the elemental software necessary for the underwater search and rescue operations.

A. *The special mounting hardware for survey launches*

Design and trial manufacture of the special mounting hardware to fix the R2Sonic 2024/2022 for survey launches were carried out. It was required simplicity and easy handling as possible for the correspondence to the urgent case. Currently, we can perform the assembling of the mounting bracket to over-side installation within two hours. It has a simple function which can change only the tilt angle by manual. The aspects that the Sonic 2024 was equipped on the board of the survey launch by the special mounting bracket produced at this time is shown in Fig. 1.

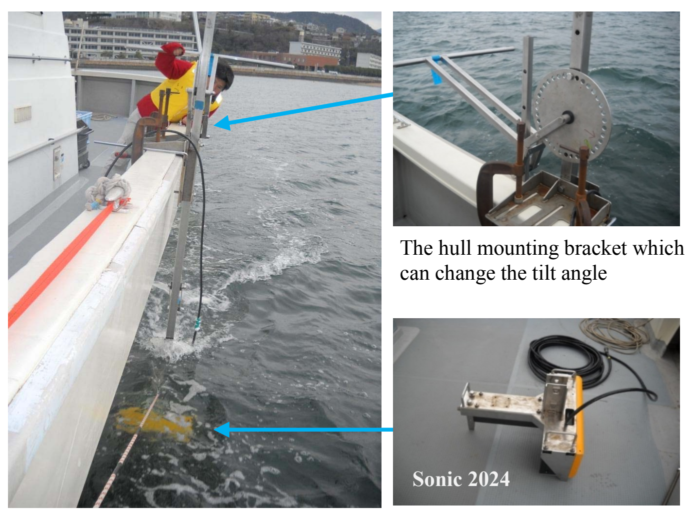

Fig. 1. The forward-looking sonar (R2 Sonic2024 multibeam echo-sounder) equipped on the board of the survey launch by the special mounting bracket.

B. The additional function of software for underwater search operations

In order to support the underwater search operation of Japan Coast Guard effectively, not only acquisition of the high-resolution acoustic image by FLS but also the development of the additional function of the software becomes necessary.

1) The real-time function at underwater searching

- The indication of the sonar image on the marine chart
- The indication of the position information of the target
- The preservation and calling up of the sonar image and the position information of the target
- The divers tracking on the sonar image on the logistical support

2) The post processing function

- The mosaicing of the seafloor image
- The labeling of the underwater objects
- The measuring and indication of such as a shape and size of the underwater objects

III. THE OPERATIVE TEST IN THE ACTUAL SEA AREA

We have carried out the field test in the Kure Bay of Hiroshima by equipping the Sonic 2024/2022 on the training boat of the Japan Coast Guard Academy. The purpose of the test is the following three points; 1) The operation check of the mounting bracket produced, 2) To check the maximum detection range as FLS, 3) To acquire the sonar data for development of the additional function of software. We used the Sonic2024 with FLS owned by TOYO Corporation and the Sonic2022 (temporary release the FLS option lock) owned by the sixth Regional Coast Guard Headquarters. Furthermore, both of the position and direction information were acquired by POS/MV with a sonar image. As an example of the results, the sonar image obtained by Sonic2024 around the Urume Island near the Coast Guard Academy is shown in Fig. 2. It is found that a large number of artificial reefs came out. During the test, the sonar image close to the actual was obtained in real-time animation on the shipboard unit.

IV. DEVELOPMENT OF THE ELEMENTAL SOFTWARE FOR THE UNDERWATER SEARCH OPERATION

In elemental software required for the underwater search and rescue operations, we made development with focus on three points as follows. And we have checked the function of the software by using the sonar data of 2024/2022 acquired in the actual sea area.

A. The indication function of the sonar image on the marine chart

When we search the underwater in the wide area, it is important to know which part of the sea area now we search by the sonar. It is also indispensable to confirm whether survey is on schedule or not, and to know the position information after having discovered the target. Then, we overlaid the sonar image on the marine chart or the aerial photograph of the sea area based on the position and the direction information. An example is shown in Fig. 3, where we have superimposed the sonar image by Sonic2024 upon the aerial photograph.

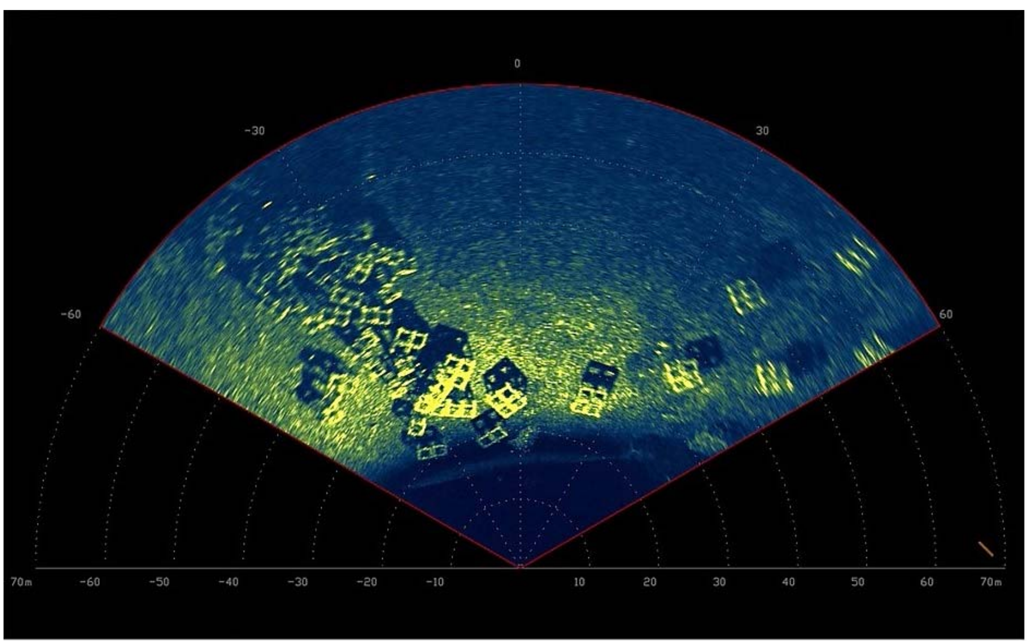

Fig. 2. An example of the sonar image obtained by Sonic 2024 around the Urume Island. It is found that a large number of artificial reefs came out. (Frequency is 400 kHz, maximum range is 70 m, and water depth is around 20 m).

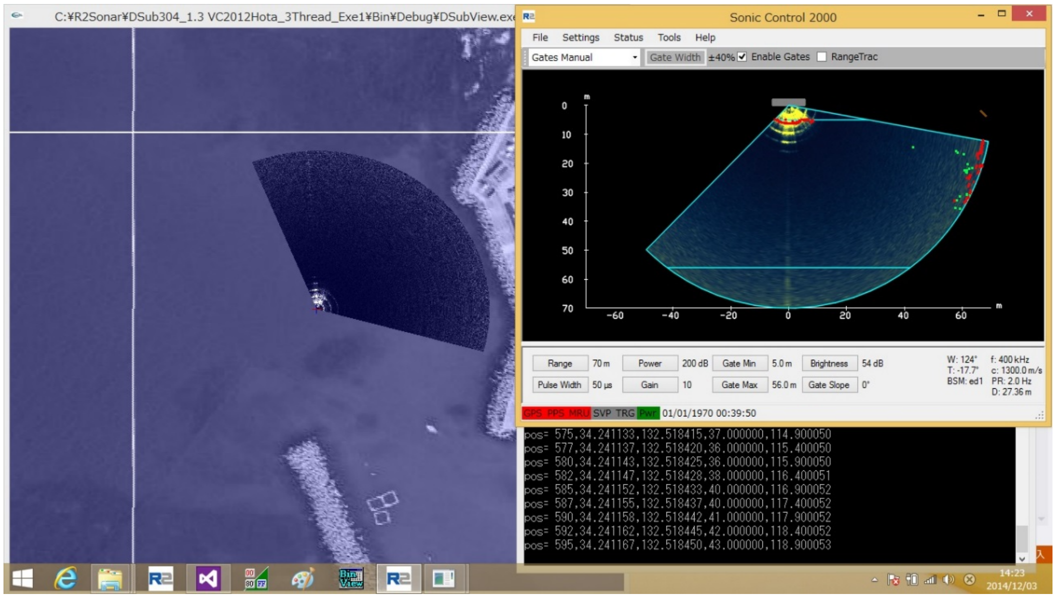

Fig. 3. Monitor display at the underwater search operation by Sonic 2024. (a) Left: The sonar image superimposed on the aerial photograph. (b) upper right: Sonic control screen. (c) lower right: Position and heading information from POS/MV.

This function enables us to search the underwater while checking the own position and the line on the marine chart or the aerial photograph. Therefore, it becomes useful for finding and capture of the target for both a ship operator and a search operator.

B. The making function of the mosaic image for the wide sea area

It is important for the rescue divers to grasp the entire situation when underwater debris scatters over the wide area. Then, the sonar images were superimposed as a mosaic and broad swath of search chart was produced [4]. The method is as follows. Firstly, the water column in the sonar image was removed. After that, the part in which the reflection strength from the seabed becomes a maximum was automatically selected and the constant strength width was fixed in every acoustic beam of 256 (a part shown with an arc-shaped band in the sonar image of Fig.4). Then, the mosaic image was made by superimposing these parts. As an example, a mosaic image made from the images with a large number of artificial reefs obtained near Japan Coast Guard Academy (Fig.2) is shown in Fig. 4. This function enable us to grasp the prospect

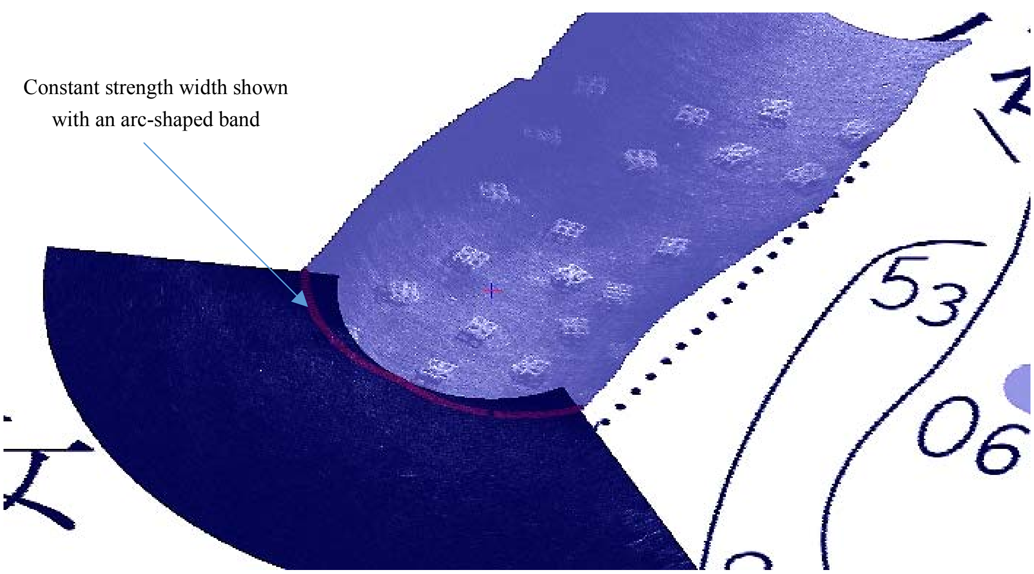

Fig. 4. The mosaic image made from the 2024 sonar images with a large number of artificial reefs obtained near Japan Coast Guard Academy (Fig.2).

of search sea area as a background beforehand, and it is expected that the search and rescue operations by divers are carried out safely and surely. Though it is the post processing function at present, making of the mosaic image in the real time is a future goal.

C. The logistical support function of the underwater search divers

One of the most important characteristics of FLS is that the forward underwater situation can be obtained as a real-time animation even if a ship is a stationary state. This is available as a logistical support function from the ship when the divers perform underwater search and rescue. Fig. 5 shows the sonar image obtained by Sonic2024 where two divers were diving forward. It is found that direct reflections from two divers appeared in water column of the front side. In addition to this, the shadows of the divers also appeared clearly on the forward seafloor. However, many reflections from reefs and bottom of the sea rising (for example, sand waves were indicated in Fig.5) are appeared elsewhere in the sonar image. For operators in the support vessel who do not usually get used to a sonar image, it is hard to distinguish between divers and these reflections [5]. Therefore, we try to develop that only the diver passing underwater is extracted and display it distinguishably on the sonar image. It is under development right now. If the diver tracking capability is available, it is possible to prevent to lose sight of the diver in the water even if the operator who does not familiar with the sonar image.

V. CONCLUSION

In order to improve the accuracy of the underwater search and rescue operations, while also increasing the efficiency and safety factors involved in these types of operations, we developed a newly optimized underwater search supporting technique using the high-resolution imaging sonar (FLS). Concretely, the special mounting hardware for survey launches to install the R2sonic 2024/2022 and the elemental software necessary for underwater diver support have been developed. And we have checked the function of the software using the sonar data of 2024/2022 acquired in the actual sea area. In the future, integration and installation of the elemental software to PC is carried out as an underwater search supporting system and verification and improvement will be attempted through the operative test in the actual sea. Furthermore, we also really apply our system to the accident and matter which arises in the spot sea area in districts of Japan Coast Guard and the more practical effectiveness as an underwater search supporting technique will be confirmed.

It seems to be very significant to establish these techniques as anti-disaster and reconstruction control technology considering that Tokai, South-eastern Sea and Southern Sea earthquake and a large tsunami disaster accompanied with them will occur at the high probability within recent years in Japan.

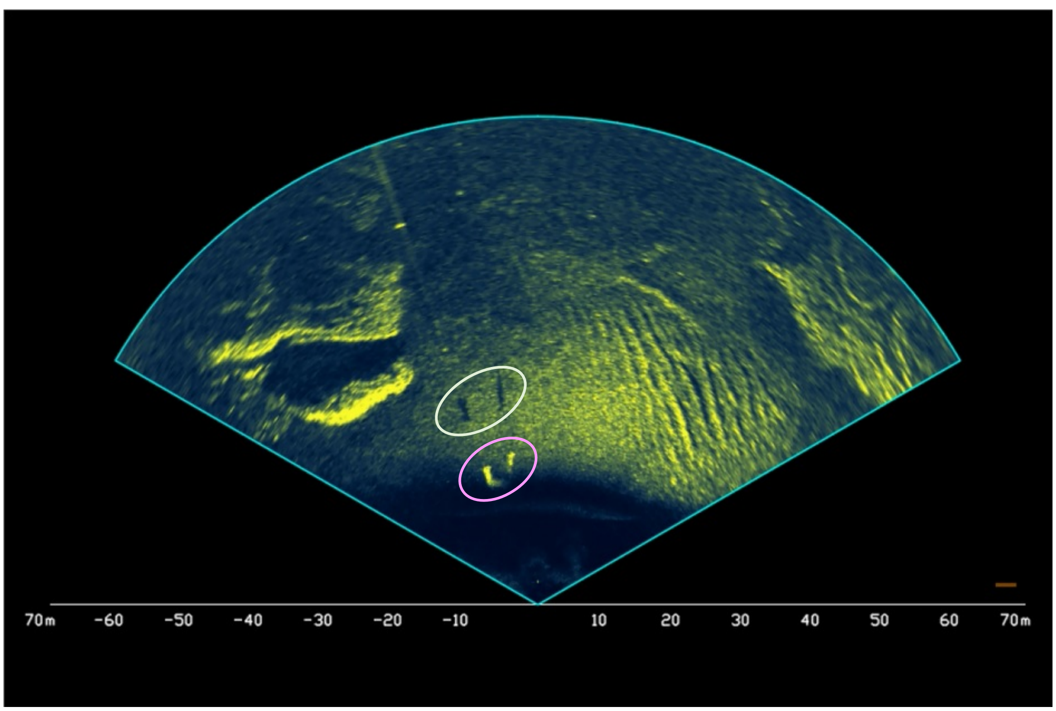

Fig. 5. The sonar image of Sonic 2024 where two divers were diving forward (frequency is 400 kHz, maximum range is 70 m, water depth is 15 m). Direct reflections from two divers appeared in the water column of the front side and the shadows of the divers also appeared on the forward seafloor.

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