Harbor Monitoring Network System for Detecting Suspicious Objects Approaching Critical Facilities in Coastal Areas

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Abstract

The proliferation of weapons and the rise of terrorism have caused us to face various threats that were hitherto inconceivable. By focusing on sensor technologies, NEC's Radio Application, Guidance and Electro-Optics Division is developing and proposing surveillance systems in the public safety domain to support the implementation of the "safe and secure society." This paper introduces some of the imaging technologies, including the downsizable uncooled infrared (IR) sensor technology and one for an underwater surveillance system for monitoring suspicious underwater incursions that are hard to detect. We also discuss aspects of the integrated collaboration needed in applying these technologies as well as the types of major conceivable threats and the sensors that will deal with them.

Keywords
underwater surveillance, acoustic sensor, diver, active, passive, erroneous detection, MHT, degree of threat, integrated collaboration, IR sensor, uncooled

1. Introduction

About 70% of the earth's surface is occupied by the sea, where many objects and humans are to be found. The coastal areas have many key facilities that support the social infrastructures such as transportation facilities, energy facilities and various installations. Moreover, the seas around the world are places where various issues occur, such as disputes regarding resources or boundaries, smuggling, fish poaching and illegal immigrants. In addition, changes in global conditions such as are caused by the proliferation of weaponry and the rise of terrorism are currently exposing the sea to risks and other threats that have been previously unimaginable. Such issues are forcing the countries of the world to improve the preparation of countermeasures. In Japan, too, the government and commercial companies is reviewing the crisis management systems of key infrastructures such as those pertaining to power plants, airports and harbors as well as urgently adopting countermeasures to deal with these issues.

For example, the measures taken for land security include intruder surveillance using radar and cameras, entry/exit systems using biometrics and IC cards, and checks on suspicious individuals using various surveillance devices. While land security is being enhanced as described above, countermeasures on the sea, particularly with regard to underwater intrusion surveillance, are not so advanced and are considered to be responsible for security holes. Since light waves and radio waves have difficulties in penetrating deep water, and also because the means of surveillance such as by radar and cameras are inadequate for such a task, the need arises of using sound waves to identify the threat sources. Particularly, for a country enclosed by the sea, as is Japan, the key facilities in the coastal areas should be well protected against threats both from the surface of the sea and underwater as well as guarding against those from the landward direction. NEC technologies include a compact uncooled IR imaging sensor as a land surveillance technology as well as sensor technologies for underwater surveillance, which is often regarded as a difficult task. Moreover, NEC also possesses highly accurate signal/information processing and information integration/display and communication technologies that feature advanced user interfaces. We combine these technologies in order to provide surveillance systems to support the security and safety of society. In this paper, we introduce both underwater and land surveillance sensors and discuss their system integration and linkages.

2. Land/Underwater Surveillance Systems in Coastal Areas

People often say, "prepare for threats both from the land and sea". Nevertheless, there exist very many kinds of threats, and moreover, the locational conditions and surveillance systems of key facilities vary significantly. As a result, the configuration and scale of the required sensors and systems also vary widely.

Consequently, the system for each key facility should be built individually to match that facility's needs. We examined the major assumable threats and based on this idea we proposed suitable sensors to function as counter measures (**Fig. 1**).

(1) Countermeasures against water-surface moving objects

When the threat is caused by a target object that is intruding the monitored water surface area at speed, for example a high-speed craft, it must ideally be detected at a certain distance in order to provide an acceptable alert. The first optional counter measure for such a target object is to use sea-based radar, but there are some small target objects such as semi-submersibles and water scooters, that are difficult to detect by radar. For such target objects the passive acoustic sensor is effective. This device detects the engine sound or other sounds emitted by the intruder. The passive acoustic sensor can calculate the direction of the intruder based on the received acoustic data. If a database of acoustic spectra of various objects is compiled, it is also possible to identify the object by matching the received acoustic data with the database.

For an operator in a surveillance room to identify a water-surface object that has been detected by the sensors, both optical and IR cameras are needed. A combination of various sensors as well as suitably linked information enables warnings and surveillance of sea-surface moving objects, without any of them being missed or overlooked.

(2) Countermeasures against underwater moving objects

Surveillance of underwater moving objects such as a diver or an unmanned underwater vehicle (UUV) is not able to use radar, optical cameras or IR cameras. However, the active acoustic sensor can plays an important role in this kind of surveillance.

This sensor transmits acoustic waves underwater, receives sound reflected from the object and obtains the distance and direction of the target object. Installing several sensors on the sea bottom, quays and/or piers can enable the detection of underwater moving objects.

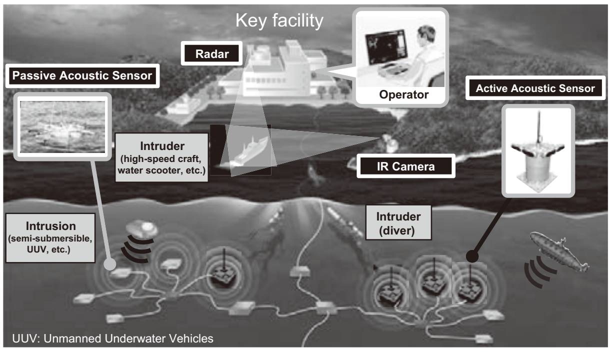

Fig. 1 Image of a harbor monitoring network system.

As described above, the harbor monitoring network system can be built by combining various sensors according to purpose and application[1)] as requested by users. Among the sensor technologies introduced above, those owned by NEC include the active and passive acoustic sensors for underwater use and the IR sensor for water-surface use. The abilities of both of these sensors are highly evaluated in the defense field. In this paper, we introduce the active acoustic sensor and the IR sensor in sections 3 and 4 respectively.

3. Technologies Supporting the Active Acoustic Sensor

Fig. 2 is a block diagram that shows the processing order of the stages performed by the active acoustic sensor, from acoustic data reception to target object detection, display and alert.

The active acoustic sensor transmits and receives sound using multiple piezoelectric sensor elements (hereafter referred to as "elements"). The sensor is composed of elements arranged in specified arrays and it converts the acoustic signals received by the elements into acoustic pressure level data per direction and per distance using directivity syntheses[2)].

The computer aided detection (CAD) processes the acoustic data obtained by the signal processing in order to detect the sounds that may be reflected from the target object. As the detection consists of simple acoustic-pressure level threshold judgments, a very large number of erroneous sounds are detected besides the sound reflected by the target object. **Fig. 3** shows an example of such detections in an at-sea test for detecting a diver swimming at a depth of 10 meters. All of the white spots on the map are detected target objects. These include a large number of erroneous detections caused by multiple acoustic reflections from the sea's surface and the seabed and by various noises.

In order to reduce the erroneous detections, acoustic data is examined by threshold judgments and also by other judgments including; signal continuity, dispersion of the direction and the Doppler effect of the target object's transition. Erroneous detections can thereby be more readily distinguished from the echoes reflected by the target object. An example of the results

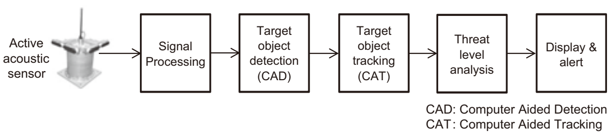

Fig. 2 Data processing blocks of active acoustic sensor.

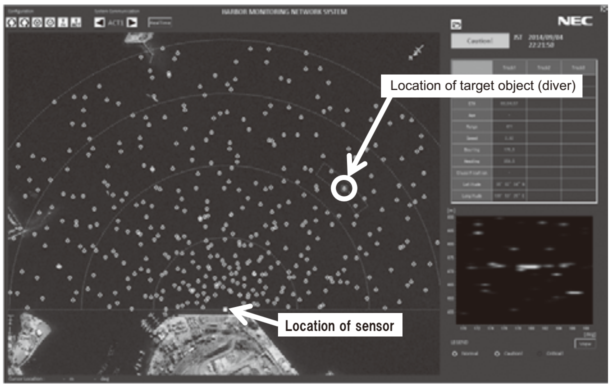

Fig. 3 Result of detection by simple threshold judgments.
(White spots on the map indicate both the target object and erroneous detections.)

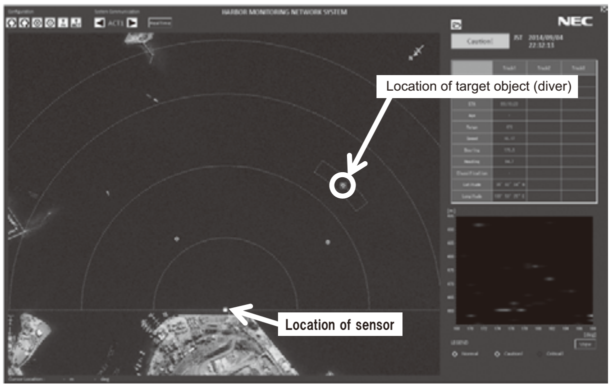

Fig. 4 Effects of the detection result improvements.
(The white spots on the map indicate the target object as well as erroneous detections.)

of this process is shown in **Fig. 4**.

Improvements in the detection results as shown above can reduce erroneous detections from some hundreds to only a few.

However, it remains a fact that the detection results include erroneous detections. The process for reducing these further and tracking the real target object is performed in the next step by computer aided tracking (CAT). In the CAT process, we focus on the fact that the target object detection results can be continuously obtained while noise detection results are only obtained randomly. With regard to this issue, we found that tracking the target object is possible by means of filtering, using the multiple-hypothesis tracking (MHT) algorithm[3]. Once tracking of the target object becomes possible, the threat level of each target object is calculated via threat level analysis based on the location and movement information of the target object. The data of each target object such as its position, movement information and expected arrival time at a key facility is then displayed, and a warning indication or alarm tone according to the threat level is generated. The threat level is defined according to the operational policy.

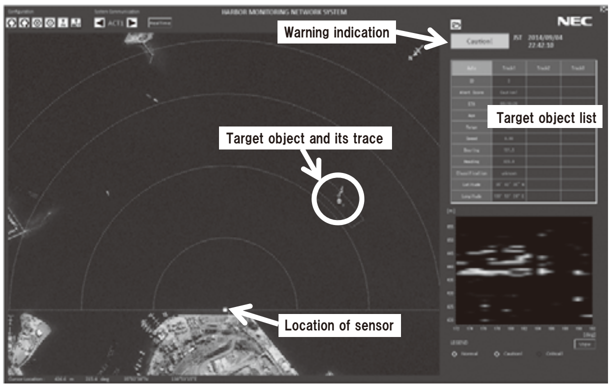

Fig. 5 Example of screen display.
(A diver swimming at a depth of 10 m is approaching from the 45° right direction.)

Fig. 5 shows an example of the result of an at-sea test conducted near a quay in Shizuoka Prefecture, Japan, in August 2013. The target object is a diver who is approaching the place where a sensor is located. The diver dives to a depth of 10 meters from a small boat that remains at 500 meters distance in the 45° right direction from the sensor. The approach of the diver should be confirmed on the display. As a warning is indicated accordingly, the test confirms the effectiveness of the active acoustic sensor.

In the future, we will make the sensor capable of capturing target objects at greater distances and with higher accuracy by tuning and improving the signal processing and auto tracking functions.

4. Technologies Supporting IR Cameras

In the coastal areas, in addition to detecting the presence of target objects, identification of small craft and humans among the detected objects is also important. This section deals with imaging examples using NEC's uncooled IR camera, which is effective for the surveillance of sea-surface targets. **Fig. 6** is an IR image shot using a telescopic lens. It shows that a large ship at about 2.5 km distance can be clearly identified and therefore the IR sensor is suitable as a means of satisfactorily performing coastal surveillance.

Fig. 7 shows the comparison of visible-light and IR cameras in a night scene with slight rain. The IR camera convincingly captures the persons in the dark and unilluminated areas, as well as those that are not recognizable due to the strong reflection of the illumination light source. The IR camera is therefore shown to be effective for day and night coastal surveillance without the need to rely on illumination.

We at NEC are developing the uncooled IR sensor, which is one of the key components of the IR camera. **Fig. 8** is a photograph of an element of the uncooled IR sensor shot by a scanning electron microscope (SEM). In order to show the

Fig. 6 IR camera image of a ship at 2.5 km distance.

Fig. 7 Comparison of visible-light camera (left) and IR camera (right).

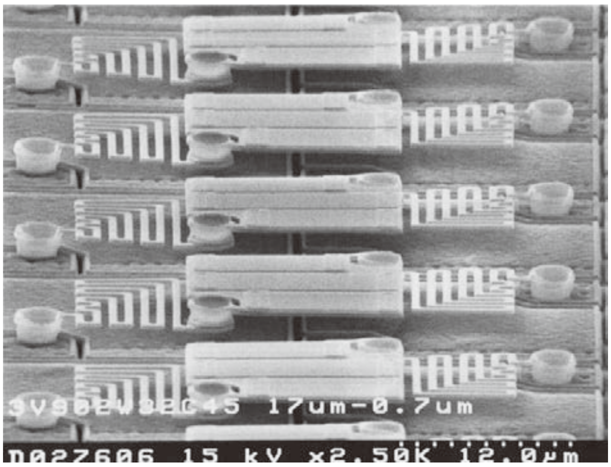

Fig. 8 Construction of uncooled IR sensor element[4].

construction of the element clearly, the membranes of the adjacent elements are removed in the photographs. This element employs a fine 3D structure and high-sensitivity materials to convert weak far-IR rays into electrical signals and produce a high-sensitivity image. We are currently continuing development aimed at achieving size reduction.

5. Conclusion

In this paper, we introduce a harbor monitoring network system for the surveillance of threats caused by suspicious intrusions into key facilities of the coastal areas and discuss suitable sensors for supporting the system. Particular focus is directed to the active acoustic sensors and IR camera technologies. In order to improve security, it is important to combine optimum sensors according to the nature of a target threat with the locational conditions of each facility. NEC is capable of providing highly reliable, flexible monitoring systems that can cover all situations from underwater to on land by employing various appropriate sensing technologies. Systems built in this way may be applied in disaster prevention as well as for security purposes. We also believe that the information collected via such systems can be deployed for other purposes by utilizing cloud technology, including for the prediction and prevention of unwelcome events. Such systems may also take advantage of big data that can be gathered via the cloud technology.

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