RESEARCH ON TECHNOLOGY DEVELOPMENT FOR FISHING VESSELS IDENTIFICATION BY SATELLITE REMOTE SENSING - STATUS IN DEVELOPED COUNTRIES AND JAPANESE PATROL SYSTEM -

T. MORIYAMA[1], H. TAMEISHI[2], J. SUWA, S. KANNO, Y. SUGIMORI[3]

Abstract

Current status and trends ov vessel detection, identification technology development and application in major countries were surveyed. According to increasing the number of foreign poaching and suspicious vessels intrusion into EEZ, patroliling by vessel and airplane does not satisfy the needs because of narrow coverege and observation frequncey. The satellite monitoring by SAR and optical sensor has been studied and partially used, but there are several disavantages such as observation frequncy, geometric occuracy and weather dependence to adopt for operational use. This paper describes an optimize system for vessel detection and identification by combining patrolling vessel, airplane and satellite.

Keyword: vessel identification by satellite image, IKONOS visible image, JERS-1, Synthetic Apature Reader

I. Introduction

Fishing vessels patrol system is becoming much important subject for the fisheries because of increasing the number of foreign poaching inside Japan's 200- nautical miles economic sea zone. Especially in the East-China Sea, it has been expected to adopt a countermeasure to meet the fact of increasing the number of foreign poaching. Currently, fishing vessels patrol has been done by surveillance vessel owned by the Fisheries Agency of Japan, but this method is not sufficient and effective to cover large area of sea, therefore the development of another kind of watch system such as satellite based monitoring has been expected.

There are two examples for fishing vessels patrol using satellite remote sensing. The first is "Ship location and moving speed detections using JERS-1 OPS stereo pair data" by RESTEC: Remote Sensing Technology Center of Japan, and the 2nd is, " Technology development for the fishing vessels management using DCS(Satellite Data Collection System)" by JAFIC: Japan Fisheries Information Service Center. Even though there are several experimental results, it should be said that no practical outputs can be reflected to develop the operational fishing vessels patrol system by remote sensing. This paper describes the result of the investigation of fishing vessels patrol system development and its applications to the selected countries, and also describes the result of the preliminary design study for the future Japanese patrol system. Based on the result of the investigation, following two issues are identified as major restrictions to establish system.

(1) Satellite Observation Period

Long satellite repeat period, narrow swath width and limited pointing capability are the

1) Remote Sensing Technology Center of Japan.
2) Japan Fisheries Information Service Center.
3) Center for Remote Sensing and Ocean Sciences, the University of Udayana.

major obstacles to achieve frequent observation in the specific region. Current each earth observation satellite owns repeat period (from 16 to 44 days), and swath width (from 15 to 60km for high resolution) and pointing capability (includes operation conflict).

(2) Data distribution time from the observation

Usually it takes two to seven days to get the data from the data provider. Only in case of urgent request, it takes several hours from the observation but with additional expense. In case of Japan's ADEOS-II, fishing vessels-aboarded DTL system can get simultaneous data. But this service is limited and the resolution (250m) may not satisfy for the patrol.

These two subjects should be solved in order to establish the operational patrol system, in parallel with the algorithm development. Recently, several high resolution satellite data can be obtained and combination of multiple satellites could be achieved much more frequent observations. On the other hands, simultaneous/quasi simultaneous time data use needs user oriented system. Meteorological data use for weather forecast is one of the typical examples. Of course, JMA has their own system, but also there are many private sectors developed the systems for weather business. Frequent observation and real/quasi real time data use is essential to use satellite data for fishing vessels patrol system.

II. Development of the satellite based fishing vessels patrol technology in foreign countries

The system survey study was done on foreign fishing vessels patrol system in UK, Norway and Canada. The survey focused on following five points.

1. Survey on regulation authorities
2. Survey on satellite use (Earth observation, telecommunications satellite, etc.)
3. Data survey on Earth observation satellite use
4. Survey on data processing and analysis
5. Survey on patrol information notification

Table-1 summarized the results of the survey. This result indicated each country has enough potential of technology to adopt satellite data to fishing vessels patrol. Each country has its own attitude to fulfill the work and this comes out the difference of practical way of patrol.

In case of UK,most of the foreign fishing boats operating in the UK national ocean territory, belong to some European countries and planned to aboard standardized ship location notice system under the framework of European Commission in the future. Therefore, UK approach to the fishing vessels patrol system is targeting to establish patrol location information system using GPS and satellite telecommunication, and less important to

Table-1 Summary of major countries activities for fishing vessels patrol by satellite remote sensing.

Nations	Current status and future plan
United Kingdom	Using GPS and satellite communication to find exact location of illegal fishing vessels. Enough potential of satellite remote sensing data use for fishing vessels patrol in the future.
Norway	Almost the same approach as UK. Research on fishing vessels detection technology by remote sensing is underway.
Canada	Own pilot system for fishing vessels patrol by remote sensing and system evaluation is underway. GPS and communication system are also developed and evaluated. Combined system will be used in the future.
United States	Fishing vessels patrol system by GPS and satellite communication has been developed and evaluated. Future remote sensing use for this purpose is not clearly determined.

adopt another methodology such as satellite remote sensing. Current, UK policy of satellite use, is acquiring location information of potential illegal fishing operation, and transmit to patrol vessels and/or airplane. In this type of application, obstruction to the location information system recognized as key issue to be solved. For this, currently UK is surveying to detect intentional illegal signal to make information system stoppage, and if in case of finding any disturbance, strict punishment will be given such as cancellation of fishing license. UK also has the scope to develop technology to identify illegal fishing vessels by satellite remote sensing in parallel with GPS application. In case of Canada, it has decided to make mandatory aboard location notification system to every Canadian fishing vessels, and giving punishment to those fishing vessels does not transmit the location signal intentionally. The project is underway and the Canadian case is expecting one of the advanced method to be followed. Table-2 shows the typical case of disturbance to fishing vessels location notification system.

III. Study on satellite remote sensing sensors for fishing vessels patrol

By reflecting the result of survey on future fishing vessels patrol system, it can be determined desirable satellite aboard remote sensing sensors. For the first step, characterization of satellite remote sensing for the fishing vessels patrol is investigated.

(1) Characterization of satellite remote sensing for the fishing vessels patrol

Trends survey of patrol system can be summarized in the following two categories.

a. Type-a: Use of satellite remote sensing
b. Type-b: GPS, communications satellite and ALGOS use

Above four countries are targeting type-b, Canada and Norway are planning to use satellite remote sensing in parallel. Obstacles to use satellite remote sensing are identified as follows:

(i) Standardization of GPS location system is necessary and proceeding. This system will be becoming mandatory for fishing vessels patrol
(ii) European Commission (EU) taking account standardization of this system in Europe,
(iii) Type-b is based on the matured technology such as GPS and satellite communications and easy to accommodate with every sort of fishing vessels. On the other hands, it is necessary to develop algorithms to use satellite remote sensing data for classify and patrol vessels.

By the result of UK survey, most of the fishing vessels operating in the UK national ocean territory, are European, and there are very few case out of Europe such as Africa.

Table-2 Typical case of disturbance to fishing vessel location notification system

Items	Disturbance Actions	Description
Suspend system operation, Destruction of system	Stoppage of location signals by suspending the system, or intensively destroy system	Just turning off the power switch Destruction, dump the system It can be detected the stoppage of location signal by watch office, but it is difficult to identify if this comes out intentionally or by accident
Counterfeit location signal	Transmit counterfeiting signal in stead of right signal	It is feasible technically , but difficult to fulfill
Jam radio signals	Transmit jam signals to interference location signal over wide region	Jamming GPS signal happened in the North Sea. It can be achieved rather small power. Tolerance to radio jam should be improved

Table-3 Characteristics of typical patrol system

Watch method	Characteristics
1 Location notification by GPS, DCS	a. Easily collect location and related informationb. b. Frequent communication provides operation status but with higher communication costc. c. Easily damaged by illegal jamming.
2. Detection, identification by satellite remote sensing	a. Wide coverage, continuous monitoringb. b. Special algorithms required for data analysisc. c. Only location and identification information available. Another communication method required to get fishing catch result and ocean data.
3. Watch plane, vessel	a. Narrow area for surveillanceb. b. Matured method for operational use. c. Regulations against illegal operation.

On the other hands, in Japan's case, it is very difficult to establish the framework to adopt the common standard such as the case of Europe by cooperating neighbor countries, because of the complicated political situations. Also it will be difficult to make rule to notice the location by GPS and equivalent method to the foreign operating fishing vessels. Therefore, the satellite remote sensing is expected as the potential method to fulfill fishing vessels patrol around Japan. Table-3 shows the characteristics of patrol system. Each system has its own merits and demerits, so it is recommended to use these system effectively combined.

As shown in the Table-3, by combining these methods, following steps will be suit to Japan's application.

(Step-1) By using satellite remote sensing, acquire the information such as vessels location, moving direction, speed, identification to another type of vessels over the wide range of sea.

Table-4 SAR and optical sensor use for vessels detection

Sensor	Application
SAR	All weather and wide area operational monitoring of vessels detection, location and speed
Optical sensor	Vessel type classification by estimate vessels length, width and deck feature

(Step-2) By using location notification system such as DCS, it could be acquired fishing vessels location and fisheries information.

(Step-3) Combined information 1 and 2, location of foreign vessels, moving direction, speed, vessel type (length, width) can be identified.

(Step-4) Notice the information on characteristics of foreign vessels to patrol plane and vessels.

The important point is well combined system by respecting each characteristics can achieve the mission very efficiently and can give the benefit corresponding to the investment to establish fishing vessels patrol system. By using the system, allocated amount offish catch can be monitoring and foreign illegal fish catch can be controlled. These activities is becoming much more important not only for illegal fishing vessels control, but also for global marine resources preservation.

(2) Satellite remote sensing sensors for fishing vessels patrol

According to the requirement of the vessels detection, higher spatial resolution is indispensable. In general, following two types of sensors are useful for the purpose.

(a) Visible/near infrared optical sensors

(b) Synthetic Aperture Radar (SAR)

Even though there are many sensors can be used for fishing vessels monitoring, only SAR is planned to use. The major reason why the optical sensors are not used for this purpose is the cloud cover. Optical sensors cannot acquire image under clouds and this prevents ship detection. Especially in case of the North Sea and Northern Atlantic Ocean, it is

almost always covered by cloud and cloud free day is only less than 10%. This situation makes optical sensor difficult to use. On the other hands, SAR is conventional of its cloud free and day and night observation capabilities. This does not mean the uselessness of optical sensors. Some developed countries such as France and India (out of the target of survey), they are studying to use high resolution optical sensor for this purpose because of its higher resolution than SAR. Typical resolution of SAR is 10 to 30m, the optical sensor has better than lm resolution. Recently, conventional commercial satellite starts to distribute less than 1 m resolution data to the public. This high resolution capability makes it easy for vessels detection and classification. By combining those two sensor data, it could be achieved much reliable and operational system for fishing vessels patrol system. Table-4 shows the characteristics of SAR and optical sensor used for vessels detection.

IV. Study on development of optimum fishing vessels patrol system

There are two major obstacles to make patrol system operational. These are real / quasi-real time monitoring, and observation coverage.

(1) Real/quasi-real time monitoring

For the monitoring from space, satellite recurrent period and pointing capability is the key. Most of earth observation satellite selecting polar sun-synchronous orbit for whole globe monitoring, and its typical recurrent period is 1 to 46 days. 1 day recurrent period can be achieved by medium resolution (250 to 1000m) with wide swath width. For the fishing boat operations watch, it is required much higher resolution and frequent observation. In order to achieve this, high resolution sensor with pointing capability is very useful, and also multiple satellites use can be achieved frequent observation. Another key parameters are the data processing, analysis and distribution time. Meteorological observation can observe hourly, and processed distributes data in every 1 to 2 hours. This is because of the meteorological satellite operating in geostationary orbit, and can observe 24 hours bases. Of course, this satellite does not have recurrent period such as orbital earth observation satellite. Typical time required from the observation to data distribution is 3 hours to 7 days. 3 hours can be achieved through network connection with operational users. In case of ADEOS-II, launched in December 2002, observation data will be transmitted to Japan Meteorological Agency, Japan Fisheries Information Service Center(JAFIC), and Japan Coast Guard within 3 hours after observation. The data processing time is depends on the accuracy of geometric and radiometric correction, which corresponds to the orbit determination accuracy, can be shorten by using the developed algorithm.

Current and planned earth observation satellites have 15 to 185km swath width. Even though it has pointing capabilities, it is insufficient to cover the whole region of Japan's exclusive economic ocean territory. So it is recommended to select intensive area to monitor frequently. The Japan's fishing vessels patrol system has been studied under the sponsorship of Fisheries Agency, and JAFIC has the responsibility to fulfill with related organization such as fishing vessels regulation authorities. JAFIC will process and analysis satellite data for patrol and distribute to the fisheries regulation authorities. This makes the system interface clear to improve the efficiency. The fisheries regulation authorities can concentrate the work for planning and decision of illegal fishing vessels and order to take action to the patrol vessels.

Major functions of each organization are described as follows

a. JAFIC
   - Vessels detection and identification
   - Calculate vessels location and speed
   - Enlarge and enhance vessels image
   - Processed image data compression
   - Reporting

b. Fisheries Regulation Authorities(FRA)
   - Indicate detected / identified vessels image
   - Overlaying with other information
   - Develop controlling report

c. Patrol Vessels
- Indicate control information
- Taka action to patrol

According to the mission operation scheme, FA (Fisheries Agency), JAFIC and JAXA (Japan Aerospace Exploration Agency) is now cooperating to develop following system:

(Fist Step) Development of fundamental infrastructure

(1) Communications link
a. JAFIC to FRA——0.5 Mbps super relay
b. FRA to Vessel——E-mail

(2) Functions
a. JAFIC——ship detection, identification by using WS
b. FRA————Information indication, Decision support function
c. Vessels——Reception of information from FRA by e-mail

(Second Step) Improve infrastructure and its function

(1) Improvement of communication capability

(2) Development of common use database with FRA (fishing operation information, patrol information, illegal operation status, fisheries license information, weather information, ocean information etc.)

(Their Step) On-line connection with satellite data center

(1) Direct connection with JAFIC and JAXA, other satellite data center

(2) Addition support system to exchange information between JAFIC and JAXA, other satellite center

V. Conclusions

Development and utilizing status of fishing vessels identification by satellite is studied. There are several ways to detect and identify vessels by satellite remote sensing and positioning system such as GPS. The study can conclude that in Europe, GPS is the major method to identify vessels and satellite remote sensing is expected as a complement of this. Among the satellite remote sensing, SAR is the most effective way to use because of

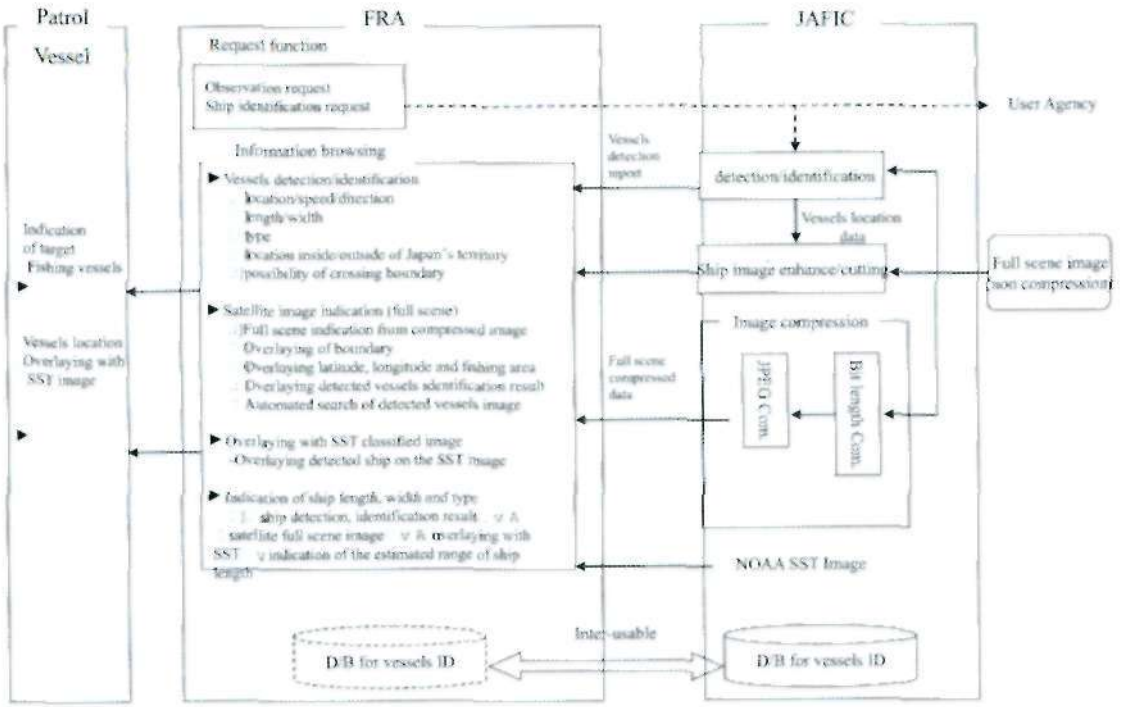

Fig. 1 shows the functional scheme among JAFIC, FRA and vessels.

the all weather capability. On the other hands, for the vessel identification, SAR does not have sufficient spatial resolution so that the high resolution optical sensor is used. The system design for the fishing vessels patrol system has been carried out. The characteristics of the system is the on line, quasi real time based service to the patrol vessel. These kinds of system will be developed by Japan Fisheries Agency for vessel identification.

Appendix-1
Investigation of organizational attitude for fishing vessels control

United Kingdom (UK)

Organization and tasks

UK navy is taking account this roll under the contract by MAFF. Patrol vessels are usually using for this purpose without the case of urgent military operations. The crew belongs to UK navy and well trained for patrol. The airplane belongs to private airline company and conclude contract for this operation. The pilot and crew are also belonging to private company who has license for patrol. The order will transmit to the vessel and airplane by FAX from the patrol division of MAFF. In the future, FAX will be replaced to electrical network.

Satellite use

Instruments for location notification such as GPS signal through INMARSAT are evaluating underway of its usability for fishing vessels patrol. This system is planned to use operationally within a couple of years for fishing vessels over 20m length. European Commission (EU) planning to make this system as a standard among EU countries, and this makes possible for all the vessels aboard the system exchanging data each other. ARGOS is also considering to use in parallel as a compliment of GPS through INMARSAT. It has been planned to transmit not only the location information but also other additional information such as fish catch data, SST, weather and ocean information. This is because the higher network capability is indispensable for the possible expansion of fisheries use.

Remote sensing data use

Remote sensing satellite image has been used for ship monitoring for military purposes, on the other hand, it seems no practical research on fisheries applications. This is because almost all fishing boat in the UK national ocean territory limited to EU fishing vessels, and this does not need to involve advanced technology such as satellite remote sensing. As described in paragraph II, UK has

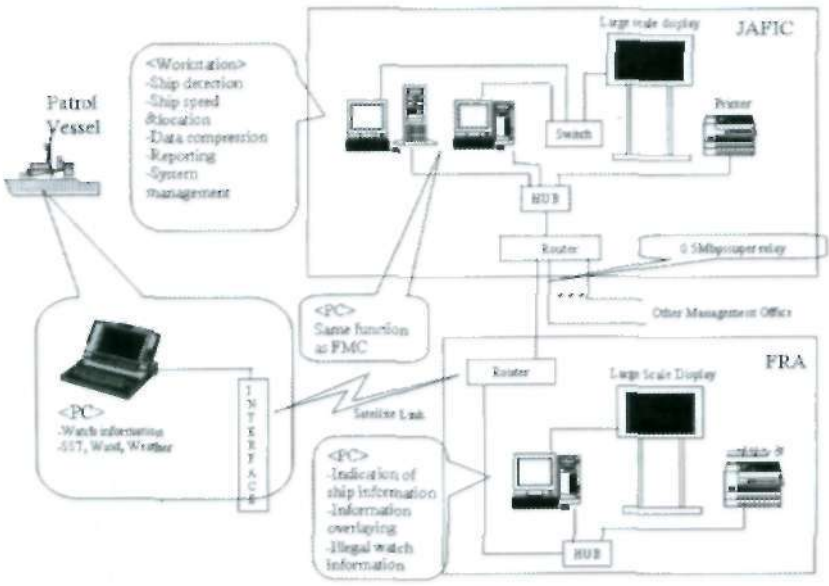

Fig.2 shows the system configuration of patrol system

been using GPS location system and there is no strong driving force to use satellite remote sensing data for this purpose. For the military use, satellite remote sensing is one of the conventional methods to monitor wide area frequently, and the observation data transmit to the UK navy ground station and process the data on an real/quasi real time bases. The processed and analyzed data volume is not so large, the data can be transmitted via FAX and e-mail to the controlling office. In the North Sea, only less than 10% is expected cloud free, so the all weather sensor such as SAR is much more conventional than optical sensors.

Data processing and analysis

Various kinds of satellite remote sensing data processing algorithms and processing software are available on commercial bases, and also some software has been opened to public via web site. The compact and higher performance computer environment makes it easy to use remote sensing data for wide spectrum of applications. The UK uses SAR on RADARS AT and EERS-1 to monitor vessels over the Dover channel for the comparison with ground based radar. The UK leads the technical development and evaluation to use satellite data for vessels monitoring.

Patrol information communications

MAFF order has been transmitted to patrol vessel and airplane by radio and FAX, changing to digital communication such as e-mail. These information has been used for military purposes, but it is also possible to use fishing vessels patrol only just transmit same information to fisheries regulation authorities via internet.

Norway

Organization and tasks

Fisheries Directorate is in charge of fishing vessels patrol. Coastal Guard has a responsibility for admittance of foreign vessels.

Satellite use

Monitoring illegal oil spill is in operational use, but fisheries application is still in research phase. Monitoring of the oil spill is targeting offshore oil field in the North Sea, spills from oil tankers and illegal cargo ship. The information taken by SAR (such as RADARSAT, EERS-1) is transmitted to Environment Controlling Office. Similar applications by using RADARSAT and EERS-1 for fishing boat operations watch has been studying by NDRE, the agency belongs to Defense Agency.

Remote sensing data use

The study and applications of ship detection by using SAR data is for military use. Some customized system can be purchased by commercial sector because the software and system are fully standardized and customized. Even for the military use, remote sensing data is the compliment to the current monitoring system and still not fully operational. The software installed W/S are two different functions, those are wake detection by RADARSAT and ship detection by EERS-1. It has to be noticed that sea ice monitoring and illegal oil spill monitoring are in operational.

Data processing and analysis

The software and analysis system becomes matured for EERS-1, but not still sufficient for RADARSAT. It is expected improving system for farther applications. The target sensors are current EERS-1 and RADARSAT, but needed to expand the capacity for ENVISAT and ALOS.

Patrol information communication

Not used for fisheries application, but for sea ice and oil spill. These data are captured and processed at the ground station, and transmitted to regulation authorities as a digital data via telephone line

Canada

Organization and tasks

DOF (Department of Fisheries) is in charge of patrol. DOA is a government agency covers local coast guard. DOF has its own vessels for patrol. DOF concludes contract with private airline to hire the plane with pilot and engineer who has a license for patrol. The order for patrol sends to vessel and/or

airplane directly from DOA via radio and FAX.

Satellite use

Fishing vessels patrol system using GPS and INMARSAT is underway of its system evaluation through experiment. The system is targeting in operational within a couple of years, for specific fishing vessels which has more than 20m length and authorized fishing. In parallel with this system, study on remote sensing using RADARSAT is underway. In the future, these compliment system is planned to operational. GPS location system can identify illegal fishing vessels that has no location signal, and remote sensing can detect the ship. Optical sensors will not be used because of the inability of all weather, day and night monitoring.

Remote sensing data use

Direct receiving of the satellite data and real time bases data processing can be carried out by the W/S at the ground station. Current system needs more than 1 hour from the reception to processing, but next system will be less than 1 hour.

Data processing, analysis

Most of all the application software for ship monitoring, illegal oil spill monitoring, and sea surface wind monitor have been developed and installed to the W/S at ground station. This over-all system is under way of its functional evaluation for operational use. The system is highly sophisticated than the same system of UK and Norway

Patrol information communications

The routine operation is still not in the phase, **but** the system itself is almost accomplished for operational use. Remote sensing data are captured and processed at ground station are distributed to Controlling Office via FAX and/or communication link. The data volume directly concern to the controlling is very small, it is sufficient to use conventional communication links.

Reference

Eldhusct, K : "An automatic ship and ship wake detection system for space-bone SAR image in coastal region", IEEE transactions on Geoscience and Remote Sensing, vol.34, No.4, pp.1010-1019, 1996.

Flett, D., Youdcn, J., Davis, S., Randell, C, Arkett, M : Detection and discrimination of iceberg and vessels using RADARSAT Synthetic Aperture Radar", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Foulkes, S. B., Booth, D.M :"Ship detection in ERS and RADARSAT imagery using a self-organising Kohonen Neural Network" , Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Lin, L. L., Kwoh, Y. L., Khoo, V :Ship and ship wake detection in the ERS SAR imagery using computer-imaged algorithms", Proc. International Geoscicnce and Remote Sensing Symposium (IGARSS[1] 97), Singapore, 1997

Kourti, N., Shepherd, J., Verbrgh, J :"Fishing boat detection by using SAR imagery", Ship Detection In coastal Water Workshop Agenda, Canada, 2000.

Olsen, R. B., Vachon, P. W, Wahl, T ["Vessels Detection Using Imagery , Current status and some view for future", Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Robertson, N., Bird, P., Brownsword, C: Ship surveillance using RADARSAT scan SAR image" .Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.

Vachon, P. W, Campbell, J. W. M., Bjerkelund, C.A., Dobson, F. W, Rey, M.T:" Ship Detection by the RADARSAT SAR: Validation of detection model prediction" , Ship Detection in Coastal Water Workshop Agenda, Canada, 2000.