

# 영해관리를 위한 인공위성 원격탐사기술

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## Space-based Ocean Surveillance and Support Capability: with a Focus on Marine Safety and Security

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**ABSTRACT :** From the 1978 Seasat synthetic aperture radar(SAR) to present systems, spaceborne SAR has demonstrated the capability to image the Earth's ocean and land features over broad areas, day and night, and under most weather conditions. The application of SAR for surveillance of commercial fishing grounds can aid in the detection of illegal fishing activities and provides more efficient use of limited aircraft or patrol craft resources. In the area of vessel traffic monitoring for commercial vessels, Vessel Traffic Service (VTS) which uses the ground-based radar system has some difficulties in detecting moving ships due to the limited detection range of about 10 miles. This paper introduces the field testing results of ship detection by RADARSAT SAR imagery, and proposes a new approach for a Vessel Monitoring System(VMS), including VTS, and SAR combination service.

**KEY WORDS :** Synthetic Aperture Radar(SAR), Vessel Traffic Service, Ship Detection

### 1. Introduction

For about the 15 years after 1951, synthetic aperture radar (SAR) technology remained almost exclusively within the domain of military reconnaissance, but by 1965 ocean scientists were already advocating the use of "present day radar technology to give a complete description of the sea state"<sup>1)</sup>. After several years of SAR applications research in both the United States and Europe, the U.S. National Aeronautics and Space Administration (NASA) launched the first civilian spaceborne SAR in 1978. Even in its unexpectedly brief 98 days, the Seasat SAR(1.275 GHz, HH-polarization) revealed marvelous patterns of winds, waves, and current features over the ocean never before seen in such abundance and scope<sup>2),3)</sup>.

The potential of SAR for Earth science commercial and civil applications is being advanced by several satellite systems, including Shuttle-based SAR flights (SIR [Shuttle Imaging Radar]-A (1981, L-band, HH) , SIR-B(1988, L-band, HH), SIR-C/X-SAR1(1991/1992, L-, C-, X-band, HH/VV/HV/VH)) and the European Space Agency's (ESA's) ERS-1(1991) and ERS-2(1995) (Table 1). Significant

contributions are also being realized from Japan's JERS-1, Canada's Radarsat-1(1995) and ESA's Advanced Synthetic Aperture Radar (ASAR)(Envisat, 2002). Future systems such as Radarsat-2 and Japan's Ministry of International Trade and Industry (MITI) SAR-2 and Phased Array type L-band Synthetic Aperture Radar (PALSAR), an instrument proposed for the Advanced Land Observing Satellite (ALOS), promise to add even more data and processing knowledge to the global pool of SAR experience.

SAR has the capability to detect both stationary and moving ships in the ocean<sup>4),5),6),7)</sup>. Ships are good microwave reflectors, or hard targets, in a sense acting as radar corner reflectors. They return a large portion of the incident energy back to the SAR sensor and may appear in the SAR imagery as relatively bright points or elongated bright blobs. Due to this strong hard target behavior, the location of fishing fleets can be easily determined using SAR imagery. Successful SAR detection of ships depends, nevertheless, on the size and type of vessel, the prevailing wind speed conditions, the SAR resolution used and the viewing angle<sup>6),7),8)</sup>.

With the increasing importance in monitoring ship traffic in both coastal and ocean waters, an automatic detection of ships, wakes, and ship velocity is very desirable<sup>4)</sup>. By using land-based radar, Vessel Traffic Service (VTS) has

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been developed and applied in waterways around ports. The control of ships near coasts is currently supported by VTS radar but it is restricted because of available information limitations. In addition to that, the coverage of monitoring ships by the traditional VTS is limited to the bay area or the approach from the sea to a harbour because of the radar range of about 10nm. There is a requirement for improving the VTS to be able to cover areas where radar coverage is almost impossible to achieve.

A VTS and SAR combination service, therefore, could be an alternative proposal to expand vessel-monitoring coverage to ocean waters. The objective of this paper is to present the results of field experiment in detecting ships using RADARSAT-1 SAR Fine mode.

## 2. VMS and User for Vessel Position Data

Conventional VMS consist of a beacon (transponder) located onboard a vessel capable of automatically reporting the vessel's position through a satellite communications link (usually Inmarsat-C) to a shore-based terminal (Fig. 1). Several U.S. and foreign fisheries require fishing vessels to carry VMS units as a condition of licensing and operating within the fishery. The United States has such a fishery in Hawaiian waters and will soon require VMS utilization in the Atka mackerel fishery in Alaska. The Australian Defense Force has recently funded a VMS involving some 1,500 vessels operating in the South Pacific within the jurisdiction of the Fisheries Forum Agency representing 16 member countries of the Central and South Pacific. This system includes a fully integrated geographic information system and is the world's largest system using Inmarsat-C.

The Fisheries Forum Agency VMS is indicative of the trend in international fisheries enforcement to monitor and control commercial fishing operations within national waters. Unfortunately, the effective use of VMS requires vessel operators to cooperate and adhere to the regulations. Vessels wishing to fish illegally are still able to do so, although at higher risk than in areas without VMS utilization.

The Korea Coast Guard is monitoring patrol boats by using VMS, and the Ministry of Maritime Affairs and Fisheries (MOMAF) is preparing a compulsory law that all ships passing the adjoining seas of Korea carry VMS units.

In the U.S.A. the primary user for offshore vessel position data is the Coast Guard 17th District Office in Juneau, which

is responsible for enforcing U.S. fishing regulations in U.S. waters, participating in enforcement of international agreements on the high seas, responding to oil spills, and rescuing those in peril at sea. The Coast Guard is particularly interested in ensuring that foreign fishing vessels are not trespassing into U.S. waters in the U.S./Russian Maritime Border region, monitoring Steller sea lion rookeries in the Aleutian Islands and illegal fishing in restricted waters around the rookeries, and monitoring illegal drift net fishing activities in international waters south of the Aleutian Islands.

VMS are affordable (\$1K-\$2K U.S.) and commercially available, and operate under all weather conditions. However, they are not sufficient in themselves to provide full monitoring capabilities of fishing vessel operations.

With limited ship and aircraft resources and a vast region of responsibility, it is anticipated that SAR information on ship location and patterns of fishing activity will aid in the efficiency of search activities, in the monitoring of compliance when assets are not available in a particular region, and in the augmentation of legal case packages for prosecution of offenders.

## 3. Data

VTS-radar data was used to validate the ship position obtained from SAR imagery, and to obtain a vessel code. Because the detection depends on the ship size and type, the incidence angle, and the sea state such as wind speed and wave height, in-situ data were measured and pictures of ships were taken aboard a ship.

### 3.1 SAR Image Data: Fine Mode

The SAR aboard RADARSAT-1 operates in the C-band and with horizontal transmit and horizontal receive polarization (C-HH). SAR images cover a swath width of about 45 km and have an across-track spatial resolution of about 9m. This instrument can produce images in seven different modes and with multiple viewing angles ranging from 10° to 59°. RADARSAT-1 is sun-synchronous satellite operating in near polar orbit at altitudes of about 800 km. In the case of ship detection, the probability of detection is enhanced at large incidence angles <sup>5),6)</sup>.

RADARSAT-1 satellite SAR data acquired on June 19, 2004 and processed at the Korea Earth Observation Center (KEOC) as shown in Fig. 2. The Fine mode is processed to the path image plus level (SGX) with 3.125m pixel

spacing (F2) and the incidence angle is  $41.2^\circ$ . SAR image is calibrated to geophysical ( $\sigma$  naught) values of radar cross section (RCS) even if data numbers (DN) on these detected images can be viewed as indicating relative radar backscatter intensities.

### 3.2 Wind and Ship Information: VTS

Wind and radar data were acquired at Hwaamchu site and transmitted to VTS center (PTMS in Fig. 3). The line in Fig. 4 shows a trajectory moved aboard a pilot ship as shown in Fig. 5. VTS refers to the services promoting effectiveness improvement in port operation and reduction in distribution cost by providing counsel or required information for safe vessel service within the range of not violating rights or exempting obligations of the shipmaster via observing movement of vessels in port area and entrance routes with the latest scientific devices of radar, CCTV and VHF, etc. for the purpose of increasing vessel safety and effectiveness as well as of protecting environment.

During the field experiment, northwest winds, with speeds from 2.6 m/s to 3.2 m/s were recorded with 0.5 m significant wave height. VTS tracks most shipping traffic using shore-based radar. VTS data are available at twelve-second intervals and consist of a vessel code (ship name, position, speed, course and speed) on a map. The code can be used to ascertain ship length, breadth, depth, and type, and the VTS display can be overlaid with radar images of ships.

A pilot ship was going around at Ulsan anchorage under the RADARSAT pass and boarded taking photos of ships along the line as shown in Fig. 4.

## 4. An Integrated SAR and VMS

The vessels tracked by the VTS and pictured aboard a pilot ship are listed in Table 2. Figure 6 represents VTS-Radar (X band) based ship locations and Fig. 7 shows RADARSAT Fine mode image calibrated to  $\sigma$  naught. Vessels at anchorage No. 1 and No.2 as shown in Fig. 4 are identified in SAR image (Fig.7). Breakwater (B.W. in Fig. 6) is also not seen in the image, but the two lighthouses at each end of the breakwater appear as a bright dot. In addition, the pilot boat of length 14 m made of FRP was detected by the Fine mode image but was not apparent. The fine line between detected or not detected is likely related to vessel type, vessel course relative to SAR look direction, or vessel material. For example, the Hanyang Ace, a petroleum product tanker has a scattered radar reflection property and

then is represented by several parts of potential ship pixels in the SAR data. The Haenam at the right-bottom of Fig. 6 was identified by the RADARSAT but because there was a discrepancy between the VTS Radar location and the real ship location as revealed in VTS radar images (here omitted). There was no evidence of ship wakes, but ship detection rate for merchant vessels is almost 100 % in this experiment.

A system integrating VMS with space-based SAR can provide global, all-weather, day-night capability. Such a system is simple and straightforward in that it does not require sophisticated spectral analysis or subpixel processing to be effective. Whereas such a system may be limited to the detection of vessels 20 m or greater in length, it will still be useful. Moreover, public awareness that space-based SAR has been used to find even a few vessels illegally fishing will serve as an effective deterrent to at least some additional illegal catches.

The blended SAR and VMS position information will quickly show vessels that are not reported by VMS (Fig. 8). Imagery provided in preparation for the Ulsan Port demonstration has shown vessel positions in relation to the offshore vessel traffic. With such information, patrol craft can be vectored to the suspect vessel for identification and for determining its legal status. In contrast to wide-area reconnaissance missions, patrol craft can be utilized more efficiently using the cuing provided by the combined SAR and VMS information.

## 5. Concluding Remarks

This paper introduces mainly the experimental result of ship detection by satellite images and land-based RADAR data, operated by the local Authority of South Korea, so called vessel traffic system (VTS) radar. The detection capability of RADARSAT is not influenced by ship speed but depends on ship's shape such as its material, length and type. Fine imagery of Ulsan Port under calm condition was used to detect stationary ships at anchorage and reveals 100% accuracy for merchant vessels with a variety of types.

The need for improved surveillance and control of vessel traffic in the territorial waters is urgent. Our results indicate that SAR can be applicable to automated ship detection for a VTS and SAR combination service.

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Table 1. Microwave frequency bands and corresponding satellites

Band	Freq., GHz	Wave length, cm	Satellite(Polarization/ Look angle(degrees))
P	0.23-0.39	133-77	AIRSAR
L	0.39-1.55	77-19	ALOS(PALSAR-HH or VV, HV or VH/20-30),TerraSAR-L
S	1.55-3.90	19-7.7	E-SAR, ALMAZ-1, MIR-Priroda
C	3.90-6.20	7.7-4.8	ERS(VV / 24), Envisat (ASAR-HH,VV,HV / 20-45), Radarsat-1(HH / 10-60)
X	6.20-10.9	5.2-2.8	SIR-C/X-SAR, TerraSAR-X
Ku	10.9-18.0	2.8-1.7	CyroSAT, RAMSES
Ka	18.0-36.0	1.7-0.8	RAMSES

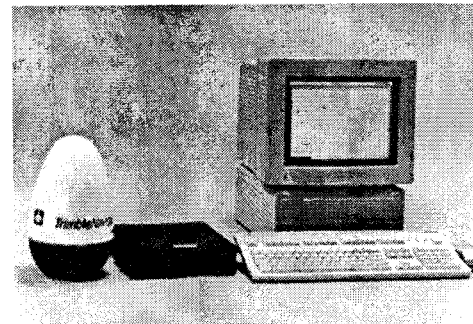


Fig. 1. A conventional vessel monitoring system.

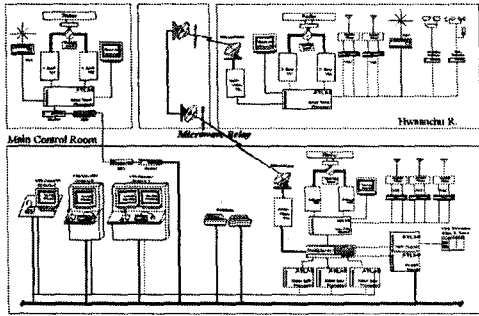


Fig. 3. Ulsan PTMS system overview.

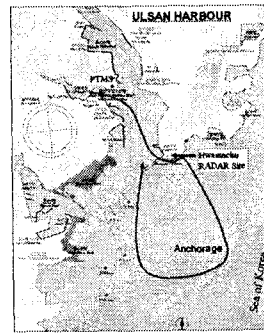


Fig. 4. Map of Ulsan Bay.

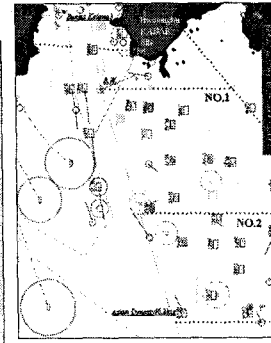


Fig. 6. VTS-Radar based ship locations and codes.

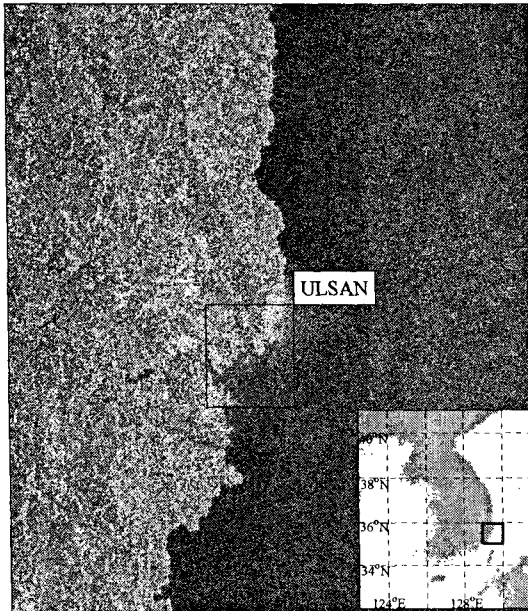


Fig. 2. RADARSAT image, Ulsan Bay-centered East Coast of South Korea, June 19, 2004.

Table 2. Ship Information tracked by the PTMS during the data acquisition as shown in Figure 2

Ship Name	Ship Code	L(m)	B(m)	D(m)	Type of ship
Hanyang Ace	HACE	78	13	7	Petroleum Product Tanker
Pacific Sambu	PSAM	84	14	8	Chemical Tanker
De Da	DEDA	90	16	8	Towing Tug
Alpha Gas	AL/G	93	16	7	LPG Tanker
Sea Line	SEAL	70	12	6	General Cargo Ship
Supertec	SUPT	185	32	16	General Cargo Ship
Hae Nam	HAEN	60	10	5	Petroleum Product Tanker
Asiana Dynasty	AS/D	193	32	20	Car Carrier
Bunga Kelana 3	<i>Alongside</i>	236	42	21	Oil Tanker

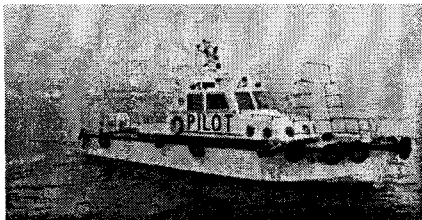


Fig. 5. Ship used during the field experiment.



Fig. 7. RADARSAT Fine mode image calibrated to sigma naught.

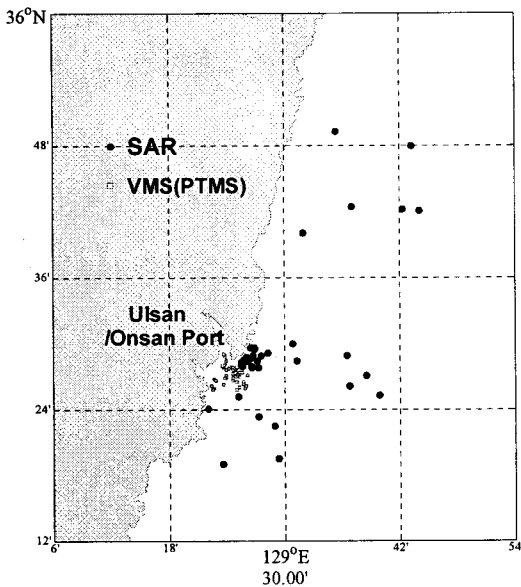


Fig. 8. An integrated VMS and SAR. Circles depict the ships detected from SAR image at the same time as VTS-radar.

No.	Ship Name	Length (m)	Width (m)	SAR Image	Optical Image
1	SAHO	120	30		
2	AEHO	140	32		
3	YUDA	114	36		
4	TA	124	42		
5	YUHO	84	42		
6	YUHO	162	28		
7	MEHO	128	28		
8	SAHO	146	74		
9	YUHO	144	28		
10	YUHO	144	34		
11	YUHO	104	44		
12	YUHO	104	44		
13	YUHO	104	44		
14	YUHO	104	44		
15	YUHO	104	44		
16	YUHO	104	44		
17	YUHO	104	44		
18	YUHO	104	44		
19	YUHO	104	44		
20	YUHO	104	44		
21	YUHO	104	44		
22	YUHO	104	44		
23	YUHO	104	44		

Fig. 9. Results of ship dimensions from SAR image.