

Ship Detection based on Synthetic Aperture Radar Technique

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Abstract. The ability of radar signals to penetrate cloud is one advantage to be used in tropical region to monitor objects on the surface from the space. Synthetic Aperture Radar (SAR) is one technique in radar remote sensing that can be utilized for marine applications such as surface waves monitoring, ocean current circulation detection, oil slick monitoring and ship detection. In order to assess the ability of SAR technique for ship detection, we analyze SAR data acquired by full polarimetric and interferometric airborne SAR in L-band type-2 (Pi-SAR L2) from Japan Aerospace Exploration Agency (JAXA). This research explains the strategy in SAR data processing for ship detection application in Lembeh Strait, North Sulawesi Sea. It is found that long wavelength i.e. L-band is able to identify ships on the sea with incidence angle of radar beam greater than 50 degree gives the best signal clutter ratio between signal from the ship to sea clutter variation. The identification includes the size estimation and the location. Horizontal-Horizontal (HH) polarization can identify ships clearer in calm sea condition, whereas Horizontal-Vertical (HV) polarization is better in severe sea condition. However, it is difficult to estimate the speed of moving ships on the sea and the ship's material. It is also found that by combining SAR data with VMS (Vessel Monitoring System) data it is possible to identify ships without VMS and useful for improving security issue in marine sector.

Keywords: SAR, ship detection, polarization, VMS

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1. Introduction

Indonesia is an archipelagic country that almost two third of its area is covered by sea. Therefore marine sector plays an important role in its development. One issue in the marine sector is ship detection that has a strong relationship to security, transportation and natural resources (fishery activities). Recently, ships or vessels in the seawater are identified by utilizing Automatic Identification System (AIS). Ships transmit their information (ship's position, direction, speed, name etc) to the observer (i.e. in the port's control station) using AIS signal which works in 161.975 - 162.025MHz. Therefore this system requires AIS in the ships and receiver equipment in control station. However, this system is not working well in Indonesia due to lack of equipment and limitation in human resources. Therefore, a combination with remote sensing technique i.e. Synthetic Aperture Radar (SAR) should be assessed to find out alternative solution. Synthetic Aperture Radar (SAR) is one of the most promising satellite or airborne remote sensing sensor for monitoring the earth surface at a regional to global scale. SAR has many useful characteristics for various applications, such as cloud-free day and night observation capability, highly spatial resolution produced by the synthetic aperture technique, and polarimetric and interferometric information. In particular, cloud-free observation by SAR is a huge advantage for monitoring of humid tropical regions such as Indonesia. To assess the SAR application for ship detection in Indonesia, collaboration research between Indonesian institutions: Agency for the Assessment and Application of Technology (BPPT), Ministry of Marine Affairs and Fisheries (KKP) and Japan Aerospace Exploration Agency (JAXA) had been conducted in 2012. This airborne based research operated the polarimetric and interferometric airborne SAR in L-band (Pi-SAR-L2) that it can serve the same performance to the JAXA's next L-band SAR (PALSAR-2: Phased Array type L-band Synthetic Aperture Radar 2, with wavelength ~ 24 cm) in the geometric resolution by expanding the frequency bandwidth. This system acquired full-polarimetric and interferometric L-band SAR data at 1-3 meters spatial resolution. The observation is located at Lembah Strait, North Sulawesi Province region. In addition, to assess the capability of satellite based SAR system, RADARSAT-2 data (C-band with wavelength ~ 5 cm) provided by Canadian Space Agency (CSA) for Jakarta bay region was also utilized to obtain the illustration of SAR data processing strategies in ship detection application

2. Data and Method

This research utilized SAR data acquired from PiSAR L-2 airborne campaign on August 8th 2012 for Lembah Strait area, North Sulawesi region. RADARSAT-2 data is observed on February 9th 2013 in Fine Beam mode acquisition. Data from Canadian Space Agency (CSA) is provided in SAR Georeferenced Fine (SGF) format, which means data is converted to ground range, is multi-looked processed, and is oriented in direction of orbit path. This data is processed to assess the ability of satellite based technique for ship detection in Jakarta bay region. Software that was used in this research are MultiSpec, a multispectral image data analysis software application (Biehl, and Landgrebe, 2002); NEST SAR Toolbox, that supports the exploitation of SAR data Level-1 or higher and provides basic and advanced tools for SAR user community (Engdahl et al., 2012); and Quantum GIS (QGIS), a user friendly Open Source Geographic Information System (GIS) and is an official project of the Open Source Geospatial Foundation (QGIS Development Team, 2013). The Pi-SAR-L2 is installed on the Japanese specialized

airplane, Gulfstream-II, and it can observe the ground with about 3-m resolution and about 15-km swath from heights of 12,000 meters. The specification is listed in Table 1.

Table 1. Specification of the Pi-SAR-L2

Frequency	1.275GHz/1.257.5 GHz
Band width	50-85 MHz
Sampling frequency	66.7 MHz/100 MHz/200MHz
Height	6-12 km
Image swath	≤ 20km
Quantization bits (I/Q)	8 bits
ρ (R), slant range	3.0 m/1.8 m
ρ (A), $\pm$ looks	3.2 m
$\Delta\sigma^0$	1.1 dB
Noise equivalent σ^0	-45 dB
Incidence angle	10-60 deg.
Beam width	8.4 deg.
Polarimetry	Full (HH, HV, VH, VV)
Pulse duration (τ)	10 μ s
Peak Power	3.5 kW
Antenna size	1.55 m x 0.65 m
Platform	Gulfstream-II

Table 2. Metadata of RADARSAT-2

#	Name	Value	Type
PRODUCT_TYPE	SGF		Product type
SPH_DESCRIPTOR	Fine		Description
MISSION	RS2		Satellite mission
ACQUISITION_MODE	Fine		Acquisition mode
BEAMS	W2		Beams used
PASS	ASCENDING		ASCENDING or DESCENDING
mds1_tx_rx_polar	HH		Polarization
azimuth_looks	1		
range_looks	1		
range_spacing	6.25	m	Range sample spacing
azimuth_spacing	6.25	m	Azimuth sample Spacing
pulse_repetition_frequency	1339.335327	Hz	PRF
radar_frequency	5404.999243	MHz	Radar frequency
ine_time_interval	-9.33E-04	s	
total_size	190296456	Mb	Total product size
num_output_lines	9129	Lines	Raster height

num_samples_per_line	10270	Samples	Raster width
srgr_flag	1	Flag	SRGR applied
avg_scene_height	250.503555	m	Average scene height ellipsoid

SAR data is processed and exploited by using NEXT ESA SAR Toolbox (NEST), mainly for RADARSAT-2 data, whereas MultiSpec is utilized to process Pi-SAR L-2 data. The processing chains include data reading and format conversion, calibration, speckle filtering, georeferencing and product writer to GeoTiff format. Once in raster data format (GeoTiff), all data is analyzed and visualized in QGIS. RADARSAT-2 data are processed by NEST ESA SAR Toolbox with Ocean Tools application. This method works in automatic processing based on Constant False Alarm Rate (CFAR) detector and discrimination algorithm based on object dimension. The basic idea of CFAR is to search the pixels which are unusually bright when compared to pixels in surrounding area. Let x_t be the pixel under test and T be a given threshold, then the detection criterion can be expressed. as:

$$x_t > T \Leftrightarrow TARGET \quad \dots (1)$$



Figure 1. Illustration of North Sulawesi Region

If $f(x)$ be the ocean clutter probability density function and x range through the possible pixel values then the probability of false alarm (PFA) is given by:

$$PFA = \int_T^{\infty} f(x)dx; \int_T^{\infty} f(x)dx < PFA \Leftrightarrow TARGET \quad \dots (2)$$

3. Results and Analysis

Visualization of Pi-SAR L-2 data is illustrated in the next figures. Since Pi-SAR L-2 data observe full polarimetric mode, therefore the image is separated in three different bands: Horizontal-Horizontal (HH), Horizontal- Vertical (HV) and Vertical-Vertical (VV). These three bands later are combined to obtain Red-Green-Blue (RGB) composite color and displayed in MultiSpec Software.

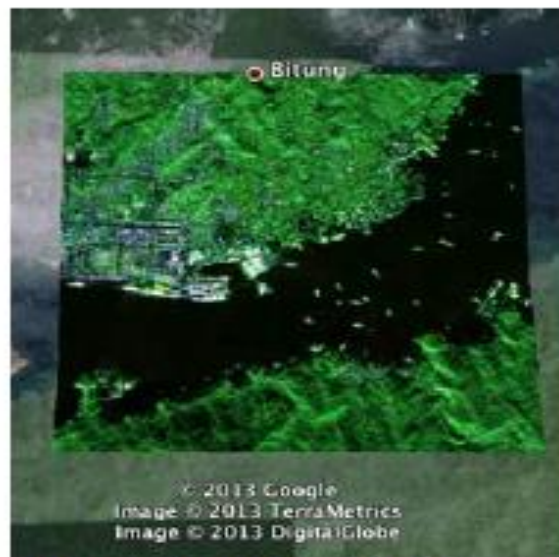


Figure 2. Illustration of Lembeh Strait



(a)



(b)

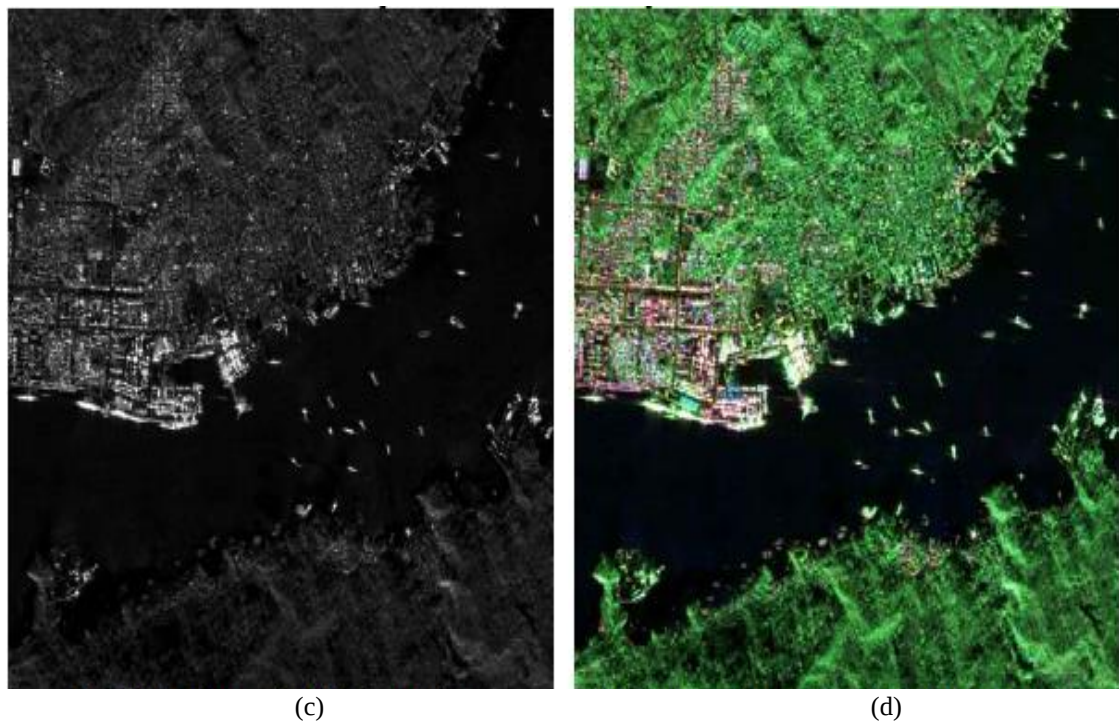


Figure 3. Pi-SAR L-2 image in HH polarization (a), Pi-SAR L-2 image in HV polarization (b), Pi-SAR L-2 image in VV polarization (c), Pi-SAR L-2 image in RGB Color Composite (d).

Processed Pi-SAR L-2 raster data is visualized in QGIS to identify (based on human-eye) and to measure the ship dimension. The illustration of ship dimension can be seen in the figure 4.

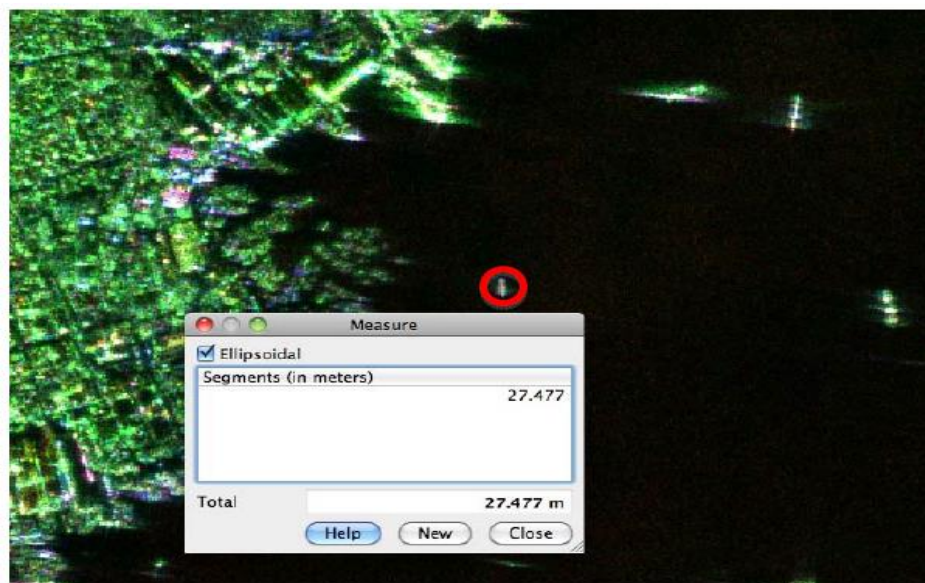


Figure 4. Dimension of small ship detected by Pi-SAR L-2

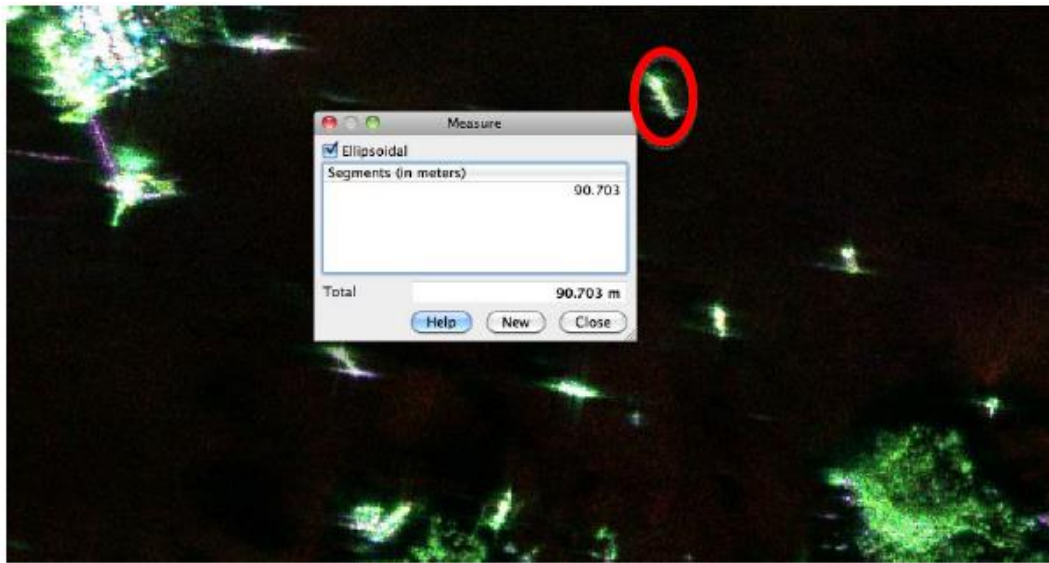


Figure 5. Dimension of big ship detected by Pi-SAR L-2 data

Based on ship dimension table published by Harre (2004) it is shown that ship with overall length less than 40 m is classified into inshore fishing vessel with less than 200 Gross Tonnage (GT), whereas ship with overall length up to 100 m is classified into collier class with 1500 GT. In operational stage, SAR satellitebased system also shows the ability to identify ship without any cloud constraint. The results by utilizing CFAR detector and discrimination algorithm can be seen in figure 6.

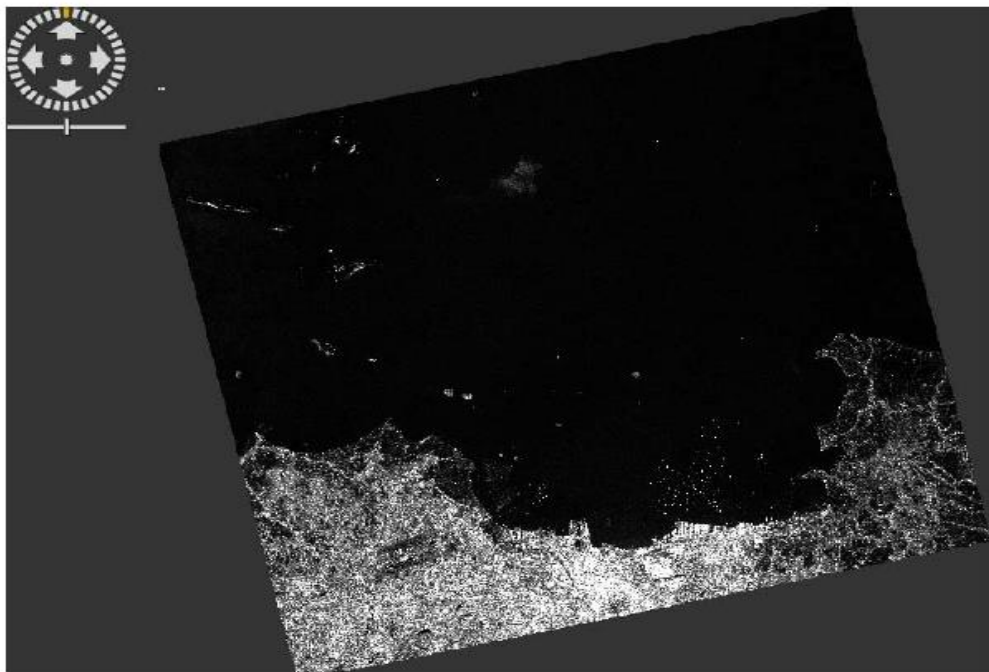


Figure 6. Illustration of Jakarta bay region observed by RADARSAT-2

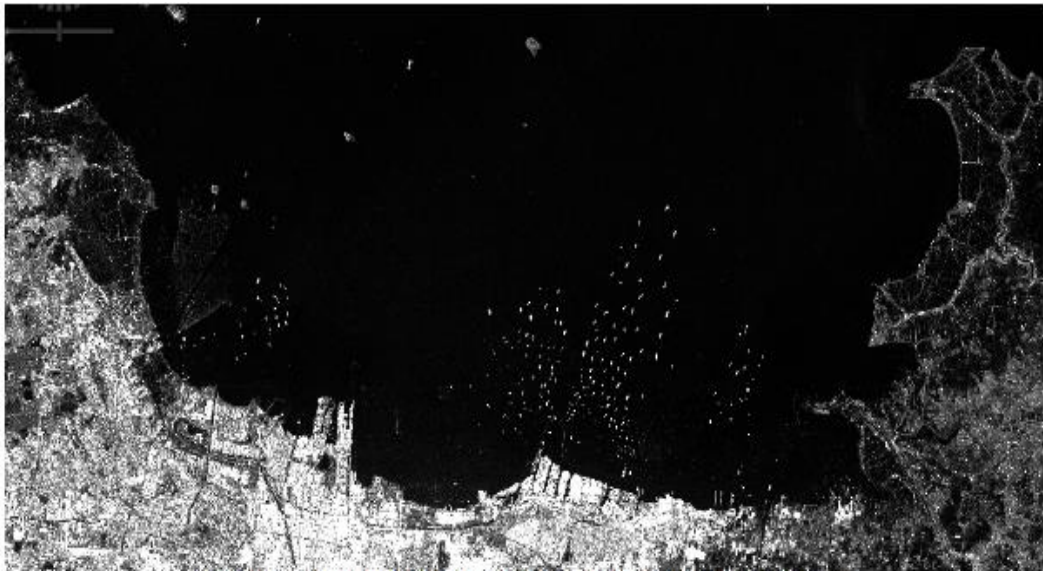


Figure 7. Illustration of subset region of RADARSAT-2

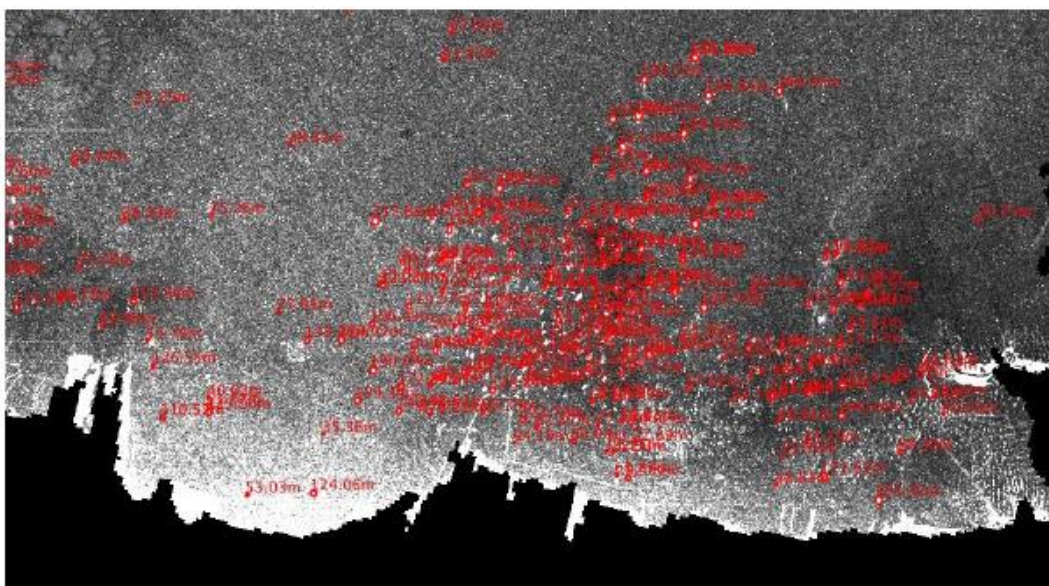


Figure 8. Automatic ship detection based on CFAR and discrimination algorithm

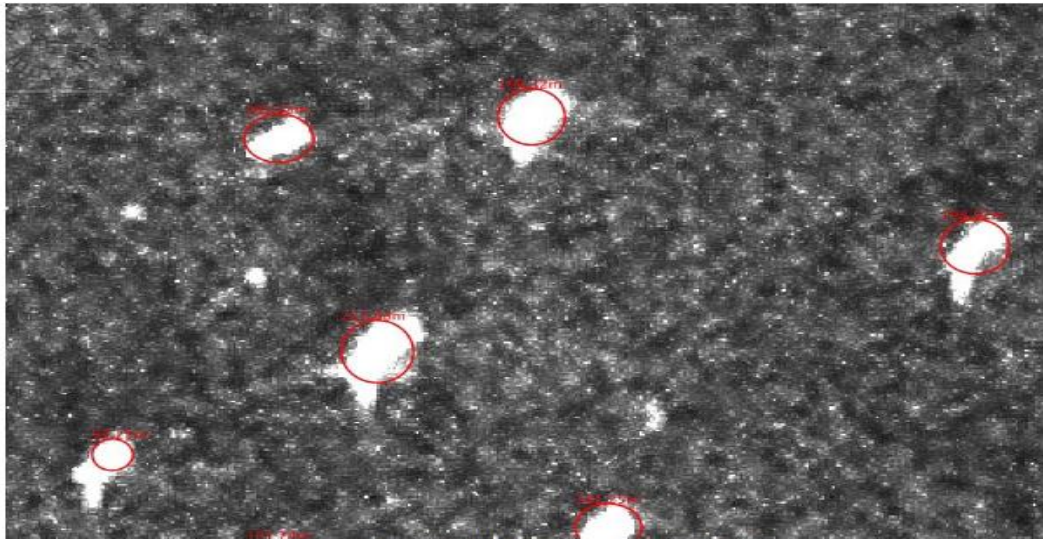


Figure 9. More detail results of automatic ship detection based on CFAR and discrimination algorithm

It is shown that SAR technique based on satellite data and processed by CFAR and discrimination algorithm can identify ships on the seawater. Combined with Indonesian Vessel Monitoring System (VMS), the ship detection can give more complete information i.e. all the attribute data of the vessel will be listed.

4. Conclusion

This research shows the ability of SAR technique to be operated in detecting ships in Indonesian water. From research stage in airborne SAR with manual data processing to operational stage in satellite-based with automatic data processing can discriminate object in the water based on the pixel's bright and the object shape. Horizontal-Horizontal (HH) polarization can identify ships clearer in calm sea condition, whereas Horizontal-Vertical (HV) polarization is better in severe sea condition. However, it is difficult to estimate the speed of moving ships on the sea and the ships material. It is also found that by combining SAR data with VMS (Vessel Monitoring System) data it is possible to identify ships without VMS and useful for improving security issue in marine sector.

5. Reference

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