ASAR AP 다중편파 및 MULTI-LOOK 에 의한 선박탐지 연구
SHIP DETECTION APPROACH BASED ON CROSS-CORRELATION FROM DUAL-POLARIZATION DATA

Chan-Su Yang*, Kazuo Ouchi**

*Ocean Satellite Research Group
Korea Ocean Research & Development Institute
1270 Sa-2-dong Sangrok-gu Ansan-city, 426-744, Korea
yangcs@kordi.re.kr
**Department of Computer Science
National Defense Academy
1-10-20 Hashirimizu, Yokosuka, Kanagawa, 239-8686 Japan
ouchi@nda.ac.jp

ABSTRACT Preliminary results are reported on ship detection using coherence images computed from cross-correlating images of multi-look-processed dual-polarization data (HH and HV) of ENVISAT ASAR. The traditional techniques of ship detection by radars such as CFAR (Constant False Alarm Rate) rely on the amplitude data, and therefore the detection tends to become difficult when the amplitudes of ships images are at similar level as the mean amplitude of surrounding sea clutter. The proposed method utilizes the property that the multi-look images of ships are correlated with each other. Because the inter-look images of sea surface are covered by uncorrelated speckle, cross-correlation of multi-look images yields the different degrees of coherence between the images and water. The polarimetric information of ships, land and intertidal zone are first compared based on the cross-correlation between HH and HV. In the next step, we examine the technique when the dual-polarization data are split into two multi-look images.

KEY WORDS: Cross correlation, multi-look processing, ship detection, speckle noise, synthetic aperture radar (SAR), dual-polarisation

1. INTRODUCTION

Dual polarisation data is important for a wide range of applications such as bare soil, vegetation studies, sea ice applications, etc. Multi-polarization and polarimetric data are expected to allow the user to exploit various polarization combinations to optimize ship detection applications. The Advanced Synthetic Aperture Radar (ASAR) is one of the instruments aboard the Environmental Satellite ENVISAT and provides dual-channel data. In an additional ASAR measurement mode, called Alternating Polarisation Mode (AP Mode), which employs a modified ScanSAR technique, it scans between two polarisations, HH and VV, within a single swath which is preselected. In addition, there are two cross-polar modes, where the transmit pulses are all H or all V polarisation, with the receive chain operating alternatively in H and V, as in the co-polar mode.

Several papers treat methods for detection of ships in SAR images. However, detection of ocean features decreases with high sea states due to higher level of clutter. Thus, an alternative method is to identify ships from their wake lines. This method cannot, of course, be used unless the wake images are clearly visible. There is also the method based on the coherence image from two multi-look images, in which the degree of coherence between ships is high [1].

In ship detection using SAR, the detection of smaller ships, the masking of land in the areas of many islands and intertidal zone, and the discrimination of ship-like surface features such as floating aids to navigation (small, medium and large buoys) is remained to be resolved.

This paper presents two case studies of ship detection approach. We first consider the polarisation property for ships and land area including intertidal zone using cross-correlation method. Masking of land is performed using the method without any reference data. In our second study, we examine the technique when the dual-polarization data are split into two multi-look images.

2. THE ALTERNATING POLARISATION (AP) MODE OF ENVISAT ADVANCED SYNTHETIC APERTURE RADAR (ASAR)

The ENVISAT Advanced Synthetic Aperture Radar (ASAR), operating at C-band (5.331 GHz), one of the 10 instruments on board of ENVISAT, is equipped with an active phased array antenna of 320 transmit/Receive modules, organised in 32 rows to produce a versatile position of the image swath by beam steering in elevation.

In addition, the instrument is designed to provide a large degree of operational flexibility, acquiring science data in 5 different modes. The Image Mode (IM) generates high spatial resolution data, in HH (H Transmit and H receive) or VV polarization, over one of seven available swaths located over a range of incidence angles spanning 15 ° to 45 °. The Wave Mode (WV) generates vignettes of 10 km by 10 km spaced 100 km along-track, in HH or VV polarisation. The position of the vignette can be selected to alternate between the centre of any two of the seven swaths. The Wide Swath Mode (WSM) and Global Monitoring Mode (GMM) are based on the ScanSAR technique using five sub-swaths (across track coverage of 400 Km) either in HH or in VV polarisation. The first one is a high resolution mode, for which typical products of 150 m geometric resolution are generated, while the second one is a low rate mode, which allows for a whole orbit operation at the cost of reducing the resolution to ~1Km. The Alternating Polarisation (AP) Mode provides two simultaneous images from the same area in HH and VV polarizations, HH and HV or VV and VH, using the ScanSAR technique, with the same imaging geometry as Image Mode and similarly high spatial resolution (Fig. 1) [2, 3]. Alternating Polarization mode is 56 - 100 km across track depending on sub-swath. Along track coverage depends on the requested time interval.

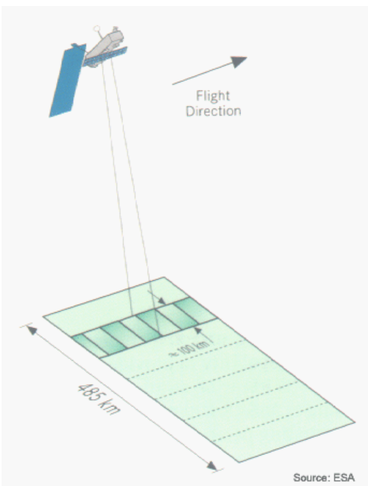

Figure 1 Alternating Polarization Mode

3. DATA (ASA_APH_0P) AND STUDY AREA

ASAR Level 0 data of alternating polarization mode used here is AP Crosspolar H Level 0 (HH/HV= H transmit H and V received), obtained on December 4, 2006. The level 0 data is processed to the GRD (Level 1) data by the SAR processor as shown in Fig. 2.

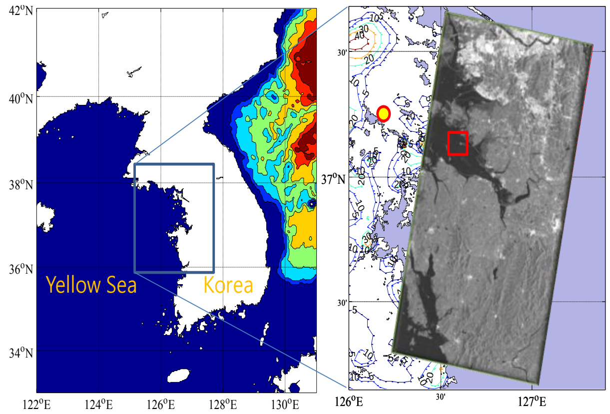

Figure 2 Area of interest for ENVISAT ASAR AP data analysis. The IS6 APH swath coverage is shown by the rectangle the intensity image (right) acquired on December 4, 2006.

Figure 2 shows a sketch map of the research area as well as an approximate outline of an IS6 descending swath. The image size is approximately 152 km and 73 km in azimuth and range directions, respectively. Both the azimuth and range pixel spacing are 12.5m. In the figure, the circle area represents an observation site of wind and wave, and at the time half hour before and after the data acquisition(01:32 GMT), the wind speeds were 6.2 m/s and 7.0 m/s, and the significant wave heights were 0.4 m and 0.3 m, respectively.

In this study, a small area (rectangle box) of the ASAR APH intensity image is selected to examine the performance of a ship detection approach from a dual polarisation data using a cross-correlation. The area of 290 × 290 pixels includes 3 different ships (warship, tug boat and container in Fig. 3), island and intertidal zone.

Validation data includes ship name, call sign, latitude/longitude position, and ship size and type, that is tracked by Automatic Identification System (AIS) and Vessel Traffic Service (VTS).

Figure 3 Ships information used as the ground trouth in this study. As for the positions of the circled numbers, refer to Fig. 4.

4. METHOD

In order to compute the inter-look and inter-polarization cross-correlation functions, the total 6 images of the same area are processed. In the multi-look processing, the bandwidth of the sub-reference signal is 682 Hz, and the Doppler center frequencies are -477.5 Hz and 204.5 Hz. The relation between the Doppler frequencies f_D and azimuth time t is given by

$$\Delta t = \frac{\lambda R}{2V^2} f_D \tag{1}$$

where λ is the radar wavelength, R is the slant-range distance, and V is the platform velocity. For this particular data set, the relative platform velocity is 7.1 km/s and slant-range distance is 1,044 km with the incidence angle of 40.1 ° at the center of the image of Fig. 1(swath area). From (1), then, the azimuth integration time of each sub-reference signal or the inter-look center time difference become 0.4 s.

The correlation between two signals is a standard approach to feature extraction. The cross-correlation can be computed in either the spatial domain directly or in the Fourier domain. The frequency domain is used here, but normalized cross-correlation is computed in the spatial domain, because the transform domain does not have a correspondingly simple and efficient expression on it.

5. SHIP DETECTION USING DUAL POLARIZATION DATA: HH & HV

Figure 4 shows HH and HV sub-images of ENVISAT ASAR APH. The top-right of the figure is the area of island and intertidal zone. Three ships are visible as bright areas in the HH image, while comparatively large two ships are shown in the HV image.

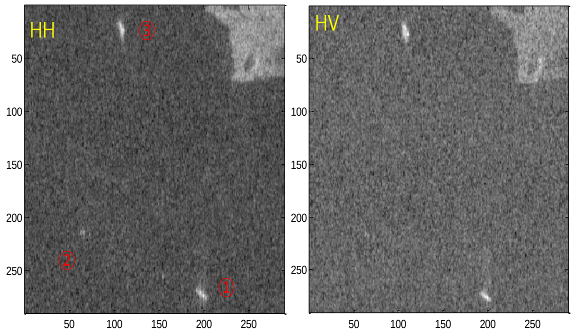

Figure 4 Sub-images of ENVISAT ASAR APH (HH/HV) as in the same area of the rectangle of Fig. 2. Note that three ships are visible in HH image.

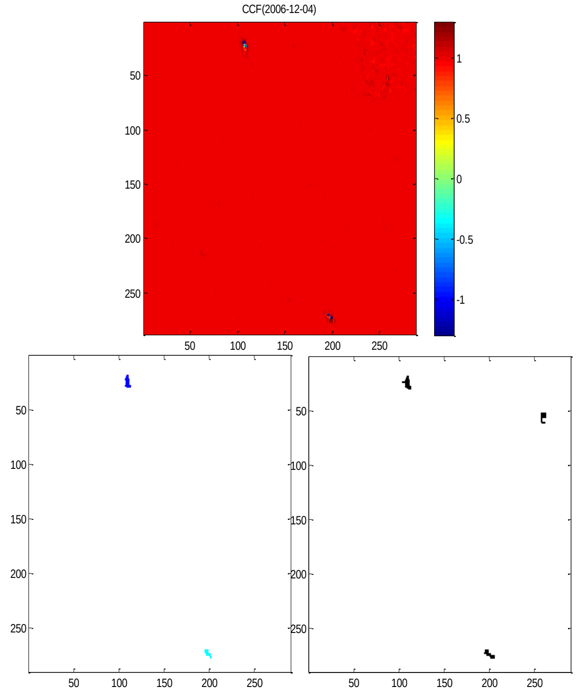

Figure 5 Coherence image(top) of moving window size 3 × 3 for the images of Fig.4. The images in the bottom row are those after thresholding with edge factors, 1.4 (left) and 1 (right).

C band imagery in HH polarization is preferred for detecting the ship because the ship-sea contrast is usually higher. This results in lower background clutter at HH polarization. The cross-polarised return is usually weaker, and often associated with multiple scattering due to surface roughness or multiple volume scattering.

The top of Fig. 5 is the coherence image computed from the two images of Fig. 4 with a 3 × 3 pixel moving window. Because two ships of the numbers 1 and 2 only have high intensity level in the both HH and HV images, it can be easily extracted from the coherence image. The ship image of the number 2 is contaminated with noise. The complex image of smaller ship, i.e. the ship No.2 did now show high coherence to be distinguished from sea images. The bottom-left and bottom-right are the coherence images labelled after thresholding the top image with edge factors of 1.4 and 1, where the thresholding values are determined by the sobel method. It is obvious that the noise is reduced, and Island and intertidal zone are masked out. However, the breakwater built on the island is also extracted during the normal processing as shown in the bottom-right of Fig. 5. If the edge factor is reduced to 0.6, the four probable ship targets including the ship No. 2 could be detected but the noise will be increased. For example, it is not easy to extract ships from the all unidentified targets including floating aids to navigation.

6. SHIP DETECTION USING MULTI-LOOK SAR IMAGES OF DUAL POLARIZATION DATA: HH & HV

Figure 6 shows multi-look HH and HV sub-images of ENVISAT ASAR APH. The left column is the look 1 intensities and the right one is those of the look 2.

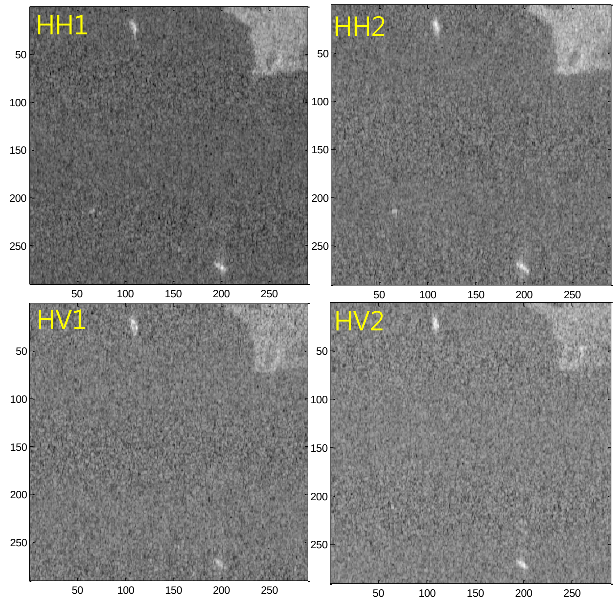

Figure 6 Multi-look HH (top row) and HV (bottom row) images of ENVISAT ASAR APH.

The left and right of Fig. 7 are the coherence images computed from the each multi-look HH and HV images of Fig. 6 with a 3 × 3 pixel moving window. Data acquired in the look 1 and look 2 images of HH polarization are highly correlated with ship, whereas those as HV are more poorly correlated.

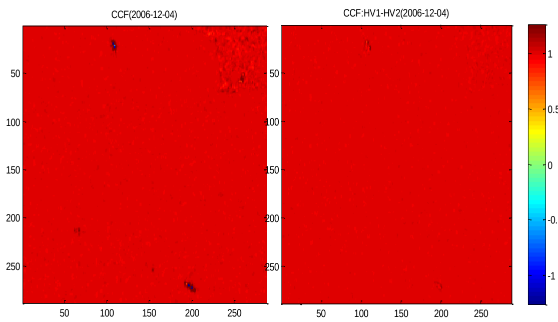

Figure 7 Coherence images of moving window size 3 × 3 for the top-row (HH1/HH2) and bottom-row (HV1/HV2) images of Fig.6.

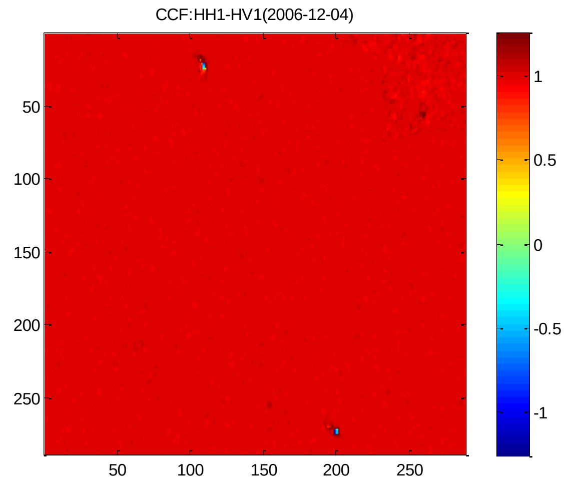

Figure 8 Coherence image of moving window size 3 × 3 for the left-column images (HH1/HV1) of Fig.6.

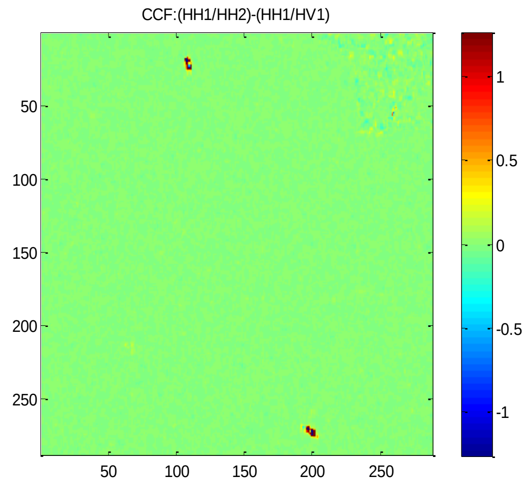

Figure 9 Coherence image (HH1/HH2) – coherence image (HH1/HV1).

Figure 8 is the coherence images computed from the look 1 images of HH1 and HV1 of Fig. 6 with a 3 × 3 pixel moving window. The correlation between the two different polarization channels has both positive and negative signatures. Thus, to enhance the cross-correlation result, this fact is applied to the maximum coherence image (HH1/HH2) and the minimum image (HH1/HV1). The difference between two coherence images, (HH1/HH2) - (HH1/HV1), reveals the high contrasts of ships against the ocean clutter background as shown in Fig. 9. The method, calculated for complex images as in the previous studies [1, 4], could be a help for a visual interpretation, but does not result in directly performance improvement of ship detection.

Figure 10 is the thresholded image for the difference image between two coherence images, HH1/HH2 and HH1/HV1.

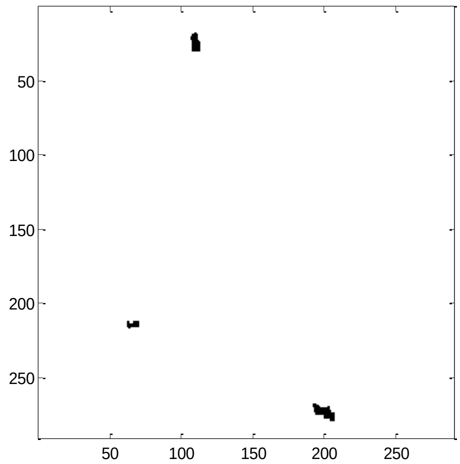

Figure 10 Thresholded image using Fig. 9 image.

7. RESULTS AND DISCUSSIONS

In the inter-look ship detection of this study, individual two sub-apertures of two different polarisation data are used. Since the west coast waters of Korea are occupied by many islands and intertidal zones, and used widely as navigational channels, the inter-look coherence technique could be useful in extracting ships from all ship-like candidates. The proposed method is applied to the HH and HV combination, and yields reasonable results in the performance improvement of smaller ship detection and the land masking.

Further quantitative evaluation is being planned based on the comparison of other AP data with the simultaneous sea truth of several ships of different sizes and floating aids.

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