A SCATTERING MECHANISM IN OYSTER FARM BY POLARIMETRIC AND JERS-1 DATA

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ABSTRACT:

Tidal flats develop along the south coast of the Korean peninsula. These areas are famous for sea farming. Specially, strong and coherent radar backscattering signals are observed over oyster sea farms that consist of artificial structures. Tide height in oyster farm is possible to measure by using interferometric phase and intensity of SAR data. It is assumed that the radar signals from oyster farm could be considered as double-bouncing returns by vertical and horizontal bars. But, detailed backscattering mechanism and polarimetric characteristics in oyster farm had not been well studied. We could not demonstrate whether the assumption is correct or not and exactly understand what the properties of backscattering were in oyster farm without full polarimetric data.

The results of AIRSAR L-band POLSAR data, experiments in laboratory and JERS-1 images are discussed. We carried out an experiment simulating a target structure using vector network analyser (V.N.A.) in an anechoic chamber at Niigata University. Radar returns from vertical poles are stronger than those from horizontal poles by 10.5 dB. Single bounce components were as strong as double bounce components and more sensitive to antenna look direction. Double bounce components show quasi-linear relation with height of vertical poles. As black absorber replaced Al-plate in bottom surface, double bounce in vertical pole decreased. It is observed that not all oyster farms are characterized by double bounced scattering in AIRSAR data. The image intensity of the double bounce dominant oyster farm was investigated with respect to that of oyster farm dominated by single bounce in JERS-1 SAR data. The image intensity model results in a correlation coefficient (R^2) of 0.78 in double bounce dominant area while that of 0.54 in single bouncing dominant area. This shows that double bounce dominant area should be selected for water height measurement using InSAR technique.

KEY WORDS: Oyster farms, double bounce, Polarimetric SAR, Image intensity

1. INTRODUCTION

L-band synthetic aperture radar (SAR) is useful to study of forest, ocean, geology, and glacier. Recently, water level measurement has developed using InSAR technique. Alsdorf *et al.* first reported that interferometric phases correlated with water levels in the Amazon flood plain by using SIR-C L-band HH-polarization (Alsdorf, 2001). Utilizing an array of oyster farm structures, Kim *et al.* have also succeeded in estimating tide height in the coastal area with an r.m.s. error of 5.7 cm and a correlation coefficient, R^2, of 0.91 from interferometeric phase and image intensity of JERS-1 SAR data (Kim, 2005). To avoid phase ambiguity problem in this study, it was overcome by exploiting the radar backscattering intensity, ie. backscattering total power. It was assumed that the radar signals from oyster farm could be considered as double-bouncing returns by vertical and horizontal bars. Detailed backscattering mechanism and polarimetric features in oyster farm, however, had not been well studied.

Recently, polarimetric SAR has drawn attention in remote sensing. The advantage of polarimetric SAR is to understand scattering mechanism at a given target. A problem of analyzing polarimetric SAR data is in understanding the scattering mechanisms that give rise to features in the different polarization parameters. We got two kind of polarimetric data set that is essential to understand scattering mechanism in oyster farm. One is the result of experiment using vector network analyser in anechoic chamber. The other is L-band NASA/JPL AIRSAR image in oyster farm.

The objective of this study is to investigate the scattering

Table 1. Parameters of experiment

Antenna	Rectangular horn
Polarization	HH,HV,VV
Frequency points	201
Wavelength	2.0 cm
Center frequency	15.0 GHz
Sweep frequency	14.0 – 16.0 GHz
Scanning points	64
Scanning interval	1.0 cm
Antenna height	154.0 cm
Incidence angle	45.0 deg.

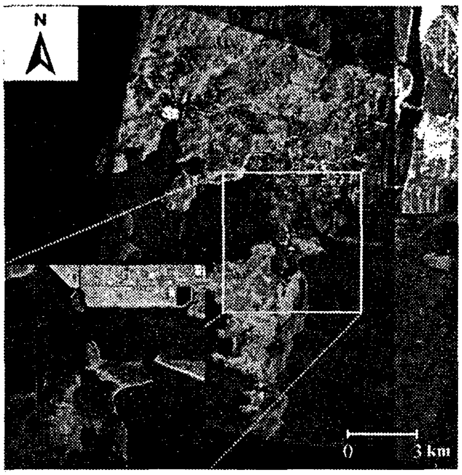

Figure 1. A location map: Averaged JERS-1 SAR image overlaid with polarimetric AIRSAR image. NASA JPL POLSAR image of oyster farm displays with HH, HV, VV: HH, HV, and VV, for red, green, and blue, respectively. A magnified inset IKONOS image shows study area.

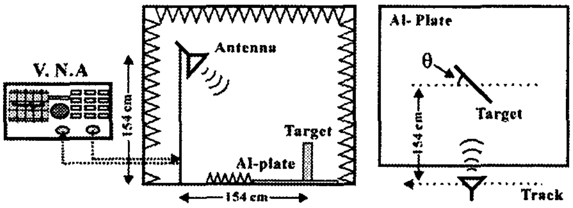

Figure 2. (a) Target geometry and Vector Network Analyzer (V.N.A). (b) Target rotation angle (θ)

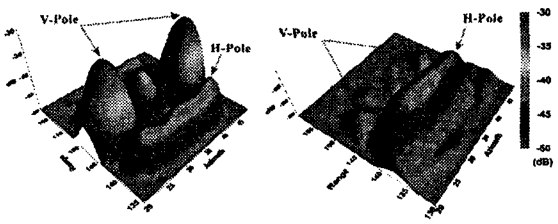

Figure 3. (a) 3-D surface map of basic target. The signals from vertical poles are represented in (23,147), (43,147). (b) Total power of target on black absorber. The signals from vertical poles disappear.

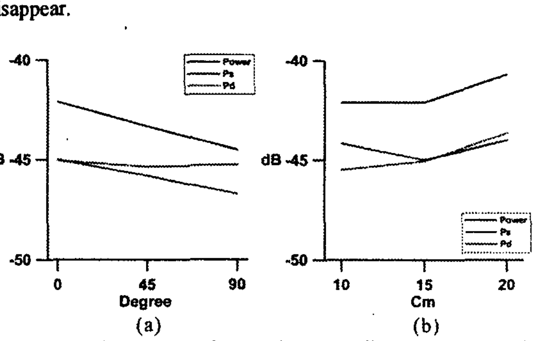

Figure 4. Variation of backscattering according to target rotation angles (a) and height of vertical poles (b). Total power (black), Single bounce (blue), and double bounce (red).

mechanism in oyster farms using polarimetric data. We will estimate image intensities in single- and double-bounce dominant area by JERS-1 SAR images and show appropriate image intensity model. It will help to determine the range of the wrapped phase.

2. TEST SITE

Tidal flats develop along the south coast of the Korean peninsula, and most of them are used for various sea farming. Strong and coherent radar returns are observed over oyster sea farms. Averaged JERS-1 SAR image overlaid with AIRSAR image (Fig. 1). Oyster farm sites are especially well detected by SAR systems. The artificial oyster farm structures, usually rectangular shaped, are composed of one horizontal and two vertical wood poles installed at the bottom and play as permanent scatterers. The horizontal pole is always exposed above water surface. Two vertical poles support a horizontal pole. The diameter of each pole is about 10 cm. An oyster farm usually consists of 50 to 100 units in an array. Left bottom image in Fig. 1 shows IKONOS image in the study area. The target structures are not so well imaged in high resolution optic images as in SAR images.

3. LABORATORY EXPERIMENT

3.1 Data and measurement

We carried out an experiment simulating a target structure using a fully polarized Ku-band antenna in a laboratory at Niigata University. A target made was a down scaled oyster farm structure. This simulated experiment was conducted under various antenna-target geometries in a wave dark chamber. Table 1 and Fig. 2 show conditions of experiment. Instead of water surface and wet wood poles, we used aluminum plate and small target covered with aluminum tape. Considering of the actual size of frame and wavelength, we reduced the size of target and observation wavelength by a scale of about 1/10. The rotation angle (θ) is defined as the direction of horizontal pole to the azimuth (Fig. 2(b)).

3.2 Laboratory Experiment Results

To compare the amplitudes of horizontal and vertical poles, total power of basic target is studied first. Measurements are displayed as a 3-D image in Fig. 3(a). The signals from the horizontal poles were 10.5 dB weaker than that from horizontal pole at 0 rotation angle. We measured HH-, HV-, and VV-polarization at three rotation angles: 0, 45, and 90 degrees. The covariance matrix can be decomposed into three scattering models (Freeman, 1998). Single bounce, double bounce and volume scattering from target were computed at each rotation angle. To estimate the effect of horizontal pole in each rotation angles, we plotted total power and three-component in three measured angles (Fig. 4(a)). Total power decreases as rotation angle increases. Single bounce is more sensitive to target rotation angle than double bounce.

We also measured the target according to height variation of vertical pole and plotted in 10, 15, 20 cm. While single bounce almost remains unchanged, double bounce and volume scattering almost linearly increase as the height of vertical pole increases (Fig. 4(b)).

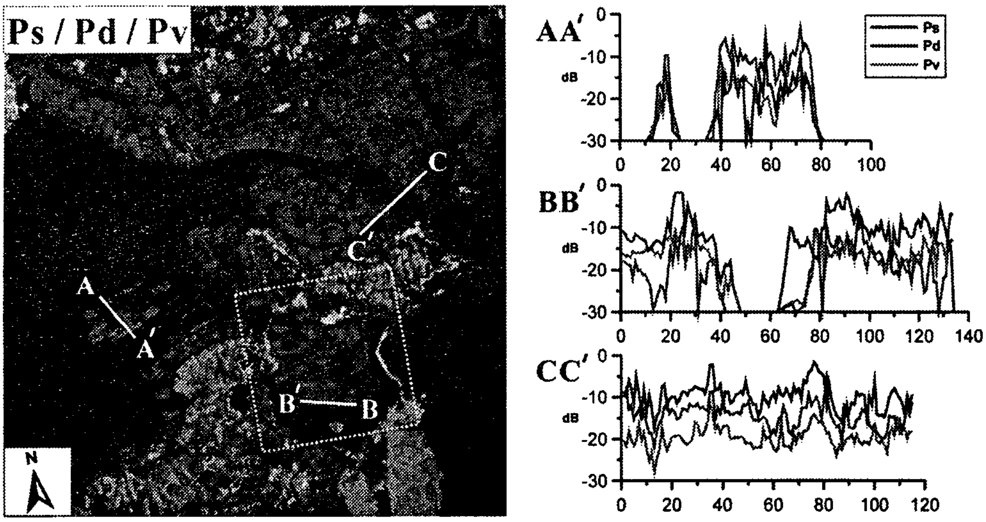

Fig. 5. (Left) NASA JPL AIRSAR image of oyster farm displayed with the Freeman decomposition using Ps, Pd, and Pv for blue, red, and green, respectively. (Right) Single bounce, double bounce, and volume scattering profiles along the AA', BB', CC' lines; AA' line (typical oyster farm), BB' line (horizontal pole runs parallel to azimuth direction), CC' line (bottom tidal flats are exposed to air).

Oyster farms are located in tidal flat. As sea level drops, bottom surface is exposed to air. In this case, Al-plate is not appropriate any more. Al-plate was replaced with black absorber. Fig. 3(b) shows 3-D surface image of target on black absorber. It is observed that vertical poles could not occur double bounce. It is noted that bottom surface condition should be considered on the ebb tide.

4. AIRSAR AND JERS-1 DATA

L-band NASA/JPL airborne SAR (AIRSAR) image was used in the oyster farm site. On 30 September 2000, AIRSAR was flown over a Kaduck-do area in the south coast of the Korean Peninsula. In the study area, highly productive oyster farms exist and an industrial complex and two islands locate. Polarimetric SAR speckle filter was applied to reduce speckle noise (Lee, 1999). We also utilized 9 JERS-1 SAR data sets obtained between May 2, 1996 and May 20, 1998.

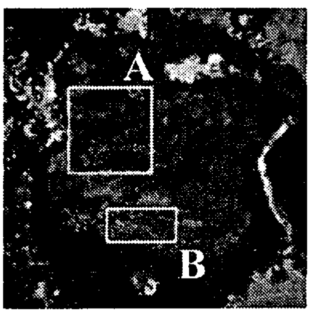

Figure 6. Boundaries of the selected sea farms dominated by double bounce(A) and by single bounce(B).

4.1 Classification

It is possible to classify the sea farms single bounce and double bounce, and volume scattering dominant areas using an AISAR image (Fig. 5). Double bounce from vertical poles after hitting water surface first is dominant scattering mechanism in oyster farms. These oyster farms correspond to AA' profiles. On the contrary, oyster farms in blue in east part of the image are typical examples of single bouncing dominant area. It shows single bounce dominant conditions that bottom tidal flats are exposed to air. As experiment result was carried on black absorber, double bounce between water surface and vertical poles reduced and single bounce directly from frames and bottom tidal flat increased. BB' profile represents this condition. Areas colored by purple inside Kaduck-do Bay represent mixed components of similarly strong single and double bounced signals. The direction of horizontal poles is normal to antenna look direction, which results in relatively strong single bounce. This specific oyster farm is shown in CC' profile (Fig. 5).

Scattering over oyster farm above seawater is dominated by double bounce scattering, while that on the exposed bottom tidal flat is characterized by single bounce scattering. It is noted that the radar signals from oyster farm are considered as not only from double bounced returns but also from single bounced returns on the ebb tide.

4.2 Image Intensity

The InSAR measured sea levels have a sign ambiguity and phase unwrapping problem. This ambiguity problem was overcome by exploiting the radar backscattering intensity (Kim, 2005). However, image intensity was modeled without considering detailed scattering mechanism in the previous study. Pixels can be categorized as single, double bounce and volume scattering based on the maximum power of the three scattering mechanism. Some pixels in oyster farm have two or three nearly equivalent scattering powers. The dominant scattering is not clearly defined. We used a mixed category by

$$N_i = \frac{P_i}{P_S + P_D + P_V} \qquad i = S, D, V \tag{1}$$

We selected two sub-areas inside Kaduk-do for comparing average of ratio. Boundaries of the two sub-areas are outlined in Fig. 6. A-area is characterized by double bounce dominant scattering. The value N_D is the biggest, 0.50 in A-area. The power of single bounce scattering (N_S) is above 0.65 in B-area. It implies that single bounce is dominant in B-area in spite of seawater surface due to direction of horizontal poles.

JERS-1 SAR does not provide a calibrated intensity image. Instead, the relative intensities of distinctive features in the images were compared. The sigma naught, σ°, was initially assumed, such that (Kim, 2005):

$$\sigma^0 = 10\log\bar{I} + CF, \text{ where } \bar{I} = \frac{\sum DN^2}{N} \tag{2}$$

where $\bar{I}$ is an average of pixel intensity, DN a digital number of a multi-look amplitude image, N the number of pixels in each group, and CF a radiometric calibration factor (-63.0 dB). The backscattering intensity of each sub-area is estimated by intensity model. Fig. 7 shows the backscatter response in each sub-area. Correlation coefficients, R^2, of A-area and B-area were 0.73 and 0.54, respectively. It shows double bounced scattering reflects sea levels better than single bounce. Though double bounce dominant area was selected as A-area, sea level was not strictly linear in relation to image intensity. The correlation coefficient of double bounce dominant area was better fitted to an image intensity model. This can be explained that the scattering mechanism varies with not only water height but also the sea surface conditions, oyster growing, radar look direction and so on. This demonstrates that double bounce dominant area was appropriate for back scattering intensity analysis in oyster farm. The results were not accurate enough to determine the sea level directly, but it is useful to determine a wrapping count for InSAR measurement.

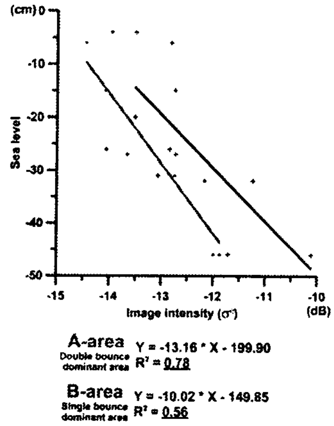

Figure 7. Backscattering intensity versus sea level in double bounce dominant A-area (red) and single bounce dominant B-area (blue).

5. CONCLUSION AND DISCUSSION

Scattering mechanism was effected by direction of horizontal pole, height of vertical pole, and bottom surface condition. Radar returns from horizontal pole are weaker than those from vertical poles by 10.5dB. Horizontal pole is more sensitive to radar look direction than vertical poles. Double bouncing from vertical poles produces the strongest radar return signals in all radar look directions and quasi-linearly increases as the height of vertical pole increases. Vertical poles of target on black absorber could not make double bounce any more.

Double bounce is dominant scattering mechanism in typical oyster farm. Oyster farms characterized by single bounce showed a close relation with bottom surface conditions and antenna look direction. Single bounce is stronger than double bounce when the bottom surface is exposed to air. Although bottom surface is covered with seawater, double bounce is not a main scattering mechanism in oyster farm when horizontal pole is normal to azimuth pass.

It was possible to separate double bounce dominant area in oyster farm by analyzing AIRSAR data. The image intensity model in double bounce dominant area correlated better with the tide gauge records with a correlation coefficient, R^2, of 0.73, while single bounce dominant oyster farms has a correlation coefficient of 0.54. This result demonstrates that we must consider backscattering mechanism and use double bounce dominant area by using full polarimetric data when estimating sea levels through InSAR technique.

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