OBSERVATION OF THE RICE PADDY FIELDS USING AIRBORNE SAR (Pi-SAR) DATA

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KEY WORDS: SAR, Rice, Polarimetry, Wavelength

ABSTRACT: South-east Asia has a rainy-season at crop growing period, and it is difficult to observe agricultural land in this season using optical remote sensing sensor. Synthetic Aperture Radar (SAR) can observe earth surface without influence of clouds. However its less use for observation of agricultural land, because satellite SAR has only one band data. SAR is coming up to observe multi band and multi polarimetric data. Pi-SAR that is one of airborne SAR can observe L and X band and full polarimetric data. Rice is the main crop in Asia, and we studied to characteristics of scatter on rice paddy field using Pi-SAR data. First we processed polarimetric color composite image. Next we calibrated phase L band data. After that we performed decomposition analysis and drew polarimetroic signature for understanding the status of rice paddy fields. At the rice planting period, rice paddy fields are filled with water. The microwave of SAR scatters on water surface like mirror, called 'mirror (or specula) reflection'. This phenomenon makes backscatter of SAR small value. Image of July is about one month after trans-planting and rice grows 20-40cm heights. X-band microwave scatter on rice surface, and L-band microwave pass through rice bodies and occur mirror refraction on water surface. Some rice paddy fields occur big backscatter especially VV polarization because bragg scattering. The fields that occur bragg scattering return strong VV scatter because space of each rice stems resonate L-band wavelength. We can easily understand the phenomena are bragg scatter using polarimetric data. Using the image of October at the just before harvest, L-band polarimetric data can detect various rice status such as standing, inclining, lying. We conclude that multi band and full polarimetric data can detect growth and status of crop as same as optical sensors in all weather condition.

1. Background and purpose

South-east Asia has a rainy-season at crop growing period, and it is difficult to observe agricultural land in this season using optical remote sensing sensor. Synthetic Aperture Radar (SAR) can observe earth surface without influence of clouds, and we can get the remote sensing data at crop growing period using SAR. However its less use for observation of agricultural land, because satellite SAR has only one band data.

SAR is coming up to observe multi band and multi polarimetric data. It is expected that information on farm products can be extracted by multi wavelength and the multi polarimetric observation. Pi-SAR that is one of airborne SAR developed by NASDA and CRL can observe L and X band and full polarimetric data. In addition, the full polarimetric observation of L band becomes possible in ALOS/PALSAR by which Japan is scheduling the launch of fiscal year 2004.

Because authors aim at the application of polarimetric information in the multi wavelength and the full polarimetric observation to agricultural sector by using this Pi-SAR data, and examined it for the rice plant, it reports to here.

2. Study area and data used

The study area was a Kojima reclaimed land in Okayama Prefecture, and the RADARSAT image of the object ground was shown in Fig. 1. Wheat is grown on the study area in winter from December to May. The rice plant is grown in summer, usually the irrigation water runs in the beginning of June, and transplanting rice is done from the middle to the end of June. The ear of rice goes out in the middle of September, it becomes a harvest period from the middle to the end of October. There are green houses of the vegetable and the lotus root field besides the rice farming rice paddy fields.

The data used for the analysis was observed on 13/July/1999 and 4/October/2000. The situation of the rice fields on each observation day was shown in Fig. 2. About one month passed from the transplant of the rice in the rice paddy fields on 13/July/1999, and the rice plant length was 20-40cm. 4/October/2000 is period immediately before the harvest, and the rice hangs the ear down, and has grown up to 100-120cm.

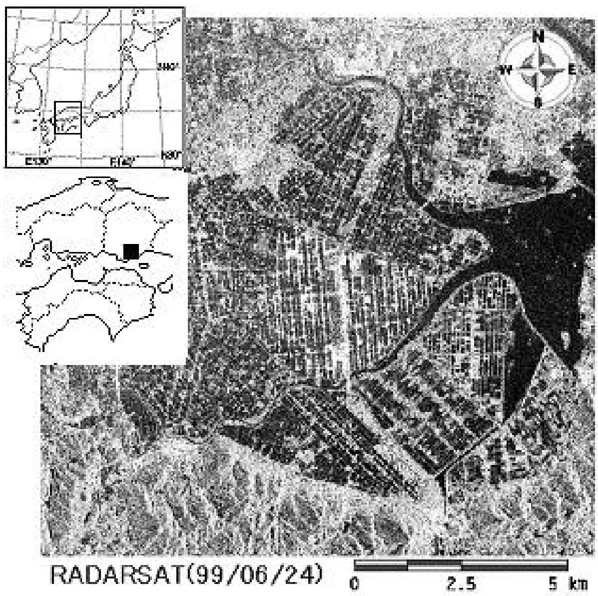


Fig. 1 Study Area

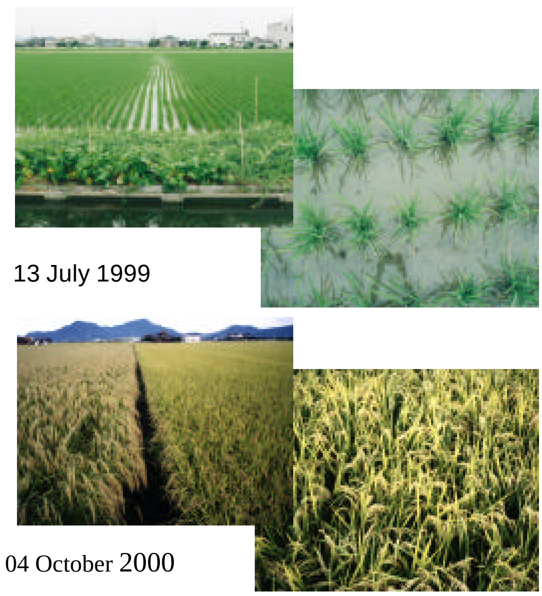


Fig. 2 Status of Observation days

3. Results and Consideration

(1)Polarimetric Color composite image

The image of the VV:VH:HH is allocated in R:G:B, and the polarimetric color composite image is made first, and the relation between the polarimetric characteristic and the growth situation of rice was analyzed according to the wavelength of L and X. However, this report is published in monotone. Therefore this report indicate only L band a few samples.

The polarimetric color composite image of L band Pi-SAR data on 13/July/1999 was shown in Fig.1, and the image on 4/October/2000 was shown in Fig. 2. The part of the triangle at the center where the river and the millrace were made a boundary was will be called a ß district to make easily to explain, the upper part be called a a district, and the lower side be called a ? district.

In Fig. 1, almost one month passes from transplanting rice and the plant length of the rice grows up to 20-40cm when observing it in July 1999. Because the microwave of L band pass through the rice plant body, and causes the specular reflection in the surface of the water, which is below, it is a black or a dark red on the SAR image. Darkness suggests that backscatter is small because the specular reflection is the main as scattering in the rice paddy fields.

A part, which is white and wide in being in the upper right of Fig. 1, are lotus root fields. The reason looks white is that the lotus root stem and leaf has grown up greatly, and the surface of the water is covered, thought the lotus root fields where water is saved just like the rice paddy fields.

Strong backscatter has been returned though the part of A marked to the upper part of the ß district is a rice paddy fields. As for this field, the direction of planting is 90° different compared with other rice paddy fields, and the rice was planted in an orthogonal direction to the range direction. This is a phenomenon which is called Bragg scattering, and it becomes big backscatter by the resonance of the rice plant and the micro wave, define the interval of the rice stubble as L, and when 2L sin? (?: angle of incidence) is integral multiples of wavelength. In the polarimetric color composite image of Fig. 3, it is understood that V element has returned strongly because the color of the rice paddy fields where Bragg scattering returns strong backscatter is red.

A polarimetric color composite image made from data that observed on 4/October/2000 immediately before the harvest shows Fig. 2. The rice plant grew, it began to drain in the rice paddy fields aiming at the harvest, and the rice paddy fields with water existed together to the rice paddy fields, which not was.

In Fig. 2, the difference is admitted in strength of backscatter by each farmland on the rice planting fields. It is thought that this difference depends on structure, volume of the rice plant, and water and moisture of the ground level, etc. It is difficult to separate them only from the strength value because it is a result to which these factors were combined.

The specular reflection causes and it darkens because most rice non-planting fields fills water to prevent the weed during summer.

The backscatter of the planted fields is growing though there are no changes in an artificial structure such as houses and filled water area when the image of L band in the middle of July and the beginning of October is compared.

Fig. 3 Polarimetric Color Composite Image of Pi-SAR/L-band on 13 July 1999 (R:G:B=VV:VH:HH)

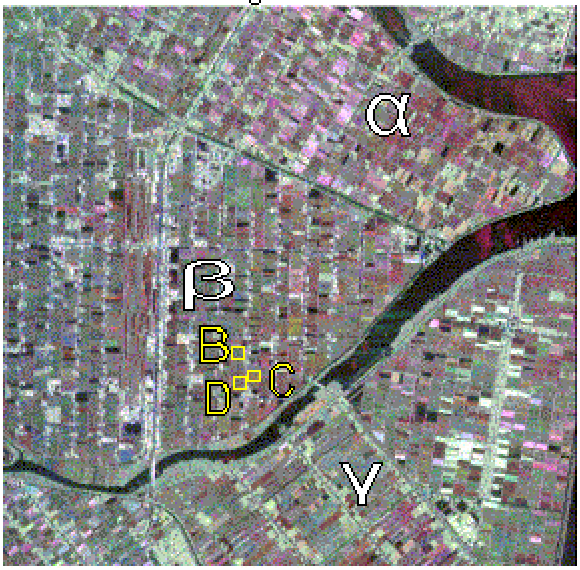


Fig. 4 Polarimetric Color Composite Image of Pi-SAR/L-band on 04 October 2000 (R:G:B=VV:VH:HH)

(2) Polarimetric Calibration

When polarimetric information, which included even phase information, was used, polarimetric calibration of the Pi-SAR data used was not done though polarimetric calibration was necessary.

Kimura designs a simple polarimetric calibration method using lost of the phase difference factor in some assumptions. This method is based on the polarimetric calibration technique using a natural target by J. J. van Zyl. We carried out polarimetric calibration for L band using the method of Kimura.

The next equation is used as a basic model of polarimetric radar system.

$$M = Ae^{j\varphi}RST + N$$
$$= Ae^{j\varphi}\begin{pmatrix} 1 & \delta_1 \\ \delta_2 & f_1 \end{pmatrix}\begin{pmatrix} S_{hh} & S_{hv} \\ S_{vh} & S_{vv} \end{pmatrix}\begin{pmatrix} 1 & \delta_3 \\ \delta_4 & f_2 \end{pmatrix} + N \quad (1)$$

where, M is measurement matrix: R is reception system matrix: T is transmission system matrix:: S is Scattering matrix: N is noise: d is Cross-talk terms. f are imbalance terms between receiver and transmitter.

If the noise and cross-talk are small enough, and the balance of the transmitting and receiving system is good, finally, equation (1) can be simplified to equation (2).

$$\angle M_{hh} - \angle M_{vv} = -\angle f_1 - \angle f_2$$
$$\angle M_{vh} - \angle M_{hv} = -\angle f_1 + \angle f_2 \quad (2)$$

where, ∠shows the amplitude of the phase difference. f1 and f2 can be obtained from coalition equation (2).

Polarimetric calibration was done using river part as the water part because there was no sea in the scene in this research though the method of Kimura was applied in the scene enclosed by the sea.

Polarimetric calibration was done by using the numerical value that 1999 year was ∠f1=3°, and ∠f2=-40° and 2000 year was ∠f1=-1.5°, and ∠f2=27.5°obtained from the coalition equation.

(3) Decomposition analysis

Enough polarimetric calibration is performed, and the analysis, which uses phase information in each polarization, becomes possible by obtaining scattering matrix. There is Decomposition analysis of Freeman in one of the analysis. This analysis divides the scattered element into three elements (Odd (Odd number and once), Even (Even number and twice), and Defuse (multiple and diffusion)) by decomposing covariance matrix. Finally, the contribution electric power of each scattered element in the number of pixels in the image can be calculated.

Decomposition analysis carried out using the pixel of 2 X 2 by the Pi-SAR data of L band. Fig. 11 shows the Odd element and the Even element from the result of the Decomposition analysis in L band data in 1999.

It is understood that the Odd element becomes small, and the Even element is superior in the rice paddy fields where the Bragg scattering has occurred. It is thought that the Bragg scattering occurred by Interval of the rice plant and incidence Angle can be judged from the excellence of the Even element from the above-mentioned. On the other hand, the Even element of the lotus root fields which had looked white as well as the rice field of the Bragg scattering was equal to the Odd element in the strength image of single polarization.

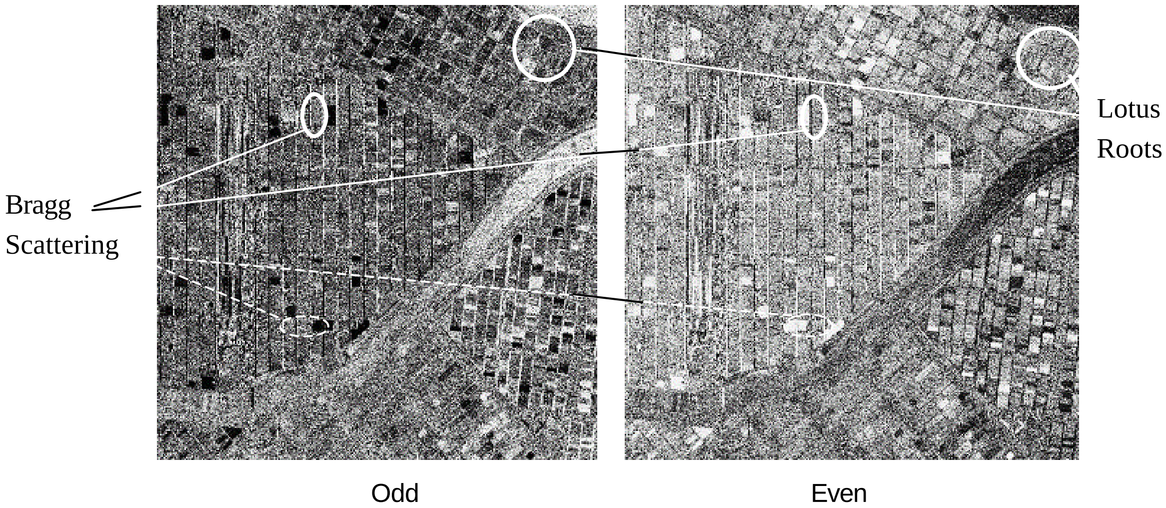


Fig. 5 Results of Decomposition Analysis (Pi-SAR/L-band on 13 July 1999)

(4) L band polarimetric signature analysis

The polarimetric signature is shown in two three dimension graphs that are Co-pol channel (Co-pol;?r=?t, ?r= ?t) and Cross-pol channel(X-pol; ?r=-?t, ?r= ?t+90°) to understand the characteristic of scatter. The concept chart of the polarimetric situation according to the change in ? and ? was shown in Fig. 12. The state of polarization becomes a straight line at ?=0°. It becomes complete round polarization at ?=45° and ?=-45°. Moreover, ?=90° is vertical polarization, and ?=0° and 180° become horizontal polarization.

The difference of the characteristics of scatter and the situation of the fields are investigated using the polarimetric signature by L band data.

The polarimetric signature of field A in Fig. 4 was shown as a field where the Bragg scattering had occurred. Those polarimetric signature draws X axis is ? and Z axis is normalized scattered strength in Y axis is ?

There is one peak in ?90° in the Co-pol signature. This suggests the object is having the structure of vertical. Moreover, it is shown that there are two peaks in ?45° and ?270° when the X-pol signature is seen, and scattering has occurred two times. The Field A where occurred the Bragg scattering is thought to be an occurrence of scattering two times by the rice plant and the surface of the water.

Fig. 5 is polarimetric signature of field B, has peaks in ? 0° and 180° when the Co-pol signature is seen, and it is suggest that the horizontal element has gone out strongly. This signature shows that the entire field is covered with the rice plant as the ear drips, and is thought to be a rice plant of for food.

The polarimetric signature of Fig. 6 in field C shows the scatterer because of no ? 90° it, which inclines a little, though has gone out strongly a vertical element. This is thought that the ear drips before it harvests, and the structure, which has inclined somewhat, is reflected, and thought to be a brewer's rice.

It connects from one to the vicinity of ? 90° though Fig. 7 is polarimetric signature of field h, and has peaks in ? 0° and 180° in the Co-pol signature. Fig. 7 is polarimetric signature of field D, It is thought that two structural middle of Fig.5 and Fig. 6, and it is especially remarkable in the Co-pol signature. As for field D, the structure that the rice ear hangs down like field B, however it is not covered with the rice ear completely, and a part of the microwave is scattered by the stalk or the ear of a vertical structure. Moreover, the color of polarimetric color composite image is a color at the middle level in Fig. 2.

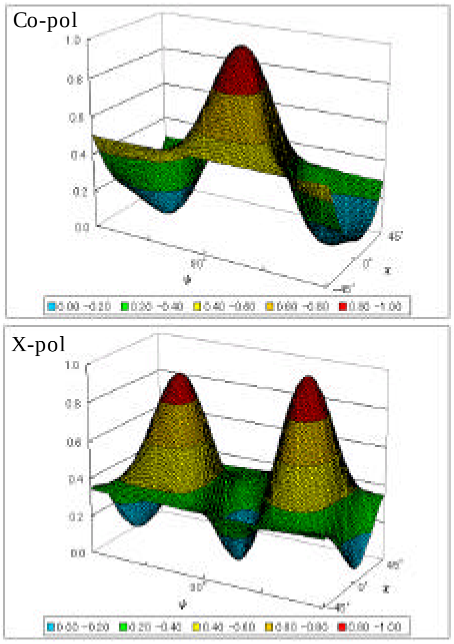


Fig. 6 Bragg Scattering

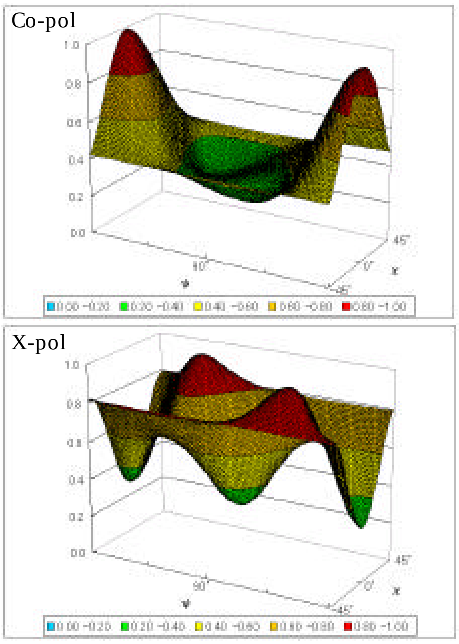
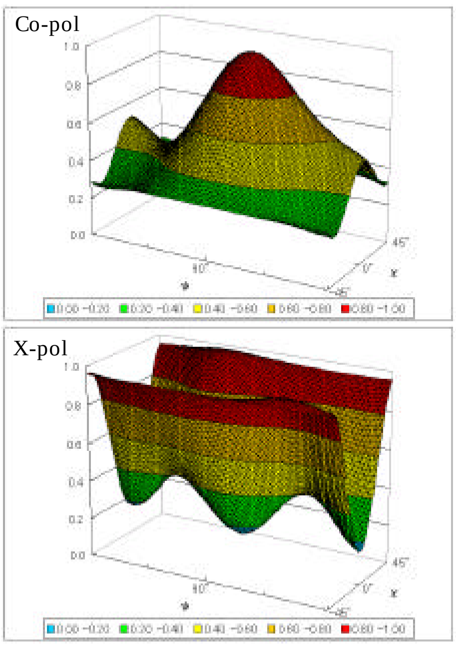


Fig. 7 Rice (Ear Laid)



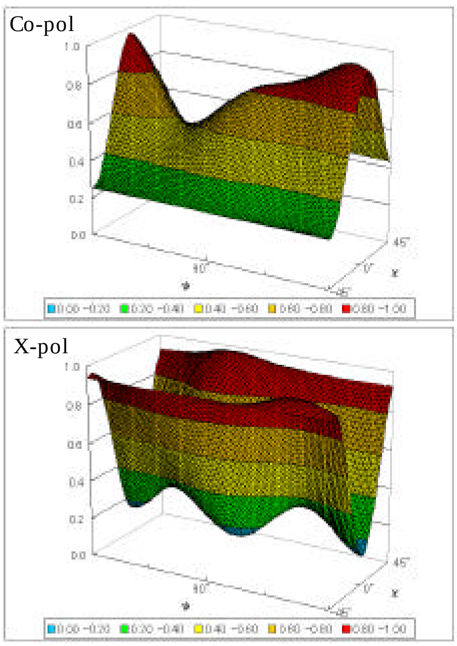


Fig. 8 Brewer's Rice Fig. 9 Rice

4. Conclusion

It reached the following conclusions from multi wavelength and the multi polarimetric observation data of the rice fields by Pi-SAR.

- It is expected that the period when filled water area can be detected is long because wavelength is long, and the penetration ability to the plant body is large in L-band. However, the Bragg scattering, which occurs the wavelength of L band resonate with the interval of the rice according to the direction of the observation, because the rice is being regularly transplanted for the rice paddy fields by the machine in Japan.
- As for polarimetric data of L band, because the structure of the rice plant was reflected, the classification possibility of high accuracy, which used polarimetric information, was shown.
- When polarimetric data was obtained, Color composite was made possible based on the power image of each polarization, and it came to be able to understand the growth situation of farm products not understood in the single polarimetric image.
- Distinction of Bragg scattering that it is not possible to do in the single polarimetric SAR data becomes possible when polarimetric data is obtained, and the planted area of rice can be calculated in high accuracy.
- When full polarimetric data is obtained, Decomposition analysis and drawing of the polarimetric signature become possible. It was thought that a quantitative analysis of the growth situation of farm products became possible.

Acknowledgments

Thank you for Dr. Wakabayashi of NASDA/EORC who gives me an analytical program and guides me the analysis of polarimetric information. And, I thanks to Dr. Kimura of Gifu University who guided the polarimetric calibration technique. This report is a part of the resulting in a joint research concerning aircraft SAR such as CRL and NASDA. We wish to express our gratitude to parties concerned. Moreover, this research was done partially of the emphasis research support cooperation member business of Japan Science and Technology Corporation by using the budget of oceanic development and Earth science technology investigation promotion expense “Research on the global environment remote sensing technology etc.”.

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