PALSAR SCANSAR-SCANSAR INTERFEROMETRY

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ABSTRACT

We have examined the capability of the PALSAR SCANSAR SCANSAR interferometry by observing the African forest and Sahara desert, both of which are separated 46 days in March and April of 2008. These two paths are well tuned for the orbital tube of 200m and the beam synchronization of the transmission positions in 200m to 500m, we have succeeded the PALSAR SCANSAR SCANSAR interferometry and achieved the detection of the height information. We will report the results in this paper.

Index Terms— PALSAR, SCANSAR, Interferometry

1. INTRODUCTION

PALSAR provides STRIP and SCANSAR operation modes for imaging. It has been demonstrating the high performance of the land observation using the imaging function and the interferometric capability [5-9]. Interferometric function of the strip-strip modes has been well evaluated and it confirmed that the PALSAR interferometry provides the high coherence for the land covered by the vegetation while the disadvantage of the strip-InSAR is the imaging swath of only 70km. Recently, the earthquake becomes larger and larger as seen from that the Peru earthquake of Aug 17 has Magnitude of 8.0, the Solomon earthquake as M.8.1, and the Sumatra-west earthquake as M. 8.2, and thus the wide imaging swath is absolutely required. SCANSAR-SCANSAR interferometry (SSI) is the only opportunity to monitor these types of the earthquake and the related surface deformation. Difficulty of the PALSAR SSI is that the synchronization of the signal burst in master and slave is not programmed and the interferometric processing of the two image data is very complex. Using the PALSAR data acquired over the south part of Africa and west part of Sahara, possibility evaluation has been conducted. Resultantly, the PALSAR first SCANSAR SCANSAR interferometry has been generated. As for the SSI for the other satellites, i.e., Radarsat and Envisat can be referred to [1][2].

With regard to the ScanSAR imaging, there are two methods available. They are Specan processing and the Zero-aperture type processing. The former provides the well focusing both in SAR amplitude and phase opposite to the very difficult software tuning. On the other hand, the zero-aperture type processing can be easily achieved by simple modification of the Range-doppler type SAR processor opposite to the less quality of the SAR imaging. For the InSAR processing, SRTM DEM was generated by the Specan method and the Radarsat ScanSAR-ScanSAR interferometry was generated by the Zero aperture type p SAR processing. In this paper we will not compare the total performance of these processing methods. We will try to apply the Specan type SAR processing for the InSAR imaging.

2. PALSAR SCANSAR SCANSAR INTERFEROMETRY

In order to achieve the PSSI, two-dimensional signal spectra of the master and slave images are required to be the same as much as possible. The two-dimensional similarity can be achieved in other words, beam synchronization in azimuth direction and the cross track tuning. After the two spectrums are well overlapped, the interferometric processing can be conducted as same as the STRIP InSAR data.

2.1 Beam Synchronization

As shown in Table 1, the PALSAR short bandwidth SCANSAR (WB1) has range dependent pulse numbers and the variable pulse repetition frequency (PRF) in azimuth direction. The wide band SCANSAR (WB2) has longer number of pulses, which has bigger allowance of the beam synchronization. L-band signal exceeds the interferometric capability than higher frequency SAR of C and X band because of the higher signal penetration in the forested regions and lower special decorrelation than the higher frequency SAR. Thus, essentially L-band signal offers the higher interferometric capability, however, it is not known how much the beam synchronization accuracy is required for the SSI. Here, we define the beam synchronization accuracy (Δp) as the ratio of the overlapped distance of the two SCANSAR beams to the distance of the each SCANSAR dwell time, as below;

$$\Delta p_j = \frac{|r_m - r_s|_j}{L_j} \quad (1)$$

where r_m is the satellite position at the first pulse of j th scan was transmitter, r_s is that of slave position, and L is the length of the along track distance when the j th SCAN lasts. Table 1 shows the pulse number for WB1 and Table 2 shows that for the WB2. Table 3 lists the number of the looks.

Table 1 Pulse numbers and dwell times (WB1)

No	Pulses	PRF	Duration(s)	Length (km)
1	247	1692.0	0.146	0.993
2	356	2369.7	0.150	1.02
3	274	1715.2	0.160	1.09
4	355	2159.8	0.164	1.15
5	327	1915.7	0.171	1.16
Total			0.791	5.38

Note: PRF values in the table are the examples. Length is based on ground satellite speed of 6.8km.

Table 2 Pulse numbers and dwell times (WB2)

No	Pulses	PRF	Duration (s)	Length (km)
1	480	1692.0	0.284	1.932
2	698	2369.7	0.295	2.006
3	534	1715.2	0.311	2.115
4	696	2159.8	0.322	2.190
5	640	1919.4	0.333	2.2644
Total			1.545	10.52

Table 3 Number of looks

No. of scans	Band width	Number of looks
5	14MHz	3.6, 5.35, 4.08, 5.34, 5.03
5	28MHz	1.85, 2.27, 1.73, 2.21, 2.13

Within the operation sequence, the PALSAR activation is commanded with the time unit of 1 s. Thus, the normal operation cannot allow the PSSSI synchronization. In order to conduct the PSSSI, special commanding as the experimental mode should be selected. The input to the PALSAR operation in this mode needs the argument of latitude, and the onboard managing system outputs the corresponding transmission time using the real time GPS data. Although the accuracy of the GPS data, i.e., x , y , and z , are well enough for providing the SAR image location, the argument of latitude is not well prepared. The averaged accuracy is the order of 100~200m.

2.2 Cross Track Tunings And Perpendicular Baseline

ALOS orbit has been controlled within 500-meter tube over the equatorial region so far. Since the orbital inclination, 99 degrees, slowly decreases to the change of 0.0118 degrees in two years and a half. This change corresponds to 5 km of ground track in the north or south most regions. During the one revisit time of 46 days, the two SAR images may be processed with the high coherence condition.

3. PROCESSING OF PALSAR SSI

3.1 Imaging

The general processing sequence is shown in Fig. 1. Two image SCANSAR data are processed using the same Doppler parameters. The Doppler centroid model is expressed by quadratic function of the slant range. Individually calculated two Doppler centroids for master and slave are averaged and used for the further imaging processes. The Doppler chirp rates are not averaged and used for its own image. The imaging is conducted by using the SPECAN algorithm [3][4]. As the end of the image creation process, the data will be corner turned to range in x and azimuth in y directions.

3.2 Coregistration

Co-registration frame is generated as a quasi-affine function of x and y . This frame is built up for each SCAN. The Coregistration frame will be made up through three steps, 1) rough matching of FFT based coregistration in x and y shifts, 2) the small patch based (64 pixel and 64 lines) amplitude matching of the master and slave images all over the images, and 3) fine tuning of two images using the complex coherence.

Fig. 1. Block diagram of the PALSAR SSI. Here, the general description of the InSAR based SAR imaging and the detection of the phase change is expressed.

3.3 Interferometric Processing

The processing is as the same as the strip SAR.

3.4 Deformation Detection

Deformation detection is based on the phase cancellation using the DEM data. Here, the detection of the phase is different from the STRIP SAR in expression of the target point. The STRIP SAR can be approximated as the SAR moving the optical sensor moving with the constant sampling spacing on the orbit. The SCANSAR can be modeled as the wide Doppler frequency spectrum up to the PRF at the short dwell time. Thus, the fun beam type expression of the positioning is required fro modeling the signal back scattering form the target. Position of the target (pixel) on the ground can be calculated by iterative method as satisfying the following equations.

$$f_d = \frac{f_{PRF}}{nn} i \left(-\frac{nn}{2} \leq i < \frac{nn}{2} \right)$$

$$f_d = \frac{2}{\lambda} \left(v_s - v_p \right) \cdot \frac{r_p - r_s}{|r_p - r|} \quad (2)$$

$$z = F(r_p)$$

Here, f_d is the Doppler frequency assigned for the each image pixel, f_{PRF} the pulse repetition frequency, nn is the number of the pulses in the SCAN (refer to Table 1 and 2), I is the address number in the azimuth SPECAN, λ is the wavelength (0.236m), v_p is the velocity of the target, v_s is the satellite velocity, r_p is the position of the target, r_s is the satellite position, z is the height of the pixel, $F()$ is a function relate the latitude, longitude of the pixel and the height. $F()$ is in other word SRTM3 model function.

4. EXPERIMAENTS USNG THE SPECAN SAR DAT FOR THE STRIP MAP MODE

Using the data acquired from the Hawaii slant on May 2 2006 and August 2 2006, the above processing was conducted. The comparison results were shown in the Figures 2, which contains the amplitude image, deformation patter, flat earth corrected fringe, and the coherence. In the same way, the interferometric datasets were obtained from the SAR strip map fine processing in the Figure 3. Although the coherence has some difference, but the general phase qualities are the same between them. Thus, the SPECAN SAR has the phase information.

Browse-InSARによる処理結果 (2006/8/2-2006/5/2)

Fig. 2 Four examples obtained from the SPECAN SAR interferometry. The data is acquired from the Hawaii on Aug. 2, 2006 and May 2, 2006. The Bperp is 88 meter.

FBS DinSARの結果 : 2006/8/2-2006/5/2

Fig. 3 four examples obtained from the standard correlation type processor. The data are the same to the Fig 2. In this scale of the image, the interferometric results are almost the same. The exception appears at the coherence.

5. PALSAR SSI

Although the normal operation for the PALSAR cannot provide the PSSI because the transmission timing is every 1s order. In order to evaluate the potential of the PSSI, we have conducted the experiments over the Africa and Amazon from the early to the mid of April 2008 using the ten path data. This test contains the narrow band and wide band SCANSAR. All the data (ten path data) are 46 days separated. Thus the there are only two paths for the PSSI.

Table 4 Synchronization parameters

Case	Master	Slave	Bp	Δp	δ length
1	20080410	20080224	228m	0.2	200m
2	2008041	2008030	168m	0.5	500m

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Note: 1) Both paths are over the Africa continents. 2) Bp is calculated at the near range.

5.1 Africa Case

Figures 4-a is the amplitude image of the target area, which is the south of Tanzania. The image covers the border among Tanzania, Malawi, and Mozambique, where the lake Nyasa is visible. This area has several land features, i.e., forested regions, and the lake area. The land cover seems to be covered by the forest areas. The width of the image is 350km and length of the image is around 300km. Baseline distance varies with the off nadir angle. It was expected to see the incidence angle dependence of the coherence. However, the incidence angle dependence was not visible in this wide scene case, where the incidence angle varies from 17 degrees to 42 degrees.

Fig. 4-b is the coherence map of the target area. Total coherence is not high as compared to the STRIP SAR interferometry. The number of the looks is the 4 in range and 2 in azimuth. The averaged looks number is 3 to 5 depending on the beam number (see Table 3).

Fig 4-c is the flat earth corrected PALSAR SSI. One fringe cycle corresponds to the height of 149m in near range and 280 m in far range. Because of the perpendicular baseline, it is not simple to retrieve the height information. But, the fringe quality is not so bad.

Fig. 4-d is the fringe map corrected for the SRTM DEM. Although there are some phase discontinuity are confirmed, the additional fringe due to the topography is not visible. Although more improvement is necessary, the PALSAR SCANSAR SCANSAR interferometry has high potential for conducting the phase observation.

Figs 4. Four PALSAR SSI images are drawn. A) the amplitude image, b) the coherence map, c) the flat earth corrected fringe, and d) the DTM corrected fringe.

5.2 Sahara Case

Another example is the Africa Sahara Case, where the master and the slave data were obtained on April 17 and March 2, 2008 respectively. Fig. 5 shows the amplitude image, coherence, flat earth corrected phase, and surface deformation pattern.

Fig. 6. Four images obtained from amplitude image, coherence pattern, digital elevation model, and the surface deformation patterns.

6. CONCLUSIONS

We introduced the first PALSAR SCANSAR SCANSAR interferometry results. Although the normal operation does not allow the beam-to-beam synchronization operation. Only the experimental purpose operation allows the SCANSAR-SCANSAR interferometry. Among the ten experiments, only two were found as the possible PALSAR SSI. Both two are processed correctly and succeeded to detect the phase information even both images are the dense forest target and the dark target of the African desert area. These are because that L-band SAR has high potential for SCANSAR interferometry although the Δp is 50%. This is the very good information for planning the SSI for some deformation detection purpose. We will continue to improve the quality of PALSAR SSI in future.

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