SCANSAR IMAGE QUALITY ENHANCEMENT USING FITTED-GEOMETRY DOPPLER SURFACE

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1. INTRODUCTION

Most of currently operational Synthetic Aperture Radar (SAR) satellites include the Scanning SAR (ScanSAR) mode for extended remote sensing applications. The extended swath provided by the ScanSAR mode can make up for the disadvantage of normal satellite SAR operation, such as limited coverage areas and short revisiting times. Therefore the ScanSAR mode is desired, especially when reduced resolution is acceptable in order to achieve global monitoring and continuous observation capabilities.

Due to its unique burst most operation, the ScanSAR processing is distinguished from conventional full aperture SAR processing techniques such as RDA or chirp scaling algorithm. Although the SPECAN algorithm is known to be the most efficient technique for processing continuous mode data, its merit is highlighted when applied for ScanSAR mode data. The SPECAN method is convenient to apply for each burst signal coming from different sub-swaths during ScanSAR operation and the processed signals are combined together later on.

However, the simplicity of the algorithms increases the efficiency of the data processing, it is inevitable to see the degradation of the SAR image quality. This may not be a considerable issue for the medium-to-low resolution images that ScanSAR mode data produce. But as the swath width increases and the SAR operation scenario becomes complicated, the estimation processes for DC(Doppler Centroid), Doppler rate parameter and PRF values over wide range intervals are highly complicated and elevates difficulties of producing high quality images. It is not straightforward to implement a high performance processor that works with diverse ScanSAR data of arbitrary mission parameters including sub-swath number, PRF, yaw steering and so on.

In this paper, an efficient and high quality ScanSAR signal processing processor is implemented based on SPECAN algorithm. The role of the accurate Doppler parameter estimation is described with regard to the processed SAR images. A method of extracting the Doppler parameter with high precision is introduced and its performance is verified when implemented on the developed ScanSAR processor. For this purpose, we have adopted a Doppler surface fitted-geometry method and demonstrated how it can contribute to the improved Doppler parameter estimation.

The SPECAN technique treats raw data as the sequence of bursts and thus provides a good efficiency in terms of processing burden. However, when the SPECAN method is used alone, the quality of the image resolution is strictly limited due to the linear RCMC approximation and irregular sample spacing in the azimuth direction. Hence a modified SPECAN algorithm is adopted to compensate the error during RCMC approximation and enhance the final image quality.

The performance of the developed processor is verified by processing a Radarsat-1 ScanSAR data over Korean peninsula with 3 sub-beams. We demonstrate that the proposed method of modifying the Doppler parameter estimation process leads to the improved SAR image quality. All the functions and algorithms are implemented using modular C++ code modules so that, in addition to the improved efficiency, they can be easily upgraded and adopted to general SAR processors for in-class academic uses.

2. SCANSAR SIGNAL PROCESSING

The block diagram of ScanSAR signal processing processor based on SPECAN algorithm is shown in Fig.1[1]. When the SPECAN algorithm is used, the azimuth compression is performed on each burst data through signal deramping and FFT operations. An additional function of azimuth stitching is required to produce continuous image along the azimuth direction.

In this procedure, the azimuth data samples should be aligned by the same intervals for the whole space and we have adopted the CZT algorithm to achieve this goal[2].

The good-points, which designate the samples used for actual burst processing, are extracted based on Doppler center frequency. A method of descalloping is introduced to form continuous image while maintaining constant resolutions along the multiple sub-swaths.

It is shown that the estimated Doppler center frequency plays a great role in selecting the good-points position and generation of descalloping filter. The accuracy of the Doppler center frequency estimation becomes an important measure of the SAR image quality in ScanSAR modes. The SPECAN is particularly vulnerable to the non-linear characteristics of the Doppler parameter variations along the azimuth and range directions, we attempt to correct the linear estimation error with the best approximate method.

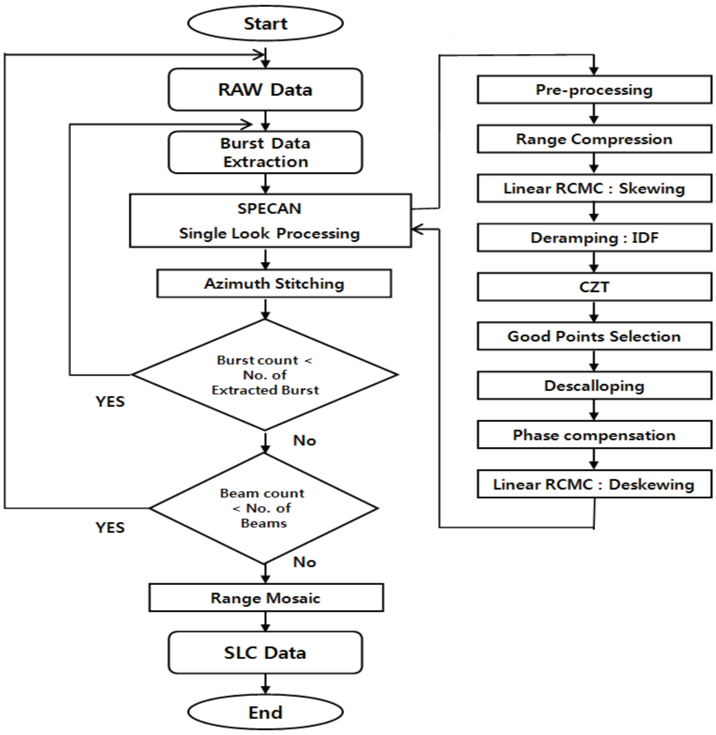

Figure 1. Functional Block Diagram of ScanSAR Processor

3. DOPPLER SURFACE FITTED GEOMETRY MODEL

A number of Doppler parameters estimation methods have been introduced and studied that can be applicable to the ScanSAR mode data[3][4][5]. In this paper, we have produced Doppler surface images corresponding to the SAR processing domains. In order to increase the reliability, an additional algorithm is adopted to the ScanSAR data similar to the method used for pitch and yaw estimation of satellite dynamics [6].

The proposed estimation procedure is as follows.

1. The ACCC angle is estimated for each burst using the CDE method[7].
2. To minimize terrain effect, Doppler surface is produced for baseband signal by performing a phase smoothing.
3. The phase unwrapping is performed using the recombination method by image division and comparison deviation. In this method, the accuracy of the unwrapping becomes highly accurate if Doppler center frequency variation in range and azimuth direction is within 3 PRF. It has a relatively good advantage in terms of simplicity and processing time.
4. The effective attitude and geometry model parameter are extracted that minimize standard deviation. It is found that the fitting algorithm of Doppler center frequency using pitch and yaw angle estimation works well for range directions but

the estimation error becomes intolerable when the data acquisition time quickly increases along the azimuth directions as in the ScanSAR mode data.

5. The linear polynominal offset parameter is calculated along both the range and azimuth directions and used for correction of the Doppler parameters previously obtained from geometry model.

Fig.1-3 show that procedure of the Doppler parameter estimation described earlier. It is clearly shown that with the combination of the both geometry model and linear parameter estimation, the margin of error is greatly reduced.

Fig. 4 demonstrates that the scalloping effect, which is a typical drawback of the ScanSAR image, has been considerably suppressed after fitted-geometry Doppler surface method is applied. In Fig. 5, we present the final ScanSAR image produced by using Doppler estimation proposed in this paper and compare it with its corresponding SCN product.

4. RESULTS AND PERFORMANCE COMPARISON

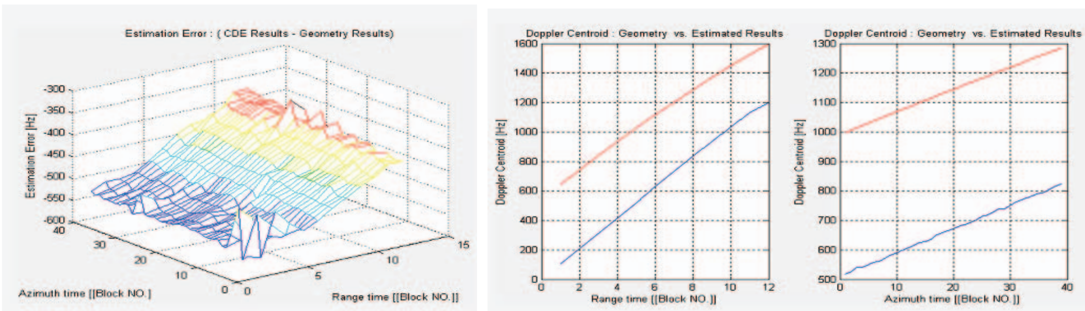

Figure 1. Estimation Error after unwrapping

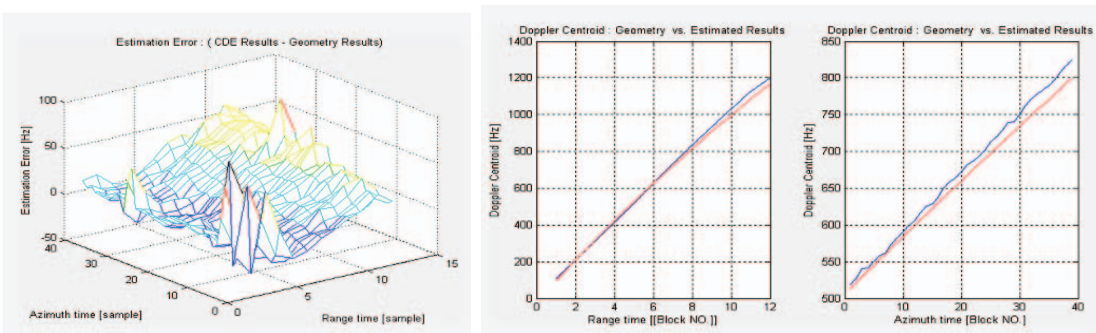

Figure 2. Estimation Error after Effective attitude estimation

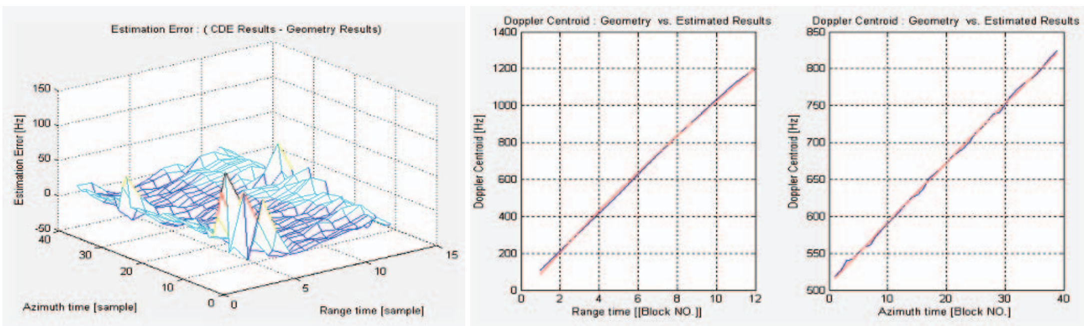

Figure 3. Estimation Error after Polynomial Offset Setting

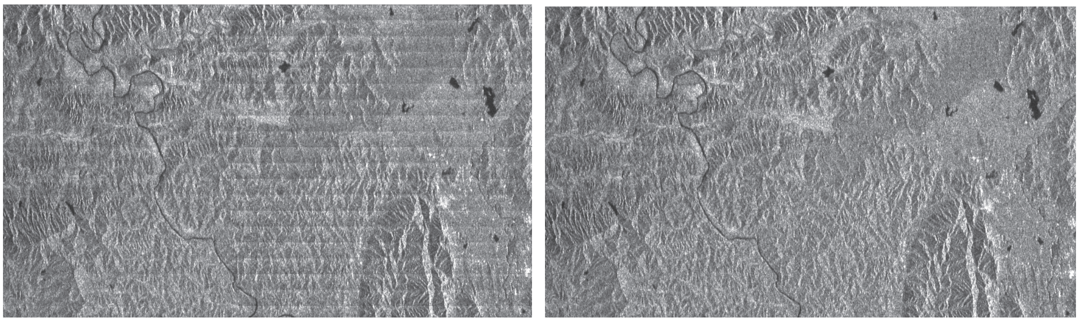

Fig 4. Image Quality Enhancement using the Fitted-geometry Doppler surface

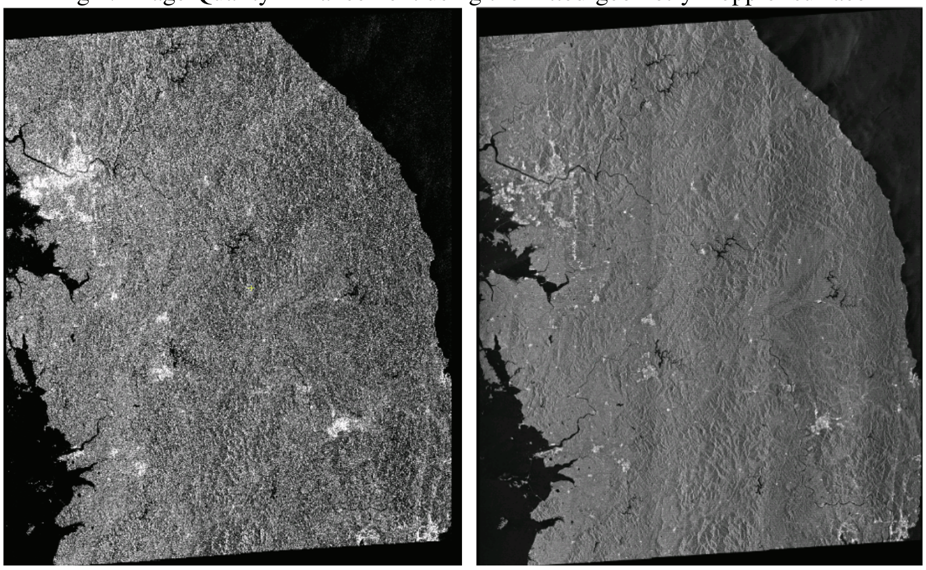

Figure 5. Radarsat-1 SCN Product(left) and ScanSAR Processed Image(right)

3. REFERENCES

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