A NOVEL THREE-STEP FOCUSING ALGORITHM FOR TOPSAR IMAGE FORMATION

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1. INTRODUCTION

TOPSAR (Terrain Observation by Progressive Scans) is a novel wide-swath high-resolution operation mode for spaceborne synthetic aperture radar (SAR) [1-3], which has been recently demonstrated by TerraSAR-X mission [4, 5]. Comparing to traditional ScanSAR mode, TOPSAR is feasible to perfectly resolve the azimuthal scalloping problem, which results in azimuthal spatial-varying AASR (Azimuth Ambiguity to Signal Ratio) and $NE\sigma_0$ (Noise Equivalent Sigma Zero), by means of properly steering radar antenna in along-track direction. However, the signal characteristic of TOPSAR is significantly different with other ordinary SAR modes, because of the azimuth folding effects in the time and frequency domains Therefore, the standard image formation algorithms are not suitable for processing TOPSAR data.

A pre- and post- processing scheme combined with a multirate filter bank algorithm was firstly introduced in [1], which is found to be difficult for implementing the filtering operations. Moreover, a refined Extend Chirp Scaling (ECS) algorithm was proposed in [3, 4], with the disadvantage of increasing the sub-aperture recombination operations. Therefore, a novel three-step image formation algorithm for precisely focusing TOPSAR data is proposed in this paper, which is much simpler for implementation by means of avoiding both multirate filtering and sub-aperture recombination operations.

2. METHODOLOGY

The main research methodology of this paper is as follows:
(1) To analyze the characteristic of the TOPSAR mode, including defining a key parameter E (namely, the ratio of the closest distance between rotation center and target to the closest distance between rotation center and sensor) based on the geometry model and deducing the signal azimuth bandwidth by using the time-frequency diagram.
(2) To build the echo signal expression and then deduce some important results connected to the key parameter, such as the scene bandwidth, resolution and so on, which are the foundation of the three-step algorithm.
(3) To illuminate the three-step algorithm step by step and the results of every step are also illustrated.
(4) To simulate the TOPSAR data and process with the three-step algorithm, and the quality measurement results are used for confirming the validity of the three-step algorithm.

3. THE THREE-STEP ALGORITHM

As shown in Fig.2, the proposed algorithm includes three steps as follows:
(1) De-rotation processing. This step employs an azimuthal convolution operation on the raw data with a linear frequency modulation function (chirp-like signal), whose chirp rate is dependent on the rotation speed from backward to forward in the along-track direction. The problem of Doppler frequency folding is perfectly resolved in the procedure, without dividing the raw data into various sub-apertures.
(2) Image formation processing. The standard Chirp Scaling (CS) algorithm [6, 7] is employed to focus the radar images.
(3) Azimuthal deramp processing. In order to deal with the azimuth folding effect in time domain, azimuthal decamping is utilized to appropriately stretch the image in azimuth time domain. And we can select appropriate parameter to output the desired azimuth spacing for sub-swath images mosaic processing.

A precisely focused SAR image can be obtained by following the above three steps. Therefore, the proposed algorithm is simple for implementation and efficient for processing TOPSAR data, in which the whole data processing procedure is implemented by just using FFT and complex multiplications.

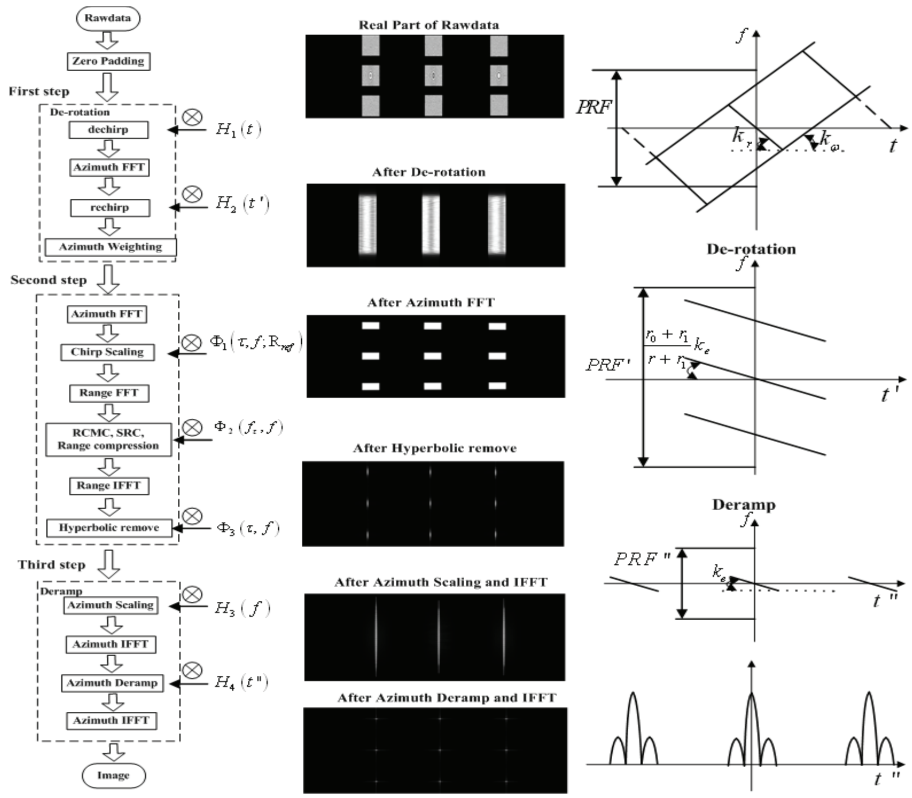

Fig.2 Flowchart of the three-step algorithm

4. CONCLUSION

A novel three-step algorithm for precise and efficient focusing of TOPSAR data is presented. The first step of the algorithm is azimuth de-rotation operation, which is adopted to accommodate the scene bandwidth. Following this operation, a standard CS algorithm is applied to data focusing. The key point of the algorithm is deramp processing, by which both the time domain unfolding processing and the desired azimuth spacing are implemented by properly adjusting deramp parameters. The algorithm is easier to implement for only employing FFT and complex multiplication in computation.

5. REFERENCES

[1] F.De Zan and A.Monti Guarnieri, “TOPSAR: Terrain Observation by Progressive Scans,” *IEEE Transactions on Geoscience and Remote Sensing*, pp. 2352-2360, 2006.

[2] Adriano Meta, Pau Prats, Ulrich Steinbrecher, Josef Mittermayer, and Rolf Scheiber, “TerraSAR-X TOPSAR and ScanSAR comparison,” *Proc. IGARSS*, 2008.

[3] Adriano Meta, Pau Prats, Rolf Scheiber, and Josef Mittermaye, “First TOPSAR image and interferometry results with TerraSAR-X,” *Proc. FRINGE*, 2007.

[4] Pau Prats, Rolf Scheiber, Josef Mittermayer, Adriano Meta, and Alberto Moreira, “A SAR Processing Algorithm for TOPS Imaging Mode Based on Extended Chirp Scaling,” *Proc. IGARSS*, *Barcelona,* pp. 148-151, 2007.

[5] Pau Prats, Adriano Meta, Rolf Scheiber, Josef Mittermayer, and Alberto Moreira, “A TOPSAR Processing Algorithm Based on Extended Chirp Scaling: Evaluation with TerraSAR-X Data,” *Proc. EUSAR*, 2007.

[6] R.Keith Raney, H.Runge, Richard Bamler, Ian G.Cumming and Frank H.Wong, “Precision SAR Processing Using Chirp Scaling,” *IEEE Transactions on Geoscience and Remote Sensing*, pp. 786-798, 1994.

[7] HUANG Yan, LI Chun-sheng, CHEN Jie, ZHOU Yin-qing, “Refined Chirp Scaling Algorithm for High Resolution Spaceborne SAR Imaging,” *ACAT ELECTRONICA SINICA*, pp. 35-38, 2000.