A THREE-DIMENSIONAL IMAGING ALGORITHM FOR TOMOGRAPHY SAR

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Tomography SAR is the extension of the conventional InSAR, which adds multiple baselines in the direction perpendicular to azimuth and to the line-of-sight, and forms an additional synthetic aperture in elevation direction, so it has resolving capability along this dimension [1-3]. A simple FFT based 3-D imaging method proposed by Dr. Reigber in [1] for tomography SAR, the SPECAN approach, which can obtain good imaging result if the synthetic aperture in elevation direction is sampled regularly. Unfortunately, at the current status of airborne SAR tomography, it is almost impossible to avoid a non-uniform track distribution in repeat-pass data acquisition, so the tomography image will encounter high side lobes and elevation ambiguities using SPECAN approach.

In order to overcome the drawbacks of SPECAN approach caused by the non-uniform track distribution, a new three-dimensional imaging algorithm based on back-projection processing technique has been proposed in this paper. The back-projection technique performs processing on a pulse-by-pulse, pixel-by-pixel basis, and maintains the 3-D geometric relationship between the exact radar positions and the illuminated area [4,5]. Therefore, it can realize accurate motion compensation of multi-baseline airborne SAR data, and acquire better imaging result.

In tomography SAR system geometry, there are K passes over the same illuminated area. In each pass, the radar moves along the azimuth direction and transmits coherent phase modulated pulses in range direction. The single SAR image derived after azimuth and slant range direction focusing for each pass can be described as [6,7]

$$s(\hat{t}, y; R_{zp}) = A \sin c[\Delta f_r (\hat{t} - \frac{2R_{zp}}{c})] \sin c[\Delta f_y (y - y_p)] \exp(-j\frac{4\pi}{\lambda} R_{zp}) \qquad (1)$$

where Δf_r is range bandwidth, Δf_y is azimuth bandwidth, and R_{zp} is the projection of the distance between the radar and the target in the xz plane. From (1) we can see that the azimuth and slant range direction focusing image of tomography SAR can be obtained with the same imaging process of classical SAR. The information of elevation direction is included in the phase of equation (1), which is not coupling with the data of azimuth and slant range directions. Consequently, the imaging process of elevation direction can be separated from the azimuth and slant range directions in tomography SAR.

Intercepting a slant range-elevation section, we can calculate the bidirectional delay time between each pixel in the selected slant range-elevation section and the radar elevation position of each pass in tomography SAR based on the principle of back-projection [4]. Then the cumulating curve of each point scatterer can be found. As the positions of different point scatterers after range compression changes with different curves in the corresponding slant range-elevation section, the focused results of different point scatterers can be given by coherent sum of the signals after phase compensation along their corresponding cumulating curves. Therefore, the three-dimensional image can be derived by processing the slant range-elevation sections correspond to each azimuth position.

There are four main parts in the paper. A general geometry model of tomography SAR is described and three-dimensional imaging principle of tomography SAR is investigated. A three-dimensional imaging algorithm based on back-projection technique is proposed, which can overcome the influence caused by non-uniform track distribution in case of airborne SAR data of multiple acquisition paths, and better result is obtained compared to the SPECAN image.

References

[1] A. Reigber, A. Moreira, "First Demonstration of Airborne SAR Tomography Using Multibaseline L-Band Data," IEEE Trans. Geosci. Remote Sens., vol.38, no.5, pp. 2142-2150, 2000.

[2] G. Fornaro, F. Serafino, and F. Soldovieri, "Three-Dimensional Focusing With Multipass SAR Data," IEEE Trans. Geosci. Remote Sens., vol.41, no.3, pp. 507-517, 2003.

[3] G. Fornaro, F. Lombardini, and F. Serafino, "Three-Dimensional Multipass SAR Focusing: Experiments With Long-Spaceborne Data," IEEE Trans. Geosci. Remote Sens., vol.43, no.4, pp. 702-714, 2005.

[4] M. D. Desai and W. K. Jenkins, "Convolution backprojection image reconstruction for spotlight mode synthetic aperture radar," IEEE Transactions On Image Processing, vol.1, no.4, pp. 505-517, 1992.

[5] L. M. H. Ulander, H. Hellsten, and G. Stenstrom, "Synthetic Aperture Radar Processing Using Fast Factorized Back-Projection," IEEE transactions on aerospace and electronic systems, vol.39, no.3, pp. 760-776, 2003.

[6] R. K. Raney, H. Runge, and R. Bamler, et al., "Precision SAR Processing Using Chirp Scaling," IEEE Trans. on GRS, vol.32, no.4, pp. 786-799, 1994.

[7] A. Moreira, J. Mittermayer, and R. Scheiber, "Extended Chirp Scaling Algorithm for Air- and Spaceborne SAR Data Processing in Stripmap and ScanSAR Imaging Modes," IEEE Trans. on GRS, vol.34, no.5, pp. 1123-1136, 1996.