Chirp Scaling Algorithm for Parallel Bistatic SAR Processing

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Abstract:

Bistatic radar imaging is currently an active area of research. The physical separation of transmitter and receiver confers several advantages to the synthetic aperture radar (SAR) applications, such as the exploitation of extra information included in the bistatic reflectivity of targets, reduced vulnerability for military applications and flexible interferometric baseline for topographic mapping. Obviously the bistatic radar constellation is the basis of the distributed spaceborne system, and thus the bistatic SAR processing becomes the fundamental research topic.

Bistatic SAR imaging is more involved than the monostatic SAR case due to the considerable separation of the transmitter and the receiver. Therefore, the bistatic SAR data can not be processed sufficiently by using the monostatic focusing algorithms. The bistatic SAR systems can be considered as Azimuth-Invariant during an aperture time, provided that the bistatic transmitter and receiver move in a constant velocity in a parallel constellation. This case is referred to as parallel bistatic SAR for simplicity, which is the focus of this paper.

Due to the separation of the transmitter and the receiver in bistatic SAR, the synchronization of frequency, time and antenna pointing should be well resolved, which is not a new problem and its possible solutions can be found in several literatures. Besides these technical problems, the focusing algorithm is another difficulty, and hence how to develop a fast and effective image formation algorithm for parallel bistatic SAR system is the purpose of this paper.

The range history of parallel bistatic synthetic aperture radar(SAR) is called 'flat top' hyperbola, compared with which of monstatic SAR, its range variation should be small enough to be neglected in equivalent side looking mode when the swath was not so wide; but which should be considered in the conditions of wide swath or equivalent squint mode. The chirp scaling(CS) algorithm is efficient and precise in processing range cell migration correction(RCMC) for monostatic SAR, but the precondition is the Doppler wavenumber domain formula of echoes can be obtained. For parallel bistatic SAR, because of the two square roots appeared in the expression of the range history, it is quite difficult, to obtain an analytical formula to describe the target echoes in both range and azimuth Doppler wavenumber domain, which makes it very difficult to develop fast focusing algorithms.

In this paper, based on the concept of instantaneous Doppler wavenumber (IDW) and by introducing a new variable called Half Quasi Bistatic Angle (HQBA), a precise 2-dimension (2-D) wavenumber analytical formula is adopted to describe the target echoes of parallel bistatic SAR. The formula and its detailed deduction can be found in reference[1]. It can be written as

$$S(k_R,k_X)=\sigma_n W_{k_X} W_{k_R}\exp\left[-j\frac{(k_R-k_{R0})^2}{2b}\right]\exp\left[-j\frac{R_{B\Sigma}}{2}\sqrt{4{k_R}^2\cos^2\beta-{k_X}^2}-jx_nk_X\right] \times\exp\left[-jh_x\tan\beta\sqrt{4{k_R}^2\cos^2\beta-{k_X}^2}+j\frac{R_{B\Delta}}{2}\tan\beta k_X\right] \tag{1}$$

Where, W_{k_R}, W_{k_X} represent the windows of echoed signal in range and azimuth direction respectively, b denotes the equivalent chirp rate. The first and second phase terms in above formula can be regarded as the equivalent monostatic term and the last term serves as an accessional one for the bistatic case.

In chirp scaling, properties of linear FM pulses are used to achieve the range-variant signal shift required in processing, without the need of implementing an interpolator. This is done by simply multiplying uncompressed

range lines by an appropriate phase function, so each pulse compresses to a desired location, such that the range dependence of the required signal shift is removed.

In order to get the appropriate phase function or the bistatic SAR linear chirp scaling factor, we transform the formula (1) into range-doppler domain:

$$S\left(r,k_X\right)=\sigma_n W_{k_X} W_r \exp\left[j\Phi\right]\times\exp\left[-j\frac{b_m}{2}(r-A_{X0}-\frac{\Delta r}{B_{X0}})^2\right] \tag{2}$$

Where $W_r=rect\left[\frac{b_m(A_{X0}+\Delta r/B_{X0}-r)}{bcT_p}\right]$ represent the signal shift along Doppler wavenumber. By analogy with the deduction method of CS algorithm in monostatic SAR, the chirp scaling phase function of bistatic SAR can be written as:

$$H_1(k_X,r)=e^{-j\frac{b_m D}{2}r^2} \tag{3}$$

The corresponding chirp scaling factor D is

$$D=\frac{1}{B_{X0}}-1 \tag{4}$$

With the above formulas, a CS algorithm is proposed for azimuth-shift-invariant bistatic SAR processing. The presented algorithm can well resolve the range variation of motion through range cell(MTRC) for bistatic SAR, and requires no interpolate; it requires only FFTs and complex multiplies, these attributes lead to efficient implementations of FFT-based signal processors and high speed parallel processors; it can be used for high resolution image formation.

Key Word: bistatic SAR, Chirp Scaling, Instantaneous Doppler

Reference

[1] Z. Zhang, M. Xing, J. Ding, and Z. Bao, Focusing Parallel Bistatic SAR Data Using the Analytic Transfer Function in the Wavenumber Domain. IEEE TRANS. ON GRS, VOL. 45, NO. 11, 2007 .3633~3645