A GPS SIGNAL BASED FAST NUMERIC RANGE MIGRATION ALGORITHM OF SPACE-SURFACE BISTATIC SAR

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Research of bistatic synthetic aperture radar (SAR) imaging is a challenging part of radar signal processing field. In comparison with monostatic SAR, bistatic SAR (BiSAR) brings several additional benefits such as getting extra forward reflective information of targets, reduced vulnerability for military applications, etc. Global navigation satellite system (GNSS) based space-surface BiSAR (SS-BSAR) is a subclass of BiSAR, which consists of a spaceborne transmitter and a receiver on or near the Earth’s surface[1]. In this situation, the GNSS satellite is used as the illuminator and the receiver could be stationary on the ground, mobile on an aircraft or on a land vehicle. Here, we only consider the case of airborne receiver and GPS signals are used as the transmitted signals, see Fig. 1. It is a typical asymmetric space-airborne BiSAR system with non-cooperative illuminator of GPS, periodic narrowband transmitted signal, limited range resolution and low power budget.

Researchers have focused on issues of low power budget and system interference of SS-BSAR and some feasible solving methods have been presented[2-4]. As shown in Fig. 1, SS-BSAR is a typically arbitrary trajectory BiSAR with spaceborne transmitted signal and airborne receiver in different velocities. Moreover, the transmitter-to-target range is disproportionate to the receiver-to-target range. So it is hard to put forward an appropriate BiSAR imaging algorithm for this arbitrary configuration SS-BSAR system. [5] has proposed a bistatic range migration algorithm (RMA) for 2-D geometry, but its disadvantage is the interpolation in the 2-D frequency domain. Quasi-monostatic processing method[6] needs compensate bistatic deformation term and leads to a large computational load. All of the above algorithms seem to deal with airborne or spaceborne symmetry construction BiSAR imaging with low computational efficiency. Recently only a few works[1,7] have been done for this asymmetry SS-BSAR, where [1] has proposed a modified range-Doppler algorithm(RDA) and shown exciting experimental results, but with quite large calculation load and the assumption of parallel configuration BiSAR.

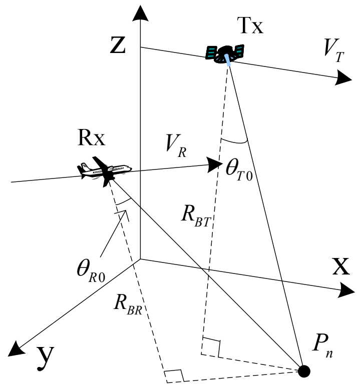

Fig. 1 GPS signal based SS-BSAR geometry

In this paper, we will present a new numerical bistatic RMA, specifically designed for GPS signal based arbitrary trajectory constellation SS-BSAR. In order to solve the well known question that the slant range history of BiSAR is the sum of two square-rooted terms, in our previously published work, we proposed a parallel trajectory with equal velocity bistatic range migration algorithm for any azimuth-shift-invariant BiSAR[8]. We now extend our algorithm to the case where the GPS satellite and the airborne receiver move in non-parallel flight trajectories with unequal velocities. The transmitted signal of GPS satellite is a continuous, periodic pseudo random sequence modulated by 1.5GHz carrier of L-band, which is different from the normal wideband signal of BiSAR.

We first compensate the Doppler shift of echo signal modulated by continuous wave, then adopt the method of motion compensation to correct the non-parallel flight course of airplane to the parallel flight course of satellite. After getting the corrected parallel configuration, on according to the concept of an instantaneous Doppler wavenumber, a 2-D analytic formula of the point target response in frequency domain is developed for BiSAR with parallel trajectory and unequal velocity. This formula is azimuth and range space-variant. For azimuth space-variant, it can be ignored within some bounds. We provide the expression of scenic scope where space-variant can be ignored. As to range space-variant, only the linear part with the nearest sum of range is reserved, nonlinear variance can be removed though controlling the imaging swath. Based on the above thinking, a fast bistatic RMA algorithm is finally deduced for the SS-BSAR, which is inherently precise despite some reasonable approximations. Related parameters in our algorithm are derived by numeric method. Based on the deduced precise analytic formula in frequency domain, the numeric calculation of the given algorithm is done through introducing some system parameters. So the computational complexity of the proposed algorithm is low. Simulation results have confirmed the effectiveness of the proposed novel approach.

Range -Azimuth Fourier Transform of GPS signal

$$s_1(t,\tau) \approx \sigma s(\tau-\tau_0)\exp(-j2\pi f_c\tau_0)\exp[-j2\pi f_d(\tau-\tau_0)]$$

$$S_3(f_a,f_r) = A(f_r)\exp[-j2\pi(f_c+f_r)\frac{R_T(\tilde{t})+R_R(\tilde{t})}{c}]\exp(-j2\pi f_a\tilde{t})$$

Arbitrary Q Point Target Expression in Frequency Domain

$$S_q(f_a,f_r) = \exp(-j\Delta\phi_q)\int S_3(t-t_q,f_r)\exp[-j2\pi\Delta f_{dq}(t-t_q)+j\pi\Delta k_q(t-t_q)^2-j2\pi f_a t]dt$$

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