FOCUSING GENERAL BISTATIC SAR DATA USING FREQUENCY SCALING

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1. INTRODUCTION

The complex configurations of bistatic synthetic aperture radar(BiSAR) result in the difficulty in deriving the bistatic imaging algorithm. To cope with this problem, Ref [1] used the method of 2-D inverse scaled FFT. And Ref [2] proposed a bistatic backprojection (BP) algorithm to focus general bistatic SAR data. However, the common shortcoming of the two methods is the heavy computational burden. Ref [3] used extend Taylor approximation(ETA) to transform squint-mode data into broadside-mode one. In the same way, Ref [4] applied the ETA to convert the velocity of the platform. The method of the ETA needs no interpolation, therefore it is very efficient.

This letter proposes a method to focus the general BiSAR data with the ETA. First, the general BiSAR data are transformed into the azimuth-invariant (AI) one. Second, the transformed data are focused using the method of frequency scaling [5].

2. SIGNAL MODEL

Two independent coordinates are combined to analysis the general bistatic SAR imaging configuration. In Fig.1, the coordinate XYZ is for the receiver and $X'Y'Z'$ is for the transmitter. First, the plane XOY and $X'O'Y'$ are located in the same plane. Second, the velocity V_R of receiver is located in the plane XOZ and the velocity V_T of transmitter is located in $X'O'Z'$.

3. IMAGING CONFIGURATION CONVERSION

To focus the general BiSAR data with the AI bistatic imaging algorithm, the general bistatic SAR data should be transformed into the AI form. To gain this goal, we may transform the general bistatic configuration into the AI one. This operation can include the two aspects:

- Paralleling the tracks of the platforms with each other and with the scene;
- Equalizing the velocities of the two platforms.

To realize the operation with the ETA, we decompose the above processing into the four steps as following:

- Rotating the transmitter in the vertical plane;
- Equalizing the transmitter's velocity to the receiver's;
- Rotating the transmitter in the horizontal plane;
- Rotating the receiver in the vertical plane.

The method of the ETA will be used in each step. However they can be combined to be realized in the single operation of dechirping. In the general bistatic configuration, the platforms do not parallel neither with each other nor with the scene. To obtain the AI bistatic configuration, the track of the transmitter (if the transmitter is further to the scene than the receiver) is rotated in the 3-D space. And the velocity of it is converted to that of receiver. At the same time, the track of the receiver is rotated in the 2-D plane to be paralleled with the scene. In this way, the ideal AI configuration can be obtained.

On the other hand, the conversion of transmitter should be decomposed into three steps. First, the track should be rotated in the vertical plane $X'O'Z'$, so that the rotated track can be paralleled with the horizontal plane $X'OY'$. Second, the velocity of transmitter is converted. Third, the rotated track should be again rotated in the horizontal plane. On the other hand, the track of receiver is rotated in the vertical plane XOZ. As the result, the tracks are paralleled both with each other and with the scene, and the platforms have the same velocity. This is the ideal AI configuration.

Using the ETA, the converted bistatic range model can be expressed as

$$\overline{R}_{bi} \approx R_{bi} + R_1 + R_2 \tag{1}$$

$$R_i = \frac{1}{m}\sum_{k=1}^{m}\frac{\Delta x_{ia}\left(x_{ia}+\frac{m-k}{m}\Delta x_{ia}-x_i\right)+\Delta y_{ia}\left(\frac{m-k}{m}\Delta y_{ia}-y_i\right)+\Delta z_{ia}\left(z_{ia}+\frac{m-k}{m}\Delta z_{ia}\right)}{\sqrt{\left(x_{ia}+\frac{m-k}{m}\Delta x_{ia}-x_i\right)^2+\left(\frac{m-k}{m}\Delta y_{ia}-y_i\right)^2+\left(z_{ia}+\frac{m-k}{m}\Delta z_{ia}\right)^2}} \qquad i=1,2 \tag{2}$$

where R_1 and R_2 describe the track conversions of the transmitter and receiver respectively. Eq. (2) can be calculated only at the scene center. If the distances between platforms and scene are much larger than the scale of scene, this approximation can be accepted.

4. IMAGING USING FREQUENCY SCALING

4.1 Reference function of dechirp-on-receive

To accomplish ideal conversion of bistatic SAR data, the reference function of dechirping [5] should be modified as

$$s'_{ref}(\tau) = \exp\left[j2\pi f_c \left(\tau - \overline{R}/c\right)\right] \exp\left[j\pi k \left(\tau - \overline{R}/c\right)^2 \right] \quad (3)$$

where $\overline{R} = R_{mref} - R_1 - R_2$, f_c is the carrier frequency, τ is the range time.

4.2 Bistatic migration factor

The bistatic migration factor can be derived as [6]

$$A_X = \frac{R_m}{R_{mT}\left(1 - K_{XT}^2 / K_{RC}^2\right)^{-\frac{1}{2}} + R_{mR}\left(1 - K_{XR}^2 / K_{RC}^2\right)^{-\frac{1}{2}}} \quad (4)$$

$$K_{XT} = (1 + \tan\beta) K_X / 2, K_{XR} = (1 - \tan\beta) K_X / 2, K_X = 2\pi f / v \quad (5)$$

where v is the velocity of the two platforms, β is the function of Doppler. However, other compensation functions can be formed by the bistatic migration factor [6].

5. SIMULATIONS

The simulation parameters are listed in Table I. In receiver coordinate XYZ, the location of the scene center is $(40e3, 300e3, 0)$, and that of O' is $(-120e3, -2e3, 0)$. The angle between X and X' axis is 5 deg. The bistatic angle is about 10 deg and the length of base line is 120 km. The processing result of points array is depicted in Fig.2. And the scale of the array is $4\,km \times 4\,km$. For the point on the boundary of the scene, the performance of 2-D compression is shown in Table II.

6. CONCLUSION

This paper derives the method to convert the general bistatic SAR data to the AI one, and obtains a closed-form migration factor for frequency scaling method [5]. The computational burden of the proposed algorithm is nearly same as the classical chirp scaling algorithm.

7. REFERENCE

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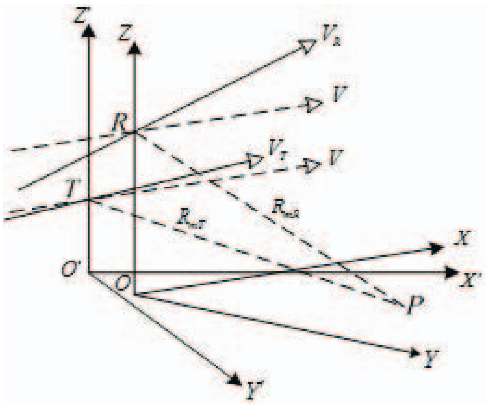

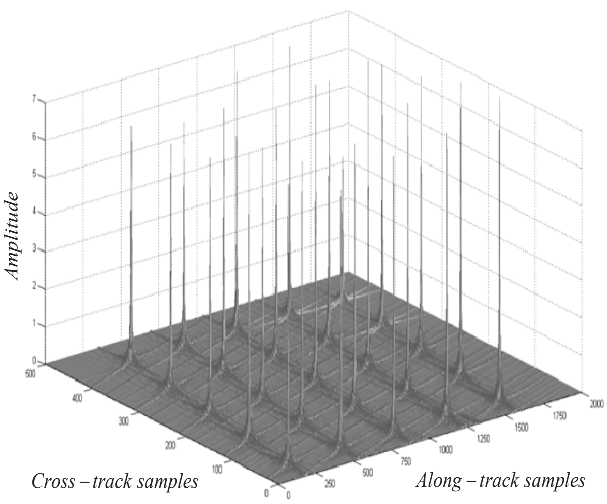

Fig. 2. The configuration of general bistatic SAR.

TABLE I SIMULATIONS PARAMETERS

Simulation parameters	Transmitter	Receiver
Angle to X' axis	5 deg	
Angle to X axis		-5 deg
Angle to Z (Z') axis	85 deg	95 deg
Squint angle	3.4 deg	13.4 deg
Aperture length		15 m
Wavelength	6 cm	
Pulse duration	43 us	
Bandwidth	20.5 MHz	
Velocity	7.75 km/s	7.8 km/s
PRF	2.4 kHz	2.4 kHz
Position in X axis	-120 km	0
Position in Y axis	-2 km	0
Position in Z (Z') axis	600 km	600 km

TABLE II PERFORMANCE OF PROCESSING RESULTS

	ISLR	PSLR	Resolution	Expansion
Azimuth	-12.04	-12.50	7.88 m	5.1%
Range	-11.68	-15.39	7.91 m	8.8%