Volume 3, Issue 5, May 2013 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

Research Paper

Available online at: www.ijarcsse.com

Synthetic Aperture Radar Data Processing

Sedighe Mirbolouk* — *Depatment of Electrical Engineering, University of Guilan, Rasht, Iran*

Mahrokh Maghsoodi — *Depatment of Electrical Engineering, University of Guilan, Rasht, Iran*

Emad Torabi — *Depatment of Electrical Engineering, University of Guilan, Rasht, Iran*

Mehregan Mahdavi — *Depatment of Computer Engineering, University of Guilan, Rasht, Iran*

***Abstract*— The initial algorithm that has been used for processing of raw data synthetic aperture radar (SAR) is Range Doppler Algorithm (RDA). This data is related to spaceborne or airborne SARs that often data gathering is done by satellite. Due to SAR sensor motion with respect to static or moving targets in ground encounter with range cell migration (RCM) phenomenon in spaceborne. In the aircraft case RCM is negligible because the platform velocity is lower. In this paper we implement the RDA on spaceborne real data gathered from RADARSAT1 to generate SAR image.**

***Keywords*— Synthetic Aperture Radar (SAR); Range Doppler Algorithm (RDA); Range Cell Migration (RCM); remote sensing; Radarsat1**

I. INTRODUCTION

Airborne or spaceborne Synthetic aperture radar, developed in the early 1950s, draws on capabilities in generating radar image with fine features in addition to its position and velocity. Synthetic aperture radar by utilizing the movement of the antenna with respect to the target without sophisticated post processing obtain high resolution image. The common SAR processing algorithms in stripmap mode are RDA, Chirp scaling algorithm (CSA) [1] and spectral analysis (SPECAN) [2]. The RDA was developed in 1976-1978 for processing SEASAT data[3]. The prefer of RDA is accurate and effective accommodation of range varying parameters. This algorithm has not computational complexity and it isn't time-consuming and use of fast Fourier transforms (FFT's) effectively. In this paper we implement the range Doppler algorithm on input image in airborne SAR and correct the effect of range cell migration.

II. SIGNAL MODEL

The purpose of processing of raw SAR data that its energy is spread in range and azimuth is focusing. In other words, we want collect this dispersed energy by the LFM transmitted pulse's duration in range and synthetic aperture length, or illumination time of target in azimuth, into a single pixel in the output image. When SAR platform moves on the scene, at first the distance of platform with respect to target in scene decreases then increases so the instantaneous slant range changes that this causes changing of phase in echo as a function of cross-range (azimuth) that is called range cell migration phenomenon and have to is corrected before azimuth compression. For processing of azimuth frequency spectrum we didn't estimate Doppler centroid here and is assumed it has already been performed.

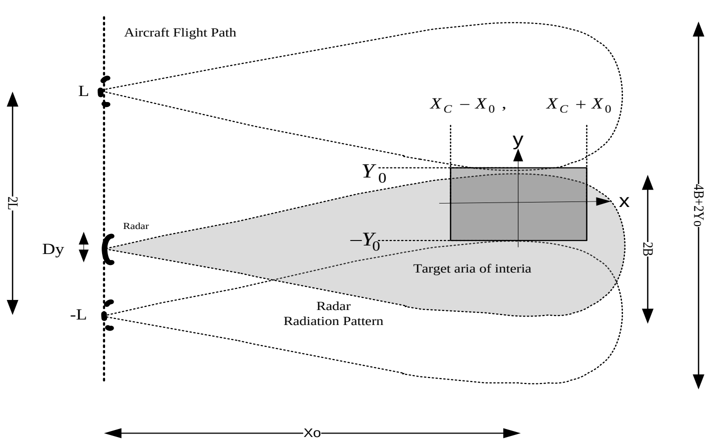

Fig. 1 Geometry of stripmap SAR [4]

In Fig.1 is demonstrated two-dimensional SAR imaging geometry. Object is composed of radar scatters that are arrayed in a Cartesian type coordinate system space x and y. The x and y axes denotes the range and cross-range directions respectively. SAR platform moves along y axis that is called the synthetic aperture domain or the slow time domain. The radar height determines the ground swath in the x domain. Length of antenna SAR along the flight path determines its footprint in the y domain that shifts as the radar is moved. This is due to the radar motion in the y domain. The main lobe of the radar radiation pattern in a stripmap SAR system is not focused on a specific target region for all the available slow time values. In this figure B means the half beamwidth and the target range domain area $[X_C - X_0 , X_C + X_0]$ is called the radar swath. 2L is the synthetic aperture interval [4].

Assume the platform move in straight line with constant forward velocity V_p along the azimuth direction and minimum range to target, X_C is at the middle point in the flight. The transmitted chirp signal is

$$s(t_r) = rect\left(\frac{t_r}{T_r}\right)\exp\left(2\pi f_c t_r + j\pi K_r t_r^2\right) \tag{1}$$

Where T_r, K_r, t_r, t_a, f_a and B_0 denotes the pulse duration, chirp rate, fast time, slow time, carrier frequency and bandwidth respectively. The received signal is time-delayed and attenuated that in following explain about it.

III. Range Doppler Algorithm

The RDA processes the raw SAR data to produce the SAR focused image. The main steps basic RDA are shown in Fig. 2. RDA is common algorithm for low squint cases**.** We consider a point target reflection located at area that has been pointed in fig. 1 and follow algorithm steps.

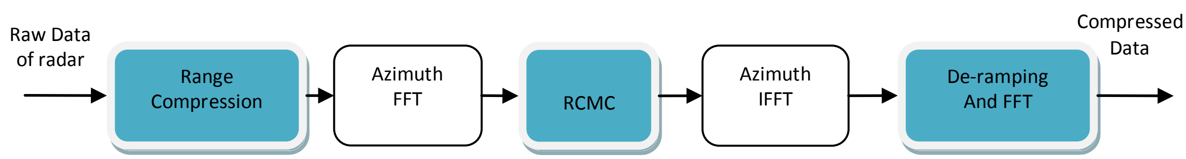

Fig.2 Block diagram of the basic RDA

A. Range Compression

A common technique in communications is matched filtering that is a main technique in RDA. A matched filter is a filter that provides the maximum output SNR when the signal is corrupted by white Gaussian noise. Matched filtering is the correlation of a reference signal with an unknown signal, which is the equivalent of convolution of an unknown signal with a time reversed reference, to detect the presence of the reference signal in the unknown signal. The chirp signal often is used in the transmitted radar signal construction due to there is more information embedded for detection. For to transform the range reference and raw data functions to frequency domain from time domain use a fast Fourier transform (FFT) then in frequency domain every raw data element is multiplied by the complex conjugate of the corresponding range reference function element. Finally inverse Fourier transform (IFFT) is done. While match filtering implementation we use smoothed window such as Kaiser for lower spectral leakage and to reduce side ripples.

The range-compressed signal of a single point target after transform to basedband can be expressed by

$$s(t_r, t_a) = K\sqrt{K_r T_r}\,\text{sinc}\left[K_r T_r\left(t_r - \frac{2R(t_a)}{c}\right)\right] \times w(t_a - t_{ac}) \times \exp\left[-j\frac{4\pi R(t_a)}{\lambda}\right] \tag{2}$$

K and c are constant reflectivity of the target and the speed of light. Beam pattern, $w(t_a - t_{ac})$, is approximately a square of sinc function. t_{ac}, referenced to the time of zero Doppler. The location of target after range compression is founded.
Parameters of SAR simulation is denoted in table. 1.

TABLE I

POINT TARGET SIMULATION PARAMETERS

Parameter	Symbol	value
Illumination time	T_p	3 seconds
Platform velocity	V_p	200 m/s
Pulse Repetition Frequency	PRF	300
Carrier frequency	f_c	5 GHz

The point target after range compression is denoted in fig. 4.

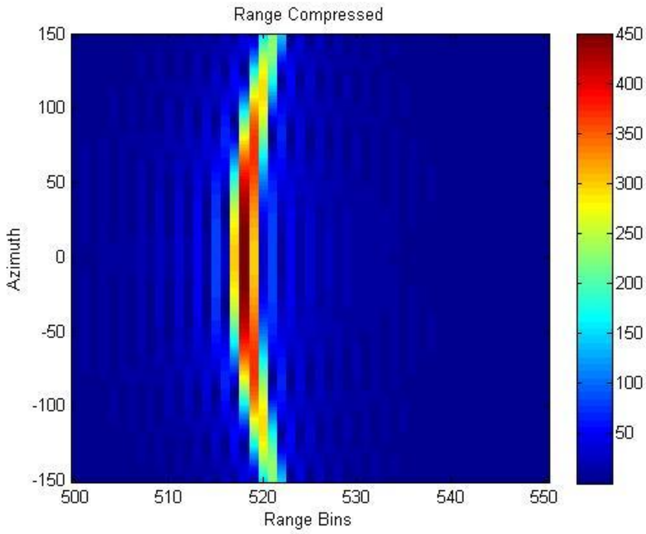

Fig.4 The point target after range compression

B. Range cell migration correction and Azimuth Compression

Due to the hyperbolic trend with respect to azimuth time of the instantaneous slant range RCMC is needed that it performed prior azimuth compression in the azimuth frequency and range time domain. After Azimuth Fourier transform on (2), the moving target signal in range-Doppler domain can be obtained by applying the principle of stationary phase (POSP) [5] as

$$S\left(t_r, f_{t_s}\right) = A\frac{\sqrt{K_r T_r}}{\sqrt{|k_{am}|}} \operatorname{sinc}\left\{K_r T_r \left\{t_r - \frac{2}{c}\left[R_0 - \frac{\lambda\left(f_{ts}^2 - f_d^2\right)}{4k_{am}}\right]\right\}\right\} \times rect\left(\frac{f_{t_s} - f_d}{T_p k_{am}}\right) \exp\left[-j\frac{\pi\left(f_{t_s} - f_d\right)^2}{k_{am}}\right] \quad (3)$$

The Doppler centroid, Doppler rate of the moving and static target at the same slant range is $f_d = \frac{2v_r}{\lambda}$, $k_{am} = -\frac{2\left(v_p - v_{az}^2\right)}{\lambda R_0}$ and $k_{as} = -\frac{2v_p^2}{\lambda R_0}$ respectively. We consider static target so $f_d = 0$ and $k_{am} = k_{as}$. The energy along the azimuth is shifted to counter cell migration, in the range direction [6]. We assume squint is zero. The residual RCM can be derived in RD domain that it is negligible here. Fig.5 shows the compressed static target after RCMC.

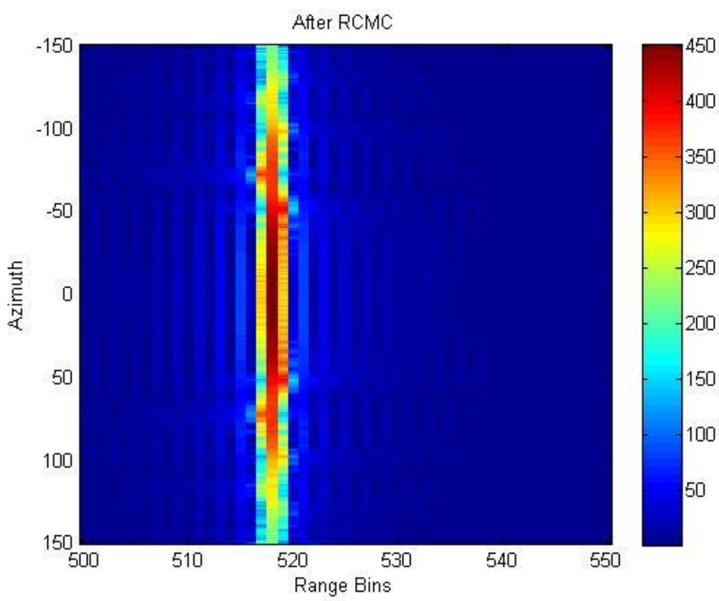

Fig. 5 the compressed target after RCMC

The azimuth reference function is like to the range reference function but due to slant range variation, frequency on the echo changes in the azimuth direction. If platform is moving toward the target, frequency increase and while it moves away, frequency decrease that is referred to as Doppler effect, is a kind of chirp. In Low Signal to noise, Doppler centroid have to is estimated accurately. Using FFT azimuth reference function is converted to frequency domain then every frequency domain element is multiplied by the complex conjugate of the corresponding frequency domain reference element. An inverse fast Fourier transform (IFFT) then completes the compression

$$s(t_r, t_a) = K\sqrt{K_r}\,T_r\,\mathrm{sinc}\left[K_r T_r\left(t_r - \frac{2R(t_a)}{c}\right)\right] \times w(t_a) \times \exp\left[-j\frac{4\pi R(t_a)}{\lambda}\right] \times \exp\left[j2\pi f_{t_s} t_a\right] \qquad (4)$$

After range cell migration correction the signal is compressed in azimuth domain that image generated from the two dimensional simulation of a single point target is shown in Fig. 7

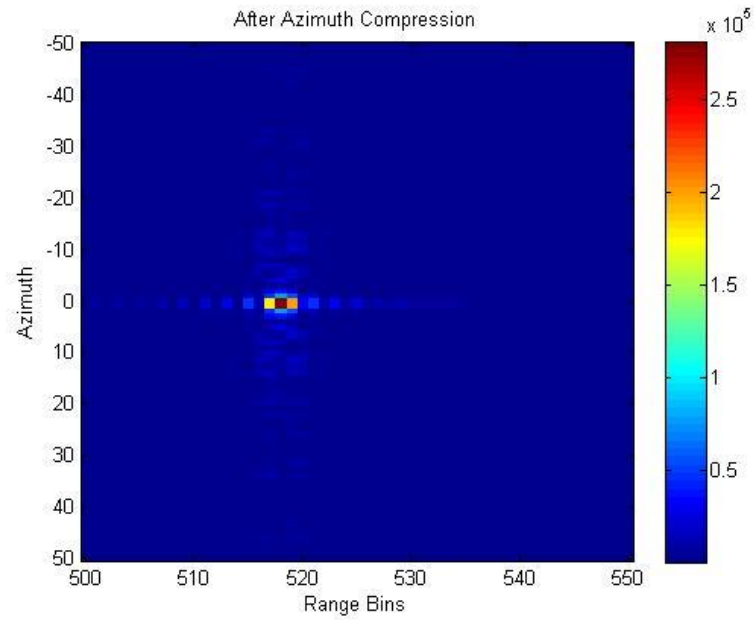

Fig. 7 Final Processed SAR Image of Single Point Target

IV. SIMULATION OF REAL DATA

Now we implement the range Doppler algorithm on spaceborne real data gathered from RADARSAT1 to generate SAR image. Data set and its parameters has been exploited from [6]. The RADARSAT1 satellite was launched by Canadian Space Agency in 1995. It operates at C-band, and its main use is the daily mapping of Arctic ice. Its main innovation is a scanning mode of operation, called ScanSAR, whereby very wide swaths are imaged by scanning the radar beam to different elevation angles within the synthetic aperture time [6]. Fig. 8 shows the original SAR image of Vancouver, Canada and Fig. 9 shows the processed image by RDA. As can be detected from processed image there is speckle noise in it. Speckle is a multiplicative noise and it is an inherent and characteristic feature of radar images [7]. Multilook processing is performed to reduce the speckle noise that it didn't applied to RDA algorithm here.

V. CONCLUSIONS

We described Range Doppler Algorithm simulation for a static target and implement this algorithm for real data gathered from RADARSAT1 that the effectiveness of this algorithm is illustrated by RADARSAT-1 fine beam data. The Range Doppler Algorithm compared to other SAR processing algorithm is less computational complexity and it isn't time-consuming.

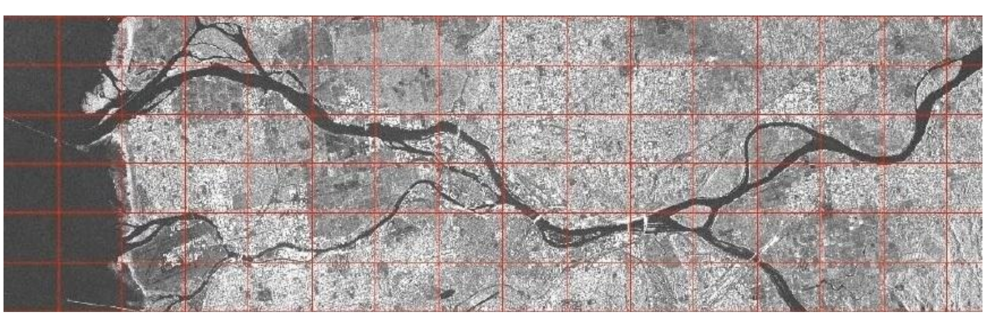

Fig. 8 Original SAR image

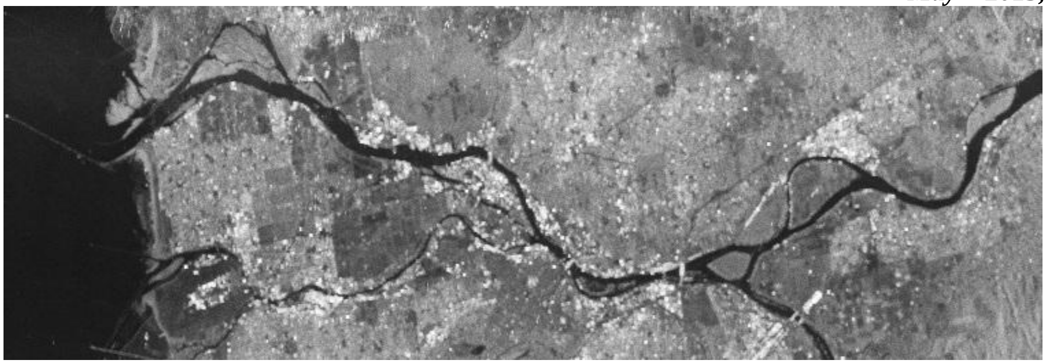

Fig. 9 Processed SAR image

References

[1] A. Moreira, Y. Huang, "*Chirp scaling algorithm for processing SAR data with high squint angle and motion error*," SAR Data Processing for Remote Sensing, 268 /SPIE Vol. 2316, 1994

[2] J. Holzner, R. Bamler, "*Burst-Mode and ScanSAR Interferometry*," IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 40, NO. 9, SEPTEMBER 2002

[3] I. G. Cumming and J. R. Bennet., "*Digital Processing of SEASAT SAR Data*", In IEEE 1979 International Conference on Acoustics, Speech and Signal Processing, Washington, D. c., April 2-4, 1979

[4] M. Soumekh, "*Synthetic Aperture Radar Signal Processing with MATLAB Algorithms*", 2nd ed. New York, United States of America: Wiley, 1999.

[5] J. Xu, Y. Zuo, B. Xia, X.-G. Xia, Y.-N, Peng, Y.-L. Wang, "*Ground Moving Target Signal Analysis in Complex Image Domain for Multichannel SAR*" IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 50, NO. 2, FEBRUARY 2012

[6] I.G. Cumming, and F.H. Wong,. "*Digital Processing of Synthetic Aperture Radar Data: Algorithms and implementation*". Artech House, 660p. , 2005

[7] . Oliver and S. Quegan. "*Understanding Synthetic Aperture Radar Images*". Artech House, Norwood, MA, 1998

