wjert, 2017, Vol. 3, Issue 4, 517 -523. Research Article ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 4.326

PROCESSING SQUINTED SAR RAW DATA USING RANGE DOPPLER ALGORITHM

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Article Received on 06/06/2017 Article Revised on 27/06/2017 Article Accepted on 18/07/2017

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ABSTRACT

Synthetic aperture RADAR imaging technique is a very widely used in imaging domain. This paper proposes the processing of point target squinted data. This digital processing is based on the Range Doppler Algorithm (RDA). RDA is one of the most efficient and accurate among its contemporary algorithms. Here we deal with the scenario where there is squint introduced into data. This paper deals with use of secondary range compression (SRC) in RDA.

INDEX TERMS: RDA, MOCO, SAR, Squint, Radar.

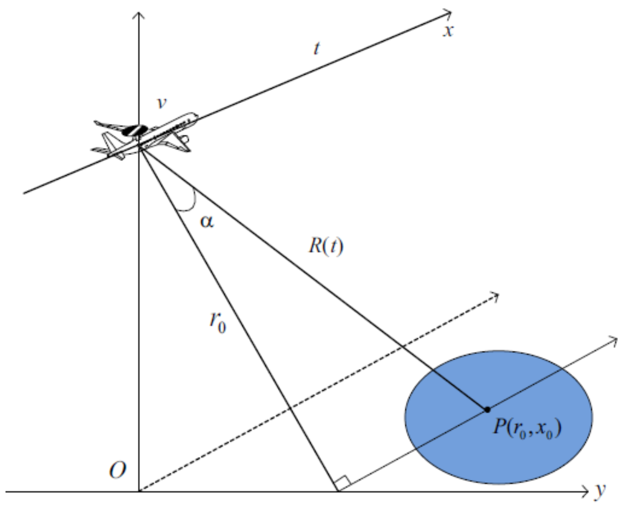
INTRODUCTION

SYNTHETIC aperture RADAR is very efficient technique used in mapping of targets or earth surface. SAR is an active microwave remote sensing technology that is used to create two-dimensional images of targets and the Earths surface through the use of radar.[1] The mapping of targets depend on their position. The SAR technique is based on the fact that when the radar or sensor mounted on a platform is in transit. during the transit the required target is illuminated by multiple pulses emitted by the sensor. These pulses are emitted by the sensor at discreet times. And these pulses get reflected by the target or reflector, according to its reflectivity. These reflected pulses are stored in memory and used for digital processing. The stored data is known as Raw data. The emitted pulses are generally linear FM pulses with positive slope, i.e. frequency will be increasing linear. LFM with negative slope can also be used. There are two direction of interest in SAR azimuth and range where azimuth direction is parallel to the motion of the radar platform, and it is also known as the slow time direction. It is so called due to relatively slow velocity of radar platform with respect to pulse velocity. The range direction is directed orthogonal to the platform motion, and parallel to the main beam direction. This direction is also known as the fast time. But generally the RDA assumes zero squint of the radar beam. Squint is described as the angle that the slant range vector makes with zero Doppler plane. The zero Doppler plane is the plane containing the sensor or radar perpendicular to the velocity vector.

Geometrical Setup

The figure 1 shows the setup of SAR geometry. As explained before the received raw data signal will be a scaled and delayed version of the transmitted signal. The range equation for the squinted antenna beam is given by

$$R(\eta) = \sqrt{R^2 + (v\eta)^2 - 2Rv\eta sin(\theta_s)} \qquad (1)$$



where R(η) is the instantaneous range vector and R is the range of closest approach. The variables v, η, θ_8 are platform velocity, instantaneous azimuth time and squint angle respectively. The transmitted signal is given by

$$s_0(\tau) = rect(\frac{\tau}{T}) * exp\{2\pi f_i \tau\} \qquad (2)$$

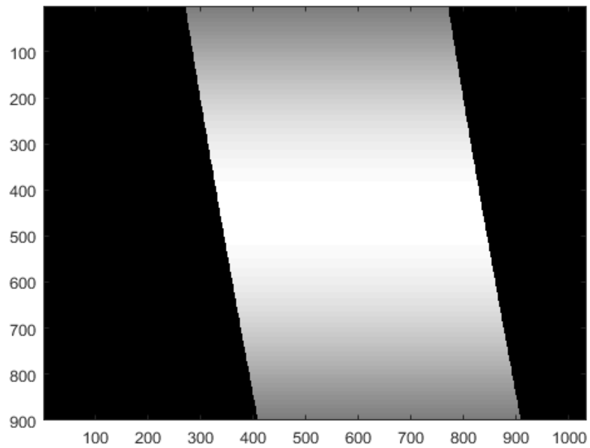
where τ is the range dimension variable, fi is the instantaneous frequency, given by $f_i = 2\pi f_0 \tau + K_r \tau$ and K_r is the range chirp rate and finally τ is the pulse duration. And the received signal is given by a two dimensional equation as the other dimension η from platform movement is included. It is given as

$$s_0(\tau,\eta) = A*rect(\frac{\tau-\tau_0}{T})*w_a(\eta-\eta_0)*exp\{-j4\pi f_0\frac{R(\eta)}{c}\}* exp\{j\pi K_r(\tau-\frac{2*R(\eta)}{c})\}[5] \quad (3)$$

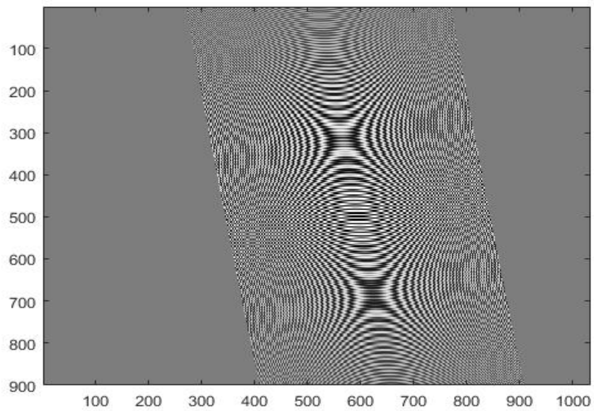
This is known as SAR raw data it is as shown in figure 2. This data undergoes several steps to form a two dimensional image.

Range Doppler Algorithm

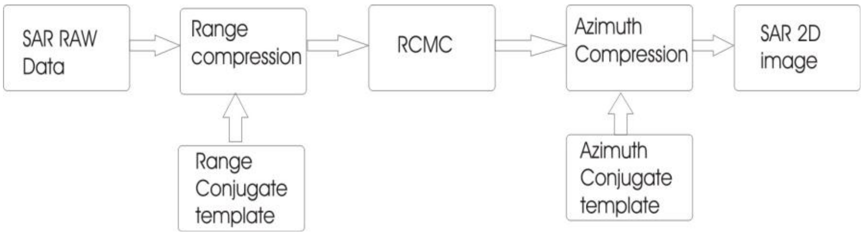
RDA is the older one among the SAR raw data processing algorithms. The RDA is based on Pulse compression technique. This pulse compression increases the resolution.[2] RDA has mainly three steps namely Range compression, Range cell migration correction (RCMC) and Azimuth compression. The algorithm is so called because of the fact that the RCMC is done in range Doppler domain.



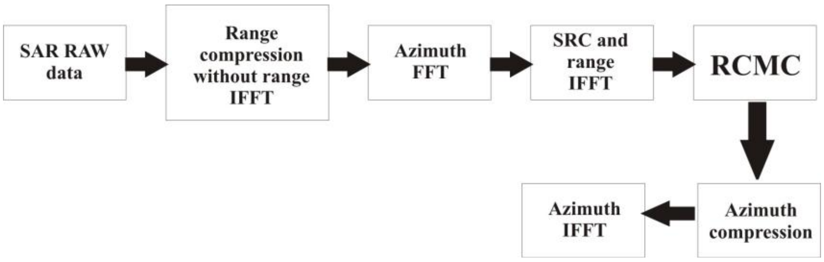
(a) Squinted Raw data.



(b) Squinted Raw data (magnitude tude).



(a) RDA signal flow for zero squint.



(b) RDA signal flow for high squint.

1) Range compression: The raw data signal is first compressed in range direction i.e. it is subjected to matched filtering in range dimension only, without affecting the azimuth direction. The signal before range compression in high squint generally consists of three steps as mentioned above but in high squint vase the final step of range IFFT is not done. Instead a azimuth FFT is done and is subjected secondary range compression to remove the non linearities due to squint.

2) Secondary range compression: This step is only performed when there is squint introduced in raw data, otherwise SRC can be neglected. This is because when the squint angle increases, the range equation must be expressed in more accurate hyperbolic form. In low squint case the there is a one-to-one relation between time and frequency. In high squint case, there also is a one-to-one relation however there is some nonlinearities. This leads to stronger coupling between range and azimuth parameters, which leads to mis-focusing. So we need another type of filtering to remove this error. This filtering is known as secondary range compression. In other words the signal is first compressed with the filter with chirp rate Kr, next it is compressed with filter of chirp rate Km.

Hence the word secondary range compression. Here the range compression filter is given by

$$H_m(f_\tau) = exp\{j\pi \frac{f_\tau^2}{K_m(R_0, f_\eta)}\} \qquad (6)$$

Implementing SRC is done ideally in range doppler domain so that the dependencies on R_0 and f_η can be accommodated. But sometimes the dependencies on these variables differ. So we go for implementation in two dimension frequency domain depending on the amount of dependency on range and Doppler frequency. So here range and frequency both cannot be accessed simultaneously, so we fix a range value R0, as here the dependency on R_0 is weak compared to that of f_η.

3) Range cell migration: Range cell migration is applied after range compression step. The instantaneous range or slant range changes as the platform moves along azimuth direction. Due to this the target has different Doppler frequency at different point of time and it subsequently appears in multiple range bins. To correct this error RCMC is applied, RCMC is impleented by nothing but shifting of target's returns by required number of range bins. The amount of shift, or migration, can be calculated for each point on the Range Doppler signal by the equation.

$$R_{rd}(f_\eta) = Xc + Xc\{\frac{1 - D(f_\eta, V_r)}{D(f_\eta, V_r)}\} \qquad (7)$$

Now after range compression the data is subjected to RCMC, The range cell migration that was predicted before the RDA filtering.[7] RCM is calculated accordingly to compensate. After RCMC the signal looks as shown in figure. After RCMC the signal is subjected to azimuth compression similar to general RDA, the signal will now be positioned in a point on the target space.

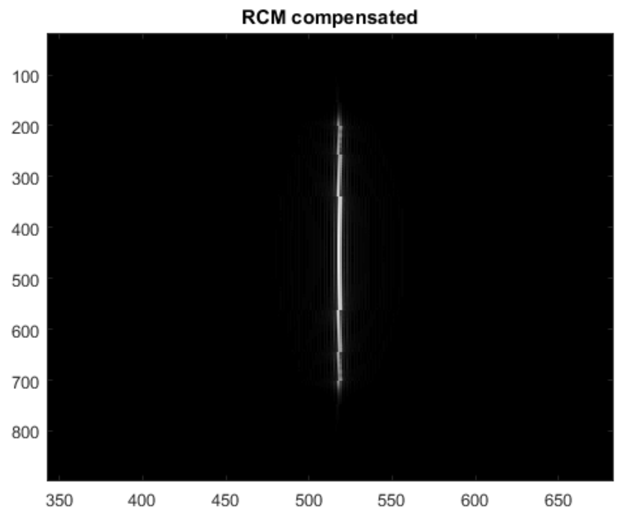
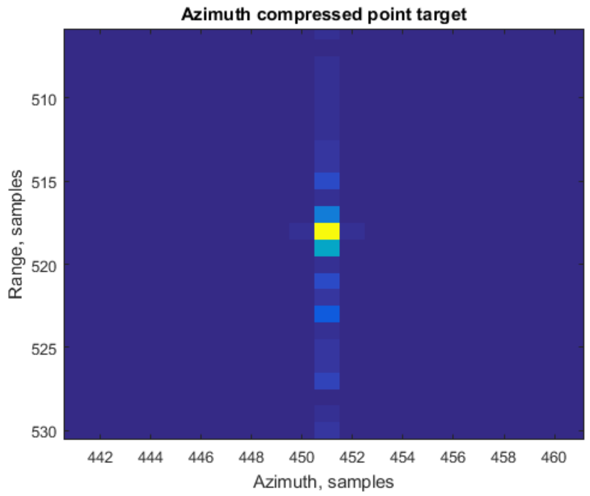
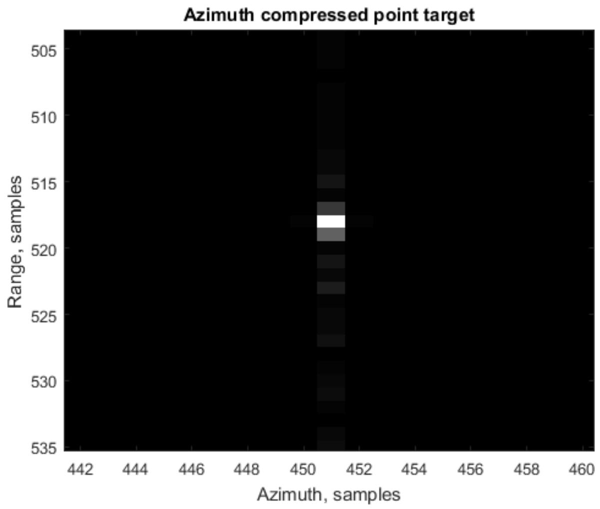


Fig. 5: RCM compensated data.

4) Azimuth Compression: After RCMC the signal is compressed in azimuth direction. Azimuth compression is same as range compression but here the conjugate template used is different. As the signal is already in frequency domain the filtering is done by just multiplying the signal by the template. It is then subjected to azimuth IFFT. Another azimuth IFFT might be required to apply in order to get a point at the desired location. From these example images we can see that this signal processing technique will work efficiently even in the presence of noise with the target motion error.



(a) Final point target.



(b) Final point target in gray scale.

CONCLUSION

In this paper we have worked with the target with squint in the raw data. We made slight changes to the basic RDA to deal with squint scenario, by introducing the SRC concept. Without SRC the RCMC will be inaccurate and the target position will be shifted from the desired one. As the SRC is more accurate to remove squint. But in this paper we only dealt with a single point target but it can be extended to multiple targets by applying SRC with high accuracy.

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