REFOCUSING ALGORITHM FOR SYNTHETIC APERTURE RADAR

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1. INTRODUCTION

In geosciences and remote sensing it is often of interest to measure some quantity as a function of location. To do this it is good if the given sensor has the ability to create 2-D or even better 3-D maps of the distribution of the quantity of interest. Sensors having such abilities include optical sensors, radiometers and Synthetic Aperture Radar (SAR). Out of these sensors, radiometers and SAR systems both have the advantage of being able to operate during the night as well as in bad weather. SAR has another advantage compared with optical sensors, the resolution obtained in the 2D-image does not depend on distance between the sensor and the scene; it only depends on the integration angle. For this reason SAR is a highly suitable sensor for use in geosciences and remote sensing applications. In order to obtain focused SAR images, there is a variety of imaging algorithms. The SAR algorithms can mainly be divided into two categories, time domain and frequency domain algorithms.

Among time domain algorithms the most basic one is Global Backprojection (GBP) [1] which consists of a coherent summation of all radar echo data along the synthetic aperture for each pixel in the SAR image. The processing time for a scene of size NxN for a synthetic aperture with N samples for GBP algorithm is proportional to N^3. Based on GBP fast algorithms have later been proposed such as Fast Factorized Backprojection (FFBP) [2] with a processing cost proportional to $N^2 \log N$. The main advantage with time domain algorithms is the ability to obtain high quality SAR images with very wide integration angle, big relative bandwidth signal and with nonlinear flight tracks, however all time domain algorithms needs interpolation.

Among frequency domain algorithms Range Migration Algorithm (RMA) [3] and Chirp Scaling Algorithm (CS) [4] are widely used. All mentioned frequency domain algorithms have a processing cost proportional to $N^2 \log N$. However for CS no interpolation is needed at all giving an advantage compared to time domain algorithms. Even if RMA has the disadvantage of an interpolation step it has the advantage of being able to generate SAR images for very wide angle SAR.

If the movement of the platform compared to the scene was not accurately measured, the SAR image will become defocused. A normal way to obtain a focused image is by using auto focusing techniques which tries to reduce the residual phase error and thereby focus the scene. Another way is to estimate the azimuth chirp in the SAR image and apply a matched filter in order to obtain a focused image.

A similar problem occurs in the case when there is a moving target in a SAR image. As shown in earlier publications, the moving target phase in azimuth can be described by a chirp signal [5]. Estimating its parameters it is possible to focus the SAR scene with the correct Normalized Relative Speed (NRS). In this paper an algorithm, which was first introduced in [5], is presented and its performance illustrated by being applied to simulated SAR data according to the parameters for the CARABAS-II system. The algorithm is based on RMA which has the ability to refocus moving targets in SAR images, where the SAR image has been created using arbitrary NRS. In the final paper the algorithm will be further tested with simulations and possibly real SAR data.

2. REFOCUSING IN WAVENUMBER DOMAIN

In this section the procedure to obtain a SAR image focused for any desired NRS γ_d given a SAR image created at arbitrary NRS γ_p is presented. This algorithm was proposed in [5]. As in RMA, the main steps of the focusing consists of making a 2D FFT, a change of variable including interpolation, multiplication with a magnitude term and a phase term and 2D IFFT. However, the change of variable, as well as both multiplications has been modified by the variables γ_d and γ_p. The processing scheme of the algorithm is illustrated in Figure 1.

To start with, the change of variable for focusing a SAR image for γ_p given by

$$k_{\gamma_p} = \sqrt{k_R^2 - \gamma_p^2 k_x^2} \tag{1}$$

where R is range, and x is azimuth.

If instead we are interested in focusing certain parts of the image using another NRS, based on the originally focused SAR image, we first compute a 2D Fourier transform and then perform the change of variable given in (2) [5].

$$k_{\gamma_d} = \sqrt{k_{\gamma_p}^2 + \left(\gamma_p^2 - \gamma_t^2\right) k_x^2} \tag{2}$$

and multiplying with

$$\frac{k_{\gamma_p}}{\sqrt{k_{\gamma_p}^2 + k_x^2\left(\gamma_p^2 - \gamma_t^2\right)}} e^{-j(ct_0/2)\sqrt{k_{\gamma_p}^2 + \left(\gamma_p^2 - \gamma_t^2\right) k_x^2}} \tag{3}$$

where t_0 is the slowtime corresponding to minimum range to the middle of the scene.

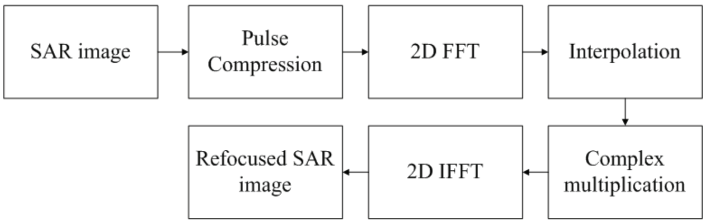

Figure 1. Processing scheme of presented algorithm. The main steps are FFTs, interpolations and a complex multiplication.

3. RESULTS

In order to illustrate the performance of the presented algorithm, simulated SAR data according to the parameters for the CARABAS-II system has been used in which a couple of moving targets have been included. The image was formed using FFBP. An area surrounding each moving target in the SAR image given in Figure 2 a was extracted and the presented algorithm was used to refocus the SAR image which can be seen in Figure 2 b. As the parameters of the targets were known, the image was refocused according to known NRS giving good focus of the target. In [5], results even more impressive however are shown. There, results on real CARABAS-II data show that the surrounding clutter has been suppressed to a level where it is barely visible in the image. This illustrates the ability to refocus a moving target while defocusing the clutter.

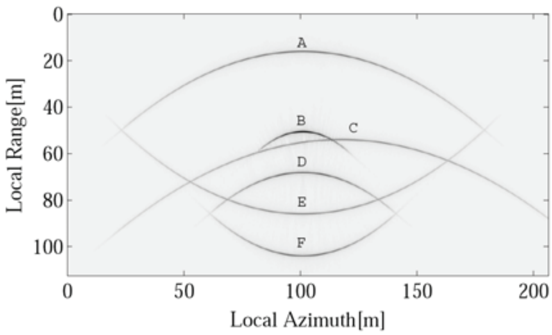

Figure 2 a SAR image before refocusing.

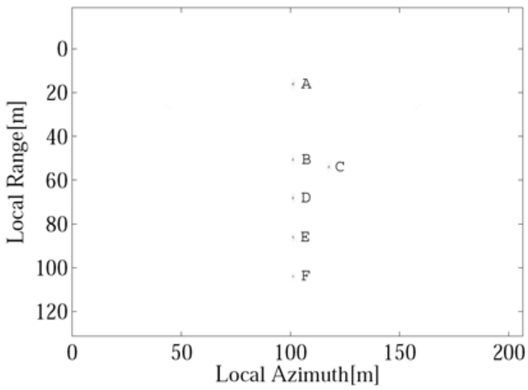

Figure 2 b SAR image after refocusing.

4. CONCLUSIONS

In this paper an algorithm for refocusing a SAR image given a SAR image processed at an arbitrary NRS is presented. The algorithm is illustrated by results on simulated SAR data according to parameters of the CARABAS-II system in which a couple of moving targets have been included. A small image is extracted from the scene and refocused. The presented algorithm is based on RMA and has the advantage that even with strong defocus of the target, the refocused image will be of high quality due to the ability of RMA to image targets with hyperbolic range history. In the final paper the algorithm will be further tested with simulations and possibly also real SAR data.

5. REFERENCES

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