Fractional Range Doppler Algorithm for SAR Imaging

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Abstract— **Synthetic Aperture Radar systems are normally used to form high resolution images from radar backscatter. The Fractional Fourier transform (FrFT), which is a generalized form of the well-known Fourier transform, has opened up the possibility of a new range of potentially promising and useful applications that involve the use and detection of chirp signals including pattern recognition and SAR. In this paper the FrFT is applied to the well established Range Doppler Algorithm in order to obtain a superior result in terms of resolution and noise rejection. The results confirm that the FrFT can be useful to perform high resolution SAR processing and to reduce the speckle noise while enhancing the resolution and focusing accuracy.**

I. Introduction

Synthetic Aperture Radar (SAR) is an imaging radar for earth observation from satellite and airborne manned/unmanned platforms; it is currently operational in recently launched polar-orbiting platforms such as TerraSAR-X, RadarSAT-2 and Cosmo SkyMed as well as in previous missions. Applicatons are tailored to disaster observation and management, mapping of renewable resources, geological mapping, snow/ice mapping and strategic surveillance of military sites. Moreover, the scientific community is more and more oriented to a wide range of applications where the first step is the focalization of SAR data [1]. The use of new signal processing techniques is a good way to achieve better resolution especially using high resolution sensors where the feature of the smaller scatterer increases its importance. In [2], [3] the Fractional Fourier Transform (FrFT) has been applied to the Chirp Scaling Algorithm [4] to obtain good results in terms of resolution. In this paper a new FrFT based Range Doppler Algorithm (FrRDA) is presented. The relative performance of the FrRDA to the conventional RDA is demonstrated.

The remainder of this paper is organized as follows. Section 2 provides an overview of the Range Doppler Algorithm. Section 3 introduces the Fractional Fourier Transform while section 4 developes the new FrRDA. Section 5 presents a comparison of the new FrRDA to the RDA on several simulated data sets. Section 6 provides some final conclusions.

II. Range Doppler Algorithm Overview

SAR data processing consists of a set of procedures for obtaining final spatial and radiometric resolution from the instrument. It should satisfy requirements of accuracy, computational complexity and technical feasibility. In the relatively small set of available techiques for SAR data processing (also referred to as SAR focusing), the range-Doppler Algorithm (RDA) and its variants is one of the most widely used. It was first developed by MacDonald Dettwiler and Associates (MDA) and the Jet Propulsion Lab (JPL) in 1979 for the processing of SEASAT data [5], [6]. The algorithm is designed to achieve block processing efficiency, using frequency domain operations in both range and azimuth, while maintaining the simplicity of the one-dimensional operations. Block processing efficiency is also achieved for the Range Cell Migration Correction (RCMC), operation because it is performed in the *range–Doppler plane*. The sequence of core steps of the algorithm are illustrated in Figure 1 where it is noted that the deconvolution is split in the range and azimuth directions. This is possible because the range between the radar and a given point target is assumed fixed for a given pulse (start-stop approximation) [1].

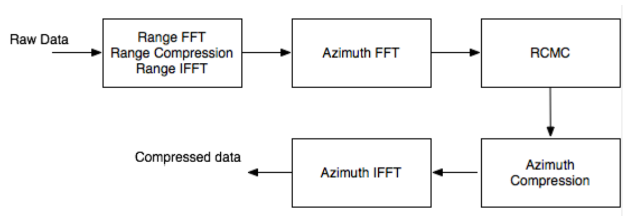

Fig. 1. Range-Doppler SAR processing algorithm

The range focusing is a filtering stage carried out in three steps:

1. **Range FFT**, that is a set of one–dimensional Fast Fourier Transforms in the range direction, one for each acquisition slot of the sensor.
2. **Range Compression**, namely a matched filtering obtained by multiplying the range transformed data by the range reference function in the frequency domain.
3. **Range IFFT**, transforms the data back into the time domain.

The azimuth focusing is a range dependent matched filtering stage that includes RCMC. It includes:

1. **Azimuth FFT**, comprising a set of one–dimensional Fast Fourier Transforms in the azimuth direction. The resulting data lie in the range–Doppler domain.
2. **Range Cell Migration Correction (RCMC)**, in the