Improving SAR Images: Built-In Geometric and Multi-Look Radiometric Corrections

O. O. Bezvesilniy, Ie. M. Gorovyi, S. V. Sosnytskiy, V. V. Vynogradov, D. M. Vavriv

Department of Microwave Electronics, Institute of Radio Astronomy of NAS of Ukraine
4 Chervonopraporna Str., Kharkov 61002, Ukraine
obezv@rian.kharkov.ua

***Abstract*—SAR systems installed on small aircrafts and UAVs suffer from trajectory deviations and instabilities of antenna orientation. These kinds of motion errors lead to significant geometric distortions and radiometric errors in SAR images. In the paper, we describe a time-domain multi-look stripmap SAR processing algorithm with built-in geometric and multi-look radiometric corrections. Geometric correction is performed due to azimuth reference functions and range migration curves specially designed to produce SAR images directly on a rectangular grid on the ground plane. Radiometric correction is based on multi-look processing with extended number of looks. The proposed techniques have been successfully tested with a Ku-band SAR system installed on a light-weight aircraft.**

I. INTRODUCTION

The formation of high-quality multi-look SAR images with SAR systems installed on small aircrafts or UAVs is a difficult problem because of significant motion and orientation errors of such light-weight platforms. Deviations of the aircraft trajectory and instabilities of the antenna orientation lead to geometric and radiometric errors in SAR images [1]-[3].

Geometric distortions in SAR images can be corrected by interpolation of images to a rectangular grid on the ground plane taking into account the measured aircraft trajectory and the orientation of the synthetic aperture beams. However, this approach becomes inefficient in case of significant geometric distortions.

The clutter lock technique is usually used to avoid radiometric errors in SAR images [1], [4]. According to this technique, the azimuth reference functions are built adaptively to track time variations of the Doppler centroid. It means that all SAR look beams are kept within the real antenna beam and the central SAR look beam is pointed exactly at the center of the real antenna beam. However, the clutter-lock should not be used in case of fast and significant instabilities of the antenna orientation when it leads to strong geometric errors in SAR images.

Instabilities of the aircraft orientation can be compensated by the antenna stabilization. It is a complicated and expensive solution. The application of a wide-beam antenna firmly mounted on the aircraft is another way to guarantee the uniform illumination of the ground scene despite of the instabilities of the platform orientation. This is a good solution; however it requires the operation at higher pulse repetition frequency.

In this paper, we propose a time-domain multi-look stripmap SAR processing algorithm with built-in correction of geometric distortions. The azimuth reference functions and range migration curves are specially designed to produce SAR images directly on a rectangular grid on the ground plane. In this way, we immediately obtain geometrically correct SAR images.

This approach cannot be combined with the clutter-lock and radiometric errors could appear in case of fast and considerable instabilities of the antenna orientation, especially for narrow-beam antenna. To solve this problem, we have proposed an effective radiometric correction technique based on multi-look processing with extended number of looks.

Both proposed techniques have been successfully tested by using a Ku-band airborne SAR system [5].

II. BUILT-IN GEOMETRIC CORRECTION

A. Time-Domain SAR Processing Algorithm

The proposed SAR processing algorithm is based on the one-dimensional time-domain convolution of the signals interpolated from range-compressed data along the migration curves

$$R_m(\tau) \approx R_m - (\lambda/2)F_{DC}(R_m)\tau - (\lambda/2)F_{DR}(R_m)\tau^2/2 \quad (1)$$

with the reference functions

$$h_m(\tau) = w_m(\tau)\exp[i(4\pi/\lambda)R_m(\tau)]. \quad (2)$$

Here R_m is the slant range, m is the range cell index, λ is the radar wavelength, $w_m(\tau)$ are the weighting windows applied for the side-lobe control.

The Doppler centroid F_{DC} and the Doppler rate F_{DR} are given by

$$F_{DC}(R_m) = \frac{2}{\lambda}\frac{(\vec{\mathbf{R}}_m \cdot \vec{\mathbf{V}})}{R_m}, \quad (3)$$

$$F_{DR}(R_m) = -\frac{2}{\lambda}\left[\frac{V^2}{R_m}\left(1 - \frac{(\vec{\mathbf{R}}_m \cdot \vec{\mathbf{V}})^2}{R_m^2 V^2}\right) - \frac{(\vec{\mathbf{R}}_m \cdot \vec{\mathbf{A}})}{R_m}\right], \quad (4)$$

where $\vec{\mathbf{V}}$ and $\vec{\mathbf{A}}$ is the aircraft velocity and the aircraft acceleration vectors, respectively.