

Elimination of Arcross-Track Phase Components in Airborne Along-Track Interferometry Data to Improve Object Velocity Measurements

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Abstract— The phase differences in airborne along-track interferometry can be used to calculate radial velocities of moving objects. This paper deals with the problem to preprocess phase and intensity data of along-track interferometry with the aim to determine velocities of slow moving objects. The phase information is often severely disturbed by quite different reasons. Beside the problem of noise sensitivity of interferometric measurements in airborne measurements additionally an unwanted across-track component could lead to systematic phase errors. We propose a first order correction of the along-track phase values by subtracting a plane which is fitted into phase values. In case of a flat scene this correction complies a ‘flat earth’ correction of the phase. The described process was applied to a scene with slow moving cargo ships.

Keywords: INSAR; arcross-track interferometry; along-track interferometry; object velocity measurements; MTI

I. INTRODUCTION

The airborne surveillance of traffic stream in large areas is more and more of interest for civil and military applications. For this application the detection of slow moving objects e.g. ships, tanks and trucks is a very difficult problem for a MTI (Moving Target Indication) system on a moving platform, due to the problem of separating the signal of the object from the stationary background (clutter) by its doppler frequency [1], [2]. The literature concerning this thematic is extensive and the investigated approaches are very divers (e.g. [3], [4], [5], [6], [7], [8], [9]).

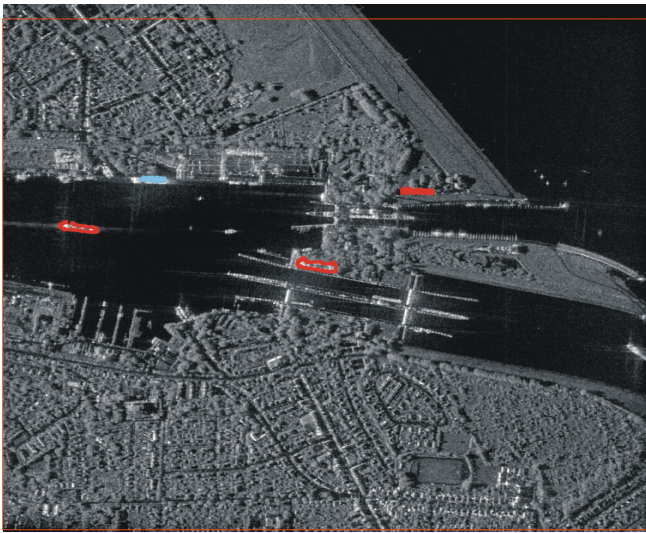
For very slow moving ground objects (e.g. velocities smaller than 15 km/h) an interferometrical evaluation is promising [10]. The data set is taken by a SAR system with at least two antennas or sub-apertures positioned parallel to the flight direction. The data set is processed coherently to obtain fine resolution information regarding the velocity of scene objects (along-track interferometry). In contrast to across-track interferometry allowing multi and single pass modus the interferometrical detection of moving objects is only possible in single pass modus. The main field of other investigations concerning along-track interferometry is regarding the measurement of radial velocity fields to identify ocean surface or coastal currents e. g. [11], [12], [13], [14].

Nevertheless, the number of available high resolution SAR-systems with interferometric along-track capabilities is increasing. These systems offer an additional opportunity to monitor slow traffic streams. For our investigations we use data that were recorded by the airborne AER-II experimental multi-channel SAR system [15], [16] of FGAN. This system is equipped with a active phased array antenna and up to 4 receiver channels. The center frequency of this X-band system is 10 GHz with signal bandwidth of 160 MHz. The ground resolution achieves a spacing of approximately 1m x 1m.

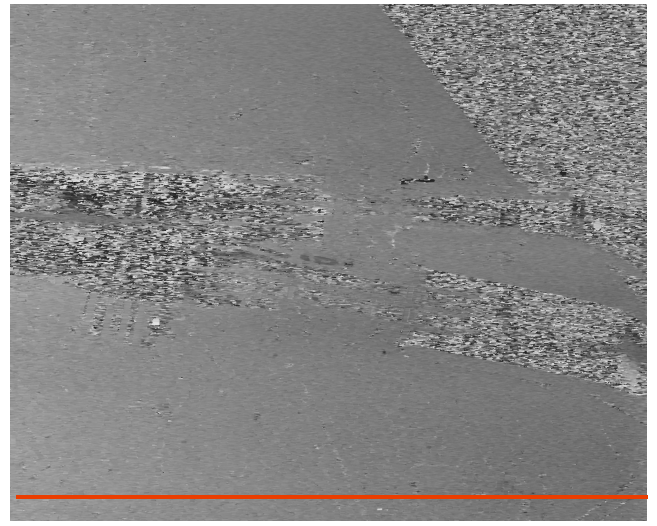
By along-track interferometry the velocity is proportional to the phase difference of the complex SAR images. But in areas with low SNR or poor coherence the phase information is severely disturbed, by statistical perturbations. Additionally systematical effects could lead to severe phase errors. Hence, the perturbations have to be removed or at least significantly reduced before further analysis. The statistical component (phase noise) is frequently eliminated by low pass filtering with sliding windows. Unfortunately, filtering results in a decreased geometric resolution and blurs signal jumps at object boundaries.

We presented a combined iconic and symbolic (model-based) approach to detect moving objects in spite of the presence of a strong phase noise [17]. This method is supported by a joined analysis of the phase and the intensity information which is quite similar to the method developed for the model based segmentation of SAR images of urban areas [18], [19]. The tasks differ mainly due to the different nature of the expected objects – cargo ships instead of roads and buildings. In both cases a combined segmentation in the phase differences and intensities is carried out, to detect areas containing candidates for objects. Afterwards, the phase differences of appropriate objects are smoothed. In this step the phase differences are weighted with their related intensity or coherence values. The cargo ships are extracted and described by a simple model [17]. Only cargo ships with a minimum velocity matching the longitudinal and transversal extension features of the model are considered in further processing. For every object a weighted average velocity is calculated.

The test data set shows a scene in the vicinity of a lock. On the waterway are several cargo ships present, which are just entering or leaving the lock area. Figure 1 gives an overview of



a



b

Figure 1. Scene with a lock: a) intensity image with detected cargoships (red), b) along-track phase distribution to the scenery

the test side. Three cargo ships can be identified. In the upper lock a cargo ship is leaving and in the lower lock a ship is entering (Figure 1a). A third ship is approaching from the left.

For the estimation of the absolute object velocity from the phase values all systematical phase perturbations should be carefully eliminated before further processing. In many cases under real measurement conditions the along-track interferometry data is superimposed by an across-track phase component which is caused by an incorrect orientation of the platform. This kind of distortions are described in the next chapter.

II. INFLUENCE AND ELIMINATION OF SYSTEMATICAL PHASE PERTURBATIONS

For the estimation of the absolute object velocity all systematical phase perturbations should be carefully eliminated for further processing of the phase information. In the case of along-track measurements a systematical phase perturbation could be easily detected, because in the ideal case, the mean local phase should be zero for the whole scenery. Only moving objects in the scenery are expected to have a significant phase

or a velocity value different from zero. Systematical phase distortions could lead to significant velocity errors. There exists many possible sources for systematical phase perturbations and most of them are related to instable or unknown flight conditions during the data acquisition. One very obvious disturbance can be produced by a small across-track component of the antennas during the data acquisition. In flat areas this would lead to a linear phase ramp if no phase jumps caused by the inherent phase ambiguity occurs. Fig. 1b) shows the phase values which belongs to the scenery depicted in Fig. 1a). The phase errors due to areas with low backscattered signal (water areas) are clear to identify in the image (Fig. 1b). But, there exist also a systematical phase effect, which become quite obvious in the phase profile along a single range line. Fig. 2a shows the phase distribution along the range line, which is marked red in Fig. 1b). The linear characteristic of the disturbance is obviously to see and can be easily corrected. For this correction a plane was fitted to the phase distribution of the whole scenery. After subtracting the fitted plane from the phase values the width of the phase histogram is significant reduced. Fig. 2c) and 2d) shows the phase histogram for the whole scenery before and after the correction respectively. As expected the number of values near zero is substantially

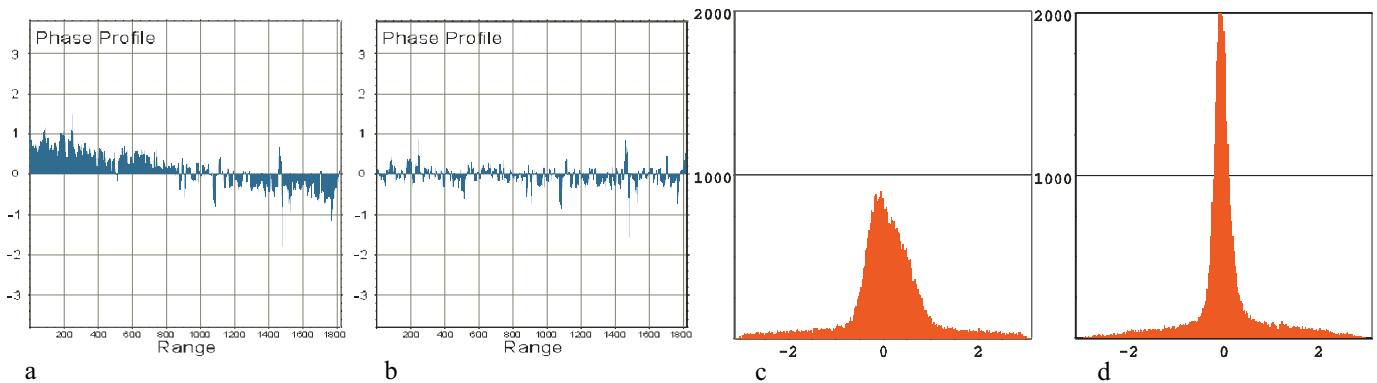


Figure 2. Phase distributions along a range line (see line in Fig. 1) and phase histograms of the whole image: a) distribution before correction, b) distribution after correction, c) histogram before correction d) histogram after correction

increased.

This correction could be interpreted to be a flat earth correction of an across-track phase component originated by a mean across-track base line smaller than 1 cm. This is within the scope of a possible misalignment of the antennas during the data acquisition. Figure 2b) shows the remaining phase error along the range line depicted in 1b). It seems to be of statistical nature most probably due to the phase noise. Nevertheless, the local mean phase value is now very close to zero. As a result of the phase correction the derived ship velocities are quite more reliable and an underestimation of the ship velocities could be significantly reduced.

III. DISCUSSION AND OUTLOOK

In flat areas a simple linear approach for the correction of the phase values is sufficient to improve the object detection and the ship velocity estimation. In areas with more topographical undulations a simple 'flat earth correction' will not be sufficient. In [17] we reported systematic but not uniform perturbation in a data set with height differences of more than 200 m. The phase distortions caused by these height differences could complicate the object segmentation and leads to errors by the velocity determination. Current investigations of these disturbances have the aim to show the correlation between the local topography and a digital terrain model (DTM). The following step is to develop an appropriate procedure to eliminate such perturbations with and without a DTM of the scenery. For this purpose the phase variation caused by the local height variation is simulated and will be compared with the achieved results by the interferometric measurement.

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