IMAGING GEODESY WITH TERRASAR-X

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1. INTRODUCTION

In the past, SAR interferometry (InSAR) was considered to be *the* method for accurate geometric measurements. While the InSAR method is accurate in a relative double difference (spatial and temporal) sense, it lacks the absolute location accuracy that is required by many geodetic applications. Furthermore, InSAR suffers from phase ambiguity problems in a spatial and temporal sense. In our paper we demonstrate how we can overcome these limitations by exploiting the high orbital accuracy of TerraSAR-X [1] and the careful calibration of the TerraSAR-X sensor and ground processing system [2]. We furthermore use atmospheric measurements to reduce the error of the propagation medium and geodetic Earth models to achieve relative (over time) location accuracies of 4 centimeters and absolute accuracies better than 10 centimeters. Our method does not exploit the SAR phase and is therefore not subject to phase unwrapping problems or unknown phase constants.

2. RANGE MEASUREMENT ACCURACY OF A SAR SYSTEM

The absolute localization accuracy of a SAR is determined by the following factors: orbit accuracy, sensor stability, propagation medium, target detection accuracy, coordinate system transforms. These factors are sketched in the following sub-chapters.

2.1. Orbit Accuracy

It has been shown in [3] that an orbital accuracy of about 4 cm is achieved for the best available TerraSAR-X science orbits. In our paper we confirm this number and suspect even smaller errors.

2.2. Radar Accuracy

The error contributions of the radar electronics are typically its timing bias often referred to as “electronic delay” or “sampling window start time bias” and stability of the sampling clock frequency. We have no measurements available but we confirm with our results, that the electronic bias is stable to better than 4 cm (2.7e-10 s) and the frequency stability better than 5 Hz over longer time spans.

2.3. Atmospheric Path Delay

During its propagation, the radar pulse experiences dispersive (frequency dependent) phase advance and group delay due the Ionosphere [4], [5]. Furthermore, a frequency independent delay is caused by the dry gases and the wet part of the troposphere. Without compensation, the time variant error components add up to ±10 centimeters. By using atmospheric measurements we reduce this component to less than 4 cm stdev.

2.4. Target Detection Accuracy

For our experiments we use random distributed targets for relative measurements and precisely measured corner reflectors for absolute measurements. Theory [6] predicts that we can locate those targets in the image with an accuracy of millimeters or centimeters, respectively.

2.4. Coordinate Transformation Accuracy

We encountered location errors of ±10 cm if the reference frames are not taken into account correctly. By compensating these effects with consolidated geodetic models [7],[8],[9],[10] we reduce their influence to less than 1 cm.

3. EXPERIMENTS

We used data from the German Geotechnologien project Exupery [11] over the Azores and a Spotlight interferometric [12] stack over Venice to develop and test our method. In both cases we achieved a relative (over time) positioning accuracy of 4 centimeters. The relative accuracy in space is even better. An absolute (space and time) accuracy of less than 10 centimeters seems to be feasible but needs some more analysis to be done in the near future.

4. OUTLOOK

Our results revultionize the accuracy of SAR measurements and transform high resolution SAR systems to geodetic instruments - without the need to use interferometry. Applications are manifold as we increase the localization accuracy from meters to centimeters thus get closer to the accuracy of permanent GPS stations - without the need of equipment on ground.

5. REFERENCES

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