INTERFEROMETRIC PROCESSING ALGORITHMS OF TANDEM-X DATA

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1. INTRODUCTION

The German TanDEM-X mission, starting in June 2010, is based on two TerraSAR-X satellites flying in close formation and establishing the first bistatic single pass interferometer in space. The primary objective of the mission is the generation of a consistent global digital elevation model (DEM) with an unprecedented accuracy, which is equaling or surpassing the HRTI-3 specification [1]. Systematic processing of SAR raw data to so-called raw DEMs is performed by one single processing system, the Integrated TanDEM Processor (ITP). The final global DEM is then calibrated and mosaicked. In this paper an overview of the InSAR algorithms of the ITP is presented.

2. ALGORITHMIC OVERVIEW

The interferometric processing chain of the Integrated TanDEM Processor (ITP) [2] is composed of five main processing blocks, as shown in Figure 1. After the SAR focusing chain, master and slave Single look Slant range Complex (SSC) data are filtered to their common spectrum (Sec. 2.1) and coregistered (Sec. 2.2), for the generation of the interferogram. A single or dual phase unwrapping operation is then performed, according to the DEM acquisition plan (Sec. 2.3, 2.4). Finally, a raw DEM and a set of files assessing the quality and the geometric properties of the scene are generated as output (Sec. 2.5). The coregistered master and slave data (CoSSC), used as a support of the dual baseline phase unwrapping, are also provided.

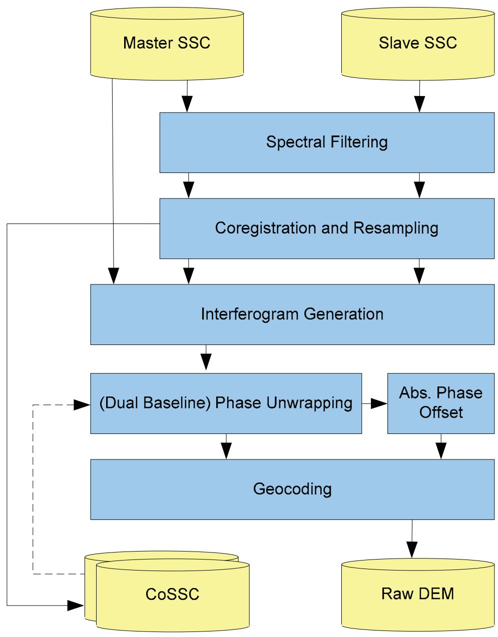

Figure 1: High level block scheme of the interferometric processing chain embedded in ITP. The internal interfaces are not shown for clarity.

2.1 Spectral filtering

Due to the different acquisition geometry, master and slave received spectra are composed of a coherent and a non-coherent band, both in range and azimuth. In order to simultaneously increase the coregistration precision [3] and reduce the variance of the final height estimate [4], the non-coherent band should be eliminated. Given the acquisition parameters of the TanDEM-X mission, the gain derived from range filtering does not justify performing processing. Thus only azimuth spectral shift filtering will be performed. The overlapping bands are estimated from the Doppler centroid and azimuth processing bandwidth annotation. A filter that selects only the common band is used. Its parameters are continuously adapted with range. Azimuth block-wise processing allows the update of the filter twice a second. This update rate is enough to follow the azimuth variation of the Doppler centroid, which is caused by the satellite's attitude control loop.

2.2 Coregistration and Resampling

SAR image rasters differ because of the parallax as a consequence of the two slightly different acquisition geometries. Coregistration is an operation which estimates the shift and distortions of an image raster with reference to another one, the so called master image. Because of the high resolution of the system and the terrain dependent distortions, coregistration polynomials are not appropriate. Instead mapping matrices are generated and used for coregistration.
The coregistration algorithm is structured in the following steps [3]:

- A geometrical calculation on a regular grid of the range and azimuth shifts of the slave scene with respect to the master scene is performed. An external DEM and precise orbit information of master and slave satellites are used as input information.
- Cross-correlation operation is performed with patches arranged on the grid. The a-priori estimates coming from the geometrical coregistration are used to coarsely locate these patches within the slave scene. Thus the overlapping area of the patches can be maximized. Since it is not desired to resample the slave patches, the a-priori estimates are rounded to an integer number. Coherent cross-correlation is firstly calculated. A simulated topographical phase has to be removed in order to correctly estimate correlation. If the correlation coefficient is lower than a certain threshold, then incoherent cross-correlation is applied. The resulting cross-correlation function is interpolated in time domain to obtain the position of the maximum.
- An outlier elimination procedure for the mapping matrices is performed.

The Slave image is finally resampled on the master grid using the mapping matrices previously estimated. This operation is performed in time domain in order to locally follow the shifts patterns.

2.3 Single and Dual baseline phase unwrapping

The purpose of phase unwrapping is to recover the absolute phase given the ambiguous wrapped interferometric phase. It constitutes the critical step in the interferometric chain.

The terrain height difference corresponding to a phase variation of one cycle is the so-called height of ambiguity and depends directly on the baseline. The smaller the height of ambiguity, the greater the phase difference between two points and the more difficult is the unwrapping process. On the contrary, a larger height of ambiguity implies that fringes are easier to unwrap, nevertheless with poorer topography accuracy. The TanDEM-X acquisition plan has been designed from this approach, i.e. a first acquisition stage with a larger height of ambiguity (ca. 40 – 50 m/cycle), and a second one with a smaller one (ca. 25 – 35 m/cycle).

The interferograms obtained with the larger height of ambiguity are unwrapped using the Minimum Cost Flow (MCF) algorithm [5], which was used successfully during the SRTM mission. Once interferograms with the smaller height of ambiguity will be available, a new approach which combines MCF and Maximum Likelihood Estimation (MLE) will be used [6]. In this case, MLE is first used to reduce phase gradient ambiguities. Then, phase unwrapping of the most accurate of the interferograms is performed with the MCF algorithm using the gradient estimates obtained previously. In this way, since ambiguities have been mostly solved, single baseline phase unwrapping is notably enhanced, helping many of its difficulties.

2.4 Absolute phase offset determination

After phase unwrapping has been performed, a reference phase for the absolute phase has to be applied. For this purpose, the coregistration information is used. Since data takes are splitted into scenes for processing, a mechanism has been designed to avoid possible phase jumps between consecutive scenes. As a quality check, a simulated interferogram from an external DEM is also used.

2.5 Geocoding

The generation of a raw DEM starting from the interferometric unwrapped phase is well known as *geocoding*. It involves the conversion of phases to terrain height and the transformation from slant-range coordinates to an Earth-related reference frame. The key concept is to find the intersection between two curves [4]:

- The interferometric phase *Φ(r)*, which has a monotonous (decreasing or increasing) behaviour as a function of range time.
- The geometric phase *φ (r)*, linking the interferometric phase to the height of one point on the ground This phase can be related to range time, as a vertical straight line of increasing terrain height crosses the circles of constant range delays, and it is monotonous as well, with a trend opposite to *Φ(r)*, intersecting thus the first one.

This concept allows in a single step to obtain the output desired, since it links all the parameters involved for geocoding: azimuth and range times, interferometric phase and terrain height. *φ (r)* is computed for every point of the desired output grid through an inverse geocoding relating different terrain heights to the satellite positions (master and slave).

3. PROCESSING RESULTS

The processing results to be shown in this chapter are planned to be based on TerraSAR-X repeat pass interferometry or - if available - on pursuit monostatic and bistatic TanDEM-X data.

4. REFERENCES

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