TanDEM-X: First Scientific Experiments during the Commissioning Phase

Irena Hajnsek, German Aerospace Center, Microwaves and Radar Institute, Germany &
ETH Zurich, Institute of Environmental Engineering, Switzerland
Gerhard Krieger, German Aerospace Center, Microwaves and Radar Institute, Germany
Kostas Papathanassiou, German Aerospace Center, Microwaves and Radar Institute, Germany
Stefan Baumgartner, German Aerospace Center, Microwaves and Radar Institute, Germany
Marc Rodriguez-Cassola, German Aerospace Center, Microwaves and Radar Institute, Germany
Pau Prats, German Aerospace Center, Microwaves and Radar Institute, Germany

Abstract

In this paper new and innovative techniques during the commissioning phase of TanDEM-X will be presented that are firstly demonstrated on a satellite platform. The focus is on the secondary goals of TanDEM-X that are assigned for the third year of the mission time life due to the tight schedule for the acquisition of the highly accurate global digital elevation model. Therefore, a variety of scientific experiments are planned to be performed already during the commissioning phase. The first experiments are related to bistatic processing, Polarimetric SAR Interferometry, double differential SAR Interferometry, decorrelation measurements, supperresolution and velocity measurements. The data quality and the results obtained will be validated and are discussed.

1 Introduction

TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurements) is an innovative spaceborne radar interferometer that is based on two TerraSAR-X radar satellites flying in close formation. The primary objective of the TanDEM-X mission is the generation of a consistent global digital elevation model (DEM) with an unprecedented accuracy, which is surpassing the new HREGP specification defined by NIMA, US.

Figure 1 Artistic view of TanDEM-X

Beyond that, TanDEM-X provides a highly reconfigurable platform for the demonstration of new radar imaging techniques and applications [1]. Both satellites will then act as a large single-pass radar interferometer with the opportunity for flexible baseline selection. This enables the acquisition of highly accurate cross- and along-track interferograms without the inherent accuracy limitations imposed by repeat-pass interferometry due to temporal decorrelation and atmospheric disturbances.

This paper is focusing on the innovative secondary goals of TanDEM-X and their demonstration during the commissioning phase in space. The key elements are the bistatic data acquisition employing an innovative phase synchronization link, a novel satellite formation flying concept allowing for the collection of bistatic data with short along-track baselines, as well as the use of new interferometric modes for system verification and DEM calibration. Beside this new modes as along-track SAR interferometry, polarimetric SAR interferometey (Pol-InSAR), digital beamforming, superresolution etc will be performed for the demonstration of innovative technology but also to use it as a tool for the development of new applications products.

2 Operating Modes

Interferometric data acquisitions with the TanDEM-X satellite formation can be achieved in three cooperative modes: Bistatic, Pursuit Monostatic, and Alternating Bistatic. The three cooperative modes may further be combined with different TerraSAR-X and TanDEM-X SAR imaging modes like Stripmap, ScanSAR, and Spotlight, the last mode being in sliding spotlight acquisition geometry. However, only the bistatic mode will be used for the acquisition of standard TanDEM-X DEM products, while others may be used for system calibration, validation and verification as well as for the acquisition of non-operational experimental data [1]. During the commissioning phase several modes will be operated and validated.

3. Scientific Experiments

The first scientific experiments will be conducted during the Commissioning Phase (CP) of TanDEM-X which is scheduled to long 5 months after launch. The CP is divided into three phases and starts with the LEOP and goes over to the monostatic phase where the two satellites will be brought closer (a maximum long baseline of approximately 20km will be available). Then TanDEM-X is going over to the bistatic phase (a baseline of 500 m is available). During the different phases several scientific experiments will be performed and are shortly described in the following.

3.1 Polarimetric SAR Interferometry

Polarimetric SAR Interferometry is an established technique using airborne SAR data at longer wavelength. In a spaceborne case and at a short wavelength as it is the case for X-band the data and experiences for crop parameter estimation are missing. TanDEM-X will be the satellite first demonstrating the potential and the capability for -bio/geo-physical parameter derivation during the commissioning phase. The first experiments will be conducted over agricultural fields covered with vegetation. The main focus of the parameters that could be potentially estimated is crop height.

3.2 Decorrelation Analysis

During the monostatic commissioning phase the satellites are separated from each other by 20 km in the along-track direction. This displacement can be used to take two consecutive monostatic SAR images from the same scene with a time lag of approx. 2.6 s. This temporal delay is well suited to investigate short term temporal decorrelation effects over vegetated areas. Disturbing effects from volume decorrelation are minimized due to the specific orbital configuration which provides almost vanishing cross-track baselines in Equatorial regions. The results from this investigation can also be used to assess the DEM performance in the pursuit monostatic mode. Further promising investigations are related to the Arctic and Antarctic where the temporal baseline can e.g. be used to observe sea ice drift with high accuracy.

3.3 Bistatic Processing

The TanDEM-X mission works on a tight schedule and, therefore, the baselines between the end of the commissioning phase until the beginning of mission's third year are usually not easily modifiable. The more demanding experiments with having the larger baselines are foreseen from mission's third year onwards. An accelerated TerraSAR-X-like commissioning phase has been designed for the TanDEM satellite, before any bistatic operation is undergone. During this time, TerraSAR and TanDEM satellites approach each other in order to prepare the close flying formation. Bistatic acquisitions with large along-track baselines (about 20 km) are foreseen during this commissioning phase to test the bistatic capabilities of the system, including dedicated bistatic SAR focussing and clock synchronisation.

3.4 Velocity Measurements

In [2] we have proposed a large along-track baseline approach for ground moving target indication (GMTI) and parameter estimation. TerraSAR-X and TanDEM-X are operated in the pursuit monostatic mode with an along-track baseline in the order of several kilometers. Such large baselines are available during the commissioning phase of TanDEM-X. By exploiting the displacement differences of the moving targets within the SAR image pairs, the true target positions and the motion parameters can be estimated with high accuracy. It will be demonstrated and evaluated the proposed approach using real SAR data and ground measurements as reference data.

3.5 Superresolution

During the monostatic pursuit phase the two satellites will be separated by 20 km in the along-track direction following approximately the same orbital tube. Therefore, by modifying the squint of one of the satellites, it can be possible to acquire contiguous portions of the azimuth spectrum almost simultaneously. A simple addition of the two spectra will result in approximately twice the azimuth resolution. For TSX/TDX, this means that long strips can be acquired with about 1.5m resolution in azimuth, i.e. a product which in terms of resolution is between the high-resolution (1m) and sliding-spotlight (2m) operational products.

The same idea of using different portions of the spectrum can be applied with a spotlight acquisition. TSX will perform a normal spotlight acquisition, while TDX, separated by 20km, will illuminate the TSX footprint. Due to the large along-track distance, TDX will need a squint of about 2º. Although this large squint will increase the grating lobes, it will not affect the performance, as TDX is quite far away from the transmitter. Furthermore, due to the large distance between both sensors, the monostatic and bistatic spectra will be enough separated, so that if combined a full resolution image can be generated (assuming the monostatic and bistatic reflectivities remain similar).

Finally, a third option is to do a spotlight acquisition with both satellites pointing forwards and backwards respectively, so that the observation time can be maximized. Again, grating lobes are not important for the bistatic acquisition (although the monostatic image will have large azimuth ambiguities). The resolution can be similar as in the previous case, but with the advantage that no combination of the spectra is necessary.

3.6 Deformation

Double differential SAR interferometry (double DInSAR) is a promising tool to monitor deformation phenomena being independent of temporal decorrelation. Using two simultaneous acquisitions with a very large baseline, a very good accuracy can be obtained in the measurement of the topographic height. A second single-pass interferogram with the same large baseline after an event has occurred will deliver again a very accurate measure of the topographic height. The difference of these two DEMs will then result in the desired deformation measurement. Note, however, that it might be very difficult to unwrap the phases to generate the DEMs. Therefore, if the two baselines are very similar, i.e. with a similar height of ambiguity, the subtraction can be already performed in the complex domain, hence avoiding the critical unwrapping step

4 Summary

TanDEM-X is a satellite with highly reconfigurable platform and is therefore ideal for the use and demonstration of new techniques. During the commissioning phase several new techniques will be demonstrated and the results validated.

References

[1] Krieger, Gerhard und Moreira, Alberto und Fiedler, Hauke und Hajnsek, Irena und Werner, Marian und Younis, Marwan und Zink, Manfred (2007) *TanDEM-X: A Satellite Formation for High Resolution SAR Interferometry.* IEEE Transactions on Geoscience and Remote Sensing , 45 (11) , Seiten 3317-3341. IEEE . DOI: 10.1109/TGRS.2007.900693.

[2] S. Baumgartner, G. Krieger and K.-H. Bethke, “A Large Along-Track Baseline Approach for Ground Moving Target Indication Using TanDEM-X,“ Proceedings of International Radar Symposium (IRS), Cologne, Germany, 2007.