Acta Astronautica 99 (2014) 130–142

Contents lists available at ScienceDirect

Acta Astronautica

journal homepage: www.elsevier.com/locate/actaastro

Review

Formation flying for along-track interferometric oceanography—First in-flight demonstration with TanDEM-X

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ARTICLE INFO

Article history:
Received 18 July 2013
Received in revised form
17 January 2014
Accepted 13 February 2014
Available online 24 February 2014

Keywords:
Formation flying
Along-track interferometry
Ocean current measurement

ABSTRACT

Beyond its primary mission objective, the TanDEM-X formation flying mission provides a unique test bed for demonstrating new SAR techniques such as Along-Track Interferometry (ATI) for ocean current measurement. In this paper we discuss the ATI formation control requirements and the limitations imposed by the implemented Helix-formation. We propose two ATI scenarios and verify their feasibility by means of software simulation and in-flight demonstration. In particular, flight results of the very first ATI experiment are presented, demonstrating the high potential of TanDEM-X for mapping ocean currents.

Contents

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http://dx.doi.org/10.1016/j.actaastro.2014.02.014
0094-5765

1. Introduction

The TerraSAR-X mission provides high-resolution Synthetic Aperture Radar (SAR) data to both science and commercial users. The TerraSAR-X satellite (TSX) was

launched on 15 June 2007 and has been operated in a 505 km high, sun-synchronous, 11-day repeat orbit. On 21 June 2010 an almost identical satellite, TanDEM-X (TDX), was launched in order to form the first configurable SAR interferometer employing formation flying with TSX (cf. Fig. 1). The main objective of the common TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) mission is to generate a global digital elevation model (DEM) with unprecedented accuracy as the basis for a wide range of scientific research as well as for commercial applications. In order to collect sufficient measurements for a global DEM, three years of formation flying are foreseen with changing across-track baselines ranging from 150 m to few kilometers [1,2].

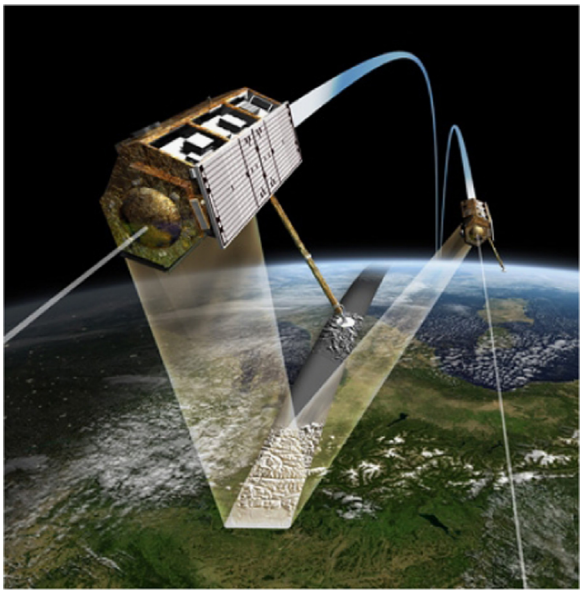

Fig. 1. The TanDEM-X and TerraSAR-X satellites in close formation flight over Europe (artist impression).

Beyond that primary mission objective, the satellite formation provides a configurable SAR interferometry test bed for demonstrating new SAR techniques and applications. In particular, it offers a unique chance to measure very slowly moving sea ice as well as ocean currents by means of Along-Track Interferometry (ATI). Due to the importance of the DEM acquisition, the first three years of the mission are executed with a formation optimized for this purpose. After finalization of the global DEM formation flying will be dedicated to a variety of scientific interferometric campaigns including ATI. However, during the first years of operation already a few data sets with appropriate parameters for ATI have been acquired for ocean currents at the Orkney Islands.

Because of the great potential of space-borne SAR ATI with along-track separations in the order of 50 m and the fact that it has not been demonstrated before, there is a strong interest in preliminary ATI experiments with TanDEM-X to validate the methods foreseen for both SAR acquisition and processing. In this paper we investigate the possibilities and limits of along-track interferometry for ocean current measurements with the TanDEM-X mission from a flight dynamics perspective.

Currently, TanDEM-X is the only space borne remote sensing system that can measure ocean surface currents with 0.1 m/s velocity resolution and a spatial resolution with a grid size of only 33 m $\times$ 33 m. When more ATI data will be acquired, it could be used, e.g. to measure slowly moving sea ice, to spot-check global ocean circulation models which are applied for climate research, or to measure tidal ocean currents nearby shores which is of interest for the navigation of ships and for the optimal placement of renewable energy sites.

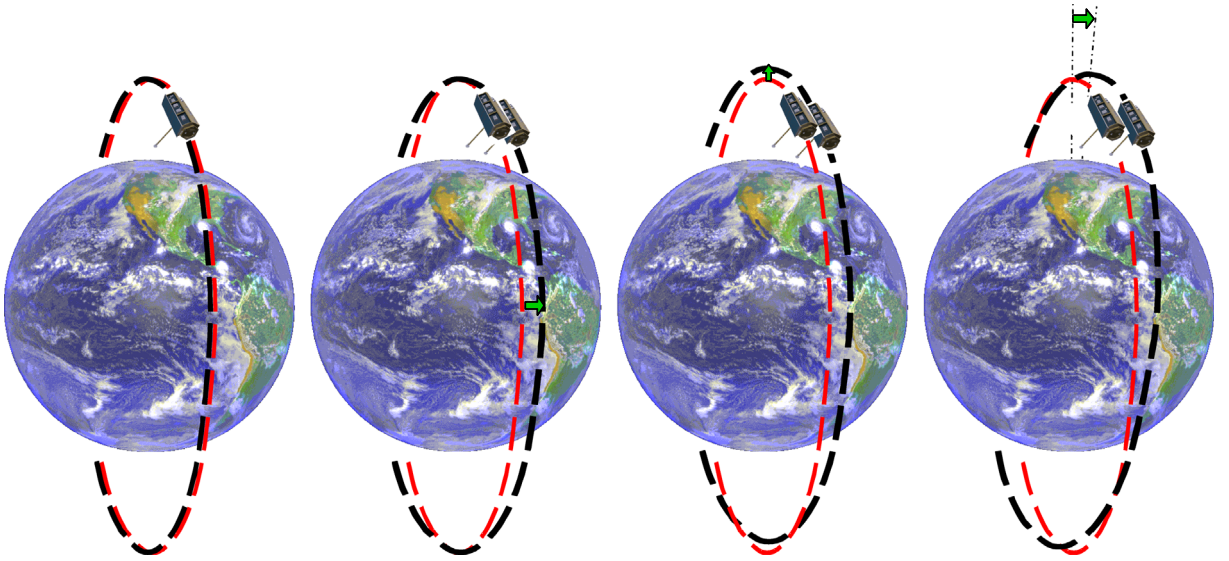

Fig. 2. Formation building with relative eccentricity/inclination vector separation. From left to right: (1) identical orbits, (2) maximum horizontal separation at equator crossings by a small offset in the ascending node (green arrow), (3) a small eccentricity offset causes different heights of perigee/apogee and hence yields a maximum radial separation at the poles. (4) Optional rotation of the argument of perigee to achieve larger baselines at high latitude regions. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)