SAR Performance Monitoring for TerraSAR-X Mission

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1. INTRODUCTION

TerraSAR-X (TSX) is Germany's first national remote sensing satellite implemented in a public-private partnership between the German Aerospace Centre (DLR) and EADS Astrium GmbH [1]. TerraSAR-X features an advanced high-resolution X-Band Synthetic Aperture Radar (SAR) based on the active phased array technology which allows the operation in Spotlight, Stripmap, and ScanSAR mode with two polarizations in various combinations and elevation angles. For this high amount of antenna beams, its active phased array antenna electronically steers and shapes the patterns in azimuth and elevation direction [2]. It combines the ability to acquire high resolution images for detailed analysis as well as wide swath images for overview applications. The resolution varies from 1 m for best Spotlight, 3.5 m for nominal Stripmap, and 18 m for ScanSAR products. The image width ranges from 10 km (Spotlight) to 100 km (ScanSAR).

The SAR performance of the system is analysed with respect to geometric and radiometric parameters like resolution and side lobe ratios. Long-term monitoring of system parameters like instrument characteristics or SAR image quality confirms the continuous stability of the system. The specified product quality can be found in a public document of the TerraSAR-X mission [3] and the radiometric accuracies are presented in [2].

By launching a twin satellite, TanDEM-X (TDX), the TerraSAR-X mission is supported by two satellites. One half of the resources is used for the systematic acquisition of a global digital elevation model (DEM) [4]. All other resources of both satellites are free for commercial and scientific exploitation of the TerraSAR-X products. The approach presented in the following shows how to keep the SAR performance for TSX and TDX.

2. PERFORMANCE MONITORING

TerraSAR-X was launched on June 15th, 2007, completed its commissioning phase in December 2007, and started the provision of high-resolution products for different SAR modes for both the scientific and commercial user community in January 2008. Since then over 30000 SAR images have been successfully commanded and acquired. Continuous monitoring of system parameters provides long-term statistics over the mission time to prove the product stability. Example statistics are shown in the following.

2.1. Instrument Temperatures

Monitoring the temperature of the radar front-end shows that the instrument is operated in its space-qualified thermal conditions (see Figure 2 top). The temperatures on the twelve antenna panels are perfectly correlated with the varying instrument data load (lower part Figure 2). No anomalies have been found. The limit temperature for the nominal performance is far from the measured panel temperature.

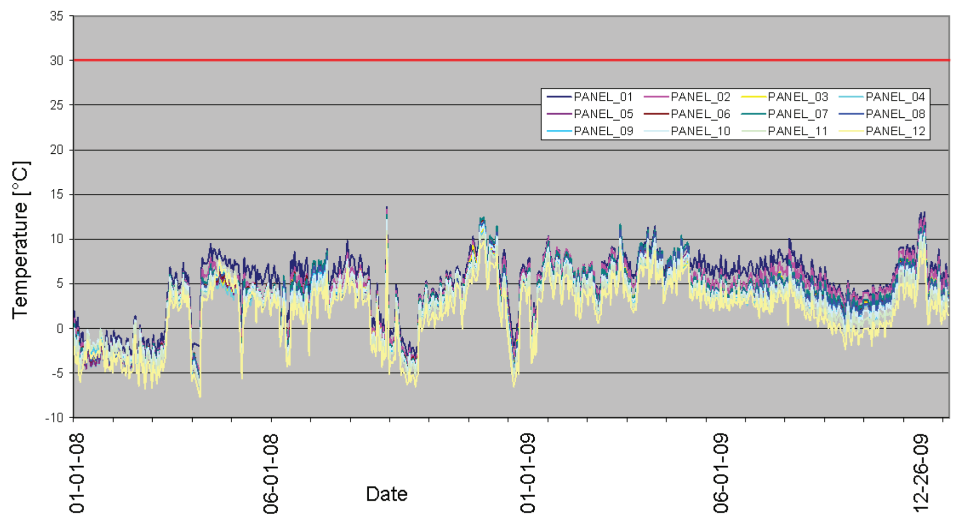

Figure 1 Temperature of all twelve antenna panels over mission time.

2.2. Instrument Gain

The central electronics (CE) of the TerraSAR-X instrument is responsible for generating and receiving the radar pulses, right before the front-end is distributing and amplifying the signal within the active antenna array. In total, TerraSAR-X hosts an internal calibration facility with three types of calibration pulses for monitoring and compensating the instrument drifts [2]. One of these calibration pulses can be used for monitoring the stability of the internal gain of the CE. Comparing the amplitude of this calibration signal over mission time with the respective CE temperature provides information on the thermal fluctuation as well as its effects on CE gain. It can be seen that the instrument is very stable in temperature and in gain which is one important fact for the good quality of all TerraSAR-X images.

2.3. Radiometric Resolution

The radiometric resolution is the expected spread of the variation in each scene reflectivity as an observed image [6]. For each image 4 distributed targets are selected and the radiometric resolution based on the image intensity is calculated (Figure 2).

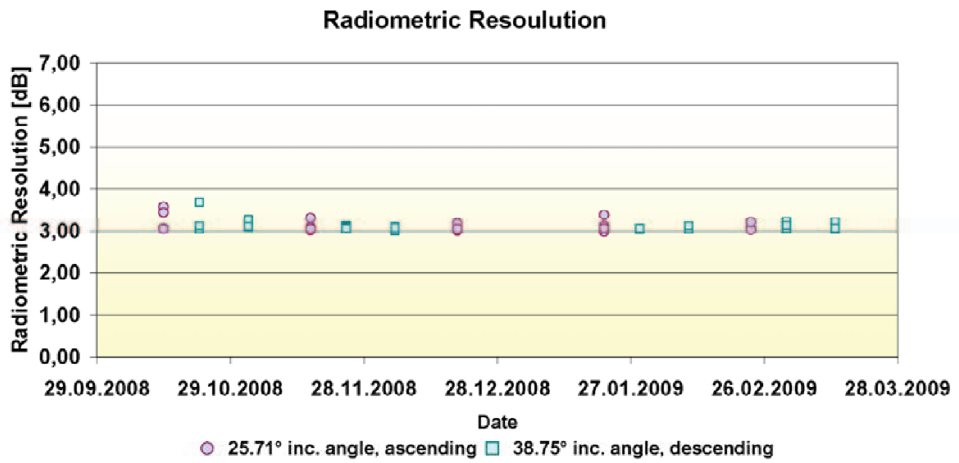

Figure 2 Radiometric Resolution from statistics (4 distributed targets for each image).

2.4. Geometric Resolution

Figure 3 shows the very stable measurements of geometric resolution in azimuth (blue and red) and in range (green and yellow). The specification for Stripmap images in azimuth is 3.3 meters (red line), the measured mean 3.00 meters and standard deviation 0.01 meters. For the ground range resolution near range images have a limit of 1.2 meters (lower dotted red line) and the far range images have a limit of 1.8 meters (upper dotted red line).

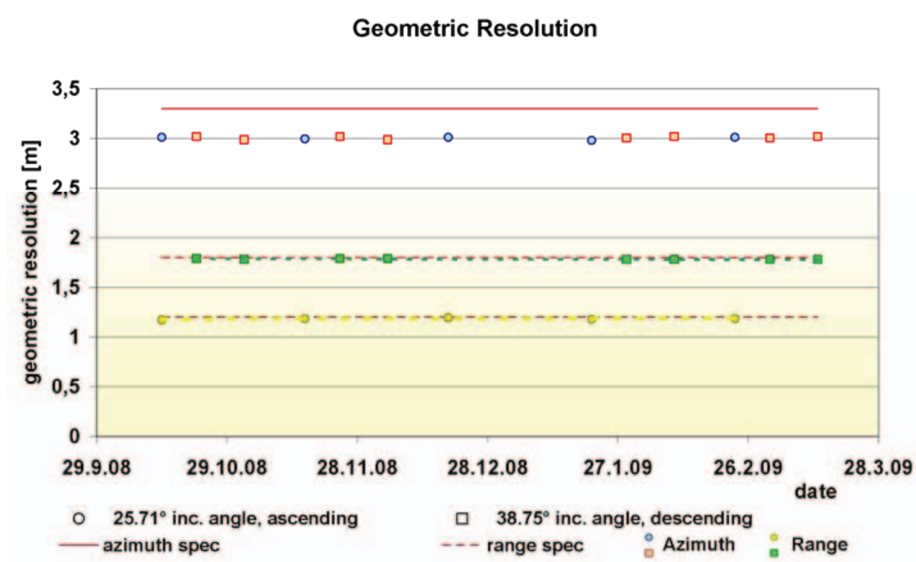

Figure 3 Geometric Resolution in azimuth and range (13 SAR images).

3. TERRASAR-X MISSION WITH TWO SATELLITES

The future TanDEM-X mission will orbit two identical satellites (TSX and TDX) in a close helix formation in order to acquire bistatic SAR images and generate an accurate global digital elevation model (DEM) [4]. In addition, TanDEM-X has to be able to perform monostatic imaging on itself, so that both instruments can be used to continue fulfilling the TerraSAR-X mission.

The TSX satellite (which is in orbit since June 2007) has a fixed footprint to assure the possibility of repeating the same image across time. The TDX satellite (launch in 2010) has a horizontally and vertically displaced baseline referred to its TSX twin. The helix baseline is variable and typically between 200 and 600 meters. Baselines between 1 km and 10 km are only considered in special helixes. This causes that the antenna footprint of TDX is shifted with respect to the TSX footprint. The footprint shift in azimuth is compensated with the timing in order to acquire the desired scene.

However the antenna pattern is shifted, too, as a displaced part of the antenna look angle range sees the desired scene on ground. In order to preserve the quality of the images by acquiring those with the TDX satellite it is proposed to include a roll steering on the TDX to follow the TSX footprint. This baseline dependent roll steering adjusts the look angle of TDX to the reference footprint of the fixed TSX orbit.

4. CONCLUSION

Since start of the operational phase of the TerraSAR-X mission the SAR system has been monitored for its performance and instrument stability. In this paper, the latest status from the SAR performance of TerraSAR-X is presented and complemented with long-term monitoring measurements. The system shows no trends or performance degradation since its launch in 2007. An outlook on the future mission extension by TanDEM-X is given by the roll steering technique to keep the product performance.

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