TerraSAR-X and TanDEM-X, two innovative Remote Sensing Stars for Space-borne Earth Observation

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Fig.1 TerraSAR-X, artists view

TerraSAR-X will be an operational German SAR Satellite system for scientific and commercial applications, Fig. 1. The system is under development and will be launched in October 2006. The goal is to provide the scientific community with multi-mode X-Band SAR data and, additionally, the establishment of a commercial EO-market in Europe by Infoterra. The broad spectrum of scientific application areas include Hydrology, Geology, Climatology, Oceanography, Environmental and Disaster Monitoring as well as Cartography (DEM Generation) with Interferometry and Stereometry.

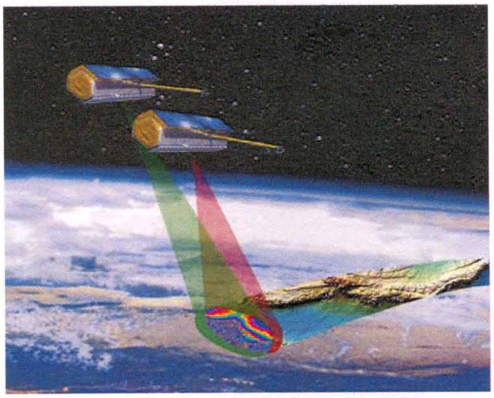

Fig. 2 Tandem-X, schematic artists view

TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) is an already approved mission (launch foreseen for 2008), with the aim to generate from space a global Digital Elevation Model with an unprecedented accuracy achieved by supplementing the TerraSAR-X Satellite with an additional X-band SAR Satellite in a tandem orbit configuration, Fig. 2. The scientific utilisation spectrum includes high-precision digital elevation models, along-track Interferometry (e.g. measurements of the ocean currents and road traffic monitoring), and innovative bi-static applications (e.g. polarimetric SAR Interferometry, digital beam-forming etc.). TanDEM-X represents an important step towards a System of radar satellites in formation flight.

The space segment of TerraSAR-X is an advanced high-resolution X-Band radar satellite with

- 300 MHz Bandwidth and long term observation with the opportunity for multi-temporal imaging,
- Dual-Polarization (HH & VV, HH &HV or VV & HV), two of the possible polarizations can be acquired simultaneously,
- Full operator access to the highly flexible active phased array antenna for the realization of four imaging Modes (Tab.2) and the acquisition of custom designed image products,
- Repeat-Pass Interferometry capability, and high synergy potential with other frequency bands on other Satellites, exemplary L-Band on ALOS, and C-Band on both ASAR and RadarSAT

Tab. 1 shows payload specifications, table 2 performance specifications of the TerraSAR Modes. The active phased array front-end is structured in azimuth direction into 3 antenna leafs which comprise of 4 antenna panels each. One antenna panel is built of 32 active sub-arrays in elevation. The phased array is therefore partitioned into 384 phase centers each controlled by one single receiver channel T/R module. A dual polarized waveguide radiator allows the polarization selection via a polarization switch in the T/R module

For the orbit selection, an altitude range between 475 km and 525 km has been investigated. The sun synchronous Orbit has an 11 day repeat period. The SAR instrument is capable of operation in three basic modes. The possibility of double sided access, enabled by a satellite roll manoeuvre further improves the operational performance. For spotlight mode, the order-to- acquisition time ranges between 10 and 60 hours and the revisit time is 2.5 days in 95% of the cases.

The Spotlight Mode is based on sliding spotlight operation. Compared to starring spotlight operation, sliding spotlight has the advantage of more uniform NESZ performance achieved in along-track direction due to the averaging of the gain variation of the main beam in azimuth. The performance data for each mode are presented in Table 2. The SAR instrument elements are fully redundant, i.e. both a main and a redundant functional chain exist.

It is possible to activate both functional chains at the same time, one being the master for timing purposes. This allows operation in Dual Receive Antenna (DRA) Mode where the echoes from the azimuth antenna halves can be received and then separated during ground processing, e.g. to serve the application of Along Track Interferometry for MTI measurements. In order to enable for tandem operation with a second TerraSAR-X-like satellite, the ultra stable oscillator signal will be broadcasted via a dedicated antenna.

The high precision satellite pointing control and determination is based on a GPS System and star trackers located close to the antenna plane so that an antenna bore sight pointing accuracy of 65 arcsec (3σ) is achieved. Precise orbit determination for geocoding purposes is performed with GPS raw data post processing on ground with an accuracy of <3 m (1σ). A laser reflector is accommodated on the bus to support the orbit determination with laser ranging if required. An additional feature is a Synchronization Antenna for provision of the TerraSAR-X Ultra Stable Oscillator signal to potential foreign "slave" satellites in a possible constellation operation (e.g. Cartwheel) using a companion SAR satellite flying in a slightly modified co-orbit of TerraSAR-X. This allows single-pass, across- and along track interferometry with freely selectable, variable baseline distances. Large baselines are required to achieve precision relative height resolution accuracies (<1m) at flat surfaces, while multiple measurements at different baseline distances are needed for appropriate 3-D mapping of mountainous terrains. Noise Equivalent Sigma Zero (NESZ) and Distributed Target Signal to Ambiguity Ratio (DTAR) both are listed over the full performance range. The "Across Resolution" holds for Slant Range

The very high resolution, the multi-polarization and multi-incidence angle capability of TerraSAR-X open very interesting perspectives for the mapping and monitoring of urban areas It also provides new capabilities for topographic mapping, DEM generation, and road network detection. Disaster assessment requires the availability of high resolution data as well. Interferometry applications like coherence analysis, differential Interferometry and permanent scatterer technique can be applied.

Center frequency	9.65 GHz	Transmit duty cycle Stripmap	18%
Antenna size (az. x el.)	4.78 m x 0.70 m	Transmit duty cycle Spotlight	20%
Scan angle range (az., el.) ±	0.75°, ± 19.2°	System noise figure	5.0 dB
Incidence angle access range	15° - 60°	Operational PRF range	3kHz– 6,5 kHz
Radiated peak output power	2260 W	Chirp bandwidth range	5 - 300 MHz

Tab.1 TerraSAR payload key specifications

	Spotlight 1	Spotlight 2	Strip Map	ScanSAR
Product coverage Along Across	 5 km 15 km	 5 km 15 km	 free 30 km	 free 100 km
Resolution Along Across	1 look 1.0 m 1.2 m	1 look 2,0 m 1.2 m	1 look 3 m 3 m	4 looks 15 m 16 m
Incidence Angle Full Performance	20° - 55° 570 km	20° - 55° 570 km	20° - 45° 350 km	20° - 45° 350 km
Incidence Angle Data Collection	15° - 60° 622 km	15° - 60° 622 km	15° - 60° 622 km	20° - 60° 577 km
NESZ/dB	-19,6.... -28,9	-19,7....-29,6	-19,0....-26,5	-18,8....-29,6

Tab.2 Performance Specifications of the four SAR Modes of TerraSAR
NESZ = Noise Equivalent Sigma Zero;

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Biography

Borne **1936** in Berlin, Germany, Degree of "Diploma" Physicist and Dr. rer. nat. (Doctor in Natural Sciences) both from the Philipps University Marburg, Germany, where he was R&D Laboratory Supervisor and Assistant Professor also. From **1967 until 1978** working with AEG-TELEFUNKEN Co. (today EADS) in Ulm, Germany and from **1978 until 2001** Director of DLR Microwaves & Radar Institute in Oberpfaffenhofen, Germany (Staff always between 90 and130), responsible for all scientific, technologic & organizational decisions including Scientific Programs, Finances and Personnel as well as for Acquisition of all Financial & Material Resources (salaries, projects, facilities).Supervision & Technical Guidance for High Resolution Air/Space-borne Radar/SAR and Microwave Multi-spectral Radiometry, Sensor Systems and Remote Sensing with civil and military Applications (oil-slick verification, stealth etc.), Antennas & Wave Propagation. **1990 - 1994** in parallel in Berlin-Adlershof founding Director of both the newly founded *Institute for Planetary Research and the Institute for Space Sensor Technology* as well (from former DDR Academie der Wissenschaften (GDR -Academy of Sciences), Institute for Cosmos Research, Adlershof/Berlin). **1990 – 1997** Elected Representative of DLR Research Department "Communications Technology & Remote Sensing (CTRS)" (6 major institutes), responsible for exterior/interior representation: Financial (exceeding TDM 100) and Personnel (senior/executive staff) Decisions, Organisational Structure. Responsible for Overall DLR Research Program Development & Execution within DLR-CTRS, specifically in Space Communications, Remote Sensing & Microwave Navigational Systems. Department has been decomposed in 1997 due to DLR reorganisation. **1997 – 1999** Speaker of newly founded DLR-Cluster for Remote Sensing and Navigation (4 Institutes in Oberpfaffenhofen and Berlin, *Institute for Radio Frequency Technology, Oberpfaffenhofen (staff 130), Institute for Optoelectronics, Oberpfaffenhofen (staff 80), Institute for Space Sensor Technology, Berlin (staff 80).*Responsible for Cluster Research Programs, Personnel and Financial Resources, Acquisition as well as for Overall Organizational Structure, exterior and interior representation of the Cluster. In 1999 the Cluster has been decomposed. **1999 – 2001** Speaker of newly founded DLR-Cluster for Radio Frequency and Communication Techniques (2 Institutes in Oberpfaffenhofen: *Institute for Radio Frequency Technology and Radar (staff 90), Institute for Communication and Navigation (staff 140)*). Since August 2001 retired , however, still working on his fields of competence as a scientist and consultant for DLR, European Union, NATO RTO, different societies and boards etc..
2002 Dr. Ing. Ehren halber, Dr. Ing.E.h, (Doctor in Engineering Sciences honoris causa degree) from University Erlangen-Nürnberg, Germany.

Field of Competence

Microwaves and Radar-Systems, -Techniques, -Technology and -Physics, mainly SAR and Microwave Radiometry, and the respective civil and military applications to reconnaissance and remote sensing.

Fields of interest

Antennas and Wave Propagation, Scattering of Electromagnetic Waves (Polarimetry, Interferometry, Radar Cross Sections, etc.), Radar Techniques and Technology (Airborne and Space-borne SAR - 5 Space Shuttle Missions in the past - , development of airborne E-SAR as well as the forward looking Sector Imaging Radar for Enhanced Vision, SIREV, Multisensorics, etc.), Microwave Radiometry for Demining, Oil Pollution, Airborne and Space-borne Radio Frequency Systems for Civil and Military Reconnaissance and Remote Sensing, for Earth Observation as well as for Navigation and Positioning.