TanDEM-X SAR System Verification
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Overview

- Monostatic Commissioning Phase
  - Verification of Power/Thermal Constraints
  - Raw Data Saturation
  - Inter-Satellite Interference
  - Instrument Noise Power
  - Accuracy of Repeat Pass Acquisitions
  - Doppler Centroid Statistics

- Bistatic Commissioning Phase
  - Exclusion Zone Functionality Verification
  - SyncWarning Performance Verification
  - SyncPulse Performance Verification
TanDEM-X and TerraSAR-X Mission Overview

**TanDEM-X Mission**
- For a data acquisition both satellites TerraSAR-X and TanDEM-X are required
- TerraSAR-X and TanDEM-X are operated in two missions
- Operated at their limits
- TerraSAR-X and TanDEM-X flying in Close Formation
- Special requirements for illumination avoidance and attitude and orbit control
- Generation of a global Digital Elevation Model

**TerraSAR-X Mission**
- For a data acquisition either TerraSAR-X or TanDEM-X satellite is used
- Monostatic acquisitions for scientific and commercial users
TanDEM-X commissioning phase - a two-step approach

1. Monostatic commissioning phase
   ➔ Goal: Fully integrate TDX-1 in the TerraSAR-X mission

2. Bistatic commissioning phase
   ➔ Goal: Start systematic global DEM data acquisition
Pursuit Monostatic Commissioning Phase (Mono-CP)

TDX-1

TSX-1

20 km
Power/Thermal Test Results (I)

- **Power Thermal Test**
  - Verification of TanDEM-X Instrument Performance
    - Phase and Amplitude Stability of TRMs
    - Units within limits of temperature range
    - Battery performance (charging and discharging behaviour)
  - Validation of Mission Planning Power/Thermal Model
    - Modulation of Power Consumption of DataTake
    - Modulation of Battery charging level (voltage)
    - Requirement for extended TanDEM-X Mission aspects
Power/Thermal Test Results (II) – Panel Temperature

- Verification of operational scenario (TanDEM-X Mission) and operational system (TanDEM-X)

- Stable Amplitude:
  - Max Deviation: < 0.9dB

- Minor changes in Phase:
  - Max. Deviation: 15°

- Temperature of panels within allowed temperature range of -15°C to 60°C
Raw data power and saturation were evaluated for 2557 TDX-1 datatakes.

TDX-1 Raw Data saturation: more than 99% blocks without saturation.

Analysis on 1324 pursuit monostatic DTs showed a power imbalance between the two satellites (TSX-1 is 2 to 4 dB higher) → commanding configuration of TDX-1 adapted.

TSX vs TDX

In phase component
Quadrature component

TSX-1 / TDX-1 [dB]

Data take couple

Update of TDX-1 configuration 23rd August, 10:00UTC
Mono-CP Results: Inter-Satellite Interferences

Direct Inter-Satellite Interference

TDX-1 starts DT approx. 3s after TSX-1, but then the pulse repetition interval (PRI) is equal on both Satellites

- Counter measure: using different chirps (up / down) for the satellites
- No impact on TanDEM-X Mission due to synchronized start time of DTs
Accuracy of Repeat Pass Acquisitions

Along track difference between commanded start position and real start position

Outstanding accuracy achieved
Mono-CP Results: Doppler Centroid Statistics

Max./Min. of Doppler Centroid Frequency in TDX-1 Datatakes

TDX-1 orbit drift towards TSX-1

2010-08-20T19:37:23
1 DT affected by S/C maneuvers

2010-08-20T19:37:23
1 DT affected by S/C maneuvers

TDX-1 Doppler centroid is as low as for TSX-1
- smaller than 120Hz
- No incidence angle dependency
Bistatic Commissioning Phase (Bistatic-CP)
Exclusion Zone Functionality Verification (I)

Avoid risk of mutual radar illumination during close formation flight

- Standard beams

- Exclusion zones (example)
  - "TDX may not transmit in asc. orbit"
  - "TSX may not transmit in desc. orbit"

- Possible beams & side-lobes
Exclusion Zone Functionality Validation (II)

Onboard mechanisms were triggered to disable transmission onboard within exclusion zone.
Exclusion Zone Functionality Verification (III)

Exclusion Zone Functionality was successfully validated on both satellites (TDX-1 and TSX-1)

First requirement for close formation is fulfilled

TX-Cal Pulse for passive DT
SyncWarning Performance Verification (I)

- **SyncWarning** provides a **1-Bit Information of the health** of the other satellite (Bi-directional).

- Basic **information retrieved by signal level evaluation** of received radar data. (Received from sync horns. **Evaluation performed on-board** in real time)

- **Disable Transmit** of own SAR instrument, if other **satellite is assumed as non nominal**, to avoid potential illumination risk. (Failed SyncWarning)
SyncWarning Performance Verification (II)

- Prediction vs. Measurement
- Too low SNR at Aspect Angles > 40°
- Aspect angle > 40° is not reliable for SynWarn DT planning
- Configuration change after formation test:
  Use only sync horn pair constellations with angles ≤ 40°
SyncPulse Performance Verification (I)

TDX-1 Compressed SyncPulse SNR Mean - Argument of Latitude

- Orbit dependent SNR due to change of aspect angles of SyncHorns

Mean SNR of Compressed SyncPulse [dB]

Standard Deviation

Acquired Region

Argon of Latitude
SyncPulse Performance Verification (II)

TSX-1 Compressed SyncPulse SNR Mean - Argument of Latitude

- Orbit dependent SNR due to change of aspect angles of SyncHorns

Acquired Region

SH 6  SH 5  SH 2  SH 3  SH 6

Mean SNR of Compressed Sync Pulse [dB]

Standard Deviation

0  10  20  30  40  50  60  70

0  2  4  6  8  10  12

0  30  60  90  120  150  180  210  240  270  300  330  360

Argument of Latitude
Conclusion

- Monostatic Commissioning Phase Result
  - Successful verification of requirements to include TDX-1 in TerraSAR-X Mission
  - Outstanding performance of TanDEM-X satellite

- Bistatic Commissioning Phase Result
  - Safety mechanism to avoid mutual illumination were verified successfully
  - Sync link performance fulfills prediction

- Operational Phase
  - Routine instrument performance monitoring performed
Thank you for your attention!