

# Long Term System Monitoring of Performance Stability – Current Status of TerraSAR-X and TanDEM-X Satellites

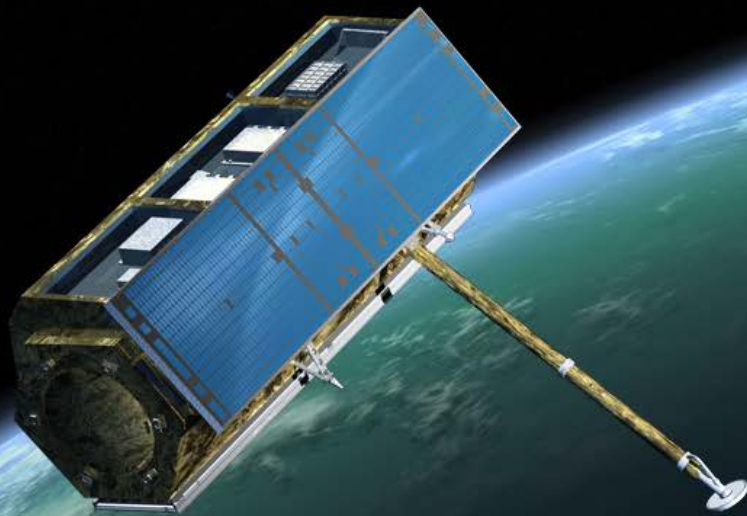
K. Schmidt, G. Castellanos Alfonso, M. Bachmann, J. Böer,  
D. Polimeni, N. Tous-Ramon, M. Schwerdt, D. Schulze

CEOS 2013, 17<sup>th</sup> October



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

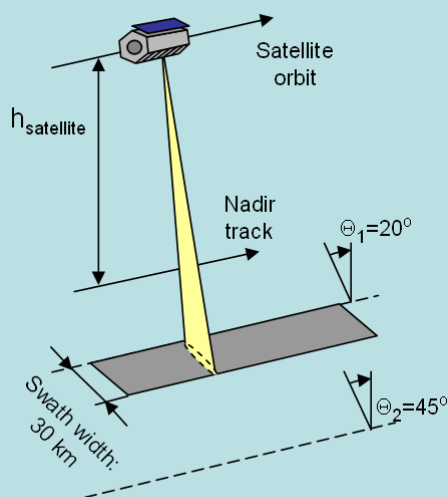




## *TerraSAR-X / TanDEM-X:*

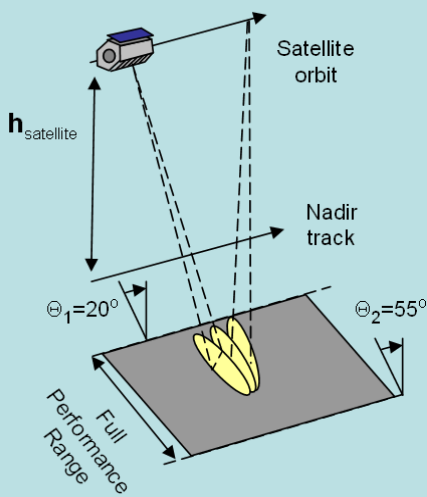
- German Earth observation SAR satellite
- X-band @ 9.65 GHz
- 514 km dusk/dawn orbit
- Multi-mode highly flexible operation
- Public Private Partnership (PPP)

### StripMap Mode



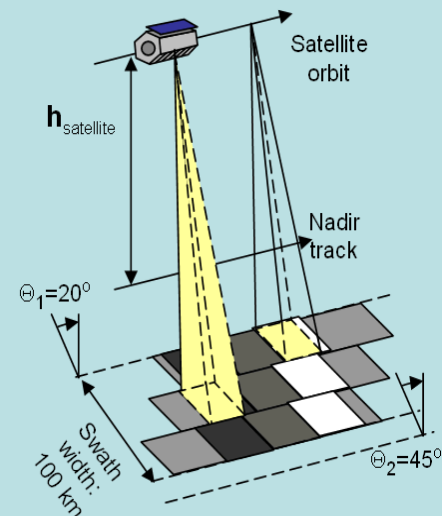
Resolution: **3.3 m x 3.3 m**  
Swath width: **30 km**

### SpotLight Mode



Resolution: **1.5 m x 1.5 m**  
Swath width: **10 km**

### ScanSAR Mode



Resolution: **17 m x 18 m**  
Swath width: **100 km**

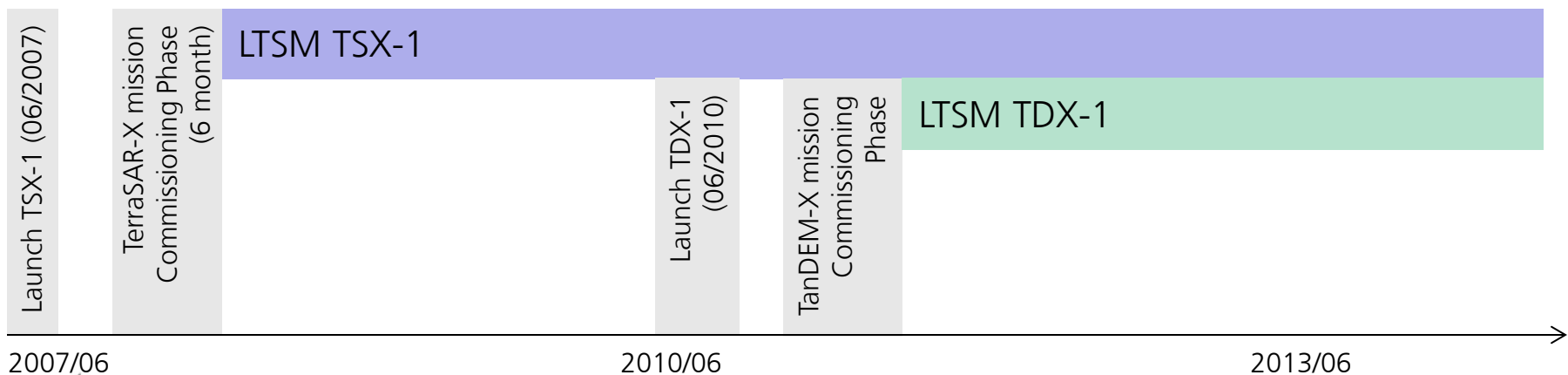


# TerraSAR-X / TanDEM-X Long-Term System Monitoring (I)

Purpose:

- **Detecting** long-term system **SAR performance changes**
- **Monitoring correct operation** of the SAR instrument and front-end
- **Evaluating any degradation** of the satellites hardware
- Guarantee a **stable quality** of the SAR products

Timeline for Long-Term System Monitoring (LTSM) periods



2007/06

2010/06

2013/06



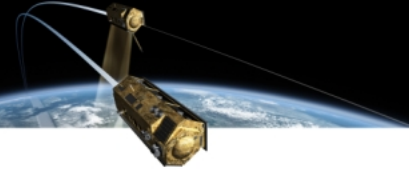
Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

Long Term System Monitoring Status of TSX-1 and TDX-1

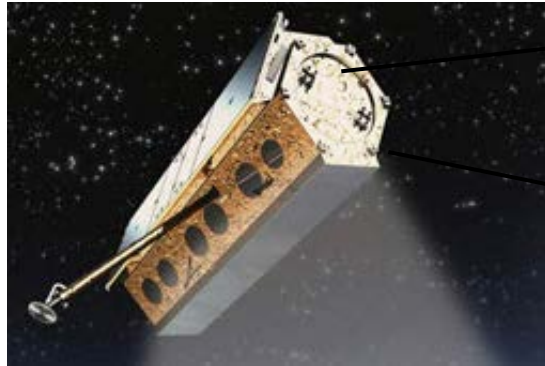
- CEOS 2013 -



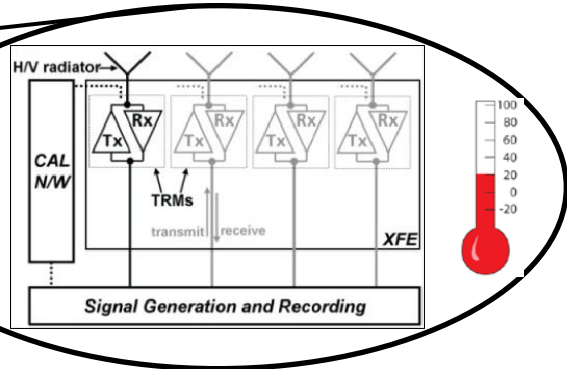
17-Oct-2013  
K. Schmidt, Slide 3



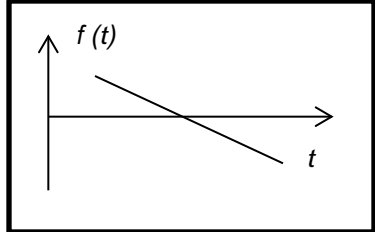
# TerraSAR-X / TanDEM-X Long-Term System Monitoring (II)



**Monitoring of SAR-transmission / receive modules (TRM)**

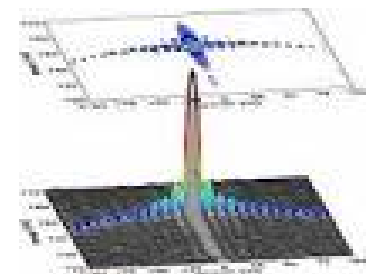
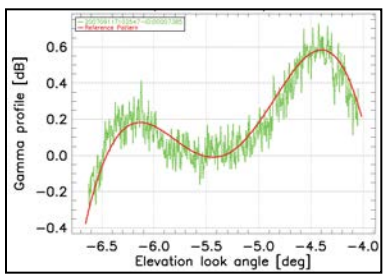


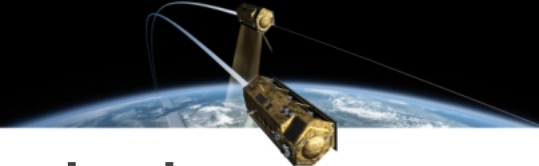
**Doppler centroid stability**



**Point target analysis**

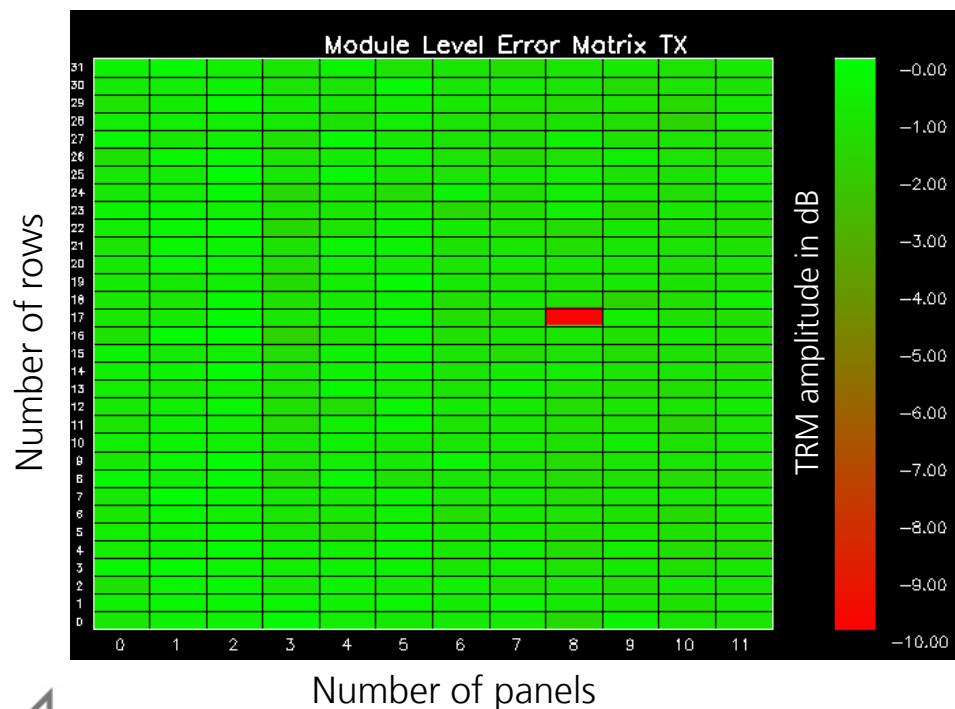
**Monitoring antenna characteristics over rainforest areas**





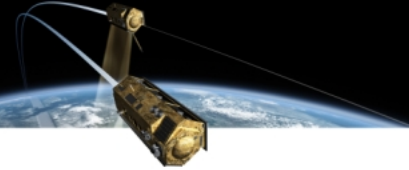
# T/R-Module Monitoring

- Data takes using the **PN-Gating method**
- **Simultaneous characterization** of all 384 T/R-modules under normal operation conditions
- Evaluation of **gain** and **phase** for **transmit (TX)** and **receive (RX)** path for both satellites (TSX-1, TDX-1)
- “Error Matrix”: Gain and phase **deviations from a reference value** can be observed (first reference values were obtained from on-ground characterization data)



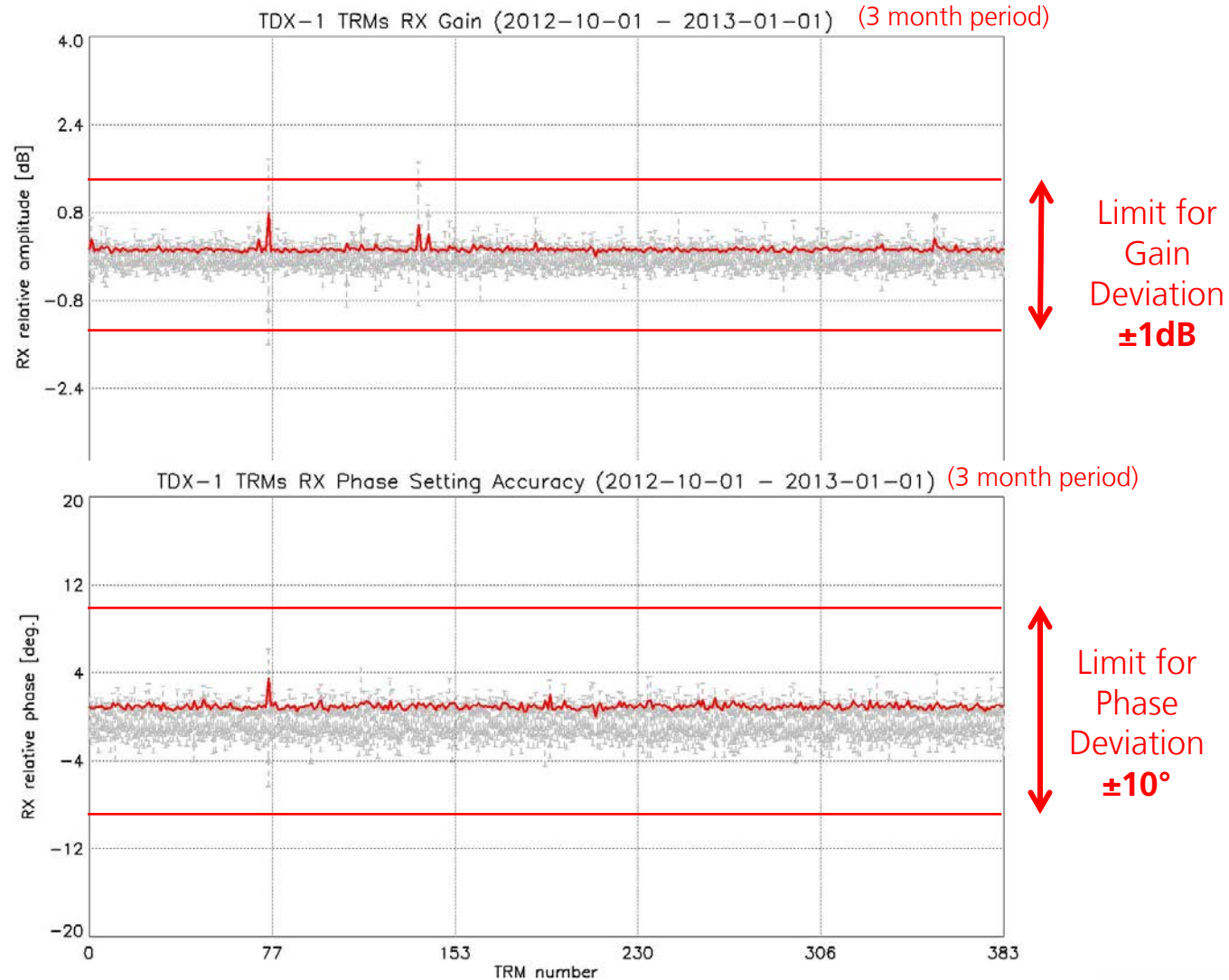
*Sample of Error Matrix derived by PN-gating method (Gain for TSX-1 satellite in transmission mode).*

*“Out-of-range modules” can be easily detected*



# T/R-Module Monitoring for given Time Period

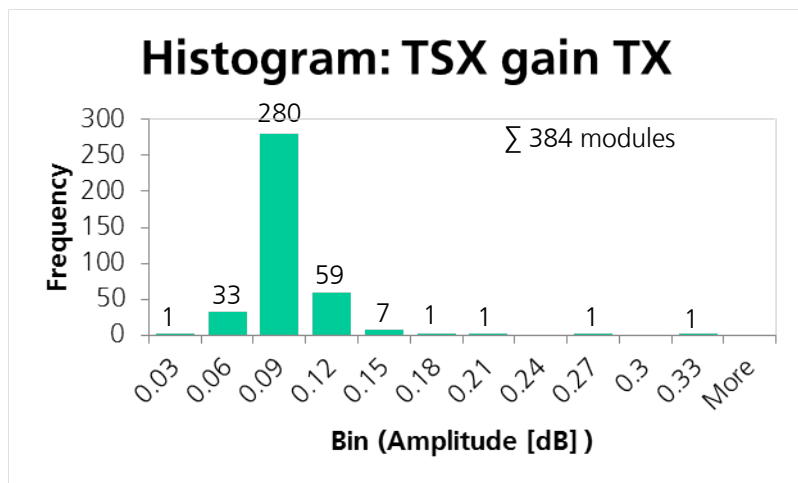
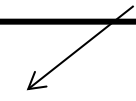
- Permanent monitoring of the gain and phase for **each T/R- module**
- Regularly reported for periods over **3 months**
- July 2011: Phase anomaly on TSX-1 for TRM 359 (fixed)
- No SAR degradations detected



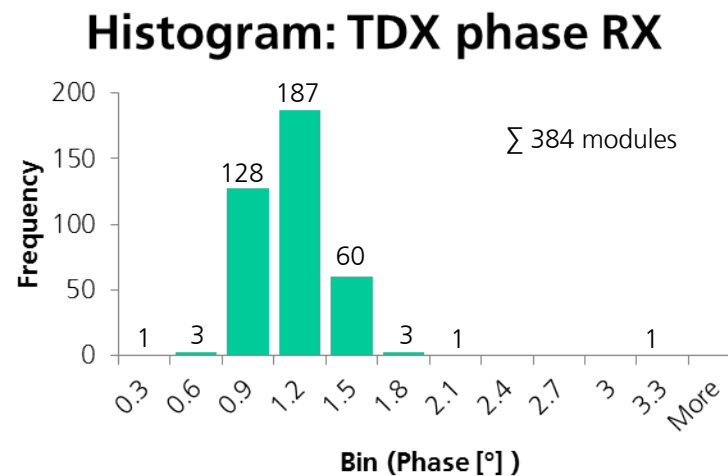


# Monitoring of T/R-Modules – Statistics for full Life Time

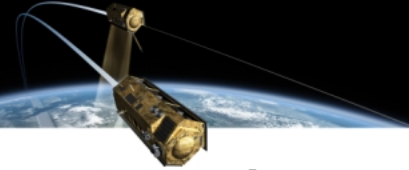
| Mean over all $\sigma$ -values of each module | TX        |           | RX        |           |
|---|-----------|-----------|-----------|-----------|
|   | Gain [dB] | Phase [°] | Gain [dB] | Phase [°] |
| TSX-1 (6 years)                               | 0.08      | 1.97      | 0.16      | 1.14      |
| TDX-1 (3 years)                               | 0.03      | 1.68      | 0.15      | 1.00      |



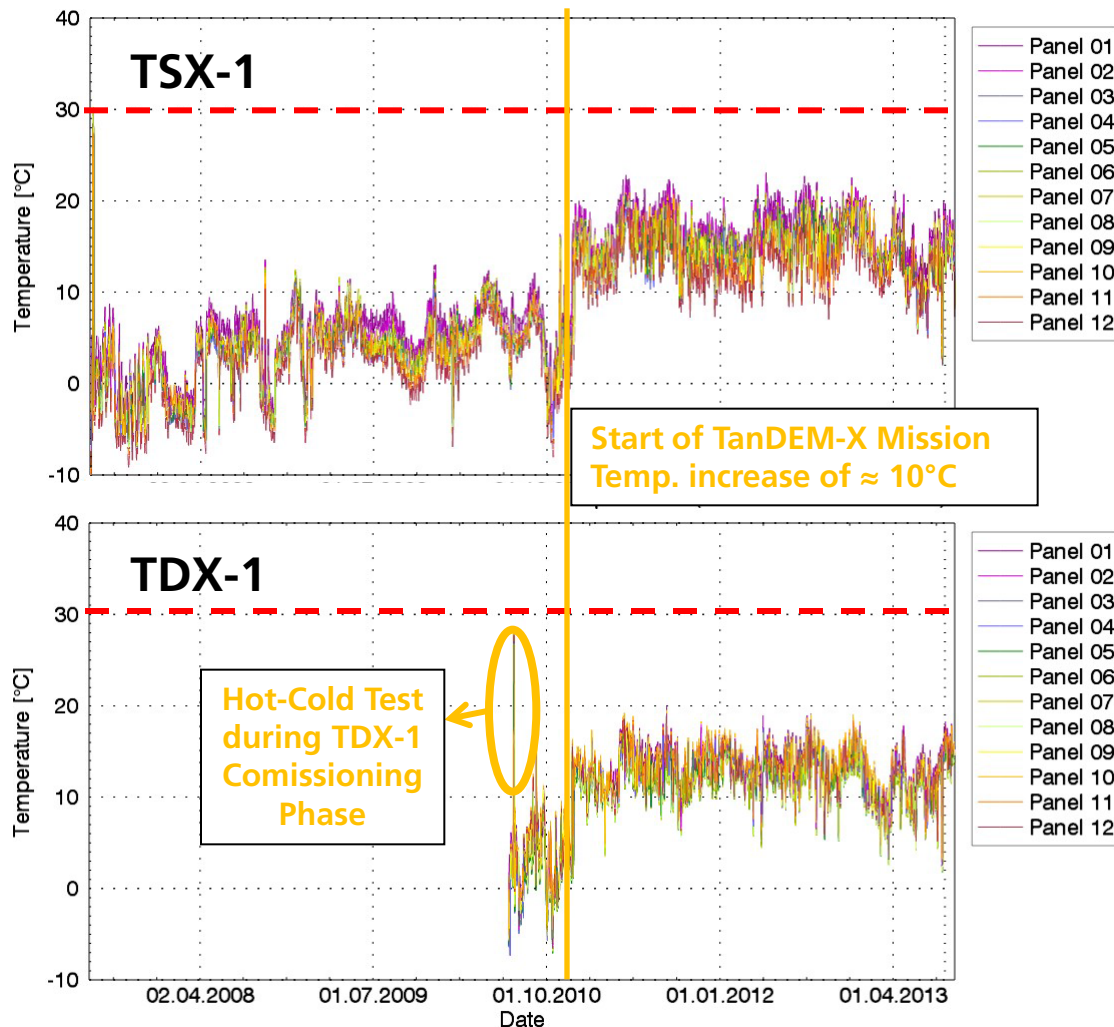
Limit for Gain Deviation: **1dB**



Limit for Phase Deviation **10°**



# Daily Maxima Temperature of T/R Modules (Front end)



- Each panel is also observed for temperature variation
- Daily maxima temperatures are far from **30 °C limit**
- Temperature increasing of around  $10^{\circ}\text{C}$  due to TanDEM-X mission
- Average temperatures of TSX-1 higher than temperatures of TDX-1 due to higher workload



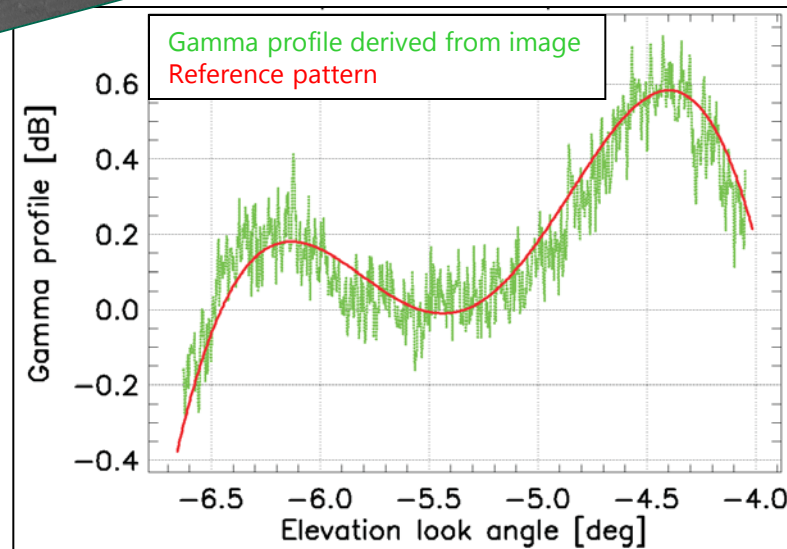


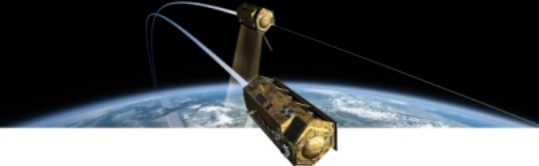
# Antenna Pattern Monitoring (over Rainforest Region)

- Required to detect any degradation of the front-end (specially the antenna wave guides not covered by the internal calibration)
- ScanSAR data takes over the Amazon rain forest are executed and evaluated
- Deviation from reference antenna patterns (derived by the antenna model)

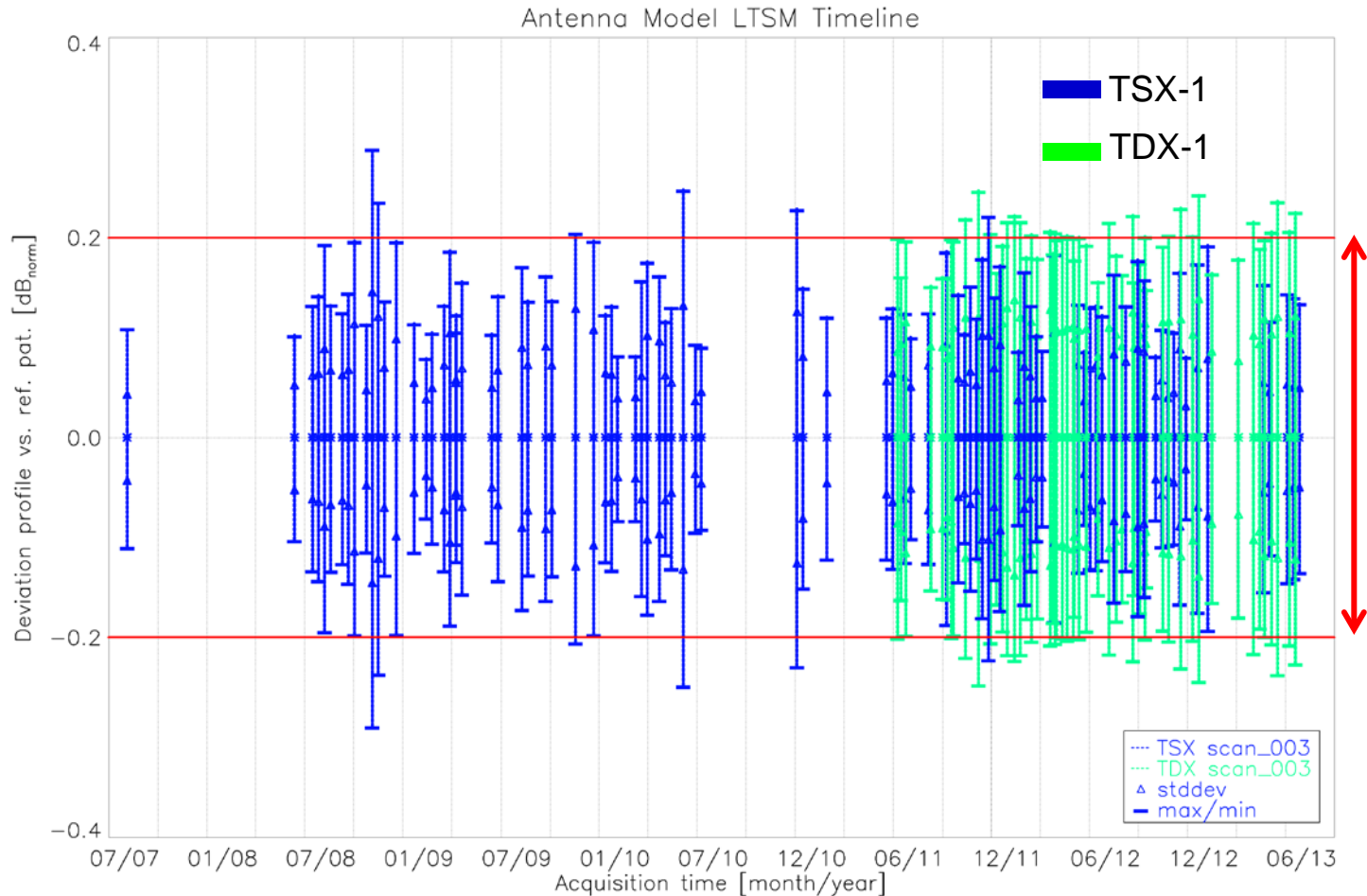


Nearly uniform distributed area



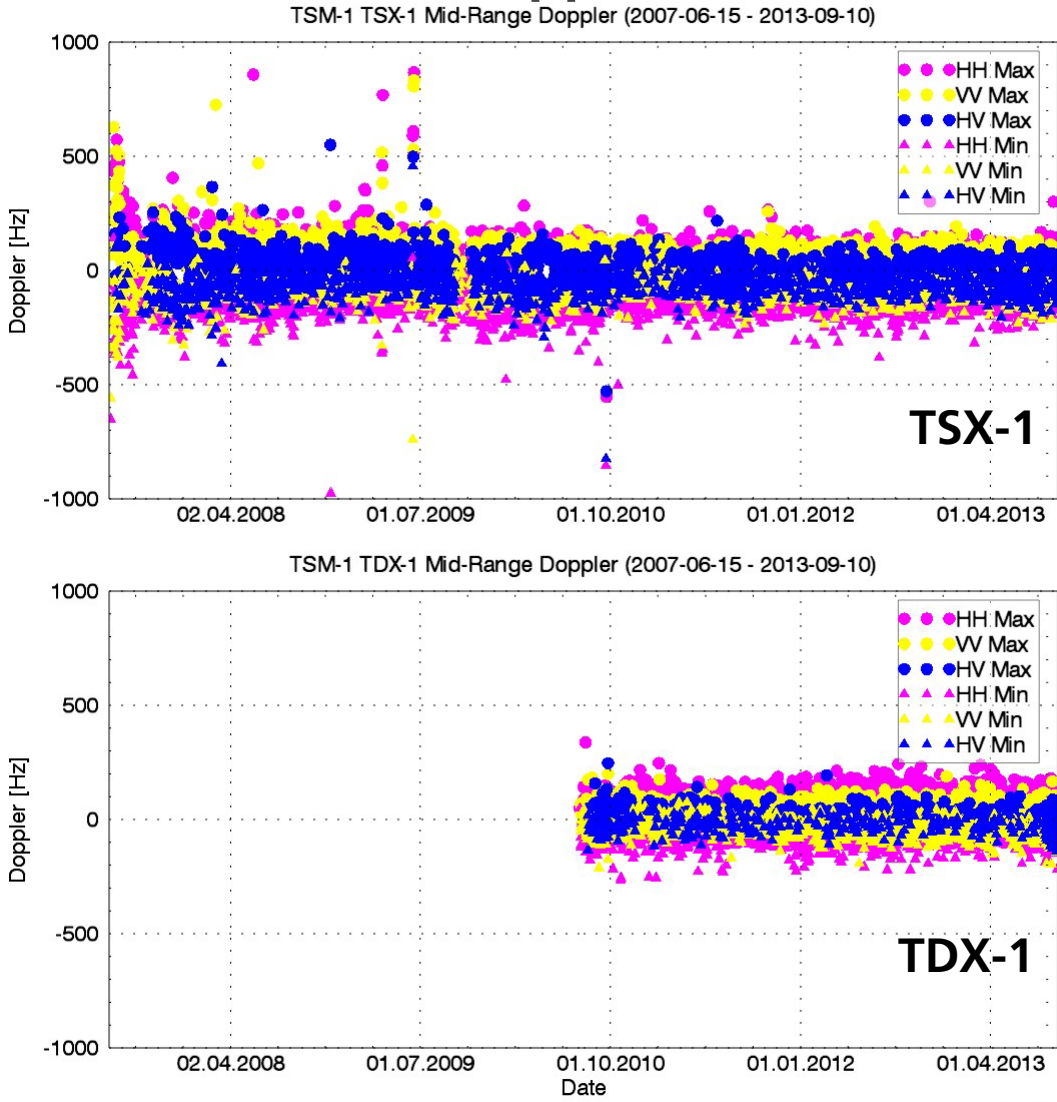


# Antenna Pattern Monitoring – TSX-1 / TDX-1





# Doppler Centroid Statistics – Timeline



- Total Zero Doppler Steering applied to compensate the Earth rotation
- Verification of the **Doppler centroid estimation and stability**
- Monitoring the stability of the satellite steering in azimuth

**95% of the total acquisitions have a Doppler centroid within the goal of  $\pm 120\text{Hz}$**



# Point Target Analysis

## Evaluation of Impulse Response Function (IRF)

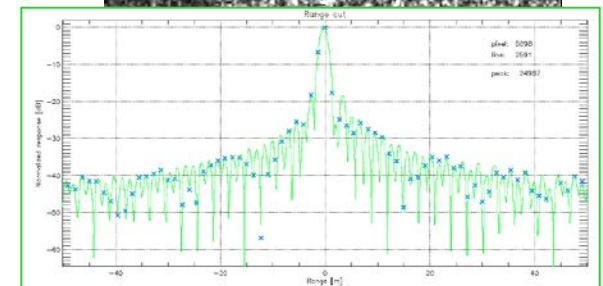
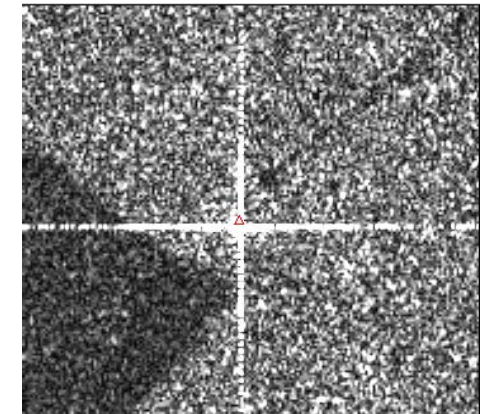
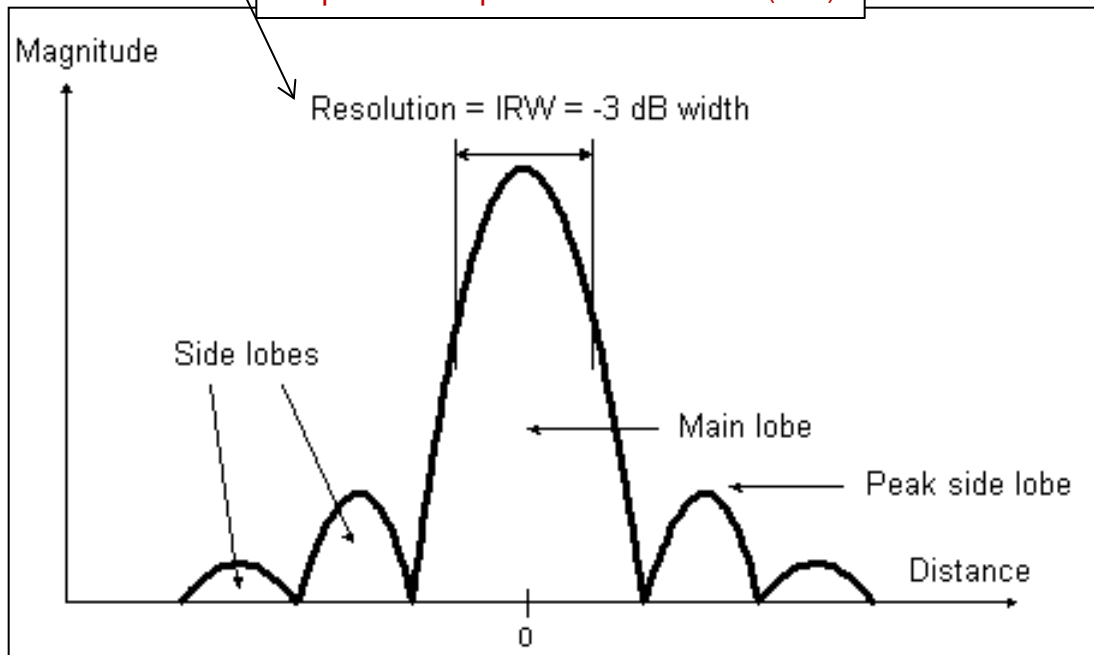
The following performance parameters are derived:

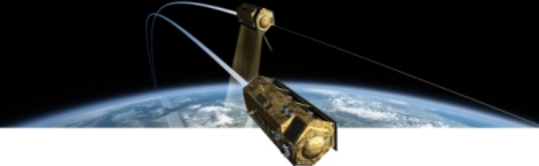
- Radar cross section (RCS)
- ISLR (Integrated Side Lobe Ratio)
- PSLR (Peak to Side Lobe Ratio)
- Geometric resolution

$$ISLR = \frac{\text{Sum of energy in the side lobes}}{\text{Sum of energy in the main lobe}}$$

$$PSLR = \frac{\text{Peak intensity of most intensive side lobe}}{\text{Peak intensity of the main lobe}}$$

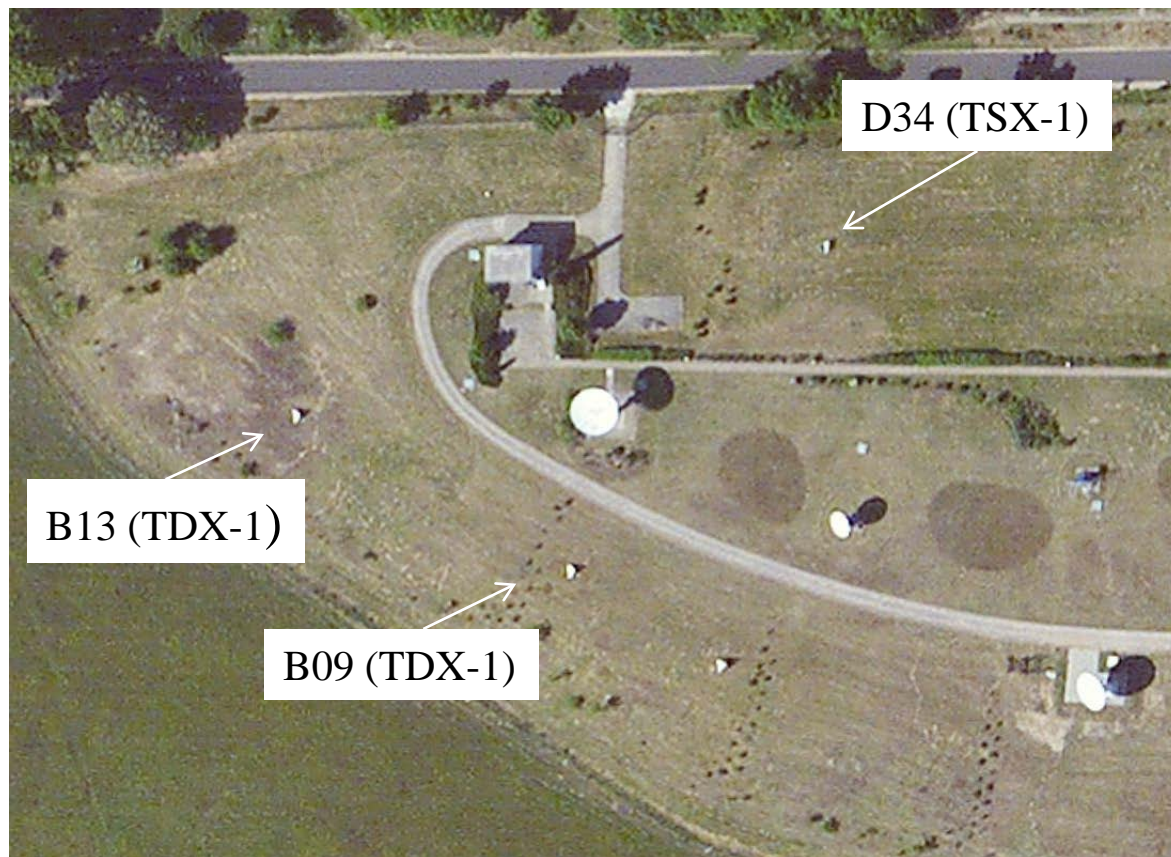
Impulse response function (IRF)





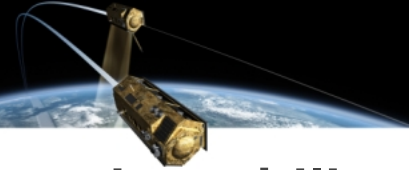
# Point Target Analysis: Image Area used for LTSM

DLR Neustrelitz

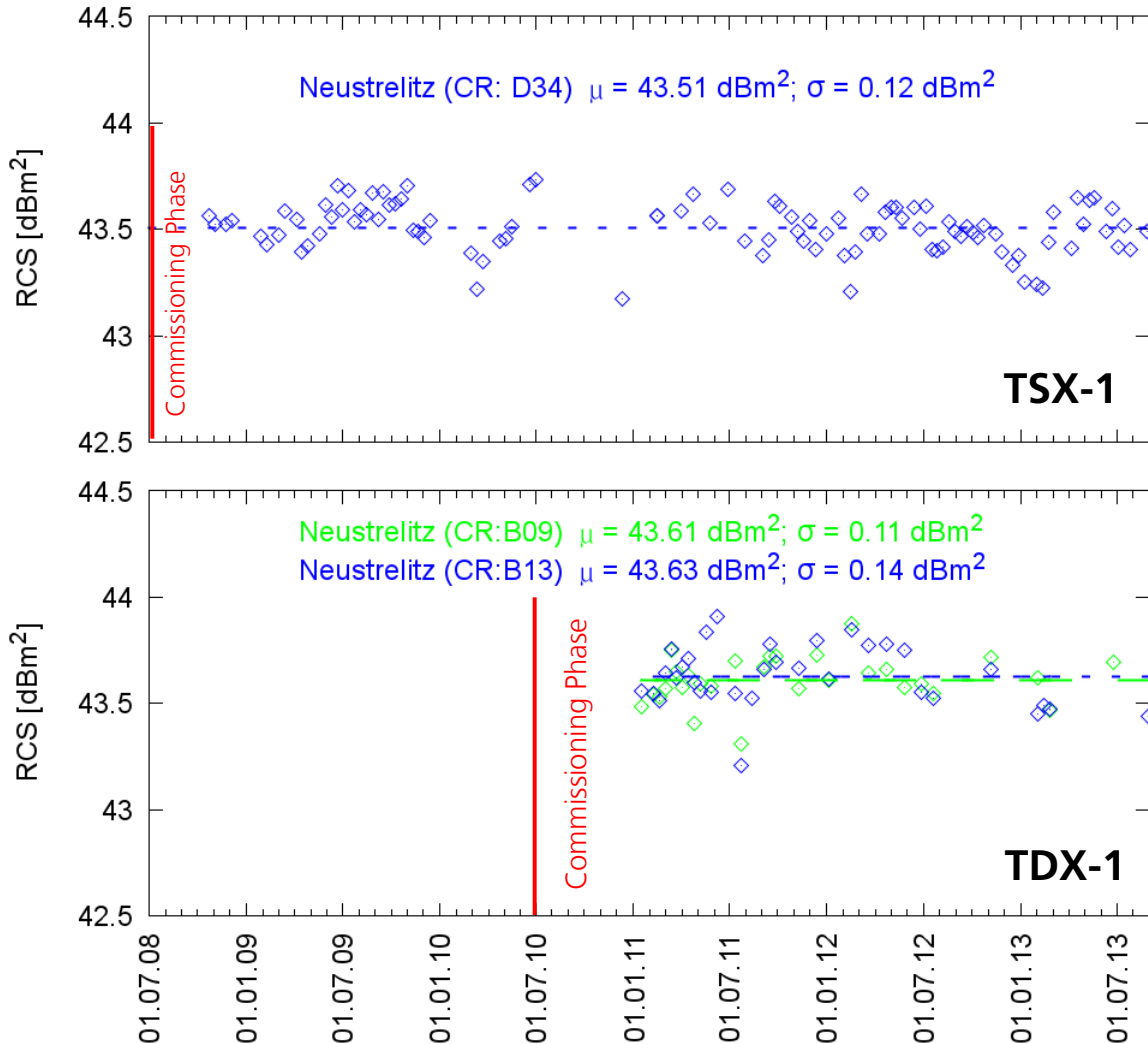


**Permanently installation** of additional corner reflectors (1.5m) near Neustrelitz (Germany):

- Advantage: no further work with manual alignment
- Disadvantage: only fixed beams are used



# Point Target Analysis – Radiometric Stability



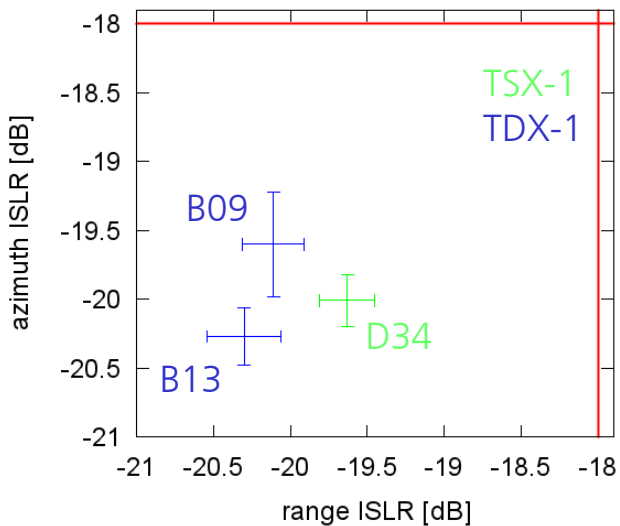
The standard deviation over life time of the target RCSs is a measure for the radiometric stability of both systems (TSX/TDX)!

High radiometric stability  
**< 0.15dB**  
 for both satellites  
 over monitored period  
 (Req.: 0.5 dB over 6 month)



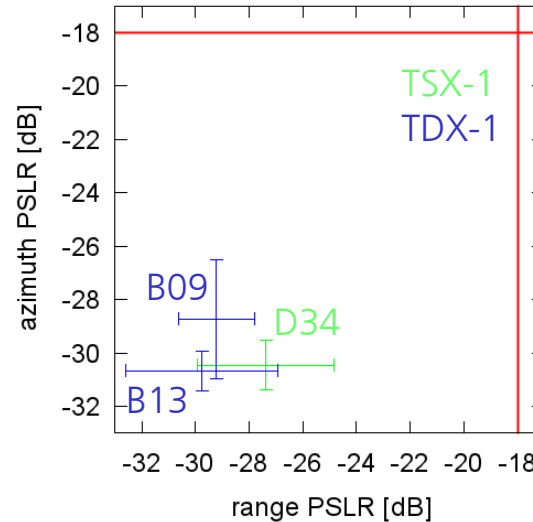
# Point Target Analysis – Statistics for ISLR, PSLR and Geometric Resolution

### ISLR (Integrated Side Lobe Ratio)



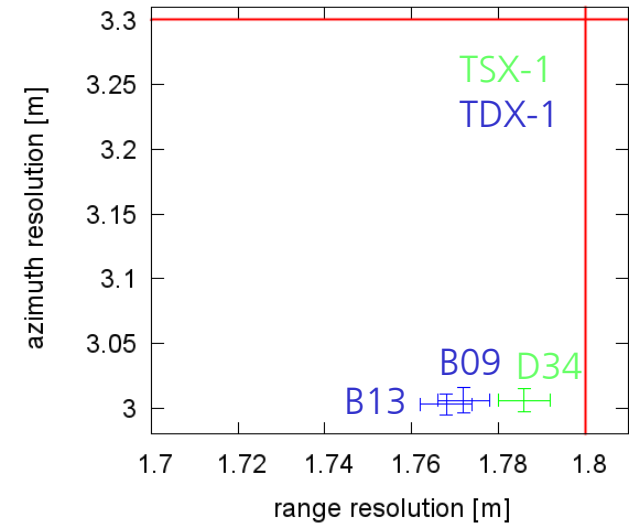
**Product Specification :**  
**-18 dB in range and azimuth**

### PSLR (Peak to Side Lobe Ratio)



**Product Specification :**  
**-18 dB in range and azimuth**

### Geometric resolution for point targets



**Product Specification :**  
**1.8 m in range  
3.3 m in azimuth**

# Conclusion

- TerraSAR-X is in orbit since 2007 / TanDEM-X since 2010
- Both satellites are being monitored for their performance, instrument stability and health:
  - ✓ T/R-module stability in gain ( $< 0.2$  dB) and in phase ( $< 2$  deg )
  - ✓ Antenna pattern over the rain forest ( $\pm 0.2$  dB)
  - ✓ Doppler centroid statistics ( $< 120$  Hz)
  - ✓ Radiometric stability by evaluating point targets ( $< 0.15$  dB)
- Both systems are very stable and offering high quality SAR products
- No performance degradations have been observed since launch

