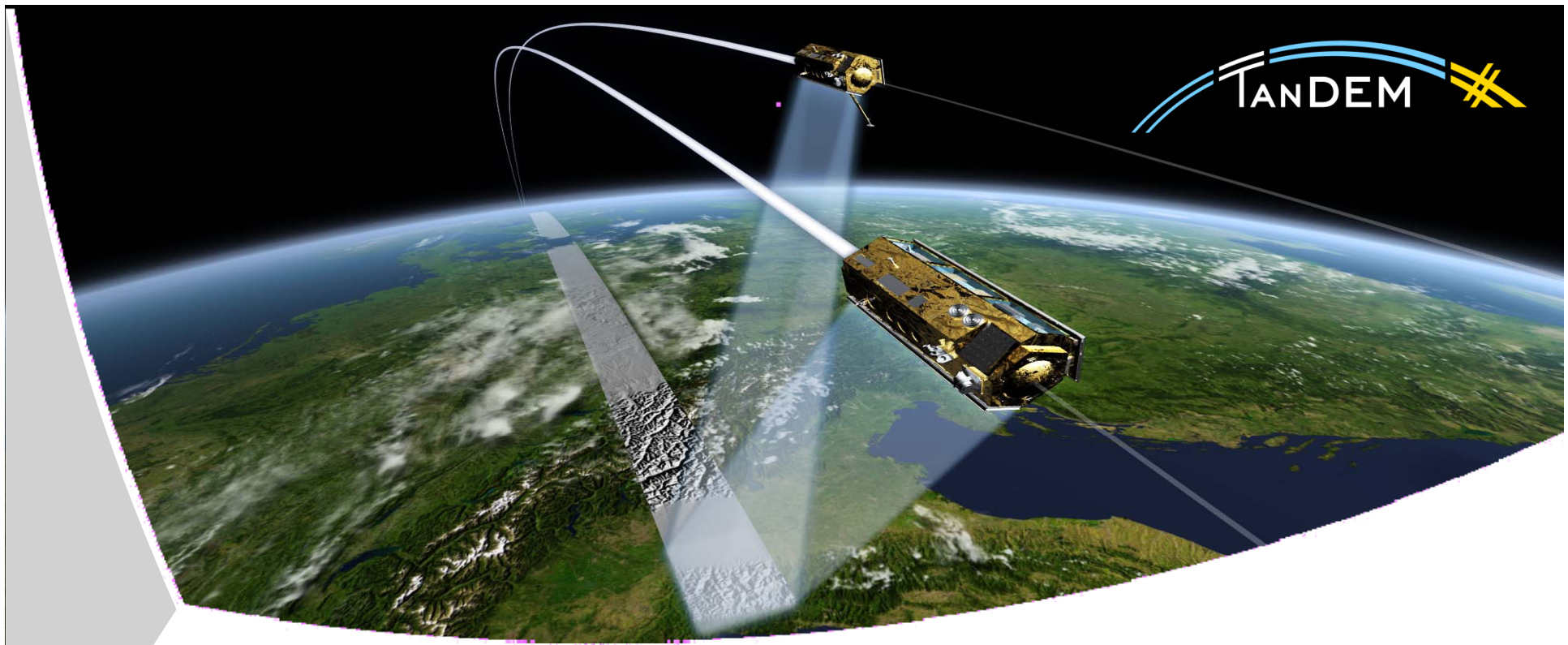
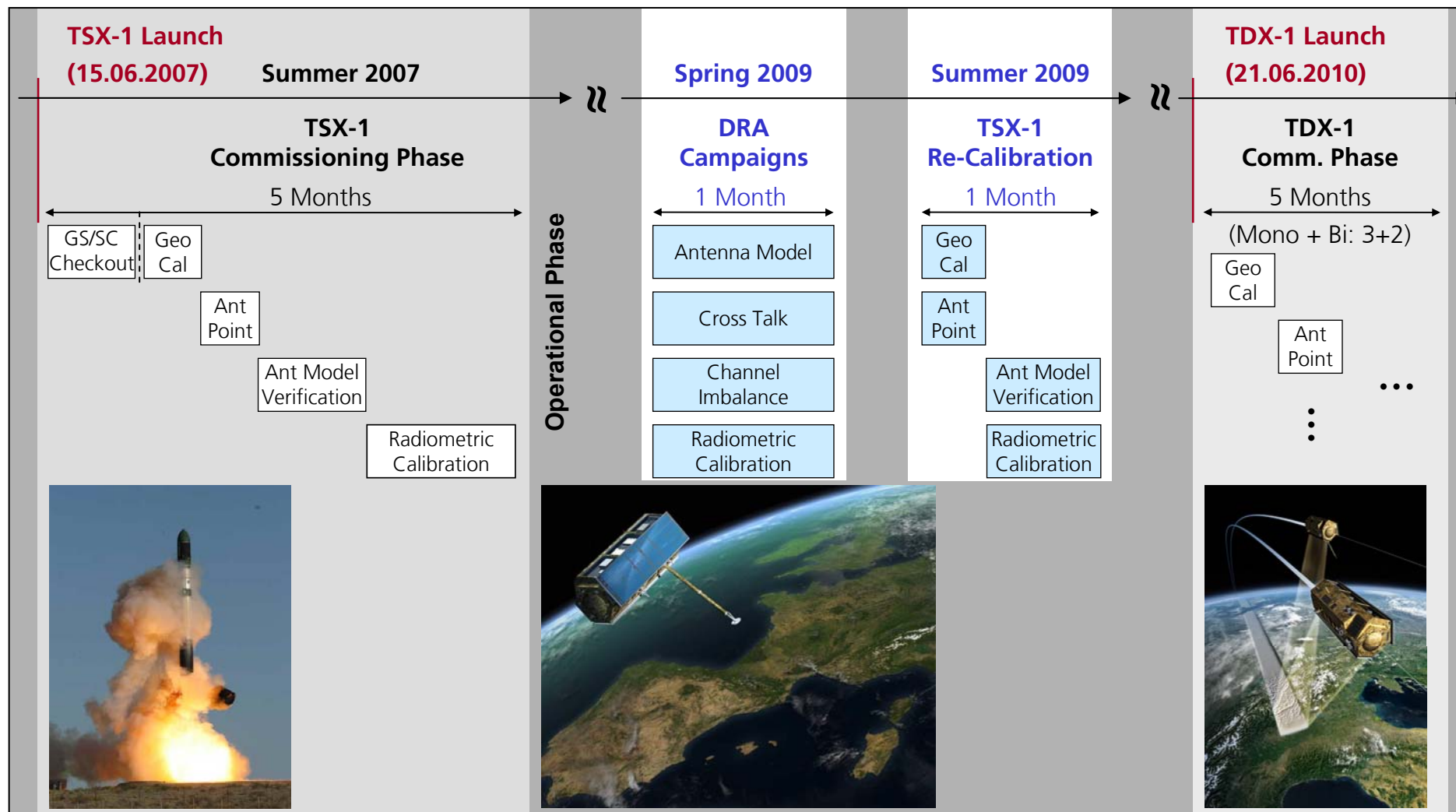


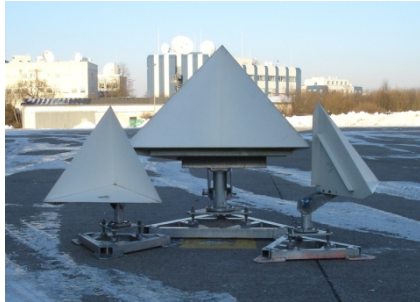


Monostatic Calibration of both TanDEM-X Satellites

Marco Schwerdt , Jaime Hueso Gonzalez,
Markus Bachmann, Dirk Schrank,
Clemens Schulz, Björn Döring

TSX-1 / TDX-1 In-Orbit Calibration Plan





TSX-1 Calibration



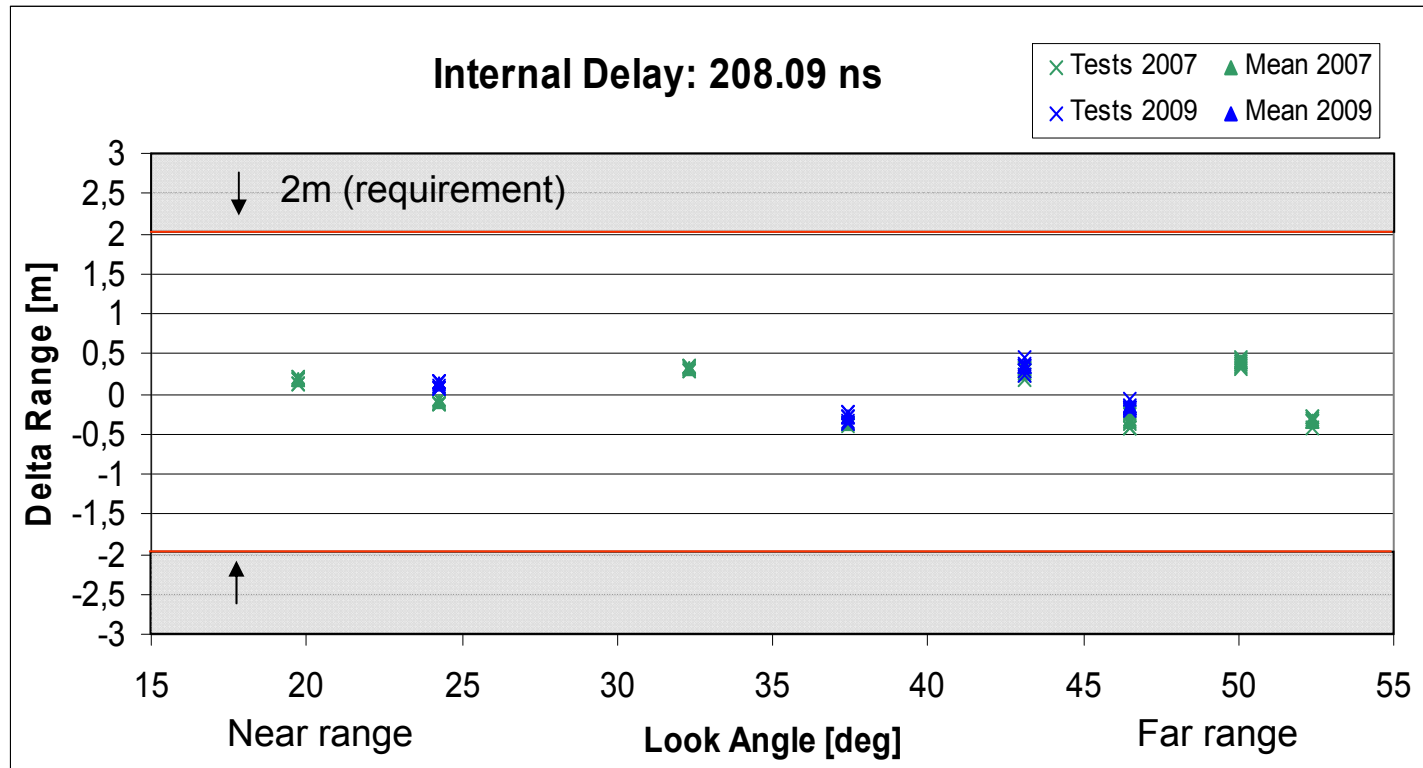
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Geometric Calibration TSX-1

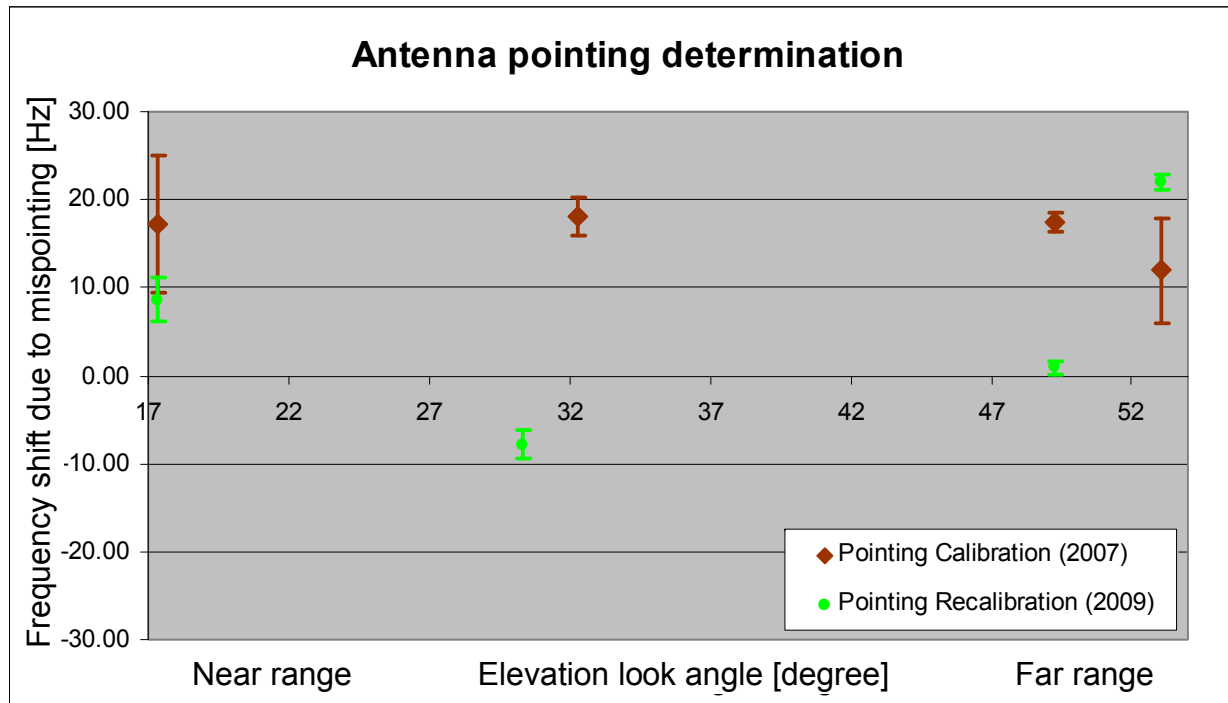


- 6 corner reflectors per pass
- 8 beams

No trend
since 2 years

- Pixel localization accuracy (range) **30 cm (1σ)** (2 ns)
- Residual offset (in-flight $\Leftrightarrow$ OGC) **3.75 cm** (0.25 ns)

Pointing Determination in Azimuth TSX-1



- Notch patterns with different look angles
- 4 ground receivers per pass

Updates

- ✓ Improved ground receiver position
- ✓ Re-adjustment between star trackers



Improvements	2007	2009
✓ Measurement accuracy per pass	≤ 7.9 Hz < 1.0 mdeg	≤ 2.6 Hz (1 σ) < 0.33 mdeg
✓ Mean doppler	16 Hz	5.9 Hz
✓ Residual pointing error	2 mdeg	0.74 mdeg

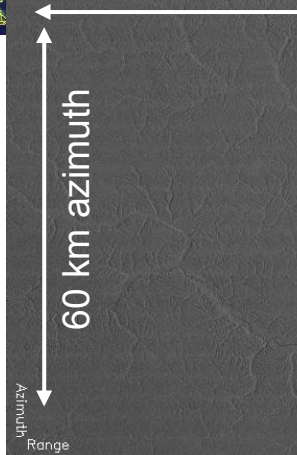


Antenna Pattern Monitoring TSX-1



- ScanSAR-mode: several beams measured during one pass
- Across an area of 750 x 750 km²

Antenna_pattern_estimation_RF00045740



Quality parameters

max

σ

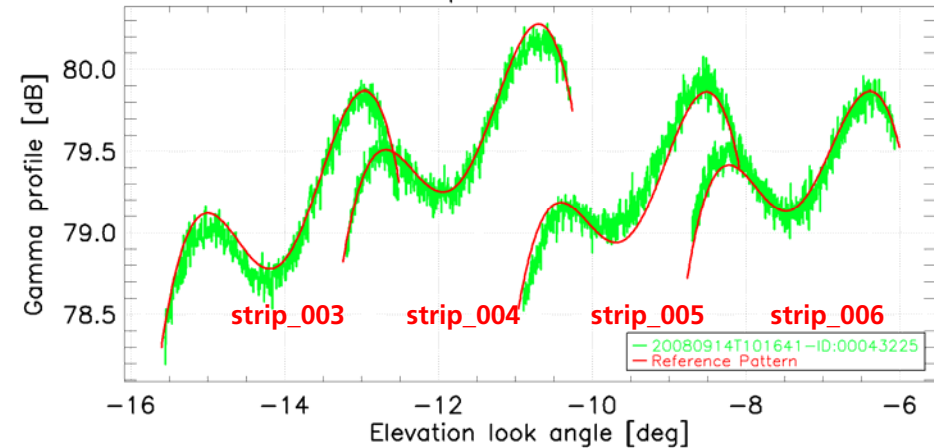
μ

σ

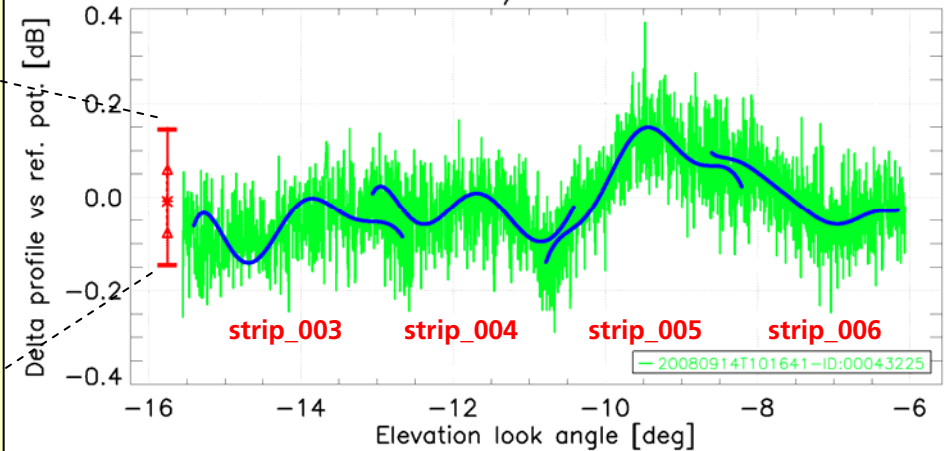
min



Gamma profile – scan_003



Difference Meas / Model – scan_003



Created: M. Bachmann, 2008-11-26T13:07:40



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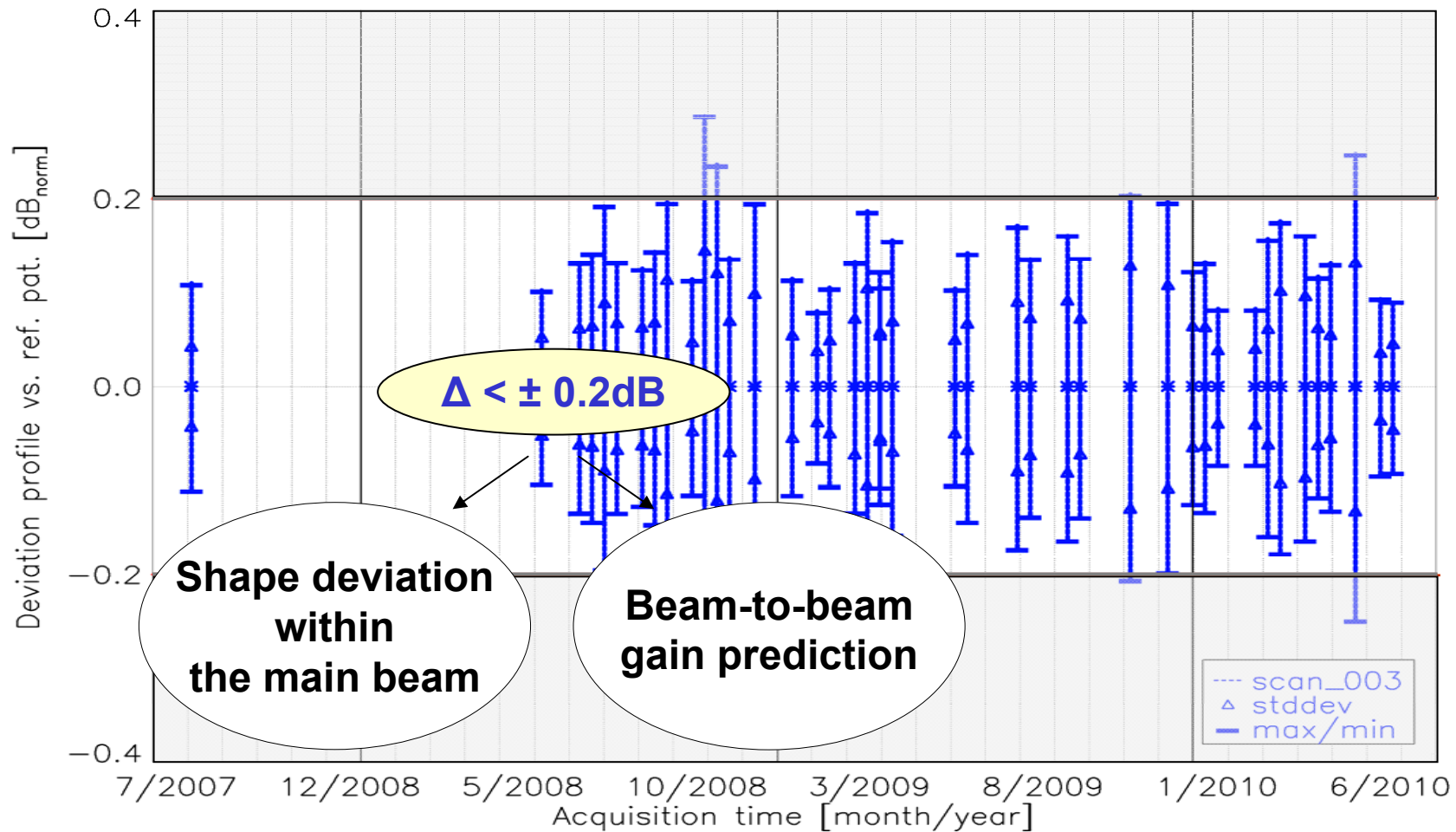


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Antenna Pattern Long Term Monitoring TSX-1



Requirement still fulfilled



stable, no trend



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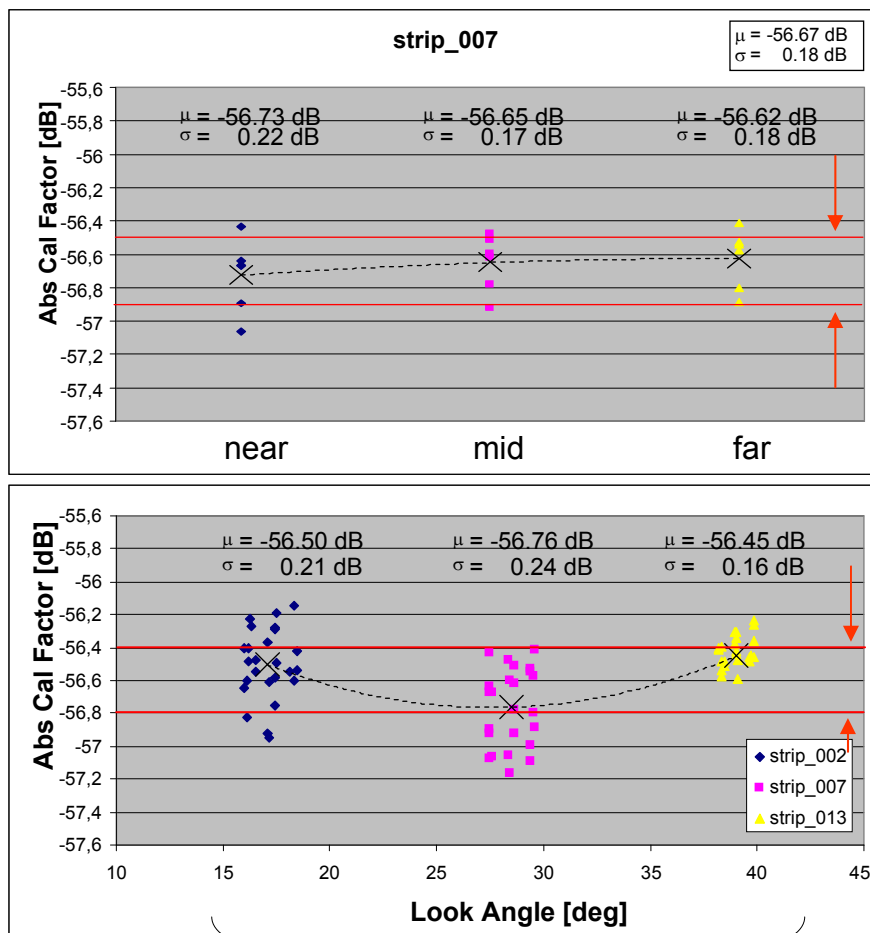


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Radiometric Calibration TSX-1



$\mu \leq \pm 0.2$ dB
within scene

$\mu \leq \pm 0.2$ dB
within full
performance
range

- 6 corner reflectors across the swath
- 3 beams (low, mid, high inc.)

• **Antenna Model**
 $\leq \pm 0.2$ dB

• **Radiometric Stability**

	<i>Abs. Cal Factor</i>
2007	- 56.58 dB
2009	- 56.43 dB

0.15dB
over 2 years

TerraSAR-X
is extremely stable

CR: corner reflector

$$\mu_{2009} = -56.53\text{dB} + 0.10\text{dB (CR)} = -56.43\text{dB}$$

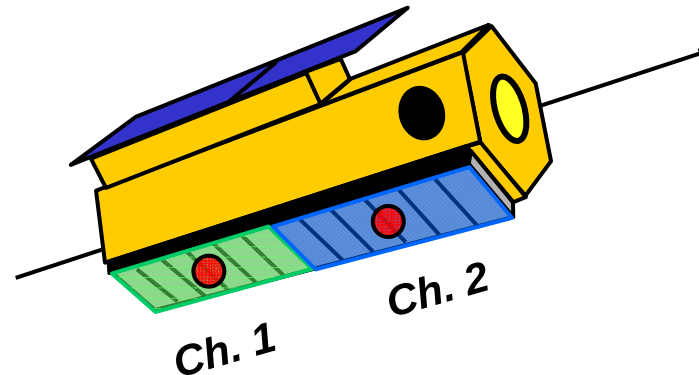
Requirement 0.5 dB (1σ)
over 6 months !



Calibration Tasks Performed in 2009 TSX-1

TerraSAR-X in Dual Receive Antenna (DRA) Mode

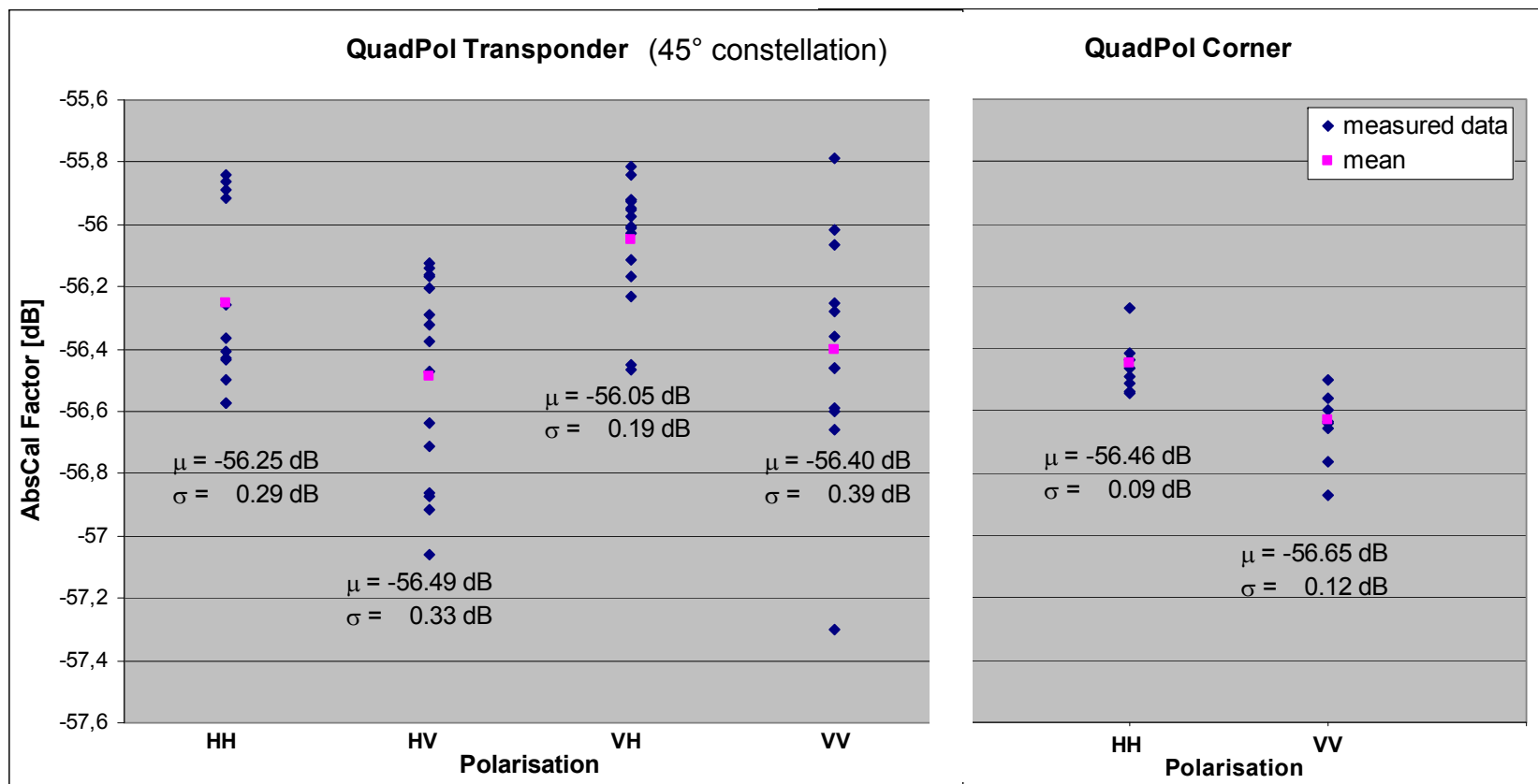
- 2 instrument chains on receive (main and redundant)
- 2 antenna halves
- Quad-pol mode
- Along track interferometry



DRA Campaigns

- ✓ Geometric calibration
- ✓ Antenna model verification
- ✓ Channel imbalance, phase
- ✓ Channel imbalance, amplitude → radiometric calibration
- ✓ Cross talk

Channel Imbalance: Amplitude TSX-1



max. offset
0.44dB

-0.18dB antenna gain
Correction, V-pol on receive

Channel imbalance

0.26 dB

Abs. rad. accuracy during DRA campaigns

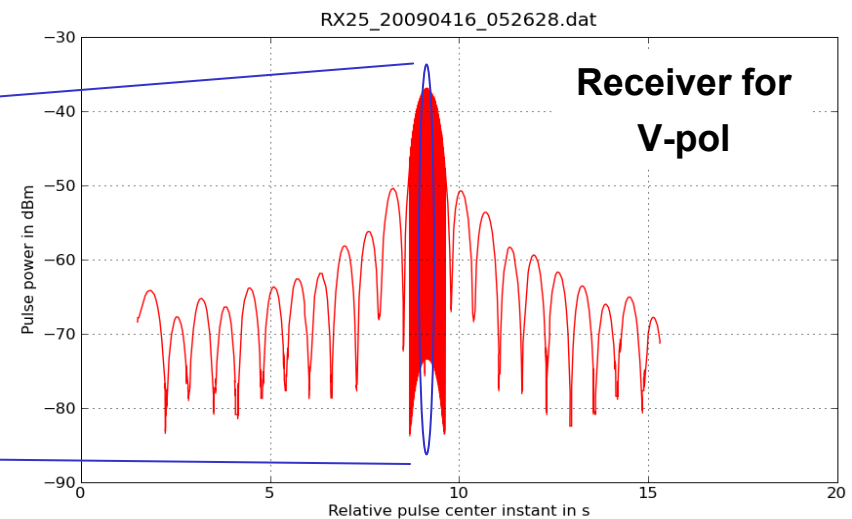
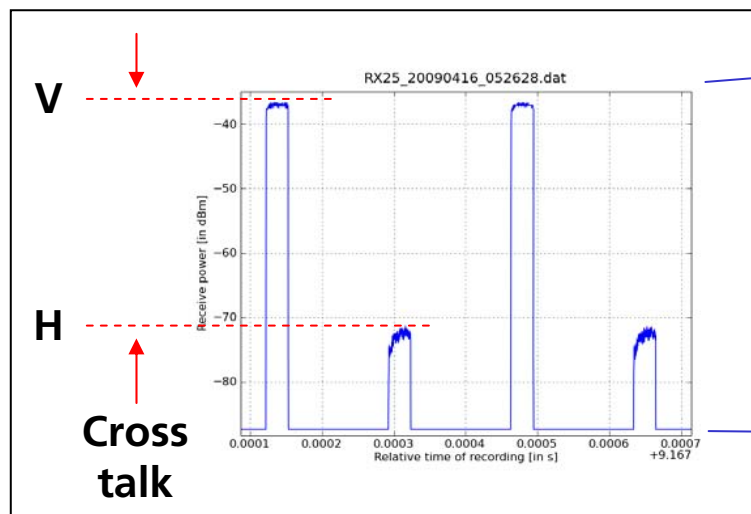
0.30 dB (1σ)



One-Way Cross Polar Isolation TSX-1

- Ground receivers aligned for V-pol
- 1-way azimuth pattern measured per pass

Strip_013, des, Inc. 43.7° (16-04-2007)

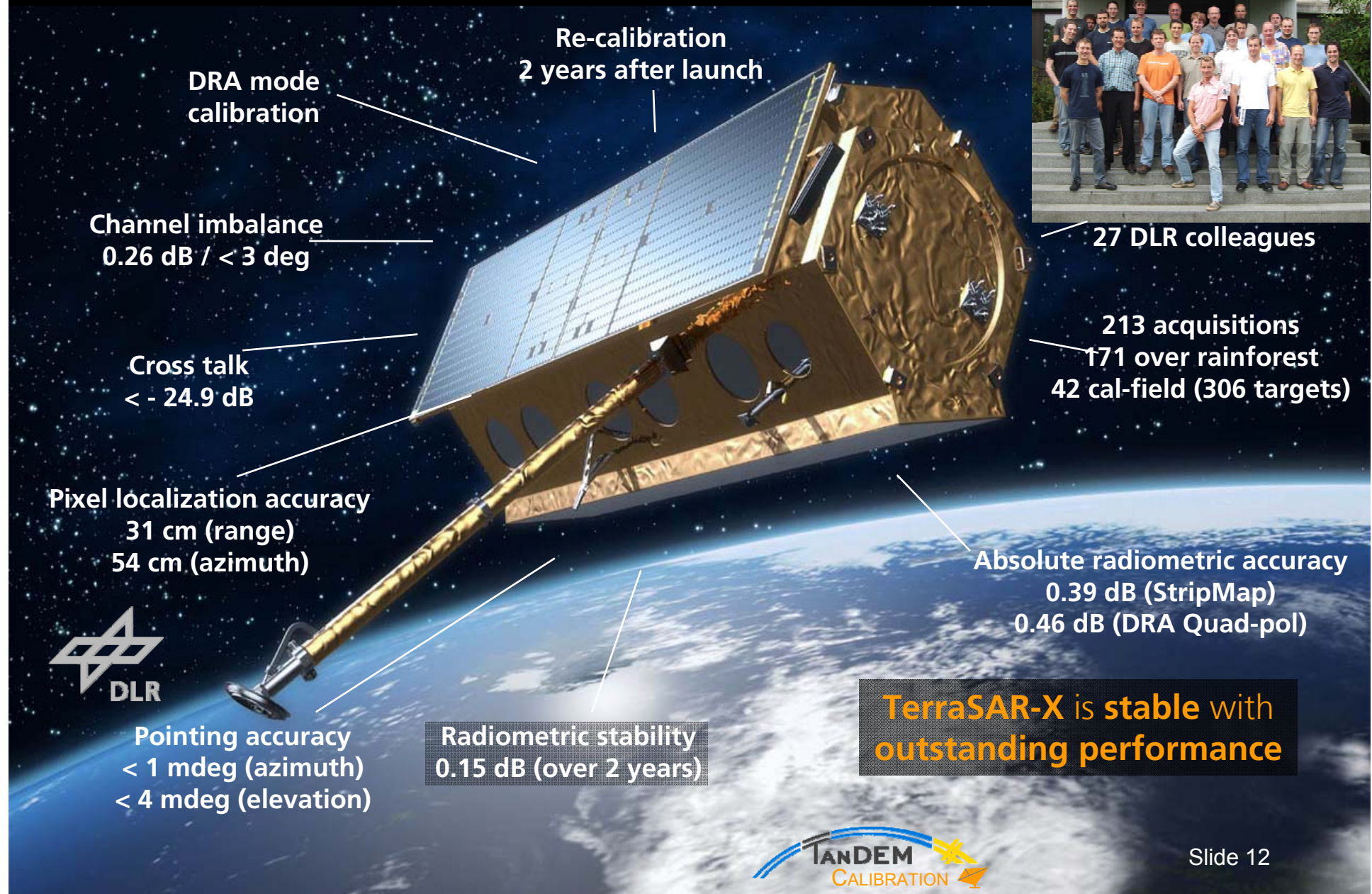


**1-way cross polar isolation
(on transmit)**

> 34dB

Requirement $\geq 24\text{dB}$ (1-way, StripMap)

TerraSAR-X Calibration Tasks Performed in 2009





TDX-1 Calibration



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TDX-1 Monostatic Calibration Strategy

2.5 months (summer 2010)

1. Geometric calibration
2. Antenna pointing
3. Antenna model
4. Radiometric calibration
StripMap and ScanSAR



Cal test sites

- * Rainforest: distributed field
- * South Germany: 30 calibration sites from which 17 are permanently installed corner reflectors

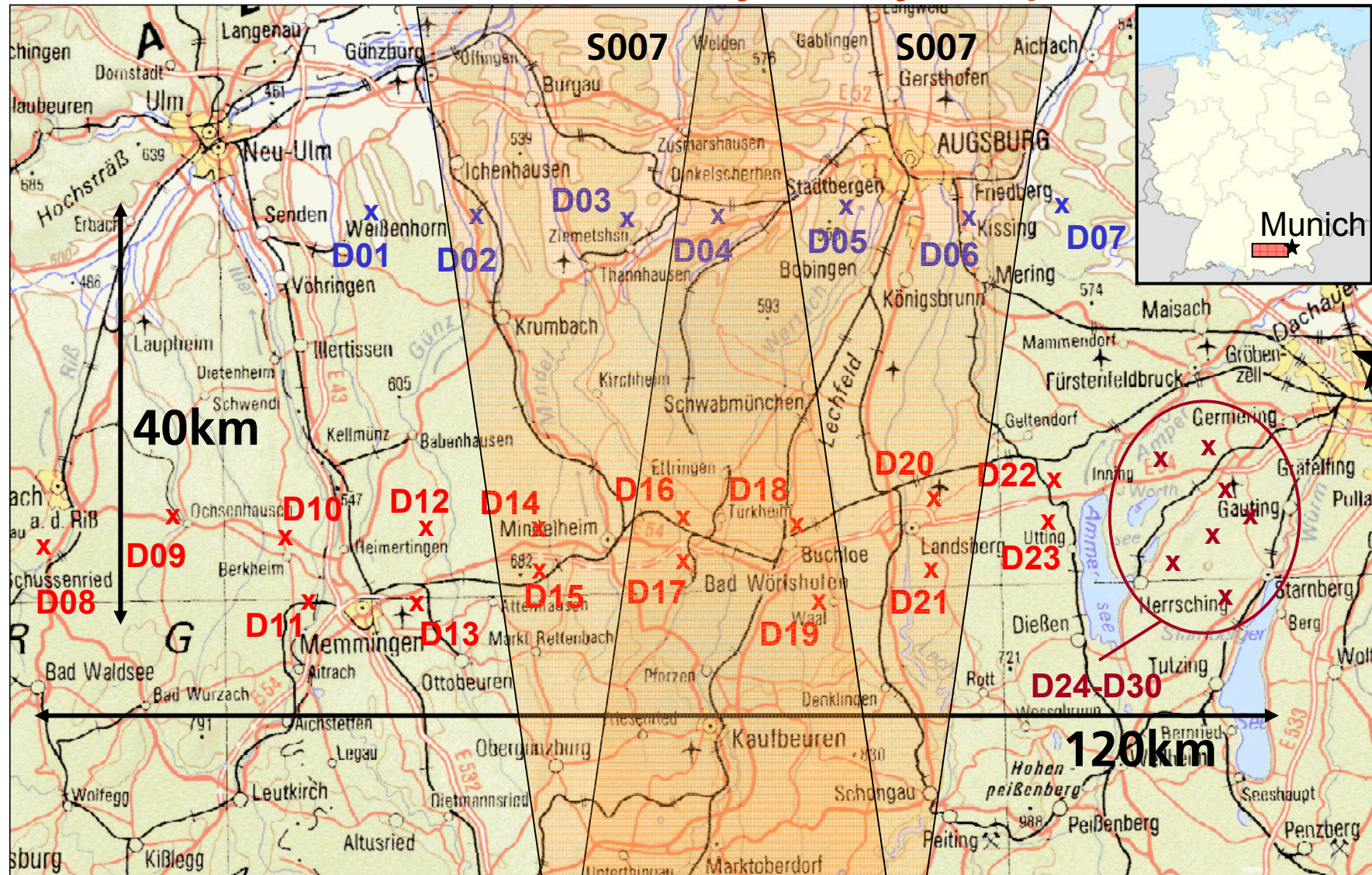
Around 60 calibration campaigns with reference point targets: transponders and corners

More than 1000 datatakes will be analyzed





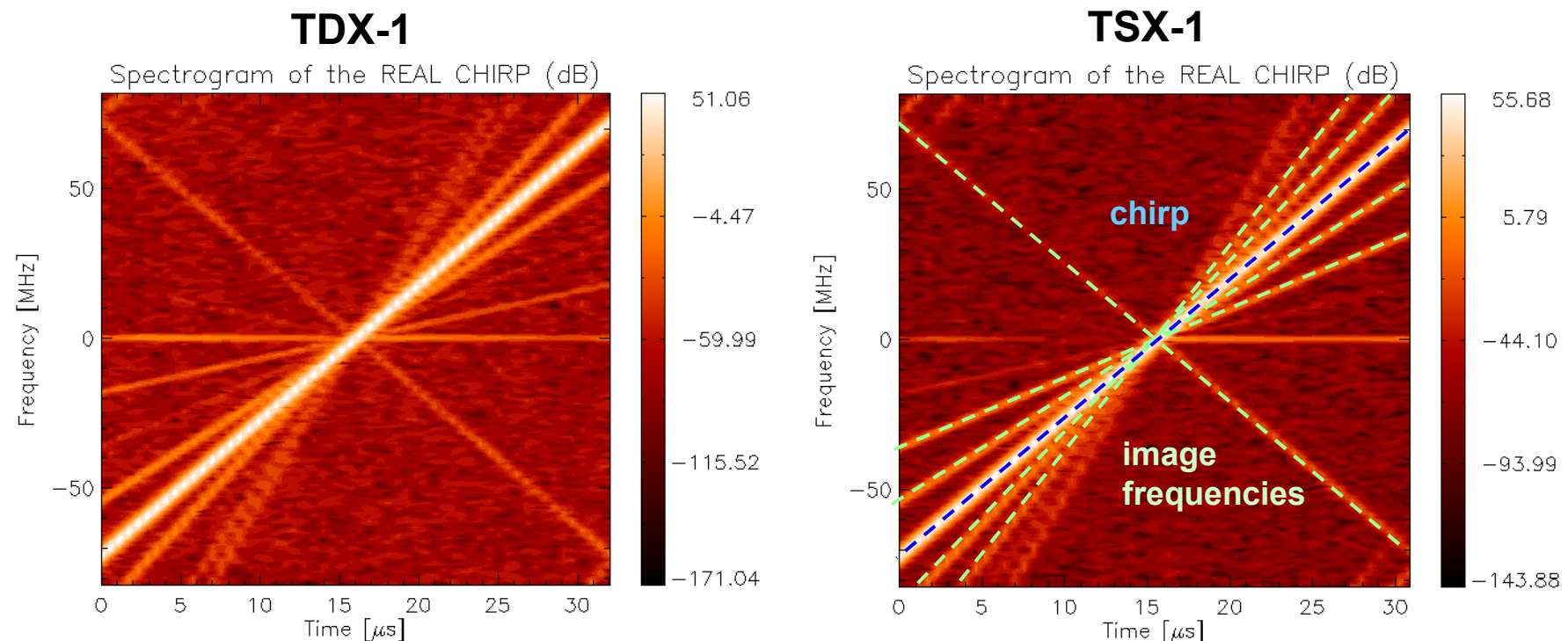
Calibration Field in South Germany near by Oberpfaffenhofen





First Results: Chirp Comparison of TDX-1 – TSX-1

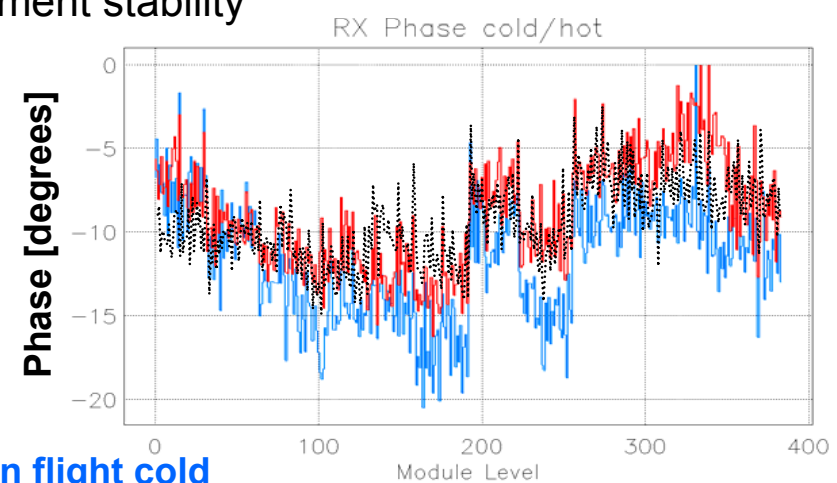
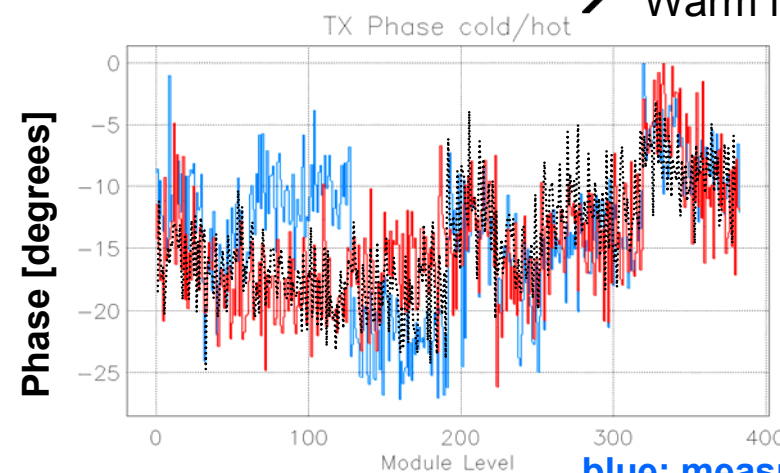
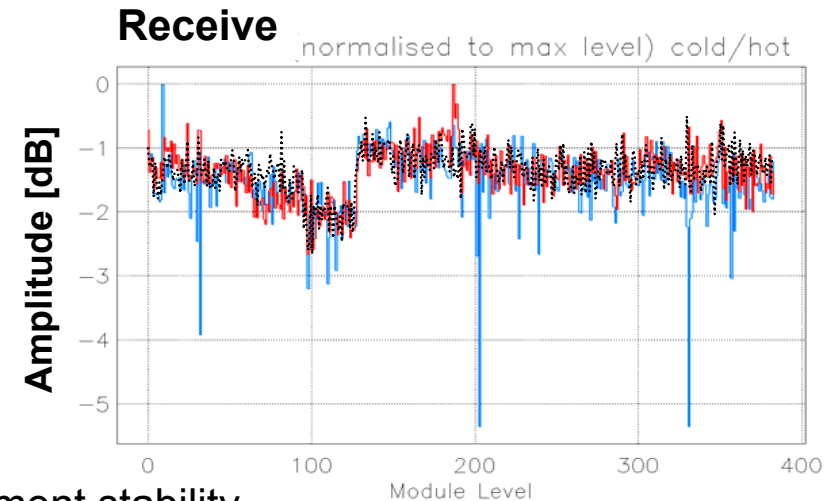
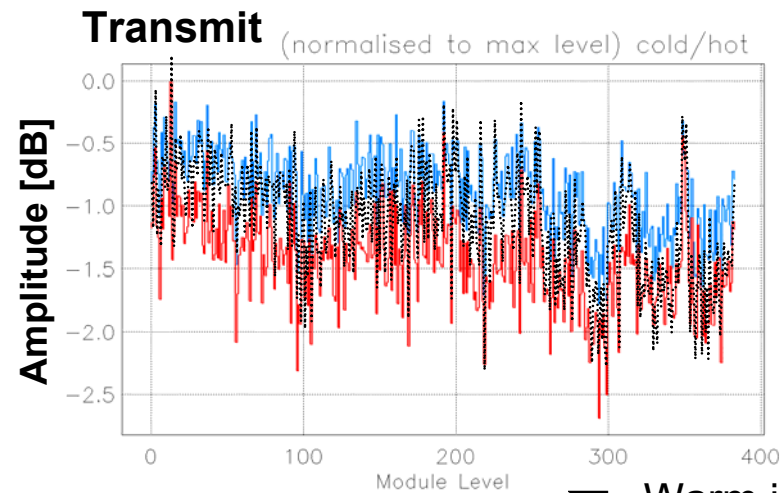
- Receive pulses, BW = 150MHz, UP-chirp, pulse length = 32 μ s



- Similar spectrograms $\Rightarrow$ important for bistatic operation



First results TDX-1: TRM Characterization – PN Gating

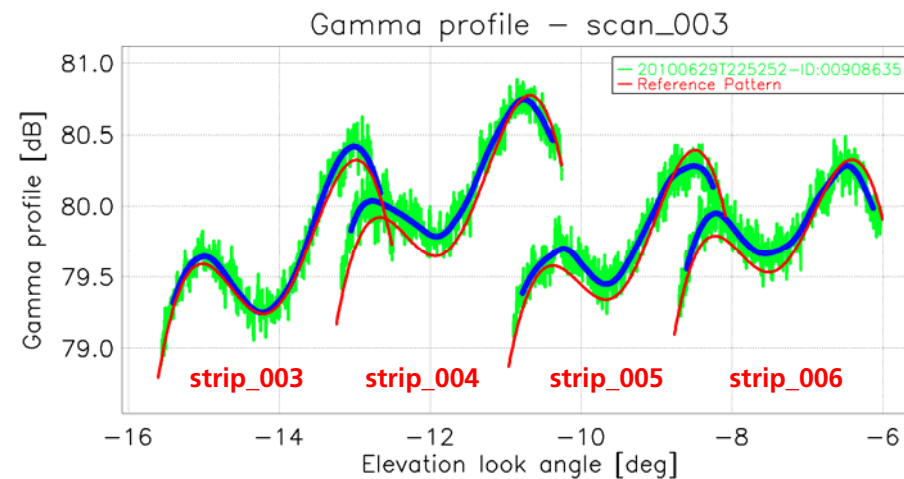


➤ Warm instrument stability

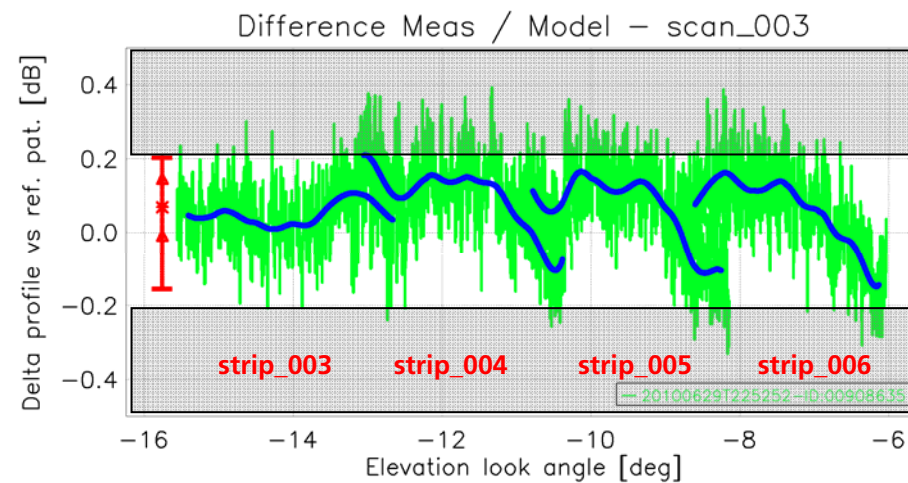
blue: measured in flight cold
red: measured in flight hot



First Results TDX-1: Antenna Pattern over Rainforest

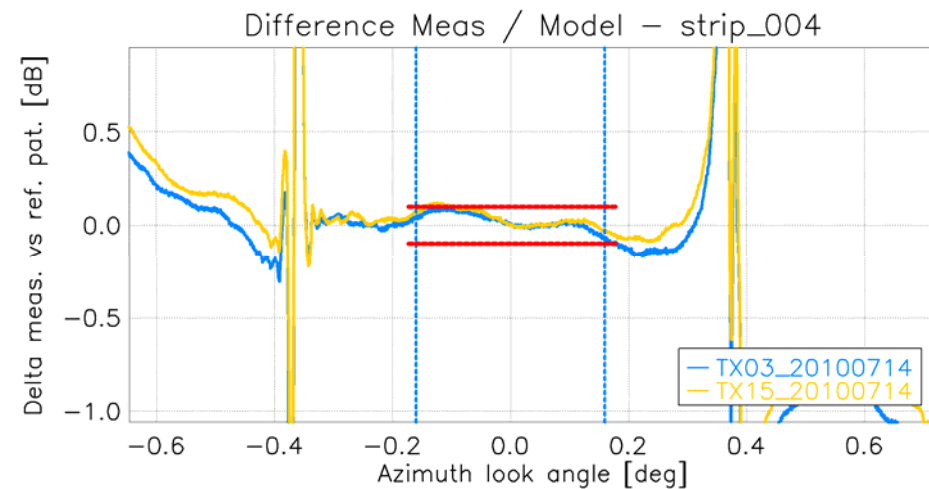
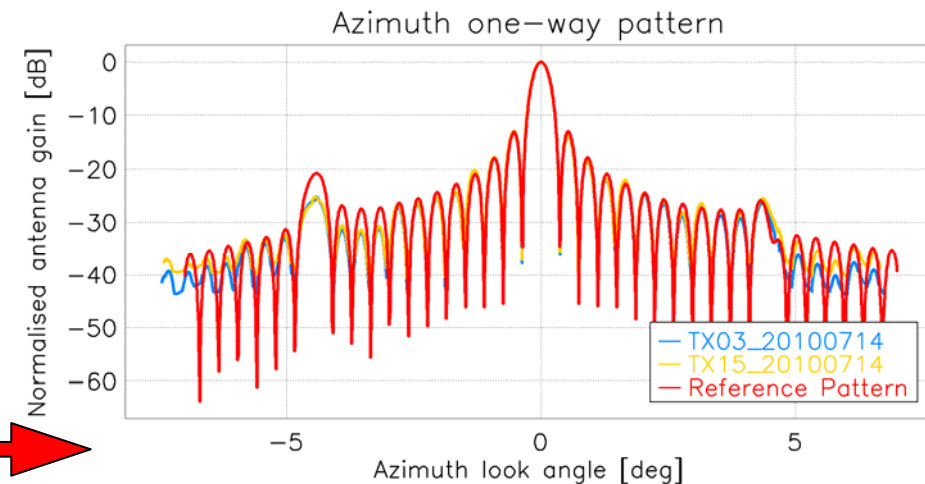
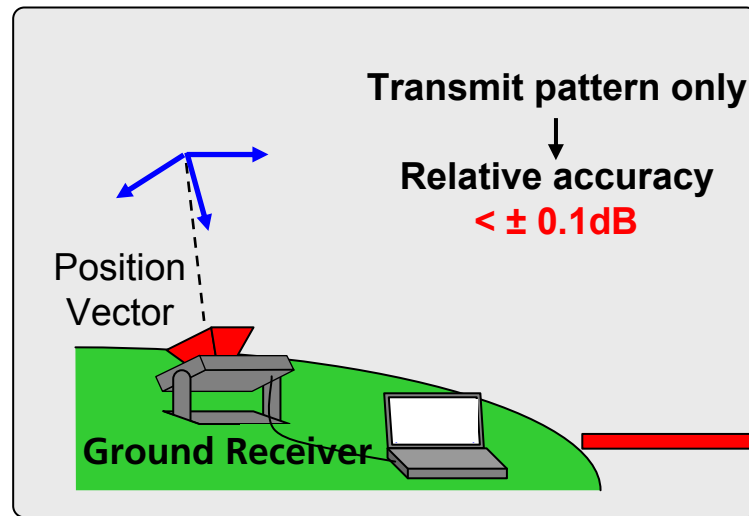


➤ Within requirements





First Results TDX-1: Antenna Pattern by Ground Receivers

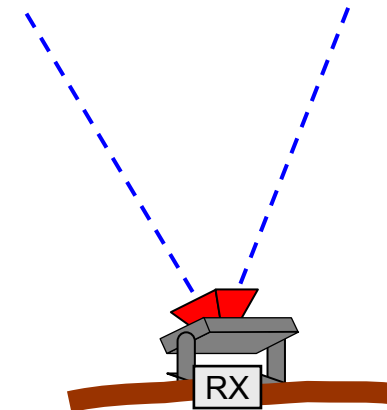
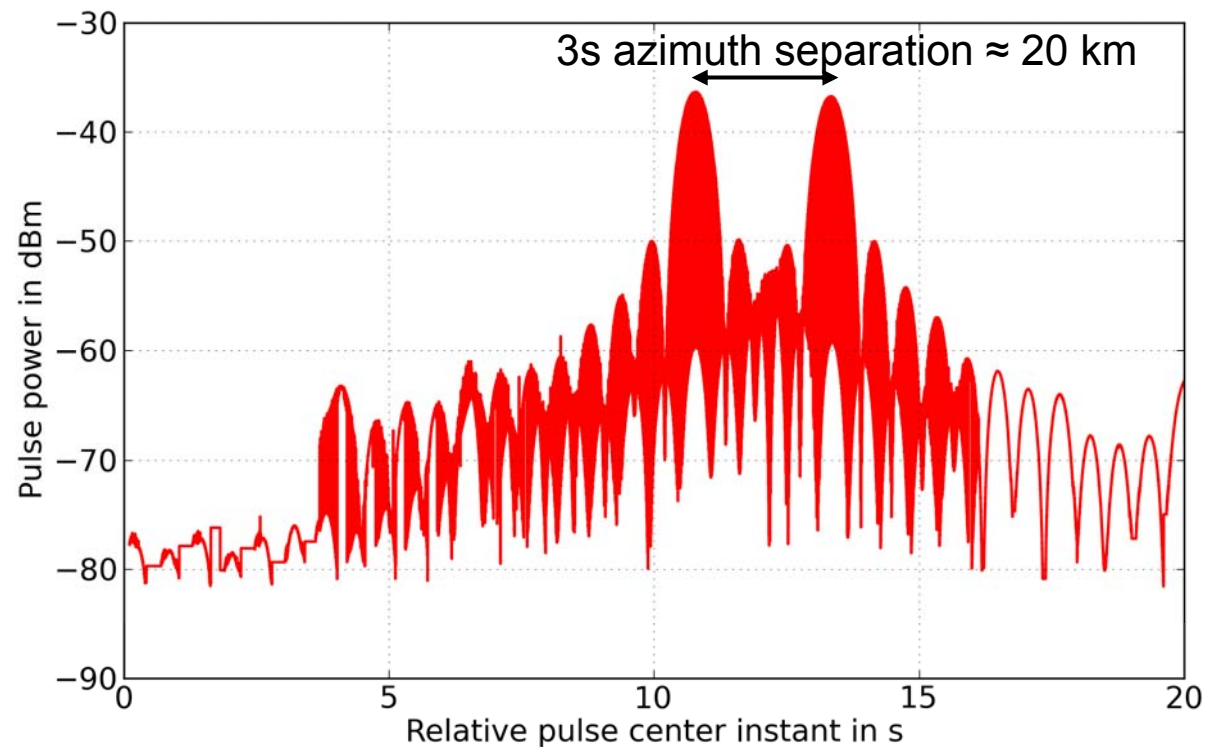


- Measurements confirm simulated reference pattern
- Within requirements



First Sequential Ground Receiver Acquisition

- Direct measurement of the satellite separation in along track
→ Pursuit monostatic phase

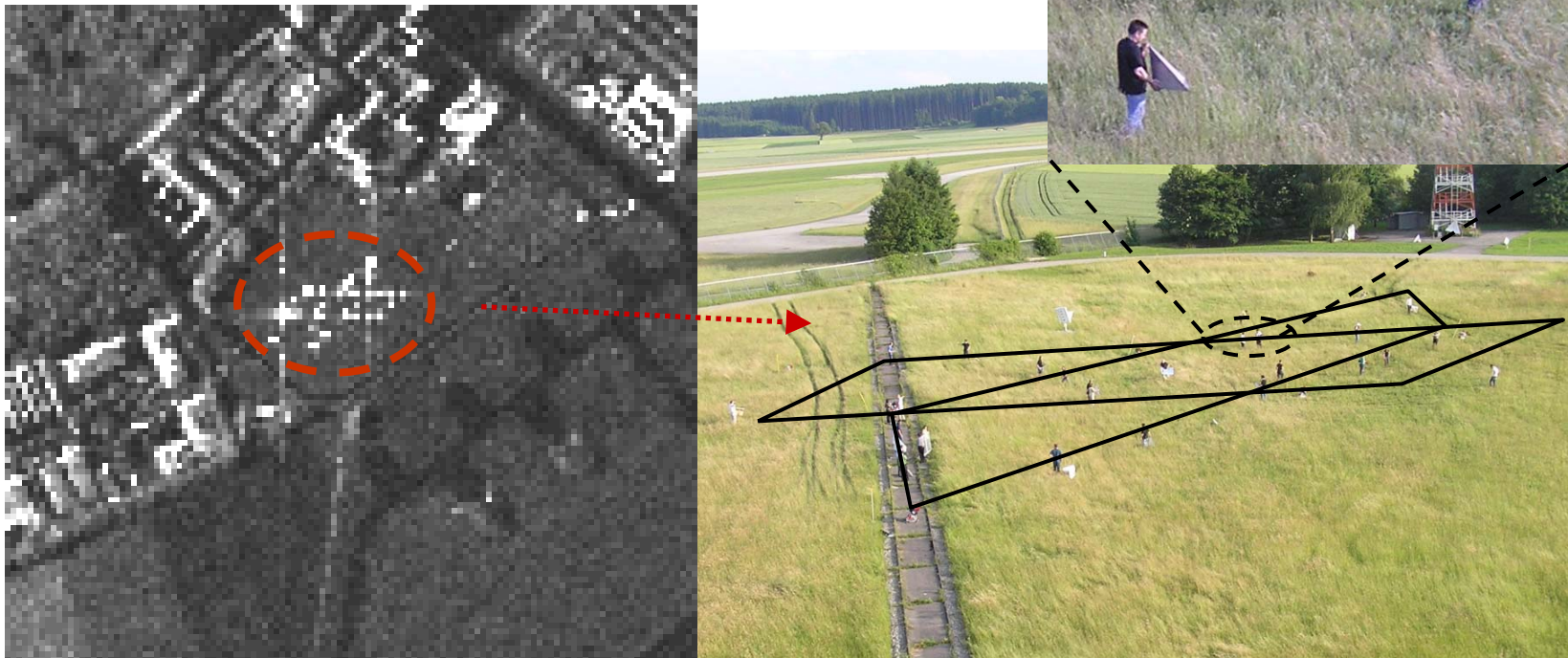


- 1st absolute comparative measurement of transmitted power
→ $<0.5\text{dB}$ difference TDX-1 – TSX-1



THE END

Questions?



TSX-1 DLR logo experiment: Oberpfaffenhofen, Bayern, Germany (19th June 2008)