

TerraSAR-X Calibration Status 2 Years in Flight

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Calibration Tasks Performed 2009

Introduction

- ✓ Challenge
- ✓ Schedule

Re-Calibration

- ✓ Geometric Calibration
- ✓ Antenna Pointing Determination
- ✓ Antenna Model Verification
- ✓ Radiometric Calibration

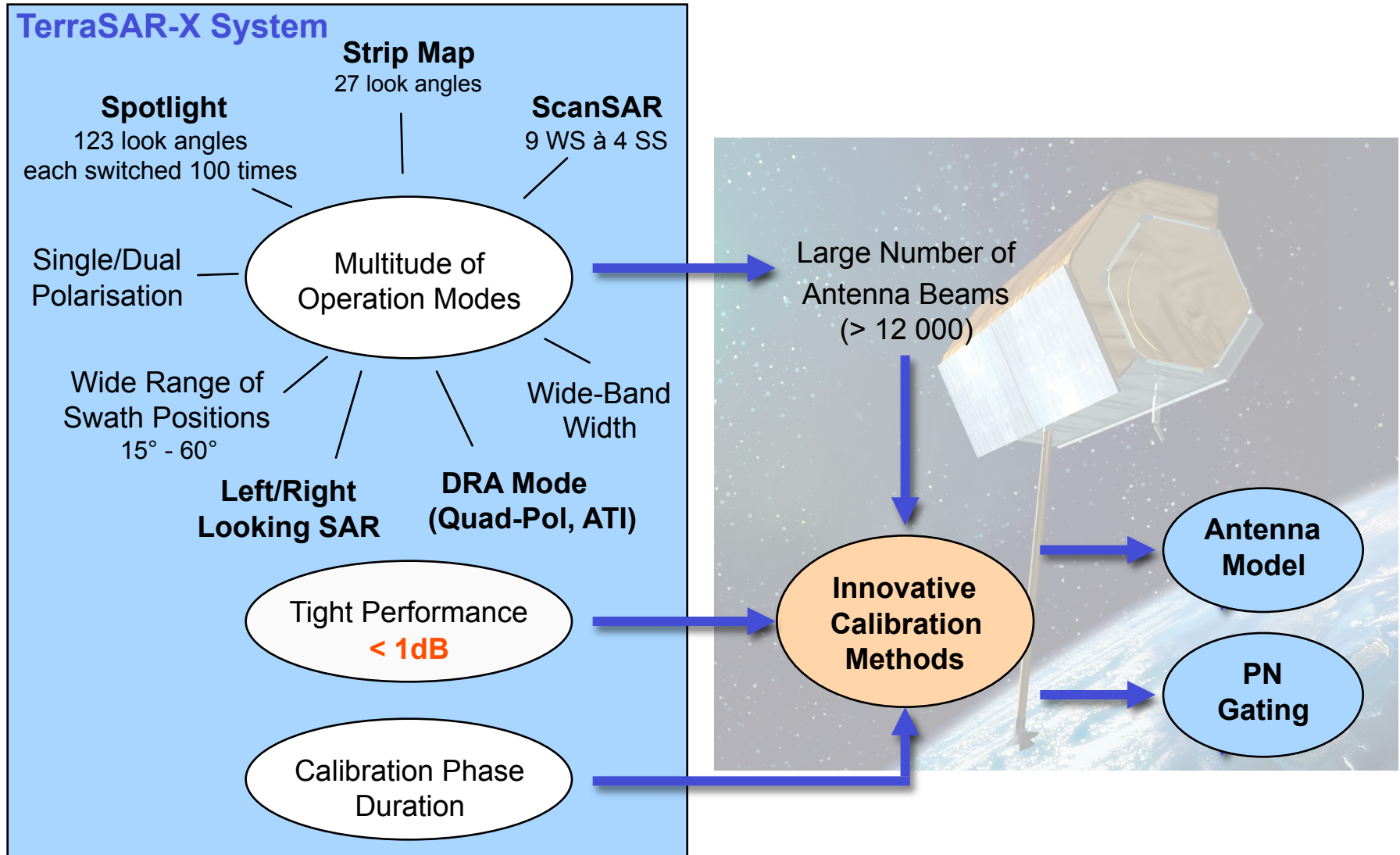


Same procedure as during Commissioning Phase but extremely reduced

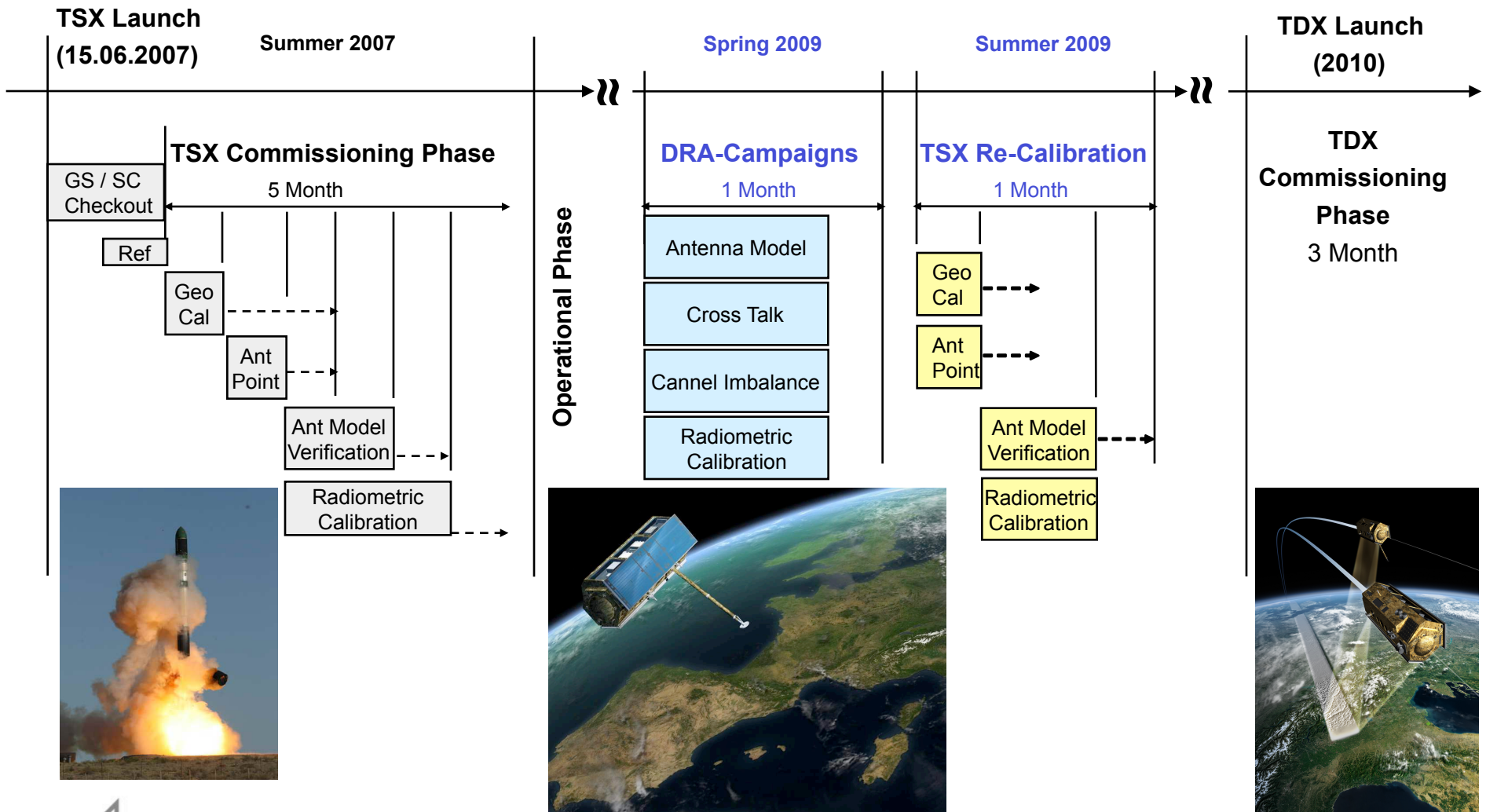
DRA Campaigns

- ✓ Antenna Model Verification
- ✓ Channel Imbalance, Amplitude => Radiometric Calibration
- ✓ Channel Imbalance, Phase
- ✓ Cross Talk

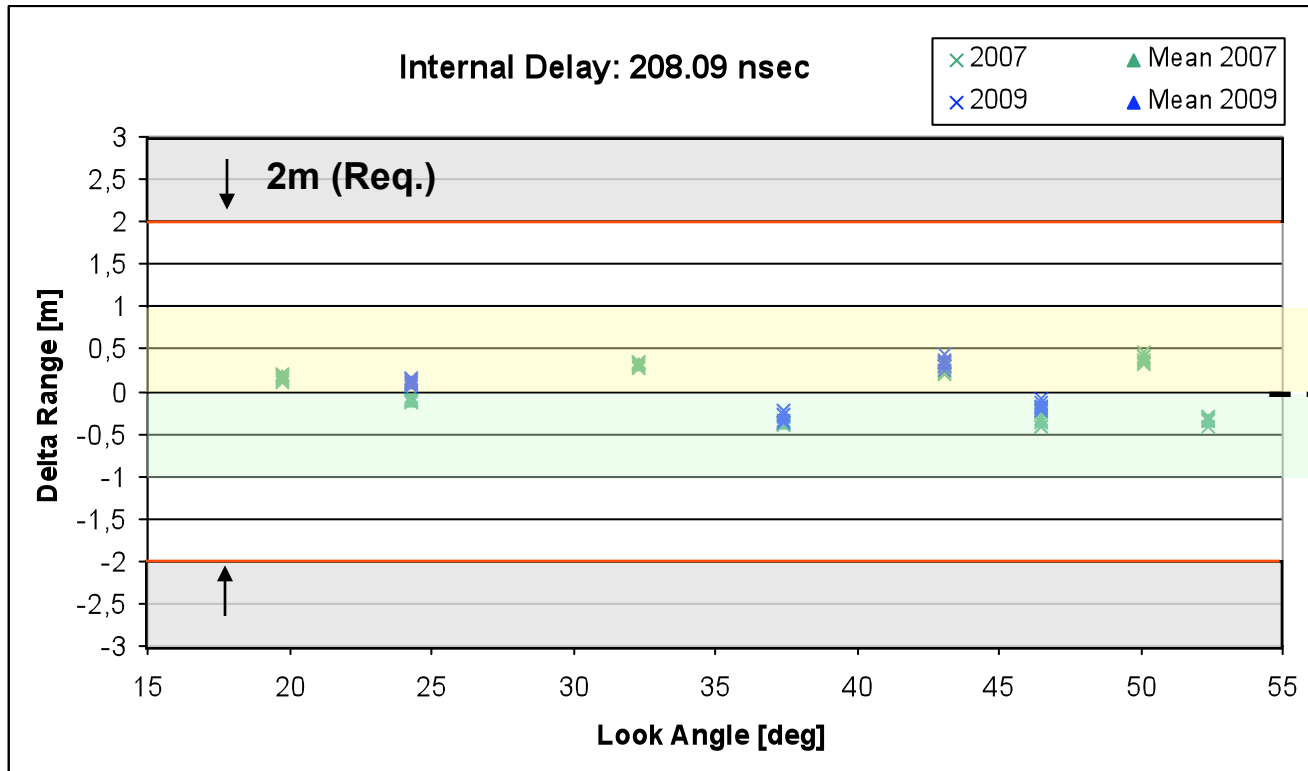
Challenge to calibrate TerraSAR-X



TSX / TDX In-Orbit Calibration Plan



Geometric Calibration

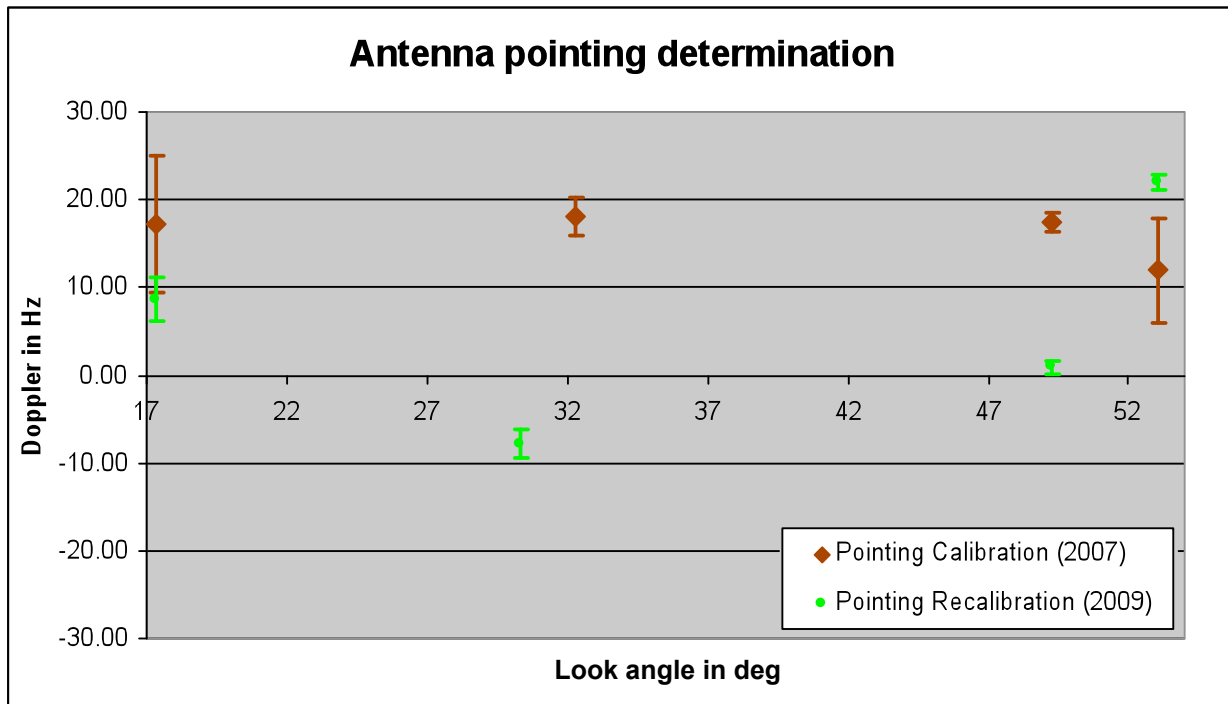


- **6 Corner Reflectors** across the **swath**
- **8 Beams**

asc orbit
des orbit
} Propagation Effects ?

- Pixel Localization Accuracy (Range) $\sigma = 31 \text{ cm}$ (1σ) → **no trend for 2 years**
- Residual Offset (In-Flight \Leftrightarrow OGC) **3.75 cm** (0.25 nsec)

Pointing Determination in Azimuth



- **Ground Receiver Measurements**
- **4 Beams**

Updates

- ✓ Re-Adjustment between Star Trackers



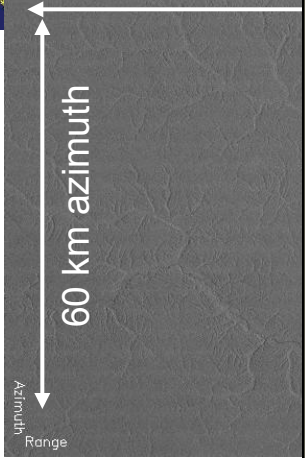
Improvements	2007	2009
✓ Measurement Accuracy	≤ 7.9 Hz ≤ 1.0 mdeg	≤ 2.6 Hz (1σ) ≤ 0.4 mdeg
✓ Mean Doppler	< 16 Hz < 2 mdeg	< 5.9 Hz < 1.0 mdeg

Antenna Pattern Monitoring



- 6 ScanSAR Beams measured during one Pass
- across an Area of 750 x 750 km²

Antenna_pattern_estimation_RF00045740



Quality Parameters

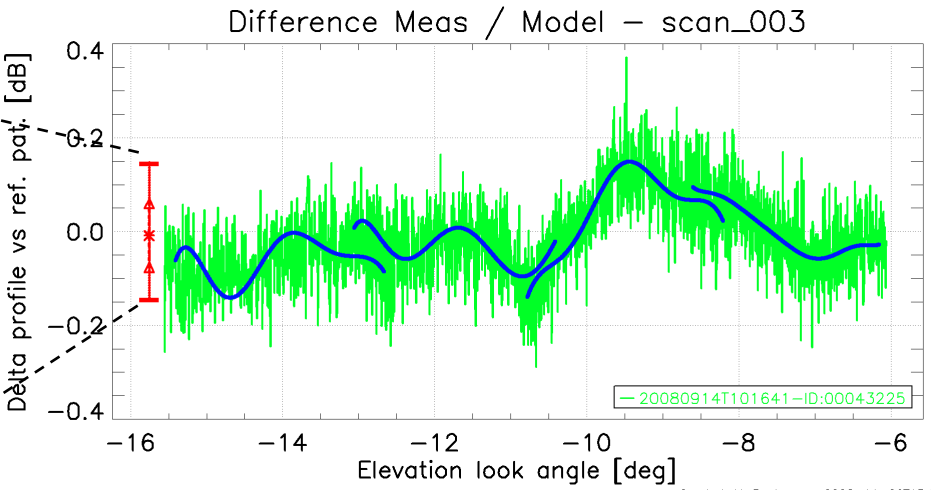
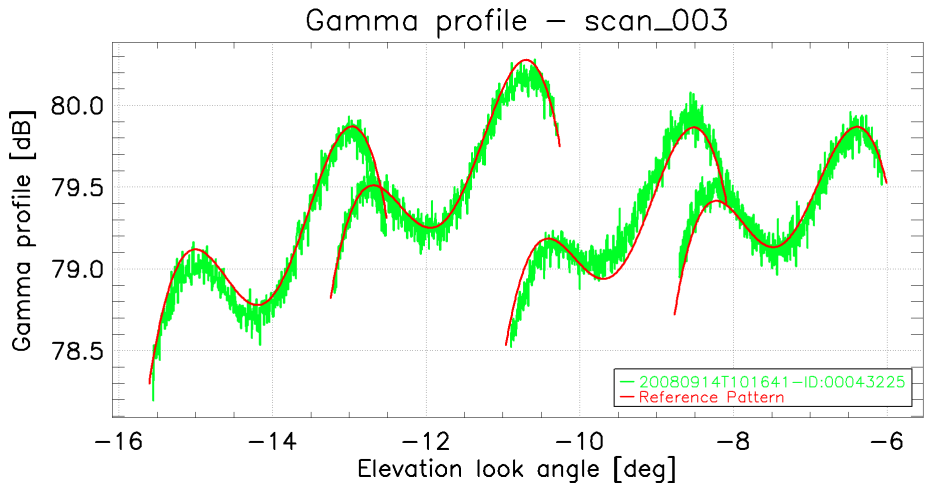
max

σ

μ

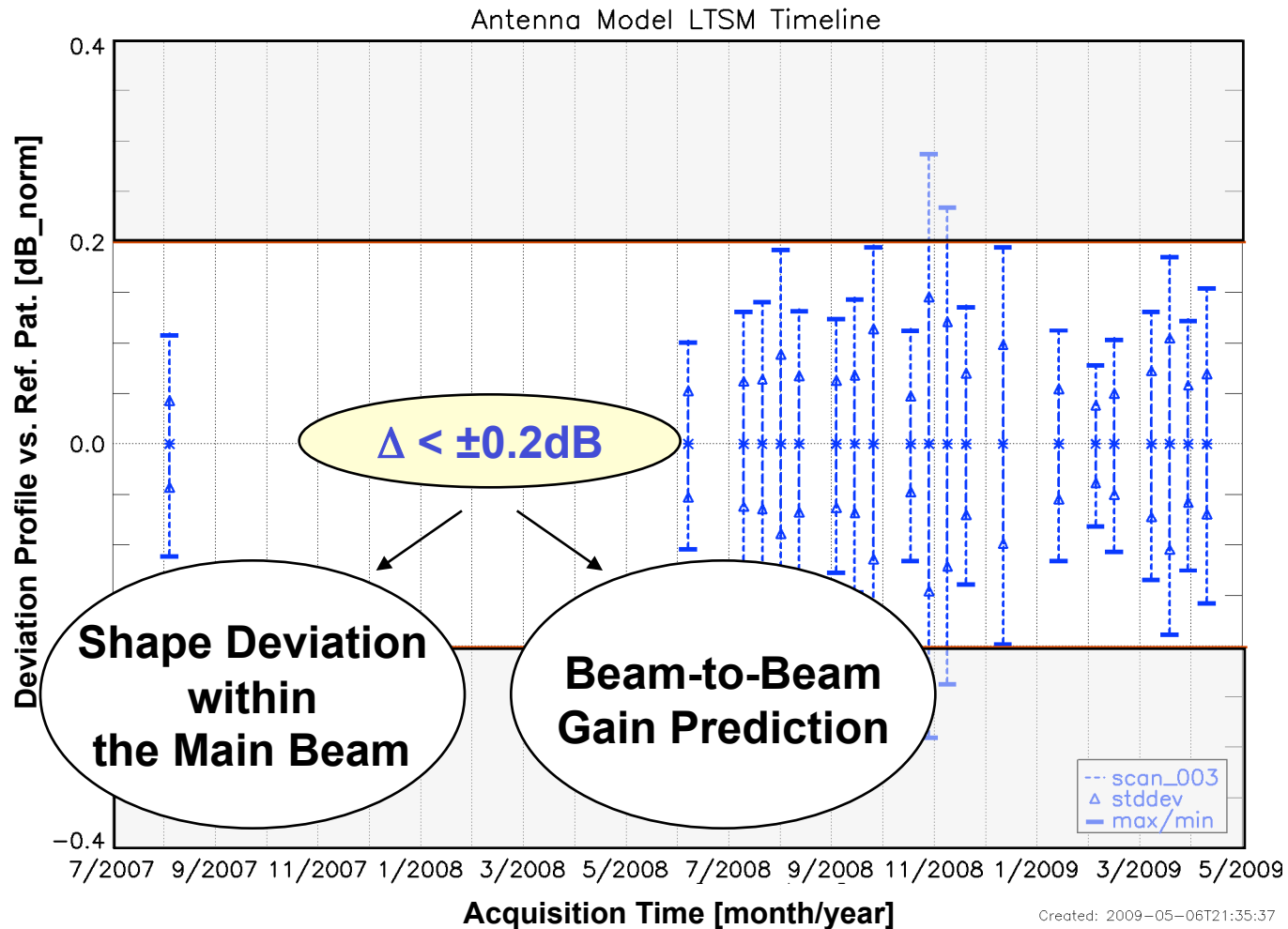
σ

min



Created: M. Bochmann, 2008-11-28T13:07:40

TSX Antenna Pattern Long Term Monitoring (relative)

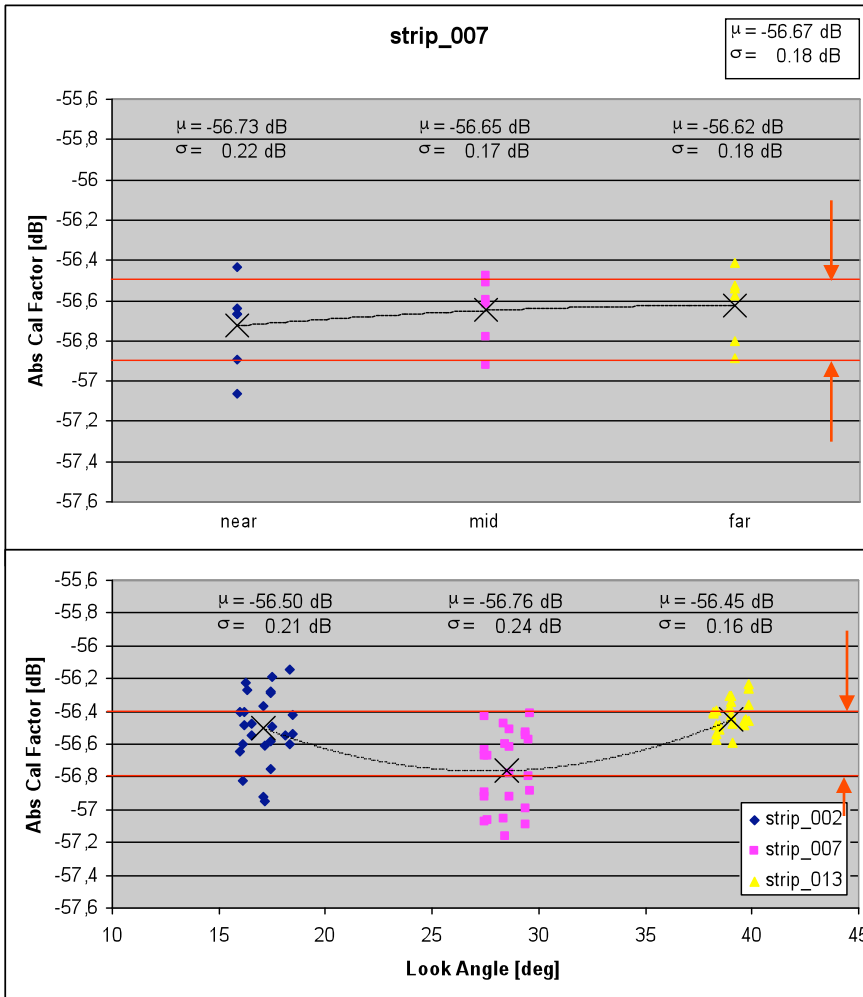


Requirement still fulfilled



stable, no trend

Radiometric Calibration



CR: corner reflector

$\mu \leq \pm 0.2\text{dB}$
within Scene

$\mu \leq \pm 0.2\text{dB}$
within full
performance
range

- **6 Corner Reflectors** across the **swath**
- **3 Beams** (low, mid, high, Inc)

• **Antenna Model**
 $\leq \pm 0.2\text{dB}$

• **Radiometric Stability**

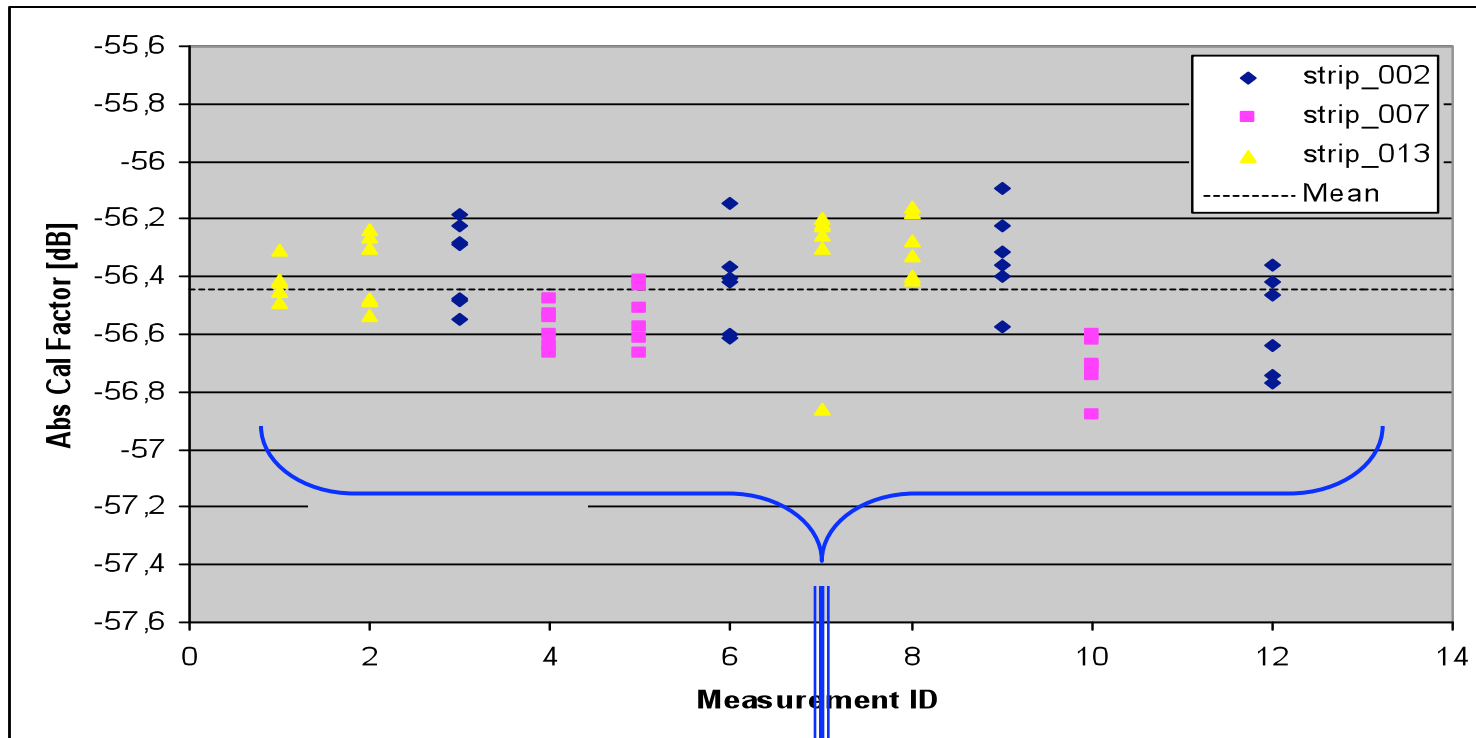
	<i>Abs. Cal Factor</i>
2007	- 56.58 dB
2009	- 56.43 dB

0.15dB
over 2 years

TerraSAR-X
is **extremely stable**

Requirement 0.5 dB (1σ)
over 6 months !

Absolute Radiometric Accuracy



Absolute Radiometric Accuracy

0.18 dB (1σ)

during Re-Cal in StripMap Operation

Final Re-Calibration Results of TerraSAR-X

Geometric Calibration		CP
- Pixel Localisation Accuracy (Azimuth / Range)	0.54 m / 0.31 m	✓
Pointing		
- Azimuth / Elevation	< 1 mdeg (5.9Hz) / < 4mdeg	} Improved
- Accuracy (Azimuth / Elevation)	< 1 mdeg / < 2 mdeg	
Antenna Model		
- Antenna Model (Shape / Gain-Offset)	$\leq \pm 0.2$ dB / $\leq \pm 0.2$ dB	✓
Radiometric Accuracy		
- Relative Radiometric Accuracy	0.18 dB*	} Improved
- Radiometric Stability (Req. 0.5dB over 6 months)	0.15 dB over 2 years	
- Absolute Radiometric Accuracy	0.39 dB* (3 years left)	

* StripMap Mode

Calibration Tasks Performed

Introduction

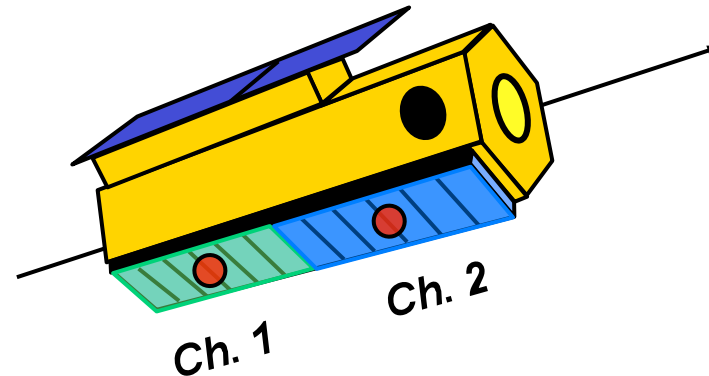
- ✓ Challenge
- ✓ Schedule

Re-Calibration

- ✓ Geometric Calibration
- ✓ Antenna Pointing Determination
- ✓ Antenna Model Verification
- ✓ Radiometric Calibration
- ✓ Internal Calibration

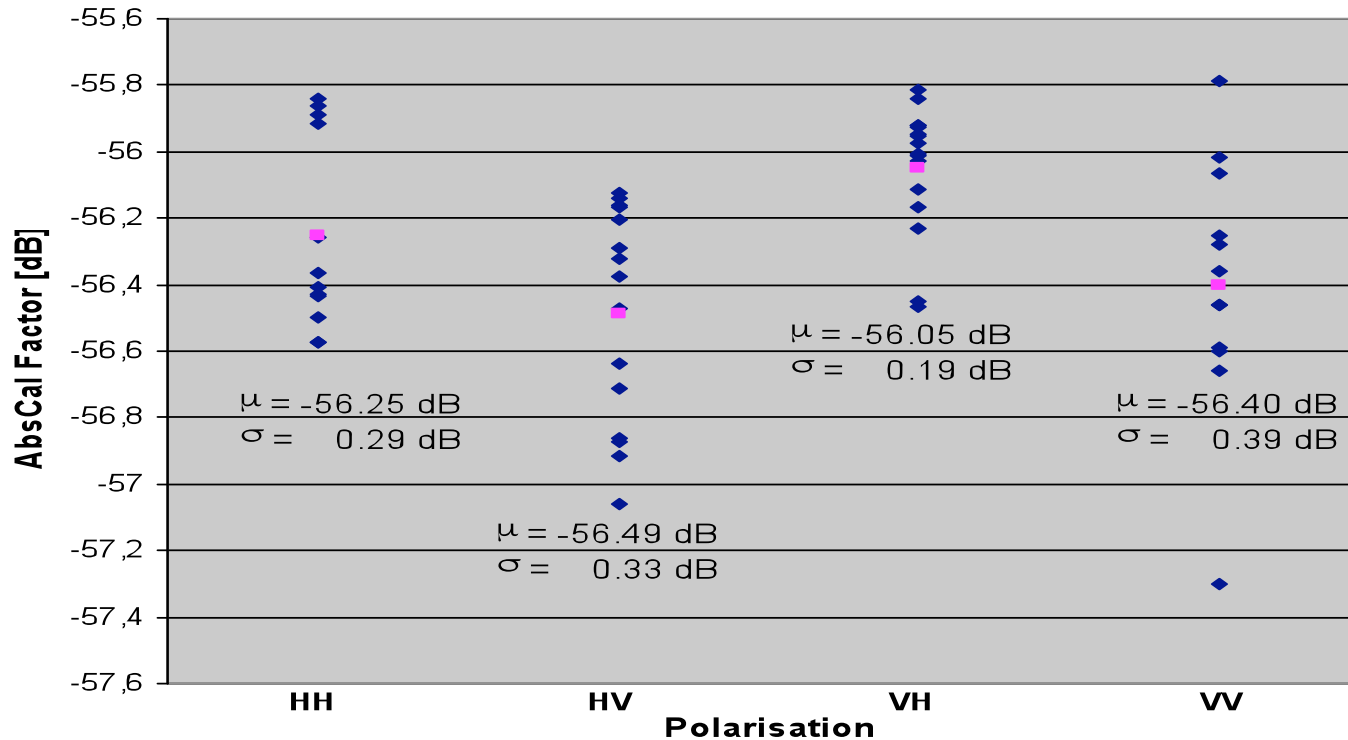
DRA Campaigns

- ✓ Antenna Model Verification
- ✓ Channel Imbalance, Amplitude => Radiometric Calibration
- ✓ Channel Imbalance, Phase
- ✓ Cross Talk



Channel Imbalance: Amplitude

QuadPol Transponder (45°-Constellation)

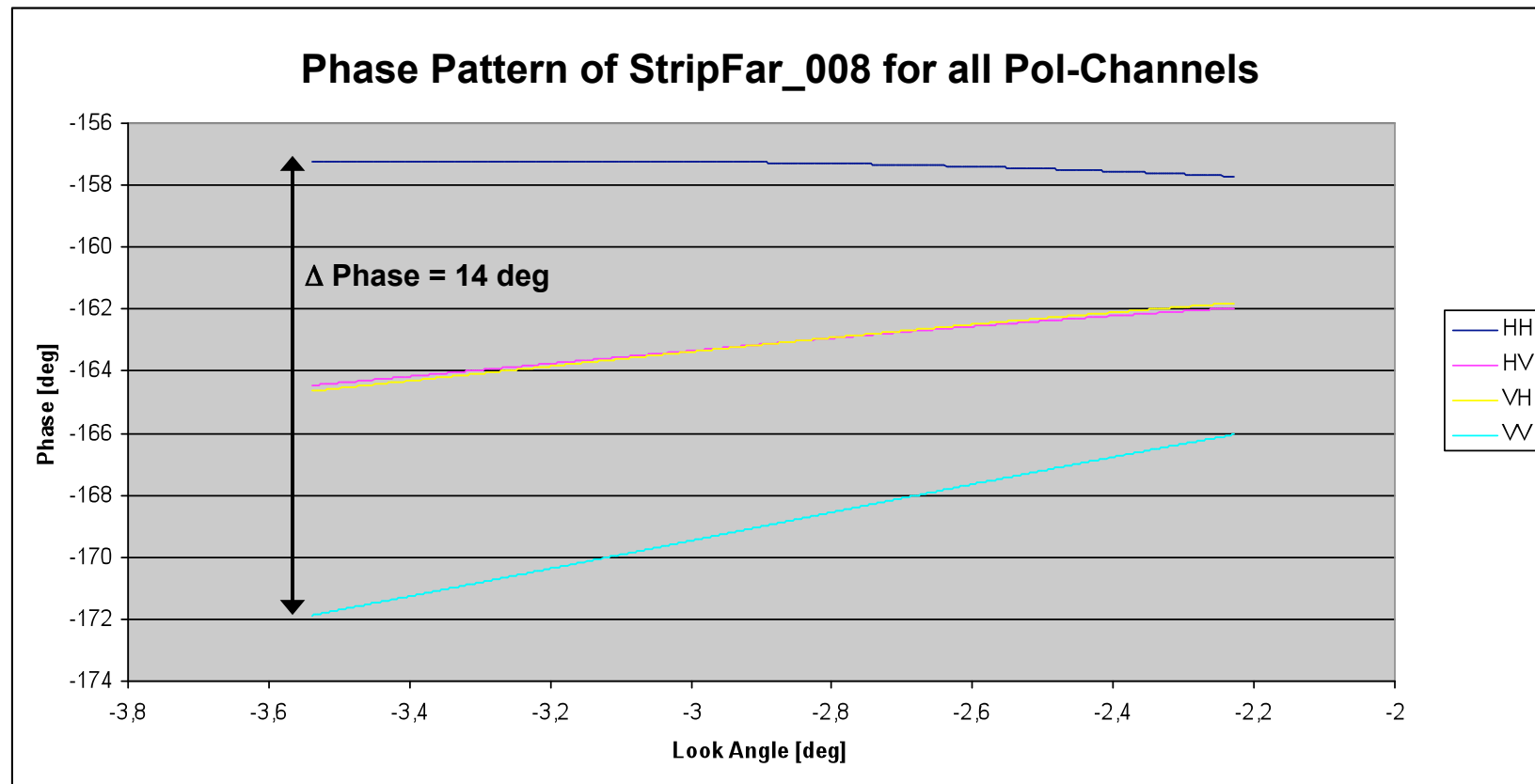


max. Offset
0.44dB

-0.18 dB Antenna Gain
Correction, V-pol on Receive

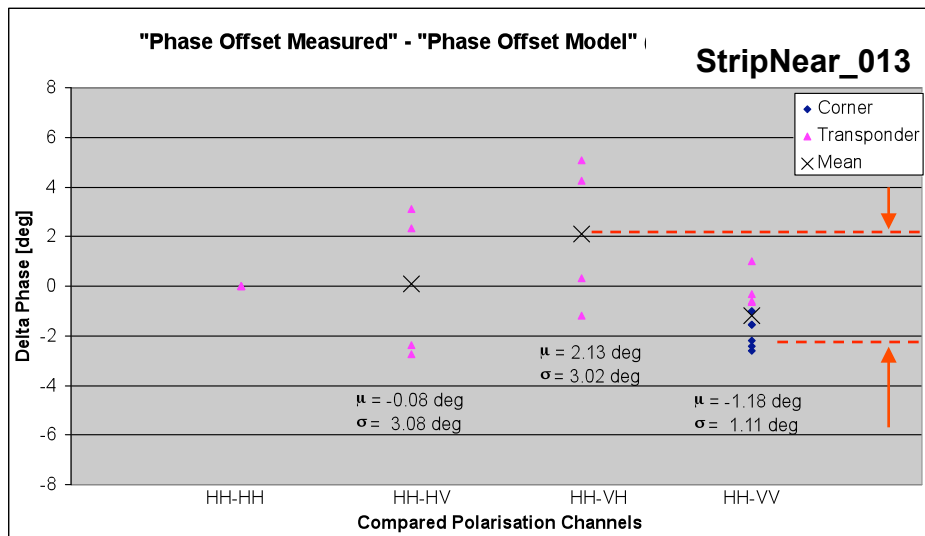
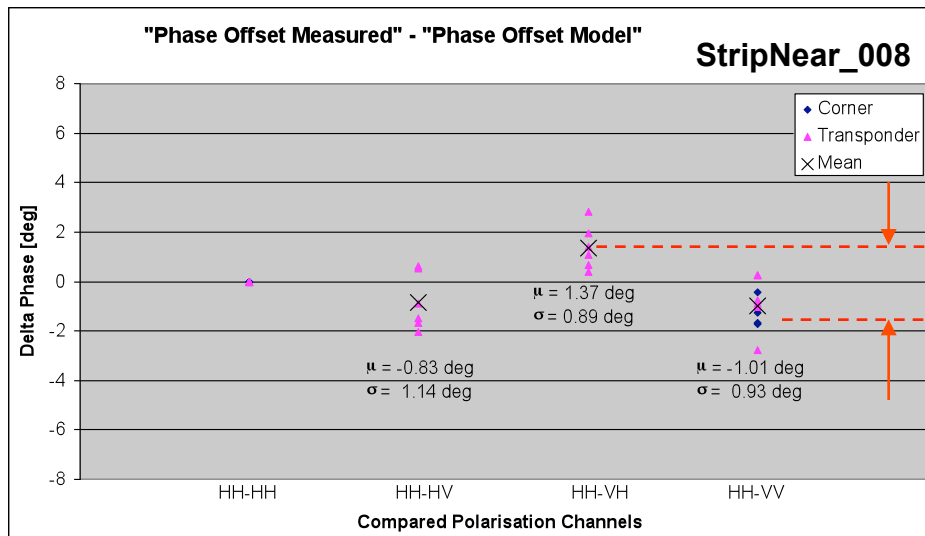
Channel Imbalance	Abs. Radiometric Accuracy
0.26 dB	0.30 dB

Channel Imbalance: Phase Pattern



Phase offset between Channels by Antenna
[- 180°; 180°]

Channel Imbalance: Phase Pattern Compensation



- **Transponder in 45°-constellation**
=> Target for all Pol Channels
- **Corner Reflectors for Co Channels**
- Channel Phase **Offset: Measured** ↔ **Model**

$\mu \leq \pm 1.37 \text{ deg}$

Residual Phase Error

Co < $\pm 1.2 \text{ deg}$
Cross < $\pm 2.2 \text{ deg}$

$\mu \leq \pm 2.13 \text{ deg}$

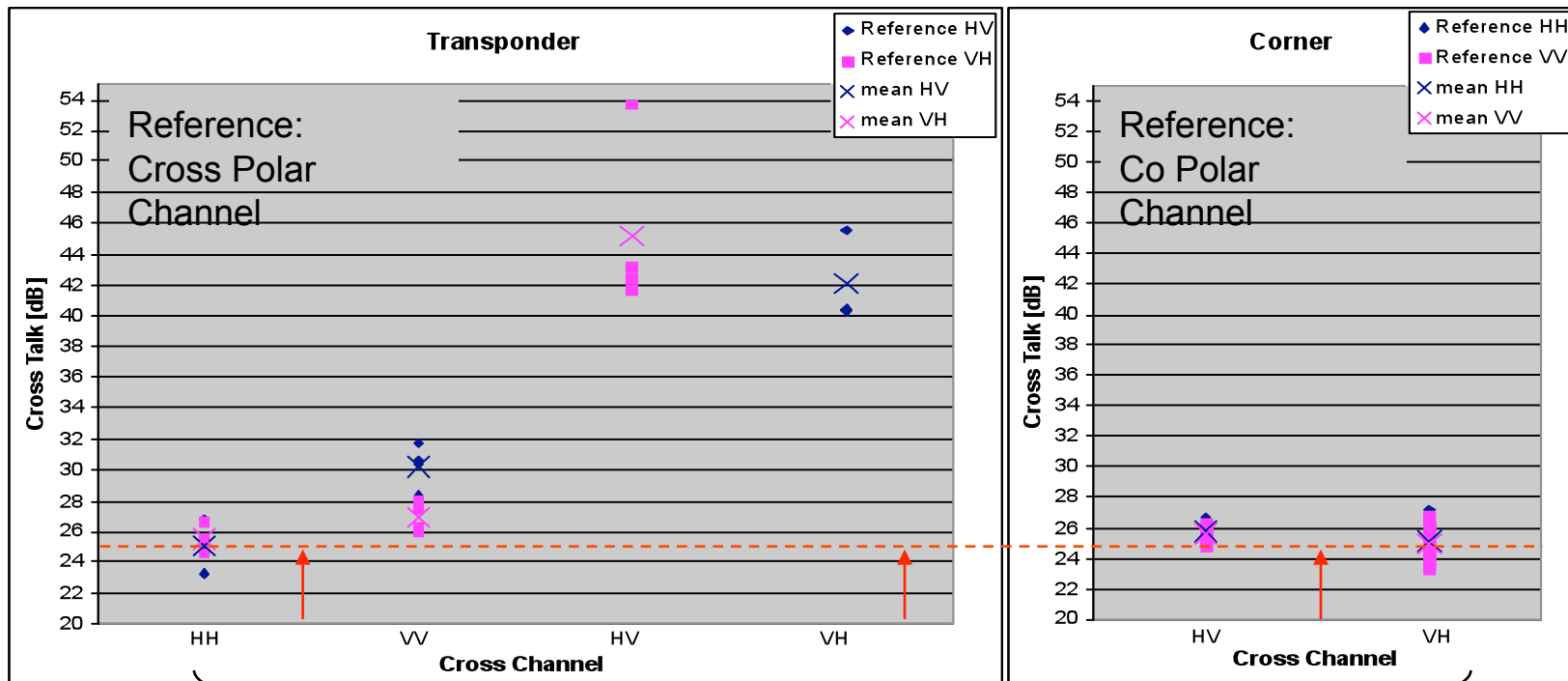
Measurement Accuracy

Co < $1.2 \text{ deg } (1\sigma)$
Cross < $3.1 \text{ deg } (1\sigma)$

➡ **Phase Imbalance only a few Degrees!**

Cross Polar Isolation

- Transponder in 0°/90°-constellation => Target for 1 Cross Polar Channel only
- Corner Reflectors for Co-Polar Channels
- Cross Talk derived from Impulse Response (SAR image)



Cross Polar Isolation

> 24.9
dB



Final Calibration Results of TerraSAR-X in DRA Mode

Antenna Model

✓ Gain / Phase Pattern $\leq \pm 0.2$ dB / 3.1 deg (1σ)

Channel Imbalance

✓ Phase Co (HH-VV) / Cross (HH-VH/HV) $< \pm 1.2$ deg / $< \pm 2.2$ deg

✓ Amplitude Co (HH-VV) / Cross (VH-HV) < 0.03 dB / < 0.26 dB

Cross Talk

✓ Co-Cross / Cross-Cross ≥ 24.9 dB / ≥ 42 dB

Radioemtric Accuracy

✓ Absolute Radiometric Accuracy 0.46 dB (3 years left)

⇒ **DRA is nearly as accurate as the nominal Modes**



Résumé

TerraSAR-X has been
not only a **precise**
but also **stable** SAR System since launch
and this
not only for **basic SAR products**
but also for **experimental** modes
like the **DRA mode**