New Approach for SAR Antenna Pointing Determination

Jens Reimann, Patrick Klenk, Marco Schwerdt, Manfred Zink

German Aerospace Center - DLR

Microwaves and Radar Institute

DLR

Introduction

- Antenna pointing calibration ensures a correctly aligned SAR antenna radiation pattern
  - **Azimuth Pointing**: for example using ground receiver measurements of an azimuth notch patterns
  - **Elevation Pointing**: gamma profile evaluation of notch patterns acquired over homogeneous distributed targets, like Amazon rain forest

Outline of the talk

1. **Azimuth:** Show results from pointing measurements using latest DLR transponders as ground receiver
2. **Elevation:** Introduce novel technique for pointing determination over non-homogeneous targets

I. AZIMUTH POINTING

DLR's remote controlled Reference Targets

- Deployed and successfully operated for Sentinel-1 since April 2014
- Being checked permanently
- Can be aligned for further spaceborne SAR missions

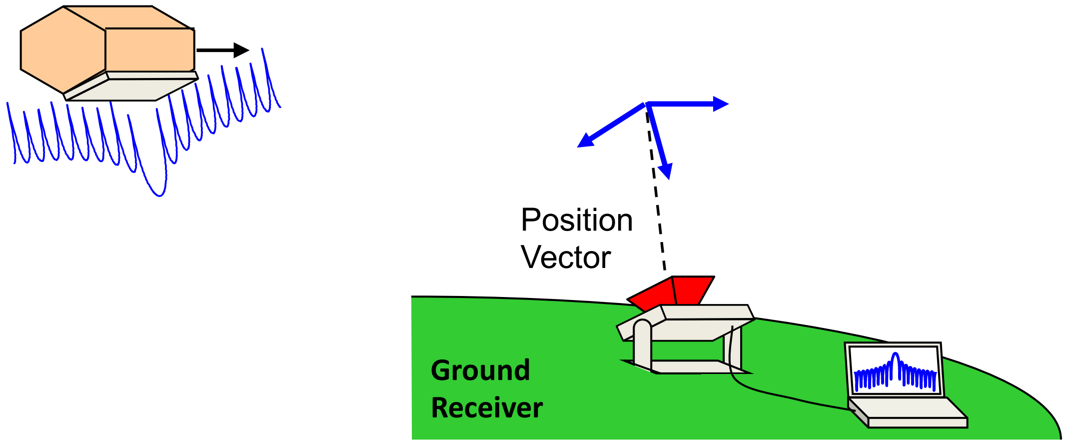
3 Corner Reflectors

- 2.8 m leg length => 49.2 dBm² RCS
- ≤ 1.0 mm mech. tolerance
- **0.2 dB (1σ) abs. rad. accuracy**

3 C-Band Transponders

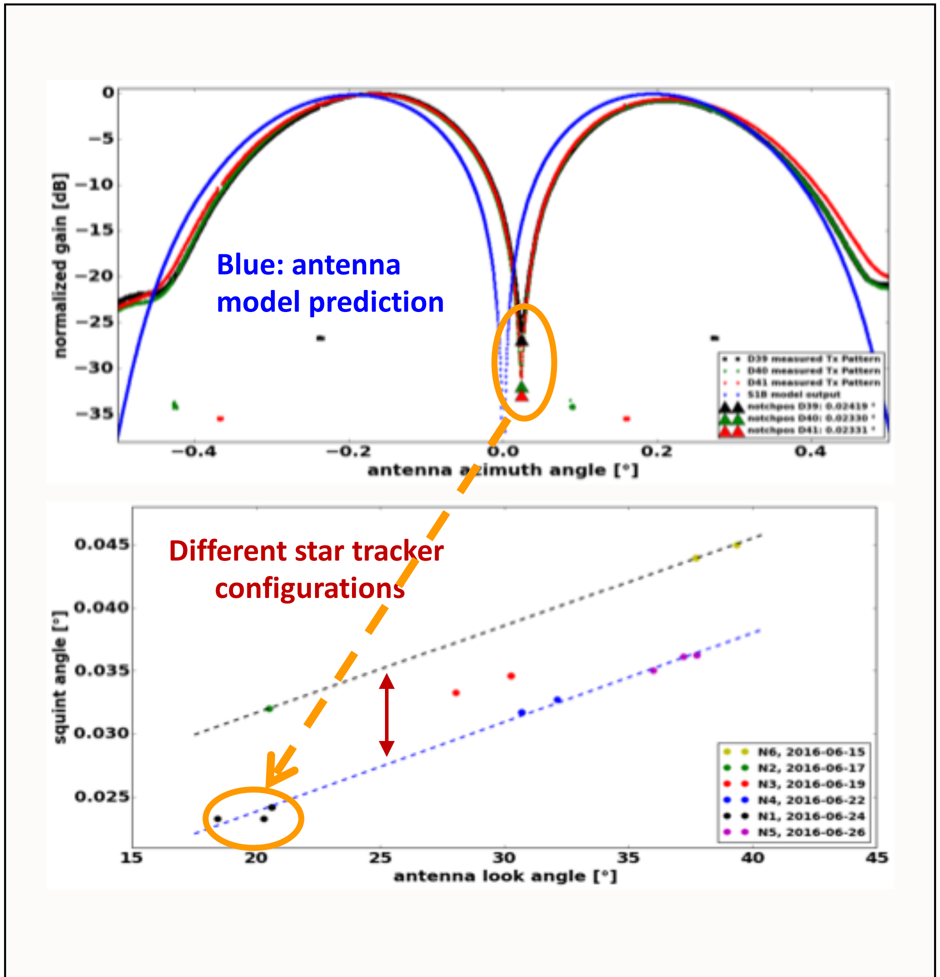
- 5.405 GHz, 100 MHz BW, 60 dBm² RCS
- ≤ 0.1 rad. stability
- **0.2 db (1σ) abs. rad. accuracy**

Ground Receiver Acquisition



- azimuth angles changes over time during satellite overpass
- tx power is constant but weighted by the antenna pattern
- azimuth cut through the antenna pattern can be recorded

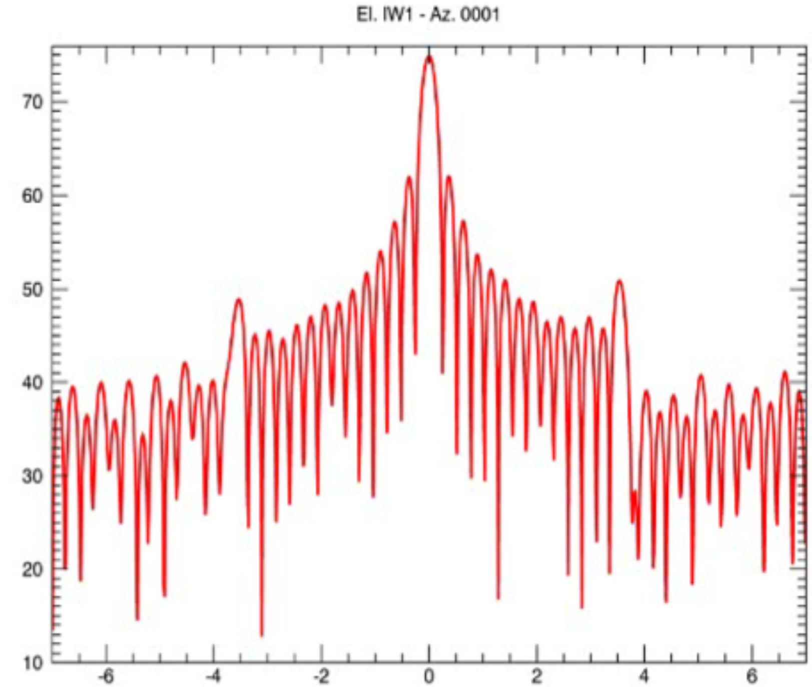
S1-B Azimuth Pointing Determination: Notch Pattern Evaluation



- Evaluation of transponder measured **azimuth notch patterns** for determining **antenna azimuth pointing**
- Very precise and efficient determination of azimuth pointing
- Elevation dependent azimuth squint indicates additional mispointing in pitch and yaw
- Based on stripmap notch acquisitions, but nominal acquisition baseline is IW

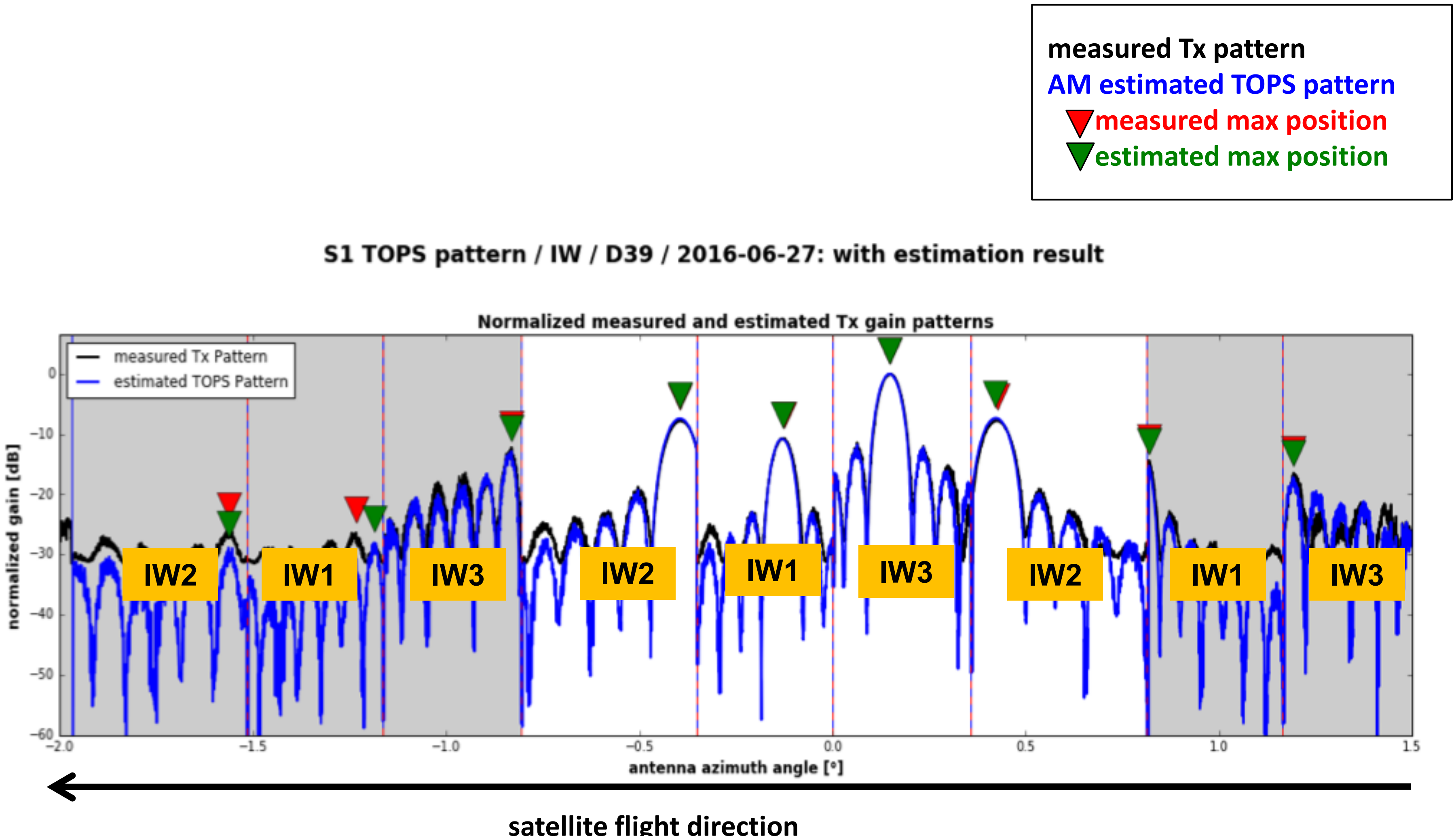
S1-AM Based Reconstruction of TOPS Mode Antenna Patterns

- In TOPS mode, several hundred beams switched for antenna steering in azimuth:
  - IW1: uses ABI 177…825
  - IW2: uses ABI 241…761
  - IW3: uses ABI 211…791
- high angular resolution of the steering in azimuth (0.002° steps)
- Measured TOPS pattern reconstructable based on accurate knowledge of:
  - image geometry
  - antenna excitation coefficients
  - sequence of steered azimuth and scanned elevation beams
  - correct timing synchronization of the data



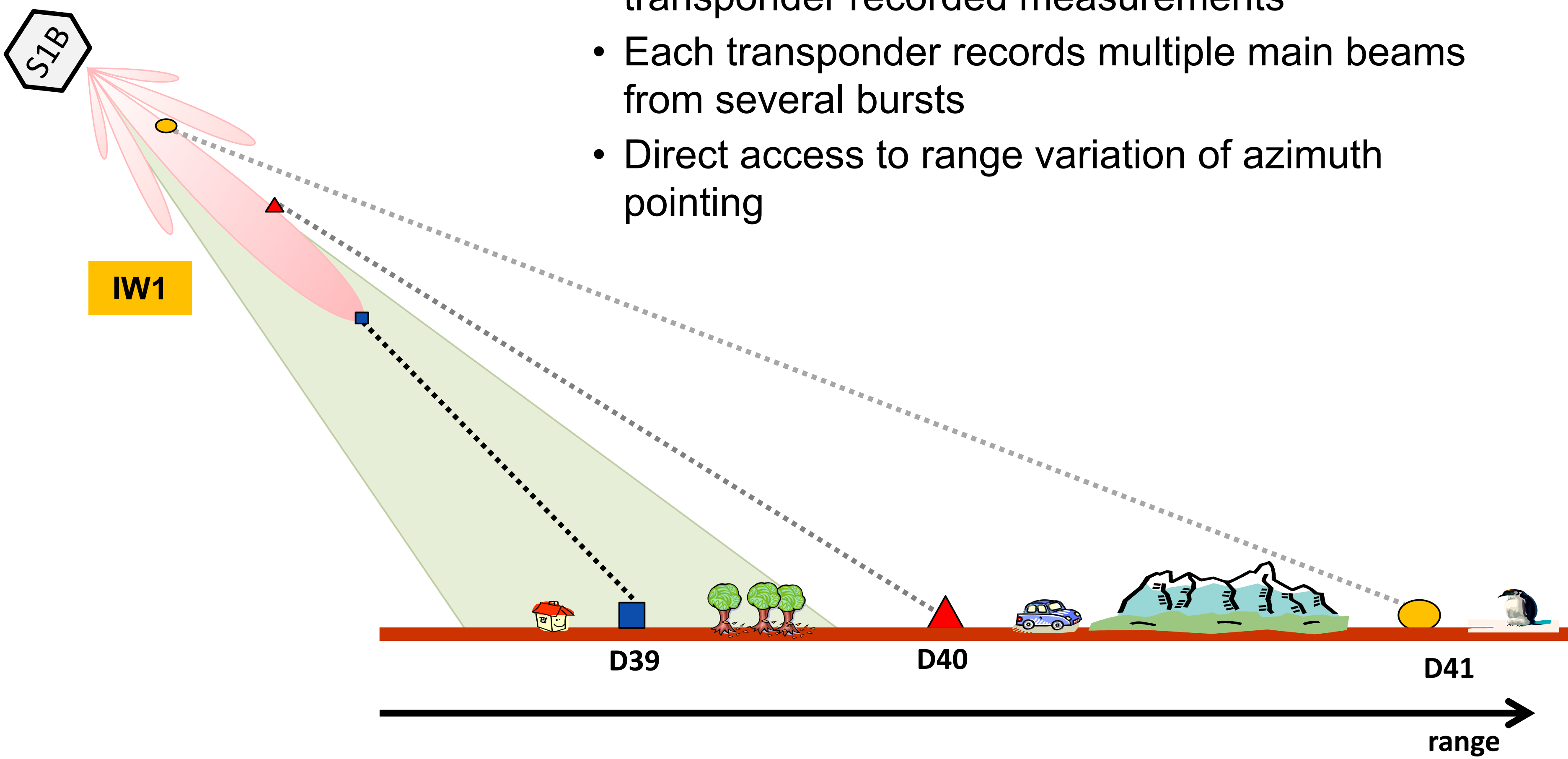
S1 AM calculated elementary beams for IW1

S1-B – IW: D39 measured example with reconstructed pattern



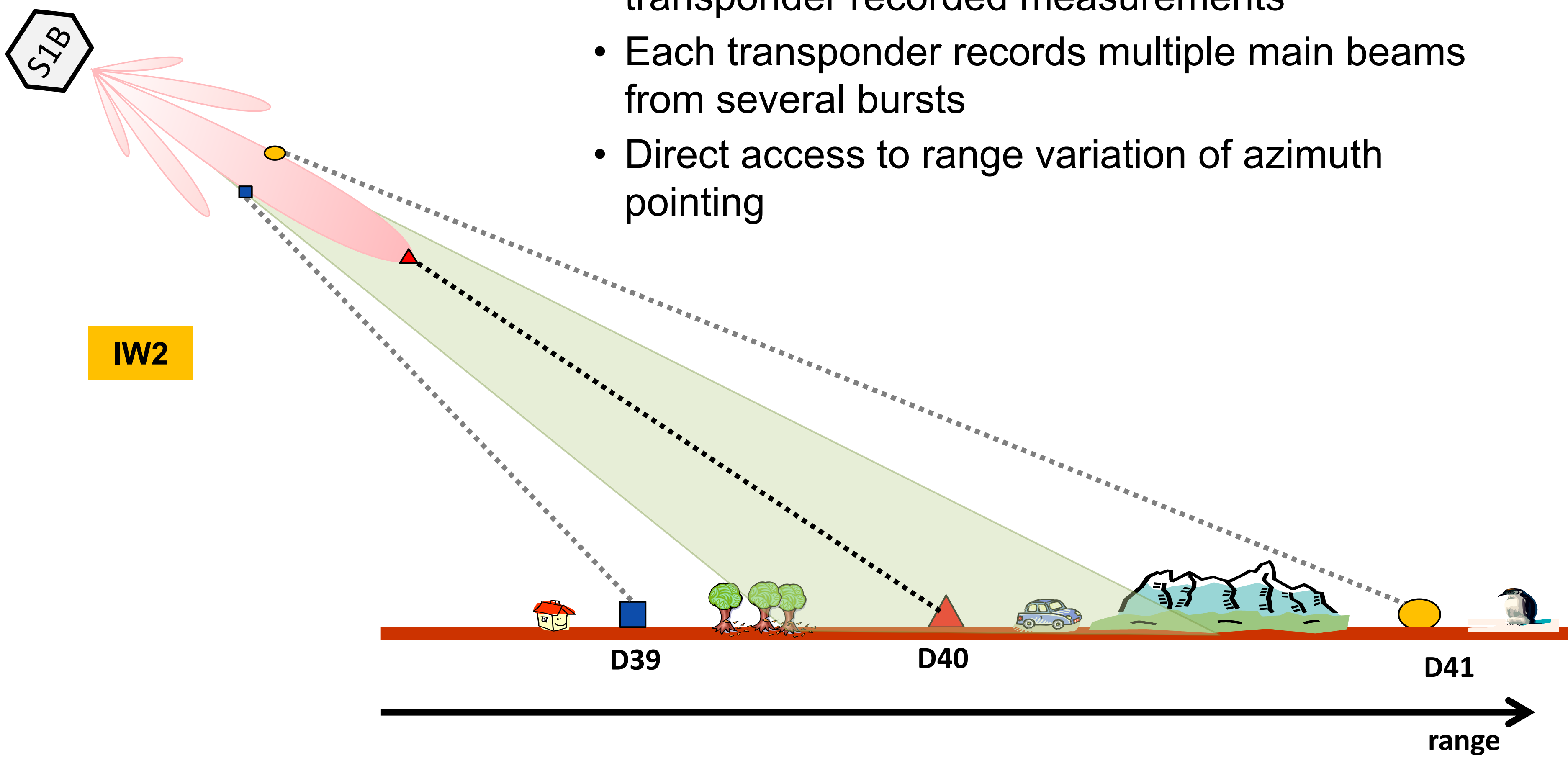
Overview of S1-B IW data acquisition over DLR transponders

- IW: One sequence of bursts ideally yields 3x3 transponder recorded measurements
- Each transponder records multiple main beams from several bursts
- Direct access to range variation of azimuth pointing



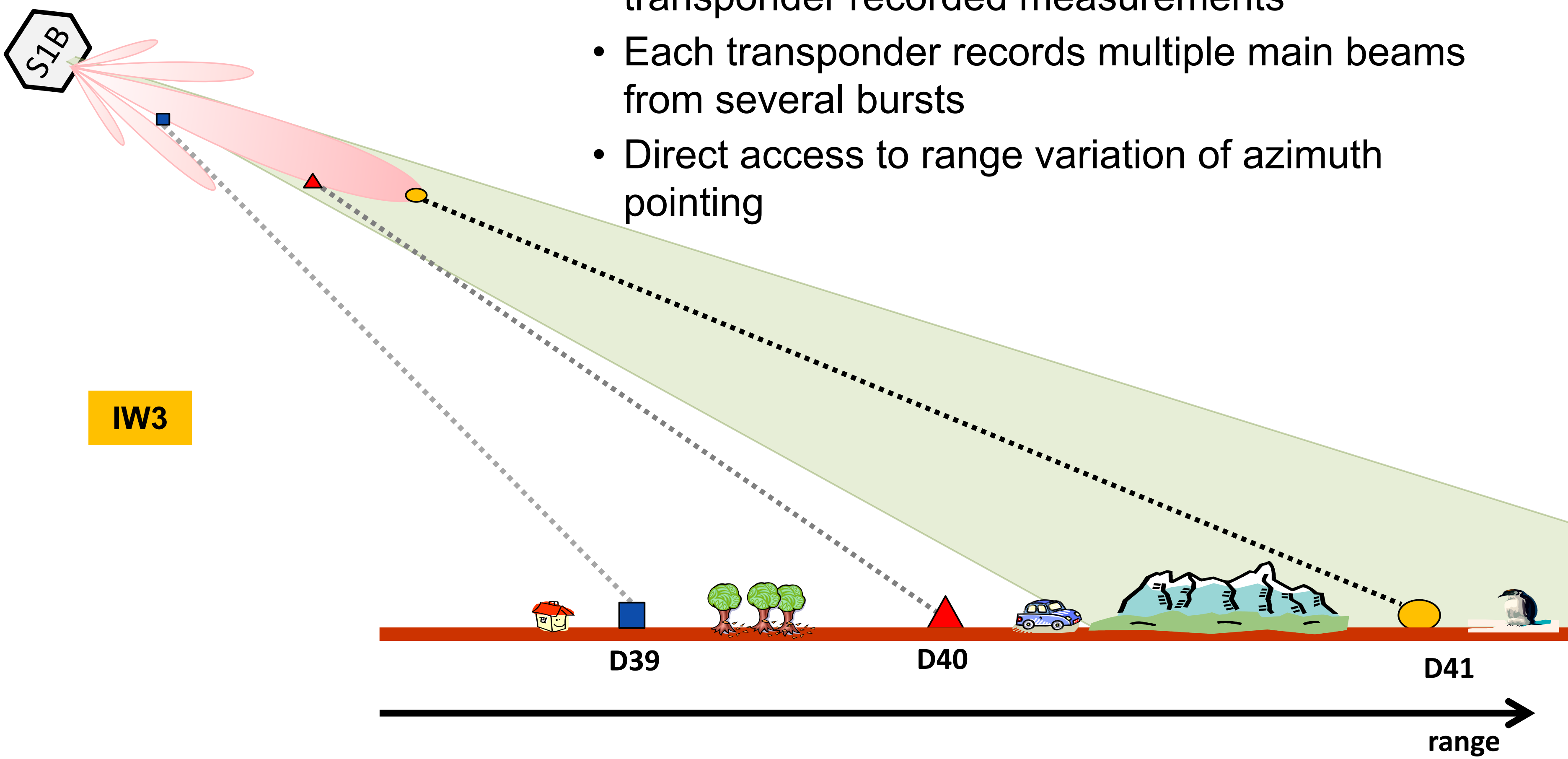
Overview of S1-B IW data acquisition over DLR transponders

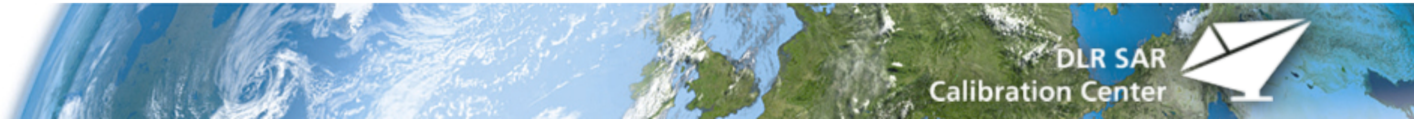
- IW: One sequence of bursts ideally yields 3x3 transponder recorded measurements
- Each transponder records multiple main beams from several bursts
- Direct access to range variation of azimuth pointing



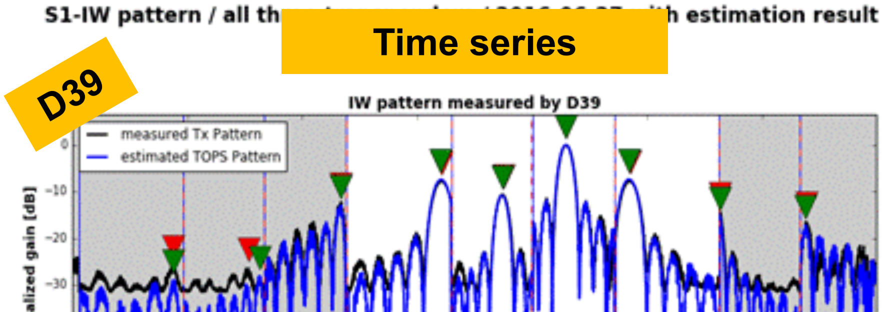
Overview of S1-B IW data acquisition over DLR transponders

- IW: One sequence of bursts ideally yields 3x3 transponder recorded measurements
- Each transponder records multiple main beams from several bursts
- Direct access to range variation of azimuth pointing

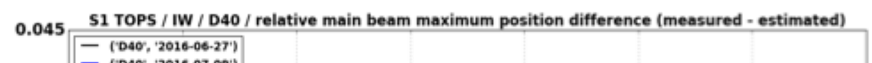




S1-B: IW-Mode Main Beam Positions: Measured - Estimated

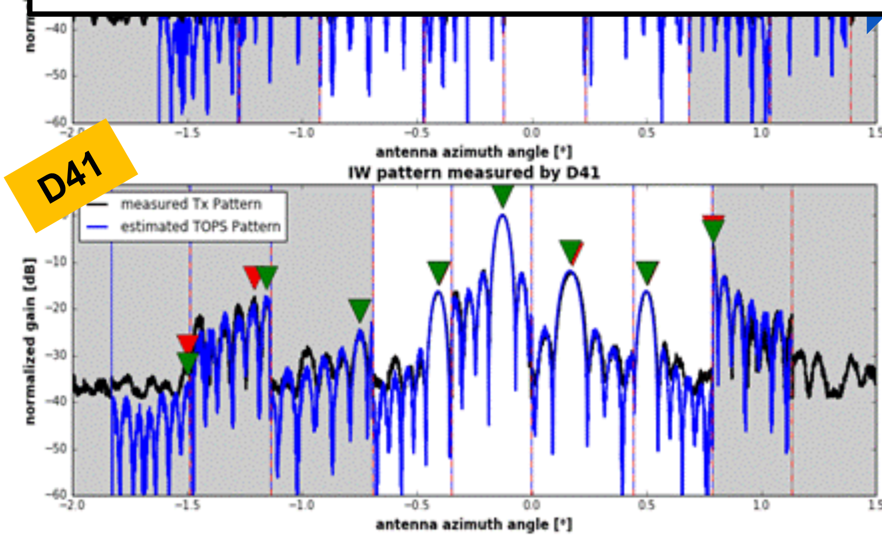


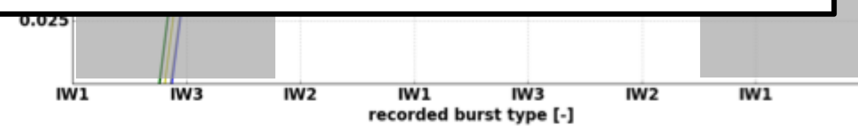
Differently colored lines: time series recorded between 2016-06-27 and 2016-10-01



Summary

- TOPS-based derivation of the elevation dependency of an azimuth squint feasible
- S1B: No significant pointing difference between aft- and forward pointing beams
- S1B: Temporal trend visible but more statistics needed to reach intended accuracy

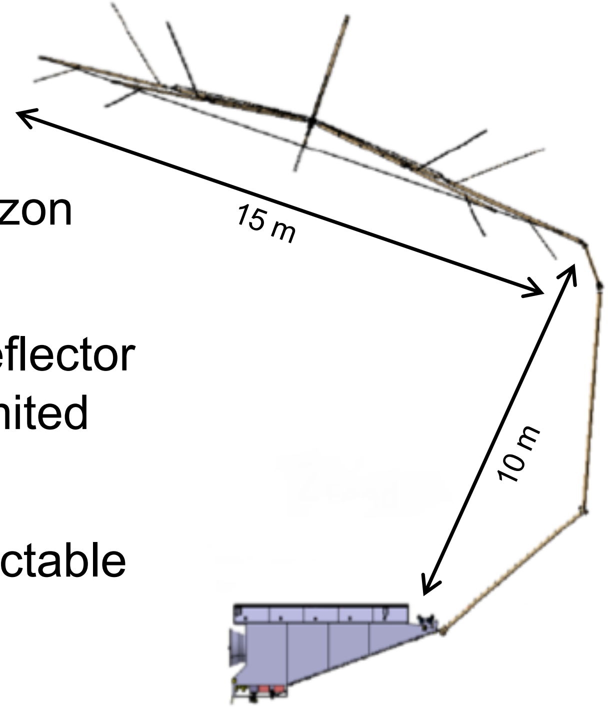




- For this acquisition geometry, each transponder measures main beam position for four different bursts

II. ELEVATION POINTING

Novel approach for Tandem-L: Continuous notch monitoring



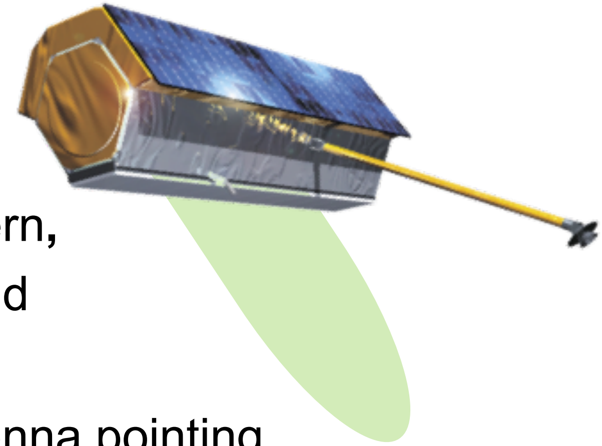
- Elevation pointing traditionally performed over homogenous distributed targets (such as the Amazon Rainforest) using the steep null in a notch-pattern
- Upcoming SAR missions using large deployable reflector antennas have no fixed antenna pointing due to limited stiffness of the huge structure
- Drawback: Intra-orbit pointing changes hardly detectable

Approach

Analyze the use of **inhomogeneous areas** for elevation notch based pointing determination

- Use of notch beam and a boresight beam
- Phase coherent pattern detection

Test of Continuous Notch Monitoring



Technique was verified using **TerraSAR-X**:

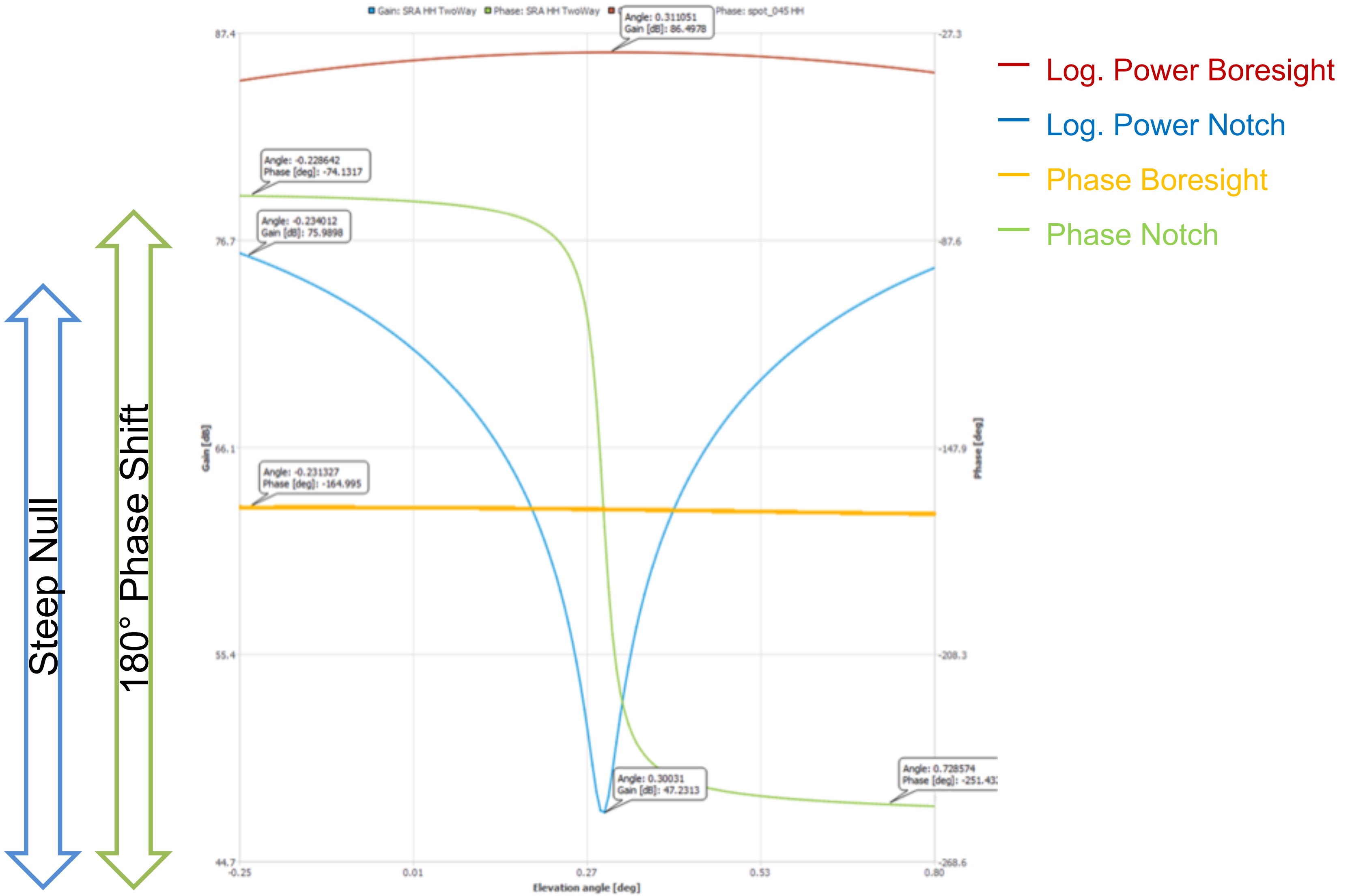
- two independent images generated by **pulse-to-pulse switching** of antenna pattern**,** alternatingly receiving nominal boresight and notch beam
- image difference analysis to derive the antenna pointing

➢ Drawback: required **high PRF** causes **small swath width** and/or notable ambiguities

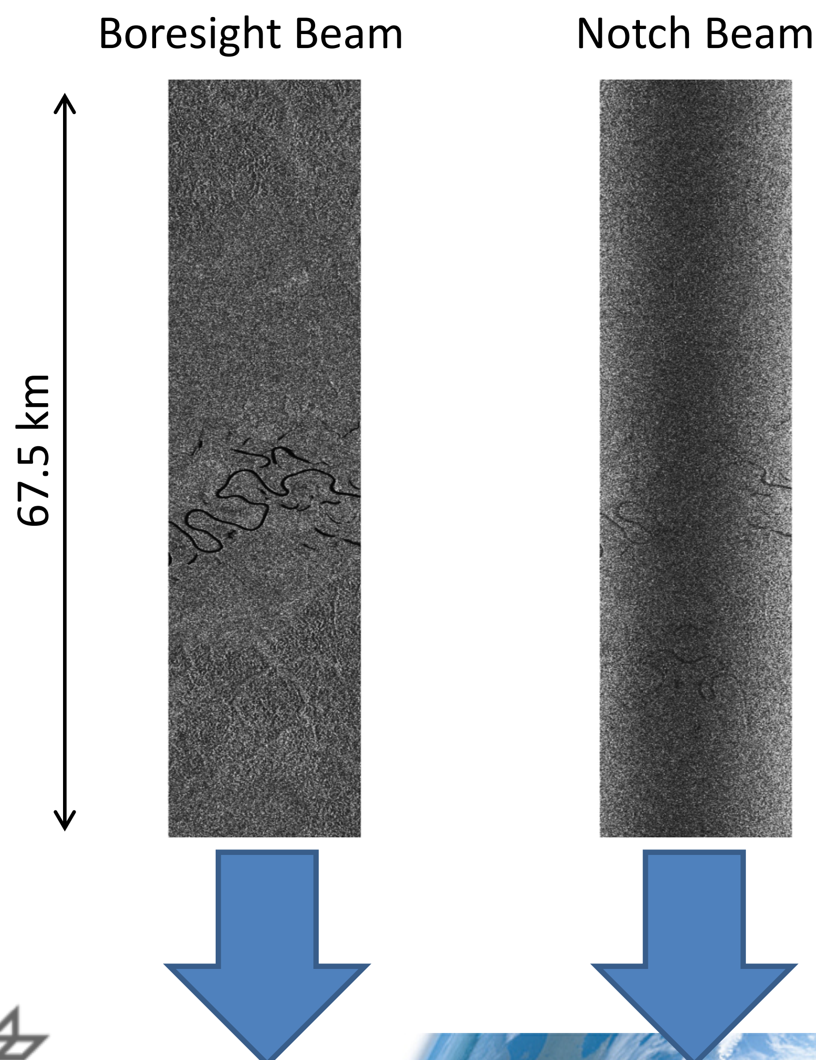
Goal for Tandem-L

- Use of digital beamforming (DBF) to simultaneously acquire boresight and notch beams
- No degradation of swath width

TerraSAR-X modeled antenna pattern: Boresight vs. Notch

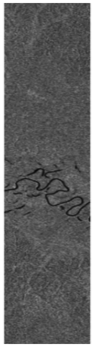


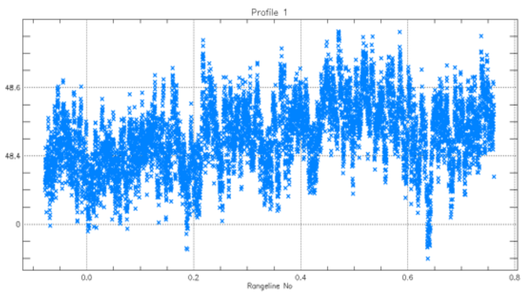
First results Permanent Notch Monitoring: Rainforest I

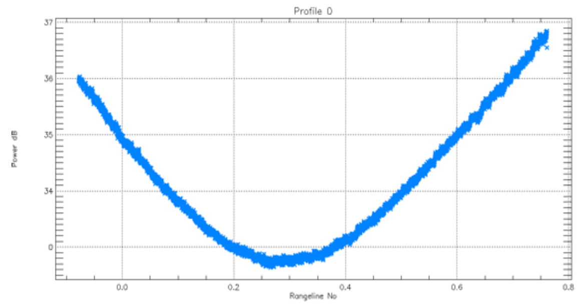


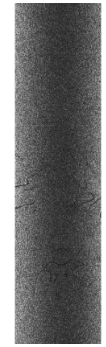
- First example: **Amazon Rainforest**
  - Rather homogeneous rainforest scene
  - No explicit masking of river features / topography / potentially deforested areas

First results Permanent Notch Monitoring: Rainforest II









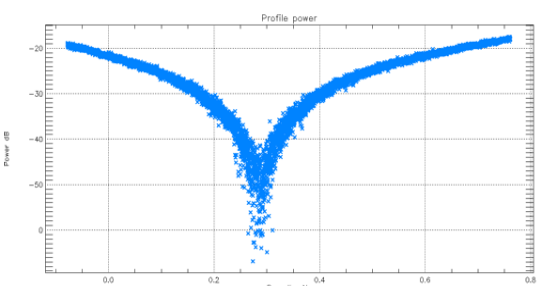
Boresight Beam

azimuth averaged power profile / dynamics: 0.5 dB

Notch Beam

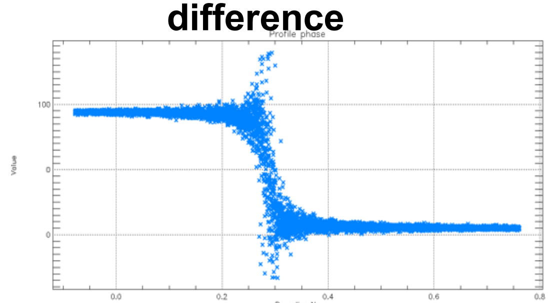
azimuth averaged power profile / dynamics: 4.0 dB

difference log power



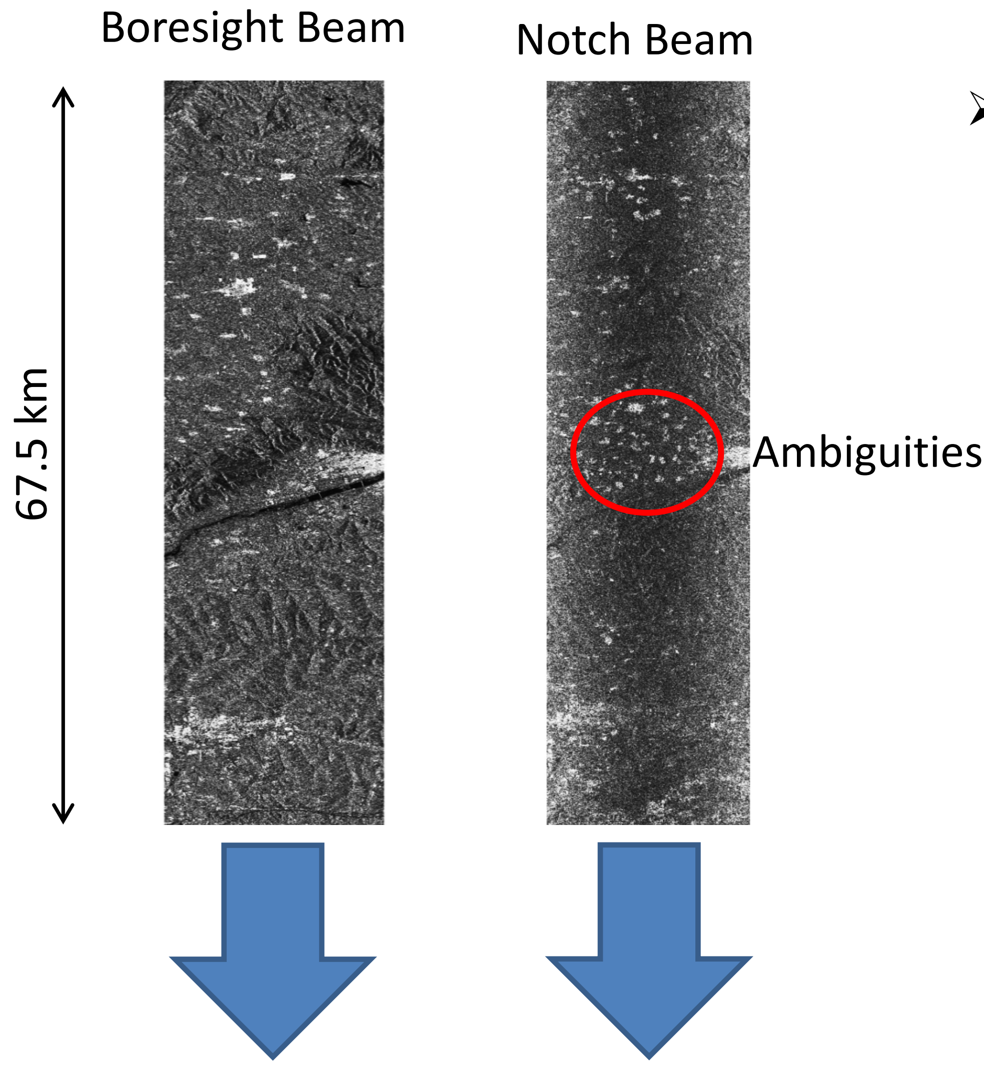
dynamics: >30 dB

phase difference



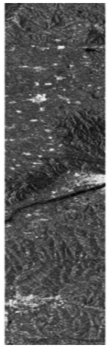
- complex subtraction of SLC images
- azimuth averaging

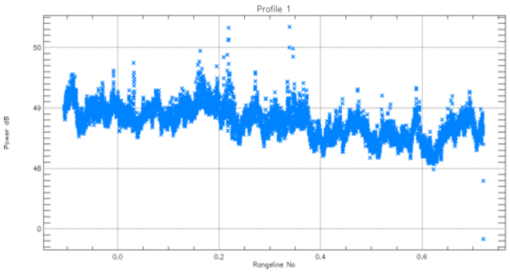
First results Permanent Notch Monitoring: China I

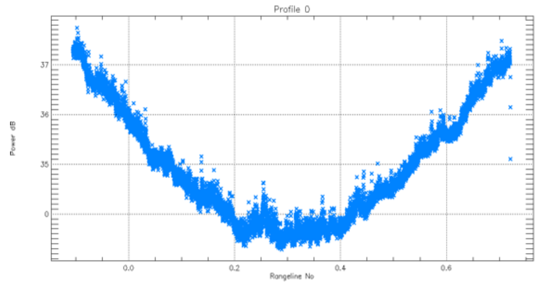


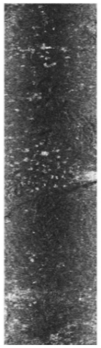
- second example: **inhomogeneous area**
  - North-Central China, Henan-Province
  - Ambiguities due to non-optimized TSX antenna patterns for this acquisition mode (experimental dataset…)

First results Permanent Notch Monitoring: China II









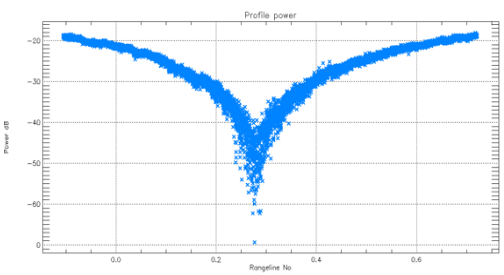
Boresight Beam

azimuth averaged power profile / dynamics: 1.5 dB

Notch Beam

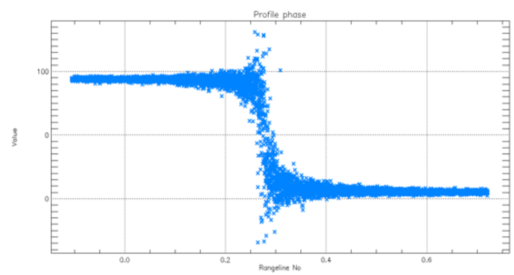
azimuth averaged power profile / dynamics: 4.0 dB

difference log power



dynamics: >30 dB

phase difference



- complex subtraction of SLC images
- azimuth averaging
- **Notch position can be determined equally well**

Conclusions

Azimuth Pointing

TOPS based analysis of antenna pointing using ground receiver:

- feasible for regular monitoring of azimuth pointing
- more data with larger variance available

Elevation Pointing

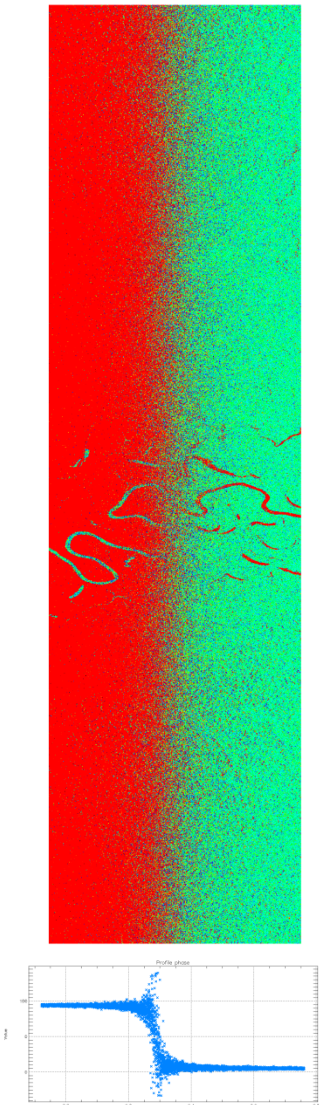
Differential analysis of concurrent boresight and notch beam acquisitions:

elevation pointing monitoring over non-homogeneous areas feasible

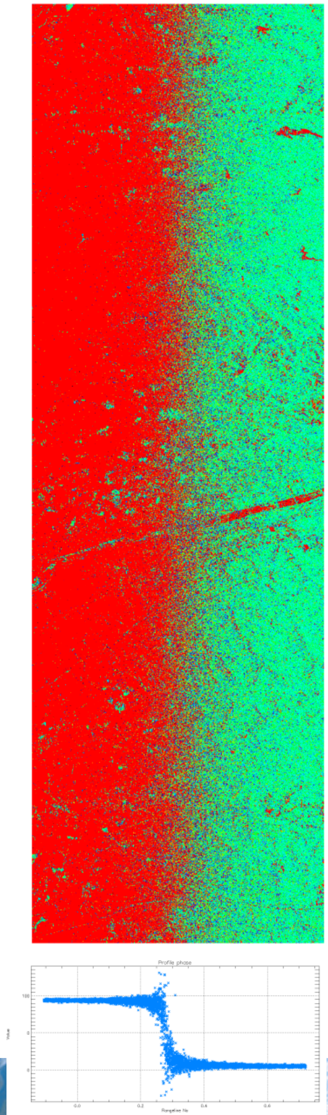
applicable for continuous pointing monitoring for future DBF based missions

First Results: Summary

Rainforest



China 1



China 2