An Internal Calibration System Model for the Estimation of SAR Instrument Errors

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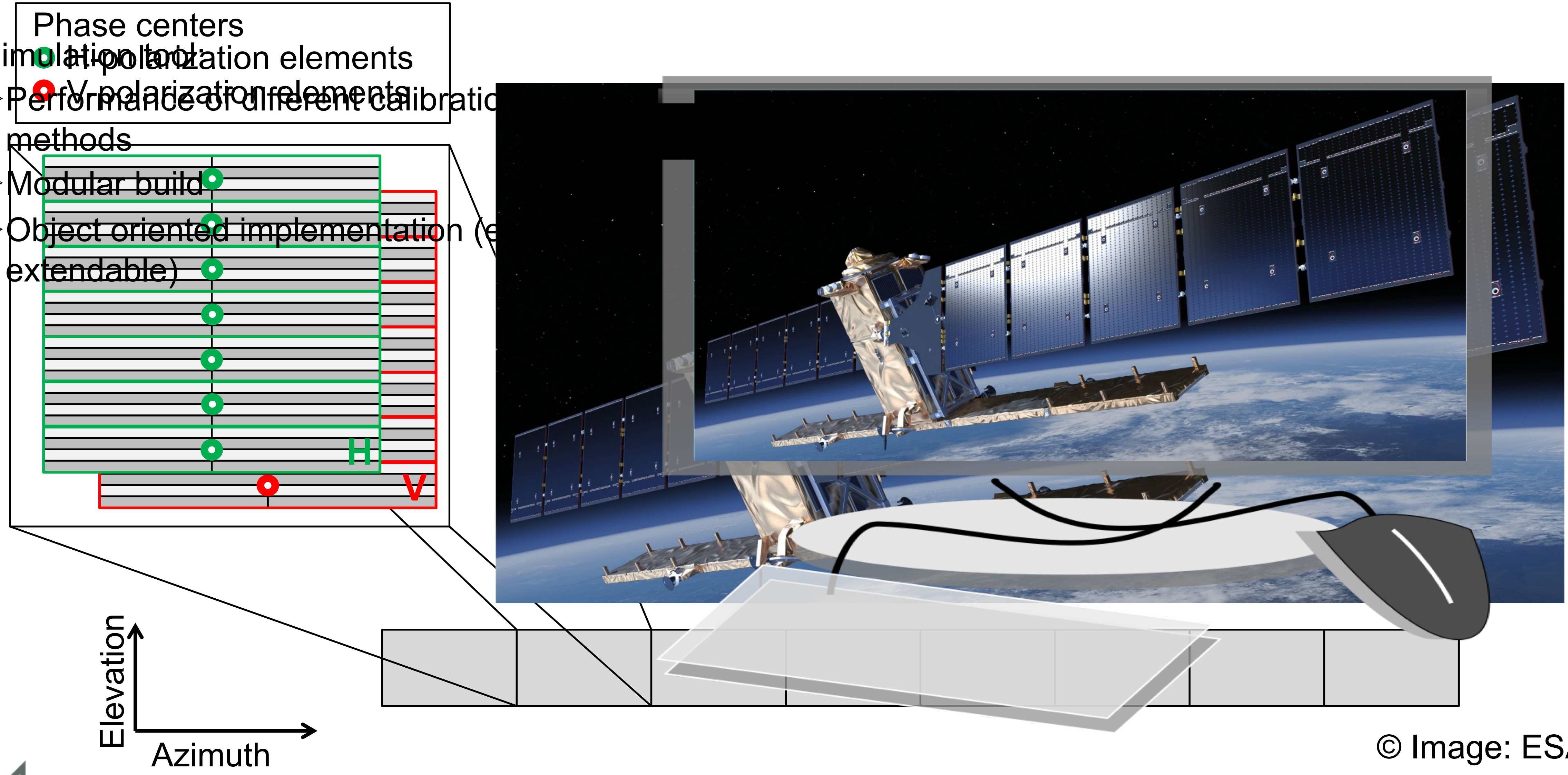
Future Systems

Simulation tool:

- Performance of different calibratio methods
- Modular build
- Object oriented implementation (e extendable)



Scan-On-Receive (SCORE)

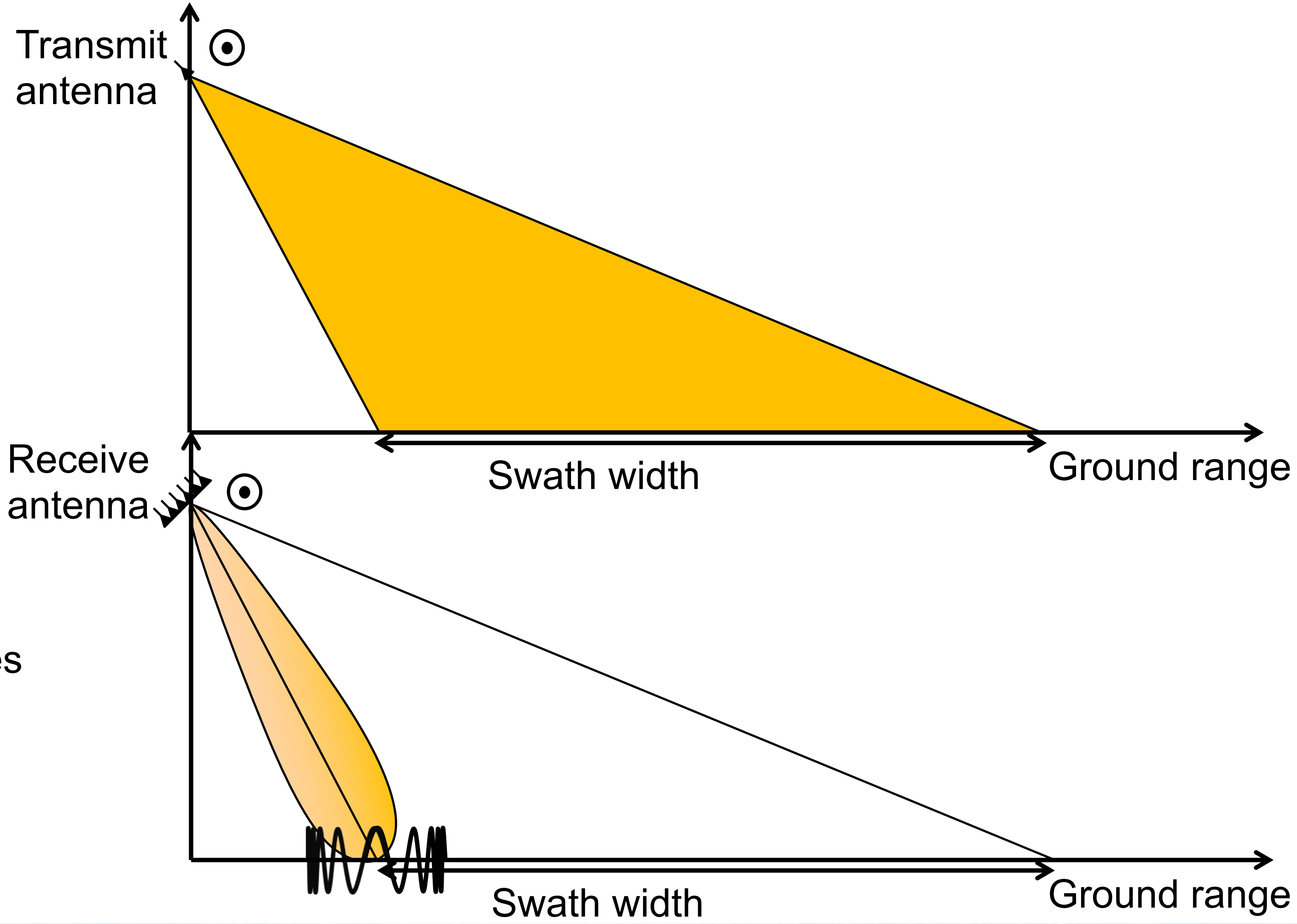
Transmit:

- ➢Transmitter illuminates the whole swath

Receive:

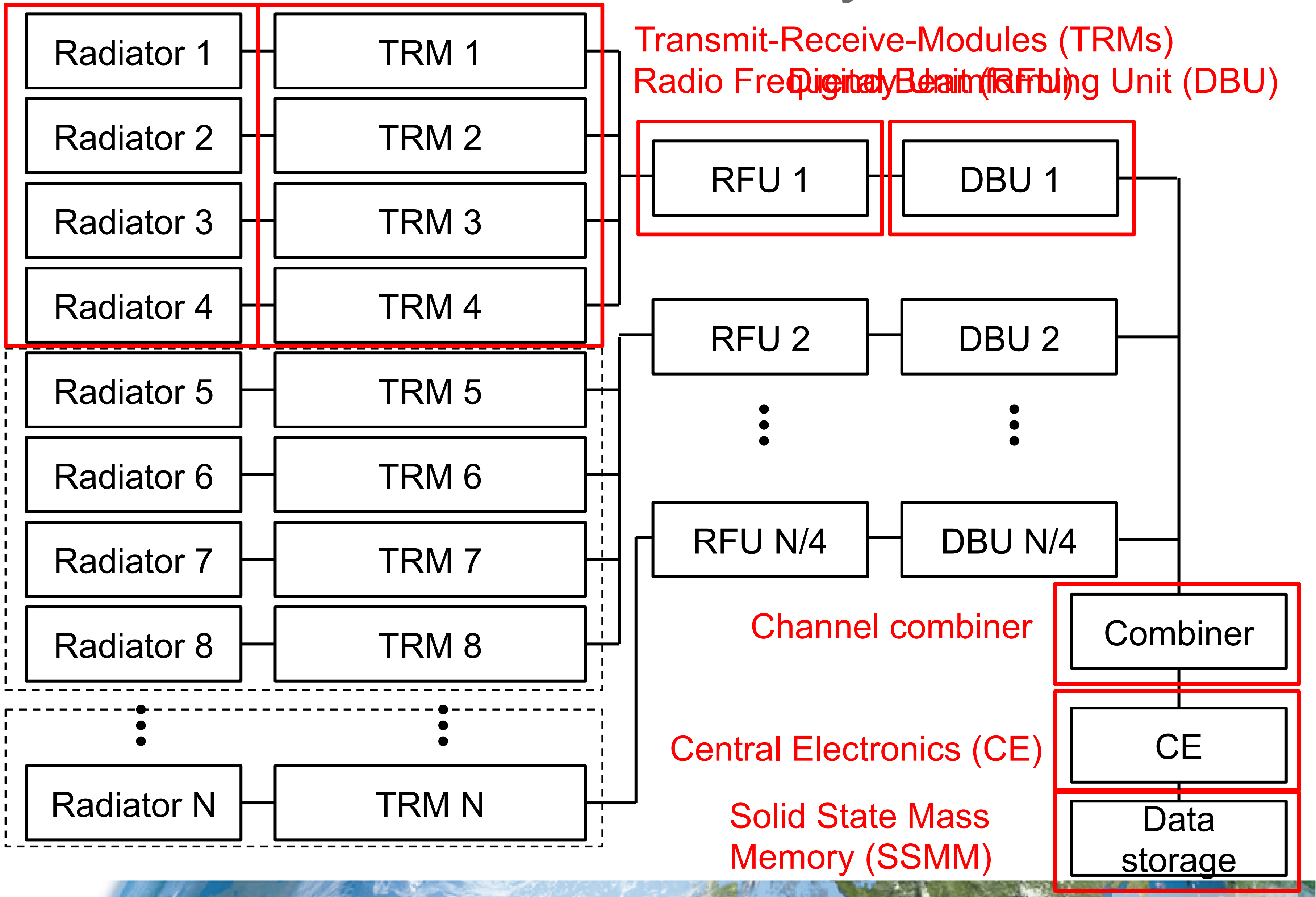
- ➢Narrow receive beam
- ➢Digital beamforming steers beam to signal on ground
- ➢Advantages:
  - High resolution, wide swath
  - Improved Signal-to-Noise Ratio (SNR)
  - Suppression of range ambiguities

Done on-board



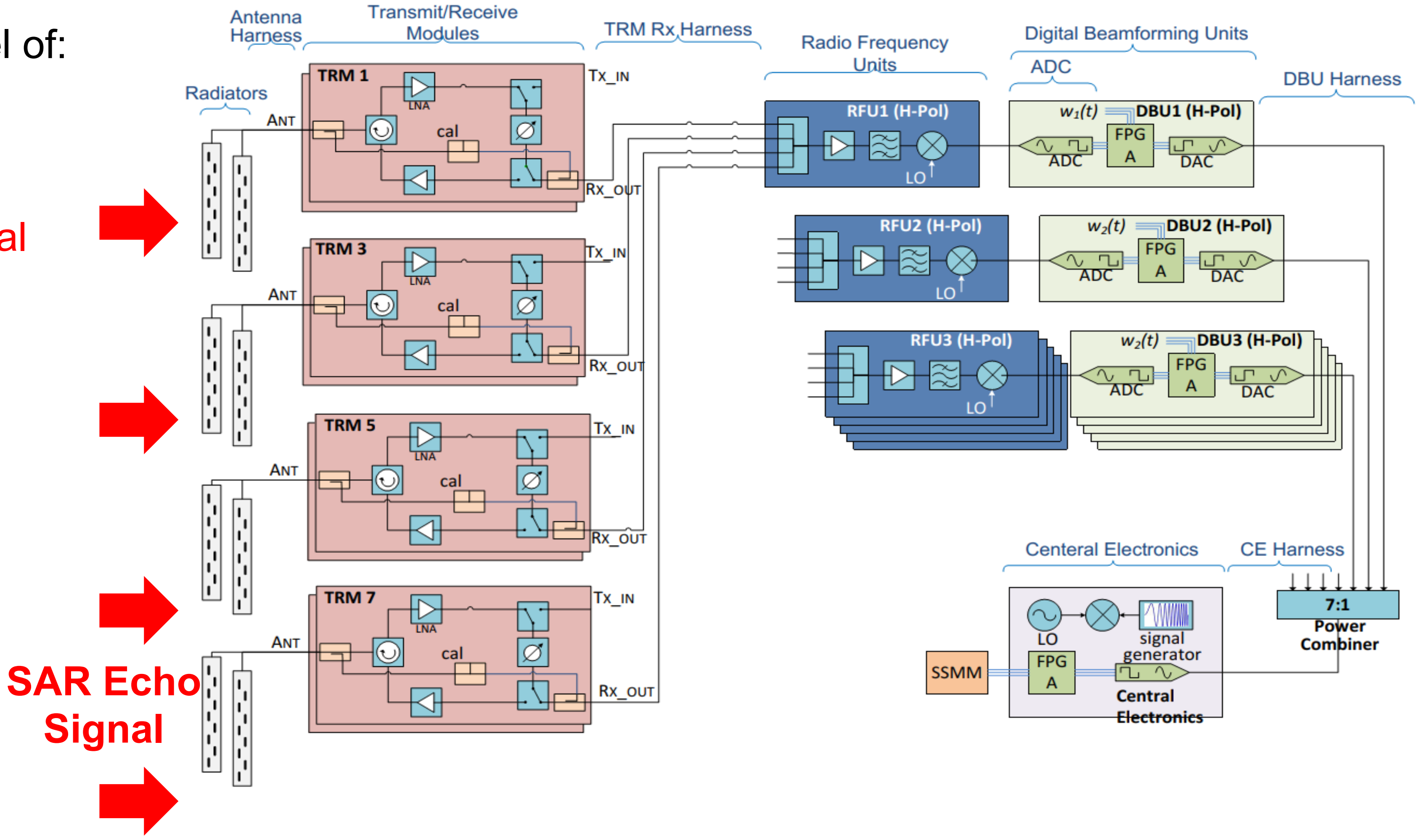
One Azimuth Channel Of A Multi-Channel SAR System

- Transmit-Receive-Module (TRM)
- Radio Frequency Unit (RFU)
- Digital Beamforming Unit (DBU)
- Combination of elevation channels



System Model

- Mathematical model of:
  - Signals
  - System
  - Errors
  - SAR echo signal

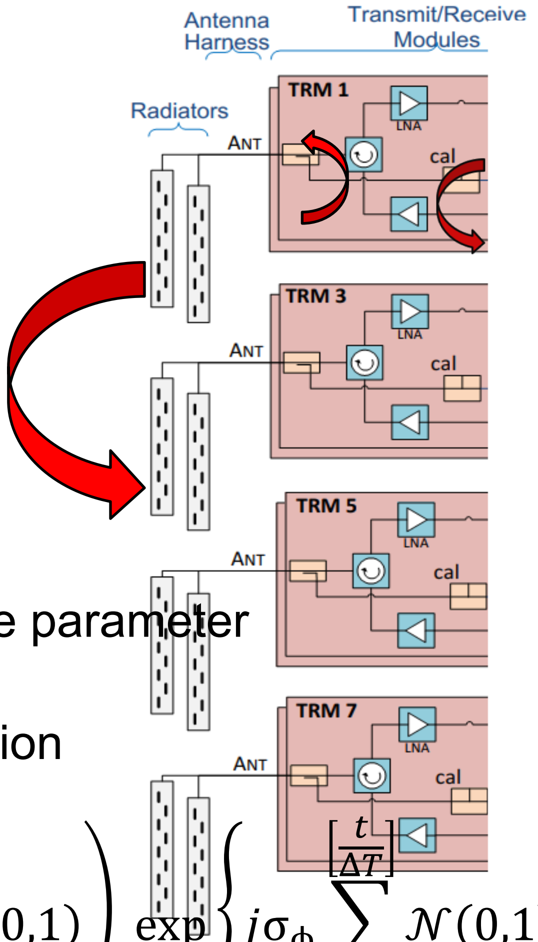


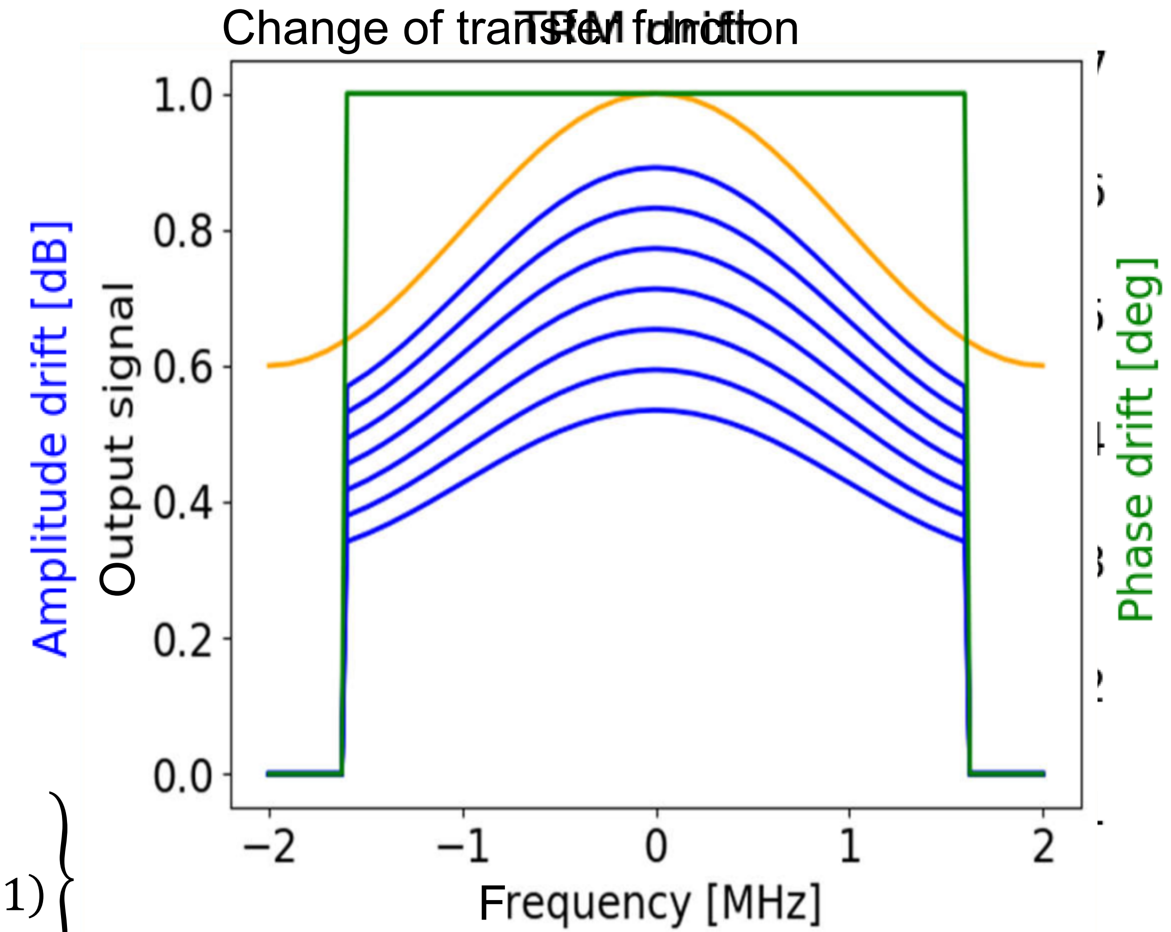
Error Sources

- Coupling
  - Antenna elements
  - Signal paths
- Temperature drift
- Random walk
- Transfer function drift
- Noise

RW = random walk
t = time
$\sigma_A; \sigma_\phi$ = amplitude, phase parameter
ΔT = time step
$\mathcal{N}(\mu, \sigma)$ = normal distribution

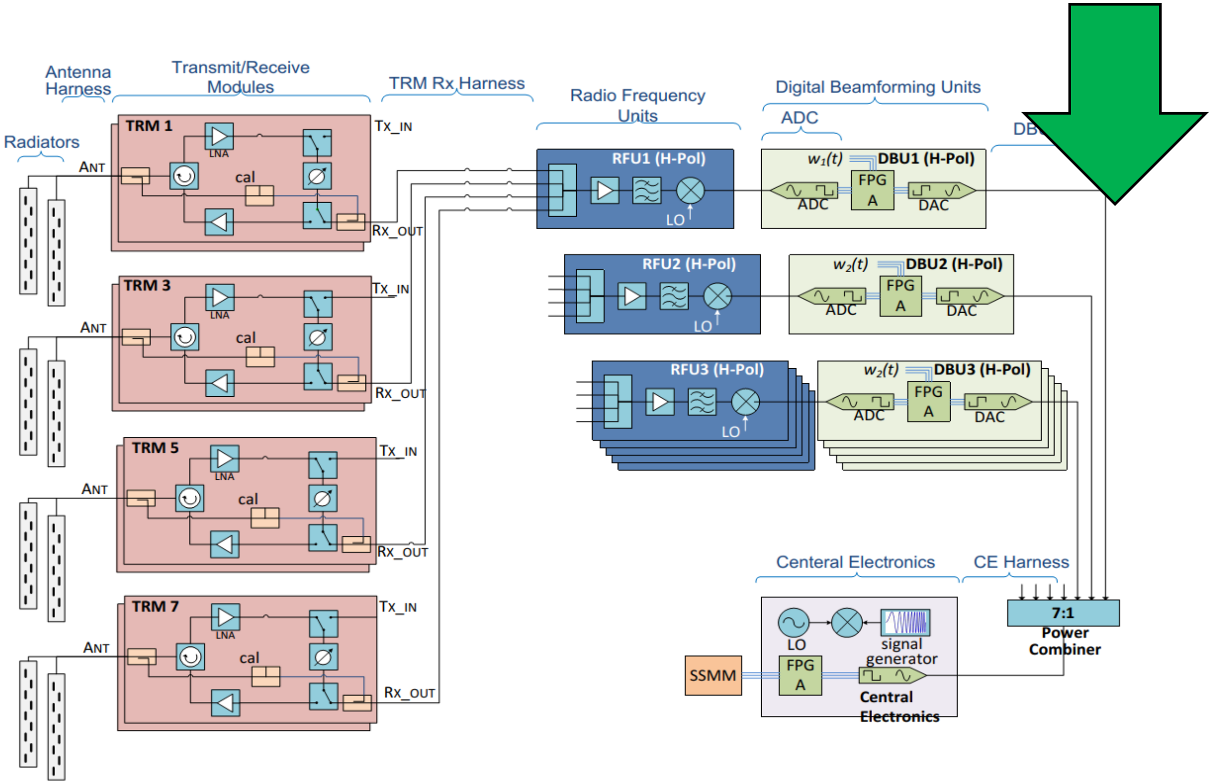
$$RW(t) = \left(1 + \sigma_A \sum_{i=0}^{\left[\frac{t}{\Delta T}\right]} \mathcal{N}(0,1)\right) \exp\left\{j\sigma_\phi \sum_{i=0}^{\left[\frac{t}{\Delta T}\right]} \mathcal{N}(0,1)\right\}$$

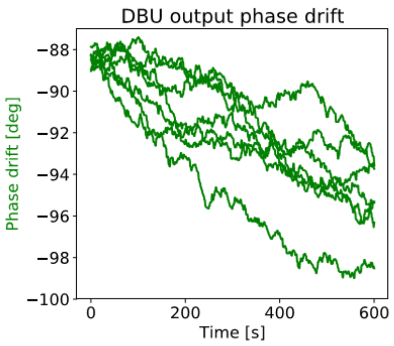




Total Error

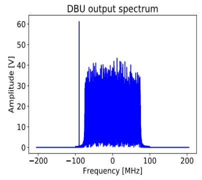
- ➢Different element parameters

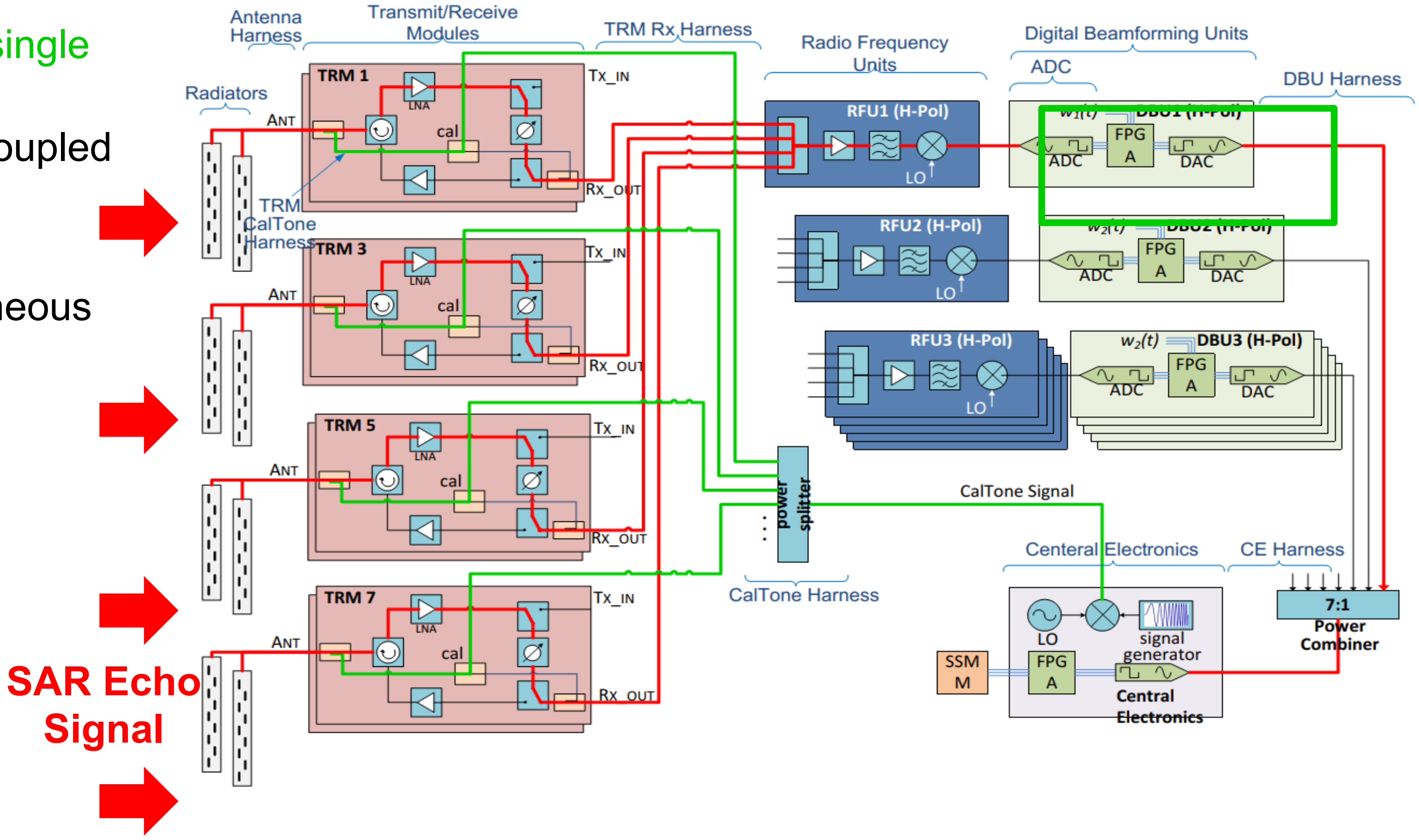




CalTone Calibration Concept

- Calibration signal (single tone signal)
- Calibration signal coupled to TRM
- Evaluation at DBU
- Calibration simultaneous to SAR operation





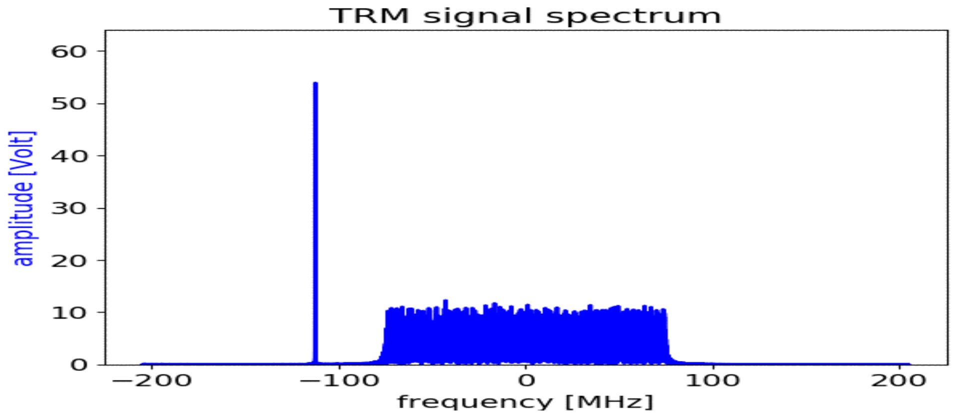
Calibration signal sequence

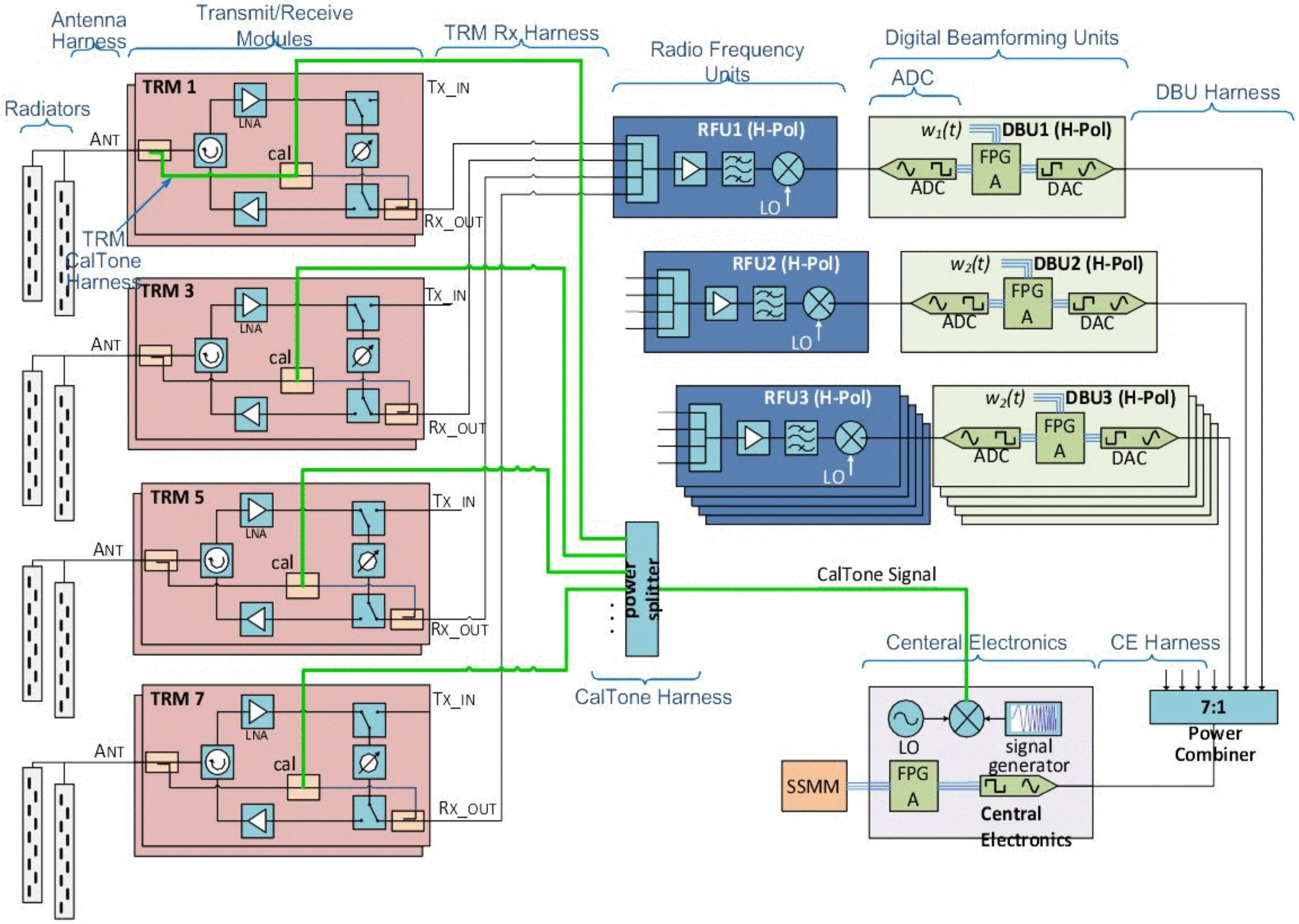
Sequence modes:

- 1 of N: calibration signal sequentially coupled to one element

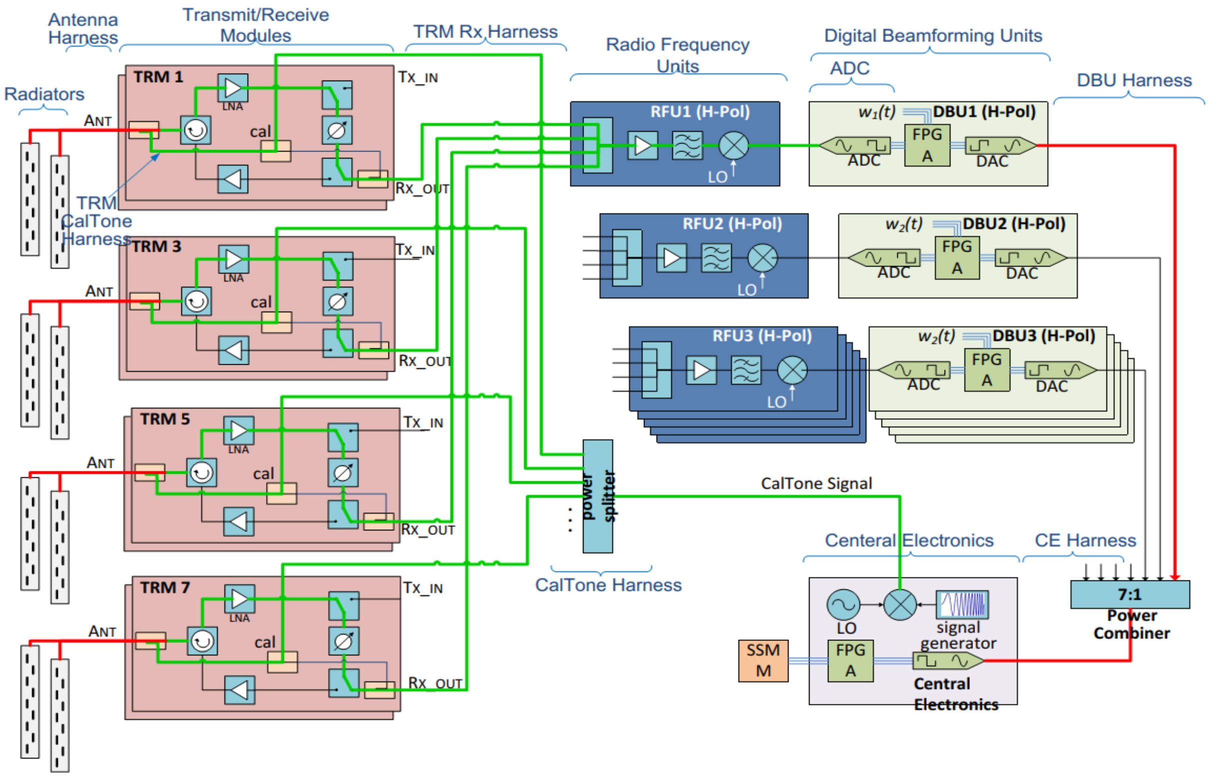
Calibration signal frequency:

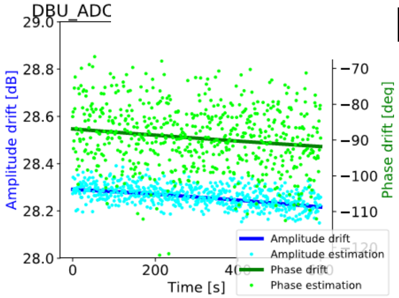
- Fixed frequency
- Frequency stepping





Estimation Of The Drift

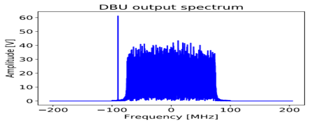




DBU output drift

kf)

section,



- ➢Accuracy of estimation depends on f_1
- ➢Estimate drift in elements passed by calibration signal

RX Drift Estimation Error

- Measured drift:

$$D_{DBU}(t_{slow}, f_1) = \frac{S_{DBU}(t_{slow}, f_1) S_{ct}^*(f|f_1)}{|S_{ct}(f|f_1)|^2}$$

$$= \frac{H[S_{RX}(t_{slow}, f_1) + S_{ct}(f|f_1)]\, S_{ct}^*(f|f_1)}{|S_{ct}(f|f_1)|^2} + N$$

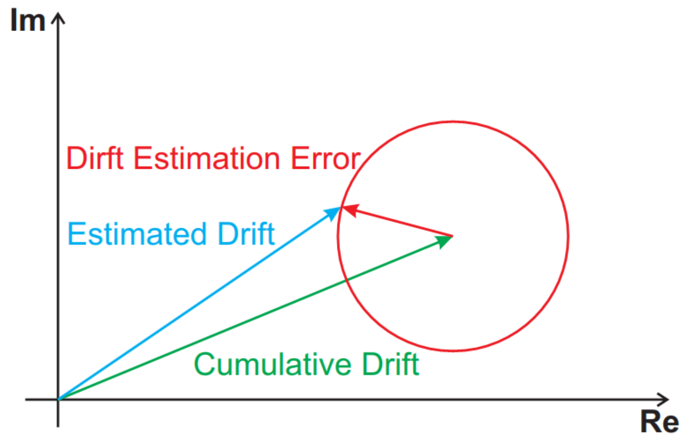
SAR echo signal

Noise

$$= H + \frac{H\, S_{RX}(t_{slow}, f_1)}{S_{ct}(f|f_1)} + N$$

Wanted

Error

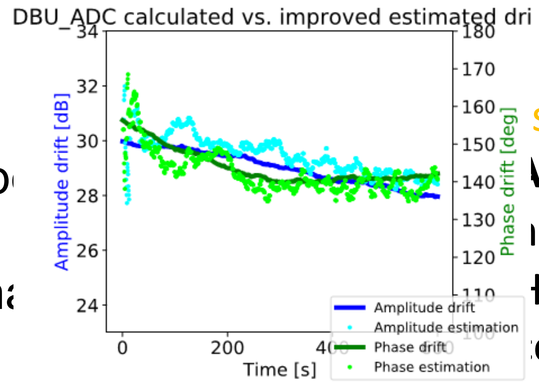


- SAR echo signal is zero mean signal
- Drift estimation is uniformly distributed around true drift
- Improve drift estimation using multiple previous values

Comparison Of Improved Estimation Methods

Estimation methods:

➢Moving average
- Performance dep
  variation/sample
- Low computationa
  complexity
- No real prediction possible



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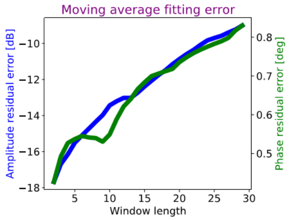
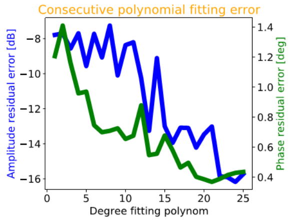
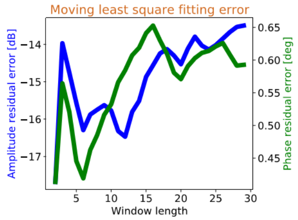
ll previous samples
eeded
igh computational
omplexity
Good prediction possible

➢Moving linear fit
Low computational complexity
Limited prediction possibilities (linear)







Summary

- ➢Mathematical model developed
- ➢Simulation tool implemented
    - Aid system design
    - Adaptable to any multi-channel instrument
    - Different calibration methods
    - Determine the errors and residual errors
    - Performance analysis
- ➢Single tone calibration analysis
- ➢Investigated drift estimation methods