MUSAR:
A Multibeam Opportunistic SAR System

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3. Exact focusing processing
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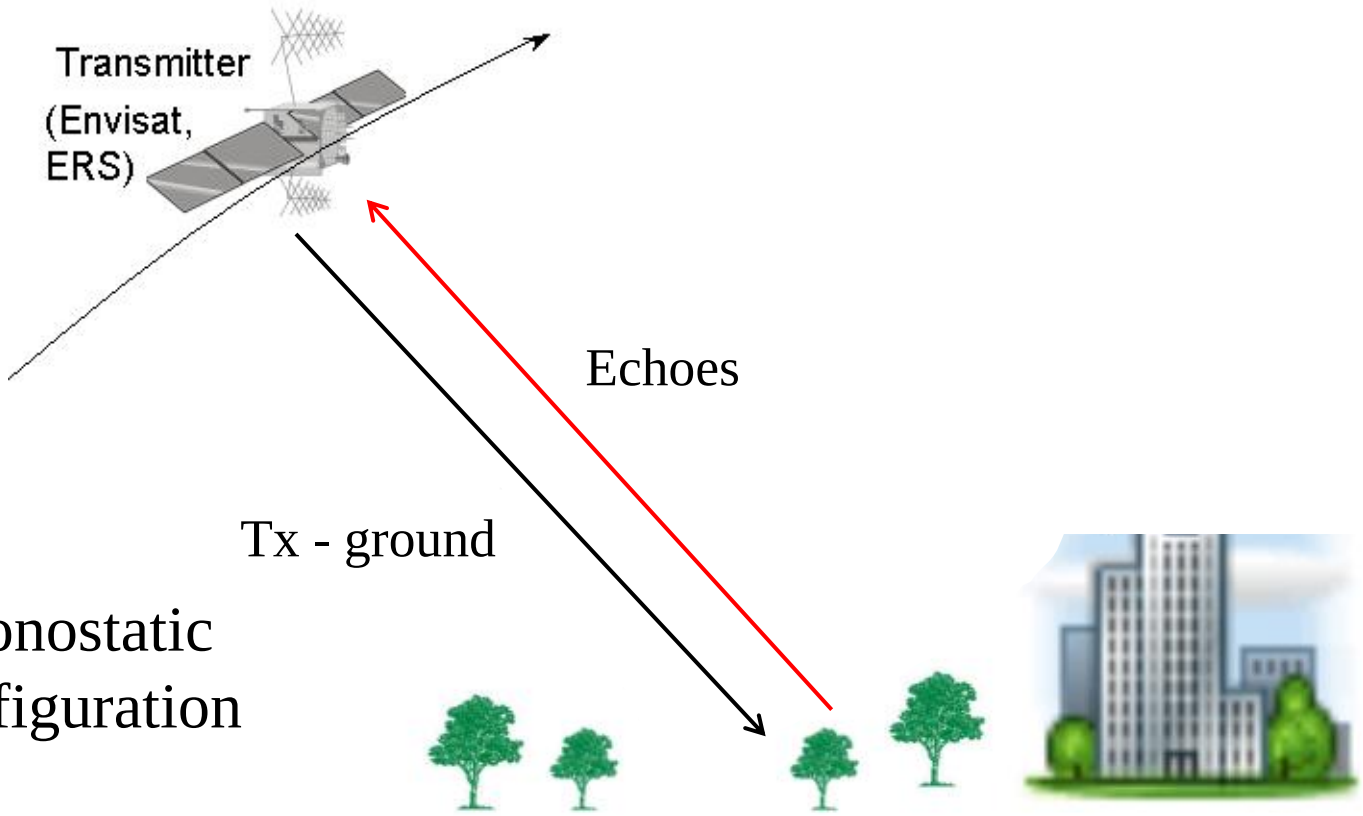
1. Introduction

- Objectives:
  - To assess feasibility of bistatic SAR imaging using C-band SAR satellites
  - To assess bistatic vs. monostatic results
  - To assess resolution and SNR
- Passive radar issues
  - Lack of synchronization

Typical Monostatic Scenario

GOAL:

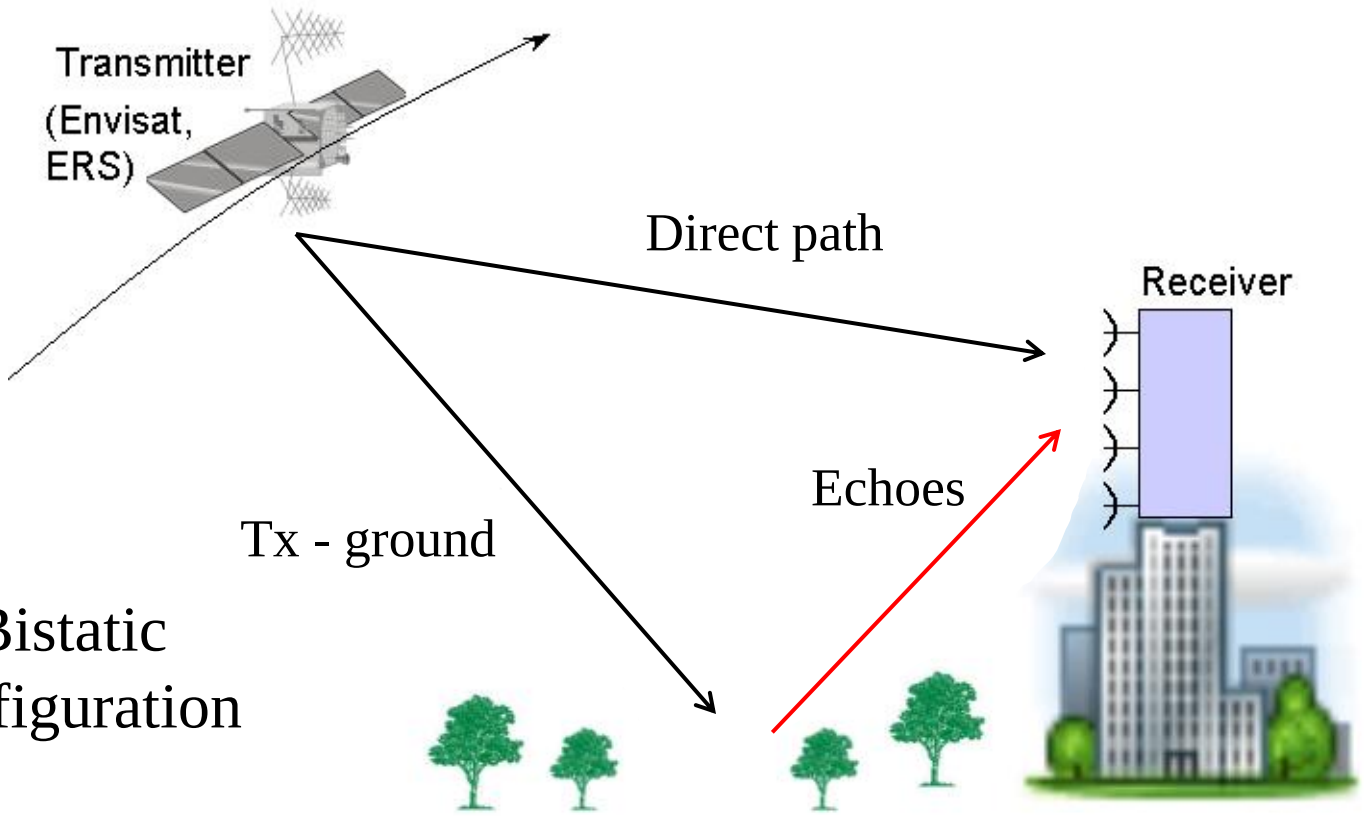
SAR image



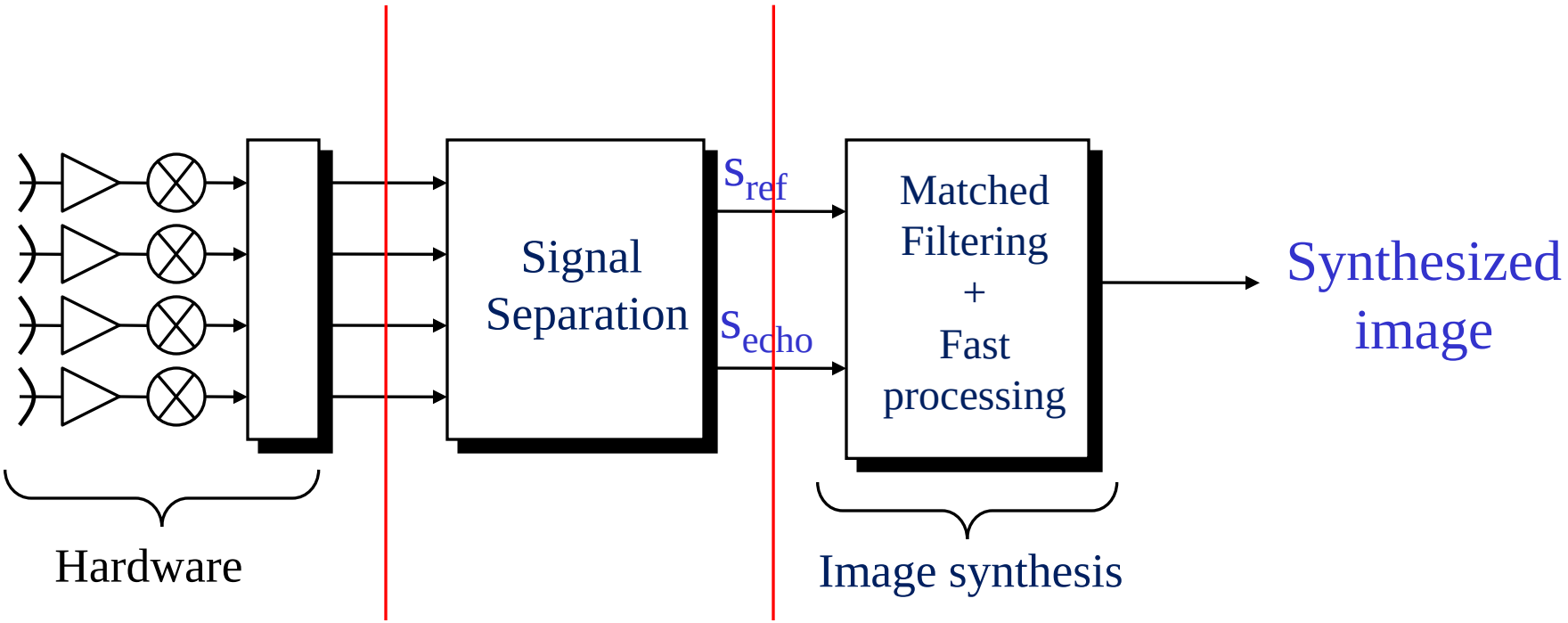
Bistatic Scenario

GOAL:

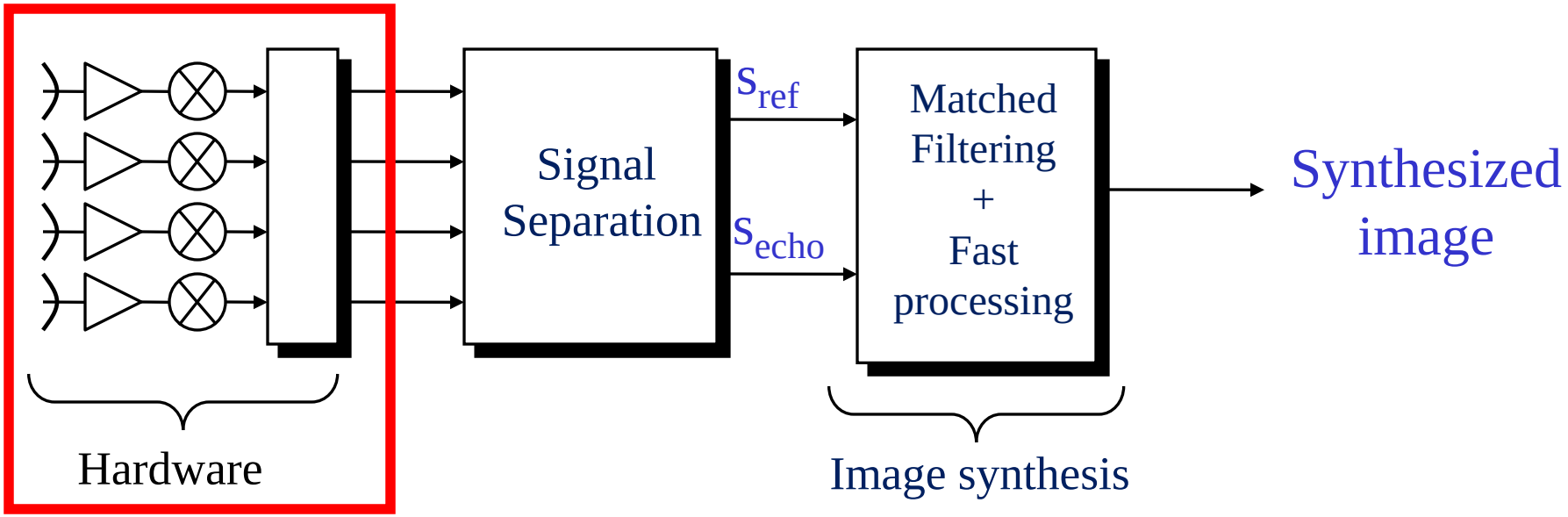
SAR image



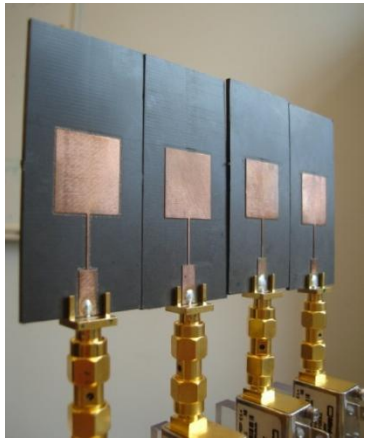
2. Reception System

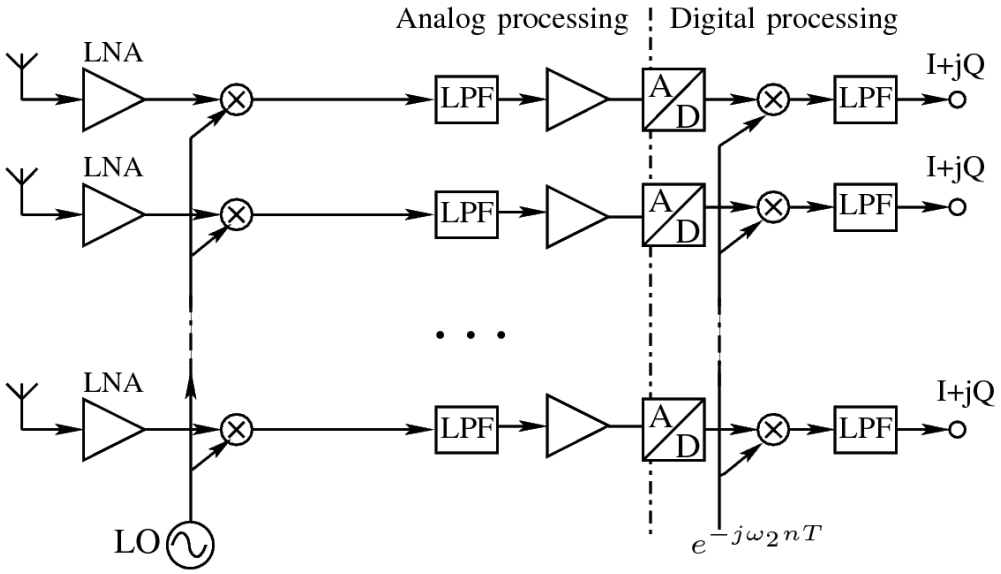


Hardware


Hardware
Signal Separation
s_{ref}
s_{echo}
Matched Filtering + Fast processing
Synthesized image
Image synthesis

Hardware

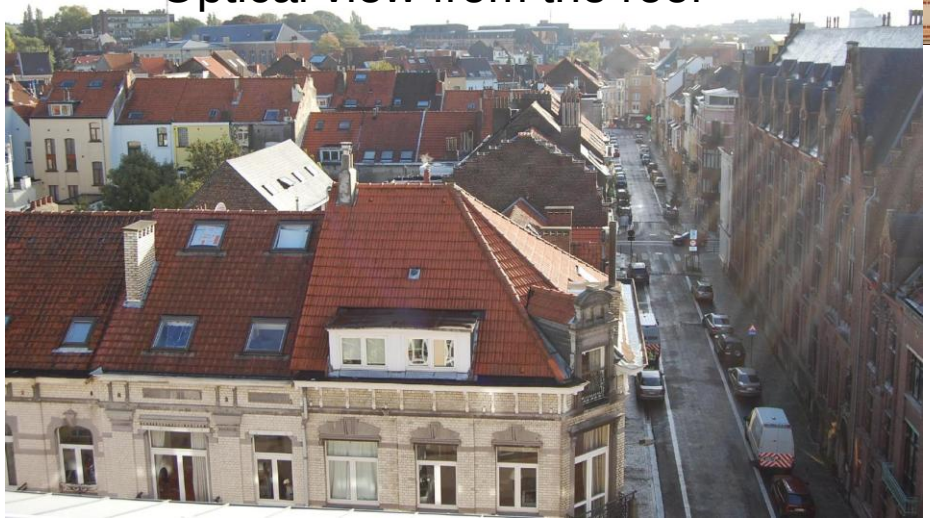


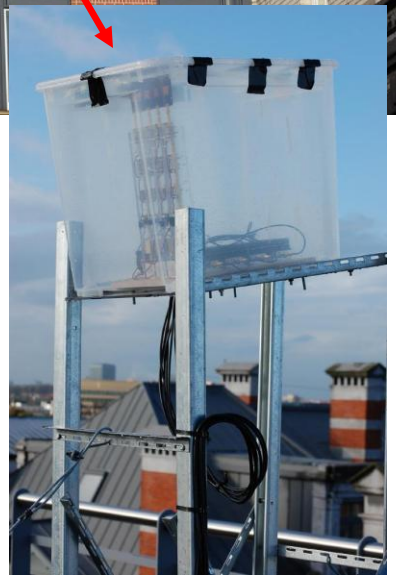

Analog processing
Digital processing
LNA
LNA
LNA
LPF
LPF
LPF
A/D
A/D
A/D
LPF
LPF
LPF
I+jQ
I+jQ
I+jQ
LO
$e^{-j\omega_2 nT}$

Location of the Receiver

Royal Military Academy

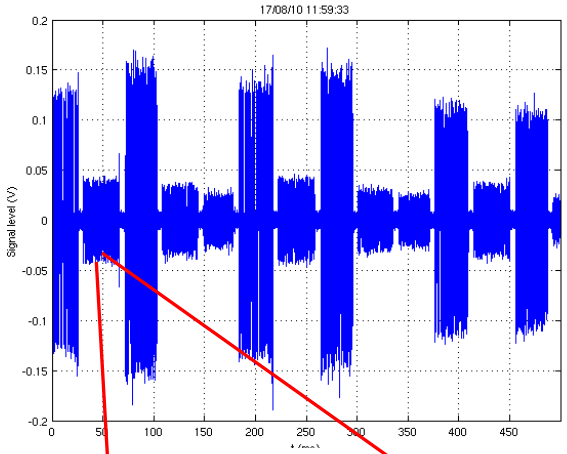
Optical view from the roof



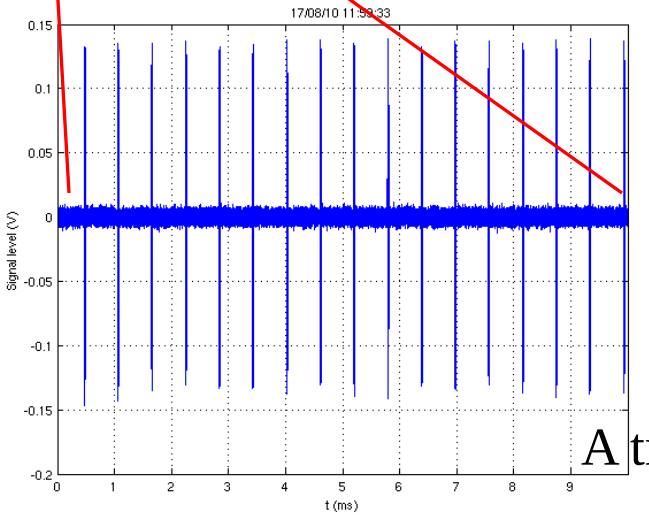


Acquired Signals

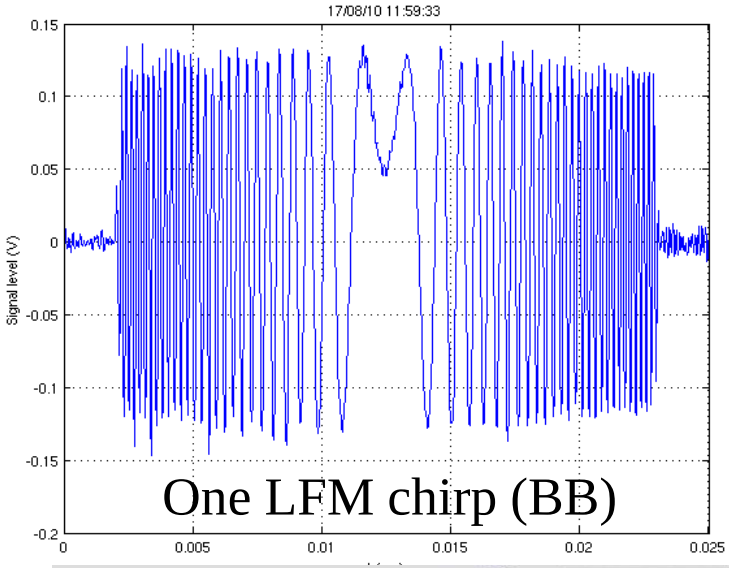
ENVISAT signals



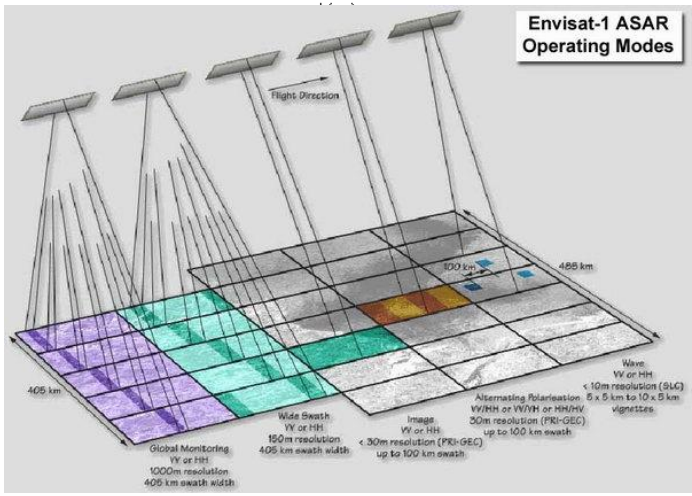
A satellite pass



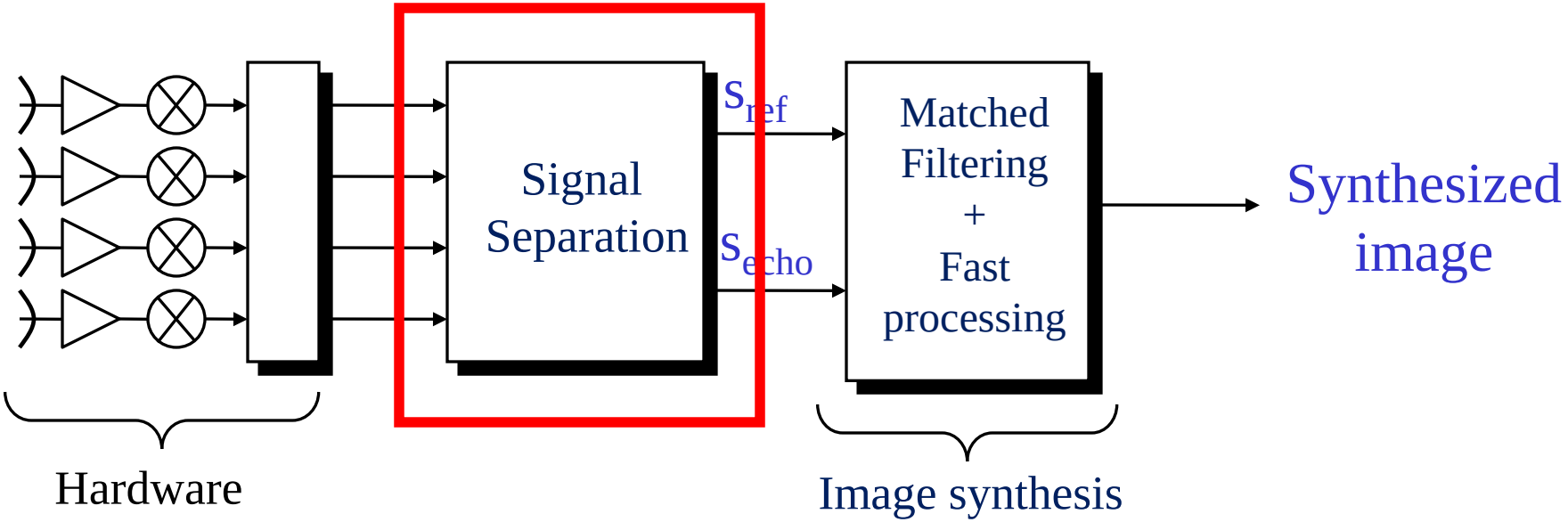
A train of pulses



One LFM chirp (BB)

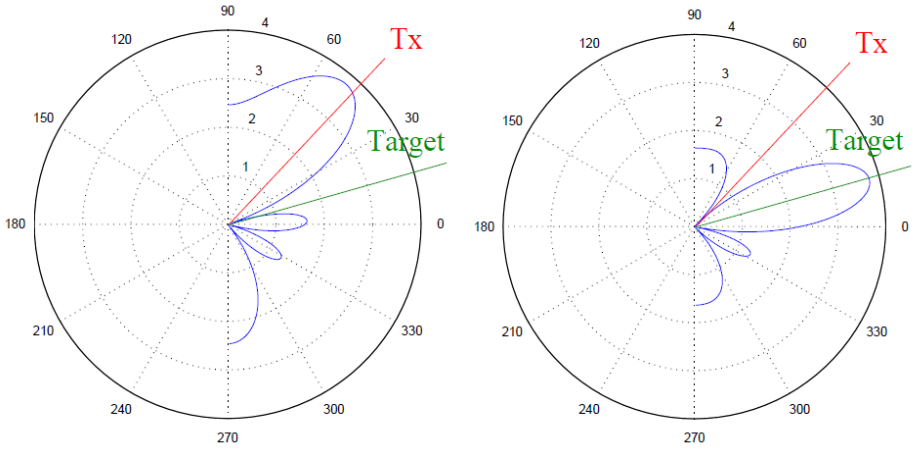


Signal Separation



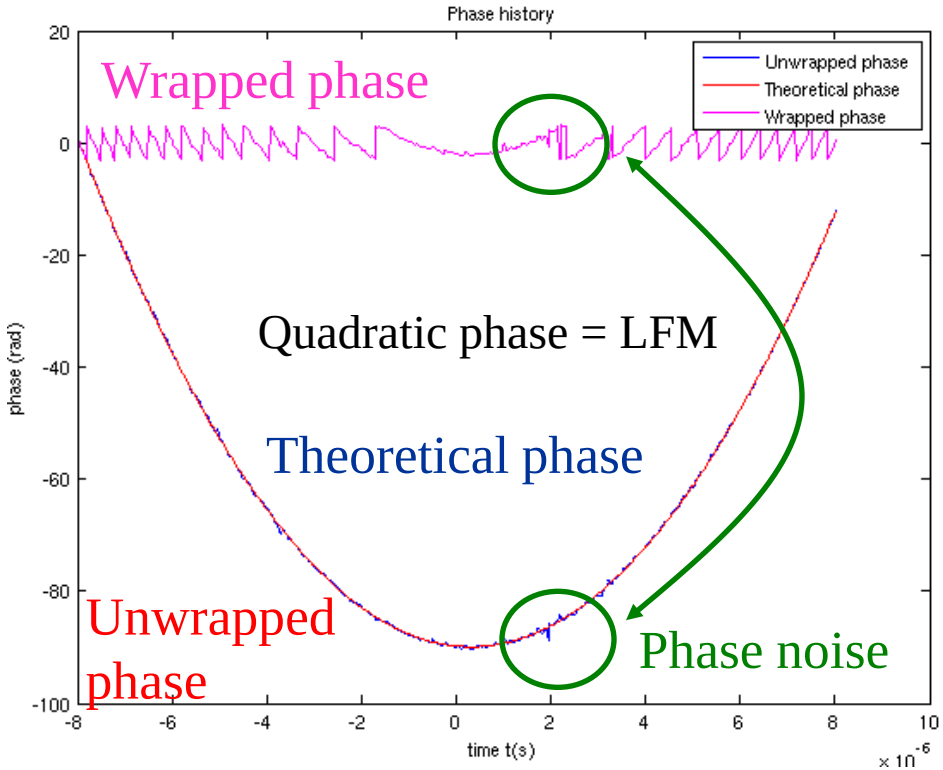
Signal Separation

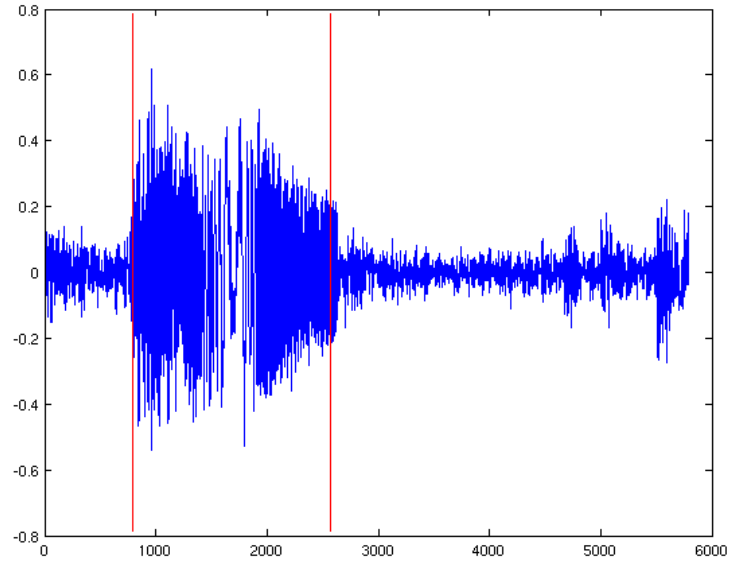
- Typically, two antennas
  - One antenna pointing to Tx, another one pointing to target
- Reference signal extraction (synchronization)
  - By resynthesis
    - Well-known transmitted signals (chirps)
    - Extract parameters
  - By spatial null-steering/beamforming (steering vectors)
    - Steering vectors are unknown. Calibration is needed.

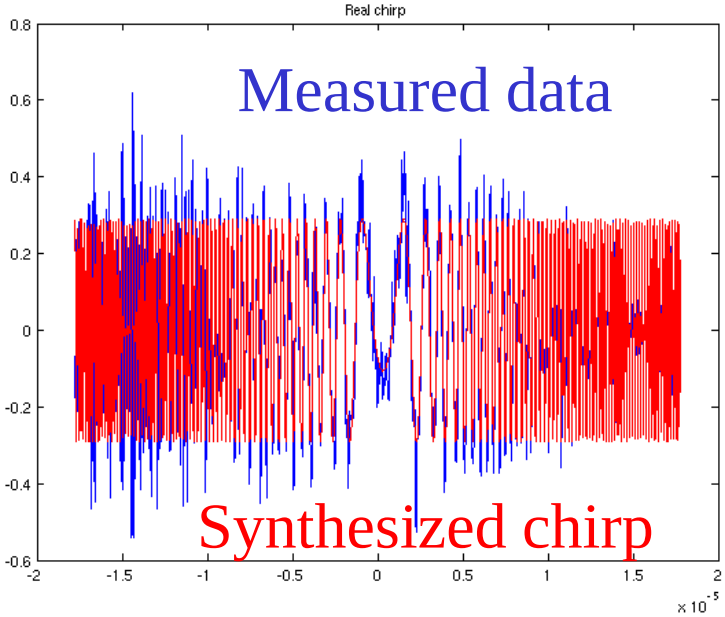


Parameters Estimation

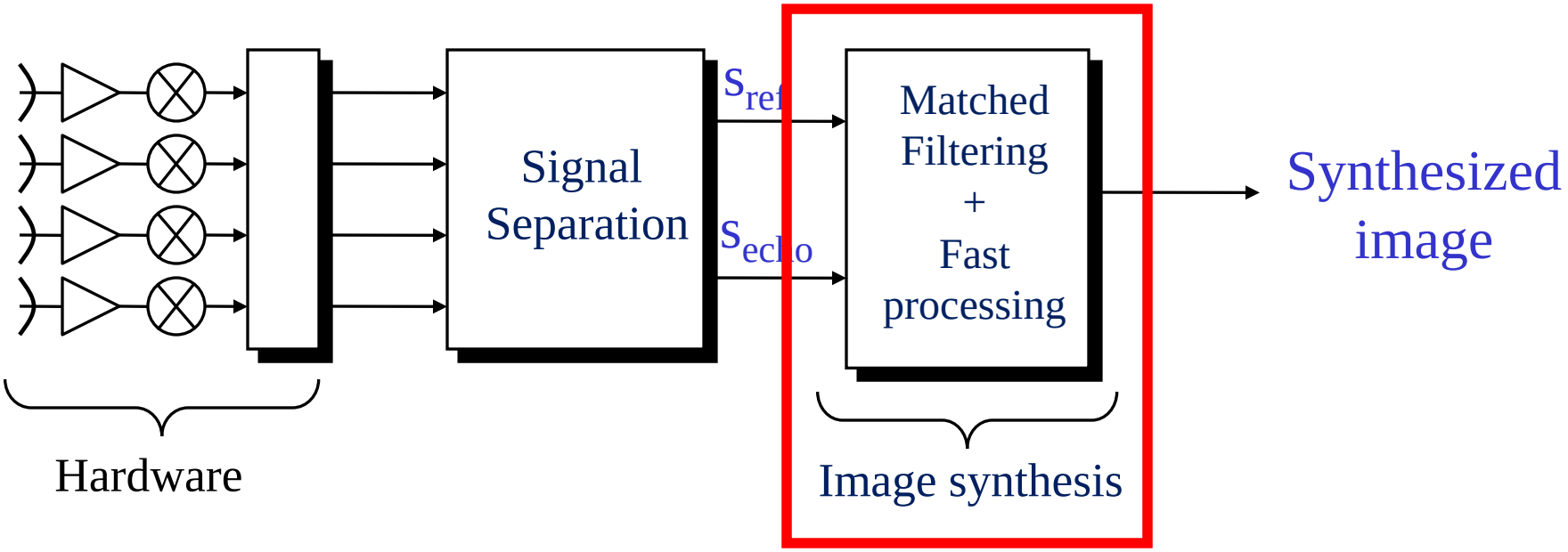
- α, φ and f_0 extraction





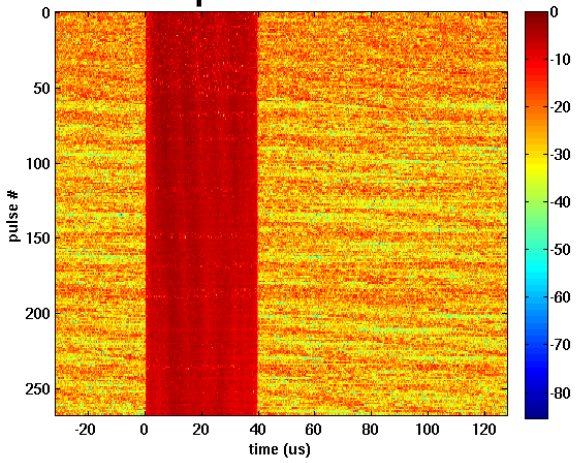


3. Exact Focusing Processing



Exact Focusing Processing

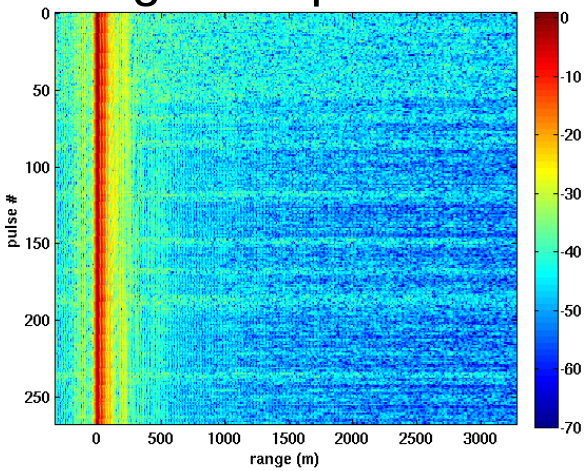
1. Acquired raw data



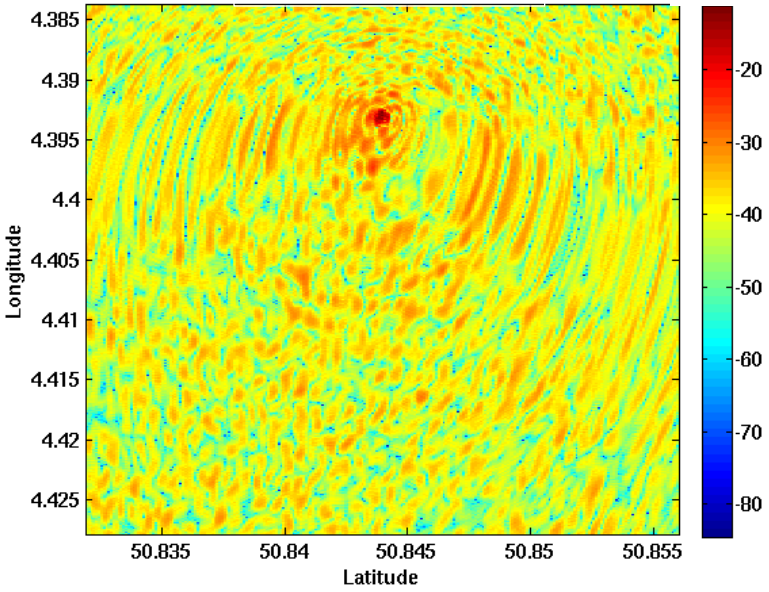
Matched Filtering

in range

2. Range-compressed data



SAR image

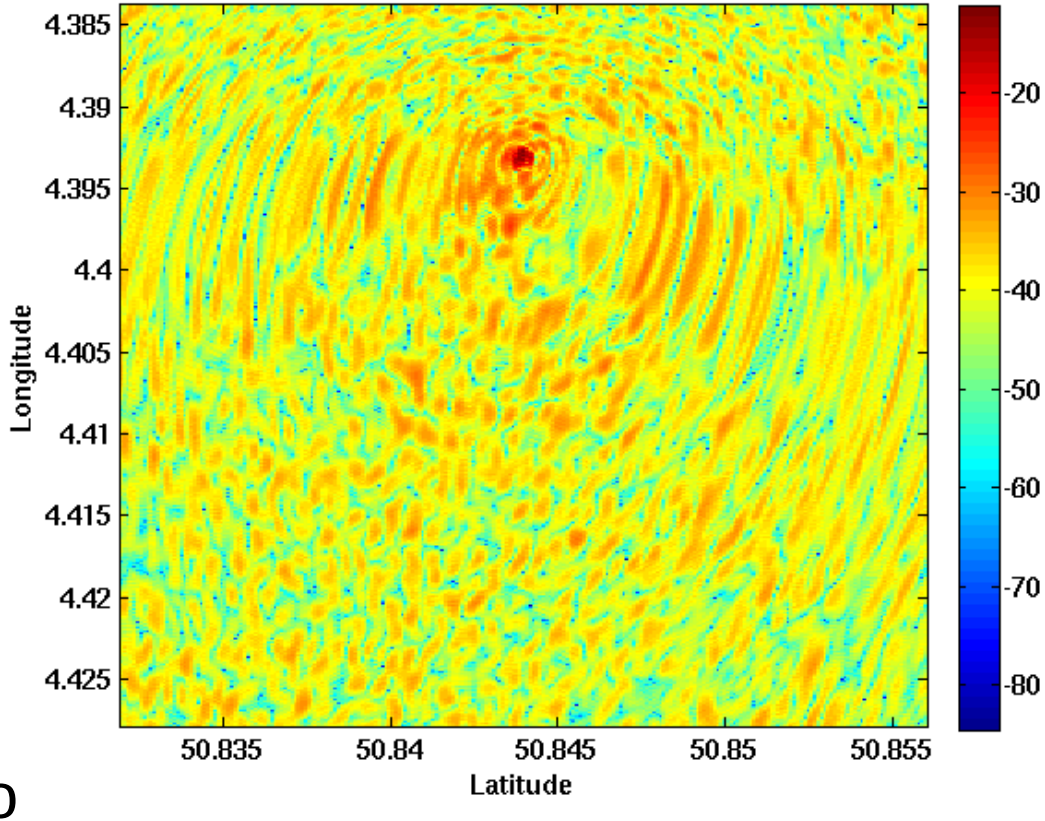


Matched Filtering in azimuth

3. Azimuth-compressed data

Early results

Early Results



SAR image

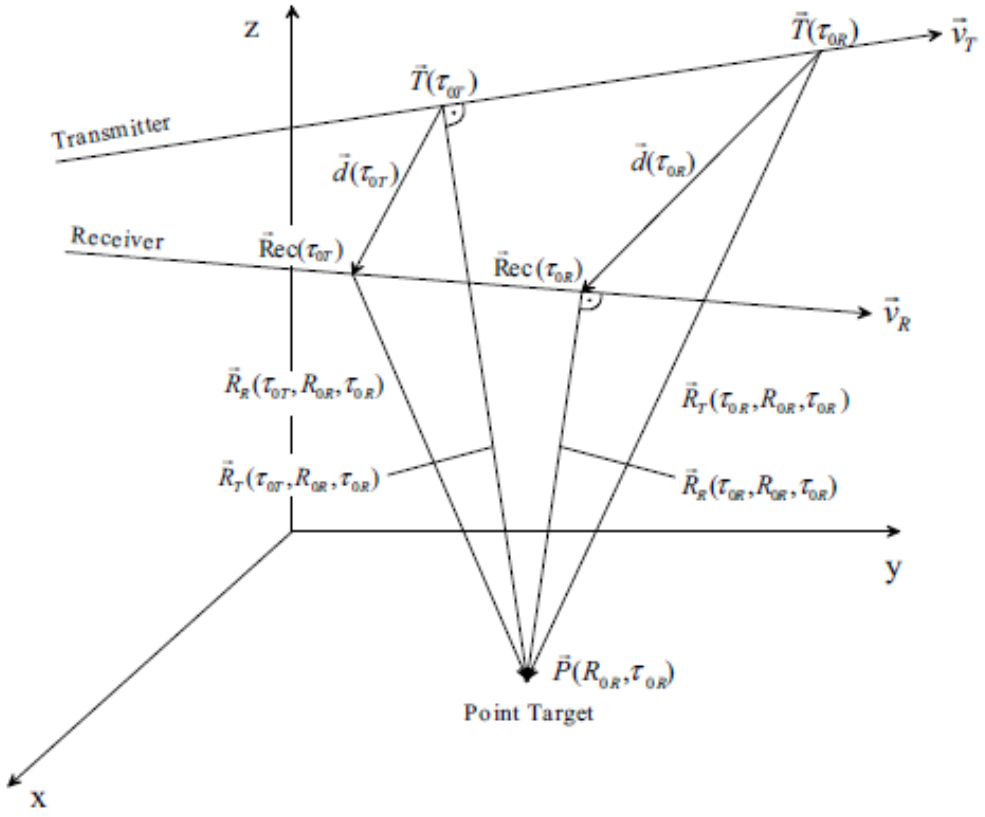
- Solution: alternative scenario
  - Should contain water (lake, pond?)
  - Using passive transponders?

4. RMA Future Work

- Obtain longer acquisitions
- Assessing image resolution and SNR
- Compare bistatic vs. monostatic images
- Using point target (passive transponder)

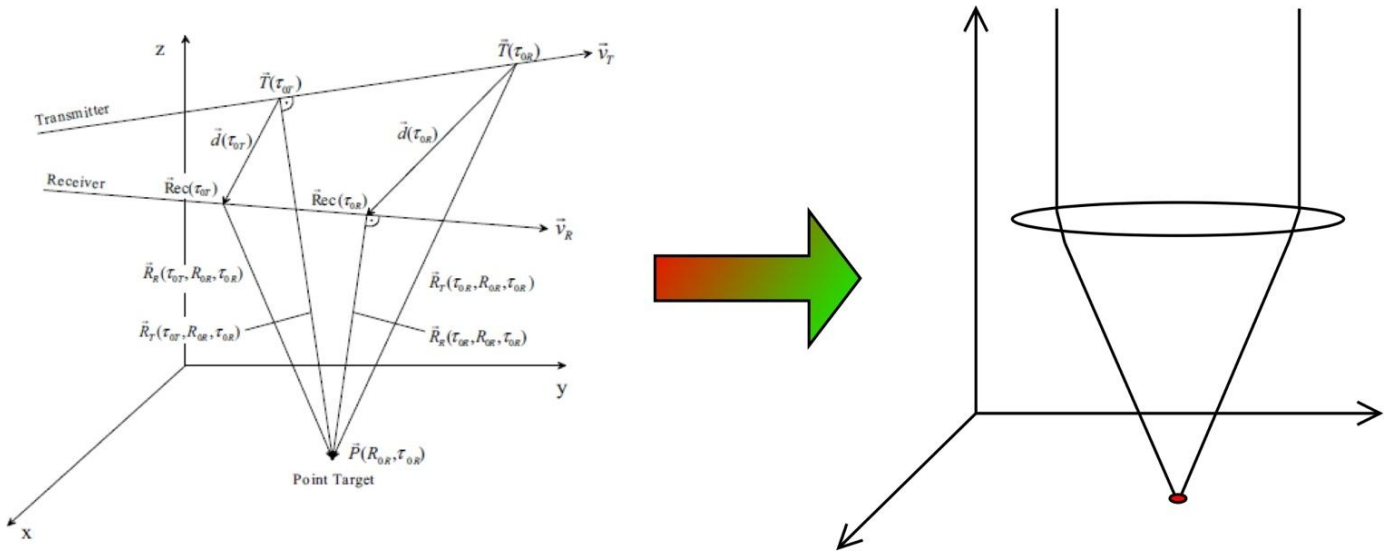
5. Fast Focusing Processing

Raw signal modeling



Fast Focusing Processing

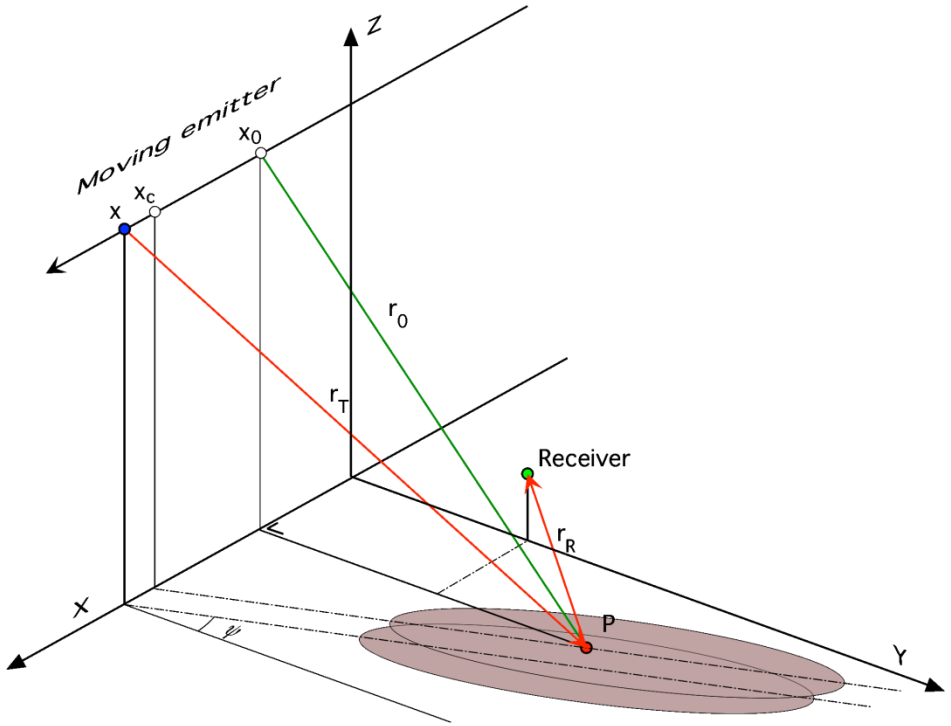
- Considering geometrical peculiarities of considered opportunistic SAR, some strong approximations are possible.
- The general scheme may be simplified.



General Considerations

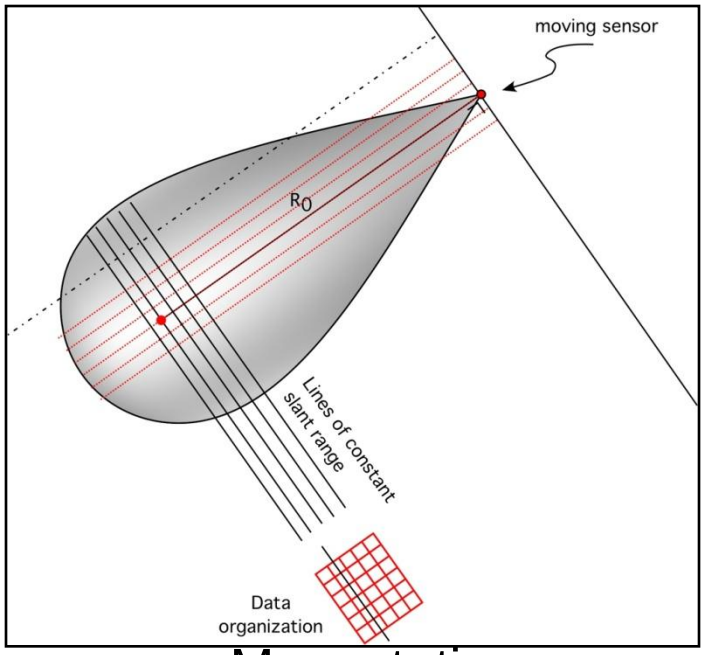
We consider a fix receiver and a moving emitter.

- X is the azimuth coordinate of the emitter.
- r_T is the range distance between the emitter and the considered point target.
- r_0 is the minimum slant range distance. x_0 is the corresponding azimuth coordinate.
- r_R is the constant distance between the point target and the emitter.



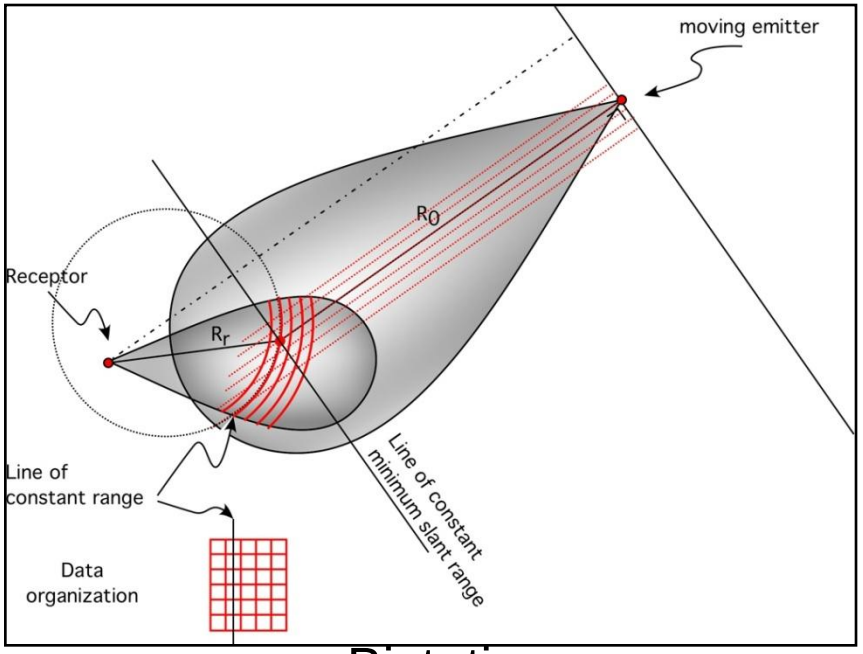
Geometrical Consideration

Data organization if considering focusing at constant range gates:



Monostatic

Translational symmetry



Bistatic

No Translational symmetry
"Data curvature"

Fast Focusing Processing

- Two focusing strategies are possible :
  - Interpolate raw data on a regular grid. Then focus along constant minimum slant range
  - Focus at constant range gates. Then georeference and geoproject focused data.
- The second strategy is the easiest and the most efficient.

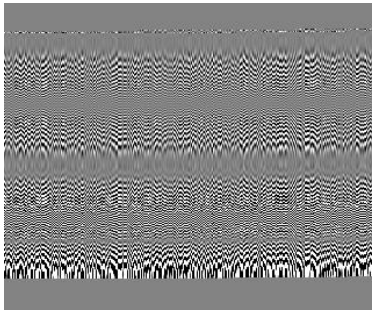
Fast Focusing Processing

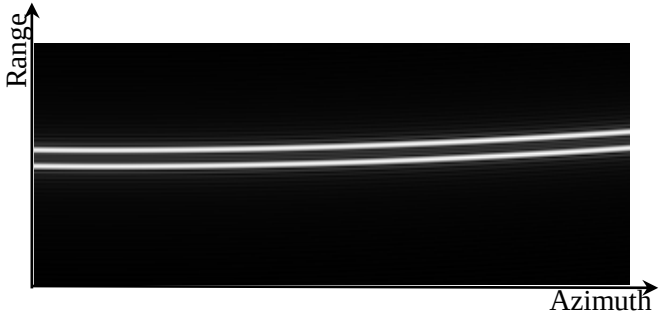
- Fast Focusing Processing of the simulated data provided by RMA:
  - ➡ Simulated data:
    - The receiver antenna is pointing toward the target.
    - The receiver - point target distance is about 50m.
    - The receiver is at an altitude 8 m higher than the point target.
    - Both the direct signal (emitter - receiver) and the backscattered signal (emitter - target - receiver) are given.
  - Range focusing is implemented in the Fourier domain.
    - Range focusing is performed using the direct signal.
      - ➡ Either a single direct pulse is used for all azimuth positions or each direct pulse is used at each azimuth position.

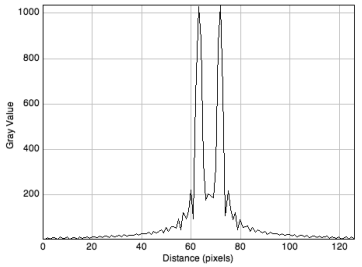
Fast Focusing Processing

Range focusing of the simulated signal:

With constant replica

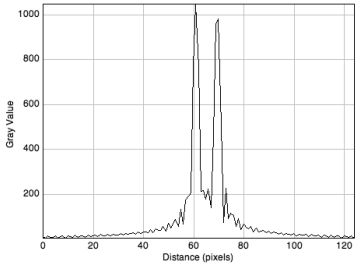






Range plot

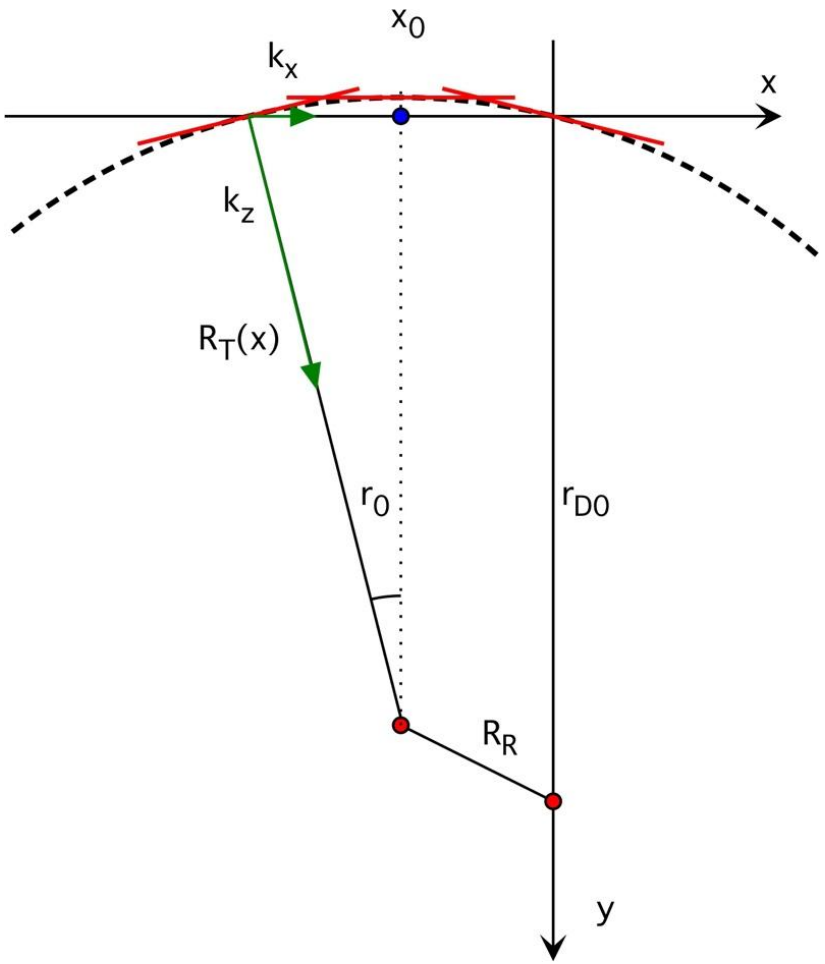
With azimuth-dependant replicas



Range plot

Fast Focusing Processing

- The range-focused signal may be seen as a decomposition of plane originating from a point at azimuth position x_0.
- Back-propagation of these plane waves will lead to the focused point.

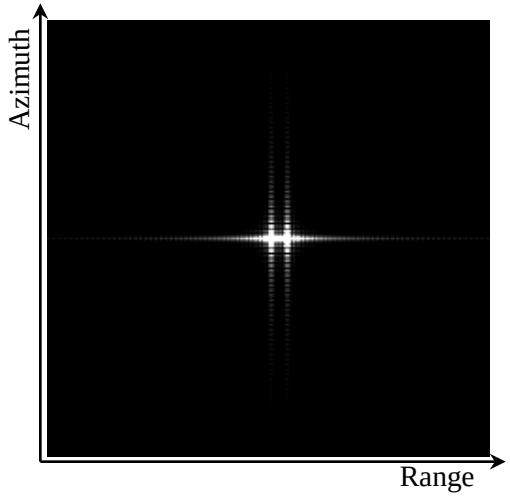


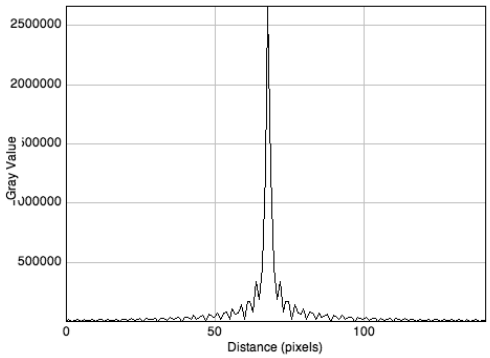
Fast Focusing Processing

- This back-propagation corresponds mathematically to a Fourier transform.
- A simple scaled Fourier transform of the range-focused data will lead to the image, provided that range focusing was performed using the direct signal and provided that the observed points are close enough to the receiver.

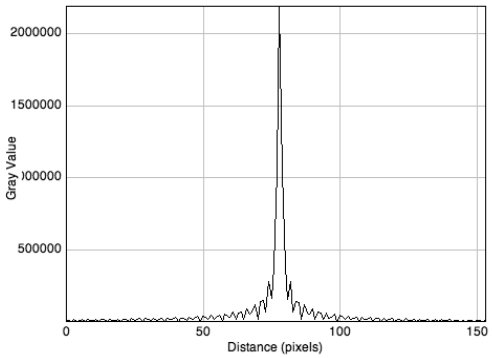
Fast Focusing Processing

Focused simulated data:





Azimuth plot of focused direct signal



Azimuth plot of focused point target

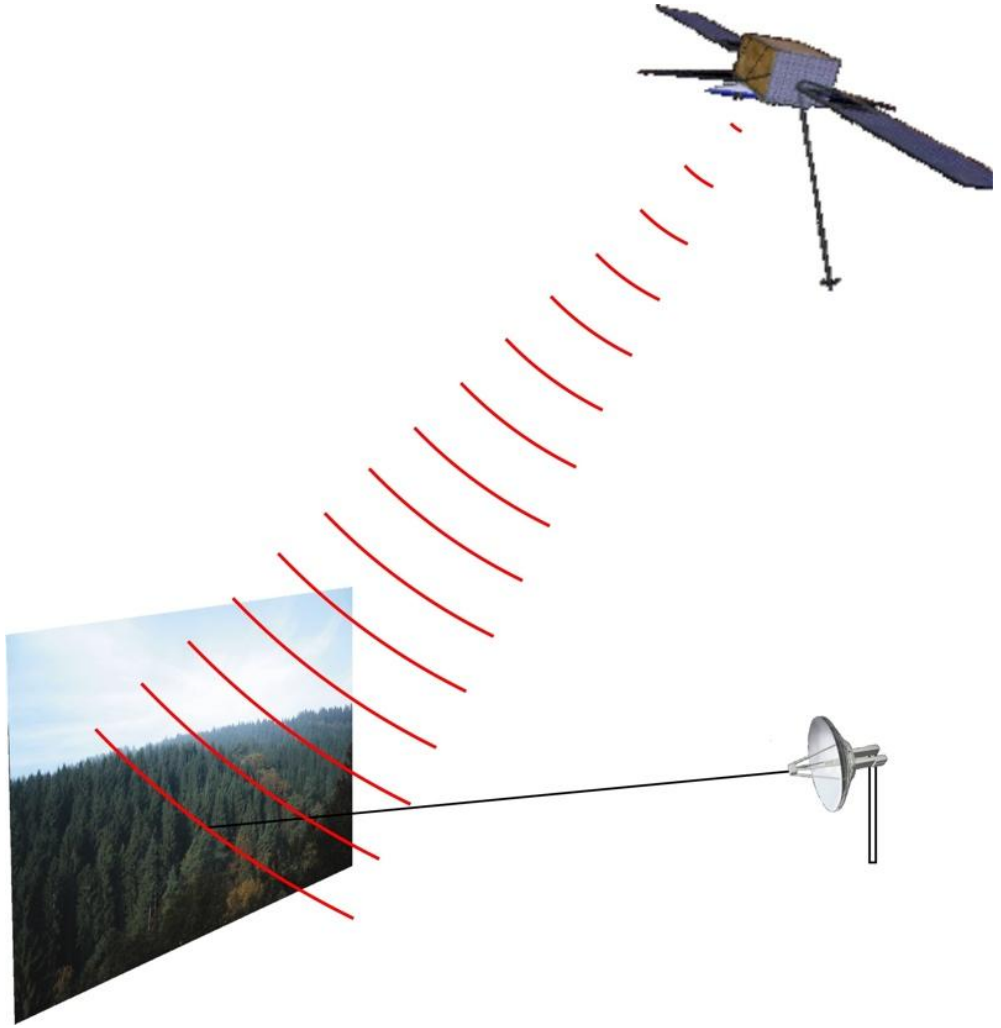
Remark: The focused data is in the natural acquisition geometry, i.e. on a curved grid.

6. CSL Future Work

- Verify the validity of the approximations with respect to target-receiver relative positions.
- Analyse the ability to translate and scale the direct signal to extend the focusing area.
- Test and validate the Fast Focusing Process on real data.

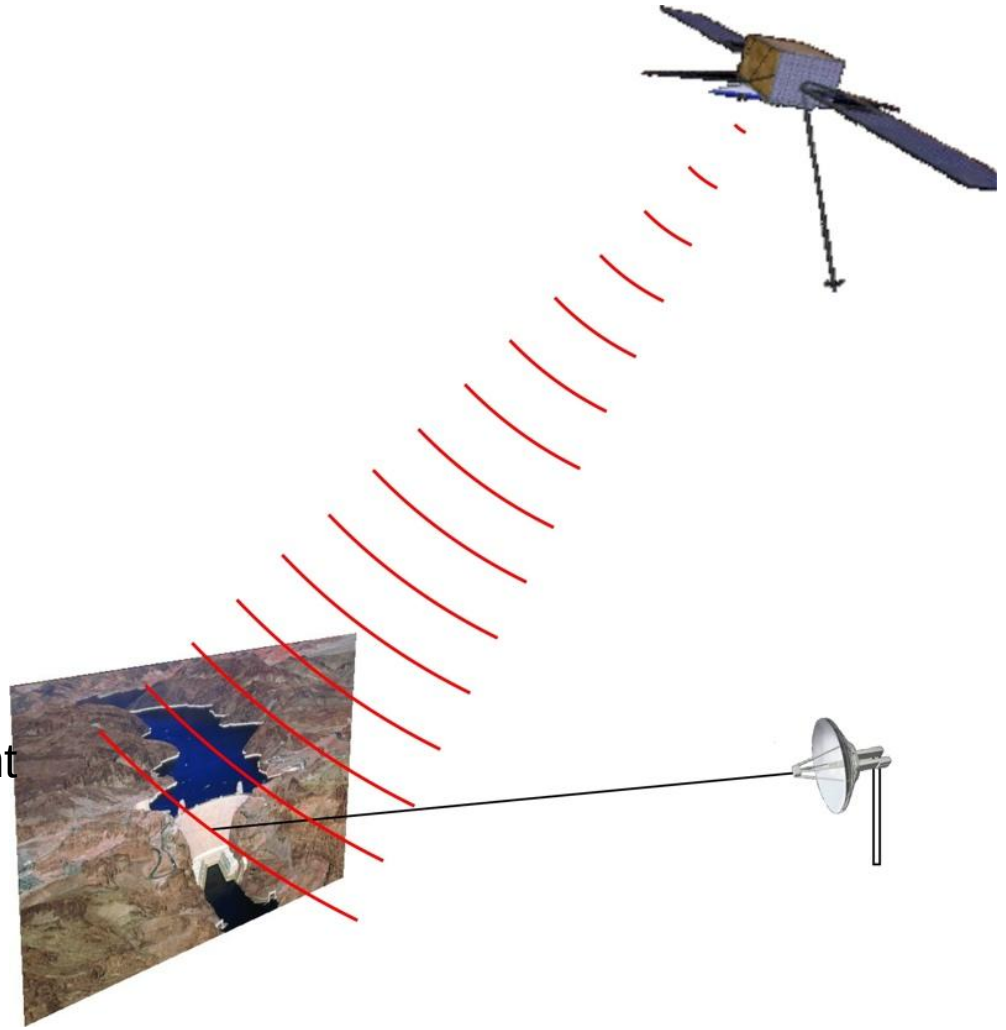
7. Application Examples

- Static and recurrent observation of :
  - Forests,
  - Crops
  - ...
  - ...



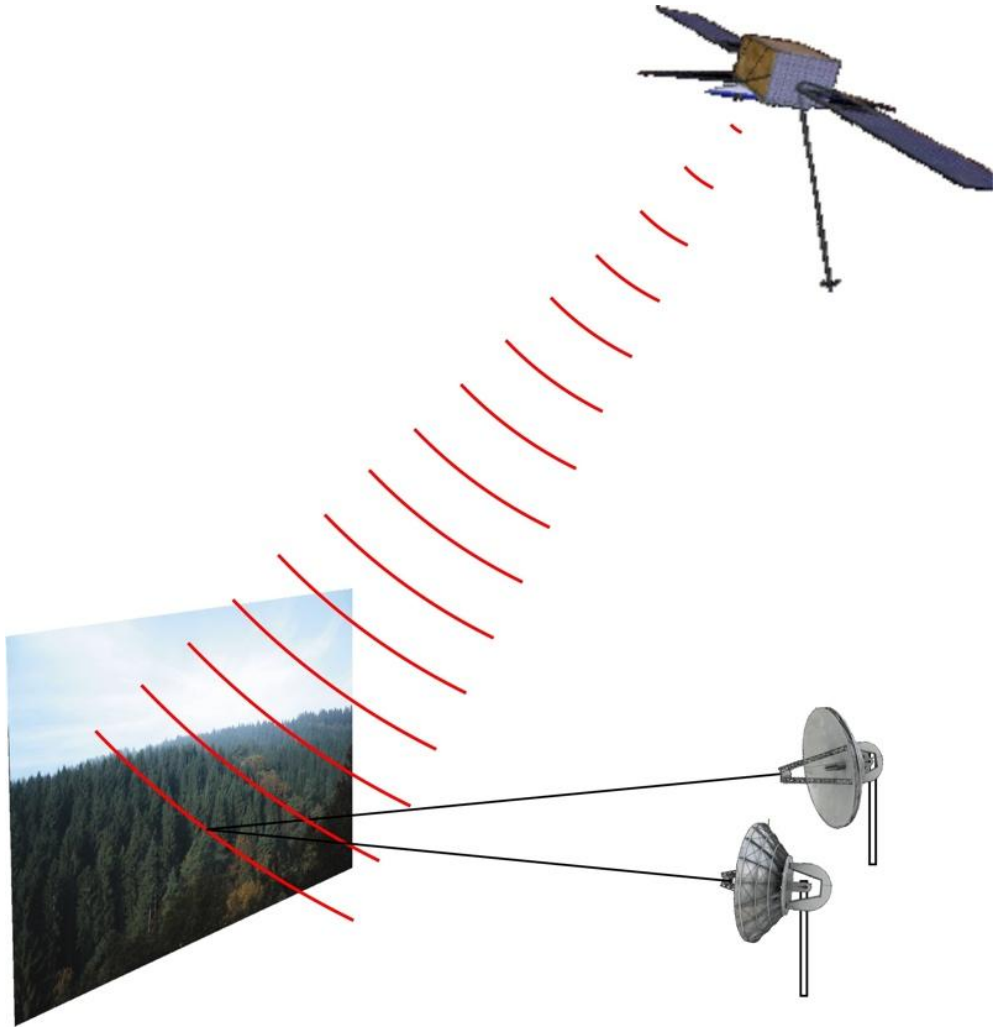
Application Examples

- Static and recurrent observation of:
  - Forests,
  - Crops,
  - Man-made structures,
  - ...
- Interferometric processing of recursive acquisitions:
  - Displacement/movement monitoring.



Application Examples

- If two reception antennas:
  - Direct and recursive interferometric measurement
  - Coherence monitoring for crop stage/volumetric estimation
  - ...



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Thank you! Any questions?