University of Zurich[UZH]

Department of Geography

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GMTI in circular SAR data using STAP

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Sensor Signal Processing for Defence Conference

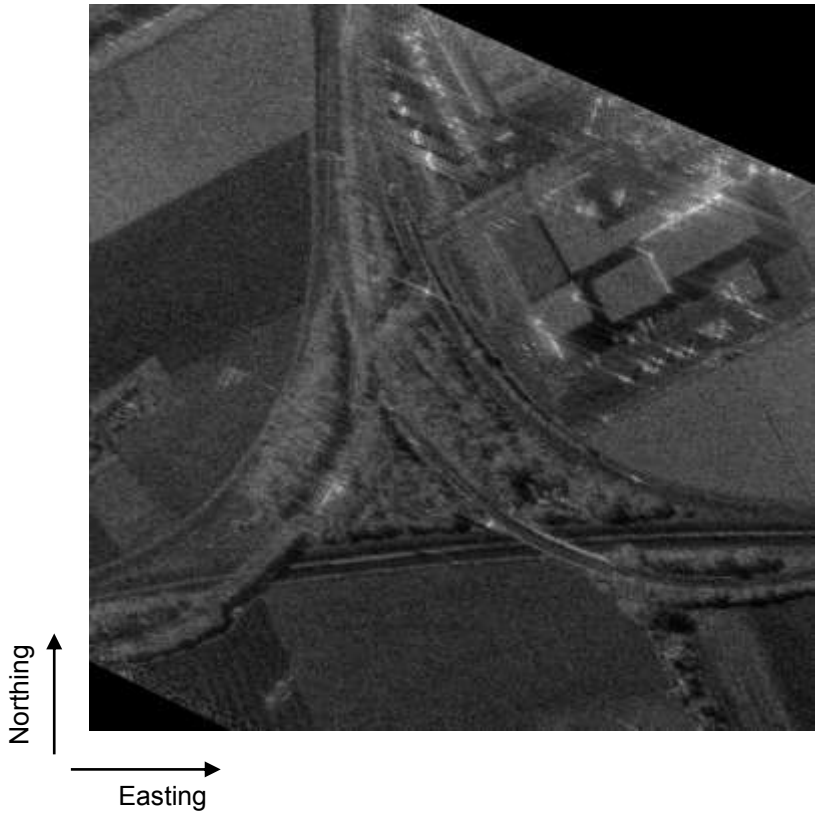
22nd and 23rd September 2016

Royal College of Surgeons

Edinburgh

SAR-GMTI

Synthetic **A**perture **R**adar **G**round **M**oving **T**arget **I**ndication



SAR-GMTI

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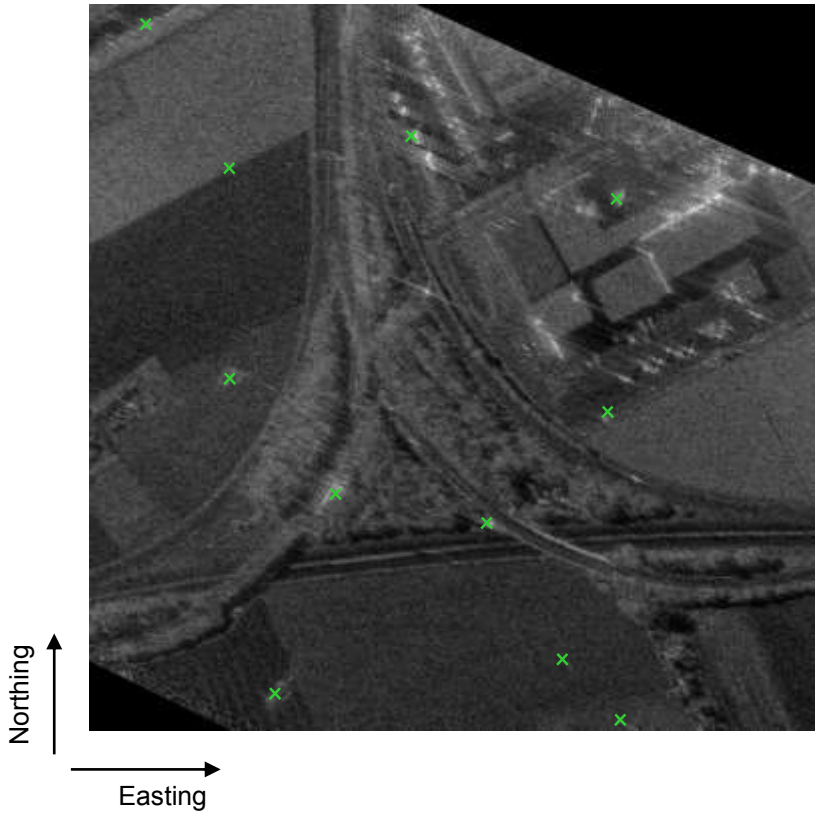


SAR-GMTI radars:

- detect ground and maritime non-cooperative moving targets;
- allow precise tracking of a moving target;
- are near real-time;
- work irrespective of weather and light conditions;
- potentially cover wide areas;
- indicate moving targets and simultaneously image the area of interest;

Enhanced situational awareness

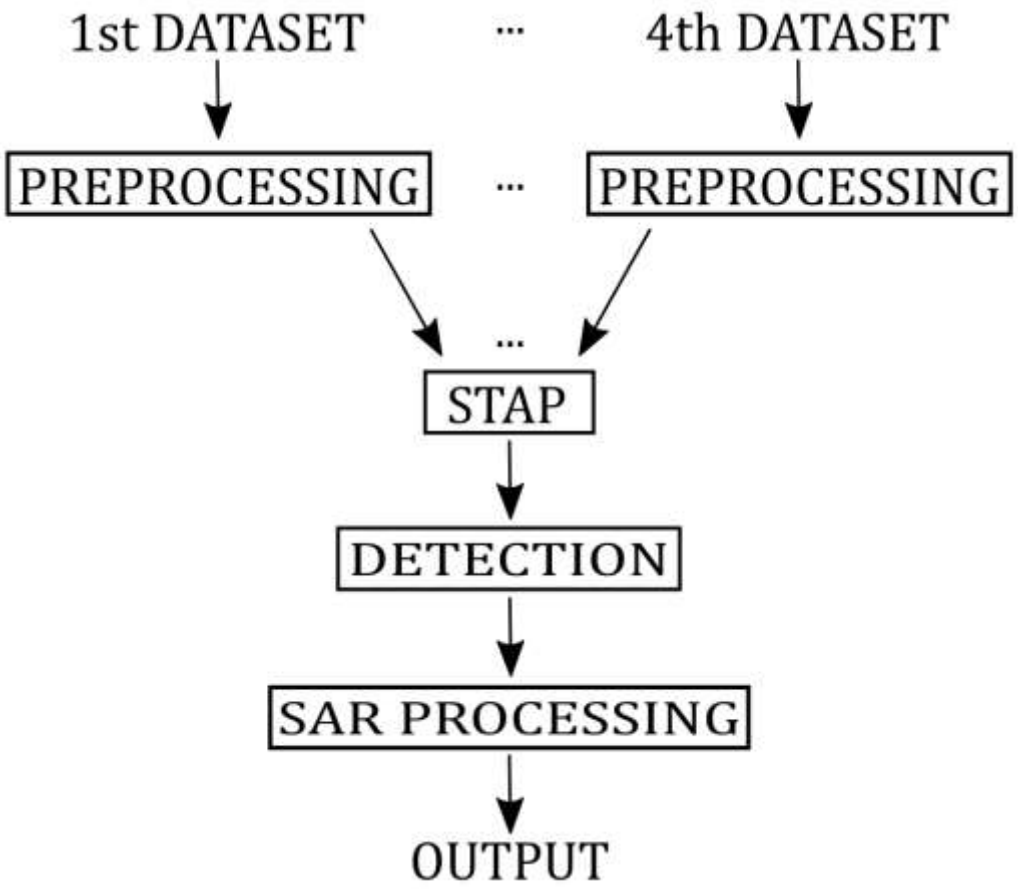
SAR SYSTEM:

- DLR's F-SAR sensor;
- 1 transmitting antenna and 4 equally spaced receiving antennae;
- 9.6 GHz carrier frequency with 100 MHz bandwidth;
- Pulse repetition frequency of ca. 2016 Hz;

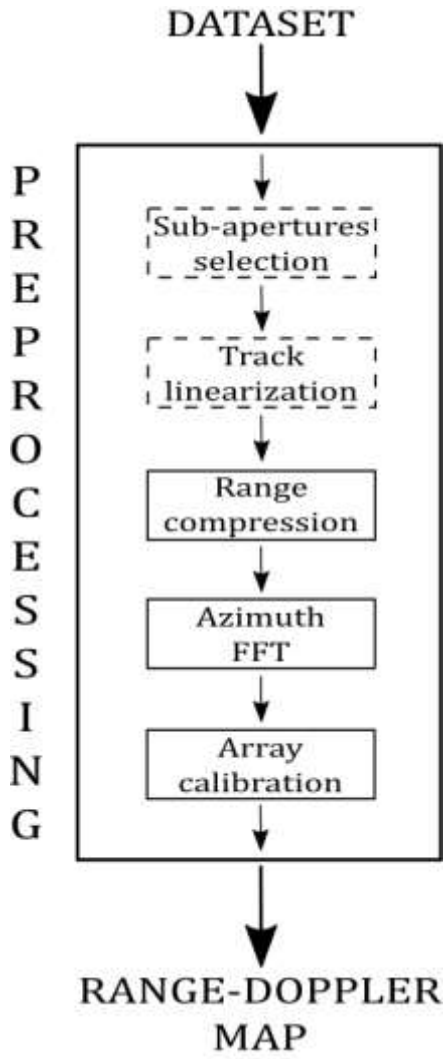
DATA SET:

- Circular acquisition geometry;
- Diameter of 3.5 km and mean altitude above ground of 2.7 km;
- > 300 thousands pulses (ca. 149 seconds);


Google earth

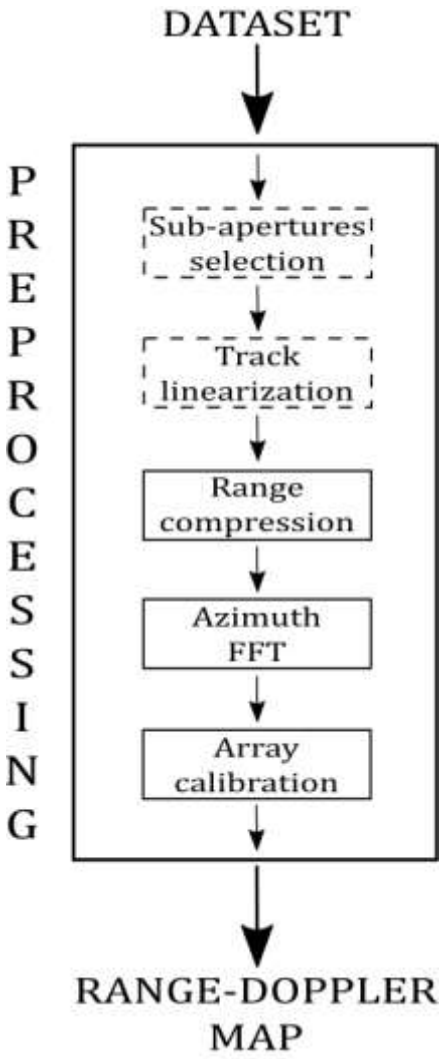

1st DATASET
...
4th DATASET
PREPROCESSING
...
PREPROCESSING
...
STAP
DETECTION
SAR PROCESSING
OUTPUT

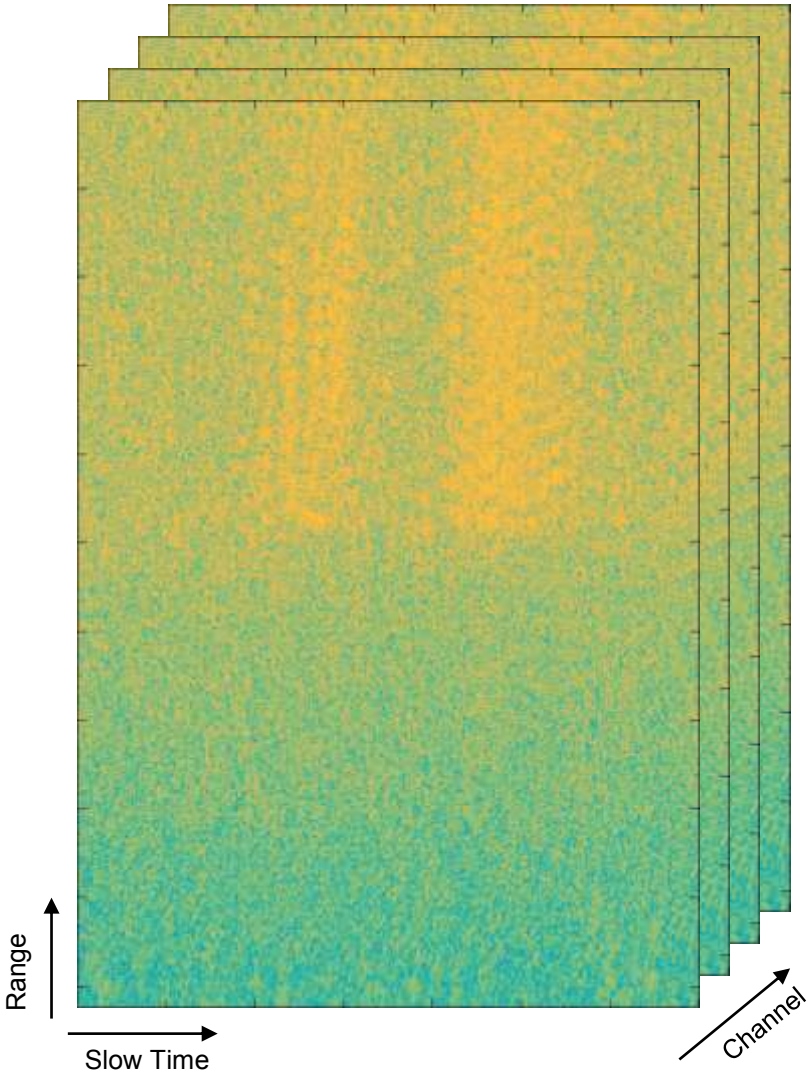
Preprocessing Block diagram



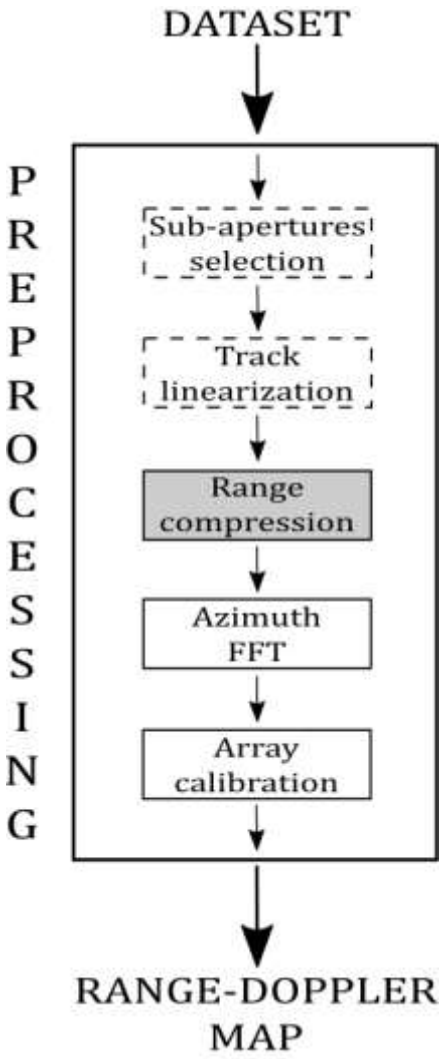
Preprocessing

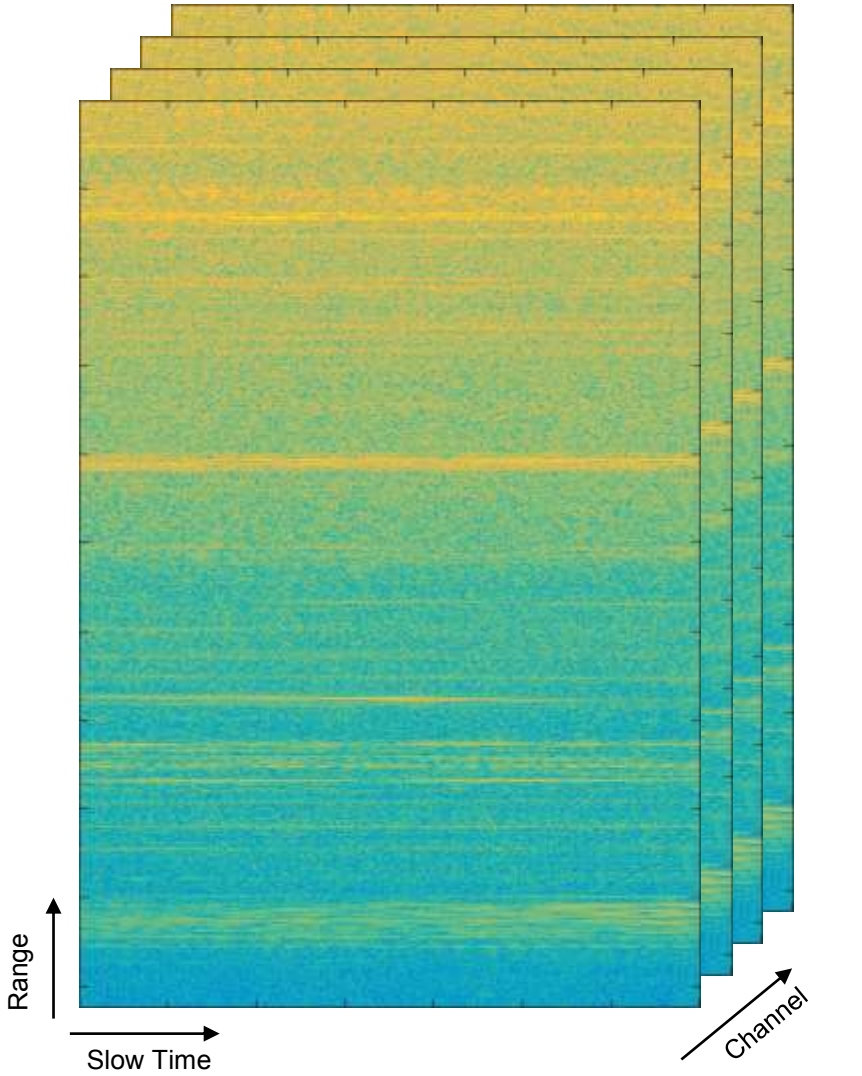
Raw datasets



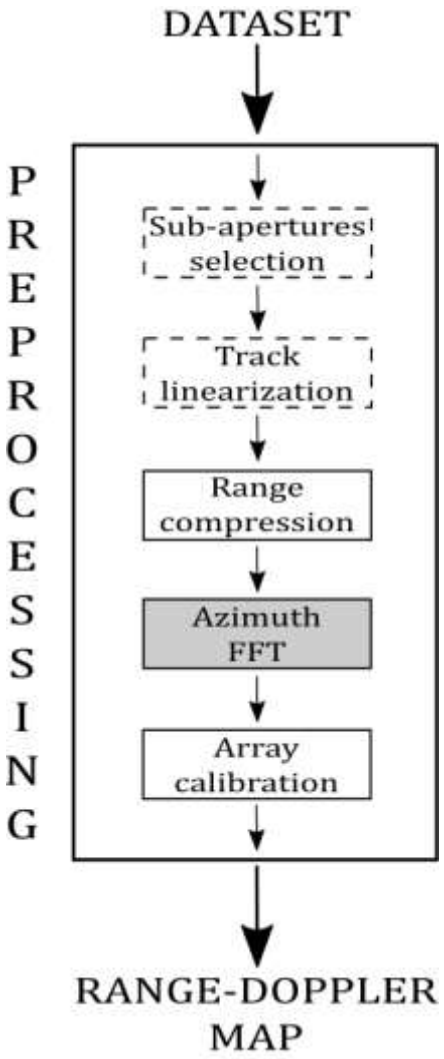


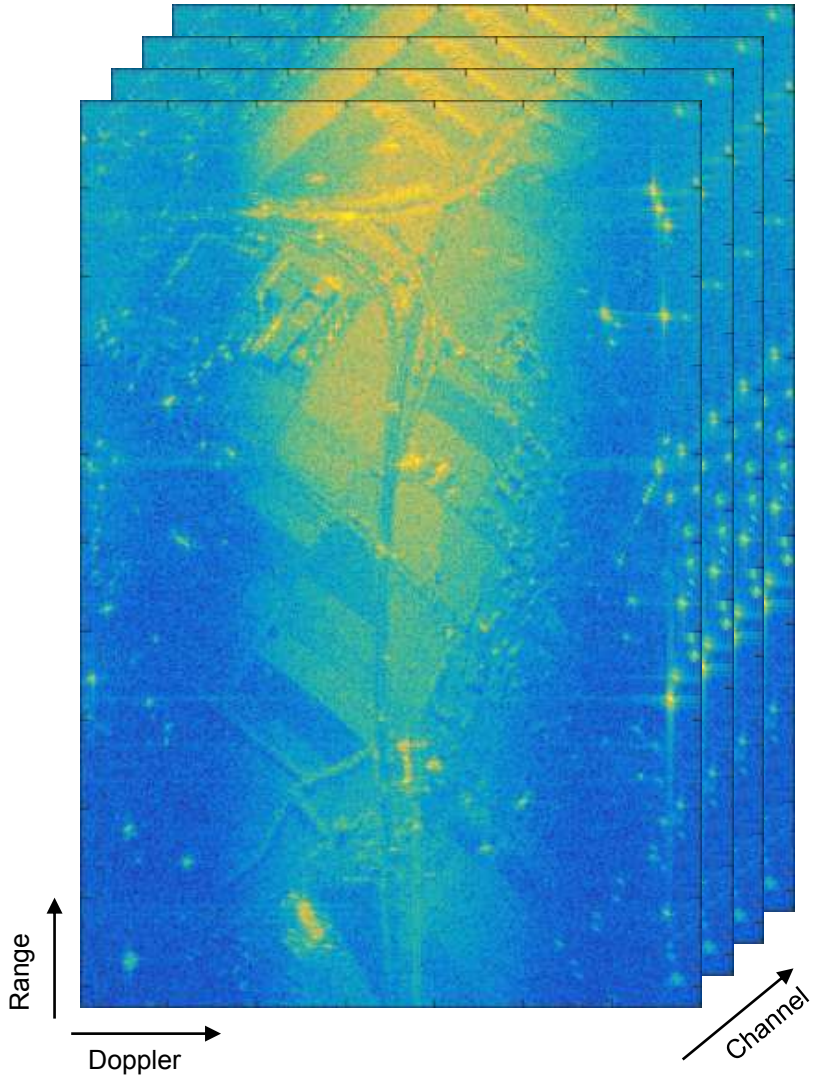
Preprocessing Range compression



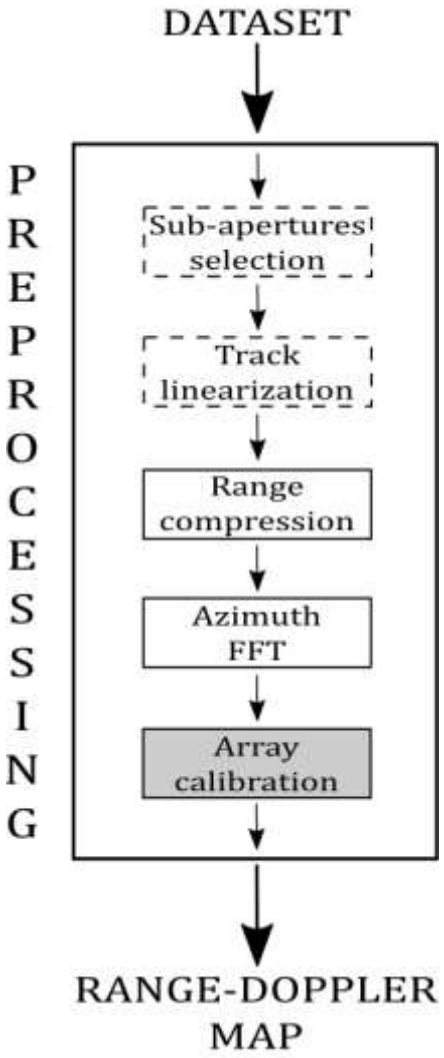


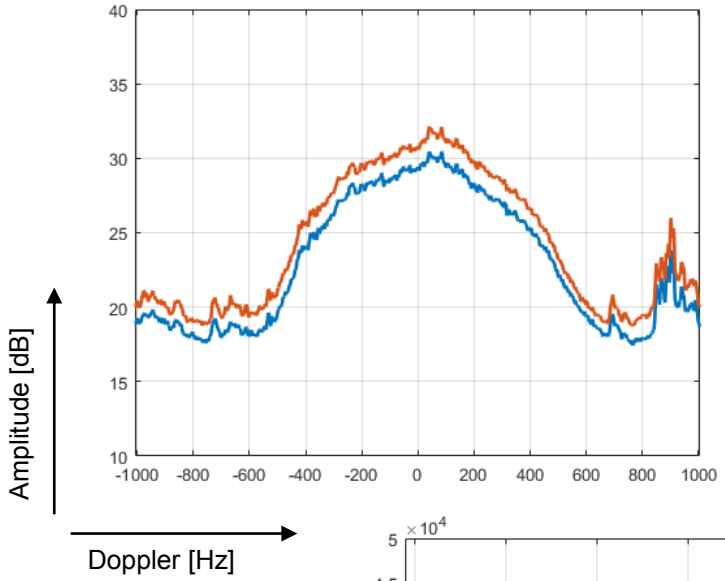
Preprocessing Azimuth FFT

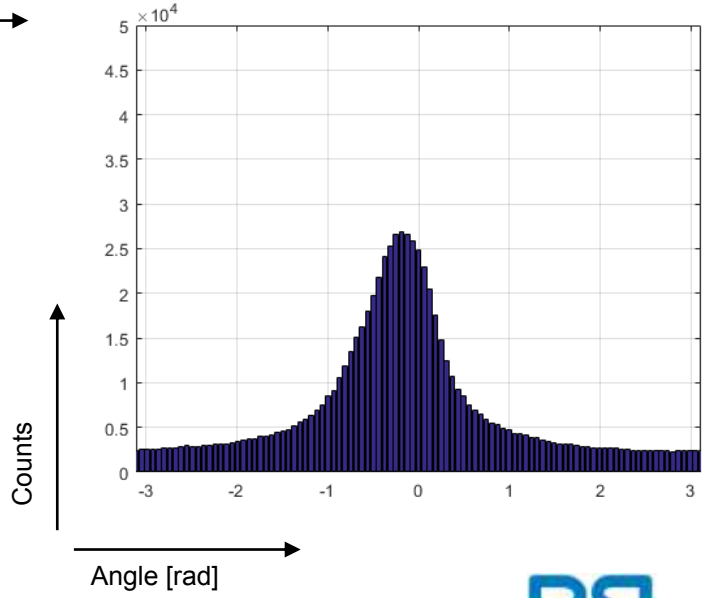




Preprocessing Array calibration







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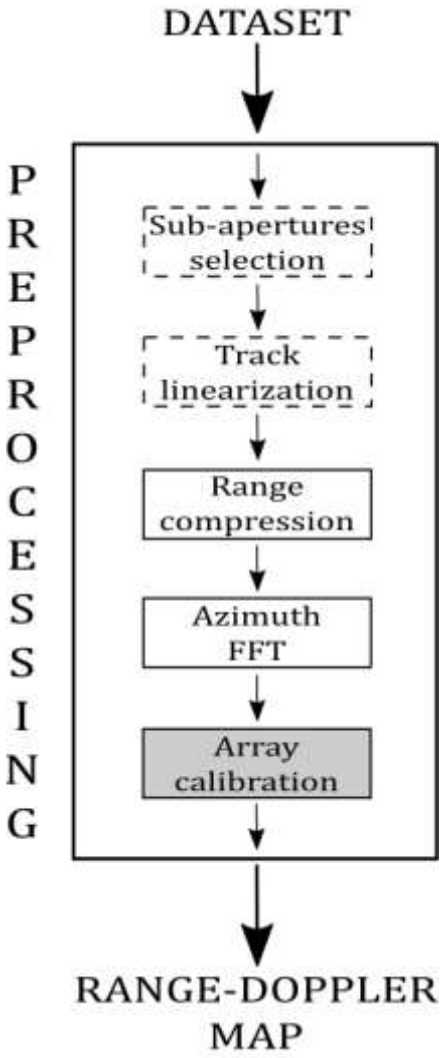

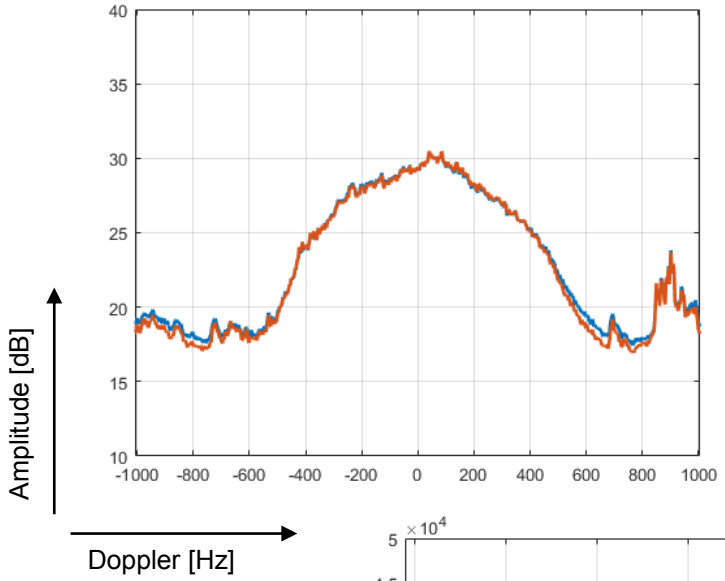

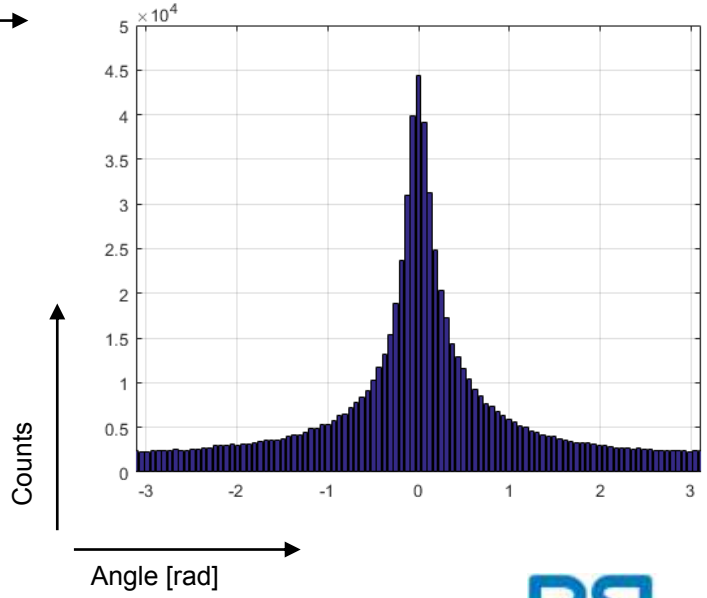

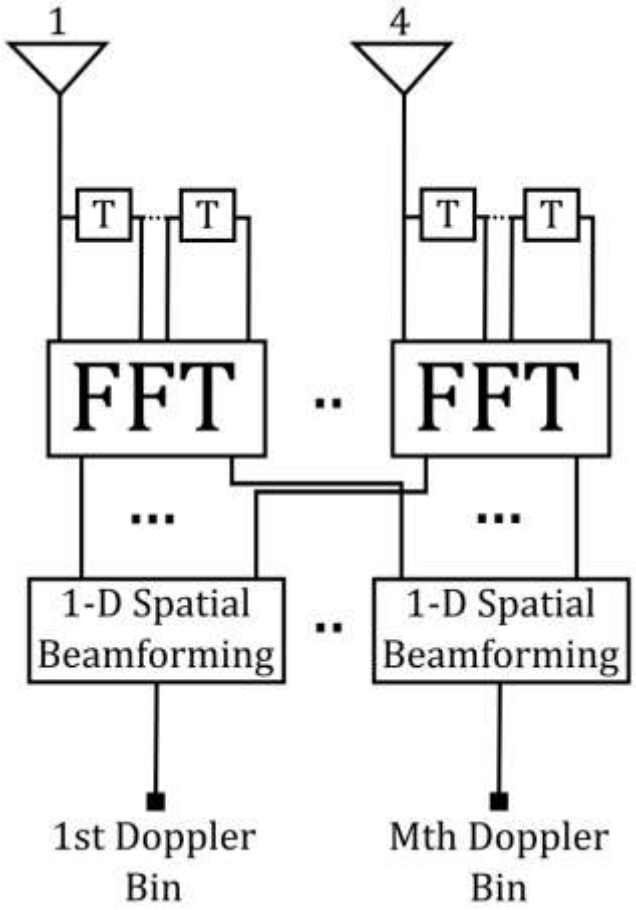
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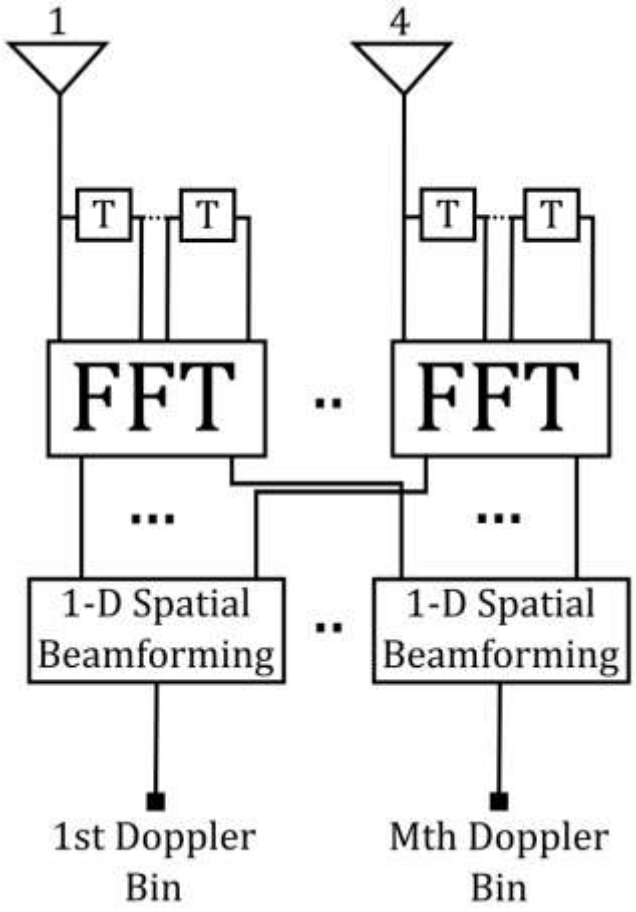
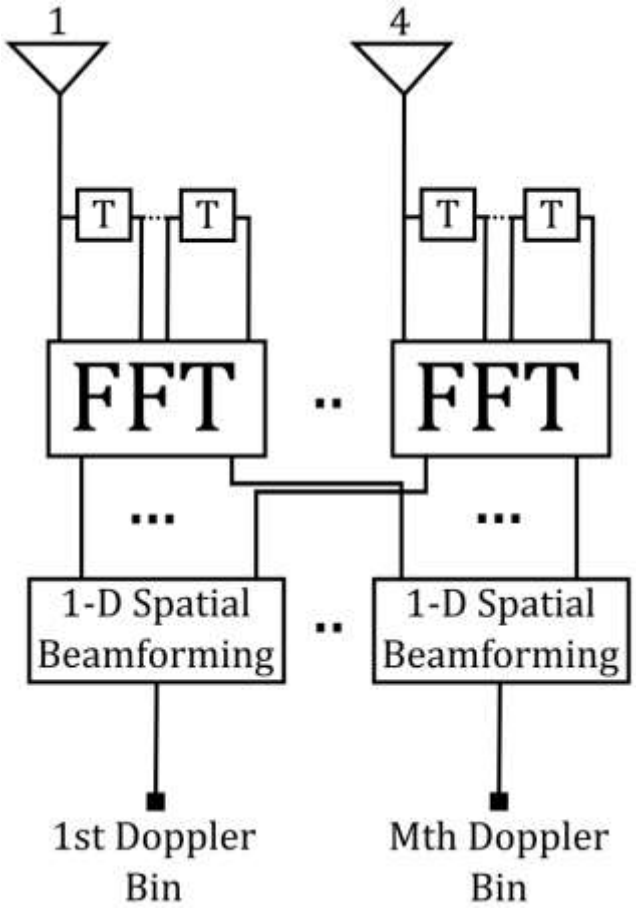
1-D Spatial Beamforming
1-D Spatial Beamforming
1st Doppler Bin
Mth Doppler Bin



$$\boldsymbol{R}(k,w) = \frac{1}{K}\sum_{k=1}^{K} \boldsymbol{Z}(k,w) * \boldsymbol{Z}^{'}(k,w)$$

$$\boldsymbol{h}(k,w) = \boldsymbol{R}^{-1}(k,w) * \boldsymbol{v}(w)$$

$$\tilde{\boldsymbol{Z}}(k,w) = \boldsymbol{h}^{'}(k,w) * \boldsymbol{Z}(k,w)$$



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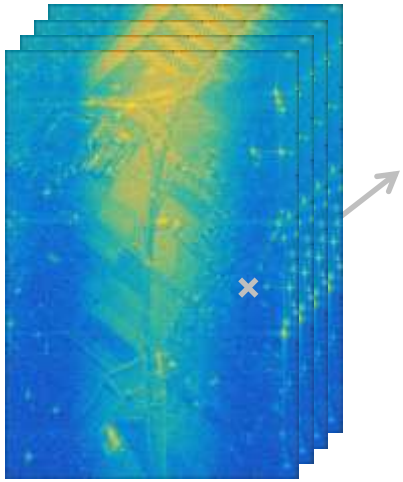
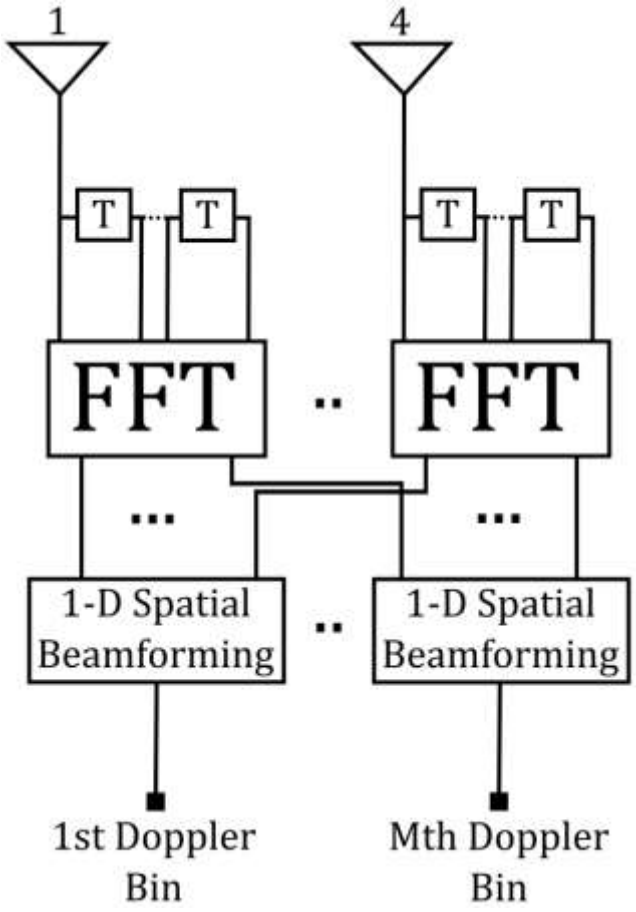


$\boldsymbol{Z}(k,w)$: spatial snapshot;



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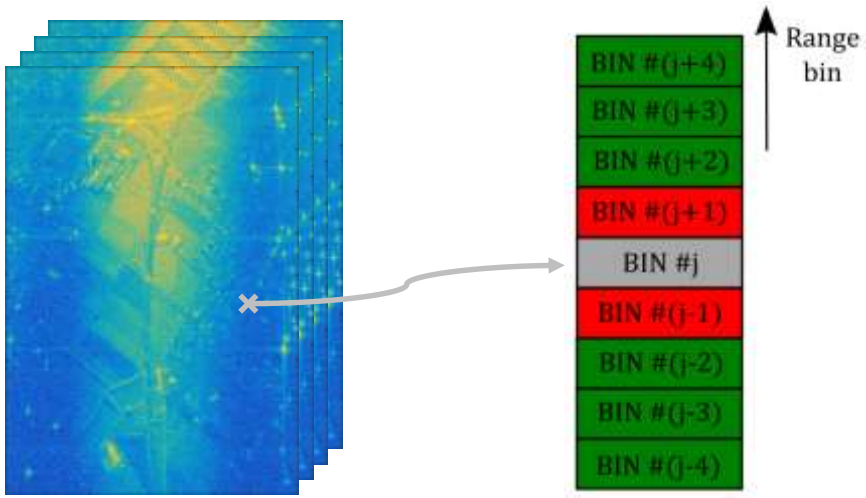
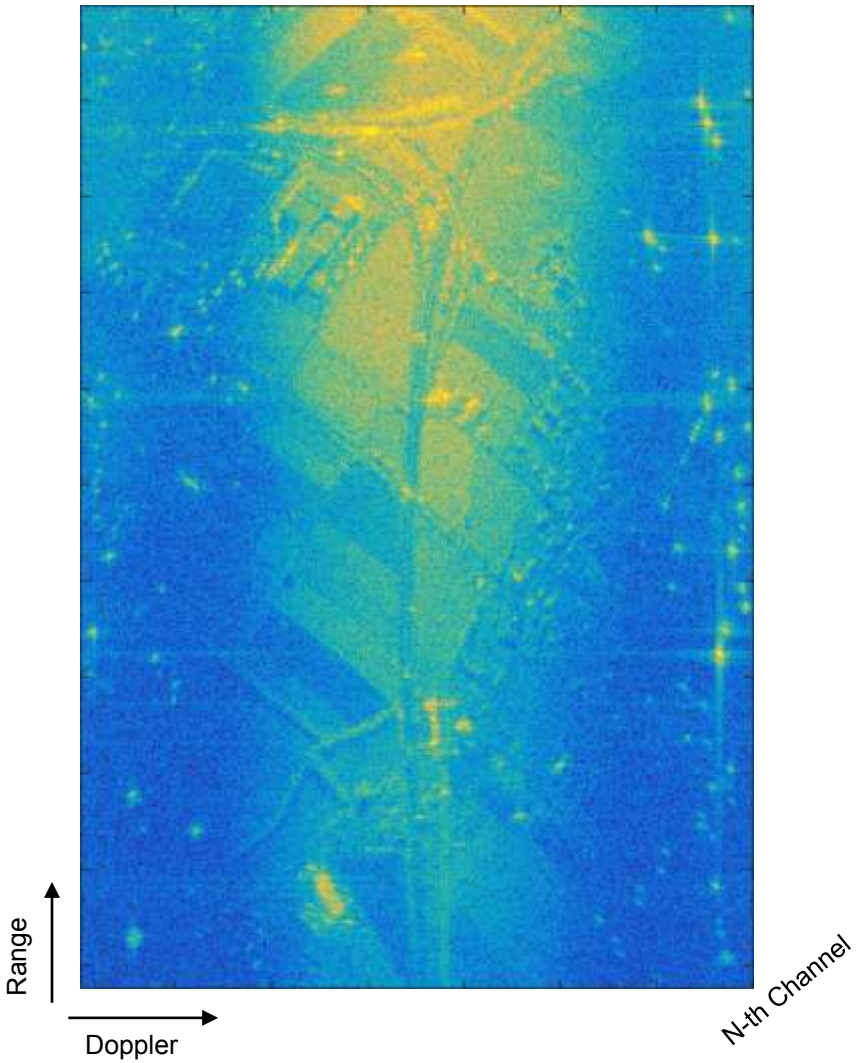
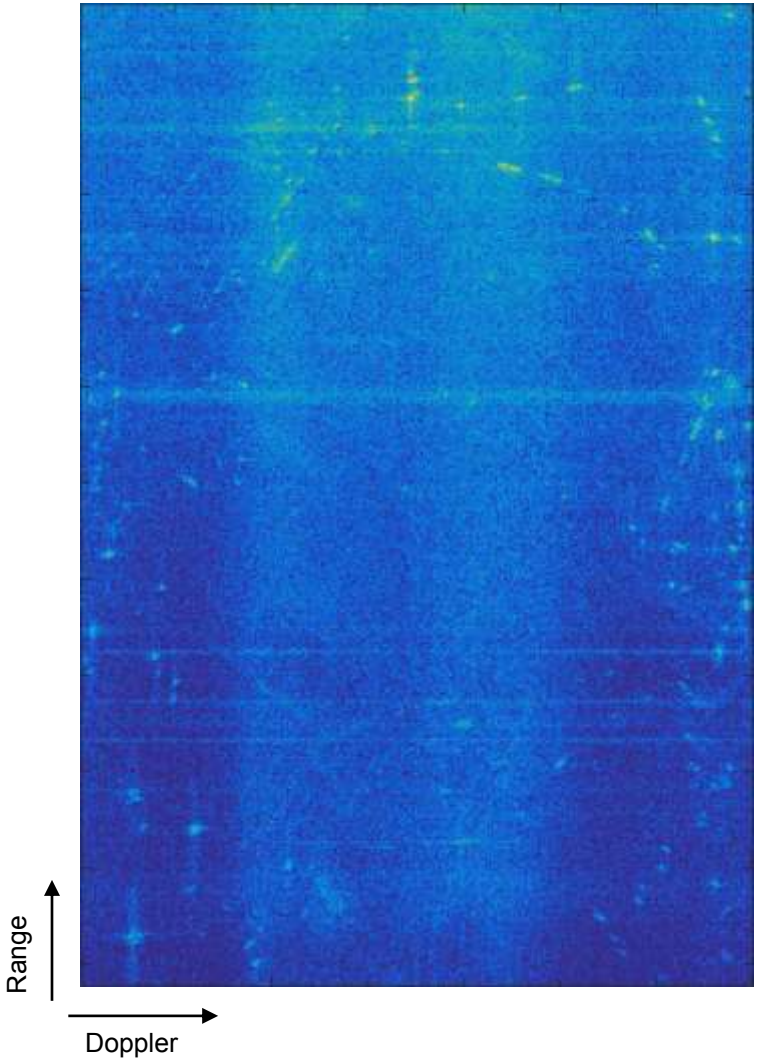


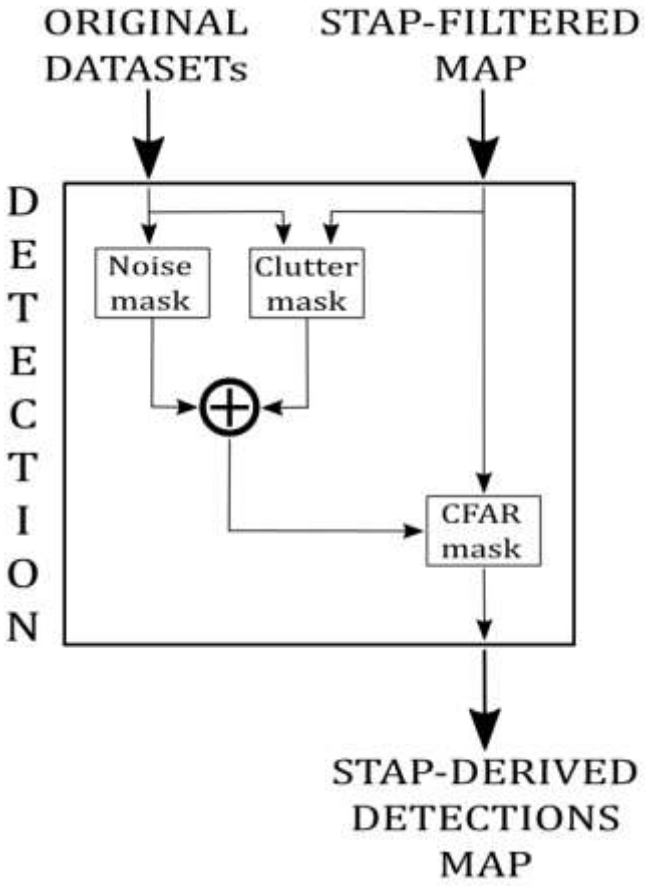
STAP Before



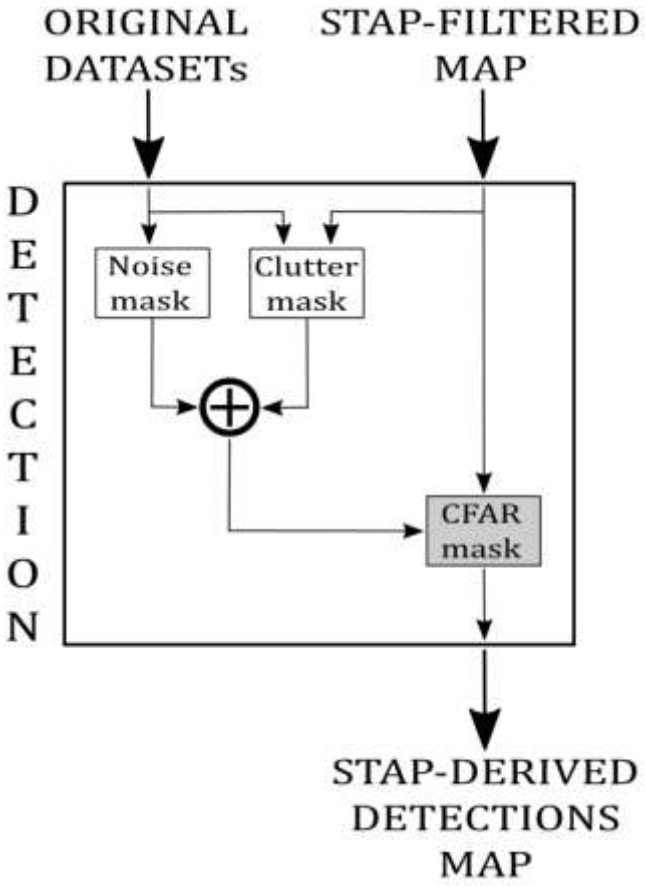
STAP After



Detection Block diagram



Detection CFAR mask

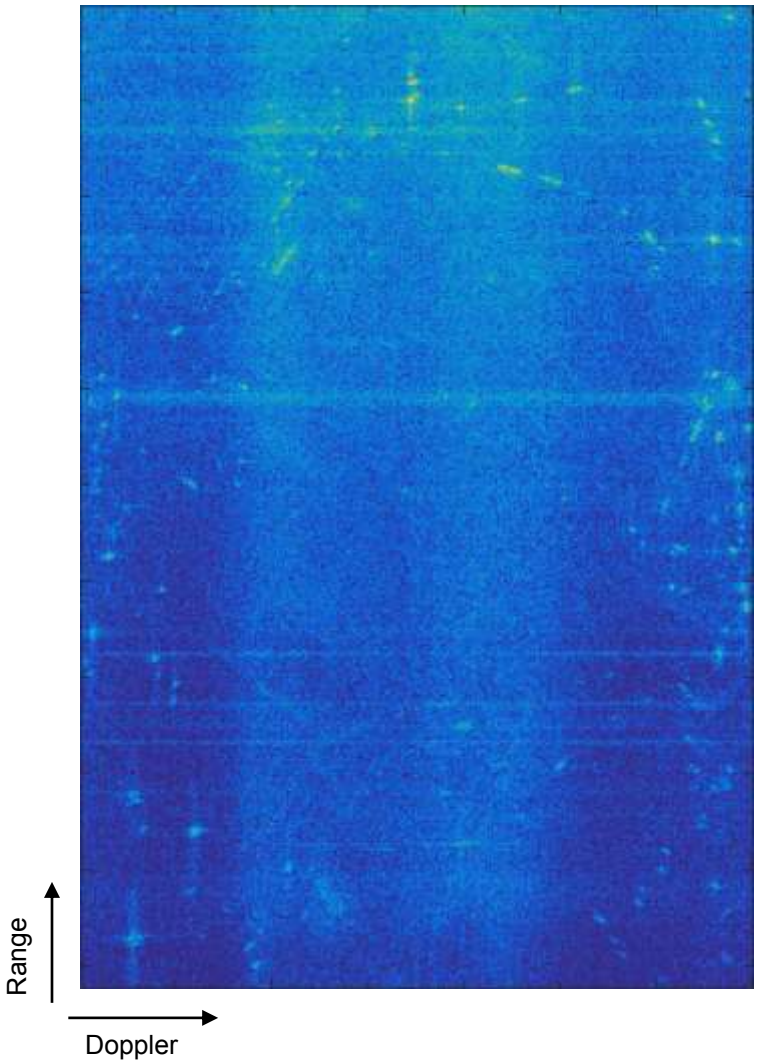


$$\boldsymbol{T}(k,w) = \frac{|\boldsymbol{v}'(w) * \boldsymbol{R}^{-1}(k,w) * \boldsymbol{Z}(k,w)|^2}{\boldsymbol{v}'(w) * \boldsymbol{R}^{-1}(k,w) * \boldsymbol{v}(w)}$$

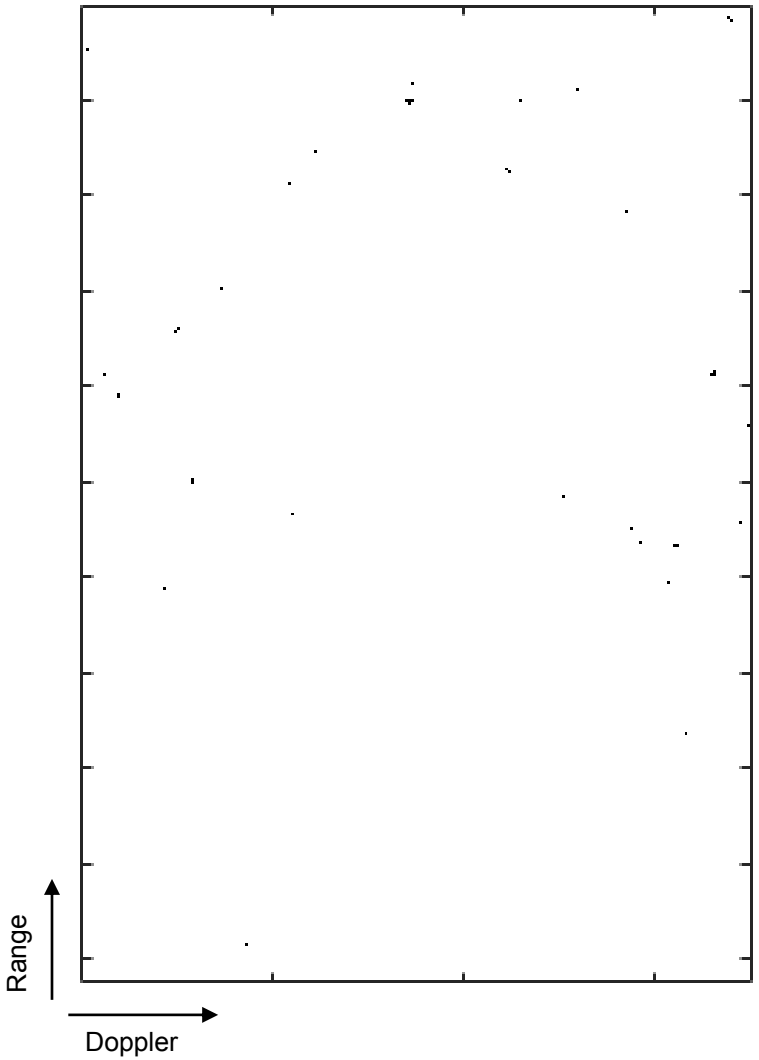
$$\gamma = g[f_T(t), P_{FA}]$$

$$\boldsymbol{M}(k,w) = \boldsymbol{T}(k,w) > \gamma$$

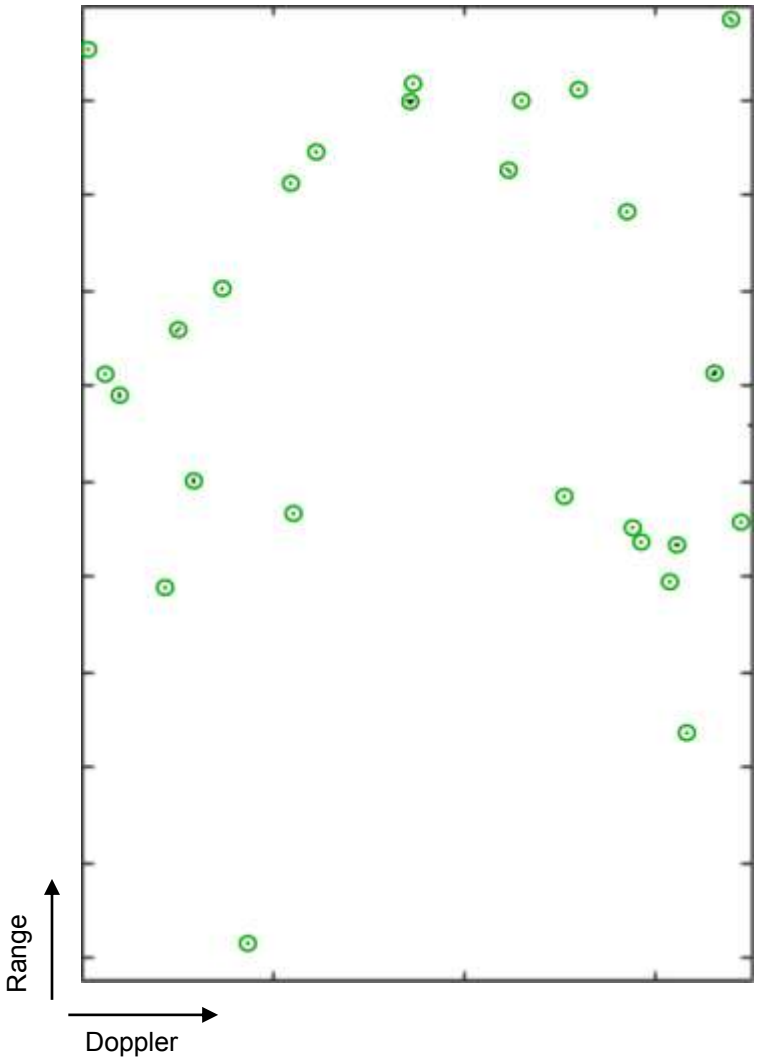
Detection Before



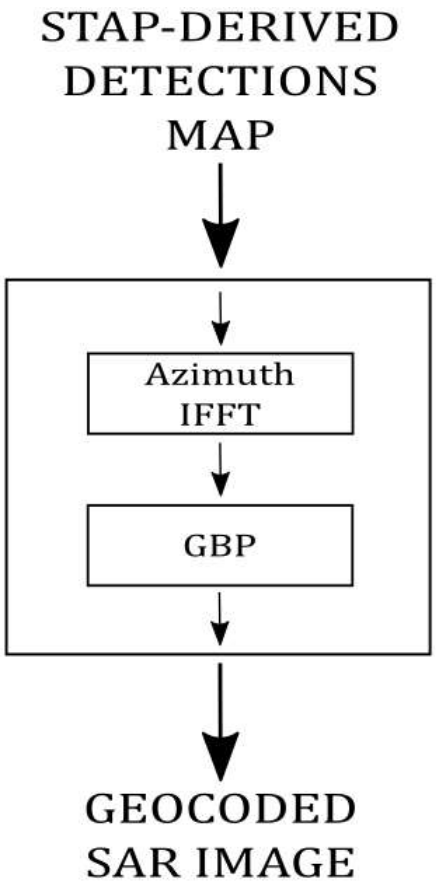
Detection After



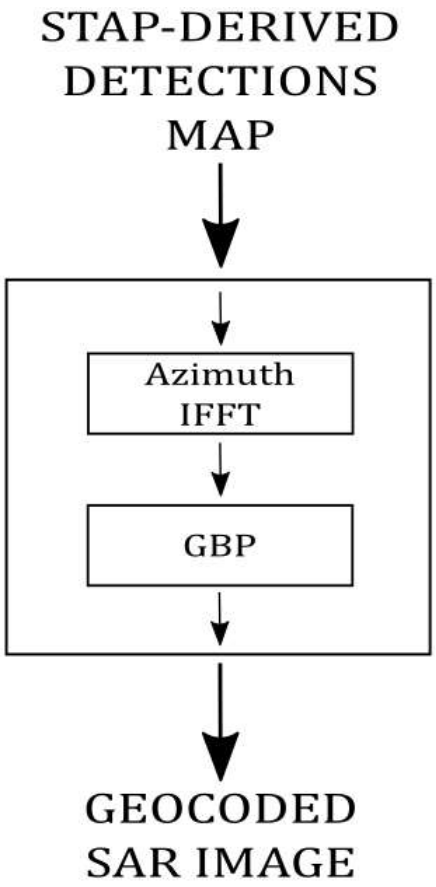
Detection After

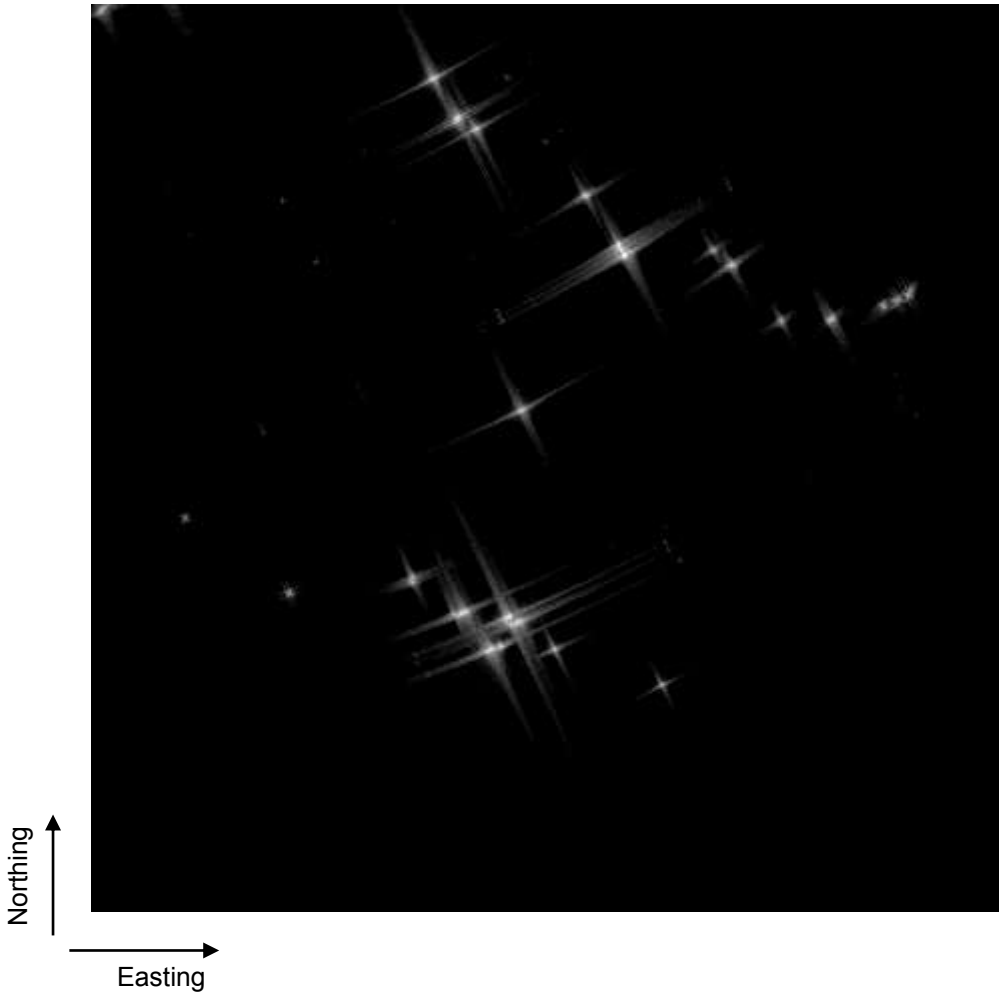


SAR Processing

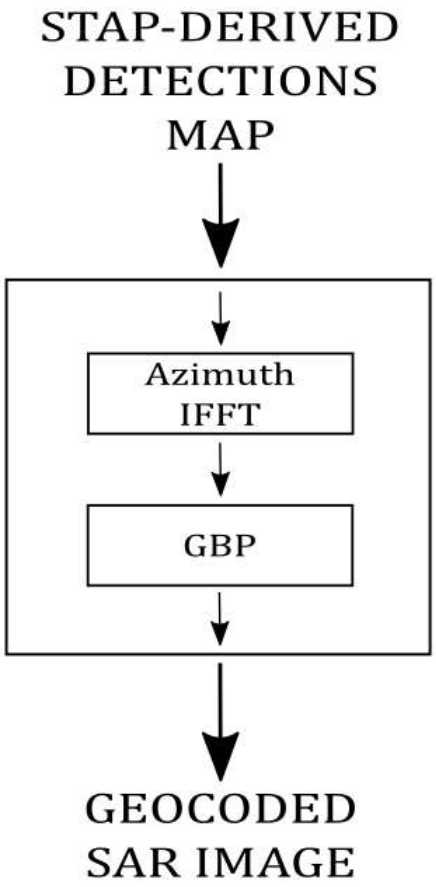


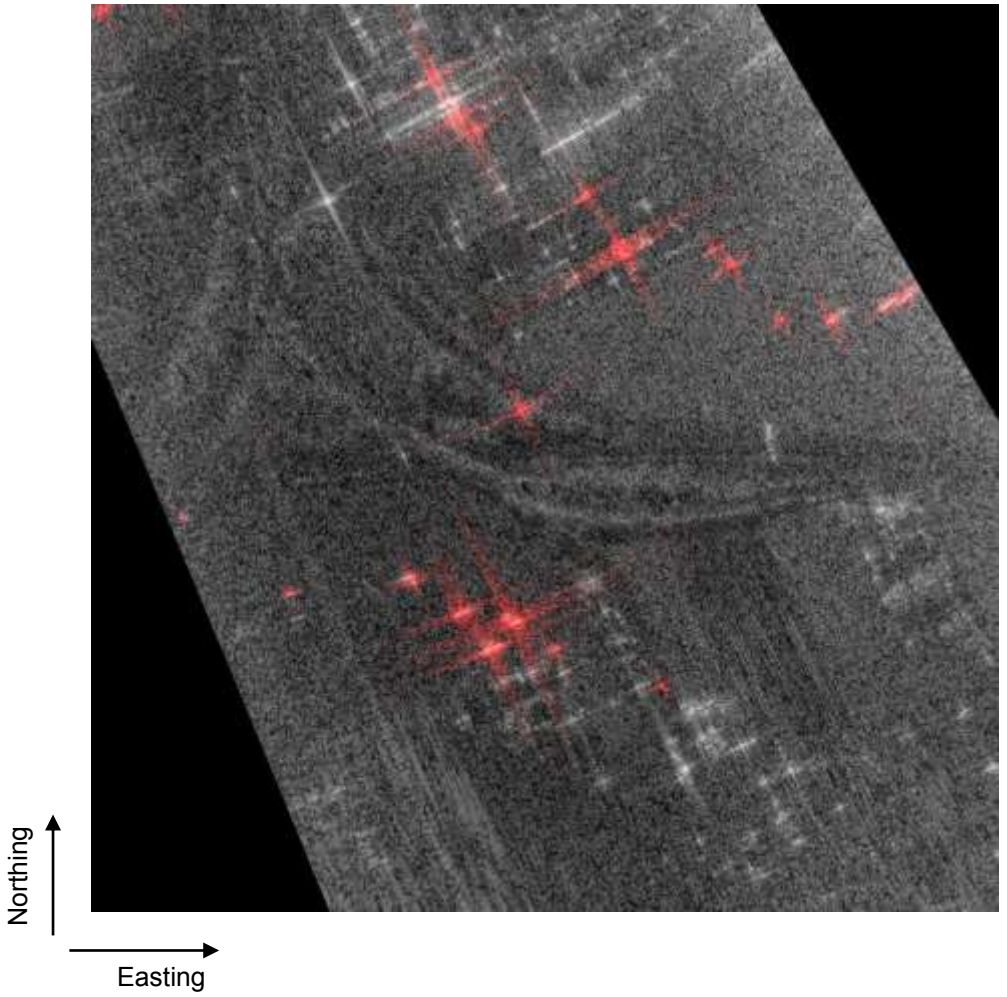
SAR Processing



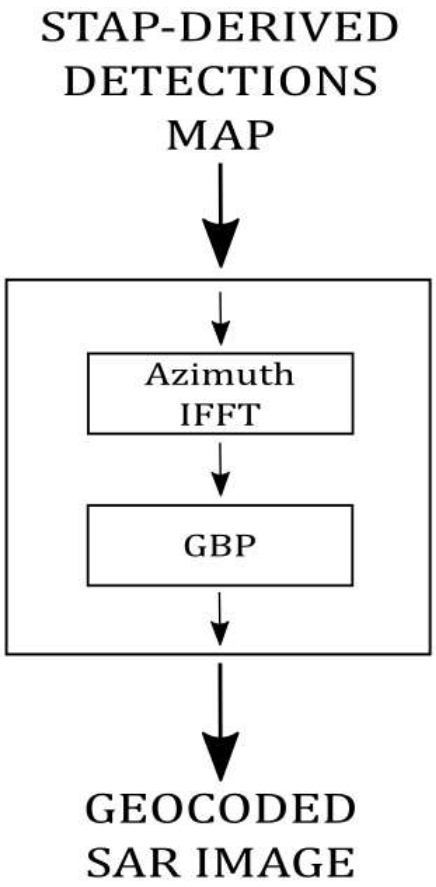


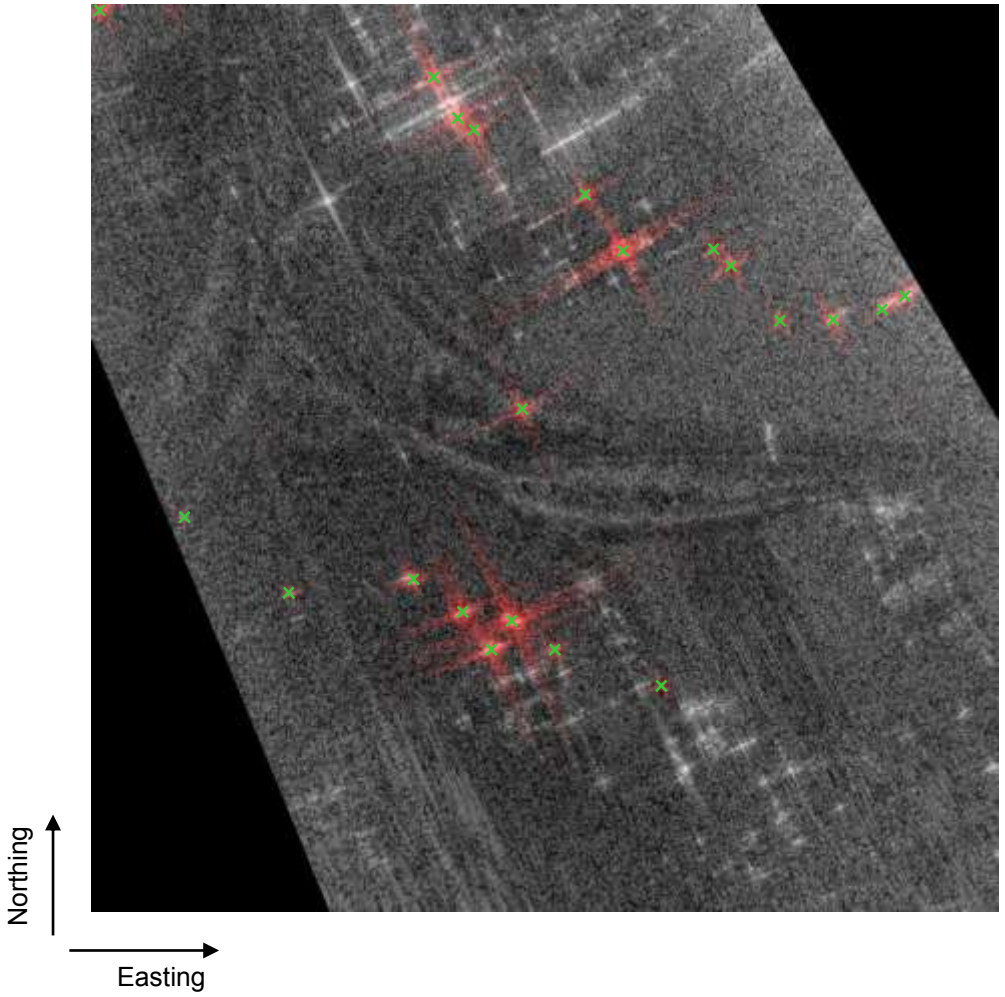
SAR Processing



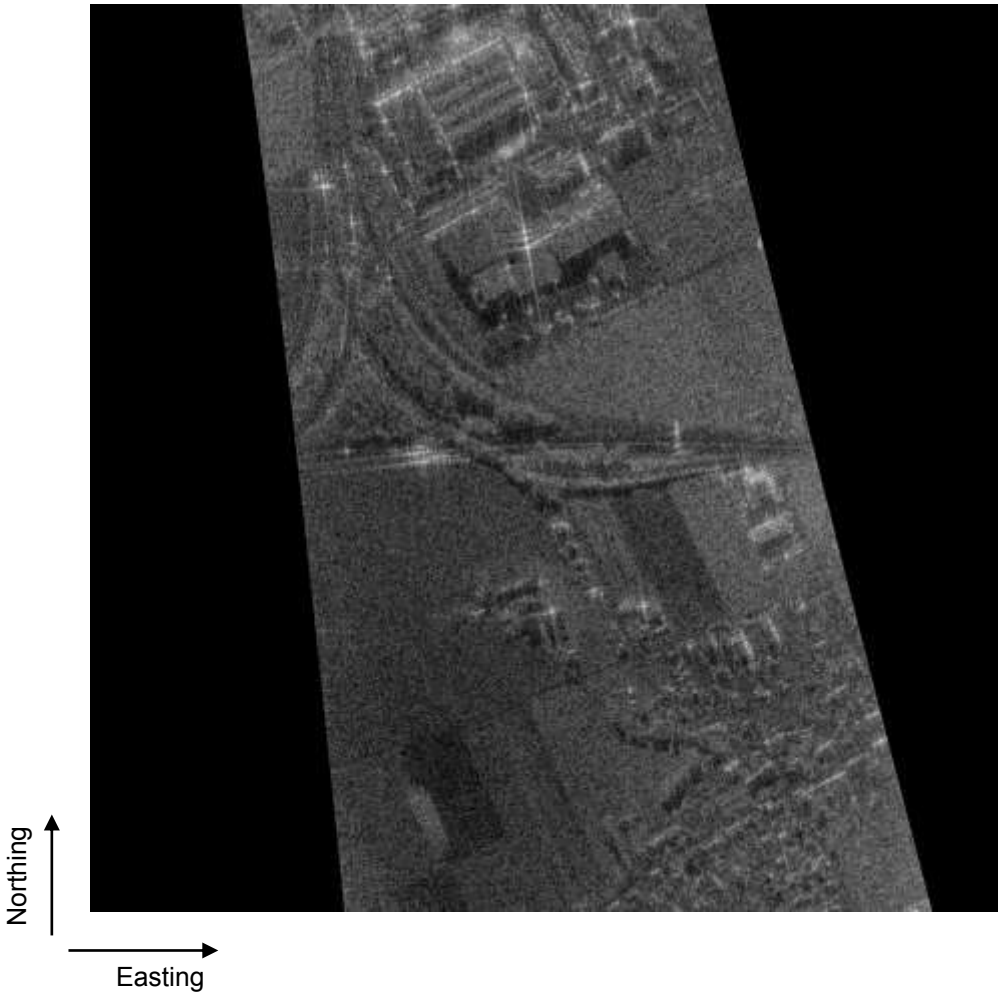


SAR Processing

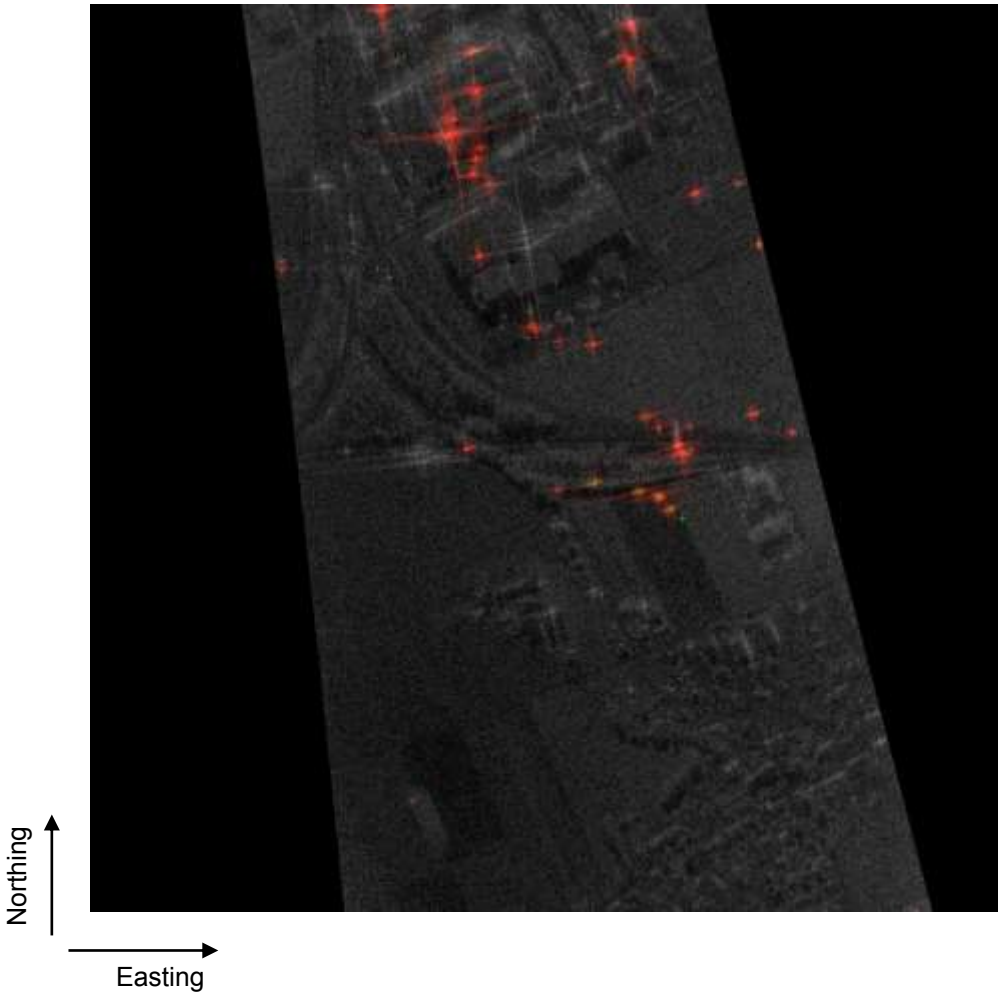




Results Video #1



Results Video #2



Results Table

	SC	ATI	SC ∩ ATI	STAP
MT #1	95	66	98	100
MT #2	42	53	93	90
MT #3	41	57	87	94
MT #4	46	66	93	95
MT #5	3	29	29	81

- SC: number of Single Channel detections;
- ATI: number of Along Track Interferometry detections;
- SC ∩ ATI: number of combined SC/ATI detections;
- STAP: number of Space Time Adaptive Processing detections;

Discussion

About circular acquisition geometries ..

- extended observation time;
- observation from different aspect angles;
- superiority in target discrimination;

About the algorithm: “pros” ..

- reliable detection rate;
- better results than SC, ATI and SC ∩ ATI;
- adaptable to any acquisition geometry;

.. and “cons” ..

- secondary data selection;
- processing time;

Conclusion

- One of the first STAP-based methods for GMTI in circular SAR data;
- average detection rate of ~90%;
- results superior to previously tested algorithms;

Outlook:

- better secondary data selection;
- implementation of *a-priori* inputs;
- merging of STAP with other methods;

Thank you!