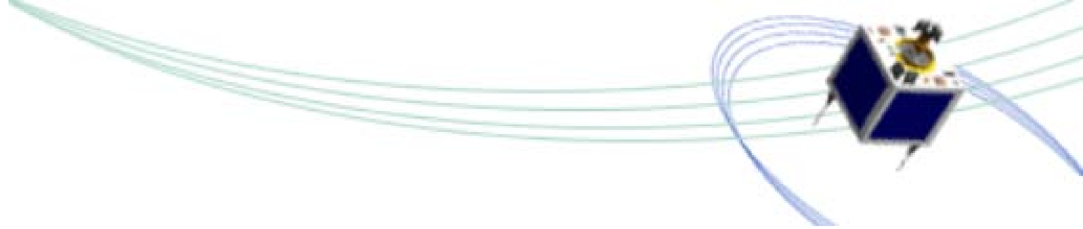


Processing techniques for a GNSS-R scatterometric remote sensing instrument

Philip J. Jales [(1)]

Martin Unwin [(2)]

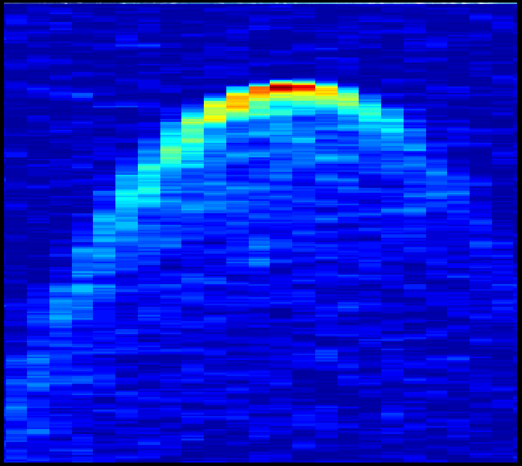
Craig Underwood [(1)]

[(1)] Surrey Space Centre, University Of Surrey, UK

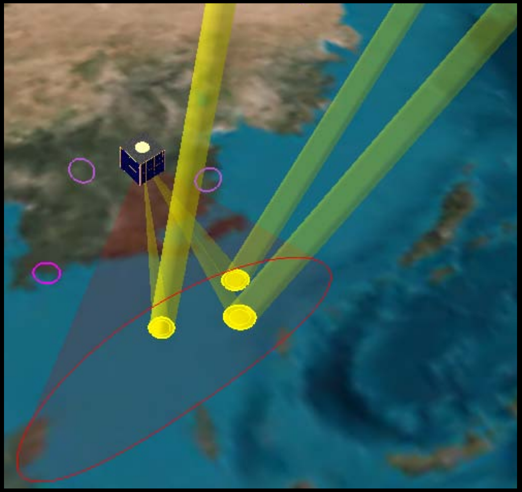
[(2)] Satellite Technology Ltd. (SSTL)

October 2010
GNSS-R 2010, Barcelona

GNSS Reflectometry at Surrey



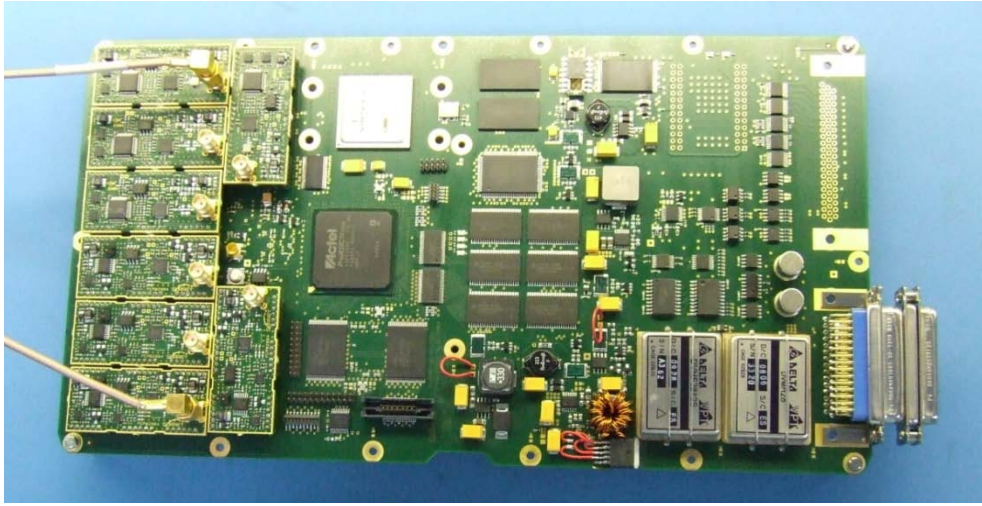
DDM real-time processing



GNSS-R stare processing

GNSS Reflectometry at Surrey

- UK-DMC GNSS-R experiment
- SGR-ReSI
  - SSTL instrument development
  - For small satellite / secondary payload
  - Flexible onboard processing architecture
- Surrey Space Centre
  - Reflectometry PhD



GNSS Reflectometry

•Low cost remote sensor

•GNSS signals:

- Ranging signals,
  Wide bandwidth,
  Global coverage
- Low signal power
  → Measurements around the specular point

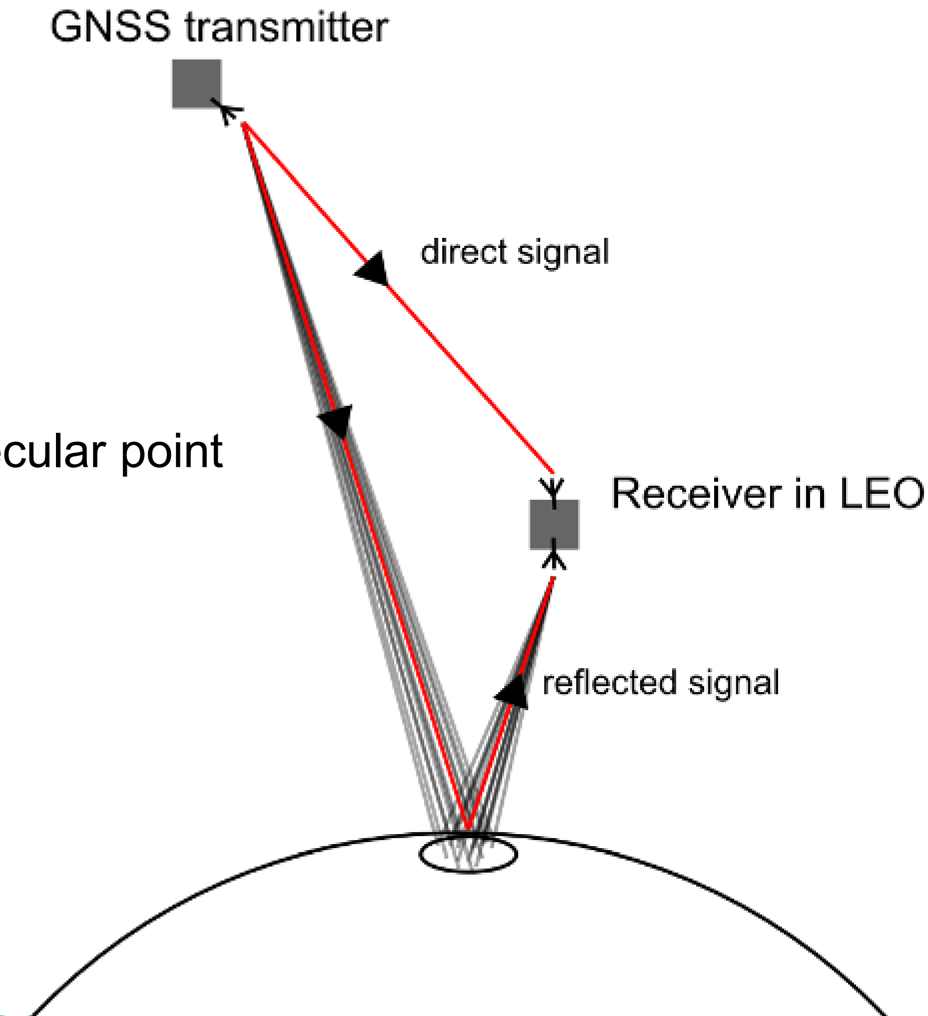
Information from:

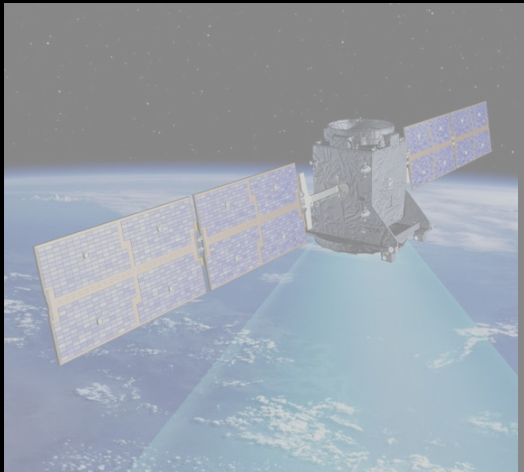
▪Delay:

- surface height → altimetry

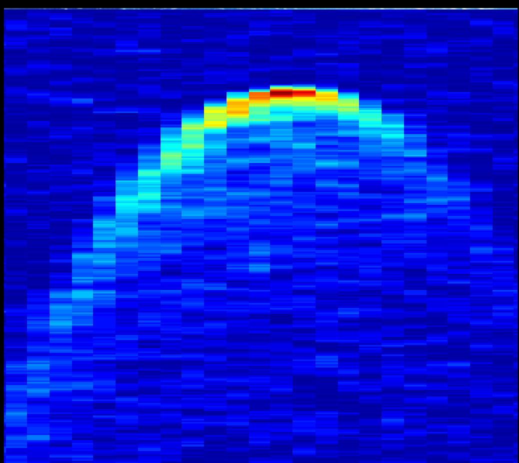
▪Distortion (delay and Doppler):

- surface roughness
- → **scatterometry**
  - **Primarily ocean roughness**

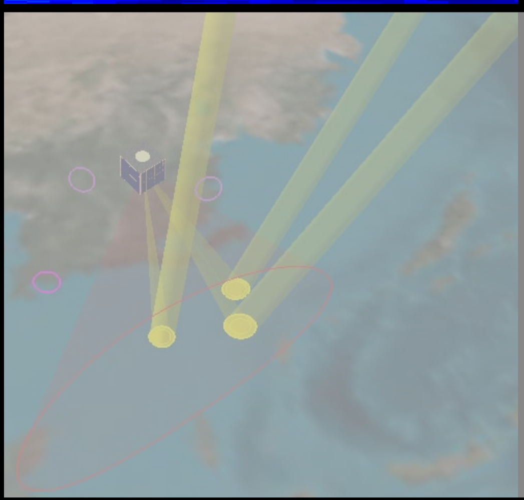




GNSS Reflectometry
at Surrey



DDM real-time processing



GNSS-R stare processing

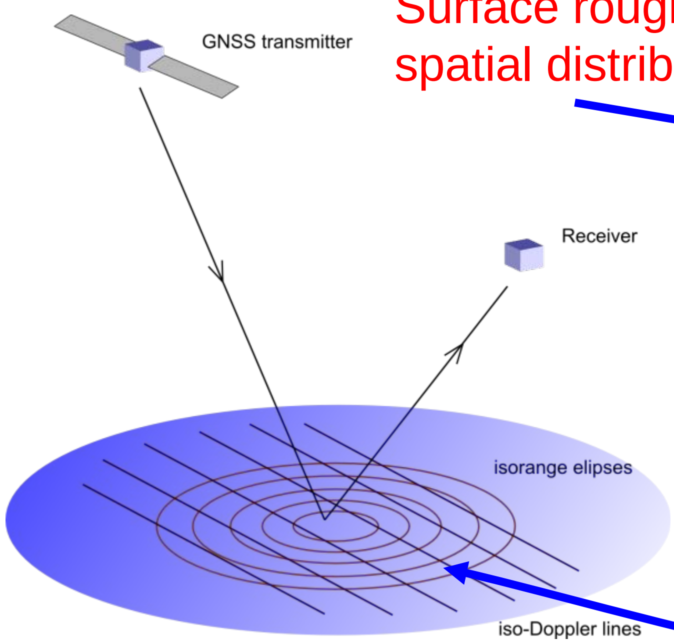
GNSS-R Ocean Roughness

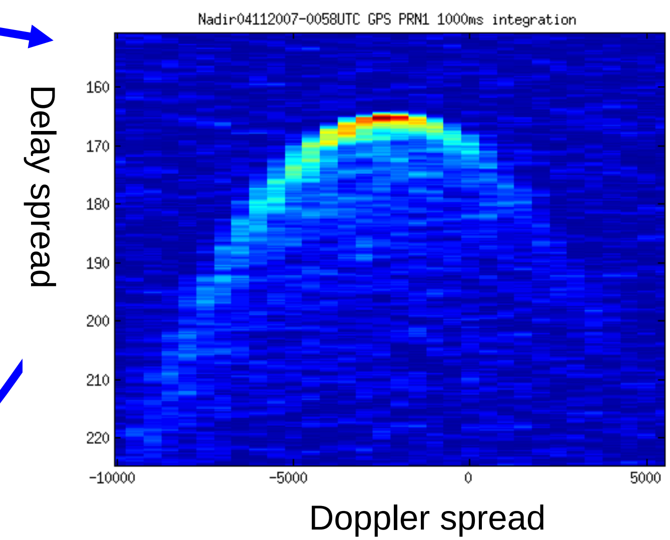
Primary goal: Surface roughness measurement

Surface roughness affects spatial distribution of scattering

Measure: Distortion of signal power

Delay Doppler Map (DDM)





Inversion

- Inversion procedure
  - 'Curve-fit' a scattering model to Delay Doppler Map

Models already exist → Validation needed → currently not enough data

Onboard processing

Limited downlink from satellite

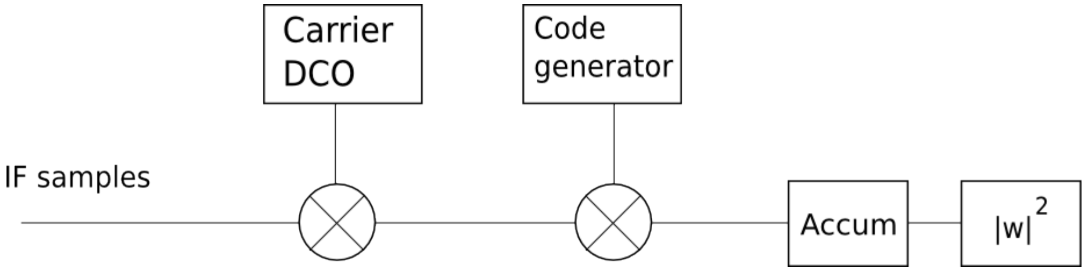
Flexibility in processing vs. Data rate

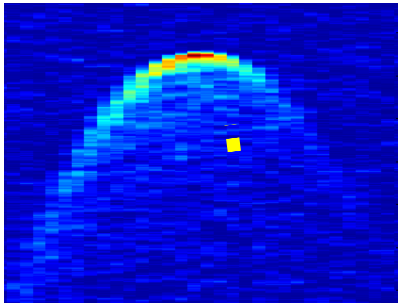
Raw samples
65Mbps (two front-ends)

DDM
100kbps
(2 reflections, 50 Doppler x 128 delay pixels)

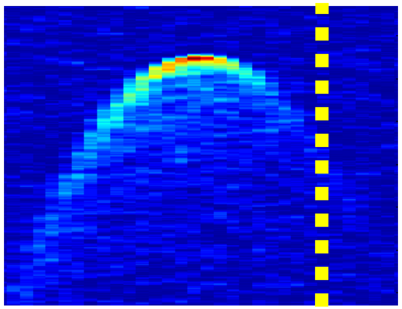
DDM generation approaches

- Correlation in discrete channels
  - Similar to a navigation, tracking receiver

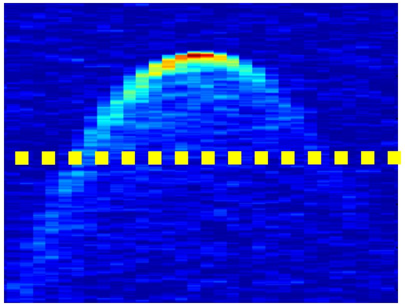




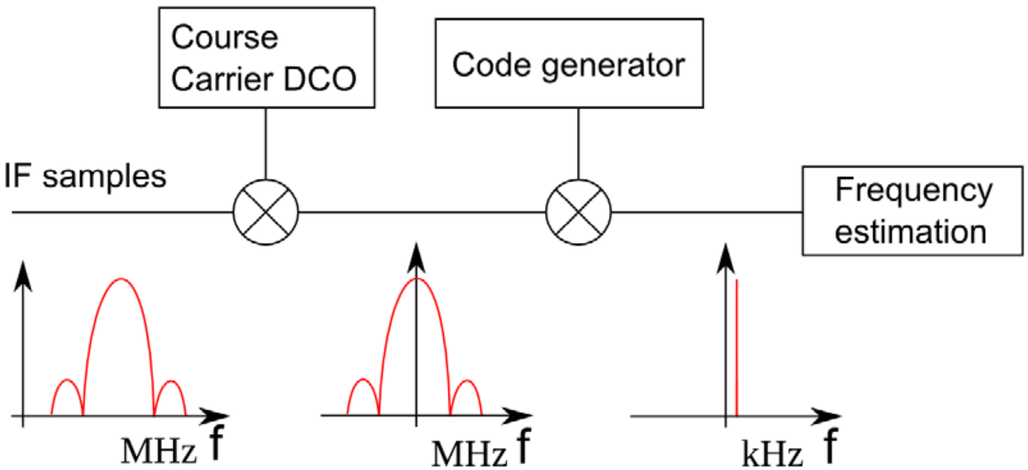
- Processing time goes with $N_{Doppler} \cdot N_{delay}$

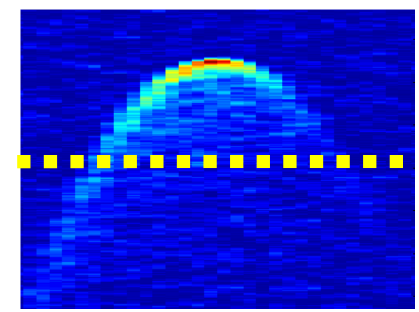


- Fourier transform based techniques
  - Parallel calculation of Doppler or delay map

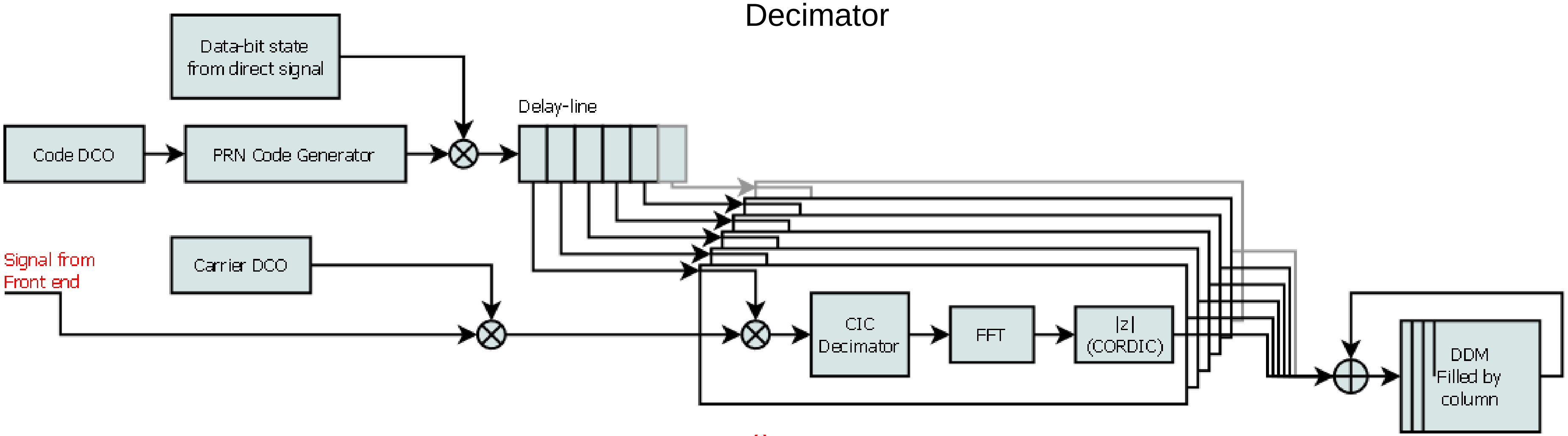


DDM generation
Real-time FPGA architecture



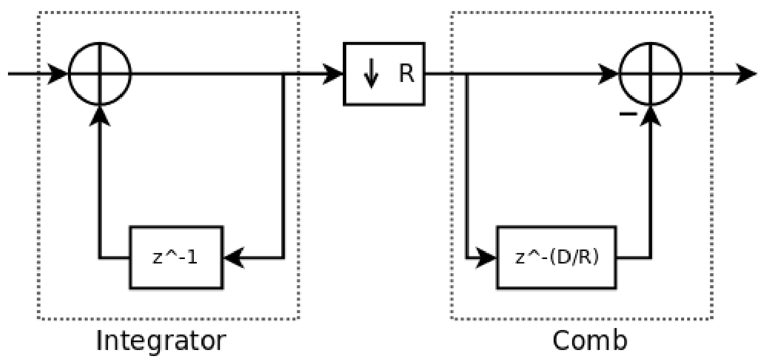


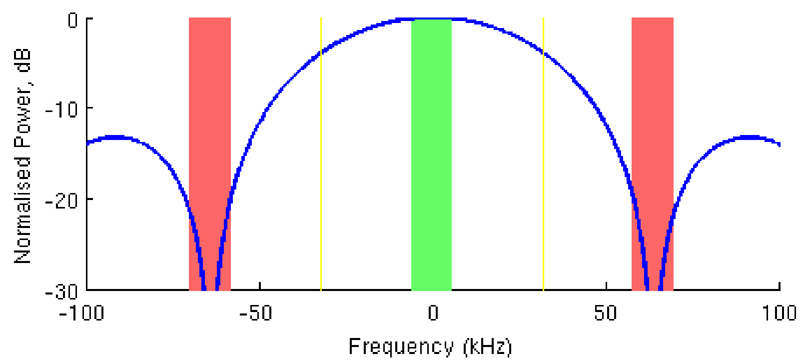
Coarse carrier wipe-off → Code wipe-off → Cascaded-Integrator-Comb Decimator → Fourier transform → Incoherent accumulation



Real-time DDM Implementation

- CIC (Cascaded Integrator-Comb) filter
  - Decimation reduces effort for the frequency search
  - Attenuates signal towards edge of band

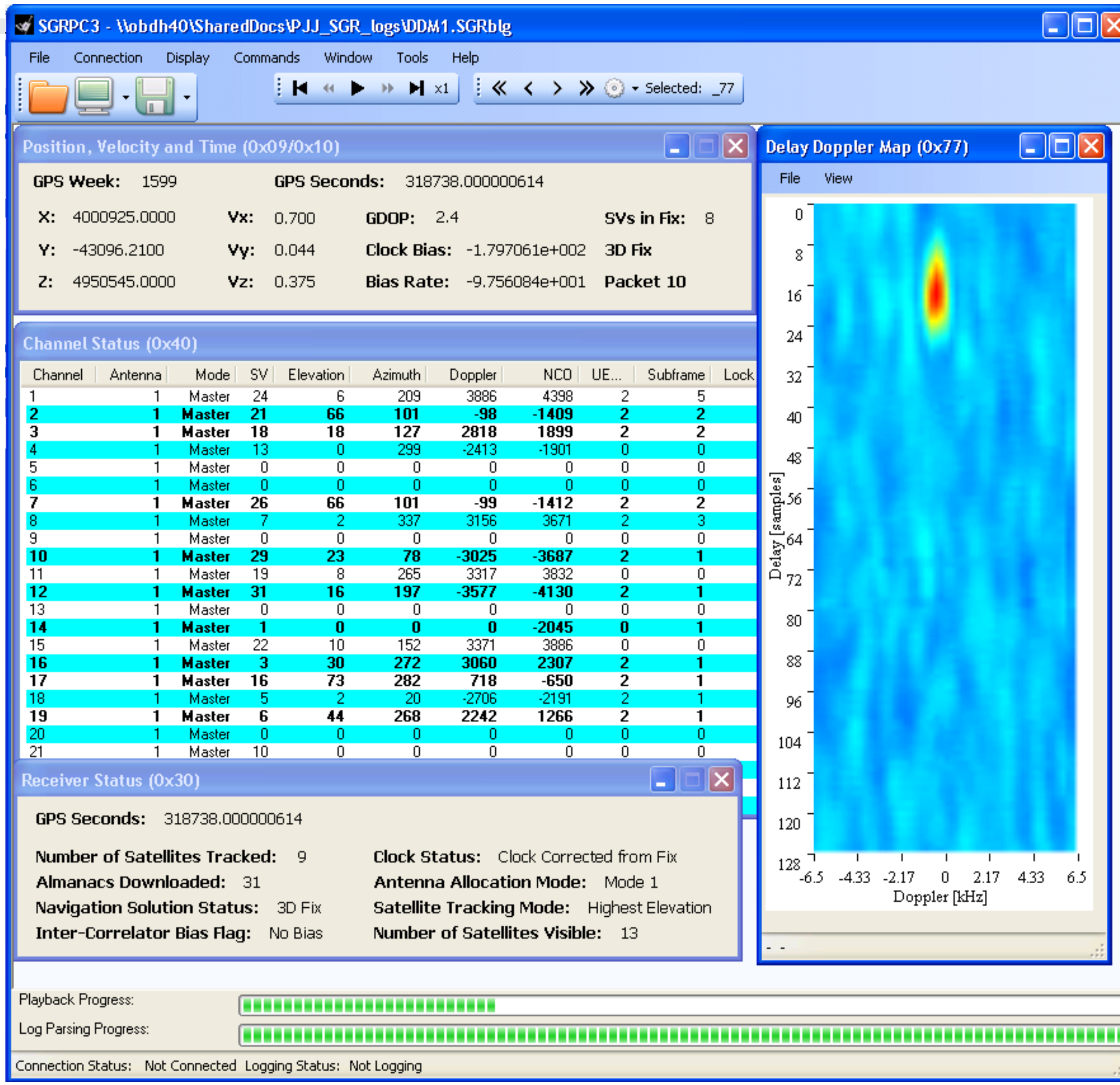


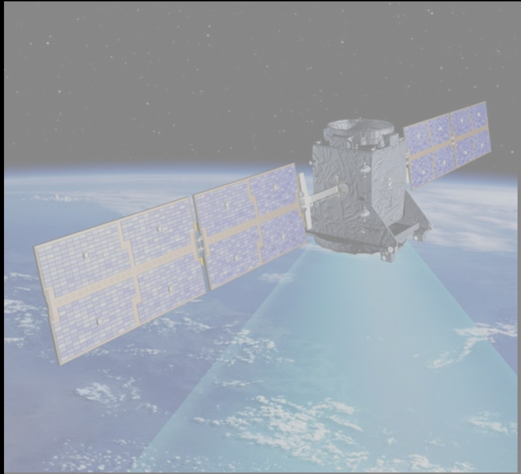


- Optimisation for FPGA implementation
  - Embedded resources more power and space efficient
  - Dual-port RAM blocks & Multipliers
  - Time-sharing (multiple processing clocks per sample)

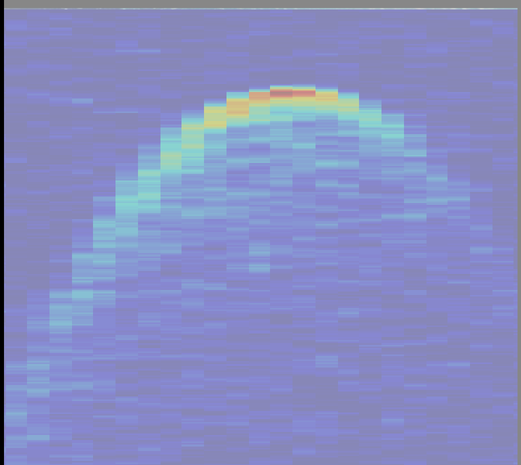
Real-time DDM

- Currently working on live signals
- Working to demonstrate:
  - Real-time reflection tracking
  - Testing on the data from UK-DMC experiment

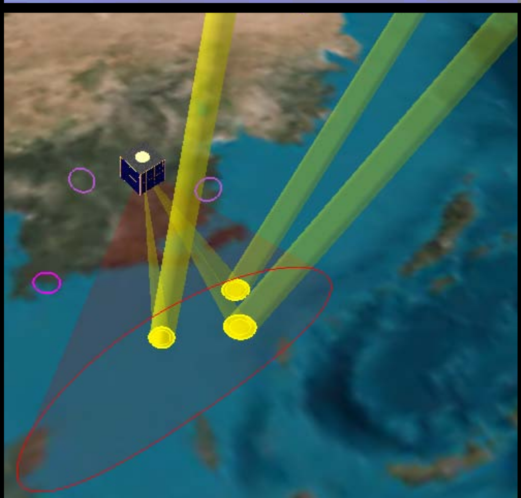




GNSS Reflectometry
at Surrey



DDM real-time processing



GNSS-R stare processing

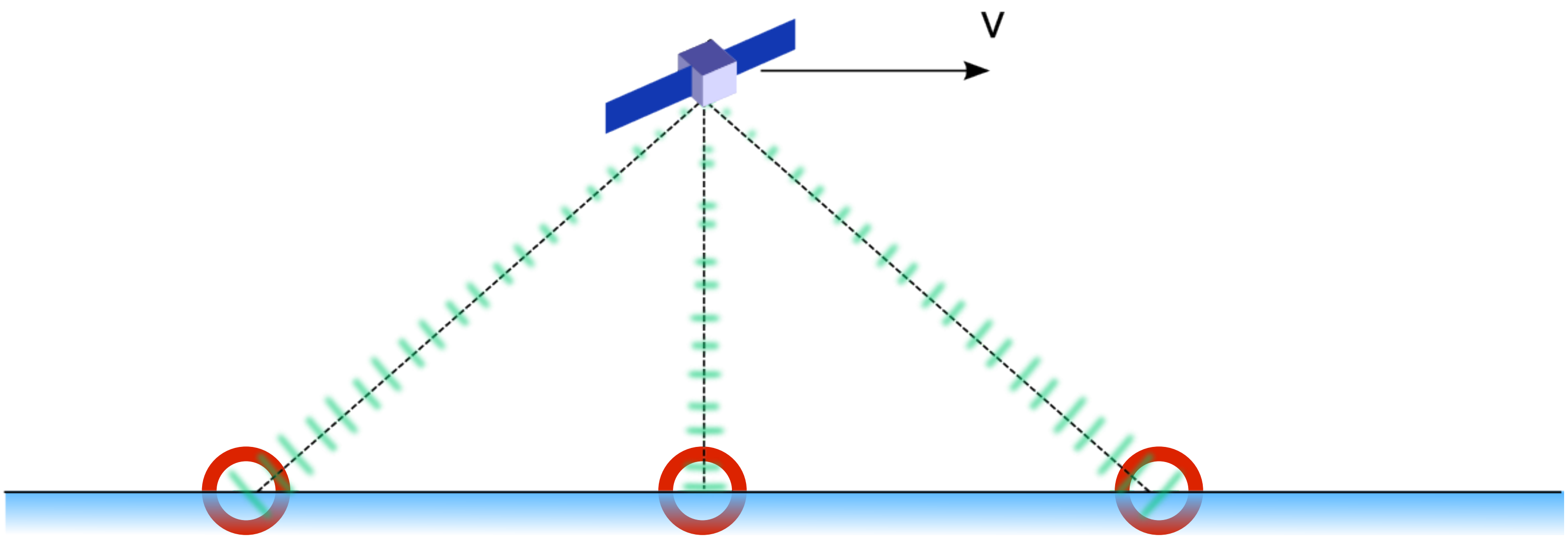
Stare processing

- Based on our interpretation of the SHARP method originally proposed by Starlab, Barcelona

- Conceptually closer to the monostatic scatterometers currently used for ocean roughness measurement
  - Few published details on SHARP method
  - Has not been demonstrated before

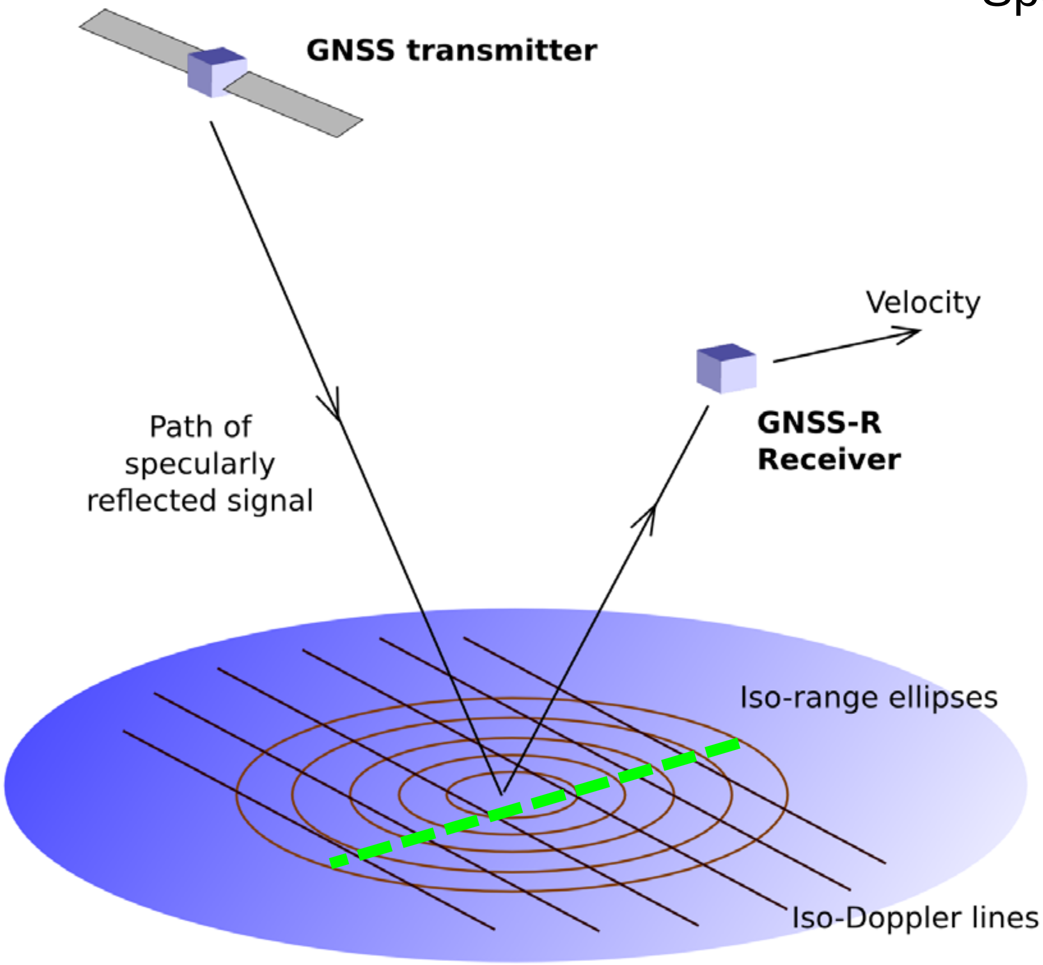
Scatterometers for measuring ocean roughness

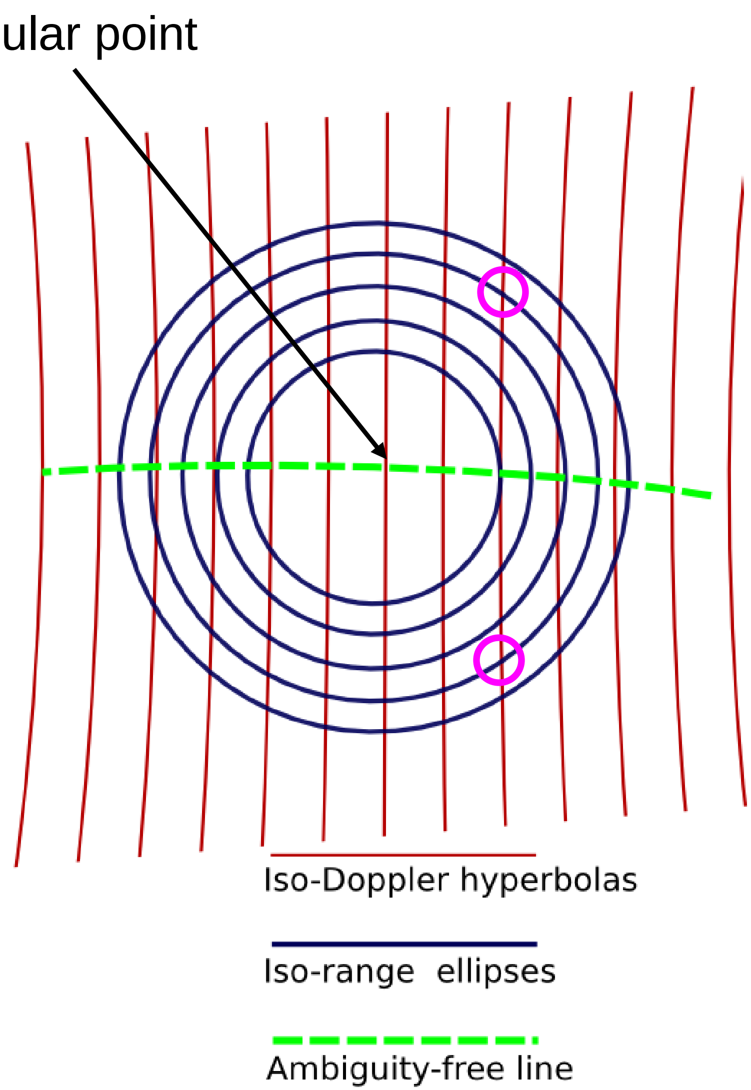
- Traditionally monostatic (no GPS!)
- e.g. QuikScat, (measured surface wind vector)



- Measure normalised **radar cross section** sigma-0, σ_0 at 3 **incidence angles**
- **Semi-empirical** model to derive wind speed and direction

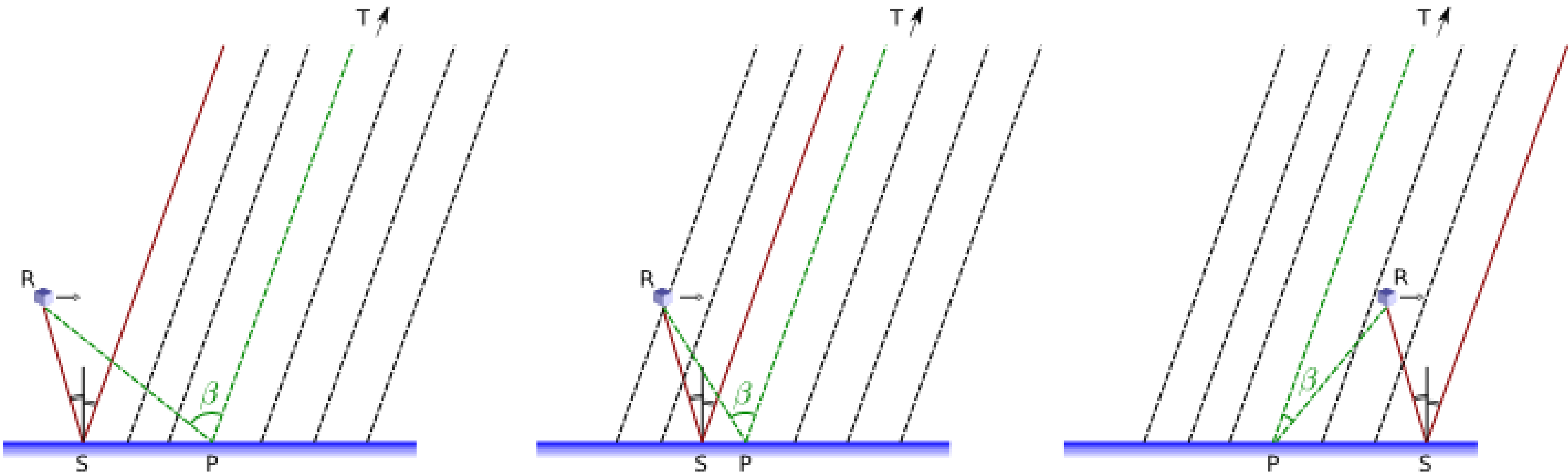
GNSS- R
The ambiguity-free line





Stare processing mode

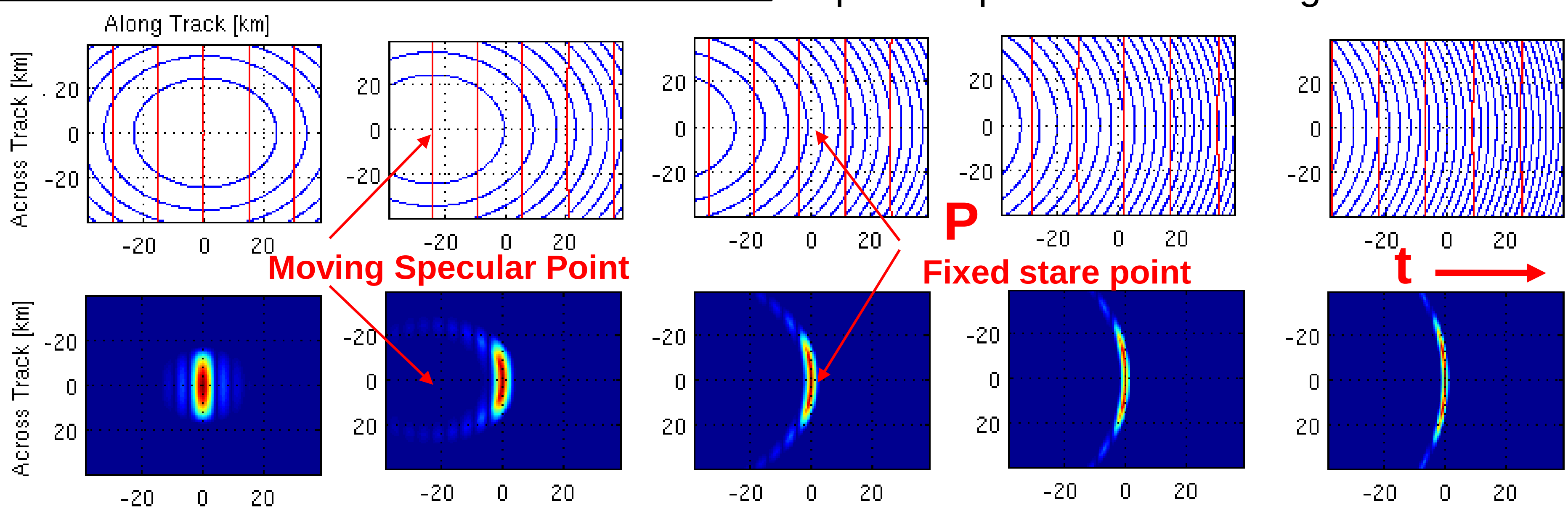
Special case of passing directly over a stare point P



Correlator-selected area

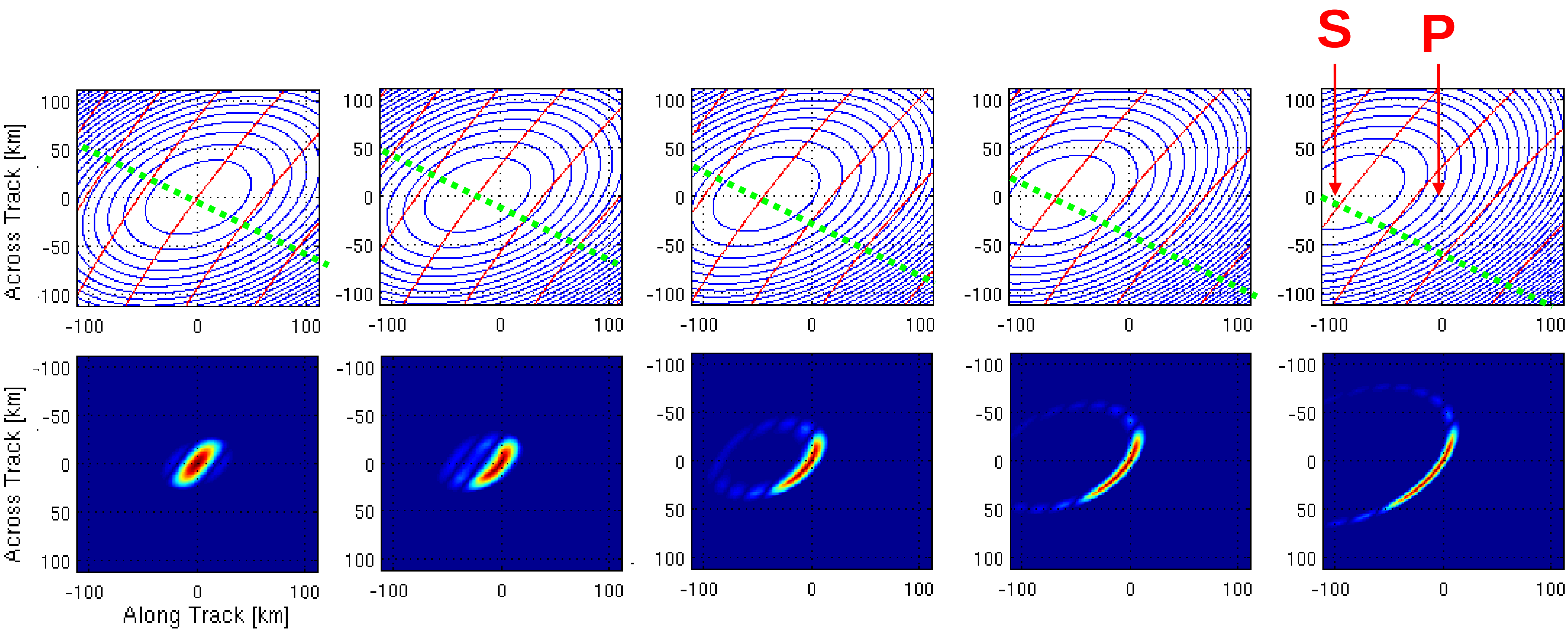
- Steer correlator to the delay and Doppler predicted for point P
- Correlation 'selects' reflected energy from this point
- The 'illumination' area varies

Ocean viewed from above
Stare point P on the ambiguity-free line
Specular point moves through P



Non-ideal geometry

- Stare point no longer on ambiguity-free line



  – Receiver velocity dominates
  – Results in minor reduction in resolution

Measuring sigma-0

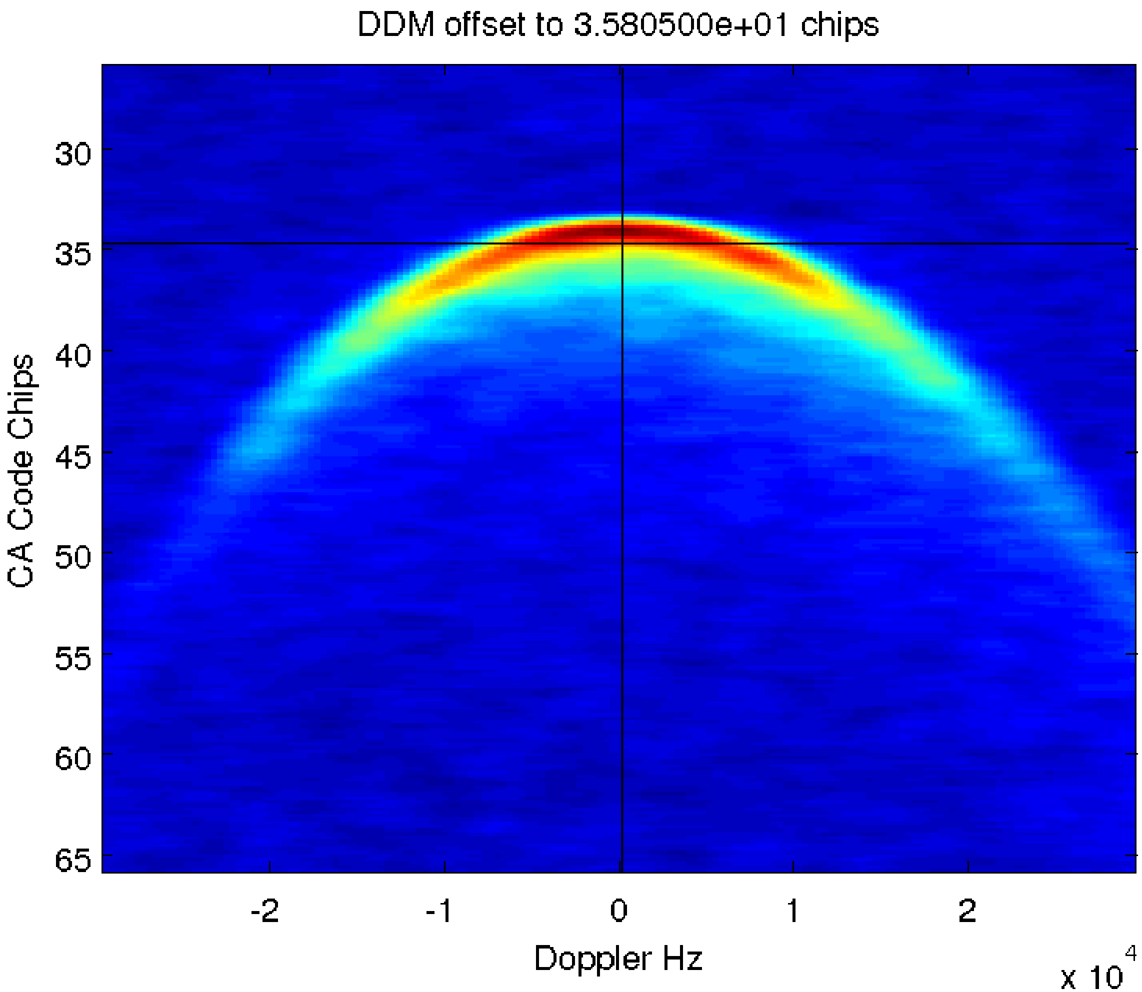
Bistatic radar equation

$$P_R = \frac{\lambda^2 P_T G_T G_R \sigma_0 A}{(4\pi)^3 R_T^2 R_R^2}$$

- σ_0 is the scattering cross-section per unit area
- Variable geometry, transmitter power, and illumination area

- Geometrical prediction accurate enough ?
- Verify link-budget

Example DDM demonstrates open-loop tracking



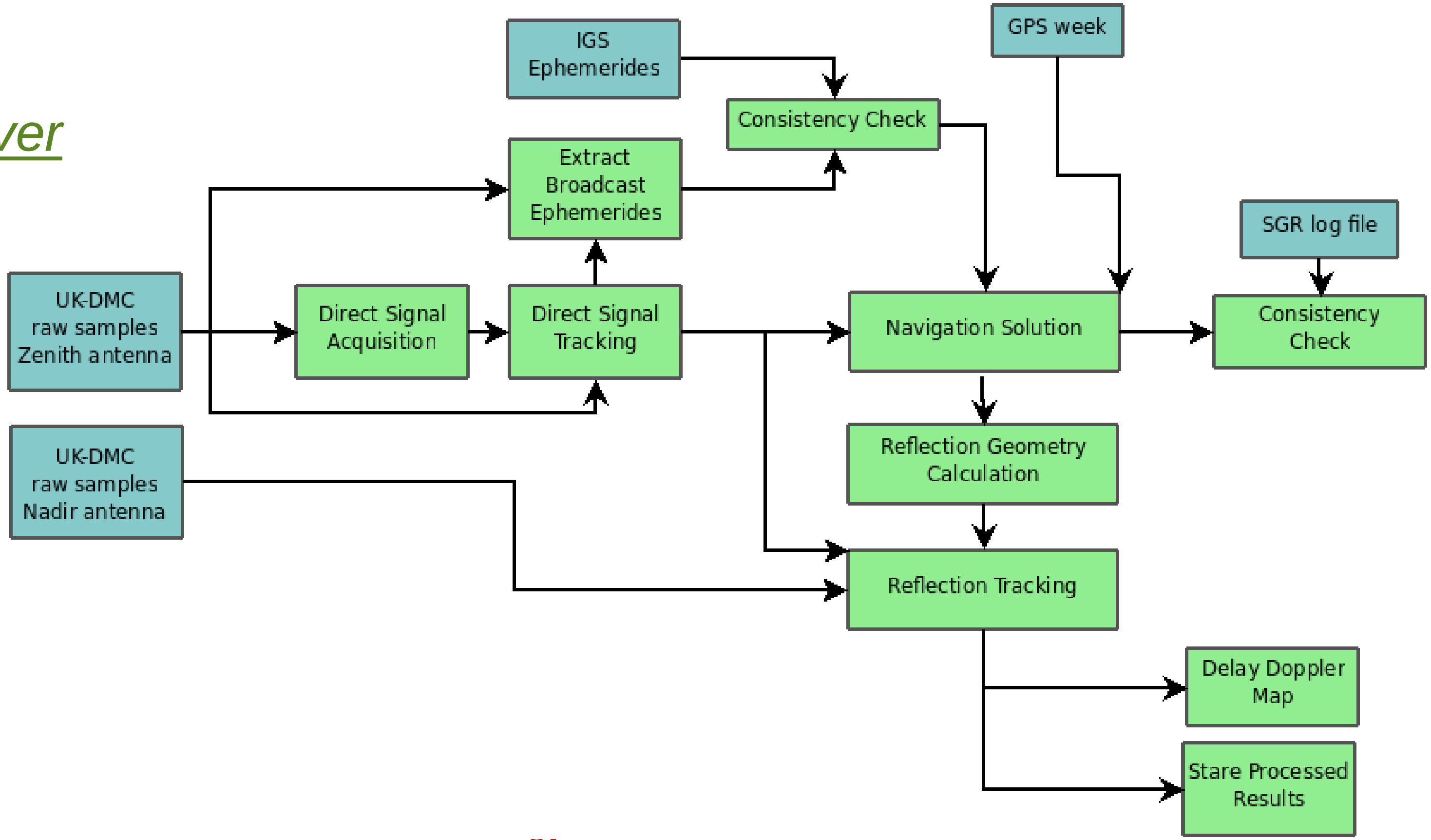
- DDM processed with open-loop tracking
- Specular point prediction and tracking demonstrated

Demonstration on UK-DMC data

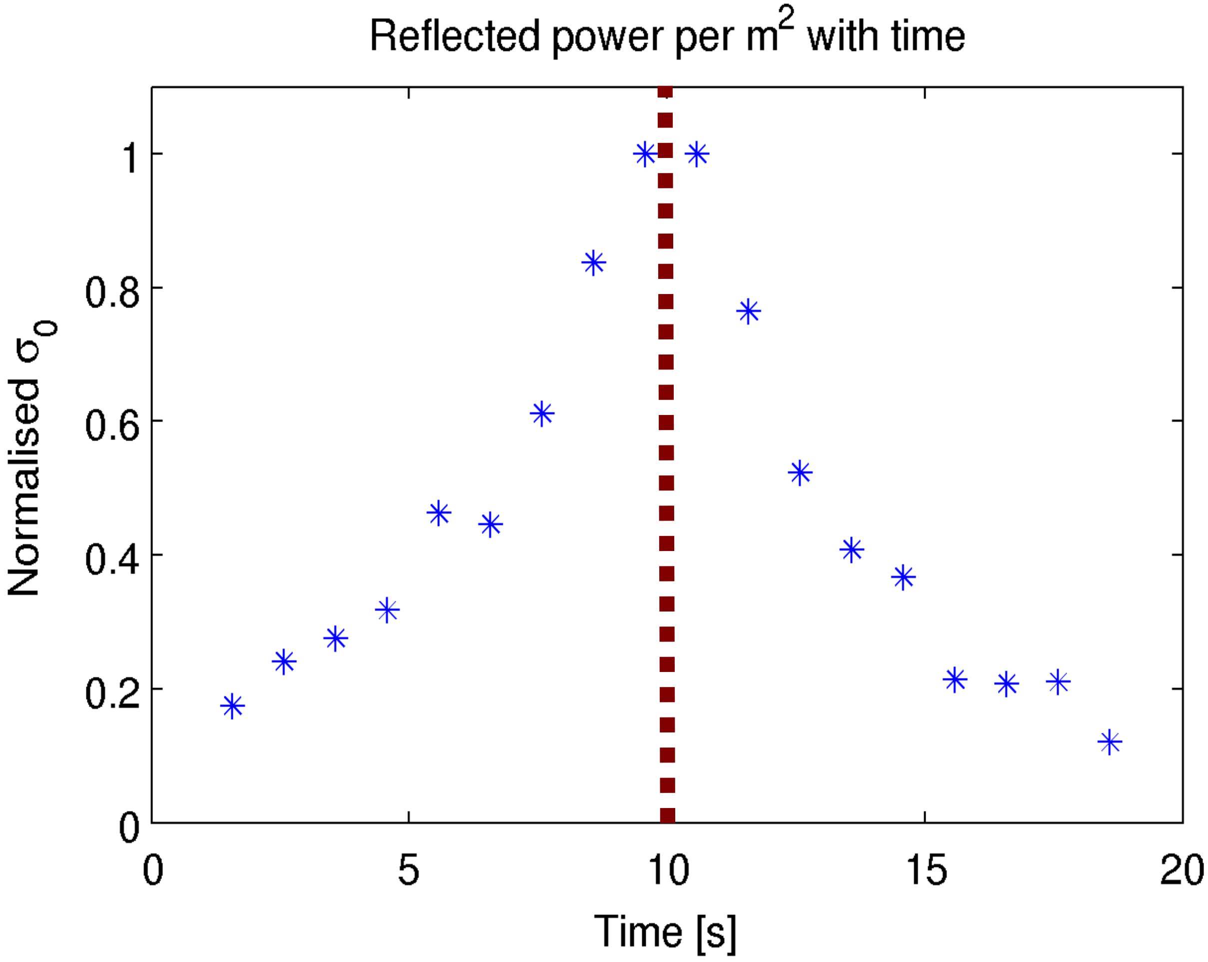
Processes the 20 second data files

1. Using zenith antenna signals to find the receiver position
2. Predict the reflection position
3. Form stare processing or DDM from nadir samples

Software receiver



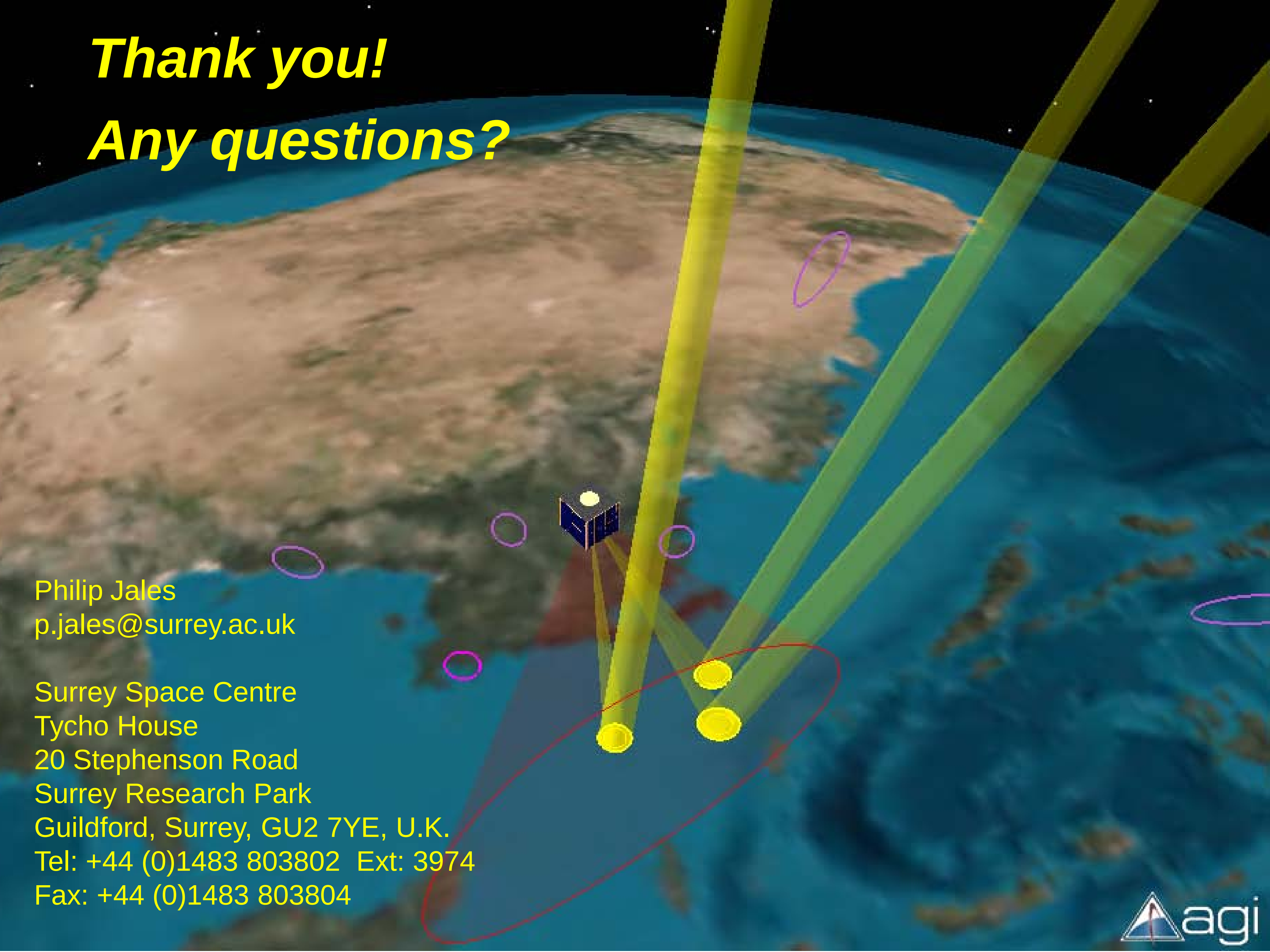
Stare processing example: Relative bistatic scattering cross-section



- Open-loop tracking successful
- Width of graph expected to give measure of surface roughness

Conclusions

- Stare processing
  - Implementation of geometric tracking
  - Verify the accuracy of tracking (using DDM)
  - First demonstration on data collected from space
  - Insufficient data from orbit to build an empirical model
- Real-time DDM processing
  - Real-time using FPGA optimised structure
  - Receiver operation being validated on UK-DMC data



Thank you!

Any questions?

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