An Efficient Processing Algorithm for RADARSAT-2 Spotlight SAR Data

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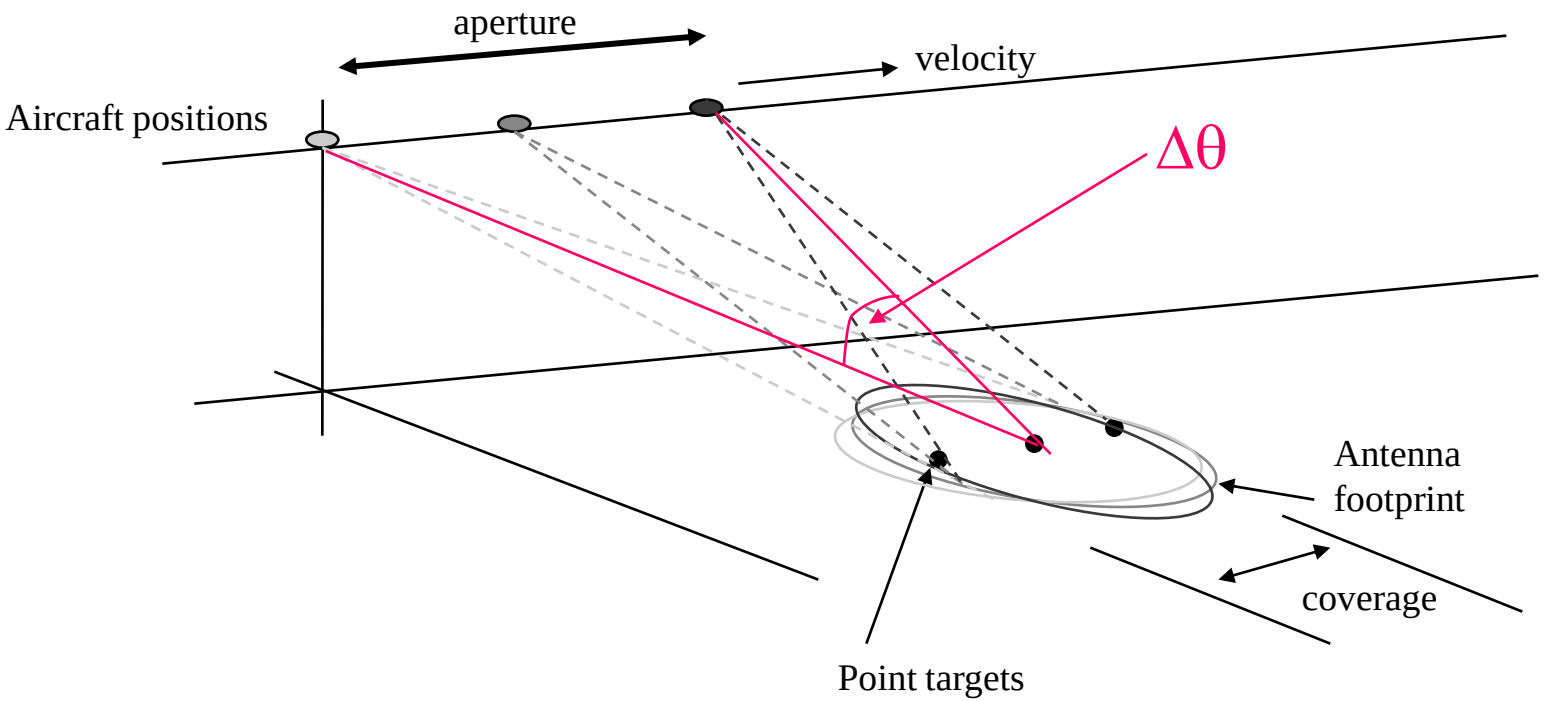
SPOTLIGHT DATA ACQUISITION

- Azimuth (cross range): unweighted resolution

$$\rho = 0.886\lambda / (2\Delta\theta)$$

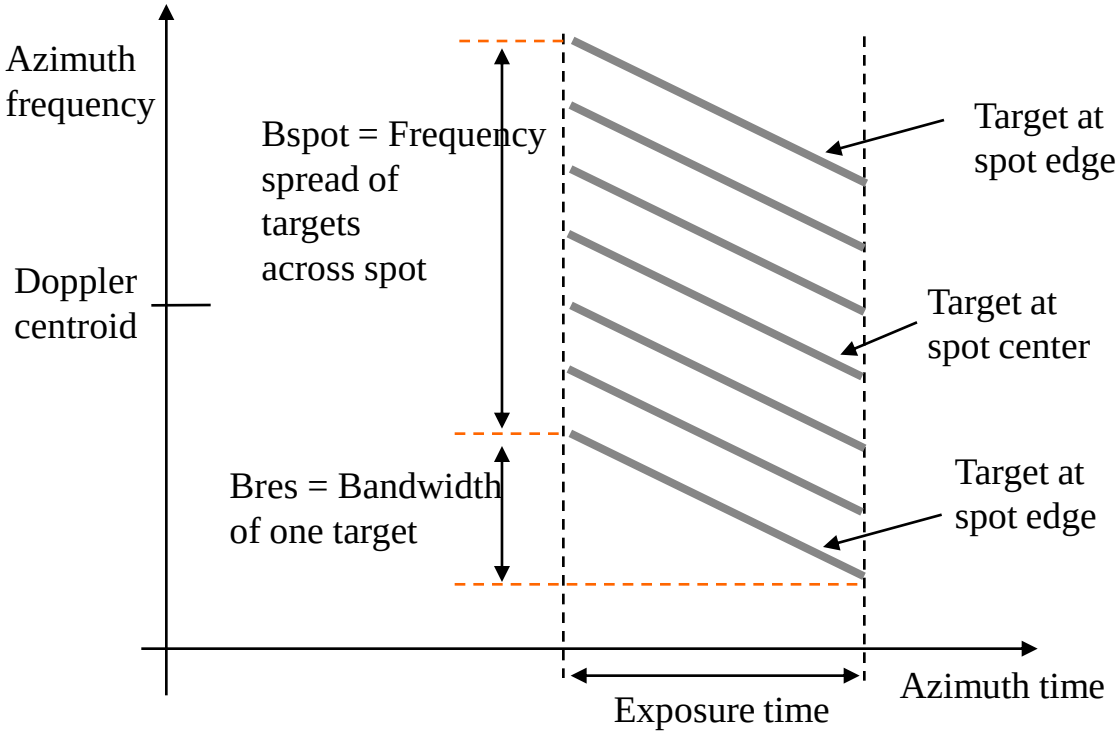
λ = wavelength, $\Delta\theta$ = synthetic aperture angle



Antenna steered to point at the same spot size => ground covered by beam-width.

PRF CONSIDERATION

- Spotlight time-frequency characteristics



PRF slightly > Bspot

That is, sampling a little over the instantaneous bandwidth.

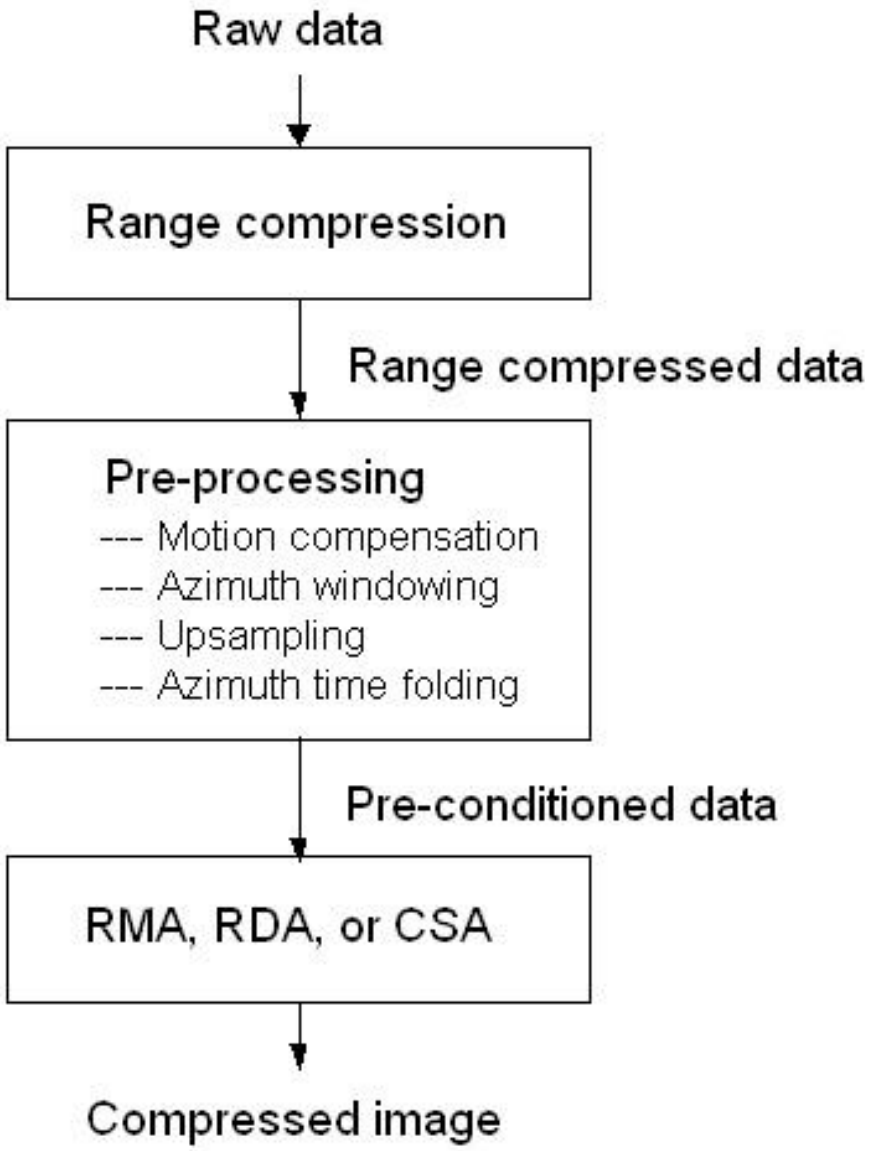
PROCESSING ALGORITHMS

- Polar format algorithm:
  - Only one target focused properly.
  - It can require patches for a large spot size.
- Prati et al:
  - Replicate signal spectrum
  - Filter out aliased energy
  - Sub-sample spectrum
- Conventional stripmap algorithms (RMA, RDA, CSA)
  - Advantage: well-proven and accurate
  - Disadvantage: data upsampled to $B_{spot} + B_{res}$

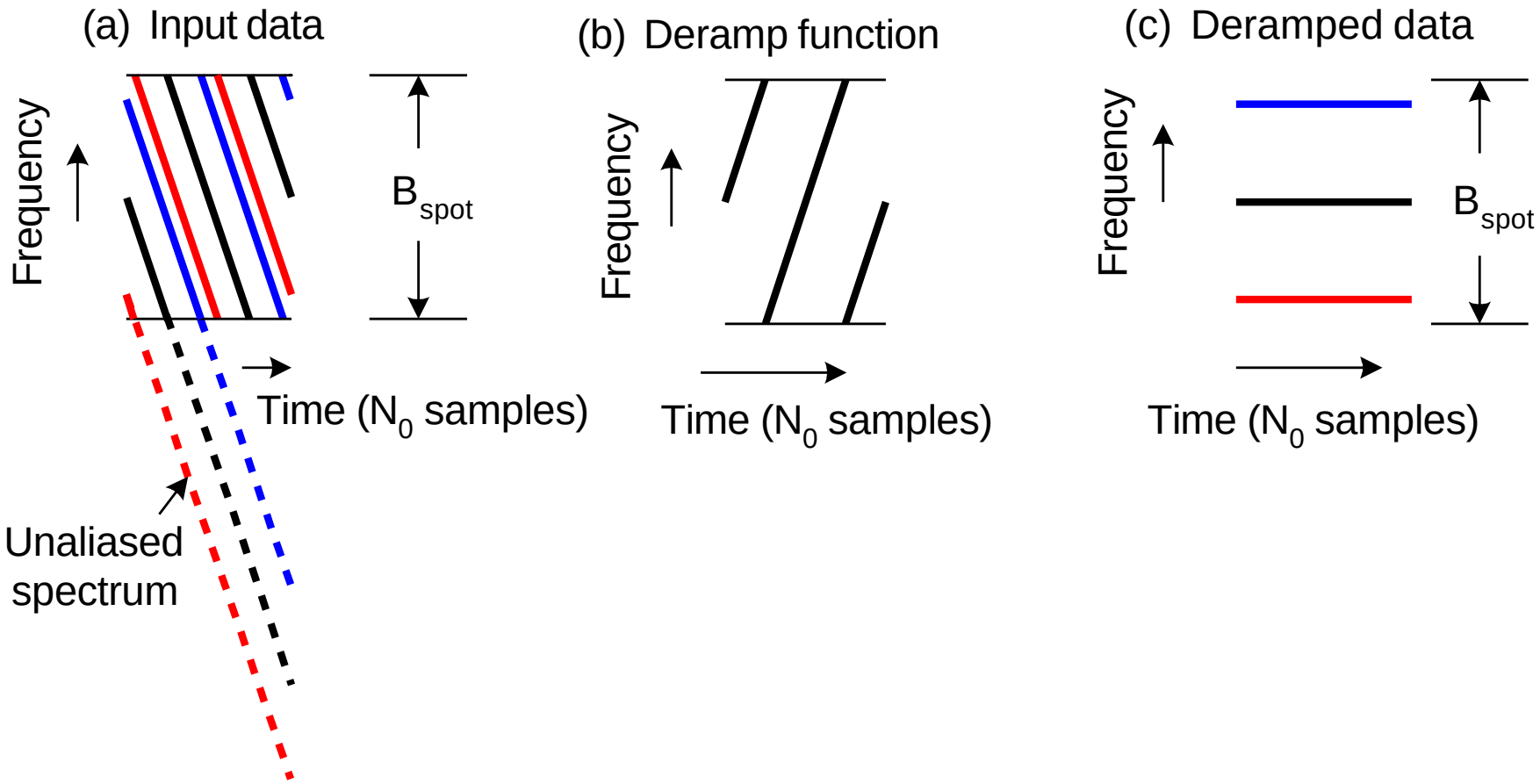
- Advantages:
  - Data acquisition --- PRF slightly larger than B_{spot}.
  - Data processing ---
    Azimuth FFT length about the same as the input data length (about the same as that in SPECAN).
  - Straightforward, easier to implement.
  - Azimuth processing window can be applied directly.
  - Pre-processing step to precondition the data, then use any conventional stripmap algorithm such as RDA, RMA or CSA.

- Pre-processing:
  - Motion compensation (phase) to hyperbolic trajectory.
  - Up-sample the input data in azimuth, to
    sampling rate > $B_{spot} + B_{res}$
  - Azimuth time folding
    folding factor = round down$\{(B_{spot} + B_{res}) / B_{spot}\}$
    This limits the output to the spot size (see simulation results).
  - The azimuth time folding counteracts the up-sampling, therefore, not much increase in the data volume to be processed.

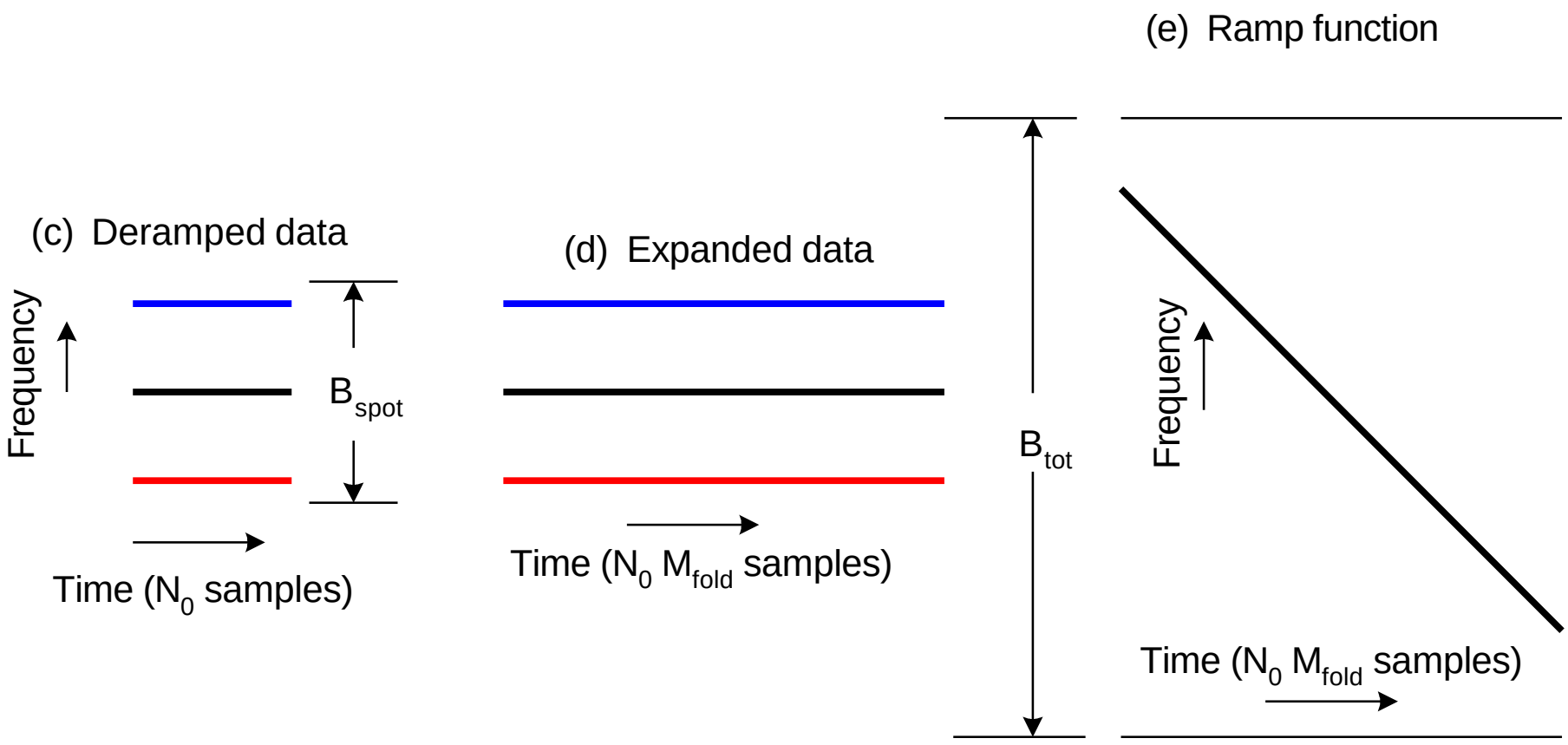
MDA ALGORITHM



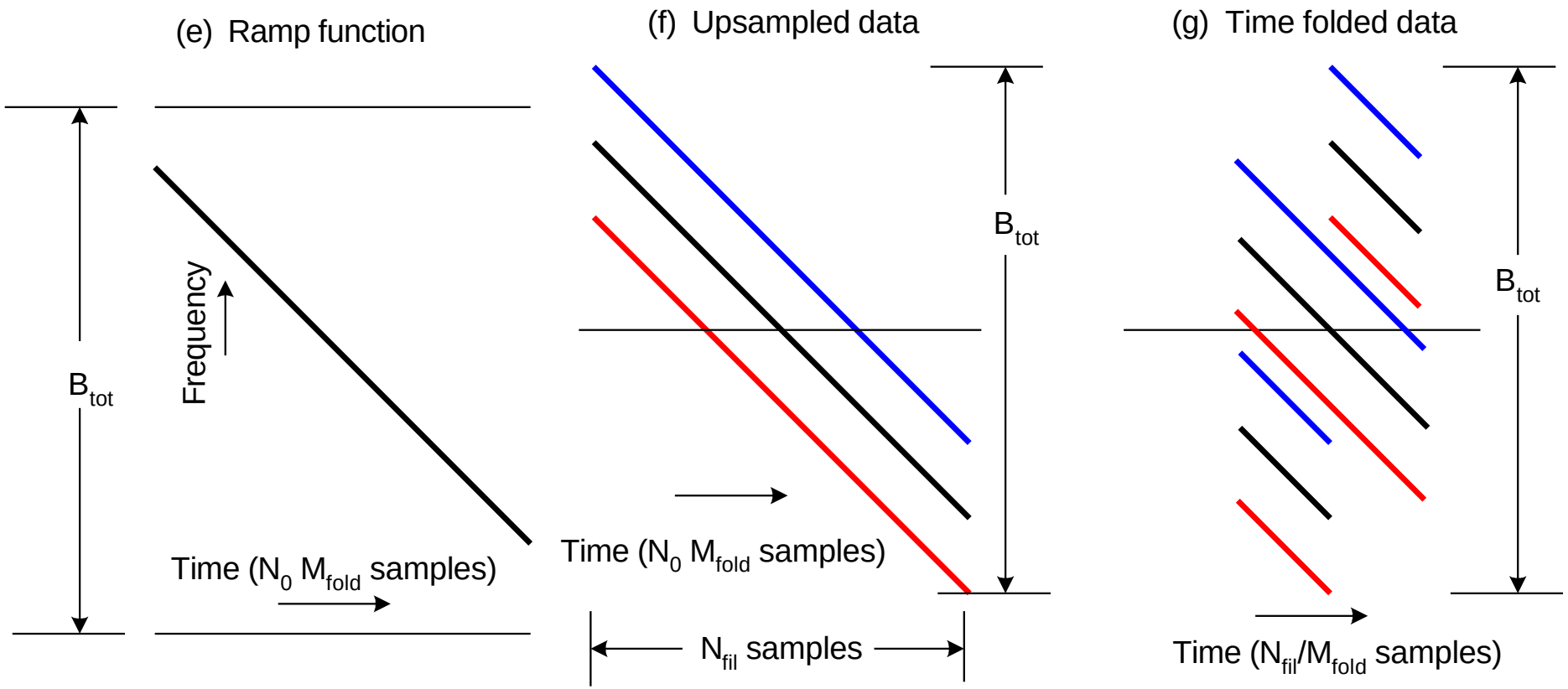
DERAMP OF INPUT DATA



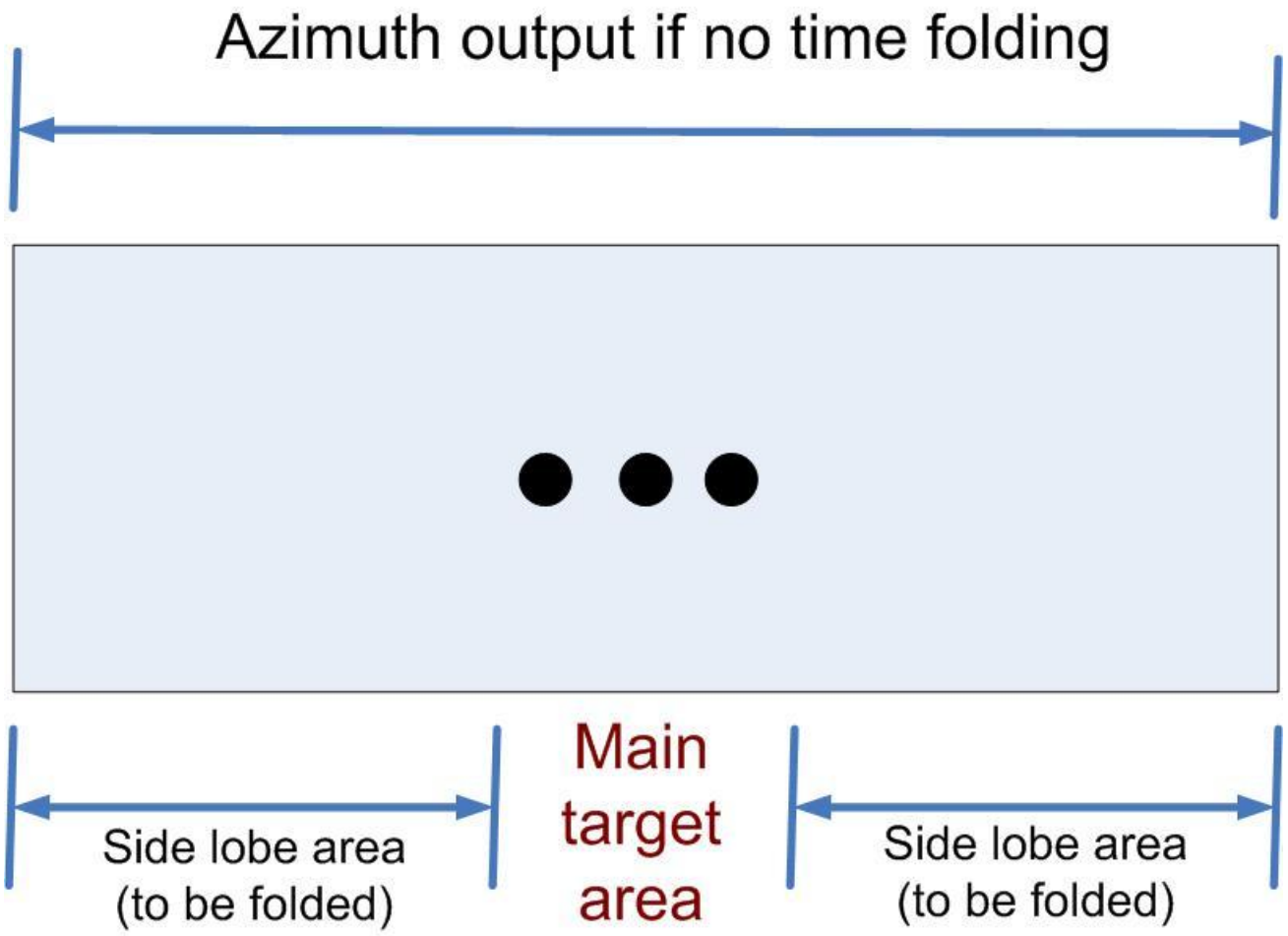
UP-SAMPLING OF DERAMPED DATA



RE-RAMPING AND TIME FOLDING

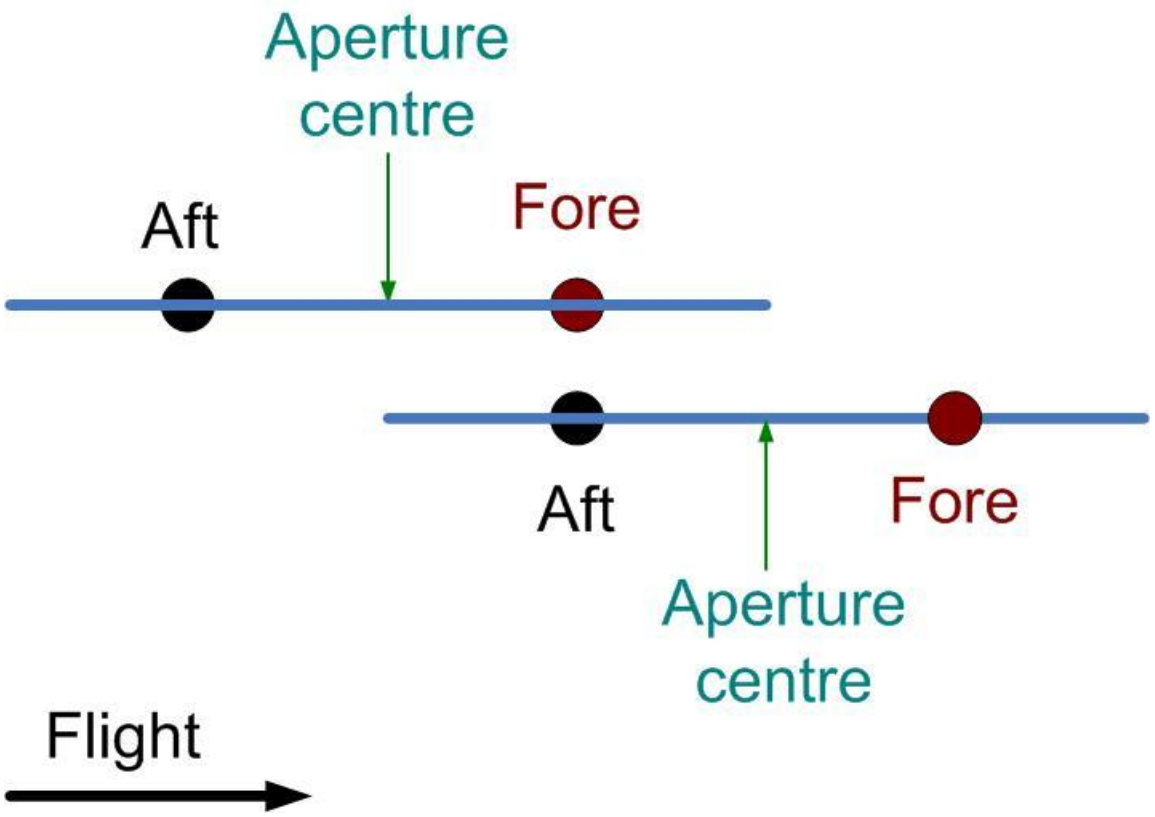


REASON FOR TIME FOLDING

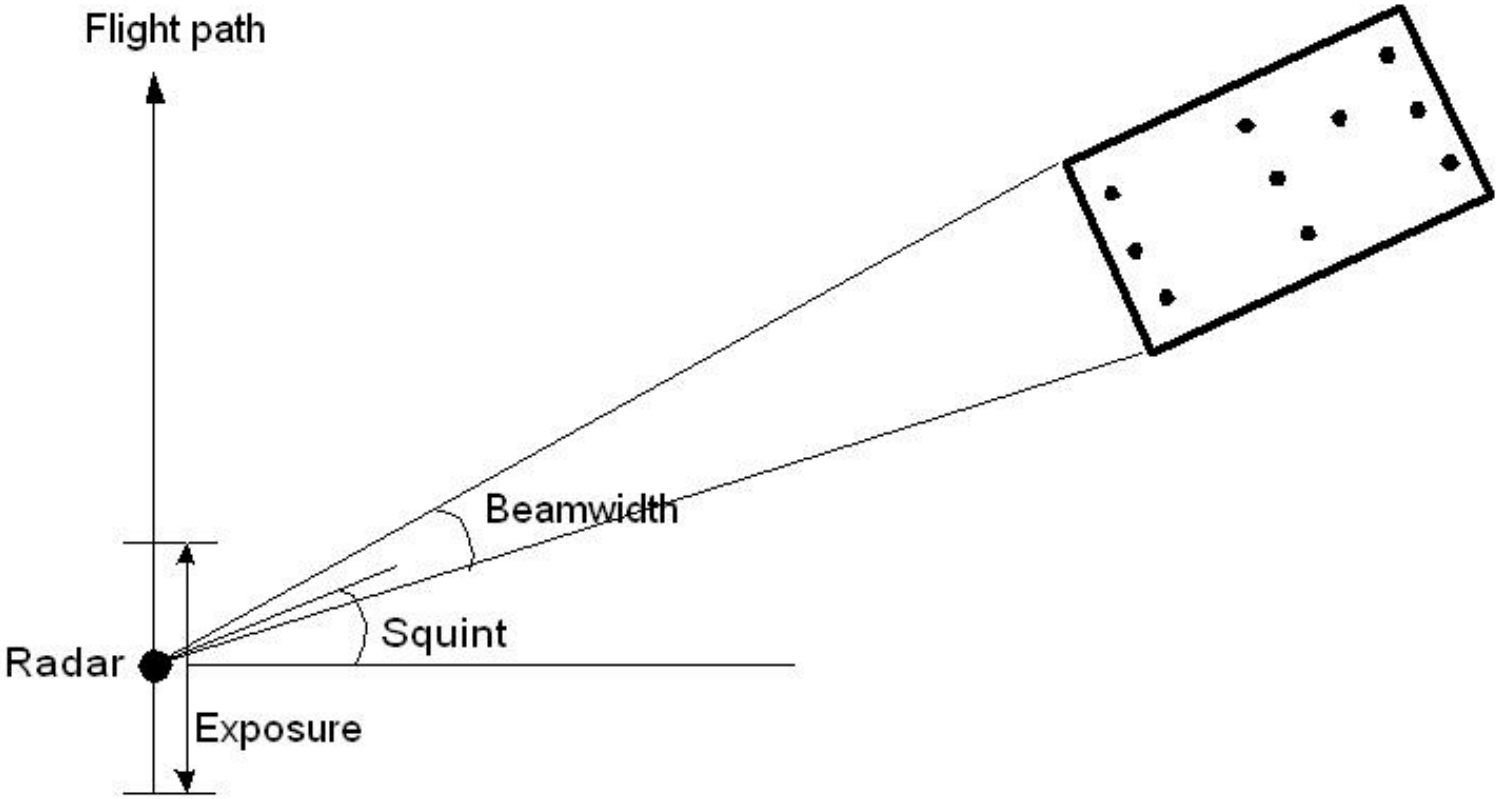


- Pulse stitching:
  - Two pulses, 50 MHz each
  - Synthesize a 100 MHz pulse
- Dual-receive:
  - Transmit at the phase centre of the whole aperture at a PRF of about 1600 Hz
  - Divide antenna into two halves, and receive at the phase centres of these two halves (fore and aft channels)
  - Interleave the echoes from the two channels
  - Effect: double the PRF to 3200 Hz

Positions of antenna between two transmitted pulses.



Arrangement of targets

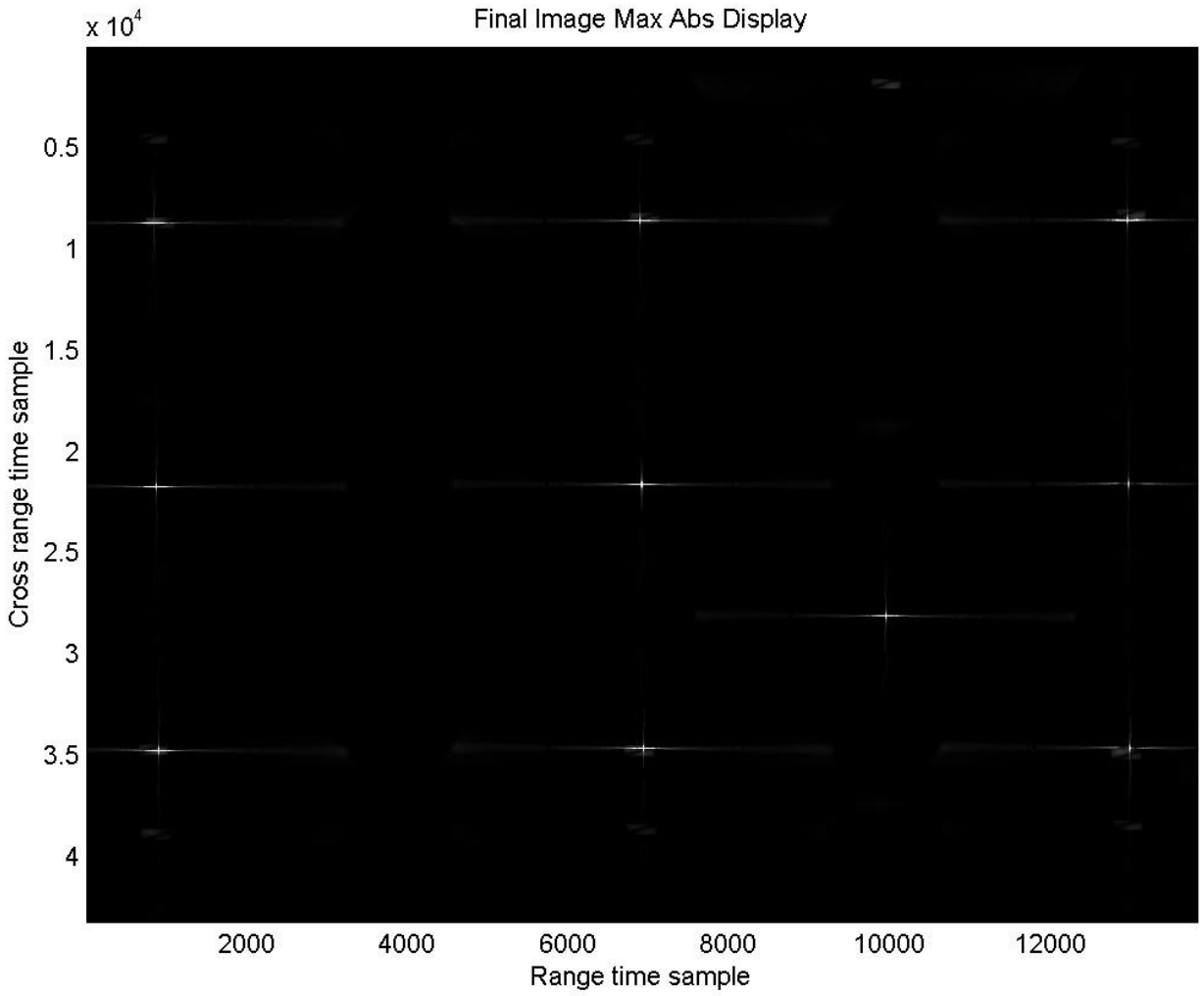


SIMULATION --- RADARSAT-2

- C-band
- Squint ≈ 0 for RASARSAT-2 spotlight
- Scene range = 1358 km (far range)
- Slant range resolution = 1.8 m (weighted)
- Azimuth resolution = 0.5 m (weighted)
- Ground range swath = 20 km
- Azimuth width = 8 km
- Azimuth fold factor = 6
- Number of range lines after interleaving = 33922
- Azimuth FFT length = 43200

SIMULATION --- RADARSAT-2

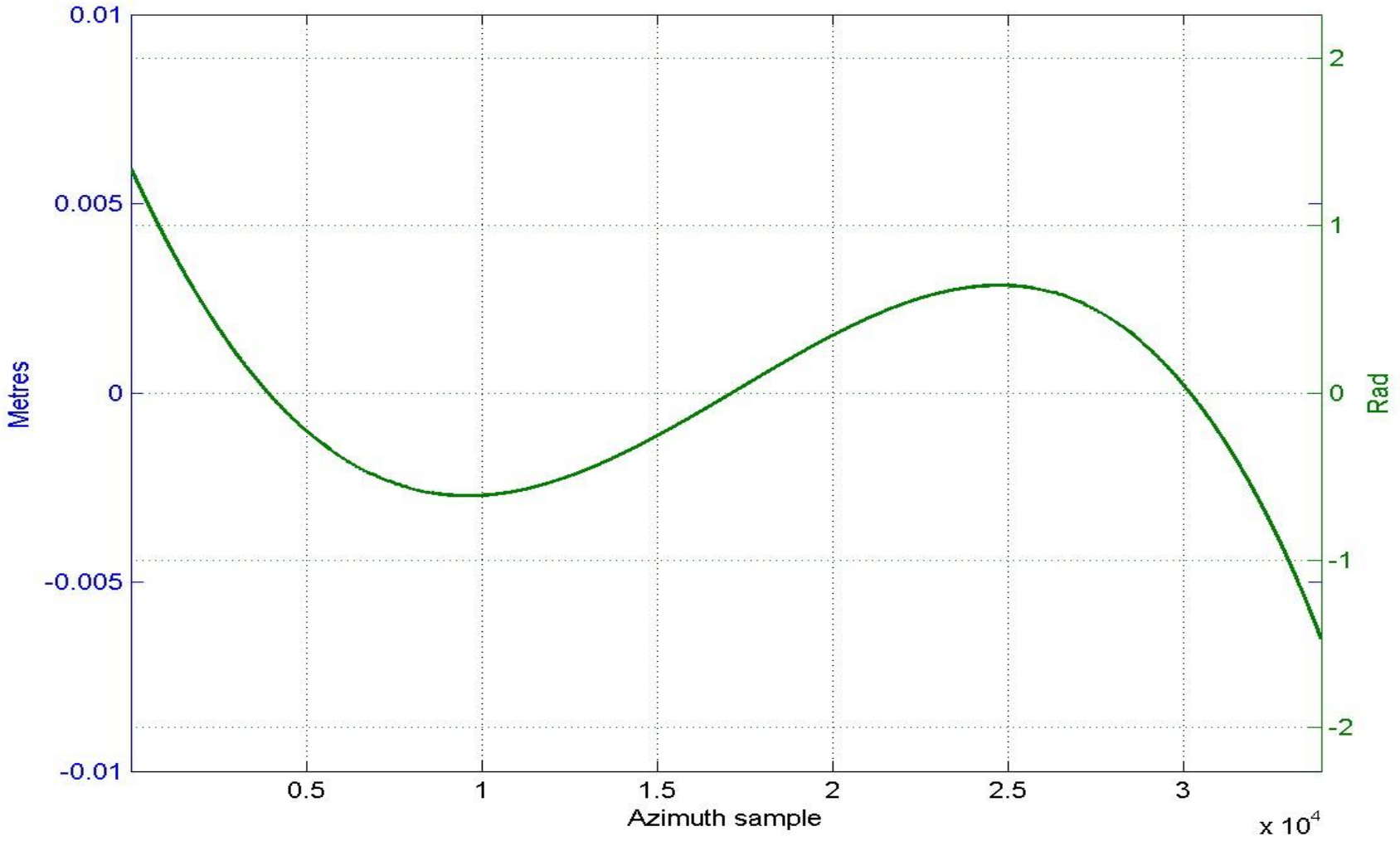
- Intensities grossly exaggerated to show targets
- If no azimuth time folding, then output larger azimuth extent, but sample spacing the same.



Target analysis:

- All targets are similar. ***Proper focusing.***
- Range broadening < 1%, azimuth broadening < 1%
- Range peak side lobe ratio –19.6 dB to –19.8 dB
  Azimuth peak side lobe ratio –19.2 dB to –20.4 dB
  (Theoretical value about –20.5 dB)
- Side lobe imbalance for top and bottom rows of targets due to mo-comp.
  Mo-comp is correct at only one point --- scene centre.
- Ghost target < -69 dB

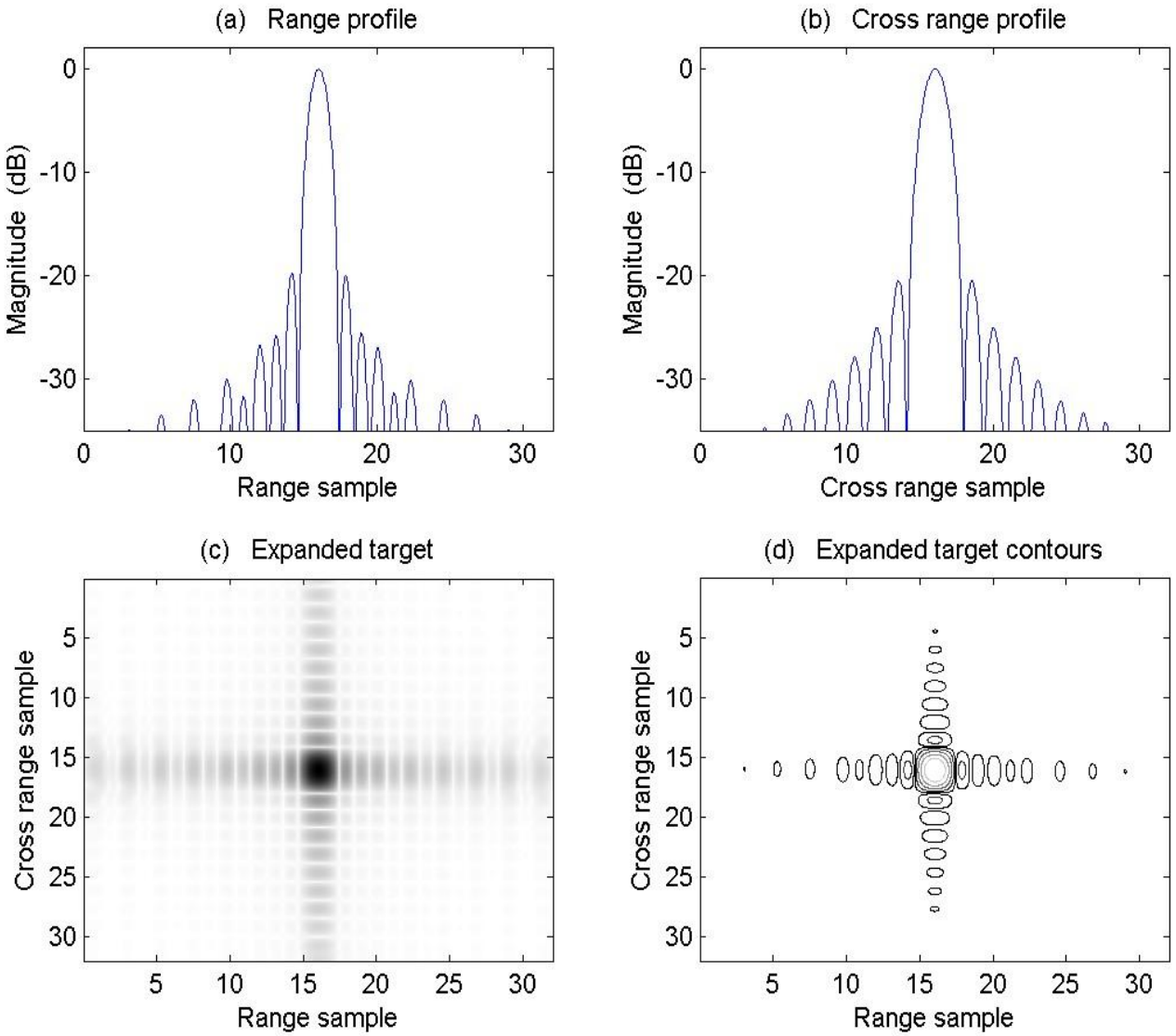
Motion compensation to hyperbolic trajectory for scene centre



SIMULATION --- RADARSAT-2

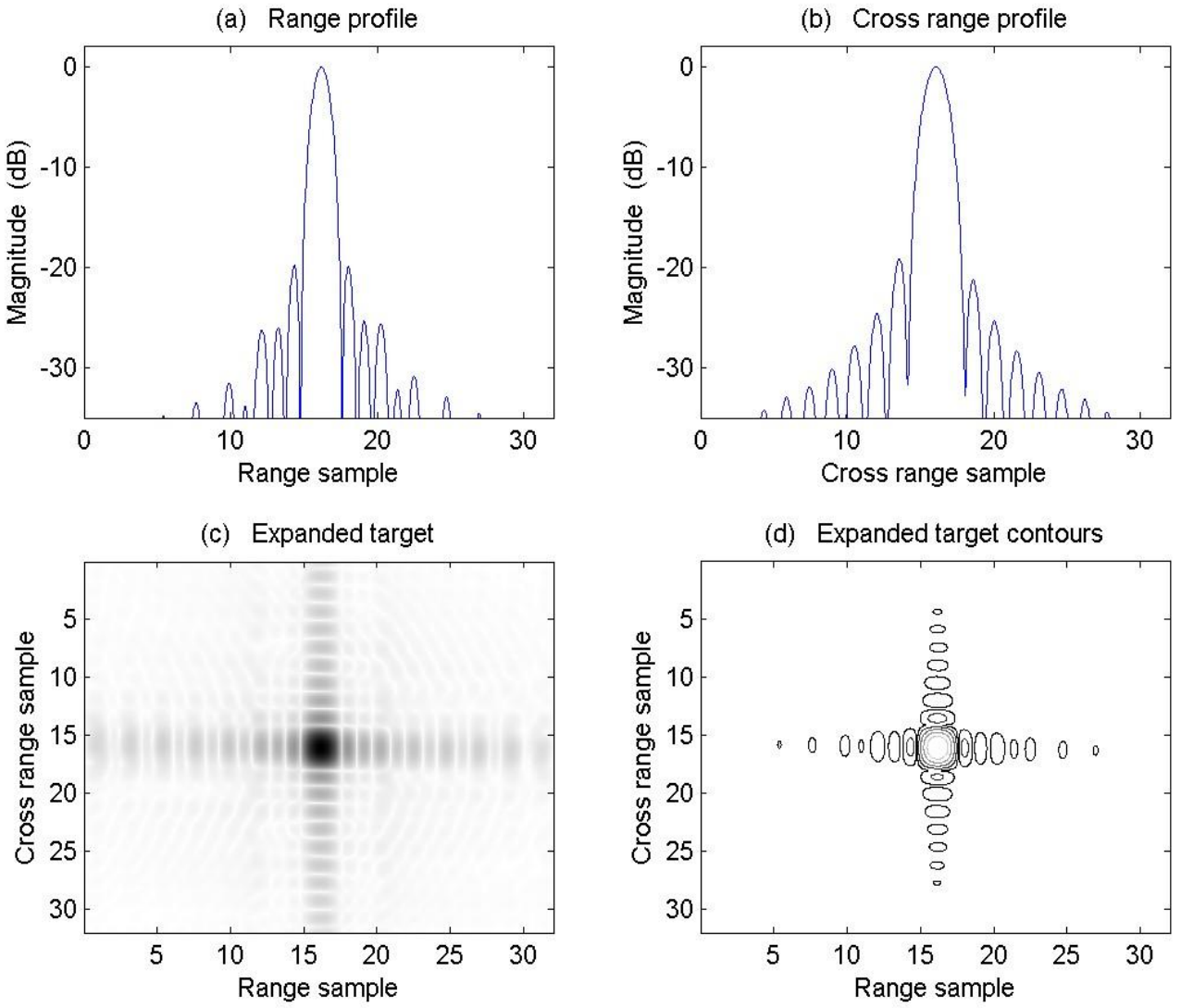
Centre target

--- results similar for centre row of targets



SIMULATION --- RADARSAT-2

Bottom right target --- results similar for bottom row of targets



Geometric accuracy in Scenes is a combination of:

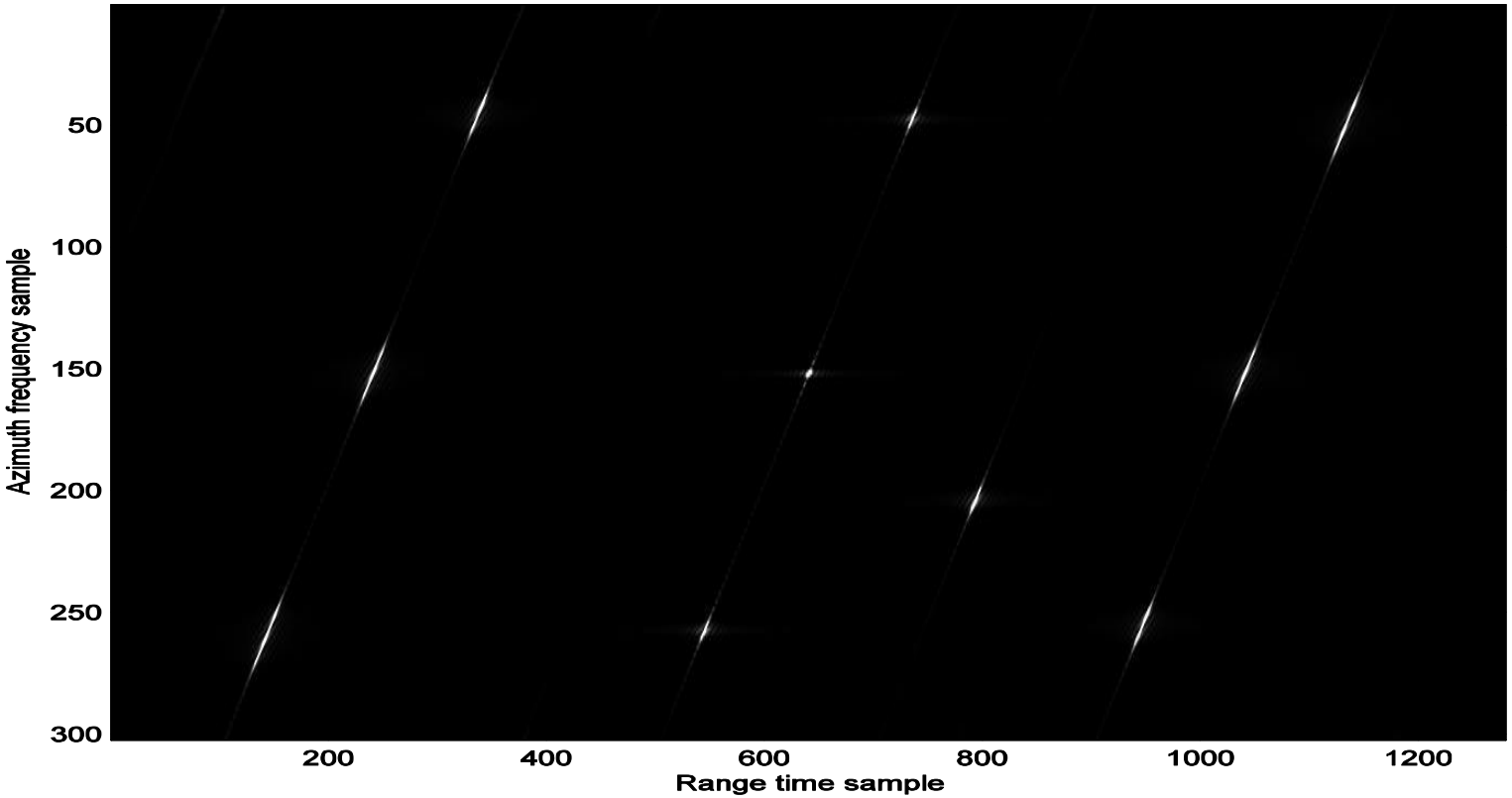
- different range positions (20° to 50° off-nadir angle)
- different global positions
- different azimuth resolutions (0.5 m to 0.8 m), range resolution 1.8 m.
- look directions (left and right)

SIMULATION --- High Squint, Airborne

- V = 200 m/s
- Range = 15 km
- Squint = 60°
- Range res = 1 m
- Cross range res = 0.5 m
- Range swath = 600 m
- Cross range width = 80 m
- Azimuth fold factor = 5
- Number of range lines = 212
- Azimuth FFT length = 320

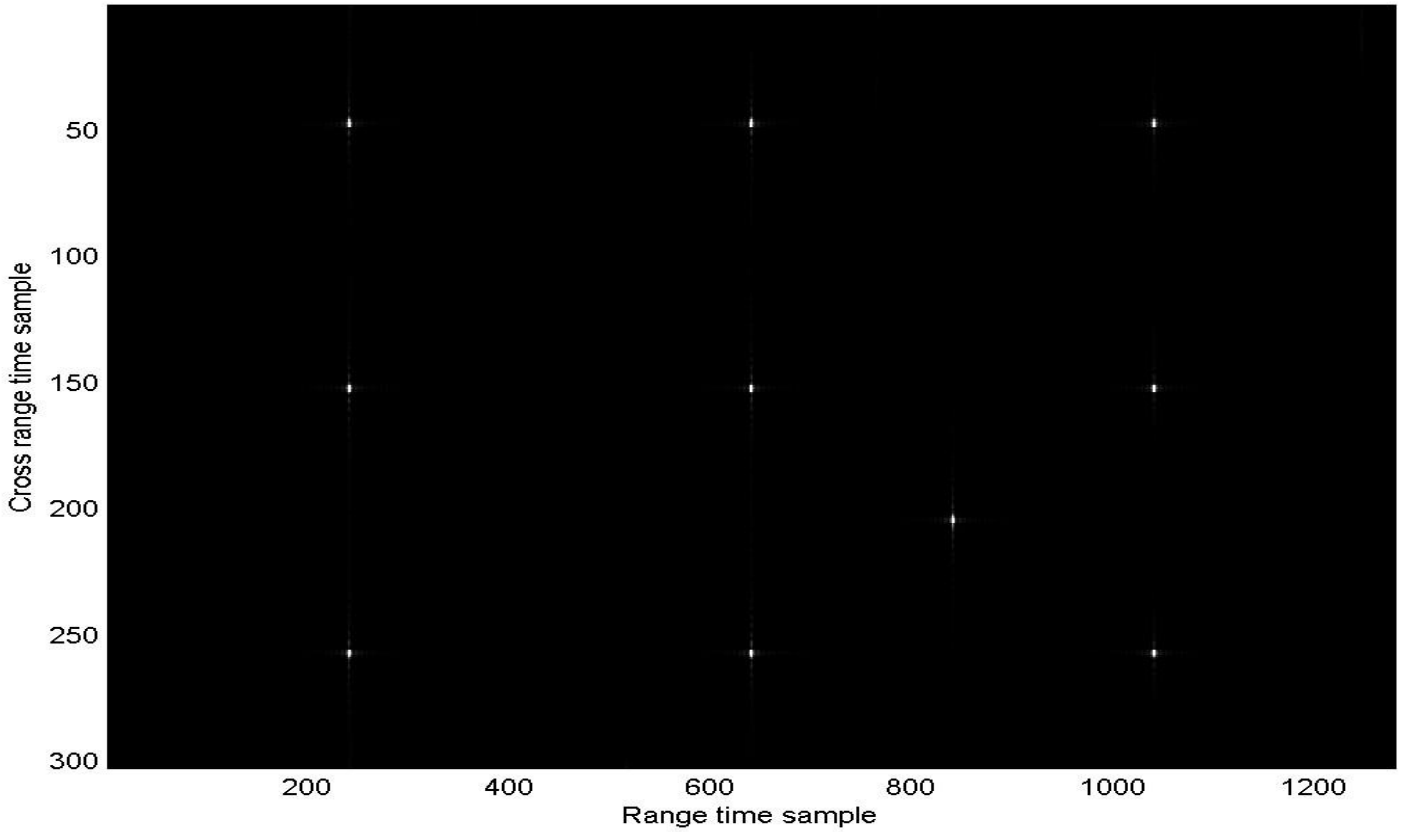
SIMULATION --- High Squint, Airborne

- Downward continued data



SIMULATION --- High Squint, Airborne

- Final compressed data



SIMULATION --- High Squint, Airborne

- Target analysis. All targets are similar. ***Proper focusing.***

Windows:

Rg --- Kaiser 2.5
Az --- Kaiser 2.5

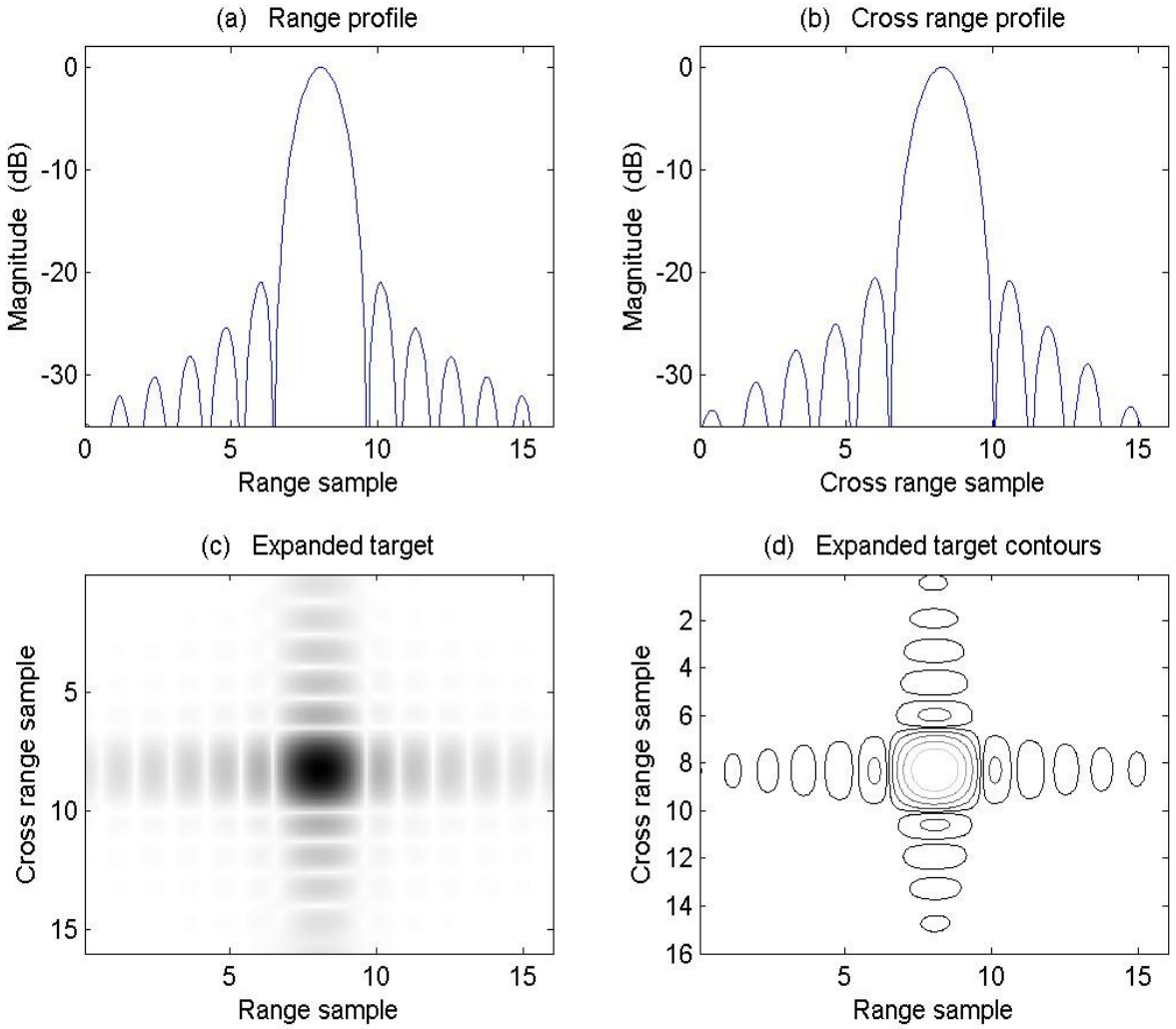
All targets:

Rg brd < 0.5%

Az brd < 3.6%

Rg PSLR -20.8 dB
to -21.0 dB

Az PSLR -20.3 dB
to -20.9 dB



CONCLUSIONS

- The new algorithm is simple, efficient and any stripmap high resolution algorithm can be used after the pre-processing step.
- Tested on RADARSAT-2 spotlight simulated data and highly squint airborne data.
- Geometric registration error is a fraction of the resolution.
- RADARSAT-2 spotlight images shown next.