An Efficient Processing Algorithm for RADARSAT-2 Spotlight SAR Data

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- Algorithm description
- RADARSAT-2 spotlight characteristics
- Point target Simulation Results
- RADARSAT-2 spotlight data
Azimuth (cross range): unweighted resolution

\[ \rho = 0.886 \frac{\lambda}{2\Delta\theta} \]

\(\lambda = \) wavelength, \(\Delta\theta = \) synthetic aperture angle

Antenna steered to point at the same spot size => ground covered by beam-width.
**Spotlight time-frequency characteristics**

- **PRF CONSIDERATION**

  - **Spotlight time-frequency characteristics**

  ![Diagram showing Doppler centroid, azimuth frequency, and exposure time with labels for Bspat and Bres.]

  - **Bspat** = Frequency spread of targets across spot
  - **Bres** = Bandwidth of one target
  - **Target at spot edge**
  - **Target at spot center**
  - **Target at spot edge**

  **PRF slightly > Bspat**

  That is, sampling a little over the instantaneous bandwidth.
- **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 \( B_{\text{spot}} + B_{\text{res}} \)
Advantages:

- Data acquisition --- PRF slightly larger than $B_{\text{spot}}$.
- 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 > $B_{\text{spot}} + B_{\text{res}}$
- Azimuth time folding
  
  folding factor = round down\{(B_{\text{spot}} + B_{\text{res}}) / B_{\text{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

Raw data

Range compression

Range compressed data

Pre-processing

--- Motion compensation
--- Azimuth windowing
--- Upsampling
--- Azimuth time folding

Pre-conditioned data

RMA, RDA, or CSA

Compressed image
DERAMP OF INPUT DATA

(a) Input data

(b) Deramp function

(c) Deramped data

Frequency

Frequency

Frequency

\( B_{\text{spot}} \)

Time (\( N_0 \) samples)

Time (\( N_0 \) samples)

Time (\( N_0 \) samples)

Unaliased spectrum
UP-SAMPLING OF DERAMPED DATA

(c) Deramped data
Frequency

B_{spot}

Time \,(N_0 \text{ samples})

(d) Expanded data
Frequency

B_{tot}

Time \,(N_0 \,M_{fold} \text{ samples})

(e) Ramp function
RE-RAMPING AND TIME FOLDING

(e) Ramp function

(f) Upsampled data

(g) Time folded data

\[ B_{\text{tot}} \]

Frequency

Time \( (N_0 \cdot M_{\text{fold}} \text{ samples}) \)

\[ N_{\text{fil}} \text{ samples} \]

Time \( (N_0 \cdot M_{\text{fold}} \text{ samples}) \)

Time \( (N_{\text{fil}} / M_{\text{fold}} \text{ samples}) \)
REASON FOR TIME FOLDING

Azimuth output if no time folding

Main target area

Side lobe area (to be folded)

Side lobe area (to be folded)
- **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
- C-band
- Squint ≈ 0 for RADARSAT-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
- 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
Centre target
--- results similar for centre row of targets
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)
- $V = 200 \text{ m/s}$
- 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
- Downward continued data
- Final compressed data
- 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
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.