Improving SAR tomography performance using efficient antenna configuration

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Outline

Multistatic radar constellation for improved range resolution

Extension to Multi-Baseline SAR tomography

Assessment from real data and need for MIMO acquisitions
**Principle using monostatic sensors**

**Single acquisition**

- Ground range resolution
  \[ r_{gr} = \frac{c}{2B \sin(\theta_1)} \]
- Equivalent beam aperture
  \[ \Delta \theta_1^{eq} = \frac{\lambda B \tan(\theta_1)}{c} \]

**Two acquisitions**

- Max diversity for contiguous apertures
  \[ \Delta \theta_{max} = \frac{|\theta_1^{eq} + \theta_2^{eq}|}{2} = \frac{\lambda B}{c} \tan(\theta_0) \]
- Combined range resolution
  \[ r_{max}^{eq} = 2r \]
MIMO acquisition

- 2 Tx-Rx sensors
- Orthogonal signals
- 3rd equivalent sensor
- Max resolution

\[ r_{eq}^{max} = 3r > N_s r \]
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Monostatic inSAR configuration

Monostatic acquisition

\[ \phi_{21} = \phi_2 - \phi_1 = k_{z2} z \]

\[ k_{z2} = \frac{2\pi}{\lambda} \frac{\partial(2r_2 - 2r_1)}{\partial z} \]

MIMO acquisition: additional equivalent sensor

\[ k'_{z2} = \frac{2\pi}{\lambda} \frac{\partial(2r_2 - (r_1 + r_2))}{\partial z} = \frac{k_{z2}}{2} \]

\[ B'_{\perp2} = \frac{B_{\perp2}}{2} \]
MIMO TOMSAR geometrical configuration

\[ k'_z = \frac{k_{z_i} + k_{z_j}}{2} \]
MIMO TOMSAR geometrical configuration

\[ \delta k_z \propto \frac{1}{\Delta k_z} \]

\[ \hat{z}_{amb} \propto \frac{1}{\delta k_z} \]
Improved resolution x 2    Improved ambiguity x 2

Coherent scatterer: arbitrary improvement factor
For a randomly rough surface \( |\gamma_{surf}(k_z)| = \frac{W_{y_{com}}}{W_{y_{tot}}} = \text{tri} \left( \frac{k_z}{k_{zc}} \right) \)
Tomographic response: distributed scatterer

\[ \gamma(k_z) = \gamma_z(k_z) \text{tri} \left( \frac{k_z}{k_{zc}} \right) \]

\[ \gamma(k_z) = \int f(z) e^{i k_z z} \, dz \Leftrightarrow f(z) = \int \gamma(k_z) e^{-i k_z z} \, dk_z \]

\[ f(z) = f_z(z) \odot \text{sinc}^2 \left( \frac{2\pi \Delta k}{\cos \theta} z \right) \]

Spread

See: Tebaldini and Rocca, IGARSS 2010
Tomographic response: high res system

Improved resolution x 2  Improved ambiguity x 2

$max_i(|k_{z_i}|) \ll k_{zc}$
Tomographic response: high res system

\[ \max_i (|k_{z_i}|) \ll k_{z_c} \]

Unchanged high resolution  Improved ambiguity x 2
Tomographic response: medium res system

SLIGHTLY Improved resolution x 2
Improved ambiguity x 2

\[ k_{zc} = 6 \max_i (|k_{zi}|) \]
Tomographic response: medium res system

\[ k_{zc} = 6 \max_i (|k_{zi}|) \]

CAPON

Unchanged high resolution  Improved ambiguity x 2
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Application to real data

- TROPISAR Campaign over French Guyana
- ONERA/SETHI MB-POLinSAR data at P band
- Resolutions: $\delta r = 1m, \delta az = 1.245m$
- $M = 6$ images
Application to real data

Full resolution

75% resolution

75% sampling
Need for MIMO acquisitions: GB-TOMSAR

Tomographic measurements of a snow pack at X and Ku band
Need for MIMO acquisitions: GB-TOMSAR
Need for MIMO acquisitions: GB-TOMSAR

- resolution + ambiguity: 8-10 images
- near range measurements: az sampling

Hours of acquisition
4-port system $\rightarrow$ time / 5