TerraSAR-X Products – Tips and Tricks

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2nd Part: SAR Processing and Spectral Properties

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Motivation for Understanding Spectral Properties

- In most situations detection of complex data requires oversampling of the complex data first in order to avoid aliasing.
- In many applications (e.g. interferometry) resampling / interpolation of complex data is required.

\[ |u(t)|^2 = u(t) \cdot u^*(t) \]
better: avoid aliasing by oversampling prior to detection =>

\[ U'(f) \otimes U'(f) \]
Motivation for Understanding Spectral Properties

- In most situations detection of complex data requires oversampling of the complex data first in order to avoid aliasing.
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Understanding and knowledge of the spectral properties of complex data (SSC) products is essential.
SAR Acquisition Geometry and Azimuth Spectrum

Quadratic approx. of range history \( R(t) \):

\[
R(t) \approx R_0 + \frac{v^2 t^2}{2 R_0}
\]

Azimuth phase history:

\[
\theta(t) = -\frac{4\pi}{\lambda} R(t)
\]

Instantaneous Doppler frequency:

\[
f(t) = \frac{1}{2\pi} \frac{d\theta(t)}{dt} \approx -\frac{2v^2}{\lambda R_0} t
\]

\[
f(t) \approx FM \cdot t
\]
SAR Acquisition Geometry and Azimuth Spectrum

\[ f(t) = FM \cdot t \]

\[ \Delta t_{\text{aperture}} \]

\[ f_{\text{DC}} = 0 \]

\[ f_{\text{DC}} = FM \cdot t_c \]

\[ PBW_{\text{azimuth}} \]

\[ R_0 \]

\[ t = t_c = 0 \]

\[ f_{\text{DC}} < 0 \]

\[ R_C \]

\[ t = 0 \]
SAR Azimuth Focusing

unfocused azimuth signal

azimuth signal focused to zero-Doppler time

focusing operation in the spectral domain:

\[ f(t) = FM \cdot t \]
Stripmap Azimuth Focusing

\[ f \]

\[ f_{DC} \]

\[ PBW_{azimuth} \]

\[ T_{raw \ data \ acquisition} \]

\[ T_{focused \ scene} \]
Spotlight: Azimuth Focusing

- **f**
- **t**
- **$f_{DC \text{ raw first}}$**
- **$f_{DC \text{ scene first}}$**
- **$f_{DC \text{ raw last}}$**
- **$f_{DC \text{ scene last}}$**

- $f = 0$
- $T_{\text{focused scene}}$
- $T_{\text{raw data acquisition}}$
- $B_{\text{target}}$
- $PBW_{\text{azimuth}}$
Spotlight: aliasing-free spectrum of the focused scene after sub-sampling

\[ f_{\text{DC scene first}} \mod B_{\text{sampling}} \]

\[ f_{\text{DC scene last}} \mod B_{\text{sampling}} \]

\[ f = 0 \]

\[ B_{\text{total}} \]

\[ B_{\text{sampling}} > B_{\text{target}} \]

\[ t \]

\[ T_{\text{focused scene}} \]
ScanSAR Burst Azimuth Focusing

\[ PBW_{\text{azimuth}} \]

\[ f = 0 \]

\[ T_{\text{raw data acquisition}} \]

\[ T_{\text{focused burst}} \]
ScanSAR: aliasing-free spectrum of focused burst after sub-sampling close to Nyquist

ScanSAR: aliasing-free spectrum of focused burst after sub-sampling close to Nyquist
ScanSAR:
aliasing-free spectrum of focused burst after „relaxed“ sub-sampling
Ambiguity Distance

Where PRF can be found in XML File:

```
<instrument>
  (...)
<settings>
  (...)
<settingsRecord>
  (...)
  <PRF code="0">3.72849239956568954E+03</PRF>
  (...)
```

PRF in Hz
Projection of SSC to MGD and vice versa

- The product type MGD has nice properties like
  - very precise interpolation and multilooking free of aliasing due to adequate oversampling of complex data prior to detection.
  - Quadratic on-ground pixel spacing
- Therefore MGD products are very suitable for classification and feature extraction.
- But, the geometric projection is not very useful.
- Therefore the SSC-> MGD projection functions are kept very simple in order to facilitate easy (real or virtual) back projection of the data into the original slant range geometry.
Options for Geo-Referencing of MGD data

- If the interest is to know the precise point-wise geo-location of certain pixels, features or classification results there are two options:
  - Use the provided annotation files “MAPPING_GRID.bin” and “GEOREF.xml”
  - or
  - Use the annotated higher-order slant-range-to-ground-range (SLT2GR) polynomial for range projection and the annotated zero-Doppler velocity for first-order azimuth projection.

- If the interest is to obtain a complete geo-referenced image in a projection of choice the two separated MGD<->SSC projection functions can be easily incorporated into any (high-precision) user-defined projection, relating map-coordinates to azimuth time \( t \), and range delay \( \tau \) using the precise orbital state vectors and DEM data.
Accuracy of MGD to SSC re-projection using polynom inversion

0.3 \text{ \textmu m}

0.0 \text{ \textmu m}

-0.6 \text{ \textmu m}