Split-Band SAR and Split Band InSAR principle and applications

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Abstract

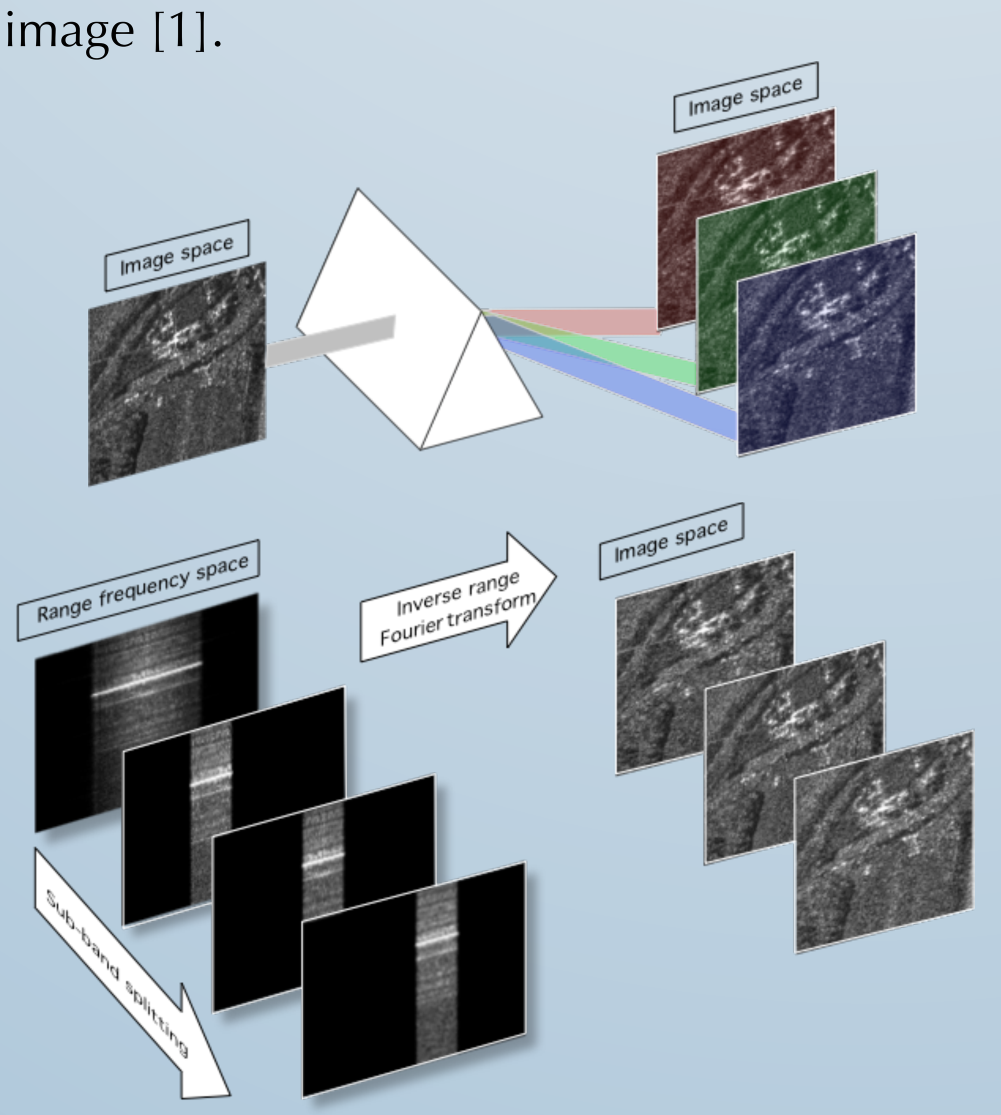
Most recent SAR sensors use wide band signals to achieve metric range resolution. One can also take advantage of wide band to split it into sub-bands and generate several lower-resolution images, centered on slightly different frequencies, from a single acquisition [1].

This process, named Multi Chromatic Analysis (MCA) corresponds to performing a spectral analysis of SAR images. From this spectral analysis, three potential applications are shown:

- ➡ Vessel detection based on spectral coherence analysis
- ➡ Absolute phase unwrapping based on Split Band Interferometry (SBInSAR)
- ➡ Ionospheric phase component retrieval in SAR interferometry

Band split principle

- Range resolution of SAR images is a function of the emitted radar signal bandwidth.
- Most recent SAR sensors use wide band signals in order to achieve metric range resolution.
- By comparison, ENVISAT or ERS sensors used 15MHz bandwidth chirps while TerraSAR-X or Cosmo-SkyMed use nominal signals having 150MHz bandwidth leading to a potentially ten times higher range resolution.
- In place of targeting high range resolution, one can also take advantage of wide band to split it in sub bands and generate several lower-resolution images from a single acquisition, each being centered on a slightly different frequency.
- This split band processes also named Multi Chromatic Analysis (MCA) corresponds to performing a spectral analysis of the SAR image [1].



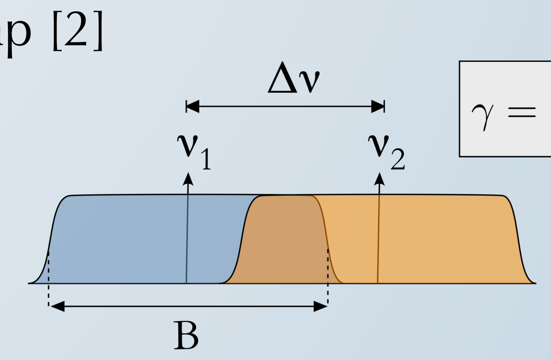
Split band schematic explanation
Above: Spectral analysis in the image domain
Below: Spectral decomposition in the spectral domain

What for...?

- ➡ Spectral coherence
  - ✓ Interferometric coherence between sub-images issued from a single acquisition can be measured.
- ➡ Split band interferometry: Images of an interferometric pair can be split, leading to a stack of interferograms:
  - ✓ Opportunity to perform absolute phase unwrapping on seed points
  - ✓ If using classical phase unwrapping, opportunity to solve for ionospheric phase screen

Spectral coherence applied to vessel tracking

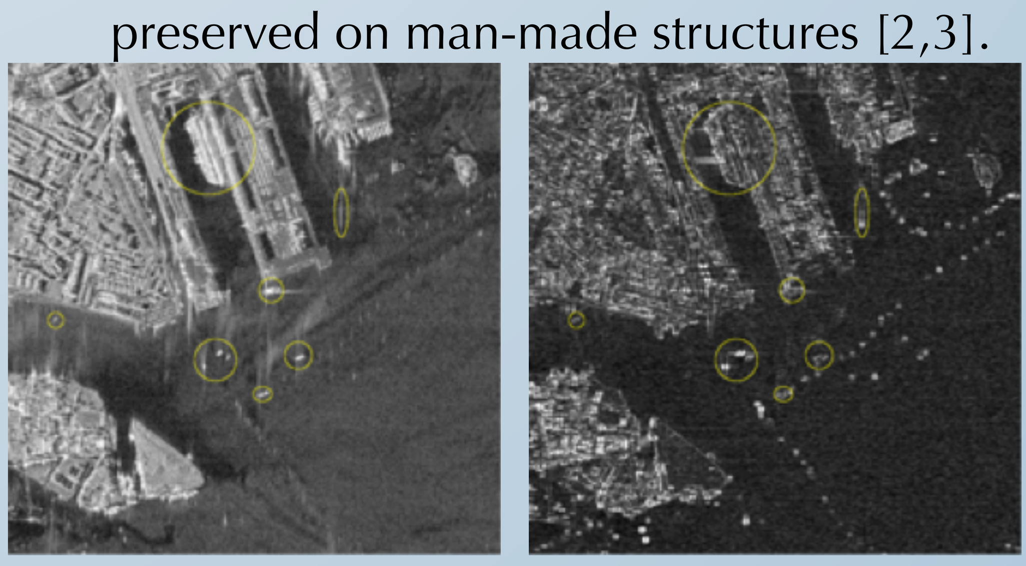
- It can be shown that in case of randomly distributed surface scatterers, spectral coherence is equal to percentage of sub band overlap [2]



$$\gamma = 1 - \frac{\Delta\nu}{B}$$

Hypothesis:

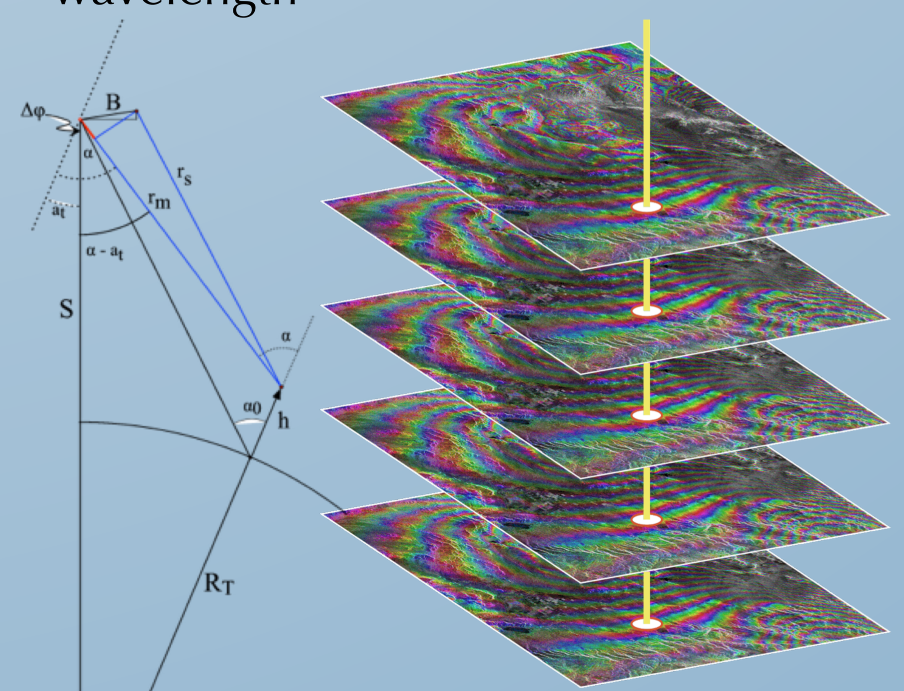
- ➡ Open sea surface can be considered as randomly distributed surface scatterers leading to a null spectral coherence
- ➡ Target that departs from this distribution may preserve a high spectral coherence level
- ➡ Spectral coherence will be almost totally lost on the sea clutter while it will be preserved on man-made structures [2,3].



Left: TerraSAR-X Intensity image of the docks of Venice (Vessels are localized by yellow circles)
Right: Corresponding averaged spectral coherence

Split band interferometry: Absolute phase unwrapping

- SBInSAR is based on this spectral analysis
  - ➡ To generate several InSAR pairs of lower resolution from a single one.
  - ➡ Each sub-band interferometric pair leads to an interferogram generated with its own frequency (or wavelength).
  - ➡ Fringe rate will vary with respect to wavelength



$$\Delta\varphi = \frac{4\pi}{\lambda}(r_s - r_m) = 4\pi\frac{\nu_0}{c}(r_s - r_m)$$

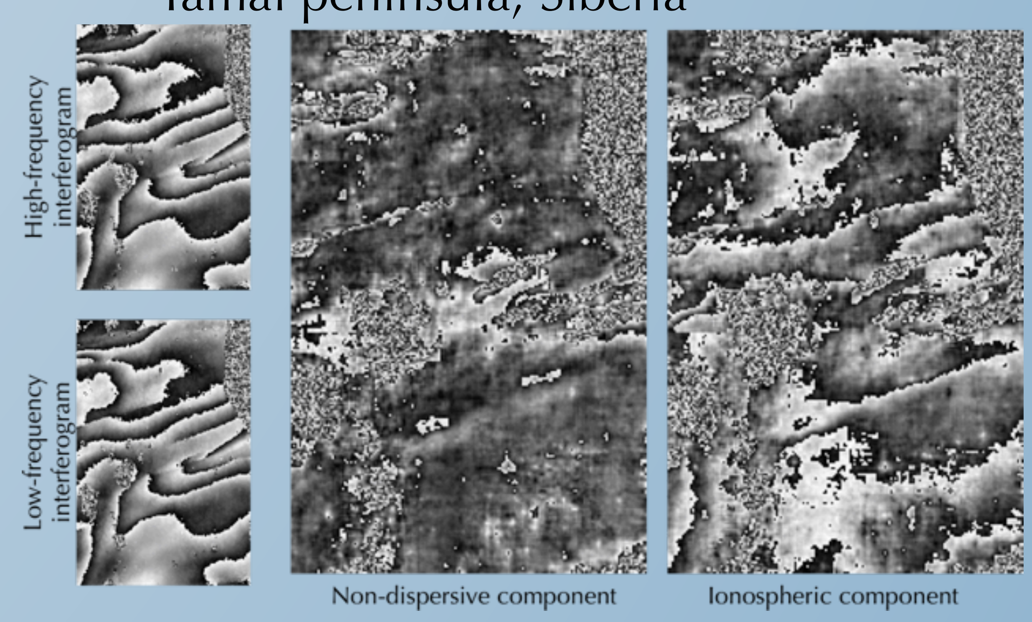
- The interferometric phase of a given point in a stack of split band interferograms will vary linearly with respect to the sub-band central frequency [4].
- The slope is proportional to the optical path difference
  - ➡ This potentially solves the phase unwrapping problem on point-wise basis

Split band interferometry: Ionospheric phase screen

- In the presence of ionospheric perturbation, the interferometric pnhase contains both a dispersive and a non-dispersive component [5]

$$\Delta\varphi = \underbrace{4\pi\frac{\nu_0}{c}(\Delta r_{topo} + \Delta r_{mov} + \Delta r_{tropo})}_{non-dispersive} - \underbrace{4\pi\frac{K}{c\,\nu_0}\Delta TEC}_{dispersive}$$

- If generating and unwrapping a low frequency and a high frequency interferogram using SBInSAR, one can solve for each component [5,6]
  - ➡ Example is shown on the flat area of the Yamal peninsula, Siberia



Non-dispersive and dispersive decomposition of the Yamal peninsula interferogram

References

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