ERTH 491-01 / GEOP 572-02
Geodetic Methods

– Lecture 12: InSAR - Making the Interferogram –

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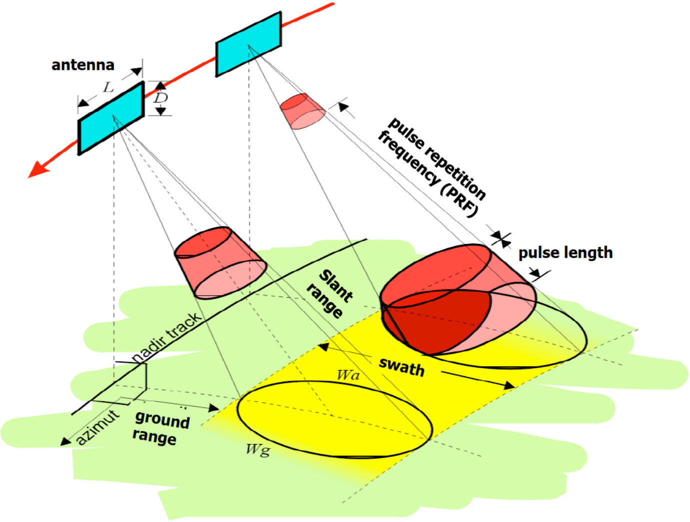
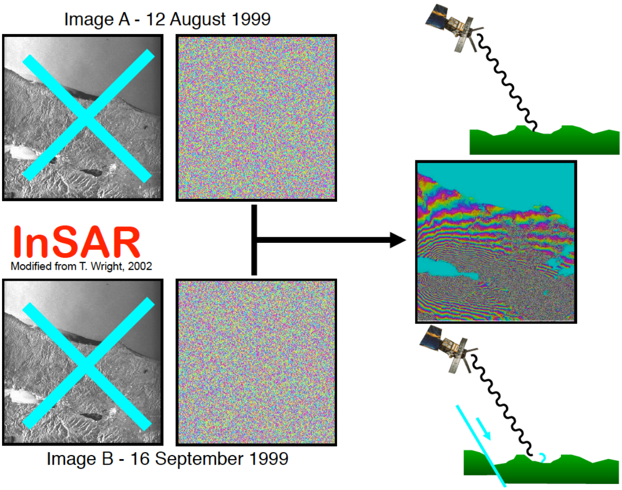
InSAR - General Concept



loaned from *J. Freymueller*

InSAR - General Concept



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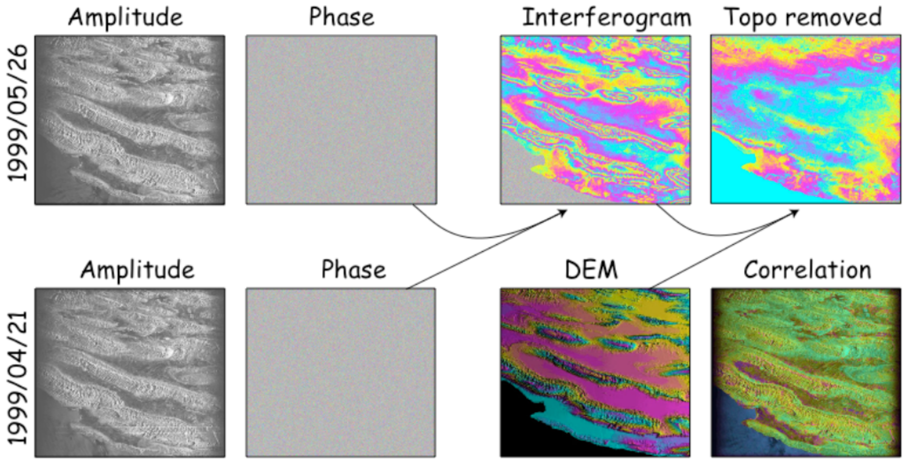
complex values radar signal contains information on amplitude $a = \sqrt{Im^2 + Re^2}$, and phase $\phi = arctan\frac{Im}{Re}$

InSAR - General Concept



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Radar Resolution Examples

- GEOSAT orbits Earth at 800 km,
- 1 m parabolic dish operates in Ku-band (13.5 GHz, $\lambda = 0.022$ m)
- footprint diameter about 43 km
- ERS: along track footprint = 8.5 km; range-direction footprint about 85 km
- optical system with 1 m aperture, but wavelength $\lambda = 5 \times 10^{-7}$ m has footprint diameter of 0.97 m

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Lesson:

Need major increase in antenna length for microwave system to get high angular resolution!

Synthetic Aperture!

Synthetic Aperture 1/4

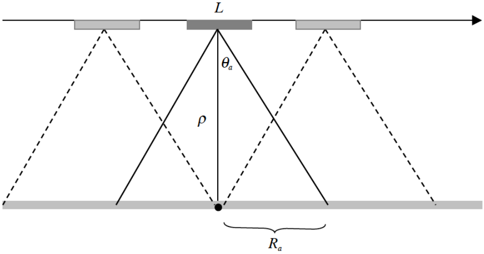

Figure A7. Top view of SAR antenna imaging a point reflector. The reflector remains within the illumination pattern over the real aperture length of $2R_a$.

Sandwell et al., 2011, GMTSAR documentation

- single point reflector on ground illuminated by radar flying by
- length of illumination (twice angular resolution) related to wavelength over antenna length (Fraunhofer diffraction)
- real aperture radar azimuth resolution:
  $R_a = \rho\, tan(\theta_r) \approx \frac{\rho\lambda}{L} = \frac{\lambda H}{L\, cos(\theta)}$
- where L is antenna length, ρ is slant range

Synthetic Aperture 2/4

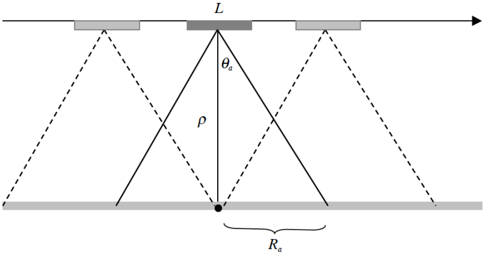

Figure A7. Top view of SAR antenna imaging a point reflector. The reflector remains within the illumination pattern over the real aperture length of $2R_a$.

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- scatterer stationary as radar flys by: can assemble synthetic aperture
- Synthtic Aperture length equal to along track beamwidth $2R_a$
- for ERS: aperture is now 8.5 km.
- new azimuth resolution: $R'_a = \frac{L}{2}$
- independent of spacecraft height!
- improves as antenna length, L, is reduced!

Synthetic Aperture 3/4

Should we make antenna as short as possible to improve azimuth resolution?

Synthetic Aperture 4/4

- Can't do that!
- radar must be pulsed at along track distance of L/2 or shorter
- avoids aliasing long wavelengths back into shorter (Nyquist)
- pulse rate frequency (PRF) can't be too large or near-range far-range returns will overlap
- for ERS ($\theta_1 = 18^\circ, \theta_2 = 24^\circ$): maximum PRF is 4777 Mhz; actual PRF is 1680 MHz
- real limitation is data link from spacecraft to ground

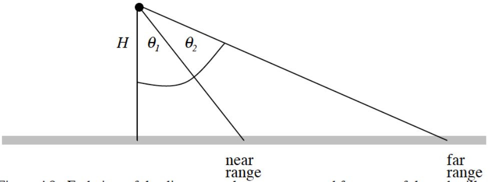
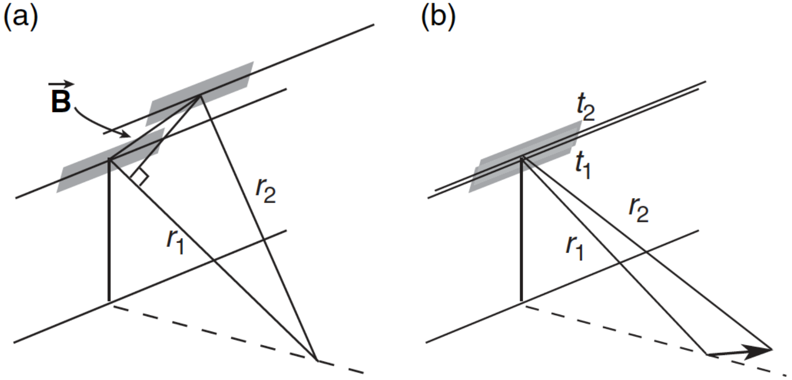


Figure A9. End view of the distance to the near range and far range of the radar illumination pattern.

Sandwell et al., 2011, GMTSAR documentation

Difference between InSARs

Topography: look at same thing from 2 views (SRTM)
Deformation: look at same thing from same point and see whether it moved



Simons and Rosen, 2007

Making an Interferogram

Make interferogram from 2 Single Look Complex images
(images are in radar coordinates: range ρ, azimuth *a*):

1. align reference and repeat images to sub-pixel accuracy
2. multiply complex images (SLC) to form complex interferogram
3. extract phase: $\phi_2 - \phi_1 = arctan\frac{Im}{Re}$

Making an Interferogram: Step 1 - Alignment

- take 100s of small sub-patches (e.g. 64×64) from master and slave
- 2D cross correlation of patch pairs
- determine 6-parameter affine transformation to align slave to master image
- affine: parallel remains, straight remains, points preserved

Making an Interferogram: Step 2 - Multiply

Complex number of each pixel, $C(x)$, in terms of amplitude, $A(x)$, and phase, $\phi(x)$:

$$C(x) = A(x)e^{i\,\phi(x)}$$

with position vector $\mathbf{x} = (\rho, a)$ defined by range and azimuth

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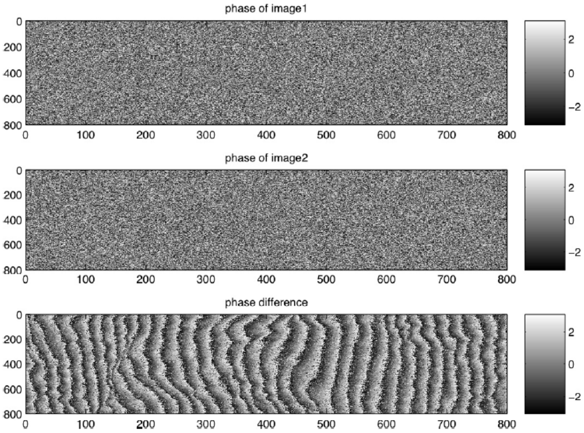
Multiply (pixel by pixel, note complex conjugate!):

$$\begin{aligned} C_2\, C_1^* &= A_2\, A_1\, e^{i(\phi_2 - \phi_1)} \\ &= Re(x) + i\, Im(x) \end{aligned}$$

Making an Interferogram: Step 3 - Get Phase

$$\phi_2 - \phi_1 = arctan\frac{Im(C_2\,C_1^*)}{Re(C_2\,C_1^*)}$$



Sandwell et al., 2011, GMTSAR documentation

Phase Contributors

What's in the phase?

Phase Contributors

$$\phi = E + \phi_{topo} + D + \epsilon_{orbit} + I + T + \epsilon$$

where:

- E: earth curvature (almost planar, known)
- ϕ_{topo}: topographic phase (broad spectrum)
- **D: surface deformation (unknown, we want to know!)**
- ϵ_{orbit}: orbit error (almost a plane, mostly known)
- I: Ionospheric Delay (plane or 40 km wavelength waves!)
- T: Tropospheric Delay (power law, unknown)
- ϵ: phase noise (white, unknown)