Airborne radar

Terrain

1 range bin

Figure 15-1: Radar returns from all points within any range bin are received at once. Thus conventional radar images cannot properly depict topographic information.
Figure 15-2: Distances to a point P from Antenna 1 and Antenna 2 are $R_1$ and $R_2$, respectively. The two arcs of these radii cross at the true position of the point in three-dimensional space.
Figure 15-3: Cross-track interferometric configurations in (a) and (b) and along-track configuration in (c).
Figure 15-4: Parallel-ray approximation for InSAR geometry with $R_1 = R$ and $R_2 = R - \delta$. Note that $R_1$ is from $A_1$ to $P$. 
Figure 15-5: Example of interferometric SAR processing: (a) SAR magnitude image, (b) phase difference (interferogram) between two images with flat-Earth phase removed, (c) correlation map between interferogram component scenes, and (d) inferred surface topography.
Figure 15-6: Relationship between slant-range and ground-range image presentations for a side-looking radar.
Figure 15-7: Geometric distortions: (a) foreshortening, which occurs when the distance between $A'$ and $B'$ in the slant range is less than the ground-range distance between $A$ and $B$, (b) layover, where $B'$ is imaged in front of $A'$, and (c) shadow, where the unilluminated mountain back yields a dark region between $B'$ and $C'$. 
**Figure 15-8:** Distortions resulting from mapping (a) ground-range to (b) slant-range format. Note that slant-range images do not faithfully reproduce shapes and lines in ground-range images.
Figure 15-9: Multipath distortion. Two separate ray paths, with different total lengths, illuminate a bridge, causing it to appear twice in the radar image.
Figure 15-10: Illuminated swath is typically centered in angle about a mean look angle $\theta_0$. 
Figure 15-11: Parallel and perpendicular components of the interferometer baseline $B$ as defined by incidence angle $\theta_0$. Range $R$ is from $A_1$ to target point.
Figure 15-12: (a) Image as seen by antenna 1 and (b) image as seen by antenna 2. The combination of angle-dependent mapping into slant range coordinates causes antenna 2 to see a shifted and scaled version of the image seen by antenna 1.
Figure 15-13: Schematic illustration of corresponding small regions in the two interferometer images: (a) image from antenna 1, with a particular small region identified, and (b) corresponding area in the image from antenna 2.
Figure 15-14: In computing the cross-correlation function, a small region from image 1 is cross-correlated against a larger piece of image 2 to enable a search range for the correlation peak.
Desired set of regions to cross-correlate with region 2

Figure 15-15: Grid of image 1 regions to cross-correlate with image 2.
Figure 15-16: Plot of noisy measured offsets as a function of range location and the least-square fit of the data. The slope and intercept of the line yield the parallel and perpendicular baseline components.
Figure 15-17: Imaging geometry for the decorrelation model. Scatterer $P$, at a distance $y$ from the pixel center, is observed from two different incidence angles, so the phase of the wave reflected from $P$ differs in each observation. The observed phase relative to the phase of the center of the pixel is that accumulated by a wave propagating a distance $y \sin \theta$ for each ray.
Figure 15-18: Baseline decorrelation for the sinc impulse function of the SEASAT SAR compared with actual data collected over Death Valley in 1978. The discrepancy in the rates of falloff between the curves is attributed to imprecise system models of the resolution. [Zebker and Villasenor, 1992.]
Figure 15-19: Simulated and theoretical dependence of InSAR correlation on (a) track rotation as a function of rotation angle, and on (b) scatterer motion as a function of rms displacement of the scatterers. These curves are for a radar with 5 m resolution in both slant range and azimuth. [Zebker and Villasenor, 1992.]
Figure 15-20: (a) Observed decorrelation with time for three different geographic regions, as measured by the SEASAT SAR in 1978; (b) scatter plot of relative backscatter intensity versus interferometric correlation for a water surface and various types of terrain [Rosen et al., 2000].
Figure 15-21: InSAR observation geometry.
Figure 15-22: Simulation of InSAR phase difference: (a) true phase $\phi$, (b) measured phase modulo $2\pi$, and (c) tropospheric component of $\phi$ after removal of flat-Earth component.
Figure 15-23: (a) DEM of the Galápagos Islands Fernandina and Isabela, acquired by the NASA/JPL TOPSAR C-band interferometer. The swath width of the instrument is only 20 km, so many parallel flight lines were collected and combined. (b) DEM of Askja, Northern volcanic zone, Iceland, derived from the C-band EMISAR topographic mapping system of Denmark. The color variation in the image is derived from L-band EMISAR polarimetry [Christensen et al., 1998].
Figure 15-24: Geometry for computing the curved-Earth phase component.
Figure 15-25: Cartoon illustrating the configuration of the SRTM instrument. Radar signals are transmitted from the main shuttle bay, and received simultaneously at that location and at an outboard antenna, forming an across-track baseline. [Courtesy NASA.] The mast is 60 m long.
Figure 15-26: SRTM topographic map of part of Italy.
Figure 15-27: Interferometer geometry to measure along-track motions. Antennas mounted at the front and rear of an aircraft capture two radar images displaced in time by the interval it takes the plane to travel the baseline distance $B$. 
Object at $t_1$

Object at $t_2$

Actual velocity $v$

Radial component $v_r$

Figure 15-28: Observing a moving object receding from the flight path of the aircraft. In the time between observation, the object moves further away, and thus the phase of the radar signal increases.
Figure 15-29: Along-track interferometer observing the velocity of the ocean surface.
Figure 15-30: Radar interferogram of a portion of the Rutford ice stream in Antarctica, based on two ERS-1 images taken six days apart. The fringe pattern (color cycle) is essentially a map of ice-flow velocity, with one fringe representing 28 mm of range change along the radar line of site. [Image courtesy Jet Propulsion Laboratory, California Institute of Technology.]
Figure 15-31: Surface deformation has displaced the location of point $P$ by $\Delta R$ along the direction of the radar line of sight.
Line-of-sight displacement (cm)

Positive defined as motion towards satellite

Figure 15-32: Interferogram due to surface deformation caused by the 6.3-magnitude L’Aquila earthquake in Italy [Walters et al., 2009].
Figure 15-33: Artist’s conception of twin TerraSAR satellites collecting simultaneous data to form the TanDEM-X system. The ability to achieve large cross-track baselines and greatly suppress atmospheric phase artifacts leads to digital elevation models with 2 m height accuracy at 12 m postings.
Figure 15-34: Stack of 12 descending ERS interferograms over the San Andreas Fault acquired between May 1992 and January 2001. The average creep rate in this section is 1.5–2.0 cm/yr, and it is easily seen in this image. Areas corrupted by spatial decorrelation, mainly because this is at a short, 6 cm wavelength, yield no useful displacement estimates and are white in this image. [Ryder and Bürgmann (2008).]
Figure 15-35: False-color map of the measured deformation rms superimposed on the SAR image amplitude of the investigated area. The temporal evolution of the deformations in the selected points identified by A, B, C are shown in Fig. 15-36(a)–(c), respectively [Berardino et al., 2002].
Figure 15-36: Time-series deformation measured at (a) point A, (b) point B, and (c) point C of Fig. 15-35 [Berardino et al., 2002].
Figure 15-37: Comparison of PS identification algorithms according to the methods by Ferretti et al. (2000), (b) Hooper et al. (2004), and (c) Shanker and Zebker (2007). Color pixels are persistent-scattering points.
Figure 15-38: (a) Average LOS displacement rate image over the San Andreas Fault, (b) average LOS displacement rate as a function of distance from the fault. Assuming that all the displacement is purely due to strike slip motion across the fault, the estimated slip rate is 22 mm/yr. [Shanker, 2010.]