Principles and Theory of Radar Interferometry

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IGARSS 04 Tutorials

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Outline of Tutorial

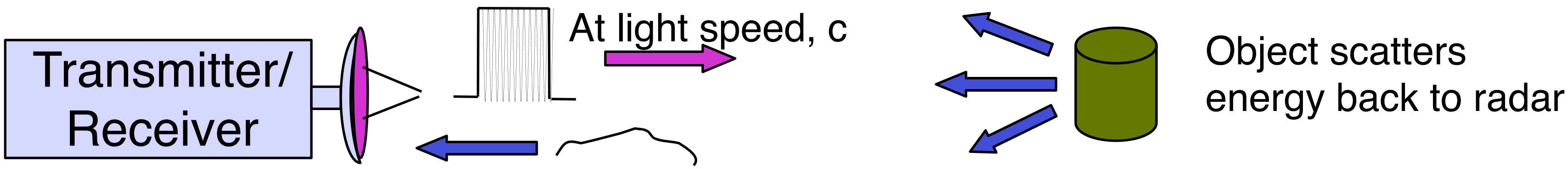
I. Quick Review of Radar Imaging Fundamentals
  - A. Basic Principles of SAR
  - B. Range and Azimuth Compression
  - C. ScanSAR vs Strip Mode Processing

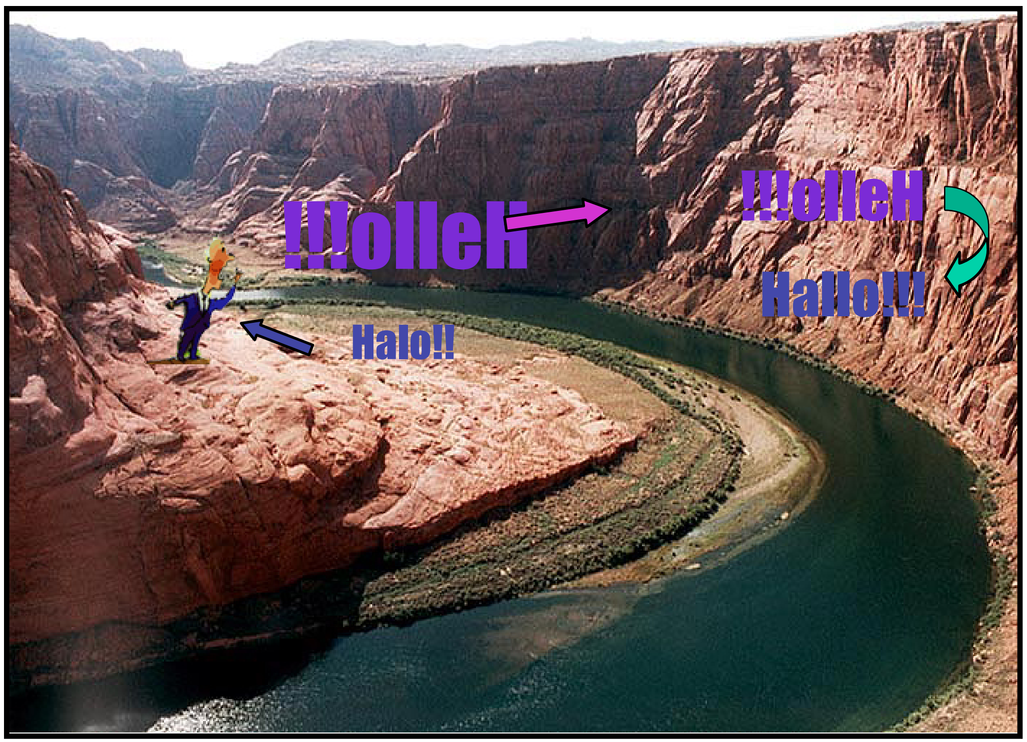
II. Geometric Aspects of Interferometric Phase Measurement
  - A. Interferometric Phase for Topographic Mapping
  - B. Interferometric Phase for Deformation Mapping
  - C. Sensitivity of Topographic Phase Measurements
  - D. Sensitivity of Deformation Phase Measurements
  - E. Comparison of Various Interferometric Mapping Schemes

III. Interferometric Correlation
  - A. Random and Deterministic Portions of the Interferometric Phase
  - B. SNR and Interferometric Correlation
  - C. Geometric Decorrelation and Range Spectral Shift
  - D. Temporal Decorrelation
  - E. Volumetric Decorrelation
  - F. Other Error Sources

IV. Interferometric Processing
  - A. Processing Flow
  - B. Interferogram Formation
  - C. Image Co-registration
  - D. Baseline Determination

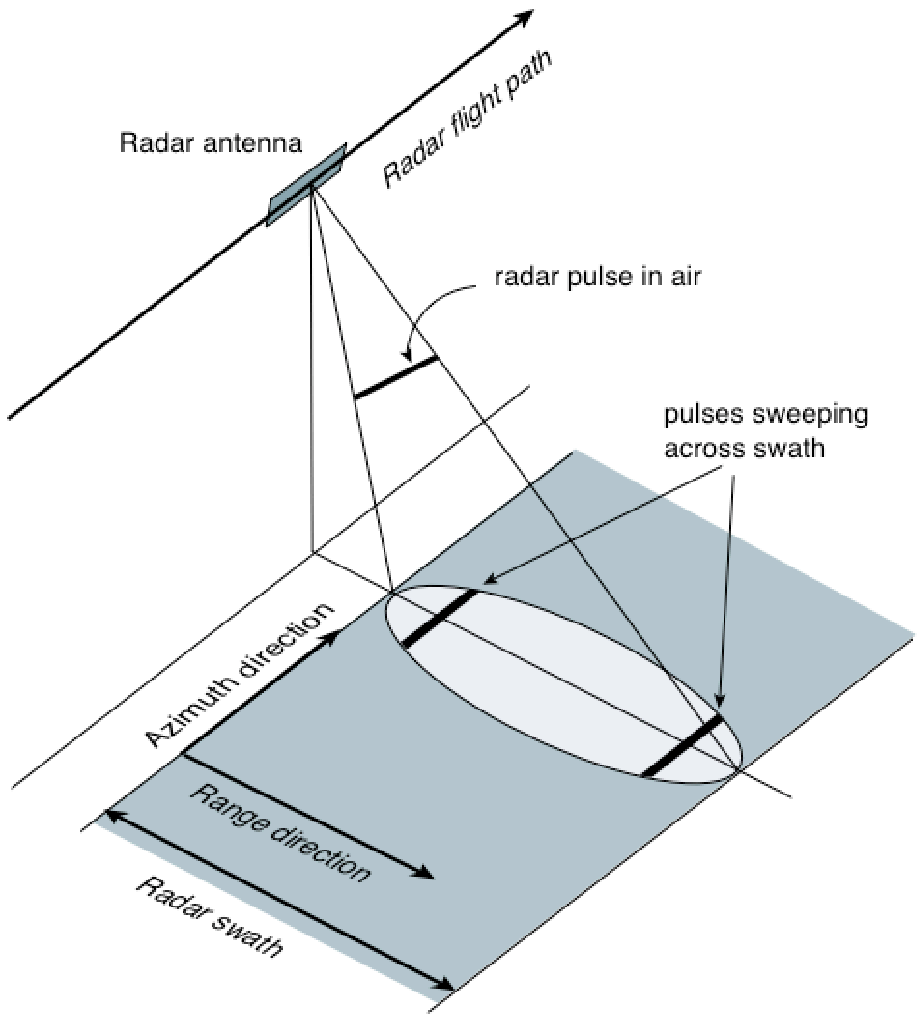
The Radar Concept





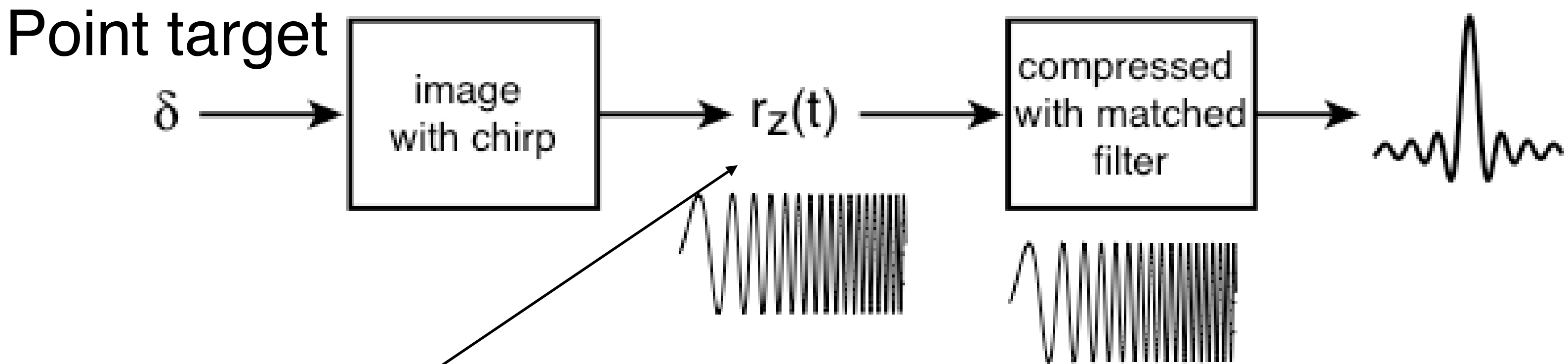
- Much like sound waves, radar waves carry information that echoes from distant objects
- The time delay of the echo measures the distance to the object
- The changes of the message in the echo determines the object characteristics

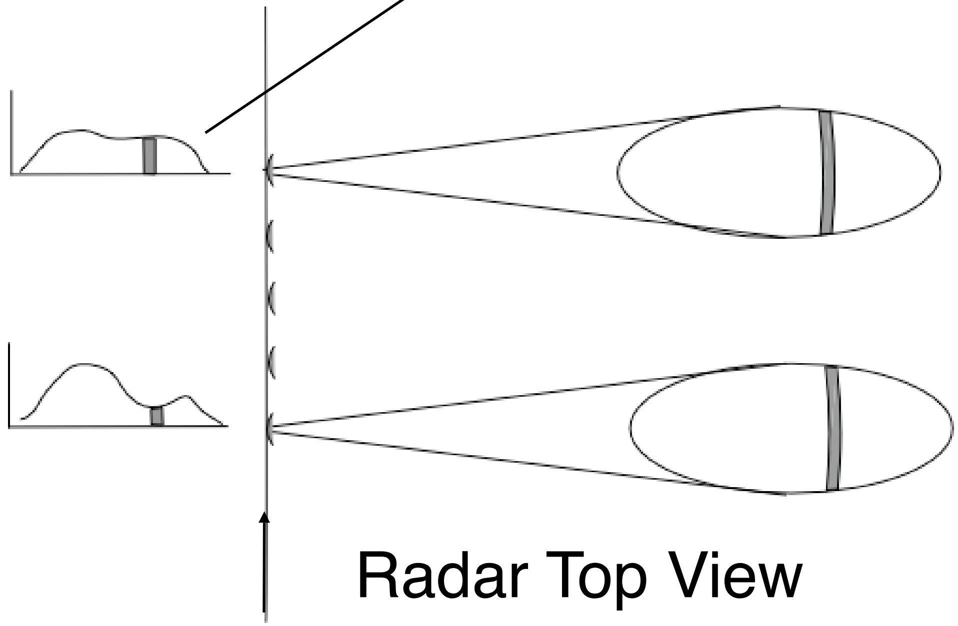
Radar on a Moving Platform



- Pulses are transmitted from the radar platform as it moves along its flight path
- Each pulse has finite extent in time, illuminating a narrow strip of ground as it sweeps through the antenna beam
- Some of the energy from the ground is scattered back to the radar instrument

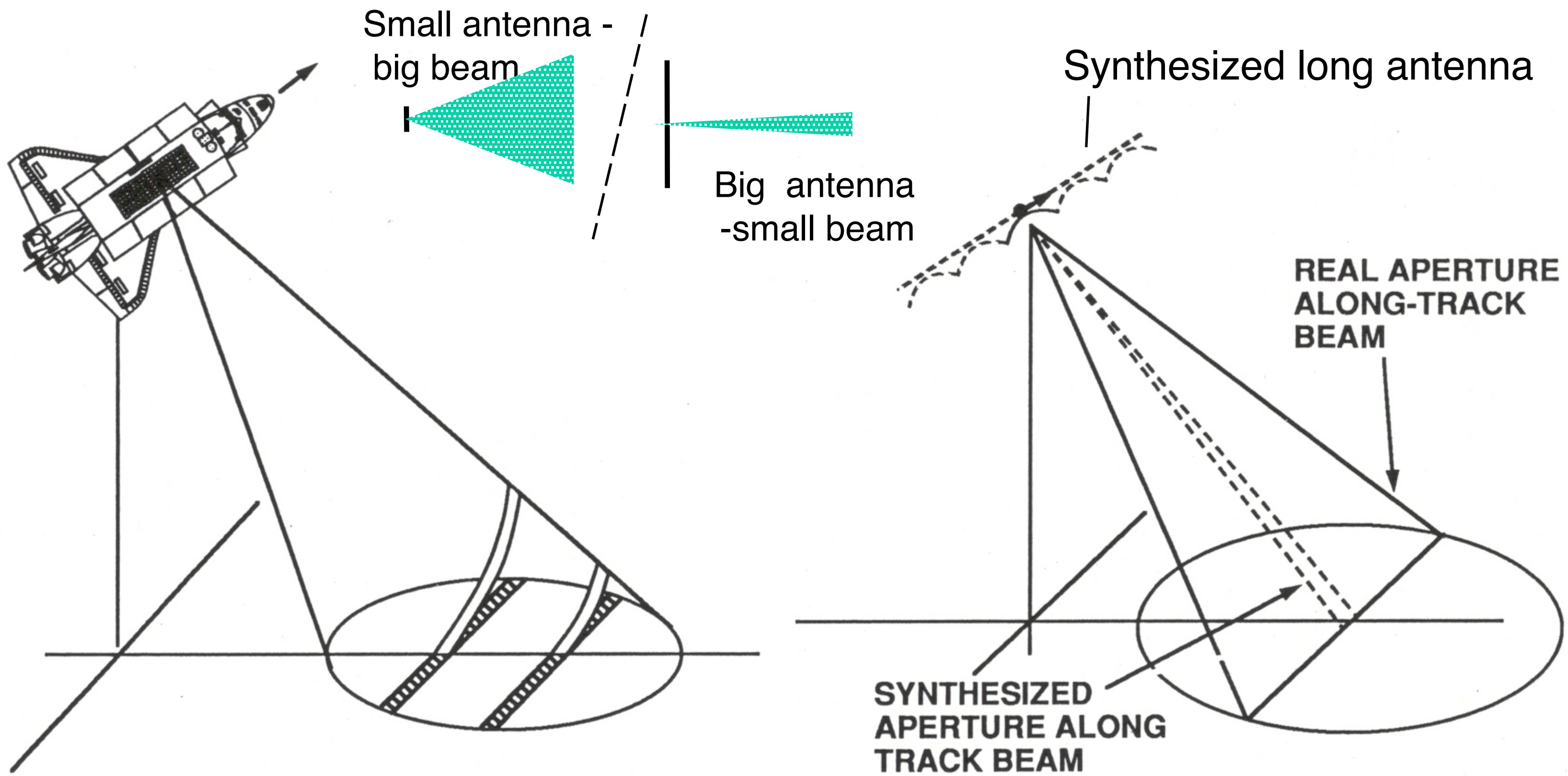
Matched Filtering of Received Echo





- Transmitted pulses are usually coded waveforms with significant bandwidth
- Matched filtering allows recovery of fine resolution features with a low peak-power pulse train

Imaging Radar

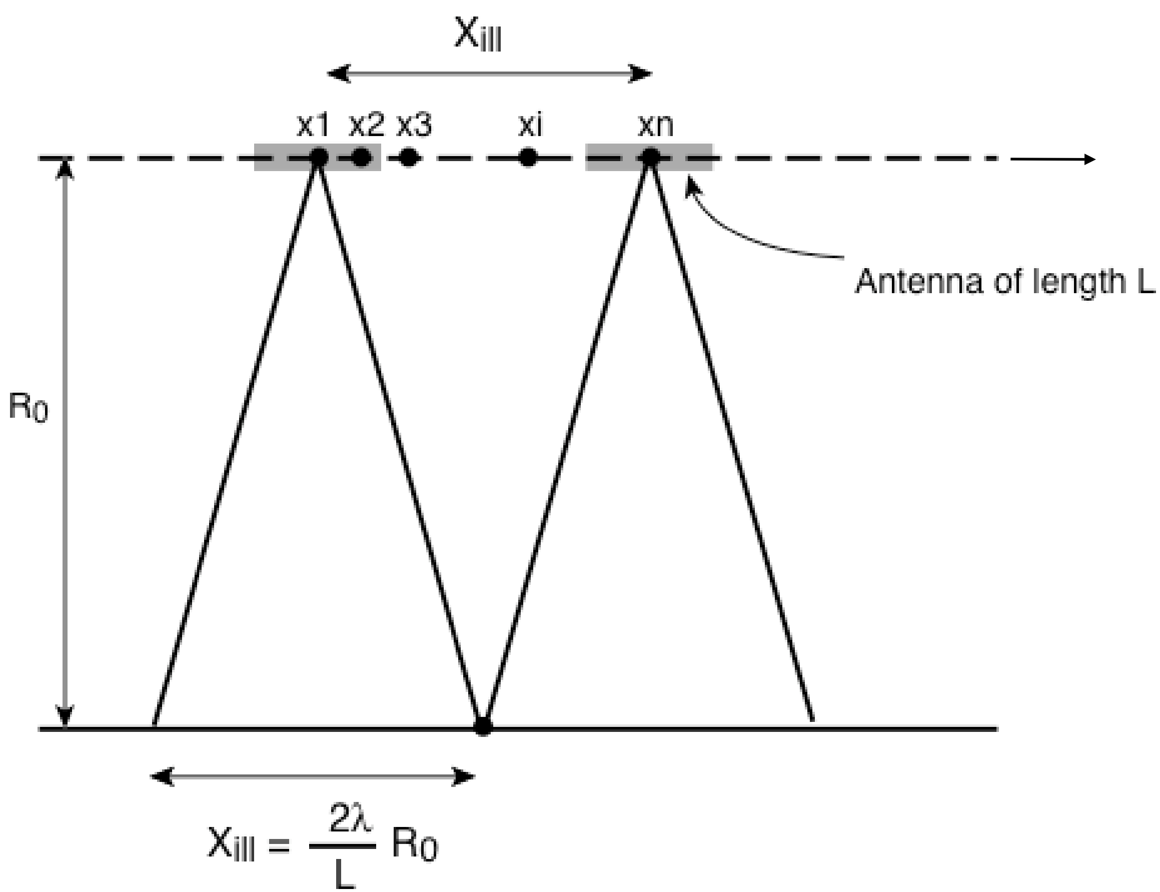


CROSS-TRACK RESOLUTION ACHIEVED BY SHORT PULSE LENGTHS (HIGH BANDWIDTH)

ALONG-TRACK RESOLUTION ACHIEVED BY COHERENTLY COMBINING ECHOES FROM MULTIPLE PULSES ALONG-TRACK (SYNTHESIZE A LONG ANTENNA)

- RESOLUTION α ANTENNA LENGTH
- INDEPENDENT OF RANGE/FREQUENCY

Azimuth Resolution from Aperture Synthesis

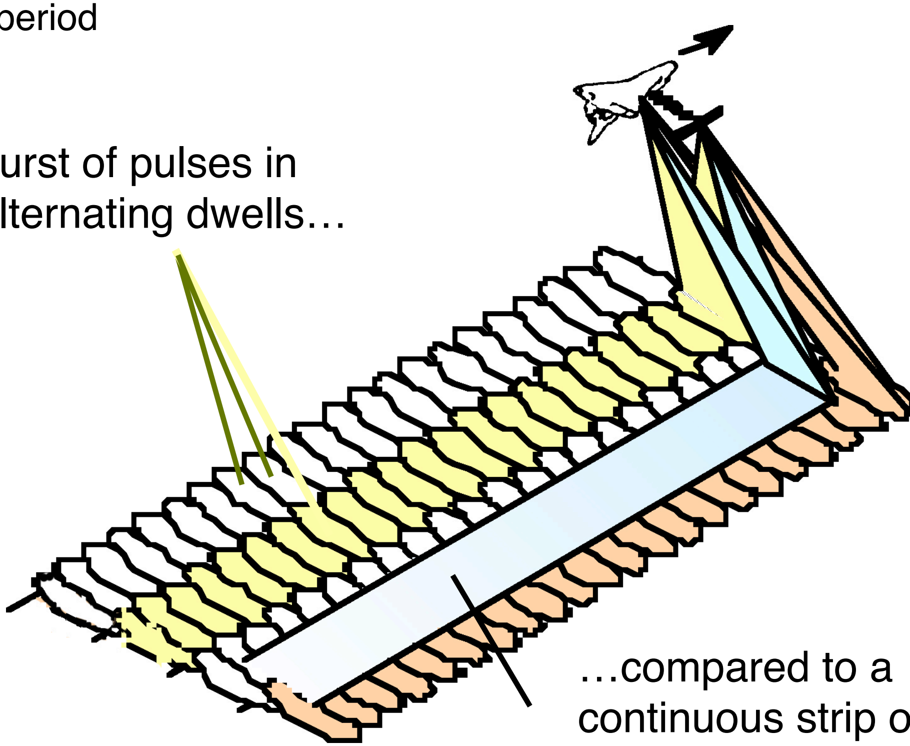


- The synthetic aperture X_{ill} lengthens as R0 increases…
- …which decreases the azimuth synthetic aperture's angular beamwidth (λ/X_{ill}) in proportion…
- …but the spatial resolution on the ground ($\lambda R_0/X_{ill} = L/2$) is constant
- Aperture synthesis processing is very similar to matched filtering in range

ScanSAR Imaging and Burst Geometry

In ScanSAR the look angle for a burst of pulses changes for each dwell period

burst of pulses in alternating dwells…



…compared to a continuous strip of pulses at fixed look angle

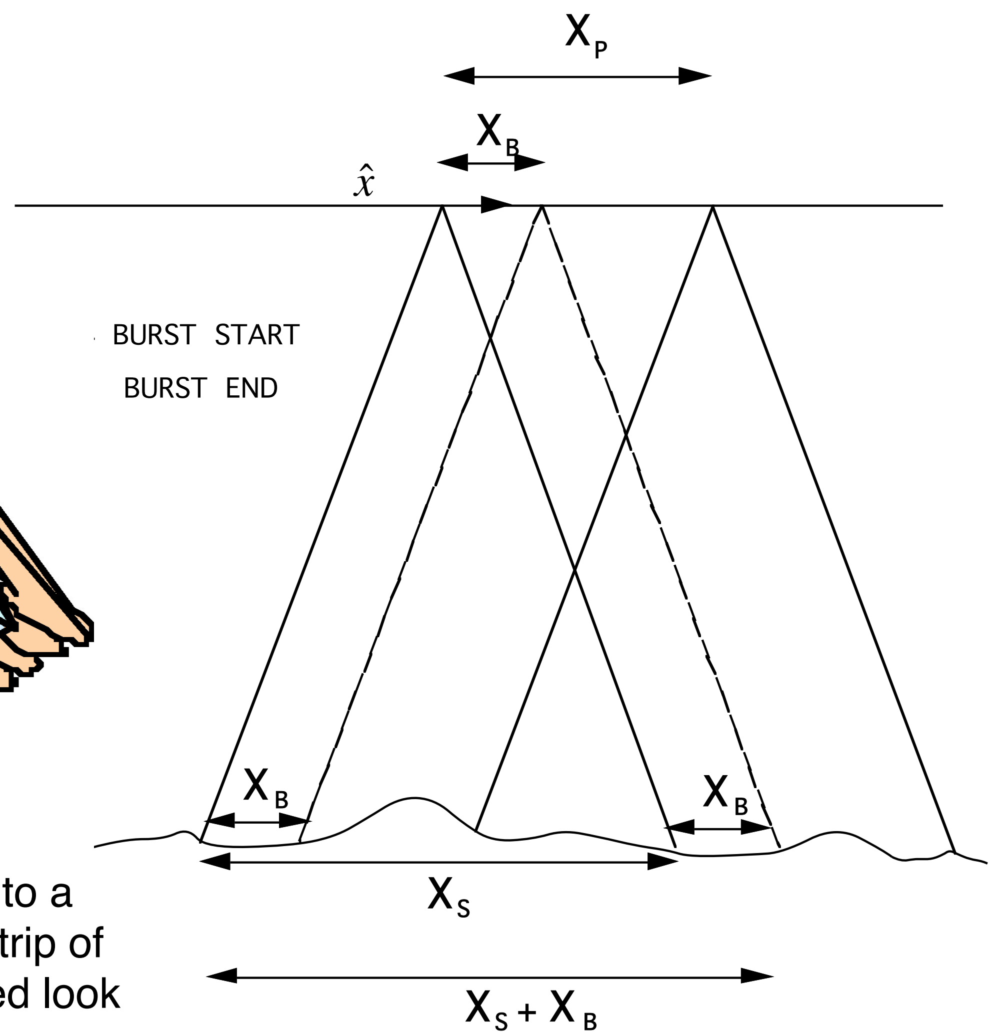
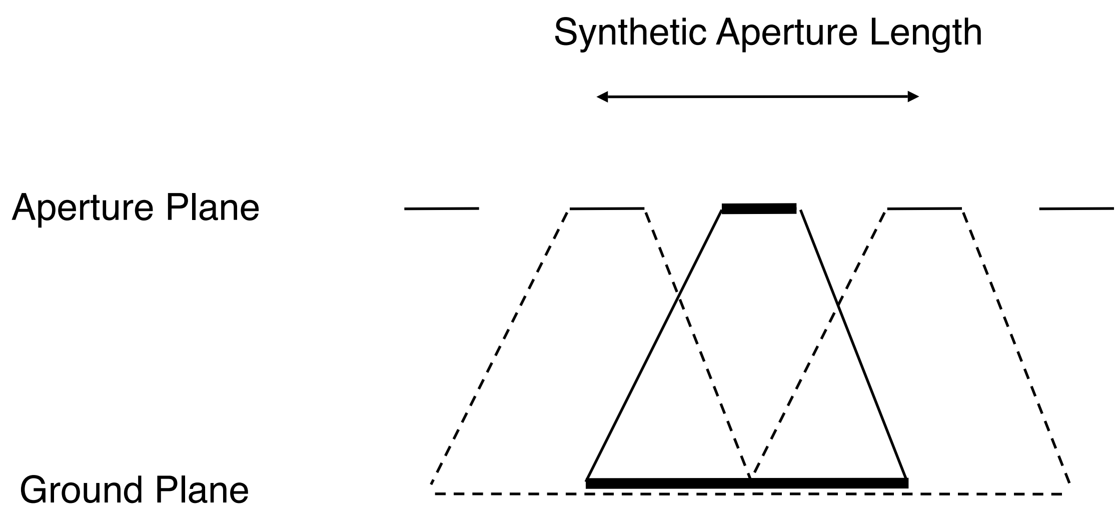


Illustration of Burst Combination

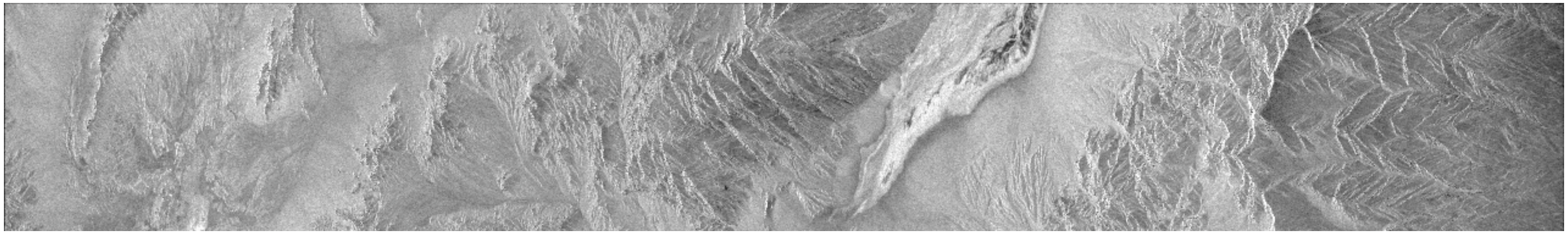


Images formed from each burst overlap in the ground plane.

Images are incoherently added (in power) to recover looks in processing.

Strip versus ScanSAR images (no radiometric calibration)

Standard Strip Mode Amplitude (4 looks; then 4x4 more)



Burst Processed Amplitude (1/4 aperture; 2 looks; then 4x4 more)

Note Amplitude Scalloping