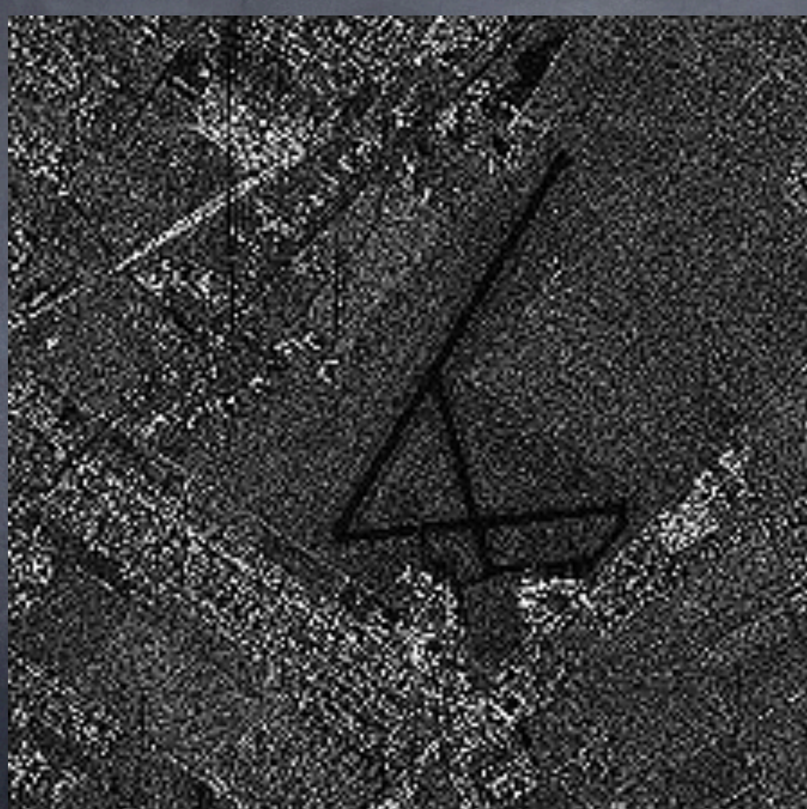
Session 40

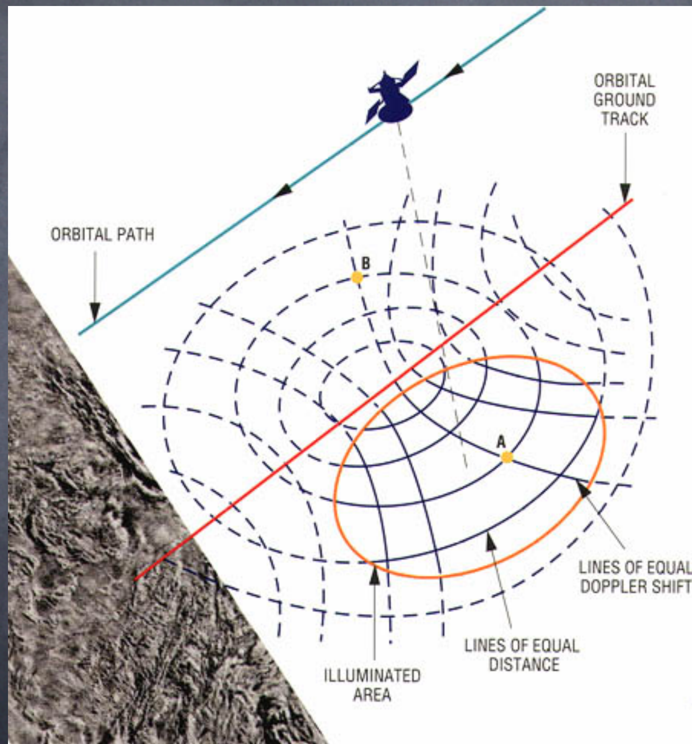
SAR Image of Airfield

40.1



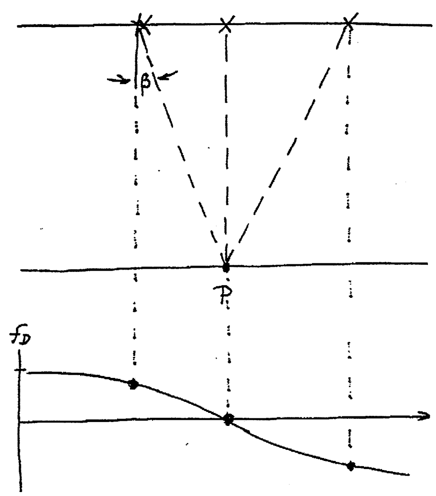
40.2

Doppler Synthesis Approach to SAR



40.3

The Doppler Synthesis Approach to SAR



As a radar flies over a target P, the Doppler shift in the signal reflected from P will change at various positions along the path.

The received signal will have a frequency $f_R = f_c + f_D$.

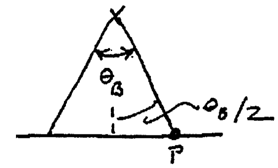
$$f_D = \frac{2v}{\lambda}\cos\left(\frac{\pi}{2} - \beta\right) = \frac{2v}{\lambda}\sin\beta.$$

The entire range of received frequencies we would expect to see over the entire synthetic aperture is

$$f_c \pm f_{D,\max},$$

where

$$f_{D,\max} = \frac{2v}{\lambda}\sin\left(\frac{\theta_B}{2}\right) \approx \frac{v\theta}{\lambda} = \frac{v}{L},$$

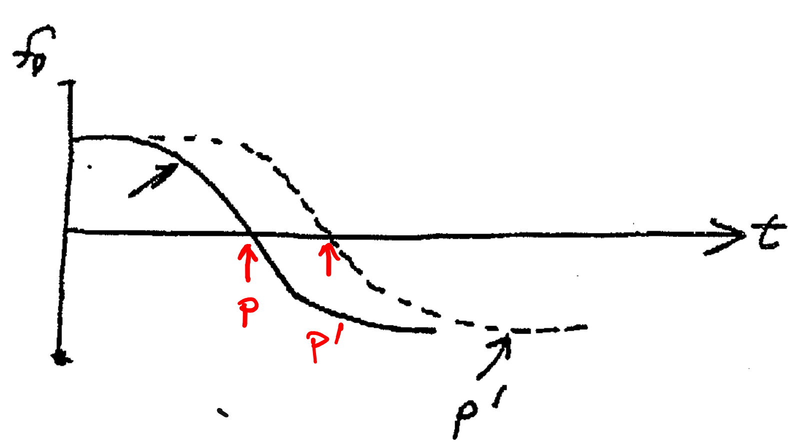


where L is the physical length of the antenna along track.

If a neghboring point P' is displaced a distance x_a further along track from P, the Doppler history of P' will be the same as P, but will be delayed by

$$t = \frac{x_a}{v}.$$

($n.b.$ v is the radar's speed.)



The shortest time displacement that can be measured after processing a signal with spectral bandwidth

$$B_D = 2 f_D$$

is

$$t_m = \frac{1}{B_D} = \frac{1}{2 f_D} = \frac{L}{2v} .$$

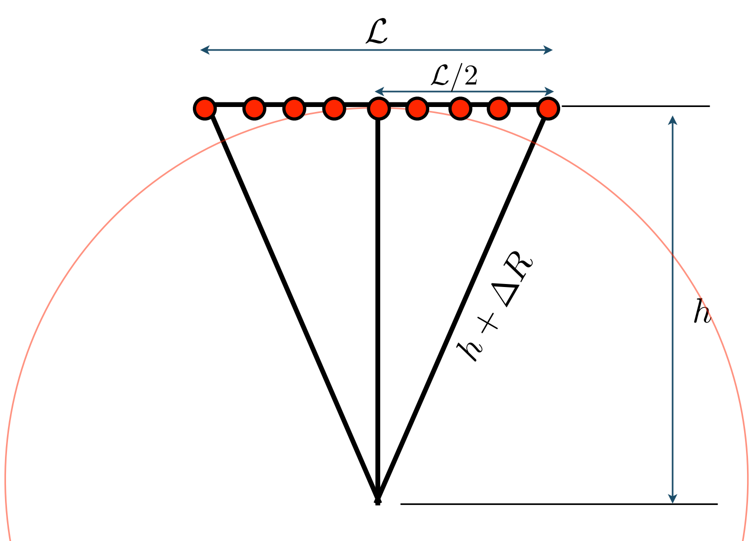
(Rayleigh Criterion)

Thus the finest possible resolution is

$$X_a = v t_m = \boxed{\frac{L}{2}}$$

Same as the synthetic array approach

Unfocused and Focused SAR



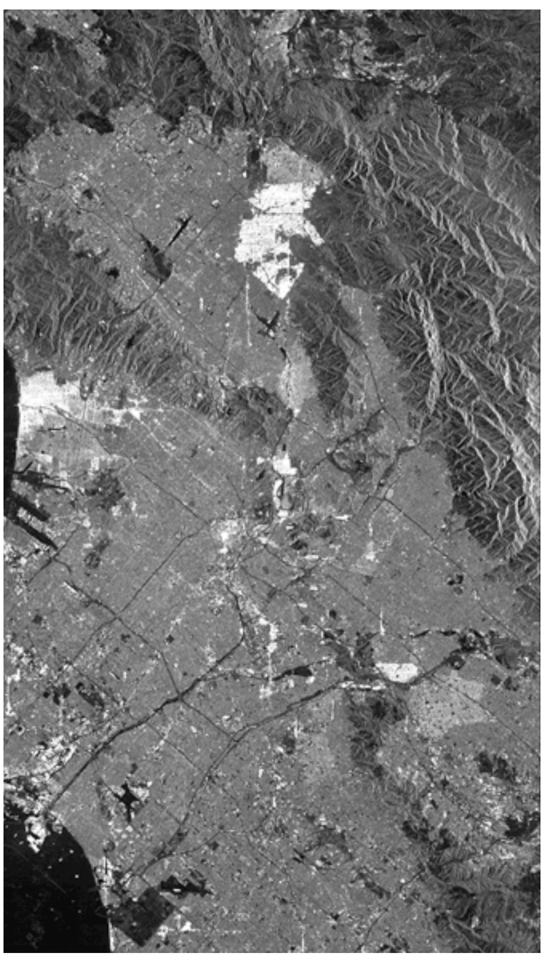
If we attempt to build a large synthetic aperture, the point we are imaging will almost never be in the far field.

In order to get an aperture of length, we must delay or phase shift the signals at the center of the array so the returns add up in phase.

This is called focusing the synthetic array.

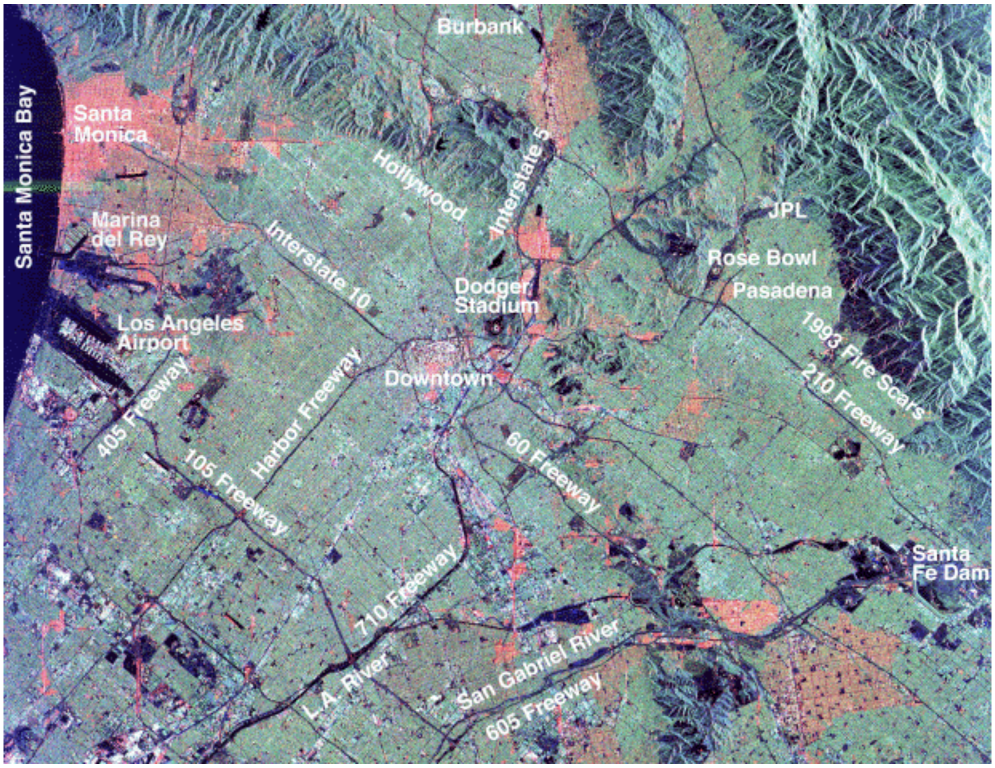
- Without focusing, the effective length of the array becomes smaller than its true length, because the signals being added do not add in phase.
- From simple geometry we see that the correction (delay) is a function of the range to the object.
- This means there are different corrections for each range cell.
- This results in increased computational complexity of SAR processing.
- Almost all current SAR systems perform focusing.

- Some Synthetic Aperture Radar Images

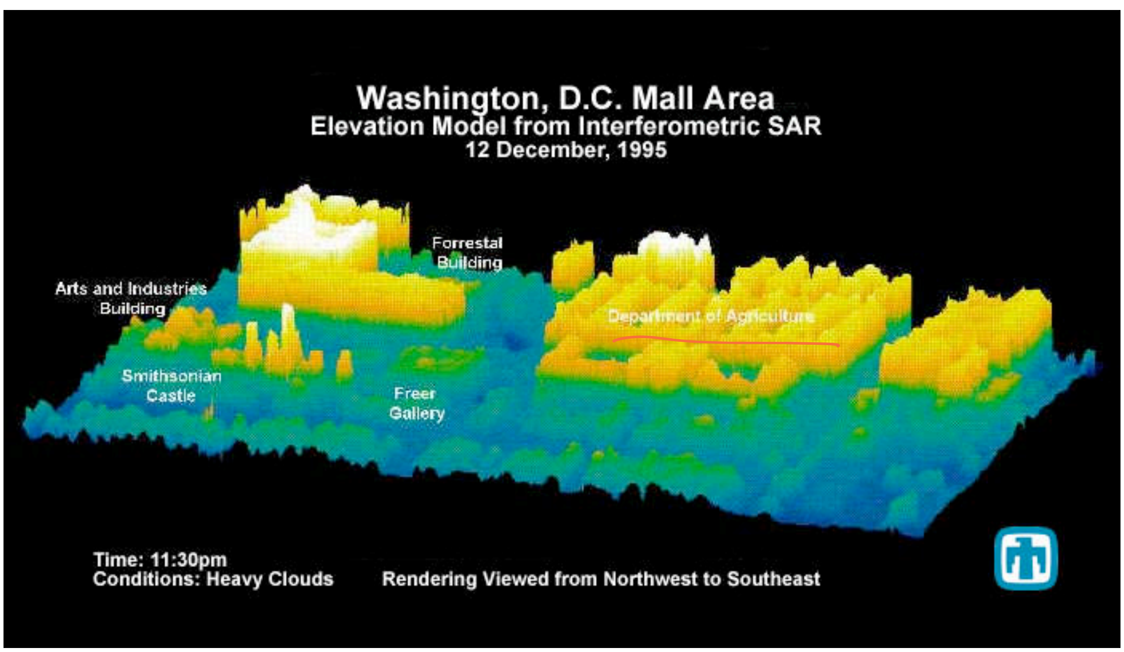


SEASAT SAR
Image of Los
Angeles Basin

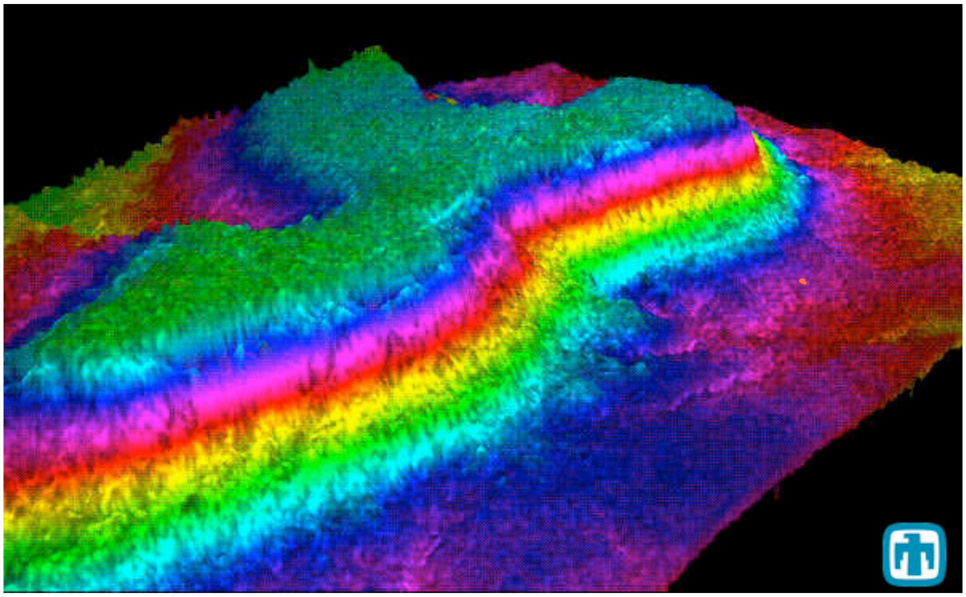
SIR-C/SAR-X (Shuttle Imaging Radar)



InSAR Image



InSAR Image
Cochiti Mesa, New Mexico



Constant False Alarm Rate
(CFAR)
Detection

- When we considered the problem of optimal signal detection, we assumed we knew the distribution of the noise under the null hypothesis.

- We not only assumed we knew the form of the distribution (e.g., Gaussian or Rayleigh), but we assumed we had perfect knowledge of the parameters of the distribution.

  - What if we are wrong about the parameters (or the distribution for that matter?)

  - Incorrect knowledge of the noise distribution results in errors in the likelihood ratio threshold.

  - This can *drastically* effect actual detection.

Assume that we must decide between two simple hypotheses

$$H_0 : \quad X \sim \exp(\mu_0),$$

$$H_1 : \quad X \sim \exp(\mu_1).$$

(assume $\mu_1 > \mu_0$.)

The resulting test will be a threshold test of the form

$$\phi(X) = \begin{cases} 1, & \text{for } X \geq x_0; \\ 0, & \text{for } X < x_0. \end{cases}$$

The threshold x_0 that yields a probability of false alarm α is

$$x_0 = -\mu_0 \ln \alpha.$$

If we have an error in μ_0, we will have a significantly different false alarm probability:

$$\alpha = (\alpha_{\text{nom}})^{\mu_{\text{nom}}/\mu_0}.$$

The effects of inaccurate noise estimates