http://topex.ucsd.edu/gmtsar/tar/GMTSAR_2ND_TEX.pdf

GMTSAR:

An InSAR Processing System
Based on Generic Mapping Tools

(Second Edition)

David Sandwell* Rob Mellors† Xiaopeng Tong*‡
Xiaohua Xu* Matt Wei§ Paul Wessel¶

May 1, 2011; Revised: June 1, 2016

InSAR Workshop, August 08-10 in this room, no cost.

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(closed now so send me an e-mail dsandwell@ucsd.edu)

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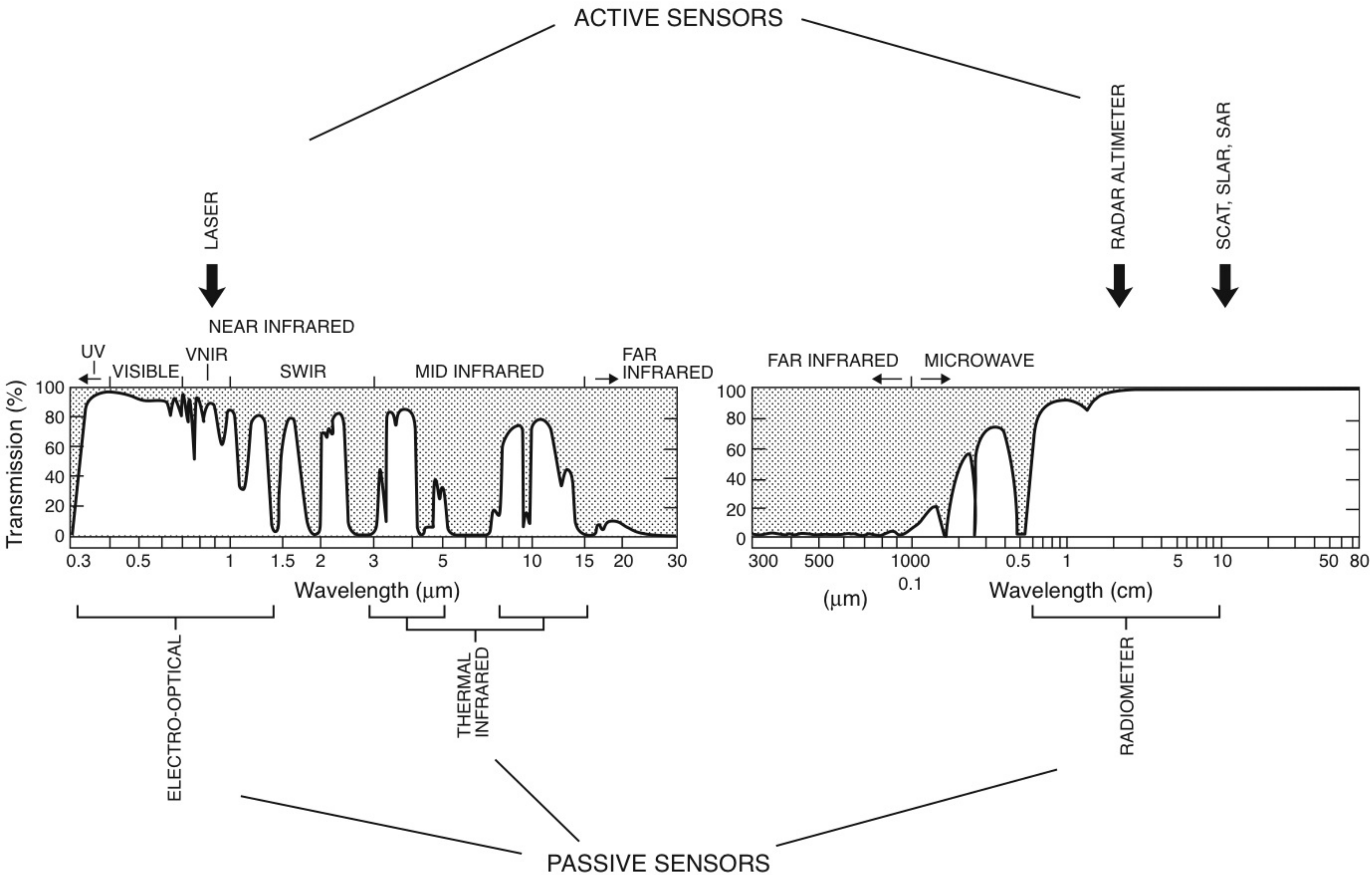
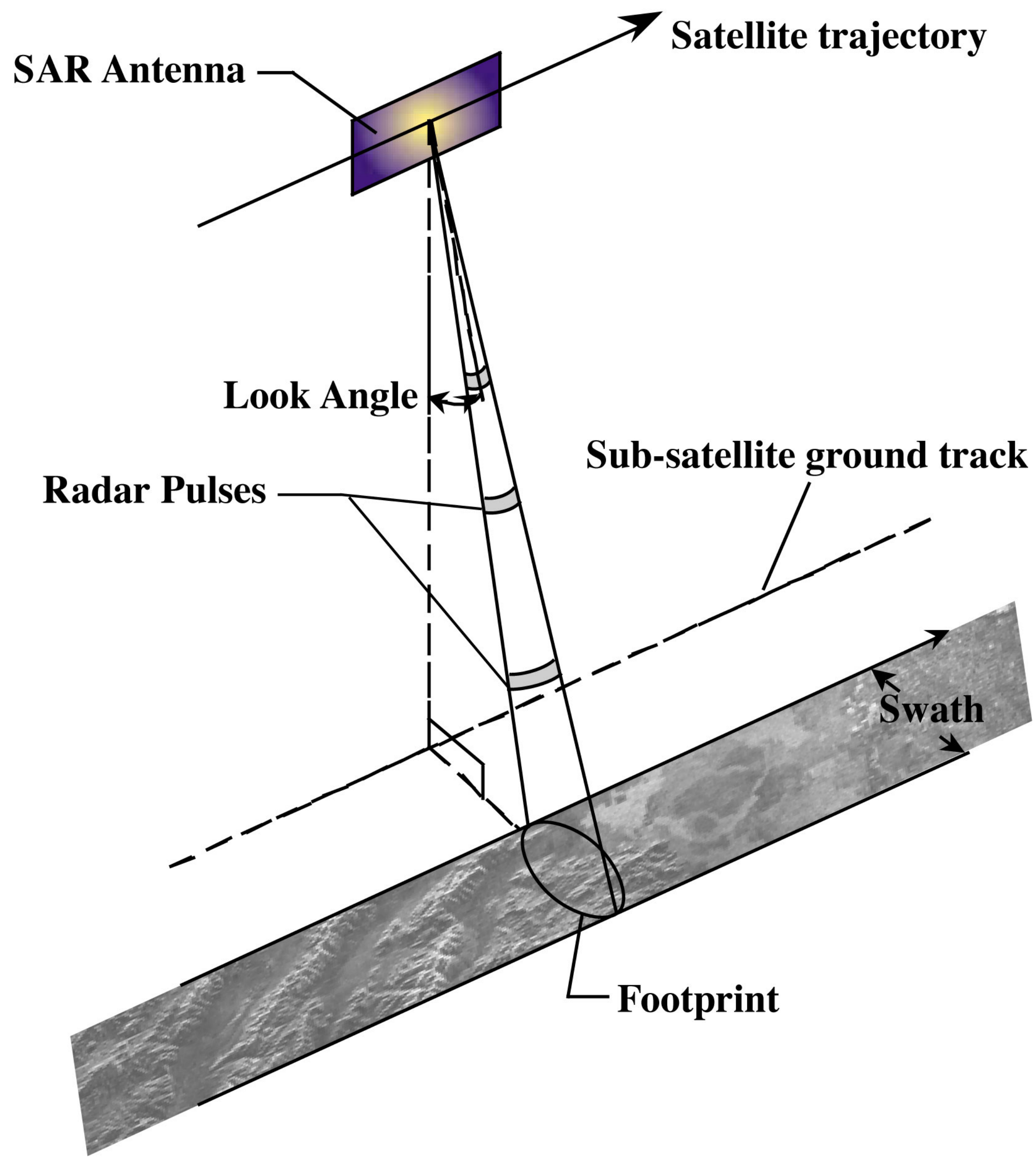
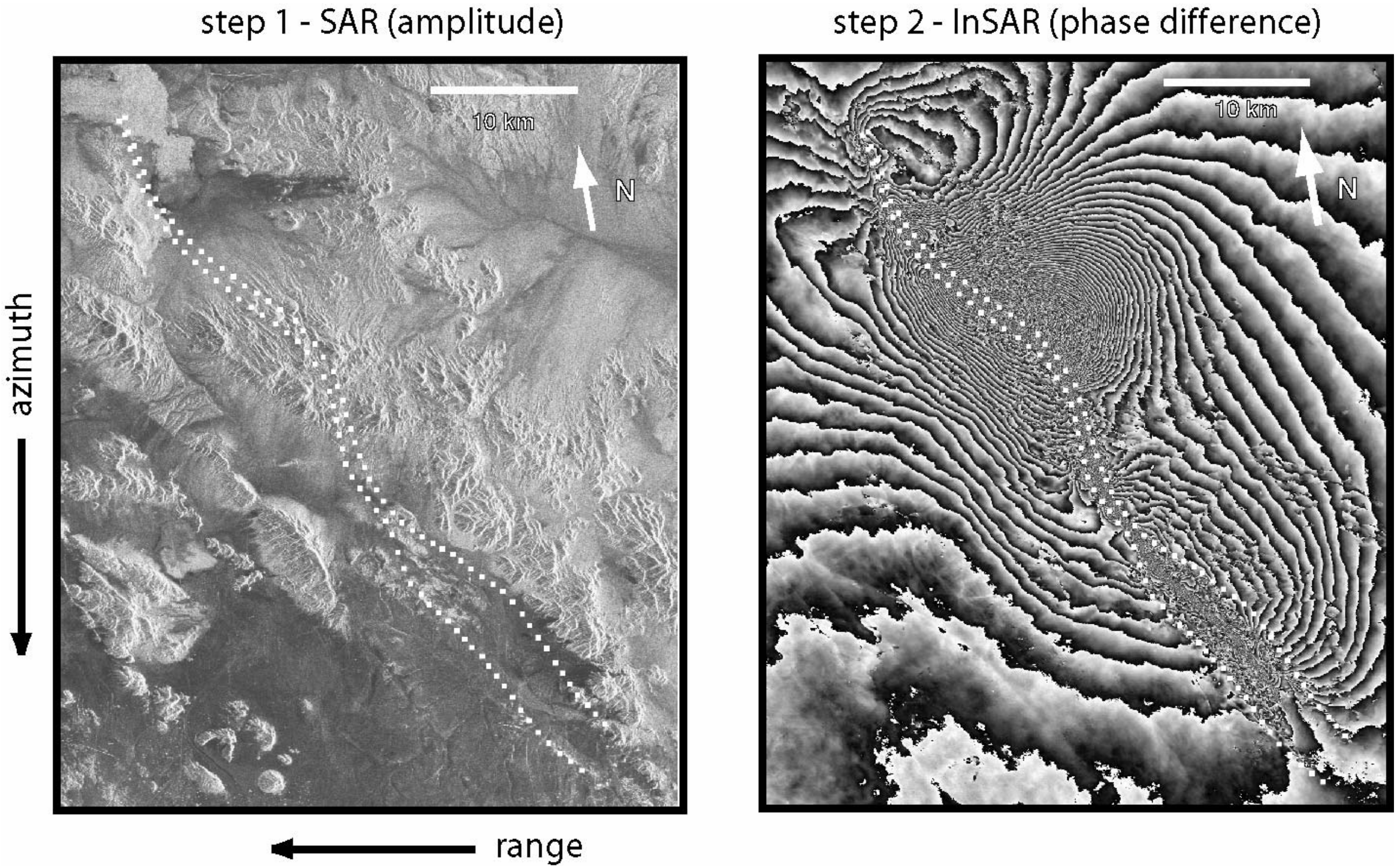

ACTIVE SENSORS
LASER
RADAR ALTIMETER
SCAT, SLAR, SAR
NEAR INFRARED
UV
VISIBLE
VNIR
SWIR
MID INFRARED
FAR INFRARED
Transmission (%)
100
80
60
40
20
0
0.3
0.5
1
1.5
2
3
5
10
15
20
30
Wavelength (μm)
FAR INFRARED
MICROWAVE
300
500
1000
0.1
0.5
1
5
10
50
80
(μm)
Wavelength (cm)
ELECTRO-OPTICAL
THERMAL INFRARED
RADIOMETER
PASSIVE SENSORS



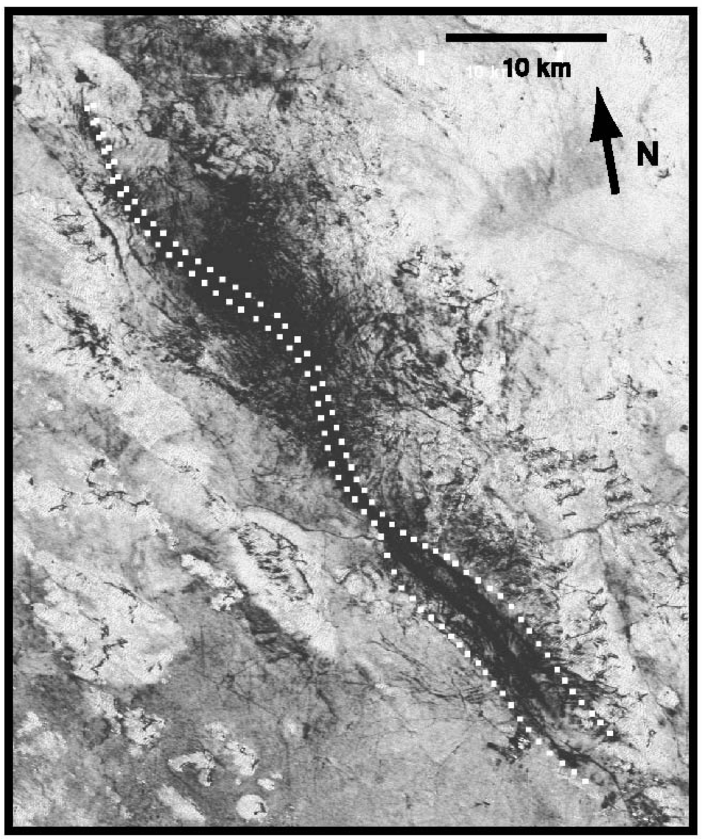
SAR Antenna
Satellite trajectory
Look Angle
Sub-satellite ground track
Radar Pulses
Swath
Footprint

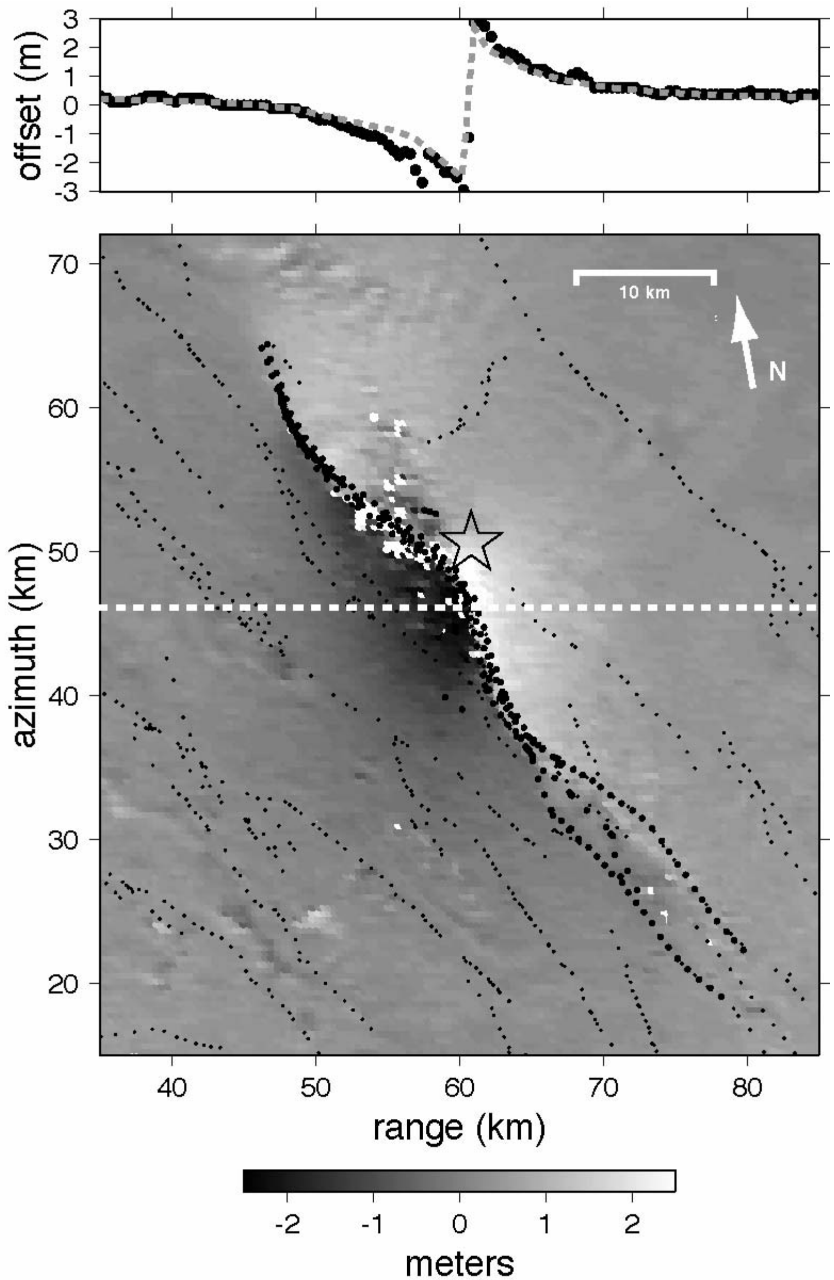
amplitude and phase

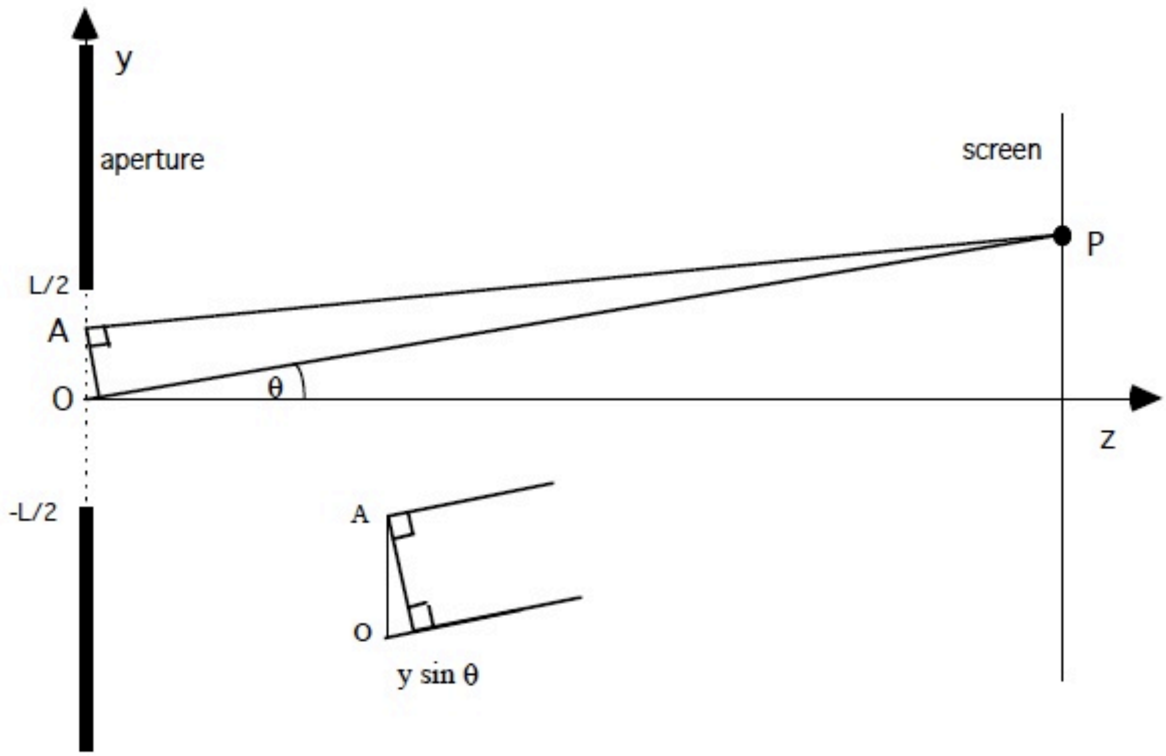


coherence and pixel matching

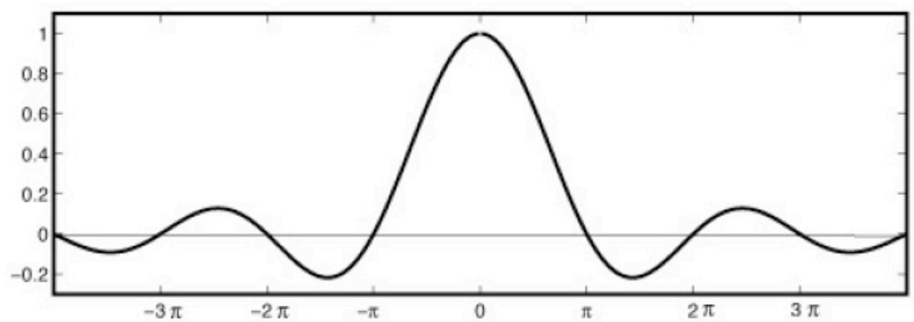
InSAR (coherence)





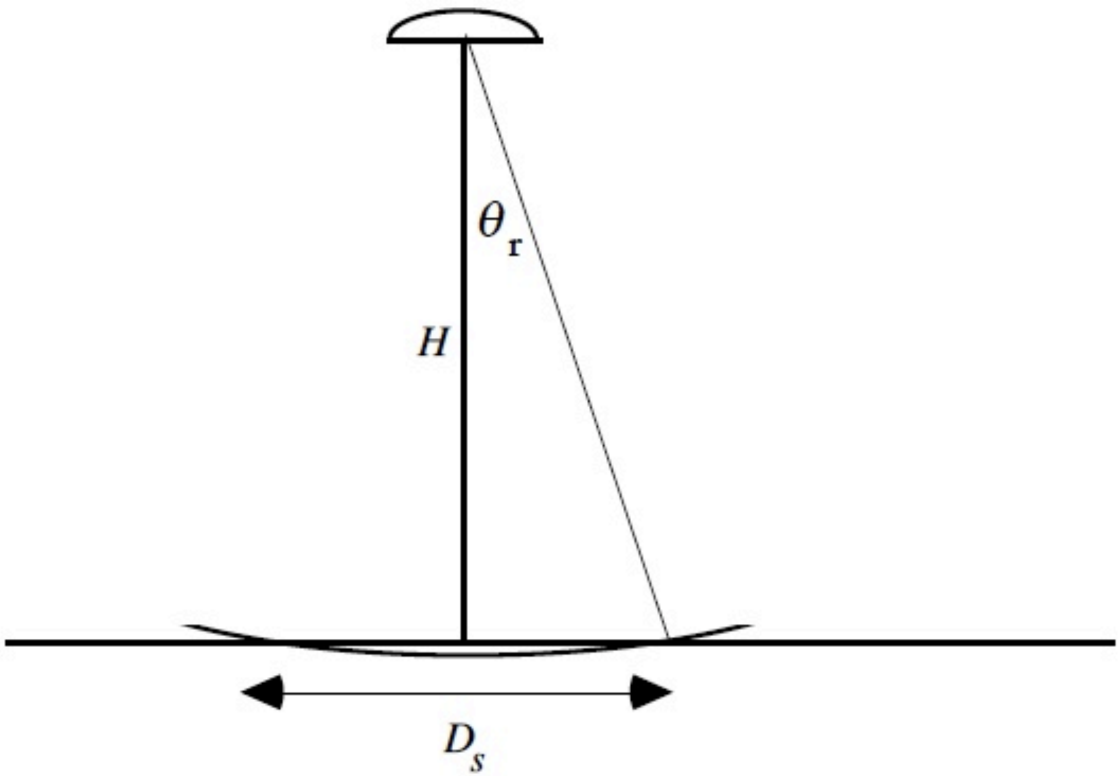


The illumination pattern on the screen is shown in the following diagram.



The first zero crossing, or angular resolution θ_r of the sinc function occurs when the argument is π so $\boxed{\sin\theta_r = \frac{\lambda}{L}}$ and for small angles $\theta_r \cong \lambda / L$ and $\tan\theta_r \cong \sin\theta_r$. Note that

resolution: optical vs. microwave



$$D_s = 2H\sin\theta_r = 2H\frac{\lambda}{L}$$

$$H = 800km.$$

Optical :

$L = 1m$

$\lambda = 0.5\mu m$

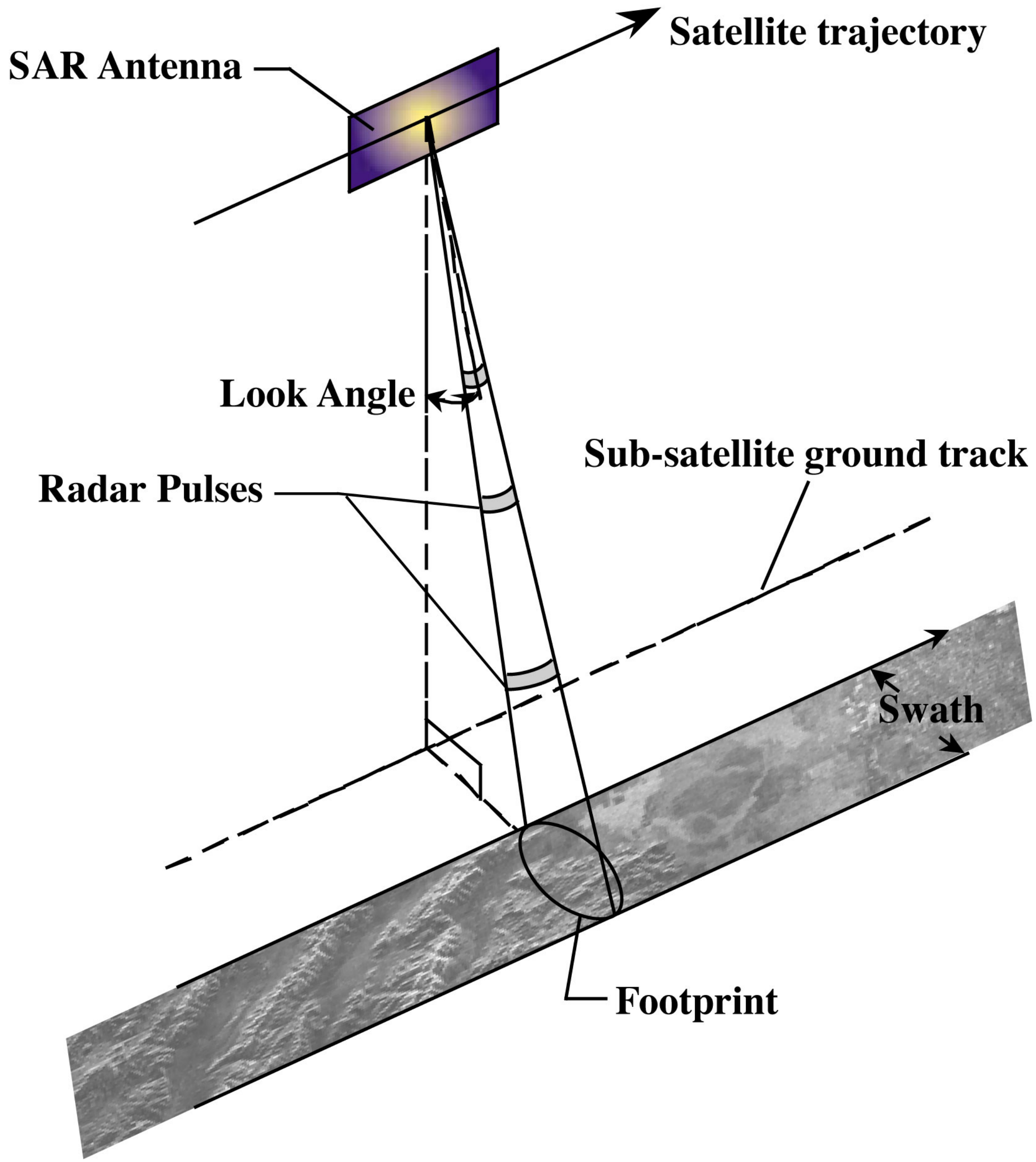
$D_s = 0.8m$

Microwave :

$L = 10m$

$\lambda = 0.23m$

$D_s = 46{,}000m$!!!!!!



SAR Antenna
Satellite trajectory
Look Angle
Radar Pulses
Sub-satellite ground track
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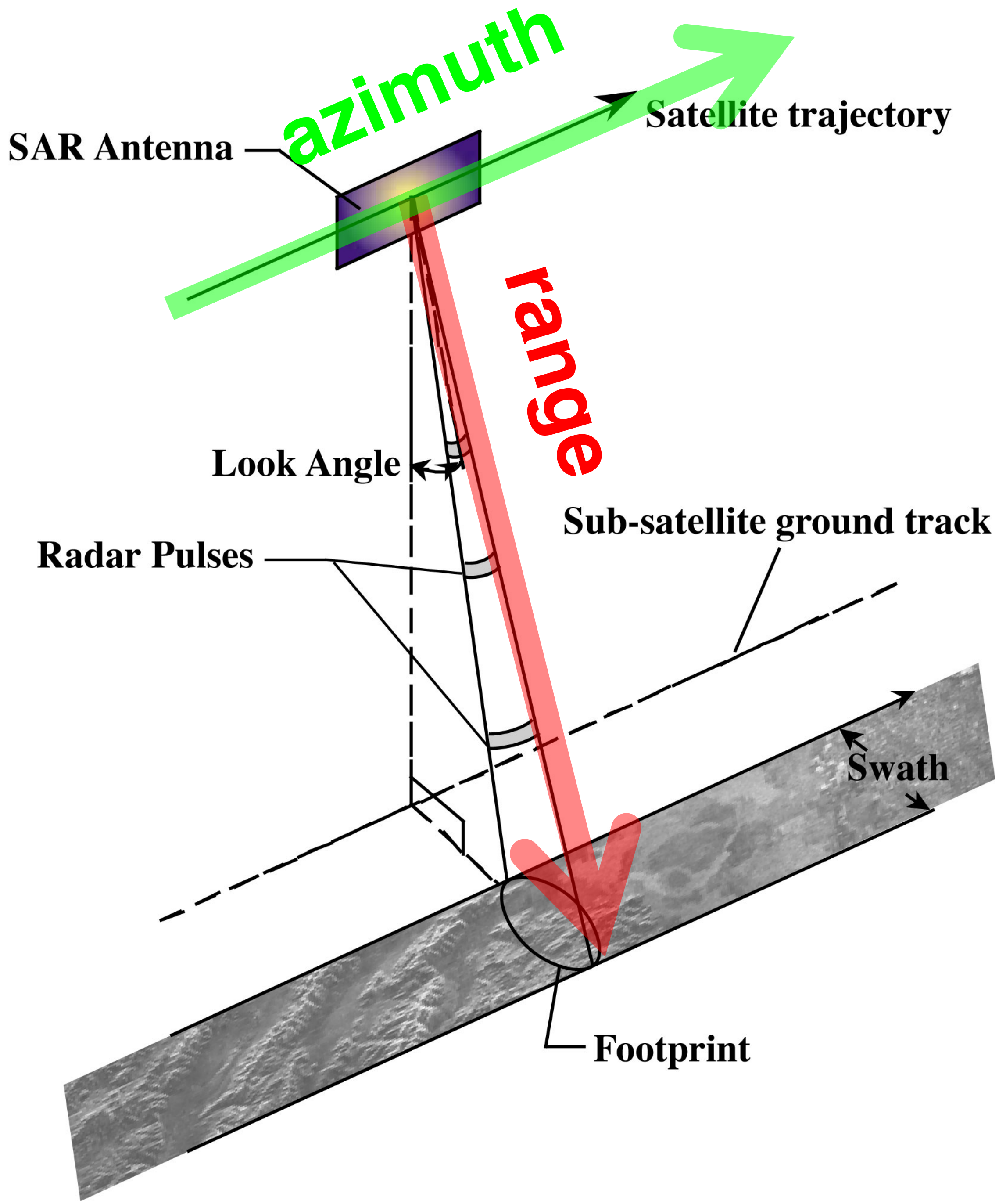
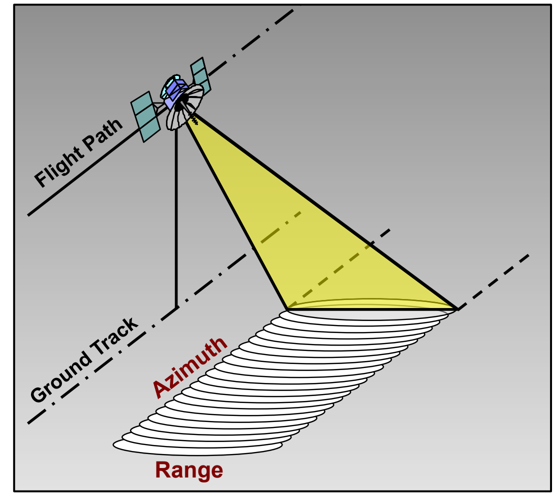
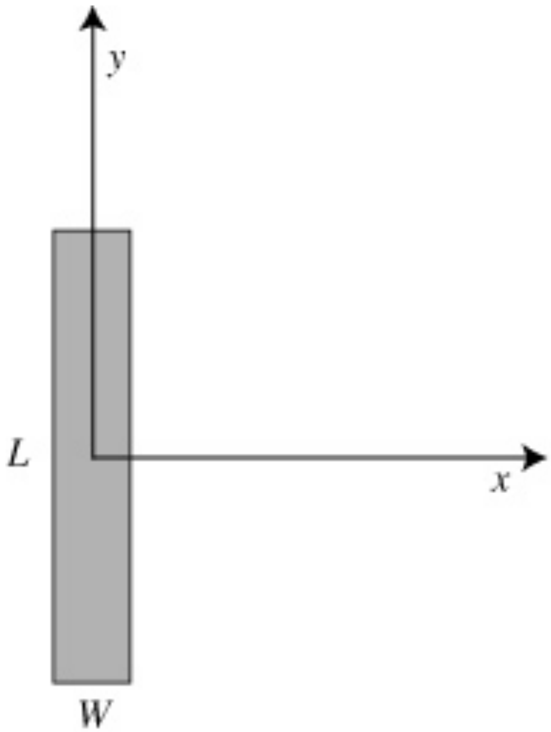
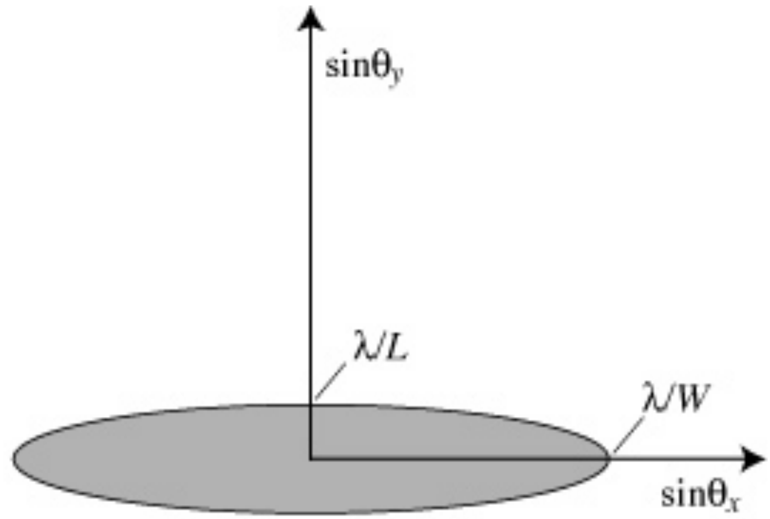
Footprint


azimuth
Satellite trajectory
SAR Antenna
range
Look Angle
Sub-satellite ground track
Radar Pulses
Swath
Footprint

2-D Aperture







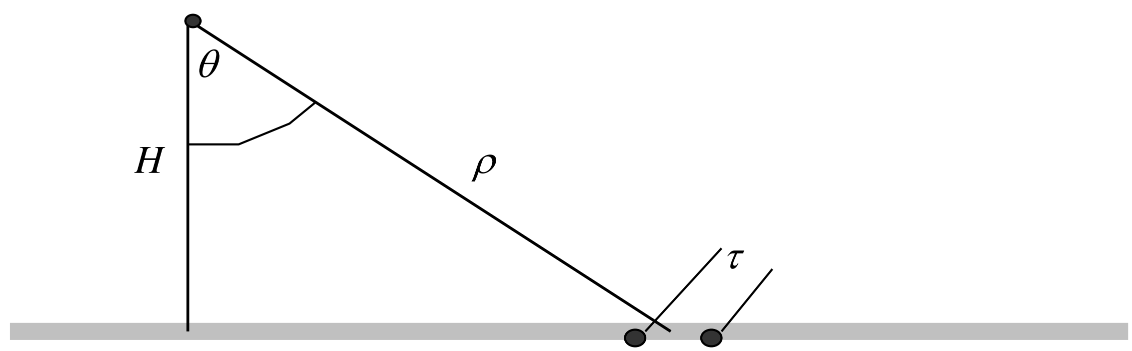
$$P(\theta_x,\theta_y) = \int_{-L/2}^{L/2}\int_{-W/2}^{W/2} A(x,y)\exp\left[i\frac{2\pi}{\lambda}\left(x\sin\theta_x + y\sin\theta_y\right)\right]dxdy$$

$$\longrightarrow$$

$$P(\theta_x,\theta_y) = LW\ \mathrm{sinc}\left(\frac{\pi W\sin\theta_x}{\lambda}\right)\ \mathrm{sinc}\left(\frac{\pi L\sin\theta_y}{\lambda}\right)$$

Notes on BB

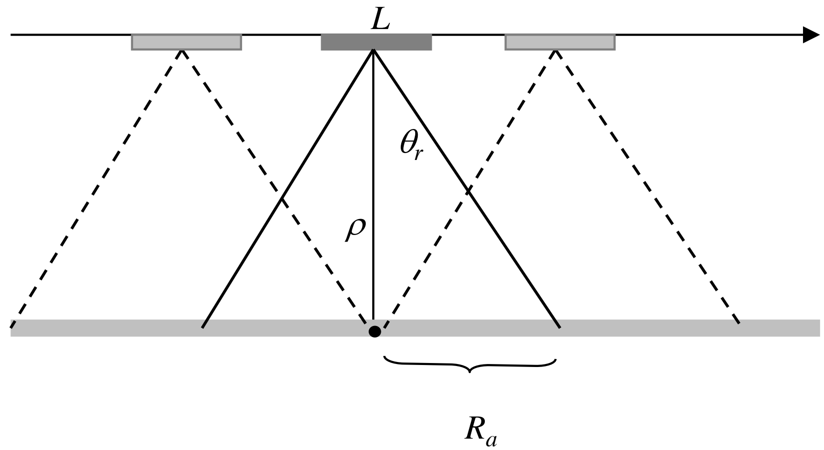
range resolution



θ - look angle
H - spacecraft height
τ - pulse length
C - speed of light

$$R_r = \frac{C\tau}{2\sin\theta}$$

azimuth resolution



L - length of radar antenna
ρ - nominal slant range $H/\cos\theta$
λ – wavelength of radar

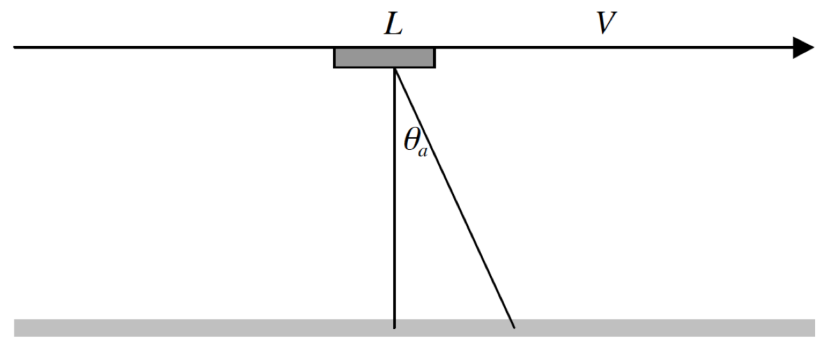
unfocussed

$$R_a = \rho\sin\theta_r = \rho\lambda/L$$

focussed

$$R_a' = \frac{\lambda H}{2R_a\cos\theta} = \frac{L}{2}$$

Pulse Repetition Frequency

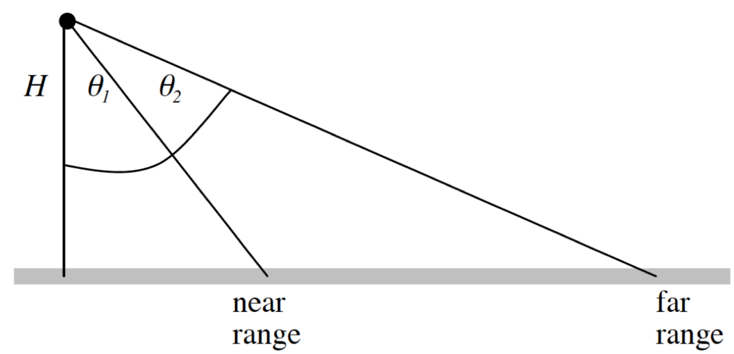


Minimum PRF (Lower Bound)

- PRF needs to be high enough to sample the entire Doppler spectrum to avoid aliasing
- PRF defines the Nyquist frequency
- Maximum Doppler shift must be less than the Nyquist

$$\frac{\Delta f}{f_0} = \frac{V \sin\theta_a}{c} \Rightarrow \Delta f = \frac{V}{L}$$

$$PRF > 2\Delta f = \frac{2V}{L}$$



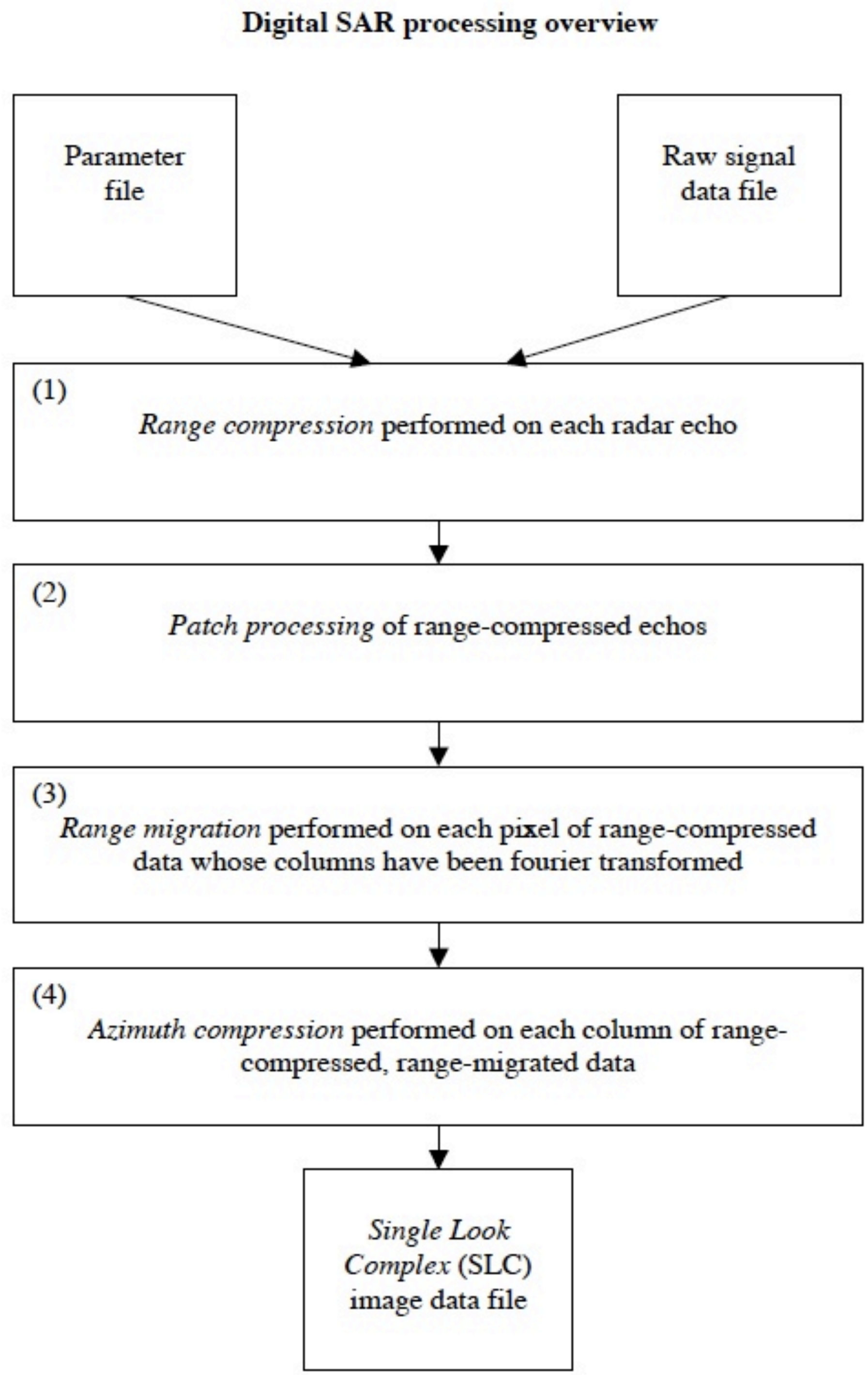
Maximum PRF (Upper Bound)

- Echo from far range of first pulse must return before the echo from near range of second pulse

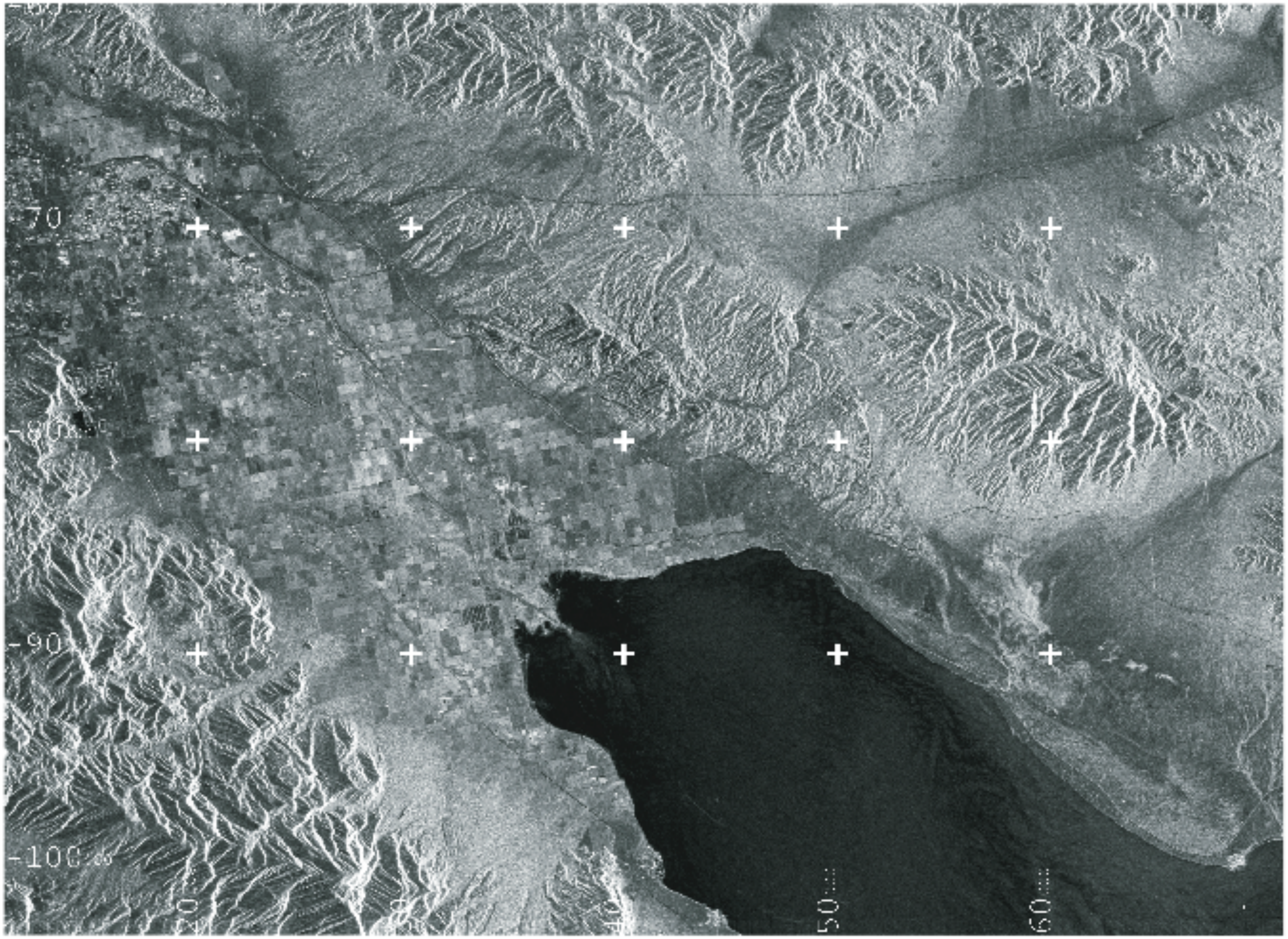
$$t_2 < t_1 + 1/PRF \Rightarrow$$

$$PRF < \frac{c}{2H}\left(\sec\theta_2 - \sec\theta_1\right)^{-1}$$

SAR processor



amplitude image



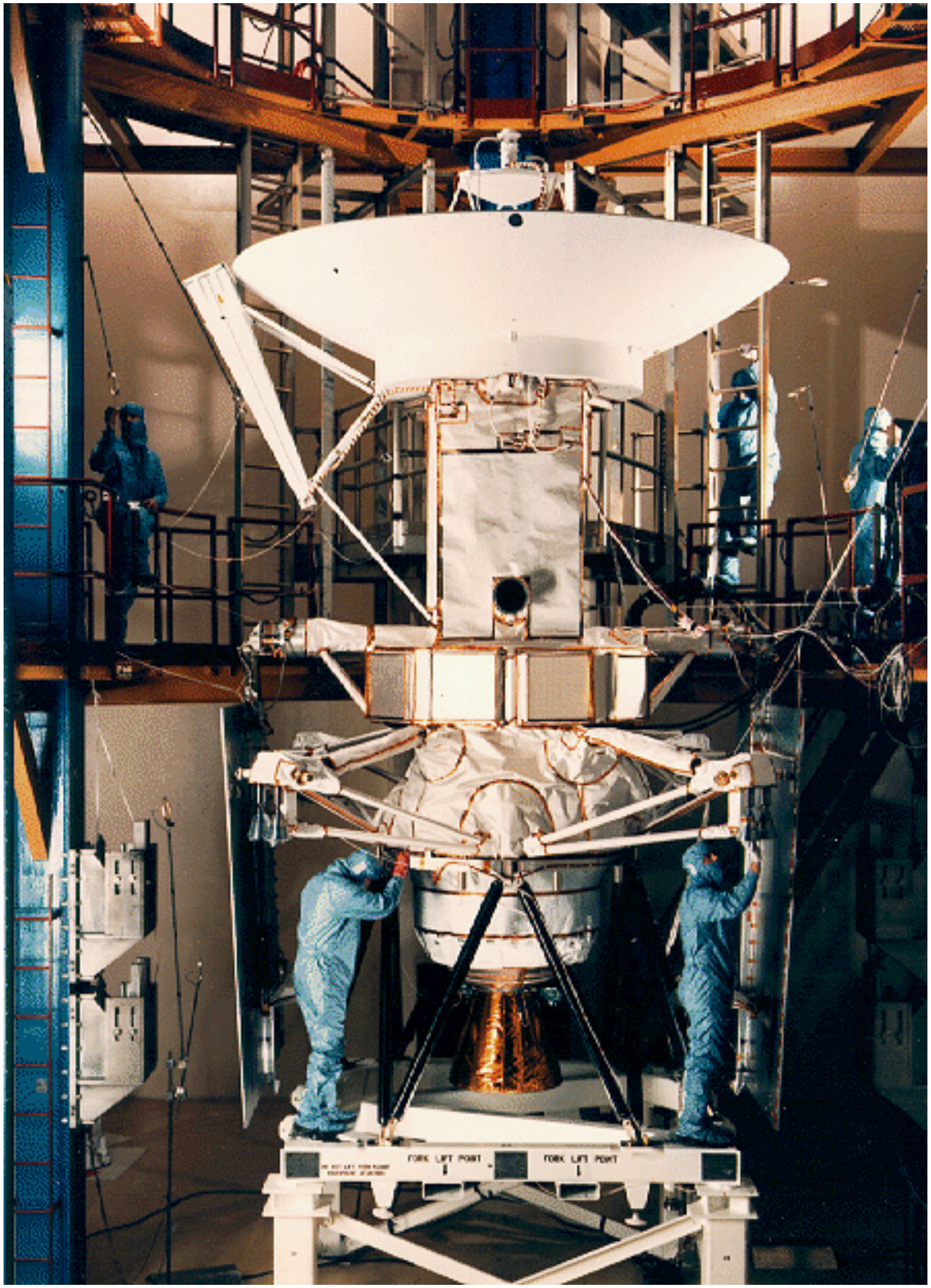
1) This is an image of radar backscatter from a stack of ERS SAR data. The flight path is top to bottom and the radar looks from the right. The area is the Salton Sea and Cochella Valley, and the tic marks are spaced at 10 km. The satellite is 7159717m from the center of the Earth, the local Earth radius is 6371593 m, and the range to the center of the image is 850148 m. Calculate the look angle to the center of the image. Identify areas of layover. What is the minimum mountain slope in the areas of layover? Why is the Salton Sea dark?

zoom of amplitude image

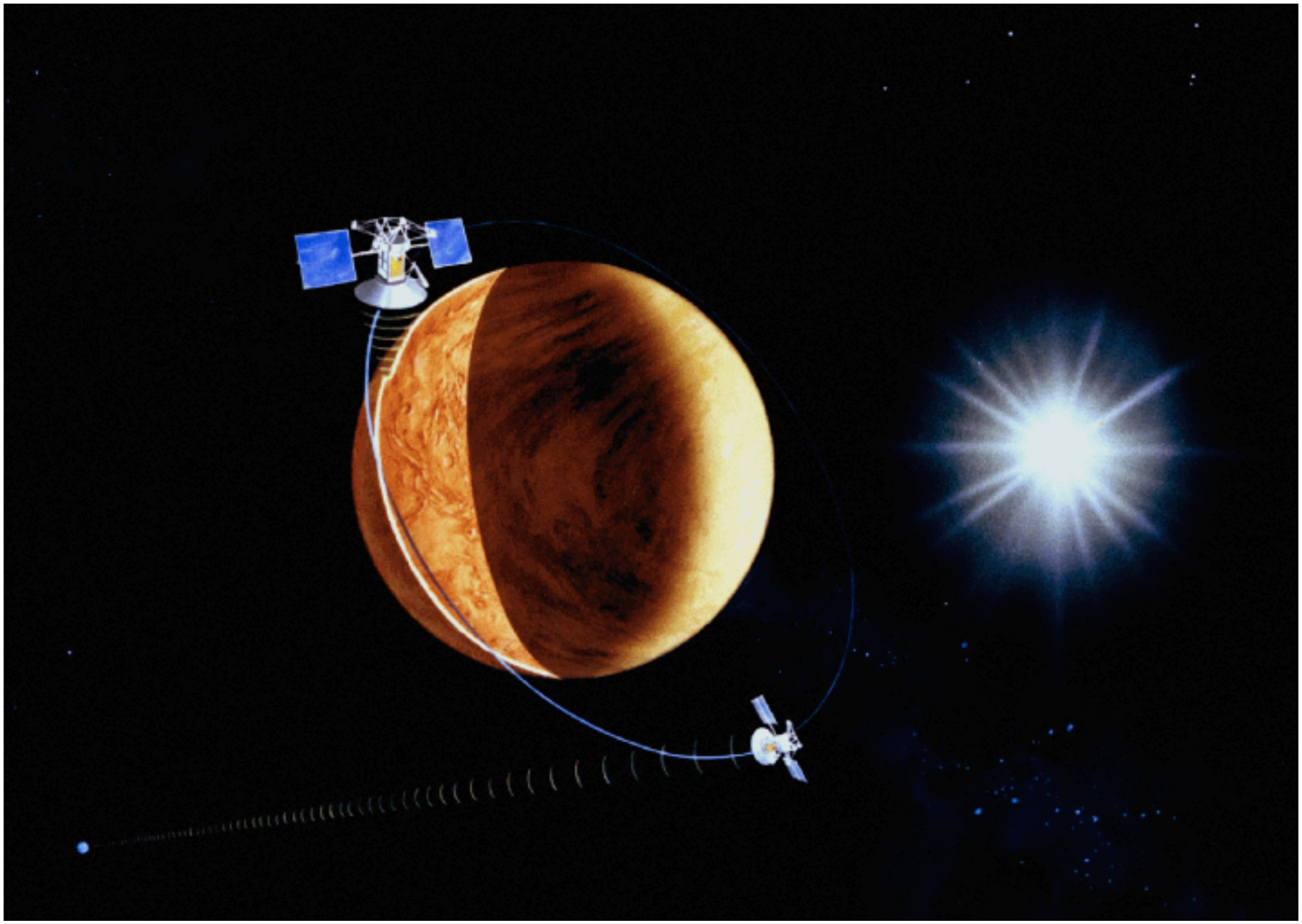
2) This is a zoom of the previous image with 5 km tic marks. Use a map to identify each of the three curved lines running through the images. Why do the fields have different backscatter? Why aren't the fields exactly square? Why do the bright spots have cross patterns?

Magellen SAR

1990-1994



Magellen SAR 1990-1994

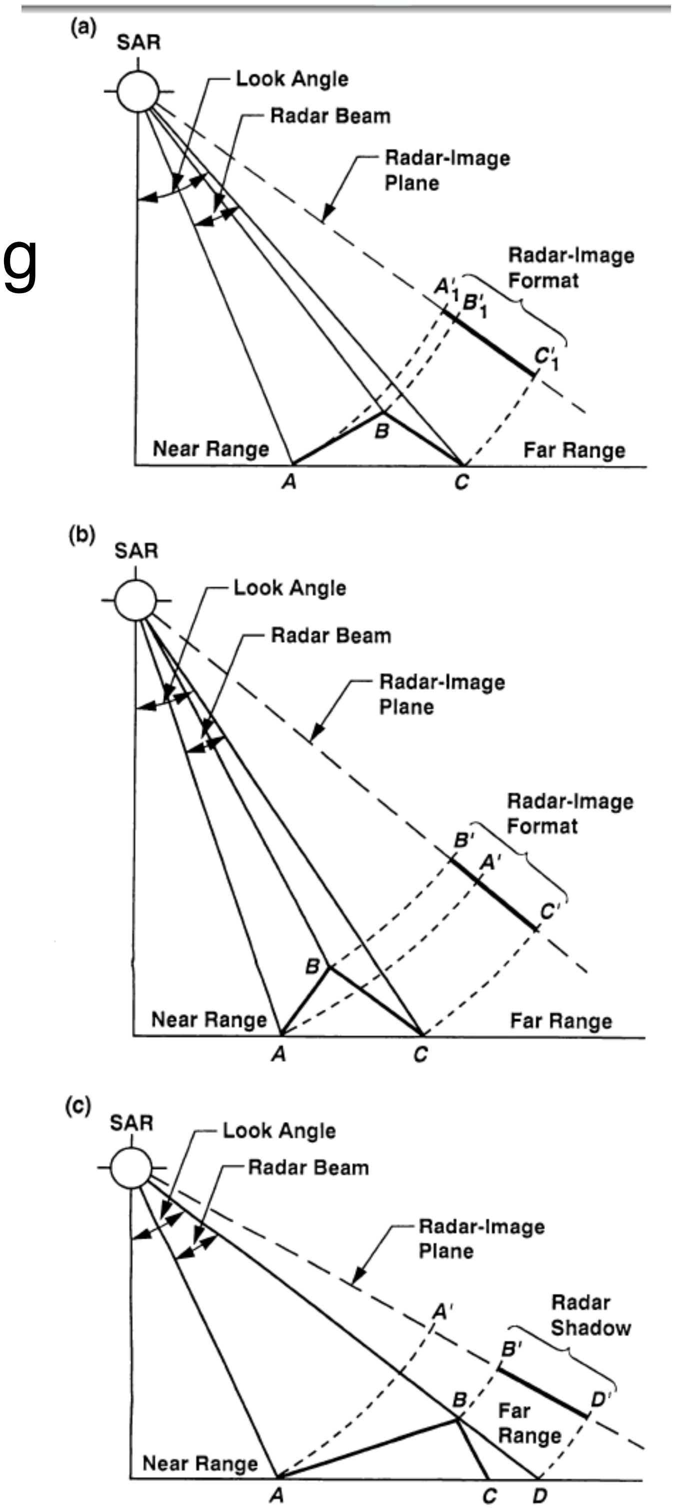


geometry

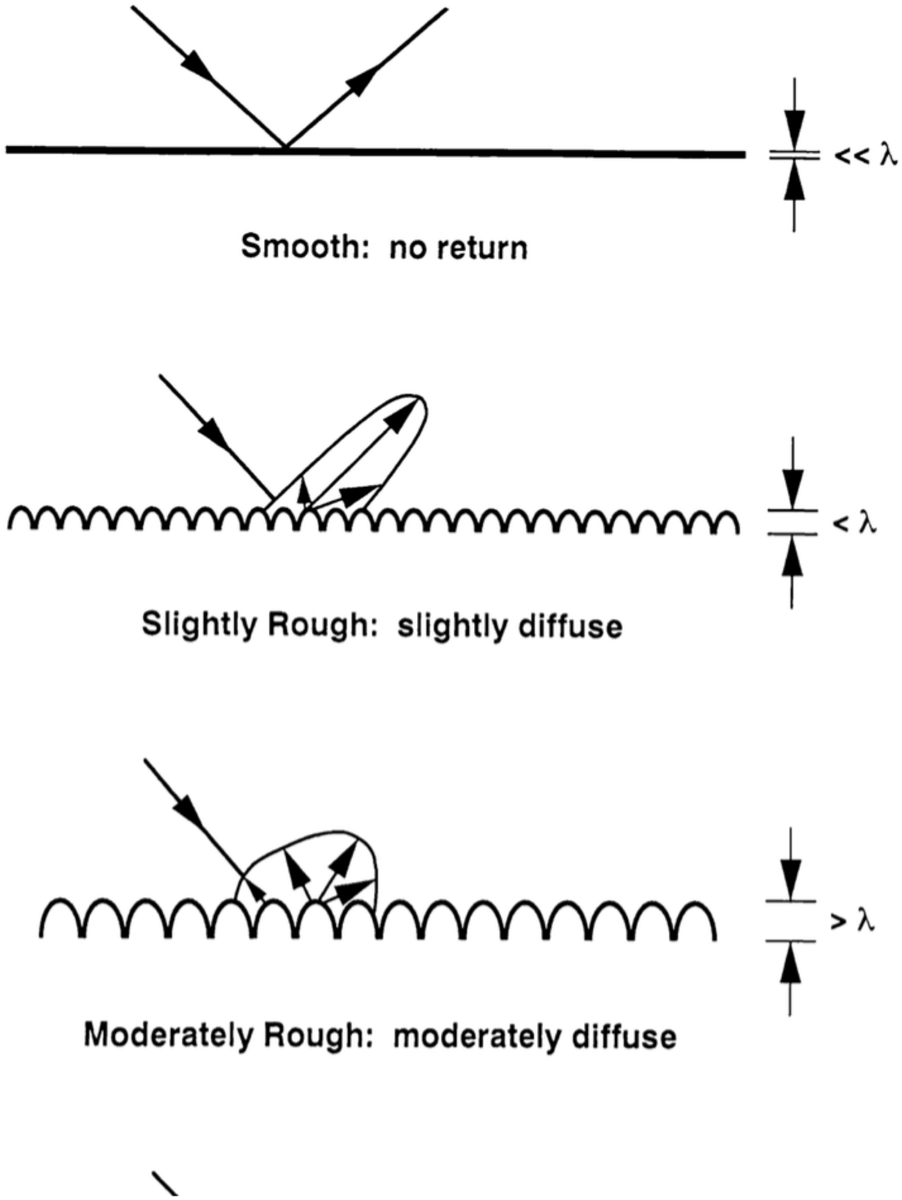
foreshortening

layover

shadowing



[Farr, 1993,Radar Interactions With Geological Surfaces]



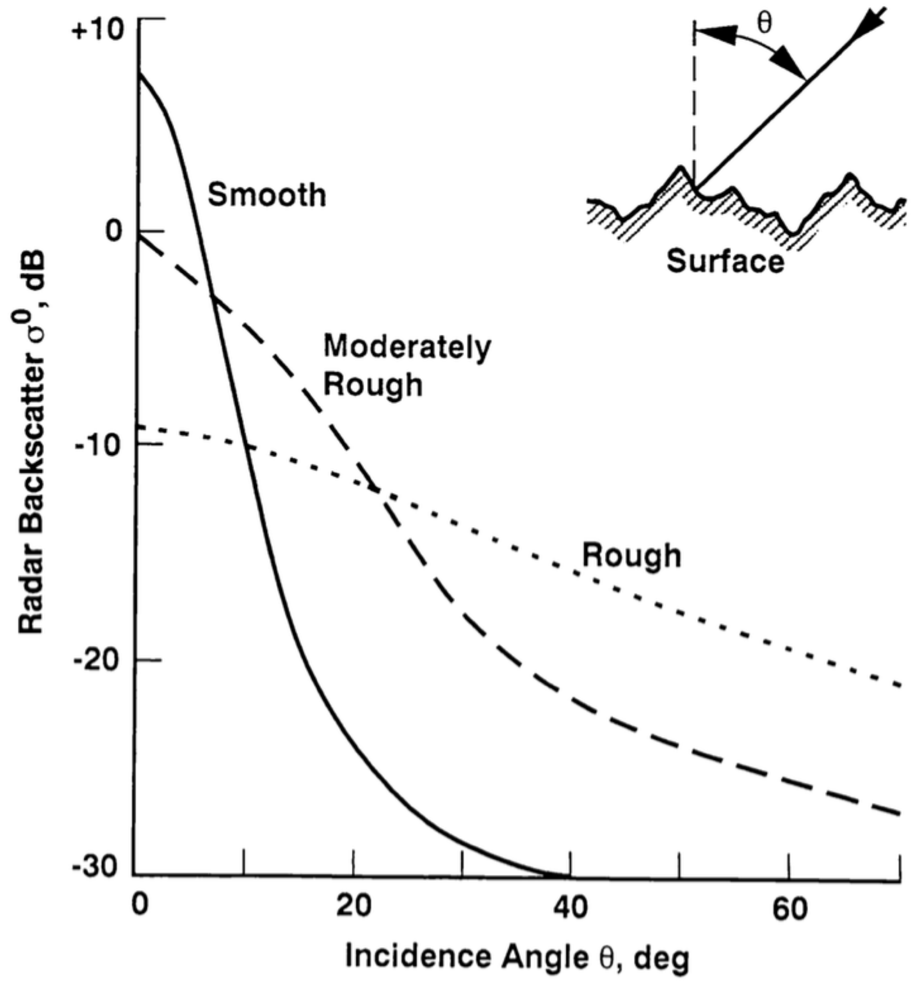
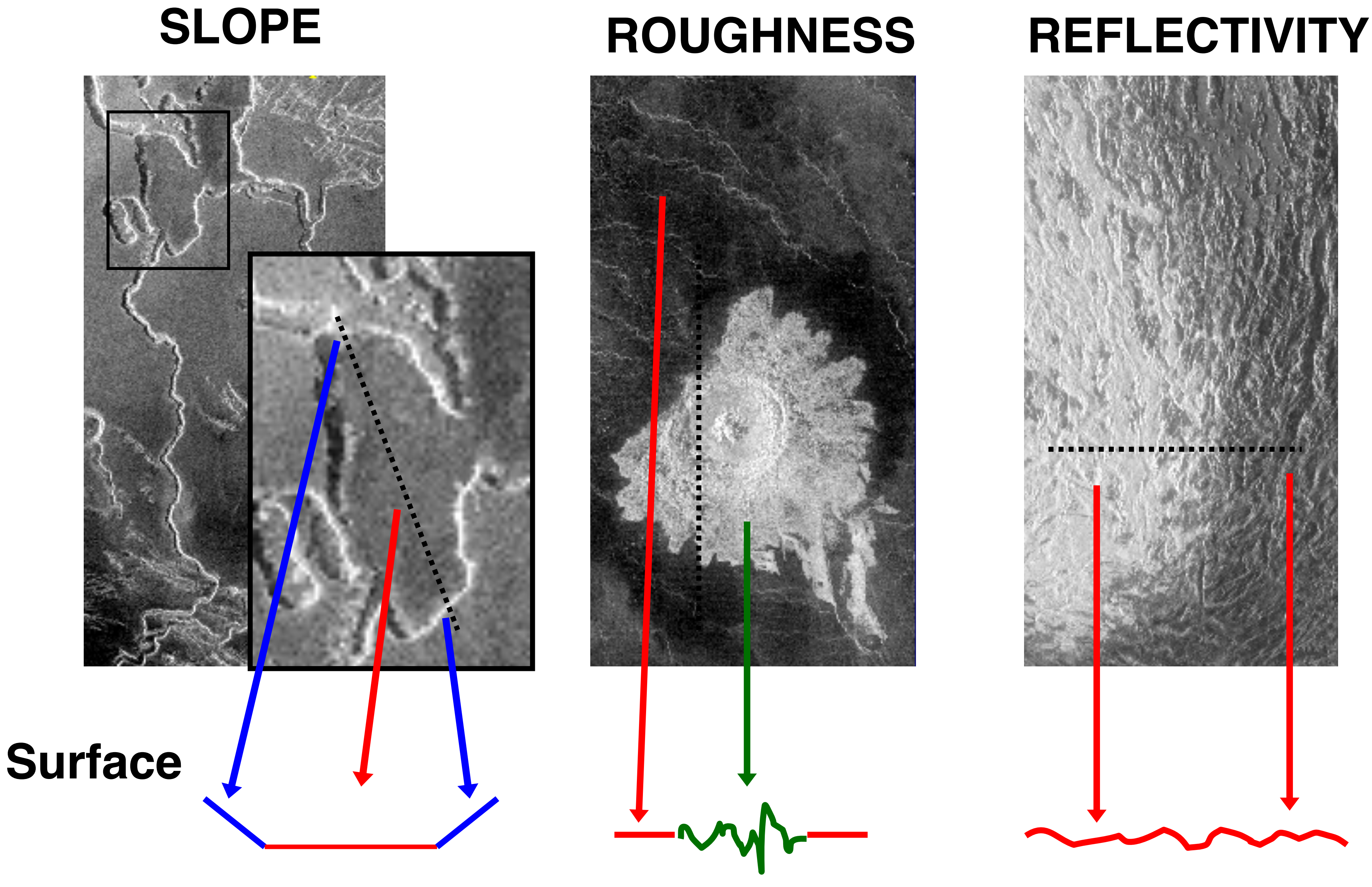


Figure 5-9. Radar backscatter as a function of incidence angle for representative surfaces. For angles less than about 25 deg, smoother surfaces have greater backscatter than rougher surfaces.

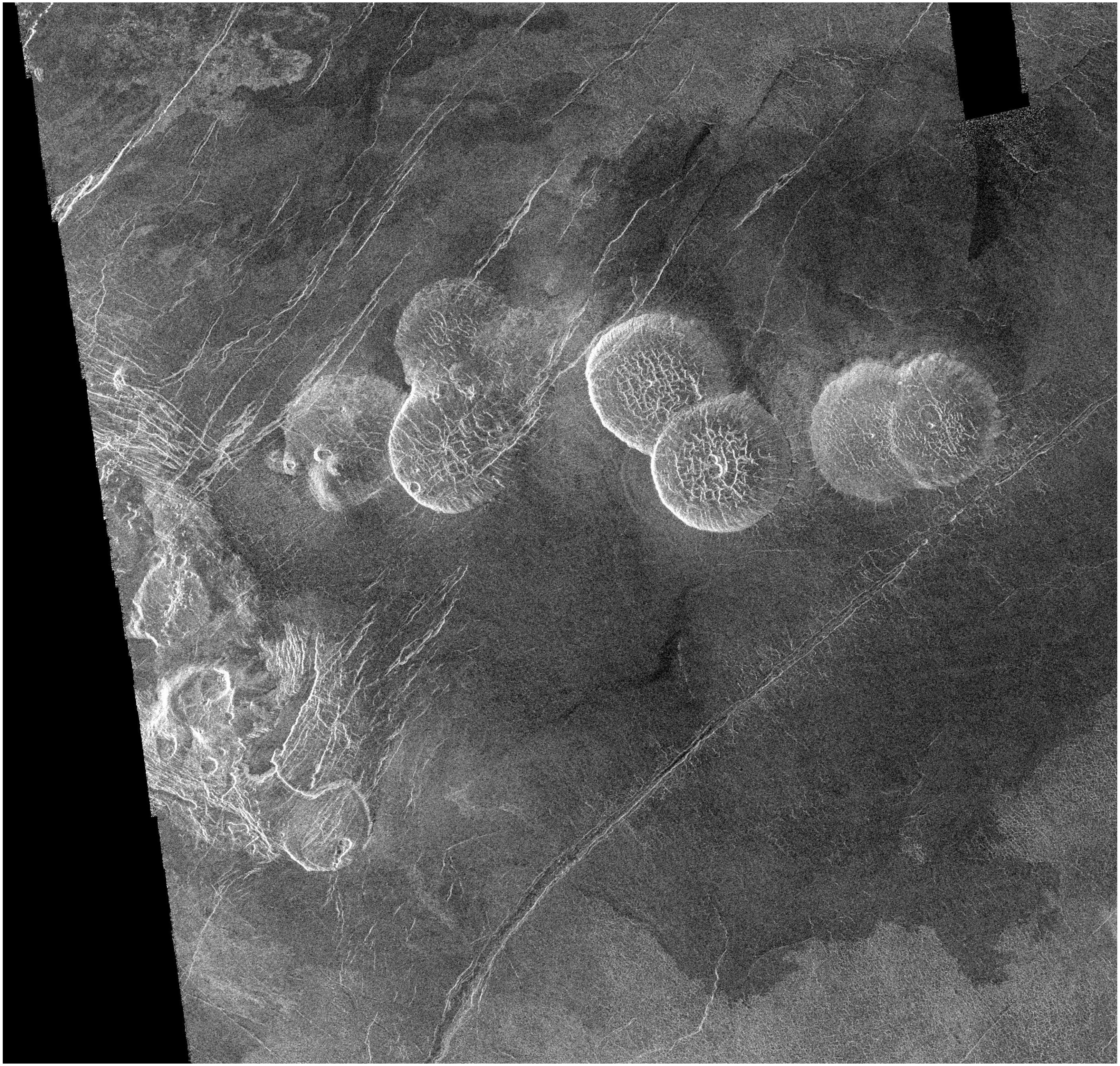
[Farr, 1993,Radar Interactions With Geological Surfaces]

Radar Image Properties



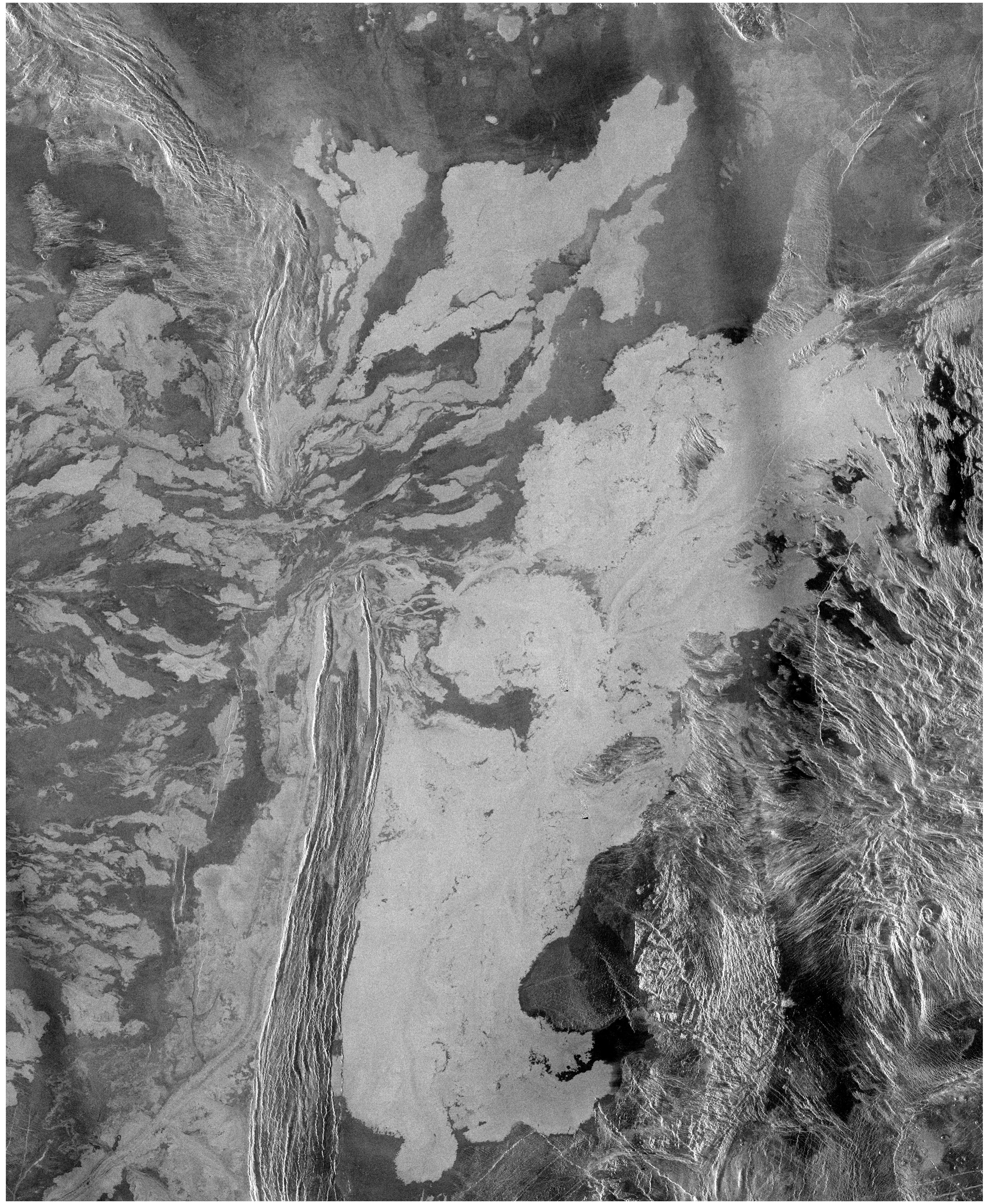
slope

pancake
domes
Venus



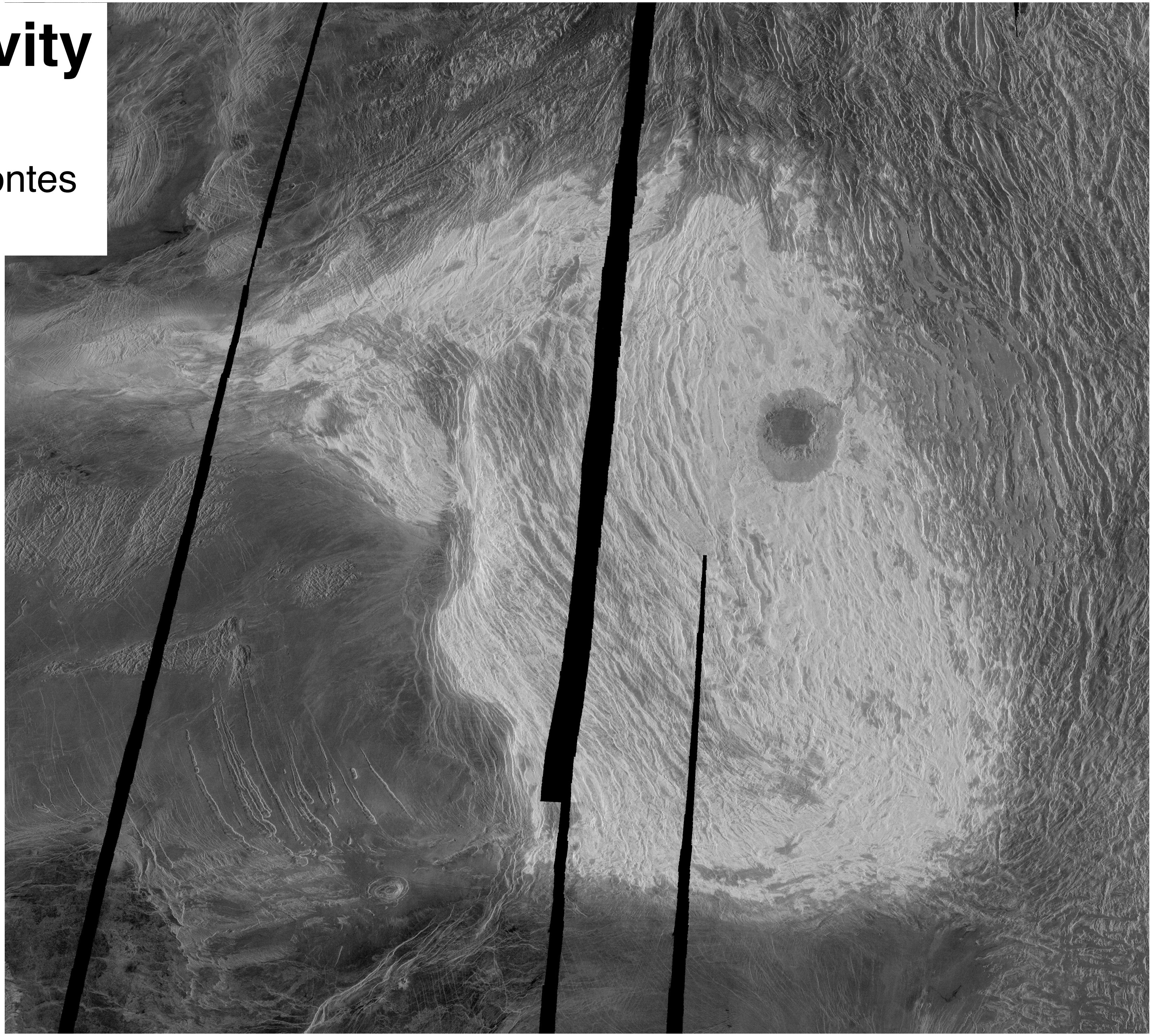
roughness

lava flows
Venus



reflectivity

Maxwell Montes
Venus



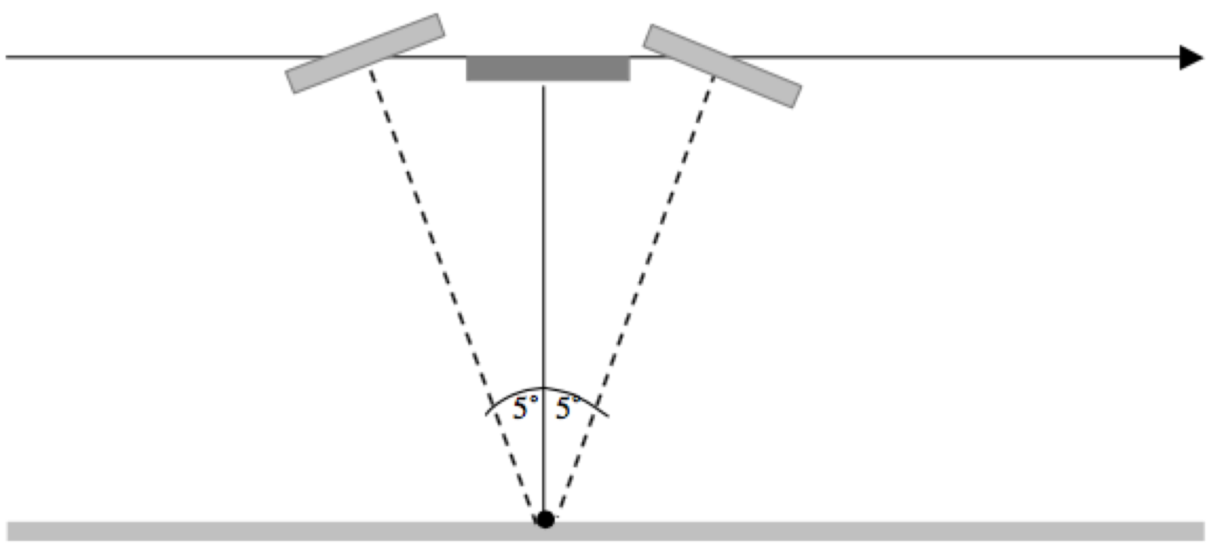
reflectivity - Venus

1) What is the illumination pattern for an aperture with a sign reversal at its center? What is $P(0)$? Is the function real or imaginary? Is the function symmetric or asymmetric?

The aperture is

$$A(y) = \begin{cases} 0 & |y| > \dfrac{L}{2} \\ 1 & 0 < y \le \dfrac{L}{2} \\ -1 & -\dfrac{L}{2} \le y < 0 \end{cases}$$

3) What is the theoretical azimuth resolution of a spotlight-mode SAR that can illuminate the target over a 10° angle as shown in the diagram below.



5) What is the ground-range resolution of side-looking radar with a pulse length of 6×10^{-8} s and a look angle of 45°?

6) (a) What is the period for a satellite in a circular orbit about the moon where the radius of the orbit is 1.9×10^{6} m? The mass of the moon is 7.34×10^{22} kg.

(b) You are developing a SAR mission for the moon. The length of your SAR antenna is 10 m. What minimum pulse repetition frequency is needed to form a complete aperture? The circumference of the moon is 1.1×10^{7}m. You will need the orbital period from problem (a).

Next Lecture

SAR Interferometry

InSAR