

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

GMTSAR:
An InSAR Processing System
Based on Generic Mapping Tools
(Second Edition)

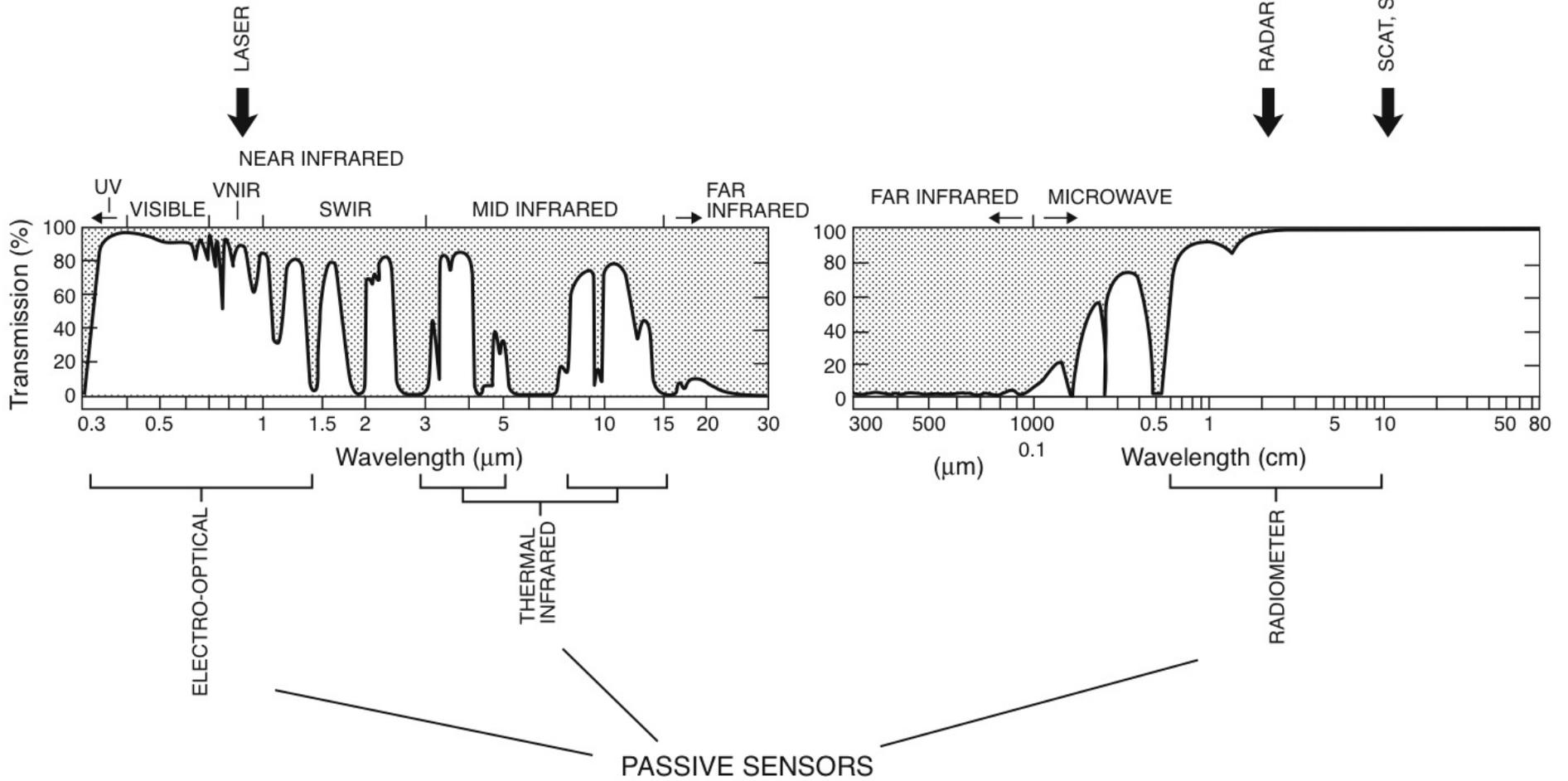
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Contents

1 Introduction	5
1.1 Objectives and limitations of GMTSAR	5
1.2 Algorithms: SAR, InSAR, and the need for precise orbits	6
1.2.1 Proper focus	7
1.2.2 Transformation from geographic to radar coordinates	8
1.2.3 Image alignment	9
1.2.4 Flattening interferogram - no trend removal	10
2 Software	11
2.1 Standard Products	11
2.2 Software Design	12
3 Processing Examples	14
3.1 Two-pass processing	15
3.2 Stacking for time series	18
3.3 ScanSAR Interferometry	26
4 Problems	32
A Principles of Synthetic Aperture Radar	33
A.1 Introduction	33
A.2 Fraunhofer diffraction	34
A.3 2-D Aperture	37
A.4 Range resolution (end view)	38
A.5 Azimuth resolution (top view)	39
A.6 Range and Azimuth Resolution of ERS SAR	40
A.7 Pulse repetition frequency	40
A.8 Other constraints on the PRF	40
A.9 Problems	42
B SAR Image Formation	44
B.1 Overview of the range-doppler algorithm	44
B.2 Processing on board the satellite	44
B.3 Digital SAR processing	45
B.4 Range compression	49
B.5 Azimuth compression	51
B.6 Example with ALOS L-band orbit	58
B.7 Problems	61
C InSAR	62
C.1 Forming an interferogram	62
C.2 Contributions to Phase	63
C.3 Phase due to earth curvature	64
C.4 Look angle and incidence angle for a spherical earth	65
C.5 Critical baseline	67
C.6 Persistent point scatterer and critical baseline	68
C.7 Phase due to topography	69
C.8 Altitude of ambiguity	70
C.9 Phase due to earth curvature and topography – exact formula	70
C.10 Problems	74
D ScanSAR Processing and Interferometry	75
D.1 Problems	80
E Sentinel TOPS-mode processing and interferometry	81
E.1 Introduction	81
E.2 Traditional Image Alignment Fails with TOPS-Mode Data	83
E.3 Geometric Image Registration	84
E.4 Enhanced Spectral Diversity	86
E.5 Elevation Antenna Pattern (EAP) Correction (IPF version change)	87
E.6 Examples of TOPS Interferogram processing	87
E.7 Processing setup and commands:	97
E.8 Problems	99
F Geolocation accuracy for Pinon corner reflectors	100
G Installation of GMTSAR	107

ACTIVE SENSORS



LASER

NEAR INFRARED

UV

VISIBLE

VNIR

SWIR

MID INFRARED

FAR INFRARED

FAR INFRARED

MICROWAVE

RADAR ALTIMETER

SCAT, SLAR, SAR

Transmission (%)

Wavelength (μm)

Transmission (%)

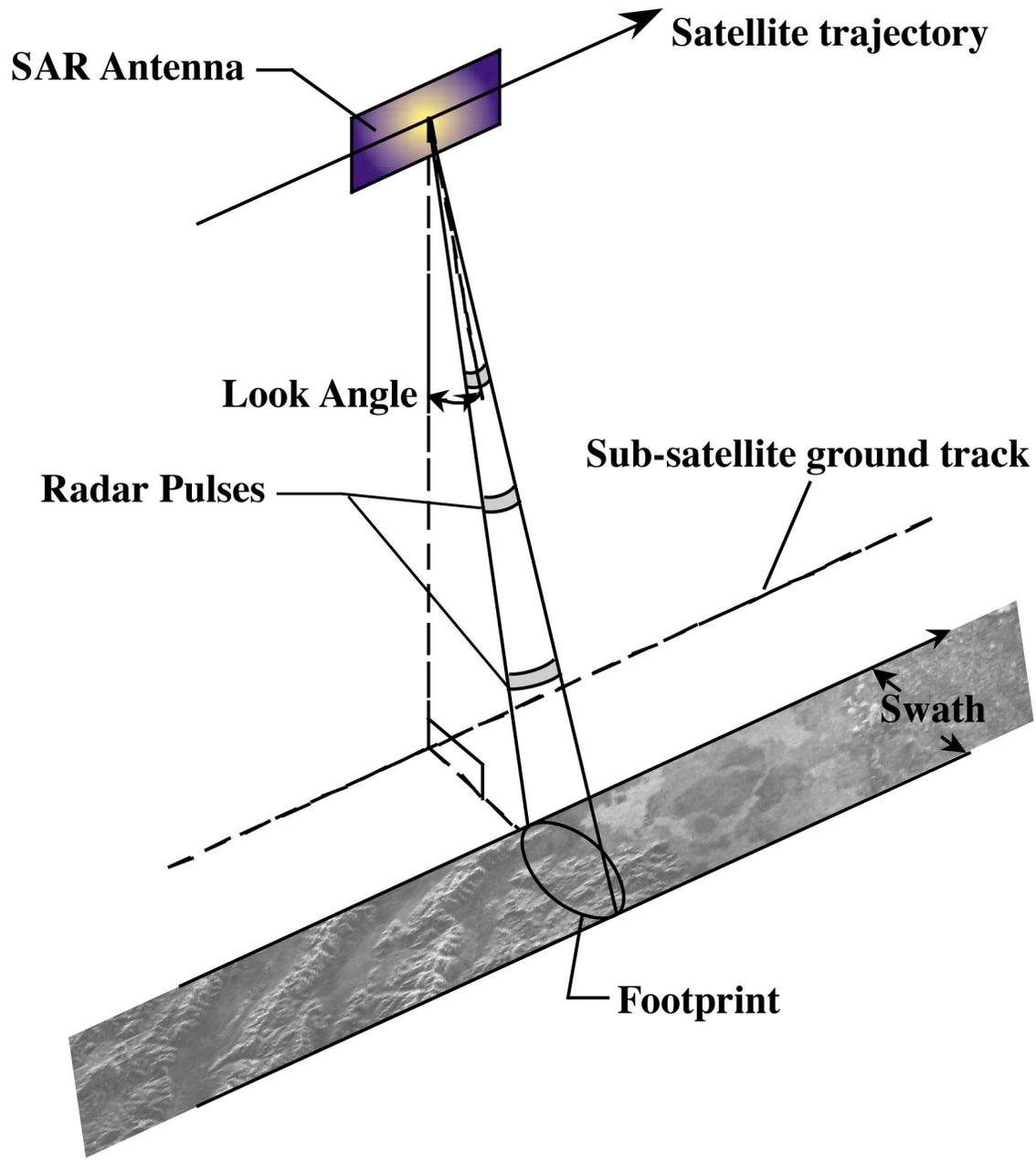
Wavelength (cm)

ELECTRO-OPTICAL

THERMAL INFRARED

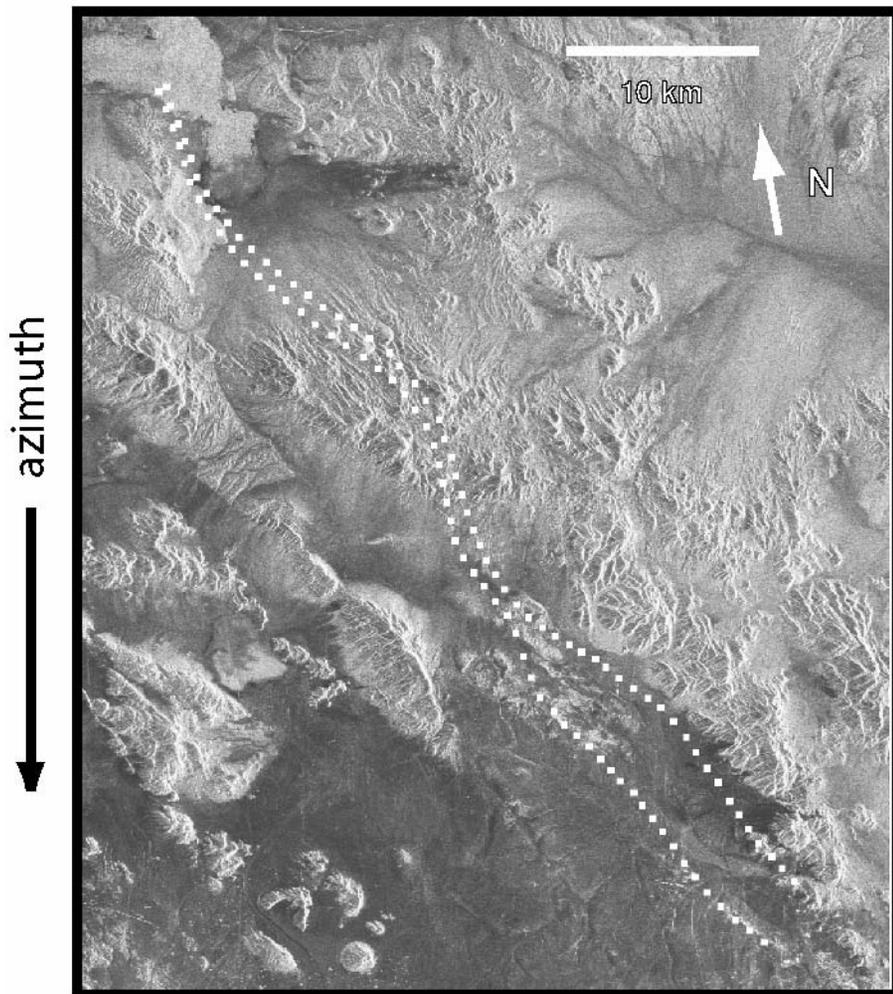
RADIOMETER

PASSIVE SENSORS

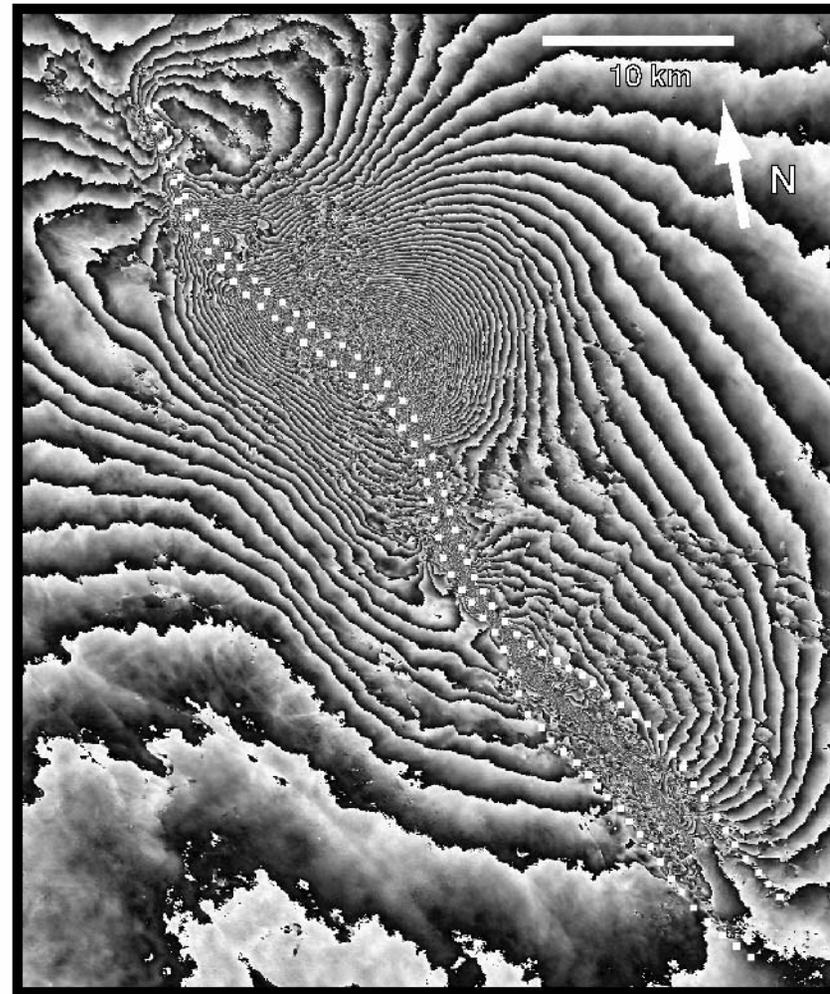


amplitude and phase

step 1 - SAR (amplitude)



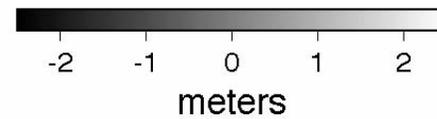
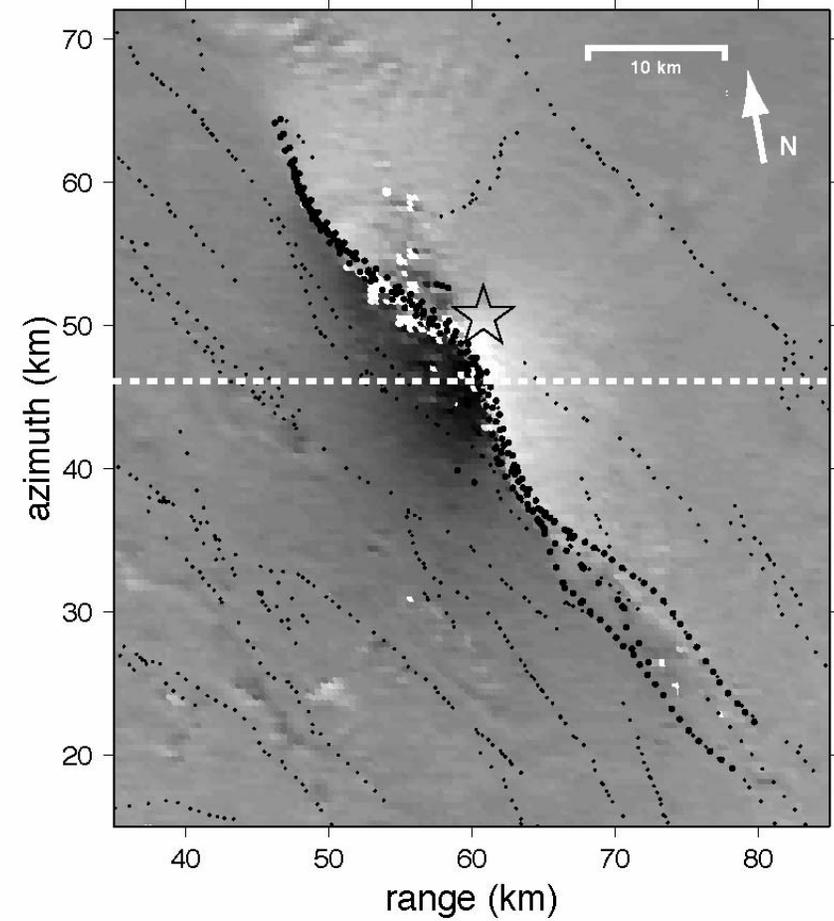
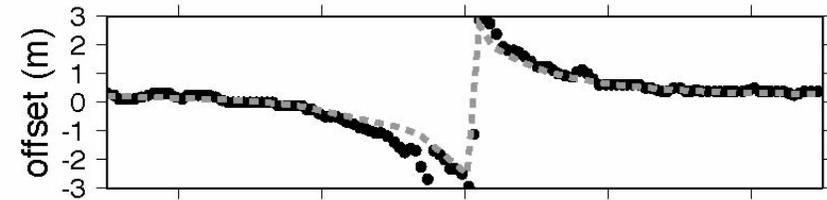
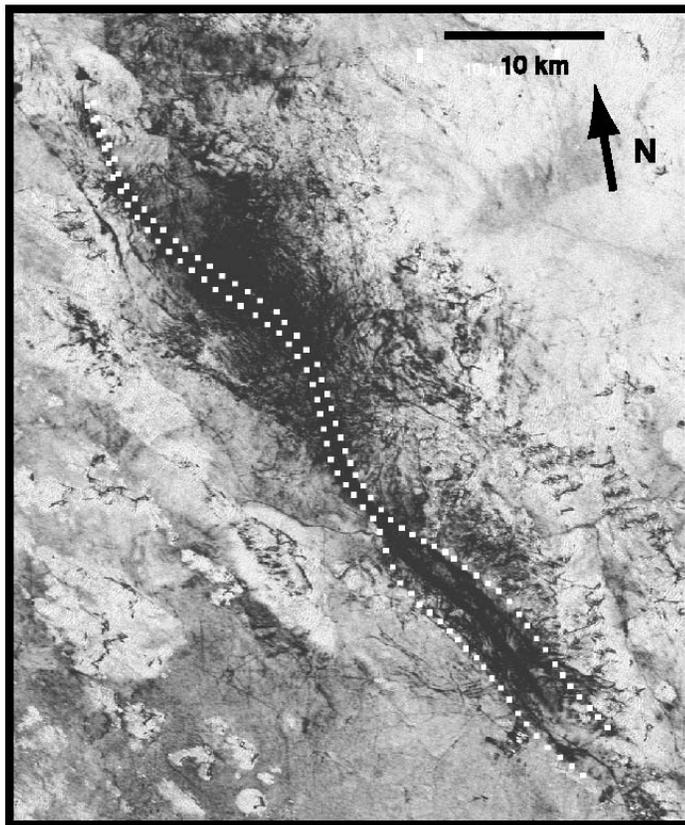
step 2 - InSAR (phase difference)

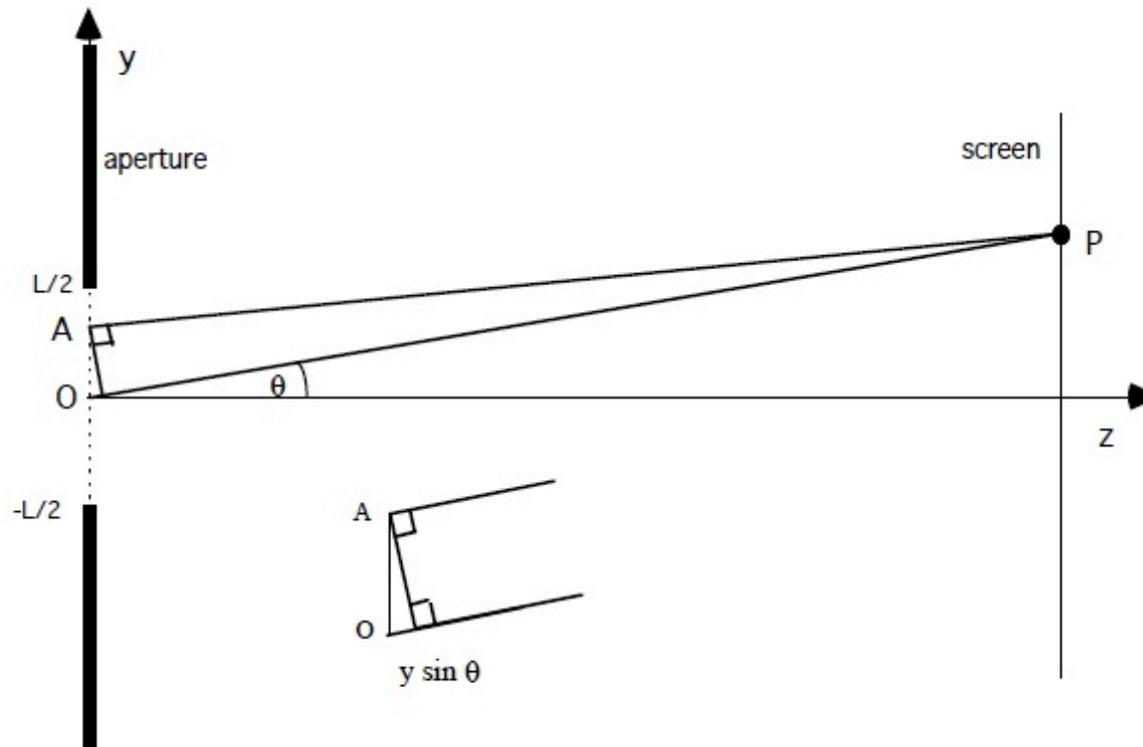


← range

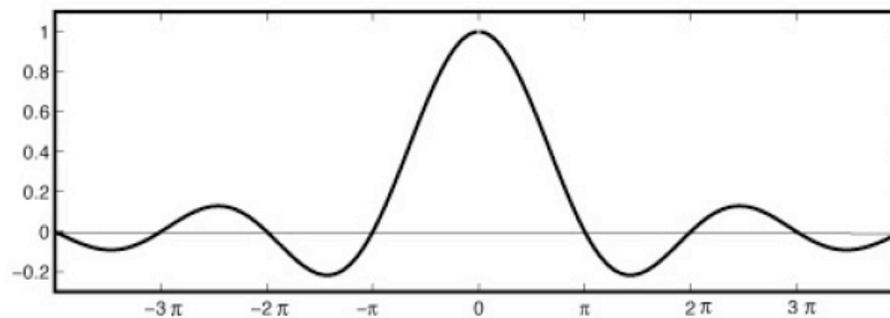
coherence and pixel matching

InSAR (coherence)



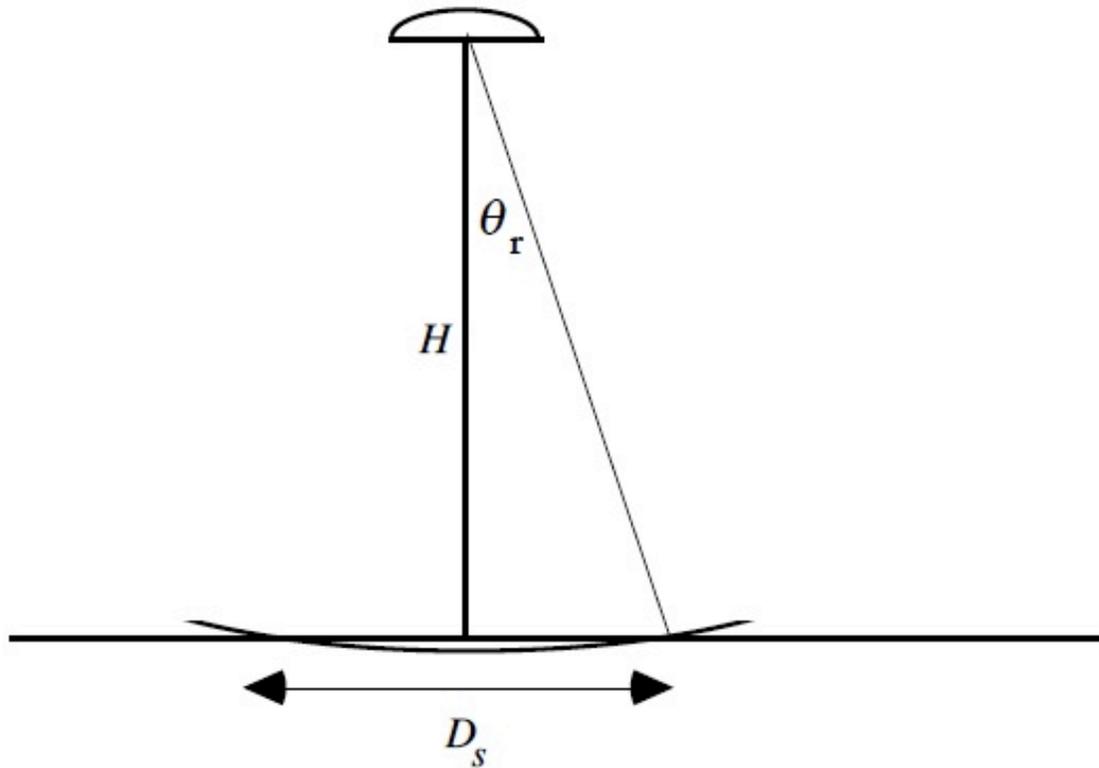


The illumination pattern on the screen is shown in the following diagram.



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

resolution: optical vs. microwave



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

$$H = 800 \text{ km.}$$

Optical :

$$L = 1 \text{ m}$$

$$\lambda = 0.5 \mu \text{ m}$$

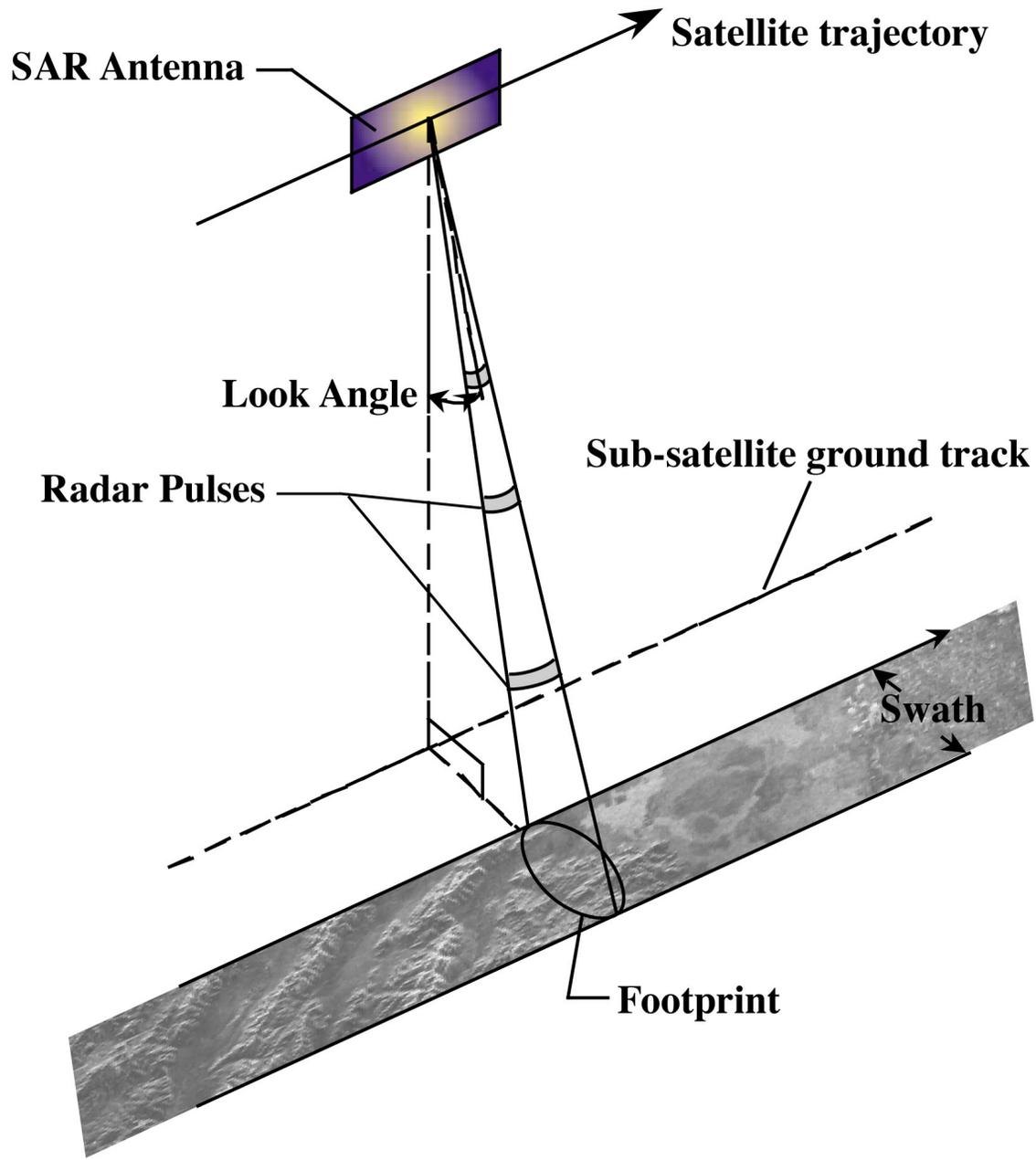
$$D_s = 0.8 \text{ m}$$

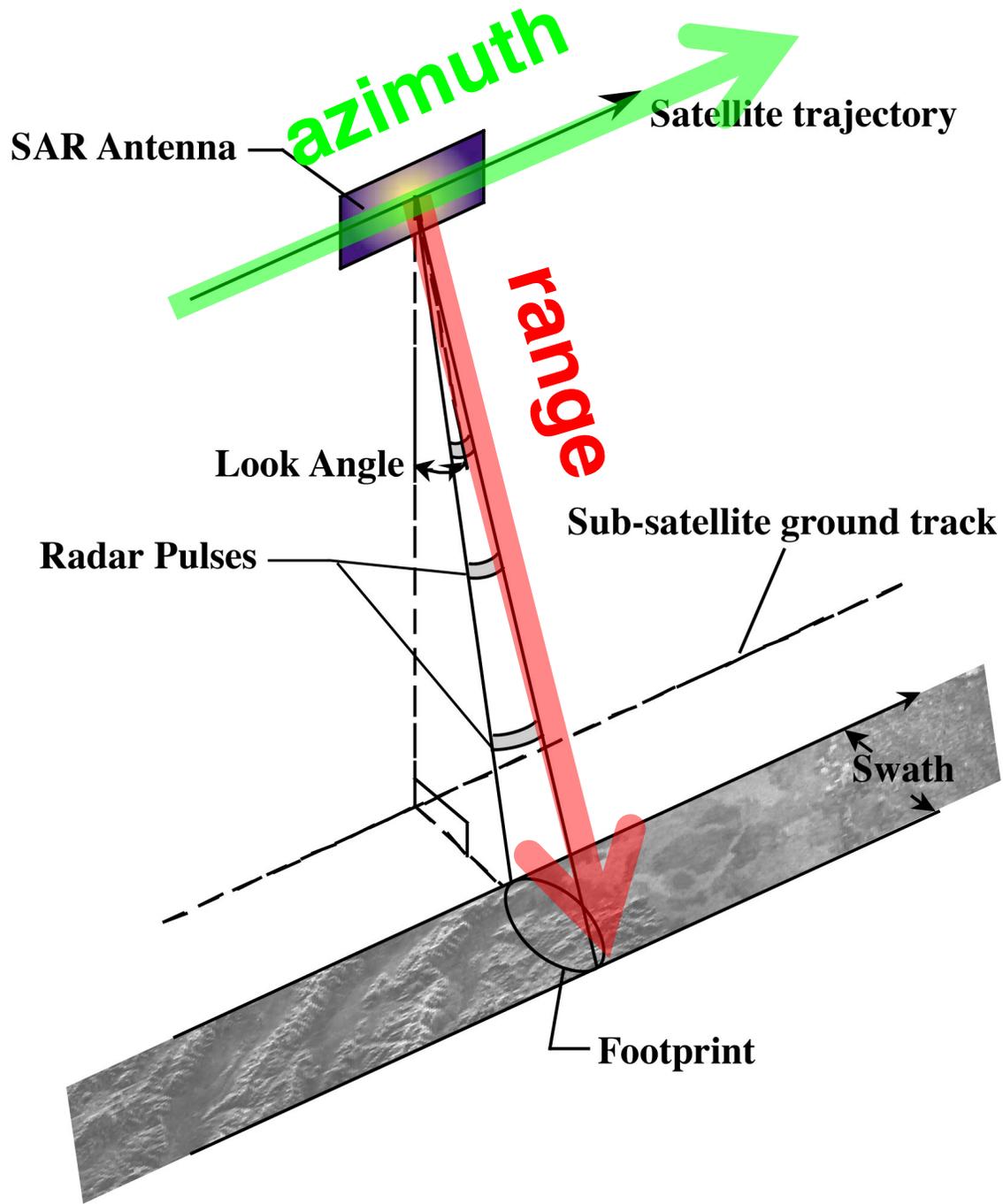
Microwave :

$$L = 10 \text{ m}$$

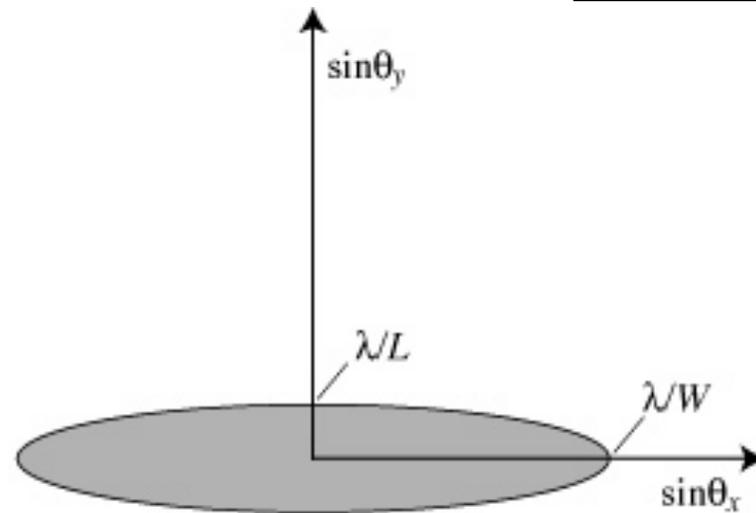
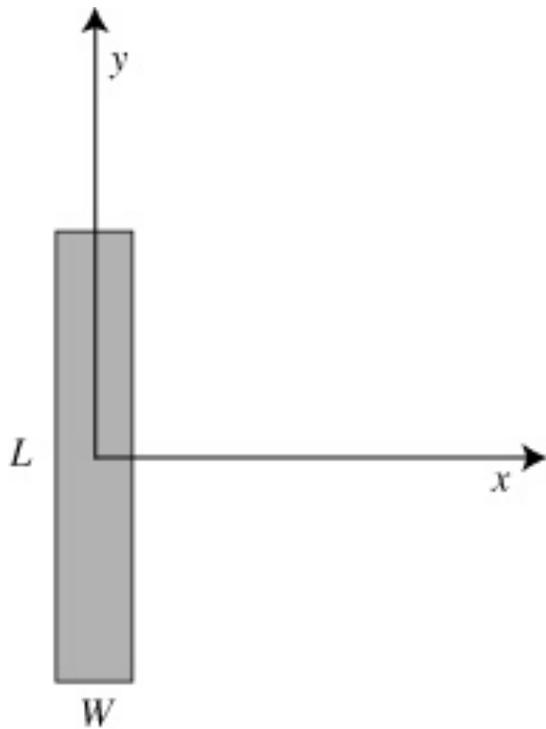
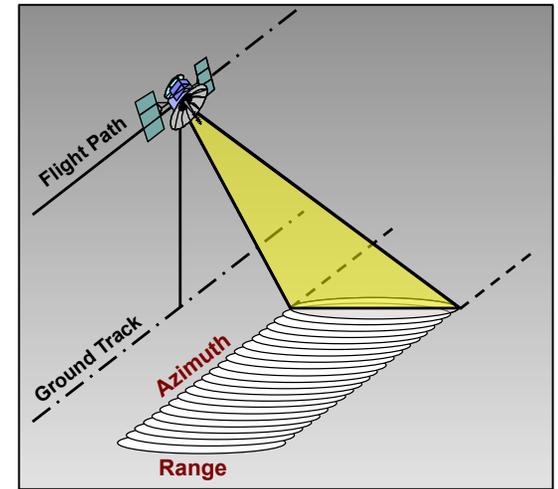
$$\lambda = 0.23 \text{ m}$$

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





2-D Aperture



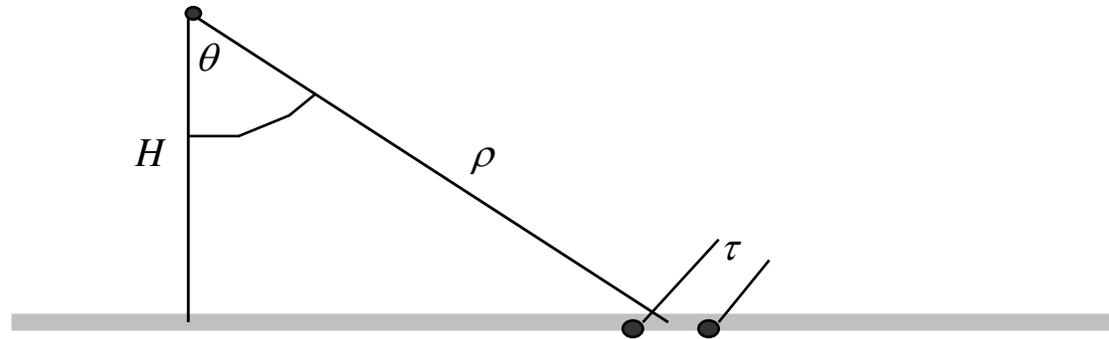
$$P(\theta_x, \theta_y) = \int_{-L/2}^{L/2} \int_{-W/2}^{W/2} A(x, y) \exp\left[i \frac{2\pi}{\lambda} (x \sin\theta_x + y \sin\theta_y)\right] dx dy$$



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

Notes on BB

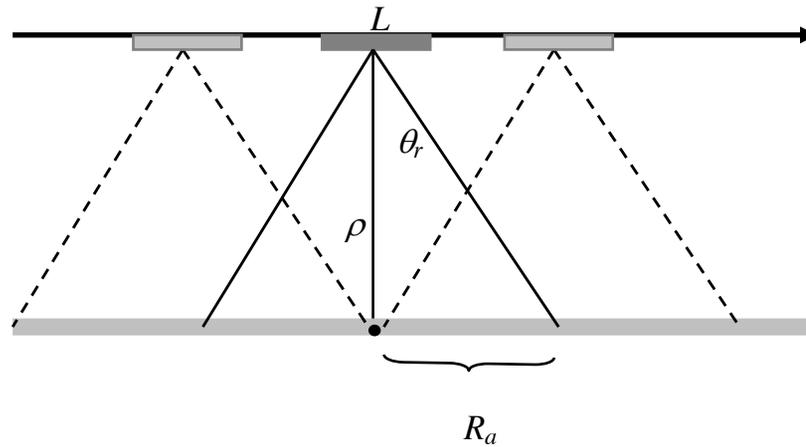
range resolution



- 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

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

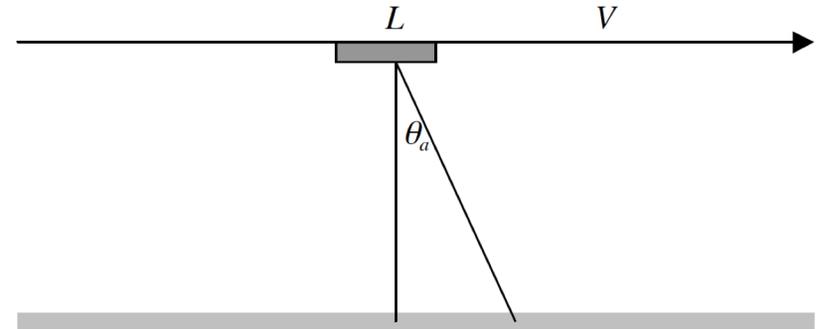
focussed

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

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

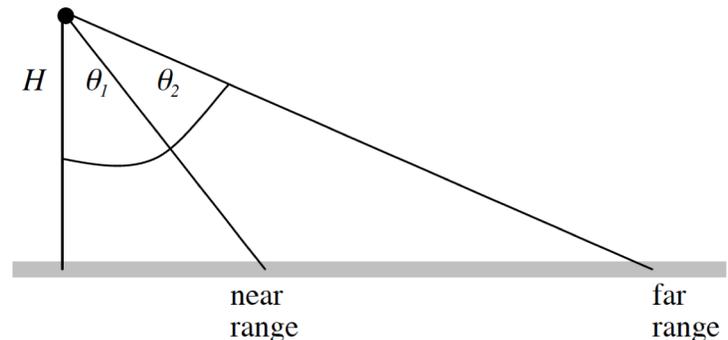


$$\frac{\Delta f}{f_0} = \frac{V \sin \theta_a}{c} \Rightarrow \Delta f = \frac{V}{L}$$

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

Maximum PRF (Upper Bound)

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

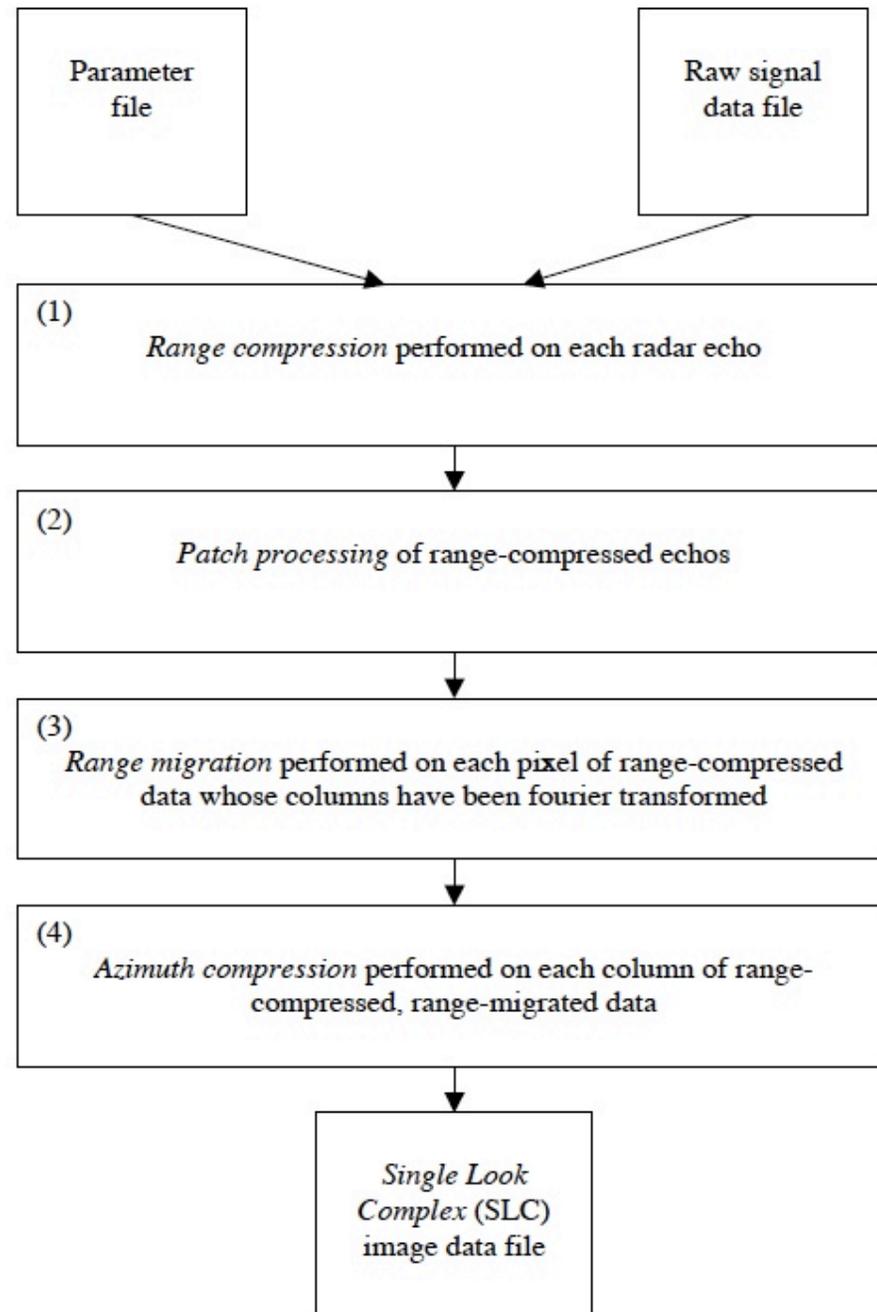


$$t_2 < t_1 + 1 / PRF \Rightarrow$$

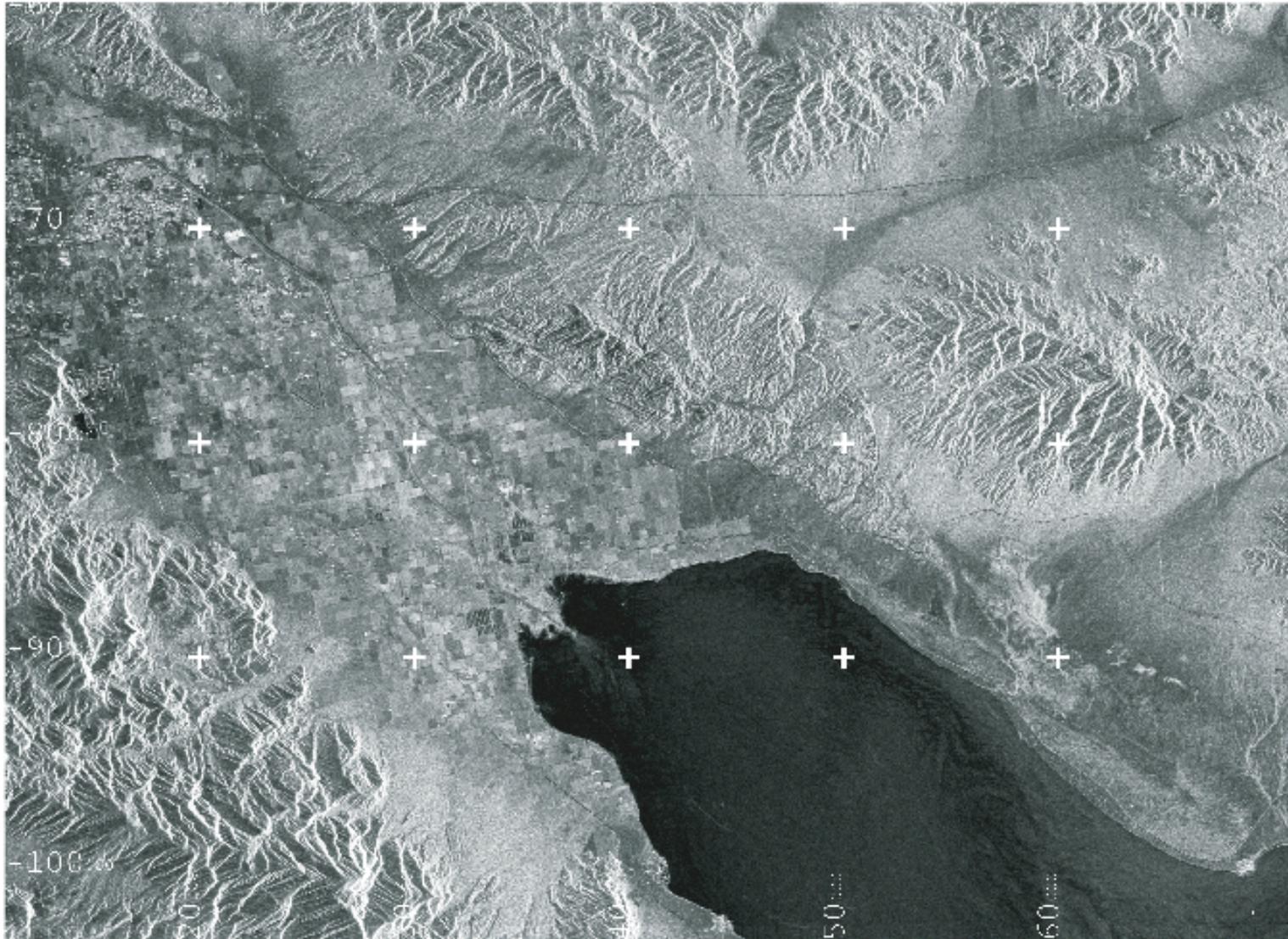
$$PRF < \frac{c}{2H} (\sec \theta_2 - \sec \theta_1)^{-1}$$

SAR processor

Digital SAR processing overview



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?

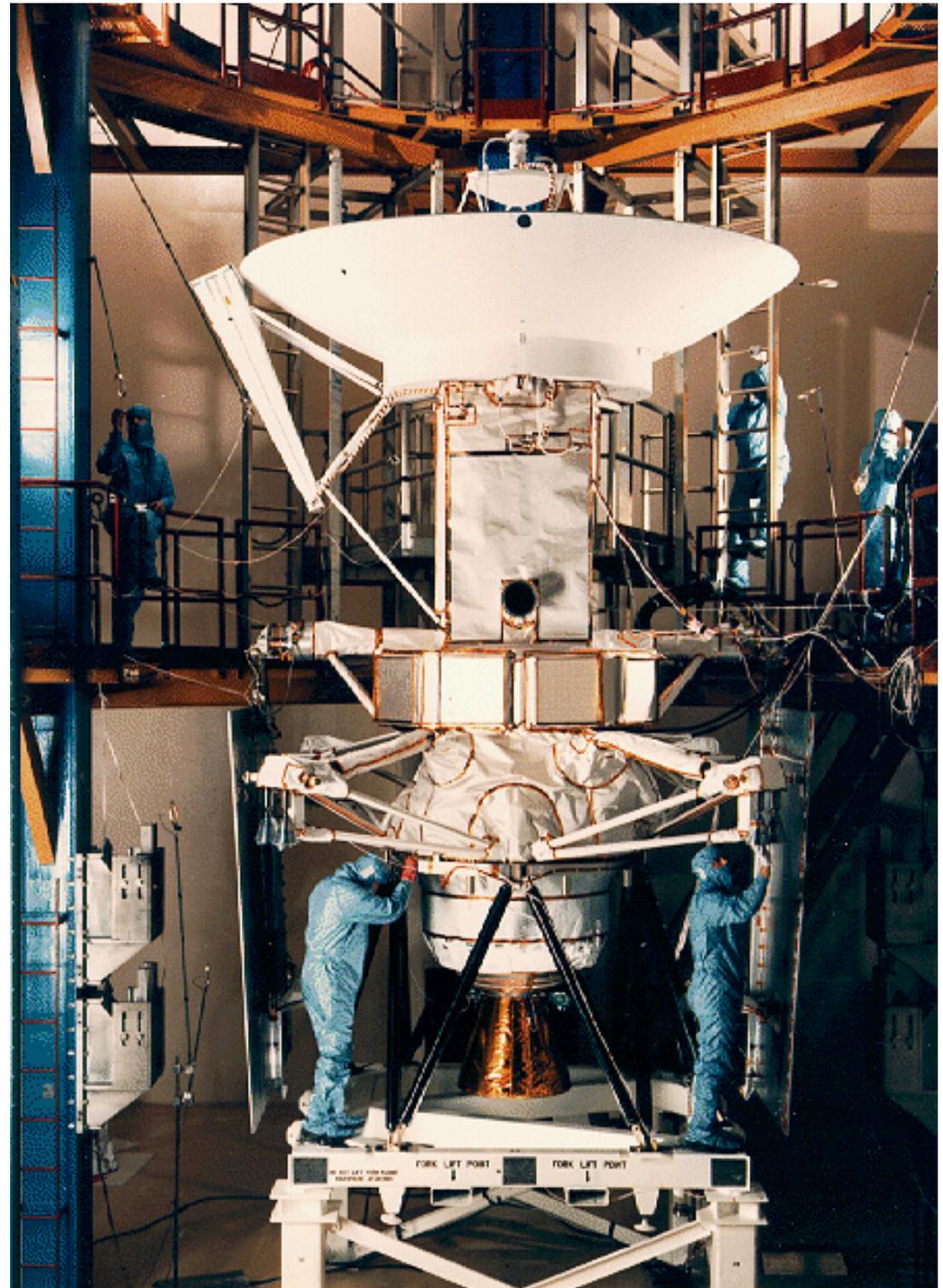
zoom of amplitude image



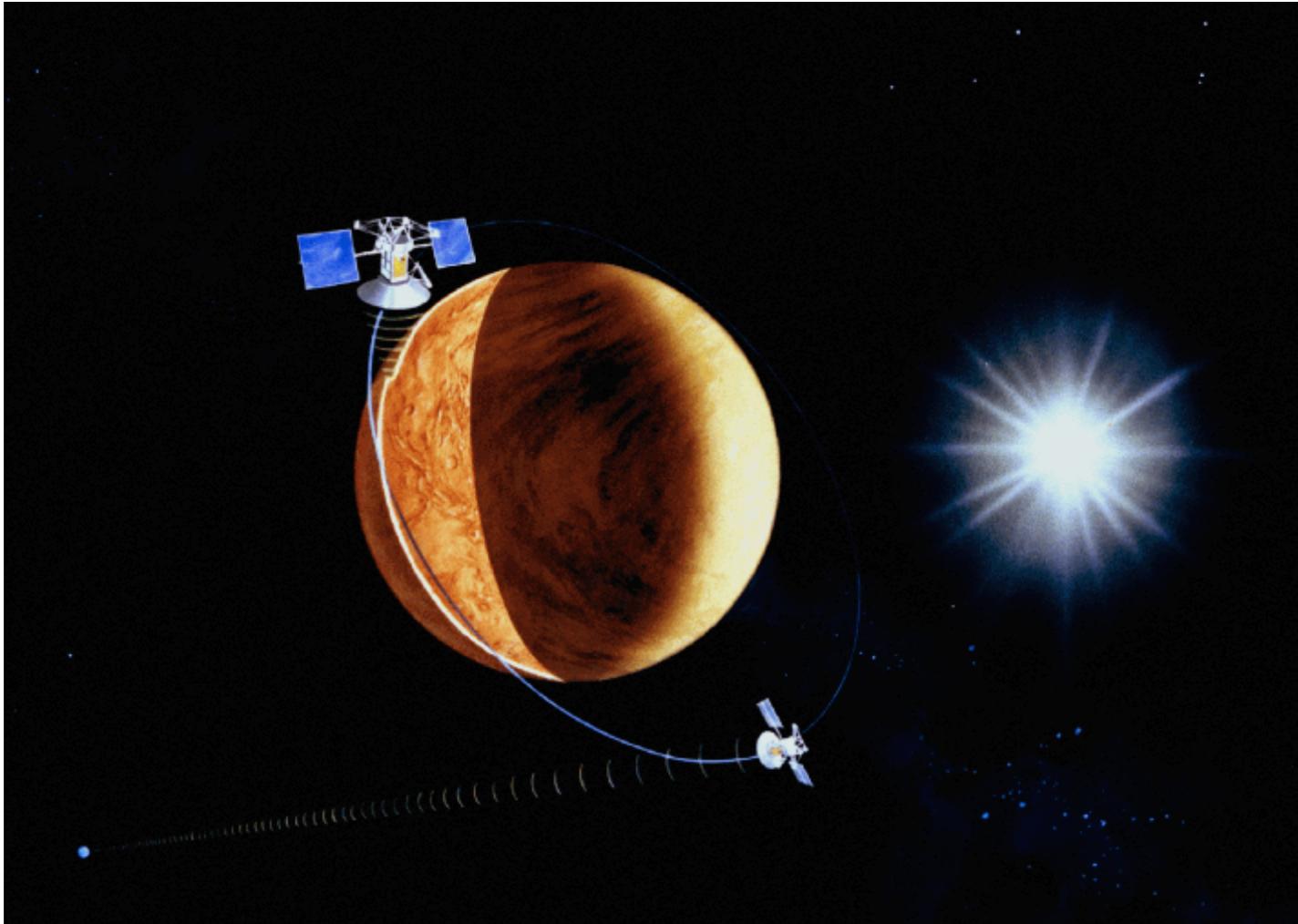
2) This is a zoom of the previous image with 5 km tic marks. Use a map to identify each of the three curved lines running through the images. Why do the fields have different backscatter? Why aren't the fields exactly square? Why do the bright spots have cross patterns?

Magellen SAR

1990-1994

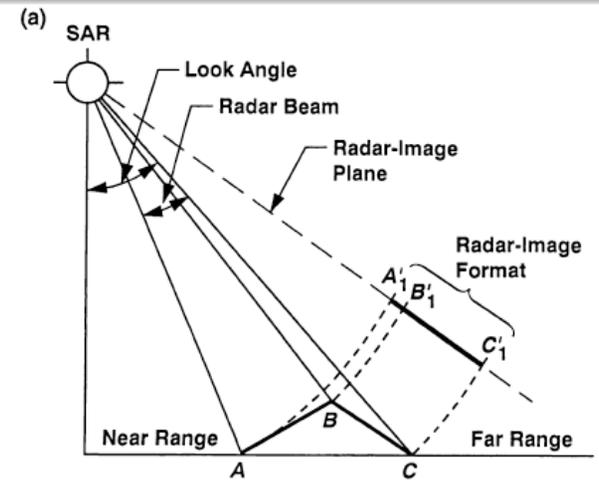


Magellen SAR 1990-1994

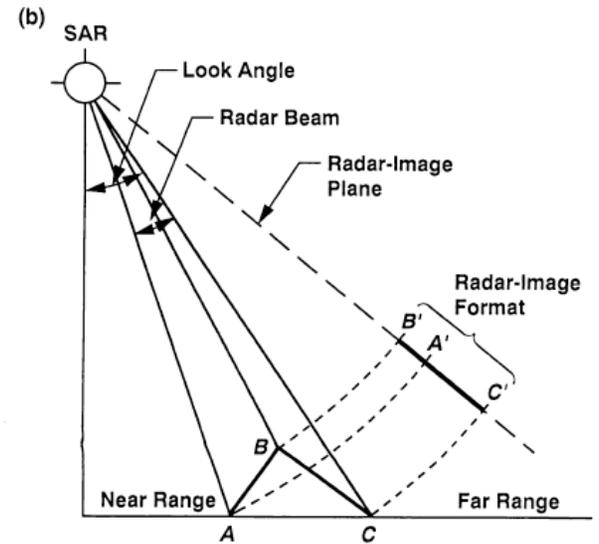


geometry

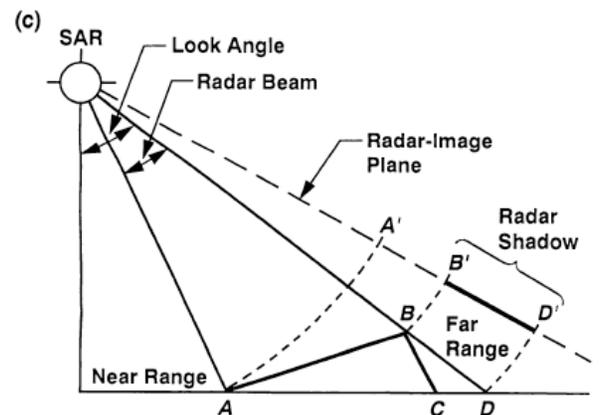
foreshortening



layover



shadowing



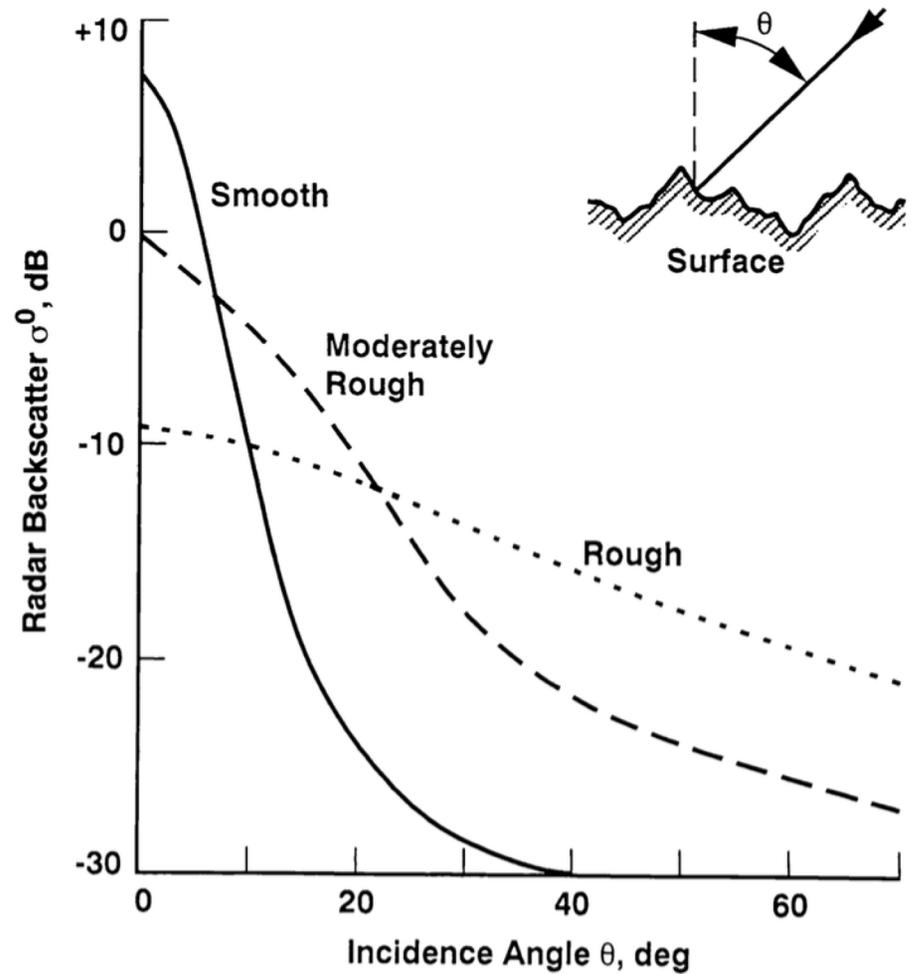
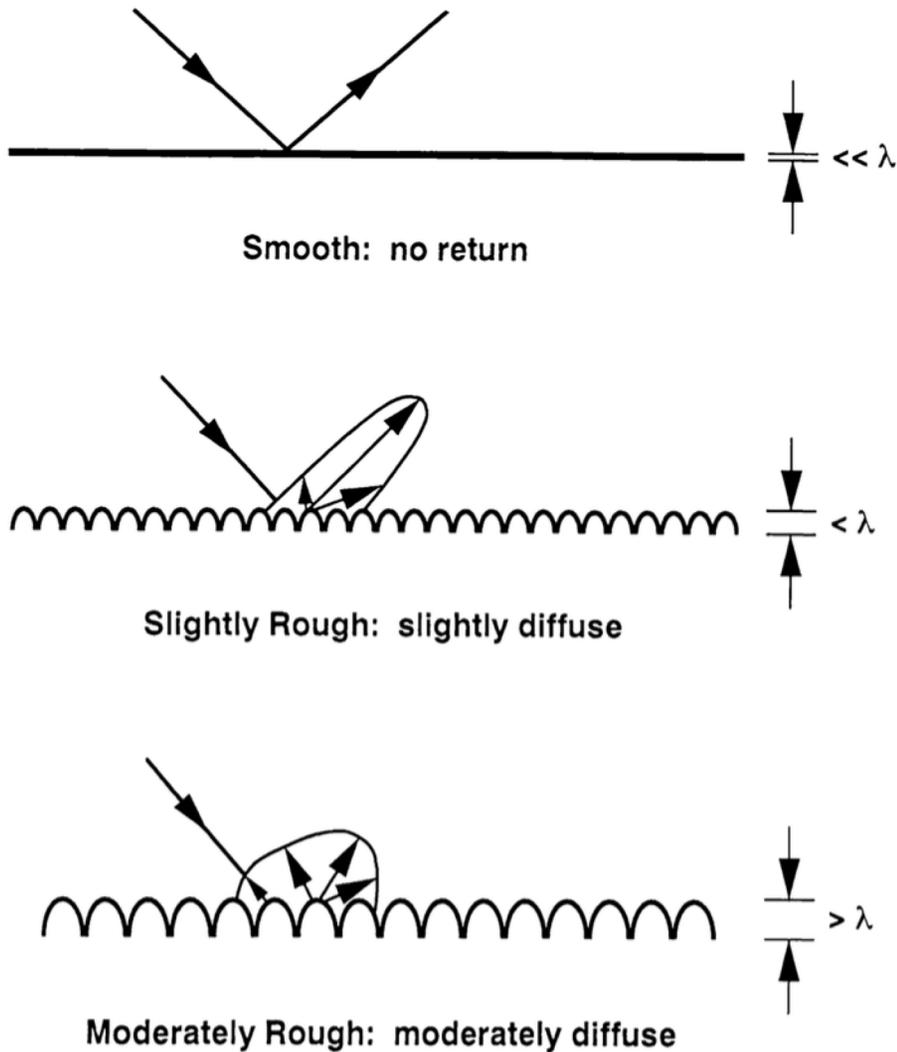
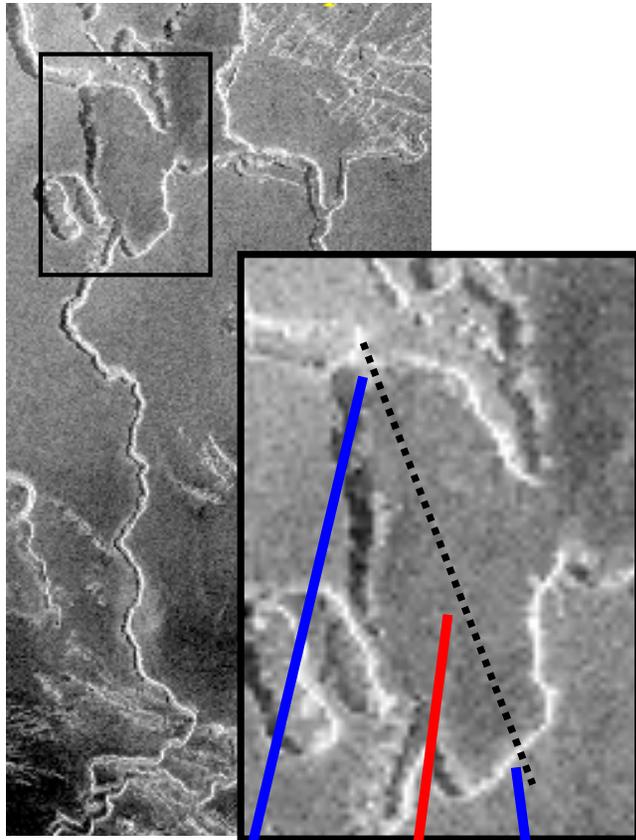


Figure 5-9. Radar backscatter as a function of incidence angle for representative surfaces. For angles less than about 25 deg, smoother surfaces have greater backscatter than rougher surfaces.

Radar Image Properties

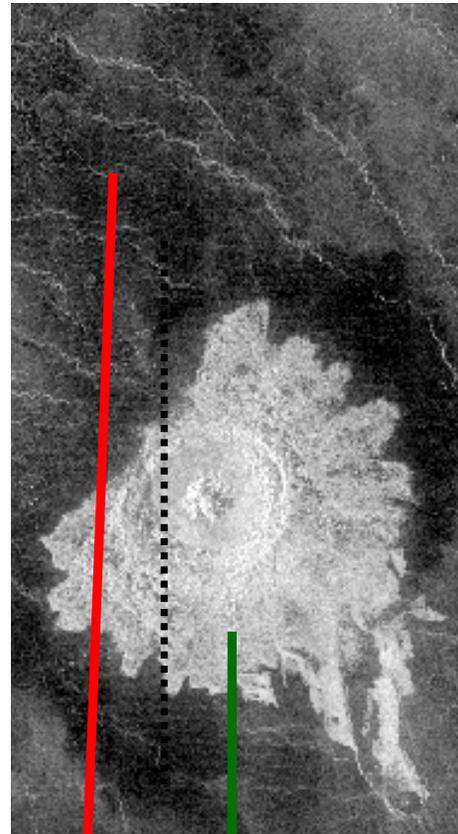
SLOPE



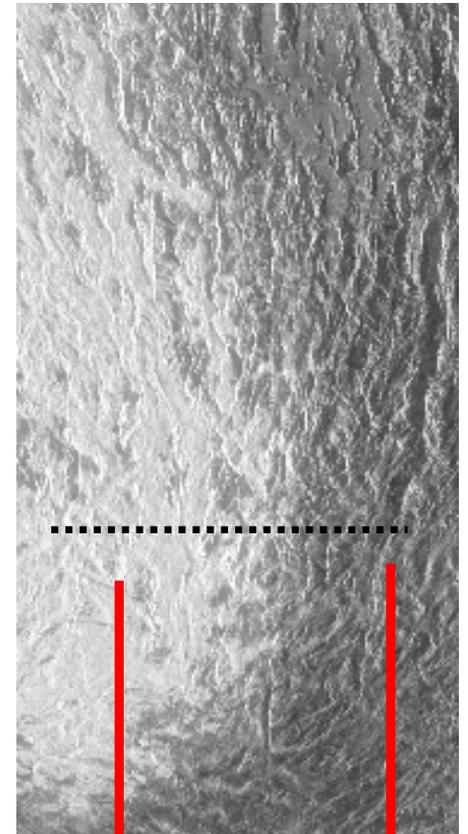
Surface



ROUGHNESS

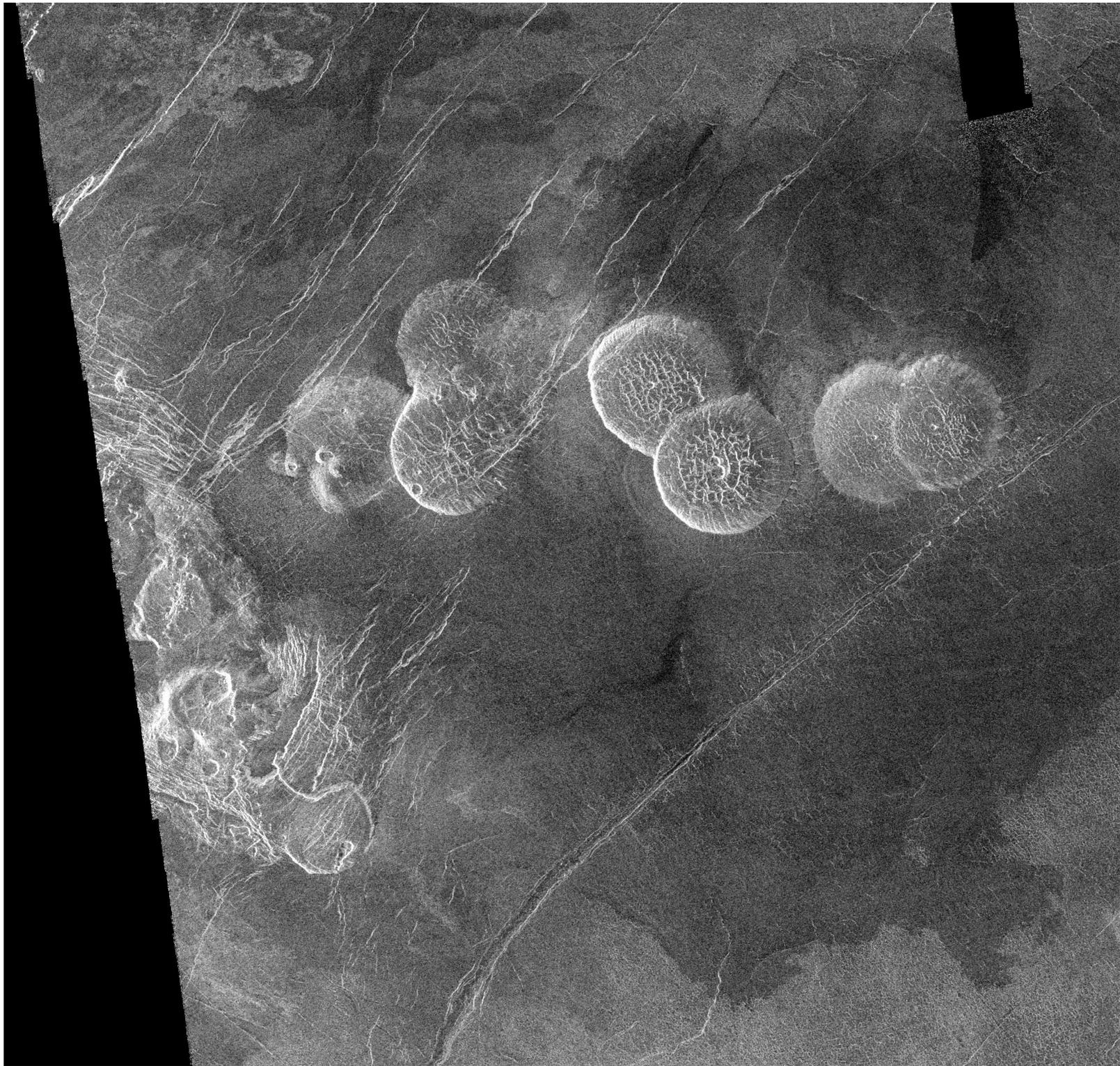


REFLECTIVITY



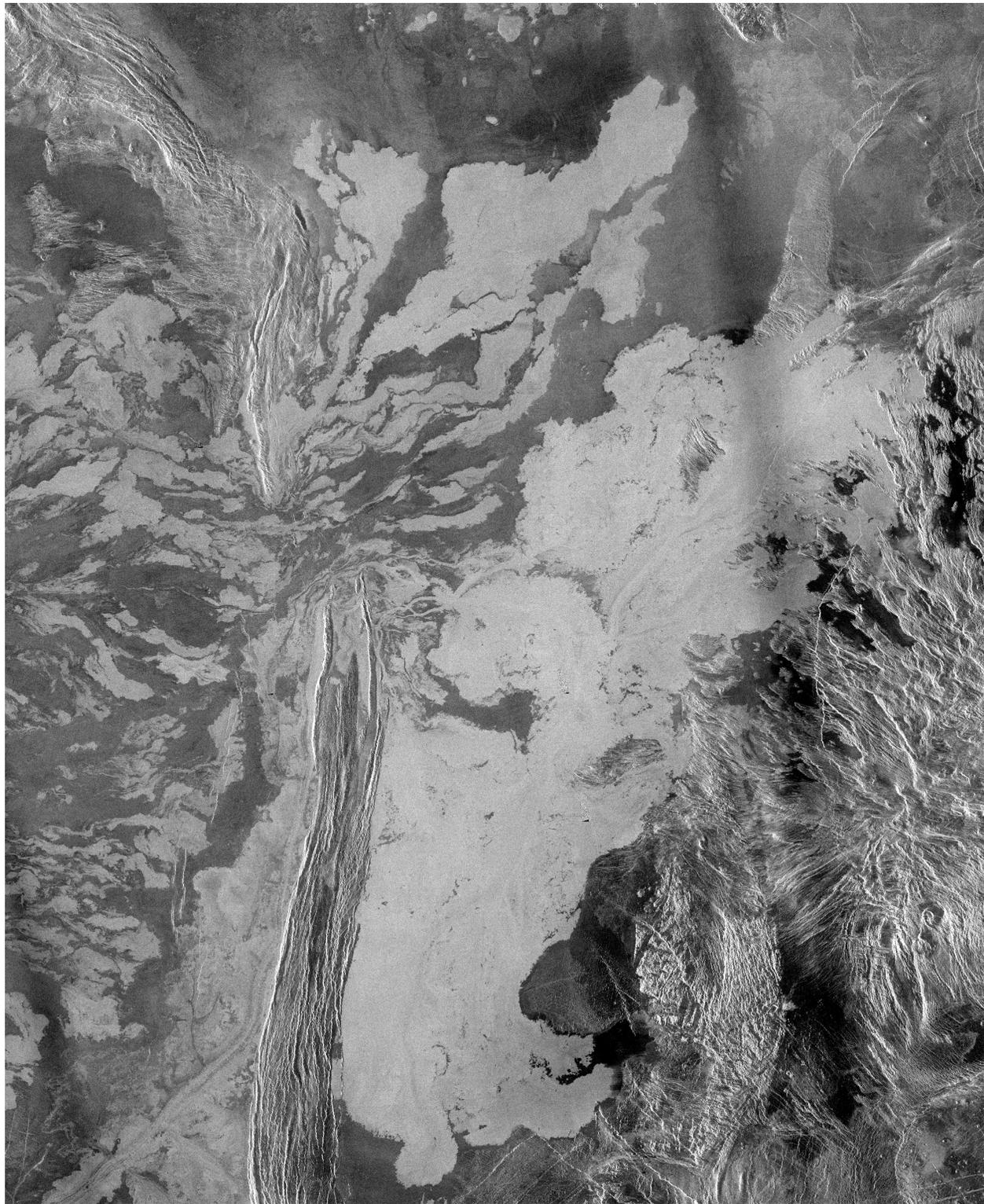
slope

pancake
domes
Venus



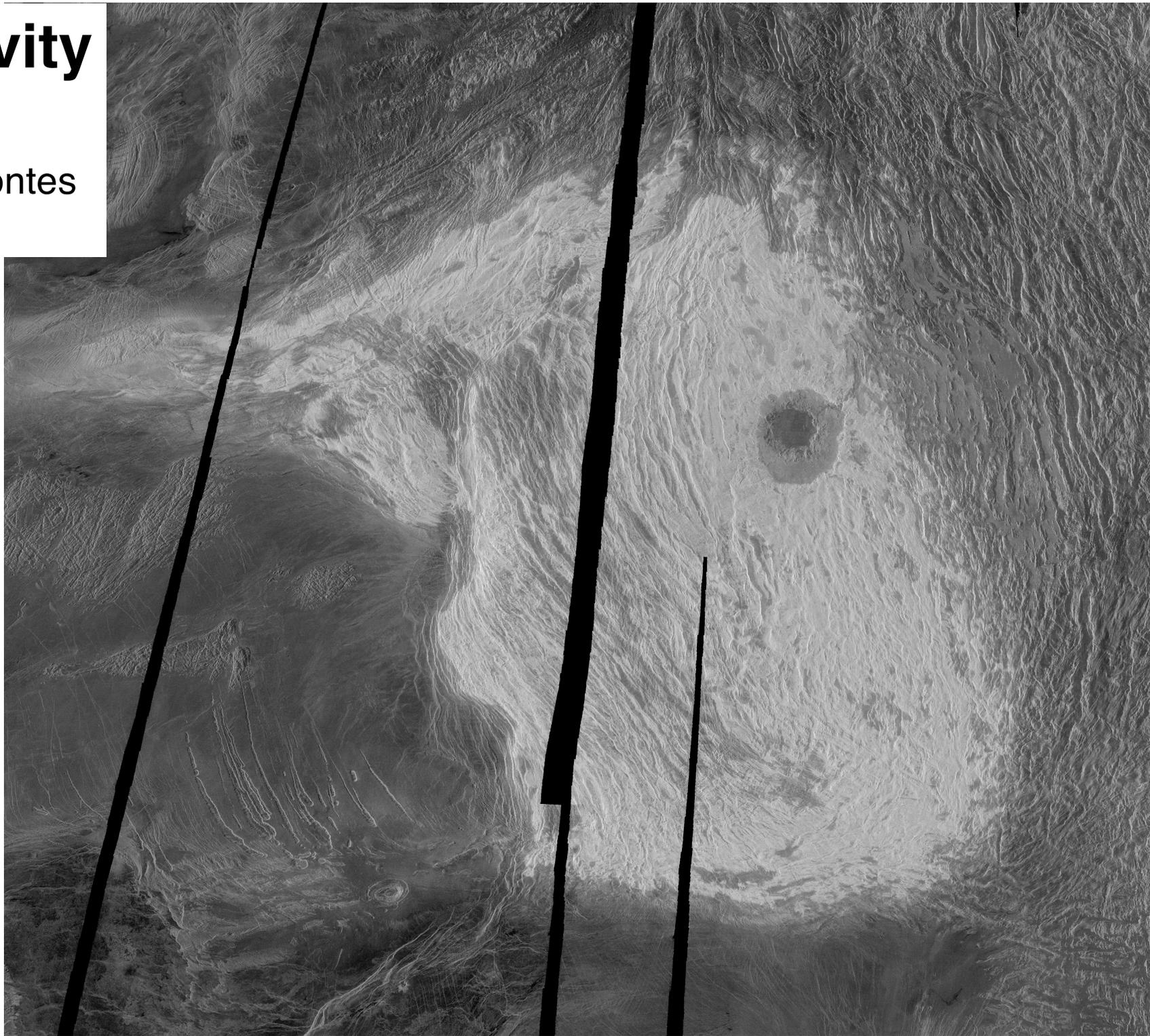
roughness

lava flows
Venus

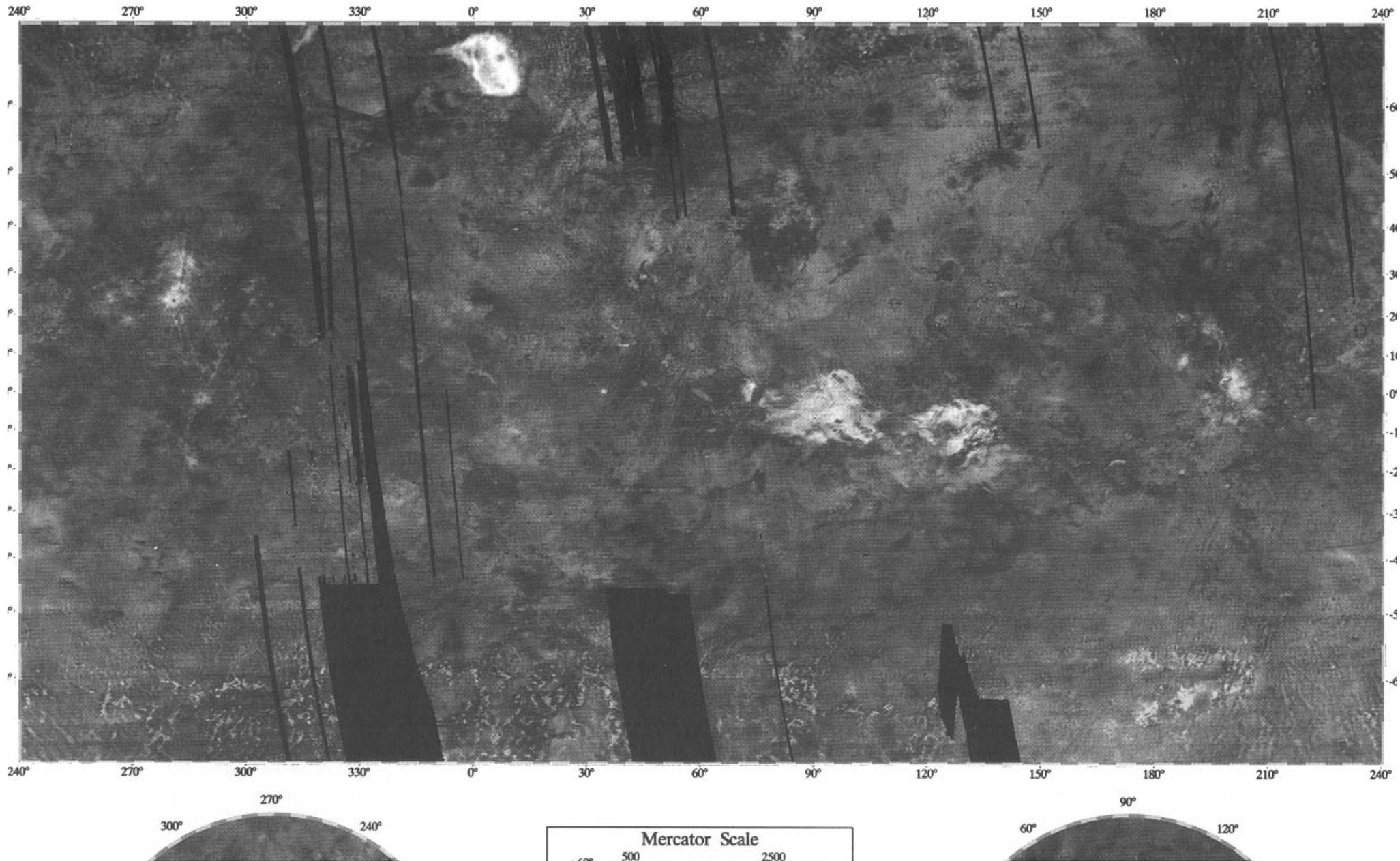


reflectivity

Maxwell Montes
Venus



reflectivity - Venus

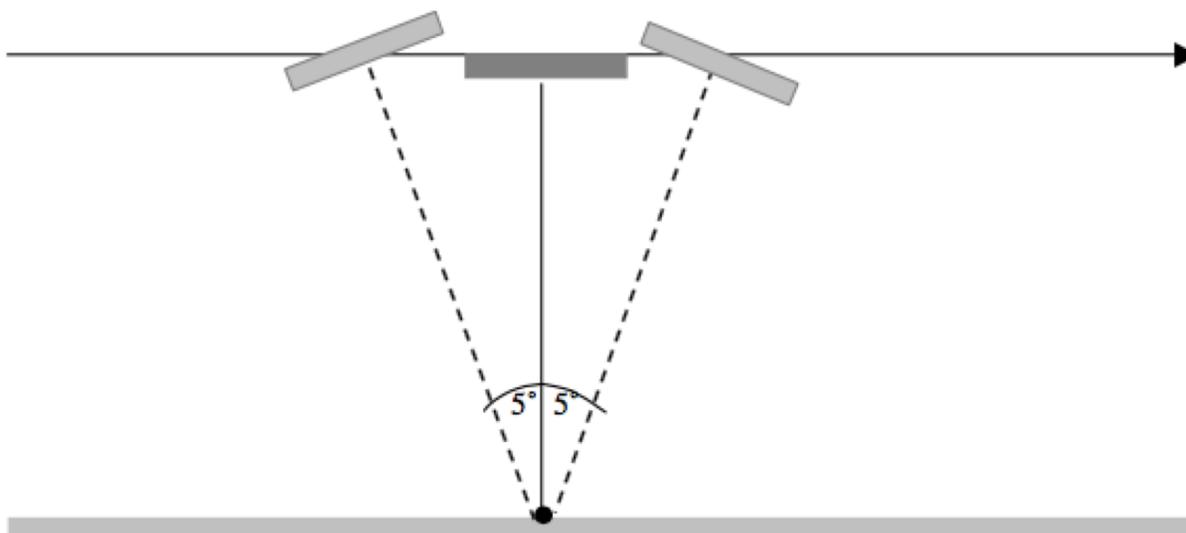


- 1) What is the illumination pattern for an aperture with a sign reversal at its center? What is $P(0)$? Is the function real or imaginary? Is the function symmetric or asymmetric?

The aperture is

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

- 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