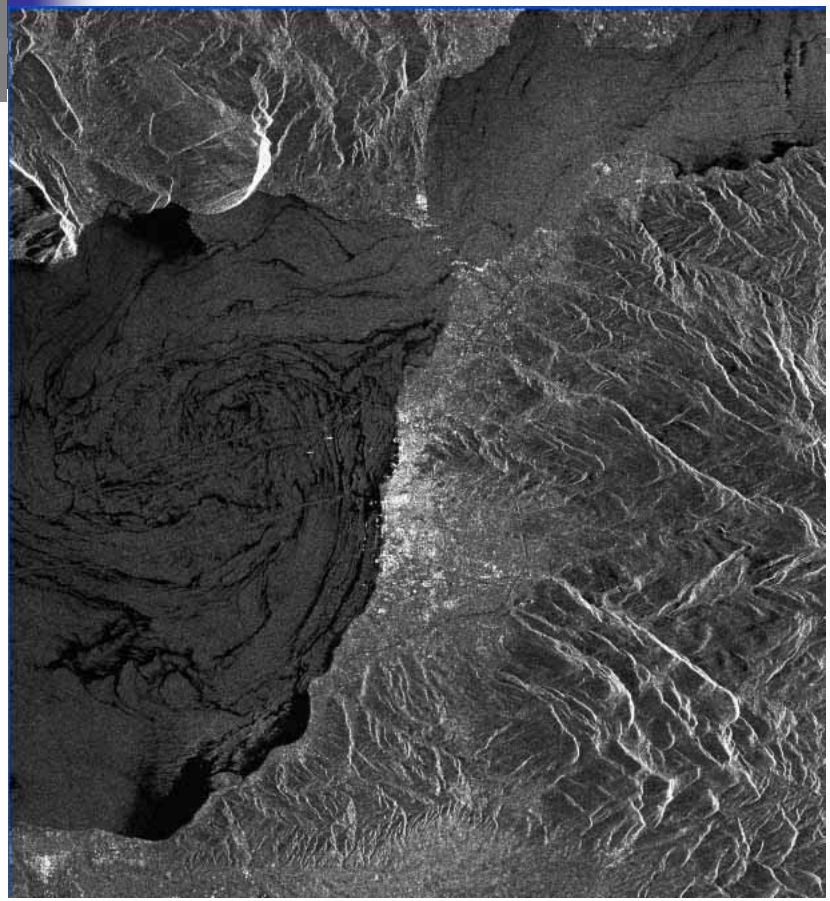
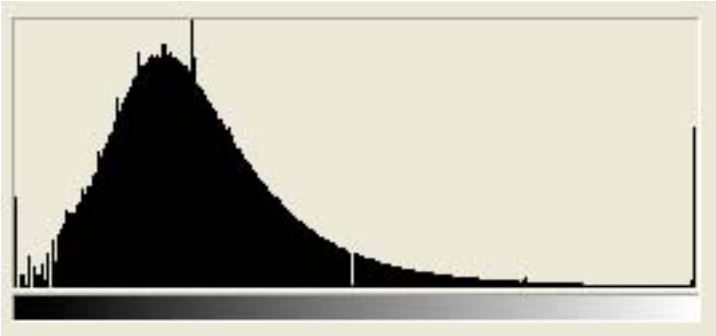
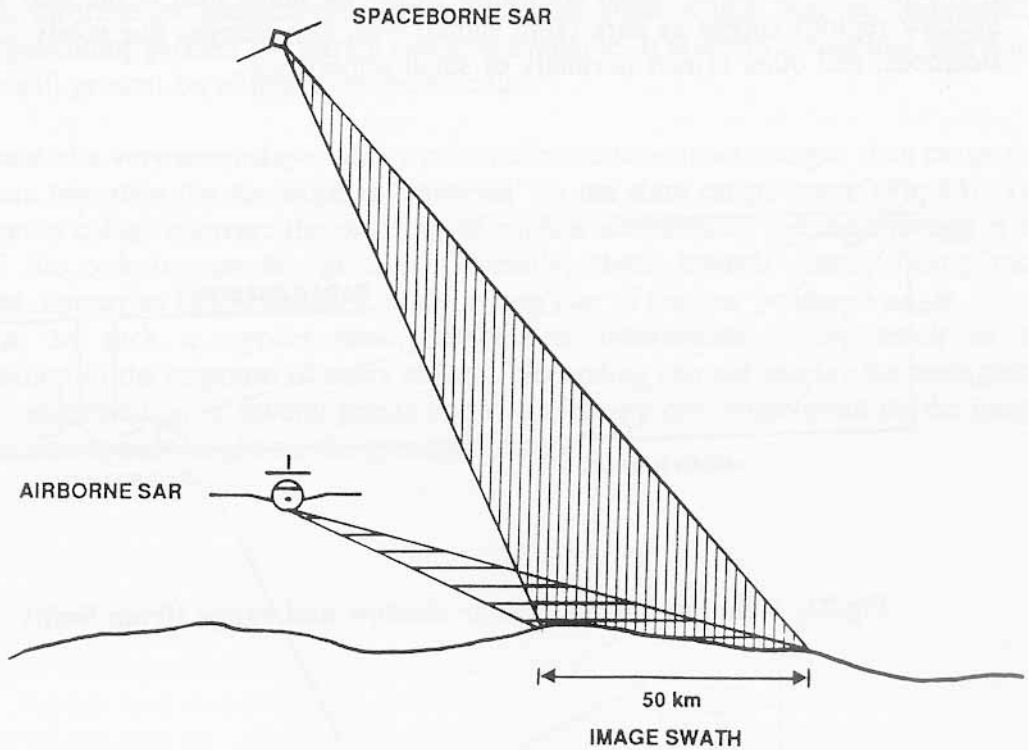
RADAR Imaging





Introduction



Airborne SAR typical altitudes 5-10 km
- Incidence angles for wide swath coverage vary considerably across the swath, in this example between 45° and 80°

Spaceborne SAR typical altitudes 250-800 km
- Incidence angles across the same swath vary only slightly, typically ≈ + 2°

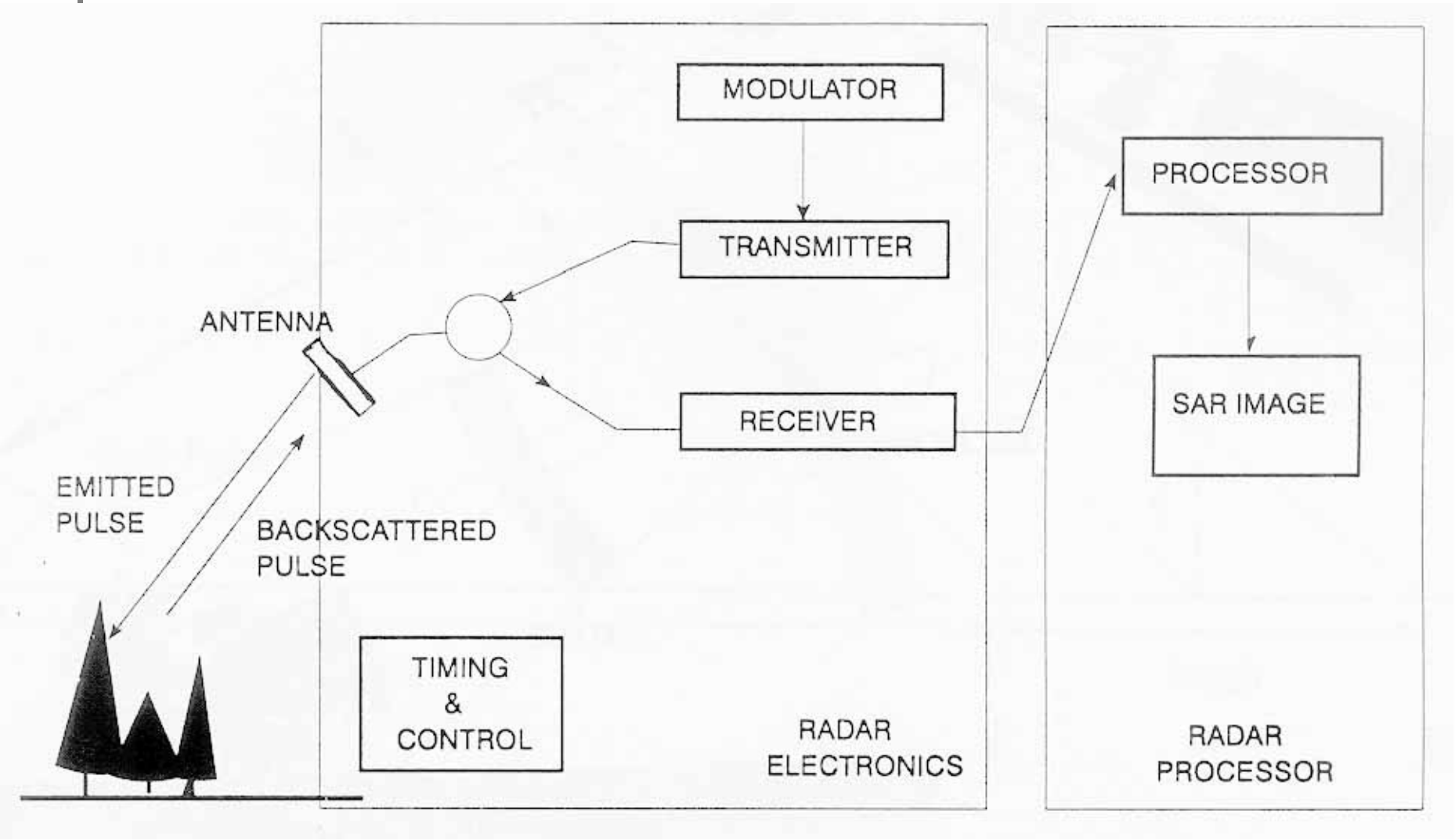
Introduction – Active microwave Radar

- *Passive* remote sensing systems record electromagnetic energy that was reflected or emitted from the surface of the Earth. There are also active remote sensing systems that are not dependent on the Sun's electromagnetic energy or the thermal properties of the Earth.

- *Active* remote sensors create their own electromagnetic energy that 1) is transmitted from the sensor toward the terrain (and is largely unaffected by the atmosphere), 2) interacts with the terrain producing a backscatter of energy, and 3) is recorded by the remote sensor's receiver.

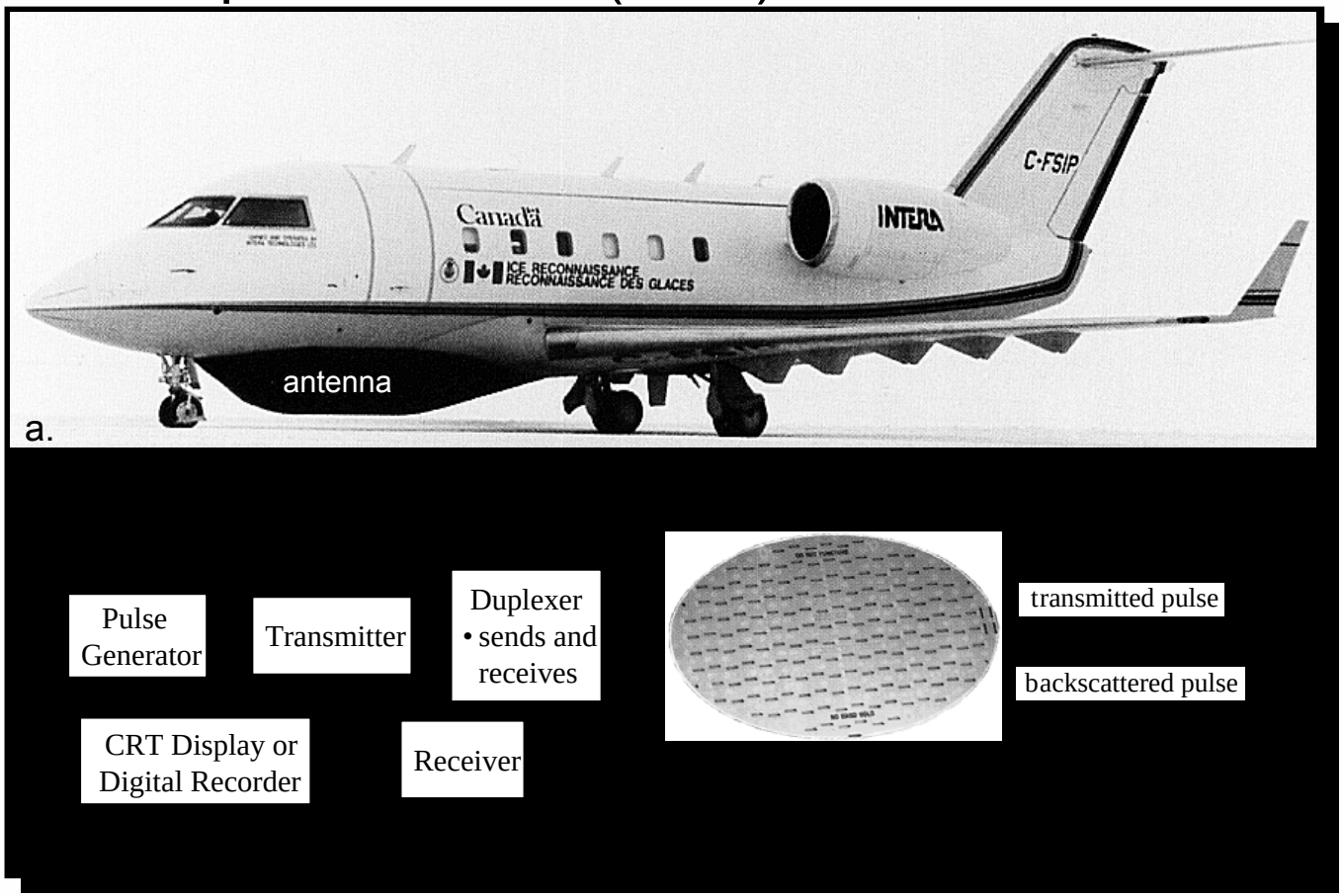
Active remote sensing systems:
• *Active microwave (RADAR),* (e.g., 3 – 25 cm);
• *LIDAR*, laser light (e.g., 0.90 mm). Records the amount of light back-scattered from the terrain;
• *SONAR*, transmission of sound waves, and then recording the amount of energy back-scattered.

Introduction – Radar procedures



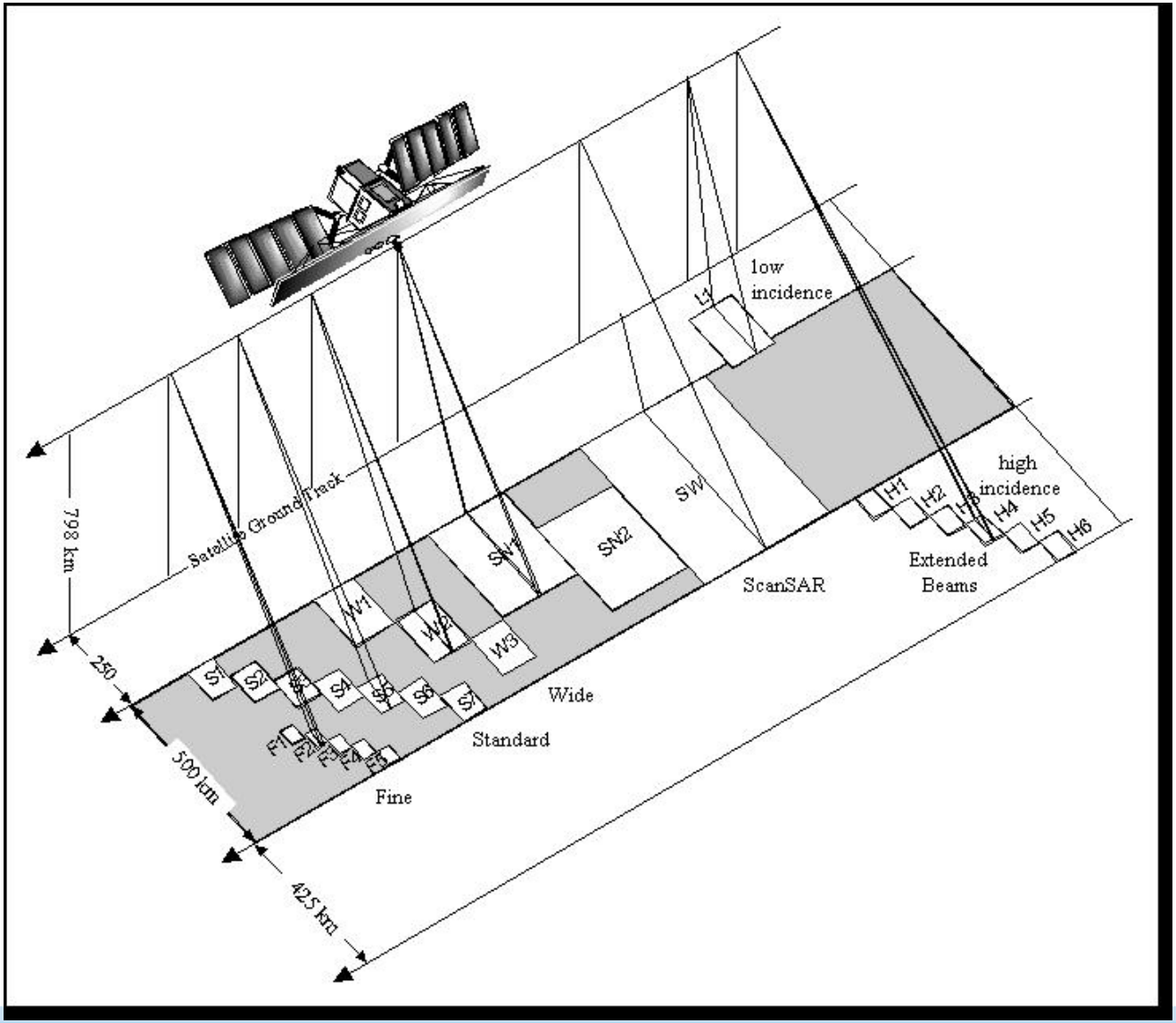
Sending and receiving a pulse in microwave

Real aperture side looking airborne radar (SLAR)
Synthetic aperture radar (SAR)

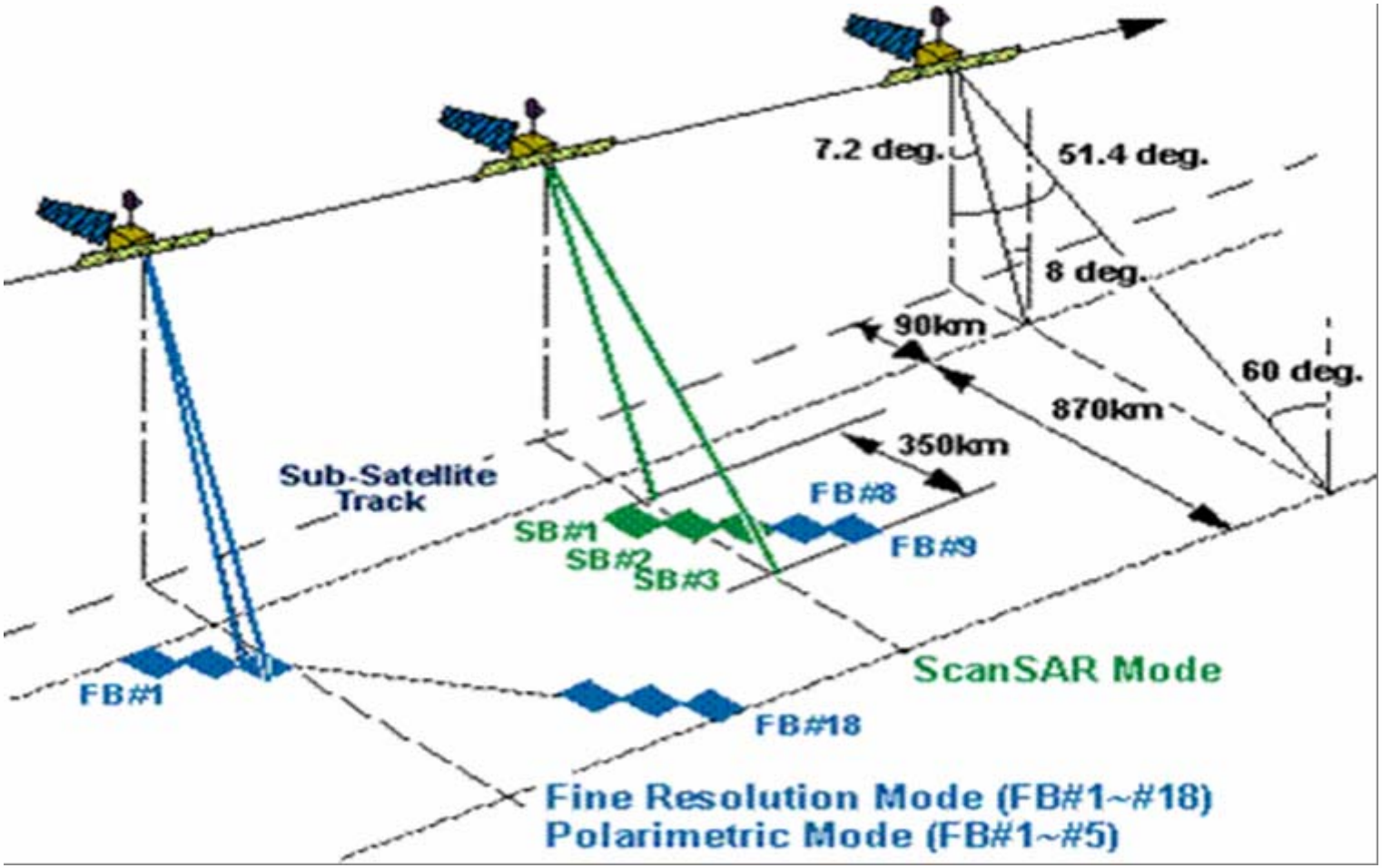


The pulse is of specific duration (in μsec)

Radarsat I

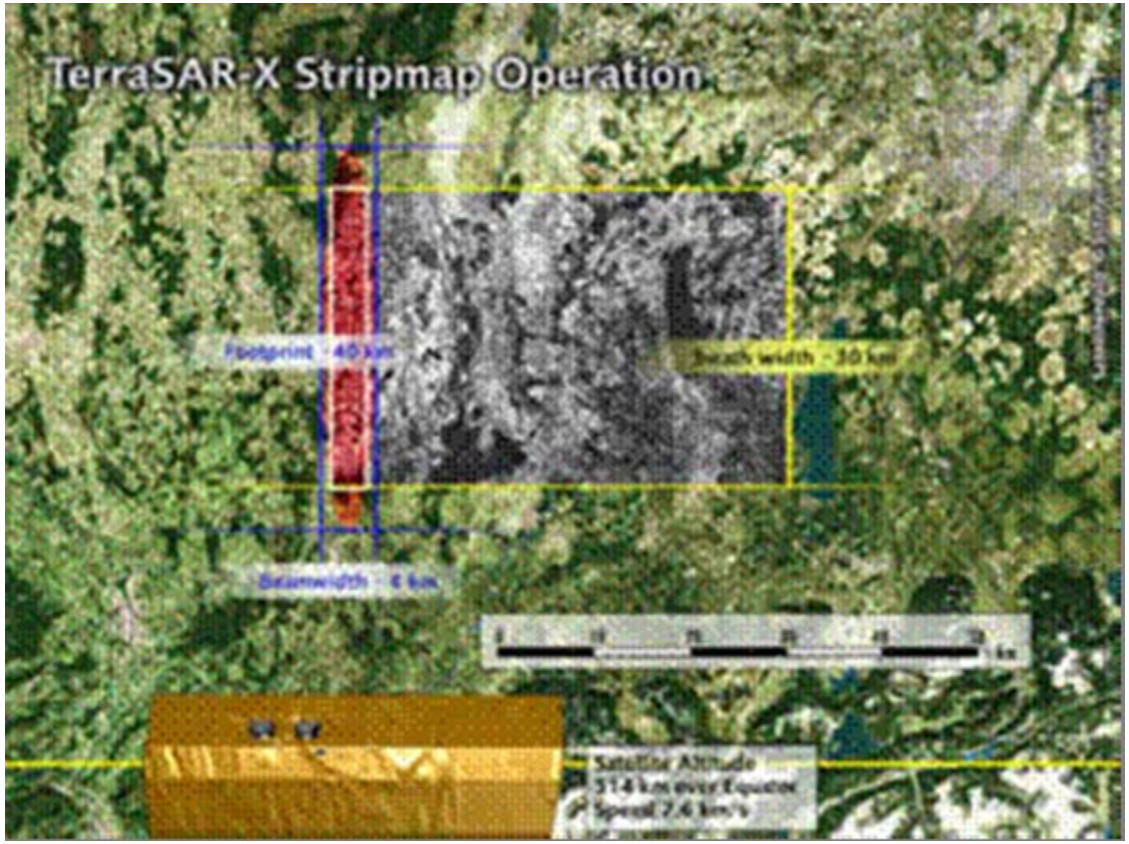

low
incidence
L1
high
incidence
H1
H2
H3
H4
H5
H6
Extended
Beams
ScanSAR
SW1
SN2
SN1
W1
W2
W3
S1
S2
S3
S4
S5
S6
S7
Wide
Standard
F1
F2
F3
F4
F5
Fine
Satellite Ground Track
798 km
250
500 km
425 km

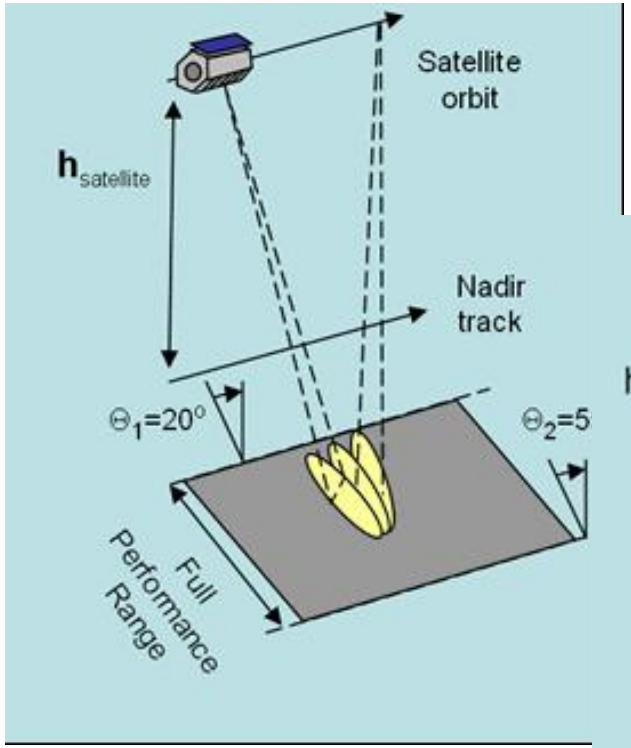
PALSAR modes



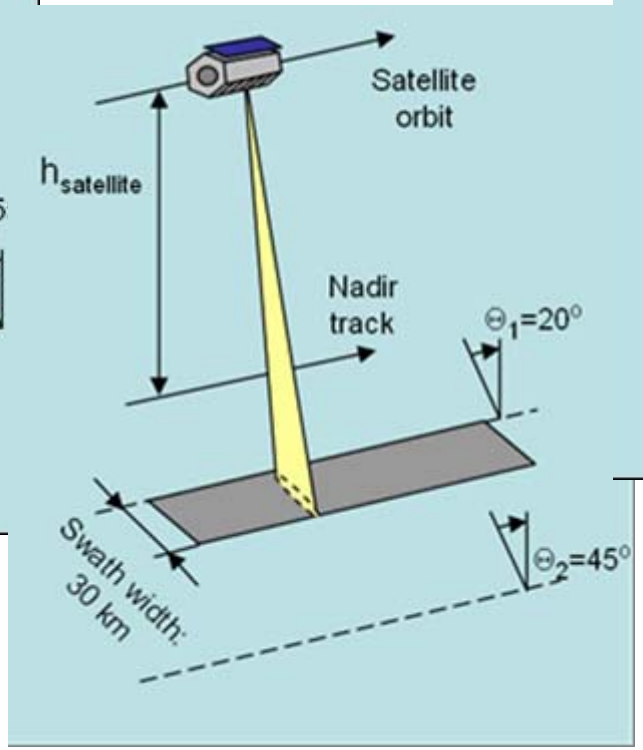
TerraSAR-X modes

- Spotlight
(ανάλυση έως και 1 m)
- StripMap
(ανάλυση έως και 3 m)
- ScanSAR
(ανάλυση έως και 16 m)

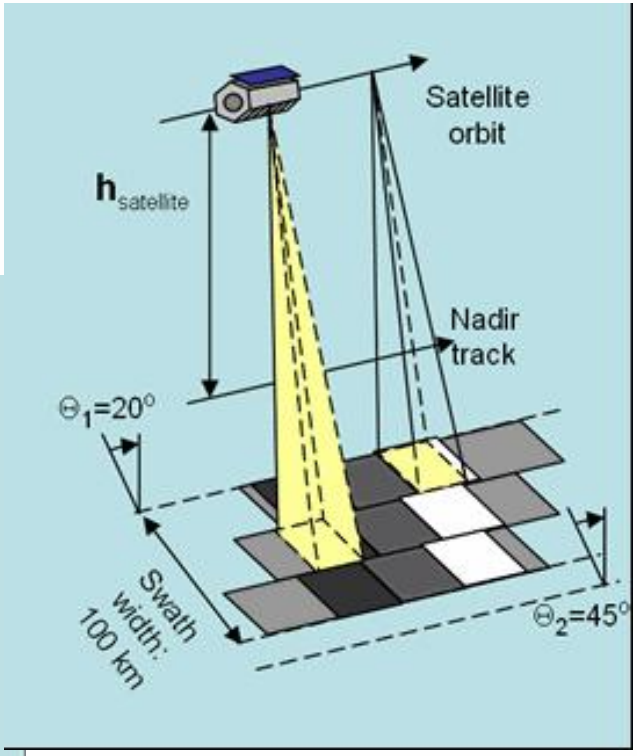




Spotlight

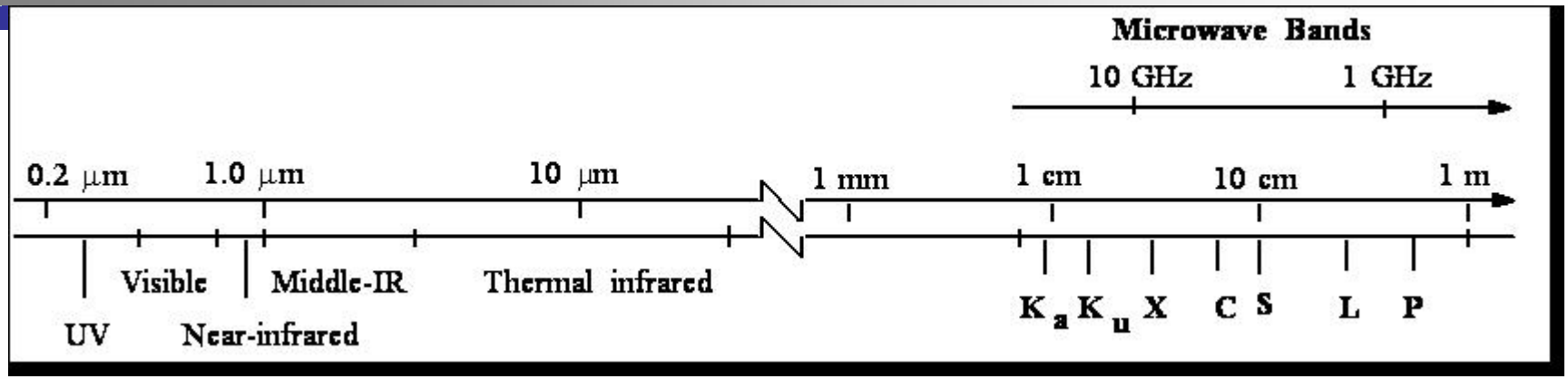


Stripmap



ScanSAR

Radar commonly used frequencies

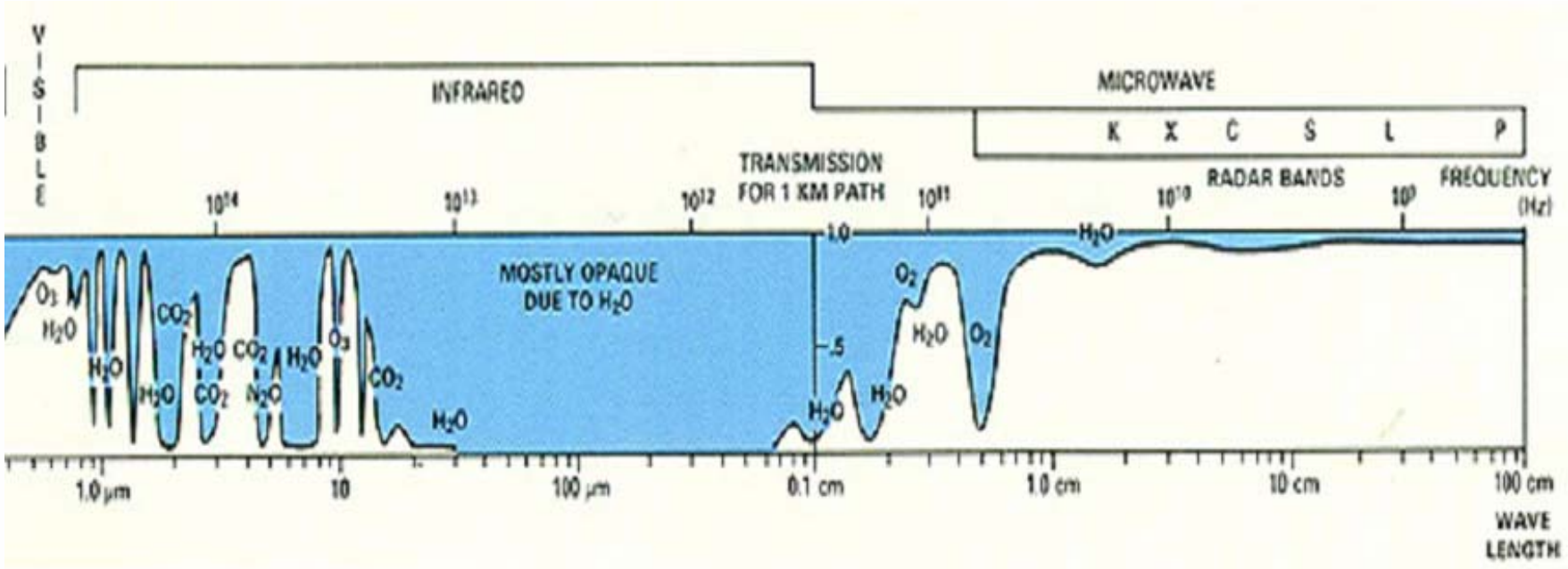


Band Designations (common wavelengths shown in parentheses)	*Wavelength in cm*	*Frequencies in GHz*
K	1.18 - 1.67	26.5 to 18.0
Ka (0.86 cm)	0.75 - 1.18	40.0 to 26.5
Ku	1.67 - 2.4	18.0 to 12.5
X (3.0 and 3.2 cm)	2.4 - 3.8	12.5 - 8.0
C (7.5, 6.0 cm)	3.8 - 7.5	8.0 - 4.0
S (8.0, 9.6, 12.6 cm)	7.5 - 15.0	4.0 - 2.0
L (23.5, 24.0, 25.0 cm)	15.0 - 30.0	2.0 - 1.0
P (68.0 cm)	30.0 - 100	1.0 - 0.3

The names (e.g., *K, Ka, Ku, X, C, S, L,* and *P*) are an artifact of the original secret work on radar remote sensing.

Atmospheric windows

- Here is a generalized diagram showing relative atmospheric radiation transmission of different wavelengths.



Blue zones mark minimal passage of incoming and/or outgoing radiation, whereas, white areas denote atmospheric windows.

Advantages of RADAR in Remote sensing

- It is an *all-weather* remote sensing system.
- *Synoptic views* of large areas, for mapping at 1:25,000 to 1:400,000;
- Permits imaging at *shallow look angles*, resulting in different perspectives.
- Provides information on surface roughness, dielectric properties, and moisture content.
- May *penetrate* vegetation, sand, and surface layers of snow.
- Enables *resolution to be independent of distance to the object*, with the size of a resolution cell being as small as 1 x 1 m.
- May operate simultaneously in several wavelengths (frequencies) and thus has *multi-frequency potential.*
- Can *measure ocean wave properties*, even from orbital altitudes.
- Can produce overlapping images suitable for stereoscopic viewing.
- Supports interferometric operation using two antennas for 3-D mapping.

Fundamental Radar Equation

The modified fundamental radar equation is:

$$P_r = \frac{P_t \times G^2 \times \sigma \times \lambda^2}{(4\pi)^3 \times R^4}$$

$$P_r = P_t \times G_t \frac{1}{4\pi R^2} \sigma \frac{1}{4\pi R^2} A_r$$

where P_r is power received, P_t is the power transmitted toward the target, G_t is the gain of the antenna in the direction of the target, R is the range distance from the transmitter to the target, σ is the effective backscatter area of the target, and A_r is the area of the receiving antenna.

Effects of terrain on the radar signal:
the amount of *radar cross-section*, σ, reflected back to the receiver, per unit area a on the ground called *radar backscatter coefficient* (σ°) $\sigma^\circ = \frac{\sigma}{a}$

- σ° for a surface depends on a number of terrain parameters like geometry, surface roughness, moisture content, and the radar system parameters (wavelength, depression angle, polarization, etc.).

Surface Roughness

- We describe the surface texture characteristics.
- Surface roughness is usually measured in centimeters (i.e. the height of stones, size of leaves, or length of branches in a tree) and not thousands of meters as with mountains.
- In radar imagery we are actually talking about *micro-relief surface roughness* characteristics rather than topographic relief.

- Specular reflecting surface where most of the energy bounces off the terrain away from the antenna. Dark area on the radar image. The quantitative expression of the *smooth criteria* is:

$$h < \frac{\lambda}{25 \sin \gamma}$$

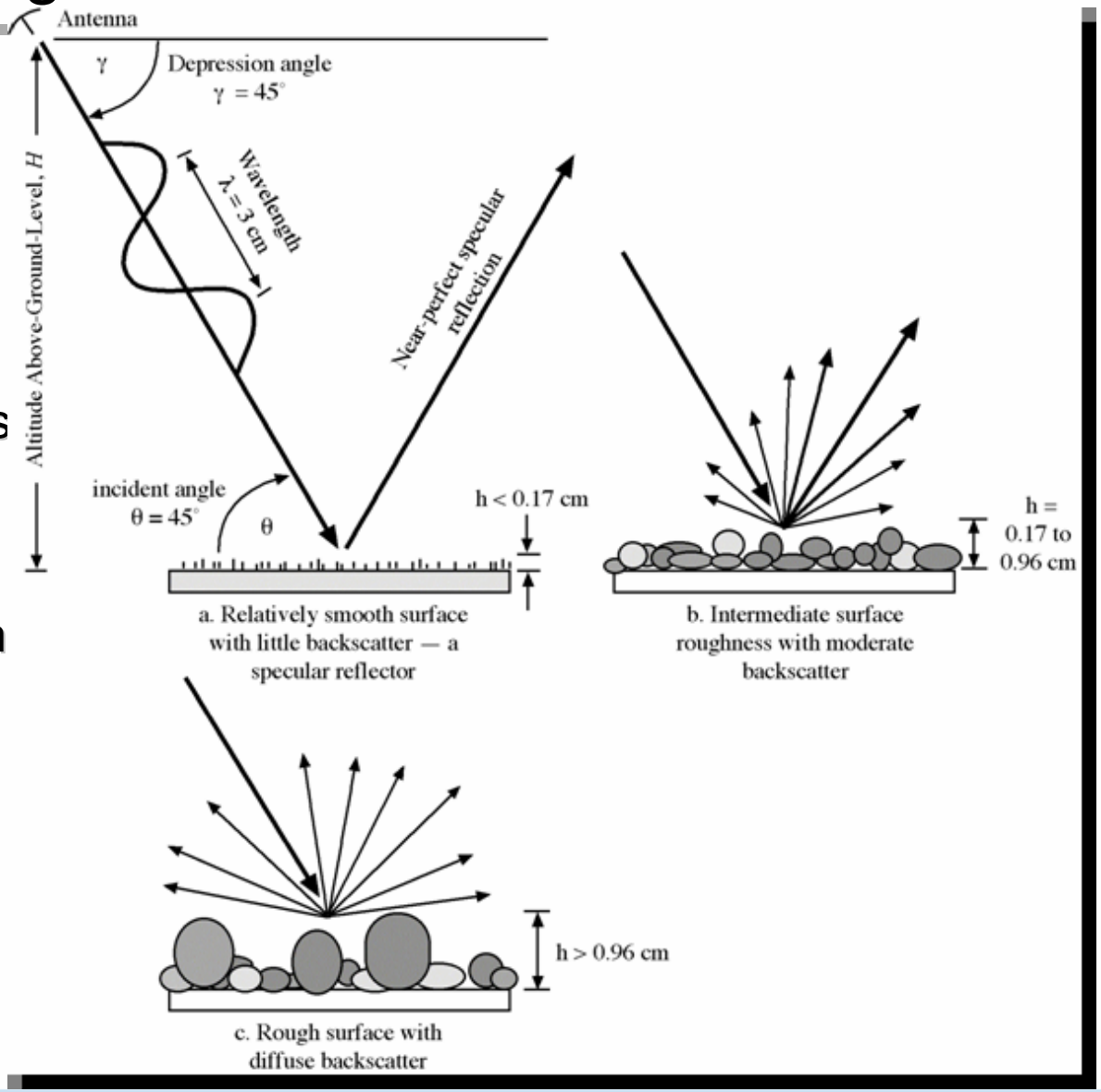
- A bright return is expected if the modified *Rayleigh rough criteria* are used:

$$h > \frac{\lambda}{4.4 \sin \gamma}$$

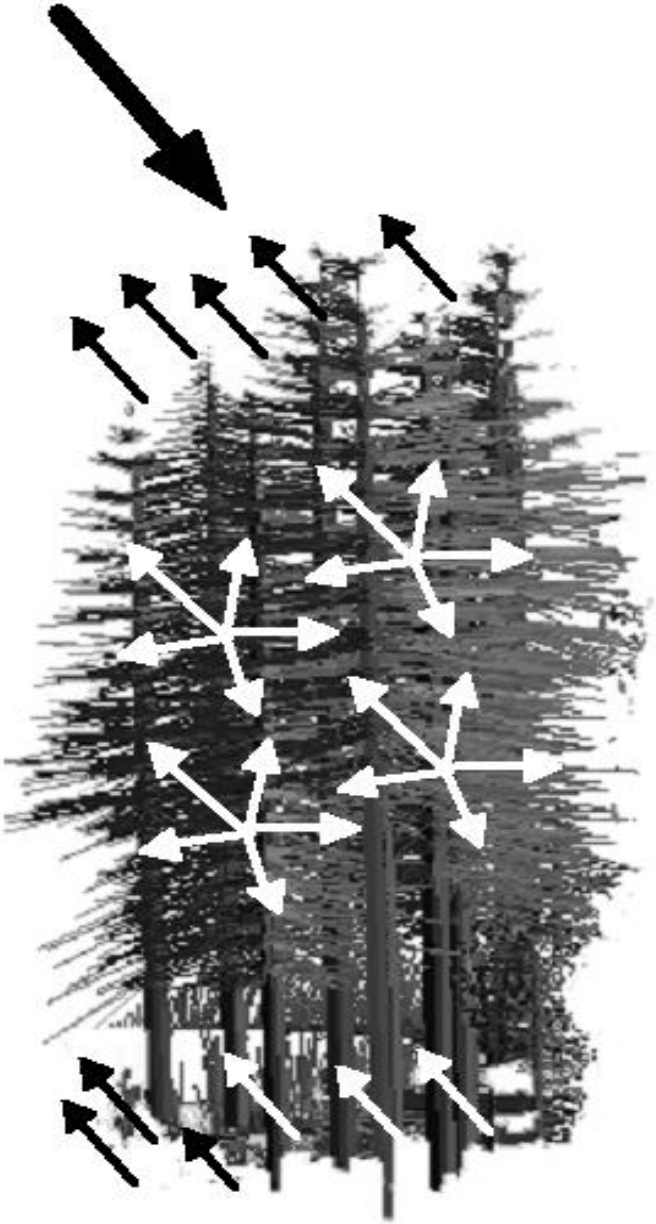
wavelength (λ), the depression angle (γ), height of objects (h in cm)

Surface Roughness

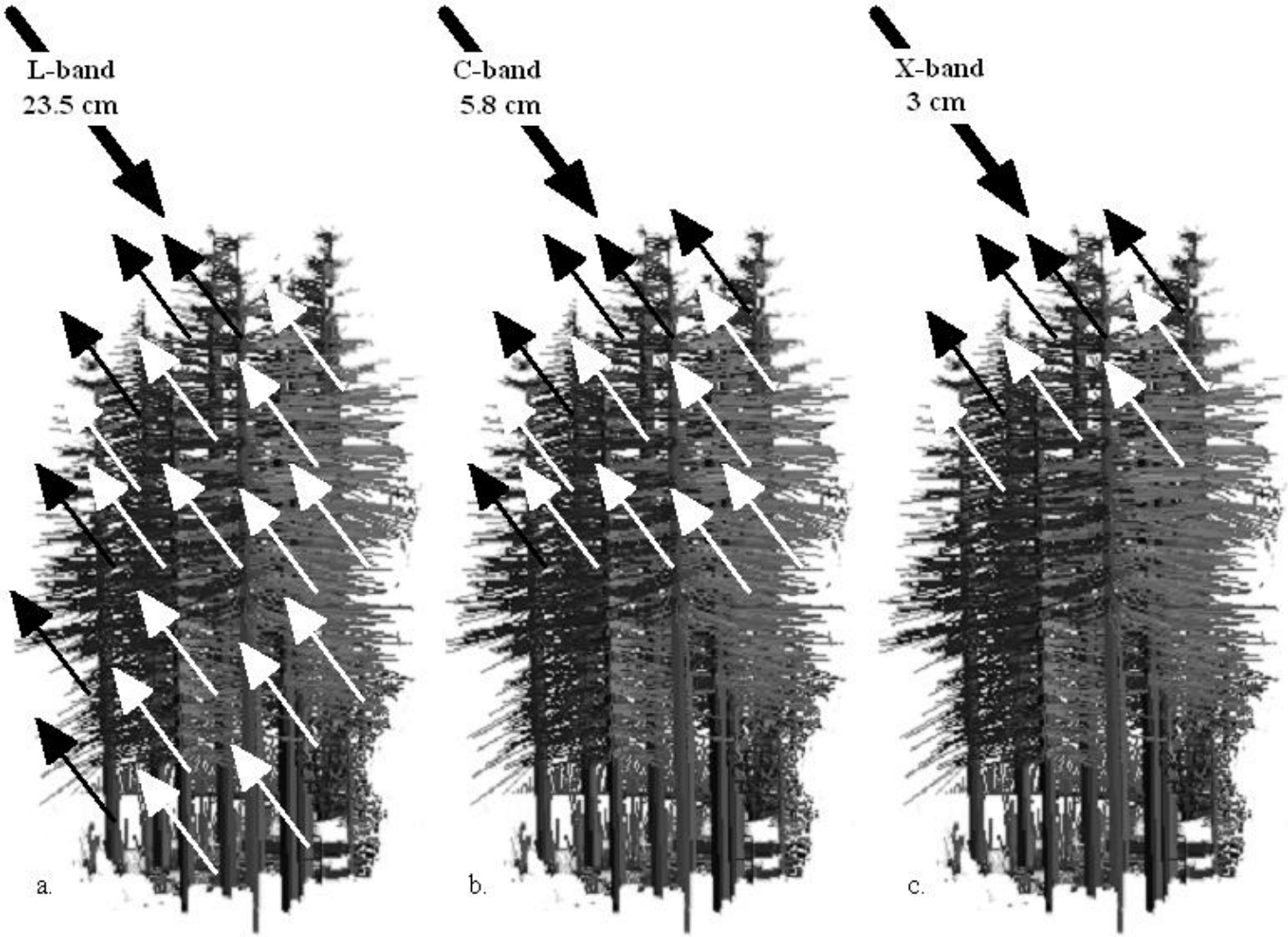
Expected surface roughness back-scatter from terrain illuminated with 3 cm wavelength microwave energy with a depression angle of 45˚.



Types of Active Microwave Surface and Volume Scattering that Take Place in a Hypothetical Pine Forest Stand

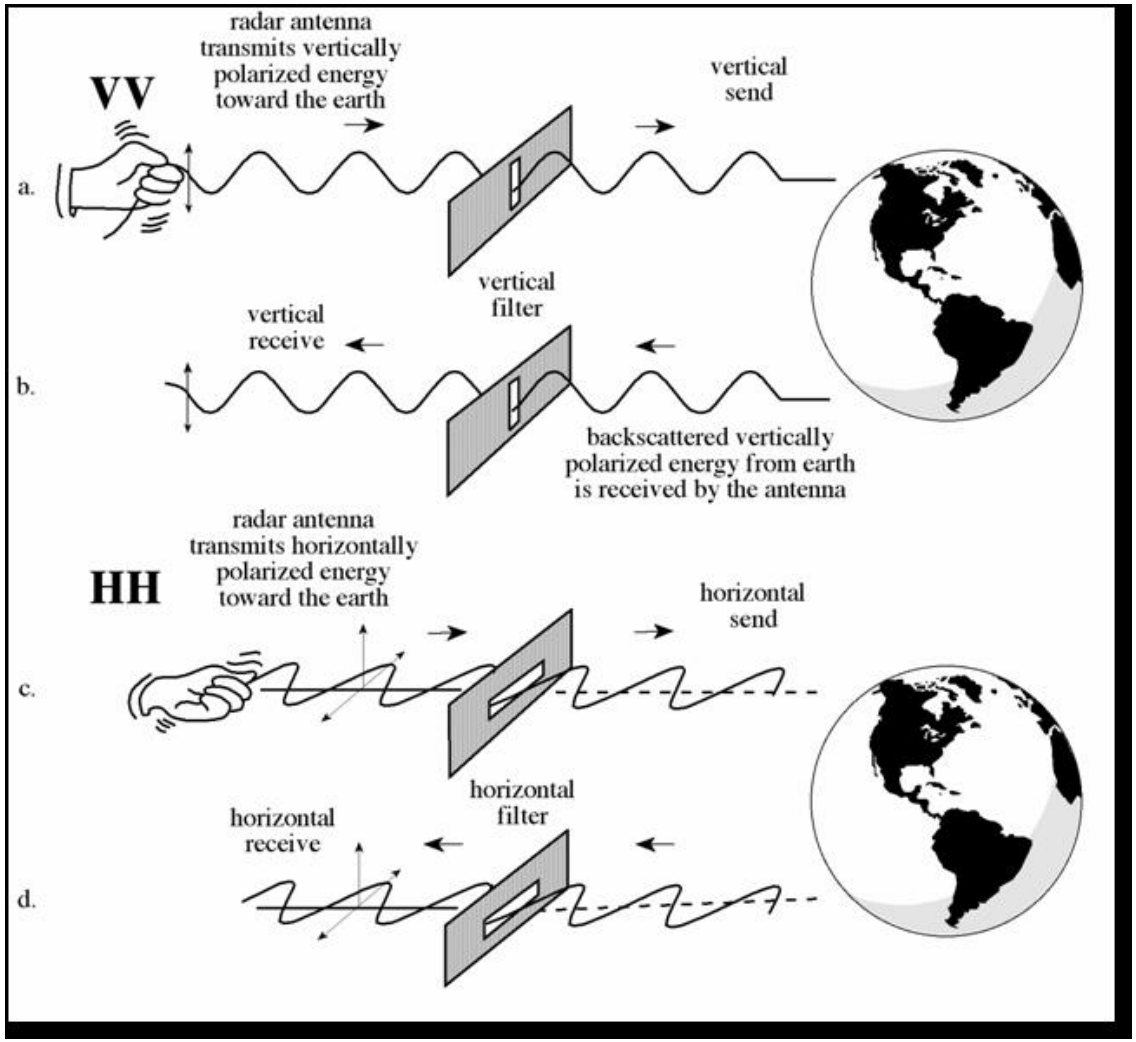


Response to X-, C- and L-band Microwave Energy



Polarization

- Radar antennas send and receive *polarized* energy.
- Electrical wave vibrations are in a single plane perpendicular to the direction of travel.
- The pulse may be *vertically* or *horizontally polarized*.



Polarization

It is possible to:

- send and receive vertically (*VV*)
- send and receive horizontally (*HH*)
- send horizontal and receive vertically (*HV*)
- send vertical and receive horizontally (*VH*)
- *HH* and *VV* produce *like-polarized* imagery.
- *HV* and *VH* produce *cross-polarized* imagery.

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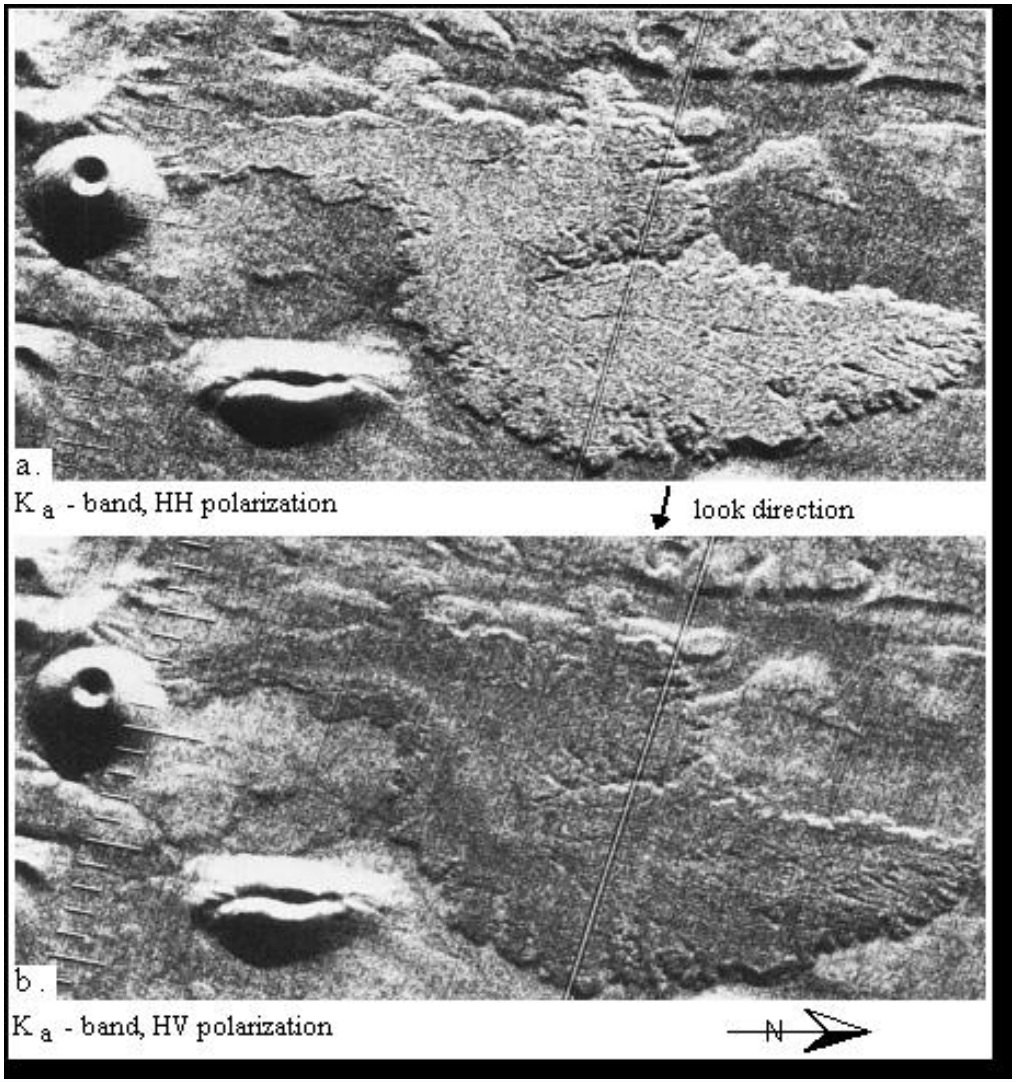
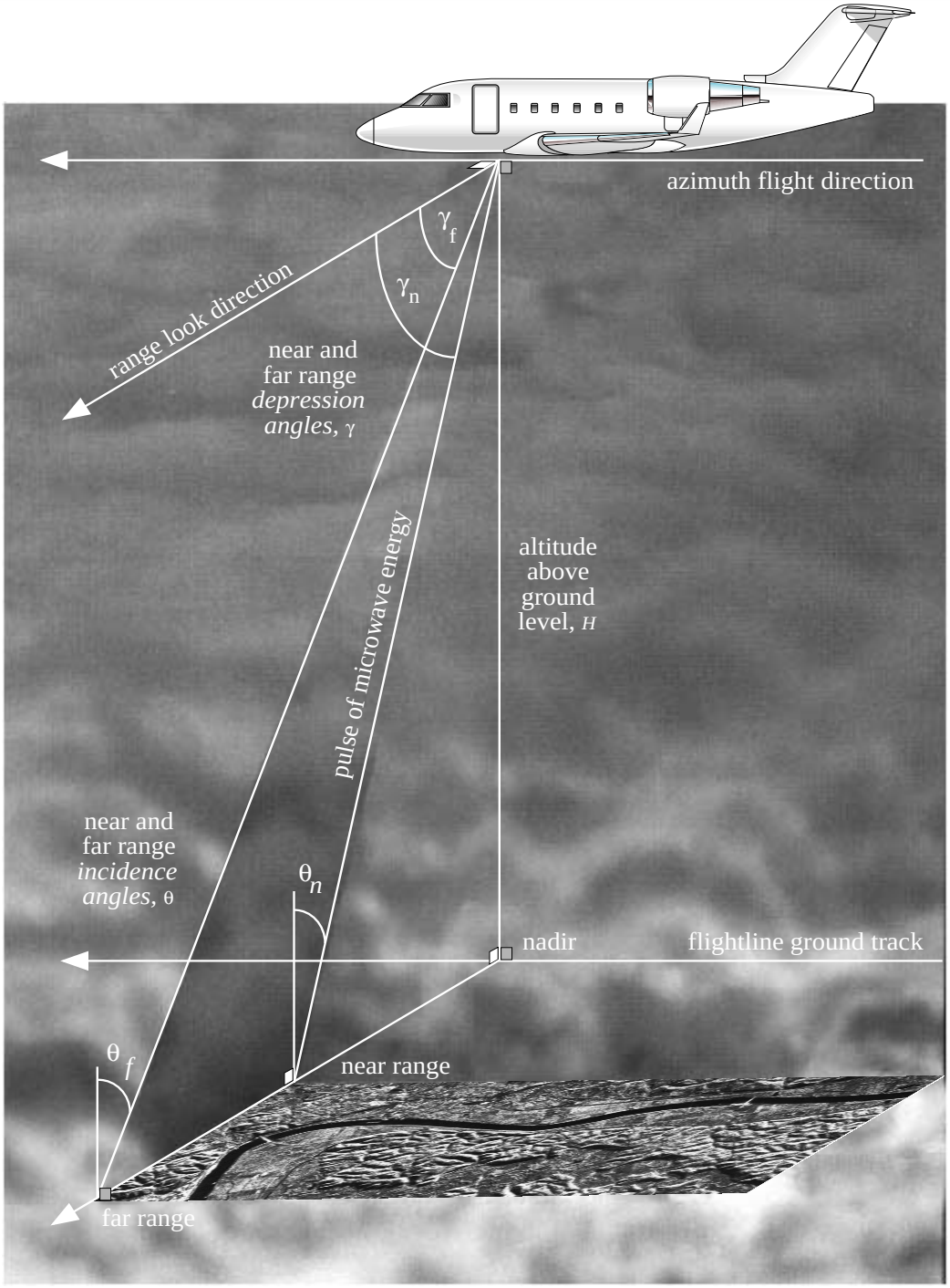
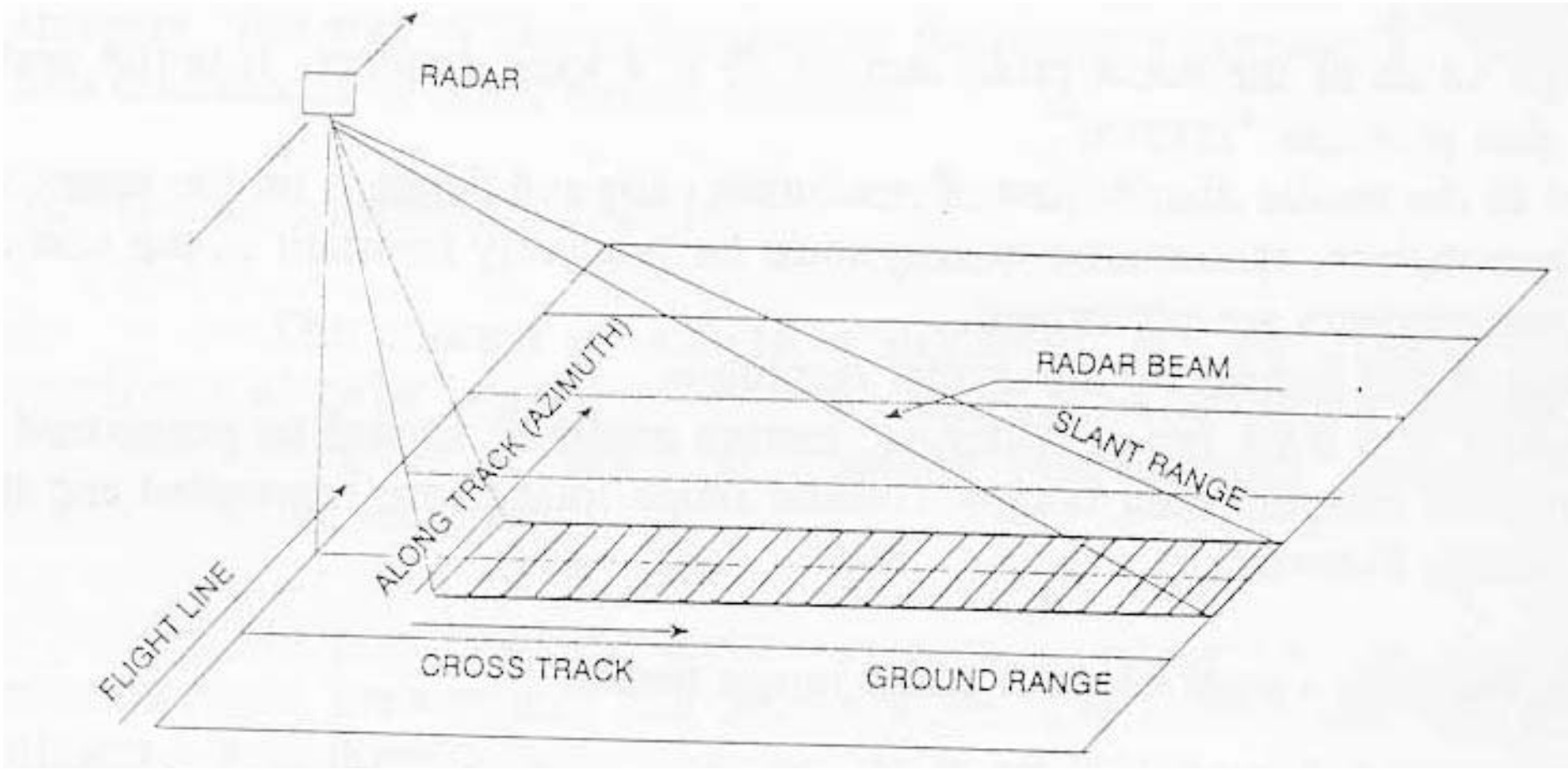


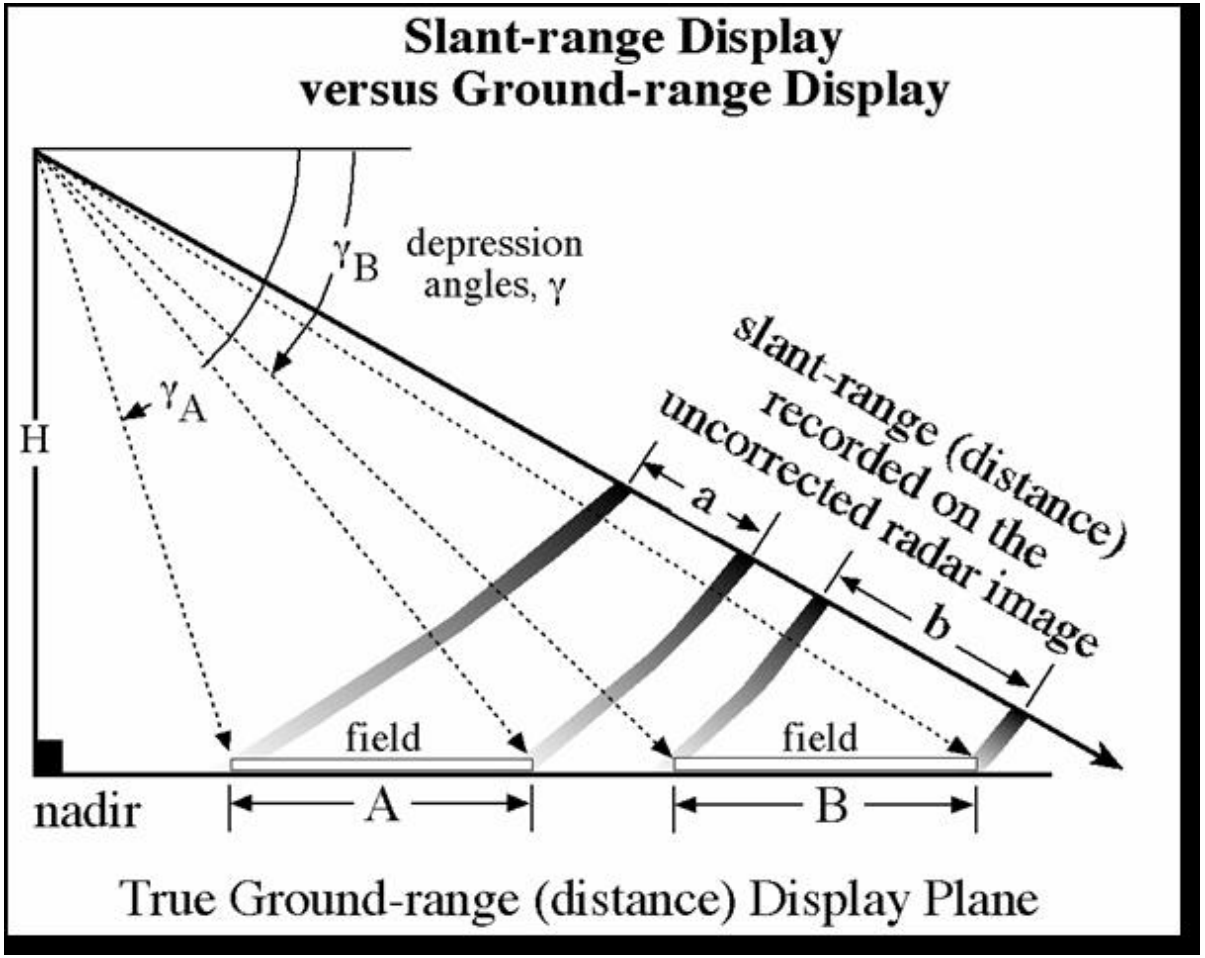
- azimuth flight direction
- look direction
- range (near and far)
- depression angle (γ)
- incidence angle (*θ=90-γ*)
- altitude above-ground-level, *H*



SAR geometry



Slant range vs ground range



- Radar imagery has a *different geometry* than that produced by most conventional remote sensor systems.
- Uncorrected radar imagery is displayed in what is called *slant-range geometry*, i.e., it is based on the actual distance from the radar to each of the respective features in the scene.
- It is possible to convert the slant-range display into the true *ground-range display* on the x-axis so that features in the scene are in their proper (x,y) position relative to one another in the final image.

Slant range vs ground range

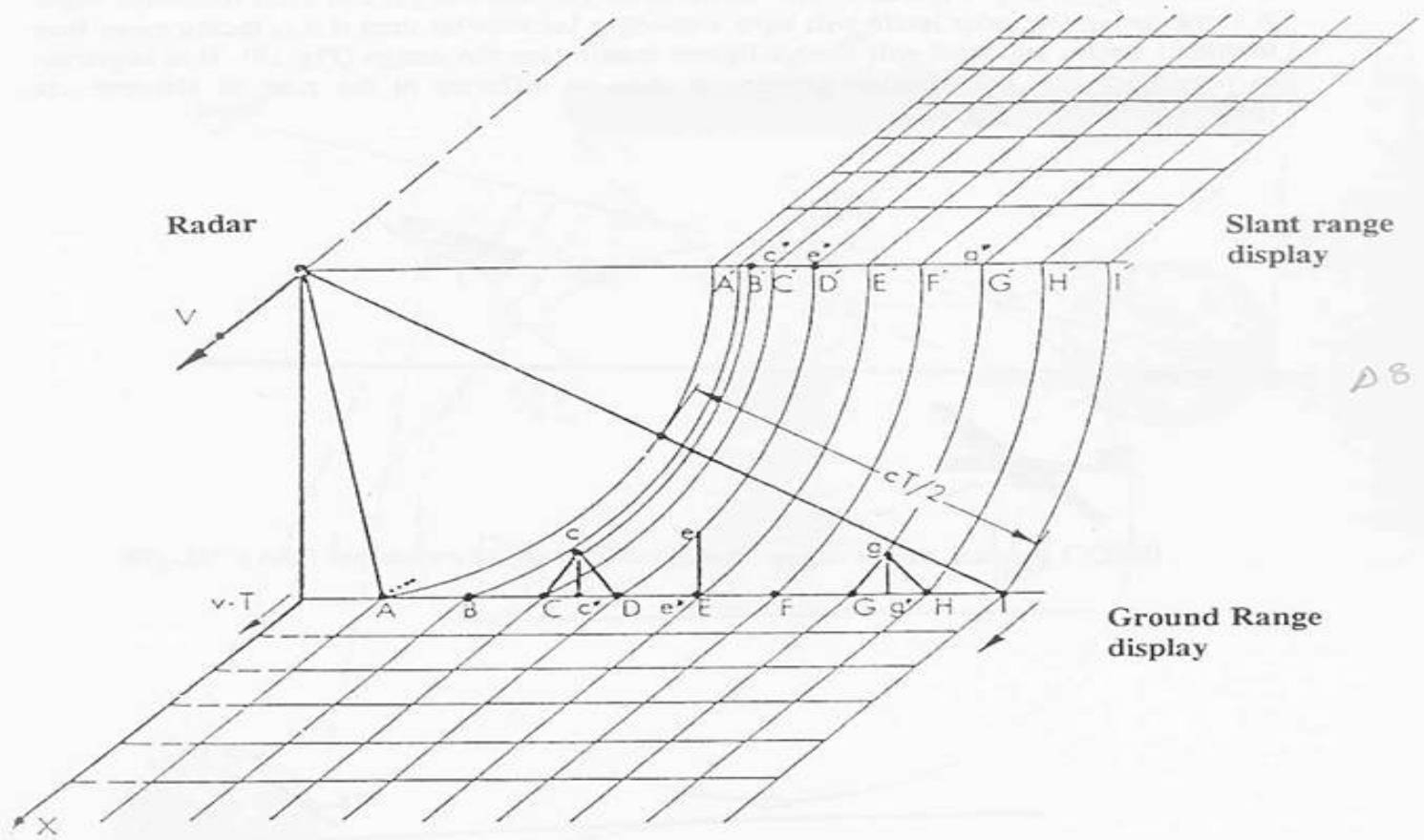


Fig.16: Two different types of display