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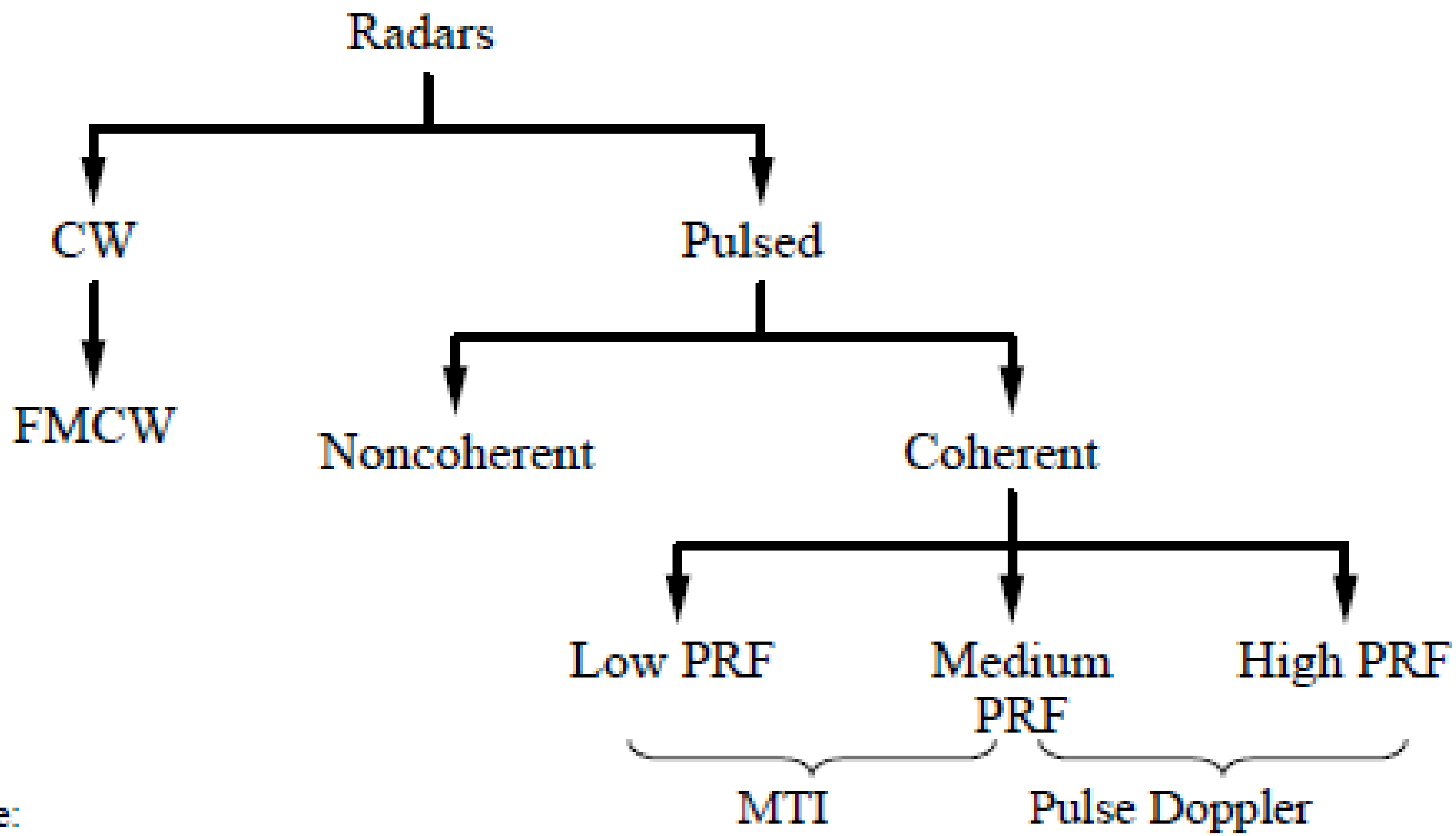
SLAR

Side-looking Airborne Radar

Introduction



Note:

CW = continuous wave
FMCW = frequency modulated continuous wave
PRF = pulse repetition frequency
MTI = moving target indicator

Radar classification

- Ground Based
- Airborne
- Space-borne
- Ship-borne

Based on Antenna type

- Phased Array ⇒

Based on frequency band

- HF
- VHF
- UHF
- L - Band
- S - Band
- C - Band
- X - Band
- Ku - Band
- K - Band
- Ka - Band
- mm Wave

Based on waveform utilized

- Continuous Wave (CW)
- Pulse Radar (PR)
  - *Low PRF*
  - *Medium PRF*
  - *High PRF* ⇒

Based on mission and/or functionality of the Radar

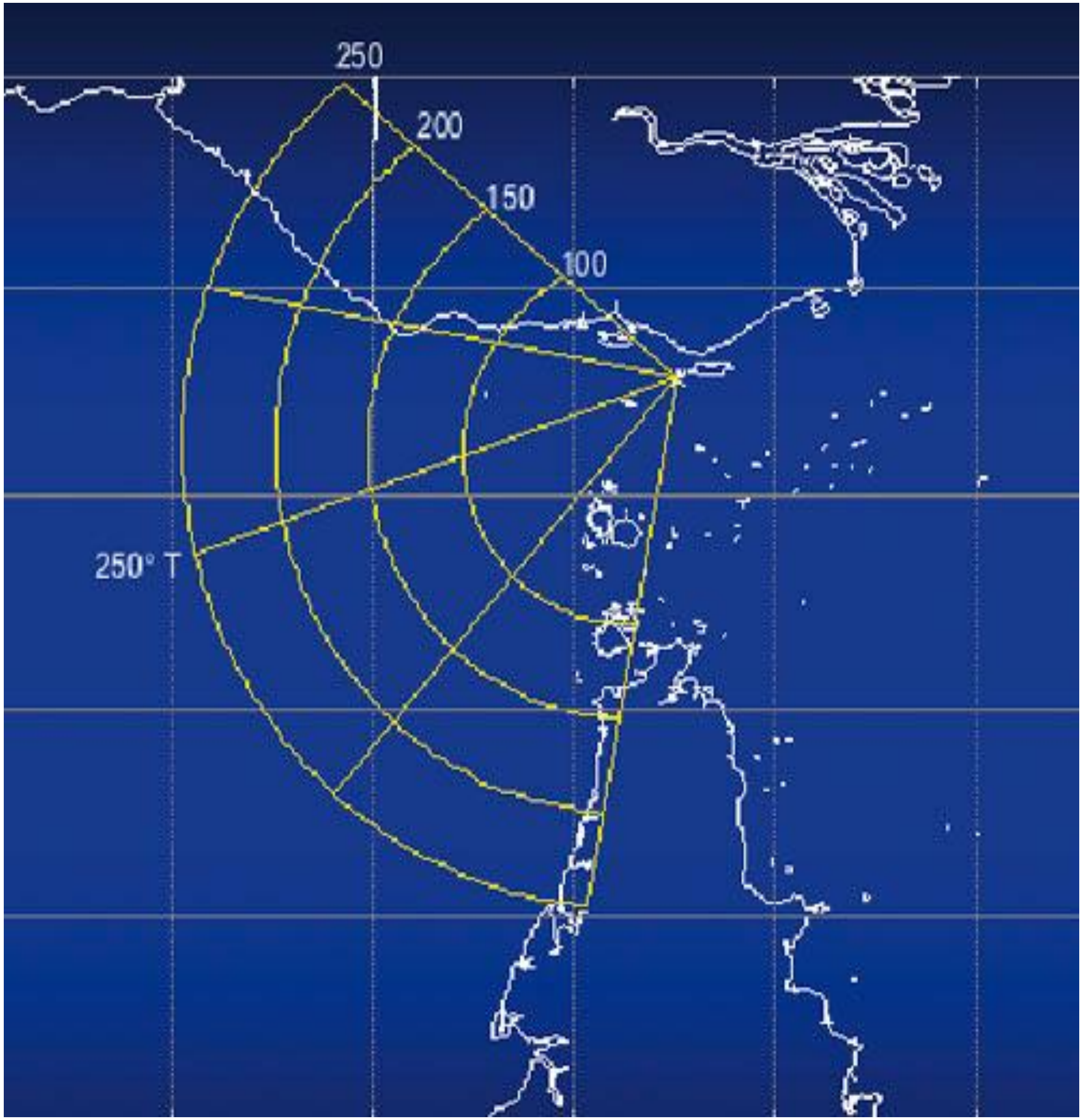
- Weather
- Acquisition & Search
- Tracking
- Track while -Scan
- Fire control
- Early warning
- Over the horizon
- Terrain following
- Terrain avoidance

- Mono static
- Bi - static ⇒

- Imaging
- Non-Imaging

Airborne Radar Applications

- Surveillance
- Early warning
- Remote Sensing
- Weapon Tracking
- Radar Altimeter
- Weather Monitoring
- Terrain Mapping



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Space-borne Radar: Radar System in Space

Applications

- Orbital Debris Detection
- Shuttle Radar
- Planetary Explorations

Design Considerations

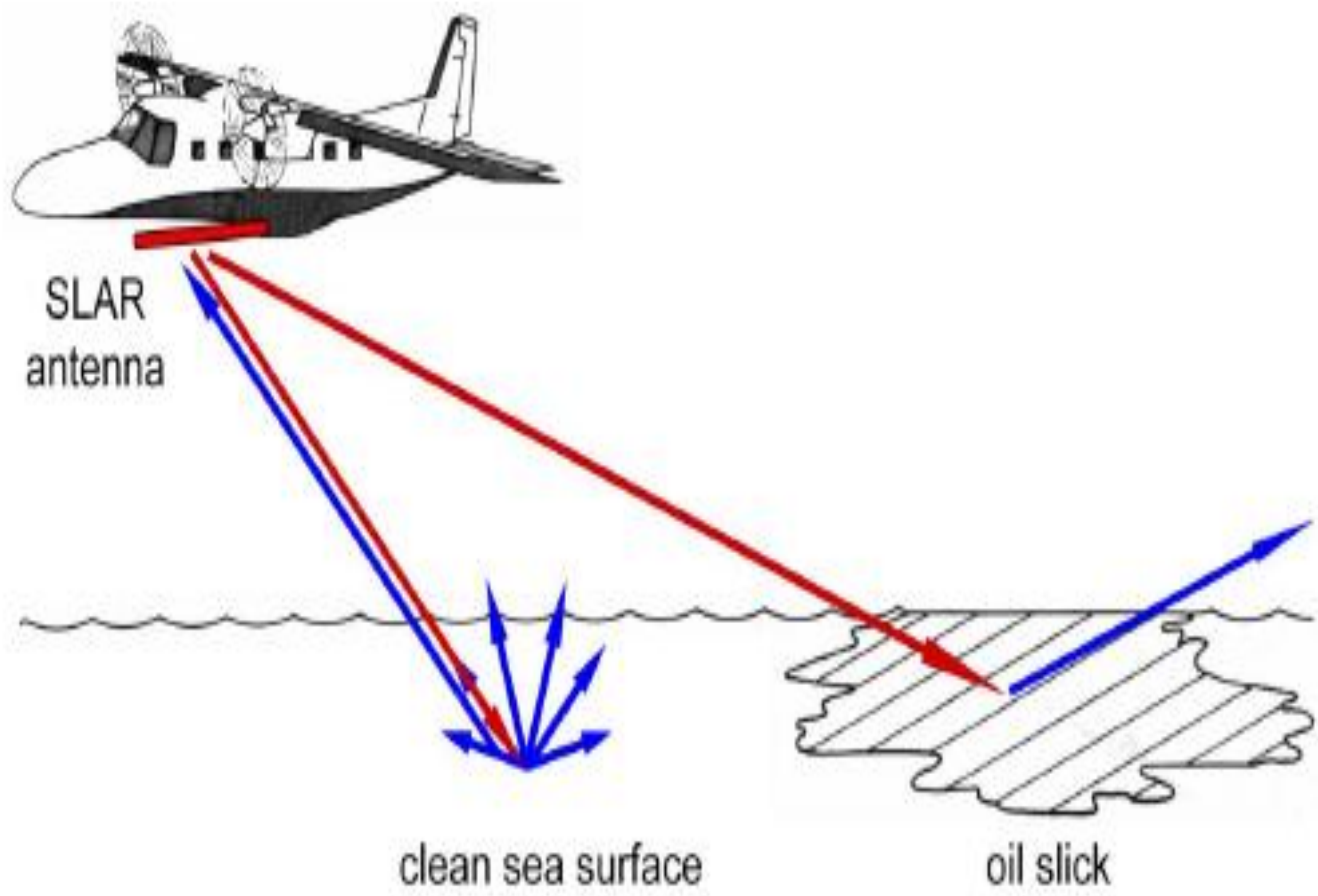
- Compact, low-cost, less weight
- Frequency Selection
- Ionospheric Effects
- Tropospheric Effects
- Antenna Type Selection
- Signal Type Selection

- Sea-sat launched in1978
    - Frequency L band
    - Swath width 100 km
    - Polarization HH
    - Ground Resolution 25 m x 25 m
- Shuttle Imaging Radar [SIR-A, SIR-B, SIR-C]
  - In 1991, European Space Agency launched a satellite :
    - ERS - 1 with a C band SAR sensor.
  - In 1992, Japanese JERS -1 launched satellite
    - JERS-1 with a L band radar

- Radarsat
  - In mid 1995, India launched Radarsat with SAR system which is very flexible in terms of configurations of
    - incidence angle,
    - resolution,
    - number of looks and
    - swath width.

Frequency	C band 5.3 GHz
Altitude	792 Km
Equatorial crossing	6:00 A.M.

Air-borne Radar



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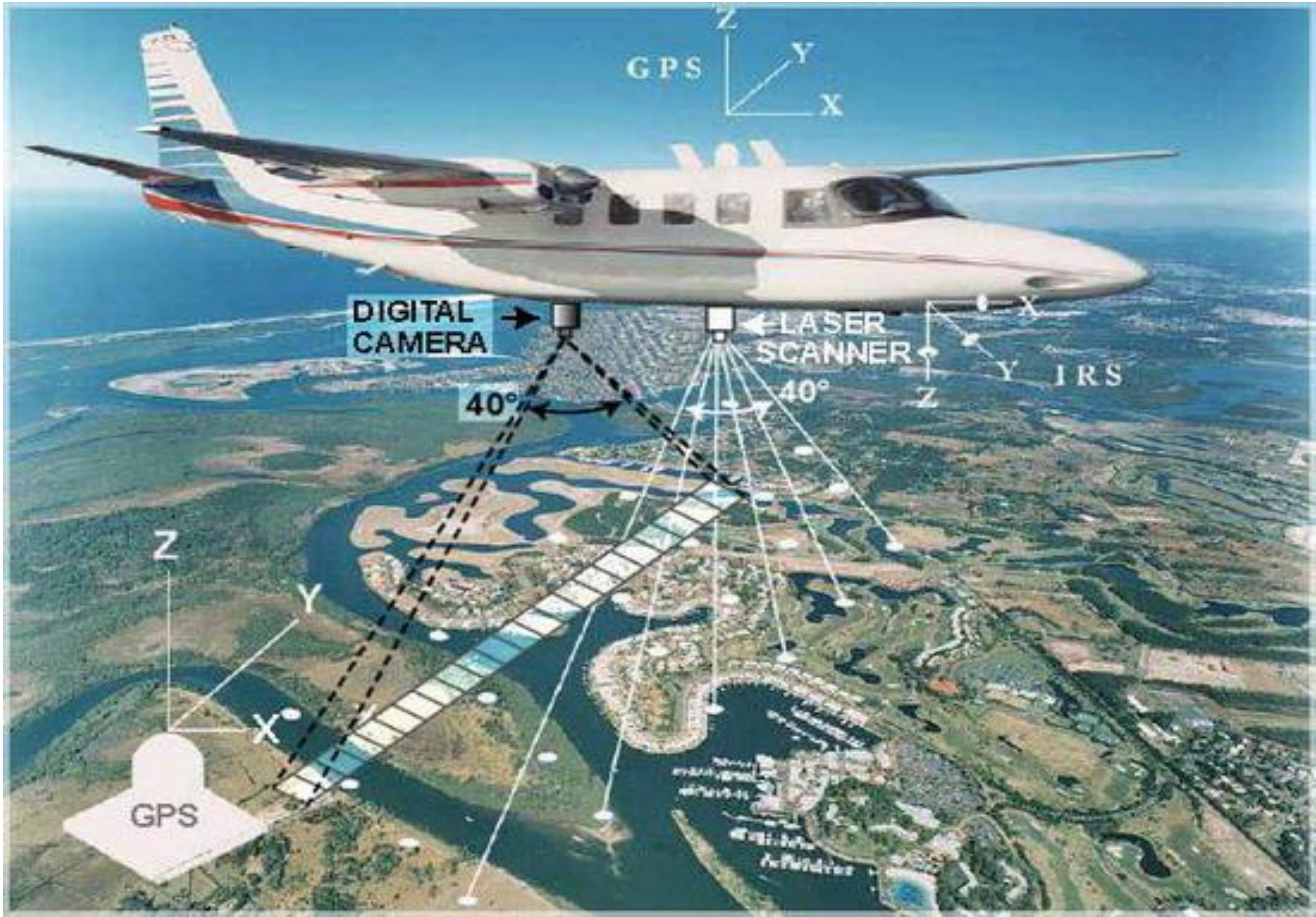

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Oil polution at sea - SLAR radar image and corresponding photo.

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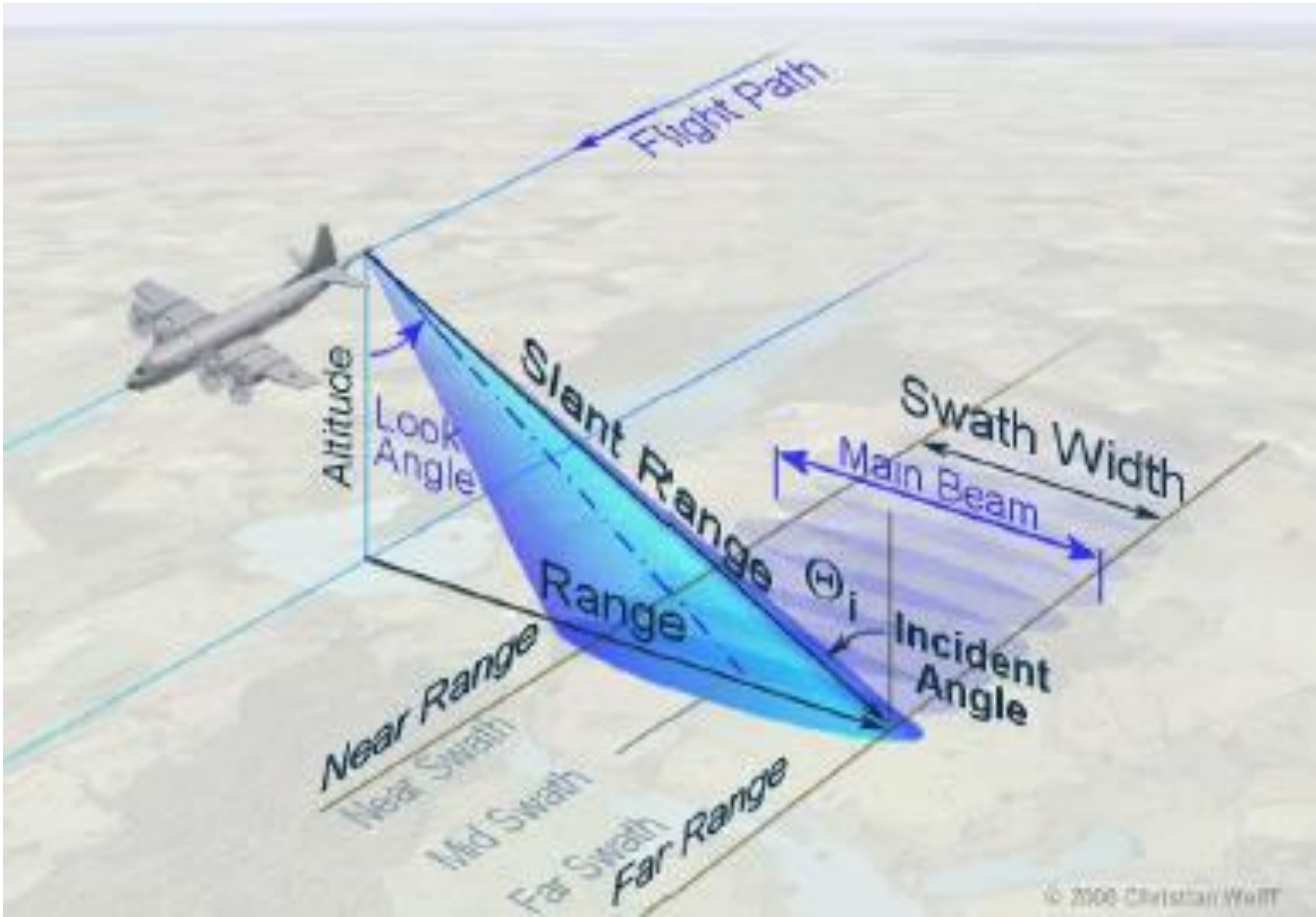
Flight Path
Altitude
Look Angle
Slant Range
Swath Width
Main Beam
Θ_i
Incident Angle
Range
Near Range
Near Swath
Mid Swath
Far Swath
Far Range
© 2006 Christian Wolff

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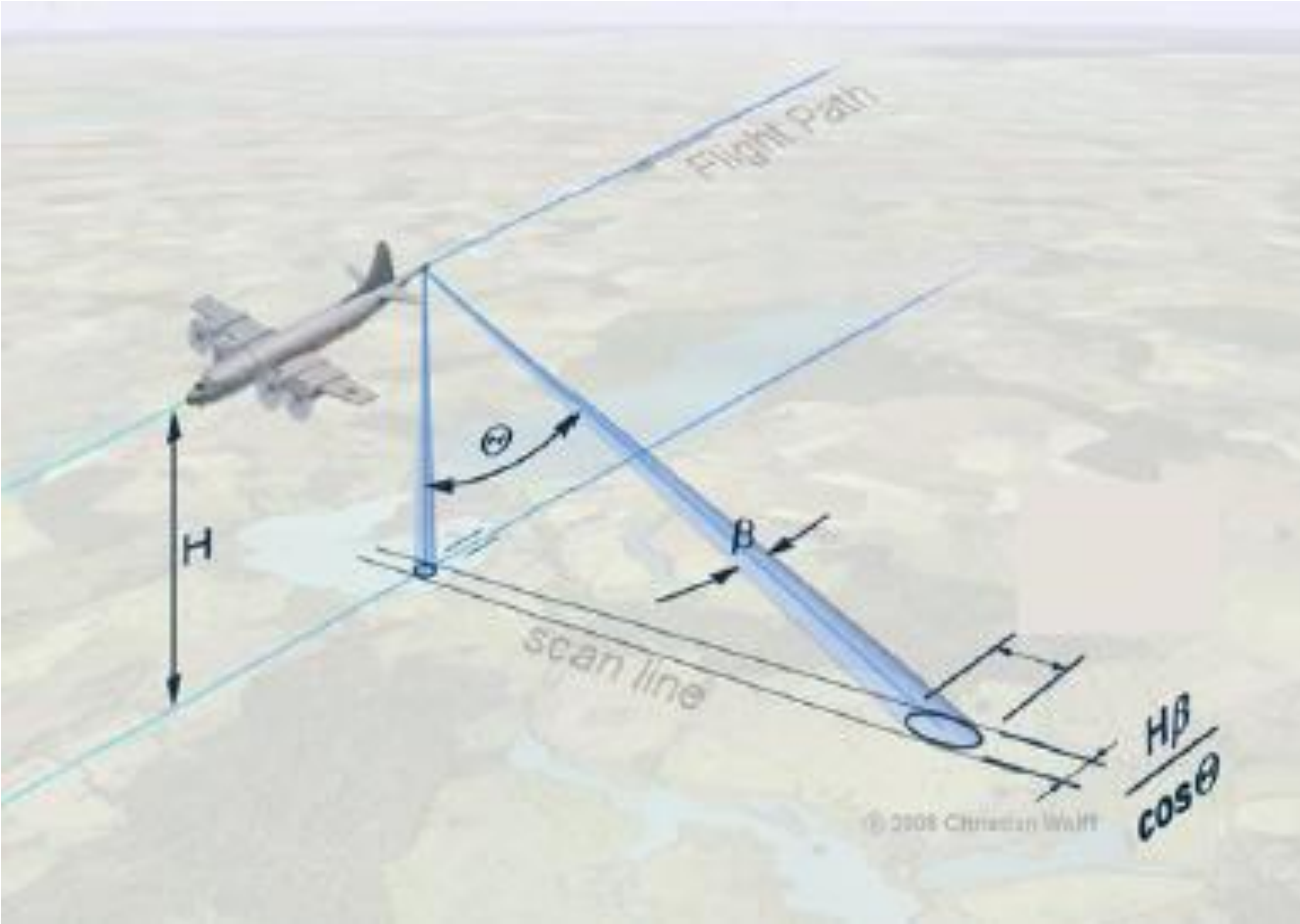

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Typical characteristics of airborne SLAR are:

- microwave frequency: f = 10 GHz
- microwave wavelength: λ = 3 cm
- radar pulse width: τ = 50 ns
- radar pulse peak power: P = 10 kW
- radar pulse repetition frequency: f = 50 Hz
- antenna length: L = 3 m
- antenna horizontal beamwidth: θ_a = 0.5°
- antenna vertical beamwidth: 50°

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Example :

For an SLAR with the following characteristics: λ = 1 cm, L = 3 m, H = 6000 m, θ = 60°, and pulse width = 100 ns.

Find resolutions.

R_a = 40 m and

R_r = 17.3 m

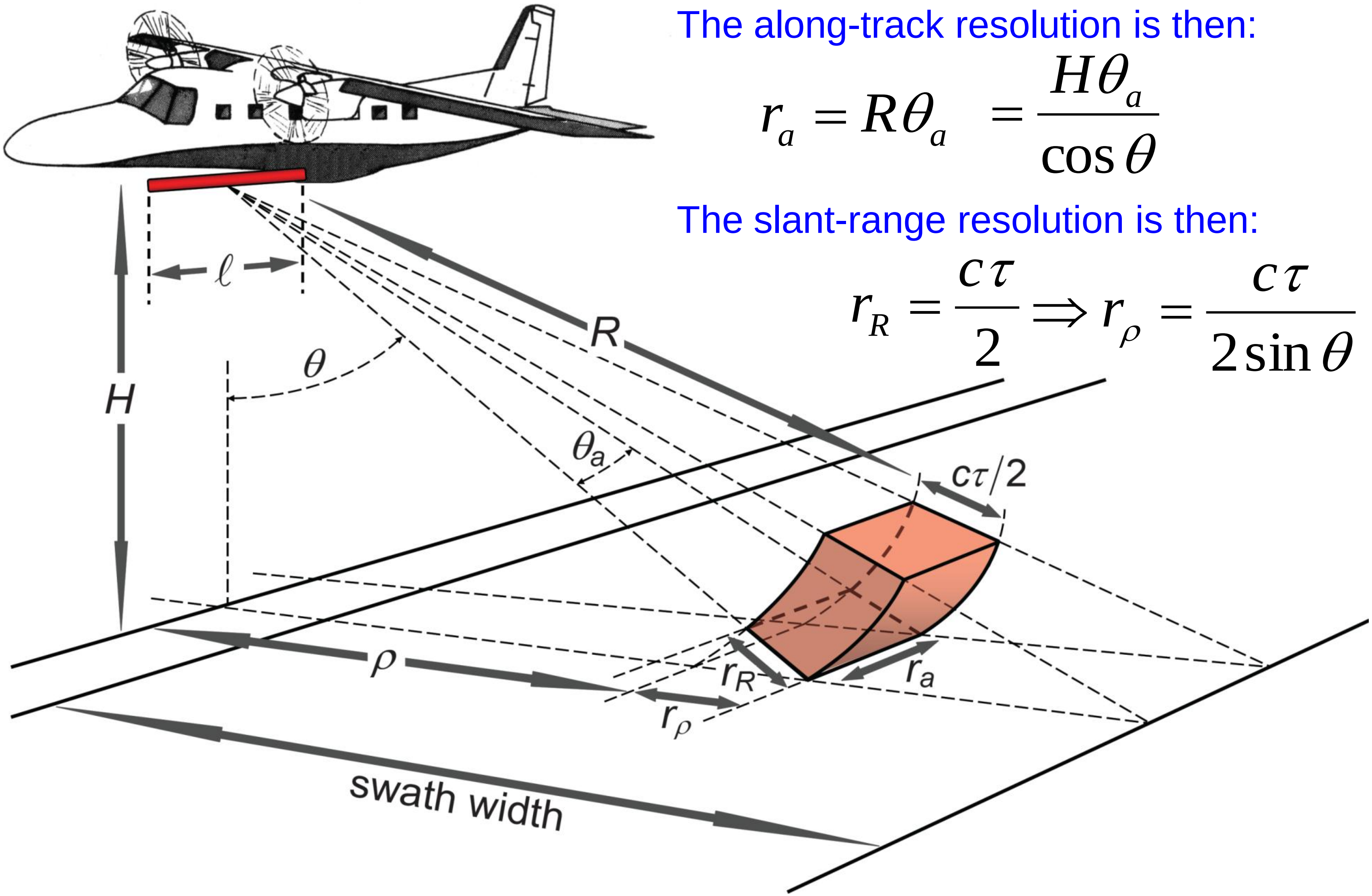
Note: The same SLAR on a platform in a height of 600 km would achieve an azimuth-resolution of R_a = 4000 m.

The along-track resolution is then:

$$r_a = R\theta_a = \frac{H\theta_a}{\cos\theta}$$

The slant-range resolution is then:

$$r_R = \frac{c\tau}{2} \Rightarrow r_\rho = \frac{c\tau}{2\sin\theta}$$



Geometry of SLAR operation and resolved surface area

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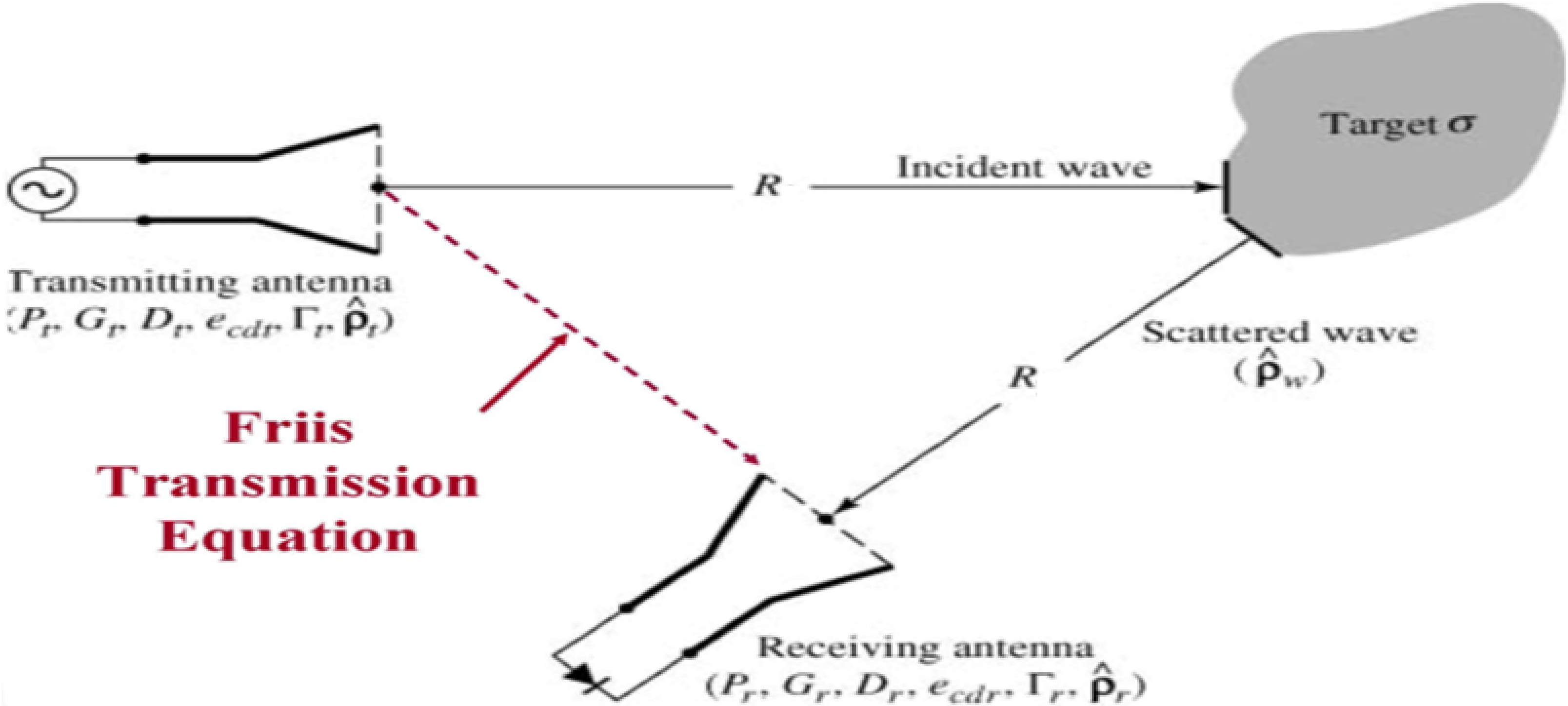
Radar Equation



$$\Rightarrow R_{\max} = \left[\frac{P_t(\omega)G_t(\omega)G_r(\omega)\lambda^2}{(4\pi)^3 L_t L_r L_p S_{\min}(\omega)}\sigma\right]^{1/4} = \left[\frac{P_t G_t G_r \lambda^2}{(4\pi)^3 k T_0 B F (S/N)_0 L_t L_r L_p}\sigma\right]^{1/4}$$

$$= \left[\frac{P_t G_t G_r \lambda^2}{(4\pi)^3 k T_0 B F (S/N)_n L_t L_r L_p}\sigma\right]^{1/4} = \left[\frac{P_t G_t G_r \lambda^2}{(4\pi)^3 k T_0 B F (S/N)_1 L_t L_r L_p}\sigma n E_i\right]^{1/4}$$

$$\Rightarrow R_{\max} = \left[\frac{P_t(\omega) G_t(\omega) G_r(\omega) \lambda^2}{(4\pi)^3 L_t L_r L_p P_r(\omega)} \sigma \right]^{1/4} \quad \Rightarrow P_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3 L_t L_r L_p R^4} \sigma$$

Where,

P_r: received power;

P_t : transmitted power;

G: antenna gain pattern;

R: distance of the target : Range,

σ: Radar Cross Section of the target (RCS) = σ_0*Area

σ_0: RCS per unit area = resolutions in x (azimuth) and y (range) directions

$$\Rightarrow P_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3 L_t L_r L_p R^4} \sigma_0 (r_a \times r_p) = \frac{P_t G^2 \lambda^2}{(4\pi)^3 L_t L_r L_p R^4} \sigma_0 \frac{H\theta_a}{\cos\theta} \times \frac{c\tau}{2\sin\theta}$$

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SLAR ANTENNA: Electrical specifications:

Horizontal Beam Width	≤ 0.6 deg
Vertical Beam Width	19 +/- 3 deg
Gain	33 dBi ± 1
Polarization	Vertical
Size	12 ft
Frequency	9.375 GHz ± 30 MHz

SLAR TRANSCEIVER: Electrical specifications:

Frequency	9375 ± 39 MHz
PRF	0-2000 Hz and Pulse Width 250 nsec ± 10 %
Magnetron Peak Power	27 KW Nominal (22 KW < Power < 32 KW)
Bandwidth	Adjusted for pulse width
Noise Figure	< 4,85 dB (typically 4.2 dB)
Supply voltage	20-30 V DC
Power consumption	< 126 W @ 250 ns pulse/300 kts

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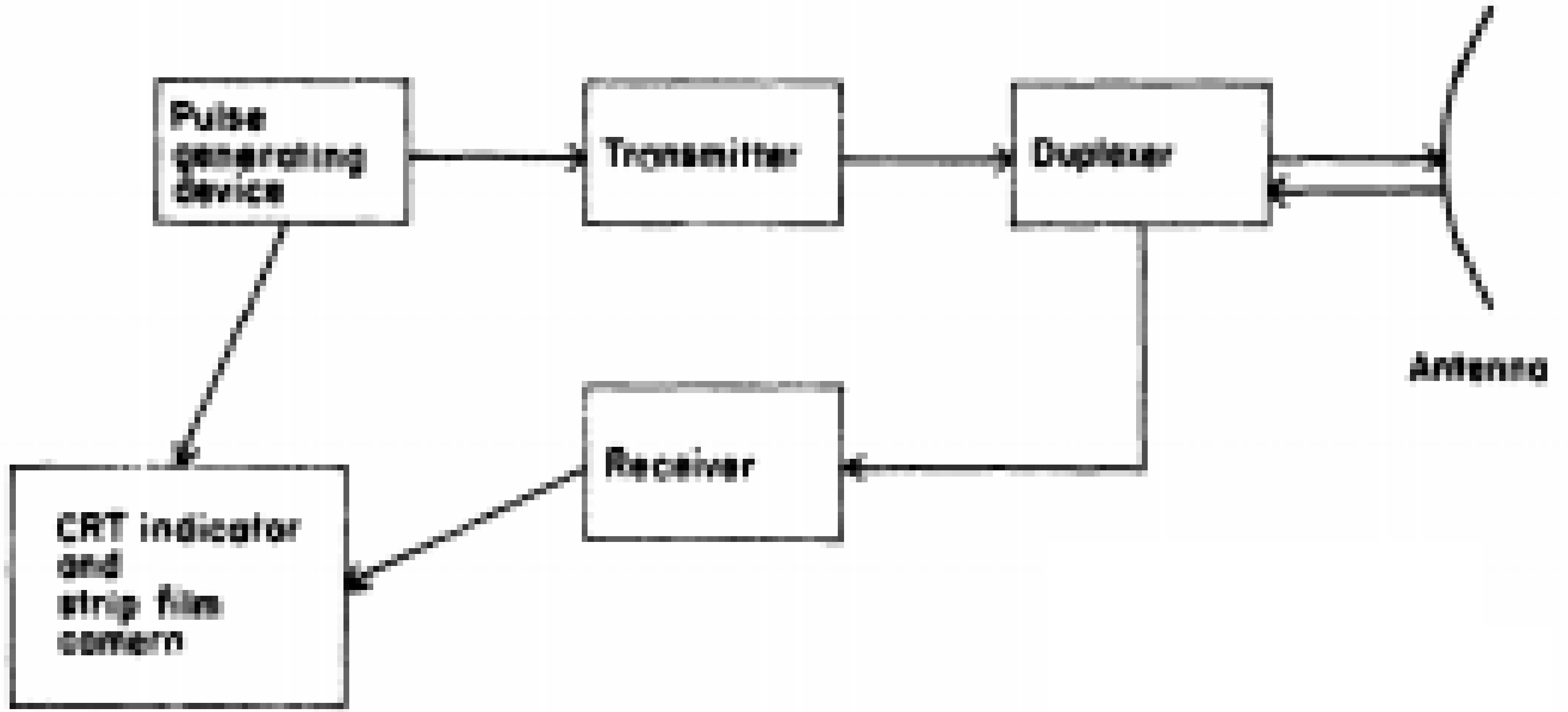
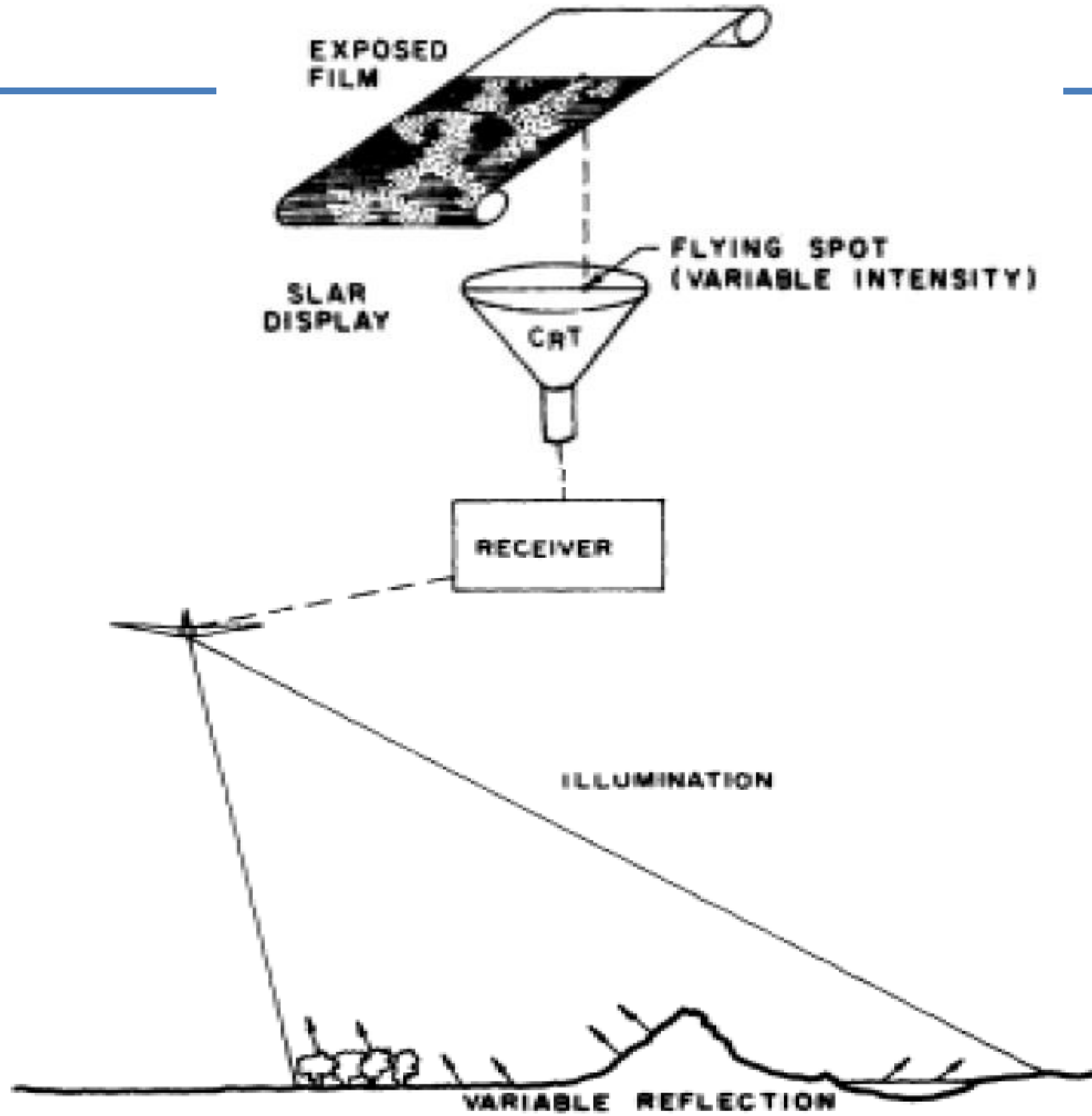
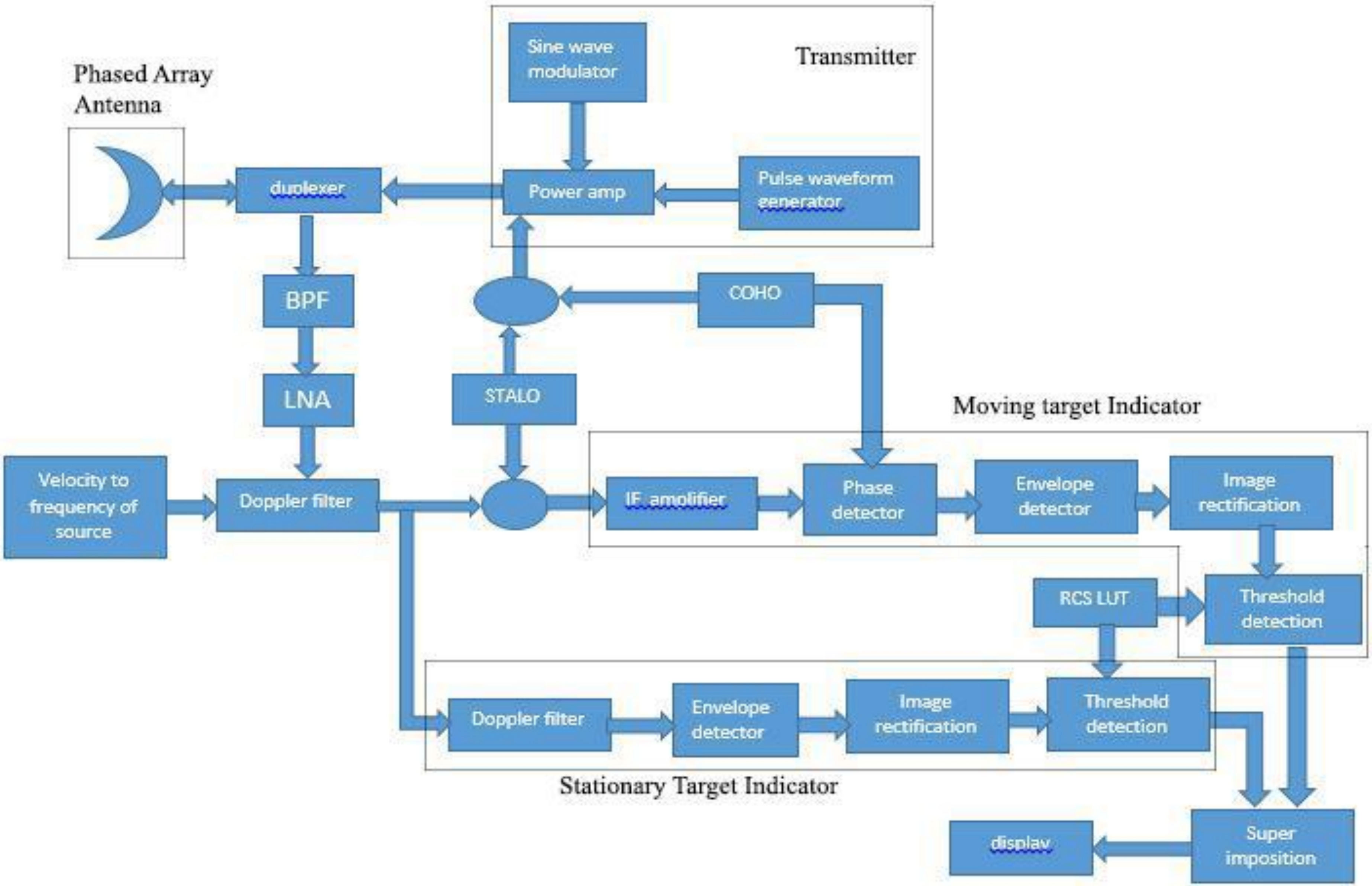
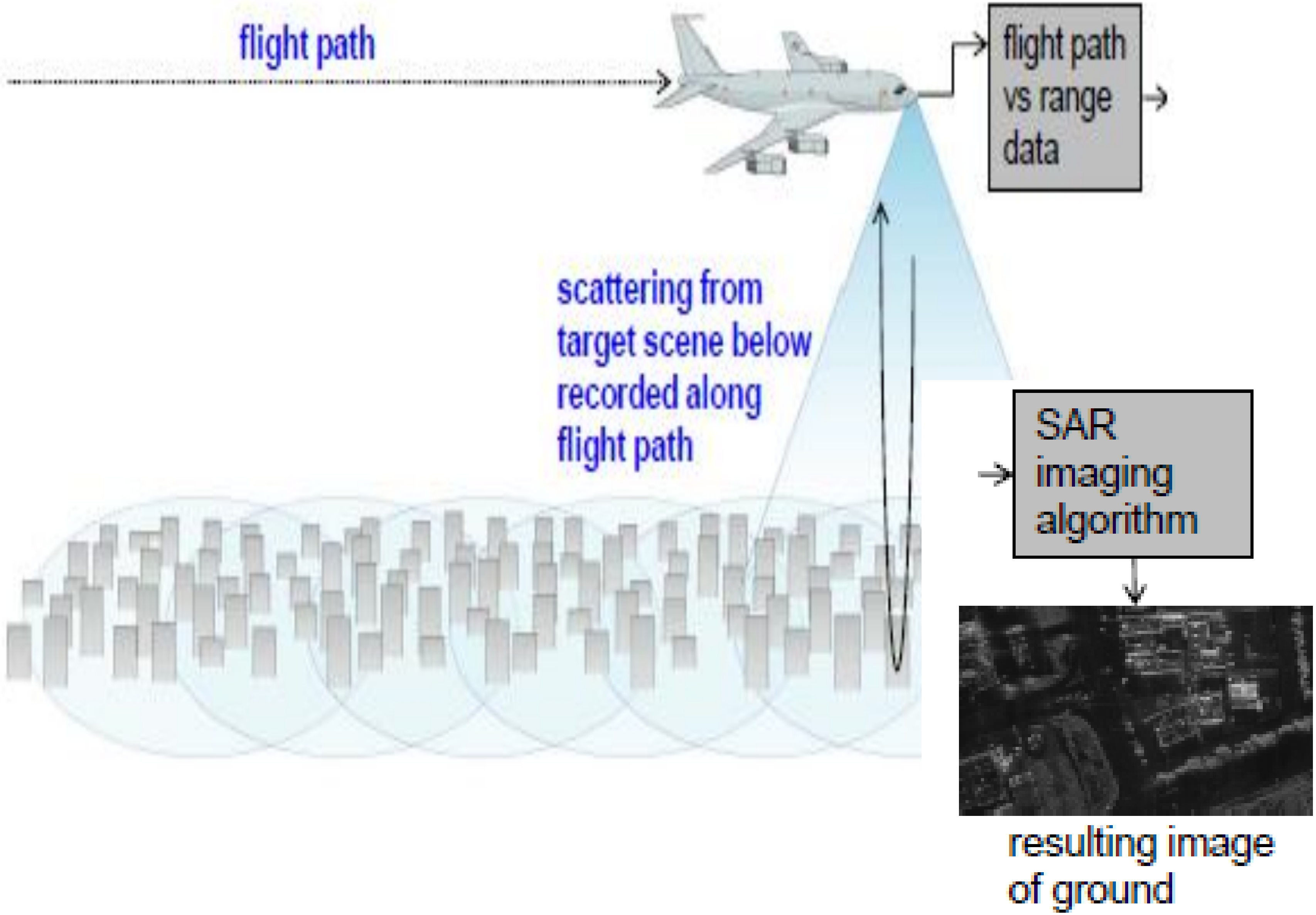
BLOCK DIAGRAM




EXPOSED FILM
FLYING SPOT (VARIABLE INTENSITY)
SLAR DISPLAY
CRT
RECEIVER
ILLUMINATION
VARIABLE REFLECTION


Transmitter
Sine wave modulator
Power amp
Pulse waveform generator
Phased Array Antenna
duplexer
BPF
LNA
COHO
STALO
Velocity to frequency of source
Doppler filter
Moving target Indicator
IF amplifier
Phase detector
Envelope detector
Image rectification
RCS LUT
Threshold detection
Doppler filter
Envelope detector
Image rectification
Threshold detection
Stationary Target Indicator
display
Super imposition

SAR: Synthetic Aperture Radar



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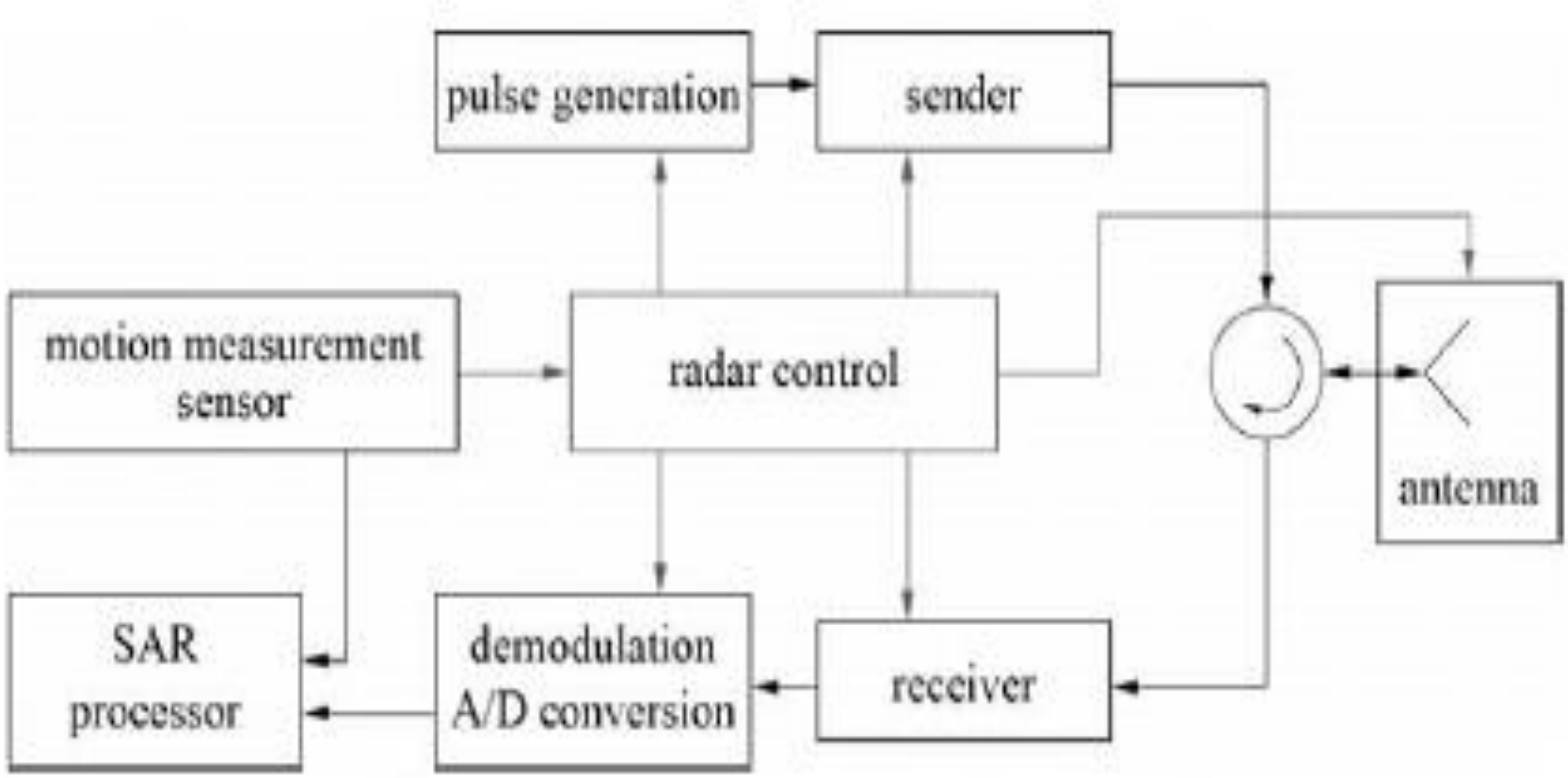
- Mostly airborne or space-borne, side-looking radar system
- Simulate a large antenna or aperture electronically
- Generates high-resolution remote sensing imagery



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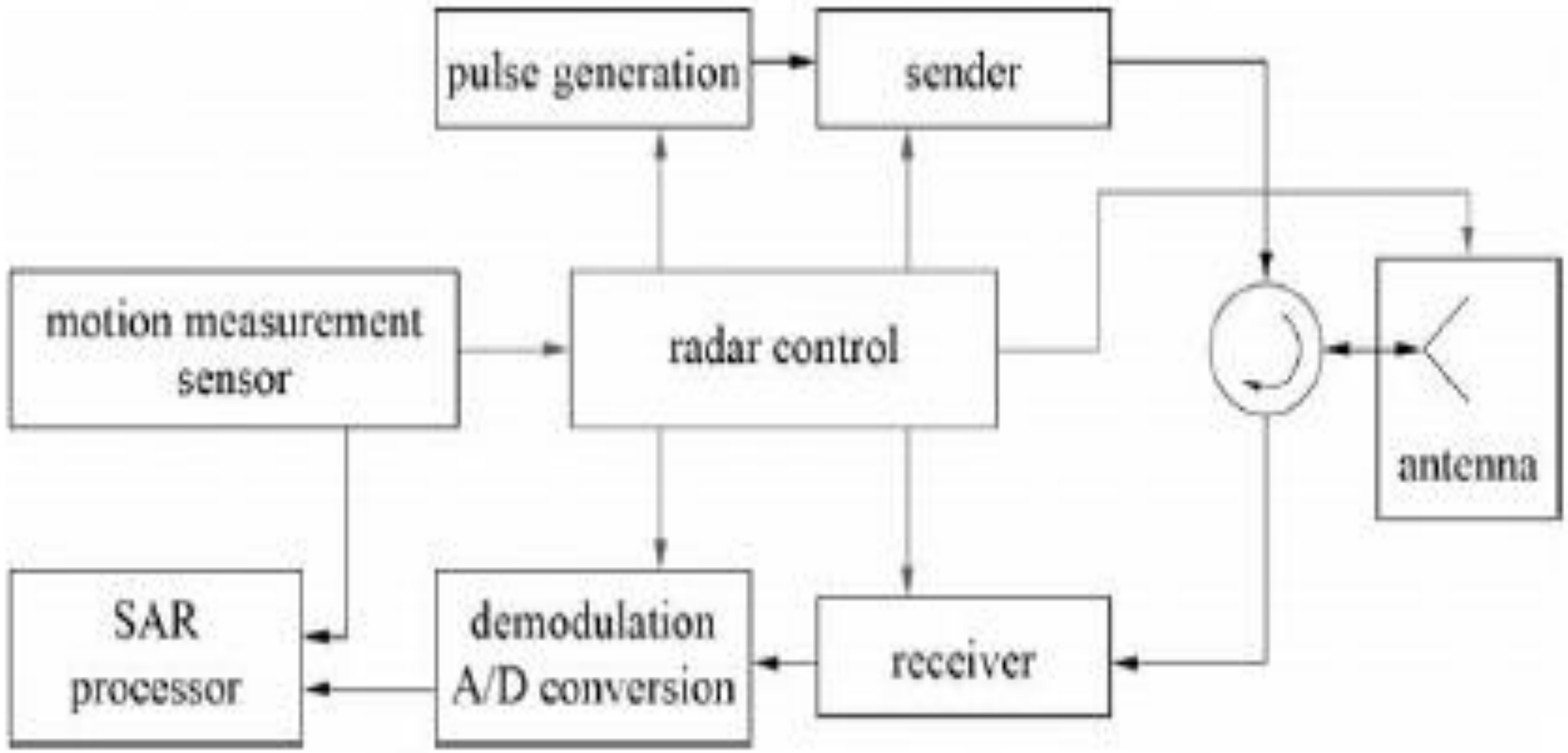

- Pulse generation creates pulses with a bandwidth according to the range resolution
- Sender amplifies the pulses and transfer it to the antenna via circulator
- Receivers amplifies the output signal of antenna and applies a band pass filter
- After the demodulation and A/D conversion, the SAR processor calculates the SAR image
- Radar control unit arranges the operation sequence particularly the time schedule

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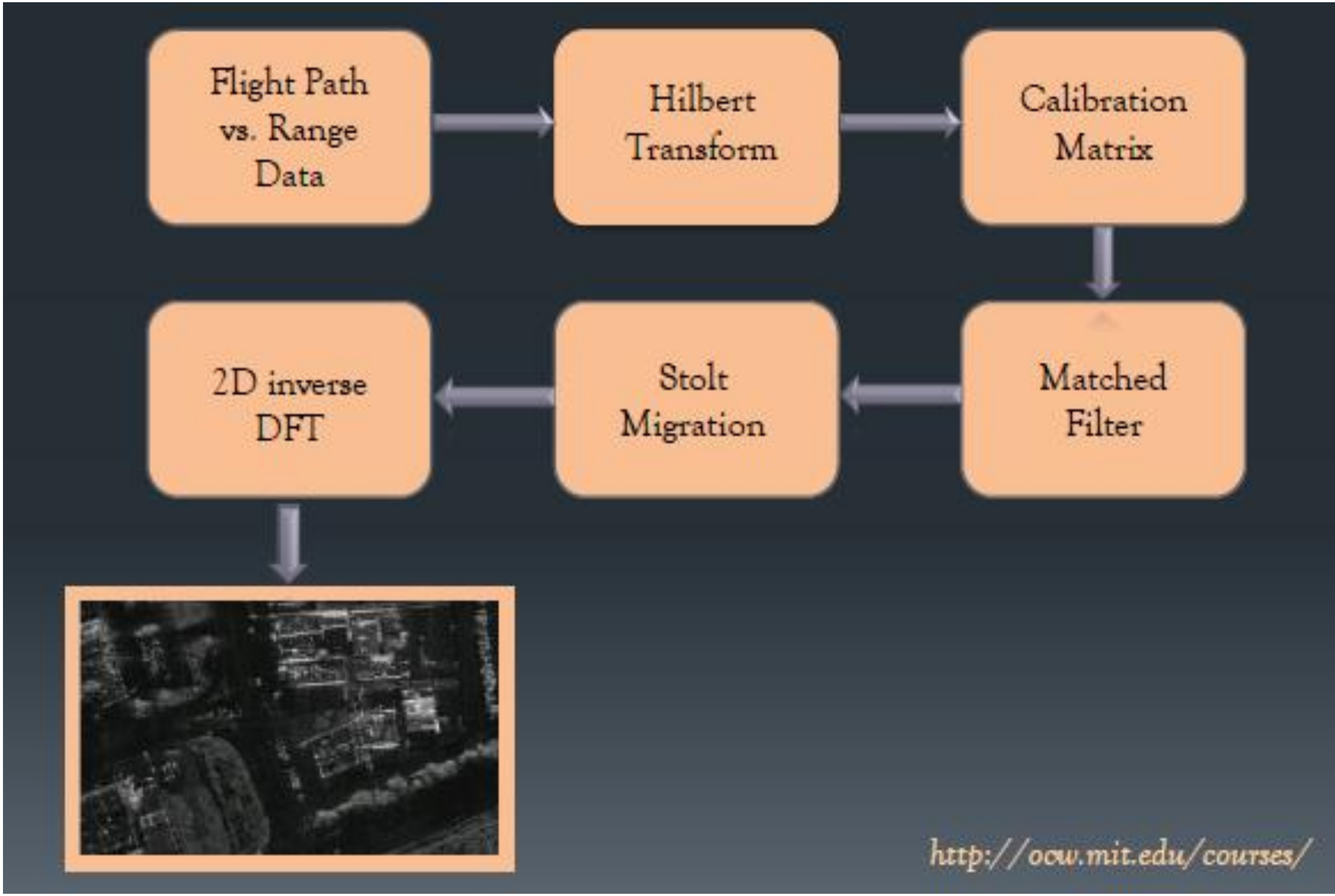
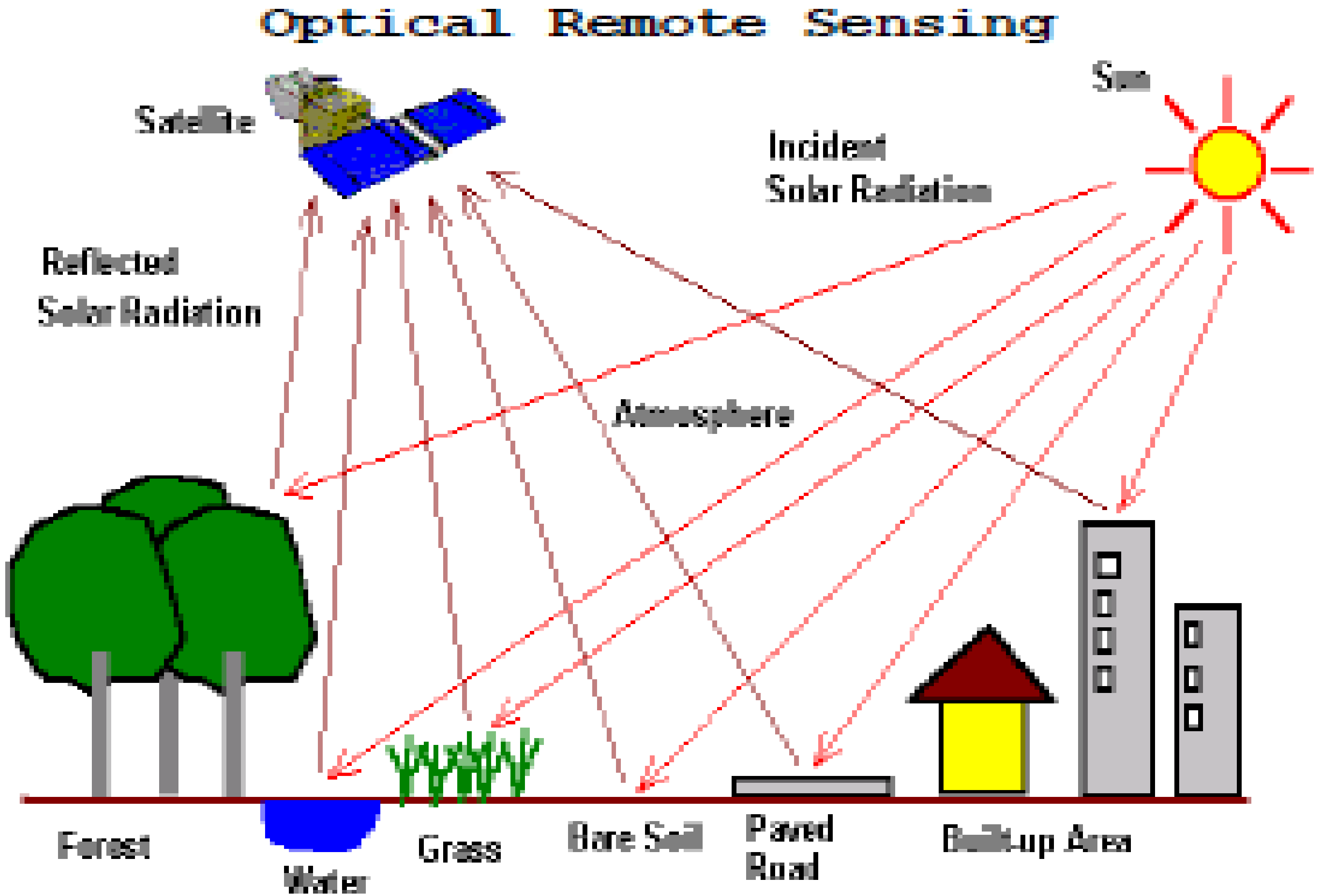

Flight Path vs. Range Data
Hilbert Transform
Calibration Matrix
Matched Filter
Stolt Migration
2D inverse DFT
http://ocw.mit.edu/courses/



Optical Remote Sensing
Satellite
Sun
Incident
Solar Radiation
Reflected
Solar Radiation
Atmosphere
Forest
Water
Grass
Bare Soil
Paved
Road
Built-up Area

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SAR vs. Optical Remote Sensing

- Independent of sun illumination
- Not affected atmospheric particles
- Accurate distance measurement
- Subsurface penetration
- Sensitivity to:
    - dielectric properties (water content, biomass, ice)
    - surface roughness (ocean, wind, speed)
    - man-made objects
    - target structure (structural details)