Active Microwave

Introduction to Remote Sensing

Chapter 7

Introduction

- Active Microwave Sensors → A sensor that broadcasts a directed pattern of energy to illuminate a portion of the Earth's surface, then receives the portion scattered back to the instrument.
- Active Microwave Sensors are not constrained by the time and weather condition, and can be used under a wider range of operational condition.

Active Microwave

- Active Sensors → Illuminate the ground with their own energy then record a portion of that energy reflected back to themselves.
- Passive Sensors → Sensitive to microwave energy emitted from the Earth's surface.

Active Microwave

- Active Microwave Sensors → Radar Devices
- Rudimentary Radar Components are Transmitter, Receiver, Antenna Array and recorder

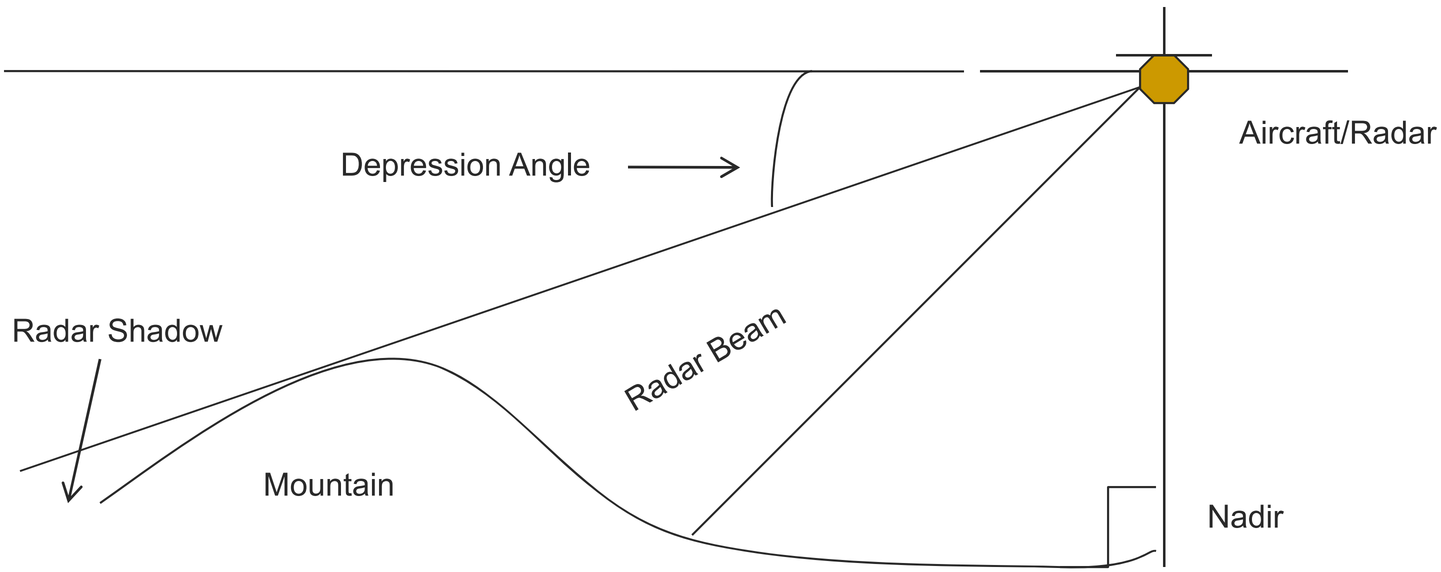
Side-Looking Airborne Radar (SLAR)

- Radar → Radio Detection and Ranging
- Radar unique abilities → Detects the distance between antena and objects, detects frequency and polarization shifts
- SLAR imagery is acquired by an antenna array aimed to the side of the aircraft, so that it forms an image strip of land parallel to and at some distance from the ground track of the aircraft
- SLAR unique abilities → Could penetrate any kinds of atmospheric condition, could be used at night (small portion of solar illumination) and has synoptic view of landscape.

Origins and History

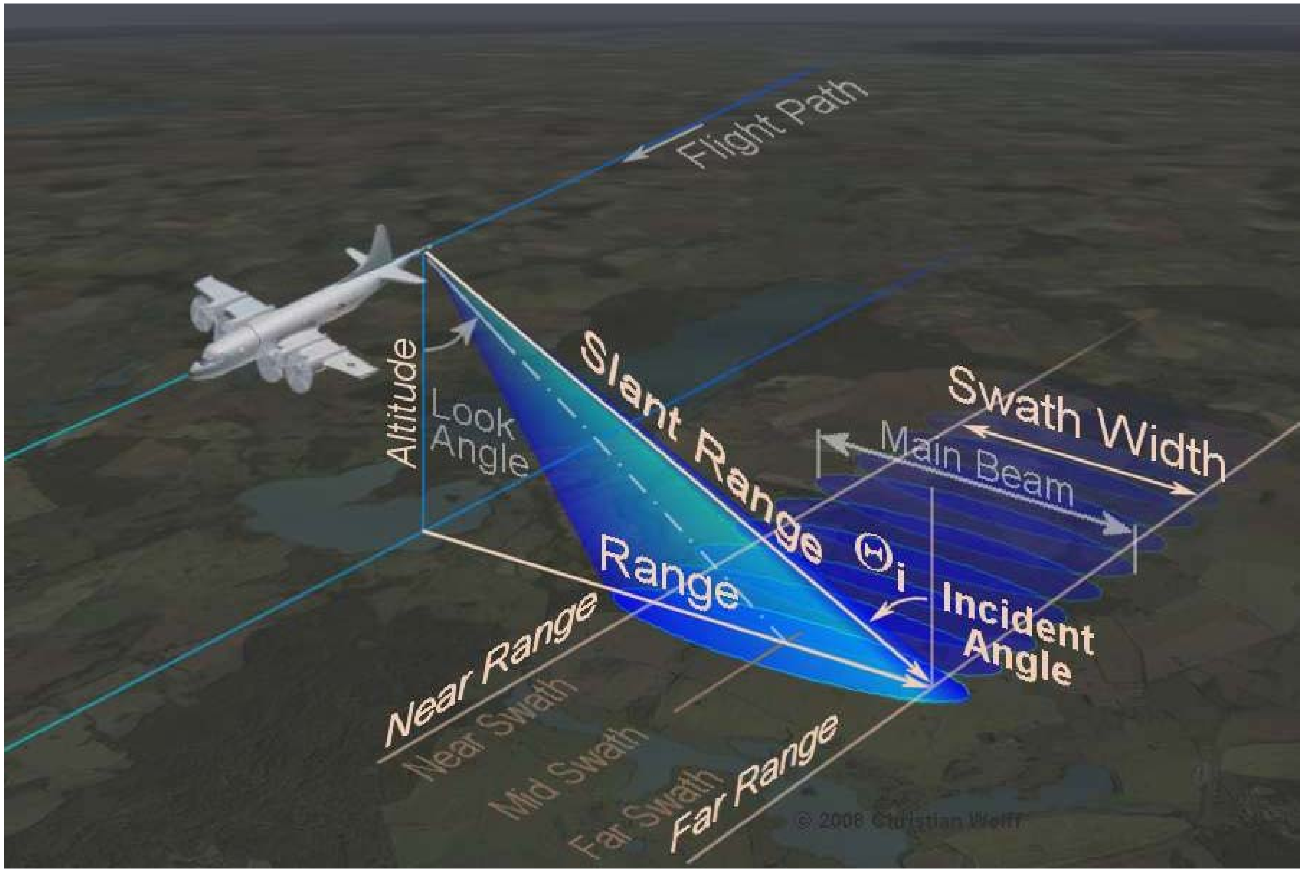
- James Clerk Maxwell (1831-1879) → Defined the essential characteristics of electromagnetic radiation
- Heinrich R. Hertz (1857-1894) → Studied properties and propagation of electromagnetic energy in microwave and radio portions of the spectrum, demonstrated reflection of radio waves from metallic surfaces
- Guilielmo M. Marconi (1874-1937) → Devising a practical antenna suitable for transmitting and receiving radio signals, demostrated the feasibility of long-range communication
- A.H. Taylor and L.C. Young (1922) → Conducted experiments with high frequency radio transmitter and started the beginning of radar era

Geometry of The Radar Image

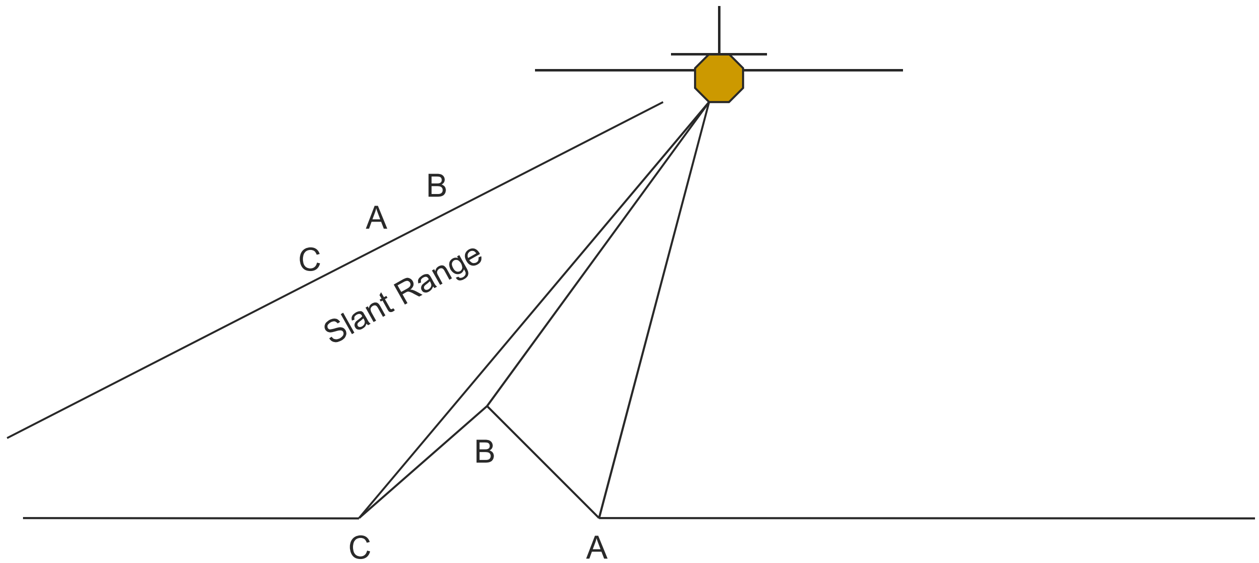


- Depression angle → An angle formed by upper edge of radar beam and horizontal line extended from the aircraft

Geometry of The Radar Image

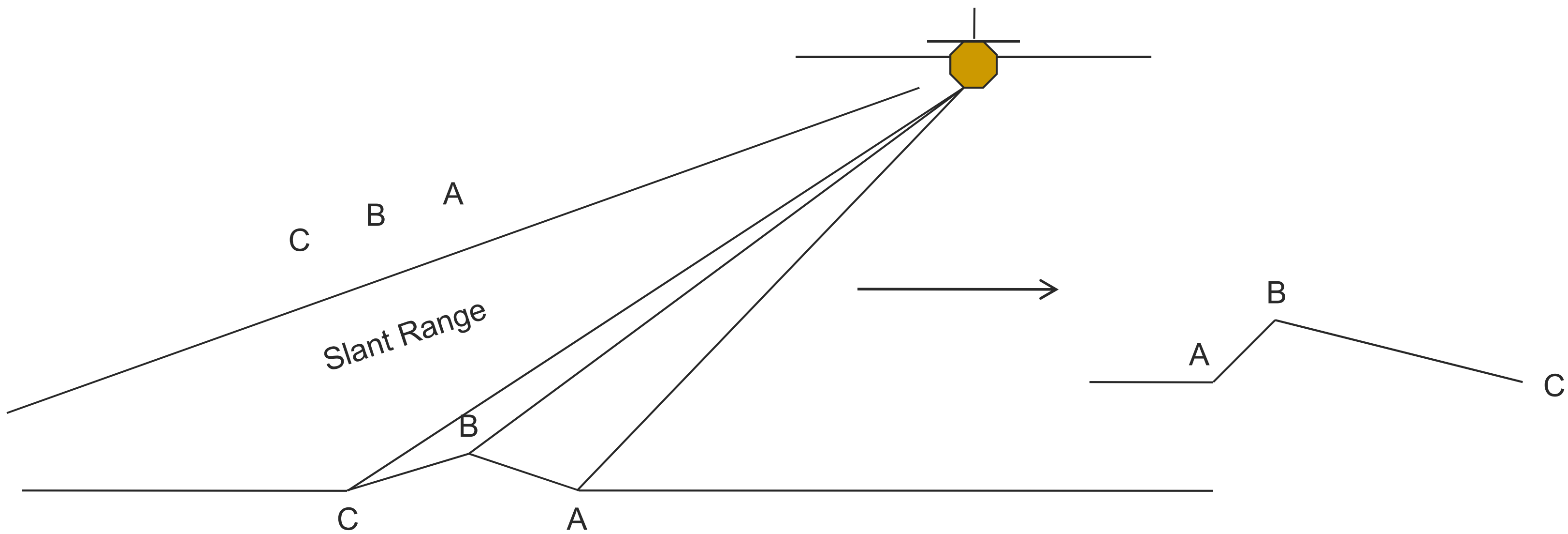


Radar Layover



- A is closer to the aircraft than B, and B is closer to aircraft than C. However, the radar shows that B is closer to aircraft than A.

Radar Foreshortening



- Ground range AB = BC, but appears that AB is closer (steep) than BC (shallow)

Wavelength

Band	Wavelength
P-Band	107-77 cm
UHF	100-30 cm
L-Band	30-15 cm
S-Band	15-7.5 cm
C-Band	7.5-3.75 cm
X-Band	3.75-2.40 cm
Ku-Band	2.40-1.67 cm
K-Band	1.67-1.18 cm
Ka-Band	1.18-0.75 cm

- Airborne imaging radars usually use C-, K-, and X-Band
- Satellite imaging radars usually use L-Band
- For real aperture imaging radars, spatial resolution improves as wavelength become shorter with respect to antenna length
- Greatest penetration gives by the longer wavelength

Penetration of The Radar Signal

- Skin depth → The depth to which the strength of a signal is reduced to 1/e of its magnitude (37%)
- Longer Wavelength → Skin depth increase
- Steeper angle (Near range edge)→ Greater Penetration
- The difficulties for image interpreter → How to distinguish penetrated effect and normal backscatter effect

Polarization

- Polarization → The orientation of the field of electromagnetic energy emitted and received by the antenna
- Radar polarization → Like-polarized mode (HH/VV) and Cross-polarized mode (HV/VH)
- Cross-polarized mode used to identify features and areas that represent regions on the landscape that tend to depolarized the signal
- Depolarization are related to physical and electrical properties of the ground

Look Direction and Look Angle

- Look direction → The direction at which the radar strikes the landscape.
- Look direction perpendicular to topographic alignment will maximize radar shadow and vice versa with the parallel one.
- Look angle → The depression angle of the radar
- Sensitivity of the signal to the ground moisture is increased as depression angle become steeper.
- Slant range geometry of radar image → all landscapes are viewed at oblique angles, thus there will be many variations of images for the same area.

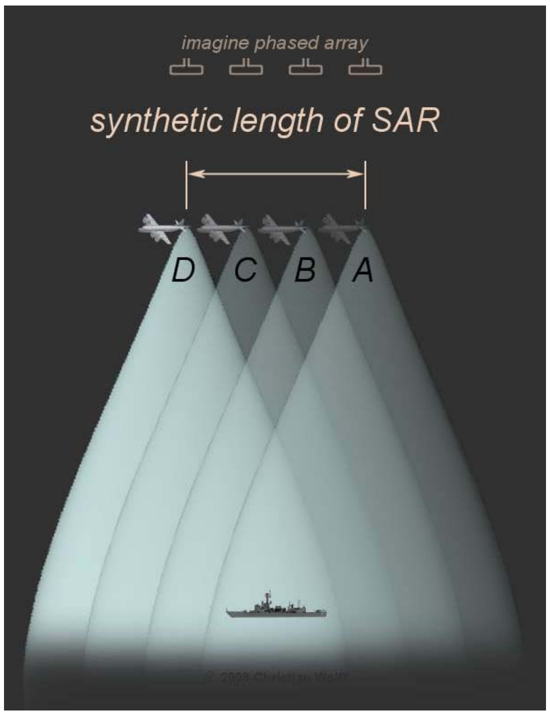
Real Aperture Systems

- Real Aperture SLAR systems → Oldest, Simplest and least expensive of imaging radar system.
- The resolution of real aperture system controlled by the focus of transmitted signal illuminated to the ground, antenna length and wavelength
- Resolution, antenna length and wavelength relation :

$$\beta=\lambda/A$$

- Real aperture systems can be designed to attain finer-long track resolution by increasing the length of antenna and decreasing the wavelength
- Shorter pulses → Can distinguish two or more different close objects

Synthetic Aperture System



- Synthetic Aperture Radar Systems (SAR) → More complex and expensive, but can overcome some limitations of Real Aperture System.
- SAR System receives the signal scattered from the landscape during scanning interval and saves the complete history of reflections from each object.
- Complexity of SAR could be solved by applying the Doppler Effect principle, by detecting the shift of frequency to the distance of aircraft and the object.

Interpreting Brightness Value

- Radar Images Brightness → The variations of landscape features and properties
- Radar Equation :

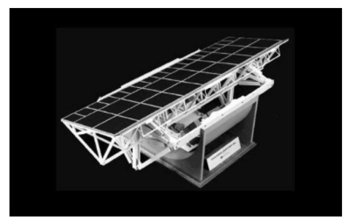
$P_r = (\sigma G^2 P_t \lambda^2)/((4\pi)^3 R^4)$

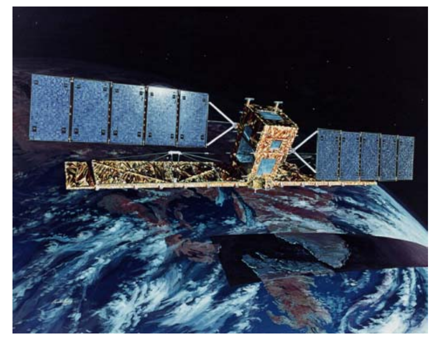
Interpreting Brightness Value

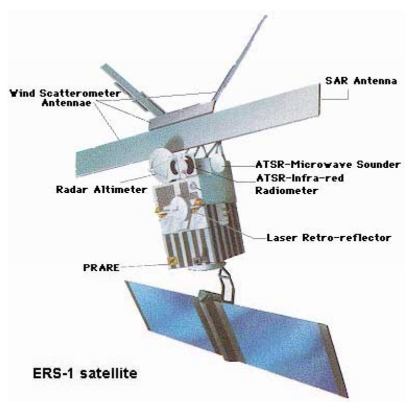
- Moisture in the landscapes influences the backscattering coefficient through changes in the dielectric constant of landscape materials.
- If the surface is homogeneous with respect to its electrical properties and ‘smooth’ with respect to the wavelength of the signal , then the reflected signal will be reflected at an angle equal to the incidence angle.
- Surface appears rougher as wavelength become shorter and will act as smooth scatterer as incidence angle become greater.
- Corner reflector is an effect caused by the complex reflection of the radar signal directly back to the antenna in a manner analogous to a ball that bounces from the corner of a pool table directly back to the player. Its usually can be found around urban area.

Satellite Imaging Radars

- Seasat Synthetic Aperture Radar
- Shuttle Imaging Radar-A
- Shuttle Imaging Radar-B
- Shuttle Imaging Radar-C/X-Synthetic Aperture Radar System
- European Resource Satellite Synthetic Aperture Radar
- RADARSAT Synthetic Aperture Radar
- Japanese Earth Resources Satellite 1
- Envisat







Radar Interferometry

- Radar Interferometry → Comparing two or more images of radar images to get more detailed features/topography.
- Radar Interferometry could be done by using two or more antenna to acquire image at different time.
- Radar Interferometry products → Temporal Baseline and Spatial Baseline
- Shuttle Radar Topography Mission (SRTM) →Application of radar interferometry that can accurately produce digital topographic data for very large portion (80%) of the earth.

Summary

- Radar Imagery is very useful to provide more detail topography data which can not possibly get by aerial photography.
- Radar Imagery and Aerial Photography could be combined to acquire more detailed data.