Bharathidasan University

Tiruchirappalli, Tamil Nadu

Programme: M. Tech Geoinformatics

Course: Microwave and Hyperspectral Remote Sensing

Title: IMAGE PROCESSING OF MICROWAVE DATA

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IMAGE PROCESSING OF MICROWAVE DATA :

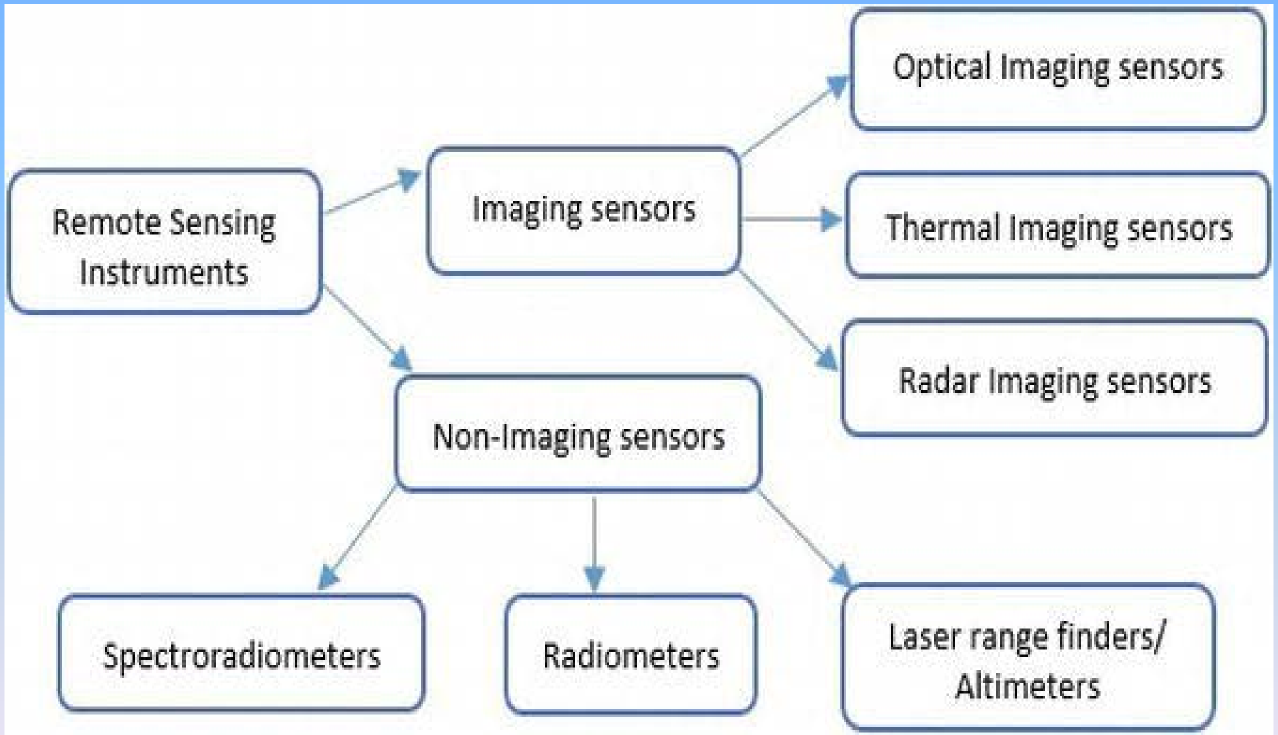
Contents

- imaging and non-imaging instruments
- interaction with earth surface
- Surface scattering
- emission , resolution concepts

INTRODUCTION

- **Microwave imaging is a science which has been evolved from detecting /location techniques (radar) in order to evaluate hidden or embedded objects in a structure using electromagnetic waves in microwaves regime .**

Remote Sensing Sensor



Imaging & Non-Imaging Instruments

Imaging Instruments

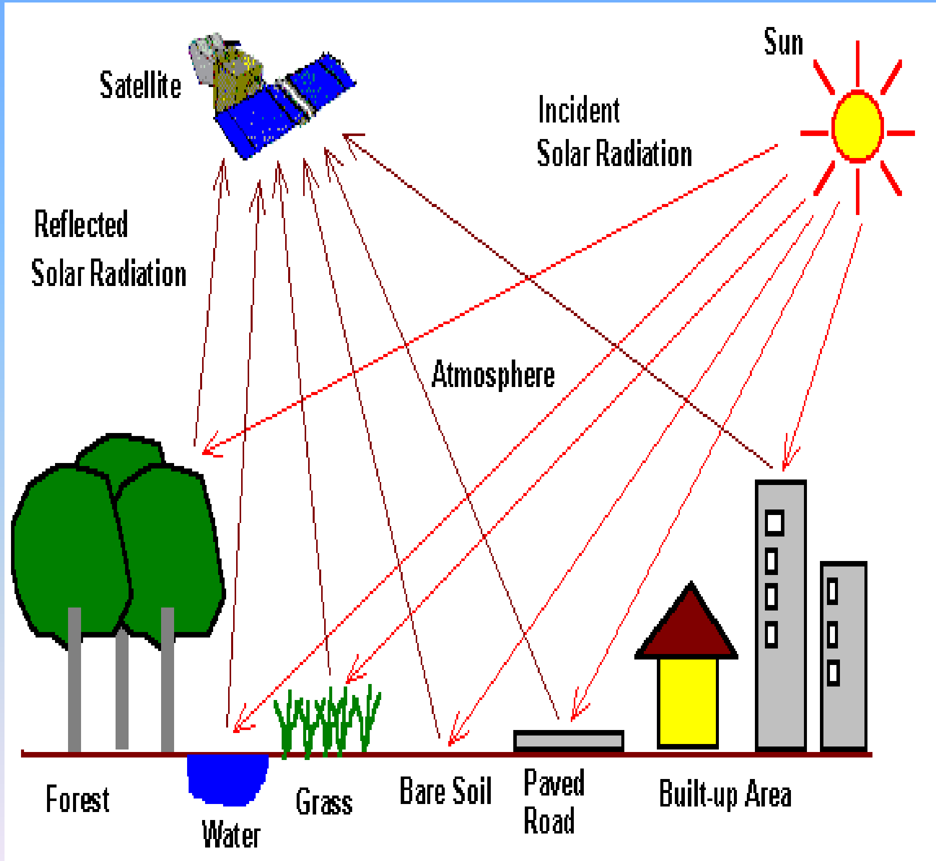
Imaging active microwave sensors in imaging radar .The Radar is an acronym for Radio Detection and Ranging .Which essentially characterizes the function and operation of a radar sensor .

Non-Imaging Instruments

Non-Imaging microwave sensors include altimeters and scatterometers .In most cases ,these are profiling devices which take measurements in one linear dimension , as opposed to the two-dimensional representation of imaging sensors .Radar altimeters transmit short microwave pulses and measure the round trip time delay to targets to determine their distance from sensor .

Optical Imaging Sensor

Optical imaging sensor makes use of visible ,near infrared and short-wave infrared sensors to form images of the earth's surface by detecting the solar radiation reflected from targets on the ground . Thus , the targets can be differentiated by their spectral reflectance signatures in the remotely sensed images.

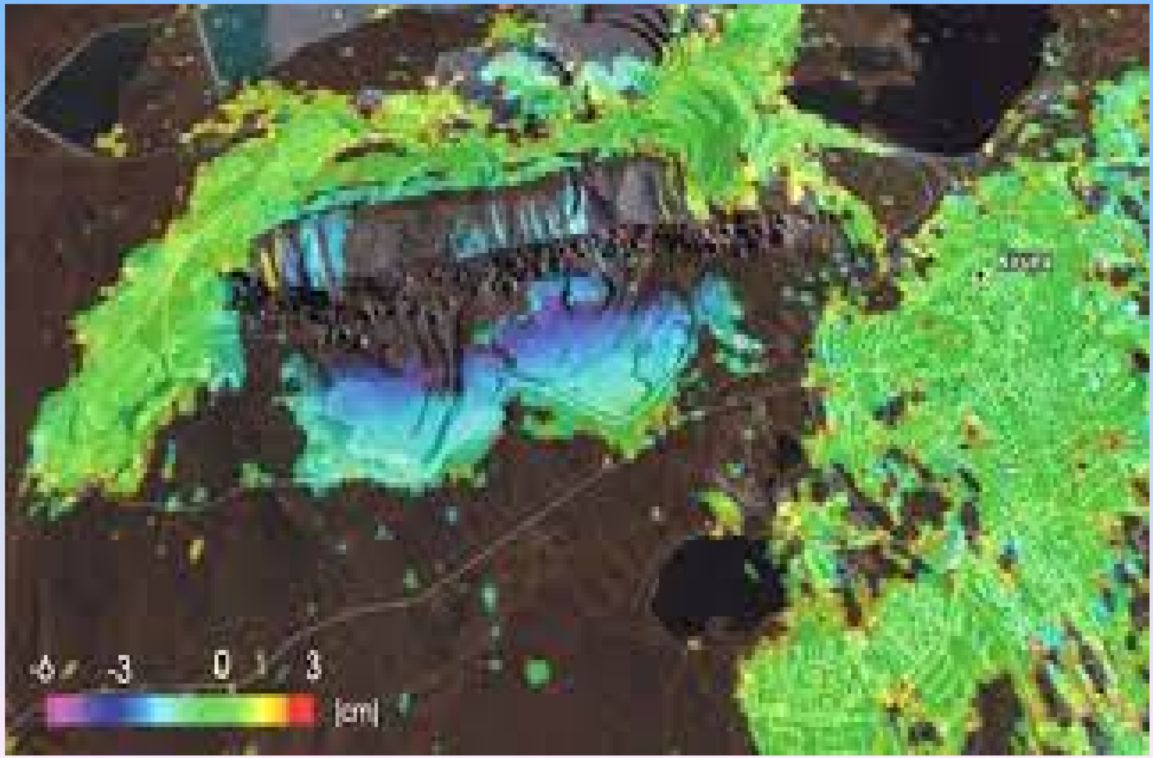


Thermal Imaging sensor

- Thermal imaging sensor refers to electromagnetic waves with a wavelength of between 3 to 20 micrometres .
- Most remote sensing applications make use of 3-5 & 8-14 micrometre range.(Due to absorption bands).
- The main difference between the thermal infrared and near infrared is that thermal infrared is emitted energy and near infrared is reflected energy similar to light .

Radar Imaging Sensors

A Radar (microwave) imaging sensor is usually an active sensor , operating in an electromagnetic spectrum range of 1mm to 1 m .The sensor transmits light to the ground and the energy is reflected from the target to the radar antenna to produce an image at microwave wavelengths .



RADAR IMAGING :

- Transmitter -which generates successive short bursts at regular intervals .
- Duplexer – which carefully coordinates when the active microwave energy transmitted and received .
- Receiver – which receives the backscattered energy and converts them into video signal .
- Radar antenna – which shapes and focuses transmitter generated each pulse into a stream to the target .This is called directional antenna .
- Recording device – which stores the information digitally for later processing .
- Non-Imaging Instrument : Non – Imaging microwave sensors include altimeters and scatterometers .Is most cases

Wavelengths and Frequency table of Radar system

Band	Wavelength (cm)	Frequency (GHz)
P	30-100	0.3-1.0
L	15-30	1.0-2.0
S	7.5-15	2.0-4.0
C	3.75-7.5	4.0-8.0
X	2.4-3.75	8.0-12.5
Ku	1.67-2.4	12.5-18.0
K	1.13-1.67	18.0-26.5
Ka	0.75-1.13	26.5-40.0

Spectrometers : Disperse natural radiation into its constituent wavelengths over a finite spectral range

- Prism Spectrometers : simply use a prism to disperse the light ,each wavelengths being refracted at a different angle determined by the index of refraction of the prism.

- Grating Spectrometers : Use a diffraction grating to disperse the wavelengths(widely used in remote sounding satellite instruments) .

- Interferometers : Use the interference effects to obtain spectral information .

Radiometter :Isolate bands of natural radiation using some form of spectral filter

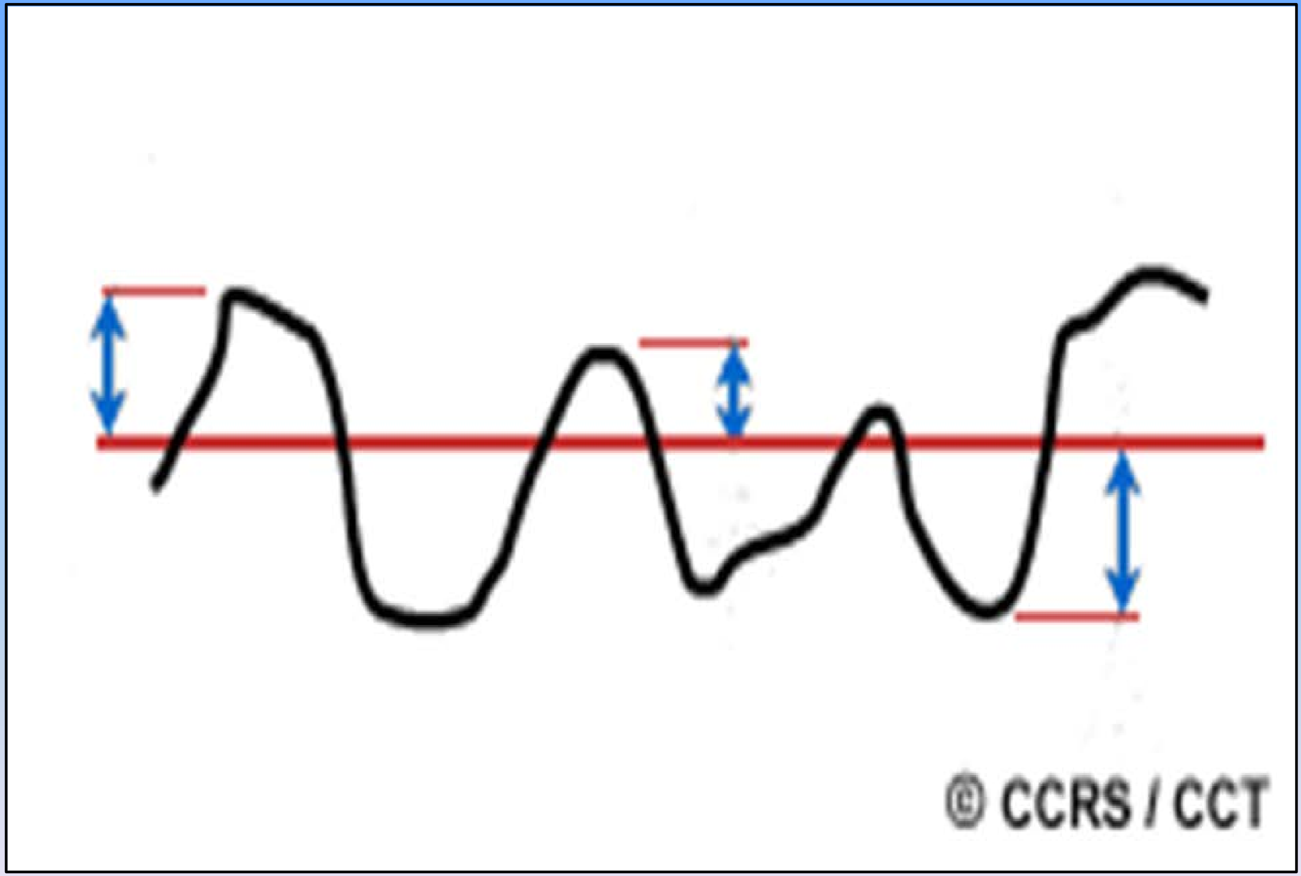
- Broad-band radiometer :**Typically use the semi-conductor filters which transmit only a limited spectral range .**
- Selective filter radiometers :**Include a sample of the gas interest in the instrument , whose transmission modulated so that only wavelengths corresponding to the gas absorption lines are detected .**
- Heterodyne radiometers :**(microwave)new signal at a difference frequency that can be more easily analysed .**

Altimeter

- **Very similar to laser profiling , but uses radar pulses .**
- **These have been flown on satellites , using at λ = 2.2 cm .**
- **Topographic measurements over land are more difficult because of the rapid variation .**

INTERACTION WITH EARTH SURFACE

- 1. **Surface roughness of the target –**
- **The surface roughness of a feature controls how the microwave energy interacts with that surface or target and is generally the dominant factor in determining the tones seen on a radar image .**
- **Surface roughness refers to the average height variations in the surface cover form a plane surface and is measured on the order of cm . whether a surface appears rough of smooth to a radar depends on the wavelengths and incidence angle .**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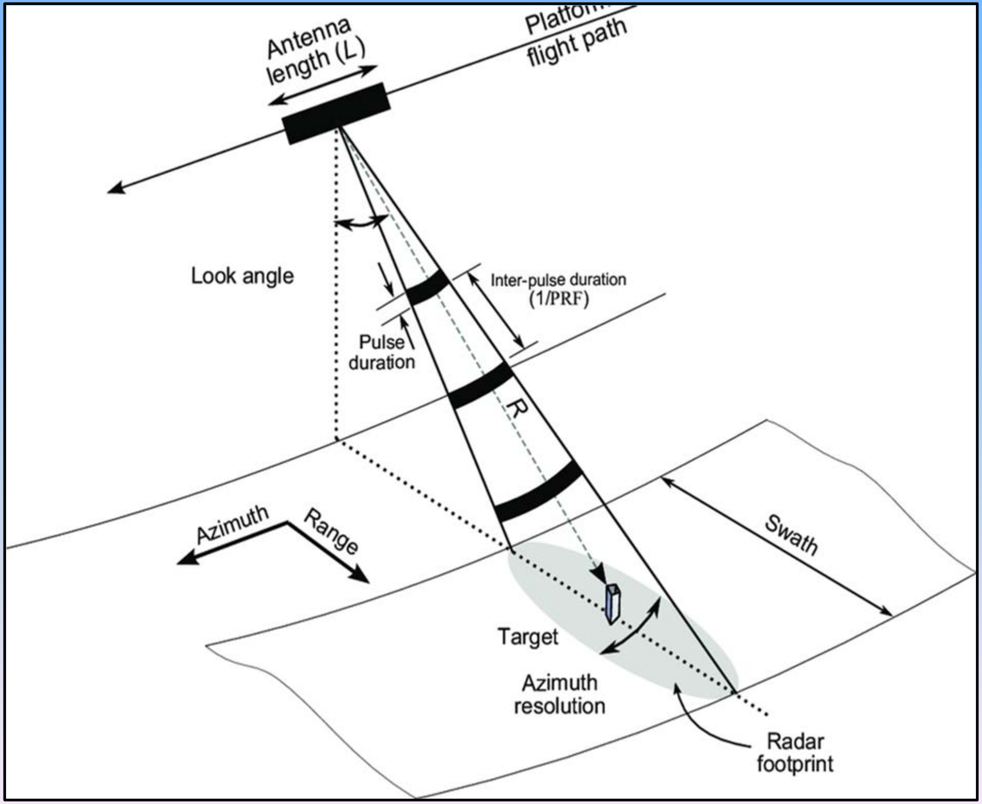
2. Radar viewing surface geometry

- The local incident angle is the angle between the radar radar beam and a line perpendicular to the slope at the point of incidence angle takes into account the local slope of the terrain in relation to the radar beam .
- The imaging geometry of a radar system is different from the framing and scanning systems commonly adopted for optical remote sensing .

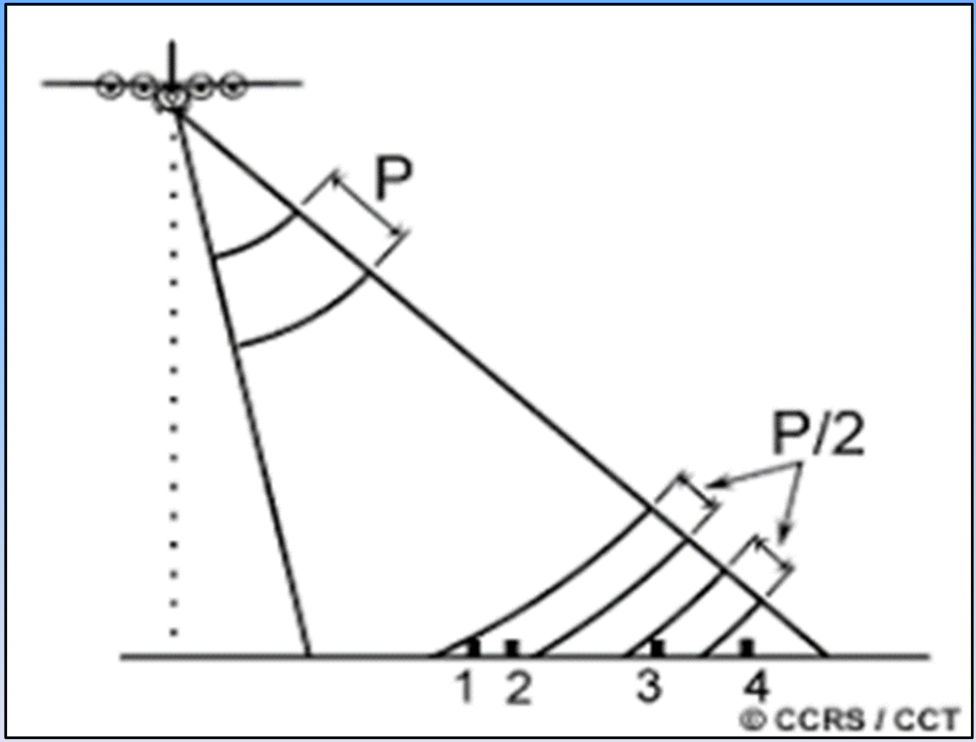


Spatial Resolution of Radar System

- **The spatial resolution of an imaging radar is primarily dependent of the effective length of the pulse (pulse length) and on the width of the illumination in the azimuth direction (beam width) . The time interval between two successive pulses(short bursts of radar)is called the pulse length .**
- **Imaging radar is classified into real aperture radar (RAR) and synthetic aperture radar (SAR) .**

RANGE RESOLUTION OF RAR AND SAR

- The range resolution is dependent on the pulse length (P).Two distinct targets on the surface are resolved in their range dimension separation is greater than half the pulse length (P/2) .Targets 1 and 2 are not separable while targets 3 and 4 Acan easily be separated . The concept of range resolution is same for Real Aperture Radar and Synthetic Aperture Radar.
- Range resolution can be defined in two different planes – slant range plane and ground range plane .



AZIMUTH RESOLUTION OF RAR

- The azimuth resolution of RAR is determined by the angular width of the radiated microwave beam and the slant range distance . This beamwidth is a measure of the width of the illumination pattern .

AZIMUTH RESOLUTION OF SAR

- **Fine azimuth resolution cannot be obtained from RAR .The SAR was developed as a means of overcoming the limitations of RAR .The SAR systems achieve good azimuth resolution that is independent of the slant range to the target ,yet use small antenna and relatively long wavelengths to do it .**

AZIMUTH RESOLUTION OF SAR

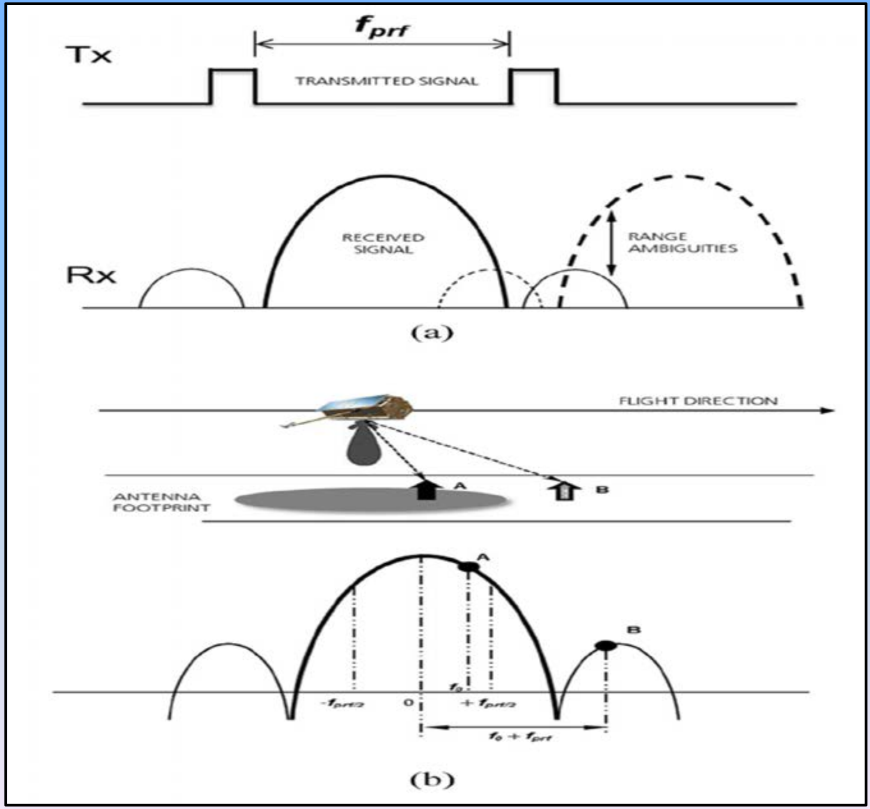
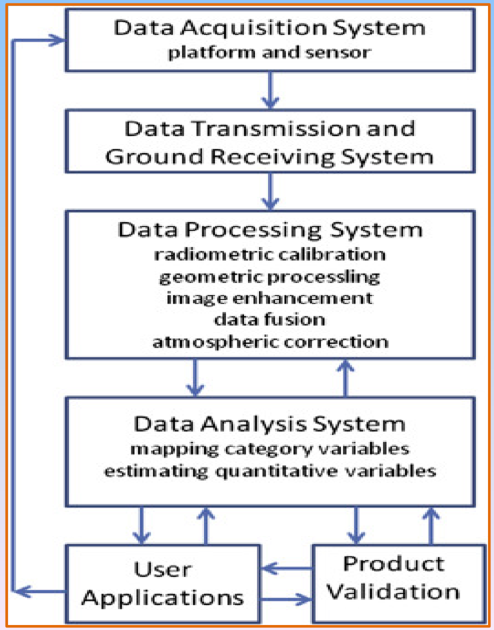
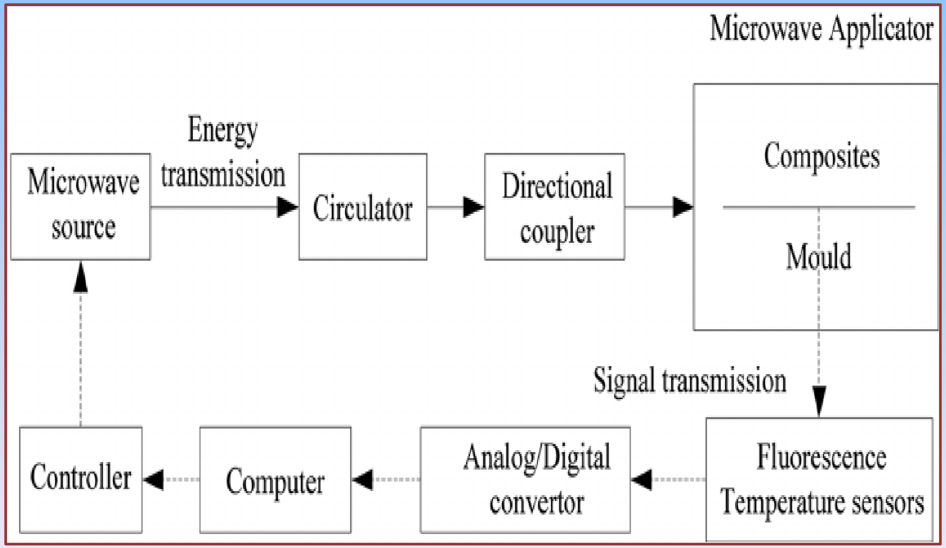


Image processing of microwave data

- It involves applying various algorithms and techniques to raw microwave data acquired by remote sensing instruments such as synthetic aperture radar (SAR), radiometers, radar altimeters, and scatterometers.
- The goal is to extract meaningful information from these data sets, which can be used for a wide range of applications including environmental monitoring, disaster management, agricultural assessment, and geological exploration.



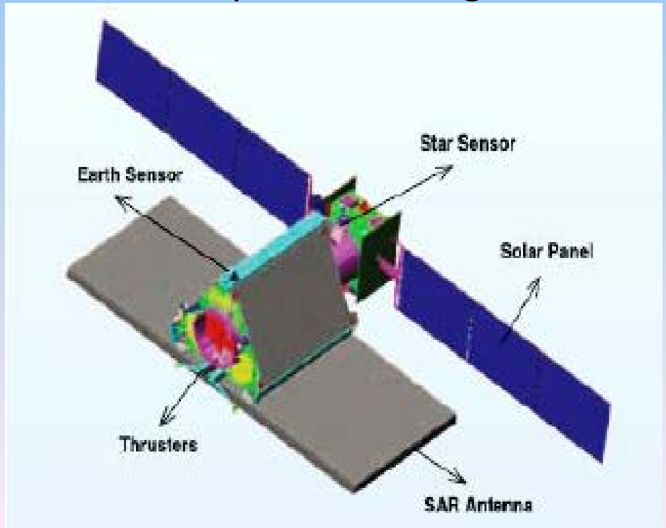


In microwave remote sensing, both imaging and non-imaging instruments are used for processing data to extract information about the Earth's surface and atmosphere. Here's an overview of both:

IMAGING INSTRUMENTS

- Synthetic Aperture Radar (SAR):

SAR systems use microwave signals to produce high-resolution images of the Earth's surface. SAR sensors emit microwave pulses and measure the backscattered signals to form images. SAR images are useful for various applications such as land cover classification, crop monitoring, and terrain mapping



IMAGING INSTRUMENTS

- Polarimetric SAR (PolSAR):

PolSAR systems transmit and receive microwave signals in multiple polarization states. By analyzing the polarimetric properties of backscattered signals, PolSAR can provide additional information about surface features such as terrain roughness, vegetation structure, and surface scattering mechanisms.

- Interferometric SAR (InSAR):

InSAR combines multiple SAR images acquired from slightly different positions to measure the phase difference between them. This technique is used for generating digital elevation models (DEMs), detecting ground deformation (subsidence or uplift), and monitoring changes in surface topography.

NON-IMAGING INSTRUMENTS:

- Radiometers:

Microwave radiometers measure the thermal emission from the Earth's surface and atmosphere at specific microwave frequencies. They are used for atmospheric sounding, temperature profiling, and monitoring properties of the Earth's surface such as soil moisture and sea surface temperature.

- Radar Altimeters:

Radar altimeters measure the time delay between the transmission and reception of microwave pulses reflected from the Earth's surface. They are primarily used for measuring the height of the Earth's surface (elevation) over oceans, ice sheets, and land surfaces with high accuracy.

NON-IMAGING INSTRUMENTS

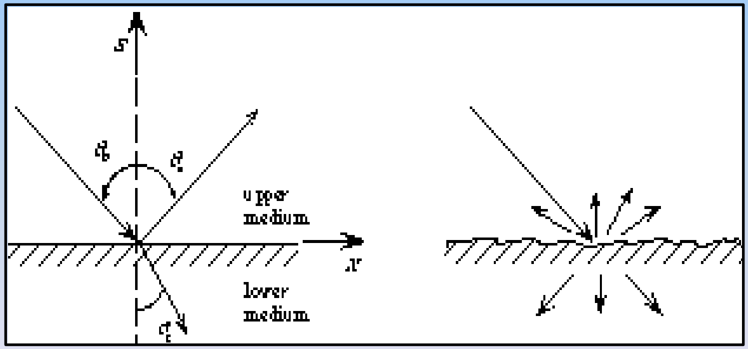
- Scatterometers:

Scatterometers transmit microwave pulses towards the Earth's surface and measure the backscattered signals to infer surface roughness and wind speed over oceans. They are used for oceanographic research, weather forecasting, and monitoring ocean surface winds for maritime operations.

In image processing of microwave data from these instruments, techniques such as speckle filtering, image enhancement, feature extraction, and classification algorithms are commonly used to extract meaningful information from the raw data and generate interpretable images or products for various applications.

SURFACE SCATTERING:

When an electromagnetic wave is incident on a boundary surface between two semi-infinite media, a portion of the energy is scattered back above the surface and the remainder is transmitted forward into the lower medium . If the lower medium can be considered uniform and homogeneous, the problem is one of *surface scattering*, since scattering only occurs at the boundary surface [Ulaby, Moore, and Fung 1986b].



Types of Surface Scattering :

- ***Specular Reflection:***

  Smooth surfaces, such as calm water bodies or flat terrain, reflect microwaves predominantly in a single direction, similar to a mirror reflection.

- ***Diffuse Reflection:***

  Rough surfaces, such as soil, vegetation, or urban areas, scatter microwaves in multiple directions due to surface roughness, leading to diffuse scattering.

- ***Transmission:***

  Microwaves can penetrate certain materials, such as vegetation canopies or thin layers of soil or water, and interact with underlying surfaces before being scattered or absorbed.

Importance : Surface scattering characteristics provide valuable information about surface properties such as roughness, moisture content, vegetation structure, and surface composition, which are crucial for land cover classification, environmental monitoring, and terrain analysis.

EMISSION:

- **Definition:**

  Emission refers to the natural radiation emitted by the Earth's surface and atmosphere at microwave wavelengths.

- **Surface Emission:**

  Surface emission arises from thermal radiation emitted by the Earth's surface, primarily influenced by surface temperature and emissivity properties.

- **Atmospheric Emission:**

  Atmospheric emission occurs due to the thermal radiation emitted by gases, clouds, and aerosols in the atmosphere.

Active Microwave Remote Sensing & Passive Microwave Remote Sensing

- **Passive Microwave Remote Sensing:**
  Passive microwave sensors measure the naturally emitted radiation from the Earth's surface and atmosphere, providing information about surface temperature, soil moisture, sea surface temperature, and atmospheric properties.

- **Active Microwave Remote Sensing:**
  Active microwave sensors, such as SAR, transmit microwave pulses towards the Earth's surface and measure the backscattered signal, which contains information about surface properties, in addition to any emitted radiation.

Resolution Concepts:

- **Spatial Resolution**:

  Spatial resolution refers to the level of detail or granularity in a microwave image, typically expressed in terms of the size of the smallest discernible feature (e.g., meters per pixel).

- **Ground Resolution**:

  Ground resolution represents the physical size of a pixel on the Earth's surface, determined by the sensor's spatial sampling interval.

- **Cross-Range and Along-Track Resolution**:

  In SAR imagery, cross-range resolution refers to the ability to resolve features perpendicular to the sensor's flight direction, while along-track resolution pertains to features parallel to the flight direction.

RESOLUTION CONCEPTS:

- **Temporal Resolution**:

Temporal resolution refers to the frequency at which images are acquired over time, influencing the ability to monitor dynamic processes and temporal changes in surface properties.

- **Radiometric Resolution**:

Radiometric resolution refers to the sensitivity of a sensor to detect and differentiate variations in signal intensity, expressed in terms of the number of bits used to represent the digital signal values.

- **Polarimetric Resolution**:

In polarimetric SAR (PolSAR) imagery, polarimetric resolution refers to the ability to capture different polarizations of the backscattered signal, providing insights into surface scattering mechanisms and material properties.

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THANK YOU