Chapter 1: Introduction to Remote sensing.

Questions:

1. Define remote sensing. Describe the general remote sensing process with neat and labelled diagram.
2. Explain remote sensing with its advantages and disadvantages.
3. Explain the importance of remote sensing.
4. Explain the multi-concept of Remote sensing:

The multi-concept of remote sensing encompasses a comprehensive understanding of the following interconnected aspects:

1. Sensing Modalities:
- Remote sensing involves passive sensing, which detects natural electromagnetic radiation (e.g., sunlight reflected off the Earth's surface) and active sensing, which emits and measures energy (e.g., radar or lidar).

2. Electromagnetic Spectrum:
- Remote sensing utilizes different regions of the electromagnetic spectrum, including visible, infrared, microwave, and radio wavelengths, each offering unique information about Earth's surface and atmosphere.

3. Platform Diversity:
- Data can be acquired from various platforms such as satellites, aircraft, drones, and ground-based sensors, each with specific advantages in terms of spatial coverage, resolution, and revisit time.

4. Data Acquisition Techniques:
- Remote sensing data can be acquired using techniques such as optical imaging, radar sensing, lidar scanning, and thermal infrared sensing, each employing specific sensor configurations and processing methods.

5. Image Processing and Analysis:
- Remote sensing data undergoes preprocessing (e.g., radiometric and geometric corrections), feature extraction, classification, change detection, and spatial analysis to extract valuable information and derive insights.

6. Applications and Use Cases:
- Remote sensing finds applications across diverse fields including agriculture, forestry, urban planning, environmental monitoring, disaster management, climate studies, and defense, contributing to informed decision-making and resource management.

7. Integration with GIS and Geospatial Technologies:
- Remote sensing data is integrated with Geographic Information Systems (GIS), Global Positioning Systems (GPS), and other geospatial technologies to enhance spatial analysis, visualization, and decision-making capabilities.

8. Remote Sensing Data Products:

- Various data products such as ortho-imagery, digital elevation models (DEMs), land cover maps, and atmospheric profiles are generated to support scientific research, policy-making, and commercial applications.

By comprehensively understanding and integrating these aspects, remote sensing practitioners can effectively acquire, process, analyze, and utilize spatial information to address a wide range of societal and environmental challenges.

Chapter 2: Physical Principles of Remote Sensing.

Questions:

1. Describe in brief about the electromagnetic spectrums used in remote sensing process.
2. Explain radiation and its interaction with target:
   (target interaction: absorption, transmission, reflection (specular and diffuse reflection), explain with figure)
3. Explain radiation and its interaction with atmosphere.
   (interaction: scattering (Rayleigh, mie, non-selective), absorption, explain with figure)
4. Explain black body radiation with black body radiation equation. (planks and Stefan- boltzmann).
5. Explain planks radiation law (black body radiation) and express planks law of radiation.
6. Explain radiation transfer mechanism in remote sensing.
   (reflection, absorption, transmission, scattering)
7. Explain the principle of EM theory used in remote sensing.
8. Short note on scattering mechanism (mie, Rayleigh, non-selective)

Radiation Theory:

Radiation theory is the study of EM radiation and its interaction with matters. Radiation is a form of energy that travels through space in the form of waves that includes broad spectrum of wavelengths ranging from radio waves to gamma rays. In remote sensing, radiation theory helps to understand the behavior of EM waves when it interacts with different materials and how can the EM waves be detected and measured and be applied.

Concepts used in radiation theory are:

1. Reflection:
- Reflection refers to the bouncing back of incident radiation from the surface of an object. When electromagnetic radiation strikes an object, some of it is reflected back to the sensor. The amount and nature of reflection depend on the properties of the surface material. Smooth and shiny surfaces tend to reflect (specular reflection) more radiation than rough and matte surfaces (diffuse reflection).

2. Absorption:
-Absorption occurs when the energy from incident radiation is absorbed by the material it interacts with. Different materials absorb different wavelengths of radiation. For example, vegetation absorbs strongly in the visible and near-infrared

portions of the electromagnetic spectrum. The absorbed energy can be transformed into heat or used in various biochemical processes.

3.Transmission:
- Transmission involves the passage/propagation of radiation through a medium without being absorbed or reflected. Some materials allow electromagnetic radiation to pass through them with minimal absorption. In remote sensing, the atmosphere is an example of a medium that can transmit certain wavelengths of radiation. However, the atmosphere can also absorb and scatter radiation, influencing what reaches the sensor.

4. Scattering:
-Scattering is the process where radiation changes direction due to interactions with particles or other irregularities in the medium. Scattering can occur in the atmosphere, affecting the path of incoming radiation. Rayleigh scattering is common for shorter wavelengths (blue light), while Mie scattering is more prevalent for larger particles at longer wavelengths (red light). Scattering can influence the quality of remote sensing data and cause haze or other atmospheric effects.

5. Electromagnetic Spectrum:
- Electromagnetic radiation is characterized by its wavelength or frequency. The electromagnetic spectrum includes different regions based on their wavelength such as radio waves, microwaves, infrared, visible, ultraviolet, x-rays and gamma rays. Different materials interact with specific wavelength in unique way, leading to their distinctive spectral signatures.

6. Emission:
- Materials can emit radiation as a result of their temperature. Objects emits radiation across range of wavelengths and their emitted radiation is related to the temperature of the object. The emission is described by Planks law and Stefan boltzman law.

Understanding these radiation transfer mechanisms is essential for interpreting remote sensing data. Different materials exhibit unique spectral signatures based on their reflective and absorptive properties, allowing scientists and researchers to identify and analyze features on the Earth's surface using remote sensing technologies such as satellites or airborne sensors.

Planks Law:

- describes the spectral distribution of radiation emitted by a black body. A black body is an idealized object that absorbs all incident electromagnetic radiation and emits radiation across the entire electromagnetic spectrum.
The mathematical expression for Planck's radiation law is given by:
$B(\lambda,T)=8\pi hc/(\lambda^5(e^{hc/\lambda kT}-1))$
Where:

- $B(\lambda,T)$ is the spectral radiance (intensity) at wavelength λ and temperature T.
- h is Planck's constant (6.626×10−34 J·s6.626×10−34J·s).

- c is the speed of light (3.0×108 m/s3.0×108m/s).
- λ is the wavelength of radiation.
- k is Boltzmann's constant (1.381×10−23 J/K1.381×10−23J/K).
- T is the absolute temperature of the black body.

Planks radiation law is crucial for understanding the behavior of black bodies and theory of EM radiation.

Emission Theory:

-Emission is the process of EM radiation being emitted or radiated by objects on earth surface. In remote sensing, emission is closely related to the thermal radiation, where objects emit infrared radiation due to its temperature.
-All objects with a temperature above absolute zero emit thermal radiation. This emission is a function of the object's temperature and its emissivity.
-Emissivity is a key parameter in emission theory for remote sensing. It represents the efficiency with which an object emits thermal radiation. Emissivity values range from 0 to 1, where 0 indicates perfect reflectivity (no emission), and 1 indicates perfect emissivity (ideal emitter).
-The Stefan-Boltzmann law describes the total energy radiated by a black body (or any object) based on its temperature. Stefan-Boltzmann equation can be given as:

$P = \sigma \cdot A \cdot T4$

Where;

- P is the total power radiated (in watts),
- σ is the Stefan-Boltzmann constant (5.67×10−8 W/(m2K4)5.67×10−8W/(m2K4)),
- A is the surface area of the emitting body (in square meters),
- T is the absolute temperature of the body (in kelvins).

-Emission theory in remote sensing revolves around the understanding that objects emit thermal radiation based on their temperatures, and this emitted radiation can be detected and analyzed using remote sensing instruments.

Black body radiation:

Black body radiation is the electromagnetic radiation emitted by a perfect absorber and emitter of radiation, known as a "black body." A black body is an idealized physical body that absorbs all incident electromagnetic radiation, regardless of frequency or angle of incidence. In thermal equilibrium, a black body also emits radiation according to its temperature. The concept of black body radiation is fundamental to the understanding of the behavior of electromagnetic radiation. Characteristics of black body radiation includes:

1. Absorption: A black body absorbs all incident radiation without reflecting or transmitting any of it. As a result, it appears completely black at all temperatures.
2. Emission: A black body also emits radiation based on its temperature. This emission is in the form of thermal radiation, and the spectral distribution of this radiation is described by Planck's radiation law.
3. Thermal Equilibrium: In thermal equilibrium, a black body absorbs as much radiation as it emits, leading to a constant temperature. The concept of thermal

equilibrium is crucial for understanding the relationship between temperature and radiation emission.

4. Planck’s Law: Planck's law to describes the spectral distribution of black body radiation. The law relates the intensity of radiation emitted at different wavelengths to the temperature of the black body which is given by:

   $B(\lambda,T)=8\pi hc/(\lambda^5(e^{hc/\lambda kT}-1))$

   Where:

   - $B(\lambda,T)$ is the spectral radiance (intensity) at wavelength λ and temperature T.
   - h is Planck's constant (6.626×10−34 J·s6.626×10−34J·s).
   - c is the speed of light (3.0×108 m/s3.0×108m/s).
   - λ is the wavelength of radiation.
   - k is Boltzmann's constant (1.381×10−23 J/K1.381×10−23J/K).
   - T is the absolute temperature of the black body.

5. Stefan-Boltzmann Law: This law describes the total power radiated per unit surface area by a black body and is given by the equation:

   $P=\sigma\cdot A\cdot T4$

   Where;

- P is the total power radiated (in watts),
- σ is the Stefan-Boltzmann constant (5.67×10−8 W/(m2K4)5.67×10−8W/(m2K4)),
- A is the surface area of the emitting body (in square meters),
- T is the absolute temperature of the body (in kelvins).

ATMOSPHERIC WINDOWS

While EMR is transmitted from the sun to the surface of the earth, it passes through the atmosphere. Here, electromagnetic radiation is scattered and absorbed by gases and dust particles. Besides the major atmospheric gaseous components like molecular nitrogen and oxygen, other constituents like water vapor, methane, hydrogen, helium and nitrogen compounds play important role in modifying electromagnetic radiation. This affects image quality. Regions of the electromagnetic spectrum in which the atmosphere is transparent are called atmospheric windows. In other words, certain spectral regions of the electromagnetic radiation pass through the atmosphere without much attenuation are called atmospheric windows. The atmosphere is practically transparent in the visible region of the electromagnetic spectrum and therefore, many of the satellite based remote sensing sensors are designed to collect data in this region.

Chapter 3: Remote Sensing Technology

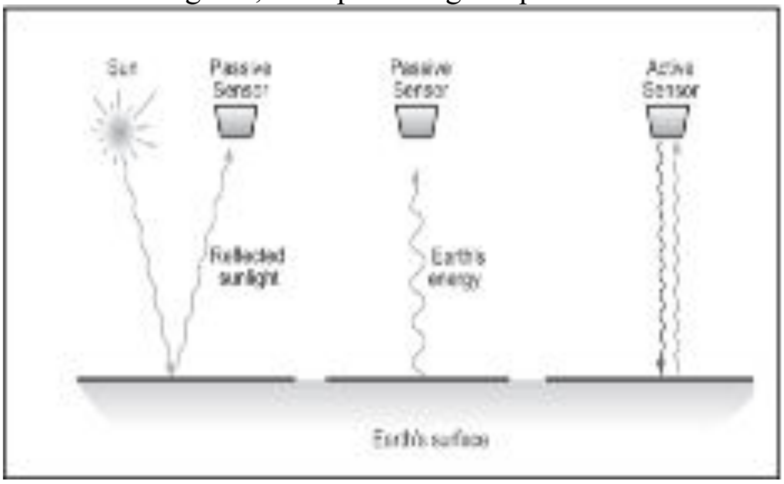
“Question related passive remote sensing, visible and infrared techniques, microwave radiometry. Advantages/disadvantages of passive and active sensors.”

Passive Remote Sensing:

Passive remote sensing is a method of acquiring information about an object or area without direct contact, using sensors to detect and measure the natural energy (e.g., sunlight) that is emitted or reflected by the object or area. This technique does not involve the transmission of any energy from the sensor to the object being observed. Instead, it relies on the detection of naturally occurring emissions or reflections.

Components used in passive remote sensing:

1. Energy source: Passive remote sensing instruments rely on natural energy sources such as sunlight, emitted or reflected by the Earth's surface and the atmosphere.
2. Sensor: sensors is used to measure the energy that is naturally reflected or emitted by the Earth's surface or its atmosphere. It captures information about the characteristics of the objects or features being observed.
3. Spectral bands: Passive remote sensing instruments can operate across various spectral bands, including the visible, near-infrared, shortwave infrared, and thermal infrared regions, each providing unique information about the target.



Visible Techniques in passive remote sensing:

1. True color imaging: it captures the same spectral bands as human eye, Red (630-700 nm), Green (520-560 nm), Blue (450-480 nm).
2. Multi spectral imaging: It captures and analyzes information from specific bands within the visible spectrum to observe variations in surface properties (400-700 nm).

Infrared Techniques in passive remote sensing:

1. Near infrared (NIR) imaging: Captures information in the near-infrared portion of the electromagnetic spectrum (700-1400nm).
2. Thermal infrared imaging: Captures the emitted thermal radiation from the Earth's surface, providing information about temperature variations and heat distribution. (3000nm plus).
3. Multispectral infrared imaging: it combines multiple infrared bands.

Microwave Radiometry:

Microwave radiometry is a remote sensing technique that involves the measurement of natural microwave radiation emitted by objects or surfaces. It is particularly useful for studying various environmental phenomena, including Earth's surface temperature, soil moisture content, and atmospheric properties. Microwave radiometry operates in the microwave portion of the electromagnetic spectrum, typically in frequencies ranging from 1 to 300 GHz.

Examples of visible/infrared passive remote sensors:

1. Digital Cameras: Digital cameras are passive remote sensors that capture visible light and convert it into digital images, allowing for detailed visual analysis of the Earth's surface and its features.
2. Multi spectral imaging sensors: Multispectral imaging sensors capture information from specific bands within the visible and near-infrared spectrum, providing data about surface properties and material composition.
3. Thermal infrared sensors: Thermal infrared sensors detect and measure the emitted thermal radiation from the Earth's surface, allowing for the assessment of temperature variations and heat distribution.
4. Sun photometer: Sun photometers measure the intensity of sunlight in different spectral bands.

Examples of microwave sensors:

- Radiometers: Radiometers measure the intensity of electromagnetic radiation in specific bands of the spectrum, providing data on the natural energy emitted or reflected by the Earth's surface and its atmosphere.
- Scatterometers: Passive scatterometers measure the backscattered microwave radiation from the Earth's surface to determine surface roughness and wind speed without actively transmitting microwave pulses.
- Passive synthetic Aperture Radar (SAR): Passive SAR systems utilize the natural microwave radiation emitted or reflected by the Earth's surface to generate high-resolution images without actively transmitting microwave pulses.

Advantages of Passive remote sensing:

1. Natural energy source: Passive remote sensing relies on natural sources of energy, such as sunlight, emitted or reflected by objects on Earth. This eliminates the need for an external energy source, making it cost-effective and reducing the impact on the environment.
2. Low cost: Passive sensors are often less complex and more cost-effective than active sensors. They do not require intricate(complex) systems for emitting and receiving energy pulses, leading to simpler instrument design and lower operational costs.
3. Multi spectral information: Passive sensors often operate in multiple spectral bands, capturing information across different wavelengths.
4. Continuous monitoring: Passive sensors can continuously monitor the Earth's surface and atmosphere over large areas and for extended periods.

Active Remote sensing:

Active remote sensing involves the use of sensors that actively emit energy, such as radar or lidar, to interact with and measure the properties of targets or objects. Unlike passive remote sensing, which relies on naturally occurring radiation, active remote sensing systems generate and transmit their own electromagnetic signals and then analyze the reflected or backscattered energy to obtain information about the target.
Examples: RADAR, LIDAR, SONAR, etc.

Advantages of active remote sensing over passive remote sensing:

1. All-Weather Capability: Active sensors, such as radar, can operate in all weather conditions, including cloudy or rainy weather. They are not reliant on sunlight for illumination, making them effective in adverse weather conditions where passive sensors may be limited.
2. Day-and-Night Operation: Active sensors can operate during both day and night. They do not depend on the availability of sunlight, providing continuous imaging capabilities regardless of the time of day.
3. Controlled Source of Energy: Active sensors emit their own energy source, allowing for better control over the characteristics of the transmitted signals. This control can be advantageous for specific applications where a known and controlled source of energy is needed.
4. Higher Spatial Resolution: Active sensors can achieve higher spatial resolutions compared to some passive sensors. This is beneficial for detailed mapping and monitoring of specific features on the Earth's surface.
5. Penetration Through Clouds and Vegetation: Active sensors, especially radar, can penetrate through clouds and vegetation to observe the underlying surface. This capability is crucial for applications such as forest monitoring, land cover classification, and terrain mapping.

Disadvantages of active remote sensing over active remote sensing:

1. System Complexity: Active remote sensing systems, especially radar and lidar, tend to be more complex in terms of instrumentation and data processing. This complexity can lead to higher costs in terms of development, deployment, and maintenance.
2. Higher Energy Consumption: Active sensors emit their own energy, which requires a power source. This can result in higher energy consumption compared to passive sensors that rely on naturally occurring radiation.
3. Limited Spectral Information: Active sensors often provide limited spectral information compared to passive sensors. Passive sensors can capture a wide range of wavelengths, enabling the analysis of specific spectral signatures for various materials.
4. Limited Global Coverage: Active sensors on satellites typically have limited global coverage compared to some passive sensors. Active sensors may require specific orbital configurations or multiple sensors to achieve comprehensive coverage.
5. Data Interpretation Challenges: Interpreting active remote sensing data can be more challenging than passive data. The characteristics of the backscattered or reflected signals depend on the target's properties, making data interpretation and analysis more complex.
6. Complex Calibration: Active sensors often require complex calibration procedures to ensure accuracy in distance measurements, signal strength, and other parameters. Calibration challenges can affect the reliability of the acquired data.
7. Limited Applications for Specific Targets: Active remote sensing techniques may be better suited for specific targets or environments and may not be as effective for certain applications or targets. Passive sensors, with their broader spectral coverage, may be more versatile in some cases.

1. **Choose a suitable radar system to track a moving target in the presence of strong ground clutter and explain its working principle with suitable diagrams.**

Theoretically, the Radar used for detecting the movable target, should receive only the echo signal due to that movable target. This echo signal is the desired one.
However, in practical applications, Radar receives the echo signals due to stationary objects in addition to the echo signal due to that movable target.
The echo signals due to stationary objects (places) such as land and sea are called **clutters** because these are unwanted signals.
Therefore, we have to choose the Radar in such a way that it considers only the echo signal due to movable target but not the clutters.
For this purpose, Radar uses the principle of Doppler Effect for distinguishing the non-stationary targets from stationary objects. This type of Radar is called Moving Target Indicator Radar or simply, **MTI Radar**
We can classify the MTI Radars into the following **two types** based on the type of transmitter that has been used.

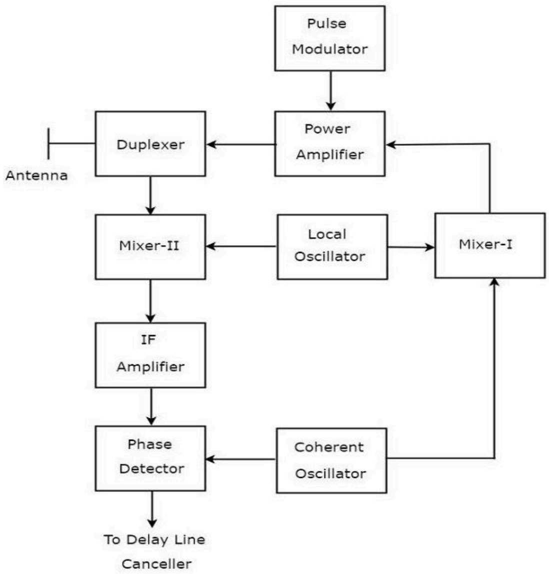
- MTI Radar with Power Amplifier Transmitter
- MTI Radar with Power Oscillator Transmitter
  (Explain any one of these for answer)

Pulse Modulator − It produces a pulse modulated signal and it is applied to Power Amplifier.
Power Amplifier − It amplifies the power levels of the pulse modulated signal.
Local Oscillator − It produces a signal having stable frequency fl. Hence, it is also called stable Local Oscillator. The output of Local Oscillator is applied to both Mixer-I and Mixer-II.
Coherent Oscillator − It produces a signal having an Intermediate Frequency, fc. This signal is used as the reference signal. The output of Coherent Oscillator is applied to both Mixer-I and Phase Detector.
Mixer-I − Mixer can produce either sum or difference of the frequencies that are applied to it. The signals having frequencies of fl and fc are applied to Mixer-I. Here, the Mixer-I is used for producing the output, which is having the frequency fl+fc.
Duplexer − It is a microwave switch, which connects the Antenna to either the transmitter section or the receiver section based on the requirement. Antenna transmits the signal having frequency fl+fc when the duplexer connects the Antenna to power amplifier. Similarly, Antenna receives the signal having frequency of fl+fc±fd when the duplexer connects the Antenna to Mixer-II.
Mixer-II − Mixer can produce either sum or difference of the frequencies that are applied to it. The signals having frequencies fl+fc±fd and fl are applied to Mixer-II. Here, the Mixer-II is used for producing the output, which is having the frequency fc±fd.
IF Amplifier − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure amplifies the signal having frequency fc+fd. This amplified signal is applied as an input to Phase detector.
Phase Detector − It is used to produce the output signal having frequency fd from the applied two input signals, which are having the frequencies of fc+fd and fc. The output of phase detector can be connected to Delay line canceller.

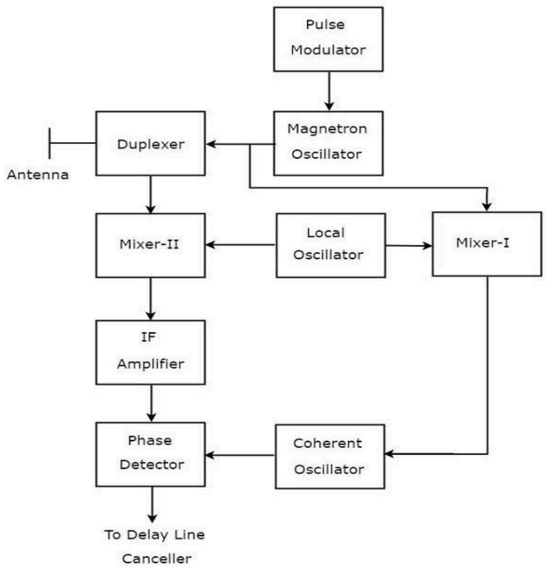
Delay line canceller: It is a filter, which eliminates the DC components of echo signals received from stationary target

For MTI Radar with Power Oscillator Transmitter

The output of Magnetron Oscillator and the output of Local Oscillator are applied to Mixer-I. This will further produce an **IF signal**, the phase of which is directly related to the phase of the transmitted signal.
The output of Mixer-I is applied to the Coherent Oscillator. Therefore, the phase of Coherent Oscillator output will be **locked** to the phase of IF signal. This means, the phase of Coherent Oscillator output will also directly relate to the phase of the transmitted signal.
So, the output of Coherent Oscillator can be used as reference signal for comparing the received echo signal with the corresponding transmitted signal using **phase detector**.



MTI Radar with Power Amplifier Transmitter



MTI Radar with Power Oscillator Transmitter

2. With arbitrarily defined orbital observational parameters, design observation geometries of a radiometer and a pulsed radar onboard a same remote sensing satellite and discuss.
   (*draw a figure of a satellite showing radar and radiometer onboard. Use parameters as range for radar and radiometer, Emitted waves from earth surface for radiometer as it is a passive sensor, transmitted and reflected wave for radar, Then explain radiometer, radar with definition and working principle, similarities as they both use microwave waves, difference as passive and active)*

3. Consider a bistatic radar system and derive basic range equation incorporating Noise Figure (F).
   -Bistatic Radar system uses two antennas for transmitting and receiving radar signals.

Derive the range equation in terms of Pr (Power received), then include noise in the radar range equation, for this,
we need to consider the signal-to-noise ratio (SNR). The SNR is given by the received signal power (Pr) divided by Noise Power (F).
Then SNR=Pr/F --- eqn(2)
Substitute the value of Pr = SNR*F in radar equation.

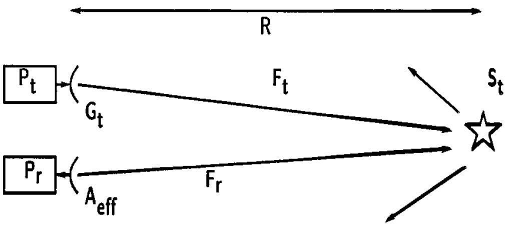
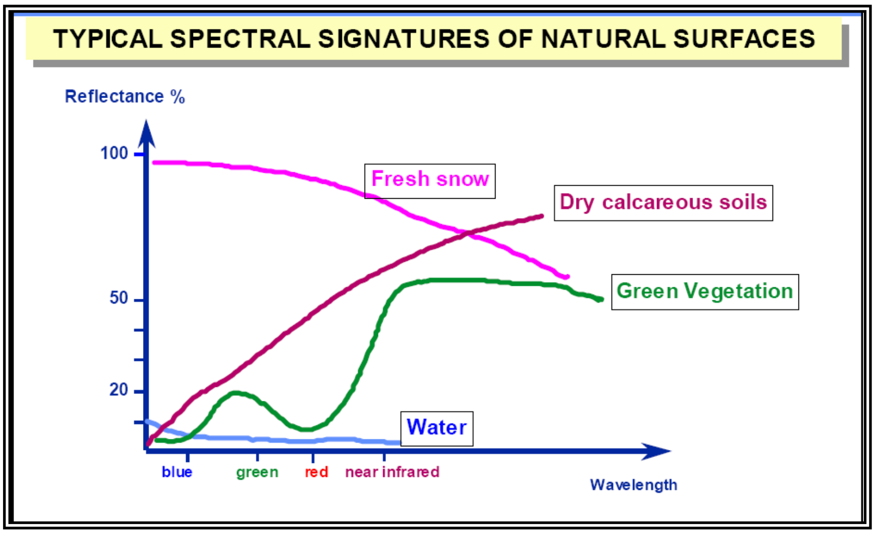


Figure for radar system

4. **Explain how a radiometer works to monitor spectral reflectance from ice-covered mountains.**

A **radiometer** is an instrument designed to measure the intensity of electromagnetic radiation within a certain range of wavelengths. Radiometers are commonly used in remote sensing to monitor spectral reflectance, which is the measure of how much incident light a surface reflects at different wavelengths.
Operation:
Radiometers operate based on the principle that different materials reflect and absorb light differently at various wavelengths. By measuring the intensity of reflected light at different wavelengths, the radiometer can provide information about the spectral characteristics of the observed surface.
Spectral Bands:
Radiometers are often equipped with sensors or detectors that are sensitive to specific spectral bands. These bands can cover a range of wavelengths from ultraviolet to infrared. The choice of spectral bands depends on the application and the specific information researchers or scientists want to gather.
Spectral Reflectance measurements:
The radiometer measures the amount of light (radiance) reflected by the Earth's surface at different wavelengths. Spectral reflectance is expressed as the ratio of reflected light to the incident light at each wavelength.



Hints: Write "ice covered mountains" instead of "earth's surface" and draw a graph of spectral reflectance for the snow as shown in figure. Remember it if questions can be asked for other targets like water, forest, soil, etc.

Spectral Radiance

Spectral radiance is a measure of the amount of light or electromagnetic radiation that a surface emits, reflects, or transmits at a specific wavelength. It describes the intensity of the radiation per unit area, per unit solid angle, and per unit wavelength.
spectral radiance is a key concept in remote sensing that helps scientists and researchers understand the characteristics of different surfaces based on the light they emit, reflect, or transmit across various wavelengths.

$L\lambda = \Phi\lambda/(\Delta\lambda \cdot \cos(\theta) \cdot A)$

where;

- $\Phi\lambda$ is the radiant flux (power) emitted, reflected, or transmitted in the wavelength range λ to $\lambda+\Delta\lambda$,
- $\Delta\lambda$ is the wavelength range,
- $\cos(\theta)$ is the cosine of the incident angle (angle between the incoming radiation and the normal to the surface),
- A is the area over which the radiant flux is measured.

In the case of emission from a blackbody, the Planck's law can be used to express the spectral radiance:

$L\lambda = 8\pi hc/(\lambda^5(e^{hc/\lambda kT}-1))$

Where:

- $B(\lambda,T)$ is the spectral radiance (intensity) at wavelength λ and temperature T.
- h is Planck's constant (6.626×10−34 J·s6.626×10−34J·s).
- c is the speed of light (3.0×108 m/s3.0×108m/s).
- λ is the wavelength of radiation.
- k is Boltzmann's constant (1.381×10−23 J/K1.381×10−23J/K).
- T is the absolute temperature of the black body.

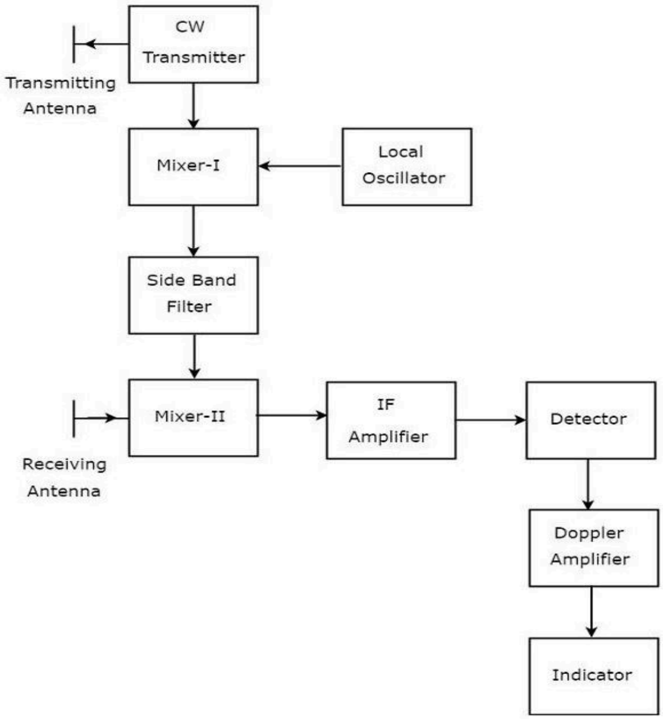
Spectral reflectance and spectral radiance are different, spectral reflectance is the ratio of spectral radiance reflected by the surface to intensity of incident wave to the surface.

5. **Continuous Wave Radar**:

This Radar system uses continuous wave for detecting moving targets.
This radar system used 2 antennae, one for transmission and another for reception.
It used doppler effect for detecting the moving targets.
Doppler effect in radar is the change of frequency of the transmitted signal from the radar and received signal by the radar.

- The **frequency** of the received signal will **increase**, when the target moves towards the direction of the Radar.
- The **frequency** of the received signal will **decrease**, when the target moves away from the Radar.
- **CW Transmitter** − It produces an analog signal having a frequency of fo. The output of CW Transmitter is connected to both transmitting Antenna and Mixer-I.

- **Local Oscillator** − It produces a signal having a frequency of fl. The output of Local Oscillator is connected to Mixer-I.
- **Mixer-I** − Mixer can produce both sum and difference of the frequencies that are applied to it. The signals having frequencies of fo and fl are applied to Mixer-I. So, the Mixer-I will produce the output having frequencies fo+fl or fo−fl.
- **Side Band Filter** − As the name suggests, side band filter allows a particular side band frequency − either upper side band frequencies or lower side band frequencies. The side band filter shown in the above figure produces only upper side band frequency, i.e., fo+fl.
- **Mixer-II** − Mixer can produce both sum and difference of the frequencies that are applied to it. The signals having frequencies of fo+fl and fo±fd are applied to Mixer-II. So, the Mixer-II will produce the output having frequencies of 2fo+fl±fd or fl±fd.
- **IF Amplifier** − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure allows only the Intermediate Frequency, fl±fd and amplifies it.
- **Detector** − It detects the signal, which is having Doppler frequency, fd.
- **Doppler Amplifier** − As the name suggests, Doppler amplifier amplifies the signal, which is having Doppler frequency, fd.
- **Indicator** − It indicates the information related relative velocity and whether the target is inbound or outbound.



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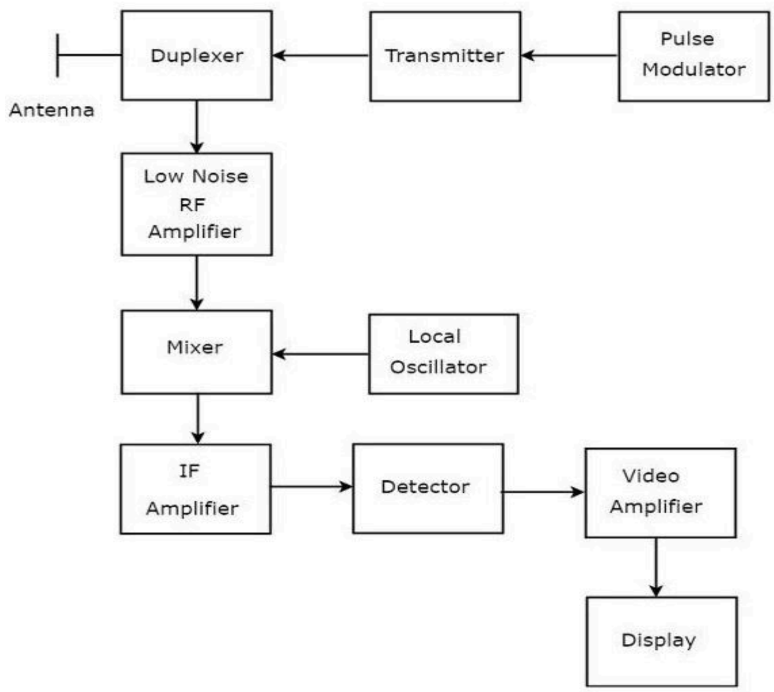
Pulse Radar System

The Radar, which operates with pulse signal for detecting stationary targets is called Basic Pulse Radar or simply, Pulse Radar

- **Pulse Modulator** − It produces a pulse-modulated signal and it is applied to the Transmitter.
- **Transmitter** − It transmits the pulse-modulated signal, which is a train of repetitive pulses.
- **Duplexer** − It is a microwave switch, which connects the Antenna to both transmitter section and receiver section alternately. Antenna transmits the pulse-

modulated signal, when the duplexer connects the Antenna to the transmitter. Similarly, the signal, which is received by Antenna will be given to Low Noise RF Amplifier, when the duplexer connects the Antenna to Low Noise RF Amplifier.

- **Low Noise RF Amplifier** − It amplifies the weak RF signal, which is received by Antenna. The output of this amplifier is connected to Mixer.
- **Local Oscillator** − It produces a signal having stable frequency. The output of Local Oscillator is connected to Mixer.
- **Mixer** − We know that Mixer can produce both sum and difference of the frequencies that are applied to it. Among which, the difference of the frequencies will be of Intermediate Frequency (IF) type.
- **IF Amplifier** − IF amplifier amplifies the Intermediate Frequency (IF) signal. The IF amplifier shown in the figure allows only the Intermediate Frequency, which is obtained from Mixer and amplifies it. It improves the Signal to Noise Ratio at output.
- **Detector** − It demodulates the signal, which is obtained at the output of the IF Amplifier.
- **Video Amplifier** − As the name suggests, it amplifies the video signal, which is obtained at the output of detector.
- **Display** − In general, it displays the amplified video signal on CRT screen.
- Pulse Radar uses the same Antenna for both transmission and reception of signals.
- This type of Radar System is used only when the target is stationary.

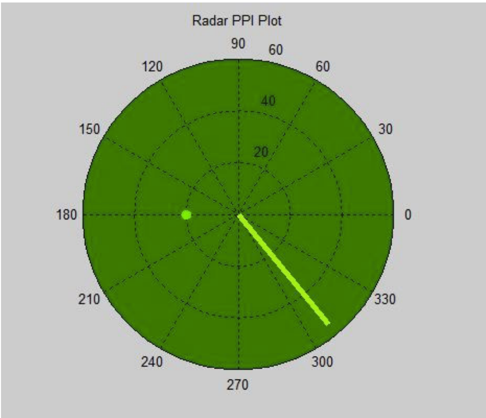


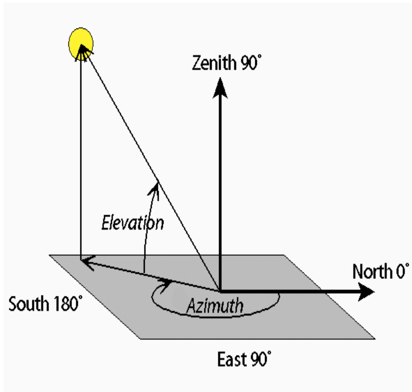
6. **RADAR Display Unit**

   Radar is an object-detection system that uses radio waves to determine the range, altitude, direction, or speed of objects

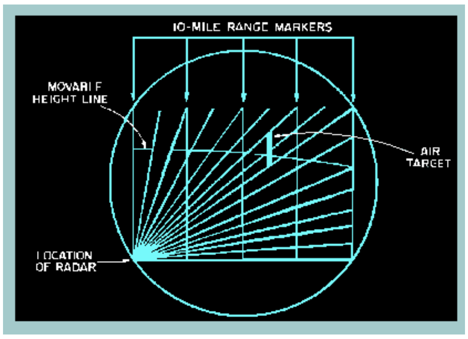
Radar systems require an indicator system to display the video information generated.
Generally, Display unit displays are the **RANGE, AZIMUTH ANGLE (or BEARING), and ELEVATION ANGLE.**
The most common types of displays, the **RANGE-HEIGHT INDICATOR (RHI)** SCOPE, **PLAN POSITION INDICATOR (PPI)** SCOPE

Plan Position Indicator (PPI):
When scanning in PPI mode, the radar holds its elevation angle constant but varies its azimuth angle. The returns can then be mapped on a horizontal plane. If the radar rotates through 360 degrees, the scan is called a "surveillance scan". If the radar rotates through less than 360 degrees, the scan is called a "sector scan".





Range Height Indicator (RHI):
When scanning in RHI mode, the radar holds its azimuth angle constant but varies its elevation angle.
The returns can then be mapped on a vertical plane. The elevation angle normally is rotated from near the horizon to near the zenith (the point in the sky directly overhead).



7. **Range equation of radar and lidar with necessary illustrations.**
   For range equation look into another pdf.
   For lidar range equation, write the power transmitted equation given below in diagram. Then change the equation in terms of Range. Also provide a nice diagram of lidar.

$$P_r = P_t * \rho * {}^{A_o}/_{\pi R^2} * \eta_o * \exp(-2R\gamma)$$

- P_r = Received power
- P_t = Transmitted power
- ρ = Target reflectivity
- A_o = Aperture area of a receiver
- R = Distance of object from the emitter unit
- η_o = Receiving optics transmission
- γ = Atmospheric extinction coefficient

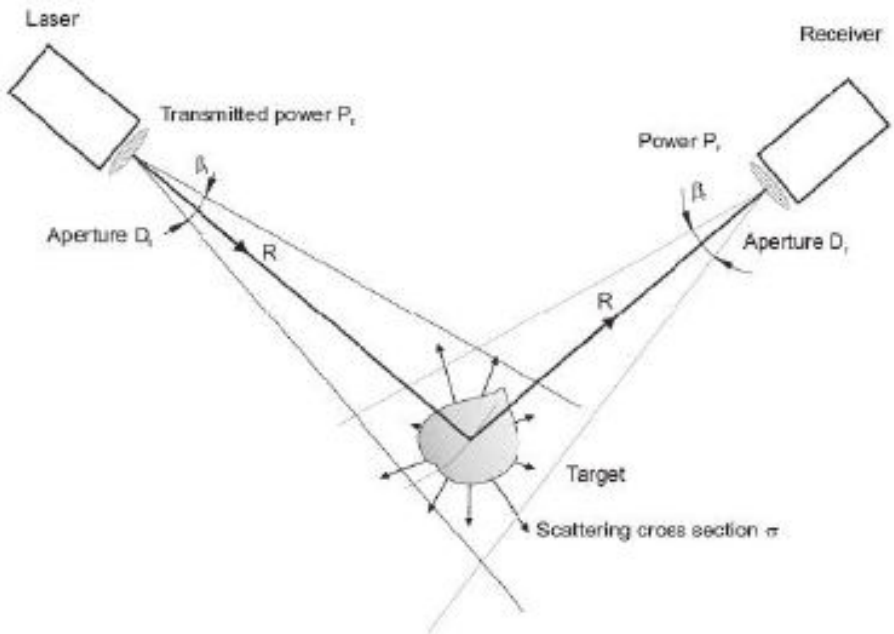


Figure for lidar for two antennas locating at same range although figure seems to have different location.

8. **Consider a long track scanning airborne active remote sensor and provide its observation geometry with arbitrarily defined observational parameters**.
   You can explain anyone among radar or lidar. Observational geometry is the figure. Radar will be easy compared to lidar as we can derive a basic range equation for it.

9. **Write short note on Scanning systems or multispectral scanner.**
   (*define and explain about the scanning system and provide explanation of two types of multispectral scanner: across and along tracking sensors)*

   Along-track scanners are a type of remote sensing instrument that captures images or data along the direction of the sensor's motion or orbit. These scanners are commonly used in satellite and airborne systems for various Earth observation applications. The term "along-track" refers to the direction of the platform's movement, whether it's an orbiting satellite or an airborne sensor, and the scanning mechanism is oriented along this track.

Here are some key features and characteristics of along-track scanners:

Direction of Scanning: Along-track scanners scan the Earth's surface in the direction of the sensor's motion. This is typically the direction of the satellite's or aircraft's orbit or flight path.
Mechanical or Electronic Scanning: Along-track scanning can be achieved through both mechanical and electronic scanning mechanisms:

- Mechanical Scanning: Involves physically moving the sensor or its optics to capture data along the track. This movement can be achieved using rotating mirrors or other mechanical devices.
- Electronic Scanning: Involves adjusting the sensor's electronics or detector arrays to capture data along the track without the need for physical movement.

Strip or Swath Imaging: Along-track scanners capture data in the form of strips or swaths along the direction of the platform's movement. The width of the strip or swath depends on factors such as the field of view and sensor design.

Across-track scanners are a type of remote sensing instrument that captures images or data across the direction of the sensor's motion or orbit. These scanners are commonly used in satellite and airborne systems for various Earth observation applications. The term "across-track" refers to the direction perpendicular to the platform's motion, and the scanning mechanism is oriented across this track.
Here are some key features and characteristics of across-track scanners:

Direction of Scanning: Across-track scanners scan the Earth's surface in a direction perpendicular to the sensor's motion. This is typically the direction across the satellite's or aircraft's orbit or flight path.
Mechanical or Electronic Scanning: Across-track scanning can be achieved through both mechanical and electronic scanning mechanisms:

- Mechanical Scanning: Involves physically moving the sensor or its optics to capture data across the track. This movement can be achieved using rotating mirrors or other mechanical devices.
- Electronic Scanning: Involves adjusting the sensor's electronics or detector arrays to capture data across the track without the need for physical movement.

Swath Imaging:
Across-track scanners capture data in the form of swaths across the direction of the platform's motion. The width of the swath depends on factors such as the field of view and sensor design.

(*use pdf for observational geometry and explanation)*

10. Spatial and spectral remote sensing

Spatial remote sensing is a field that involves the collection and analysis of information about the Earth's surface from a distance, with a primary focus on the spatial characteristics of the data. This field encompasses various technologies and

techniques for capturing, processing, and interpreting imagery and data to understand the spatial distribution of features on the Earth's surface.
The key aspect of spatial remote sensing is spatial resolution. In remote sensing, spatial resolution describes how clearly an image can show small details or objects. It's like the sharpness of a photo. A high spatial resolution means the image can show very small things clearly, like individual trees or buildings, while a low spatial resolution makes it hard to see small details, and everything might look blurry. The quality of the sensor or camera determines how well these small details can be seen in the image.

Spectral remote sensing involves capturing and analyzing information about the interaction of electromagnetic radiation with objects or features on the Earth's surface across different wavelengths or bands. This type of remote sensing focuses on the spectral characteristics of the reflected or emitted radiation, providing valuable insights into the composition and properties of materials on the Earth. The key concepts used in spectral remote sensing are:

1. EM spectrum: The electromagnetic spectrum encompasses a range of wavelengths of electromagnetic radiation, including visible, infrared, and microwave. Spectral remote sensing utilizes specific bands within this spectrum to gather information about the Earth's surface.
2. Spectral bands: Spectral bands are specific ranges of wavelengths captured by remote sensing sensors. Each band corresponds to a specific region of the electromagnetic spectrum. Different bands are sensitive to particular features on the Earth's surface, allowing for material identification and classification.
3. Spectral signatures: Spectral signatures are unique patterns of reflectance or emission for different materials. These signatures are characteristic of the way materials interact with light across different wavelengths. Analyzing spectral signatures enables the identification of land cover types, vegetation health, and other surface characteristics.

11. Write similarities and difference of radar and lidar.
Look into the pdf provided.

12. Write short note on Geo-stationary orbit
(*also look at the pdf provided, include the characteristics also)*

13. Explain ground truth
(*also provided in the pdf)*

14. Write short notes on highway surveillance radar

Highway surveillance radar systems are advanced technologies designed for monitoring and managing traffic on highways. These radar systems utilize electromagnetic waves to detect and track the movement of vehicles, providing essential data for traffic management, safety enforcement, and incident detection. Most highway surveillance radar systems operate based on Doppler radar technology. These radars emit radio waves toward moving vehicles, and the system measures the frequency shift in the reflected waves caused by the motion of the vehicles. This information is then used to determine the speed and direction of each vehicle. It is used for:

- Vehicle Speed Measurement: The primary function of highway surveillance radar is to measure the speed of vehicles on the road accurately. This data is crucial for enforcing speed limits and managing traffic flow efficiently.

- Traffic Monitoring: Radar systems continuously monitor traffic conditions, providing real-time information on traffic density, congestion, and vehicle movement. This data is invaluable for traffic management and planning.

- Incident Detection: Radar systems are capable of detecting sudden changes in vehicle speed or unexpected stops, signaling potential incidents such as accidents or road hazards. This allows for prompt response and intervention by traffic authorities.

Chapter: 4 Application of Remote sensing:

Questions:

1. **Based on theoretical aspects and by providing technical specification, explain any one of remote sensing application.**

   Here are the names of several satellites with their technical specification equipped with Synthetic Aperture Radar (SAR):

   (write any one of the following technical specification and explain radar as a remote sensing application with observational geometry)

1. TerraSAR-X:
   - Orbit: Sun-synchronous orbit
   - Altitude: Approximately 514 km
   - Inclination: 97.44 degrees
   - Repeat Cycle: 11 days
   - Period: Approximately 98.9 minutes
   - Eccentricity: 0.00025
   - Operating Frequency: X-band (9.65 GHz)

2. RADARSAT-2:
   - Orbit: Sun-synchronous orbit
   - Altitude: Approximately 798 km
   - Inclination: 98.6 degrees
   - Repeat Cycle: Various modes, including daily, weekly, and longer intervals
   - Period: Approximately 100.6 minutes
   - Eccentricity: 0.00014
   - Operating Frequency: C-band (5.405 GHz)

3. Cosmo-Skymed:
   - Orbit: Sun-synchronous orbit
   - Altitude: Approximately 619 km
   - Inclination: 97.9 degrees

- Repeat Cycle: 16 days
- Period: Approximately 97.3 minutes
- Eccentricity: Nearly 0.0001
- Operating Frequency: X-band (9.6 GHz)

4. Sentinel-1A and Sentinel-1B (European Space Agency):
   - Orbit: Sun-synchronous orbit
   - Altitude: Approximately 693 km
   - Inclination: 98.18 degrees
   - Repeat Cycle: 12 days
   - Period: Approximately 98.5 minutes
   - Eccentricity: Nearly 0.0001
   - Operating Frequency: C-band (5.405 GHz)

5. SAOCOM 1A and SAOCOM 1B (CONAE, Argentina):
   - Orbit: Sun-synchronous orbit
   - Altitude: Approximately 620 km
   - Inclination: 97.88 degrees
   - Repeat Cycle: 16 days
   - Period: Approximately 97.3 minutes
   - Eccentricity: Nearly 0.0001
   - Operating Frequency: L-band (1.275 GHz)

(*if you want to explain any other application of remote sensing such as lidar, multispectral scanning system, then research technical specification of satellite having those sensors, and explain it with observational geometry, while explaining you can write the application of the sensors too;*
For example:
Application of Radar:
1.Ground-based radar is applied chiefly to the detection, location and tracking of aircraft of space targets.
2. Shipborne radar is used as a navigation aid and safety device to locate buoys, shorelines and other ships. It is also used to observe aircraft.
3. Spaceborne radar is used for the remote sensing of terrain and sea, and for redezvous/docking.
4. Airborne radar is used to detect aircraft, ships and land vehicles. It is also used for mapping of terrain and avoidance of thunderstorms and terrain.)

2. Describe any one remote sensing application by highlighting its application, merits and sensing technology.
   (*same as question no. 1 without the technical specification, however, for the sensing technology radar is active remote sensing technology and explain how radar is active remote sensing)*

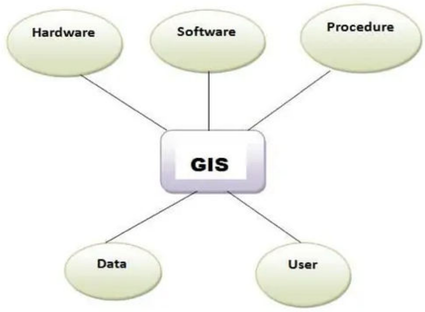
3. What is GIS? Explain its model to provide good approach to take decision.
4. What is GIS? What are its key components? How GIS is fruitful for human being. State its limitation.
   (*fruitful to human beings- explain the application of GIS being advantageous to human beings)*

5. Explain the concept and role of GIS in remote sensing.
   (*role of GIS in remote sensing: Application of GIS in remote sensing)*

GIS is a computerized database system for capturing, storing, receiving, analyzing and displaying the spatial data.
Simply, it is a computer-based system used to capture, store, analyze and display the geographic information.
It is a general-purpose technology for handling geographic data into digital form and satisfy the following needs:
- Ability to preprocess data from the large stores into a form suitable for analysis, including operations like formatting, sampling and generalization.
- Direct support for analysis and modelling
- Post processing of results into table, reports or map.

Map making and geographic analysis are not new, but a GIS performs these tasks better and faster than do the old manual methods.
And, before GIS technology, only a few people had the skills necessary to use geographic information to help with decision making and problem solving.

Components of GIS:



Five key components:
1. Hardware
2. Software
3. Data
4. Procedure
5. Personnel/user

Hardware:
Hardware is the computer system on which the GIS Software operates. Hardware with powerful processing capacity, high speed connectivity for data transfer and ample disk space for storage. Hardware components consists of:
Motherboard, Processor, RAM, Hard Disk/ SSD, Graphics, Monitor, Printer, etc.
GIS Software:
GIS software provides functions and tools needed to store, analyze and display the analyzed information. Software components needed are:
1. DBMS
2. GIS Software
3. Graphical User Interface

Some GIS Software are;
ArcGIS, AutoCAD map, SAGA GIS, MapInfo, etc.
Data:
Most important component of GIS
Any spatial and non-spatial information stored digitally in computers or servers are referred as GIS data.
Types of Data:
Spatial Data: Describes the absolute and relative location of geographic features
Attribute Data: describes the characteristics of spatial features.
Methods:
Method is an important part of GIS that uses various techniques to turn data into useful and meaningful information for easy interpretation. This may include algorithms, statistics, formulas and models that are predefined and unique to each organization.

User:
Anyone who used the GIS are the user of GIS. GIS user range from the technical experts who design and maintain the system to those who use them to do their everyday work.
Working of GIS, *good approach to take a decision:*
5 step process allowing to apply GIS to any business or organizational problem that requires a geographical decision.
<u>Request:</u>
What is the problem you are trying to solve or analyze and where is it located?
The guidance to this question will help you decide what to analyze and present the results to your audience.
<u>Acquire:</u>
Then you need to find the data needed to complete your project. The type of data and geographic scope of your project will help direct your data collection methods and perform the analysis.
<u>Examine:</u>
You will surely not know the data collected is appropriate for your study after having thoroughly examined it. This includes how data is organized, the accuracy and the origins of the data.
<u>Analyze:</u>
Geographical Analysis is the key strength of GIS. Depending upon the project, there are many different methods of analysis to choose form. GIS modelling tools make it relatively easy to make these changes and create new outputs.
<u>Act:</u>
The results of your analysis can be shared through reports, maps, tables delivered in print or digitally over the network or web. You must decide the best way for describing and presenting the analysis.

Application of GIS:
1. **Agriculture:**
- GIS is a useful tool in agriculture.
- It uses data about the farms, weather and water resources to help determine the best agriculture practices.
- Researchers can assist farmers in finding suitable weather conditions for specific crops and locating nearby water resources for irrigation.

Application of GIS in agriculture:
- **Drought management:**
    - GIS helps manage droughts by identifying areas or lands that are experiencing a lack of water.
    - It helps prevent damage to plant seeds, human efforts, and expensive fertilizers.
- **Pest control:**
    - It is also used for pest control by predicting attacks from pests like locusts and rodents by analyzing spatial data of specific agricultural lands.
    - It allows the government and farmers to plan how to deal with these pests.

Land and soil analysis:
- By studying previous data sets, satellite images, or even analyzing the field directly, field workers can gather information about the land and soil conditions.

Planning of future food demand:
- By considering the population's needs, the government and farmers can plan and produce enough crops to meet the demand.

Useful Tools: ArcGIS and QGIS.

Real Example: Rice Crop Plantation

A software named "ENVI" is a useful tool that helps with the plantation of rice crops worldwide. It uses GIS to create layers of agricultural land and allows farmers to decide what parts are best for rice production.

2. Environment

- GIS can monitor how clean the air is in a specific area.
- It uses data from satellites that monitor air quality to create maps that show places with high pollution.
- Government can use this map to create policies to improve the air quality in those places.

Applications of GIS in Environment:

- **Quality of Life:**
    - It helps monitor the air and water quality to analyze real-life habitat conditions.
- **Planning:**
    - It simplifies the process of selecting the proper location for new infrastructure plans by checking the project's impact on the environment.
- **Resource management:**
    - Governments can locate areas with natural resources like water bodies, forests, and agricultural lands.
- **Climate change:**
    - They can analyze climate data to assess the risks associated with climate change.

Useful Tools: ENVI and GRASS GIS

Real Example: Construction Project Approval

Parivesh is an online system in India where people can submit construction proposals for approval. Using GIS, the software checks if the project can harm the environment, which lets the government decide whether to accept or reject these proposals. Government officials claim that it can reduce the time it takes to approve proposals by **30%.**

3. Urban Planning and Transportation

- GIS helps city planners and transportation experts combine different types of information like maps, satellite pictures, population statistics, and infrastructure data.
- It helps them make better decisions when designing cities and transportation systems that are sustainable and good for the environment.

Applications of GIS in Urban Planning and Transportation:

1. **Growth Forecast**:

- It's useful in developing models to predict and plan for the future expansion of cities.
- **Planning Land Usage:**
    - It lets infrastructure experts analyze and allocate land for various purposes like residential, commercial, and industrial use in urban areas.
- **Transportation network:**
    - Countries can improve transportation systems, including roads, public transit, and pedestrian infrastructure, to ensure smooth movement within cities.
- **Infrastructure management:**
    - Cities can efficiently manage urban infrastructure, such as bridges and public facilities, to support sustainable development.

Useful Tools: GRASS GIS and Whitebox GAT.

Real Example: Dubai Integrated Rail Master Plan

Dubai's Roads and Transport Authority (RTA) wanted to make sure that people could travel freely while the country's population was growing. So they developed the Dubai Integrated Rail Master Plan. This plan uses GIS to manage its transportation system by improving the use of traffic signals as well as checking the flow of traffic. GIS helps RTA collect data like land space, population, traffic zones, etc., to create suitable transport networks.

Disaster Management

- GIS can keep an eye on places that have a higher chance of natural disasters.
- So, it can alert the environment-related authorities in case of emergencies, and they can act accordingly.
- It can help them reach the affected areas in time, respond to victims, develop recovery plans, and take measures to prevent future disasters.

Applications of GIS in Disaster Management:

1. **Risk-Prone Locations:** It helps in identifying risk-prone locations such as hospitals.
2. **Isolation Centers:** It assists in establishing isolation centers near high-risk zones.
3. **Calamity Records:** Government officials can use them to maintain records of past calamities in an area.
4. **Previous Impact:** GIS helps analyze the impact of previous disasters to plan for future contingencies.

Real Example: HAZUS (Hazards US)

FEMA is a US agency that helps the US government prepare for natural disasters, mainly earthquakes. They have a GIS system called HAZUS that predicts how disasters will affect specific areas. This information helps FEMA create safety plans, such as strengthening buildings and establishing emergency recovery programs in high-risk locations.

5. Business and Marketing

Businesses and companies can use GIS tools to evaluate their competitors as well as analyze the markets. This way, they can create impactful marketing strategies to maintain a strong position in the market. They can also improve production processes to make operations more efficient and effective.

Applications of GIS in Business Management:

- **Target Markets:** It lets businesses understand customer demographics and behavior patterns to find target locations for new business ventures.
- **Choosing Advertising Sites:** It can help companies find suitable places for billboards or other advertising mediums.
- **Managing Product Distribution:** Businesses can select the best transport routes to save money and make their distribution process more efficient.

Useful Tools: CARTO and MapInfo Pro

Real Example: Starbucks

Starbucks uses GIS to find ideal locations for new stores. They use the system to check the income level of people living in high-population areas. They also check if there are any competitors in the area and if opening a store in the area will be profitable or not.

6. Health and Human Services

The government can use GIS to find areas where the population may suffer from specific health conditions. It can help health professionals take the necessary actions in time. GIS can also help coordinate with emergency services during disease outbreaks.

Applications of GIS in Health and Human Services:

- **Identifying High-Risk Zones:** By mapping the distribution of diseases in a specific location, authorities can find areas at high health risk.
- **Educating about Health:** GIS can assist the government in raising awareness about health-related issues, promoting healthy behaviors, and achieving other objectives.
- **Emergency Response:** GIS helps coordinate emergency responses by mapping healthcare facilities, emergency services, evacuation routes, and more.

Useful Tools: MapInfo and Google Earth.
Real Example: Sightsavers
The Sightsavers team in Kenya helps people by treating diseases that can cause blindness. They use GIS to find such houses amidst hundreds of houses. GIS uses data about the town's population to identify homes in urgent need of care. It also keeps track of previously visited houses, saving time by avoiding revisits to the same families.

7. Tourism
GIS helps the tourism industry find popular tourist spots and use the knowledge for effective marketing. It also promotes sustainable tourism practices to enhance visitor experiences.
Applications of GIS in Tourism:

- **Navigation:** GIS can create maps with routes, landmarks, and more to make navigation easier.
- **Destination Marketing:** Tourism authorities can promote tourist destinations by highlighting attractions, accommodations, restaurants, and other points of interest.
- **Preserving Cultural Heritage:** GIS helps protect important historical landmarks, archaeological sites, and significant places for nations.

Useful Tools: ArcGIS and Google Maps API
Real Example: Connecting with hidden tourist spots
The Bulawayo City Council (BCC) is a local governing body responsible for managing and administrating the city of Bulawayo in Zimbabwe. BCC have started using the GIS system to connect with hidden gems like local hotels and heritage sites to promote tourism, increasing their global earnings. They use GIS maps to find places that are unsanitary and improve them for better visitor experiences.

8. Oil and Gas
GIS uses spatial data to explore the world and find areas with oil and gas resources. It also helps test the benefits of a new project and check if these projects affect the environment in any way.
Applications of GIS in Oil and Gas:

- **Finding locations:** Organizations can find the best places to drill for oil and gas by looking at the Earth's features.
- **Pipeline Management:** GIS is important for planning pipeline routes and ensuring they are leak-free and secure.
- **Regulatory Compliance:** GIS assists companies in meeting regulations by utilizing data on who owns the land, lease agreements, environmental rules, and zoning restrictions.

Useful Tools: Petrel and GeoGraphix
Real Example: Niti Aayog and ISRO
Niti Aayog and ISRO collaborated to create a system that uses GIS to find all the places in India that have energy (oil and gas) reserves. This system creates a simple map with all the routes for safe and cost-effective transportation of these resources.

9. Astronomy

GIS technology helps astronomers visualize and understand information about space, allowing them to explore the universe. This way, they can discover new things and also learn about its evolution. They can also use it to study the different parts of space and various celestial phenomena.

Applications of GIS in Astronomy:

- **Track Celestial Objects:** It helps astronomers accurately track and locate celestial objects using celestial coordinate systems.
- **Space Mapping:** GIS helps create 3D maps and models of celestial bodies in our solar system, allowing us to visualize astronomical data.
- **Observation Sites:** It makes it easier to select optimal sites for observatories, considering factors like light pollution and atmospheric conditions.

Useful Tools: Starlink and Stellarium

Real Example: Confirming the presence of water on Mars

According to a study by Gaetano Di Achille and Brian Hynek from the University of Colorado at Boulder, Mars had a large ocean covering around one-third of its surface approximately 3.5 billion years ago. They used the GIS mapping system to analyze data from NASA and the European Space Agency. The researchers created a model resembling the surface of Mars and examined features such as deltas, valley networks, and topography.

10. Banking

Banks can use GIS to make better decisions in various areas of their operations. They can study factors like population density, income levels, and existing branches to find the best location for their new branches. They can analyze all this data to customize their products and services to meet the specific needs of their customers. It helps them enhance their customer service.

Applications of GIS in Banking:

- **Risk evaluation:** Banks can assess risk indicators like property values, environmental risks, etc., to create appropriate lending strategies.
- **Fraud detection:** They can use GIS to find any unusual patterns in financial transactions that may indicate fraudulent activity.
- **Asset Management:** GIS helps banks study real estate assets like offices and properties to make informed decisions about acquiring or leasing properties.

Useful Tools: PostGIS and GeoDjango

Real Example: Providing banking services to underbanked areas

United Bank of Africa (UBA) uses GIS to study maps and data of regions with limited access to banking services. By doing so, they understand the challenges people in these areas face regarding financial services. This understanding enables them to provide customized services to areas with poor or no banking services.

11. Crime & Defence

Defense authorities can use GIS to create maps of borders and critical areas. These maps can help in the development of effective security policies and plans. Moreover, by uploading important spatial data into GIS, they can monitor resource allocation for better crime prevention.

Applications of GIS in Crime and Defence:

- **Enforcing Policy:** It allows law enforcement to examine criminal incidents, understands criminal activity patterns, and find areas where incidents happen frequently.

- **Crime Scene Mapping:** Officials can use GIS to create maps of crime scenes, helping them investigate cases, gather evidence, track suspects, and reconstruct crime scenes.
- **Facility Management:** Defense agencies can use GIS to find suitable locations for facilities like military bases, training grounds, and equipment storage.

Useful Tools: IBM i2 and ERDAS.

Real Example: Preventing illegal activities near defense zones

The Centre of Excellence on Satellite & Unmanned Remote Vehicle Initiative (CoE-SURVEI) in India uses GIS-based software. This software uses satellite images to find any suspicious activities in the country's defense lands. It can also find authorized or unauthorized constructions, helping to prevent illegal activities.

12. Education

GIS technology is useful in education for making subjects like geography and environmental studies easier to understand. It can also help decide where to build schools to provide education to students who don't have many opportunities. Additionally, GIS helps improve the student experience by making sure resources are allocated properly through careful planning.

Applications of GIS in Education:

- **Geographical data:** It enhances geography education by enabling students to delve into geographical data, create maps, and comprehend spatial relationships
- **Studying the Ecosystem:** It aids in the study of ecosystems, tracking habitat changes, and assessing the impact of human activities on the environment.
- **Historical mapping:** It lets students explore historical maps, analyze social patterns, and gain insights into the evolution of cities and civilizations over time.
- **Hazards:** It assists students in simulating potential risks and creating effective evacuation plans.

Useful Tools: ArcGIS storymaps and OpenStreetMap.

Real Example: Teaching using GIS

Esri UK, an England-Based software company, created a program called "Teach with GIS" to help teachers in their classrooms. This program offers different resources such as lesson plans, videos, interactive maps, and dashboards. These resources can help teachers effectively educate students aged 7 to 18.

Challenges and Limitations of GIS:

1. **Costs:** It can be difficult for some organizations to buy and use, as GIS technology can be very costly.
2. **Huge Data:** GIS deals with a large amount of data, which can take a lot of time and require powerful hardware and efficient software.
3. **Technical Expertise:** Using the GIS system effectively requires specific knowledge and technological expertise.
4. **Integration Problem:** Combining data from many sources can be challenging and time-consuming.
5. **Privacy and Security:** A major concern is keeping private and confidential data safe from unauthorized access.

6. Explain remote sensing applications in forest resource management highlighting remote sensing techniques, advantages, types of data format and interpretation of data.
   Some of the application of remote sensing are:

Atmospheric monitoring:

- Measurements and observation of the atmosphere are the most pre-requisite to the understanding of weather and climate.
- The accuracy of the weather forecasting relies on the initial state of the atmosphere and detailed measurements through out the atmosphere.
- The weather prediction and monitoring is accurately improving due to the advancement of new observing systems based on airborne and space borne platforms.
- These platforms continuously monitors earth atmosphere process and parameters continuously.
- The television infrared observation satellite (TIROS-1) launched in 1960, was the first satellite based platform for monitoring atmospheric process of the earth.
- Then lots of satellite have been launched with different sensors that provides wide range of atmospheric parameters that helped the understanding of earth atmospheric process.
    i. Cloud cover: Clouds play a pivotal role in regulating temperature, precipitation, and even sunlight. Remote sensing satellites equipped with specialized sensors can capture high-resolution images of cloud cover. These images are essential for meteorologists to track the movement, type, and density of clouds, enabling them to make more accurate predictions about **precipitation and weather patterns**.
    ii. Temperature: Temperature variations in the atmosphere are key indicators of weather changes. Remote sensing instruments can measure temperature profiles at various altitudes, providing invaluable data for meteorologists. This information aids in identifying temperature inversions, as well as monitoring temperature gradients that **influence weather** phenomena such as thunderstorms.
    iii. Ocean current: The oceans are a major driver of weather patterns, and monitoring ocean currents is crucial for accurate weather forecasting. Remote sensing technology, including satellites, allows scientists to track the movement and temperature of ocean currents. This data helps predict the development of weather systems, including hurricanes and typhoons, which draw energy from warm ocean waters.
    iv. Air Quality: Understanding air quality is not only important for human health but also for weather forecasting. Remote sensing instruments can detect pollutants in the atmosphere, such as particulate matter and greenhouse gases. By monitoring air quality, meteorologists can assess how these pollutants may impact weather conditions and make more informed forecasts.
    v. Precipitation: Accurate precipitation forecasts are essential for agriculture, water resource management, and disaster preparedness. Remote sensing technology, such as radar and satellite imagery, provides real-time data on precipitation intensity and distribution. This information

enables meteorologists to issue timely warnings for floods, droughts, and other weather-related events.

vi. Atmospheric Moisture: The amount of moisture in the atmosphere plays a crucial role in weather patterns. Remote sensing instruments, such as microwave radiometers, can measure atmospheric moisture levels with high precision. This data is vital for predicting humidity, cloud formation, and the likelihood of precipitation.

vii. Wind: Remote sensing technology, provides real-time measurements of wind speed and direction at different altitudes. This information is crucial for predicting the behavior of storms, including their intensity and track. Remote sensors provide valuable data on wind speeds and directions, crucial for safety in various industries including aviation.

viii. Solar Radiation: Solar radiation is a key driver of weather and climate. Remote sensing instruments can measure solar radiation levels, helping meteorologists understand how it influences temperature, evaporation, and atmospheric circulation. This knowledge is vital for accurate weather forecasting and climate research

Remote sensing has revolutionized weather forecasting by providing a wealth of data on various atmospheric parameters. As technology continues to advance, we can expect even more accurate and timely weather forecasts.

Land use and land cover mapping:

- Land use refers to the man's activities on land, i.e. it is related to the utilization of land.
- Land cover refers to the coverage of the land by vegetation or artificial construction.
- Remote sensing plays a vital role in modern land use planning by providing accurate and timely spatial data.
- It enables the planner to analyze the land cover changes, monitor urban expansion, access environment impact, and make informed decisions for sustainable development

I. Urban Planning and growth monitoring:

- Through satellite imagery and aerial photography, urban planners can gain insights into the expansion and evolution of cities.
- By analyzing land cover changes and population growth, planners can make informed decisions about infrastructure development, housing projects, and green spaces

II. Agriculture and crop management:

- Satellite sensors equipped with various spectral bands can capture data about crop health, moisture levels, and nutrient content.
- This information empowers farmers to make informed decisions about irrigation, fertilization, and pest control.
- Remote sensing technology enables the creation of detailed crop health maps, which assist in identifying areas requiring attention.

III. Forestry and bio-diversty conservation:

- Remote sensing plays a pivotal role in monitoring forest cover, deforestation, and changes in biodiversity.
- By utilizing satellite imagery and LiDAR technology, experts can assess the health of forests, detect illegal logging, and measure carbon sequestration.
- This information is crucial for formulating conservation strategies and policies.

- Moreover, remote sensing aids in monitoring endangered species' habitats and identifying areas requiring protection.

IV. Environment impact assessment:

- Remote sensing offers a comprehensive approach to environmental impact assessment.
- Satellite imagery and **aerial surveys** provide detailed information about the project area's existing conditions. By comparing **before-and-after images**, experts can quantify changes in land cover, vegetation, and topography.
- This data aids in evaluating the project's impact on ecosystems, biodiversity, and water resources.

V. Disaster management and mitigation:

- Remote sensing technology plays a crucial role in disaster management and mitigation efforts.
- Satellite images can assess the extent of damage caused by events like earthquakes, floods, and wildfires.
- These images aid in coordinating emergency response, identifying affected areas, and planning evacuation routes.
- Additionally, remote sensing assists in assessing post-disaster conditions, enabling efficient recovery and reconstruction processes.

VI. Infrastructure development:

- Efficient infrastructure development relies on accurate spatial data and insights.
- Remote sensing provides a cost-effective and timely way to collect information about terrain, land use, and existing infrastructure.
- This data guides the planning and design of roads, bridges, utilities, and public spaces.
- Remote sensing also aids in monitoring construction progress, ensuring adherence to project timelines and specifications.

VII. Transportaiton Planning:

- Efficient transportation systems are the backbone of modern societies.
- Remote sensing provides invaluable data for transportation planning and management.
- Satellite imagery and geospatial data help identify traffic congestion, analyze transportation patterns, and assess road conditions.
- By understanding how people move within urban areas, planners can optimize road networks, design effective public transportation routes, and reduce traffic congestion.

VIII. Green Space Planning:

- Remote sensing aids in identifying suitable locations for parks, gardens, and recreational areas.
- Satellite imagery and LiDAR data provide insights into land cover, vegetation density, and topography, helping urban planners select optimal locations for green spaces.

Remote Sensing in Vegetation, Forestry and Ecology:

- In order to monitor the health of forests, evaluate crops, and classify land cover, remote sensing is a vital tool for vegetation study.

- It makes it possible to identify environmental changes like drought and deforestation, supports conservation initiatives like mapping wetlands and protecting biodiversity, and helps with environmental impact studies and analyses of urban green spaces.
  a) <u>Forest Monitoring:</u>
     i. Through remote sensing technologies, we can monitor the health, size, and diversity of these crucial ecosystems.
     ii. **Satellite imagery** provides invaluable data for **tracking changes in forest cover** over time.
     iii. This becomes particularly vital in areas that are difficult to reach or monitor through conventional means.
  b) <u>Vegetation Health Monitoring:</u>
     i. Vegetation health is a primary concern for both environmental scientists and agricultural experts.
     ii. Remote sensing offers a non-intrusive means to monitor plant health by assessing various indices like the Normalized Difference Vegetation Index (NDVI).
     iii. It provides a numerical value that represents the relative greenness of an area, which can be used to monitor vegetation growth, drought conditions, and land use change over time.
     iv. **NDVI measures the difference between the amount of light reflected by vegetation in the near-infrared (NIR) and visible (VIS) portions of the electromagnetic spectrum.**
     v. These techniques are invaluable in predicting crop yields and analyzing plant stress levels.
  c) Crop Assessment:
     i. Detailed satellite images help farmers assess the state of their crops, check for diseases, and determine areas that need irrigation or fertilization.
     ii. This data-driven approach enhances productivity and ensures food security.
  d) Deforestation Detection:
     i. By comparing satellite images taken at different intervals, we can identify areas where deforestation is occurring and at what rate.
     ii. This enables authorities and conservation organizations to take timely actions.
     iii. The data also feeds into global reports on forest loss, contributing to international efforts to combat climate change
  e) Drought Detection:
     i. Drought is a devastating natural phenomenon, affecting both agriculture and water supply.
     ii. With remote sensing, it becomes possible to monitor parameters like soil moisture levels and vegetation stress.
     iii. By analyzing these data, early warnings can be issued, enabling preventive measures to mitigate the impact of drought on affected communities
  f) <u>Erosion Control:</u>
     i. Remote sensing allows for the rapid assessment of areas susceptible to erosion.
     ii. Data such as soil composition, topography, and vegetative cover can be analyzed to develop erosion control measures.
  g) <u>Carbon Sequestration Assessment:</u>

i. Remote sensing offers an efficient way to estimate the carbon storage capacity of forests, grasslands, and even agricultural lands.
ii. Carbon sequestration: the practice of removing the carbon from the atmosphere and storing it.
iii. This data can contribute to both national and global carbon budgeting efforts (total amount of carbon emission that may be released in certain period.

h) Fire Detection and Management:

i. Remote sensing technology has become indispensable in the detection and management of wildfires.
ii. It offers real-time monitoring capabilities, aiding firefighting efforts and post-fire impact assessment.
iii. Not only does it help in identifying active fire locations, but it also allows for the evaluation of damage, including assessing the loss of vegetation and impacts on soil

Remote Sensing in Water Planet:

- One of the most vital application of remote sensing is in water resources management.
- Water resources are essential for the life on Earth
- Water sustainable management is critical for the well-being of both humans and the environment.

Accessing Water Availability:

- Satellite-based sensors provide comprehensive data on various water bodies, including lakes, rivers, and reservoirs.
- These sensors measure the surface area, volume, and water levels of these bodies, enabling us to track changes over time.
- This information aids in understanding water availability trends, identifying water-stressed regions, and making informed decisions for water allocation and distribution.

Detecting Water Pollution:

- Remote sensing offers an effective means of detecting water pollution sources and monitoring their spread.
- By using specialized sensors, it becomes possible to identify and track pollutants like oil spills, chemical discharges, and sediment runoff.
- This early detection aids in mitigating the environmental impact of pollution, reducing harm to aquatic ecosystems and biodiversity.

Mapping Watershed Boundaries:

- Remote sensing allows for the mapping of watershed boundaries and delineating (describing) their drainage patterns.
- This information facilitates water resource planning, flood risk assessment, and **land use management**, ensuring optimal water utilization within each watershed.

Costal Zone Management:

- Coastal zones are vulnerable to various environmental challenges, including erosion, pollution, and rising sea levels.
- Remote sensing aids in monitoring coastal changes, assessing shoreline erosion, and detecting coastal pollution sources.
- This data informs coastal zone management strategies and supports the conservation of coastal ecosystems.

Irrigation Management:

- Efficient irrigation practices are essential for sustainable agriculture and water conservation.
- Remote sensing provides data on crop health, soil moisture, and evapotranspiration rates, allowing farmers to optimize their irrigation schedules.
- This technology enhances water use efficiency, minimizes water wastage, and improves crop productivity.

Groundwater Exploration:

- Remote sensing helps in locating potential groundwater reservoirs by mapping subsurface geological structures and identifying areas with high groundwater potential.
- This valuable information supports sustainable groundwater management and prevents overexploitation of this vital resource.

Remote Sensing in Geology:

- Remote Sensing enables geologists to gather vital data about the Earth's surface and subsurface without physical contact.
- This technology aids in mapping geological features, identifying mineral deposits, monitoring land use changes, and assessing natural hazards.

Mineral Exploration:

- With technologies like hyperspectral imaging and radar, geologists can detect the spectral signatures of various minerals.
- This allows them to identify, map, and quantify mineral deposits remotely, leading to discoveries that would have been impossible with conventional ground surveys alone.

Landform Analysis:

- By capturing large-scale images of the Earth's surface, geologists can analyze terrain morphology, land use, and slope stability.
- This can help in understanding the geological history of an area, predicting future geological events, and making informed decisions on land use planning.

Geological Hazard Assessment:

- Remote sensing is invaluable in monitoring and predicting geological hazards such as earthquakes, landslides, and volcanic eruptions.
- Through various sensors and imagery, geologists can assess risk levels, identify vulnerable areas, plan evacuation routes, and even initiate early warning systems.
- The use of remote sensing in this context helps to save lives and reduce damage to infrastructure.

Structural Geology:

- Technologies like satellite imagery and radar are used for studying structural geology.
- They allow geologists to detect and analyze the Earth's structural features.
- This helps in understanding the forces and processes involved in the Earth's crustal deformation and mountain-building processes.

Paleo-geographical Reconstructions:

- Remote sensing also aids in the identification and reconstruction of ancient geographical features.
- By studying changes in the landscape over time, geologists can reconstruct the Earth's past environments, which helps to understand its geological history and the evolutionary processes that have shaped it.

Soil Study:

- Soil characteristics, including moisture content, organic matter, and mineral composition, can be assessed remotely.
- This provides critical data for agricultural practices, land use planning, and environmental conservation.

Extraterrestrial Geology:

- Remote sensing has expanded the field of geology beyond the confines of our planet.
- It allows scientists to study the geology of other planets, moons, and asteroids, helping us understand the universe and our place within it.

Chapter-5 Remote sensing Data

Questions:

Types of data formats of remote sensing data:

Based on Storage:

1. **Analog Data**:
   - Analog data represents continuous signals or information in a physical form. In remote sensing, analog data may include photographic films, aerial photographs, or hardcopy prints. These formats require physical storage and are typically not directly compatible with digital systems.
2. **Digital Data**:
   - Digital data represents information in a discrete, numerical format, commonly stored as binary code (0s and 1s). Digital remote sensing data include digital images, raster datasets, and vector datasets stored in electronic files. Digital data can be easily manipulated, analyzed, and transmitted using computers and digital processing techniques.

Based on Data Taken:

1. **Georectified Data**:
   - Georectified data are spatially corrected to align with a specific map projection or coordinate system, ensuring accurate geographic referencing. This process involves correcting geometric distortions caused by sensor orientation, terrain variations, or platform motion. Georectified data are commonly used in GIS and mapping applications, where precise spatial referencing is essential.
2. **Georeferenced Data**:
   - Georeferenced data are spatially referenced to a known coordinate system or reference frame but may not be geometrically corrected to remove distortions. These datasets provide spatial context and location information but may still contain inherent geometric errors or inaccuracies. Georeferenced data are used in various applications, including navigation, location-based services, and geographic analysis.

Based on Display:

1. **Vector data:**

   Vector data is a type of geospatial data that represents geographic features as discrete points, lines, and polygons. Unlike raster data, which represents the Earth's surface as a grid of cells with each cell having a value, vector data represents features as individual objects with defined geometric shapes and attributes.

General components of vector data:

- **Points**: Represent specific locations on the Earth's surface, defined by their x, y coordinates. Points can represent features such as cities, landmarks, or sampling locations.
- **Lines (Polylines)**: Represent linear features composed of connected line segments, such as roads, rivers, or boundaries.
- **Polygons**: Represent enclosed areas defined by a series of connected vertices, such as countries, lakes, or administrative boundaries.

2. **Raster data:**

Raster data is a type of geospatial data that represents the Earth's surface as a grid of regularly spaced cells or pixels. Each pixel in a raster dataset contains a value representing a specific attribute, such as elevation, temperature, land cover type, or spectral reflectance. Raster data is commonly used in remote sensing, digital image processing, and geographic information systems (GIS).

General components of raster data:

- **Grid Structure**:
    - Raster data is organized into a grid structure, with rows and columns of equally sized cells or pixels covering the extent of the study area.
    - Each cell or pixel in the grid represents a discrete unit of space on the Earth's surface.
    - The resolution of the raster dataset determines the size of each pixel and the level of detail captured in the data. Higher resolution datasets have smaller pixels and capture more detailed information.
- **Pixel Values**:
    - The value stored in each pixel represents a specific attribute or measurement at that location on the Earth's surface.
    - Examples of attributes represented in raster data include elevation (in digital elevation models - DEMs), temperature, precipitation, land cover classification, and spectral reflectance bands from remote sensing imagery.
    - Pixel values can be continuous (e.g., elevation values) or categorical (e.g., land cover classes).

- **Data Formats**:
    - Raster data can be stored in various file formats, such as GeoTIFF (.tif), JPEG (.jpg), PNG (.png), and Erdas Imagine (.img).
    - Each format has its own structure for encoding pixel values, spatial metadata, and other relevant information.
- **Multispectral and Hyperspectral Raster Data**:
    - Multispectral and hyperspectral raster datasets contain multiple bands representing different wavelengths of light collected by remote sensing sensors.
    - Multispectral datasets typically have a few bands corresponding to specific ranges of the electromagnetic spectrum (e.g., visible, near-infrared, and thermal bands).

- Hyperspectral datasets consist of numerous narrow bands covering a broader range of the spectrum, enabling detailed analysis of surface materials and vegetation characteristics.

Raster model	Vector model
Advantages	**Advantages**
1. It is a simple data structure. 2. Overlay operations are easily and efficiently implemented. 3. High spatial variability is efficiently represented in a raster format. 4. The raster format is more or less required for efficient manipulation and enhancement of digital images.	1. It provides a more compact data structure than the raster model. 2. It provides efficient encoding of topology, and, as a result, more efficient implementation of operations that require topological information, such as, network analysis. 3. The vector model is better suited to supporting graphics that closely approximate hand-drawn maps.
Disadvantages	**Disadvantages**
1. The raster data structure is less compact. 2. Topological relationships are more difficult to represent. 3. The output of graphics is less aesthetically pleasing because boundaries tend to have a blocky appearance rather than the smooth lines of hand-drawn maps. This can be overcome by using a very large number of cells, but it may result in unacceptably large files.	1. It is a more complex data structure than a simple raster. 2. Overlay operations are more difficult to implement. 3. The representation of high spatial variability is inefficient. 4. Manipulation and enhancement of digital images cannot be effectively done in the vector domain.

Retrieval Algorithms:

1. Classification Algorithm:
 - Classification algorithms categorize data into different classes or categories based on their characteristics or features. In remote sensing, this involves assigning pixels or objects within an image to predefined classes representing land cover types, features, or phenomena.
 - Used for tasks such as land cover mapping, vegetation classification, urban sprawl detection, and habitat delineation.

2. Thresholding:
 - Thresholding involves assigning pixels to classes based on a predefined threshold value applied to a specific image attribute, such as pixel intensity or spectral value. Pixels above the threshold are assigned to one class, while those below are assigned to another.
 - Commonly used for binary classification tasks, such as delineating water bodies from land areas or separating vegetation from non-vegetation.

3. Supervised Classification:
- Supervised classification requires training data, where known samples of different classes are used to train a classification algorithm. The algorithm learns the spectral signatures of each class and then assigns pixels in the image to the appropriate class based on their spectral similarity to the training samples.
- Widely applied in land cover mapping, crop identification, and urban land use classification.

4. Unsupervised Classification:
- Unsupervised classification does not require predefined training samples. Instead, it automatically groups pixels into clusters based on statistical similarity in their spectral characteristics. Users then interpret the resulting clusters to assign meaningful class labels.
- Useful for exploratory analysis, identifying patterns, and delineating homogeneous regions within an image without prior knowledge of class distributions.

5. Maximum Likelihood:
- Maximum Likelihood classification assigns pixels to classes based on the probability of them belonging to each class, calculated using statistical models of class distributions. It selects the class with the highest likelihood for each pixel.
- Particularly effective when class distributions are well-defined and follow specific statistical distributions, such as Gaussian distributions.

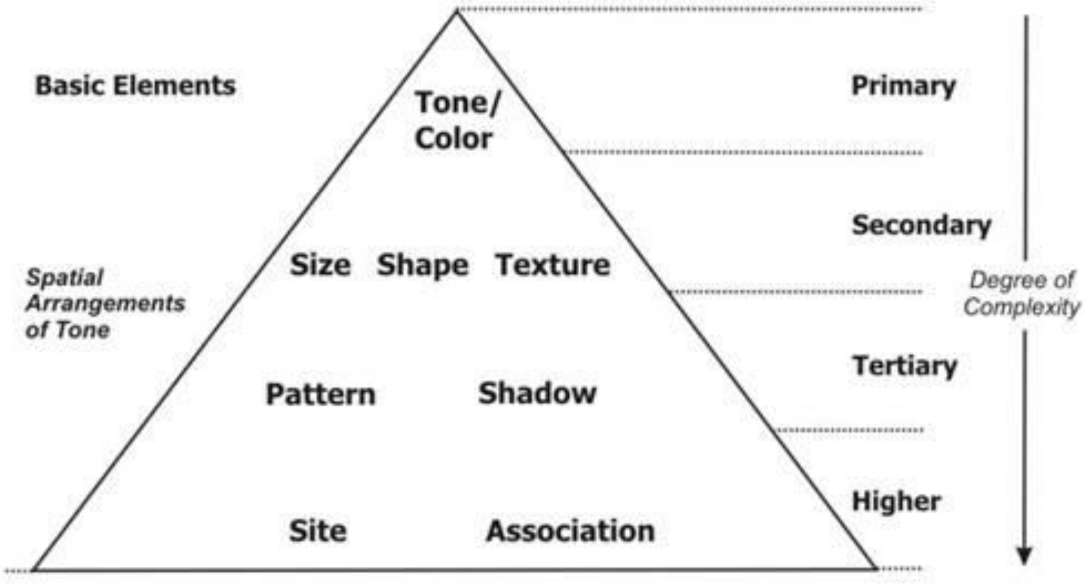
6. Mean Distance to Means:
- Mean Distance to Means classification assigns pixels to the class with the closest mean spectral value. Each class is represented by its mean spectral signature, and pixels are assigned to the class with the smallest Euclidean distance to its mean.
- Suitable for situations where class separability is high and classes exhibit distinct spectral characteristics.

7. Neural Networks:
- Neural networks are computational models inspired by the biological neural networks in the human brain. In remote sensing, artificial neural networks (ANNs) learn patterns and relationships between input data (e.g., spectral bands) and output classes through a training process.
- Effective for complex classification tasks, feature extraction, and pattern recognition in remote sensing imagery.

These retrieval algorithms are fundamental tools in remote sensing for extracting valuable information from digital imagery and facilitating a wide range of applications in environmental monitoring, land management, and resource assessment.

Elements (General Criterion) of visual image interpretation:

(*explain the elements: tone, shape, size, pattern, texture, shadow, site and association)*



Characteristics of Visual Image Interpretation:

1. Slant Range Distortion:
   - Slant range distortion is a geometric effect that occurs in radar imaging due to the varying distance between the radar sensor and the ground surface across the image.
   - It causes objects located farther away from the radar sensor to appear compressed or foreshortened compared to objects at closer ranges.
   - This distortion can affect the accuracy of measurements and interpretation of features, especially in areas with significant elevation changes.

2. Speckle:
   - Speckle is a form of noise commonly observed in radar and synthetic aperture radar (SAR) imagery.
   - It appears as a grainy or mottled pattern superimposed on the image, caused by the interference of coherent radar waves reflected from rough surfaces.
   - Speckle can reduce image quality, making it difficult to discern fine details and features.
   - Techniques such as speckle filtering are used to reduce speckle noise while preserving image information.

3. Relief Displacement:
   - Relief displacement is a cartographic effect that occurs in aerial or satellite imagery due to the three-dimensional nature of the Earth's surface.
   - It causes features on terrain with elevation variations to appear displaced from their true geographic positions when viewed from an oblique angle.
   - This displacement is most noticeable near the edges of elevated terrain, where features may appear shifted horizontally or vertically compared to their actual locations on the ground.

4. Parallax:
   - Parallax refers to the apparent shift in the position of objects relative to each other when viewed from different perspectives or angles.

- In remote sensing, parallax is particularly relevant in stereo imagery, where two or more images of the same area are acquired from different viewpoints.
- By analyzing the differences in object positions between stereo image pairs, it is possible to derive depth information and create three-dimensional (3D) representations of the terrain.

5. Stereo Capability:
   - Stereo capability refers to the ability of remote sensing systems to acquire images of the same area from multiple viewpoints or angles.
   - Stereo imagery enables the generation of 3D models and terrain reconstructions through stereo photogrammetry techniques.
   - By comparing corresponding points in stereo image pairs, it is possible to measure distances, elevations, and terrain features in three dimensions, providing valuable information for mapping, geospatial analysis, and visualization.

These characteristics are important considerations in remote sensing and image analysis, as they influence the accuracy, quality, and interpretation of imagery acquired from various sensors and platforms.

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VIRS: Visible and infrared scanner used to study precipitation, five channel imaging spectroradiometer
PR: Precipitation radar, first spaceborne instrument designed to provide 3D maps of storm structure.
TMI: radiometer designed to measure the rain rates over a wide swath.
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