- The sensor measures the EMR in its range.
- The total intensity of the energy from 0 to the maximum amount of the sensor measures is broken down into 256 brightness values for 8-bit data, and 128 brightness values for 7-bit data.

2.4 TEMPORAL RESOLUTION IN REMOTE SENSING:

- Temporal resolution refers to the amount of information available over a given time period.
- For example, the Landsat satellite can view the same area of the globe once every 16 days.
- On the other hand, SPOT can revisit the same area every three days.
- It is the revisit time of a satellite over a certain area. In other words, temporal resolution means the frequency of capturing images of a certain area by the satellite in a given time period.
- The availability of information over a given time period depends on the frequency of rotation of a satellite around earth.
- If a satellite comes over a specific area 2 times a day, its temporal resolution will be 12 hours. Similarly, if the satellite revisits a specific area every hour, its temporal resolution will be 1 hour.
- Temporal resolution is important to understand the direction and amount of change of phenomena in the study area.
- Land-use analysis needs monthly or yearly temporal resolution because land use changes slowly whereas disaster management needs hourly temporal resolution because disasters occur very fast and need regular monitoring.

3. SCANNERS:

- In remote sensing, a scanner is an instrument or device that captures information from the Earth's surface or the atmosphere without direct physical contact.
- These scanners are typically mounted on various platforms, including satellites, aircraft, or ground-based systems.
- The primary function of a scanner is to collect data about the environment, which can then be used to create images, maps, and other valuable information.
- Remote sensing scanners are equipped with sensors that detect electromagnetic radiation, and they come in various types depending on the specific needs of the application.
- Here are some common types of scanners in remote sensing:

➢ **Optical Scanners**

- Optical scanners capture data in the form of visible and near-infrared light.
- These scanners are commonly used for tasks such as land cover classification, vegetation monitoring, and urban mapping.
- Charge-Coupled Device (CCD) cameras are an example of optical scanners.

➢ **Infrared Scanners**

- Infrared scanners focus on capturing data in the infrared portion of the electromagnetic spectrum.

- These scanners are valuable for applications such as thermal mapping, monitoring vegetation health, and detecting heat anomalies.

➢ **Microwave Scanners**

- Microwave scanners, particularly Synthetic Aperture Radar (SAR), use microwave frequencies to capture data.
- SAR is useful for all-weather imaging and is often employed in applications like terrain mapping, agriculture monitoring, and disaster assessment.

➢ **Lidar scanners**

- Lidar scanners use laser beams to measure distances between the sensor and the Earth's surface.
- Lidar technology is frequently used for creating high-resolution topographic maps, assessing vegetation structure, and studying terrain features.

➢ **Hyperspectral Scanners**

- Hyperspectral scanners capture data across numerous narrow and contiguous spectral bands.
- These scanners are beneficial for applications requiring detailed information about the composition of materials, such as mineral identification, environmental monitoring, and precision agriculture.

➢ **Multispectral Scanners**

- Multispectral scanners capture data in a few broad spectral bands.
- These scanners are commonly used for tasks like land cover mapping, crop monitoring, and environmental studies.

➢ **Thermal Infrared Scanners**

- Thermal infrared scanners focus on detecting heat radiation emitted by the Earth's surface.
- They are often used for applications such as monitoring temperature variations, studying thermal properties of surfaces, and detecting heat anomalies.

- The choice of scanner depends on the specific objectives of the remote sensing mission, considering factors such as spatial resolution, spectral characteristics, and the type of information required.

3.1 ALONG AND ACROSS TRACK SCANNER:

- Scanning systems can be used on both aircraft and satellite platforms and have essentially the same operating principles.
- A scanning system used to collect data over a variety of different wavelength ranges is called a multispectral scanner (MSS) and is the most commonly used scanning system.

- There are two main modes or methods of scanning employed to acquire multispectral image data - across-track scanning, and along-track scanning.
- The terms "along-track scanner" and "across-track scanner" refer to the scanning geometry or movement of a sensor on a remote sensing platform.
- These terms are commonly used in the context of satellite or airborne imaging systems.

➢ **Along Track Scanner:**

- ✓ An along-track scanner is a type of remote sensing instrument where the sensor collects data along the direction of the platform's movement or orbit.
- ✓ In the case of a satellite, this would be along the orbital path.
- ✓ The sensor records a continuous strip of data or imagery as the platform moves forward.
- ✓ Satellite sensors with along-track scanning capabilities typically have a field of view that is oriented in the direction of the satellite's motion.
- ✓ This type of scanning is suitable for wide-area coverage.
- ✓ Examples of along-track scanners include pushbroom sensors, which acquire continuous strips of imagery along the direction of the satellite's motion.
- ✓ Along-track scanners also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction.
- ✓ However, instead of a scanning mirror, they use a linear array of detectors located at the focal plane of the image formed by lens systems, which are "pushed" along in the flight track direction.
- ✓ Each individual detector measures the energy for a single ground resolution cell and thus the size and IFOV of the detectors determines the spatial resolution of the system.
- ✓ A separate linear array is required to measure each spectral band or channel.
- ✓ For each scan line, the energy detected by each detector of each linear array is sampled electronically and digitally recorded.
- ✓ Along-track scanners with linear arrays have several advantages over across-track mirror scanners.
- ✓ The array of detectors combined with the pushbroom motion allows each detector to "see" and measure the energy from each ground resolution cell for a longer period of time (dwell time).
- ✓ This allows more energy to be detected and improves the radiometric resolution.
- ✓ Thus, finer spatial and spectral resolution can be achieved without impacting radiometric resolution.

➢ **Across Track Scanner:**

- ✓ Across-track scanners scan the Earth in a series of lines.
- ✓ The lines are oriented perpendicular to the direction of motion of the sensor platform.
- ✓ Each line is scanned from one side of the sensor to the other, using a rotating mirror.
- ✓ The sensor scans side to side, usually in a fan-like pattern, acquiring data across the swath width.

- ✓ Unlike along-track scanners, across-track scanners capture data across the direction of motion, allowing for the collection of a wider swath in a single pass.
- ✓ Whiskbroom scanners are an example of across-track scanners.
- ✓ As the platform moves forward over the Earth, successive scans build up a two-dimensional image of the Earth´s surface.
- ✓ The incoming reflected or emitted radiation is separated into several spectral components that are detected independently.
- ✓ A bank of internal detectors detects and measures the energy for each spectral band and then, as an electrical signal, they are converted to digital data and recorded for subsequent computer processing.
- ✓ The angular field of view measured in degrees is used to record a scan line and determines the width of the imaged swath.
- ✓ Airborne scanners typically sweep large angles (between 90º and 120º), while satellites, because of their higher altitude need only to sweep fairly small angles (10- 20º) to cover a broad region.
- ✓ Because the distance from the sensor to the target increases towards the edges of the swath, geometric distortions are introduced to the images.

- The choice between along-track and across-track scanning depends on the specific requirements of the remote sensing mission.
- Along-track scanning is more suitable for applications requiring continuous coverage along a path, while across-track scanning is advantageous for acquiring wider swaths of data in a single pass.
- Both scanning geometries have their advantages and trade-offs, and the selection depends on factors such as spatial resolution, coverage area, and mission objectives.

4. OPTICAL INFRARED SENSORS:

- Optical-infrared sensors are devices that detect and measure electromagnetic radiation in the optical and infrared (IR) regions of the electromagnetic spectrum.
- These sensors play a crucial role in various applications, including imaging, remote sensing, surveillance, astronomy, and industrial processes.

4.1 Overview of Optical-infrared Sensors:

➢ **Optical-infrared sensors work by:**

- Applying a voltage to a pair of IR light-emitting diodes (LEDs).
- Emitting infrared light.
- Propagating the light through the air.
- Reflecting the light towards the sensor when it hits an object.
- Detecting changes in IR radiation.

- **Optical Spectrum:**
  - **Visible Light (Optical):** This part of the spectrum includes wavelengths that are visible to the human eye (approximately 400 to 700 nanometres). Cameras, imaging devices, and other optical sensors operate in this range.
  - **Ultraviolet (UV):** Some optical sensors can also detect ultraviolet light, which has shorter wavelengths than visible light.

- **Infrared Spectrum:**
  - **Near - Infrared (NIR):** Wavelengths just beyond the visible spectrum, roughly 700 to 2500 nanometres. NIR is used in applications such as night vision and vegetation monitoring.
  - **Mid – Infrared (MIR):** Wavelengths between approximately 2,500 and 25,000 nanometres. MIR is often utilized in chemical analysis and environmental monitoring.
  - **Far – Infrared (FIR):** Wavelengths beyond 25,000 nanometres, used in applications like thermal imaging.

4.2 Types of Optical Infrared Sensors

- **Photodetectors:** Convert light signals into electrical signals. Examples include photodiodes, phototransistors, and photomultiplier tubes.
- **Cameras:** Capture visual information in the optical spectrum.
- **Thermal Infrared Sensors:** Detect infrared radiation emitted by objects due to their temperature. Infrared thermometers and thermal imaging cameras are common examples.
- **Spectrometers**: Analyse the composition of materials based on their spectral characteristics in the optical or infrared range.
- **LIDAR (Light Detection and Ranging):** Uses laser light to measure distances and create detailed, three-dimensional maps of the surroundings.
- **Infrared Gas Sensors** Detect the presence of specific gases based on their absorption of infrared light.

4.3 Applications:

- **Security and Surveillance**: Infrared cameras are used for night vision and surveillance applications.
- **Astronomy:** Telescopes equipped with infrared sensors allow astronomers to study celestial objects that emit infrared radiation.
- **Medical Imaging:** Infrared sensors are used in devices like pulse oximeters and thermal imaging cameras for medical diagnostics.
- **Environmental Monitoring:** Remote sensing applications, such as monitoring vegetation health or assessing pollution levels.
- **Automotive Safety:** Infrared sensors are used in collision avoidance systems and night vision systems in vehicles.

4.4 Challenges:

- **Atmospheric Absorption:** Certain wavelengths in the infrared spectrum can be absorbed by atmospheric gases, impacting sensor performance.
- **Temperature Sensitivity:** Some optical-infrared sensors are sensitive to temperature changes, which can affect their accuracy.
- **Cost:** Advanced infrared sensors can be expensive, limiting their widespread adoption in certain applications.

5. THERMAL SENSORS:

- Thermal sensors, also known as infrared or thermal imaging sensors, are devices designed to detect and measure infrared radiation emitted by objects.
- These sensors operate in the thermal infrared part of the electromagnetic spectrum, typically beyond the range of visible light. Here are some key aspects of thermal sensors:

5.1 Principle of Operation:

- **Infrared Radiation:** All objects with a temperature above absolute zero emit infrared radiation. Thermal sensors detect this radiation, which is proportional to the temperature of the object.
- **Thermography:** The process of creating an image based on the temperature variations of the objects in the scene.

5.2 Thermal Infrared Spectrum:

- **Wavelength Range:** Thermal sensors typically operate in the mid-infrared (MIR) and far-infrared (FIR) regions of the electromagnetic spectrum. The MIR range is approximately 3 to 5 micrometers, while the FIR range is around 8 to 14 micrometers.
- **Temperature Detection:** Objects emit thermal radiation based on their temperature, and thermal sensors can detect and quantify this emission.

5.3 Types of Thermal Sensors:

- **Thermal Cameras:** These devices capture infrared radiation and create visual representations of temperature variations. They are widely used for applications like security, search and rescue, and industrial inspections.
- **Infrared Thermometers:** Handheld or fixed devices that measure the temperature of a specific spot or surface without the need for contact. They are commonly used in medical, industrial, and HVAC applications.
- **Infrared Arrays**: Arrays of sensors used in thermal cameras to capture a two-dimensional image of a scene. Microbolometer and thermopile arrays are common technologies.

5.4 Applications:

- **Security and Surveillance:** Thermal cameras are effective for nighttime surveillance and can detect heat signatures, making them useful for security applications.
- **Search and Rescue:** Thermal imaging helps locate people or animals in low-visibility conditions, such as darkness, smoke, or dense vegetation.
- **Industrial Inspections:** Detecting overheating components, monitoring equipment performance, and identifying insulation issues in buildings.
- **Medical Imaging:** Infrared thermometers and thermal cameras are used for non-contact temperature measurements in medical applications.
- **Fire Fighting:** Thermal cameras can help firefighters locate hotspots and people in smoke-filled environments.

5.5 Advantages:

- **No Light Requirement:** Thermal sensors can operate in complete darkness because they detect heat rather than relying on visible light.
- **Wide Range of Temperatures:** Thermal sensors can measure temperatures across a broad range, from extremely cold to very hot.
- **Non – Contact Operation:** Infrared thermometers and thermal cameras can measure temperatures without direct contact with the object, making them suitable for remote or hazardous environments.

5.6 Challenges:

- **Cost:** High-quality thermal imaging sensors can be relatively expensive.
- **Resolution:** Achieving high spatial resolution in thermal imaging can be challenging, particularly in cost-effective devices.
- **Atmospheric Interference:** Some atmospheric conditions, such as humidity and fog, can affect the performance of thermal sensors.

6. MICROWAVE SENSORS:

- Microwave sensors penetrate the atmosphere (especially clouds) more effectively than visible or infrared sensors.
- Microwave sensors are important tools in remote sensing, offering unique capabilities for observing and monitoring the Earth's surface.
- Unlike optical sensors that rely on visible or infrared light, microwave sensors operate in the microwave portion of the electromagnetic spectrum.
- Here are key aspects of microwave sensors in remote sensing:

6.1 Microwave Spectrum:

- **Frequency Range:** Microwave sensors operate in the microwave frequency range, typically from 1 millimetre to 1 meter wavelength.
- This range is further divided into different bands, such as X-band, C-band, Ku-band, and L-band, each offering specific advantages for different applications.

6.2 Types Microwave Sensors:

- Microwave sensors in remote sensing can be grouped into two major groups: passive and active:

➢ **Active Sensors:**
  - ✓ 5Active sensors, such as RADAR systems, send out pulses and record the echoes scattered back by the objects to the sensor.
  - ✓ **Synthetic Aperture Radar (SAR):** It is an example of Active microwave sensor. SAR is a radar imaging technology that uses microwave signals to generate high-resolution images of the Earth's surface. It is particularly useful for applications like terrain mapping, monitoring changes in land cover, and disaster response.

➢ **Passive Sensors:**
  - ✓ Passive sensors, such as radiometers, collect the radiation that is naturally emitted by the observed surface.
  - ✓ **Passive Microwave Sensor:** These sensors measure naturally emitted microwave radiation from the Earth's surface. They are commonly used for studying soil moisture, sea surface temperature, and precipitation.

➢ **Examples of active microwave sensors include:**
  - ✓ Synthetic aperture radar (SAR)
  - ✓ Microwave scatterometers
  - ✓ Radar altimeters

➢ **Examples of passive microwave sensors include:**
  - ✓ Multi frequency scanning/imaging radiometers
  - ✓ Atmospheric sounder

6.3 Applications of Microwave Sensors:

- **Earth Observation and Mapping:** SAR sensors are widely used for mapping the Earth's surface, providing information on topography, land cover, and changes over time. They are especially valuable in regions with frequent cloud cover, as microwaves can penetrate clouds.
- **Agriculture:** Microwave sensors are employed to monitor soil moisture content, which is crucial for precision agriculture and water resource management. They can also assess crop health and estimate biomass.
- **Glacier Monitoring:** Microwaves can penetrate snow and ice, making them useful for monitoring glaciers and ice sheets. SAR sensors can track changes in ice cover and detect ice movement.
- **Oceanography:** Microwave sensors are used to study ocean surface winds, sea surface temperature, and wave heights. They can penetrate clouds and provide continuous observations in maritime regions.

- **Deforestation and Land Cover Change:** Microwave sensors can detect changes in land cover, including deforestation, even in cloudy conditions. This makes them valuable for monitoring large-scale environmental changes.

6.4 Advantages in Remote Sensing:

- **All Weather Capability:** Microwaves can penetrate clouds, rain, and fog, allowing for observations in adverse weather conditions. This is particularly advantageous in tropical regions with persistent cloud cover.
- **Day and Night Observations:** Microwave sensors can operate day and night, providing continuous monitoring capabilities.

6.5 Challenges:

- **Resolution:** Achieving high spatial resolution with microwave sensors can be challenging compared to optical sensors.
- **Complex Data Processing:** The interpretation of microwave data often requires sophisticated processing techniques due to the interaction of microwaves with surface features and the atmosphere.

7. CALIBRATION OF SENSORS:

- Calibration is an adjustment or set of adjustments performed on a sensor or instrument to make it function as accurately, or error free, as possible.
- Calibration of sensors is a critical process to ensure that they provide accurate and reliable measurements.
- Calibration involves adjusting the sensor's output to match the known or reference values of the quantity being measured.
- **Some types of calibration include:**
  - ➢ **Offset**
    - ✓ An offset means that the sensor output is higher or lower than the ideal output. Offsets are easy to correct with a single-point calibration.
  - ➢ **Sensitivity or Slope**
    - ✓ A difference in slope means that the sensor output changes at a different rate than the ideal.

- The goal of calibration is to improve a sensor's performance by removing structural errors from its measurements.
- Structural errors are differences between a sensor's expected output and its measured output. These errors can be caused by various reasons, including:

  - ➢ Improper zero-reference
  - ➢ Shifts in sensor range.
  - ➢ Mechanical damage

7.1 General Steps Involved in Sensor Calibration:

- **Define Calibration Objectives:** Clearly define the calibration objectives, including the range of measurements, accuracy requirements, and any specific standards or regulations that must be met.

- **Select Calibration Equipment:** Choose appropriate calibration equipment, including reference standards and measurement devices. The accuracy of the calibration equipment should be higher than the accuracy required for the sensor being calibrated.

- **Pre-Calibration Inspection:** Inspect the sensor for any physical damage or issues that may affect its performance. Ensure that the sensor is clean and in good condition.

- **Zero Calibration (Baseline Adjustment):** For many sensors, especially those measuring continuous values, a zero calibration is performed. This involves adjusting the sensor to read zero when there is no input or when the input is known to be zero.

- **Span Calibration:** Adjust the sensor to read correctly at the upper end of its measurement range. This step ensures that the sensor provides accurate readings across the entire range of measurements.

- **Perform Calibration Measurements:** Use the calibration equipment to make measurements at various points within the sensor's operating range. Compare the sensor's readings to the known values and make adjustments as necessary.

- **Record Calibration Data:** Record all calibration data, including the sensor's readings and the corresponding reference values. This documentation is crucial for traceability and quality control purposes.

- **Calculate Calibration Uncertainty:** Determine the uncertainty associated with the calibration process. This includes considering uncertainties in both the reference standards and the sensor being calibrated.

- **Adjustments and Iterations:** If the sensor's readings do not match the reference values within the acceptable tolerance, make additional adjustments and repeat the calibration process until satisfactory results are achieved.

- **Final Verification:** Verify the sensor's performance after calibration by comparing its readings to reference values. Ensure that the sensor meets the required accuracy specifications.

- **Issue Calibration Certificate:** Provide a calibration certificate that includes details of the calibration process, results, uncertainties, and any adjustments made. This certificate is often required for compliance with quality standards.