Q.1 Define resolution of sensor. Also explain its various types.

Ans.

- Resolution of a sensor system is **ability to discriminate** between information.
- Clarity of image/picture.
- Discrimination refers to the ability of the sensor to distinguish a specific object from other objects.
- Discriminate determine that the object is there (detection) or it may imply as well a precise delimitation of its shape (identification).

Types of Resolution

1. **Spatial Resolution**
2. **Spectral Resolution**
3. **Radiometric Resolution**
4. **Temporal Resolution**
5. **Angular Resolution**

1. Spatial Resolution

- **Spatial resolution identifies the smallest object that can be detected on an image.**
- **It is measured in millimeters on the photograph or in meters on the ground, and it depends on the focal length of the camera and the height of the camera above the ground.**
- **In optical electronics, IFOV (**instantaneous field of view**) is defined as the angular cone of observation by the sensor, in radians, at a given moment in time.**
- **Size of the projected IFOV on the ground (*d*).**

$$d = 2h \tan\left(\frac{\text{IFOV}}{2}\right)$$

where
d is the distance on the ground per each information unit (pixel)
h is the height of the observation

2. Spectral Resolution

- Defines wavelength intervals.
-High Spectral Resolution is required.

3. Radiometric Resolution

- Radiometric resolution denotes the sensitivity of the sensor, that is, its capacity to discriminate small variations in the recorded spectral radiance (reflected or emitted).
- Sensor's sensitivity to magnitude of the electromagnetic energy determines radiometric resolution.
-

4.Temporal Resolution

- Temporal resolution specifies the length of the time satellite will take to be able to image the same area again.
- It refers to the observation frequency (revisiting period) provided by the sensor.
- It is the revisit period and the length of time for a satellite to complete one entire orbit cycle,i.e. start and back to the exact same area at the same viewing angle.
- Example –LANDSAT needs 16 days ,MODIS needs 1 day,NEXRAD needs 6 days.
- The temporal resolution of EO sensor system varies according to the objectives set for the mission.
-

5.Angular Resolution

This concept of resolution is very recent and refers to the sensor's capacity to make observations of the same area from different viewing angles.

Q.2 Why microwave region is preferred over all other regions for remote sensing. Explain surface roughness with respect to it.

Ans . region is its high atmospheric transmissivity, which makes it possible to observe areas regardless of weather conditions.

- **Surface roughness** affects the intensity of the return signal. A land surface is considered rough if -

where $$s_h \geq \frac{\lambda}{8} \sin \gamma$$

sh is the standard deviation of the height of the surface
λ is the wavelength of observation
γ is the radar incidence angle (between the radar beam and the normal to surface)

3. (a) Define working of LIDAR.

- **LIDAR is the acronym of "light detection and ranging."**
- **Lidar is an active sensor system, emitting pulses to the ground, which are collected after being reflected from the target surface.**
- **There are several differences between the two sensors working for RADAR & LIDAR.**
- **First, they work at different wavelengths: radar with microwave energy, while lidar systems at the range from ultraviolet to NIR.**
- **Radars observe mostly obliquely, while lidar mostly vertically.**
- **Lidar systems use laser pulses (*light amplification by stimulated emission of radiation (laser), which are collimated, polarized, and have coherent radiation.***
- **Differential absorption lidars estimate medium properties based on how reflectance varies at two or more wavelengths crossing that medium.**

- **If the sensor location is very precisely determined, the relative distances between the object and sensor can be converted to absolute coordinates (*X,Y,Z); therefore, measurements of vertical* properties can be obtained from lidar systems.**

3.(b) Write short note on atmospheric interaction.

- **EM radiation from the observed surface is dependent on the surface properties and observation conditions alone.**
- **Between the observed surface and the observing sensor, the atmosphere interacts with both the incoming and outgoing radiation, thus distorting the signal that comes originally from the ground.**
- **This factor needs to be taken into account to accurately retrieve surface properties from satellite observations, as they observe the Earth from high elevations (commonly 600–900 km), and therefore the detected energy will most likely be affected by the different atmospheric layers.**

<u>The effects of the gaseous components can be grouped into three classes:</u>

- **(1) Total or partial absorption of incoming or outgoing radiant energy;**
- **(2) Reflection and scattering of incoming energy, which alters its path direction and intensity; and**
- **(3) Emission, which adds new radiation to that emanating from the surface**

<u>Atmospheric Absorption-</u>

The atmosphere behaves as a selective filter at different wavelengths, such that remote observations cannot be partially or totally conducted over certain spectral regions.The main causes for this absorption are the following atmospheric components:

- **Atomic oxygen (O_2), which filters the ultraviolet radiation below 0.1 µm, as well as short ranges in the TIR and MW bands.**
- **Ozone (O_3), which eliminates most of the ultraviolet radiation below 0.3 µm,as well as some narrow bands in the VIS spectrum.**
- **Water vapor (H_2O), with one strong absorption around 6 µm and secondary absorption bands between 0.6 and 2 µm.**
- **Carbon dioxide (CO_2), which absorbs in the TIR (15 µm), with important effects too in the MIR, between 2.5 and 4.5 µm.**

<u>Atmospheric Scattering-</u>

The scattering of EM radiation is caused by the reflection of incoming solar radiation by gases, aerosols, and water vapor present in the atmosphere.

- **As a result, radiation detected by the sensor is a mixture of both surface and atmospheric reflected energy, and thus contains an undesirable noise that needs to be removed during the retrieval of the surface properties.**

4. **Explain working of along track and across track scanner along with its neat and clean diagram.**

Ans .

<u>Across -Track Scanners</u>

- Digital sensors perform an onboard analog-to-digital conversion recording the incoming radiation in digital values that can be directly transmitted to the ground segment.
- The most commonly used in satellite missions have been the cross-track scanners.
- The detected radiance is directed to a series of detectors that amplify the signal and convert it to a numerical value that can be stored on board or transmitted to a receiving antenna.
- The incoming radiation is commonly divided into several spectral bands, which are recorded by different detectors (most commonly Si photodiodes in the visible and near infrared and InGaAs in the SWIR).

The information received on the ground is stored in magnetic media for further processing and distribution to end users.

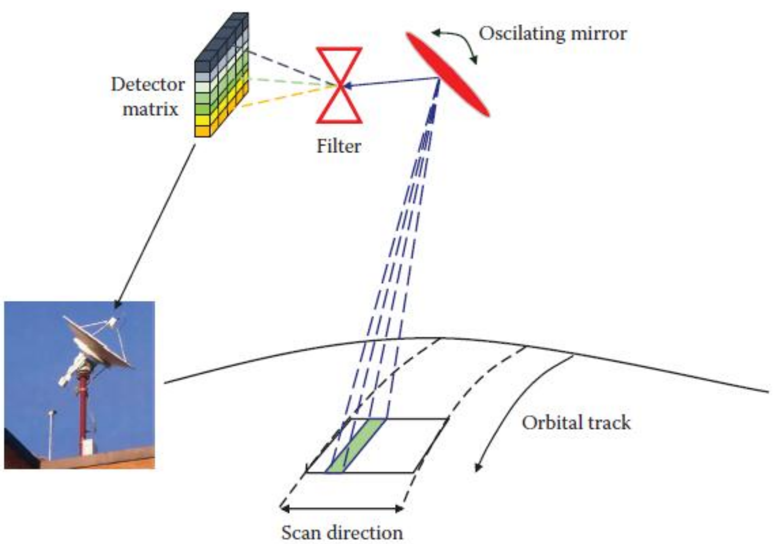


Figure-Across track Scanner

<u>Along-Track (Push-Broom) Scanners</u>

- Along-track scanners avoid the use of an oscillating mirror by detecting the whole FOV of the sensor system at once, using a linear array of detectors.

- The sensor explores each line simultaneously and creates the image along with the satellite orbital track .
- For this reason, these sensors are named push-broom or along-track scanners.

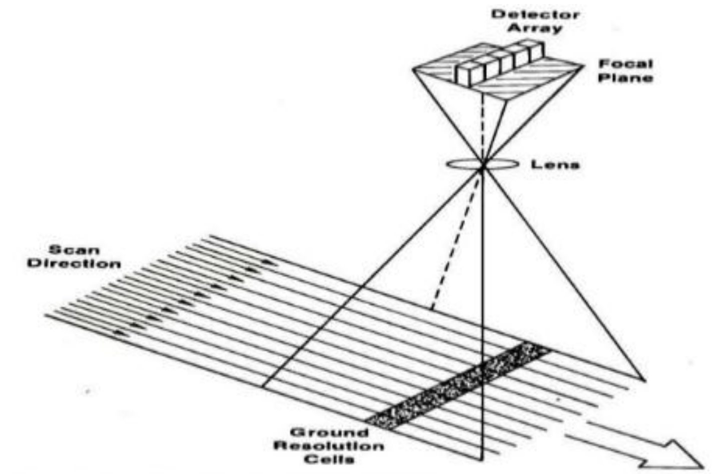


Figure-Along track Scanner

5 . Define sensors and its various types.

Ans-

Sensors- Sensors are the device which are used to sense the information.

There are two types of sensors.

1.Passive Sensors 2.active Sensors

PASSIVE SENSORS

- Passive sensors are limited to measuring the electromagnetic radiation derived from external sources—energy either reflected from solar radiation or emitted by the Earth's surface.
- These sensors have been extensively used in remote sensing for the last few decades and include photographic cameras, electro-optical scanners, and MW radiometers.
- 1)Photographic Cameras
- 2) Across track scanner
- 3)Along track scanner
- 4)Video
- 5)Microwave radiometers

Active Sensors: RADAR & LIDAR

- Active systems have the capacity to generate energy pulses and collect them after the surface target reflects them back.

1. Radar

- Radar is the best-known active sensor system. Ex. SLAR, SAR.
- It is an active MW system working in different spectral bands between 0.1 cm and 1 m.
- Each pixel in a radar image represents the backscattering coefficient of that area on the ground, and the stored value is greater as more intense signals are received.

2. LIDAR

- It is the acronym of "light detection and ranging."
- Lidar is an active sensor system, emitting pulses to the ground, which are collected after being reflected from the target surface.

6 .Define the thermal properties of vegetation in thermal infrared domain.

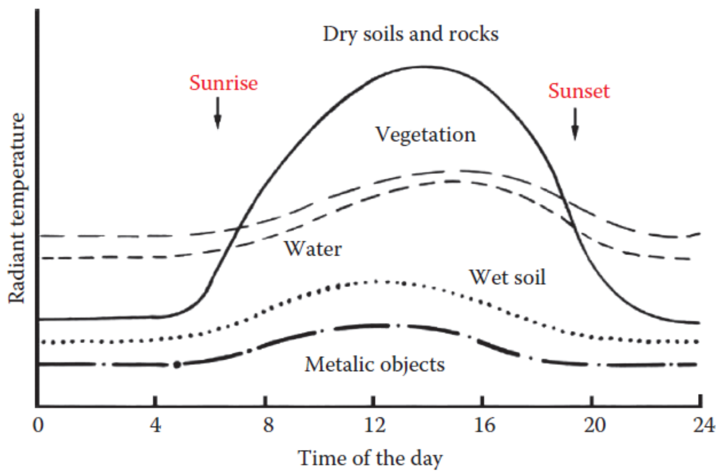
Ans . Thermal Behavior is dependent upon following factors-

- Thermal Capacity (C)-Capacity of cover to store heat.
- Conductivity (K)-It measures the rate at which the heat in a land cover is transmitted.
- Diffusivity (k (small k)-how well the temperature of a surface changes through heat conduction.
- Thermal inertia (P)-the resistance of a material to temperature changes.

Heating index (I)-function of the intensity of the radiation and the absorptance of the object.

Thermal Properties of Vegetation-

- Plants absorb a high amount of incident solar energy to drive photosynthesis. This energy is reemitted during the night to maintain the energy balance.
- Another important factor controlling vegetation thermal patterns is evapotranspiration (ET), which regulates plant water and temperature.
- ET rates depend upon atmospheric humidity ,availability of light, air temperature & soil moisture.



7 . Write down short notes on following – (a) LANDSAT Programs (b)Geostationary meteorological satellites (c) Terra-Aqua

(a) LANDSAT Programs

- The success of the space photographic missions during the 1960s led NASA to develop the first program oriented toward monitoring Earth resources. This effort led to the launch of the first Landsat satellite, which was originally named Earth Resources Technology Satellite (ERTS), on July 23, 1972.
- After the second launch in 1975, the series was renamed Landsat and extended in 1978, 1982, and 1984 with the subsequent launches of Landsat 3, 4, and 5, respectively. Landsat 6 was lost shortly after the launch in 1993, while Landsat 7 was launched in 1999 and is still working.
- Landsat 8 was developed within the program termed Landsat Data Continuity Mission (LDCC: Irons et al.2012).
- Finally launched in February 2013, Landsat 8 started operations 3 months later. In April 2015, the U.S. Congress approved the development of Landsat 9, expected to launch in 2023. The Landsat program has been the most important EO mission ever designed.
- The first three Landsat satellites had a Sun-synchronous polar orbit at 917 km, with a revisiting period of 18 days and a 10:30 a.m. equatorial crossing time. For the fourth and fifth Landsat satellites, their instrument configuration and orbital characteristics were modified.
- The orbital height was reduced to 705 km, and the revisiting observation was improved to 16 days in temperate latitudes. Overpass time remained similar to the previous Landsat, crossing the Equator around 10:10 a.m.
- The next two satellites of the mission, Landsat 6 and 7, were changed in their appearance again (Figure 3.29), although they maintained the orbital characteristics of their two predecessors.
- The first three Landsat satellites included-
- The MSS sensor and three video cameras(RBV).
- The cameras did not work properly in the first two satellites; hence, the MSS was really the most useful sensor of the mission until the launch of Landsat 4.
- The MSS had an 11.56° FOV and could observe an area of 185 × 185 km at 57 × 79 nominal pixel resolution. It covered four bands of the spectrum (green, red, and two in the near infrared, numbered 4, 5, 6, and 7, respectively.

(b) Geostationary meteorological satellites-

- Geostationary satellite images are well known because they are commonly used in TV weather forecasting.
- These satellites are coordinated by the World Meteorological Organization (WMO) through the Global Atmospheric Research Program (GARP).
- The first geostationary satellite, Applications Technology Satellite (ATS), was launched in 1966 by NASA.
- Other geostationary satellites are the European Meteosat, the Indian INSAT, the Russian Elektro-L, the Chinese FY-2D, and the Japanese MTSAT.

- Geosynchronous satellites orbit the Earth at 36,000 km in the Equatorial plane, therefore observing the same area.
- In operational form, this satellite became the series SMS, known as Geostationary Operational Environmental Satellite (GOES) since 1975.
- There are two operational GOES satellites: one located at 75° west (eastern coast of the United States) and the other at 135° west (between Hawaii and California).
- Both satellites include different sensors for atmospheric observation.
- The most important is named Imager, a multispectral scanning sensor with five channels (visible, two in the MIR, and two in the TIR), with a spatial resolution of 1 km for the visible, 8 km for the long MIR, and 4 km for the rest of the bands.
- The Earth disc full scanning takes 26 min. The GOES satellites also include an atmospheric profiler, called Sounder, with 19 spectral bands.
-

GOES Imager Band	Name	Central Wavelength (µm)	Objective
1	Visible	0.63	Cloud cover and surface features during the day, smoke, etc.
2	Shortwave window	3.9	Low cloud/fog, fire detection, winds, etc.
3	Water vapor	6.48	Upper-level water vapor, winds, etc.
4	Longwave window	10.7	Surface or cloud-top temperature, precipitation, etc.
5	N/A	N/A	N/A
6	CO_2 band	13.3	CO_2 band: Cloud detection, etc.

c) Terra Aqua

- The Terra and Aqua platforms are part of the NASA Earth-Observing System (EOS) program (Parkinson et al. 2006), which includes several other platforms for terrestrial observations. Terra was successfully launched in **December 1999**.
- The orbital height is 705 km, with a period of 98.88 min and a repeat cycle of 16 days. It carries five sensors (MODIS, CERES, MISR, MOPITT, and ASTER) designed for global observations of critical land, oceans, and atmospheric variables.
- **Aqua** was launched in **May 2002**, and it has similar orbital characteristics as Terra, but with a lag period of 3 h and, therefore, crosses the equator at 1:30 and 13:30. This satellite carries six sensors (AIRS, AMSR-E, CERES, HSB, and MODIS), with an instrument configuration oriented toward oceanographic studies.
- It works in 36 spectral bands.
- The first two bands have finer spatial resolution (250 m) and include the red and NIR spectral wavelengths to monitor vegetation activity. Another five bands are acquired at 500 m resolution, covering the visible and SWIR, and are mainly intended for retrieval of vegetation, snow, and soil properties. All the other bands have 1000 m resolution and cover additional wavelengths in the visible, MIR, and TIR.
- MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.

- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths.

Sensors on Aqua

- AMSR-E — Advanced Microwave Scanning Radiometer-EOS
- MODIS (Moderate-resolution Imaging Spectroradiometer)
- CERES (Clouds and the Earth's Radiant Energy System)
- AMSU-A — Advanced Microwave Sounding Unit
- AIRS — Atmospheric Infrared Sounder
- HSB — Humidity Sounder for Brazil

Sensors on Terra

- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)
- CERES (Clouds and the Earth's Radiant Energy System)
- MISR (Multi-angle Imaging SpectroRadiometer)
- MODIS (Moderate-resolution Imaging Spectroradiometer)
- MOPITT (Measurements of Pollution in the Troposphere)