CHAPTER 3

Remote Sensing (RS)

Learning Objectives

By the end of this chapter students should be able to:

3.1 Understand the Remote Sensing Technology (RS)

3.2 Know the Fundamentals of Remote Sensing

3.3 Understand the Physics of Electro Magnetic Radiation (EMR)

3.4 Understand about Remote sensing platforms sensors and data products

3.5 Understand the Indian Remote sensing Satellite System

3.6 Understand about Remote sensing applications

3.1 Overview of Remote Sensing Technology (RS)

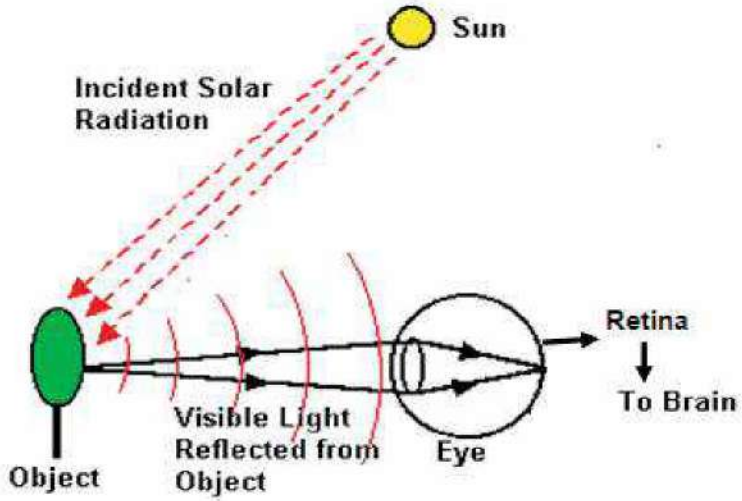
We perceive the surrounding world through our five senses. We acquire information about our surroundings through the senses of sight and hearing which do not require close contact between the sensing organs and the external objects. In another words, we are performing Remote Sensing all the time. ` Of our five senses (sight, hearing, taste, smell, touch), three may be considered forms of "remote sensing", where the source of information is at some distance for example Telephone conversation, smelling of the object etc. The other two senses (taste & touch) rely on direct contact with the source of information.

Fig. 33

Eating Ice Cream is an example for Direct Sensing

Telephone conversation an example for Indirect Sensing

Remote Sensing refers to the activities of recording / observing / perceiving (sensing) objects or events at far away. In remote sensing, the sensors are not in direct contact with the objects or events being observed. The information needs a physical carrier to travel from the objects/events to the sensors through a medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The human visual system is an example of a remote sensing system.



Function of Human eye
(www.cvigp.nus.edu.sq)

Fig. 34

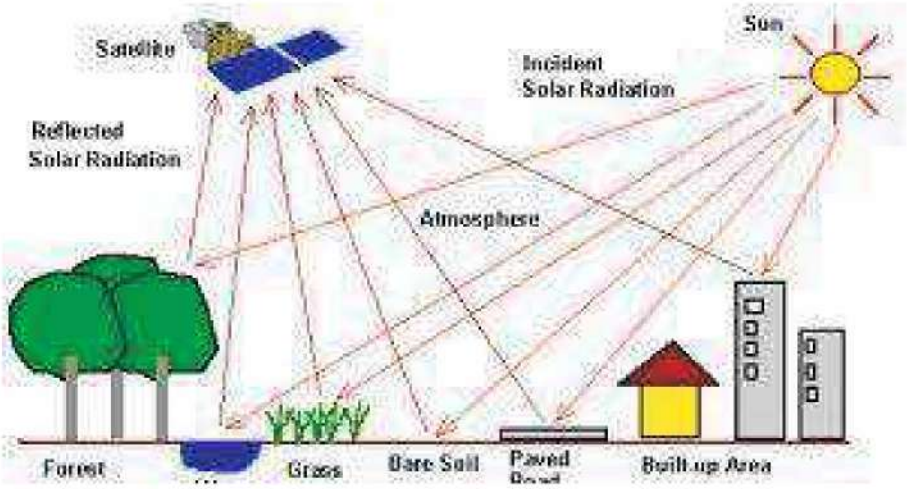
Light emanates from the source of radiation. The radiated light passes over a distance, and is captured by a sensor (your eyes). Each eye sends a signal to a processor (your brain), which records the data and interprets this into information.

Remote sensing is a technology which is used to create maps, without having physical touch of the territory being described. These remote sensing technologies are often deployed from a plane or satellite

Remote Sensing is the science and art of acquiring information about material objects, area or phenomenon, without coming into physical contact with the objects or area or phenomenon under investigation.

(a) Definition of remote sensing:

Remote sensing is the technology used to gather/analyze the information of the earth surface from a far end. This can be done by a few meters from the Earth's surface, from an aircraft flying hundreds or thousands of meters above the surface, or by a satellite orbiting hundreds of kilometers above the Earth.



(Remote sensing system: www.cvigp.nus.edu.sq)

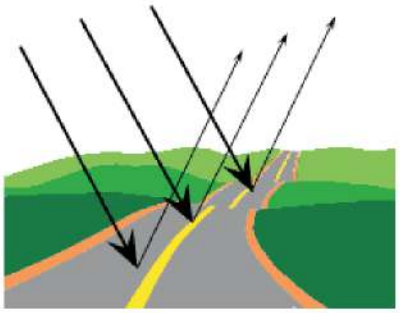
Fig. 35

Remote sensing is a technique used to collect data about the earth without taking a physical sample of the earth's surface Such examination can occur with devices (e.g. cameras) based on the ground, and/or sensors or cameras based on ships aircrafts, satellites, or other spacecraft.

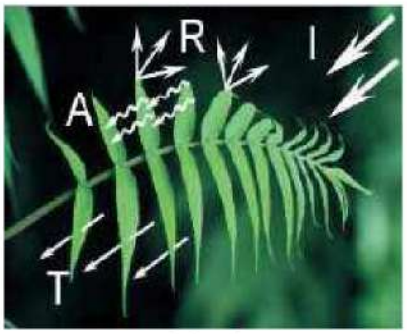
3.2 Fundamentals of Remote Sensing

The light originates from the sun or any other source of energy. It lets the earth, hit the earth, bounces and then comes back to the earth into our eyes. The sun provides a source of energy for remote sensing. Radiation can reach and interact with the Earth's surface. There are three forms of interaction that can take place when energy strikes, or is incident (I) upon the surface. These are: absorption (A), transmission (T); and reflection (R). The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the

feature. Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through the target. Reflection (R) occurs when radiation "bounces" off the target and is redirected. Remote sensing measures the radiation reflected from targets.



CCRS



CCRS

Fig. 36

Why in this picture does the rose look red and leaves look green? The color of an object is determined by the energy which it reflects. Sun is the source of energy which emits the electromagnetic radiations. These radiations strike the earth objects and reflect back. The reflected energy decides the color of the object. This reflectince' in that fraction of the radiation falling upon a surface which is reflected back by the surface. This reflectance depends upon the chemical composition and physical properties of the object. Different type of objects different patterns of reflectance. Because of this phenomenon we can distinguish the colors of objects. The objects which reflect the green color look green and the objects reflecting red color, look red. If all the energy is reflected back to atmosphere then the object looks white.

Why black board looks black?

What happens to absorbed energy ?

3.3 Physics of Electro Magnetic energy (EMR)

Generally in remote sensing we use Sun as source of energy. The energy emitted by the sun has both magnetic and electric fields. These two fields are propagating perpendicular to each other. This energy is called Electromagnetic energy. As it propagates in the forms of waves we call it Electromagnetic waves.

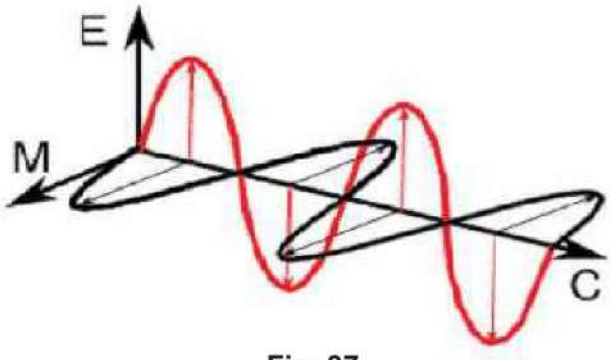


Fig. 37

Electric and magnetic fields are propagating perpendicular to each other.

Sun is the source of Energy. The energy emitted by the sun is travels at the speed of light, that is, 3x10 m/s.

Electromagnetic Waves have different wavelengths. When we listen to the radio, watch TV, or cook in a microwave oven, we are using electromagnetic waves. Radio waves, television waves, and microwaves are different types of electromagnetic waves. They differ from each other in wavelength

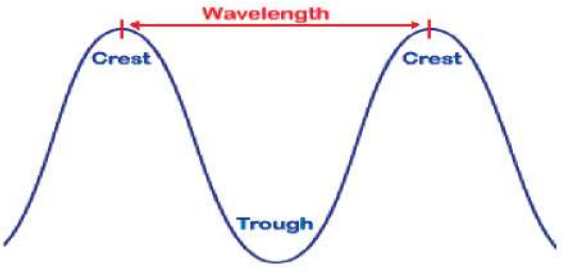
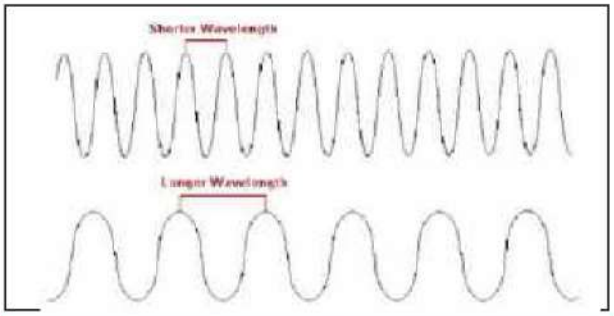


Fig. 38

(a) Wavelength: The distance between successive crests of waves is called wavelength

(b) Frequency: The number of crests per second is called frequency. The larger the distance between two crests the longer is the wavelength, but shorter is the frequency.



Frequency and wavelength

Fig. 39

(c) Electro Magnetic Spectrum:

Electromagnetic radiation is classified into several types according to the frequency of its wave. These types include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays. A small variable window of frequencies is sensed by the eyes of various organisms; this is called visible spectrum.

The light which our eyes can detect is part of the visible spectrum. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. This visible part of the electromagnetic spectrum consists of the colors (VIBGYOR) that we see in a rainbow - from reds and oranges, through blues and purples. As shown in the Figure. (40)

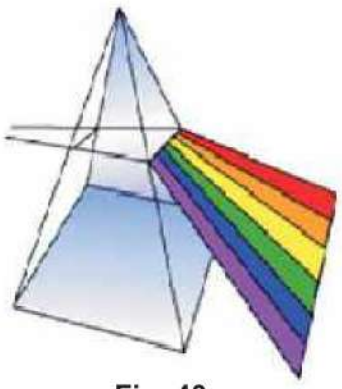


Fig. 40

The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of colors.

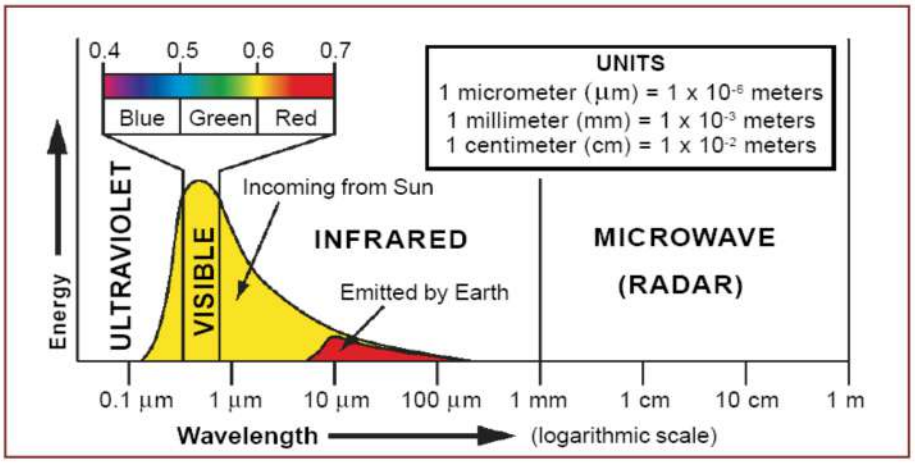


Fig. 41

Electromagnetic Spectrum Source RSE

Visible Wavelength Spectrum Coverage	
Wavelength (µm)	**Color**
0.4 - 0.446	Violet
0.446 - 0.500	Blue
0.500 - 0.578	Green
0.578 - 0.592	Yellow
0.592 - 0.620	Orange
0.620 - 0.700	Red

Table 1

The next to visible band in EMR spectrum is Infrared band which is not visible to human eye. The reflection by this band is very prominent to identify the features. The remote sensing sensors can recognize this infrared band of electromagnetic spectrum. So in the case of satellite based remote sensing we are using infrared band along with normal visible band.

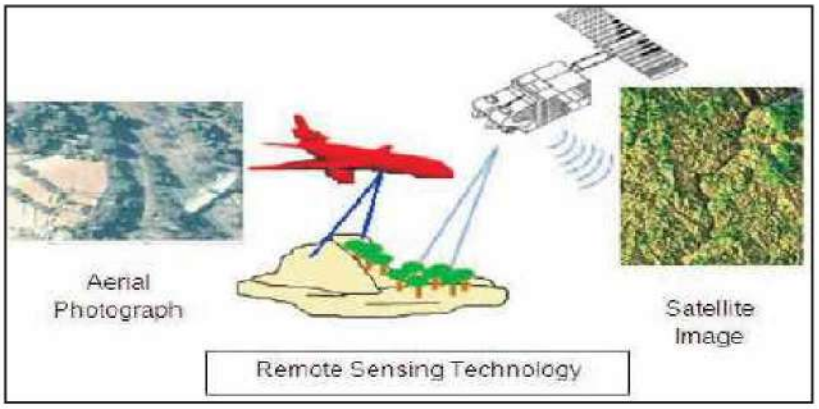


Fig. 42

Photographs acquired by the camera can view only visible range EMR for example Aerial Photographs. Satellite sensors can view beyond the visible band for example satellite imagery.

(a) Spectral Signature

As we discussed earlier each and every object has a unique kind of reflection pattern based on their chemical composition and physical properties. This unique reflectance pattern of individual object is called spectral signature. Spectral reflectance is the portion of incident radiation that is reflected by a non-transparent surface. The reflectance of features varies at different wavelengths.

This is an essential property of matter that allows for different features to be identified and separated by their spectral signatures. The graph shows the different objects which reflect different amounts of energy in various spectral bands. For example longer wavelength visible and near infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths. If there is suspended sediment present in the upper layers of the water body, then this will allow better reflectivity and a brighter appearance of water.

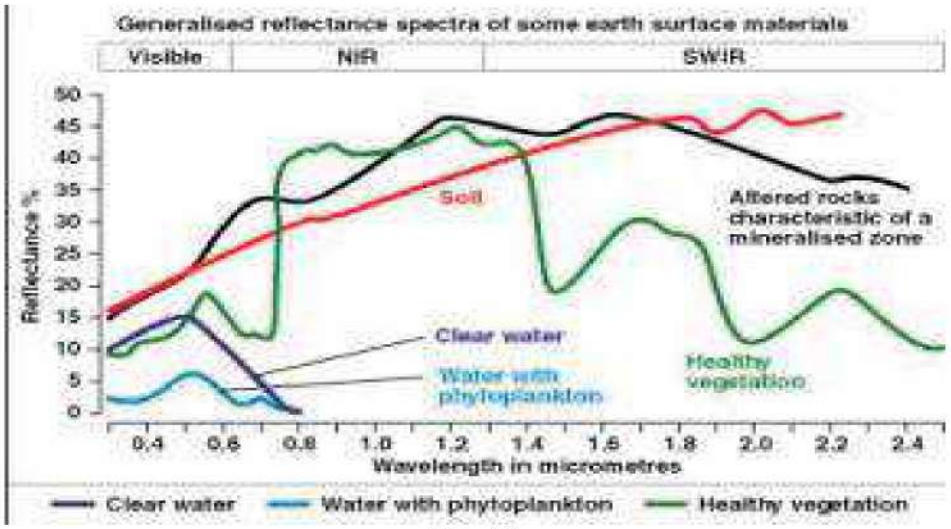


Fig. 43

Spectral signature of different elements

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Suspended sediment can be easily confused with shallow (but clear) water, since these two phenomena appear very similar. Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear greener in color when algae are present. The topography of the water surface (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of spectral reflection and other influences on color and brightness. In case of vegetation may reflect somewhat similarly in the visible wavelengths but are almost always separable in the infrared. Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g. "green-ness" of leaves) and location. The barren land looks white in color because it reflects all the energy received by the sun. An object absorbing all visible wavelengths will appear black.

(e) Remote Sensing Process flow: Remote sensing process is completed through some steps using different techniques and equipments as indicated below:

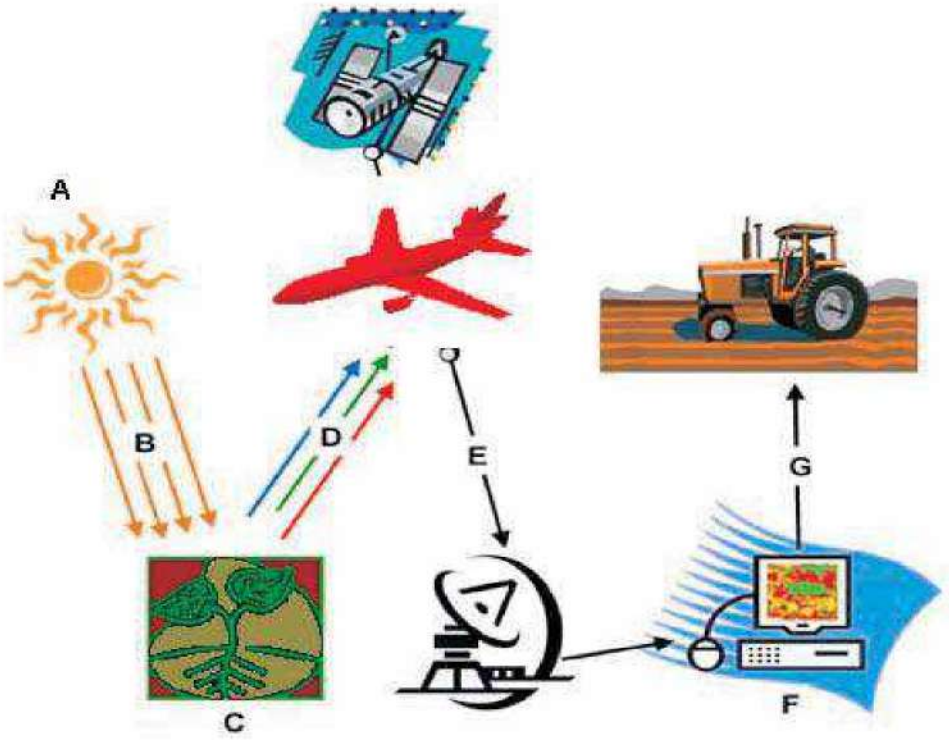


Fig. 44

Remote Sensing Process flow

1. **Energy Source or Illumination** (A) - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. **Radiation and the Atmosphere** (B) - as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place for the second time as the energy travels from the target to the sensor.

3. **Interaction with the Target** (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. **Recording of Energy by the Sensor** (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.
5. **Transmission, Reception, and Processing** (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital). Examples for Remote Sensing products are shown below.

Fig. 45

Satellite Imagery

Fig. 46

Aerial Photography

6. **Interpretation and Analysis** (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.
7. **Application** (G) - the final element of the remote sensing process is achieved when we apply the knowledge we have been able to extract information from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem

Aerial Photographs can be captured by using the Analog camera or by Digital Camera.

3.4 Remote Sensing Platforms Sensors and Data Products

(a) Remote Sensing Platforms

Platform is a stage to mount the camera or sensor to acquire the information about a target under investigation. The sensor needs to be placed on suitable observation platforms. They can be stationary or mobile depending upon the needs of observation and constraints. The resolution becomes poorer as the platforms height increases, and the area coverage also increases. Platforms for remote sensors may be situated on the ground, on an aircraft or balloon (or some other platform within the Earth's atmosphere), or on a spacecraft or satellite outside of the Earth's atmosphere. In broad sense we can classify the Platforms in three groups

1. Ground based Platforms
2. Airborne Platforms
3. Space borne Platforms

(i) Ground based Platforms

Ground-based platforms are mainly used for collecting the detailed information of the earth surface. In these cases the sensors or cameras are placed on a ladder, tall building, crane etc. The images or photographs collected by these platforms are very clear compared to the rest of the platforms. But its viewing area is very limited so Ground based platforms cannot be used for large area mapping

Ground Based Platform

Fig. 47

Activity – 1 Capture the two photographs of your school building

By standing next to your school building

By standing 500 m away from the school building

Compare both the photographs for resolution and area coverage

(ii) Airborne Platforms

Airborne Platforms are basically used to collect detailed photographs of the target area. The sensors are mounted on the balloons or aircrafts etc. Compared to ground based platform these platforms collect the information from a larger area because the general altitude of these platforms is around 2000-3000 meters.

Fig. 48

Airborne Platform

Analog Aerial Photography, Videography and Digital Photography commonly use airborne platforms

(iii) Space borne Platforms

Here mainly satellites are used to carry the sensors. These satellites are revolving round the earths surface at an altitude of around 800 Km. The data obtained from the satellites are in the form of Images and they cover more area. The resolution of the satellite Images is comparatively less than that of aerial photographs. Nowadays we have advanced sensors which provide the Images at a resolution of 0.6m.

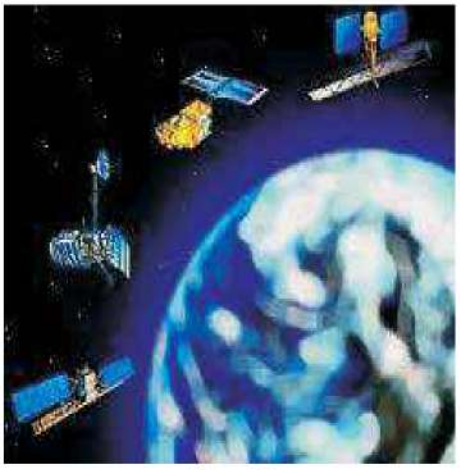


Fig. 49

Space born Platform

Resolution defines the clarity of the picture. When height is more the picture clarity will be less but we can view more data as in satellite Images. Aerial Photographs are taken at a Low altitude than the satellite Images so we can get better pictures but area coverage is less.

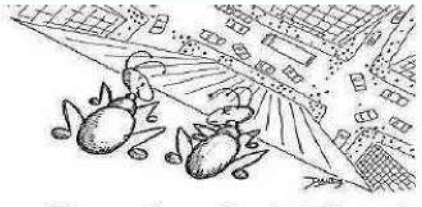


Fig. 50

(b) Remote Sensing Sensors

Sensors are electronic devices which collect and record electromagnetic energy which is reflected/emitted from the target or surface.

There are two basic types of sensors:

- Passive Sensors
- Active Sensors

(i) Passive Sensors

Passive sensors record radiation reflected from the earth's surface. The source of this radiation must come from outside the sensor; in most cases, this is solar energy. Because of this energy requirement, passive solar sensors can only capture data during daylight hours.

Fig. 51

(ii) Active Sensors

Active sensors are different from passive sensors. Unlike passive sensors, active sensors require the energy source to come from within the sensor. For example, a laser-beam remote sensing system is an active sensor that sends out a beam of light with a known wavelength and frequency. This beam of light hits the earth and is reflected back, recording the time it took for the beam of light to return.

Fig. 52

Example: Camera without Flash light is the Passive Sensor. Camera with flashlight is the active sensor.

(c) Remote Sensing data Products

The data captured by the Remote Sensing Technology are classified as:

- Analog Data
- Digital Data

Fig. 53

These are captured by using ground based Platforms or airborne platforms. The platform like balloons and aircraft carry the Analog camera to capture the images of earth surface. The analog camera uses thin films to record and store the reflected light energy. These films are made by the light sensitive material. When EMR strikes this material it causes chemical change in the material. These variations are then developed to produce a photograph. Analog photography is capable of providing high resolution. These photographs need to be scanned while feeding to the system.

(a) Digital Images

(i) Digital Camera Imagery

These images are captured by the digital camera which is mounted on the ground based or airborn platforms. The reflected energy from the features is stored in the digital Format and can be transmitted directly to the system for further analysis.

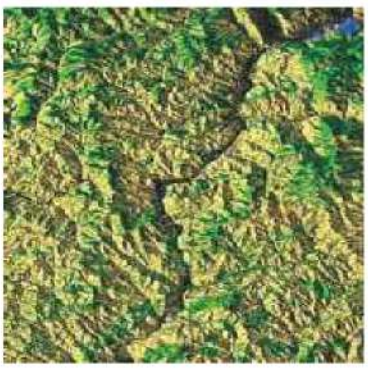
Fig. 54

(b) Satellite Imagery

The sensors which are mounted on Remote sensing satellites are the source for Satellite Imagery. The sensor records the reflected EMR and converts it into digital numbers. These digital numbers are collected by the ground receiving station. Receiving station processes these data and converts each digital number into picture element. These are called pixels. The pixels arranged into a matrix format give the complete image of a particular location. The digital number of each pixel is determined by the brightness associated with it.

Fig. 55

Overview of Ground Station Complex, Shadnagar Near Hyderabad



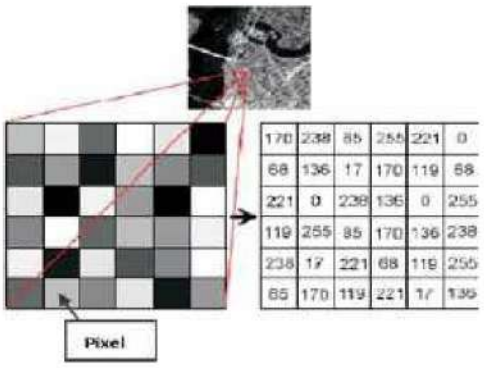


Fig. 56

Pixels (Picture Element) Pixel is the smallest possible feature that the sensor or digital camera can detect. Pixel determines the resolution of the data.

(c) Spatial Resolution

Spatial Resolution refers to the size of smallest object that can be identified on the ground. In a digital image, the resolution is limited by the pixel size, i.e. the smallest object identified by sensor cannot be smaller than the pixel size. For example, IRS LISS have resolution of 72.5 m; it means sensors can identify the object of size 72.5 m on the ground. Similarly satellite sensor for example Cartosat-1 – 2.5 m resolution can identify the object of size 2.5 m

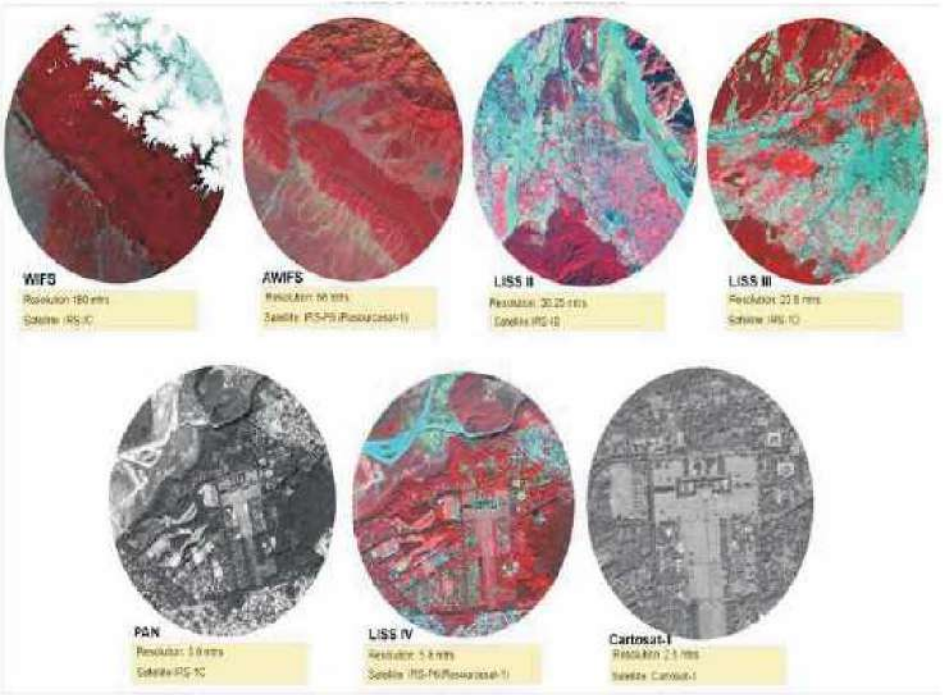


Fig. 57

High resolution has more clarity than low resolution

(Soure : RRSC - North)

Remote Sensing Satellites

The remote sensing satellites are placed in Sun synchronous orbits. A sun synchronous orbit means that a satellite passes over each area of the Earth's surface at a constant local time of day called local solar time. These satellites follow the path of North to South Direction (pole-pole direction) as earth revolves in direction of West to East. The altitudes of these satellites are around 700 - 800 km. The sensors mounted on the satellite 'sees' a certain portion of the earth surface, this is called Swath. Swaths for space borne sensors generally vary between tens and hundreds of kilometers wide.

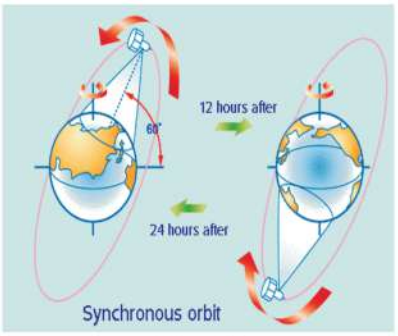


Fig. 58

Remote Sensing Satellite Orbits

Satellite Orbits

The path followed by a satellite in space is referred to as its orbit. Every satellite has to maintain its own orbit. Basically there are two types of orbits.

- **Sun synchronous**
- **Geostationary**

All the remote sensing satellites follow sun synchronous orbits. (Eg-IRS series The Communication satellites follow the geostationary orbit (Inset Series) In Geostationary orbits satellites always view a particular portion of the earth.

3.5 Indian Remote Sensing Satellite Systems (IRS)

Indian Remote sensing systems (IRS) commission was established in 1988. It has the world's largest constellation of five remote sensing satellites IRS - 1C, IRS - 1D, IRS-P3, IRS - P4 (OCEANSAT1) offering space base data in a range of spectral band spatial resolution and swaths. The data is used to several applications covering agriculture, water resource, urban development, Forestry, Drought and Flood forecasting and Ocean resources. National Remote Sensing Centre (NRSC) is one of the centers of Indian Space Research Organization under the Department

of Space, Govt. of India, engaged in operational remote sensing activities. NRSC has its own ground station at Shadnagar, 60 Km south of Hyderabad to acquire remote sensing satellite data from the Indian Remote Sensing satellites. India's first civilian remote sensing satellite IRS - 1A was launched in March 1988. Subsequently, IRS - 1B, having similar sensors, was launched in August 1991, and they provided better receptivity. The LISS - III, PAN and WiFS sensors on IRS - 1C (December 1995) and IRS - 1D (September 1997) further strengthened the scope of remote sensing. The launch of IRS - P6 (Resourcesat - 1) in October 2003, provided an excellent opportunity to obtain high resolution multi-spectral data. IRS - P5 (Cartosat - 1), launched on May 5, 2005, catapulted the Indian Remote Sensing program into the world of large scale mapping and terrain modeling applications. Subsequently in Jan 2008 CARTOSAT- 2 was launched, which led Indian Remote Sensing to the class of high resolution satellites. It has a PAN camera with 0.8 m resolution. Ocean sat - 2 was launched on September 23, 2009

3.6 Remote Sensing Applications

Remote sensing technology collects the earth surface features in the form of imagery. The collected imagery from this technology helps to monitor and map the natural resources and manage them properly. In recent years the high resolution data integrated with GIS tools play a major role in the mapping of natural resources like agriculture, forestry, geology, water, ocean etc It also allows monitoring the environment and thereby helping in conservation. Some of the major applications of Remote sensing data are discussed below:

(a) Coastal Zone Studies

Under the Coastal Zone Studies project are included mapping & monitoring of coastal zone, mangroves and coral reefs and development of Coastal Zone Information System. The mapping includes monitoring of vital / critical habitats, marine protected areas, shore line changes and impact of sea level rise and integrated coastal zone management.

Fig. 59

Image Shows Coastal Zone

(b) Flood Mapping and Monitoring

Remote sensing techniques are used to measure and monitor flooded areas to efficiently target rescue efforts and to provide quantifiable estimates of the amount of land and infrastructure affected. A constant watch is kept on the flood situation in the country through hydrological and meteorological information from remote sensing sources. Major floods/cyclones are mapped and monitored with the high resolution satellite data. Remotely sensed data integrated with GIS allows for quick calculations and assessments of water levels, damage, and areas facing potential flood danger.

Fig. 60

Flooded area by Yamuna River

(c) Land Cover & Land Use

With multi-temporal analyses, remote sensing gives an overview of the city. The remote sensing helps in mapping rural to urban land use changes. By this we can discriminate between rural usage (farming, pasture, forests) and urban usage (residential, commercial, and recreational). Remote sensing methods can be employed to classify types of land use over large areas.

(d) Other Remote Sensing Satellites

Apart from the Indian Remote Sensing Satellites, NRSA acquires and distributes data from a number of foreign satellites. During the 1970's and 80's, India's remote sensing data needs were being addressed by foreign satellites like LANDSAT, NOAA, SPOT etc. With the setting up of an Earth Station at Hyderabad in 1979, data reception started from LANDSAT satellite. NRSA continues to acquire or distribute data from foreign satellites to supplement the data requirements of its users. Currently, NRSA is acquiring data from NOAA - 17, NOAA-18, TERRA, AQUA and ERS. Apart from acquiring, NRSA also distributes data collected by RADARSAT, IKONOS, QUICKBIRD, ORBIMAGE and ENVISAT.

Let's us wrap up what we covered in this chapter:

- Remote sensing is the technology to collect the information about the earth features without any direct contact.
- Remote sensing can be done by a few meters from the Earth's surface, from an aircraft flying hundreds or thousands of meters above the surface, or by a satellite orbiting hundreds of kilometers above the Earth.
- The sun provides a source of energy for remote sensing.
- When sun light hits on the target elements, it process three types of actions viz. absorption, transmission and reflection.

- Absorption (A) occurs when radiation (energy) is absorbed into the target while transmission (T) occurs when radiation passes through a target. Reflection (R) occurs when radiation "bounces" off the target and is redirected.
- Remote sensing measures the radiation reflected from targets.
- Sun radiation is composed of electric and magnetic fields, so it is called electromagnetic radiation
- Electromagnetic radiation is classified into several types according to the frequency of its wave; these types include (in order of increasing frequency and decreasing wavelength): radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays.
- A small and somewhat variable window of frequencies sensed by the human eyes is called the visible spectrum.
- Satellite based remote sensing uses infrared band along with normal visible band.
- Spectral reflectance is the portion of incident radiation that is reflected by a non-transparent surface. The reflectance of features varies at different wavelengths.
- Processes involved in Remote Sensing are Energy Source or Illumination, Radiation and the Atmosphere, Interaction with the Target, Recording of Energy by the Sensor, Transmission-Reception- Processing, Interpretation and Analysis, Application.
- Platform is a stage to mount the camera or sensor to acquire the information about a target under investigation.
- Platforms are categorized in three groups like, Ground based, Airborne, and Space borne
- Sensors are electronic devices which collect and record electromagnetic energy which is reflected/emitted from the target or surface.
- Passive sensors use sun as energy source.

- Active sensors use their own energy source
- The data captured by the remote sensing Technology can be classified as: Analog Data and Digital Data
- Remote sensing satellites move in sun synchronous orbit
- Pixel represents the smallest element that the sensor can view at an instant
- Resolution defines the clarity of the Image
- National Remote Sensing Centre (NRSC) is one of the centers of Indian Space Research Organization under the Department of Space, Govt. of India, engaged in operational remote sensing activities.

Review

Very Short Answer Questions

1. Name any one example of direct sensing
2. Which is the source of energy for remote sensing
3. What is wavelength?
4. What is frequency?
5. What is the range of visible spectrum?
6. Can human eye recognize beyond visible band?
7. Why green leaves look green?
8. Wow can you see seven colors in a rainbow?
9. What is the altitude of remote sensing satellite?
10. Every object has a unique pattern of reflection. Yes or no.
11. Name types of remote sensing platforms.
12. In ground based platform where are camera/sensors placed?
13. Name types of sensors.
14. Name any five types of application of remote sensing.
15. Active sensors use sun as an energy source. True or False.
16. Name the remote sensing data products.
17. What is the source of satellite imagery?

Short Answer Questions

1. Define Remote Sensing?
2. Explain Electromagnetic radiation?
3. Name the various bands in EMR
4. What is Spectral Signature?
5. Why does water look blue, green and black?
6. What is the difference between active and passive sensors?
7. What is Analog data?
8. What is the difference between Analog Photo & digital Image?
9. What is a satellite image?
10. What is (i) a pixel and (ii) resolution?
11. What is the relationship between height and resolution?
12. What is sun synchronous Orbit?
13. Name some of Indian Remote sensing satellites

Long Answer Questions

1. Give an example of remote sensing system and explain.
2. Explain the fundamentals of remote sensing.
3. Explain with diagram the spectral signature of following features, vegetation, soil, barren land water body.
4. Explain the processes involved in Remote sensing
5. Explain types of platforms.
6. Write a brief note on sensors.
7. What is difference between 10 m , 20 m , 30m resolution?
8. Write a brief note on Indian remote sensing system.
9. Explain any one of the Remote sensing applications.