MODULE – 1 LECTURE NOTES – 1

BASIC CONCEPTS OF REMOTE SENSING

1. Introduction

Remote sensing is an art and science of obtaining information about an object or feature without physically coming in contact with that object or feature. Humans apply remote sensing in their day-to-day business, through vision, hearing and sense of smell. The data collected can be of many forms: variations in acoustic wave distributions (e.g., sonar), variations in force distributions (e.g., gravity meter), variations in electromagnetic energy distributions (e.g., eye) etc. These remotely collected data through various sensors may be analyzed to obtain information about the objects or features under investigation. In this course we will deal with remote sensing through electromagnetic energy sensors only.

Thus, remote sensing is the process of inferring surface parameters from measurements of the electromagnetic radiation (EMR) from the Earth's surface. This EMR can either be reflected or emitted from the Earth's surface. In other words, remote sensing is detecting and measuring electromagnetic (EM) energy emanating or reflected from distant objects made of various materials, so that we can identify and categorize these objects by class or type, substance and spatial distribution [American Society of Photogrammetry, 1975].

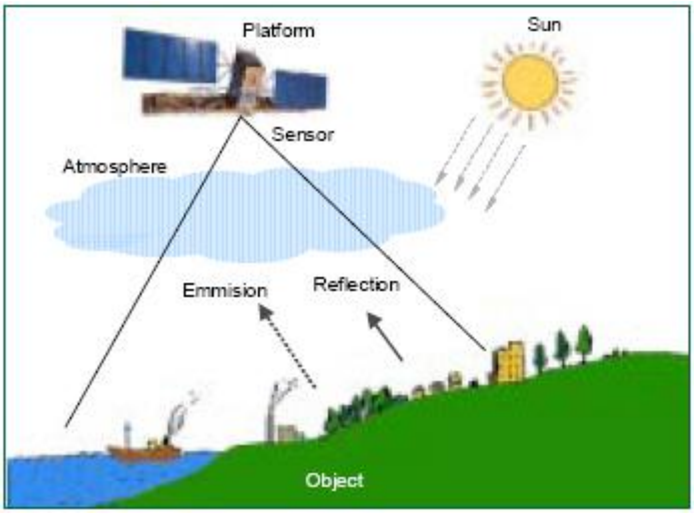

Fig. 1. Schematic representation of remote sensing technique

(Source: http://geoportal.icimod.org)

Remote sensing provides a means of observing large areas at finer spatial and temporal frequencies. It finds extensive applications in civil engineering including watershed studies, hydrological states and fluxes simulation, hydrological modeling, disaster management services such as flood and drought warning and monitoring, damage assessment in case of natural calamities, environmental monitoring, urban planning etc.

Basic concepts of remote sensing are introduced below.

2. Electromagnetic Energy

Electromagnetic energy or electromagnetic radiation (EMR) is the energy propagated in the form of an advancing interaction between electric and magnetic fields (Sabbins, 1978). It travels with the velocity of light. Visible light, ultraviolet rays, infrared rays, heat, radio waves, X-rays all are different forms of electro-magnetic energy.

Electro-magnetic energy (E) can be expressed either in terms of frequency (f) or wave length (λ) of radiation as

$$E = h\,c\,f \quad \text{or} \quad h\,c/\lambda \qquad (1)$$

where h is Planck's constant (6.626×10^{-34} Joules-sec), c is a constant that expresses the celerity or speed of light (3×10^{8} m/sec), f is frequency expressed in Hertz and λ is the wavelength expressed in micro meters ($1\mu m = 10^{-6}$ m).

As can be observed from equation (1), shorter wavelengths have higher energy content and longer wavelengths have lower energy content.

Distribution of the continuum of energy can be plotted as a function of wavelength (or frequency) and is known as the EMR spectrum (Fig. 2).

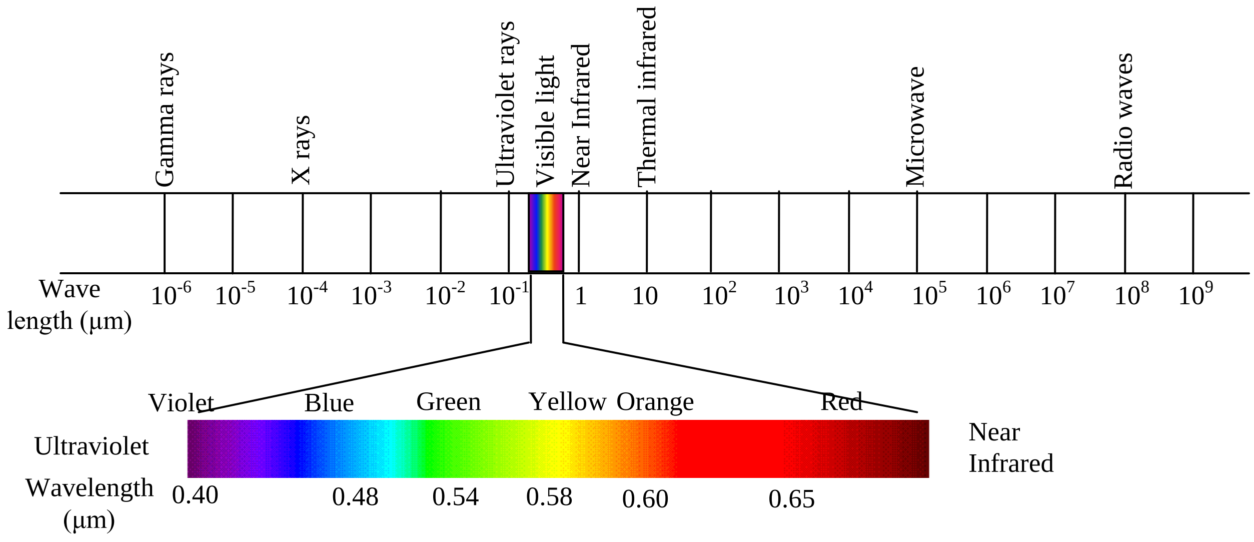

Fig. 2. Electromagnetic radiation spectrum

In remote sensing terminology, electromagnetic energy is generally expressed in terms of wavelength, λ.

All matters reflect, emit or radiate a range of electromagnetic energy, depending upon the material characteristics. In remote sensing, it is the measurement of electromagnetic radiation reflected or emitted from an object, is the used to identify the target and to infer its properties.

3. Principles of Remote Sensing

Different objects reflect or emit different amounts of energy in different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both the material and the incident energy (angle of incidence, intensity and wavelength). Detection and discrimination of objects or surface features is done through the uniqueness of the reflected or emitted electromagnetic radiation from the object.

A device to detect this reflected or emitted electro-magnetic radiation from an object is called a "sensor" (e.g., cameras and scanners). A vehicle used to carry the sensor is called a "platform" (e.g., aircrafts and satellites).

Main stages in remote sensing are the following.

A. Emission of electromagnetic radiation
    - The Sun or an EMR source located on the platform

B. Transmission of energy from the source to the object
    - Absorption and scattering of the EMR while transmission

C. Interaction of EMR with the object and subsequent reflection and emission

D. Transmission of energy from the object to the sensor

E. Recording of energy by the sensor
    - Photographic or non-photographic sensors

F. Transmission of the recorded information to the ground station

G. Processing of the data into digital or hard copy image

H. Analysis of data

These stages are shown in Fig. 3.

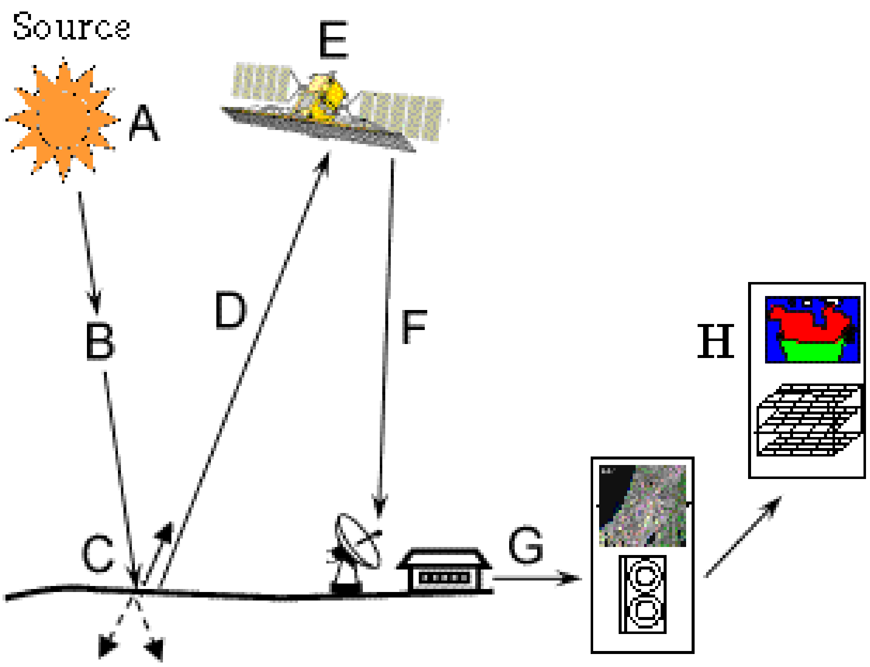

Fig.3 Important stages in remote sensing

4. Passive/ Active Remote Sensing

Depending on the source of electromagnetic energy, remote sensing can be classified as passive or active remote sensing.

In the case of passive remote sensing, source of energy is that naturally available such as the Sun. Most of the remote sensing systems work in passive mode using solar energy as the source of EMR. Solar energy reflected by the targets at specific wavelength bands are recorded using sensors onboard air-borne or space borne platforms. In order to ensure ample signal strength received at the sensor, wavelength / energy bands capable of traversing through the atmosphere, without significant loss through atmospheric interactions, are generally used in remote sensing

Any object which is at a temperature above 0^o K (Kelvin) emits some radiation, which is approximately proportional to the fourth power of the temperature of the object. Thus the Earth also emits some radiation since its ambient temperature is about 300^o K. Passive sensors can also be used to measure the Earth's radiance but they are not very popular as the energy content is very low.

In the case of active remote sensing, energy is generated and sent from the remote sensing platform towards the targets. The energy reflected back from the targets are recorded using sensors onboard the remote sensing platform. Most of the microwave remote sensing is done through active remote sensing.

As a simple analogy, passive remote sensing is similar to taking a picture with an ordinary camera whereas active remote sensing is analogous to taking a picture with camera having built-in flash (Fig. 5).

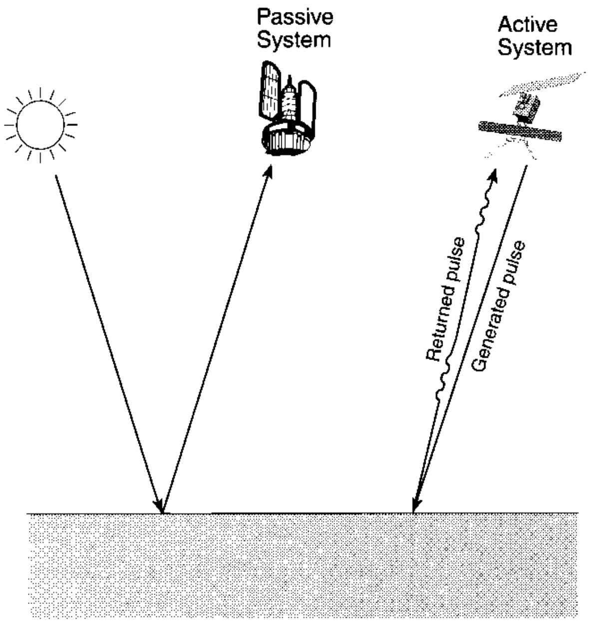

Fig. 5 Schematic representation of passive and active remote sensing

5. Remote Sensing Platforms

Remote sensing platforms can be classified as follows, based on the elevation from the Earth's surface at which these platforms are placed.

- Ground level remote sensing
    - Ground level remote sensors are very close to the ground
    - They are basically used to develop and calibrate sensors for different features on the Earth's surface.
- Aerial remote sensing
    - Low altitude aerial remote sensing
    - High altitude aerial remote sensing
- Space borne remote sensing
    - Space shuttles
    - Polar orbiting satellites
    - Geo-stationary satellites

From each of these platforms, remote sensing can be done either in passive or active mode.

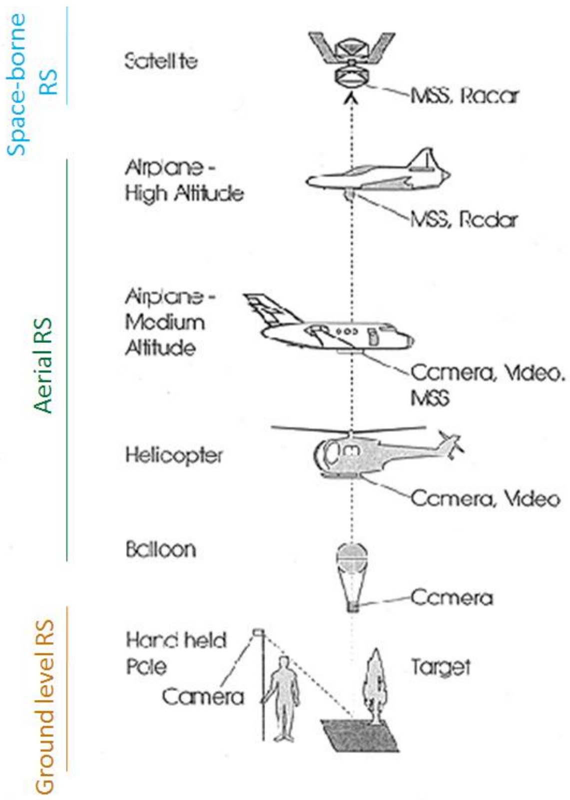

Fig. 6. Remote sensing platforms

(Modified from http://www.ilmb.gov.bc.ca/risc/pubs/aquatic/aerialvideo/assets/figure1.gif)

6. Airborne and Space-borne Remote Sensing

In airborne remote sensing, downward or sideward looking sensors mounted on aircrafts are used to obtain images of the earth's surface. Very high spatial resolution images (20 cm or less) can be obtained through this. However, it is not suitable to map a large area. Less coverage area and high cost per unit area of ground coverage are the major disadvantages of airborne remote sensing. While airborne remote sensing missions are mainly one-time operations, space-borne missions offer continuous monitoring of the earth features.

LiDAR, analog aerial photography, videography, thermal imagery and digital photography are commonly used in airborne remote sensing.

In space-borne remote sensing, sensors mounted on space shuttles or satellites orbiting the Earth are used. There are several remote sensing satellites (Geostationary and Polar orbiting) providing imagery for research and operational applications. While Geostationary or

Geosynchronous Satellites are used for communication and meteorological purposes, polar orbiting or sun-synchronous satellites are essentially used for remote sensing. The main advantages of space-borne remote sensing are large area coverage, less cost per unit area of coverage, continuous or frequent coverage of an area of interest, automatic/ semiautomatic computerized processing and analysis. However, when compared to aerial photography, satellite imagery has a lower resolution.

Landsat satellites, Indian remote sensing (IRS) satellites, IKONOS, SPOT satellites, AQUA and TERRA of NASA and INSAT satellite series are a few examples.

7. Ideal Remote Sensing System

The basic components of an ideal remote sensing system include:

i. A Uniform Energy Source which provides energy over all wavelengths, at a constant, known, high level of output
ii. A Non-interfering Atmosphere which will not modify either the energy transmitted from the source or emitted (or reflected) from the object in any manner.
iii. A Series of Unique Energy/Matter Interactions at the Earth's Surface which generate reflected and/or emitted signals that are selective with respect to wavelength and also unique to each object or earth surface feature type.
iv. A Super Sensor which is highly sensitive to all wavelengths. A super sensor would be simple, reliable, accurate, economical, and requires no power or space. This sensor yields data on the absolute brightness (or radiance) from a scene as a function of wavelength.
v. A Real-Time Data Handling System which generates the instance radiance versus wavelength response and processes into an interpretable format in real time. The data derived is unique to a particular terrain and hence provide insight into its physical-chemical-biological state.
vi. Multiple Data Users having knowledge in their respective disciplines and also in remote sensing data acquisition and analysis techniques. The information collected will be available to them faster and at less expense. This information will aid the users in various decision making processes and also further in implementing these decisions.

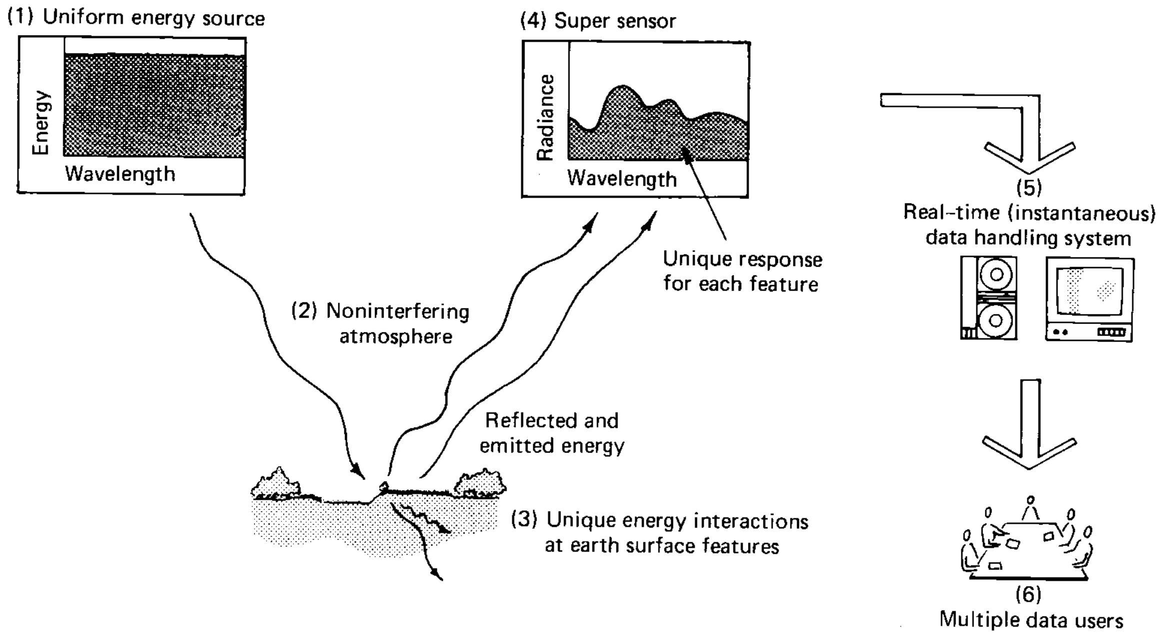

Fig. 7 Components of an ideal remote sensing system

8. Characteristics of Real Remote Sensing Systems

Real remote sensing systems employed in general operation and utility have many shortcomings when compared with an ideal system explained above.

i. Energy Source: The energy sources for real systems are usually non-uniform over various wavelengths and also vary with time and space. This has major effect on the passive remote sensing systems. The spectral distribution of reflected sunlight varies both temporally and spatially. Earth surface materials also emit energy to varying degrees of efficiency. A real remote sensing system needs calibration for source characteristics.

ii. The Atmosphere: The atmosphere modifies the spectral distribution and strength of the energy received or emitted (Fig. 8). The effect of atmospheric interaction varies with the wavelength associated, sensor used and the sensing application. Calibration is required to eliminate or compensate these atmospheric effects.

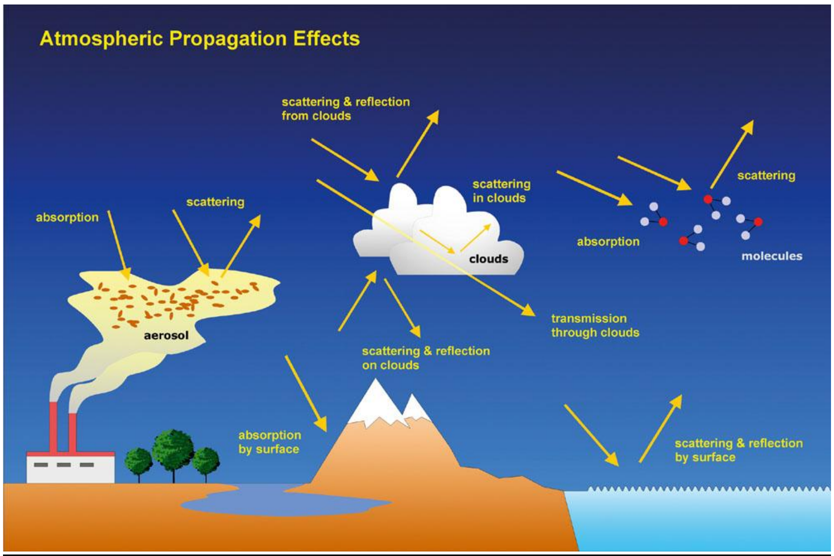

Fig. 8. Interactions of the electromagnetic energy with the atmosphere

(Source: https://earth.esa.int/)

iii. The Energy/Matter Interactions at the Earth's Surface: Remote sensing is based on the principle that each and every material reflects or emits energy in a unique, known way. However, spectral signatures may be similar for different material types. This makes differentiation difficult. Also, the knowledge of most of the energy/matter interactions for earth surface features is either at elementary level or even completely unknown.

iv. The Sensor: Real sensors have fixed limits of spectral sensitivity i.e., they are not sensitive to all wavelengths. Also, they have limited spatial resolution (efficiency in recording spatial details). Selection of a sensor requires a trade-off between spatial resolution and spectral sensitivity. For example, while photographic systems have very good spatial resolution and poor spectral sensitivity, non-photographic systems have poor spatial resolution.

v. The Data Handling System: Human intervention is necessary for processing sensor data; even though machines are also included in data handling. This makes the idea of real time data handling almost impossible. The amount of data generated by the sensors far exceeds the data handling capacity.

vi. The Multiple Data Users: The success of any remote sensing mission lies on the user who ultimately transforms the data into information. This is possible only if the user understands the problem thoroughly and has a wide knowledge in the data generation. The user should know how to interpret the data generated and should know how best to use them.

9. Advantages and Disadvantages of Remote Sensing

Advantages of remote sensing are:

a) Provides data of large areas
b) Provides data of very remote and inaccessible regions
c) Able to obtain imagery of any area over a continuous period of time through which the any anthropogenic or natural changes in the landscape can be analyzed
d) Relatively inexpensive when compared to employing a team of surveyors
e) Easy and rapid collection of data
f) Rapid production of maps for interpretation

Disadvantages of remote sensing are:

a) The interpretation of imagery requires a certain skill level
b) Needs cross verification with ground (field) survey data
c) Data from multiple sources may create confusion
d) Objects can be misclassified or confused
e) Distortions may occur in an image due to the relative motion of sensor and source