# BASICS OF REMOTE SENSING

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From a general perspective, remote sensing is the science of acquiring and analyzing information about objects or phenomena from a distance (Jensen, 2000, Lillesand and Keifer, 1987). However, conventionally, Remote Sensing (RS) refers to the identification of earth features by detecting the characteristic electromagnetic radiation that is reflected/emitted by the earth surface. The sensors on-board various platforms detect the radiation received from the targets in different spectral regions. Compared to conventional monitoring from the ground, the advantages of satellite remote sensing are:

- capability to achieve a synoptic view,
- potential for fast survey,
- capability of repetitive coverage to detect the changes
- low cost involvement
- higher accuracy
- use of multispectral data for increased information,
- inaccessible area coverage
- all weather / day and night capability
- simultaneous observations from a single platform at different resolutions / angles, spectral regions over land, atmosphere and oceans

## 1. COMPONENTS OF REMOTE SENSING

Though the methods for collection, processing, and interpretation of remotely sensed data are very diverse, imaging systems have the following essential components (Panigrahy and Ray, 2006):

### 1.1 Energy Source or Illumination

The first requirement for remote sensing is to have an energy source, which illuminates or provides electromagnetic energy to the target of interest. Sensors can be classified as passive or active, based on the energy source they are using. Sensors, which sense natural radiations, either emitted or reflected from the Earth, are called passive sensors. Most of the remote sensing sensors are passive in nature, which measure the solar radiation reflected from the target. On the other hand, the sensors which produce their own electromagnetic radiation, are called active sensors (e.g. LIDAR, RADAR).

### 1.2 Interaction with the Target

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 a second time as the energy travels from the target to the sensor. 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. A number of interactions are possible when Electromagnetic energy encountersmatter, whether solid, liquid or gas.

- Radiation may be transmitted, that is, passed through the substance.
- Radiation may be absorbed by a substance and give up its energy largely toheating the substance.
- Radiation may be emitted by a substance as a function of its structure and temperature. All matter at temperatures above absolute zero, 0°K, emits energy.
- Radiation may be scattered, that is, deflected in all directions and lost ultimately to absorption or further scattering (as light is scattered in the atmosphere).
- Radiation may be reflected.

### 1.3 Recording of Energy by the Sensor

After the energy has been scattered by, or emitted from the target, we require a sensor (mounted on a satellite orbiting in space) to collect and record the electromagnetic radiation.

The sensors are popularly known by the EMR region they sense. Remote sensing can be broadly classified as optical and microwave (Navalgund et al, 2007). In optical remote sensing, sensors detect solar radiation in the visible, near-, middle- and thermal-infrared wavelength regions, reflected/scattered or emitted from the earth (Table 1). On the other hand, when the sensors work in the region of electromagnetic waves with frequencies between $10^9$ and$10^{12}$ Hz, it is called microwave remote sensing. This is highly useful, as it provides observation of the earth's surface, regardless of day/night and the atmospheric conditions. The Radar is an active microwave remote sensing system, which illuminates the terrain with electromagnetic energy, detects the scattered energy returning from the terrain (called radar return) and then records it as an image. Intensity of radar return, for both aircraft and satellite-based systems, depends upon radar system properties and terrain properties.

**Table-1. The spectral regions used in satellite based remote sensing**

| **Region** | **Wavelength** | **Property** |
|---|---|---|
| Visible (blue, red, green) | 0.4-0.7μm | Reflectance |
| Reflective Infrared | 0.7-3.0μm | Reflectance |
| Thermal Infrared | 3.0-15.0μm | Radiative Temperature |
| Microwave | 0.1-30 cm | Brightness Temperature (Passive)<br>Backscattering (Active) |

The sensor, for taking observations, needs to be mounted on a platform. This platform can be ground-based (e.g. handheld radiometers), airborne (e.g. AVIRIS sensor of NASA) or space borne, i.e. satellite based. The operational remote sensing systems are generally space borne.

Resolution is a major sensor parameter, which has bearing on optimum utilization of data. There are four types of resolution.

- Spatial Resolution: Sensor's Ability to image (record) closely spaced objects so that they are distinguishable as separate objects
- Spectral Resolution: The spectral bandwidth in which the data is collected. (Full Width at Half Maximum)
- Radiometric Resolution: The capability of the sensor to differentiate the smallest change in the spectral reflectance/emittance between various targets. This is represented as the noise equivalent change in reflectance (NE$\Delta\rho$ ) or temperature (NE$\Delta$T))
- Temporal Resolution represents the capability to view the same target, under similar conditions, at regular intervals. It is time interval between imaging collections over the same geographic location

### 1.4 Transmission, Reception, and Processing

The energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station at earth where the data are processed and stored in digital form.

### 1.5 Interpretation and Analysis

The processed data is interpreted, visually and/or digitally to extract information about the target which was illuminated. Specialized instruments/hardware and software are used for this purpose that are commonly known as image processing tools. The final element of the remote sensing process is achieved when we apply the extracted information in solving a particular problem. Specialists working in each application field/theme generally are able to carry out this task.

Image processing, also called digital image processing as it handles digital data, involves four basic steps. Those are:

a. Image correction/ restoration - Image data recorded by sensors on a satellite or aircraft contain errors related to geometry and brightness values of the pixels. These errors are corrected using suitable mathematical models, which are either definite or statistical models.

b. Image enhancement - Image enhancement is the modification of image, by changing the pixel brightness values, to improve its visual impact. Image enhancement techniques are performed by deriving the new brightness value for a pixel either from its existing value or from the brightness values of a set of surrounding pixels.

c. Image transformation- The multi-spectral character of image data allows it to be spectrally transformed to a new set of image components or bands with a purpose to get some information more evident or to preserve the essential information content of the image (for a given application) with a reduced number of transformed dimensions. The pixel values of the new components are related to the original set of spectral bands via a linear operation.

d. Image classification - The overall objective of image classification procedures is to automatically categorize all pixels in an image into land cover classes or themes. A pixel is characterized by its spectral signature, which is determined by the relative reflectance in the different wavelength bands. Multi-spectral classification is an information extraction process that analyses these spectral signatures and assigns the pixels to classes based on similar signatures.

For a detailed study on digital image processing the readers may refer Richards & Xia (2006) and Jensen (2003).

## 2. CONCEPT OF SPECTRAL SIGNATURES

In order to appreciate the role of remote sensing in various fields one has to understand the behaviour of various targets with respect electromagnetic spectrum. Spectral behaviour of objects is the basic characteristics for understanding and interpretation of remotely sensed data. Figure 1 shows the how the reflectance varies as a function of wavelength for various natural targets. This reflectance pattern, which is otherwise known as spectral signature, is used for target discrimination in a multispectral remote sensing image.

Spectral signature of any object and/or its condition comprises a set of values for its reflectance and/or its emittance in different spectral bands. This directly or indirectly leads to the identification of an object and/or its condition. There are four principal characteristics of spectral signature.

i) Spectral Variations - Changes as a function of wavelength

ii) Spatial Variations - Determined by the shape, size and texture of the target

iii) Temporal Variations - Diurnal and/or seasonal changes in reflectance

iv) Polarisation variations - Caused by the degree of polarisation.

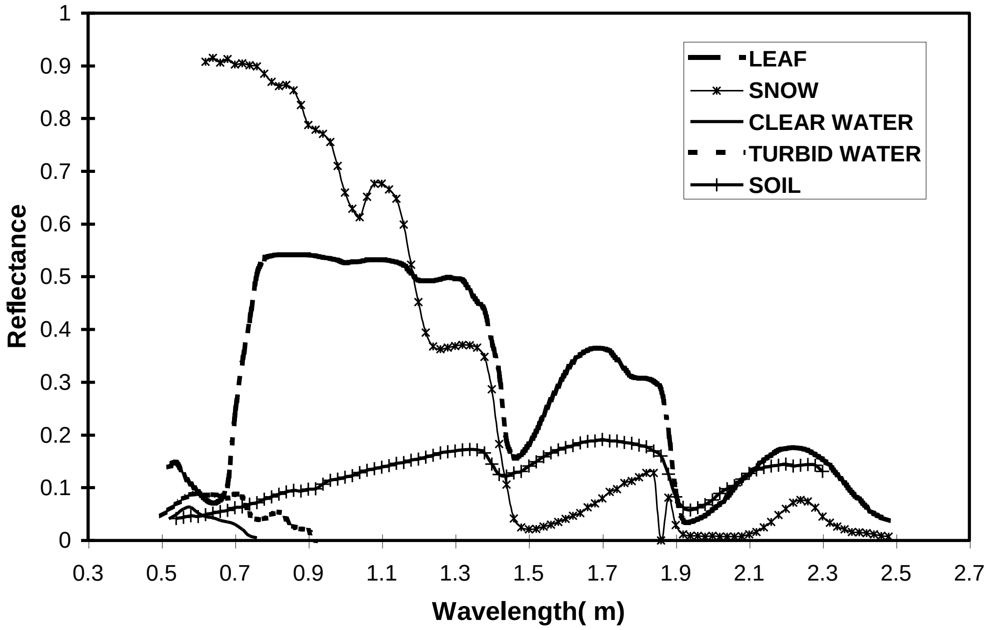


**Figure 1. Spectral signatures of various land targets**

## 3. EARTH OBSERVATION SYSTEMS

Since the early 1960s, numerous satellite sensors have been launched into orbit to observe and monitor the Earth and its environment. Most early satellite sensors acquired data for meteorological purposes. The advent of earth resources satellite sensors (those with a primary objective of mapping and monitoring land cover) occurred when the first Landsat satellite was launched in July 1972. Currently, more than a dozen orbiting satellites of various types provide data crucial to improving our knowledge of the Earth's land, ocean, atmosphere, ice and snow. Each of these sensors enables direct observation of the global land surface in a consistent fashion, with data having unique characteristics of spectral, spatial, and temporal resolution. To varying degrees, the data gathered by each sensor are suited for the variety of specific interests associated with monitoring the effects of natural events and human actions on land cover. The sensors include the U.S.MODIS sensor on-board Terra/Aqua, the U.S. Landsat Thematic Mapper (TM) sensors, the French SystemeProbatoired'Observation de la Terra (SPOT) High Resolution Visible (HRV) and VEGETATION Sensor, the Canadian Microwave satellite Radarsat -2 and the Indian Remote Sensing Satellites.

Indian earth observation (EO) programme has continuously evolved. From experimental satellites like Bhaskara to present generation thematic satellites, like Resourcesat, Oceansat and Cartosat, Risat, India’s EO capability has increased manifold. Improvements are not only in spatial, spectral, temporal and radiometric resolutions but also in their coverage and value added products. A detailed account of Indian Remote Sensing Programme has been provided by Joseph (2003) and various applications of remote sensing data are documented in Navalgund et al. (2007). Table 2 provides a list of Indian Earth Observation sensors, while Table 3 gives the specifications of currently available major International sensors.

## 4. REMOTE SENSING APPLICATIONS

Remote sensing data can be used for various applications in three different ways. These are, i) Mapping/Monitoring of earth resources, ii) Retrieval of bio-geo-physical parameters, which are used in models to predict the changes in geosphere and biosphere, iii) Management/Decision Support, where remote sensing derived information is used to arrive at decision for sustainable management of earth resources. There are various fields in which remote sensing applications have been shown to be highly useful, which include agriculture, water resources, forest and ecosystem, disaster management, infrastructure development, atmospheric and oceanic sciences and many others. There is another lecture note, in this volume, which discusses the remote sensing applications, in detail.

## 5. FUTURE OF REMOTE SENSING

The technology of remote sensing is growing day-by-day. New types of platforms, better observations using advanced sensors (such as microwave and hyperspectral), modern data analysis approaches are making remote sensing more and more amenable to use for societal benefits. In future, remote sensing tools will be highly useful for not only making decisions at grassroots level but also understanding the global change issues.

**Table 2. Specifications of Indian Earth Observation Satellites**

| **Mission** | **Year of Launch** | **Sensors** | **Sensor Specifications (Resolution & Swath)** |
|---|---|---|---|
| Bhaskara-I / II | 1979 / 1981 | Microwave Radiometer (SAMIR) | 19/22/31 GHz |
| IRS-1A, 1B | 1988, 1991 | LISS-I Multispctral | Resol. :72.5 m, Swath: 148 km |
| | | LISS-II Multispectral | Resol.:36.25 m, Swath: 142 km |
| IRS-P2 | 1994 | LISS-II Multispectral | Resol:36 m; Swath:148 km |
| IRS-1C, 1D | 1995, 1997 | Panchromatic | Resol.:5.8 m, Swath: 70 km |
| | | LISS-III Multispectral | Resol.: 23.5m, 70.5 m, Swath : 141 km |
| | | WiFS | Resol.:188.3 m, Swath: 810km |
| IRS-P3 | 1996 | WiFS | Resol.:188.3 m, Swath: 810km |
| | | MOS-A,B,C | Resol.: 0.5- 1.5 km, Swath : 248 km |
| IRS-P4 (Oceansat-1) | 1999 | OCM Ocean colour monitor | Resol.: 360 m , 20 nm Spectral Swath: 1420 km |
| | | MSMR Microwave Radiometer | 6.6, 10.75, 18, 21 GHz channels Resol.: 40-120 km, 1°K Accuracy; Swath: 1360 km |
| IRS-P6 (Resourcesat-1) | 2003 | LISS IV Multispectral | Resol.:5.8 m, Swath: 70 km |
| | | LISS-III Multispectral | Resol.: 23.5m, 70.5 m; Swath : 141 km |
| | | AWiFS | Resol.: 56 m, Swath: 737 km |
| Cartosat 1 | 2005 | Panchromatic (Fore +26°& Aft −5°) | Resol.: 2.5 m, Swath: 30 km |
| Cartosat 2, 2A, 2B | 2007, 2008, 2010 | Panchromatic (Steerable ±26°) | Resol.: < 1 m, Swath: 9.6 km |
| IMS-1 | 2008 | MX Multispectral | Resol.: 37 m, Swath: 151 km |
| | | HySIHyperspectral | 64 bands, Resol.: 506 m, Swath: 129.5 km |
| Oceansat 2 | 2009 | OCM Ocean colour monitor | Resol.: 360 m,Swath: 1420 km |
| | | Ku – Band Scatterometer | 13.515 GHz |
| Resourcesat 2 | 2011 | LISS IV Multispectral | Resol.:5.8 m, Swath: 70 km |
| | | LISS-III Multispectral | Resol.: 23.5m, 70.5 m; Swath : 141 km |
| | | AWiFS | Resol.: 56 m, Swath: 740 km |
| MeghaTropiques | 2011 | MADRAS ; SAPHIR; ScaRaB; ROSA | |
| RISAT-1 | 2012 | C-band Synthetic Aperture Radar (SAR) | 5.35 GHz |

**Table 3.Description of current major imaging earth observation satellites available in the world* (Adapted from Navalgund et al., 2007)**

| Country/organization | Satellite | Major sensors | Description (Spatial resolution, spectral bands) |
|---|---|---|---|
| USA/NASA | Terra<br><br>Terra/Aqua<br><br>NMP EO-1 | Aster<br><br>MODIS<br><br>ALI | 15 m (VNIR), 30 m (SWIR), 90 m (TIR); 14 XS (VNIR, SWIR, TIR)<br>250–1000 m, 36 bands (VIS–TIR)<br>10 m (Pan), 30 m (VNIR/SWIR); Pan & 9 XS (VNIR/SWIR)\ |
| USA/USGS | Landsat-7 | ETM+ | 15 m (Pan), 30 m (Vis-SWIR), 60 m (TIR), Pan & 8 XS (VIS-TIR) |
| EU/ESA | Envisat | ASAR<br><br>MERIS | C Band, multi-polarization, multi-imaging mode SAR<br>260 m–1200 m, 15 bands (VNIR) |
| Canada/CSA | Radarsat-2 | SAR | C band 5.405 GHz. HH, VV, HV, VH polarization; multi-imaging modes |
| France/CNES | SPOT-5 | HRG<br><br>HRS<br>VEGETATION | 5 m (Pan), 10 m (MS); Pan + 4 XS (VNIR/SWIR)<br>High resolution (10 m, pan) stereo<br>1.15 km, 3 XS(VNIR/SWIR), |

*This list is not exhaustive, but just an indicative list. For detailed list the readers are referred to http://ceos-sysdb.com/CEOS/db/db_instruments_high_level.php;

VNIR – Visible and near infrared; SWIR – short-wave infrared, TIR – Thermal Infrared, XS – Multispectral bands.

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