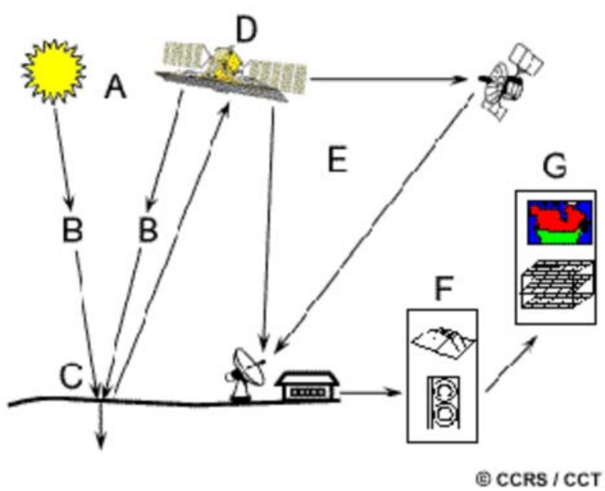
Remote sensing:

Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.

In much of remote sensing, the process involves an interaction between incident radiation and the targets of interest. This is exemplified by the use of imaging systems where the following seven elements are involved. Note, however that remote sensing also involves the sensing of emitted energy and the use of non-imaging sensors.



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 a 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.

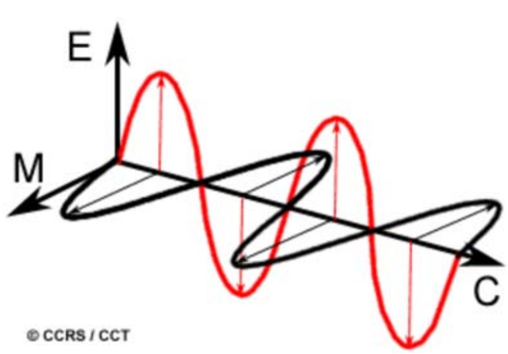
5.Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

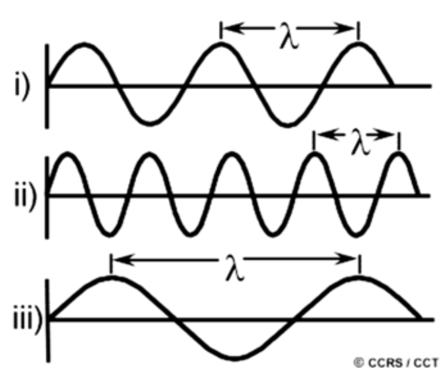
6.Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7.Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

Electromagnetic Radiation

As was noted in the previous section, the first requirement for remote sensing is to have an energy source to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.





All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular

to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c). Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the wavelength and frequency.

The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ). Wavelength is measured in meters (m) or some factor of meters such as nanometers (nm, 10-9 meters), micrometers (µm, 10-6 meters) (µm, 10-6 meters) or centimeters (cm, 10-2 meters).

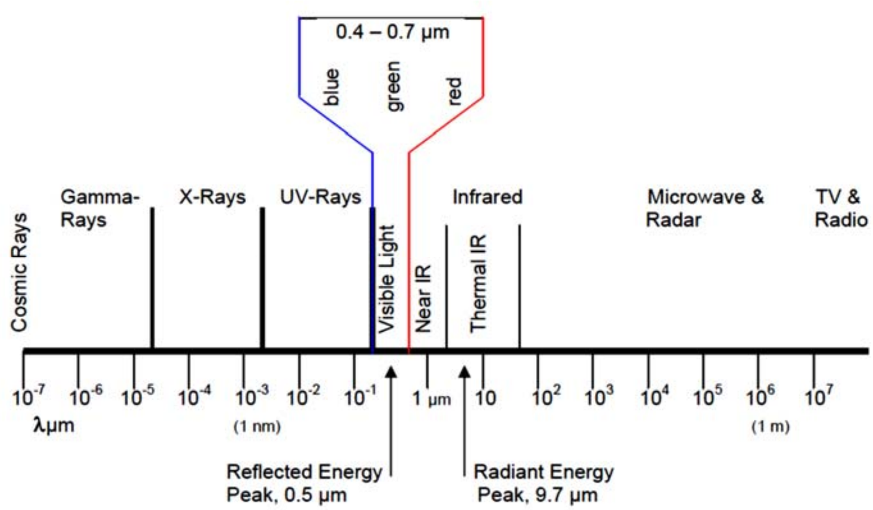
Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in hertz (Hz), equivalent to one cycle per second, and various multiples of hertz.Wavelength and frequency are related by the following formula:

$$c = \lambda * v$$

Where:

$c = speed\ of\ light\ (3 * 10^8 m.s^{-1})$, $\lambda = wavelength(m)$ and v = **Frequency** (Hz)

Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency.



Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data. The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.

Gamma rays	<0.30 nm	This range is completely absorbed by the upper atmosphere and not available for remote sensing.
X-rays	0.03—30.0 nm	This range is completely absorbed by the atmosphere and not employed in remote sensing.
UV-rays	0.03—0.40 µm	This range is completely absorbed by the atmosphere and not employed in remote sensing.
Photographic UV	0.30—0.40 µm	This range is not absorbed by the atmosphere and detectable with film and photo detectors but with severe atmospheric scattering.
Visual Blue	0.45—0.52 µm	Because water increasingly absorbs electromagnetic (EM) radiation at longer wavelengths, band 1 provides the best data for mapping depth-detail of water-covered areas. It is also used for soil-vegetation discrimination, forest mapping, and distinguishing cultural features.
Visual Green	0.50—0.60 µm	The blue-green region of the spectrum corresponds to the chlorophyll absorption of healthy vegetation and is useful for mapping detail such as depth or sediment in water bodies. Cultural features such as roads and buildings also show up well in this band.
Visual Red	0.60—0.70 µm	Chlorophyll absorbs these wavelengths in healthy vegetation Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries.
Near IR	0.70—0.80 µm	The near IR corresponds to the region of the EM spectrum, which is especially sensitive to varying vegetation biomass. It also emphasizes soil-crop and land-water boundaries.

Near IR	0.80—1.10 µm	The second near IR band is used for vegetation discrimination, penetrating haze, and water-land boundaries.
Mid-IR	1.55—1.74 µm	This region is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice.
Mid IR	2.08—2.35 µm	This region is used for mapping geologic formations and soil boundaries. It is also responsive to plant and soil moisture content.
Mid-IR	3.55—3.93 µm	µm A thermal band which detects both reflected sunlight and earth--emitted radiation and is useful for snow-ice discrimination and forest fire detection.
Thermal IR	10.40—12.50 µm	This region of the spectrum is dominated completely by radiation emitted by the earth and helps to account for the effects of atmospheric absorption, scattering, and emission. It is useful for crop stress detection, heat intensity, insecticide applications, thermal pollution, and geothermal mapping. This channel is commonly used for water surface temperature measurements.
Microwave-Radar	0.10—100 cm	Microwaves can penetrate clouds, fog, and rain. Images can be acquired in the active or passive mode. Radar is the active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
TV & Radio	>10 m	The longest-wavelength portion of the electromagnetic spectrum.

Passive vs. Active Sensing

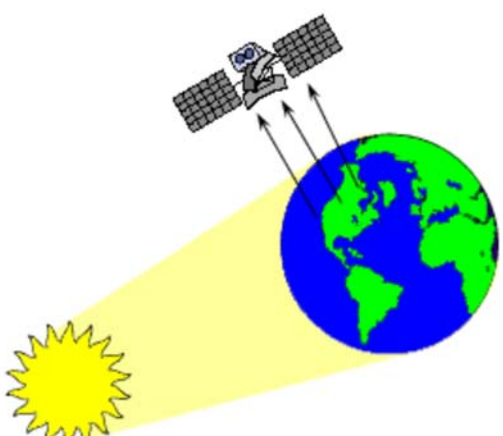
So far, throughout this chapter, we have made various references to the sun as a source of energy or radiation. The sun provides a very convenient source of energy for remote sensing.

The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re- emitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called passive sensors.

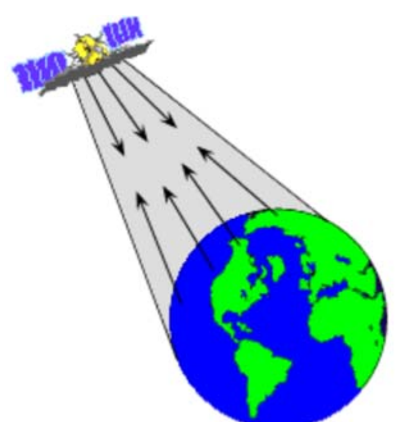
1. Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.

2. Active sensors, on the other hand, provide their own energy source for illumination. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated. However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets. Some examples of active sensors are a laser fluorosensor and a synthetic aperture radar.

Passive



Active

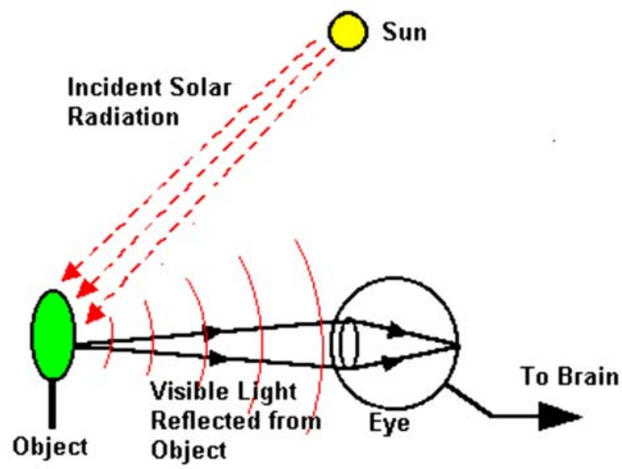


Types of Remote Sensing System

1. Visual remote sensing system: The human visual system is an example of a remote sensing system in the general sense. The sensors in this example are the two types of photosensitive cells, known as the cones and the rods, at the retina of the eyes. The cones are responsible for colour vision. There are three types of cones, each being

sensitive to one of the red, green, and blue regions of the visible spectrum. Thus, it is not coincidental that the modern computer display monitors make use of the same three primary colours to generate a multitude of colours for displaying colour images. The cones are insensitive under low light illumination condition, when their jobs are taken over by the rods.

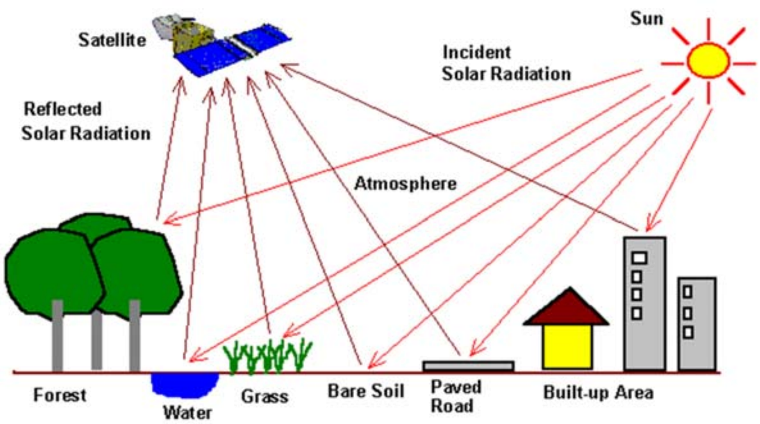
The rods are sensitive only to the total light intensity. Hence, everything appears in shades of grey when there is insufficient light. As the objects/events being observed are located far away from the eyes, the information needs a carrier to travel from the object to the eyes. In this case, the information carrier is the visible light, a part of the electromagnetic spectrum.



The objects reflect/scatter the ambient light falling onto them. Part of the scattered light is intercepted by the eyes, forming an image on the retina after passing through the optical system of the eyes. The signals generated at the retina are carried via the nerve fibers to the brain, the central processing unit (CPU) of the visual system. These signals are processed and interpreted at the brain, with the aid of previous experiences. The visual system is an example of a "Passive Remote Sensing" system which depends on an external source of energy to operate. We all know that this system won't work in darkness.

2. Optical Remote Sensing: In Optical Remote Sensing, optical sensors detect solar radiation reflected or scattered from the earth, forming images resembling photographs taken by a camera high up in space. The wavelength region usually extends from the visible and near infrared VNIR to the short-wave infrared SWIR. Different materials such as water, soil, vegetation, buildings and roads reflect visible and infrared light in different ways. They have different colours and brightness when seen under the sun. The interpretations of optical images requires the knowledge of the spectral reflectance signatures of the various materials (natural or man-made) covering the surface of the earth.

3. Infrared Remote Sensing: Infrared remote sensing makes use of infrared sensors to detect infrared radiation emitted from the Earth's surface.

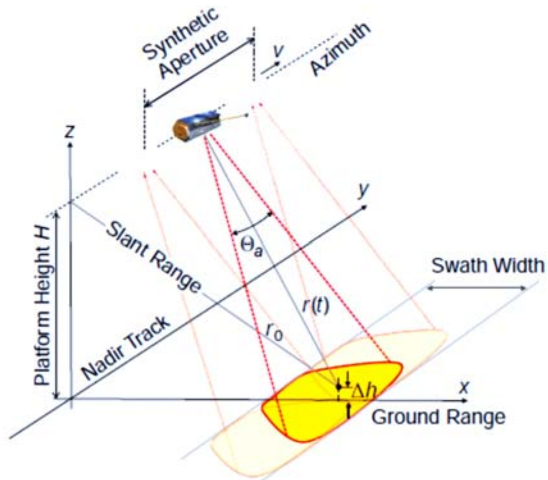


The middle-wave infrared (MWIR) and long-wave infrared (LWIR) are within the thermal infrared region. These radiations are emitted from warm objects such as the Earth's surface. They are used in satellite remote sensing for measurements of the earth's land and sea surface temperature. Thermal infrared remote sensing is also often used for detection of forest fires, volcanoes, oil fires.

4. Microwave Remote Sensing: There are some remote sensing satellites which carry passive or active microwave sensors. The active sensors emit pulses of microwave radiation to illuminate the areas to be imaged.

Images of the earth surface are formed by measuring the microwave energy scattered by the ground or sea back to the sensors. These satellites carry their own "flashlight" emitting microwaves to illuminate their targets. The images can thus be

acquired day and night. Microwaves have an additional advantage as they can penetrate clouds.



Images can be acquired even when there are clouds covering the earth surface. A microwave imaging system which can produce high resolution image of the Earth is the synthetic aperture radar (SAR). Electromagnetic radiation in the microwave wavelength region is used in remote sensing to provide useful information about the Earth's atmosphere, land and ocean. When microwaves strike a surface, the proportion of energy scattered back to the sensor depends on many factors:

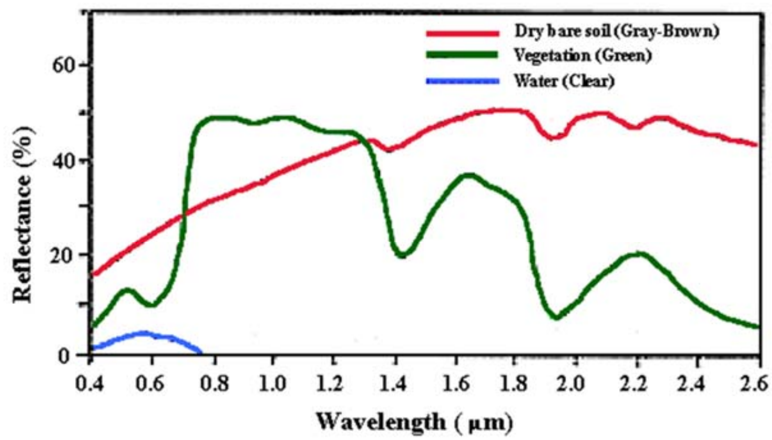
1. Physical factors such as the dielectric constant of the surface materials which also depends strongly on the moisture content;
2. Geometric factors such as surface roughness, slopes, orientation of the objects relative to the radar beam direction;
3. The types of land cover (soil, vegetation or man-made objects).
4. Microwave frequency, polarization and incident angle.

Satellite Remote Sensing:

In this, you will see many remote sensing images acquired by earth observation satellites. These remote sensing satellites are equipped with sensors looking down to the earth. They are the "eyes in the sky" constantly observing the earth as they go round in predictable orbits. Orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, which in conjunction with larger scale aerial or ground-based sensing and analysis provides researchers with enough information to monitor

trends. Other uses include different areas of the earth sciences such as natural resource management, agricultural fields such as land usage and conservation, and national security and overhead, ground-based and stand-off collection on border areas.

Satellite sensors record the intensity of electromagnetic radiation (sunlight) reflected from the earth at different wavelengths. Energy that is not reflected by an object is absorbed. Each object has its own unique 'spectrum', some of which are shown in the diagram below.



Typical spectral reflectance curves for vegetation, soil, and water

Remote sensing relies on the fact that particular features of the landscape such as bush, crop, salt-affected land and water reflect light differently in different wavelengths. Grass looks green, for example, because it reflects green light and absorbs other visible wavelengths. This can be seen as a peak in the green band in the reflectance spectrum for green grass above. The spectrum also shows that grass reflects even more strongly in the infrared part of the spectrum. While this can't be detected by the human eye, it can be detected by an infrared sensor.

Instruments mounted on satellites detect and record the energy that has been reflected. The detectors are sensitive to particular ranges of wavelengths, called 'bands'. The satellite systems are characterized by the bands at which they measure the reflected energy. The Landsat TM satellite, which provides the data used in this project, has bands at the blue, green and red wavelengths in the visible part of the spectrum and at three bands in the near and mid infrared part of the spectrum and one band in the thermal infrared part of the spectrum. The satellite detectors measure the intensity of the reflected energy and record it.