BASICS OF REMOTE SENSING

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History

The history of remote sensing began with the invention of photography more than 150 years ago. The term "photography" is derived from two Greek words meaning "light" (phos) and "writing" (graphien). Joseph Nicéphore Niépce (French) in 1827 takes first picture of nature from a window view of the French countryside using a camera obscura and an emulsion using bitumen of Judea, a resinous substance, and oil of lavender (it took 8 hours in bright sunlight to produce the image).

Although the first, rather primitive photographs were taken as "stills" on the ground, the idea and practice of looking down at the Earth's surface emerged in the 1840s when pictures were taken from cameras secured to tethered balloons for purposes of topographic mapping. Gasper Felix Tournachon (Popularly know as Nadar) takes the first aerial photograph in 1858 from a captive balloon from an altitude of 1,200 feet over Paris. During 1860's, aerial observations, and possible photography, for military purposes were acquired from balloons in the Civil War. During 1887, Germans began experiments with aerial photographs and photogrammetric techniques for measuring features and areas in forests.

Perhaps the most novel platform at the end of the last century is the famed pigeon fleet that operated as a novelty in Europe. By the first World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that proved invaluable in military reconnaissance. From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the surface from a vertical or oblique perspective.

In 1934, Photogrammetric Engineering first published. American Society of Photogrammetry founded and renamed Photogrammetric Engineering and Remote Sensing. The Society was again renamed, and is now The American Society of Photogrammetry and Remote Sensing.

Satellite remote sensing can be traced to the early days of the space age (both Russian and American programs) and actually began as a dual approach to imaging surfaces using several types of sensors from spacecraft. In 1946, V-2 rockets acquired from Germany after World War II were launched to high altitudes from White Sands, New Mexico. These rockets, while never attaining orbit, contained automated still or movie cameras that took pictures as the vehicle ascended. Sputnik 1 the first artificial Earth satellite launched by the Soviet Union into an elliptical low Earth orbit on 4 October 1957, orbiting for three weeks before its batteries died, then silently for two more months before falling back into the atmosphere. Then, with the emergence of the space program in the 1960s, Earth-orbiting cosmonauts and astronauts acted much like tourists by taking photos out the window of their spacecraft.

Remote sensing as a technology started with the first photographs in the early nineteenth century. Many significant events led to the launch of the Landsat satellites, which are the main focus of this tutorial. To learn about the milestones in remote sensing prior to the first Landsat, you can view a timeline of remote sensing in one of three areas - Photographic Methods, Non-Photographic Sensor Systems, Space Imaging Systems (taken from a table that appeared in the NASA Reference Publication 1078 on The Landsat Tutorial Workbook). That review ends with events in 1979.

The photographic camera has served as a prime remote sensor for more than 150 years. It captures an image of targets exterior to it by concentrating electromagnetic (EM) radiation (normally, visible light) through a lens onto a recording medium (typically silver-based film). The film displays the target objects in their relative positions by variations in their brightness of gray levels (black and white) or color tones. Although the first, rather primitive photographs were taken as "stills" on the ground, the idea photographing the Earth's surface from above, yielding the so-called aerial photo, emerged in the 1840s with pictures from balloons. By the first World War, cameras mounted on airplanes provided aerial views of fairly large surface areas that were invaluable for military reconnaissance. From then until the early 1960s, the aerial photograph remained the single standard tool for depicting the surface from a vertical or oblique perspective.

The first non-photo camera sensors mounted on unmanned spacecraft were aboard satellites devoted mainly to looking at clouds. The first U.S. meteorological satellite, TIROS-1, launched by an Atlas rocket into orbit on April 1, 1960, looked similar to this later TIROS vehicle.

TIROS, for Television Infrared Observation Satellite, used vidicon cameras to scan wide areas at a time. The image below is one of the first (May 9, 1960) returned by TIROS-1 (10 satellites in this series were flown, followed by the TOS and ITOS spacecraft, along with Nimbus, NOAA, GOES and others. Superimposed on the cloud patterns is a generalized weather map for the region.

Then, in the 1960s as man entered space, cosmonauts and astronauts in space capsules took photos out the window. In time, the space photographers had specific targets and a schedule, although they also have some freedom to snap pictures at targets of opportunity.

During the '60s, the first sophisticated imaging sensors were incorporated in orbiting satellites. At first, these sensors were basic TV cameras that imaged crude, low resolution (little detail) black and white pictures of clouds and Earth's surface, where clear. Resolution is the size of the smallest contrasting object pairs that can be sharply distinguished.

The Indian space program began in 1962. In 1969 the Indian space Research Organization (ISRO) was set up and headquartered in Bangalore (presently Bengaluru) for the purpose of rapid development of space technology and its application. In 1972, space commission was established. In 1975, India launched its first satellite, Aryabhata, and thus entered the space age. Over the last four and half decades, the Indian space programme has made impressive progress through a well integrated, self:reliant programme.

Starting with IRS-1A in 1988, ISRO has launched many operational remote sensing satellites. Today, India has one of the largest constellations of remote sensing satellites in operation. Currently, *thirteen* operational satellites are in Sun-synchronous orbit – RESOURCESAT-1, 2, 2A CARTOSAT-1, 2, 2A, 2B, RISAT-1 and 2, OCEANSAT-2, Megha-Tropiques, SARAL and SCATSAT-1, and *four* in Geostationary orbit- INSAT-3D, Kalpana & INSAT 3A, INSAT -3DR. Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral and temporal resolutions to cater to different user requirements in the country and for global usage. The data from these satellites are used for several applications covering agriculture, water resources, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management.

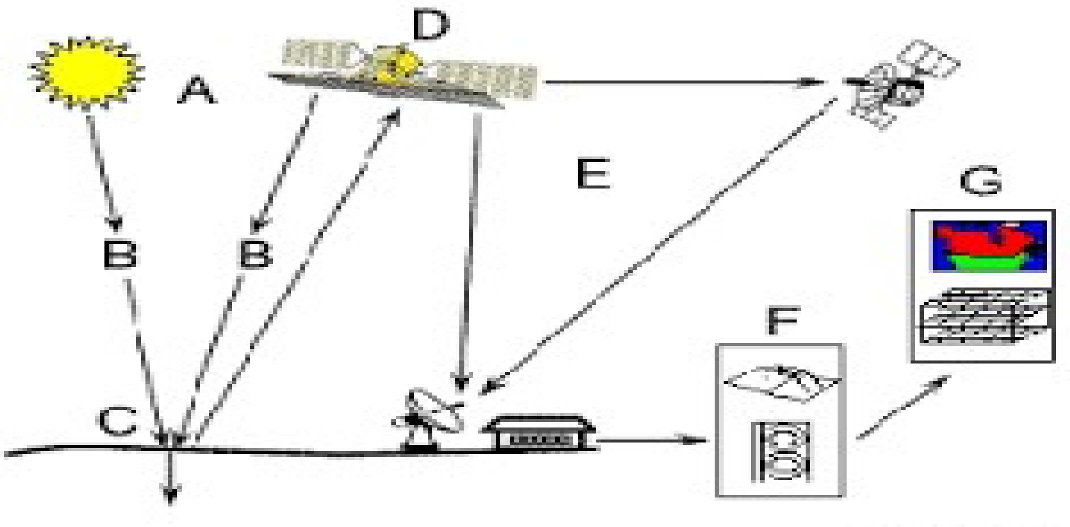
Definition

Remote Sensing can be defined as *"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."*It works by exploiting the electromagnetic radiation from a source that interacts with targets on the earth's surface in a unique fashion, depending on its physical, chemical, and biological properties, to be reflected, emitted, or backscattered towards a sensor.

The process of remote sensing involves an interaction between incident radiation and the targets of interest. However, the entire process of remote sensing is explained in the following figure where seven elements are involved.

The process of Remote Sensing

1. Energy Source or Illumination (A) - the first requirement for remote sensing is to have an energy



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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.

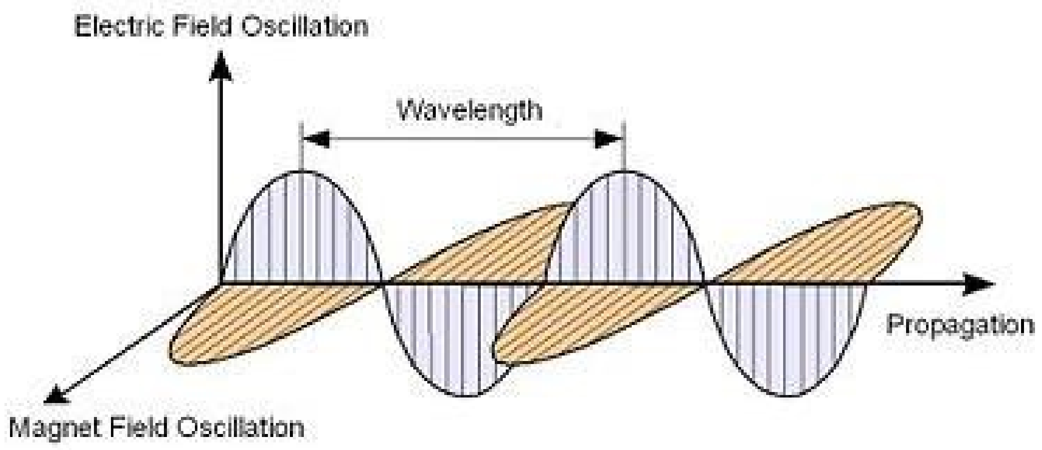
These seven elements comprise the remote sensing process from beginning to end.

Electromagnetic Radiation

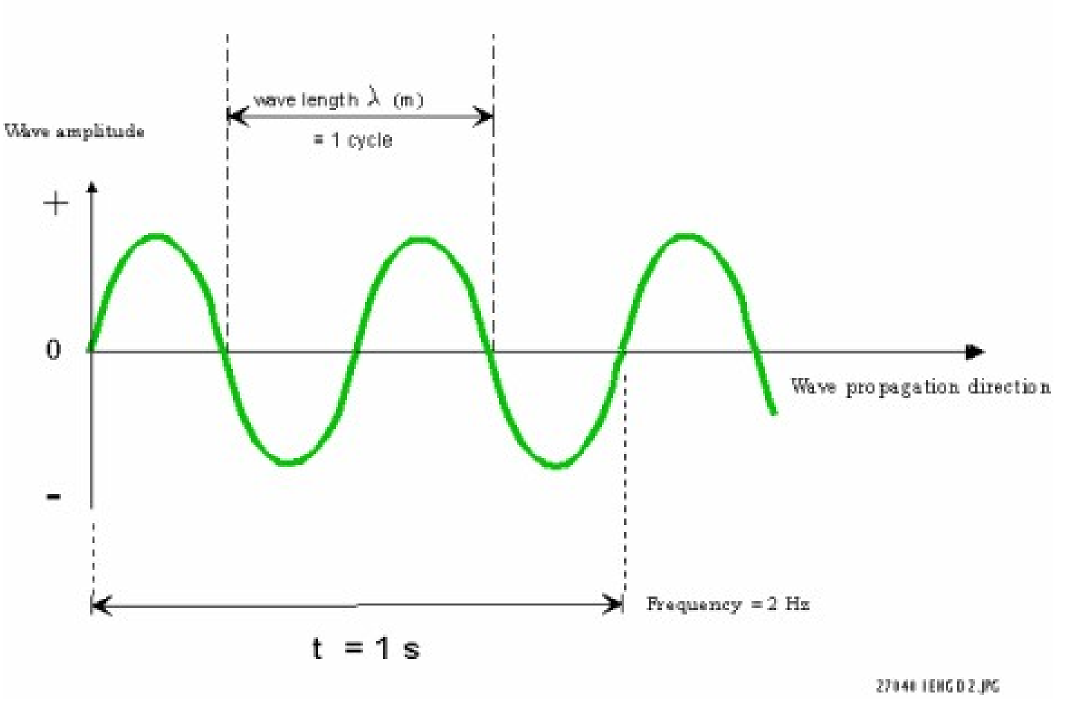
The first requirement for remote sensing is to have an **energy source to illuminate the target** (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.

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).

Electromagnetic Radiation

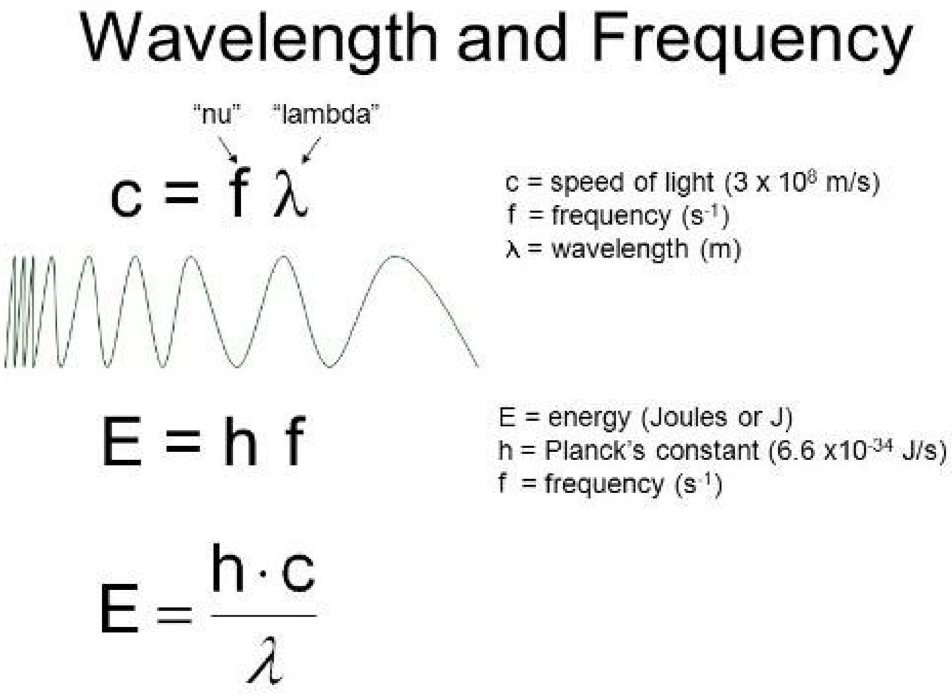


Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the **wavelength and frequency.**



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 metres (m) or some factor of metres such as **nanometres** (nm, 10-9 metres),

micrometres (µm, 10-6 metres) (µm, 10-6 metres) or centimetres (cm, 10-2 metres). 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:

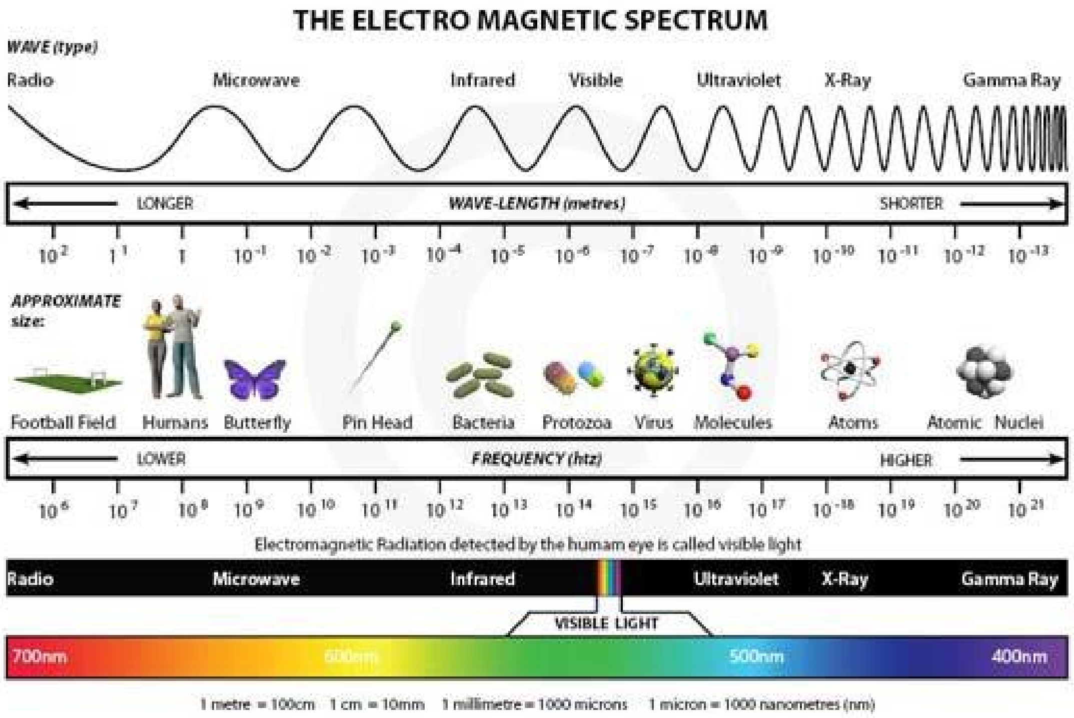


Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency.

The Electromagnetic Spectrum

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.

The electromagnetic spectrum ranges from the very short wavelengths of the gamma-ray region (measured in fractions of nanometers) to the long wavelengths of the radio region (measured in hundreds of meters). This is divided on the basis of wavelength into regions that are described in above figure. It may be noticed that the visible region (0.4 to 0.7 µm wavelengths) occupies only a small portion of the spectrum. Energy reflected from the earth during daytime may be recorded as a function of wavelength. The maximum amount of energy is reflected at 0.5 µm wavelength, which corresponds to the green band of the visible region, and is called the *reflected energy peak*. The earth also radiates energy both day and night, with the maximum energy radiating at 9.7 µm wavelength. This*radiant energy peak* occurs in the thermal band of the IR region.



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Wavelength regions of the electromagnetic spectrum.

The earth's atmosphere absorbs energy at less than 0.3 µm, which includes the entire γ-ray and X-ray regions and part of the UV region. These regions of the electromagnetic spectrum are therefore not used for remote sensing. However, some earth surface materials fluoresce or emit visible light when illuminated by longer wave UV radiation. Wavelength regions used for remote sensing therefore include the visible & near infrared, reflected infrared, thermal infrared and microwave regions.

The Ultraviolet Spectrum:

Ultraviolet radiation can be split into the shorter wavelength far ultraviolet and the longer wavelength near ultraviolet (the boundary between the two being at approximately 200nm). The extreme ultraviolet range overlaps with the far ultraviolet at wavelengths of between 1 and 100 nm). Ultraviolet radiation is absorbed by Ozone at an altitude of between 20 and 40 km.

The Visible Spectrum:

Part of the electromagnetic spectrum that our eyes can detect is the **visible spectrum**. Notice how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected and measured by sensors and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colours from the visible portion of the spectrum are listed below. The visible spectrum includes the reflected energy peak of the earth at 0.5 µm, and can be used for imaging with film and photodetectors.

The Infrared Spectrum:

Another portion of the electromagnetic spectrum which is of interest in remote sensing is the infrared (IR) region. It covers the wavelength range from approximately 0.7 µm to 100 µm - more than 100 times as wide as the visible portion! Interaction with matter varies with wavelength. Atmospheric transmission windows are separated by absorption bands. The infrared region can be divided into two categories based on their radiation properties - the reflected IR, and the emitted or thermal IR. Radiation in the reflected IR region covers wavelengths from approximately 0.7 µm to 3.0 µm, and is used for remote sensing purposes in ways very similar to radiation in the visible portion. (The region from 0.7 to 0.9 µmis detectable with film and is called the photographic IR band). The thermal IR region, covering a range of 3.0 µm to 100 µm is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. Principal atmospheric windows occur in the thermal region.

The Microwave Spectrum:

The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts. This portion of the electromagnetic spectrum is used for active remote sensing. Radar images are acquired at various wavelength bands. Longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.

Longest wavelength portion of electromagnetic spectrum - the radio waves - having wavelengths from 1 m to 100 km are not used for remote sensing, except for some classified radars with very long wavelength which operate in this region.

Natural Sources of Electromagnetic Radiation

All objects with a temperature above absolute zero (–273o C, 0K) emit EMR continuously. In remote sensing, the sun is the most obvious source of EMR (solar radiation), although all terrestrial objects are also a source. The term radiant exitance (Me) refers to the rate at which radiation is emitted from a unit area (W m–2) of a source object. The distribution of the amount of radiation at each wavelength across the spectrum emitted from a target is not uniform, but depends on the temperature of that object.

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Artificial Sources of Electromagnetic Radiation

Wavelengths beyond ~20.0 µm, the energy of the EMR from both the sun and the earth is so low that to use these wavelengths for remote sensing could prove problematic. Therefore, in many instances, active remote sensing is conducted. In this instance, EMR is produced artificially by the sensor rather than by natural sources. A sensor able to do this is the radar (radio detection and ranging), which transmits, usually sideways, short pulses of EMR at microwave wavelengths towards the earth's surface and then receives the radiation backscattered from the earth's surface. Here, two pieces of information are important. The first is the time taken for the radiation pulse to reach the target on the earth's surface and return, and the second is the strength and origin of the backscatter received from the targets within the sensor's field of view. The information on the time taken for the EMR to be backscattered indicates the location of targets on the earth's surface and the strength of the backscatter provides information on the targets' characteristics.
