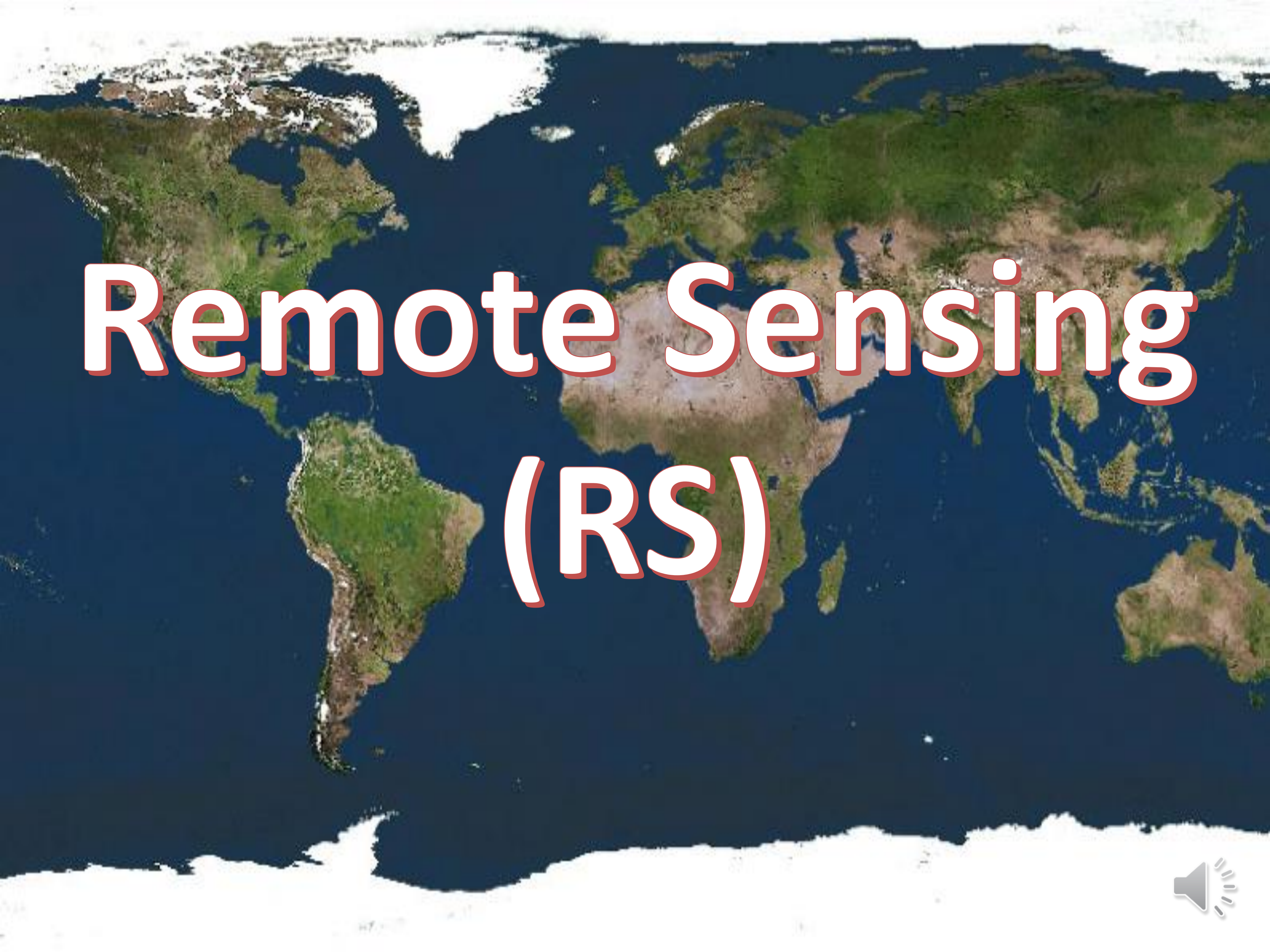
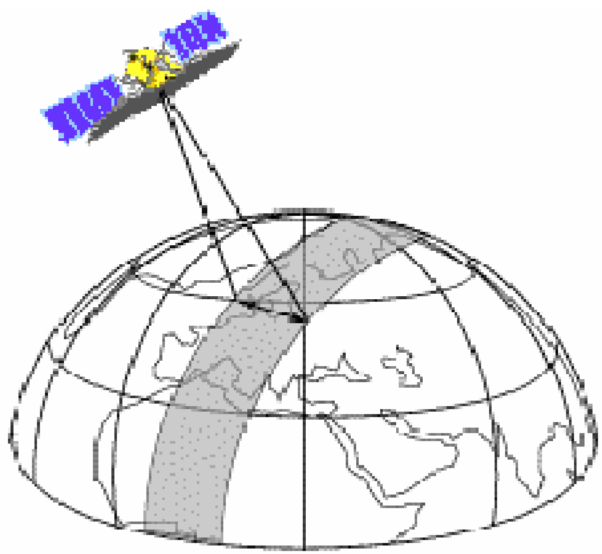
Remote Sensing (RS)



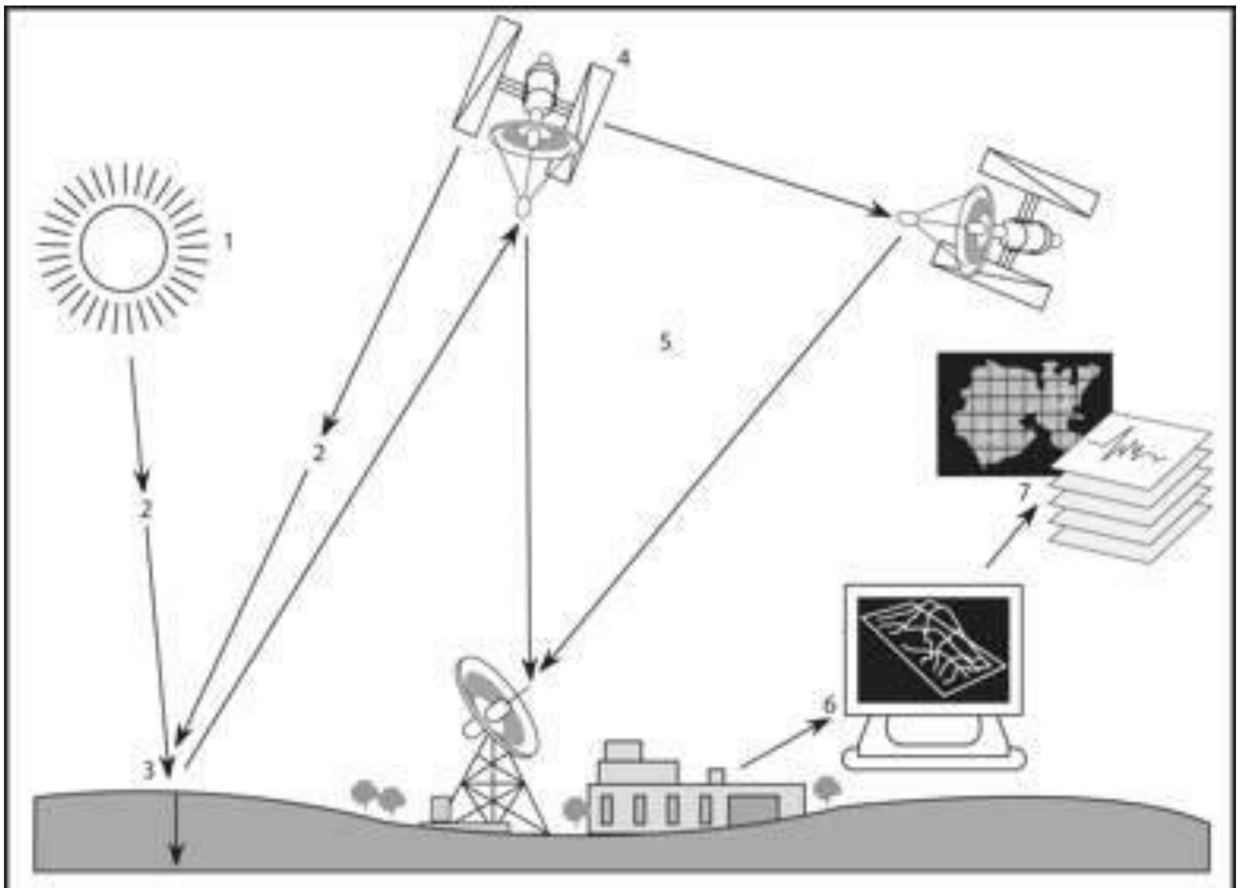
Definition of Remote Sensing

“The science of deriving information about the earth's land and water areas from images acquired at a distance. It usually relies on measurement of electromagnetic energy reflected or emitted from the features of interest“

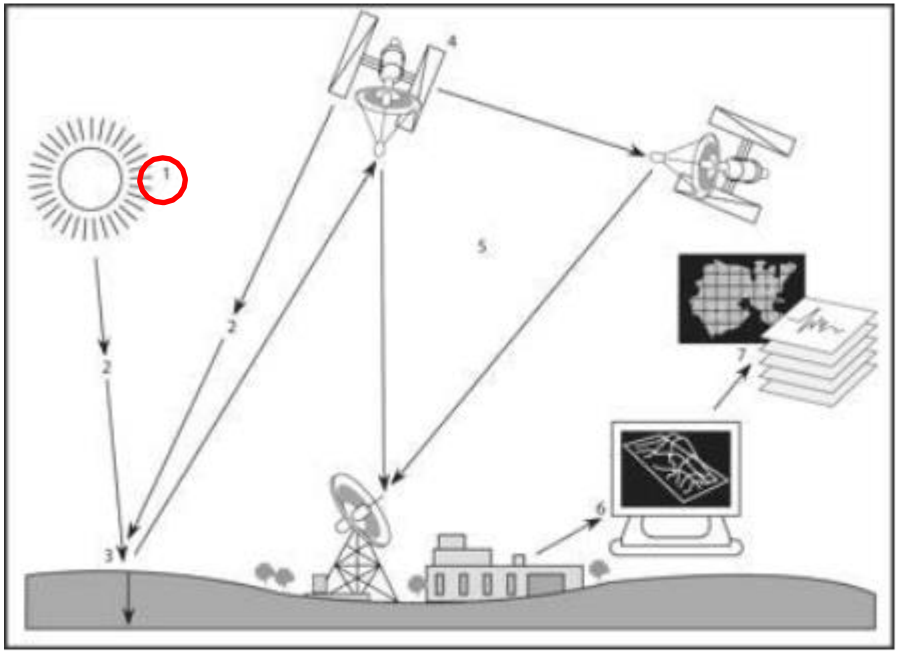


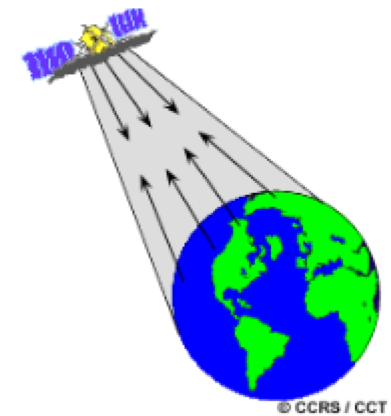
Step involved in Remote Sensing process

Remote sensing involves the interaction between incident radiation and targets of interest that requires the systems and involvement of seven specific elements. It also involves the sensing of emitted energy and use of non-imaging sensors.

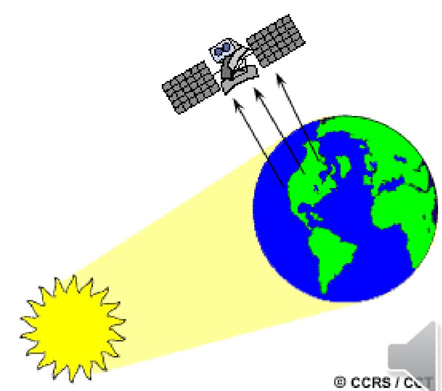


1. Energy Source or Illumination: the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.



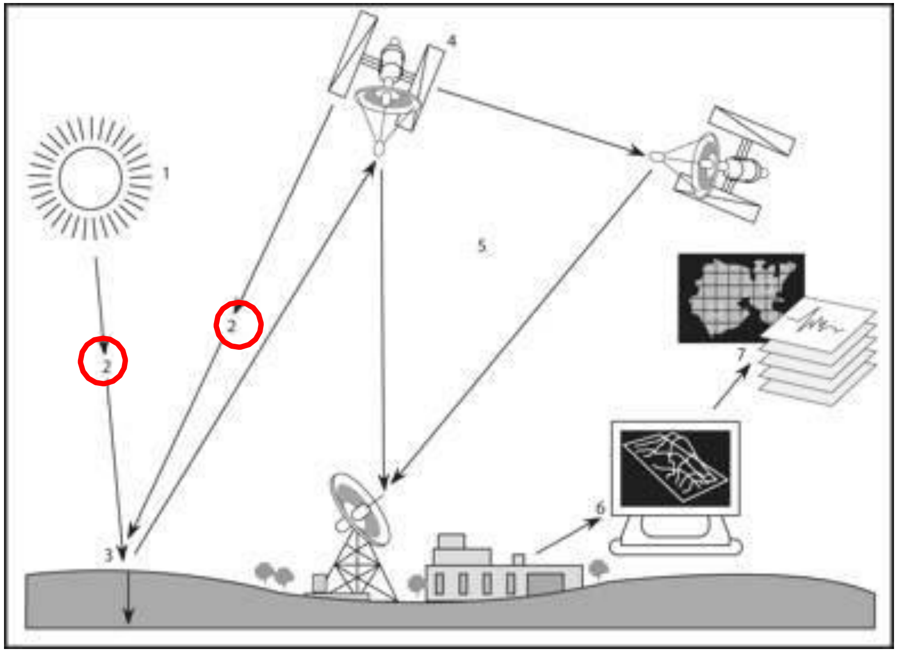


a. Active sensor: detect reflected responses from objects that are irradiated from artificially- generated energy sources such as radar

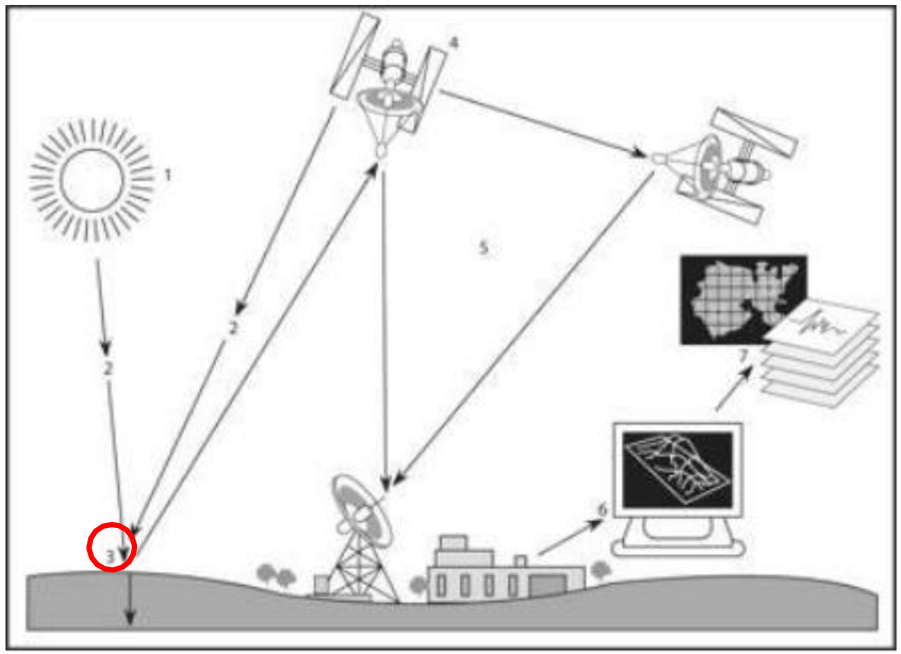


b. Passive sensor: detect the reflected or emitted electromagnetic radiation from natural sources

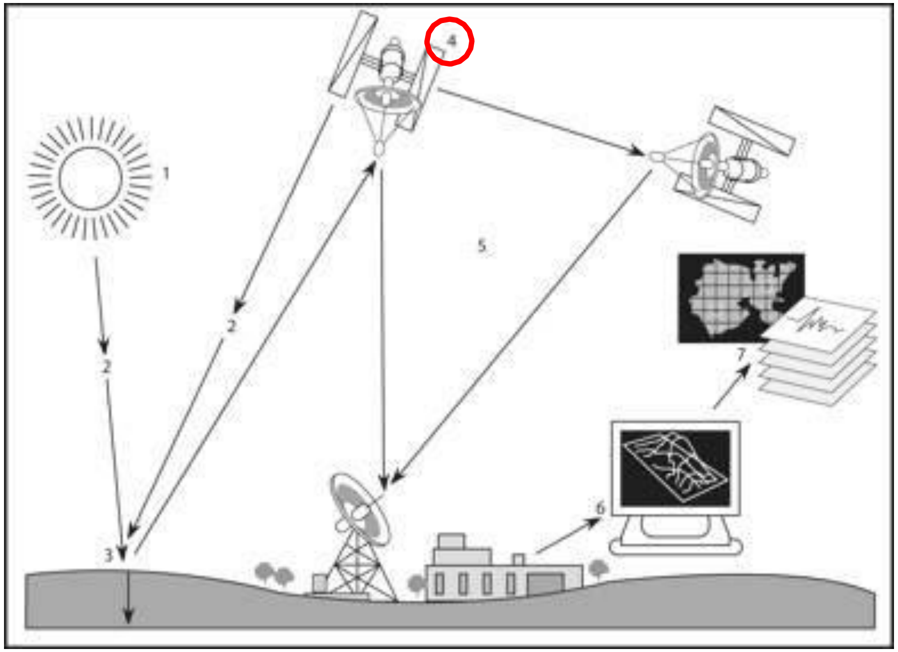
2. Radiation and the Atmosphere: as the energy travels from its source to the target, it will come in contact and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.



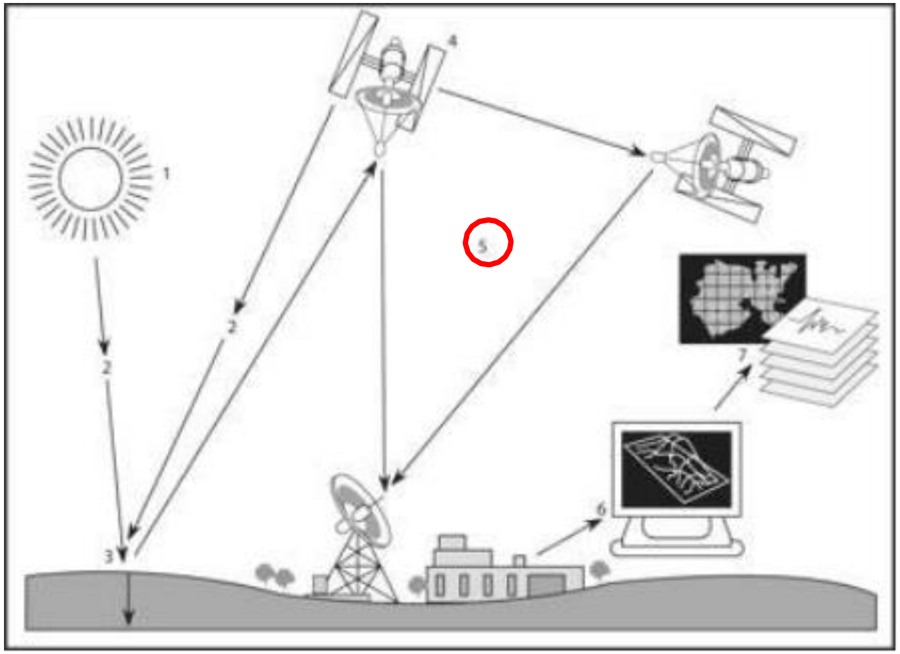
3. Interaction with the Target: once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.



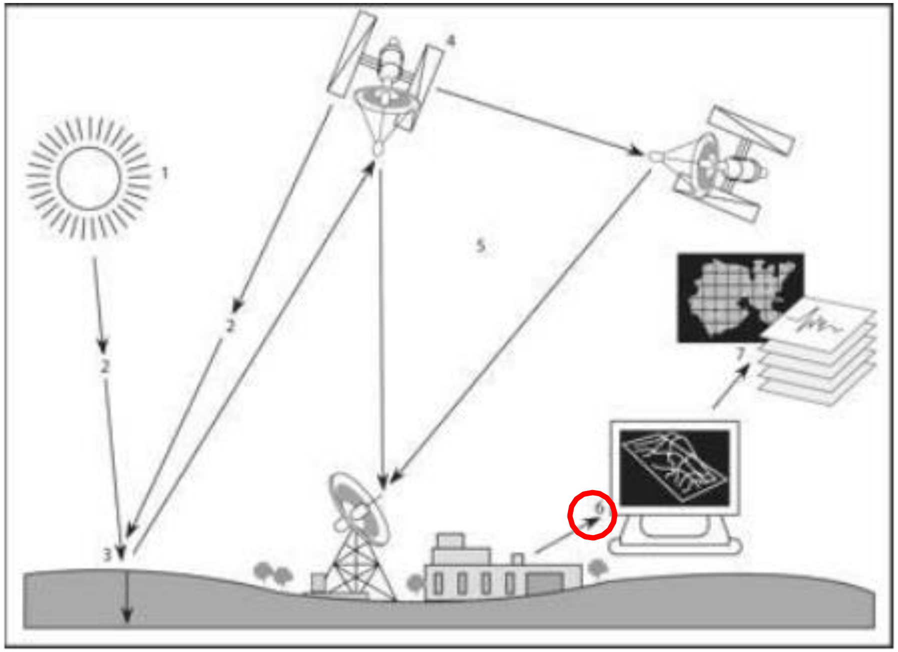
4. Recording of Energy by the Sensor: a sensor is required (remote, not in contact with the target) to collect and record the electromagnetic radiation after the energy has been scattered by, or emitted from, the target.



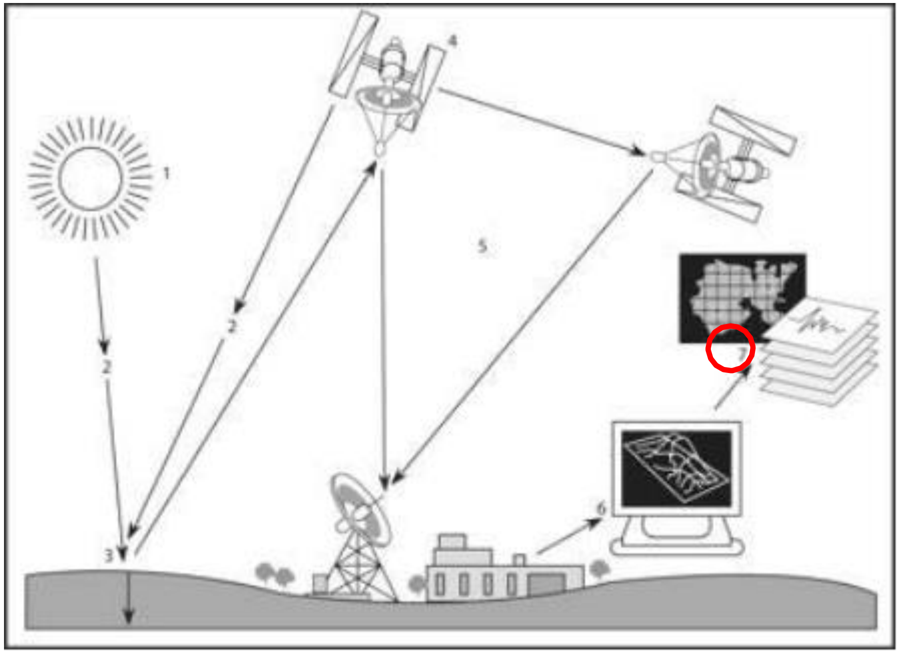
5. Transmission, Reception, and Processing: the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving station where the data are processed by computer software into an image (hardcopy and/or digital)



6. Interpretation and Analysis: the processed image is interpreted, visually and/or digitally or electronically, to extract information about the illuminated target.



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



Instruments for data acquisition

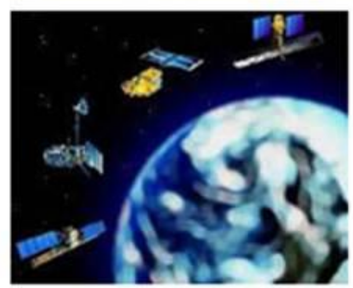
In order for a sensor to collect and record energy, it must reside on a platform

Platforms may be situated on:

- Ground, Aircraft or Balloon
- Spacecraft and satellite outside of the Earth's atmosphere

Ground-based sensors record detailed information about the surface which is compared with information collected from aircraft or satellite sensors

Aircraft collect very detailed images and facilitate the collection of data over any portion of the Earth's surface at any time



Satellites revolve around the Earth

Satellites permit repetitive coverage of the Earth's surface on a continuing basis

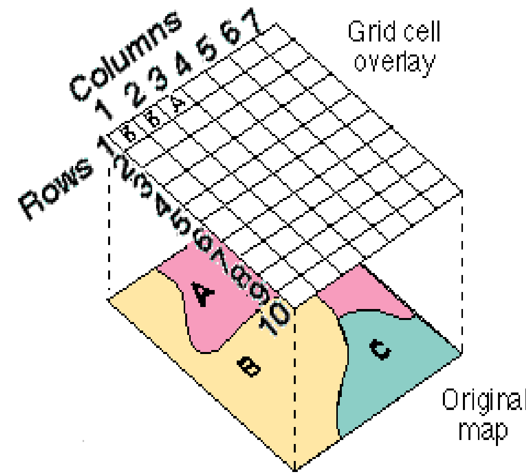
Cost is often a significant factor in choosing among the various platform options

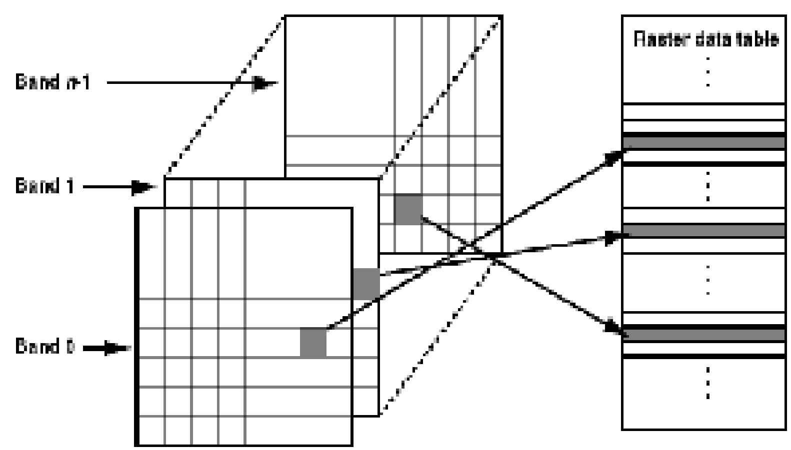
Data acquisition

An image is a two dimension representation of object in a real scene

A digital image is a two dimensional array of pixel, referred to a raster data

Each pixel has an intensity values (digital number) and a location address (its row and column location)

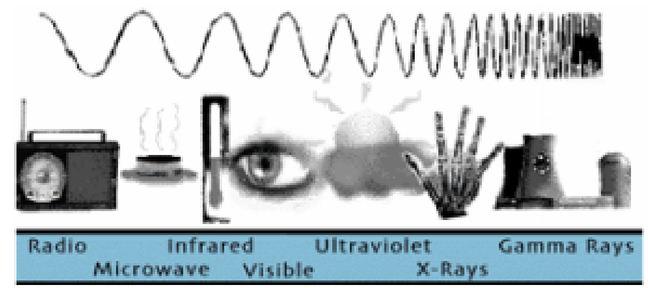




Electromagnetic radiation (EMR)

Visible light is only one of many forms of electromegnetic energy

The electromagnetic spectrum stretches from radio waves to gamma rays



Source: www.nasa.gov

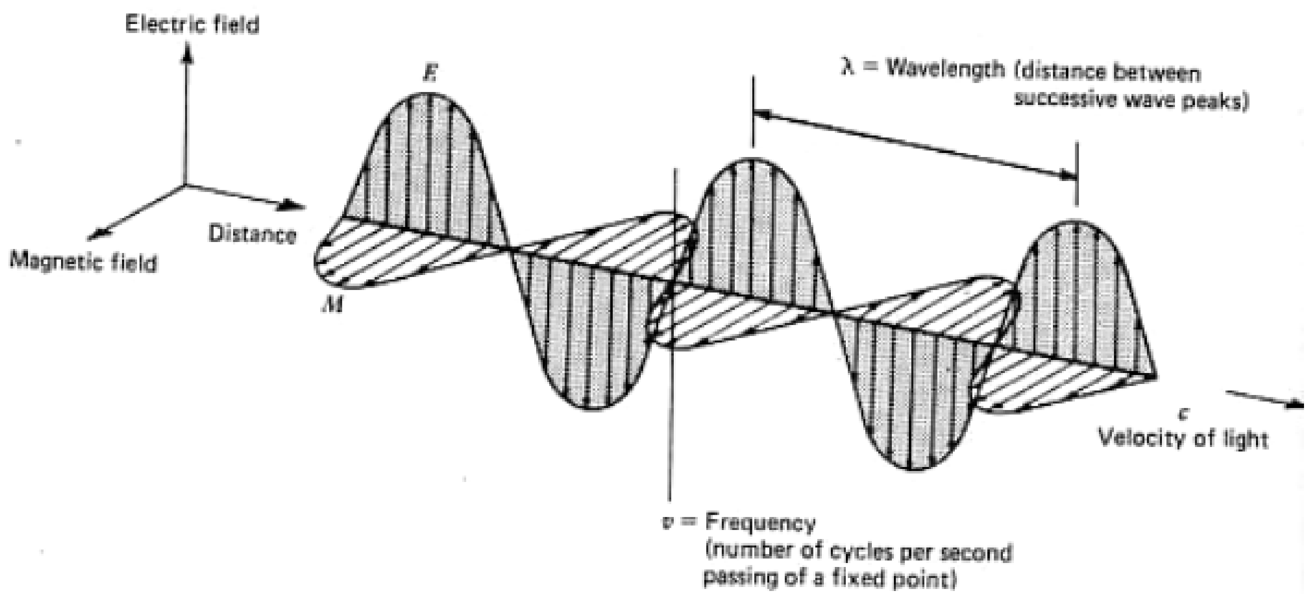
All this energy radiates in accordance with basic wave theory

Basic wave theory

Electromagnetic radiation consist of:

- an **electrical field (E)** which varies in magnitude in a direction perpendicular to the direction in which the radiation is travelling
- a **magnetic field (M)** oriented at right angles to the electrical field

Both these field travel at the speed of light : c=λv

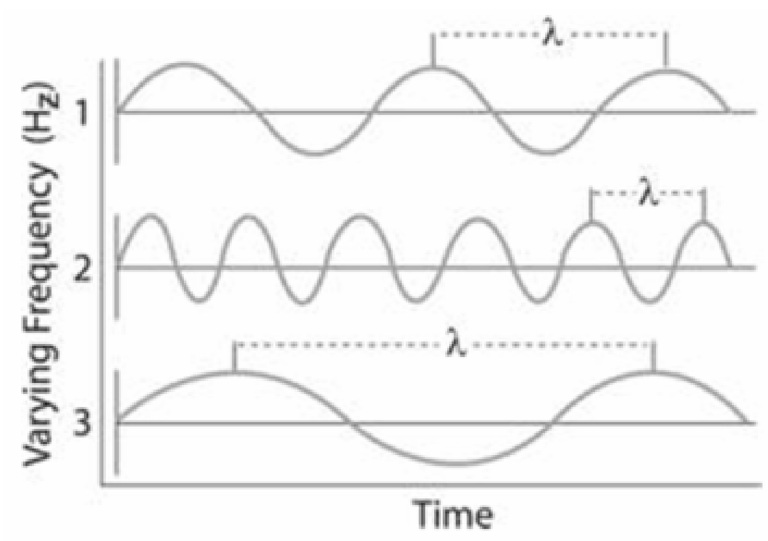


(Source Lillesand T.M., Kiefer R.W, 2000)

The two characteristics of electromagnetic radiation that are particularly important for understanding remote sensing are:

Wavelength: the length in m of one wave cycle measured as the distance between successive wave crests

Frequency: number of cycles per second passing of a fixed point, Hz



Wavelength and frequency are related by the following formula:

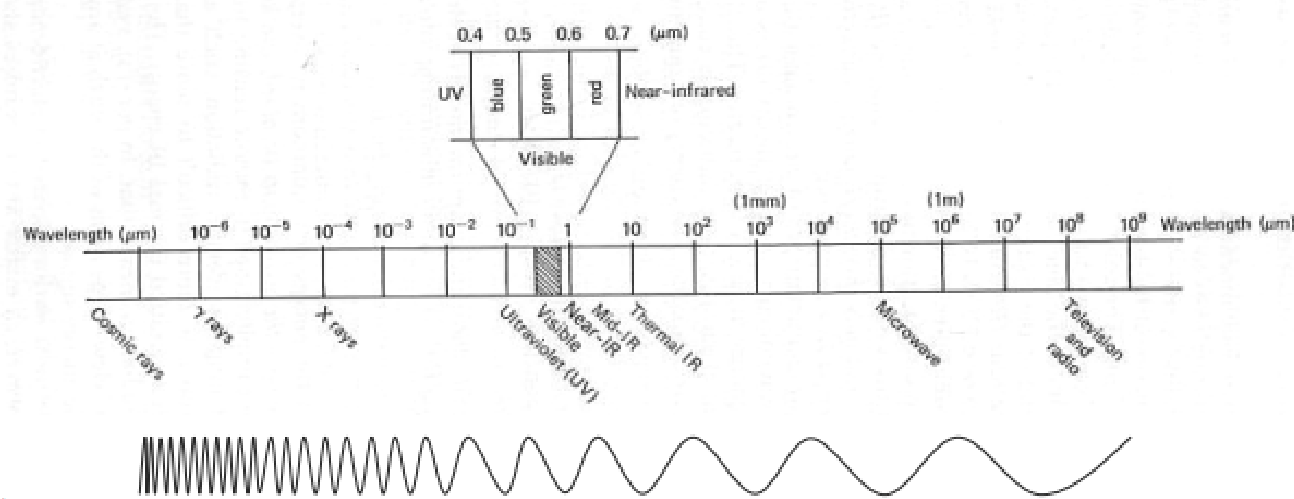
$$c = \lambda v$$

where:
c = speed of light (3×10^8 m/s)
λ = wavelength
v = frequency

Electromagnetic spectrum

The electromagnetic spectrum ranges from the shorter wavelengths (ultraviolet including x rays) to the longer wavelengths (microwaves, radar waves)

Visible:	0.4 – 0.7 μm
Near infrared:	0.7 – 1.3 μm
Middle infrared:	1.3 – 3 μm
Thermal infrared:	3 – 100 μm
Microwaves:	1 mm – 1 m

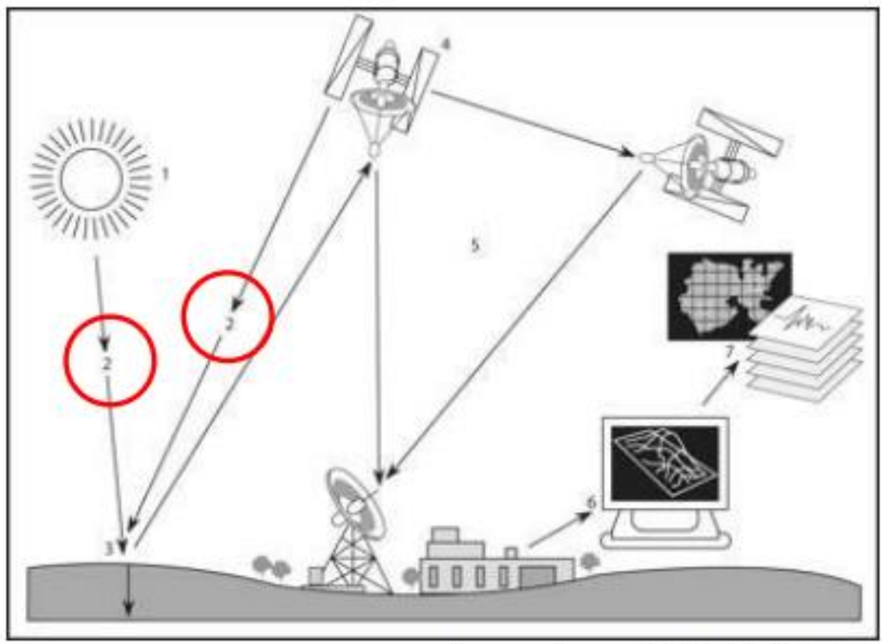


shorter wavelengths

Longer wavelengths

Interactions with the atmosfere

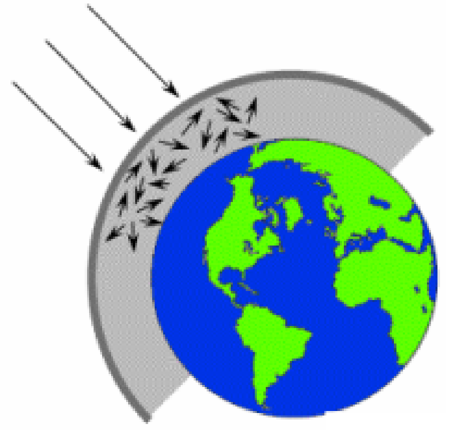
Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of **scattering, absorption and emission**.



Source: James A. Tindall, 2006.

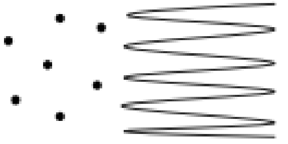
Scattering

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.



There are **3 types of scattering** which take place.

1. Rayleigh scattering

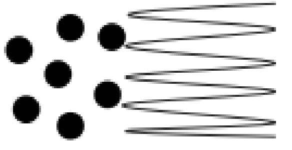


occurs when particles are very small compared to the wavelength of the radiation

these could be particles such as small specks of dust or nitrogen and oxygen molecules

rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths.

2. Mie scattering

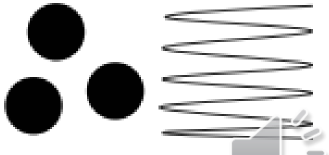


occurs when the particles are just about the same size as the wavelength of the radiation

dust, pollen, smoke and water vapour are common causes of Mie scattering

Mie scattering tends to affect longer wavelengths than those affected by Rayleigh scattering.

Non selective scattering



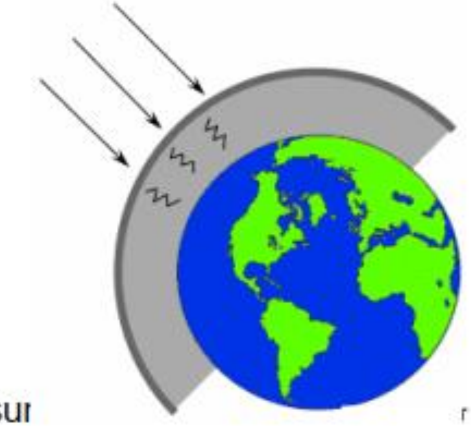
this occurs when the particles are much larger than the wavelength of the radiation

water droplets and large dust particles can cause this type of scattering

nonselective scattering gets its name from the fact that all wavelengths are scattered about equally.

Absorption.

In contrast to scattering, absorption causes molecules in the atmosphere to absorb energy at various wavelengths.



Ozone

serves to absorb the harmful (to most living things) ultraviolet radiation from the sur

without this protective layer in the atmosphere our skin would burn when exposed to sunlight

Carbon dioxide

it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere.

Water vapour

water vapour in the atmosphere absorbs much of the incoming longwave infrared and shortwave microwave radiation

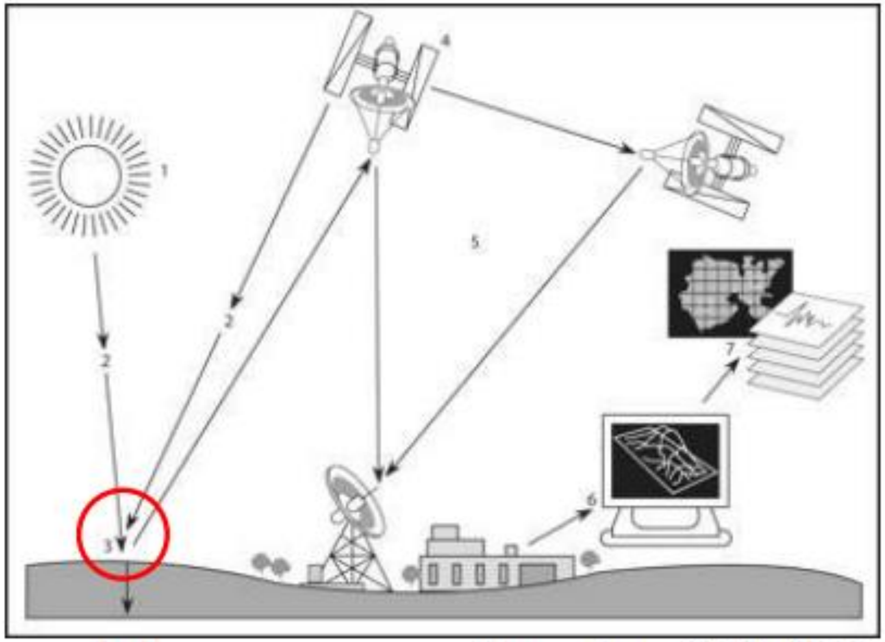
the presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year

very little water vapour to absorb energy

high concentrations of water vapour

Emission from the atmosphere occurs in the mid infrared regiona

Target interactions

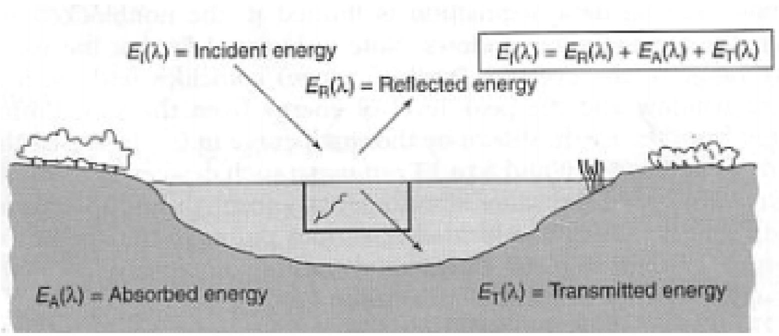


Source: James A. Tindall, 2006.

(I) Incident energy - $E_I(\lambda)$
Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface.

There are **3 forms of interaction** that can take place:

(A) Absorption - $E_A(\lambda)$
(T) Transmission - $E_T(\lambda)$
(R) Reflection - $E_R(\lambda)$



Energy balance equation

$$E_I(\lambda) = E_A(\lambda) + E_T(\lambda) + E_R(\lambda)$$

Incident energy

Absorbed energy

Transmitted energy

Reflected energy

The proportions of EA(λ), ET(λ) and ER(λ) will depend on:

the wavelength of the energy

for a given feature type the proportion of absorbed, transmitted and reflected energy will vary at different wavelength

for example, two materials may be not distinguishable in one spectral range and be very different in another wavelength band

the material type and condition of the feature

these differences permit us to distinguish different feature on an image

Radiation reflected from a target

Many remote sensing system are interested in measuring the radiation reflected from targets

Energy balance equation can be expressed as:

$$E_R(\lambda) = E_I(\lambda) - [E_A(\lambda) + E_T(\lambda)]$$

Reflected energy

Incident energy

Absorbed energy

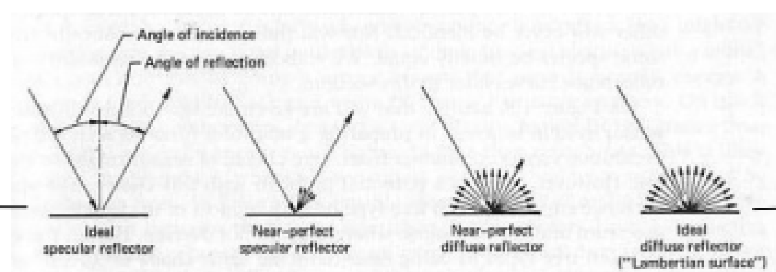
Transmitted energy

There are two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target:

a. specular reflection; b. diffuse reflection

The geometry manner in which an object reflects energy is a function of the surface roughness of the object

specular reflectors are flat surface; the angle of reflection equals the angle of incidence



diffuse reflectors are rough surface that reflect uniformly in all direction

Spectral reflectance of targets

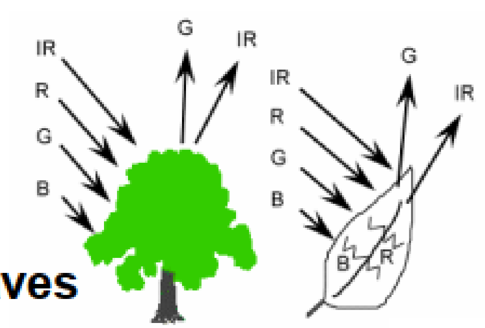
The reflectance characteristics of targets may be quantified by measuring the portion of incident energy that is reflected

This is measured as a function of wavelength and it is called

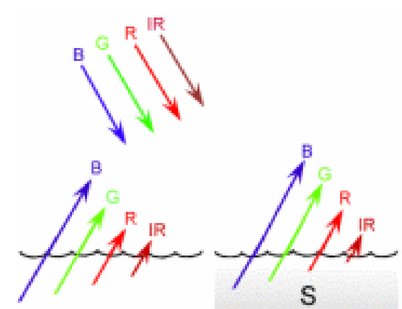
Spectral reflectance = $E_R(\lambda) / E_I(\lambda) \times 100$

A couple of examples of targets and how energy at the visible and infrared wavelengths interacts with them.

1. Leaves



2. Water



Chlorophyll strongly **absorbs** radiation in the **red and blue** wavelengths but **reflects green** wavelengths. The internal structure of healthy leaves act as excellent **diffuse reflectors of near-infrared wavelengths.**

Longer wavelength visible and **near infrared** radiation is **absorbed more** by water **than shorter visible wavelengths**. Thus water typically looks blue or blue-green at shorter wavelengths, and darker if viewed at red or near infrared wavelengths.

Thank you