UNIT I

REMOTE SENSING

DEFINITION AND PROCESS OF REMOTE SENSING

INTRODUCTION

Now-a-days the field of Remote Sensing and GIS has become exciting and glamorous withrapidly expanding opportunities. Many organizations spend large amounts of money on these fields. Here the question arises why these fields are so important in recent years. Two main reasons are there behind this. 1) Now-a-days scientists, researchers, students, and evencommon people are showing great interest for better understanding of our environment. Byenvironment we mean the geographic space of their study area and the events that take place there. In other words, we have come to realize that geographic space along with the datadescribing it, is part of our everyday world; almost every decision we take is influenced or dictated by some fact of geography. 2) Advancement in sophisticated space technology (which can provide large volume of spatial data), along with declining costs of computerhardware and software (which can handle these data) has made Remote Sensing and G.I.S. affordable to not only complex environmental / spatial situation but also affordable to anincreasingly wider audience.

REMOTE SENSING AND ITS COMPONENTS:

Remote sensing is the science of acquiring information about the Earth's surface without being in contact with it. This is done by sensing and recordingreflected or emitted energy and processing, analyzing, and applying that information." In much of remote sensing, the process involves an interaction between incident adiation and the targets of interest. This is exemplified using imaging systems where the following seven elements are involved. However, that remote sense also involves the sensing of emitted energy and the use of non-imaging sensors.

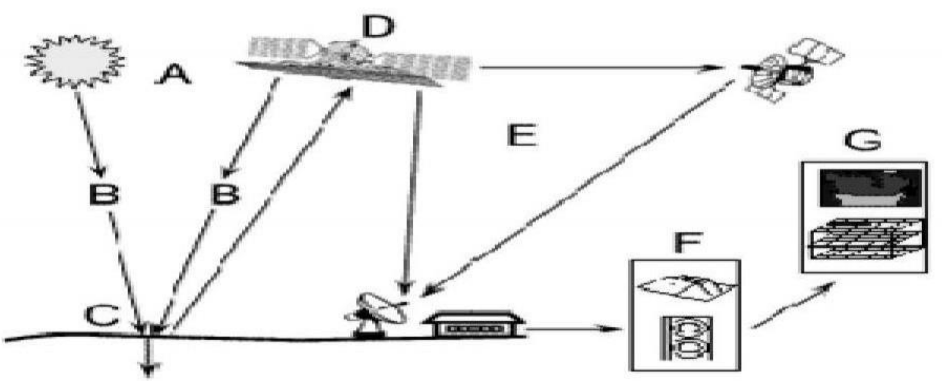

Fig 1.1- Components of Remote Sensing

- Energy Source or Illumination (A) – the first requirement for remote sensing is to have anenergy source which illuminates or provides electromagnetic energy to the target of interest.
- 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 interactionmay take place a second time as the energy travels from the target to the sensor.
- 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.
- 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.
- 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).
- Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally orelectronically, to extract information about the target which was illuminated.
- 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.

HISTRY OF REMOTE SENSING:

1839 - first photograph

1858 - first photo from a balloon1903 - first plane

1909 first photo from a plane1903-4 -B/W infrared filmWW I and WW II1960 – space

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, sources of energy is naturally available such as the Sun. Most of the remote sensing systems work in passive mode using solar energy as the sourceof EMR. Solar energy reflected by the targets at specific wavelength bands are recorded usingsensors on board air-borne or space borne platforms.

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 sensingAny object which is at a temperature above 0o K (Kelvin) emits some radiation, which is approximately proportional to the fourth power of the temperature of the object.

Thus, the Earthalso emits some radiation since its ambient temperature is about 300o K. Passive sensors can also be used to measure the Earth ‘s radiance but they are not very popular as the energy contentis 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 from the targets are recorded using sensors on board 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.

What is Sensor Platform?

Platform is a stage where sensor or camera is mounted to acquire information about a target under investigation. According to Lillesand and Kiefer (2000), a platform is a vehicle, from which a sensor can beoperated. For remote sensing applications, sensors should be mounted on suitable stable platforms as the platform height increases the spatial resolution and observational area increases.

The types or characteristics of platform depend on the type of sensor to be attached and itsapplication.

Type of Platforms:

Platforms can vary from stepladders to satellites. There are different types of platforms based on their altitude above earth surface.Three types of platforms are used to mount the remote sensors.

1. Ground based Platform
2. Air - borne Platform, and
3. Space-borne Platform Ground based Platforms:

Ground Based Platform:

- Ground based platforms are used to record detailed information about the objects or features of the earth’s surface.

- These are developed for the scientific understanding on the signal-object and signal-sensor interactions.
- It includes both the laboratory and field study, used for both in designing sensors and identification and characterization of land features.
- Example: Handheld platform, cherry picker, towers, portable masts and vehicles etc.
- Portable handheld photographic cameras and spectroradiometers are largely used in laboratory and field experiments as a reference data and ground truth verification.
- Crane, ground based platform (cherry Picker Platform extend up to approx. 15m).

Air- borne/ based Platforms:

- Airborne platforms were the sole non-ground-based platforms for early remote sensing work.
- Aircraft remote sensing system may also be referred to as sub-orbital or airborne, or aerial remote sensing system.
- At present, airplanes are the most common airborne platform.
- observation platforms include balloons, drones (short sky spy) and high-altitudesounding rockets. Helicopters are occasionally used.

Balloons:

- Balloons are used for remote sensing observation (aerial photography) and nature conservation studies.
- The first aerial images were acquired with a camera carried aloft by a balloon in 1859.
- Balloon floats at a constant height of about 30 km.
- Balloons as platforms are not very expensive like aircraft. They have a great variety of shapes, sizes and performance capabilities.
- The balloons have low acceleration, require no power and exhibit low vibrations.
- It consists of a rigid circular base plate for supporting the entire sensor system which is protected by an insulating and shock proof light casing.
- The payload used for Indian balloon experiment of three Hasselblad cameras with different film filter combinations, to provide PAN, infra-red, black, and white and infra-red false color images.
- Flight altitude being high compared to normal aircraft height used for aerial survey, balloon imagery gives larger synoptic views.
- The balloon is governed by the wind at a floating altitude.
- There are three main types of balloon systems, viz. free balloons, Tethered balloons, and Powered Balloons.

- Free balloons can reach almost the top of the atmosphere; hence, they can provide a platform at intermediate altitude between those of aircraft and spacecraft (shown in fig.)
- Have an altitude range of 22-40 km and can be used to a limited extent as a platform.

Drone:

- Drone is a miniature remotely piloted aircraft.
- It is designed to fulfill requirements for a low-cost platform, with long endurance, moderate payload capacity and capability to operate without a runway or small runway.
- Drone includes equipment of photography, infrared detection, radar observation andTV surveillance. It uses satellite communication link.
- An onboard computer controls the payload and stores data from different sensors and instruments.

Aircraft Platform:

- Aircraft are used to collect very detailed images.
- Helicopters can be for pinpoint locations, but they vibrate and lacks stability.
- Special aircraft with cameras and sensors on vibration less platforms are traditionally used to acquire aerial photographs and images of land surface features.
- While low altitude aerial photography results in large scale images providing detailed information on the terrain, the high-altitude smaller scale images offer advantage to cover a larger study area with low spatial resolution.
- Aircraft platforms offer an economical method of remote sensing data collection for small to large study areas with cameras, electronic imagers, across- track and along- track scanners, and radar and microwave scanners.
- Low Altitude Aircraft: It is most widely used and generally operates below 30,000 ft.
- It is suitable for obtaining image data for small areas having large scale.
- High altitude aircraft: It includes jet aircraft with good rate of climb, maximum speed,and high operating ceiling. It acquires imagery for large areas.

Rockets as Platforms:

- High altitude sounding rocket platforms are useful in assessing the reliability of the remote sensing techniques as regards their dependence on the distance from the target is concerned.
- Balloons have a maximum altitude of approximately 37 km, while satellites cannot orbit below 120 km. High altitude sounding rockets can be used to a moderate altitude above terrain.
- Synoptic imagery can be obtained from rockets for areas of some 500,000 square km.

Space-borne/ based Platforms:

- In space- borne remote sensing, sensors are mounted on-board a spacecraft (space shuttle or satellite) orbiting the earth.
- Space-borne or satellite platform are onetime cost effected but relatively lower cost perunit area of coverage, can acquire imagery of entire earth without taking permission.
- Space-borne imaging ranges from altitude 250 km to 36000 km.
- Space-borne remote sensing provides the following advantages:large area coverage.
- Frequent and repetitive coverage of an area of interest.
- Quantitative measurement of ground features using radiometrically calibrated sensors.
- Semi-automated computerized processing and analysis.
- Relatively lower cost per unit area of coverage.Spacecraft as Platform:
- Remote sensing is also conducted from the space shuttle or artificial satellites. Artificial satellites are manmade objects, which revolve around another object.
- Satellite can cover much more land space than planes and can monitor areas on a regular basis.
- Later, with LANDSAT and SPOT satellites program, space photography received ahigher impetus.

ELECTROMAGNETIC SPECTRUM

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 to understand remote sensing. These are the **wavelength and frequency.**

Electromagnetic radiation (EMR) as an electromagnetic wave that travels through space at the speed of light C which is $3x10^8$ meters per second.

Theoretical models of random media including the anisotropic effects, random distribution discrete scatters, rough surface effects, have been studied for remote sensing with electromagnetic waves. Ligh t - can be thought of as a wave in the 'electromagnetic field ' of the universe.

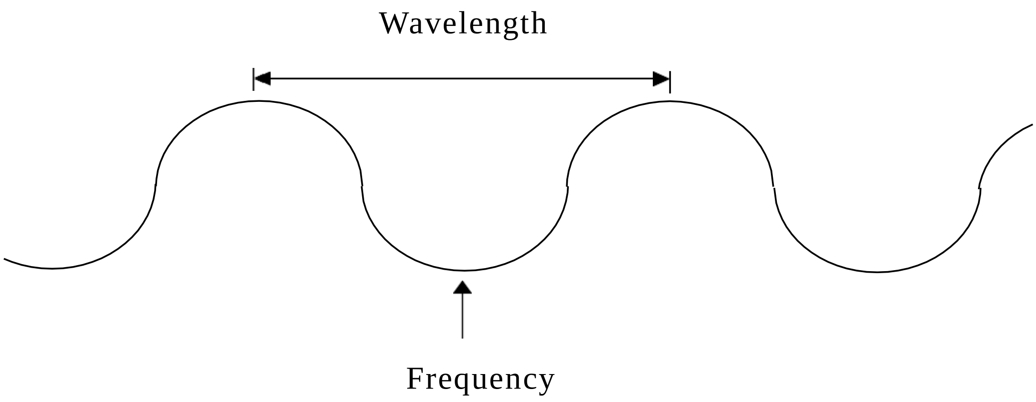

Fig 1.2 – Wavelength and frequency

A wave can be characterized by its wavelength or its 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 variousmultiples of hertz.

Wavelength and frequency are related by the following formula:

$$c = \lambda \nu$$

where:

λ = wavelength (m)
ν = frequency (cycles per second, Hz)
c = speed of light (3×10^8 m/s)

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.

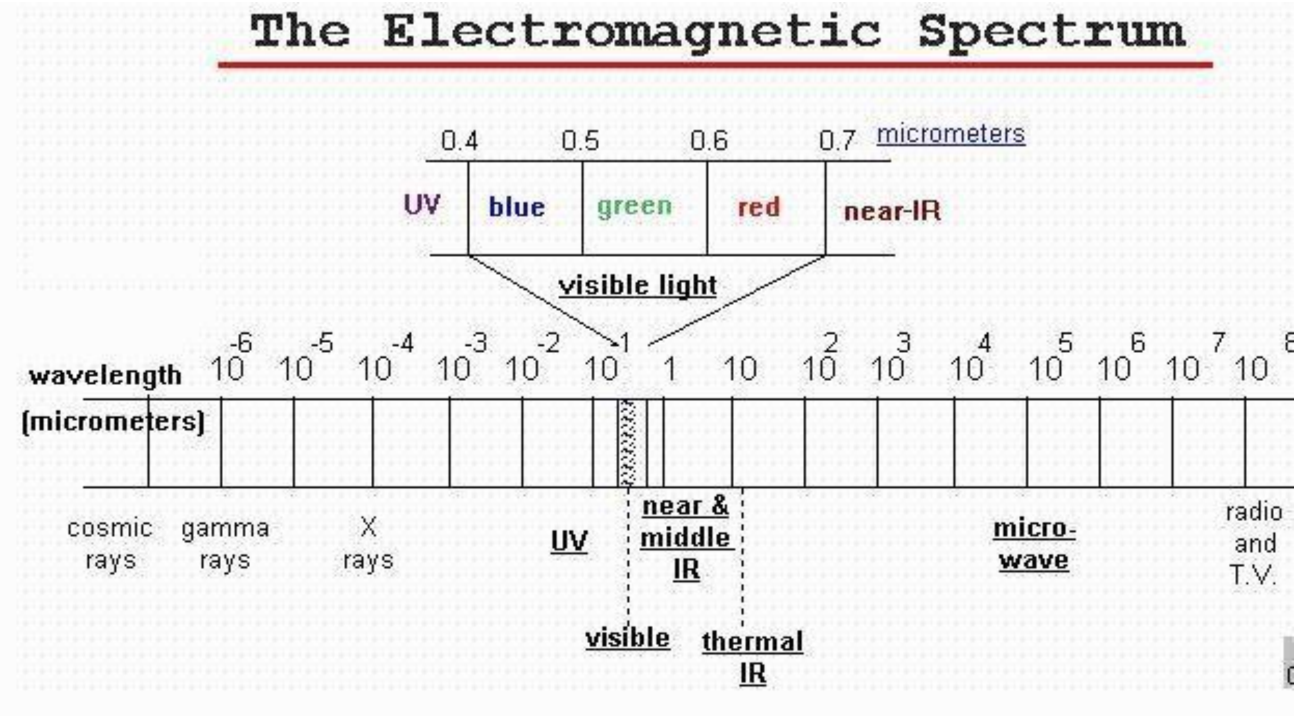

Fig 3 – Electromagnetic Spectrum

WAVELENGTH REGIONS IMPORTANT TO REMOTE SENSING:

Ultraviolet or UV

For the most purposes ultraviolet or UV of the spectrum shortest wavelengths are practical forremote sensing. This wavelength is beyond the violet portion of the visible wavelengths hence itnames. Some earth surface materials primarily rocks and materials emit visible radiation when illuminated by UV radiation.

Visible Spectrum

The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum**. Itis important to recognize 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 by other remote sensing instruments 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 shortestis violet. Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum are listed below. It is important to note that this is the only portion of the spectrum we can associate with the concept of **colors**.

Violet: 0.4 -0.446 µm

Blue: 0.446 -0.500 µm

Green: 0.500 -0.578 µm

Yellow: 0.578 -0.592 µm

Orange: 0.592 -0.620 µm

Red: 0.620 -0.7 µm

Blue, **green**, and **red** are the **primary colors** or wavelengths of the visible spectrum. They aredefined as such because no single primary color can be created from the other two, but all other colors can be formed by combining blue, green, and red in various proportions. Althoughwe see sunlight as a uniform or homogeneous color, it is composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colors when sunlight is passed through a **prism**, which bends the light in differing amounts according to wavelength.

Infrared (IR)

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 µm to 100 µm more than 100 times as wide as the visible portion. The infrared can be divided into 3 categories based on their radiation properties- the reflected near- IR middle IR and thermal IR.

The reflected near IR covers wavelengths from approximately 0.7 µm to 1.3 µm is commonly used to expose black and white and color-infrared sensitive film.

The middle-infrared region includes energy with a wavelength of 1.3 to 3.0 µm.

The thermal IR region is quite different than the visible and reflected IR portions, as this energyis essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 µm to 100 µm.

Microwave

This wavelength (or frequency) interval in the electromagnetic spectrum is commonly referredto as a band, channel, or region. The major subdivision

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 radiobroadcasts.

Region	Wavelength	Remarks
Gamma ray	<0.03 nm	Incoming radiation is completely absorbed by the upper atmosphere and is not available for remote sensing.
X-ray	0.03 to 3.0 nm	Completely absorbed by atmosphere. Not employed in remote sensing.
Ultraviolet	0.3 to 0.4 μm	Incoming wavelengths less than 0.3 μm are completely absorbed by ozone in the upper atmosphere.
Photographic UV band	0.3 to 0.4 μm	Transmitted through atmosphere. Detectable with film and photodetectors, but atmospheric scattering is severe
Visible	0.4 to 0.7 μm	Imaged with film and photodetectors. Includes reflected energy peak of earth at 0.5 μm.
Infrared	0.7 to 1.00 μm	Interaction with matter varies with wave length. Atmospheric transmission windows are separated.
Reflected IR band	0.7 to 3.0 μm	Reflected solar radiation that contains information about thermal properties of materials. The band from 0.7 to 0.9 μm is detectable with film and is called the photographic IR band.
Thermal IR	3 to 5 μm band	Principal atmospheric windows in the 8 to 14 μm thermal region. Images at these wavelengths are acquired by optical mechanical scanners and special vidicon systems but not by film. Microwave 0.1 to 30 cm longer wavelengths can penetrate clouds, fog, and rain. Images may be acquired in the active or passive mode.
Radar	0.1 to 30 cm	Active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
Radio	>30 cm	Longest wave length portion of electromagnetic spectrum. Some classified radars with very long wavelengths operate in this region.

WAVE THEORY AND PARRTICAL THEORY

Light can exhibit both a wave theory, and a particle theory at the same time. Much of the time,light behaves like a wave. Light waves are also called electromagnetic waves because they are made up of both electric (*E*) and magnetic (*H*) fields. Electromagnetic fields oscillate perpendicular to the direction of wave travel, and perpendicular to each other. Light waves are known as transverse waves as they oscillate in the direction traverse to the direction of wave travel.

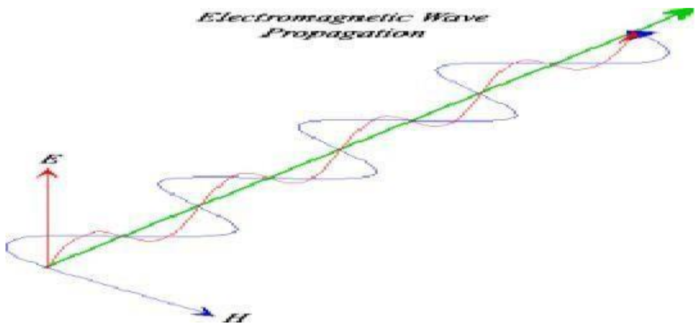

Fig 1.4 – Electromagnetic propagation

Waves have two important characteristics - wavelength and frequency.

The sine wave is the fundamental waveform in nature. When dealing with light waves, we referto the sine wave. The period (*T*) of the waveform is one full 0-to-360-degree sweep. The relationship of frequency and the period is given by the equation:

$$f = 1 / TT \ = 1 / f$$

The waveforms are always in the time domain and go on for infinity. The speed of a wave can be found by multiplying the two units together. The wave's speed is measured in units of length (distance) per second:

Wavelength x Frequency = Speed

As proposed by Einstein, light is composed of photons, a very small packets of energy. The reason that photons are able to travel at light speeds is due to the fact that they have no mass and therefore, Einstein's infamous equation - $E=MC^2$ cannot be used. Another formula devisedby Planck, is used to describe the relation between photon energy and frequency - *Planck's Constant* (*h*) - 6.63×10^{-34} Joule-Second. $E = hf$(or)$E = hc$

E is the photonic energy in Joules, *h* is Planks constant and *f* is the frequency in Hz.

PARTICAL THEORY

The basic idea of quantum theory is that radiant energy is transmitted in indivisible packetswhose energy is given in integral parts, of size hv, where h is Planck's constant = 6.6252 x 10-34 J - s, and v is the frequency of the radiation. These are called quanta or photons.

The dilemma of the simultaneous wave and particle waves of electromagnetic energy may be conceptually resolved by considering that energy is not supplied continuously throughout a wave, but rather that it is carried by photons. The classical wave theory does not give the intensity of energy at a point in space but gives the probability of finding a photon at that point.Thus, the classical concept of a wave yields to the idea that a wave simply describes the probability path for the motion of the individual photons.

The particular importance of the quantum approach for remote sensing is that it provides the concept of discrete energy levels in materials. The values and arrangement of these levels are different for different materials. Information about a given material is thus available in electromagnetic radiation because of transitions between these energy levels. A transition to a higher energy level is caused by the absorption of energy, or from a higher to a lower energy level is caused by the' emission of energy. The amounts of energy either absorbedor emitted correspond precisely to the energy difference between the two levels involved in thetransition. Because the energy levels are different for each material, the amount of energy a particular substance can absorb or emit is different for that material from any other materials. Consequently, the position and intensities of the bands in the spectrum of a given material are characteristic to that material.

STEFAN–BOLTZMANN LAW

Stefan–Boltzmann law, also known as **Stefan's law**, describes the power radiated from a blackbody in terms of its temperature. Specifically, the Stefan–Boltzmann law states that the total energy radiated per unit surface area of a black body across all wavelengths $j^{\star}$ per unit time (also known as the black-body *radiant exitance* or *emissive power*), isdirectly proportional to the fourth power of the black body's thermodynamic temperature *T*:

$$j^{\star} = \sigma T^{4}.$$

WIEN'S DISPLACEMENT LAW

Wien's displacement law states that the black body radiation curve for different temperatures peaks at a wavelength inversely proportional to the temperature. The shift of that peak is a direct consequence of the Planck radiation law which describes the spectralbrightness of black body radiation as a function of wavelength at any given temperature.

PLANCK'S LAW

Planck developed that more general equation and described the entire shift of the spectrum ofblack body radiation toward shorter wavelengths as temperature increases.

Formally, Wien's displacement law states that the spectral radiance of black body radiationper unit wavelength, peaks at the wavelength λ_{max} given by:

$$\lambda_{max} = \frac{b}{T}$$

where T is the absolute temperature in degrees kelvin. b is a constant of proportionality called *Wien's displacement constant*, equal to $2.8977721(26)\times10^{-3}$ mK.[1], or more conveniently to obtain wavelength in microns, b≈2900 μm K.

If one is considering the peak of black body emission per unit frequency r per proportional bandwidth, one must use a different proportionality constant. However, the form of the law remains the same: the peak wavelength is inversely proportional to temperature (or the peak frequency is directly proportional to temperature).Wien's displacement law may be referred to as "Wien's law", a term which is also used for the Wien approximation.

Blackbody Radiation

A blackbody is a hypothetical, ideal radiator. It absorbs and reemits the entire energy incident upon it.Total energy emitted by a black body varies with temperature as given in Eq. 4. The total energy is distributed over different wavelengths, which is called the spectral distribution or spectral curvehere. Area under the spectral curve gives the total radiant exitance *M*.

In addition to the total energy, the spectral distribution also varies with the temperature. Fig. 4 shows the spectral distribution of the energy radiated from black bodies at different temperatures. The figure represents the Stefan-Boltzmann's law graphically. As the temperature increases, area under the curve, and hence the total radiant exitance increases.

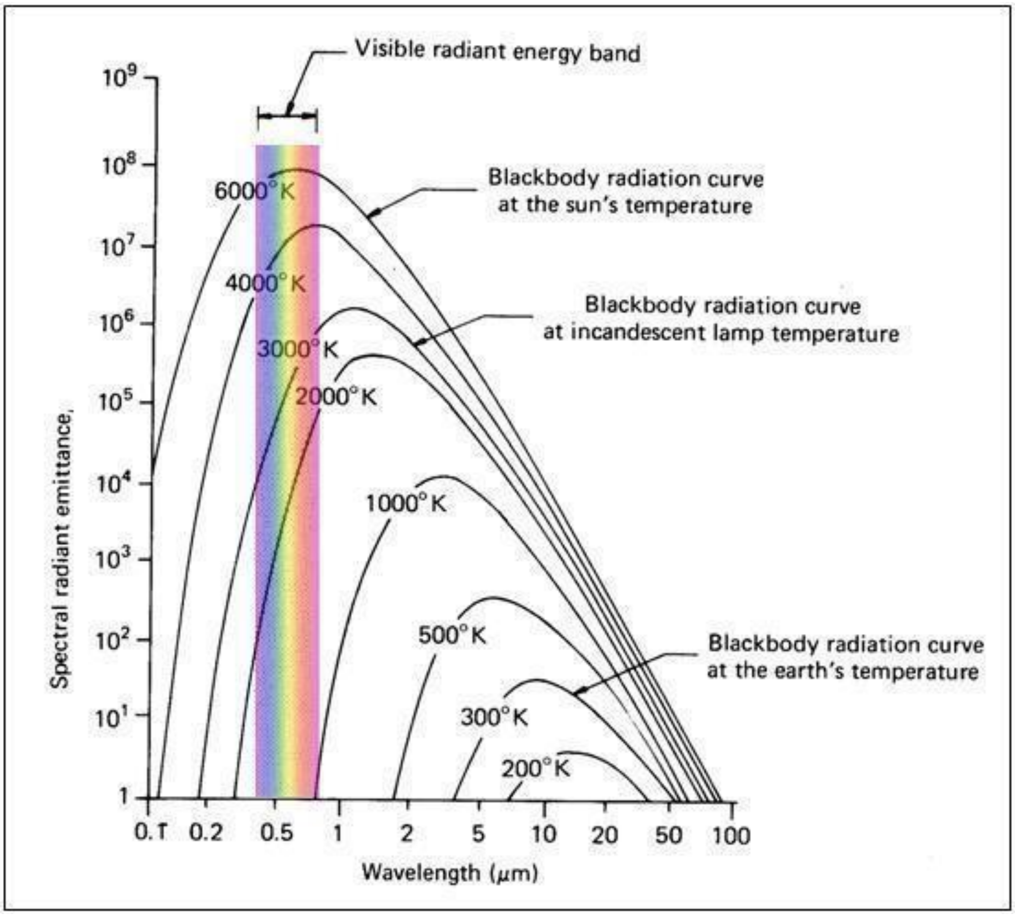

Figure5. Spectral energy distribution of blackbody at various temperatures

From Fig. 4, it can be observed that the peak of the radiant exitance varies with wavelength. Asthe temperature increases, the peak shifts towards the left. This is explained by the Wien's displacement law. It states that the dominant wavelength at which a black body radiates λm is Inversely proportional to the absolute temperature of the black body (in K) and is represented asgiven below.

RADIATION SOURCES

Remote sensing involves the use of various technologies to gather information about the Earth's surface and atmosphere from a distance. Radiation sources are crucial components in remote sensing, as they emit or reflect electromagnetic radiation that can be detected by sensors to gather information about the Earth's features and properties. Here are some common radiation sources used in remote sensing.

Sunlight (Solar Radiation):

The Sun is the primary natural radiation source for remote sensing. Sunlight emits a broad spectrum of electromagnetic radiation, including visible, infrared, and ultraviolet wavelengths. Sensors onboard satellites and other remote sensing platforms capture this solar radiation reflected or emitted by Earth's surface and atmosphere.

SAR (Synthetic Aperture Radar):

SAR systems emit microwave radiation towards the Earth's surface. The emitted radiation interacts with the surface, and the reflected signal is captured by the sensor. SAR can operate in various modes, such as single-pass, repeat-pass, and interferometric modes, providing valuable information about surface characteristics, topography, and changes over time.

LIDAR (Light Detection and Ranging):

Lidar systems emit laser pulses towards the Earth's surface and measure the time it takes for the laser to return after reflecting off objects. This information is used to create detailed 3D maps of the terrain, vegetation, buildings, and other features. Lidar is commonly used for forest monitoring, topographic mapping, and urban planning.

Passive Microwave Radiation:

Microwave radiation is emitted by the Earth's surface in the form of thermal radiation. Sensors can detect these microwave emissions to study soil moisture, ice cover, and ocean salinity, among other parameters. Passive microwave sensors can operate in different frequency bands to capture specific information.

Artificial sources (Active sources):

In some cases, remote sensing platforms carry their own radiation sources. These active sensors emit radiation and measure the reflected or backscattered signal. For example, some satellite altimeters emit radar signals that bounce off the ocean surface to measure sea level changes.

Infrared Emission (Thermal Infrared):

All objects with a temperature above absolute zero emit thermal infrared radiation. Sensors that detect thermal infrared radiation can capture information about surface temperature, energy balance, and thermal properties of various materials.

Hyperspectral Imaging:

Hyperspectral sensors capture electromagnetic radiation in numerous narrow and contiguous spectral bands. This allows for the identification and differentiation of various materials based on their unique spectral signatures. Hyperspectral data is valuable for applications like mineral exploration, land cover classification, and environmental monitoring.

X-Ray and Gamma Ray Sensors:

In some specialized applications, X-ray and gamma-ray sensors are used to detect radiation emitted by the Earth's surface. These sensors can provide information about soil composition, minerals, and even detect radioactive sources.

Magnetometers:

While not emitting radiation themselves, magnetometers are used to measure the Earth's magnetic field. Variations in the magnetic field can provide information about subsurface structures, mineral deposits, and geological formations.

These various radiation sources and sensors contribute to a comprehensive understanding of the Earth's surface, atmosphere, and processes. They enable scientists and researchers to study and monitor changes in the environment, natural disasters, climate patterns, and much more from a remote perspective.

KIRCHOFF’S LAW:

Kirchhoff's law of thermal radiation, often referred to as Kirchhoff's law in remote sensing, is an important principle used to understand the relationship between the emissivity and absorptivity of a material at a particular wavelength. This law is relevant in the context of thermal remote sensing, where the emitted thermal radiation from the Earth's surface is measured to extract information about surface properties.

Kirchhoff's law states that at thermal equilibrium, the emissivity (ε) of a material is equal to its absorptivity (α) at a given wavelength. In mathematical terms:

$$\varepsilon(\lambda) = \alpha(\lambda)$$

Where:

$\varepsilon(\lambda)$ is the emissivity of the material at wavelength λ.

$\alpha(\lambda)$ is the absorptivity of the material at wavelength λ.

RADIATION QUANTITIES:

In the context of remote sensing and the study of electromagnetic radiation, there are several fundamental radiation quantities that are commonly used to describe the characteristics and behavior of electromagnetic waves. These quantities help us understand the properties of radiation and how it interacts with various materials and surfaces. Here are some important radiation quantities:

Radiant flux (Power):

Radiant flux, often referred to simply as power, is the total amount of energy emitted by a radiation source per unit time. It is measured in watts (W).

Radiant intensity:

Radiant intensity is the amount of radiant flux emitted by a point source in a particular direction within a solid angle. It is measured in watts per steradian (W/sr).

Radiance:

Radiance is the radiant flux emitted or reflected by a surface per unit area, per unit solid angle, and per unit wavelength interval. It describes the intensity of radiation from a surface in a specific direction. Radiance is measured in watts per square meter per steradian per nanometer ($W/(m^2 \cdot sr \cdot nm)$).

Irradiance:

Irradiance is the radiant flux incident on a unit area of a surface. It quantifies the power received by a surface per unit area. Irradiance is measured in watts per square meter (W/m^2).

Radiosity:

Radiosity is the total radiant flux emitted by a surface per unit area and is the sum of the emitted radiance and the reflected irradiance. It is often used in radiative heat transfer calculations.

Exitance (Emittance):

Exitance, also known as emittance, is the radiant flux emitted by a surface per unit area. It is similar to irradiance, but it accounts for both emitted and reflected radiation.

Reflectance:

Reflectance is the ratio of the radiant flux reflected by a surface to the incident radiant flux upon it. It is a dimensionless quantity often expressed as a percentage.

Transmittance:

Transmittance is the ratio of the transmitted radiant flux through a medium (such as atmosphere or water) to the incident radiant flux upon the medium.

Absorptance:

Absorptance is the ratio of the absorbed radiant flux by a surface to the incident radiant flux upon it. It is complementary to reflectance and transmittance.

Emissivity:

Emissivity is the ratio of the radiant flux emitted by a surface to the radiant flux emitted by a blackbody.