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.

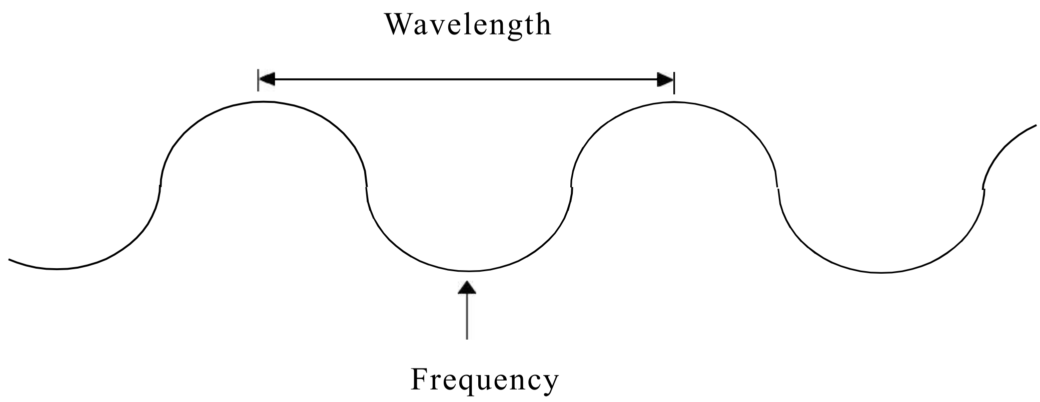

Fig 1.2 – Wavelength and frequency

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.

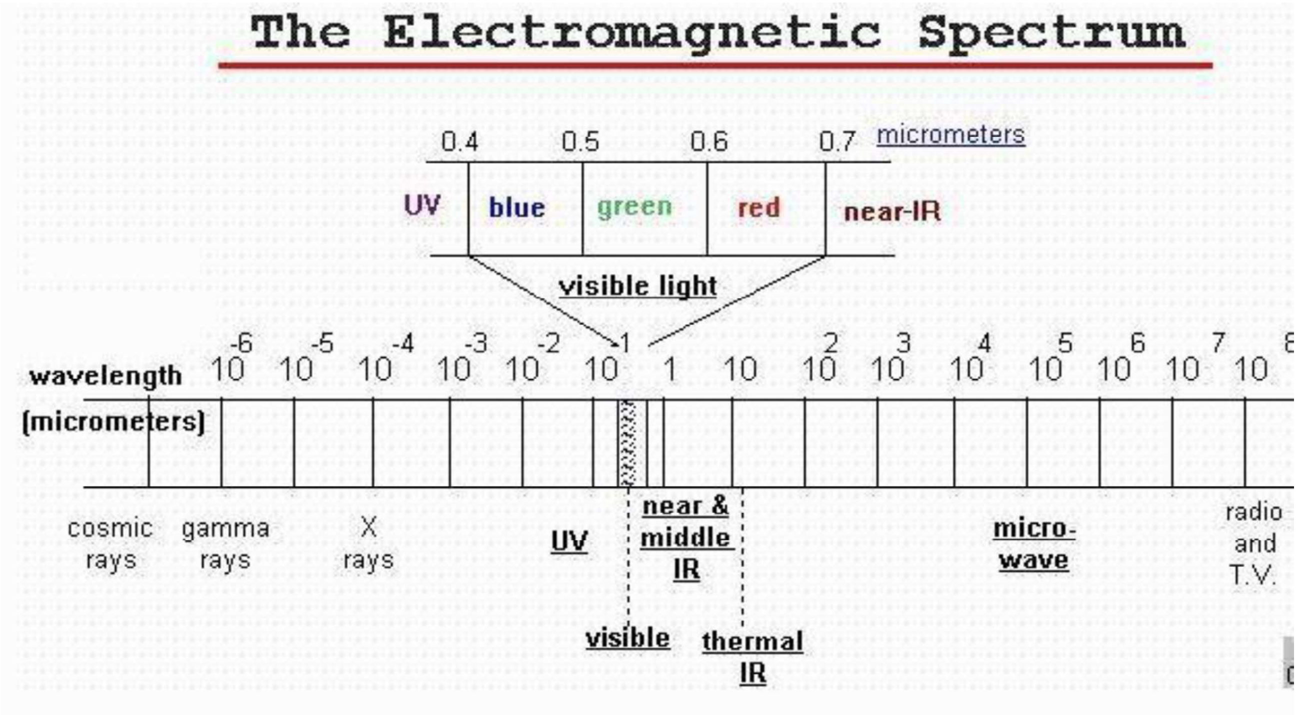

Fig 3 – Electromagnetic Spectrum

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.

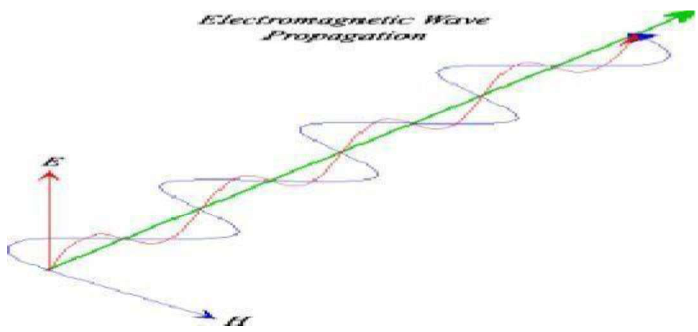

Fig 1.4 – Electromagnetic propagation

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:

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

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*) - 6.63x10^{-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.

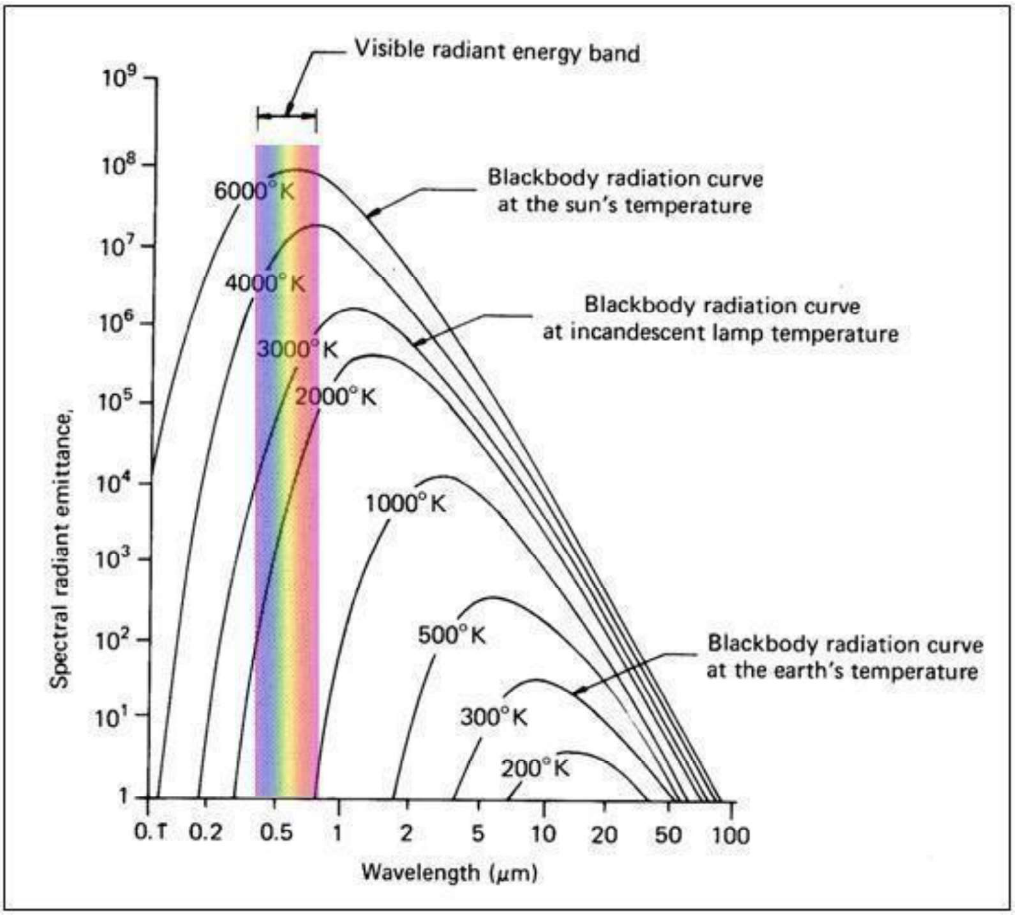

Figure5. Spectral energy distribution of blackbody at various temperatures

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 λ_m 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.