Electromagnetic Radiation

Electromagnetic radiation is the important basis for remote sensing technology. Everything on the earth surface **with a temperature above absolute zero (-273° C) emit** electromagnetic radiation. Because radiation can transport energy even without a medium, it is the only way in which the earth interacts with the rest of the universe. The Sun is a major source of electromagnetic radiation on Earth, emitting energy across several regions of the spectrum.

Electromagnetic radiation or EMR is the term used to describe all of the different types of energies released by electromagnetic processes. Visible light is one of the most familiar forms of electromagnetic energy. Radio waves, infrared light and X rays are all forms of electromagnetic radiation. The electromagnetic spectrum is the term used to describe to entire range of all possible frequencies of electromagnetic radiation. Remote sensing technologies rely on a variety of electromagnetic energy. Sensors detect and measure electromagnetic energy in different portions of the spectrum. Therefore it is important to understand the fundamentals of electromagnetic radiation.

To explain the nature of electromagnetic energy (EMR) and its propagation through space and interaction with matter, three different models i.e. Particle model, Wave model and Wave Particle Duality model have been given below.

Particle Model of Electromagnetic Energy

The particle model of electromagnetic energy was given by Sir Isaac Newton in 1704. According to this theory light behaves as a stream of particles travels in straight line. He also knew that light had wave like characteristics based on his experiments. Following are the properties of the particle model of electromagnetic energy:

1. Light travels in straight lines.

2. Light can be reflected
3. Light can travel through a vacuum

Wave Model of Electromagnetic Energy

The wave model was formulated by Maxwell in 1862. According to this theory, electromagnetic energy is considered to propagate through space in the form of sine waves which has electric (E) and magnetic (M) fields and they are perpendicular to each other. For this reason, the term electromagnetic energy is used. The vibration of fields is perpendicular to the direction of travel of the wave. Both the fields propagate through space at the speed of light which is approximately $3x10^8$ m/s.

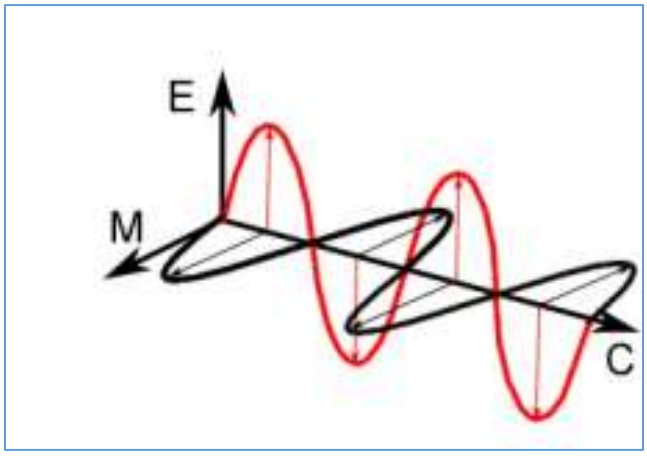

Figure: Electric and Magnetic vectors of an electromagnetic wave

The waves have certain characteristics such as **wavelength, frequency and amplitude** which are particularly important for understanding the concept of the remote sensing.

A ***wavelength*** is the distance between two consecutive peaks of a wave. The 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) or centimetres (cm, 10^{-2} metres).

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

$$C=\lambda \times \nu$$

Since the speed of light is constant, the wavelength and frequency are inversely related to each other. The shorter the wavelength, the higher the frequency because one cycle can pass in a shorter amount of time. The longer the wavelength, the lower the frequency because each cycle takes longer to complete.

Amplitude is the height of each peak. Typically expressed in Watts/ meter2 / mmeter.

This model is able to explain phenomenon such as propagation, dispersion, reflection, refraction and interference of electromagnetic waves.

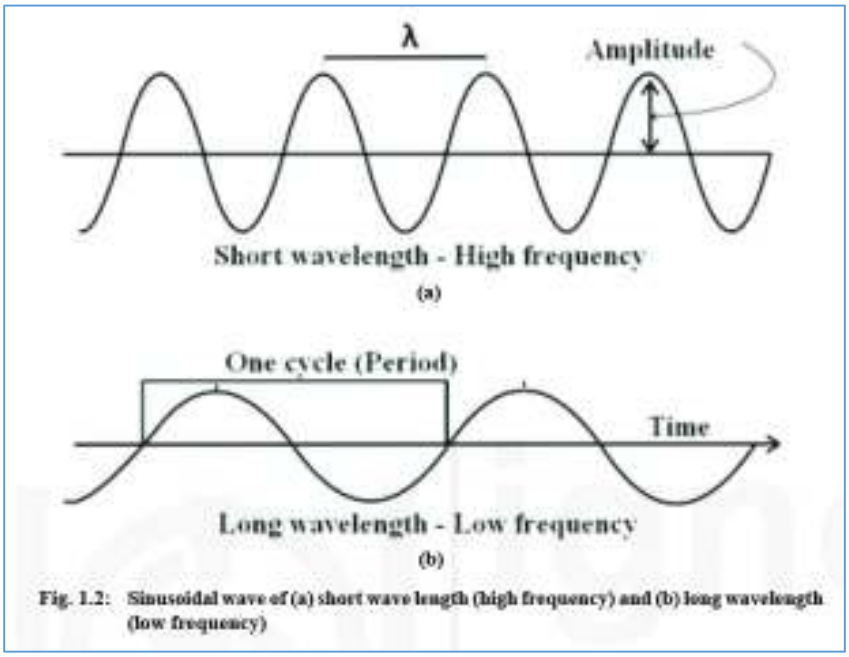

Fig. 1.2: Sinusoidal wave of (a) short wave length (high frequency) and (b) long wavelength (low frequency)

Wave Particle Duality Model

Scientists like Huygens (1690) and Young (1804) had given definite proof that light behaves like a wave. On the basis of experimental evidence, Planck and Einstein showed that light must be a particle. Both aspects (wave and particle) make up light at the same time. This leads us to the current way of describing light, the model known as *Wave Particle Duality*. Wave particle duality postulates that all matter exhibits both wave and particle properties. Albert Einstein was able to come up with a solution as long as he assumed that energy came in little pieces, called ***Quanta***. This led Einstein to come up with a theory that joined the idea of Quanta to an explanation of light. This meant the light came in little pieces that were named ***photons***. This also helped to explain the phenomenon called ***Blackbody Radiation***.