

## CHAPTER 2

# Electromagnetic Energy

### 2.1 RADIANT ENERGY

To understand the concept of aerial photography and other remote sensors, the mapper, map user, or image analyst must have at least a nodding acquaintance with radiant energy (flux).

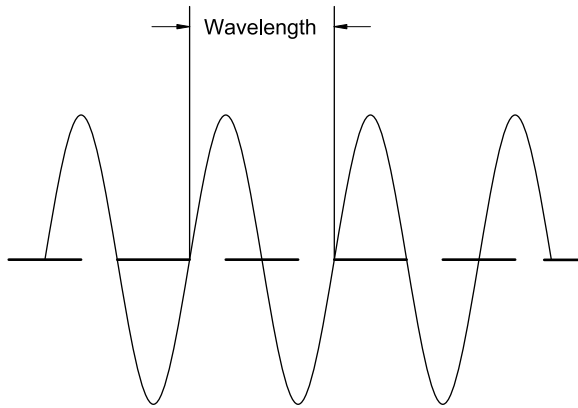
#### 2.1.1 Radiant Waves

All forms of radiant energy, which are components of the electromagnetic spectrum, travel in waves similar to those illustrated in [Figure 2.1](#). Electromagnetic energy involves two functions: frequency and wavelength. Frequency is the rate at which the oscillations pass a given point. Wavelength is the distance between any point on one wave and the analogous point on the next wave. Velocity of electromagnetic energy, a constant in a vacuum, is the product of these factors, which are both variables. In this chapter, only the wavelength is mentioned in the discrimination of various spectral regions (ultraviolet, visible, infrared, microwaves).

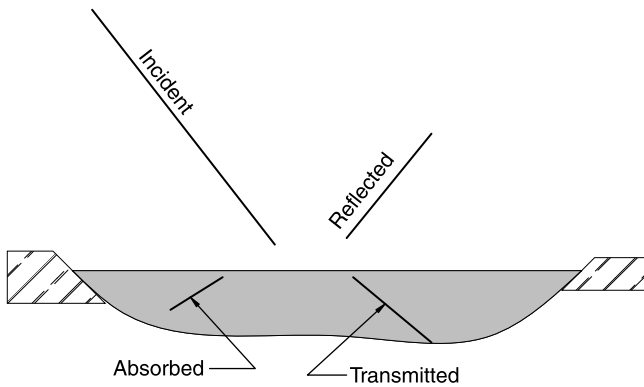
Radiant waves are deflected by colliding with any foreign particle of matter which is larger than that wavelength. The shorter the wavelength, the more it is scattered by dirt particles, water droplets, vapor, and gas in the air.

#### 2.1.2 Distribution of Energy

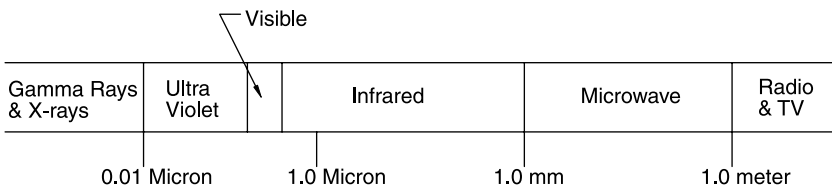
The sun emits solar energy that permeates the earth, and objects on the surface absorb, transmit, and/or reflect varying amounts of solar energy ([Figure 2.2](#)). Aerial films are sensitive to visible light waves that reflect from these objects. Some specialty films react to near infrared radiation.



**Figure 2.1** Radiant energy waves.



**Figure 2.2** Distribution of solar energy.

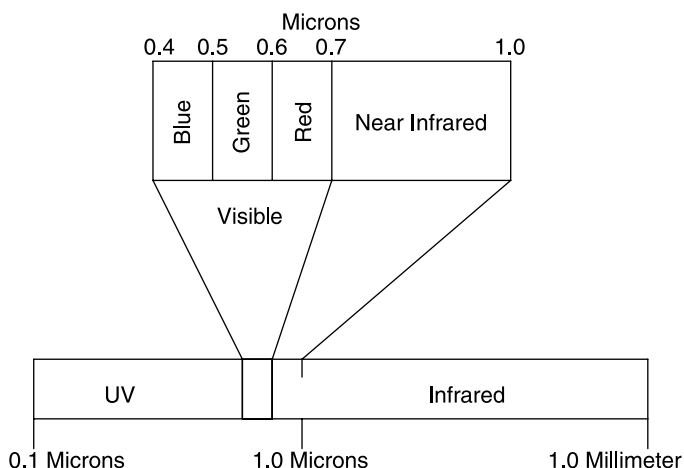


**Figure 2.3** Components of the electromagnetic spectrum.

## 2.2 ELECTROMAGNETIC SPECTRUM\*

Figure 2.3 represents the electromagnetic spectrum, indicating component energies detected by remote sensors in their relative wavelength regions. Elements of

\* Internet keyword “electromagnetic spectrum” leads to a number of illustrated perspective views of radiant energy.



**Figure 2.4** Basic components of visible light and their relationship with shorter and longer wavelengths.

the electromagnetic spectrum that are currently utilized in photogrammetry and remote sensing are the ultraviolet to a limited extent along with visible, infrared, and microwave to a considerable extent.

At the lower end of the portion of the spectrum utilized by remote sensors, wavelengths are measured in fractions of micrometers ( $\mu\text{m}$ ). At the upper range measurements are in millimeters (mm) to centimeters (cm) and are termed microwaves.

### 2.2.1 Visible Light

Human eyes see only that portion of the electromagnetic spectrum denoted as visible energy. This visible energy makes up a very small portion of the radiance that is scattered around the sky at any point in time.

Humans see the visible portion of the electromagnetic spectrum as various colors that span a range encompassing 0.4- to 0.7- $\mu\text{m}$  wavelengths. Various colors of the rainbow are blends of the additive primary physical colors of red, green, and blue.\* Visible light is sensed by a camera or multispectral sensor. Figure 2.4 visualizes the basic components of visible light and their relationship with shorter and longer wavelengths.

Blue wavelengths are the shortest of the visible light portion of the spectrum, and they ricochet off the most minute particles of gas and vapor, causing them to disperse all over the sky. Green and red are longer and are deflected by minuscule particles of dust and water droplets.

This prolific scattering of the shorter waves dominates the sense of vision and compels humans to see a blue sky. However, as the size of the particulate matter increases — caused by smoke, moisture, or dust storms — the longer waves are forced to rebound. Thus, more of the greens and reds fill the sky.

\* Equal parts of blue, green, and red appear as white light. The absence of all three results in black.

## **2.2.2 Infrared**

Infrared may be a confusing term, but it simply refers to heat radiation. Two types of radiation will be detectable by specific sensors: reflected and emitted. Both may be used to good advantage by the image analyst.

### **2.2.2.1 Reflected Infrared**

Near infrared, or reflected infrared, refers to the shorter infrared wavelengths and indicates the relative amounts of solar radiation which reflect off the molecular composition of the surface of an object. Near infrared radiation fits into the electromagnetic scheme in the 0.7- to 1.1- $\mu\text{m}$  wavelength range. Reflected infrared does not indicate the actual temperature of the mass.

Reflected infrared can be detected by a camera. Examples of this application would be:

- Healthy vegetation (whether leaves on trees or bushes, blades of grass, or foliage of cultivated crops) produces sugar through the process of photosynthesis. When this chemical function decreases or stops, the leaf surface takes on a modified molecular structure. The amount of infrared reflection differs at these various stages and is seen as different hues. This effect is especially striking with color infrared imagery, where healthy vegetation appears red and various stages of lesser vigor result in more subdued pinks.
- Clean water absorbs near infrared waves, so this image tends to be very dark on infrared images. As the amount of suspended particles increases, the infrared waves collide with this foreign material and are reflected, resulting in a lighter image tone.

### **2.2.2.2 Emitted Heat**

Thermal infrared, or emitted heat, wavelengths are longer, contained within the 1.0- to 13- $\mu\text{m}$  band, and denote actual temperature radiation emitting from an object. These fall into two categories: middle infrared and far infrared. A thermal scanner rather than a camera must sense emitted heat images. For example, if an infrared scanner were aimed at a house in winter it would sense heat leakage from poorly insulated areas on the surface of the building by exhibiting a greater radiometric value on the image than that of the dark return of the colder background. Appropriate computer instrumentation breaks this information into variable light intensity pulses that are used to create the pictorial image.