Electromagnetic Spectrum

The **electromagnetic spectrum** is the distribution of **electromagnetic radiation** according to energy, frequency, or wavelength. Electromagnetic radiation can be described as a stream of **photons**, which are particles traveling in a wavelike pattern, moving at the speed of light.

Type of Radiation	Frequency Range	Wavelength Range
Gamma rays	$>3 \times 10^{20}$	<1 fm
X rays	3×10^{17}–3×10^{20}	1 fm–1 nm
Ultraviolet	7.5×10^{14}–3×10^{17}	1 nm–400 nm
Visible	4×10^{14}–7.5×10^{14}	0.4 μm–0.75 μm
Near-infrared	10^{14}–7.5×10^{14}	0.75 μm–3.0 μm
Midwave infrared	5×10^{13}–10^{14}	3.0 μm–6 μm
Longwave infrared	2×10^{13}–5×10^{13}	6.0 μm–15 μm
Extreme infrared	3×10^{11}–2×10^{13}	15 μm–1 mm
Micro- and radio waves	$<3 \times 10^{11}$	>1 mm

Frequencies in the visible and infrared spectral bands are measured in the millions of megahertz, commonly referred to as wavelengths rather than frequencies. Wavelength can be measured interferometrically with great accuracy and is related to the optical frequency by the universal equation

$$c = \lambda \nu$$

where λ is the wavelength, ν is the optical frequency, and c is the speed of light in free space (3×10^8 m/sec).

The difference between the categories of electromagnetic radiation is the amount of energy found in their photons. The energy of a photon is inversely proportional to the wavelength and is given by

$$\mathcal{E} = h\nu = \frac{hc}{\lambda}$$

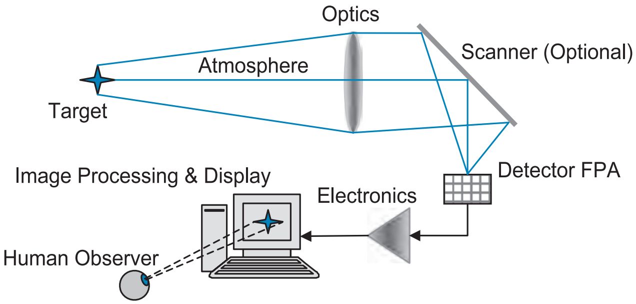
where h is Planck's constant (6.62×10^{-34} J · sec).

Radio waves have photons with very low energies, while gamma rays are the most energetic of all. The electromagnetic spectrum is classified based on the source, detector, and materials technologies employed in each of the spectral regions.

Infrared Concepts

Infrared-imaging systems are often used to form images of targets under nighttime conditions. The target is seen because of **self-radiation** rather than the reflected radiation from the sun. Self-radiation is a physical property of all objects that are at temperatures above absolute zero (i.e., 0 K = –273.15 °C).

In order to make this radiation visible, the infrared system depends on the interaction of several subsystems.



The self-radiation signature is determined by the **temperature** and the surface characteristics of the target. Gases in the atmosphere limit the frequencies at which this radiation is transmitted. The configuration of the optical system defines the **field of view (FOV)**, the **flux collection efficiency**, and the **image quality**. These parameters, along with the detector interface, impact the radiometric accuracy and **resolution** of the resulting image. The detector is a transducer that converts the optical energy into an electrical signal, and electronics amplify this signal to useful levels.

For typical terrestrial and airborne targets, **Planck's equation** dictates that, within the range of temperatures from 300 K to 1000 K, emission of radiation occurs primarily in the infrared spectrum. However, the background is self-luminous as well, causing terrestrial targets to compete with background clusters of similar temperature. Infrared images have much lower **contrast** than corresponding visual images, which have orders of magnitude higher reflectance and emittance differences.