Electromagnetic Spectrum

Electromagnetic (EM) waves carry energy and comprise transverse vibrations in electric and magnetic fields, not vibrating particles. They can travel through empty space (vacuum), without requiring any material to carry them. In vacuum, all EM waves travel at 299 792 458 ms^{-1} (the fastest possible speed). When passing through matter (e.g. air or glass), speed is reduced, though seldom less than half that when moving in a vacuum. Wave speed, frequency and length are related by the equation: **speed = frequency × wavelength**

The higher the frequency, the higher the energy.

The graphic below shows how the spectrum has been divided into seven 'types' according to use.

SI: kg, m, s, A, K, mol, cd

MYTH BUSTER! Cosmic rays are **not EM radiation** but high energy particles

EM Spectrum USING IT

wavelength × **frequency** = 299 792 458 ms^{-1} = the **speed of light**

time: MSF signal sets UK radio-controlled clocks **60 kHz**

Wi-Fi, mobile phones and Bluetooth are all **microwave**

Channel 4 on SKY UK

microwave oven

Cosmic **Microwave** Background from Big Bang

Solar **IR** absorbed by atmospheric CO_2

IR TV remote control

human eyes 'see' this range

UV tanning booth

UV purifies water by killing bacteria

x-rays for medical/mechanical/security imaging and determining crystal structure

gamma rays used in cancer treatment

wavelength (to 1 sig. fig.)

wavelength	frequency
3×10^8 m / 300 000 km	**1 Hz**
3×10^5 m / **300 km**	10^3 Hz / **1 kHz**
300 m	10^6 Hz / **1 MHz**
30×10^{-2} m / **30 cm**	10^9 Hz / **1 GHz**
300×10^{-6} m / **300 µm**	10^{12} Hz / **1 THz**
300×10^{-9} m / **300 nm**	10^{15} Hz / **1 PHz**
300×10^{-12} m / 300 pm	10^{18} Hz / **1 EHz**
300×10^{-15} m / 300 fm	10^{21} Hz / **1 ZHz**

radio waves | microwaves | infrared (IR) | ultraviolet (UV) | x-rays | gamma rays

non-ionising | ionising

frequency

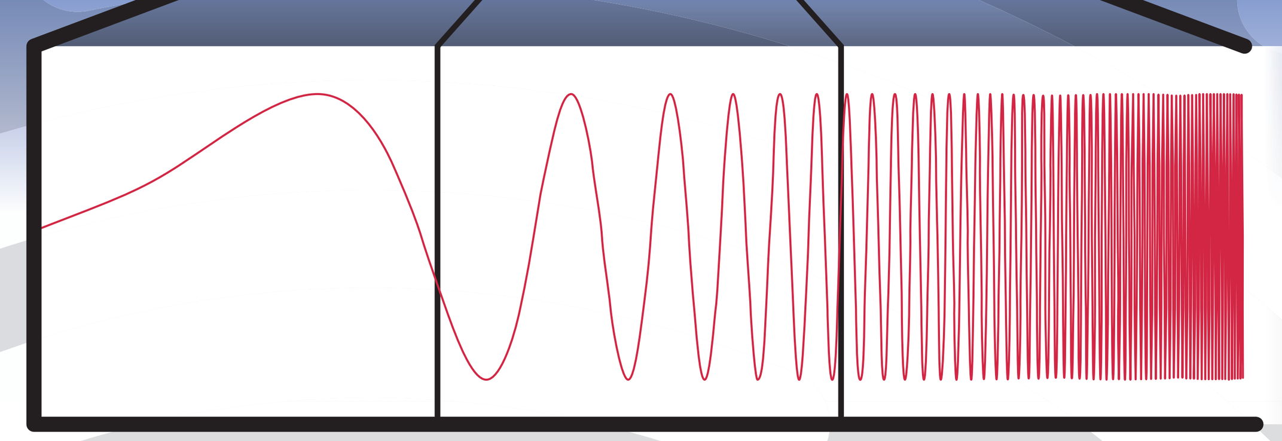
gamma rays or x-rays?

< 1 EHz also called 'soft x-rays',

> 1 EHz also called:

- 'hard x-rays' if originating from electron
- gamma rays if originating from atomic nucleus

EM Spectrum MEASURING WITH IT



radar: first UK radar invented by NPL's Robert Watson-Watt **22-50 MHz**

electrical current standard pumped by **microwave 2 GHz**

temperature: microwave volume measurements contribute to kelvin redefinition

length standard uses red laser **474 THz (red)**

luminosity: candela definition

frequency standard in NPL's Yb+ ion optical clock **682 THz (blue)**

mass: **x-ray** crystallography finds **amount of substance** in silicon weights

NPL uses EM spectrum in precision measurement

radio waves, **microwave**, **IR** and **visible** all used to measurement cauliflower ripeness

NPL anechoic chambers used for traceable measurement of EM wave properties **radio waves**, **microwave**, **20 Hz – 110 GHz**

NPL portable DIAL instrument measures airborne pollutants like methane and NO_2 using **IR**, **visible** and **UV**

temperature: thermal imagers measure **IR**

feet | explosion | electronics | heating system | heat loss

Did you know?

The National Physical Laboratory (NPL) evaluates the power of EM sources, the responsivity of EM detectors and uses many forms of the spectrum in high precision measurement.

The values used are correct at the time of going to press

NPL
npl.co.uk