# Electromagnetic Waves

## Characteristics of Electromagnetic Waves

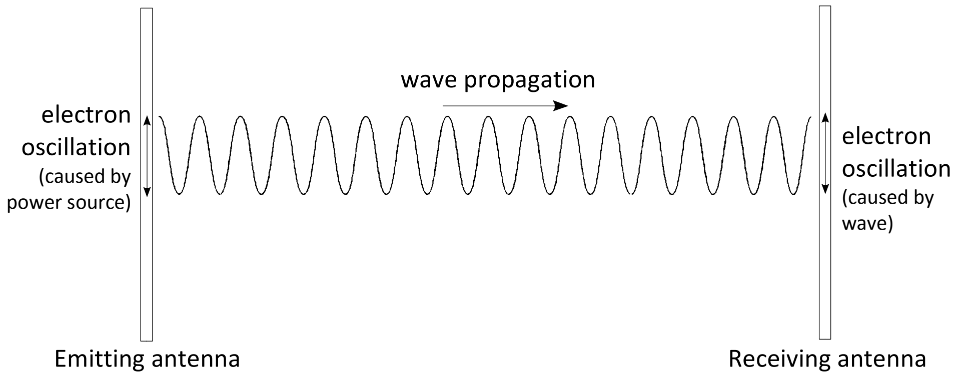
Any charged particle creates an electric field. Any moving charged particle, along with this electric field, creates a magnetic field. An *accelerating* charged particle *radiates* electromagnetic *waves*.

Electromagnetic waves propagate, meaning the oscillating energy moves through the fields from one point to another, because electric fields and magnetic fields interact with each other. Specifically, a changing magnetic field produces a changing electric field, and a changing electric field produces a changing magnetic field, and so on until the destination is reached.

An electromagnetic wave can be seen as two transverse waves (wave vibration at right angles to wave propagation); one electric field wave and one magnetic field wave, always at right angles to each other.

The plane along which the oscillating electric field vectors point is called the *plane of polarisation*. If the electric field oscillation twists around the direction of propagation then this plane cannot be defined and so is not *plane polarised*. The orientation of the oscillating electric field is defined by the movement of the charges which create the wave.

The diagram below shows the electric field part of an electromagnetic wave (the magnetic field part would be in and out of the page) created by a charge moving up and down the page. Since the charge oscillation is in a constant orientation, the wave is plane polarised (the plane of polarisation is the page in this case).




This diagram could be an example of a radio station or television channel transmitter on the left, the wave from which causes the the electrons in the receiving antenna to oscillate, producing a current. The electrons in the receiving antenna will oscillate with the frequency of the wave.

The signal strength of city channels in the country and country channels in the city are too weak to be pleasant to watch but can be strong enough that they could interfere with each other. This interference is minimised by polarising each at right angles to the other, since waves that are polarised at right angles will not interfere with each other.

## Speed, Frequency, and Wavelength

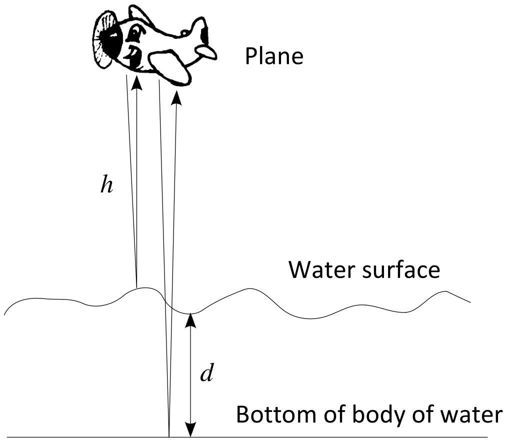
The propagation of waves in any given medium is constant. Electromagnetic waves in a vacuum, for example, travel at a constant speed $v = c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$. The constant $c$ is known as *the speed of light*. Note that when passing through air or transparent matter, the electromagnetic wave speed $v$ is slower than in a vacuum, due to delays caused by the waves' interaction with the matter.

The speed of a wave $v$ is related to its frequency $f$ and its wavelength $\lambda$ by $v = f\lambda$.

Remember: if you have the frequency or wavelength of light, you have both (by using $c = f\lambda$)

## Laser Airborne Depth Sounder (LADS)

The depth of a body of water can be determined by detecting the reflections of laser light from the surface and the bottom of the water. An aircraft equipped with a laser flies over the desired area and sends out laser pulses. The difference in time taken for the reflection from the water and the reflection from the bottom to return can be used to calculate the depth of the water (if the speed of light in water is known).




Usually the $h$ beam is an infrared beam fixed pointing directly downwards, and the $d$ beam is a green beam which scans side to side as the aircraft travels, sweeping out the depths of the area it travels over.

The results of the pulses can be taken as three variables:

$t_s$ the time for light to travel to the *surface* and back

$t_b$ the time for light to travel to the *bottom* and back

$t_w$ the time for light to travel the water depth in one direction

$\therefore\ t_b = t_s + 2t_w$

Since $t_w$ is the unknown, this can be rearranged to $t_w = \dfrac{t_b - t_s}{2}$

Now distance = speed$\times$time so the water depth is the speed of light in water multiplied by $t_w$

The speed of light in water is usually around $2.24\times10^{8}\ \mathrm{ms^{-1}}$

Note that the above calculations are for lasers that are assumed to be hitting the water at *normal incidence* (90°).

LADS systems need to use high powered lasers, since only a small percentage of the light sent out will be detected returning, due to the following reasons:

- The water is not still – it reflects light in many directions
- The bottom may be dark coloured and therefore absorb (i.e. not reflect) much light
- Light is scattered and/or absorbed by air, water and particles suspended in the water

The laser must also be low enough intensity that it is safe for people to accidentally look up into it. For this reason the laser is usually diverged (spread out) so that a lot of light is sent out but not focused enough to hurt someone's eyes.