8 Waves – Part 1

Introduction

Waves are responsible for most of the processes in life where energy is transferred from one place to another. Heat and light energy from the sun, for example, come to us as *electromagnetic waves*. Sound travels through the air as a wave; it is not the same sort of wave as light or heat, but it obeys many of the same properties. Damage is caused to coastal margins by the waves of the sea – again, another type of wave, but still obeying many of the same properties. Radio waves are of the same type as heat and light waves, as are gamma rays, X-rays, ultra-violet waves and infra-red waves. So, once we begin to understand what radio waves do, we are also learning about a huge chunk of physics at the same time! All these waves are part of the *electromagnetic spectrum*. The word 'spectrum' simply means a 'range', so what we have is a range of electromagnetic waves – that's all!

Sensing things

Light waves are invisible, but our eyes can detect the *effect* they have on different materials because the waves produce an effect on the retina of the human eye which the brain can interpret. We cannot see heat waves either, but we can feel the *effect* they have on our skin. Gamma rays and X-rays are also invisible, but their detrimental *effects* on human tissue are well known. It is not surprising, then, that we cannot see radio waves. We cannot sense them, either, until we produce a device upon which they have an *effect*. That device is a **radio receiver**; it is able to process certain characteristics of radio waves, and make these characteristics audible by generating sound waves from the loudspeaker or headphones. Other characteristics of the same waves may be turned into light as a TV picture on a cathode-ray tube, or as a fax image on a sheet of paper.

Visible waves

Let's start our description with some waves that we can actually see! When a small stone is thrown into a pond, we see circular water waves *radiating* from the point where the stone fell into the water, as **Figure 1** shows. (Notice that we use the word *radiating*, even with water waves; it is not a radio term, but one which describes any motion where the *radius* of a circle is increasing. In this case, it is the radius of the circular waves which is

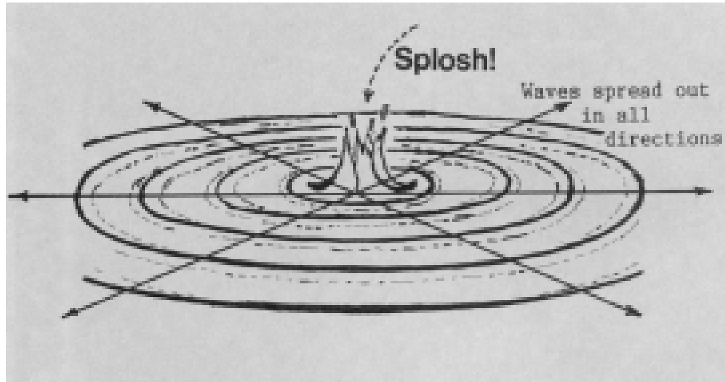

Figure 1 The waves move out from the point where the stone landed

increasing.) If you were to watch the water waves down at the water level, perpendicular to the direction in which they are travelling, you would see something like the illustration in **Figure 2**.

The horizontal line represents the water level before the wave started, and the vertical line represents the direction in which the water is displaced at any instant.

All waves are described in the same way

'Freezing' the motion of the water in this way allows us to define two very important characteristics of a wave, characteristics which we talk about every day – *wavelength* and *amplitude*. The wavelength of a wave is simply the distance (measured in metres) from any point on one wave to the same point on the adjacent wave. Look at the diagram and you will see what is meant by 'the same point on the adjacent wave'. The amplitude of a wave

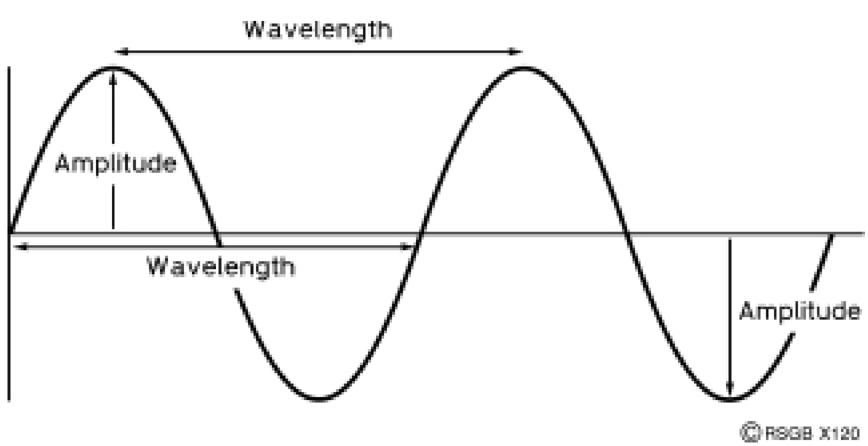

Figure 2 A water wave, viewed in cross-section

is always measured from the centre (undisturbed) position of a wave to the peak (or the trough) of the wave. Both these positions are shown, the arrow indicating that the measurement is taken *from* the centre *to* the peak or trough. The amplitude of a wave is defined as the maximum displacement of the wave from the centre position – the direction (up or down) of that displacement does not matter. Waves of greater amplitude carry more energy with them.

If we now 'unfreeze' the wave, we will see it travel from left to right (or right to left, depending on where we are looking). The speed at which it moves is called its *velocity*, and is measured in metres per second.

Another useful word is *propagate*; it means *travel*. We talk about radio waves propagating from a transmitter to a receiver. This velocity of propagation (for electromagnetic waves) is very fast indeed – they will cover 300 million metres in one second. This is virtually incomprehensible, so think of a radio wave travelling around the earth – it can travel $7\frac{1}{2}$ times round the earth in one second! We use the symbol *c* for the velocity of radio waves (which is the same as the velocity of light, of course – all electromagnetic waves travel at this speed through air and space).

The last thing we need to know about the wave is its *frequency*. Imagine a cork floating on the water in the path of the wave; it will bob up and down. If we were able to count the number of times it went through its highest position in one second, then that number would be its frequency. Any periodic motion like this is said to go through one *cycle* each time one complete wave passes a point (in this case, our cork). We are thus counting the number of cycles per second of the cork's motion. The unit of frequency is thus 'cycles per second'; this unit is now named after Hertz, a radio pioneer, and is abbreviated to Hz.

Our description of the wave is now quite simple – we need only four quantities:

(a) **Frequency** symbol f – unit, hertz (Hz)
(b) **Wavelength** symbol λ (Greek letter lambda, pronounced 'lamb-da') – unit, metre (m)
(c) **Amplitude** symbol a – unit depends on application
(d) **Velocity** symbol c – unit, metres per second (m/s or ms^{-1})

The basic formula

Whatever may happen to a wave while it travels through different media (vacuum, air, brick, wood, etc.), one thing and **only** one thing remains constant – its frequency. Its wavelength, amplitude *and* velocity may change, but its frequency never does. Three of the four characteristics already identified are connected by the simple relationship

$$c = f \times \lambda.$$

Remember that *c* is constant if the wave travels in air or in a vacuum. This means that waves having higher frequencies (*f* large) must have smaller wavelengths (λ small) and vice versa. You can imagine frequency and wavelengths being on opposite ends of a see-saw!

Divisions of units

Because the frequencies of radio waves are so high (despite them having the lowest frequencies in the electromagnetic spectrum!) we have a problem with writing them down. Do you write in your log book that you have just heard a station on 14 100 000 Hz? Of course not, you write it as 14.1 MHz, knowing that the prefix mega (M) means 'one million'. The prefixes which you need to know (when applied to frequency) are:

kHz	kilohertz	meaning	1000 Hz
MHz	megahertz	meaning	1 000 000 Hz
GHz	gigahertz	meaning	1 000 000 000 Hz.

Notice that the 'k' in kilohertz is a lower case letter. It is **incorrect** to write it as an upper case letter. 'K' is a computer-related prefix meaning **not** 1 000 but 1 024!

When we come on to discuss heat and light waves, we will use wavelengths rather than frequencies, because of the see-saw effect – as the frequencies get larger and larger, the wavelengths get smaller, and hence are numbers which are more manageable, both to talk about and to write down!

Bands

Gamma rays, X-rays, ultra-violet waves, light waves, infra-red waves are all part of the electromagnetic spectrum, but we divide them up because they have different properties. This is why we divide up our radio frequencies into different bands. The radio waves of top-band signals (around 2 MHz) have completely different properties compared with those in the 20 metre band, so we are dividing up the *radio spectrum* in the same way – by property.