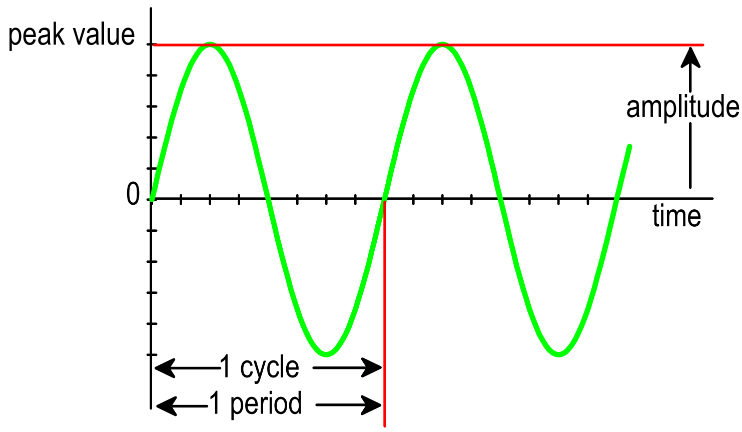
Basic Radio Theory.

Wave terms

A wave is a system by which energy is sent from one place to another without being carried directly by the particles within the medium.

The **amplitude** is the maximum positive or negative value. It is also known as the **peak** value.

The **period** (T) of a wave is the time taken for one complete wave, or one cycle of the wave. It is measured in seconds



The **frequency** (f) is the number of waves per second and is equal to 1/period and is measured in Hertz (Hz).

So $\text{frequency} = \dfrac{1}{\text{period}}$ $\quad f = \dfrac{1}{T}$

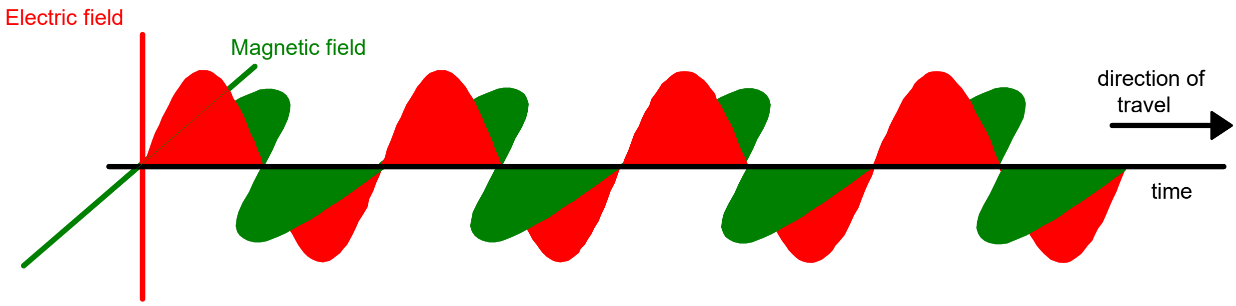
The **wavelength** (λ) is how far the wave travels in one time period and is measured in metres.

Since $\text{speed} = \dfrac{\text{distance}}{\text{time}} = \dfrac{\lambda}{T}$ the speed of the wave $= \dfrac{\lambda}{T} = \lambda f$

so the speed of a wave (v) = frequency × wavelength =fλ

$$v = f\lambda$$

Introduction
Radio signals consist of a varying electric and a varying magnetic field travelling away from their source at the same speed as light. Both fields carry the same energy and information, but is many radio systems it is only the varying electric field that is received.

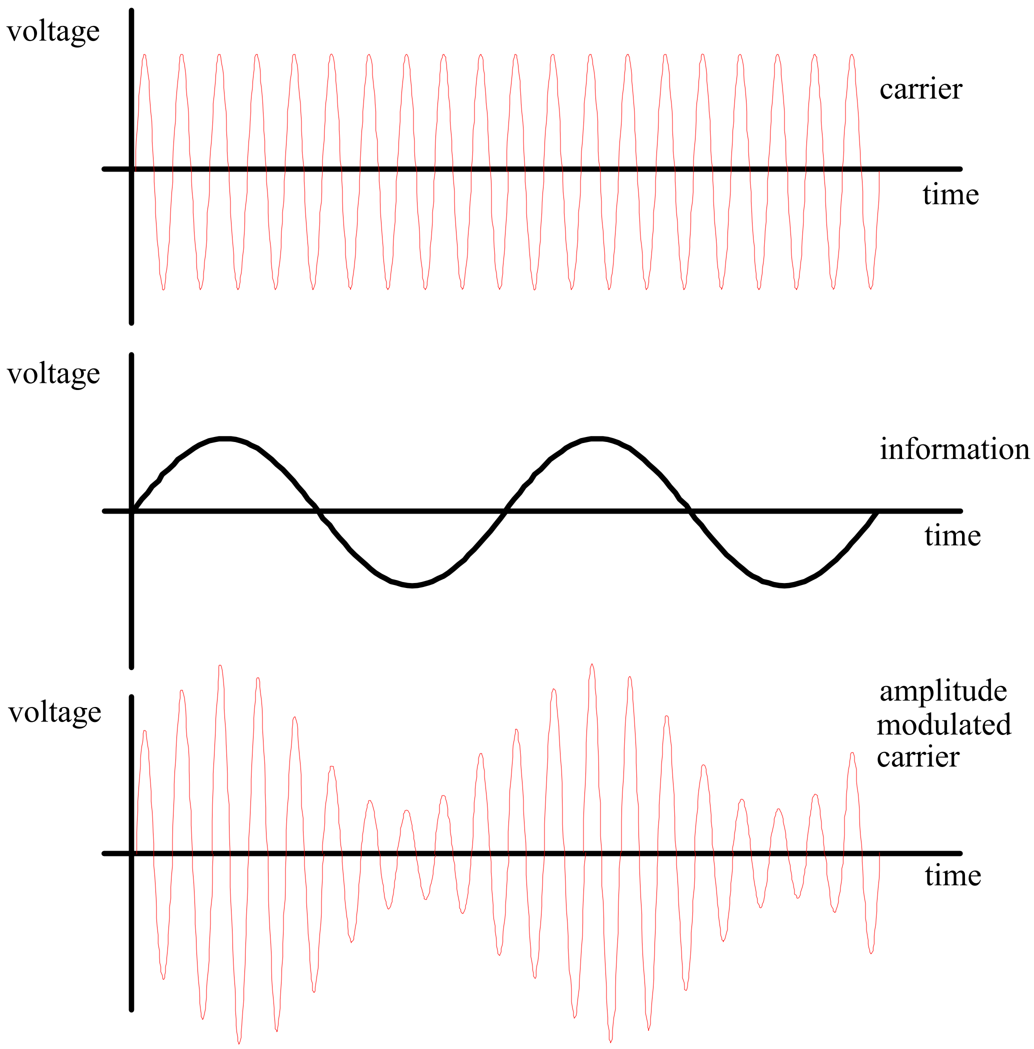


Radio signals can be transmitted at any frequency, but the lower the frequency the larger the aerials need to be for both transmitting and receiving the radio signals.
If normal sounds (speech and music) were directly converted into radio signals then the aerials would need to be around 15km long and only one radio station (this one) could transmit at any one time. If more than one transmitted at the same time then they would interfere with each other.

To solve this problem a system known as Frequency Division Multiplexing (FDM) is used, whereby each radio station is allocated a small range of frequencies that it can use. The information is then superimposed (modulated) onto a radio transmission (carrier) at the centre of this frequency allocation.
This means that many different radio stations can all transmit at the same time without causing interference, and by using a high frequency, the aerials needed can be small.

There are two main ways in which information can be put onto a radio carrier transmission - either the amplitude of the carrier is varied (amplitude modulation, AM) or the frequency of the carrier is varied (frequency modulation, FM)

Amplitude Modulation
The diagram below shows an amplitude modulated wave. The amplitude of the carrier is varied in proportion to the information signal. With a 100% amplitude modulated carrier the amplitude of the radio signal varies from zero to twice the amplitude of the carrier wave.
If the carrier is given any further modulation then the signal becomes distorted and interference to adjacent radio stations will be produced.
Most broadcast stations limit their modulation to 80%.



Depth of modulation

Consider the diagram below: x is the modulating signal amplitude and y is the carrier wave amplitude.

The **modulation depth, m**, of the resulting amplitude modulated signal is defined by:

$$\mathbf{m = \frac{x}{y} \times 100\%}$$

The modulation depth of the waveform in the diagram below is approximately 65% and can be verified by measuring the amplitudes of the waves in the diagram. The peak amplitude of the modulated wave is the sum of the modulating and carrier waves. If **x** is equal to **y** then the carrier is 100% modulated. If x is increased further then over modulation occurs and the region represented by **y-x** in the diagram becomes zero.

When the depth of modulation exceeds 100%, the information will be distorted and the bandwidth of the signal will be increased as a result of the carrier actually disappearing. However, if the modulation depth is too small then the received signal will be of poor quality because the signal-to-noise ratio will be reduced. The usual depth of modulation for good quality reception is approximately 80%.

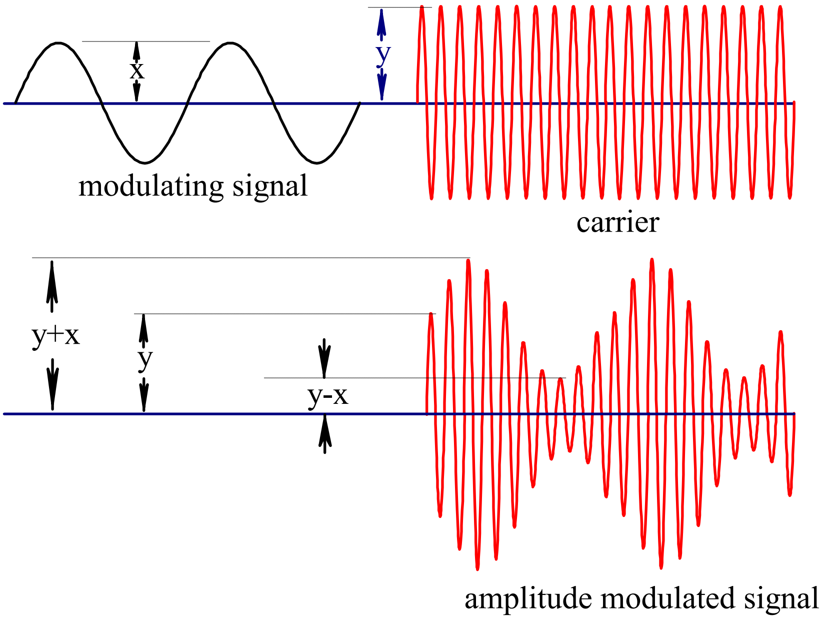
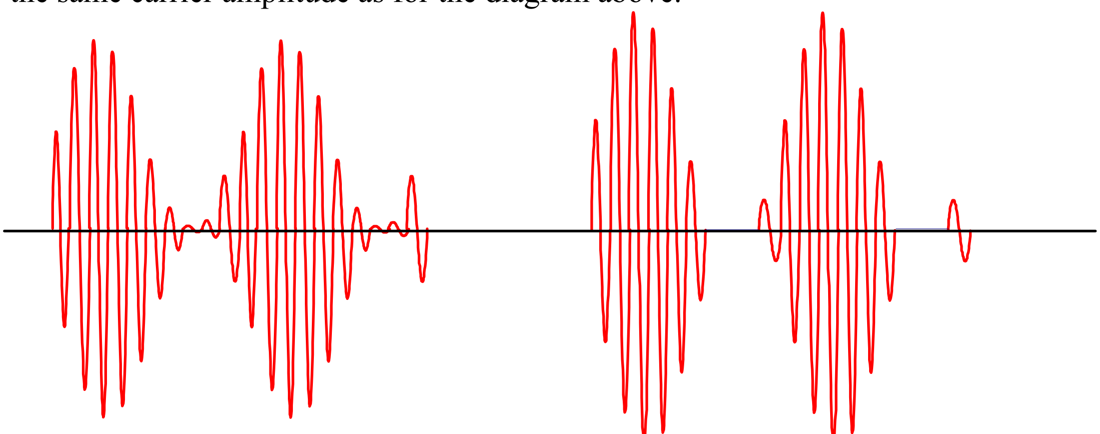


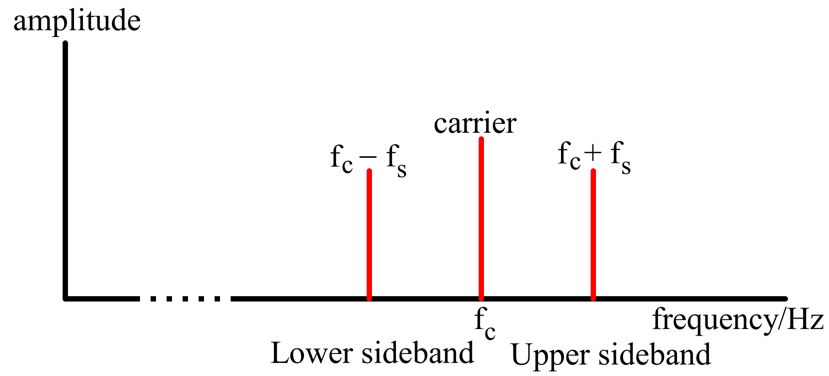
Diagram (a) below show an amplitude modulated wave at 100% and diagram (b) shows an amplitude modulated wave that is being over modulated (i.e. greater than 100%). Both diagrams assume the same carrier amplitude as for the diagram above.



(a) (b)

Sidebands

The process of modulation results in the production of frequencies other than those of the carrier and the modulating signal. When a modulating signal of frequency f_s, is combined with the carrier wave of frequency f_c, a signal comprising of three frequencies, $(f_c - f_s)$, f_c and $(f_c + f_s)$, results as shown in the diagram below. Since the modulating signal usually consists of a band of frequencies, the resulting frequency spectrum of the modulated signal will be as shown in the diagram below.



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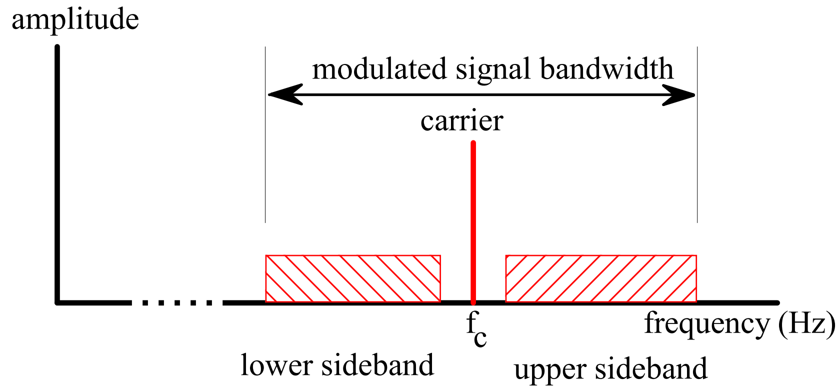


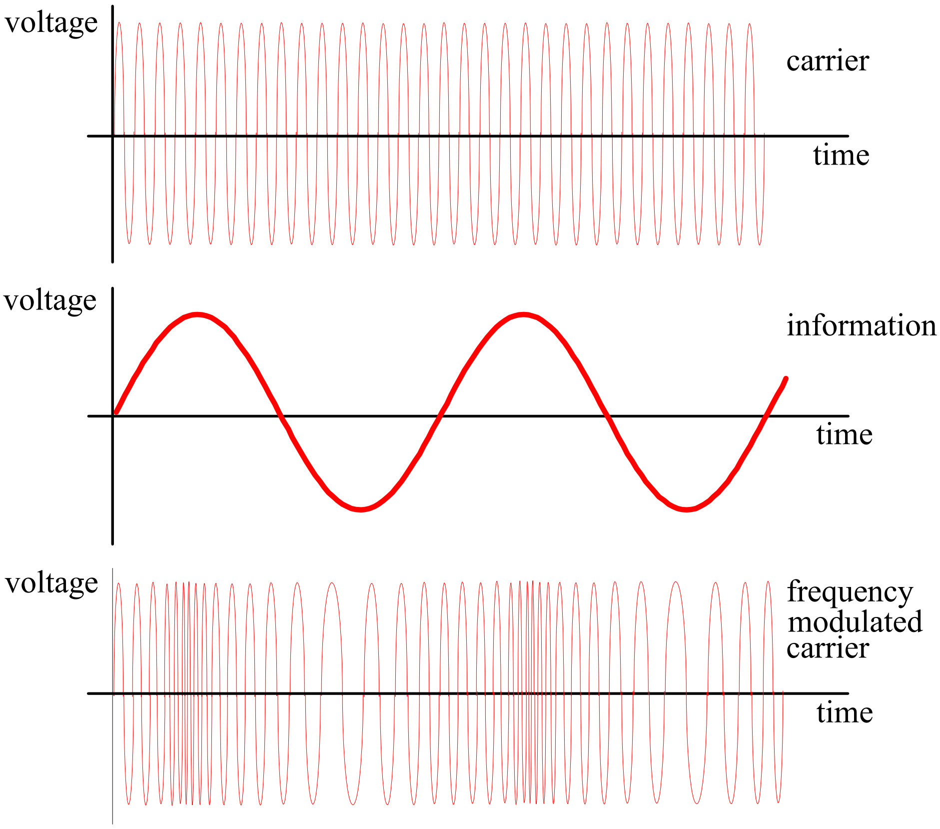
If the frequency of the modulating signal ranges from 100Hz to 5kHz then the lower sideband will range from (f_c–5000)Hz to (f_c–100)Hz, the upper sideband will range from (f_c+100)Hz to (f_c+5000)Hz, and the bandwidth of the transmitted radio signal will be 10kHz or twice the bandwidth of the modulating signal.

When an AM signal is demodulated the carrier is removed. The information is then extracted from the remaining sidebands. It therefore saves transmitting power if the strength of the carrier is reduced or even completely suppressed, any need for a carrier can be added by the receiver. However, signal bandwidth is still what it would have been with the carrier present.
To reduce the bandwidth of the signal, one of the sidebands can also be suppressed, since only one sideband is necessary to recover the modulated information. The transmitting power of a normal AM signal can be concentrated into just the one sideband, resulting in a much more potent signal. Such radio signals are known as Single SideBand (SSB) and are used extensively for speech communication. However, such transmissions cannot be received on a simple radio receiver.

Information can also be sent in digital form by switching the carrier on and off. The simplest form of this method of transmission is when Morse Code is used.

Frequency Modulation

In frequency modulation the carrier frequency varies or deviates according to the amplitude of the AF signal. A typical FM carrier frequency (for radio broadcast transmission) is 100MHz and the maximum frequency deviation is limited, by international agreement, to ±75kHz. The bandwidth of an FM signal is, theoretically, very broad, but in practice the outer extremities of the frequency spectrum of an FM signal can be omitted without causing audible distortion.



A principal advantage of FM transmission over AM is its improved immunity to impulsive noise and static interference. Impulsive noise produces momentary variations in the amplitude of the signal which are suppressed in an FM receiver by a limiter circuit. The limiter circuit is simply an amplifier in saturation so the output is not capable of rising as a result of impulsive noise. FM transmission is used for high quality signal transmission, but at the cost of a much wider bandwidth and a more complex receiver. Most commercial FM stations use the VHF waveband since it enables the larger bandwidth to be accommodated, but such high frequencies can make circuit design more difficult.