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# Do u wan2 tlk> ;-)

**GCSE key words**
Electromagnetic spectrum
Carrier wave
Audio wave
Modulation

*Mobile phones are everywhere; most people in the UK own one. But how do they work? This article looks at the science behind this popular piece of technology.*

Radio waves form part of the **electromagnetic spectrum** (Figure 1), so they carry energy at the speed of light. Guglielmo Marconi pioneered the transmission of radio waves at the end of the nineteenth century, but radio did not capture the public imagination until 1910 when the long arm of the law stretched all the way to Canada. Dr Crippen, who had murdered his wife, believed he had got away with his crime when he escaped Britain with his secretary on a ship bound for Canada. However, the British police were able to alert their Canadian counterparts by radio. On arrival he was arrested and returned to Britain to face trial and execution.

Since then, radio has revolutionised the way we live. Television broadcasts, mobile telephones and microwave ovens all make use of radio waves (see Table 1). Mobile phones mean that people can be contacted just about anywhere, and they have even saved the lives of people drifting out to sea or stranded on a mountainside.

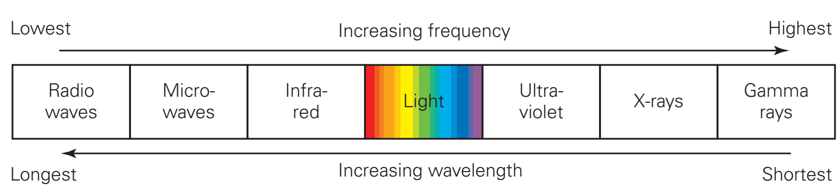



***Figure 1*** *The electromagnetic spectrum*

***Table 1*** *Typical wavelengths and frequencies in the radio spectrum*

| Use | Wavelength (m) | Frequency |
|---|---|---|
| LW radio | 1500 | 200 kHz |
| AM radio | 300 | 1 MHz |
| Cordless phones | 6 | 50 MHz |
| Radio-controlled cars and planes | 4 | 75 MHz |
| FM radio | 3 | 100 MHz |
| Television | 1.5 | 200 MHz |
| Mobile phones | 0.3, 0.16 | 900 MHz, 1800 MHz |
| Microwave ovens | 0.12 | 2500 MHz |

**In the UK, there are more phones than people.**


*This base station carries aerials for several phone networks. You can also see two dish aerials which are used for microwave links between base stations*

**The first mobile phones needed a battery the size of a car battery to work. They were usually used in cars — hence the term 'carphones'.**

- **It has been suggested that house sparrows are in decline because they are affected by the radiation from phone masts. How could you test this idea?**

## How does a mobile phone work?

A mobile phone transmits and receives radio waves, depending on whether a message is being sent or received. Inside, there is a circuit called an **oscillator** which causes a current to flow up and down the phone's aerial at a frequency of about 900 MHz (or 900 million times a second). This produces a radio wave that spreads out in all directions. Any nearby phone mast absorbs some energy from this radio wave, causing electrons (i.e. a current) to move up and down at the same frequency as the original signal. These radio waves do not themselves transmit a message, but they can be used as **carrier waves** to carry information.

### Carrier waves

A message needs to be imprinted on the carrier waves. One way to do this might be to use Morse code. You could use a tapping key to switch the radio transmitter on and off repeatedly, so that shorter and longer bursts of carrier waves would travel to the receiver. The receiver would then translate the dots and dashes into a written message.

But it is much better if the receiver can hear the speaker's voice. A microphone picks up the voice and converts it into an electrical signal or **audio wave**. This is used to change or **modulate** the carrier wave.

- In **amplitude modulation**, the audio wave is used to change or modulate the **amplitude** of the carrier wave. This is shown in Figure 2.
- In **frequency modulation**, the audio wave is used to modulate the **frequency** of the carrier wave. This is shown in Figure 3a.

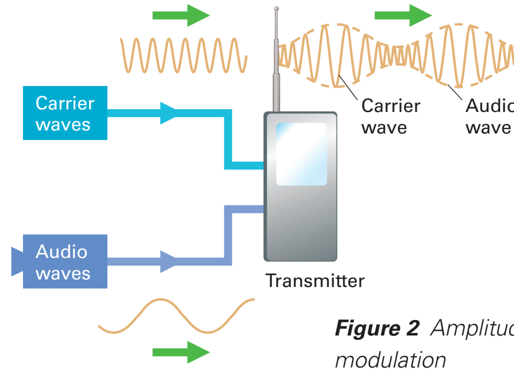



***Figure 2*** *Amplitude modulation*

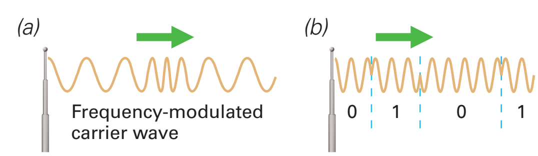



***Figure 3*** *(a) Frequency modulation and (b) phase modulation*

At the receiver, the electrical signal is demodulated. The carrier wave is removed, leaving just the audio wave that can be converted back into sound.

### Digital signals

Mobile phones work in a slightly different way. First, the signal from the microphone is digitised; this means that the height of the original analogue signal is measured many times a second and converted into a series of ones and noughts. This is then used to modulate the carrier wave by **phase modulation** (Figure 3b).

Digital signals are good because, even if they become slightly degraded by noise, they can be recovered. They also enable several calls to be transmitted simultaneously; this is multiplexing.

## What is a 'cell phone'?

Mobile phone companies divide up areas, such as cities, into **cells**. This is why mobile phones are also known as 'cell phones', particularly in the USA. A base station with transmitting and receiving aerials serves

## Box 1 Why are the aerials for mobile phones so short?

In order to transmit or receive signals, a current of electrons must run up and down an aerial. If these aerials are not long enough, the electrons run out of aerial before the signal tells them to switch direction and the transmitted or received signal will be highly distorted.

Mobile phones operate at about 900 MHz or $900 \times 10^6$ cycles per second. The period of the wave is given by:

$$T = 1/f$$
$$= 1.11 \times 10^{-9} \text{ seconds}$$

During each cycle the electrons change direction so they are only moving in either direction for half of this time.

If the signal were to travel up the aerial at the speed of light it would travel:

$$\text{distance} = \text{speed} \times \text{time}$$
$$= 3 \times 10^8 \text{ m/s} \times 5.55 \times 10^{-10} \text{ s}$$
$$= 0.17 \text{ m}$$
$$= 17 \text{ cm}$$

However, within the aerial the signal travels more slowly than this so aerials can be even shorter. In fact, they are so small that they are usually hidden inside the handset itself (Figure 4).

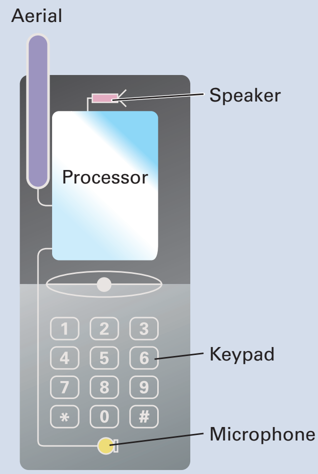



***Figure 4*** *Inside every mobile phone there is a processor, a microchip which carries out all the phone's functions*

**Most mobile phones now include GPS satellite technology. Your phone provider can tell where you are to within a few metres. This could be useful in an emergency.**

each cell, as shown in Figure 5. Cells can vary in size from **micro cells** with a radius as small as 50 m in densely populated areas to **hyper cells** with a 20 km radius. They can also vary in shape, but they are typically hexagonal.

Base stations operate at low power so that transmissions do not reach far into neighbouring cells. Because the nearest base station is never far away, mobile phones do not need powerful transmitters either. Once a phone has made contact with a base station, its power output is reduced to the level needed to maintain contact. The low power at which mobile phones operate means that they only need small batteries, so they are small enough to be carried around. Box 1 explains why the aerials of mobile phones are so small that they can be hidden inside the handsets themselves.

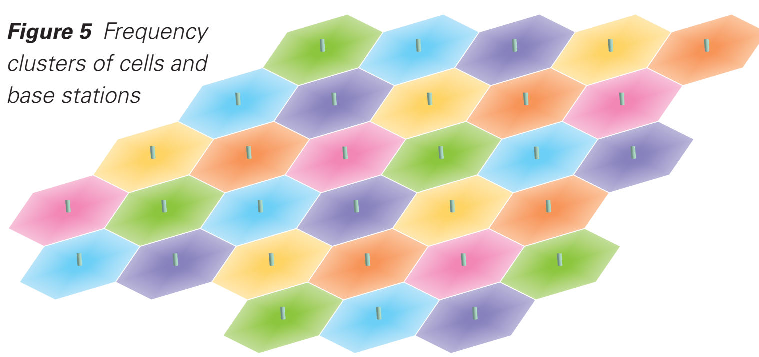

***Left:*** *Early mobile phones were a lot bigger than those we use today*

## Cells and base stations

The cellular approach requires a large number of base stations in a city but, because so many people use mobiles, the cost per user is low. To avoid interference, neighbouring cells must use different frequencies. However, people in the cells shaded green, for example, in Figure 5 can use the same frequencies to make their calls with no danger of interference between calls. The available radio spectrum can be divided up between a cluster of seven cells. The same frequencies can be reused in other clusters.

What happens if you move between cells during the same phone call? The signal received by the base station belonging to the cell you are leaving will get weaker while that received by the base station you are approaching will get stronger. At some point your phone receives a signal telling it to change frequencies

***Figure 5*** *Frequency clusters of cells and base stations*



and this **hand off** switches your phone to the new cell. By comparing the relative strengths of the signals received by the nearest base stations and working out how long it takes a signal from your phone to reach them, the phone companies can work out where you are to within a few metres. This information can be used to alert mobile phone users to things like the location of the nearest hotels and cash dispensers.

● **See 'For debate: Can your mobile phone damage your health?' on page 19 for a discussion of the hazards of mobile phones.**

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