Section 1 - Communication Using Waves

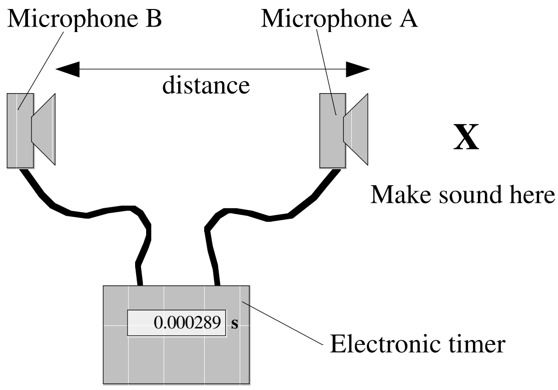
The Speed of Sound

The speed of sound in air is much less than the speed of light.

Speed of sound in air is about 340 m/s
Speed of light in air is 300,000,000 m/s

An example of this is when a flash of lightning (light) is seen before the thunder (sound) is heard, although both were produced at the same time

Measuring the Speed of Sound



Make a loud sound at X.

When the sound reaches microphone A the electronic timer starts and when sound reaches microphone B the timer stops.

Measure the distance between the microphones with a ruler.

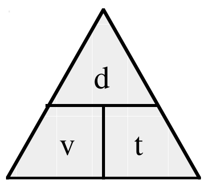
$$\text{Speed of sound} = \frac{\text{distance}}{\text{time}}$$

Speed, Distance and Time

(sound waves)

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

speed: m/s; distance: m; time: s



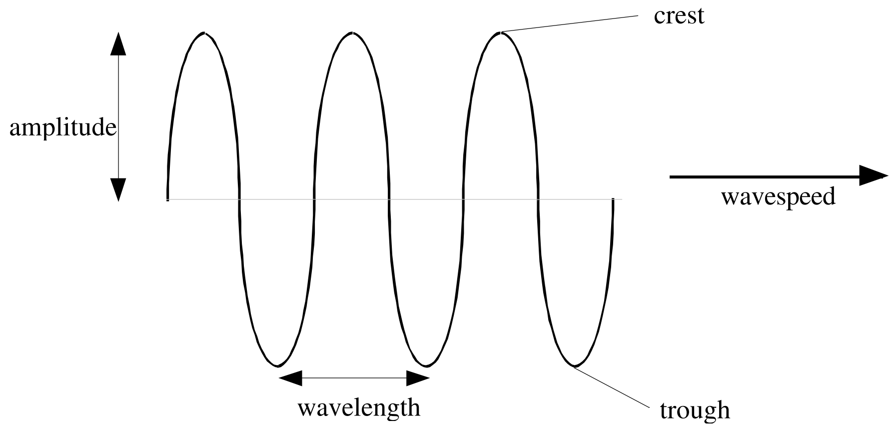
$d = v\,t$

$v = \frac{d}{t}$

$t = \frac{d}{v}$

Wave Terms

Waves carry **energy** from place to place and therefore they can be used to transmit signals.



Frequency, **f** - Number of waves passing a point each second. Hertz (Hz)

$$\text{frequency} = \frac{\text{number of waves}}{\text{time (in seconds)}}$$

Wavespeed, **v** - Distance travelled by a wave in one second. metres per second (m/s)

$$\text{speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

Amplitude - Size of maximum disturbance from centre (zero) position. -

Wavelength, **λ** - Distance from one point on a wave to the same point on the next wave. metres (m)

Period, **T** - Time taken for one wave to pass a point. seconds (s)

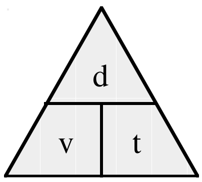
$$\text{period} = \frac{\text{time}}{\text{number of waves}}$$

$$T = \frac{1}{f} \quad \text{or} \quad f = \frac{1}{T}$$

Speed, Distance and Time
(water waves)

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

speed: m/s; distance: m; time: s



$d = v\,t$

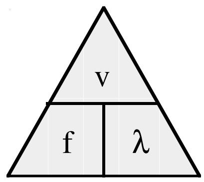
$v = \frac{d}{t}$

$t = \frac{d}{v}$

The Wave Equation
(water waves)

speed = frequency x wavelength

speed: m/s; frequency: Hz; wavelength: m



$v = f\,\lambda$

$f = \frac{v}{\lambda}$

$\lambda = \frac{v}{f}$

Equivalence of f x λ and d/t

Waves move a distance of one wavelength in a time equal to one period.

So when $\mathbf{d = \lambda}$ then $\mathbf{t = T = 1/f}$

Therefore

$$\mathbf{v = \frac{d}{t} = \frac{\lambda}{1/f} = f\,\lambda}$$

Section 2 - Communication Using Cables

Transmitters and Receivers

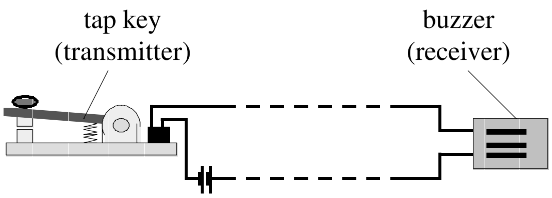
Sound is of limited use as a method of communication since it can only travel short distances and it is difficult to keep the communication private.

Other methods of communication (e.g. the Morse code telegraph and the telephone) permit communication over much longer distances.

In such methods the message is encoded and sent out by a **transmitter** and then picked up by a **receiver**.

Morse Code Telegraph

In the Morse code telegraph electrical signals are transmitted along wires at very high speed (almost 300,000,000 m/s).



Each letter of the alphabet is encoded as a series of long and short pulses ('dashes' and 'dots') of electricity:

A = • —, B = — • • •, C = — • — •

Telephone

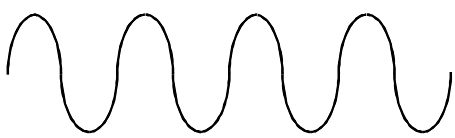
In a telephone, sound is converted directly into an electrical signal at the **mouthpiece** (the transmitter), which is then sent along a wire to an **earpiece** (the receiver) where it is converted back into sound. The electrical signal travels along the wire at almost the speed of light (300,000,000 m/s)

The mouthpiece contains a **microphone** which converts *sound into electrical energy* and the earpiece contains a **loudspeaker** which converts *electrical into sound energy*.

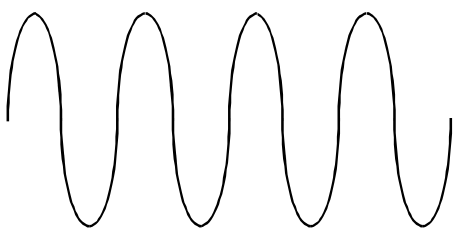
The telephone can communicate over long distances, there is no need to know a special code and is is fairly private.

Wave Patterns

Loudness

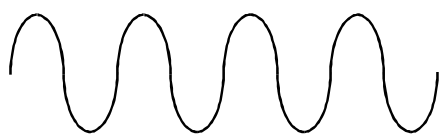


Quiet note
(small amplitude)

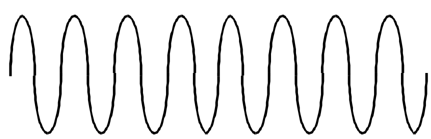


Loud note
(large amplitude)

Frequency



Low pitch note
(low frequency)



High pitch note
(high frequency)

Wave Patterns (continued)

Loud notes have more energy than quiet notes and therefore have a larger amplitude

High pitch notes produces more waves per second than low pitch notes and therefore have a higher frequency

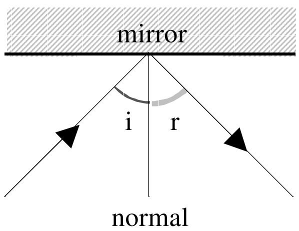
Electrical signal patterns in telephone wires show the same changes as those for sound signals when loudness and frequency are altered.

Optical Fibres

An **optical fibre** is a *long, thin thread of glass through which light can travel.* Light signals can travel along an optical fibre at very high speed (around 200,000,000 m/s). Optical fibres can carry telephone signals and modern telephone systems consists of both optical fibres and electrical cables.

Reflection

Light can be reflected as shown below :



i = angle of incidence
r = angle of reflection

When light is reflected from a plane (flat) mirror it is found that the *angle of incidence is equal to the angle of reflection*. This is known as the **law of reflection**.

Principle of Reversibility.

If the direction of a ray of light is reversed it will follow same path, but in the opposite direction

Advantages of Optical Fibres

Optical fibres have many advantages over electrical cables. These include :

1) smaller in size
2) cheaper to make
3) lighter
4) greater signal capacity (more information transmitted)
5) higher signal quality
6) less energy loss per km (less repeater station required)
7) are not affected by interference
8) not easily 'tapped'.

However, light signals in optical fibres only travel at 200,000,000 m/s as opposed to almost 300,000,000 m/s for electrical signals in a wire.

Optical fibres are also more difficult to join together than electrical cables

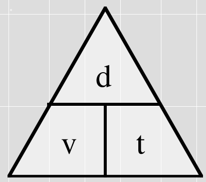
Operation of an Optical Fibre

Optical fibres work because of **total internal reflection**. This is when all the light is reflected inside the glass and none escapes into the air. Total internal reflection occurs when the angle of the incident ray is greater than an angle known as the **critical angle** (about 42° for glass). In this way light can travel great distances through optical fibres without ever leaving the fibre

Speed, Distance and Time
(light)

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

m/s (speed), m (distance), s (time)



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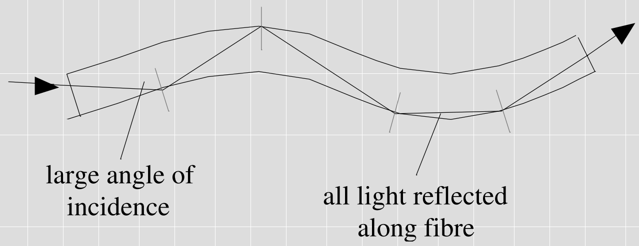


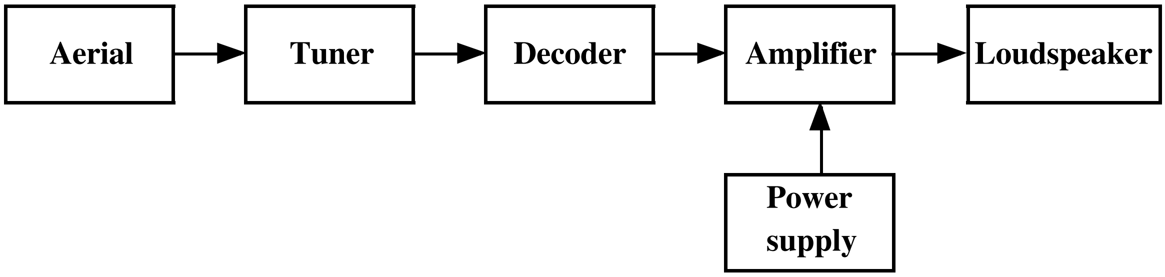
An Optical Fibre Transmission System

In an optical fibre transmission system, such as a telephone system, electrical signals are converted into pulses of light by **laser**. These pulses of light then travel down the **optical fibre** and at the other end are converted back into electrical signals by a **photodiode**. The laser and photodiode are so fast acting that hundreds of different signals can be transmitted down the same fibre simultaneously.

Section 3 - Radio and Television

Radio Receiver

The main parts of a radio receiver can be represented in a block diagram :



The **aerial** picks up radio waves of many different frequencies and converts them into electrical signals.

The **tuner** selects one particular frequency from the many received by the aerial.

The **decoder** extracts the audio (sound) signal from the transmitted radio signal.

The **amplifier** increases the strength of the electrical signal.

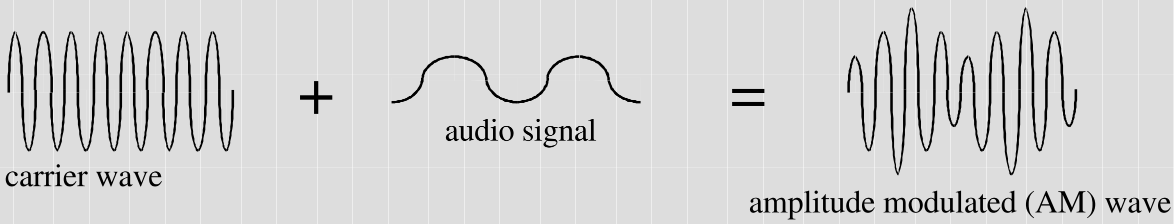
The **loudspeaker** converts the electrical signal into sound.

The **power supply** supplies extra energy for the amplifier.

Radio Transmission

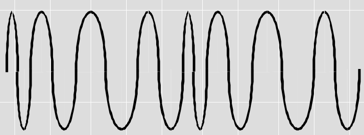
Radio signals are produced by changing (modulating) the **amplitude** of a high frequency **carrier wave** according to the **audio signal** that is to be carried.

This known as **amplitude modulation (AM)**.



These modulated signals are converted from electrical signals into radio waves at the **transmitter**. The radio waves travel through the air and are then converted back into electrical signals at the **receiver** where the audio signal is extracted from the modulated signal.

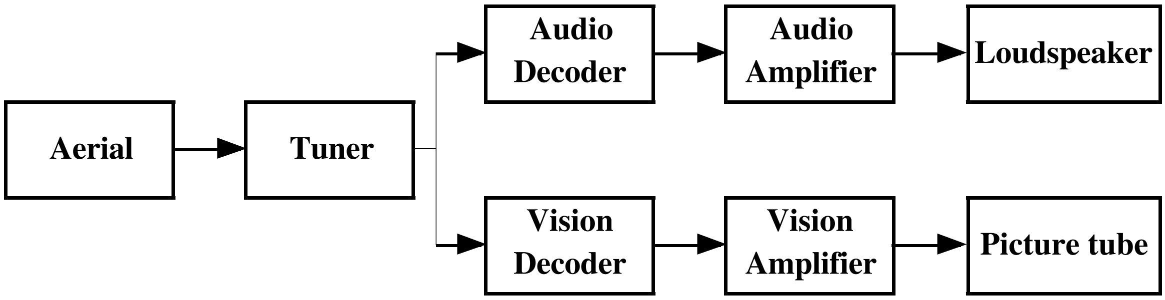
In **frequency modulation (FM)** it is the frequency of the carrier wave that is changed according to the audio signal. This produces a higher quality signal since interference has little effect on the frequency of the transmitted radio wave.



frequency modulated (FM) wave

Television Receiver

The main parts of a television receiver can be represented in a block diagram :



The **aerial** picks up television waves of many different frequencies and converts them into electrical signals.

The **tuner** selects one particular frequency from the many received by the aerial.

The **audio decoder** extracts the audio (sound) signal from the transmitted television signal.

The **audio amplifier** increases the strength of the electrical audio signal.

The **loudspeaker** converts the electrical signal into sound.

The **vision decoder** extracts the vision (picture) signal from the transmitted television signal.

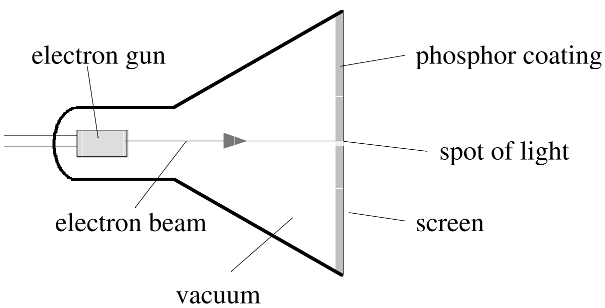
The **vision amplifier** increases the strength of the electrical vision signal.

The **picture tube** converts the electrical signal into light.

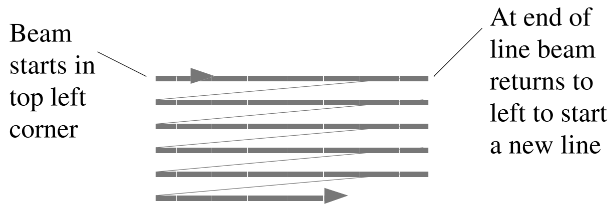
There is also a **power supply** to supply extra energy to the amplifiers.

The Picture Tube

A picture tube consists of an **electron gun** situated inside an **evacuated glass tube**, which is painted with a special **phosphor coating**. The electron gun fires a **beam of electrons** at the phosphor paint on the screen where the kinetic energy of the electrons is turned into a spot of light.



A picture is built up on the TV screen by moving the electron beam across the screen in a series of **lines** (there are 625 lines on a UK TV).



As the beam moves across the screen the **brightness** of the spot is altered by changing the **number of electrons** hitting each part of the screen. A new picture is produced 25 times each second and because **our eyes retain the image** on the retina of the eye each picture merges into the next. Since each picture is only slightly different from the previous one the picture appears to move.

Colour Television

A colour television has three different coloured phosphor dots at each point on the screen. One electron gun fires at each colour and by altering the number of electrons fired at each dot they are lit up with varying brightness. This allows all the colours to be produced by colour mixing.

The three colours of dots that are used are **red**, **green** and **blue**. These are the **primary colours of light**.

The primary colours can be mixed in equal intensities to produced the **secondary colours** as follows:

red + green = yellow
red + blue = magenta
blue + green = cyan (turquoise)
red + green + blue = white

Other colours can be produced by varying the relative intensities of the primary colours (e.g. yellow is produced by equal intensities of red and green, but if the red light is more intense than the green then orange is seen)

TV Transmission

Television signals are transmitted in the same way as radio signals except that the carrier wave is modulated to carry two synchronised signals , one audio and one video. Each signal is then extracted by a separate decoder (see above).

Section 4 - Transmission of Radio Waves

Radio Waves, Television Waves and Microwaves

Mobile telephones, radio and television are all examples of long distance communication that do not require any cables between transmitter and receiver. All these methods of communication use waves to carry the signals. Mobile phones use microwaves to carry the signals, radio uses radio waves and television uses television waves. Microwave, radio and television waves all travel at very high speed (300,000,000 m/s in air).

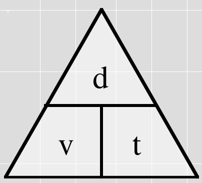
Different radio transmitters can be identified by their different frequency or wavelength values (e.g. Radio 1 has a frequency of 99.5 MHz and Radio 4 LW has a wavelength of 1500 m)

Speed, Distance and Time

(radio, television and microwaves)

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

speed: m/s; distance: m; time: s



$d = v\,t$

$v = \frac{d}{t}$

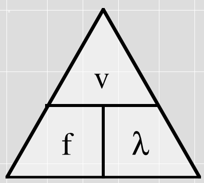
$t = \frac{d}{v}$

The Wave Equation

(radio, television and microwaves)

$$\text{speed} = \text{frequency} \times \text{wavelength}$$

speed: m/s; frequency: Hz; wavelength: m



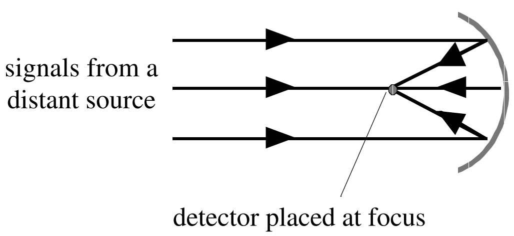
$v = f\,\lambda$

$f = \frac{v}{\lambda}$

$\lambda = \frac{v}{f}$

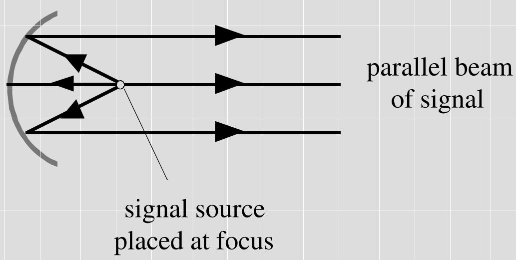
Curved Dishes - Receivers

Curved reflectors are used to *increase the strength* of a received signal from a satellite or other source. The curved shape of the reflector collects the signal over a large area and brings it to a **focus**. The detector is placed at the focus so that it receives a strong signal



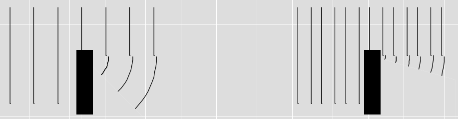
Curved Dishes - Transmitters

Curved reflectors are also used on certain transmitters to transmit a strong, parallel beam of signal. In a dish transmitter the signal source is placed at the focus and the curved shape of the reflector produces a parallel beam of signal.



Diffraction

Diffraction is *the bending of light around obstacles*. All waves diffract to some extent, but longer wavelengths diffract more than shorter wavelengths.



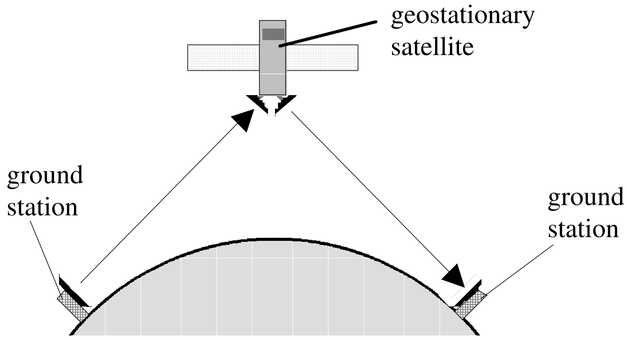
Radio waves have a longer wavelength than television waves and therefore can bend round obstacles such as hills, buildings or trees more easily. Therefore radio reception is better than television reception in such areas

Satellites

The time taken for a satellite to complete one orbit of the Earth depends on it's height above the Earth; the higher the orbit of the satellite the longer it will take to orbit.

Geostationary satellites take 24 hours to orbit the Earth. This is the same time that Earth takes to complete one rotation and so the satellite always remains above the same point on the Earth's surface.

Ground stations send signals to the satellite using a curved dish transmitter to transmit a strong signal. At the satellite the signal is **collected** by a curved dish receiver, then **amplified** and finally **retransmitted** (at a different frequency) back to the ground using another curved dish transmitter.



With three geostationary satellites placed in orbit around the equator worldwide communication is permitted with each satellite communicating with ground stations on different continents.

In satellite television systems the signal from the satellite is broadcast over a wide area and collected by dish aerials on peoples homes.