Signalling

Analogue Signals

Analogue signals are continuous - they can take any value within a given range.

Disadvantages:
- Prone to interference.
- Hard to regenerate the original signal once it is interfered with.

Digital Signals

Digital signals are discrete - they can only take 2 values – on or off (1 or 0).

Advantages:
- Prone to less interference/noise because of the ease of removal using regeneration.
- More information can be carried per second.
- Perfect re-constitution of a signal because of the two level system.
- Errors can be detected and removed by suitably encoding the signal.

Disadvantages:
- Possible loss of information – sampling reduces the frequency range.
- Possible loss of signal resolution because of limited bits per sample.

Digitising a Signal

To convert analogue signals into digital signals, we label each voltage with an 8-bit **binary code** (256 alternative voltages), and take samples of the signal at **regular intervals**. To increase the **resolution** of the signal received or sent, we need to increase the sample rate. The higher the frequency, the more samples per second needed (because higher frequencies have smaller wavelengths).

Sampling needs to be often enough (fast enough) to pick out the highest frequencies in a signal.

Sample rate $\geq$ 2 X maximum frequency of signal

So, for human speech, the sample rate would be around 40kHz. It is twice the maximum frequency in order to sample the peaks and troughs.

Noise is interference in a signal, occurring due to electromagnetic radiation, sparks etc. Digital signals are easier to recover from noise because there are only two options – 1 or 0. But with analogue, you need to guess roughly what voltage it was, hence detail will be lost.

This is important in **relay stations** which need to boost the signal. Relay stations get rid of the interference a lot more efficiently in digital than analogue.

Telephones sample up to about 8kHz because human speech is mainly 4kHz. CDs have a bandwidth up to around 20kHz. This means CD quality is much better because it includes many more frequencies.

The low end of the EM spectrum is used for communications because it is not dangerous.

Waveforms and Spectra

A Cathode Ray Oscilloscope (C.R.O.) will give a **waveform** view of the spectra. This is amplitude (volts), plotted against a timebase (s).

- It represents several different frequencies.
- It shows how the wave changes with time.

If you could make a pure note (one frequency), it would be a sine wave. Musical instruments, for example, are made up of many different, harmonious frequencies.

It is sometimes important to analyse a waveform to find out which frequencies are present.
e.g. In a plane – if we can analyse the frequency, we may be able to detect a fault.

This is called analysing the **frequency spectrum**, which we do by using **Fourier analysis**.

Frequency spectrum – the spectrum of frequencies required to synthesise the signal.

Fourier analysis allows the individual frequencies to be identified in a waveform. This is done by computer software, and gives you the frequency spectrum. These are the frequencies, in Hertz, which make up the sound. The spectrum is in the **range of frequencies present in a waveform**.

The quality of a musical note or human voice is a blend of all the frequencies present. This is why we all sound different, and this can be used by the police, for example.

The graph of the spectrum has frequency on the x-axis against amplitude (V). Amplitudes represent the volume of frequency. They are always straight lines, the highest being the loudest, and hence predominant frequency.

We can use the formula **f = 1/t** to draw a frequency spectrum of a wave, given its waveform.

The bandwidth of a signal is the range of frequencies in the signal.

The **more information** you need to put into a signal, the **bigger** the **bandwidth** required. The bigger the bandwidth required, the **higher the frequency** you must transmit it on.

Radio signals/TV signals etc. have to be transmitted within a certain bandwidth which can allow the frequencies to be transmitted without crossing over into the bandwidth of a different station.

Multiplexing

Multiplexing is sending any type of signal down the same cable. For analogue signals, they used to use **frequency division multiplexing** – different frequencies would be sent down the wires and a certain frequency would be sent to a certain person.

For digital signals, we use **time division multiplexing**. This is when the time available to transmit a signal can be **divided** up into chunks, where it allows more than one signal to be **sampled** and **sent** at the same time.

Fibre optic cables make use of infra red frequencies so thousands of signals can be multiplexed at the same time.

Polarisation

Electromagnetic waves are made from electrons becoming excited, going into an unstable orbital and releasing energy to get back to the stable electron arrangement. The EM waves vibrate in many different directions but they are all transverse.

Polarisation is when most of the axes of vibration are removed from the wave leaving the wave vibration in only one plane. Polarisation can happen by:

- Using a polarisation filter; or,
- By reflection off some surfaces (insulating, not conducting materials); or,
- By scattering.

Polarisation filters are used in cameras and in sunglasses to reduce glare. When looking through the polarisation filter, the light intensity does not change when reflected off conducting materials. This is because the light is unpolarised.

EM waves can be polarised because they are transverse. However, because sound waves are longitudinal, they cannot be polarised.

In order to receive a television or radio broadcast, the receiving aerial has to be lined up with that of the transmitter. This is because radio waves broadcast from aerials are polarised. For radio and television broadcasts the plane of polarisation is usually either vertical or horizontal.

Light waves are not normally polarised, and nor are radio waves from stars. In an unpolarised wave the vibrations are in all planes at right angles to the direction of travel.

Stress Analysis Using Polarisation Filters

Materials stress – Stress = F/A

- Place a material in between two polarisation filters, which are at right angles to each other, then illuminate from behind.
- Light is polarised as it passes through the first filter.
- Where the test material is under stress, the plane of polarisation is altered which means some light can pass through the second filter.
- This gives rise to a pattern of light and dark lines (caused by superposition), which indicates areas of stress. **Closely packed lines mean more stress at that point**.
- If there is no stress in the material, no light will get through.
- This is useful for analysing materials used in propellers, aircraft wings etc. where the high velocity will cause the material to be under stress.