# Radio

The term “Radio” is often used to refer to audio radio receivers, but that’s just one use. Radio transmissions are also used for terrestrial and satellite television, mobile phone communications, GPS and many other uses.

From Wikipedia:

*Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Radio waves have frequencies from 300 GHz to as low as 3 kHz, and corresponding wavelengths ranging from 1 millimeter (0.039 in) to 100 kilometers (62 mi). Like all other electromagnetic waves, they travel at the speed of light. Naturally occurring radio waves are made by lightning, or by astronomical objects. Artificially generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, communications satellites, computer networks and innumerable other applications. Radio waves are generated by radio transmitters and received by radio receivers. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; long waves can diffract around obstacles like mountains and follow the contour of the earth (ground waves), shorter waves can reflect off the ionosphere and return to earth beyond the horizon (skywaves), while much shorter wavelengths bend or diffract very little and travel on a line of sight, so their propagation distances are limited to the visual horizon.*

## Use Of Radio for HAB

For a balloon we use GPS to find out where the balloon is, and we use a separate radio signal to relay that information to the ground.

The GPS part is very similar to what is inside the Sat Nav in your car, and uses a receiver to listen to up to 12 of the 24 active GPS satellites, each of which orbits the Earth at an altitude of over 20,000 km. The only “special” part is that many GPS receiver modules refuse to work at above 18km altitude due to their manufacturers not understanding the “CoCom limits” which forbid GPS devices to report their position and speed when moving faster than 1000 knots (1,200mph) *and* above 18km altitude. Note the word “and” which is different to “or”, but despite that the majority of GPS modules implement “or” in their firmware. High Altitude Balloons routinely exceed 18km but never 1000 knots!

The radio part is a simple digital link sending telemetry (where the balloon is, temperatures, pressure etc.) and sometimes images too. In the UK we have our own system that was built some years ago by HAB enthusiasts, using a low-power ISM (Industrial Scientific and Medical) transmitter at the balloon, and one of more amateur radio receivers, usually with an internet connection, on the ground. This is proven to be a very reliable system, particularly because of its distributed nature, and has been used in many other countries too. There are alternatives:

* APRS - This uses amateur radio frequencies to transmit the position to a network of ground stations. UK laws prohibit use of amateur radio transmissions from airborne devices.
* GSM - Mobile phone signals (GPRS, 3G). These do not work at altitudes above about 2km, so are useless if you want data throughout the flight. Which you do. Also they rely on luck - landing within GSM coverage which is far from 100% in the UK.
* Satellite - e.g. Iridium. Here the data is sent up to a satellite and then down to a ground station and then to the internet. It’s possible to build a GSM tracker with an Iridium module (e.g. RockBlock) or use a packaged device (SPOT) but both are fairly expensive items to lose. SPOT suffers from the CoCom issue mentioned above, and both options can fail if they land with the aerial pointing down.

## UKHAS System

The UK HAB community is very active and helpful, with members very keen to help track your flight. Anyone with a suitable aerial, radio receiver and PC can become part of the receiving network.

The system works by having a radio transmitter under the balloon, sending telemetry down to all the ground stations. Each ground station independently decodes the data and uploads to an internet server. That server then provides data for a live map so that you can see the location of your flight at any time.

If your balloon is sending images, those are split into small tiles and sent one at a time. The same receiving software decodes those too, and uploads to a second server which in turn feeds a web page showing the latest images.

The strength of the above is that it only needs one receiving station to successfully decode each “packet” of information. This is good because, depending on distance and other factors, some stations will miss some packets that others receive, and vice versa.

In addition to the balloon position, it’s also possible to show the chase car position on the map. Here the car position is sent directly to the server by 3G/4G, from an app on a phone.

## Frequency and Wavelength

Like other waves (for example those on a pond caused by dropping a stone) radio waves have a speed, a wavelength (the distance between peaks) and a frequency (how quickly they rise and fall). Frequency and wavelength are directly related, so sometimes a radio signal might be referred to by wavelength (e.g. 70cm) or frequency (434MHz); if you know one then you can easily calculate the other (frequency is the speed of travel divided by the wavelength). Radio waves travel at the speed of light, which is a big number, so for low frequencies the wavelength can be huge.

This is a problem when making an antenna, since the ideal antenna size for many designs is 1 quarter of the wavelength. For example, a quarter-wave antenna for long wave (which you may remember from before the days of VHF radios) would be 1.5km long … not ideal for a balloon!

Fortunately the UKHAS system uses UHF (Ultra High Frequency) so the wavelength is short, and our aerials are typically 164mm long. We use a part of the UHF band where it is allowed to use ISM (Industrial, Medical and Scientific) devices airborne, albeit at rather low powers (10mW - about the same emitted power as an LED).

## Modulation

It’s not enough to just send a UHF signal - it has to have the data (telemetry or images) imprinted on it, or “modulated”. Then the UHF signal carries the information that we want to send to the receiver,

There are many ways of doing this, including Amplitude Modulation (AM) as used for Medium/Long Wave radio for many years, and Frequency Modulation (FM) which is used on commercial VHF broadcasts. For UKHAS we use FM which is more resistant to fading and interference.

We cover modulation in more detail in the RTTY and LoRa sections of the course.

## Line Of Sight

Radio signals can go a long way provided there is “line of sight” between transmitter and receiver. A high altitude balloon is an ideal place to have a transmitter, since the horizon is a long way away (400km and up at high altitudes). Even our low power transmitters can be easily picked up at that sort of distance and beyond.

Due to the frequencies used and the low transmitter power available, our radio signals are easily blocked by solid items (hills, buildings, trees). So it’s important for receiving stations to put their aerials up high so they are not obstructed.

## Aerials

Receiving and transmitting aerials are exactly the same thing, and in either case they have the job of connecting between an electrical signal in the aerial itself with an electromagnetic waves.

The size of an aerial is basically dictated by the type of aerial and the wavelength of the radio signal it’s designed for. Aerials do not work well at frequencies other than their design frequencies.

Some aerials have “gain”, though this is more properly thought of as an ability to concentrate on a particular direction instead of all directions. This is much like using a telescope to enlarge a distant object, at the expense of not having a wide field of view.

For balloons, we want the transmitting aerial to transmit equally in all directions, or at least equally to all parts of the horizon and below. The closest practical design is the “¼ wave” which is very easy to make. Similarly, on the ground we generally want a unidirectional design, but sometimes a directional aerial (Yagi - looks like a TV aerial) is useful.

## Flight Stages

From the above, you can see that the range of your balloon signals depends primarily on how high it is.

### Launch

Before and soon after the launch, only those at or very close to the launch site will be able to receive the transmissions. The range on the ground is typically about 1 mile, so it is almost certain that only those at the launch site will be in a position to receive and upload the telemetry and images. So, the only way that you will know that the balloon tracker is transmitting its position and images will be if you receive them yourself. Some flights have, sadly, failed because the launchers were too lazy to perform this simple step.

Further, if you are receiving and uploading data, then this is useful information for others who intend to track your flight for you. They will soon see that the balloon has been launched, and will then start searching for the signal so that they can help with the tracking.

### Flight

Once the balloon has been launched, its radio horizon will increase rapidly. Within minutes it will be in range of the closest receivers, and the higher it goes the more receivers there will be adding to the network. During this stage your own receiving station(s) are much less important.

**Landing**

Of course, the reverse happens as the flight comes in to land; the lower it gets the fewer stations will be in range. You might get lucky and land close enough to a receiver for them to pick up the actual landing position, but do not count on it (it’s happened to me just 3 times in 53 launches).

Instead, you should do your best to be as close to the landing flight as you can, before it lands. If you’re within about 1 mile you will quite likely be able to receive even after the landing, but more likely you’ll be 2-3 miles away and will have a final position from about 200 metres above the ground. That final position will be quite close to the actual landing position, but it’s always best to then get a bit closer till you can decode that landing position. Sometimes it’s not easy to get that last position decoded, as you’re far from the payload or it’s in a ditch, and this is where that Yagi aerial can come in handy.