Propagation

Key concepts

5A1

Recall that radio waves normally travel in straight lines.

Recall that they can be refracted, diffracted and reflected.

Recall that radio waves get weaker as they spread out.

Propagation concerns itself with how radio waves travel once they have left the transmitting antenna. It is a vast subject and one many amateurs have devoted a considerable amount of time and study to understanding. For the purposes of the foundation course, this section serves as an introduction to some of the more fundamental principles of propagation so that you will be aware of what to expect and understand how things work.

The first thing to remember is that radio waves, like light waves, travel in straight lines. However, they can be deflected by obstacles through reflection or diffraction. Sometimes these effects are beneficial, at other times they are not. Different radio frequencies are affected by different obstacles.

It is important to remember that radio waves get weaker as they travel, like throwing a stone into a pond; the ripples get weaker as they travel outwards. A radio receiver close to a transmitting antenna will pick up a strong signal but as the receiver moves further away then the received signal becomes weaker. This is like shining a torch onto a wall. If the torch is held close to the wall the area lit up is small and as a result, the intensity of the light is bright, whereas if the same torch shines on the wall from a larger distance the area illuminated is greater and therefore the intensity of the light is reduced.

5A2

Recall that VHF and UHF signals normally pass through the ionosphere and at these frequencies propagation is within the troposphere situated below the ionosphere.

One of the main causes of radio waves being diffracted or refracted is an area of the upper atmosphere known as the ionosphere. However, the Ionosphere does not affect all wavelengths or frequencies in the same way. In particular, the ionosphere usually has no effect on signals at VHF or UHF.

VHF/UHF signals usually pass straight through the ionosphere and continue into outer space, this makes these frequencies very useful for space communications but does limit their usefulness in a terrestrial setting.

The atmosphere is split into several distinct zones or layers as shown in the table below:

Height of Commencement (km)	Height of Termination (km)	Thickness (km)	Name	Notes
0km	10km	10km	Troposphere	Low Cloud – approx 2km Medium Cloud – approx 6km High Cloud - approx 8km Mt Everest – approx 9km
10km	50km	40km	Stratosphere	Typical Passenger Aircraft approx 10km – 11km Blackbird Spy Plane approx 21km
50km	100km	50km	Mesosphere	Ionosphere starts approx 70km
100km	1000km	900km	Thermosphere	Ionosphere extends to approx 400km Space officially starts 100km ISS Orbit 330km - 400km Geostationary or geosynchronous orbit 35,786km

The lowest layer is the Troposphere, located well below the better-known Ionosphere. This is the region where weather systems concentrate and clouds are formed. This is the region that has the most effect on VHF/UHF signals. Except in abnormal or unusual conditions VHF and particularly UHF signals are limited to "**line of sight**".

Ionosphere

5B1

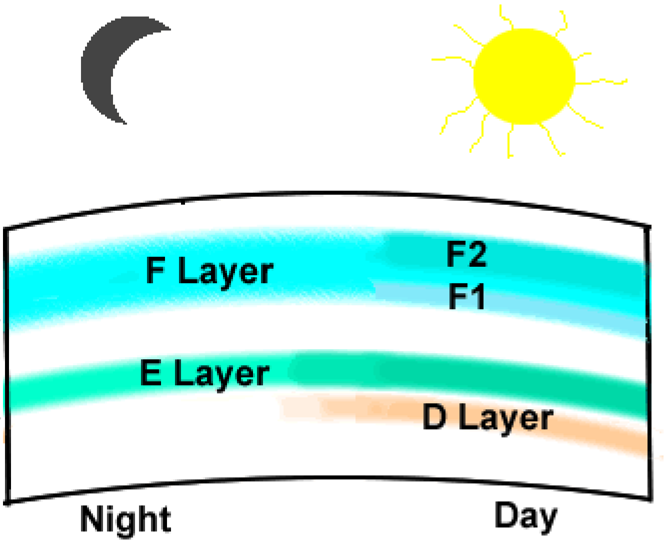
Recall that the ionosphere comprises layers of ionised gases at heights between 70 and 400km above the earth.

Understand that ionisation is caused mainly by ultraviolet rays from the sun.

The ionosphere is a section of the upper atmosphere between about 70km altitude (well above commercial or even military aircraft) and 400km altitude.

At this altitude the impact of ultraviolet radiation from the sun causes the atoms in the upper atmosphere to become charged, forming ions. It is this ionisation or charging of the upper atmosphere that allows the ionosphere to refract or reflect certain frequencies of electromagnetic waves.

As the process is linked to ultraviolet radiation it follows that the amount of ionisation increases during the day when the sun is up and dissipates overnight when the sun goes down. The shorter the day and hence longer the night the less the upper atmosphere ionises. It also follows that the upper layers of the ionosphere ionise first and lose their charge last.



5B2

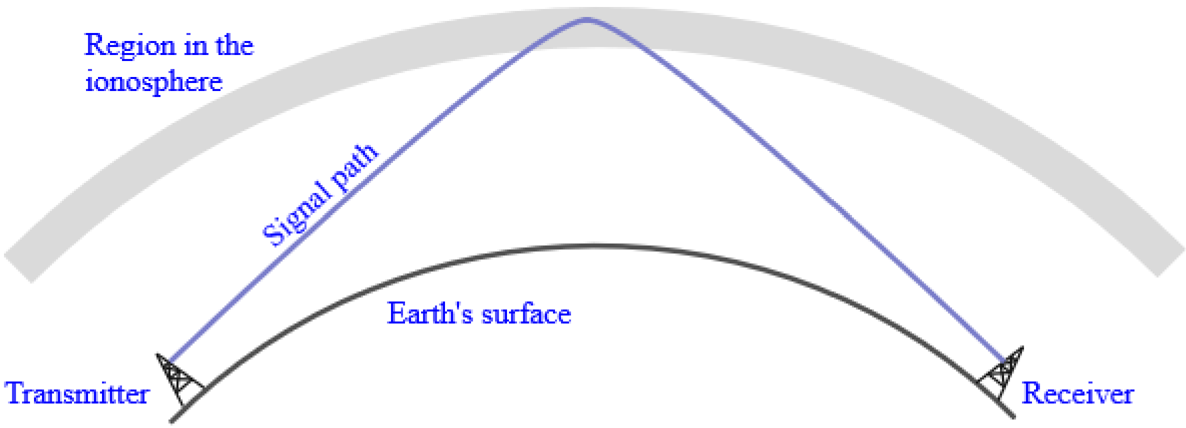
Recall that on HF most communication relies on the waves being refracted in the ionosphere.

Recall that HF can provide world-wide propagation depending on how well the ionosphere refracts the waves back to the earth.

Recall that this varies with frequency, time of day, season and solar activity.

Recall that a band is said to be ‘open’ when it supports skywave propagation.

HF communication, that is communication using frequencies below 30MHz, relies on the presence of ionisation in the upper atmosphere to refract or reflect the signals back towards the earth.



There is a small region around the Transmitter where the transmitted signal is received directly, this region is known as "**ground wave**", but is of limited coverage. Beyond the region of the ground wave the transmitted signal may not be received at all, this is known as a "**dead zone**" or "**skip zone**".

The "**skip distance**", that is the distance between the transmitting and receiving station, is not constant. Not only is the skip distance dependent on the operating frequency, but the ionosphere is constantly changing throughout the day, through weeks, months, seasons and even over longer "**sunspot cycles**". When taking part in a QSO on the HF frequencies the apparent "**fading**" of a signal is a sign that the level of ionisation and/or the height of the ionised layer is varying, resulting in the signal path changing.

Under the right conditions, a multi-hop path can allow world-wide propagation making it possible to contact stations on the opposite side of the globe. Under the correct circumstances, a single hop can cover about 4000km so, clearly, contact with continents on the opposite side of the globe (a distance of around 15,300km) would require 3 or even 4 hops to complete.

An HF band is said to be "**open**" when the frequencies in use are refracted or reflected by the ionosphere. Some HF bands are quite reliable, 20m being an example of a band that regularly supports DX propagation during the day whilst other bands are much more variable such as 10m where a much higher level of ionisation is required to reflect or refract signals back to earth. Lower frequency bands such as 80m and 160m often exhibit different propagation characteristics throughout the day typically closing around the middle of the day, being limited to the UK during early and late daylight hours but opening into Europe overnight.

As described, the time of day has an impact on the propagation of HF signals. During the day as the ionosphere is more highly ionised then signals as high as 30MHz may be reflected or refracted back to earth. During the night the upper limit may be as low as 3MHz. Summer tends to result in less extreme changes between daylight hours propagation and nighttime propagation whilst during the winter the change is more marked.

The highest frequency that will be returned to the earth is known as the "**Maximum Usable Frequency (MUF)**". For any given level of ionisation in the upper atmosphere then a signal at any frequency will only bend by so much. The higher the level of ionisation the greater the amount of bending and the higher the effect reaches in terms of practical frequencies.

To work close-in stations a lower frequency should be chosen where the amount of bending is greater. Due to the changeable nature of the ionosphere, bands might only be "**open**" for a few hours each day. During the day higher bands will open progressively and close in reverse order.

VHF and above

5C1

Recall that hills cause radio shadows and that signals become weaker as they penetrate buildings.

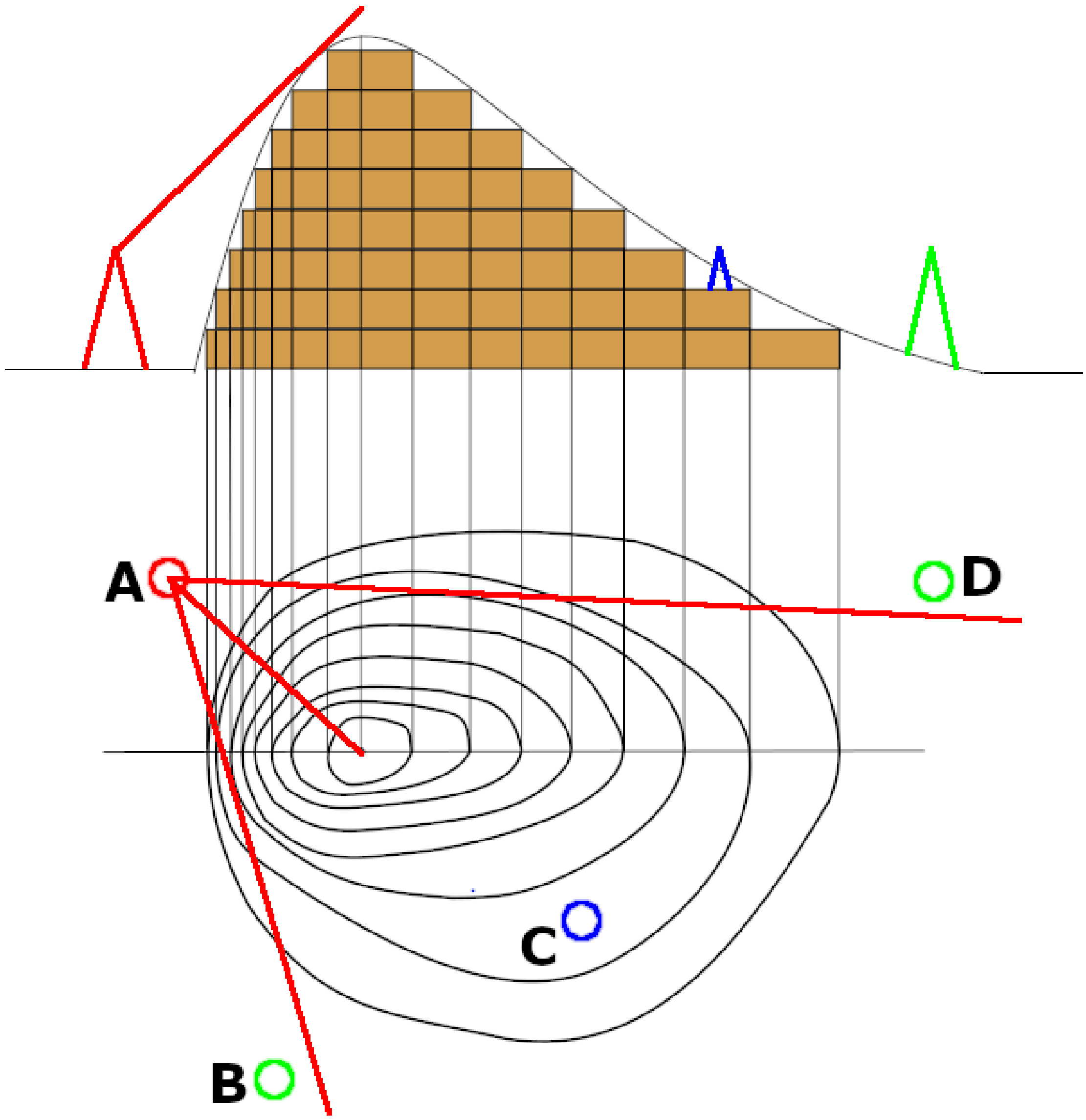
Recall that at VHF/UHF, range decreases as frequency increases and that in general VHF/UHF waves have a range not much beyond line of sight.

Recall that sporadic E and atmospheric ducting, can increase the range of VHF and UHF signals.

The terrain has much more effect on VHF and UHF signals than it does on HF signals. As described previously VHF signals and particularly UHF signals are limited to "**line of sight**". That is to say that the transmitting and receiving antennas have to be able to "see" each other to be sure of a reliable signal path. VHF will generally get further than UHF and as the frequency increases the range of a signal is generally reduced, so UHF signals will not go as far as a VHF signal with equivalent effective power.

Natural and manmade topographic features also affect VHF and UHF propagation; hills can create "blind spots" or "**shadows**" that limit transmission and reception distances in certain directions.

The following diagram shows 4 stations: A, B, C and D. All have antennas that are capable of "seeing" anything below the third contour on the hill. Stations A, B and D are able to communicate with each other, but Station C is "hidden" from Station A by the hill. Note that Station C is able to communicate with Stations B and D. Under these circumstances, either Station B or Station D would have to "relay" information between stations A and C as they are not able to communicate directly.

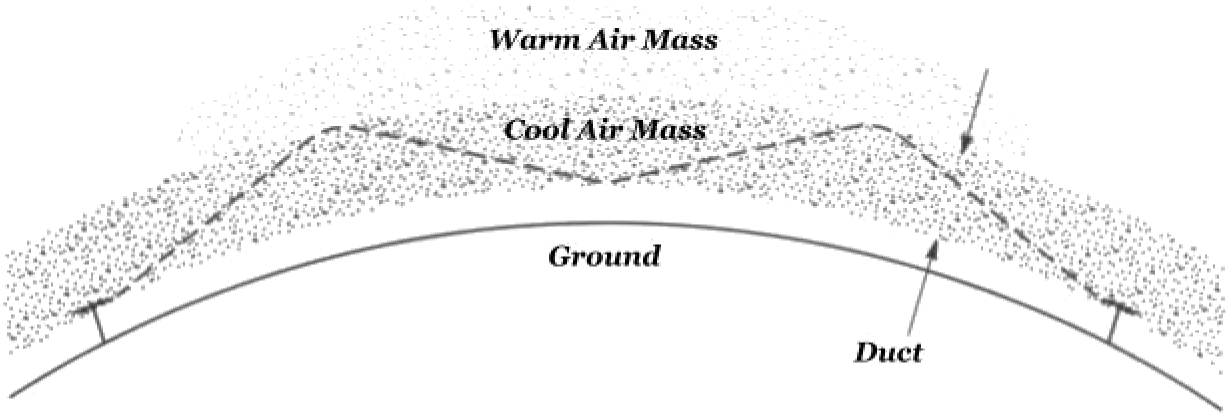


The situation becomes more complex if any of the stations are moving as it is possible for the moving station to move in and out of areas where communications are possible.

An alternative solution to relaying information would be to site a "**repeater**" on the top of the hill that would allow all 4 stations to stay in direct contact with the repeater and hence each other. More information on repeaters will be given in a later section of the course.

Having said that signals at VHF and UHF are generally limited to "**line of sight**" there are some conditions that can enhance or improve the distance that a VHF/UHF signal can propagate over.

One of these conditions is known as "**tropospheric ducting**". The Troposphere is a low level in the atmosphere, typically extending up to about 10km above the Earth's surface. This is the region where clouds and weather systems form. Generally, the temperature in the atmosphere should decrease with increasing altitude, that is as you go higher you get colder. However, in some circumstances warm moist air can be trapped above colder air and it is possible for the VHF/UHF signal to be trapped in the "**duct**". When this happens signals are forced to travel through the duct and emerge at the other end significantly increasing the normal distance.



Another phenomenon known to influence VHF and sometimes UHF propagation is "**Sporadic E**". This phenomenon is by no means fully understood. What is known is that occasionally patches of very highly ionised air can occur at much lower altitudes that are typically associated with HF propagation, in the "E" layer. These pockets of ionisation are localised and usually of relatively short duration but can refract frequencies up to and including 2m and less often 70cm. During a Sporadic E opening distances of 2000km can be possible. The causes of Sporadic E conditions are not well understood and very difficult to predict.

5C2

Recall that falling snow, hailstones and heavy rain can attenuate signals at UHF and above.

Weather also affects signals at UHF. Conditions such as heavy rain, snow and hailstorms can attenuate (reduce in power and hence range) UHF signals.

5C3

Recall that the range achieved at VHF/UHF is dependent on antenna height, antenna gain, a clear path and transmitter power.

Understand that higher antennas are preferable to higher power as they improve both transmit and receive performance.

Recall that outdoor antennas will perform better than indoor antennas.

There are many factors that can affect the range obtainable at VHF and UHF: antenna height, antenna gain, the proximity of tall buildings or topographic features such as hills, and transmitter power.

When operating at VHF and UHF the higher the antenna is sited the better will be the range of the transmitted signal. Additionally, antenna height and antenna gain provide benefits on both transmit and receive, whereas boosting power (within the Foundation Licence limits) is only beneficial on the transmit side of the operation.

An external antenna is going to perform better than one that is within a building as the building construction "saps" some of the energy in the signal on both transmit and receive.